Development of Emissions Estimating Methodologies for Lagoons and Basins at Swine and Dairy Animal Feeding Operations

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U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Sectors Policies and Programs Division
Research Triangle Park, NC 27711

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Executive Summary

In 2005, the EPA offered animal feeding operations (AFOs) an opportunity to participate in a voluntary consent agreement referred to as the Air Compliance Agreement (Agreement) (70 FR 4958). Under the Agreement, participating AFOs provided the funding for the National Air Emissions Monitoring Study (NAEMS) – a two-year, nationwide emissions monitoring study of animal confinement structures and manure storage and treatment units in the broiler, egg-layer, swine, and dairy industries. The purpose of this study was to gather emissions data that would be used by the EPA to develop emissions-estimating methodologies (EEMs). The EEMs will be used by the AFO industry to estimate daily and annual emissions for use in determining their regulatory responsibilities under the Clean Air Act (CAA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA).

The NAEMS began in the summer of 2007 and consisted of 25 monitoring sites located in 9 states. Because the monitoring plan and quality assurance procedures were developed to be consistent with the NAEMS, the EPA also considered a monitoring study of two Kentucky broiler operations conducted by Tyson Foods from 2006 to 2007 to be an integral part of the NAEMS.

In accordance with the Agreement, the EPA developed EEMs for animal housing structures and manure storage and treatment units using the emissions and process data collected under the NAEMS and other relevant information submitted to the EPA in response to its Call for Information (76 FR 3060).

This report presents the background information, data collected, data analyses performed, statistical approach taken and the EEMs developed by the EPA for dairy and swine basins and lagoons. In the NAEMS documentation, the terms “lagoon” and “basin” were used inconsistently to describe the impoundments at the various monitoring sites. Although the EPA acknowledges that there might be differences between a lagoon and a basin (e.g., the degree of microbial activity), the term “lagoon” is used throughout this report to refer to lagoons and basins.

The EPA developed the EEMs using emissions and process information collected from nine lagoon monitoring sites across the country. Monitoring was conducted at three dairy farms located in Indiana, Washington and Wisconsin. Monitoring was also conducted at six swine farms: three breeding/gestation operations and three grow/finish operations. The breeding/gestation operations were located in Iowa, North Carolina and Oklahoma. The grow/finish operations were located in Indiana, North Carolina and Oklahoma. At the dairy and swine sites in Indiana, monitoring was conducted continuously for one year. The remaining

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seven sites were monitored for up to 21 days each season for two years by a team of researchers that moved sequentially from farm to farm.

The EPA used the emissions and process information collected at the nine study sites and SAS® statistical software to develop the NH_3 EEMs. Because of the limited number of some data values and gaps in coverage of seasonal meteorological conditions across monitoring sites, the EPA evaluated the combined dairy and swine data when developing the lagoon EEMs. This approach was taken to allow the effects of meteorological conditions on lagoon NH_3 emissions at a given site to inform the EEM for a site where meteorological data was limited. For example, limited data were submitted to the EPA for dairy lagoons at high ambient temperatures. By evaluating the dairy and swine data simultaneously, the EEM for dairy lagoons could be informed by the variability in swine emissions data that are available for the missing dairy lagoon temperatures.

The EPA developed three types of EEMs that include as predictor variables a combination of ambient meteorological data (e.g., temperature, relative humidity) that were continuously monitored and categorical (i.e., static) data that characterize the farm and lagoon configuration (i.e., animal type, farm capacity, lagoon surface area). The three EEMs resulted from the paired combinations of categorical farm and lagoon variables (i.e., animal type/surface area, animal type/farm size, farm size/surface area). Each EEM produces a point prediction (i.e., mean) of NH_3 emissions for a 30-minute period for a given set of input data. The animal type/farm size and animal type/surface area EEMs produce different emissions for swine and dairy lagoons. The EEMs also produce a 95-percent prediction interval to quantify uncertainty around the point prediction. The EEMs can be used to provide daily and annual estimates of NH_3 emissions from dairy and swine lagoons.

The EPA is currently developing EEMs for H_2S emissions. However, due to the very limited amount of H_2S emissions and process data available, the EPA is interested on obtaining feedback on the approach used for the NH_3 EEMs before completing development of the H_2S EEMs. Because VOC emissions data were not submitted to the EPA, EEMs for this pollutant were not developed. The EPA was unable to develop EEMs for VOCs, as the data for lagoon sources was not received.

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1.0 INTRODUCTION

There are approximately 1 million livestock and poultry farms in the United States. About one-third of these farms raise animals in confinement, which qualifies them as Animal Feeding Operations (AFOs) (USDA, 2007). AFOs are potential sources of the following emissions: ammonia (NH_3), hydrogen sulfide (H_2S), total suspended particulate matter (TSP), particulate matter with aerodynamic diameters less than 10 micrometers (PM_{10}), PM with aerodynamic diameters less than 2.5 micrometers ($PM_{2.5}$) and volatile organic compounds (VOCs).

This report presents emissions-estimating methodologies (EEMs) for lagoons at swine and dairy sites. The methodologies were developed based on data collected in a National Air Emissions Monitoring Study (NAEMS) and other relevant information obtained through the EPA's January 19, 2011, Call for Information (see Section 3.0).

The EPA's previous effort to quantify potential emissions from this source sector and the evolution of the Air Compliance Agreement, are described in Section 1.1. Section 1.2 outlines the requirement for the NAEMS established by the Air Compliance Agreement. Section 1.3 describes how the data collected during the NAEMS was used to develop the EEMs.

1.1 Consent Agreement for Animal Feeding Operations

In August 2001, the EPA published methodologies for estimating farm-level emissions from AFOs in the beef, dairy, swine and poultry (broilers, layers and turkeys) animal sectors (*Emissions from Animal Feeding Operations*, Draft, August 2001). To develop the methodologies, the EPA: (1) identified the manure management systems typically used by AFOs in each animal sector, (2) developed model farms, (3) conducted literature searches to identify emission factors related to model farm components (e.g., confinement, manure handling and treatment system) and (4) applied the emission factors to the model farms to estimate annual mass emissions.

After publication of the EPA's 2001 report, the Agency and the United States Department of Agriculture (USDA) jointly requested that the National Academy of Science (NAS) evaluate the current knowledge base and the approaches for estimating air emissions from AFOs. In its 2003 report (*Air Emissions From Animal Feeding Operations: Current Knowledge, Future Needs*, National Research Council), the NAS concluded the following: reliable emission factors for AFOs were not available at that time; additional data were needed to develop estimating methodologies; current methods for estimating emissions were not appropriate; and the EPA should use a process-based approach to determine emissions from an AFO.

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In January 2005, the EPA announced the voluntary Air Compliance Agreement with the AFO industry. The goals of the Air Compliance Agreement were to reduce air pollution, monitor AFO emissions, promote a national consensus on methodologies for estimating emissions from AFOs and ensure compliance with the requirements of the Clean Air Act (CAA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA).

To develop the Air Compliance Agreement, the EPA worked with industry representatives, state and local governments, environmental groups and other stakeholders. Approximately 2,600 AFOs, representing nearly 14,000 facilities that included broiler, dairy, egg layer and swine operations, received the EPA's approval to participate in the Air Compliance Agreement. Participating AFOs paid a civil penalty, ranging from $200 to $100,000, based on the size and number of facilities in their operations. They also contributed approximately a total of $14.6 million to fund the NAEMS.

As part of the Air Compliance Agreement, the EPA agreed not to sue participating AFOs for certain past violations of the CAA, CERCLA and EPCRA, provided that the AFOs comply with the Air Compliance Agreement's conditions. However, the Air Compliance Agreement does not limit the EPA's ability to take action in the event of imminent and substantial danger to public health or the environment. The Air Compliance Agreement also preserves state and local authorities' ability to enforce local odor or nuisance laws. After the EPA publishes the final emissions-estimating methodologies (EEMs) for the broiler, swine, egg layer and dairy sectors, participating AFOs must apply the final methodologies for their respective sectors to determine what actions, if any, they must take to comply with all applicable CAA, CERCLA and EPCRA requirements. If a participating facility ***does not*** trigger CAA, CERCLA or EPCRA permitting or release notification requirements based on the data collected, the facility will have 60 days from the publication date of the final EEMs to submit a written certification to EPA confirming compliance with current applicable requirements under these regulations. If a participating facility ***does*** trigger CAA, CERCLA or EPCRA permitting or release notification requirements, the facility will have 120 days from the publication date of the final EEMs to apply for any required permits under the CAA, or submit any required release notifications under CERCLA or EPCRA. Finally, AFOs that did not participate in the Air Compliance Agreement can use the appropriate EEMs for their sectors to determine what, if any, measures they must take to comply with applicable CAA, CERCLA and EPCRA requirements.

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1.2 National Air Emissions Monitoring Study for AFOs

1.2.1 Overview of Emissions and Process Parameters Monitored

In the early planning stages of the NAEMS, representatives from the EPA, USDA, AFO industry, state and local air quality agencies and environmental organizations met to discuss and define the parameters that would be collected by the study. The goal was to develop a comprehensive list of parameters that must be monitored to provide a greater understanding and accurate characterization of emissions from AFOs. By monitoring these parameters, the EPA would have the necessary information to develop EEMs for PM, NH_3, H_2S and VOCs from animal feeding operations.

The Air Compliance Agreement provided guidance on the emissions and process parameters to be monitored under the NAEMS and the specific components that were to be included in the emissions monitoring plans. In addition, the Air Compliance Agreement identified the technologies and measurement methodologies to be used to measure emissions and process parameter data at dairy and swine open-source monitoring sites. The Air Compliance Agreement required the use of optical remote sensing (ORS) techniques upwind and downwind of the lagoon combined with 3-dimensional (3D) wind velocity measurements. The Air Compliance Agreement required the following measurements:

- NH_3 and the various hydrocarbons concentration using open-path Fourier transform infrared spectroscopy (FTIR).
- H_2S and NH_3 concentration using collocated open-path ultraviolet differential optical absorption spectroscopy (UV–DOAS).
- Environmental parameters (air and lagoon temperatures, humidity, wind speed and direction, atmospheric pressure and solar radiation).

The NH_3 and H_2S emissions were to be calculated from the difference in upwind and downwind concentration measurements using two different methods: an Eulerian Gaussian approach [computed tomography (CT)], and a Lagrangian Stochastic approach [backward Lagrangian stochastic method (bLS)]. For the VOC emissions, samples of the lagoon liquid were to be collected and analyzed for VOC, and the EPA model WATER9 used to estimate emissions based on measured VOC concentrations, pH, and other factors.

There were some variations in process parameters collected, as not all were applicable to each animal type or site. Additionally, some of the NAEMS researchers opted to collect more data than required by the Air Compliance Agreement. Table 1-1 shows the process parameters monitored at the NAEMS open source sites. Section 4.0 discusses the data received submitted to the EPA, including the amount of data received, in more detail.

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Table 1-1. Continuous Parameters Monitored at the NAEMS Lagoon Sites

Parameter		Units
Lagoon liquid conditions	Temperature	^{o}C
	pH	pH
	Reduction/oxidation potential	millivolts
Meteorological conditions	Ambient temperature	^{o}C
	Ambient relative humidity	%
	Barometric pressure	kPa
	Surface wetness	millivolts
	Solar radiation	$Watts/m^2$
	Wind speed	ft/sec
	Wind direction	Degrees

1.2.2 NAEMS Monitoring Sites

Under the NAEMS, monitoring was conducted at 20 farms in nine states (California, Indiana, Iowa, New York, North Carolina, Oklahoma, Texas, Washington and Wisconsin). The study was conducted by a team of researchers from the following eight universities: Purdue University, Iowa State University, University of California-Davis, Cornell University, University of Minnesota, North Carolina State University, Texas A&M University, and Washington State University. Consistent with the NAEMS Monitoring Protocol, the monitoring sites selected for the NAEMS provided representative samples of typical broiler, egg-layer, swine and dairy operations. The EPA provided oversight on site selection and monitoring plans. For the broiler sector portion of the NAEMS, Tyson Foods sponsored an earlier monitoring study at two broiler farms in Kentucky (sites KY1B-1 and KY1B-2) from 2006 to 2007. The quality assurance project plan (QAPP) for the Tyson study was developed to be consistent with the NAEMS. Therefore, the EPA considered the data collected at the Tyson study sites to be an integral part of the NAEMS. Table 1-2 presents the NAEMS monitoring sites.

For the open sources, monitoring was conducted at three dairies (IN5A, WA5A and WI5A), three breeding and gestation swine farms (IN4A, NC4A and OK4A) and three swine growing and finishing farms (IA3A, NC3A and OK3A). All farms operated under the overarching QAPP for the open source portion of the NAEMS (Appendix A).

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Table 1-2. Monitoring Sites Under the NAEMS

State	County	Site Name	Type of Operation Monitored
California	Stanislaus	CA1B	Broiler (2 Houses)
California	San Joaquin	CA2B	Egg-Layer (2 High-Rise Houses)
California	San Joaquin	CA5B	Dairy (2 Barns)
Iowa	Marshall	IA4B	Swine Sow (2 Barns, 1 Gestation Room)
Iowa	Jefferson	IA3A	Swine Finisher (1 Lagoon)
Indiana	Wabash	IN2B[a]	Egg-Layer (2 Manure-Belt Houses)
		IN2H[a]	Egg-Layer (2 High-Rise Houses)
Indiana	Carroll	IN3B	Swine Finisher (1 "Quad" Barn)
Indiana	Clinton	IN4A	Swine Sow (1 Lagoon)
Indiana	Jasper	IN5B[b]	Dairy (2 Barns, 1 Milking Center)
Indiana	Jasper	IN5A[b]	Dairy (1 Lagoon)
North Carolina	Nash	NC2B	Egg-Layer (2 High-Rise Houses)
North Carolina	Duplin	NC3B	Swine Finisher (3 Barns)
North Carolina	Bladen	NC3A	Swine Finisher (1 Lagoon)
North Carolina	Duplin	NC4A[c]	Swine Sow (1 Lagoon)
		NC4B[c]	Swine Sow (2 Barns, 1 Gestation Room)
New York	Onondaga	NY5B	Dairy (1 Barn, 1 Milking Center)
Oklahoma	Texas	OK3A	Swine Finisher (1 Lagoon)
Oklahoma	Texas	OK4A[c]	Swine Sow (1 Lagoon)
		OK4B[c]	Swine Sow (2 Barns, 1 Gestation Room)
Texas	Deaf Smith	TX5A	Dairy (Corral)[d]
Washington	Yakima	WA5A[c]	Dairy (1 Lagoon)
		WA5B[c]	Dairy (2 Barns)
Wisconsin	Saint Croix	WI5A[c]	Dairy (2 Lagoons)[e]
		WI5B[c]	Dairy (2 Barns)
Kentucky[f]	Union	KY1B-1	Broiler (1 House)
	Hopkins	KY1B-2	Broiler (1 House)

[a] Two different types of barns located at the same site were monitored.
[b] Monitoring occurred on two separate dairy farms in Jasper County, IN.
[c] Barns and lagoons were located at the same site.
[d] The reported emission estimates represent the entire corral.
[e] Instrumentation was deployed around two of the lagoons in the three-stage system. The emissions from the two lagoons were reported as a combined value.
[f] The Kentucky sites were part of an earlier Tyson Foods sponsored study, which were designed to be consistent with the NAEMS.

1.3 Emission-Estimating Methodology Development

The EPA developed an EEM to estimate daily and annual NH_3 emissions from swine and dairy lagoons. Section 5 describes the statistical methodology used to analyze the data and develop the EEMs. The EPA is currently developing EEMs for H_2S emissions. Because VOC emissions data were not submitted to the EPA, EEMs for this pollutant were not developed. The EPA was unable to develop EEMs for VOCs, as the data for lagoon sources was not received. Sections 3 and 4 discuss the NAEMS data received by the EPA to date.

The EPA used the continuous emissions, meteorological and lagoon data and categorical data collected under the NAEMS and SAS® statistical software to develop the NH_3 EEMs for swine and dairy lagoons. In the NAEMS documentation, the terms "lagoon" and "basin" were used inconsistently to describe the impoundments at the various monitoring sites. Although the EPA acknowledges that there might be differences between a lagoon and a basin (e.g., the degree of microbial activity), the term "lagoon" is used throughout this report to refer to lagoons and basins.

All of the NAEMS meteorological, lagoon and categorical data were assessed for data completeness and statistically evaluated to determine if they were reasonable predictor variables. In addition, the EPA evaluated whether the predictor variables that would be used in the EEM would be readily available to the growers, state and local agencies and other interested parties.

The EEM input parameters based on the continuous data are the ambient temperature, relative humidity, solar radiation (represented by Julian day) and wind speed. Due to the very limited amount of data received for the nitrogen concentration, solid content and pH of the lagoon liquid, these data were not included in the EEM. The limited number of sites monitored under the NAEMS also limited the number of categorical (i.e., static) variables that could be included in the EEM without compromising the performance of the methodology to two variables. The EPA developed three EEM variations to evaluate the paired combinations of the following three categorical variables that were expected to have the greatest influence on NH_3 emissions from lagoons: animal type, farm size and lagoon surface area.

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2.0 OVERVIEW OF OPEN SOURCES

As previously mentioned, the goal of the NAEMS was to quantify emissions from animal feeding operations. This included quantifying emissions from confinement sources (e.g., barns) and open sources (i.e., lagoons and corrals). For this report, manure is defined as any combination of fecal matter, urine and other materials that are mixed with manure (e.g., bedding material, waste feeds, wash water). Manure can be in a solid, slurry, or liquid state (e.g., surface liquids from storage facilities). The state of the manure often dictates the management practices and the degree to which pollutants are emitted.

Section 2.1 provides an overview of the general practices of the dairy and swine industry to provide context to study decisions (e.g., the types of farms to monitor). Section 2.2 describes the manure handling practices of the dairy and swine industry. Section 2.3 provides typical emissions from open sources. Section 2.4 describes the dairy and swine sites monitored under the NAEMS.

2.1 Overview of Dairy Industry

Dairies are AFOs that produce milk, raise dairy replacement heifers or raise calves for veal. Typically, dairy operations combine milk production and the raising of heifers (immature females) as replacements for mature cows that no longer produce milk economically. However, some milk producers obtain some or all replacement heifers from stand-alone heifer operations. Although some dairies raise veal calves, veal production is typically specialized at operations solely raising veal calves. For several decades, the number of milk producing cows has steadily decreased while the volume of milk produced has continually increased. This increased productivity has been the result of improvements in breeding programs and feeding and management practices.

Concurrently, there has been an ongoing consolidation in the dairy industry resulting in fewer but larger farms. Between 1991 and 2007, the number of dairy farms decreased by 58.4 percent, while milk production increase by 23.1 percent. As of the 2007 USDA census of Agriculture, the states with the largest number of dairy operations are Wisconsin (14,900), Pennsylvania (8,700), New York (6,400) and Minnesota (5,400).

2.1.1 Production Cycle

The primary function of a dairy is the production of milk, which requires a herd of mature dairy cows that are lactating. In order to produce milk, the cows must be bred and give birth. The gestation period is nine months, and dairy cows are bred again four months after calving. Thus, a mature dairy cow produces a calf every 12 to 14 months. Therefore, a dairy

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operation will have several types of animal groups present, including calves, heifers, mature cows (lactating and dry cows), veal calves, and bulls. The production cycle in the dairy industry begins with the birth of calves which causes the onset of lactation (milk production). A period of between 10 and 12 months of milk production is followed normally by a two-month dry period. The dry period allows for physiological preparation for the next calving. At the time milking normally is stopped, a cow normally will be in the seventh month of a nine month pregnancy. A high frequency of calf production is necessary to maintain a cost-effective level of milk production. The rate of milk production peaks shortly after calving and then slowly declines with time.

2.1.2 Animal Confinement

How dairy cows are confined depends on the size of the operation, age of the animal, and the operator preference. Dairies predominantly use some type of multiple animal area for unweaned calves, weaned calves, and heifers. Mature cows, when not being milked, are confined in freestall barns, drylots, tie stalls/stanchions, pastures, or combinations of these. Dry cows are confined in loose housing or freestalls.

Lactating cows require milking at least twice per day and are either milked in their tie stalls or are led into a separate milking center. Milking centers (also called parlors) are separate buildings, apart from the lactating cow confinement. Approximately 60 percent of dairy operations reported that they milk the cows from their tie stalls, while 40 percent reported that they used a milking center. However, 78 percent of the lactating cow population is milked in a milking center. Therefore, it can be interpreted that many of the large dairies are using milking centers, while the smaller dairies are typically using tie stalls.

2.1.3 Manure Management

Dairy manure management systems are generally designed based on the physical state of the manure being handled. Dairy cattle manure is collected and managed as a liquid, a semi-solid or slurry, and a solid, and most dairies have both wet and dry manure management systems.

In a slurry or liquid system, manure is flushed from alleys or pits to a storage facility. Typically, effluent from the solids separation system or supernatant from ponds or anaerobic lagoons is used as flush water. The supernatant is the clear liquid overlying the solids that settle below. Dairy manure that is handled and stored as a slurry or liquid may be mixed with dry manure. Liquid systems are usually favored by large dairies for their lower labor cost and because the larger dairies tend to use automatic flushing systems.

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Manure accumulates in confinement areas such as barns, drylots, and milking center, and is primarily deposited in areas where the herd is fed and watered. Drylots are used to house calves, and heifers. Due to loss of moisture through evaporation and drainage, drylot manure can either be spread directly after collection or stored in stockpiles for subsequent disposal by land application. Either drylots or freestall barns are used to house the lactating herd when they are not milked. Dairy cattle manure accumulations in freestall barns are typically collected and removed by mechanized scraping systems or by using a flush system. The milking center houses the lactating herd when they are being milked.

2.1.3.1 Manure Storage

Solid manure (from the feedlot and from scraped freestall barns) is typically stored in uncovered storage stockpiles. Because open piles are subjected to rain, they exhibit emission profiles of both aerobic and anaerobic conditions over time. When wet, the stockpiles will be potential sources of NH_3, H_2S, nitrous oxide, and odor causing compounds due to anaerobic decomposition. When dry, they will be emission sources of nitrous oxide from aerobic decomposition, and particulate matter.

Manure handled as a slurry or liquid is stored in earthen impoundments (e.g., anaerobic lagoons). Above ground tanks are another option for storage of these types of manures but are not commonly used. Storage impoundments are designed to hold the total volume of manure and process wastewater generated during the storage period, the increase in volume due to normal precipitation and the increase in volume due to the 25-year, 24-hour storm event while maintaining a minimum freeboard depth of one foot at all times. Emissions from storage tanks and ponds include NH_3, H_2S, VOCs and CH_4. The magnitude of emissions will depend primarily on the length of the storage period and temperature of the manure. Low temperatures will inhibit the microbial activity responsible for the creation of H_2S and CH_4, but may increase VOC emissions and odors. Long storage periods will increase the opportunity for emissions of VOCs, H_2S and NH_3.

2.1.3.2 Solids Separation

In the dairy industry, liquid-solids separation may be used to remove solids from run-off collected from drylots and flushed manure from freestall barns and milking centers. The liquid from solids separation is sent to a storage pond or anaerobic lagoon; the solid is stored in piles. Solids separation is necessary to reduce the organic loading to storage ponds and lagoons so they do not overflow. Mechanical separators (stationary screens, vibrating screens, presses, or centrifuges) or gravity settling basins may be used for this purpose. Emissions from separation activities are dependent on how frequently solids are removed. If solids remain in settling basins

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and mechanical separation systems longer, emissions of NH_3, H_2S, VOCs and CH_4 may be significant. Generally, the retention time of separation activities is short (i.e., less than one day).

2.1.3.1 Waste Stabilization

Stabilization is the treatment of manure to reduce odor and volatile solids prior to land application. Run-off from drylots and liquid manure from flush alleys are often stabilized in anaerobic lagoons. Anaerobic lagoons use bacterial digestion to decompose organic carbon into CH_4, CO_2, water and residual solids. Single-cell systems combine both stabilization and storage in one earthen structure whereas two-cell systems separate stabilization and storage (i.e., anaerobic lagoon followed by a storage pond).

2.2 Overview of Swine Industry

Swine operations are those that deal with the breeding and growth of pigs for meat. Typical swine operations combine various stages of swine development. The number of swine sites in the U.S. has been steadily declining since 1959; however, the number of pigs marketed has increased. This is in part due to improvements in animal health (i.e., decrease in mortality rates) and increased sow fertility. It is also characteristic of the domestic hog industry becoming increasingly dominated by large totally enclosed confinement operations capable of handling 5,000 hogs or more at a time.

In 2007, there were 75,442 swine operations in the U.S. These operations produced 89.6 million pigs. Farms vary in size from operations with a few hundred pigs to some newer operations that house hundreds of thousands of animals at one time. These data show the increasing dominance by large operations. In 2006, 88 percent of the farms had a capacity of 2,000 pigs or less. These smaller operations confined 20 percent of the total inventory of pigs. In contrast, larger operations, which represent 12 percent of the number of farms, confined 80 percent of the inventory. The largest 4 percent of farms (>5000 head) confined 54 percent of the inventory. Swine production historically has been centered in the Midwest. As of 2006, Iowa was the largest hog producing state with 17.3 million pigs, followed by North Carolina (9.5) Minnesota (6.9), Illinois (4.2) and Indiana (3.4).

2.2.1 Production Cycle

The production cycle for hogs has three phases: farrowing, nursing, and finishing. Some farms specialize in a single phase of the growth cycle, while other farms may handle two or all three phases. The first phase begins with breeding and gestation over a 114 day period followed by farrowing (giving birth). After farrowing, the newly born pigs or piglets normally are nursed for a period of three to four weeks until they reach a weight of 10 to 15 pounds. Sows can be

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bred again within a week after a litter is weaned. Sows normally produce five to six litters of 8 to 10 piglets per litter before they are sold for slaughter.

After weaning, pigs are relocated to a nursery where swine typically are fed a corn-soybean meal based diet that may include small grains such as wheat and barley and other ingredients. Nursery operations receive weaned pigs and grow them to a weight of 40 to 60 pounds. The third phase of swine production is the growing-finishing phase where the gilts (young females) and young castrated boars (males) not retained for breeding are fed until they reach a market weight, typically between 240 and 280 pounds. Growing-finishing usually takes between 15 and 18 weeks, and hogs normally are slaughtered at about 26 weeks of age.

Swine operations can be of several types. According to the 2007 USDA Census of Agriculture, the most common operation is the growing-finishing operation, followed by the farrow-to-finish operation that encompasses all three phases of swine production. Another common production mode is the combination of the farrowing and nursing phases, which provide feeder pigs for stand-alone grow-finish operations. Although not as common, some newer farms may operate only the farrowing phase or only the nursery phase.

2.2.2 Animal Confinement

Although there are still many operations where pigs are raised outdoors, the trend in the swine industry is toward larger operations where pigs are raised in totally or partially enclosed confinement facilities. Typically, the gestation and farrowing, nursery, and grow-finish phases of the production cycle occur in separate, specially designed facilities. Farrowing operations require intense management to reduce piglet mortality. Houses will have farrowing pens, and the piglets are provided a protected area of about 8 square feet. Nursery systems are typically designed to provide a clean, warm, dry, and draft-free environment in which animal stress is minimized to promote rapid growth and reduce injury and mortality. Nursery buildings are cleaned and disinfected thoroughly between groups of pigs to prevent transmission of diseases from one herd to another. Finishing pigs require less intensive management and can tolerate greater variations in environmental conditions without incurring health problems.

2.2.3 Manure Management

Although use of open lots for swine production still occurs, this method of confinement generally is limited to small operations. Swine manure produced in open lots is handled as a solid in a similar fashion as at beef cattle feedlots and dairy cattle drylots. In enclosed confinement facilities, swine manure is handled as either a slurry or a liquid.

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There are four principal types of waste management systems used with total and partially enclosed confinement housing in the swine industry: deep pit, pull-plug pit, pit recharge, and flush systems. The deep pit, pull-plug pit, and pit recharge systems are used with slatted floors whereas flush systems can be used with either solid or slatted floors. These practices do not represent all of the practices in use today; however, they are the predominant practices currently used by swine operations.

2.2.3.1 Manure Storage

Most large hog farms have from 90 to 365 days of manure storage capacity (NPPC, 1996). Storage is in either an anaerobic lagoon or a storage facility. Typical storage facilities include deep pits, tanks, and earthen ponds. Anaerobic lagoons provide both manure stabilization and storage. The use of storage tanks and ponds generally is limited to operations with deep pits and pull-plug pits where manure is handled as a slurry. Pit recharge and flush systems typically use anaerobic lagoons, because of the need for supernatant for use as recharge or flush water. Anaerobic lagoons emit less VOCs and noxious odors than storage facilities, but emit more CH_4.

Storage facilities and anaerobic lagoons are operated differently. Storage facilities hold manure until the vessel is full and then are fully emptied at the next available opportunity. To maintain proper microbial balance, lagoons are sized for a design manure acceptance rate and are emptied on a schedule (but are never fully emptied). This section describes the types of lagoons and storage facilities used and the factors affecting their design.

Storage facilities include deep pits (beneath confinement buildings), in-ground tanks, above-ground tanks, and earthen ponds. Most storage facilities are open to the atmosphere. Manure storage tanks and earthen ponds not only must have adequate capacity to store the manure produced during the storage period but must also store any process wastewaters or runoff that require storage. In addition, provision for storage of the volume of settled solids that will accumulate for the period between solids removal is necessary. Due to the size of storage structures for liquid and slurry type manures, it is difficult to completely mix and empty these facilities during draw down at the end of each storage period. Thus, an accumulation of settled solids will occur requiring a complete clean out of the facility periodically. Estimates of rates of settled solids accumulation for various manures can be found in the Agricultural Waste Management Field Handbook (USDA, 1992).

The microbial processes responsible for CH_4 and VOC formation also occur in storage tanks and ponds. However, the necessary balance in microbial populations for the complete reduction of organic carbon to CH_4 and CO_2 is never established due to higher organic loading rates and accumulations of high concentrations of VOCs, which inhibit CH_4 formation. Thus,

emissions of CH_4 from manure storage tanks and ponds will be lower than at anaerobic lagoons, and emissions of VOCs will be higher. Rates of formation of NH_3 and H_2S will not differ, but emission rates may differ depending on hydraulic retention time, pH and the area of the liquid-atmosphere interface. The pH of storage facilities normally will be acidic due to the accumulation of organic acid, which will reduce the rate of NH_3 emission but increase the rate of H_2S emission. The reverse is true for anaerobic lagoons, which have pH values that typically are slightly above neutral. However, time and surface area are probably the more significant variables controlling the masses of NH_3 and H_2S emitted.

2.2.3.2 Waste Stabilization

The anaerobic lagoon has emerged as the overwhelmingly predominant method used for the stabilization and storage of liquid swine manure. Methods of aerobic stabilization (e.g., oxidation ditches or aerated lagoons) were abandoned many years ago due to high electricity costs and operational problems such as foaming. Solids separation is typically not practiced at swine facilities.

Several factors have contributed to the use of anaerobic lagoons for swine waste management. One is the ability to handle the manure as a liquid and use irrigation for land application. A second is the potential to reduce noxious odors by maximizing the complete reduction of complex organic compounds to CH_4 and CO_2, which are odorless gases. Finally, the use of anaerobic lagoons in the swine industry was driven, in part, by the potential to maximize nitrogen losses through NH_3 volatilization thereby reducing land requirements for ultimate disposal. With the shift to phosphorus as the basis for determining acceptable land application rates for animal manures, maximizing nitrogen loss is ceasing to be an advantage.

The design and operation of anaerobic lagoons for swine and other animal manure has the objective of maintaining stable populations of the microorganisms responsible for the reduction of complex organic compounds to CH_4 and CO_2. The microbial reduction of complex organic compounds to CH_4 and CO_2 is a two-step process, in which a variety of VOCs are formed as intermediates. Many of these VOCs, such butyric acid, are sources of noxious odors when not reduced further to CH_4. Methanogenic microorganisms have slower growth rates than the microbes responsible for the formation of VOCs. Therefore, anaerobic lagoons must be designed and operated to maintain a balance between the populations of these microorganisms and methanogens to avoid accumulations of VOCs and releases of associated noxious odors.

Both single cell and two cell systems are used for the stabilization and storage of swine manure. In single cell systems, stabilization and storage are combined. In a two-cell system, the first cell has a constant volume and provides stabilization while the second cell provides storage.

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With two cell systems, water for pit recharge or flushing is withdrawn from the second cell. In climates with low precipitation and high evaporation rates, there may be one or more additional cells for the ultimate disposal of excess liquid by evaporation. Anaerobic lagoons use bacterial digestion to decompose organic carbon into CH_4, CO_2, water, and residual solids. Periodic removal of settled solids will be necessary. Typically, lagoons are dredged every 10 to 15 years, and the sludge is applied to land.

The design of lagoon treatment cells is similar to storage ponds with one exception. Lagoons are never completely emptied, except when accumulated solids are removed. Lagoons require permanent retention of what is known as the minimum treatment volume that should be reflected in design. Thus, lagoons must be larger in total volume than ponds that provide storage for the same volume of manure.

Determination of minimum treatment volume for lagoons is based on Natural Resources Conservation Services recommended total volatile solids (TVS) loading rates and the daily TVS loading to the lagoon. For anaerobic lagoons, recommended rates range from 3 lb TVS per 1,000 ft^3 per day in northern parts of Montana and North Dakota to 12 lb TVS per 1,000 ft^3 per day in Puerto Rico and Hawaii. This is a reflection of the effect of temperature on the rate of microbial activity. The calculation of minimum treatment volume is simply the daily TVS loading to the lagoon divided by the recommended TVS loading rate for the geographical location of the lagoon (USDA, 1992).

With open manure storage tanks, ponds, and lagoons, provision also is necessary to store the accumulation of normal precipitation directly falling into the structure less evaporation during the storage period. The storage requirement for normal precipitation less evaporation varies geographically. In addition, there are provisions for storage of precipitation from a 25-year, 24-hour storm event, which also varies geographically, with a minimum of one foot of free board remaining. Design values used for the accumulation of normal precipitation less evaporation are based on mean monthly precipitation values for the location of the storage facility obtained from the National Oceanic and Atmospheric Administration.

In some situations, manure storage ponds or lagoons also may be used for the storage of runoff captured from open confinement areas. In these situations, provision for storage of runoff collected from normal precipitation during the storage period as well as from a 25-year, 24-hour storm event must be included in the design storage capacity of the pond. Expected annual and monthly runoff values for the continental U.S., expressed as percentages of normal precipitation, for paved and unpaved open lots can be found in the Agricultural Waste Management Field Handbook (USDA, 1992).

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2.3 Emissions from Open Sources

Animal feeding operations emit particulate and gaseous substances during the three primary stages: confinement, manure storage and treatment, and land disposal. For the manure storage and treatment stage, emissions generally include H_2S, NH_3, methane (CH_4), VOCs and carbon dioxide (CO_2).

Open sources primarily produce gaseous emissions that are the products of the microbial decomposition of manures. Decomposition and the formation of these gaseous compounds begin immediately at excretion and will continue until the manure is incorporated into the soil. Therefore, the substances generated and the subsequent rates of emission depend on a number of variables, including the species of animal being produced, feeding practices, type of confinement facility, type of manure management system, and land application practices.

Emissions generation at any point in the process depends on several factors. The potential for PM emissions depends on whether the manure is handled in a wet or dry state. The potential for gaseous emissions generally depends on several factors: (1) the presence of an aerobic or anaerobic microbial environment, (2) the precursors present in the manure (e.g., sulfur), (3) pH of the manure, and (4) time and temperature in storage, which primarily affects mass emitted. To form H_2S (and other reduced sulfur compounds), CH_4, and VOCs requires an anaerobic environment. Therefore, the potential to emit these substances is greatest when manure is handled as a liquid or slurry. Ammonia will be generated in both wet and dry manure. Nitrous oxide will be formed only when manure that is handled in a dry state becomes saturated (thus forming transient anaerobic conditions). Emissions of NH_3 and H_2S are influenced by pH. The manure pH affects the partitioning between these compounds and their ionized forms (NH_4^+ and HS^-), which are nonvolatile.

Temperature has two effects: (1) Temperature affects gas phase vapor pressure, and therefore, the volatility. For substances that are soluble in water (i.e., NH_3, some VOCs, H_2S and other reduced sulfur compounds), emissions will be greater at higher temperatures. Emission rates of these substances will be greater in warmer climates and in the summer rather than winter. Methane is insoluble in water, and at any temperature will be emitted very quickly after formation. (2) Higher temperature favors the microbial processes that generate CH_4 and other substances.

Long periods of manure residence time in, either confinement, storage or stabilization facilities, provide greater opportunities for anaerobic breakdown and volatilization to the air. In addition, masses emitted will increase with time. The amount of sulfur ingested by an animal will affect the potential for H_2S production in manure. Sulfur can be present in feed additives and, in some cases, from water supplies. The amount of nitrogen in feed (proteins and amino

acids) affects NH_3 and nitrous oxide emission potential. The amount of carbon affects CH_4 and CO_2 potential. Ensuring that the composition of feedstuffs does not exceed the nutritional needs of the animal will reduce emissions.

2.4 NAEMS Open-Source Monitoring Sites

The following section provides an overview of the NAEMS open source monitoring sites listed in Table 2-1. For more detail on the sites and the monitoring conducted, please see the site monitoring plans and final reports provided in Appendix D.

2.4.1 Dairy Sites

Three dairy lagoons were monitored under the NAEMS (Table 2-1). The sites were selected to capture different stages and manure practices typical of the industry. The sites selected also represent the broad geographical extent of dairy production to also represent different climatological settings for farm and any regional differences in farm practices.

Dairy lagoon emissions were to be measured continuously at one farm (IN5A) for one year and for up to 21 days each season for two years at the three remaining farms (WA5A and WI5A). Sampling periods for each site are also listed in Table 2-1.

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Table 2-1. Summary of NAEMS Open-Source Sites

Site	Phase[a]	Source Type	Manure Collection	Monitoring Period									
				1	2	3	4	5	6	7	8	9	10
IN4A	Sow	Lagoon	PP[b]	7/1/07 - 8/31/07	9/1/07 - 11/30/07	12/1/07 – 2/28/08	3/1/08 – 5/31/08	6/1/08 - 7/14/08					
NC4A[c]	Sow	Lagoon	PPR[d]		10/4/07 - 10/22/07	1/29/08 - 2/11/08	3/31/08 - 4/16/08	8/13/08 - 9/2/08	9/4/08 - 9/23/08	1/14/09 - 2/2/09	4/28/09 - 5/11/09	7/1/09 - 7/21/09	
OK4A[c]	Sow	Lagoon	PPR	6/27/07 - 8/29/07	11/7/07 - 11/27/07	11/28/07 - 12/18/07	4/23/08 - 5/6/08		10/1/08 - 10/15/08	1/8/09 - 1/27/09	4/1/09 - 4/21/09	6/25/09 - 7/14/09	
IA3A	Finisher	Lagoon	PP		8/30/07 - 9/26/07	12/19/07 - 1/15/08	5/14/08 - 6/4/08	6/4/08 - 6/25/08	11/13/08 - 11/25/08	11/25/08 - 12/16/08	4/8/09 - 4/23/09	7/28/09 - 8/17/09	
NC3A	Finisher	Lagoon	PPR		10/24/07 - 11/7/07	2/13/08 - 3/5/08	3/6/08 - 3/26/08		9/25/08 - 10/14/08	2/4/09 - 2/23/09	5/12/09 - 6/2/09	6/2/09 - 6/22/09	9/24/09 - 12/1/09
OK3A	Finisher	Lagoon	PPR		8/30/07 - 9/18/07	1/24/08 - 2/19/08	5/7/08 - 5/29/08	5/29/08 - 6/10/08	11/5/08 - 12/2/08	12/2/08 - 12/16/08	4/23/09 - 5/14/09	7/15/09 - 8/4/09	
IN5A	Dairy	Lagoon	Scrape						9/11/08 - 11/30/08	12/1/08 - 2/28/09	3/1/09 - 5/31/09	6/1/09 - 8/17/09	
WA5A	Dairy	Lagoon	Flush			2/25/08 - 3/12/08	3/12/08 - 3/26/08	8/8/08 - 9/3/08	9/3/08 - 9/26/08		5/18/09 - 6/4/09	6/4/09 - 6/20/09	
WI5A[c]	Dairy	Lagoon	Flush	7/18/07 - 8/28/07	11/13/07 - 11/28/07	11/28/07 - 12/18/07	4/23/08 - 5/13/08	6/25/08 - 7/14/08	10/21/08 - 11/11/08	12/17/08 - 1/7/09	3/10/09 - 4/7/09		

[a] Characterizes type of farm.
[b] PP= pull-plug pit.
[c] Area site that also had barns sites.
[d] PPR = pull-plug pit with recharge.

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2.4.1.1 IN5A

The Indiana dairy consisted of three barns, a feed storage area, special needs barn, milking parlor, an office and tool and repair shops (Figure 2-1). Construction of the dairy was completed in 2002. The farm has a capacity of 2,600 cows.

Manure was vacuumed from the lactating cow barns and special needs barn every 12 hrs and placed in lagoons near the barns. Manure was flushed from the holding area and milking parlor every half hour. Manure from the barns was scraped into pits that are located at the end of each barn (Figure 2-1). A small fraction of scraped waste was held in a slurry tank. The wastewater (flush) from the holding area and milking parlor was transferred into a rectangular settling lagoon south of the road then into the waste lagoon south of the road. The inlet to the lagoon was located at its north end. The clay-lined waste lagoon was 85 m (280 ft) wide and 116 m (380 ft) long, and is oriented north to south. At maximum capacity, the liquid depth was 5 m (16 ft) with a surface area of 9,884 m^2 (106,400 ft^2) and volume of 48,200 m^3 (1,702,400 ft^3). Sludge had never been removed from the lagoon.

Figure 2-1. Aerial View of IN5A

2.4.1.2 WA5A

The Washington farm consisted of six barns, a milking parlor, and an office (Figure 2-2). The facility had a capacity of 4,400 milking cows and 1,200 dry cows in three units. Construction of the dairy was completed in 2002.

The farm had freestall style barns, with automated flushing that occurred four times daily. Manure was transferred to the upper lagoon from a sand separation pit. The two earthen-lined settling lagoons were located to the south of the barns, and were used in alternate years. Liquids were skimmed, separated and returned as flush to the barns. One lagoon was actively filled while the other was drying or sludge was being entirely removed. The settled solids (sludge) were completely removed within a year by front-end loader. These removed solids were then strained through screens and centrifugal/screw presses with the liquid transferred to large serpentine concrete basins for secondary settling. These settled solids were then dried for bedding. Removed water from the settled solids was stored in a large clarified water storage basin for dilution of barn flush water from the lagoon. Sludge from the settling basins prior to complete removal was periodically applied on surrounding land utilizing underground pressurized pipes and a no-till soil injector. Wastewater entered the measured lagoon from the northwest corner.

Gaseous emissions occur both during lagoon filling and during sludge removal. The east lagoon was rectangular with dimensions of 183 m (600 ft) by 72 m (235 ft). The west lagoon was five-sided with dimensions of approximately 183 m (600 ft) long and 83 m (271 ft) wide with the southwest corner of the lagoon cut off. The east lagoon was measured for gaseous emissions. At maximum capacity this lagoon had a liquid depth of 5 m (18 ft), surface area of 13,098 m^2 (141,000 ft^2) and a volume of 186,300 m^3 (2,005,500 ft^3). Sludge was last removed from the lagoon in 2006.

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Figure 2-2. Aerial View of WA5A

2.4.1.3 WI5A

The Wisconsin farm had a total of six barns, a milking parlor with holding pen and a special needs area. The farm had a capacity of 1,700 Holstein cows. Construction of the dairy was completed in 1994.

Manure from the freestall barns and the milking parlor complex was removed by flushing three times daily. The manure flushed from the parlor, holding pen, and freestall barns flowed to a solids separator, from which the solids are removed and stacked on a pad until they are spread on fields (the nearest of which is approximately 100 m (328 ft) from the barns) (Figure 2-3). The liquid effluent from the solids separator was pumped back into vertical tanks for reuse to flush the barns. Once a week, enough water was removed from the third stage of the three-stage lagoon and added to the flush tanks to compensate for water lost in the recycled flush system. The lagoons were pumped out into trucks twice yearly. The first and second stages of the three-stage lagoon system were monitored (Figure 2-3). The first lagoon had a width of 52 m (170 ft) and length of 82 m (270 ft). At maximum capacity, the first lagoon had a surface area of 4,264 m^2 (45,900 ft^2) and a volume of 10,561 m^3 (373,000 ft^3). The second lagoon had a width of 37 m (120 ft) and length of 79 m (260 ft). At maximum capacity, the second lagoon had a

surface area of 2,898 m^2 (31,200 ft^2) and a volume of 6,420 m^3 (226,700 ft^3). Both lagoons had liquid depths of 3 m (11 ft) and sludge was last removed from the second lagoon in 2006.

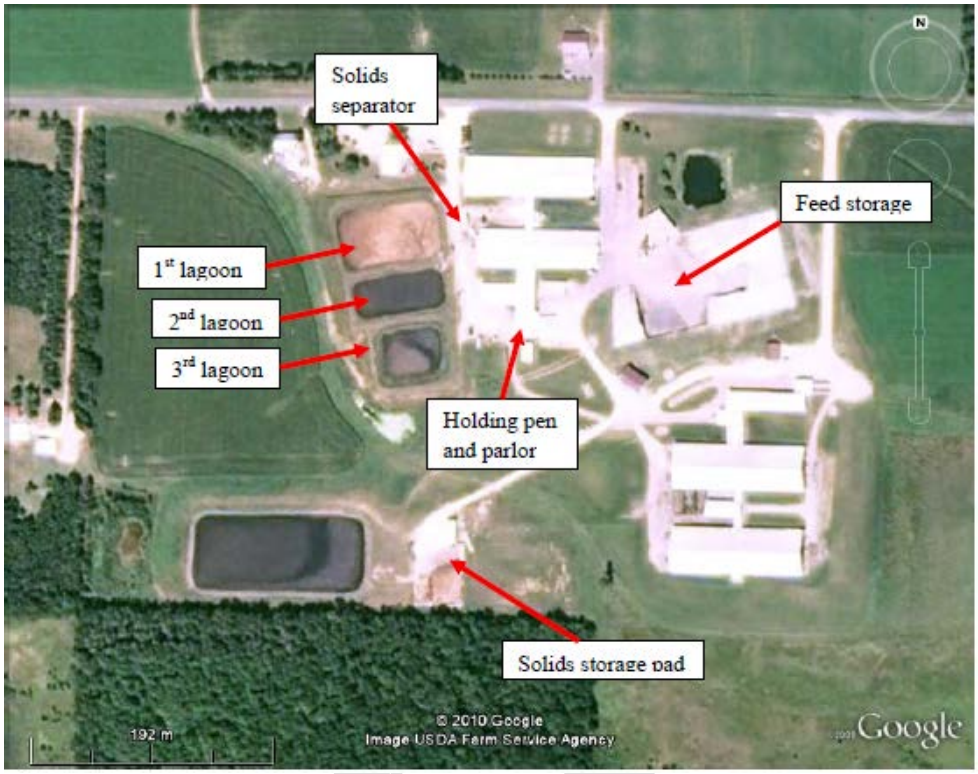

Figure 2-3. Aerial View of WI5A

2.4.2 Swine Sites

The six swine farms that had lagoons monitored as part of the NAEMS are listed in Table 2-1. The swine manure lagoon emissions were measured continuously at one farm (IN4A) for one year and up to 21 days for each season over two years at the remaining farms (IA3A, NC3A, NC4A, OK3A, OK4A). The sampling periods for each site are also listed in Table 2-1. Sites for monitoring were selected to capture different stages (i.e., breeding-gestation and growing-to-fishing) and manure practices typical of the industry. The sites also represent the broad geographical extent of swine production to also represent different climatological settings for farm and any regional differences in farm practices.

2.4.2.1 IN4A

The Indiana breeding/gestation farm consisted of nine barns and a lagoon (Figure 2-4), and had a capacity of 1,400 sows. The facility had been added to for many years, starting

operations in 1968, while the last building addition was completed in 1992. In 1998, the facility was changed from a finisher operation to a farrow-to-wean operation.

Liquid waste from the deep pits of the barns was transferred once every two weeks to the lagoon by a single inlet on the east side of the lagoon (Figure 2-4). The lagoon was south from the barns. The clay-lined waste lagoon was 111 m (365 ft) by 115 m (378 ft). At maximum capacity, the liquid depth was 4 m (12 ft) with surface area of 11,240 m^2 (121,000 ft^2) and a volume of 33,975 m^3 (1,200,000 ft^3). Sludge has never been removed from the lagoon. During the growing season, corn completely surrounded the lagoon.

Figure 2-4. Aerial View of IN4A

2.4.2.2 NC4A

The breeding/gestation farm in North Carolina consisted of three barns, one each of gestation, breeding, and farrowing, and an office (Figure 2-5). The facility had a capacity of 2,000 sows in three units. Construction of the farm was completed in 1994.

Manure from the barns was transferred once a week from the gestation, farrowing, and breeding barns to the lagoon by pull plug with lagoon water recharge of the pits. Wastewater from all three buildings combined into one inlet (SW corner of lagoon- Figure 2-5). The waste

lagoon was located to the north of the barns. The clay-lined, trapezoidal-shaped lagoon was oriented east to west and measured 125 m (410 ft) wide and 190 m (624 ft) long. The lagoon had a surface area of 23,193 m^2 (249,672 ft^2) and a volume of 56,851 m^3 (2,077,450 ft^3). At the beginning of the NAEMS, the sludge depth was approximately 0.7 m (2 ft). Liquid was removed as weather permitted. Sludge from the lagoon had not been removed since construction (15-yr sludge removal cycle). Barns on this farm were also monitored as a part of the NAEMS.

Figure 2-5. Aerial View of NC4A

2.4.2.3 OK4A

The Oklahoma breeding/gestation farm consists of three barns and one office (Figure 2-6). The facility has a capacity of 2,784 sows. Construction of the sow farm was completed in 1994.

Manure from the barns was transferred weekly from the two gestation units and every 2.5 weeks from the farrowing unit to the lagoon by pull plug and lagoon water recharge. Waste water from the two gestation units combined into one inlet (the southerly inlet in Figure 2-6), while wastewater from the farrowing unit entered the lagoon from the northerly inlet (Figure 2-6). The rectangular waste lagoon was located to the east and was separated by a

drainage swale from the barns. The clay-lined lagoon was 117 m (383 ft) wide and 193 m (632 ft) long, and was oriented north to south. Liquid depth was approximately 5.5 m (18 ft). The lagoon had a surface area of 22,486 m^2 (242,056 ft^2) and volume was approximately 72,800 m^3 (4,357,008 ft^3). Sludge from the lagoon has not been removed since construction (20-yr sludge removal cycle). Field applications occurred up to two times per year, based on rainfall.

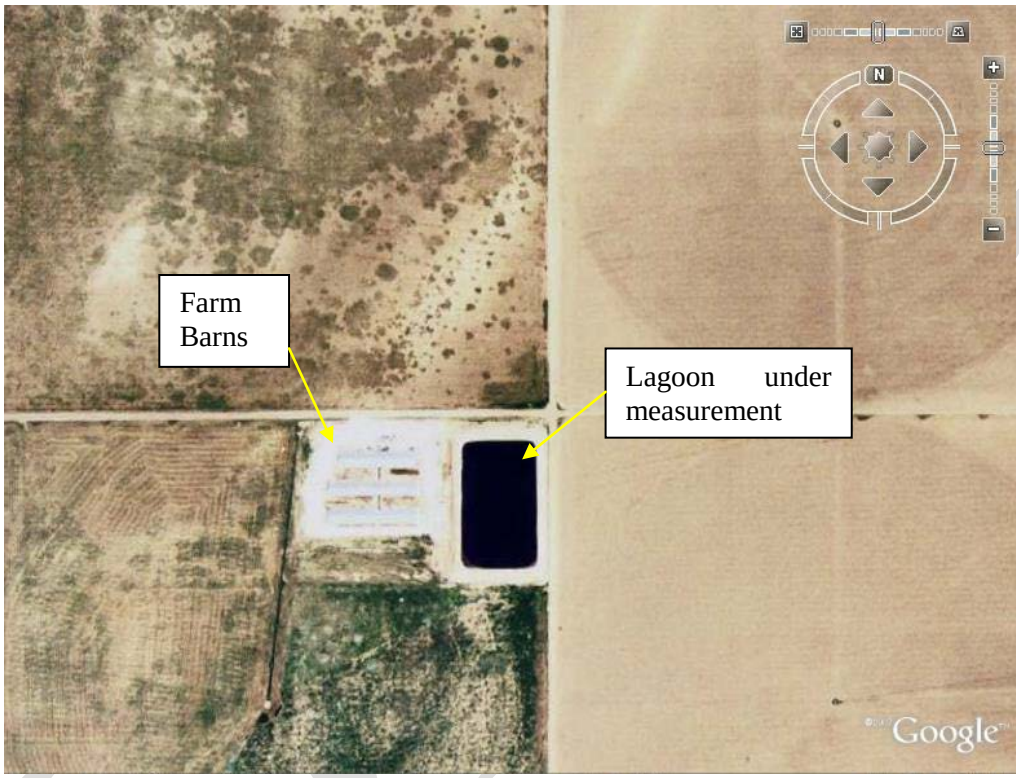

Figure 2-6. Aerial View of OK4A

2.4.2.4 IA3A

The growing/finishing farm in Iowa consisted of four barns and a manure lagoon (Figure 2-7). The facility had a capacity of 3,840 finishers in the four units. The construction of the facility was completed in 1998.

Manure from the 2 ft deep pits in each of the four barns was transferred to the lagoon, which was west of the barns (Figure 2-7), approximately once every ten weeks through two inlets (Figure 2-7). The concrete, circular structure had a diameter of 55 m (180 ft) with its sides approximately 0.5 m (1.5 ft) above and 2 m (6.5 ft) below ground level. At maximum capacity the structure had a liquid depth of 2 m (7 ft), surface area of 2,363 m^2 (25,442 ft^2) and a volume of 5,763 m^3 (203,537 ft^3). Sludge had never been removed from the lagoon.

Figure 2-7. Aerial View of IA3A

2.4.2.5 NC3A

The North Carolina growing/finishing farm consisted of five barns (Figure 2-8) and an office, in addition to the lagoon itself. The facility had a capacity of 8,000 finishing pigs in five units. Construction of the farm was completed in 1996.

Manure from the barns was transferred daily to the lagoon by pull plug and lagoon water recharge. Wastewater combined into one inlet (Figure 2-8). The rectangular waste lagoon was located to the north and was separated by a drainage swale from the barns. The clay-lined lagoon was 113 m (370 ft) wide and 173 m (568 ft) long and was oriented east to west. The lagoon had a maximum liquid depth of 3.3 m (11 ft), a surface area of 18,986 m^2 (204,386 ft^2) and a volume of 45,961 m^3 (1,623,326 ft^3). Wastewater was removed for irrigation as weather permitted. Sludge from the lagoon had not been removed since construction (15-year sludge removal cycle).

Figure 2-8. Aerial View of NC3A

2.4.2.6 OK3A

The Oklahoma growing/finishing farm consisted of three barns (Figure 2-9). The facility had a maximum capacity of 3,024 finishing pigs. Construction was completed in 1997.

Manure from the barns was transferred three times a week to the lagoon by a pull plug system with lagoon water recharge. Wastewater from all three units combined into one inlet. The waste lagoon was rectangular and was located to the west of the barns (separated by a drainage swale). The clay-lined lagoon was 59 m (193 ft) wide and 208 m (683 ft) long, and was oriented north to south. At maximum capacity, the lagoon had a liquid depth of 6 m (20 ft) with a surface area of 11,203 m^2 (120,600 ft^2) and a volume of 28,637 m^3 (1,011,463 ft^3). Liquid was removed approximately every six months. Sludge from the lagoon had not been removed since construction (20-yr sludge removal cycle).

Figure 2-9. Aerial View of OK3A

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3.0 DATA AVAILABLE FOR EEM DEVELOPMENT

In the Air Compliance Agreement, the EPA committed to developing EEMs for estimating daily and annual emissions from swine and dairy lagoons using the emissions and process data collected under the NAEMS and any other relevant data and information that are available. Section 3.1 summarizes the NAEMS emissions and process data for swine and dairy lagoons. Section 3.2 discusses the other relevant data that the EPA has gathered both under a Call for Information (CFI) that was issued by the Agency on January 19, 2011 and through previously-conducted literature searches.

3.1 NAEMS Data

3.1.1 Data Received

The EPA received final reports and data spreadsheets for three swine breeding and gestation operations (sites IN4A, NC4A and OK4A), three swine growing and finishing operations (sites IA3A, NC3A and OK3A), and three dairy operations (sites IN5A, WA5A and WI5A). In general, the final reports for each site describe the monitoring locations and sampling methods and present the results of the emissions measurements expressed in various units (e.g., daily average emissions in kg NH_3/day, g NH_3/day-head and g NH_3/day-animal unit). The final reports also contain summaries of producer activities at the site (e.g., lagoon pump-out events), notable weather conditions, lagoon appearance and the results of liquid sampling events that occurred during the monitoring period. Appendix D contains the final reports submitted for each monitoring site. Microsoft Excel® spreadsheets containing 30-minute values for emissions and lagoon condition data and 5-minute values for meteorological data were also submitted to the EPA.

To increase public involvement and maintain transparency throughout the EEMs development process, the EPA has made information and data relating to the NAEMS available at http://www.epa.gov/airquality/agmonitoring/. This website provides links to background information regarding the Air Compliance Agreement, the NAEMS (including information describing the monitoring sites, site-specific data files and final reports) and the EPA's CFI. Additionally, the EPA has included all information received pertaining to the NAEMS in the public docket (EPA Docket ID No. EPA-HQ-OAR-2010-0960), which is available at: http://www.regulations.gov.

Table 3-1 summarizes the emissions and process data elements that were required to be monitored by either the NAEMS Monitoring Protocol, the QAPPs, the SMPs or the SOP documents submitted to the EPA. The NAEMS Monitoring Protocol was developed in a

collaborative effort by representatives from the EPA, USDA, AFO industry representatives, agricultural researchers, state and local air quality agencies and environmental organizations. The NAEMS Monitoring Protocol identified the parameters to be monitored during the study and, for some parameters, specific measurement methodologies and frequencies. For those parameters for which either or both the measurement methodology and frequency was not specified, the study's Science Advisor provided the specific information in the study's QAPP. Table 3-1 also provides specific information regarding data availability that is based upon the EPA's review of the final reports and data spreadsheets.

During its review of the final reports and data spreadsheets, the EPA identified missing emissions and process data. A summary of the issues and discrepancies identified by the EPA's review are presented in Section 5. The EPA's review of the data spreadsheets also identified that the daily and 30-minute emissions values reported by the NAEMS researchers contained negative values. After discussion with the study's Science Advisor, it was determined the negative values were a result of instrumentation drift, and are considered to be valid values. To avoid possible complications with EEM development (e.g., the EEM predicting negative emissions), the negative values were withheld from the data sets used for EEM development. The amount of measured negative values is low (less than 2 percent) compared to the total number of emissions records for NH_3, which indicates that the steps taken to calibrate and maintain instrumentation and to minimize the influence of other on-site sources of ambient NH_3 emissions were reasonably effective. Because of their relatively small number, excluding the negative values does not compromise the EEM datasets for NH_3. The EPA's review of the data spreadsheets also identified daily average emissions and parameter values that were exactly zero. After further review and discussion with the study's Science Advisor, it was determined the values were valid reported values and were used for EEM development.

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Table 3-1. NAEMS Emissions and Process Parameter Data Received

Parameter Information				NAEMS Data		
Parameter	**Required by the NAEMS Monitoring Protocol**	**Measurement Methodology**	**Measurement Frequency**	**Data Description**	**Measurement Methodology**	**Measurement Frequency**
Concentrations						
NH_3	Yes	Fourier transform infrared spectroscopy (FTIR) and UV differential optical absorption spectroscopy (UV–DOAS)	Not specified	Average measured concentration values	TDLAS/ Boreal Laser, Inc. GasFinder2, INNOVA 1412 multi-gas analyzer	Logged every 15 & 60 seconds, for up to 21 days per season; 30-minute averages and daily averages provided
H_2S	Yes	UV differential optical absorption spectroscopy (UV–DOAS)	Not specified	Average measured concentration values	UV differential optical absorption spectroscopy (UV–DOAS), pulsed fluorescence	Logged every 15 & 60 seconds, for up to 21 days per season; 30-minute averages and daily averages provided
Hydrocarbons emissions (continuous)	Yes	Fourier transform infrared spectroscopy (FTIR)	Not specified	Data not received [a]	PAS/ INNOVA 1412 multigas analyzer	Logged every 15 & 60 seconds, for 24 months
VOC Samples	Yes	Analysis of liquid samples	Not specified	Data not collected [b]		
Emissions						
NH_3	Yes	backward Lagrangian stochastic method (bLS) computed tomography (CT) method using Eulerian Gaussian statistics and a fitted wind profile from the two 3D sonic anemometers	Not specified	Average calculated emission rate values	Radial Plume Mapping (RPM) & backward Lagrangian stochastic method (bLS)	30-minute averages and daily averages provided
H_2S	Yes			Average calculated emission rate values	backward Lagrangian stochastic method (bLS) & Ratiometric Method	30-minute averages and daily averages provided
Hydrocarbons emissions (continuous)	Yes			Data not received [c]	Ratiometric to RPM Model	Data not received [c]
VOC Samples	Yes	WATER9 model	Not specified	Data not collected [b]		
Lagoon Parameters						
Lagoon temperature	Yes	Not specified		5-minute average values	Thermistor	Logged every minute for up to 21 days per season; 5-miute average values provided
pH	Yes	Not specified		5-minute average values	Electrochemical pH meter	Logged every minute for up to 21 days per season; 5-miute average values provided
Oxidation Reduction Potential	No	Not applicable		5-minute average values	ORP Sensor	Logged every minute for up to 21 days per season; 5-miute average values provided
Lagoon Solids depth	No	Not applicable		Partial data received [c]	Sludge level detector	One measurement per period at IN4A, NC4A, OK4A, NC3A and OK3A
Ambient Meteorological Parameters						
Wind speed	Yes	3D sonic anemometers at heights of 2 and 12 meters (m)	Not specified	5-minute average values	3D Sonic anemometer & Cup anemometer	Logged every 15 & 60 seconds for up to 21 day per season; 30-minute averages provided
Wind direction	Yes	3D sonic anemometers at heights of 2 and 12 meters (m)	Not specified	5-minute average values	3D Sonic anemometer & Cup anemometer	Logged every 15 & 60 seconds for up to 21 day per season; 30-minute averages provided
Solar radiation	Yes	Not specified		5-minute average values	Pyranometer	Logged every 15 & 60 seconds for up to 21 day per season; 5-minute averages provided

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Table 3-1. NAEMS Emissions and Process Parameter Data Received

Parameter Information				NAEMS Data		
Parameter	**Required by the NAEMS Monitoring Protocol**	**Measurement Methodology**	**Measurement Frequency**	**Data Description**	**Measurement Methodology**	**Measurement Frequency**
Ambient pressure	Yes	Not specified		5-minute average values	Aneroid barometer	Logged every 15 & 60 seconds for up to 21 day per season; 5-minute averages provided
Ambient temperature at site	Yes	Not specified		5-minute average values	Thermistor	Logged every 15 & 60 seconds for up to 21 day per season; 5-minute averages provided
Ambient relative humidity at site	Yes	Not specified		5-minute average values	Hygrometer	Logged every 15 & 60 seconds for up to 21 day per season; 5-minute averages provided
Surface Wetness	No	Not specified		5-minute average values	VAC resistance grid	Logged every 15 & 60 seconds for up to 21 day per season; 5-minute averages provided
Nitrogen Mass Balance						
pH of manure	No	Not applicable		Partial data received [d]	Electrochemical pH meter	Sporadic measurements received for NC4A, OK4A, IA3A, NC3A and OK3A.
NH_4 content of manure	No	Not applicable		Partial data received [d]	Kjeldahl/titrimetric	Sporadic measurements received for NC4A, OK4A, IA3A, NC3A and OK3A.
Solids content of manure	No	Not applicable		Partial data received [d]	Gravimetric	Sporadic measurements received for NC4A, OK4A, IA3A, NC3A and OK3A.
TKN content of manure	No	Not applicable		Partial data received [d]	Kjeldahl/titrimetric	Sporadic measurements received for NC4A, OK4A, IA3A, NC3A and OK3A.

[a] The QAPP mentions this parameter was measured; however, these data are not provided in the final report(s).
[b] Data not expected. This parameter is not referenced in the QAPP or final report.
[c] The QAPP mentions this parameter was to be measured once per period; however, these data are only provided for IN4A, NC4A, OK4A, NC3A and OK3A in the final report(s).
[d] The QAPP mentions this parameter was to be measured once per period or every 90 days; however, these data are only provided for NC4A, OK4A, IA3A, NC3A and OK3A in the final report(s) and do not always fall within monitoring periods. Also, the report is unclear if the range is for nitrogen or TKN.

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3.1.2 Emissions Levels Reported in the NAEMS Final Reports

Table 3-2 summarizes the average and maximum emissions cited in the final reports submitted to the EPA. The average and maximum daily values were reportedly based on all valid days over the site monitoring periods. A valid monitoring day is one in which 75 percent of the hourly average data values used to calculate the daily value were valid measurements. An hourly average is considered valid if 75 percent of the data recorded during that hour were valid. Data were invalidated due to special events (e.g., audits, calibrations and maintenance), failure of quality control limits (e.g., unreasonably low or high compared with normal ranges combined with supporting evidence that the values are not correct) or when a sample is contaminated. A summary of the major data invalidation events identified by the NAEMS researchers is provided in the final site reports (see Appendix D). The results of EPA's assessment of data completeness are presented in Section 4.

Table 3-2. Reported Emission Rates for NAEMS Lagoon Sites

Site	Average Farm Capacity[a] (head)	Average Animal Weight[a] (lbs)	Average Daily Emissions (kg/day)[b]		Maximum Daily Emissions (kg/day)[b]	
			NH_3 (RPM)	H_2S (bLS)	NH_3 (RPM)	H_2S (bLS)
IN4A	1,400 (sows)	475 (sows)/ 8 (piglets)	58.4 [c]	0.4	58.4 [c]	2.2
NC4A	2,000 (sows)	433 (sows)	70.8	0.3	102.8	1.0
OK4A	2,784	490 (sows)	177.2	8.4	317.9	25.3
IA3A	3,840	150	47.1	2.2	52.8	12.3
NC3A	8,000	135	58.2	2	117.8	10.4
OK3A	3,024	170	102.8	6.3	184.4	25.4
IN5A	2,600	1,500	23.4	0	34.6	42.9
WA5A	5,600	1,400	NA[d]	NA[d]	NA[d]	NA[d]
WI5A	1,700	1,400	NA[d]	0.6	NA[d]	1.9

[a] The average farm capacity and average animal weight values were based on the values provided by the growers in the SMPs.
[b] The emissions as provided in the final reports.
[c] Only one day met the 75% completeness criteria during the study; therefore the average and maximum daily emission values are the same.
[d] The site did not meet the 75% completeness criteria for any day during the study; therefore there are no average or maximum daily emission values.

3.2 Other Relevant Data

Since 2001, the EPA conducted several literature searches and a CFI to identify data and information that were relevant to support a preliminary investigation into air pollution from large AFOs (see the EPA's *Emissions From Animal Feeding Operations* (draft, August 15, 2001)). The EPA evaluated all of the articles and publications received through its own literature searches and obtained through the CFI to identify data and information that could be useful in developing EEMs for swine and dairy lagoons. In conducting this evaluation, the EPA retained for further consideration those resources that satisfied each of the following conditions:

- The resource pertained to monitoring conducted on lagoons at commercial sites.
- The resource contained emissions rates (e.g., mass/time, mass/animal) for NH_3, H_2S or VOC, or data to characterize the inputs or outputs necessary to construct a nitrogen mass balance across the lagoon.
- The resource used methods to measure the emissions concentrations, estimate the emissions rate and characterize mass balance parameters that were consistent with the NAEMS procedures.

The EPA then evaluated the resources that satisfied the Agency's initial review to determine if the data were appropriate for consideration in either developing the EEMs or assessing the predictive accuracy of the EEMs. Section 3.2.1 summarizes the EPA's CFI and the review of the resources obtained. Section 3.2.2 summarizes the Agency's review of the resources obtained by previous EPA literature searches.

3.2.1 CFI

The EPA issued a CFI on January 19, 2011, seeking peer-reviewed, quality-assured emissions and process data relevant to developing EEMs for animal feeding operations. The CFI was designed to help ensure that the Agency would obtain the broadest range of scientific data available. All data and information received by the EPA is contained in the public docket for the Air Compliance Agreement (EPA Docket ID No. EPA-HQ-OAR-2010-0960) and is available online at http://www.regulations.gov.

In the CFI, the EPA requested emissions and process data for AFOs in the broiler, swine, egg-layer, dairy, beef and turkey industries. Although the EPA is interested in all air pollutants emitted from animal confinement, manure storage and treatment and manure land applications sites associated with AFOs, the CFI specifically requested emissions data and related process information for NH_3, H_2S, PM_{10}, $PM_{2.5}$, TSP and VOC.

To ensure compatibility with the NAEMS data, the CFI requested that, to the extent possible, the emissions and related process data provided to the EPA be accompanied by documentation that addresses the following parameters:

General information:

- Description of AFO process measured (e.g., anaerobic lagoon).
- Location of AFO process measured (e.g., physical address, latitude/longitude coordinates of facility).
- Beginning and ending dates of the monitoring period.

Monitoring data:

- Plan for quality assurance and quality control procedures.

- Site-specific monitoring plan.
- Test methods, instrumentation and SOPs used to collect emissions and process data measurements.
- Results of audits conducted on instruments and procedures.
- Field notes and associated documentation collected during the study.
- Emissions data (raw or analyzed) and associated process data.
- Meteorological data, including average ambient temperature, relative humidity, pressure, wind speed, wind direction and insolation (solar radiation) for each day that the study was conducted.
- Sampling dates and times.
- Production data (e.g., quantity of milk produced per day or number of swine produced).
- Calculations and assumptions used to convert concentration data (e.g., ppmv) into mass emissions (e.g., lb/hr).

Animal confinement structures:

- Dimensions of structures monitored.
- Designed and permitted animal capacity.
- Type, age, number and weight of animals contained in the confinement structure over the duration of the monitoring period.
- Manure management system (e.g., pull-plug pit, scrape).
- Manure removal activities over the duration of the monitoring period.
- Ventilation method (i.e., natural or mechanical).
- Calculations and assumptions used to estimate the ventilation rate of the monitored confinement structure.
- Calibration procedures for instruments (e.g., flow meters, fan relays) used to collect data for calculating ventilation rate of the monitored confinement structure.
- Nitrogen content of process inputs and outputs (e.g., feed, water, bedding, eggs, milk).
- Nitrogen content of manure excreted.
- Description of any control device or work practice used in the monitored structure to reduce emissions.

Manure storage and treatment processes:

- Type, age, number, and weight of animals contributing manure to the storage and treatment process over the monitoring period.
- Dimensions of storage/treatment unit monitored (e.g., storage pile, tank, lagoon).

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- Design specifications of storage/treatment unit monitored (e.g., volume, volatile solids loading rate).
- Depth of settled solids in storage/treatment unit.
- Temperature, pH and reduction/oxidation potential of manure contained in the storage/treatment unit.
- Moisture, total solids, volatile solids, total Kjeldahl nitrogen and ammoniacal nitrogen content and pH of manure entering storage and treatment process over the monitoring period.

Manure land application sites:

- Type, age, number, and weight of animals contributing manure to the land application site.
- Method used to apply manure (e.g., direct injection, broadcast spreading and frequency of application).
- Area (e.g., acres, square feet) used for manure application over the monitoring period.
- Quantity and moisture content of manure applied.

Table 3-3 and Table 3-4 lists the articles and publications received by the EPA in response to the CFI that pertained to swine and dairy operations, respectively, and their possible application for the NAEMS. As shown in the tables, most of the articles and publications submitted to the EPA did not contain emissions or process data that met the EPA's initial review criteria (e.g., the measurement methods differed from the NAEMS methods). However, a few resources contained material composition data that could be used to supplement the nitrogen mass balance data collected by the NAEMS.

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Table 3-3. Review of Swine Lagoon Articles Received in Response to EPA's CFI

Year	Title - Author(s)	Brief Description	Relevant Data	Methodology	Possible Application for NAEMS
2008	*Characterizing ammonia and hydrogen sulfide emissions from a swine waste treatment lagoon in North Carolina* (Blunden, Aneja)	This study investigated the seasonal variations in NH_3 and H_2S flux from a swine waste storage lagoon. The lagoon physicochemical properties were also monitored	NH_3 emissions	NH_3 flux was measured with a dynamic flow-through chamber and a chemiluminescence analyzer (Model 17C).	This study used flux chambers to measure lagoon emissions rather than remote sensing techniques. Thus, applicability to EEM development is limited.
			H_2S emissions	H_2S flux was measured with a dynamic flow-through chamber system and a pulsed fluorescence H_2S/SO_2 analyzer (Model 450C).	
			Lagoon surface water temperature	Two Campbell Scientific 107 temperature probes	
			Lagoon pH	Model CSIM11 pH probe	
			Lagoon water total Kjeldahl nitrogen (TKN)	Samples were submitted to the North Carolina Division of Water Quality (NC DWQ) for TKN analysis.	
			Lagoon water total ammoniacal nitrogen	Samples were submitted to the NC DWQ for total ammoniacal nitrogen (TAN) analysis.	
			Lagoon water total sulfide concentration	Samples were submitted to the NC DWQ for total sulfide analysis.	
			Ambient meteorology: wind speed, wind direction, air temperature, relative humidity, solar radiation	Met One Instruments Model 034-B Windset, Model CS500-L Vaisala 50Y temperature and RH probe, Model LI200X Silicon Pyranometer, Model CSIM11 pH probe	
2000	*Characterization of Atmospheric Ammonia Emissions from Swine Waste Storage and Treatment Lagoons* (Aneja, Chauhan, Walker)	This study investigated the seasonal variations in NH_3 flux from a swine waste storage lagoon.	NH_3 emissions	NH_3 flux was measured using a dynamic flow-through chamber system floating and a series of gas analyzers. NH_3 concentration was determined by subtracting the NOx from the total N.	This study used flux chambers to measure lagoon emissions rather than remote sensing techniques. Thus, applicability to EEM development is limited.
			Lagoon surface water temperature	Continuous measurement with temperature probe (Fascinating Electronics)	

Table 3-3. Review of Swine Lagoon Articles Received in Response to EPA's CFI

Year	Title - Author(s)	Brief Description	Relevant Data	Methodology	Possible Application for NAEMS
			Lagoon pH	Measured continuously using a double junction submersible electrode (Cole Parmer)	
			TKN	Lagoon water samples taken daily and measured for TKN	
2008	*Characterizing Ammonia Emissions from Swine Farms in Eastern North Carolina: Part 1—Conventional Lagoon and Spray Technology for Waste Treatment* (Aneja, Pal Arya, Kim, Rumsey, Arkinson, Semunegus, Bajwa, Dickey, Stefanski, Mottus, Robarge, Williams)	NH_3 flux from waste treatment lagoons and barns at two conventional swine farms were measured. The waste treatment lagoon data were analyzed to elucidate the temporal (seasonal and diurnal) variability and to derive regression relationships between NH_3 flux and lagoon temperature, pH and ammonium content of the lagoon, and the most relevant meteorological parameters.	Lagoon NH_3 emissions	NH_3 flux from the lagoons was measured by a dynamic flow-through flux chamber system and a chemiluminescence analyzer (TEI Model 17C).	This study used flux chambers to measure lagoon emissions rather than remote sensing techniques. Thus, applicability to EEM development is limited.
			Lagoon surface water temperature	Temperature probes (Campbell Scientific Instruments Model 107)	
			Lagoon pH	pH probe (Innovative Sensors)	
			Lagoon water TKN	Not specified.	
			Lagoon water total nitrate and ammoniacal nitrogen	Not specified.	
			Meteorology: wind speed, wind direction, air temperature, relative humidity, solar radiation	Campbell Scientific Instruments CS500 temperature and relative humidity (RH) probe, a LI-Cor 200SZ pyranometer, and a Met One 034A-LC Windset anemometer and wind vane.	
2008	*Characterizing Ammonia Emissions from Swine Farms in Eastern North Carolina: Part 2—Potential Environmentally Superior Technologies for Waste Treatment* (Aneja, Pal Arya, Kim, Rumsey, Arkinson, Semunegus, Bajwa, Dickey, Stefanski, Mottus, Robarge, Williams)	NH_3 fluxes from waste water holding structures and barns at six swine farms using non-lagoon ESTs for waste treatment were measured two two-week periods in warm and cold seasons. NH_3 fluxes were measured on the water-holding structures by a flow through dynamic chamber system. Open-path Fourier transform infrared (FTIR) spectrometers were used	NH_3 flux from surface of water-holding structures	Continuous measurement, recorded 15 minute average, measured with dynamic flow-through chamber system	This study did not examine emissions from conventional swine waste lagoons, but it did compare emissions from these six farms to emissions from a conventional farm lagoon. Because this study used flux chambers to measure emissions, applicability to EEM development is limited.
			NH_3 emissions from the ventilation systems at animal houses	Measured with open-path Fourier transform infrared (OP-FTIR) spectroscopy. NH_3 emissions from barn houses were estimated from average NH_3 concentration measured by OP-FTIR and the rated flow rate for the fan size and setting.	

Table 3-3. Review of Swine Lagoon Articles Received in Response to EPA's CFI

Year	Title - Author(s)	Brief Description	Relevant Data	Methodology	Possible Application for NAEMS
		to measure NH_3 concentrations at the barn vent inlets and outlets for estimating NH_3 emissions from the animal housing units (barns).	Number of pigs, average and total pig mass (kg)	Not specified	
			Feed consumed (kg/pig/week)	Not specified	
			Feed N content (%)	Not specified	
			Nitrogen excretion (kg N/week/1000 kg live weight animals)	N excretion rate (E) in units of kg-N/week/1000 kg-lw) = Fc x Nf x (1-er)/w x 1000, where Fc is the feed consumed (kg/pig/week), Nf is the fraction of N content in feed, er is the feed efficiency rate (ratio of average gain of N to N intake), and w is the average live animal mass (kg/pig).	
2008	*Modeling Studies of Ammonia Dispersion and Dry Deposition at Some Hog Farms in North Carolina (*Bajwa, Pal Arya, Aneja)	This study investigated the NH_3 emissions and local deposition of NH_3 from the lagoons and barns of one hog farm. Dry deposition velocity, dispersion, and dry deposition of NH_3 were studied over different seasons and under different stability conditions using the short-range dispersion/air quality model, AERMOD.	Emissions data from the study *Characterizing Ammonia Emissions from Swine Farms in Eastern North Carolina: Part 1—Conventional Lagoon and Spray Technology for Waste Treatment (2008)* from the Barham and Moores farms. Dry deposition of NH_3 was modeled, not measured.	NH_3 flux measurements were made over waste lagoons using a dynamic flow-through chamber system.	This study has limited applicability to EEM development.

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Table 3-4. Review of Dairy Lagoon Articles Received in Response to EPA's CFI

Year	Title - Author(s)	Brief Description	Relevant Data	Methodology	Possible Application for NAEMS
2006	*Quality Assured Measurements of Animal Building Emissions: Gas Concentrations* (Heber, Ni, Lim, Tao, Schmidt, Koziel, Beasley, Hoff, Nicolai, Jacobson, Zhang)	This study focuses on the methodology of measuring gas concentration and the difficulty in achieving the desired results for livestock houses due to their unique traits.	None	Not applicable	None. The article provides an overview of the emissions monitoring system and instrumentation but does not contain emissions or process data.
2007	*Modeling Atmospheric Transport and Fate of Ammonia in North Carolina—Part I: Evaluation of Meteorological and Chemical Predictions* (Wu, Krishnan, Zhang, Aneja)	This study discusses the application of EPA's Community Multiscale Air Quality (CMAQ) modeling system to study the deposition and fate of NH_3 emissions from activities. Part I of the study describes the model configurations, evaluation protocols, databases and the operational evaluation for meteorological and chemical predictions.	None	Not applicable	None. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
2007	*Modeling Atmospheric Transport and Fate of Ammonia in North Carolina—Part II: Effect of Ammonia Emissions on Fine Particulate Matter Formation* (Wu, Hu, Zhang, Aneja)	This study discusses the application of EPA's CMAQ model to study the deposition and fate of NH_3 emissions from agricultural activities. Part II of the study describes the sensitivity simulations applied to various emission scenarios.	None	Not applicable	None. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
2008	*Ammonia Assessment from Agriculture: U.S. Status and Needs* (Aneja, Blunden, James, Schlesinger, Knighton, Gilliam, Jennings, Niyogi, Cole)	This article summarizes recent research on agricultural air quality and describes best management practices for reducing NH_3 emissions.	None	Not applicable	None. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
2008	*Auditing and Assessing Air Quality in Concentrated Feeding Operations* (Cole, Todd, Auvermann, Parker)	This paper discusses AFO emissions and the current air quality regulations and techniques for measuring and quantifying emissions.	None	Not applicable	None. The article does not contain emissions or process data that could be used to supplement the NAEMS data.

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Table 3-4. Review of Dairy Lagoon Articles Received in Response to EPA's CFI

Year	Title - Author(s)	Brief Description	Relevant Data	Methodology	Possible Application for NAEMS
2008	*Commentary: Farming Pollution* (Aneja, Schlesinger, Erisman)	This article provides commentary on the U.S. efforts to regulate farms. It provides general information related to agricultural emissions and the state of knowledge of processes and a comparison of U.S. regulations to European regulations.	None	Not applicable.	None. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
2009	*Ammonia Emissions and Animal Agriculture* (Gay, Knowlton)	This article provides general information regarding AFO emissions and the effects of farming on pollution.	None	Not applicable	None. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
2009	*Does Animal Feeding Operation Pollution Hurt Public Health? A National Longitudinal Study of Health Externalities Identified By Geographic Shifts In Livestock Production* (Sneeringer)	This article discusses an epidemiological study that assessed the relationship between livestock farming and infant mortality.	None	Not applicable	None. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
2009	*Effects of Agriculture upon the Air Quality and Climate: Research, Policy, and Regulations* (Aneja, Schlesinger, Erisman)	This article describes the state of the science and how research can be improved.	None	Not applicable	None. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
2009	*2008 Dairy Emissions Study - Summary of Dairy Emission Factors and Emission Estimation Procedures* (Schmidt, Card)	This study measured air emissions from the surface of feed (total mixed ration), silage, and the corral at two dairies in CA. Emissions for the entire dairy were calculated based on surface areas, and diurnal/seasonal variations in emission rates for each surface.	None	This study used an EPA surface emissions isolation flux chamber to measure emissions from the various surfaces at the dairies. TNMNEO emissions were quantified using South Coast Air Quality Management District (SCAQMD) Method 25.3. NH_3 was measured using SCAQMD Method 207.1.	None. This study did not measure emissions from a lagoon.

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3.2.2 Previous Literature Searches

Beginning in 2001, the EPA conducted several literature searches using the Agricultural Online Access (AGRICOLA) bibliographic database to identify data and information that were relevant to support a preliminary investigation into air pollution from large AFOs (see the EPA's *Emissions From Animal Feeding Operations* (draft, August 15, 2001)). The EPA also conducted literature searches to support development of the EPA's National Emissions Inventory (NEI) for NH_3 emissions from animal agricultural operations.

Table 3-5 and Table 3-6 lists additional articles and publications pertaining to swine and dairy operations, respectively, that the EPA identified through literature searches it conducted prior to the CFI. Articles that were common to both the CFI and previous literature searches are reported in Table 3-3 and Table 3-4 only. As shown in the Table 3-5 and Table 3-6, none of the articles previously obtained by the EPA to support emissions factor development used remote sensing techniques to measure lagoon emissions. Consequently, none of the articles were applicable for EEM development.

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Table 3-5. Review of Swine Lagoon Articles Obtained by Previous EPA Literature Searches

Date	Title	Author	Possible Application for NAEMS
1971	*Desorption of Ammonia from Anaerobic Lagoons*	Koelliker, Miner	None. This study used a mass balance method to estimate the amount of NH_3 lost from the storage lagoon due to desorption. Emissions were estimated, rather than measured. Consequently, these data were not considered for use in EEM development.
1981	*Storage of Piggery Slurry*	Williams, Evans	None. This study examined the changes in composition of swine manure over time. Changes in organic matter solubility, NPK value, BOD, odor offensiveness, and malodorous compounds were examined. Emissions rates were not examined. Consequently, these data were not considered for use in EEM development.
1988	*Odors of Swine Waste Lagoons*	Hammond, Heppner, Smith	None. This study focused on the effect of lagoon temperature on odor concentrations of emissions. Consequently, these data were not considered for use in EEM development.
1993	*Factors Affecting Ammonium Concentrations in Slurry from Fattening Pigs*	Aarnink, A., Hoeksma, and Ouwerkerk	None. This study investigated the effect of various factors (animal growth, feed protein content, feed intake, water-feed ratio) on the NH_3 content in the MESPRO model (NH_3 content of the swine waste slurry). This study did not measure NH_3 emissions. Consequently, these data were not considered for use in EEM development.
1994	*Biotreatment of Swine Manure by intensive Lagooning during winter*	Noue, Sevrin-Reyssac, Mariojouls, Marcel, and Sylvestre	None. This study investigated removal of nitrogen and phosphorus compounds from swine manure in a lagoon system consisting of algae ponds daphnid ponds and a polishing fish pond. This experiment did not evaluate emissions from the lagoon surface. Consequently, these data were not considered for use in EEM development.
1997	*Effect of Lagoon Aeration on Odor Emissions from a Swine Grow-Finish Facility*	Heber	None. This study focused on the methodology for collecting and analyzing samples for odor concentrations. Consequently, these data were not considered for use in EEM development.

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Table 3-5. Review of Swine Lagoon Articles Obtained by Previous EPA Literature Searches

Date	Title	Author	Possible Application for NAEMS
1998	*Ammonia Emissions from Swine Waste Lagoons in the Southeastern U.S. Coastal Plains*	Harper and Sharpe	None. This study investigated the effect of diurnal variations, seasonal variations, lagoon ammonium (NH_4^+) concentration, lagoon acidity, temperature, and wind turbulence on NH_3 emissions from two lagoons on two farms using gas sensors and meteorological instruments placed over the lagoons. NH_3 concentrations were determined using air drawn through gas washing bottles; wash water was examined using colorimetric analysis.
1999	Ammonia Emissions from Swine Waste Operations in North Carolina	Aneja, Bunton, Chauhan, Malik, Walker, Li	None. This study examined NH_3 emissions from six swine lagoons using a dynamic chamber system, with the intent of parameterizing the NH_3-N flux with respect to lagoon physicochemical properties for use in air quality modeling. Water temperature and water NH_3-N content were monitored, as were NH_3-N emissions. NH_3 emission rate was determined as a factor of temperature and water NH_3-N content. The article did not specify the method by which NH_3 in the flux chamber was measured.
1999	*Odor Emissions from a Swine Finishing Facility with a Surface-Aerated Lagoon*	Heber and Ni	None. This study focused on the methodology for collecting and analyzing samples for odor concentrations. Consequently, these data were not considered for use in EEM development.
1999	*Slurry Covers to Reduce Ammonia Emissions and Odour Nuisance*	Hornig, Turk, Wanka	None. This study investigated the effect of floating covers on swine waste lagoons at four farms as a means of reducing NH_3 and odor emissions. This study did not quantify NH_3 emissions. Consequently, these data were not considered for use in EEM development.
1999	*Stakeholders Feedlot Air Emission Data Collection Project: Final Report, 12/30/99*	Jacobson	None. This report presents the results of monitoring for NH_3, H_2S, and odor at five swine farms in Minnesota. Emissions were estimated from short-term grab samples. NH_3 concentrations were quantified using colorimetric tubes. H_2S concentrations were measured using a Jerome gas analyzer.

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Table 3-5. Review of Swine Lagoon Articles Obtained by Previous EPA Literature Searches

Date	Title	Author	Possible Application for NAEMS
2000	*Characterization of Atmospheric Ammonia Emissions from Swine Waste Storage and Treatment Lagoons*	Aneja, Chauhan, Walker	None. This study investigated the seasonal variation in NH_3 flux from a swine waste storage lagoon using a dynamic chamber system. Lagoon physicochemical properties (water temperature, NH_3-N content, and pH) were monitored. NH_3 flux was measured with a Measurement Technologies 1000N NH_3-to-NO converter and API Model 200 chemiluminescence based NO monitor.
2000	*A Comparison of the Performance of Three Swine Waste Stabilization Systems*	Martin, J.	None. This study compared emissions of CH_4, CO_2, and NH_3 from the surface of three lagoons (covered anaerobic lagoon with CH_4 capture, open lagoon with ozone injection, and open lagoon. The method for determining emissions was not discussed. Consequently, these data were not considered for use in EEM development.
2000	*Hydrogen Sulfide from Lagoons and Barns*	Secrest, C.	None. This one-page summary shows H_2S emissions from seven swine lagoons. The emissions were calculated based on results from four different estimation methods. Two of the methods were based on mass balance and two were based on measurements made in independent studies. Consequently, these data were not considered for use in EEM development.
2001	*Measurement and Analysis of Atmospheric Ammonia Emissions from Anaerobic lagoons*	Aneja, Bunton, Walker, Malik	None. This study examined the NH_3 flux from six anaerobic swine lagoons using a dynamic flux chamber system. Lagoon physicochemical properties (water temperature, NH_3-N content, and pH) were monitored. NH_3 flux was measured with a Measurement Technologies 1000N NH_3 to NO converter and API Model 200 chemiluminescence based NO monitor. The study examined the NH_3 flux as a factor of daily diurnal time, pH and water N content.
2001	*Measurement and Modeling of Ammonia Emissions at Waste Treatment Lagoon-Atmospheric Interface*	Aneja, Malik, Tong, Kang, Overton	None. This study investigated two mass transport models as predictive models for predicting NH_3 emissions from swine waste lagoons The model results were compared with NH_3 emission experiments at a swine lagoon. NH_3 emissions were measured using flux chambers.

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Table 3-5. Review of Swine Lagoon Articles Obtained by Previous EPA Literature Searches

Date	Title	Author	Possible Application for NAEMS
2002	*Methane Emissions from Swine lagoons in Southeastern U.S.*	Sharpe, Harper, Byers	None. This study measured the emissions of CH_4 from two swine waste lagoons. Meteorological conditions were monitored. Methane concentrations were measured above the lagoon at two heights with tunable diode laser spectroscopy. Lagoon water was sampled for total organic carbon, volatile solids, and pH.
2003	*Atmospheric Pollutants and Trace Gases--Odor and Gas Release from Anaerobic Treatment Lagoons for Swine Manure*	Lim, Heber, Ni, Sutton, Shao	None. This study analyzes the effect of lagoon loading rate on emissions of NH_3, H_2S, CO_2, SO_2 and NO from a swine lagoon using a buoyant conductive flux chamber for sampling concentrations above the lagoon surface, downwind air samplers for sampling concentrations on the lagoon berm, and a gas chromatograph for analyzing gas samples.

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Table 3-6. Review of Dairy Lagoon Articles Obtained by Previous EPA Literature Searches

Date	Title	Author	Possible Application for NAEMS
1991	*Nitrogen Concentration Variability in Dairy-Cattle Slurry Stored in Farm Tanks*	Patni, Jui	None. This study examined the nitrogen content of slurry stored in tanks over a period of several months. Emissions were not measured. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
1995	*Separation of Manure Solids from Simulated Flushed Manures by Screening or Sedimentation.*	Powers, Montoya, Van Horn, Nordstedt, Bucklin	None. This study investigated the amount of solids, nitrogen, phosphorus that could be removed from cow feces and urine diluted in water using screening versus various precipitation methods. NH_3 emissions from lagoons were not measured. The article does not contain emissions or process data that could be used to supplement the NAEMS data.
1999	*Wheat Straw Cover for Reducing Ammonia and Hydrogen Sulfide Emissions from Dairy Manure Storage*	Xue, S.K., S. Chen, R.E. Hermanson	None. This study investigated the use of wheat straw cover for reducing NH_3 and H_2S emissions from liquid manure. The study was conducted in the laboratory and using pilot-scale tanks. The method used to analyze the gas samples was not specified in the article.
2002	*Particulate and Dissolved Phosphorus Chemical Separation and Phosphorus Release from Treated Dairy Manure*	Dao, Daniel	None. This study investigated the effect of water treatment polymers and phosphorus immobilizing chemicals on particulate and dissolved reactive phosphorus reduction mechanisms in dairy manure. The article does not contain emissions or process data that could be used to supplement the NAEMS data.

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4.0 NAEMS DATA PREPARATION

This section provides an overview of the data assessment procedures followed by the NAEMS researchers in collecting the emissions and process parameter data from the swine and dairy lagoon monitoring sites and the procedures followed by the EPA in preparing the data for use in development of EEMs for lagoons.

Section 4.1 discusses the Quality Assurance/Quality Control (QA/QC) procedures outlined in the NAEMS QAPP to ensure collection of high-quality emissions and process data. Section 4.2 summarizes the steps the EPA followed to process and review the data submitted to the EPA prior to developing the lagoon EEMs. Section 4.3 compares the design and operating parameters and reported emissions of each site.

4.1 NAEMS Data Assessments

4.1.1 QA/QC Procedures

The NAEMS researchers followed QA/QC procedures throughout the data collection and preliminary data analyses processes. The NAEMS researchers developed QAPPs, SOPs for sampling systems and monitoring instruments and site-specific monitoring plans (SMPs) and provided training for on-site operators and producers. Appendix A contains the QAPPs, Appendix B contains the SMPs for each monitoring site and Appendix C contains the SOPs.

Remote sensing instruments, synthetic open-path sampling systems, and gas analyzers underwent initial and periodic calibration, bias and precision checks and were corrected if they failed the QC checks. The frequency of each check/calibration event was dependent on the type of instrument and on the site investigators. For example, the calibration checks were conducted daily, at the beginning and end of each measurement period, every 180 days at Purdue Air Monitoring Lab (PAML), annually or a combination of these intervals.

All of the monitoring sites were equipped with data acquisition (DAQ) systems that allowed on-site operators, and other authorized personnel via high-speed Internet connection, to view the measured data and parameter values daily through real-time computer displays. The DAQ systems also generated email notifications for project personnel when monitored parameter values were outside of preset ranges.

The NAEMS researchers also used control charts extensively in QA/QC procedures to assess data quality and measurement variability and to evaluate long-term trends in the instrument/equipment performance. The control charts provided a graphical means of determining whether the measured parameters were within acceptable upper and lower control

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limits. Data values outside the control limits triggered corrective actions by site operators to maintain data quality. The control charts were generated on site using Microsoft ® Excel templates to provide a real-time assessment of the data quality.

Measurement data recorded at each site were transferred to PAML each day for review and evaluation. The NAEMS field operations staff used custom-designed software to apply flags to measurement data that were considered invalid or outliers and to calculate emissions rates for the lagoons.

4.1.2 Data Validation

In general, the NAEMS researchers invalidated measurement data if the data values were:

- Unreasonably low or high when compared to normal ranges if there was supporting evidence that the data value is not correct (e.g., lagoon temperature sensor producing a reading of less than -40 ° C).
- Obtained during system installation, testing or maintenance during which uncorrectable errors might be introduced.
- Obtained when a sensor or instrument was proven to be malfunctioning (e.g., unstable).
- Obtained during calibration or precision check of a sensor or instrument and before the sensor or instrument reached equilibrium after the check.
- Obtained when the data acquisition and control hardware and/or software were not functioning correctly.

Data that the NAEMS researchers deemed invalid were retained in the preprocessed data sets. However, the EPA did not use the flagged data to calculate pollutant emissions rates.

For averaged data, data were invalidated to avoid errors introduced into calculated mean values due to partial-data days (e.g., only a few hours of valid data) that would result in biased time weights:

- Daily means were invalidated if less than 75 percent of the 30-minute intervals recorded during that day were valid.
- Quarters, or monitoring periods, achieved the 75-percent completeness criteria if 7.5 days of valid daily measurements were obtained during a 10-day period.
- Three of the four quarters each year must attain the quarterly completeness criteria for the year to be adequately represented in the study results.

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4.1.3 Data Completeness

As specified in the open-source QAPP, the goal of the NAEMS was to measure emissions from lagoons at nine farms that represented the dominant manure management systems for each animal type. At each of the nine sites, data were collected on a continuous and intermittent basis.

4.1.3.1 Continuous Data

For the swine and dairy sites, the continuous sampling program under the NAEMS consisted of long- and short-term monitoring. Under long-term monitoring, continuous measurements were taken over a one-year period at a single site for each animal type (site IN4A for swine and site IN5A for dairy). The short-term monitoring consisted of continuous measurements taken at multiple sites on a rotating sampling schedule over a two-year period. Meteorological and lagoon liquid data were recorded as 5-minute average values, and emissions data were reported as 30-minute averages. These data were aggregated by the NAEMS researchers to obtain daily values.

Consistent with the EPA's *Guidance for Quality Assurance Project Plans* (EPA QA/G-5), data completeness is defined as the measure of the amount of valid data obtained from a measurement system, compared to the amount of data that was expected to be obtained under normal conditions. Data completeness is expressed as the percent of valid data obtained from the measurement system. For data to be considered valid, they must meet all the acceptance criteria. As specified in the NAEMS QAPP, a valid day for a pollutant or process parameter was one in which more than 75 percent of the 30-minute measurement values recorded were valid (i.e., 36 half hours in the day passed all QA checks). The long-term monitoring sites had a second completeness goal to obtain valid emissions measurements for 75 percent of the total number of monitoring days on site (273 days would meet daily completeness criteria). For the short-term monitoring sites, the second completeness goal was to obtain emissions measurements for 10 days per quarter. The duration of the sampling events at any one site was dictated by weather conditions with a maximum duration of 21 days per quarter. The maximum duration was intended to ensure that the data quality indicator of 75 percent completeness of 10 days per quarter would not be prevented by adverse weather. Table 4-1 summarizes the monitoring schedule, the number of valid emissions days and data completeness by site. Table 4-1 also shows the quarter and season corresponding to each monitoring day. To simplify the seasonal assignments, if the monitoring period overlapped with another season by less than 15 days, the EPA assigned the monitoring period to the season that had the majority of days. The EPA assigned monitoring periods that overlapped the next season by more than 15 days as mixed-season periods (e.g., Fall/Winter). In the development of EEMs, the EPA considered all valid data days regardless of whether or not the NAEMS completeness goal was achieved.

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At all of the short-term monitoring sites, the measurement instrumentation was on site for at least once each quarter/season over the 2-year monitoring period. For NH_3 emissions calculated using the RPM model, the 75-percent completeness criteria was achieved only at site OK4A. The final reports submitted to EPA do not discuss data completeness and do not provide detailed reasons for why the completeness goals were not achieved.

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Table 4-1. Reported Number of Valid Emissions Days by Site

Site ID	Monitoring Period	Start Date	End Date	Quarter	Season[a]	Days On Site	No. of Valid Emissions Days				Data Completeness			
							NH_3 RPM	NH_3 bLS	H_2S bLS	H_2S Ratio	NH_3 RPM	NH_3 bLS	H_2S bLS	H_2S Ratio
IN4A[b]	1	7/1/2007	8/31/2007	3	Summer	61	0	7	0	0	0%	11%	0%	0%
	2	9/1/2007	11/30/2007	4	Fall	90	0	19	0	0	0%	21%	0%	0%
	3	12/1/2007	2/28/2008	1	Winter	89	0	0	6	0	0%	0%	7%	0%
	4	3/1/2008	5/31/2008	2	Spring	91	0	9	3	0	0%	10%	3%	0%
	5	6/1/2008	7/14/2008	3	Summer	43	1	2	6	0	2%	5%	14%	0%
NC4A	2	10/4/2007	10/22/2007	4	Fall	18	0	0	0	0	0%	0%	0%	0%
	3	1/29/2008	2/11/2008	1	Winter	13	0	2	0	0	0%	20%	0%	0%
	4	3/31/2008	4/16/2008	2	Spring	16	0	6	3	0	0%	60%	30%	0%
	5	8/13/2008	9/2/2008	3	Summer	20	0	1	3	0	0%	10%	30%	0%
	6	9/4/2008	9/23/2008	4	Fall	19	1	6	5	2	10%	60%	50%	20%
	7	1/14/2009	2/2/2009	1	Winter	19	0	1	1	0	0%	10%	10%	0%
	8	4/28/2009	5/11/2009	2	Spring	13	0	0	0	6	0%	0%	0%	60%
	9	7/1/2009	7/21/2009	3	Summer	20	3	0	0	5	30%	0%	0%	50%
OK4A	1	6/27/2007	8/29/2007	3	Summer	63	9	12	0	0	**90%**	**120%**	0%	0%
	2	11/7/2007	11/27/2007	4	Fall	20	0	2	0	0	0%	20%	0%	0%
	3	11/28/2007	12/18/2007	1	Winter	20	0	5	0	0	0%	50%	0%	0%
	4	4/23/2008	5/6/2008	2	Spring	13	0	2	2	0	0%	20%	20%	0%
	6	10/1/2008	10/15/2008	4	Fall	14	2	7	7	1	20%	70%	70%	10%
	7	1/8/2009	1/27/2009	1	Winter	19	0	0	2	0	0%	0%	20%	0%
	8	4/1/2009	4/21/2009	2	Spring	20	10	10	8	0	**100%**	**100%**	**80%**	0%
	9	6/25/2009	7/14/2009	3	Summer	19	9	8	5	1	**90%**	**80%**	50%	10%
IA3A	2	8/30/2007	9/26/2007	4	Fall	27	0	2	0	0	0%	20%	0%	0%
	3	12/19/2007	1/15/2008	1	Winter	27	0	7	0	0	0%	70%	0%	0%
	4	5/14/2008	6/4/2008	2	Spring	21	0	3	0	0	0%	30%	0%	0%
	5	6/4/2008	6/25/2008	2	Spring	21	0	5	1	0	0%	50%	10%	0%
	6	11/13/2008	11/25/2008	4	Fall	12	0	6	3	0	0%	60%	30%	0%
	7	11/25/2008	12/16/2008	4/1	Fall/ Winter	21	0	4	1	0	0%	40%	10%	0%
	8	4/8/2009	4/23/2009	2	Spring	15	0	3	1	0	0%	30%	10%	0%
	9	7/28/2009	8/17/2009	3	Summer	20	4	2	0	1	40%	20%	0%	10%
NC3A	2	10/24/2007	11/7/2007	4	Fall	14	0	0	0	0	0%	0%	0%	0%
	3	2/13/2008	3/5/2008	1	Winter	21	0	2	1	0	0%	20%	10%	0%
	4	3/6/2008	3/26/2008	2	Spring	20	0	1	1	0	0%	10%	10%	0%
	6	9/25/2008	10/14/2008	4	Fall	19	0	0	0	0	0%	0%	0%	0%

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Table 4-1. Reported Number of Valid Emissions Days by Site

Site ID	Monitoring Period	Start Date	End Date	Quarter	Season[a]	Days On Site	No. of Valid Emissions Days				Data Completeness			
							NH_3 RPM	NH_3 bLS	H_2S bLS	H_2S Ratio	NH_3 RPM	NH_3 bLS	H_2S bLS	H_2S Ratio
	7	2/4/2009	2/23/2009	1	Winter	19	2	1	0	1	20%	10%	0%	10%
	8	5/12/2009	6/2/2009	2	Spring	21	0	0	0	0	0%	0%	0%	0%
	9	6/2/2009	6/22/2009	3	Summer	20	1	0	0	1	10%	0%	0%	10%
	10	9/24/2009	12/1/2009	4	Fall	68	0	4	4	0	0%	40%	40%	0%
OK3A	2	8/30/2007	9/18/2007	4	Fall	19	4	8	0	0	40%	**80%**	0%	0%
	3	1/24/2008	2/19/2008	1	Winter	26	0	8	2	0	0%	**80%**	20%	0%
	4	5/7/2008	5/29/2008	2	Spring	22	1	6	7	0	10%	**60%**	70%	0%
	5	5/29/2008	6/10/2008	3	Summer	12	0	8	2	0	0%	**80%**	20%	0%
	6	11/5/2008	12/2/2008	4	Fall	27	0	7	5	0	0%	**70%**	50%	0%
	7	12/2/2008	12/16/2008	1	Winter	14	0	3	0	0	0%	30%	0%	0%
	8	4/23/2009	5/14/2009	2	Spring	21	0	4	5	0	0%	40%	50%	0%
	9	7/15/2009	8/4/2009	3	Summer	20	4	6	3	2	40%	60%	30%	20%
IN5A[b]	6	9/11/2008	11/30/2008	4	Fall	80	8	22	5	0	10%	28%	6%	0%
	7	12/1/2008	2/28/2009	1	Winter	89	0	15	4	0	0%	17%	4%	0%
	8	3/1/2009	5/31/2009	2	Spring	91	8	27	10	1	9%	30%	11%	1%
	9	6/1/2009	8/17/2009	3	Summer	77	2	9	5	0	3%	12%	6%	0%
WA5A	3	2/25/2008	3/12/2008	2	Spring	13	0	0	0	0	0%	0%	0%	0%
	4	3/12/2008	3/26/2008	2	Spring	14	0	0	0	0	0%	0%	0%	0%
	5	8/8/2008	9/3/2008	3	Summer	26	0	0	0	0	0%	0%	0%	0%
	6	9/3/2008	9/26/2008	4	Fall	23	0	0	0	0	0%	0%	0%	0%
	8	5/18/2009	6/4/2009	2	Spring	16	0	1	0	0	0%	10%	0%	0%
	9	6/4/2009	6/20/2009	3	Summer	15	0	0	0	0	0%	0%	0%	0%
WI5A	1	7/18/2007	8/28/2007	3	Summer	41	0	0	0	0	0%	0%	0%	0%
	2	11/13/2007	11/28/2007	4	Fall	15	0	4	0	0	0%	40%	0%	0%
	3	11/28/2007	12/18/2007	1	Winter	20	0	2	0	0	0%	20%	0%	0%
	4	4/23/2008	5/13/2008	2	Spring	20	0	2	0	0	0%	20%	0%	0%
	5	6/25/2008	7/14/2008	3	Summer	19	0	3	1	0	0%	30%	10%	0%
	6	10/21/2008	11/11/2008	4	Fall	21	0	5	2	0	0%	50%	20%	0%
	7	12/17/2008	1/7/2009	1	Winter	21	0	1	0	0	0%	10%	0%	0%
	8	3/10/2009	4/7/2009	2	Spring	28	0	5	3	0	0%	50%	30%	0%

[a] The seasons are defined in the NAEMS open-source QAPP as follows: Fall= September, October, November; Winter= December, January, February; Spring= March, April, May; Summer= June, July, August.

[b] Long-term monitoring was conducted at this site.

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4.1.3.2 Intermittent Data

The intermittent data collected under the NAEMS consisted of lagoon composition data, lagoon coverage and animal inventory values. For the lagoon composition data, the QAPP states that samples of manure were to be collected at the lagoons every measurement period (i.e., four times per year). Table 4-2 summarizes the manure sampling schedule for each site, the availability of composition data and whether or not the sampling data coincided with the monitoring periods for each site. Although most of the sites reported liquid composition data once per measurement period, the sampling dates rarely coincided with a NAEMS monitoring date. Considering alignment with the NAEMS monitoring dates, the data completeness goal for liquid composition data of quarterly sampling was not achieved at any of the NAEMS monitoring sites. Liquid composition data were not collected at site WA5A and the data for sites IN4A, IN5A and WI5A were reported as ranges and the sampling dates were not provided.

Completeness criteria for the lagoon coverage and animal inventory values were not specified in the QAPP. Table 4-3 shows the dates that observations were recorded for lagoon coverage. Table 4-4 shows the dates for which an animal inventory value were provided.

Table 4-2. Summary of Intermittent Data

Site	Sampling Date	Number of Samples	Content Data Available?					Sampling Date Coincident w/NAEMS Monitoring Date?
			pH	Nitrogen	Solids	NH_3	Sulfur	
IN4A	The final report contained ranges of composition data without sampling dates.							Unknown
NC4A	12/1/2006	1	Y	Y	N	N	Y	N
	1/24/2007	1	Y	Y	N	N	Y	N
	3/22/2007	1	Y	Y	N	N	Y	N
	4/19/2007	1	Y	Y	N	N	Y	N
	6/15/2007	1	Y	Y	N	N	Y	N
	8/1/2007	1	Y	Y	N	N	Y	N
	9/25/2007	1	Y	Y	N	N	Y	N
	11/20/2007	1	Y	Y	N	N	Y	N
	1/24/2008	1	Y	Y	N	N	Y	N
	5/16/2008	1	Y	Y	N	N	Y	N
	7/9/2008	1	Y	Y	N	N	Y	N
	8/26/2008	1	Y	Y	N	N	Y	N
	10/15/2008	1	Y	Y	N	N	Y	N
	2/18/2009	1	Y	Y	N	N	Y	N
	4/3/2009	1	Y	Y	N	N	Y	N
	4/3/2009	1	Y	Y	N	N	Y	N
	5/25/2009	1	Y	Y	N	N	Y	N
	5/26/2009	1	Y	Y	N	N	Y	N
	7/17/2009	1	Y	Y	N	N	Y	Y
	8/31/2009	1	Y	Y	N	N	Y	N
	12/16/2009	1	Y	Y	N	N	Y	N

Table 4-2. Summary of Intermittent Data

Site	Sampling Date	Number of Samples	Content Data Available?					Sampling Date Coincident w/NAEMS Monitoring Date?
			pH	Nitrogen	Solids	NH_3	Sulfur	
OK4A	11/1/2008	1	Y	Y	Y	Y	Y	N
IA3A	6/4/2008	3	Y	N	Y	Y	N	Y
	4/9/2009	3	Y	Y	Y	Y	N	Y
	4/15/2009	3	Y	Y	Y	Y	N	N
	7/29/2009	3	Y	Y	Y	Y	Y	Y
NC3A	12/1/2006	1	Y	Y	N	N	Y	N
	1/24/2007	1	Y	Y	N	N	Y	N
	3/22/2007	1	Y	Y	N	N	Y	N
	4/19/2007	1	Y	Y	N	N	Y	N
	6/15/2007	1	Y	Y	N	N	Y	N
	8/6/2007	1	Y	Y	N	N	Y	N
	9/27/2007	1	Y	Y	N	N	Y	N
	11/20/2007	1	Y	Y	N	N	Y	N
	1/23/2008	1	Y	Y	N	N	Y	N
	3/25/2008	1	Y	Y	N	N	Y	Y
	5/16/2008	1	Y	Y	N	N	Y	N
	7/10/2008	1	Y	Y	N	N	Y	N
	8/26/2008	1	Y	Y	N	N	Y	N
	10/15/2008	1	Y	Y	N	N	Y	N
	12/16/2008	1	Y	Y	N	N	Y	N
	2/18/2009	1	Y	Y	N	N	Y	Y
	3/31/2009	1	Y	Y	N	N	Y	N
	5/21/2009	1	Y	Y	N	N	Y	Y
	7/13/2009	1	Y	Y	N	N	Y	N
	9/1/2009	1	Y	Y	N	N	Y	N
OK3A	11/28/2007	1	Y	Y	Y	Y	Y	N
	11/19/2008	1	Y	Y	Y	Y	Y	Y
	7/17/2009	1	Y	Y	Y	Y	Y	Y
IN5A	The final report contained ranges of composition data without sampling dates.							Unknown
WA5A	None	N	N	N	N	N	N	Not applicable
WI5A	The final report contained ranges of composition data without sampling dates.							Unknown

Table 4-3. Dates of Lagoon Coverage Observations

Site	Observation Date
IN4A	07/20/2007 - 03/12/2008, 07/24/2007 - 03/17/2008, 08/08/2007 - 03/20/2008, 08/10/2007 - 03/21/2008, 08/15/2007 - 04/07/2008, 08/16/2007 - 04/08/2008, 08/17/2007 - 04/14/2008, 08/20/2007 - 04/15/2008, 08/22/2007 - 04/30/2008, 08/23/2007 - 05/01/2008, 08/30/2007 - 05/12/2008, 09/04/2007 - 05/20/2008, 09/05/2007 - 05/21/2008, 09/12/2007 - 05/27/2008, 09/19/2007 - 05/28/2008, 09/20/2007 - 06/05/2008, 10/04/2007 - 06/19/2008, 10/18/2007 - 06/20/2008, 10/23/2007 - 06/24/2008, 11/01/2007 - 07/01/2008, 11/13/2007 - 07/02/2008, 11/15/2007 - 07/03/2008, 01/29/2008 - 07/08/2008, 01/30/2008 - 07/14/2008, 01/31/2008 - 07/15/2008, 02/12/2008 - 07/16/2008, 3/5/2008

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Table 4-3. Dates of Lagoon Coverage Observations

Site	Observation Date
NC4A	10/2/2007, 10/3/2007, 10/4/2007, 10/5/2007, 10/22/2007, 1/29/2008, 1/30/2008, 1/31/2008, 2/1/2008, 2/11/2008, 2/12/2008, 3/31/2008, 4/1/2008, 4/2/2008, 4/14/2008, 4/15/2008, 4/16/2008, 4/17/2008, 8/12/2008, 8/13/2008, 8/14/2008, 8/26/2008, 9/2/2008, 9/3/2008, 9/4/2008, 9/22/2008, 9/23/2008, 1/14/2009, 1/15/2009, 1/16/2009, 2/2/2009, 2/3/2009, 4/28/2009, 4/29/2009, 5/11/2009, 5/12/2009, 6/30/2009, 7/1/2009, 7/21/2009, 7/22/2009
OK4A	6/27/2007, 6/28/2007, 7/9/2007, 7/18/2007, 7/19/2007, 7/30/2007, 7/31/2007, 8/1/2007, 8/2/2007, 8/3/2007, 8/4/2007, 8/18/2007, 8/16/2007, 8/28/2007, 8/29/2007, 11/7/2007, 11/8/2017, 11/27/2007, 11/28/2007, 12/18/2007, 12/19/2007, 4/23/2008, 4/24/2008, 5/6/2008, 10/1/2008, 10/2/2008, 10/14/2008, 10/15/2008, 1/7/2009, 1/8/2009, 1/27/2009, 4/1/2009, 4/2/2009, 4/21/2009, 6/23/2009, 6/24/2009, 6/25/2009, 7/14/2009
IA3A	08/30/2007 - 06/24/2008, 08/31/2007 - 11/12/2008, 09/17/2007 - 11/13/2008, 09/18/2007 - 11/14/2008, 09/26/2007 - 11/25/2008, 12/19/2007 - 12/15/2008, 12/20/2007 - 12/16/2008, 01/14/2008 - 04/08/2009, 01/15/2008 - 04/09/2009, 05/14/2008 - 04/22/2009, 05/15/2008 - 04/23/2009, 06/04/2008 - 07/27/2009, 06/05/2008 - 07/28/2009, 06/12/2008 - 07/29/2008, 06/23/2008 - 08/18/2009
NC3A	10/24/2007, 10/25/2007, 10/26/2007, 11/7/2007, 2/13/2008, 2/14/2008, 3/6/2008, 3/26/2008, 3/27/2008, 9/24/2008, 9/25/2008, 2/4/2009, 2/5/2009, 2/6/2009, 2/24/2009, 5/12/2009, 5/14/2009, 6/3/2009, 6/22/2009, 6/23/2009, 9/22/2009, 9/23/2009, 9/24/2009, 10/13/2009, 10/26/2009, 10/27/2009, 11/10/2009, 11/11/2009, 12/2/2009
OK3A	8/30/2007, 8/31/2007, 9/18/2007, 9/19/2007, 1/24/2008, 1/25/2008, 2/5/2008, 2/6/2008, 2/19/2008, 5/6/2008, 5/7/2008, 5/8/2008, 5/19/2008, 5/28/2008, 5/29/2008, 6/10/2008, 11/5/2008, 11/6/2008, 11/7/2008, 11/17/2008, 12/2/2008, 12/3/2008, 12/16/2008, 4/21/2009, 4/22/2009, 4/23/2009, 5/6/2009, 5/14/2009, 7/14/2009, 7/15/2009, 7/16/2009, 8/4/2009
IN5A	9/11/2008, 9/16/2008, 9/24/2008, 10/8/2008, 10/9/2008, 10/10/2008, 10/22/2008, 10/27/2008, 10/28/2008, 11/19/2008, 11/20/2008, 12/9/2008, 12/10/2008, 12/11/2008, 12/29/2008, 12/30/2008, 1/12/2009, 1/21/2009, 1/23/2009, 1/29/2009, 2/9/2009, 2/13/2009, 2/25/2009, 5/26/2009, 5/28/2009, 6/9/2009, 6/15/2009, 6/16/2009, 6/23/2009, 7/2/2009, 7/8/2009, 7/9/2009, 7/10/2009, 7/15/2009, 7/16/2009, 7/20/2009, 7/22/2009, 7/23/2009, 8/12/2009, 8/18/2009
WA5A	2/25/2008, 2/26/2008, 2/27/2008, 2/28/2008, 2/29/2008, 3/12/2008, 3/13/2008, 3/26/2008, 8/8/2008, 8/9/2008, 8/10/2008, 8/11/2008, 8/12/2008, 8/13/2008, 9/4/2008, 9/26/2008, 5/19/2009, 5/20/2009, 5/21/2009, 6/4/2009, 6/19/2009
WI5A	7/17/2007, 7/18/2007, 7/19/2007, 8/6/2007, 8/7/2007, 8/9/2007, 8/28/2007, 11/13/2007, 11/14/2007, 11/27/2007, 11/28/2007, 11/29/2007, 12/17/2007, 12/18/2007, 4/24/2008, 5/12/2008, 5/13/2008, 6/24/2008, 6/25/2008, 7/14/2008, 7/15/2008, 11/11/2008, 12/17/2008, 12/18/2008, 1/6/2009, 1/7/2009, 3/9/2009, 3/10/2009, 4/6/2009, 4/7/2009

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Table 4-4. Dates or Animal Inventory Records

Site[a]	Monitoring Period	Dates for Which an Inventory Value Was Provided[b]
OK4A	2	11/6/2007 – 11/28/2007
	3	11/28/2007 - 12/19/2007
	4	4/22/2008 - 5/6/2008
	6	9/30/2008 - 10/15/2008
	7	1/7/2009 – 1/27/2009
	8	4/1/2009 - 4/21/2009
	9	6/22/2009 - 7/14/2009
IA3A	2	8/30/2007 - 9/26/2007
	3	12/19/2007 -1/15/2008
	4	5/14/2008 - 6/4/2008
	5	6/4/2008-6/25/2008
	6	11/13/2008-11/25/2008
	7	11/25/2008 - 12/16/2008
	8	4/8/2009-4/23/2009
	9	7/28/2009 - 8/17/2009
NC3A	2	10/24/2007 - 11/7/2007
	3	2/13/2008 - 3/5/2008
	4	3/6/2008 - 3/26/2008
	6	9/25/2008 - 10/14/2008
	7	2/4/2009 - 2/23/2009
	8	5/12/2009 - 6/2/2009
	9	6/2/2009 - 6/22/2009
	10	9/24/2009 - 12/2/2009
OK3A	3	1/24/2008 - 2/19/2008
	4	5/7/2008 - 5/29/2008
	5	5/29/2008 - 6/10/2008
	6	11/4/2008 -12/3/2008
	7	12/3/2008 - 12/16/2008
	8	4/21/2009 - 5/14/2009
	9	7/14/2009 - 8/4/2009
IN5A	6	9/11/2008 -11/30/2008
	7	12/1/2008 - 2/28/2009
	8	3/1/2009 - 5/31/2009
	9	6/1/2009 - 8/17/2009
WA5A	3	2/25/2008 - 3/12/2008
	4	3/12/2008 - 3/26/2008
	5	8/8/2008 - 9/3/2008
	6	9/3/2008 - 9/26/2008
	8	5/18/2009 - 6/4/2009
	9	6/4/2009 - 6/20/2009
WI5A	1	7/17/2007 - 8/28/2007
	2	11/12/2007 - 11/29/2007
	3	11/29/2007 - 12/18/2007
	4	4/22/2008 - 5/13/2008
	5	6/24/2008 - 7/15/2008
	6	10/20/2008 - 11/11/2008
	7	12/17/2008 -1/7/2009
	8	3/09/2009 - 4/7/2009

[a] Inventory data were not provided for sites IN4A and NC4A.
[b] A single inventory value was reported for the time period.

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4.2 EPA Assessments

4.2.1 Data Processing

The NAEMS researchers provided the daily emissions, lagoon conditions and ambient meteorological data to the EPA in the form of final site reports (pdf format). The EPA also received Microsoft Excel® spreadsheets that contained emissions and lagoon condition data reported as 30-minute average values and ambient meteorological data reported as 5-minute average values.

Due to the very limited number of daily NH_3 emissions values reported, the EPA prepared a database of half-hour values by combining the 30-minute emissions data and 5-minute meteorological data provided by the NAEMS researchers. To obtain values for each meteorological variable for a given half-hour, the EPA used the mean of the 5-minute data values within that half hour, as long as at least one of the values was not missing. Because it is unlikely that the value of any of these variables would vary enough within the consecutive 5-minute periods that comprise a half hour to significantly change the mean value of the variable during the half-hour, applying a completeness criterion to this aggregation would unnecessarily reduce an already limited data set. In the data aggregation, the EPA did not include any 30- or 5-minute data that had been flagged by the NAEMS researchers as invalid.

4.2.2 Data QA

The EPA developed a comprehensive list of the emissions, farm and lagoon operating parameters, meteorological data and other information that were expected to be submitted to the EPA by the NAEMS researchers based on the EPA's review of the QAPPs, SOPs and SMPs. As the final reports and data spreadsheets were received from the NAEMS researchers, the EPA compared the information received to the comprehensive list to identify missing information. After determining whether the data submittals to the EPA were complete and identifying missing data elements, the EPA verified that the units of measurement for the emissions and supporting data were consistent between the final reports and spreadsheet data files. In addition, the EPA assessed whether the units of measurement and the magnitude of emissions were consistent across the monitoring sites. The EPA prepared and provided summaries of the missing data elements to the NAEMS researchers.

The EPA's review identified that the daily and 30-minute emissions values reported by the NAEMS researchers contained negative values. Table 4-5 shows the number of negative emissions by pollutant and measurement method.

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Table 4-5. Negative Emissions Values by Pollutant and Measurement Method

Pollutant	Measurement Method	No. of Valid Emissions Values		No. of Negative Emissions Values		Percent Negative	
		Daily	30-min	Daily	30-min	Daily	30-min
NH_3	RPM	69	17,292	0	134	0%	1%
	bLS	285	6,416	18	1,108	6%	17%
H_2S	Ratiometric	21	6,325	1	876	5%	14%
	bLS	117	3,963	2	816	2%	21%

After discussion with the NAEMS Science Advisor, the EPA determined that the negative emission values occurred due to drift in the instrument readings between calibrations. The EPA did not include the negative values when developing EEMs for swine and dairy lagoons to avoid possible complications with EEM development (e.g., the EEM predicting negative emissions) the negative values were withheld from the data sets used for EEM development. The EPA's review also identified a few instances (less than 2 percent) of zero emission values (i.e., instances where the upwind/background and downwind concentrations were the same). However, because the zero values were not the result of instrument drift, the EPA included the zero emissions values in the data sets used in the development of the EEMs for lagoons.

4.2.3 Emissions Data Completeness Assessment

The EPA assessed the data completeness of the average daily emissions values to verify the completeness goals specified in the lagoon QAPP. The final reports did not include assessments of data completeness. Based upon its analysis, the EPA confirmed that the completeness goal for the two long-term monitoring sites was not achieved. Additionally, the completeness goal for the short-term monitoring sites was achieved only at site OK4A.

The EPA looked at the seasonal distribution of the data to determine if any pollutant was under-represented during a particular season (see Table 4-6 and Table 4-7). The NAEMS QAPP for lagoons defined the seasons as follows:

- Spring: March 1 through May 31.
- Summer: June 1 through August 31.
- Fall: September 1 through November 30.
- Winter: December 1 through February 28.

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Table 4-6. Number of Valid Emissions Days Available in the Spring and Summer

Site ID	Spring				Summer			
	NH_3 RPM	NH_3 bLS	H_2S bLS	H_2S Ratiometric	NH_3 RPM	NH_3 bLS	H_2S bLS	H_2S Ratiometric
IN4A	0	9	2	0	1	9	9	0
NC4A	0	6	3	0	3	1	2	1
OK4A	10	12	10	6	18	20	5	5
IA3A	0	6	1	0	4	7	1	1
NC3A	0	1	1	0	1	0	0	1
OK3A	1	11	12	0	4	13	5	2
IN5A	8	27	10	1	2	9	5	0
WA5A	0	0	0	0	0	1	0	0
WI5A	0	7	3	0	0	3	1	0

Table 4-7. Number of Valid Emissions Days Available in the Fall and Winter

Site ID	Fall				Winter			
	NH_3 RPM	NH_3 bLS	H_2S bLS	H_2S Ratiometric	NH_3 RPM	NH_3 bLS	H_2S bLS	H_2S Ratiometric
IN4A	0	19	0	0	0	0	4	0
NC4A	1	6	6	1	0	3	1	0
OK4A	2	10	7	2	0	4	2	0
IA3A	0	8	3	0	0	11	1	0
NC3A	0	4	4	0	2	3	1	1
OK3A	4	15	5	0	0	11	2	0
IN5A	8	16	4	0	0	21	5	0
WA5A	0	0	0	0	0	0	0	0
WI5A	0	11	2	0	0	1	0	0

The seasonal distributions of valid NH_3 and H_2S emissions were weighted towards the spring and summer. At the other sites, the seasonal distributions of the emissions data were relatively consistent across each season. However, during each season, the amount of H_2S emissions data collected was lower than the NH_3 emissions data collected.

4.3 Comparison of Lagoon Monitoring Sites

Table 4-8 summarizes the configuration of each of the lagoon monitoring sites. The EPA developed comparative statistics and graphs of emissions data for each site to determine if there were any notable differences or data anomalies among the sites at the process, location or emissions level. Each of these comparisons is discussed in more detail in the following sections.

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Table 4-8. NAEMS Data for Swine and Dairy Lagoon Confinement Operations

Site	Animal Sector	Confinement Description	Unit Measured	Manure Management System
IN4A	Swine	Sow	Anaerobic lagoon	Deep pit (emptied once every two weeks)
OK4A	Swine	Sow	Anaerobic lagoon	Pull plug pit w/pit recharge (emptied weekly from the two gestation units and every 2.5 weeks from the farrowing unit)
NC4A	Swine	Gestation, farrowing, and breeding	Anaerobic lagoon	Pull plug pit w/pit recharge (emptied once every week)
IA3A	Swine	Grow/finish	Storage lagoon	Deep pit (emptied ~ every 10 weeks)
NC3A	Swine	Grow/finish	Anaerobic lagoon	Pull plug pit w/pit recharge (emptied daily)
OK3A	Swine	Grow/finish	Anaerobic lagoon	Pull plug pit w/pit recharge (emptied 3 times a week)
IN5A	Dairy Lagoon	Milking Operation	Anaerobic lagoon	Scrape (daily)
WA5A	Dairy Lagoon	Milking Operation	Upper lagoon	Freestall flush (4 times/day)
WI5A	Dairy Lagoon	Milking Operation	1st and 2nd stages of the 3-stage lagoon system	Freestall, flush (3 times/day) w/solids separation

4.3.1 Process-Level Comparison

Table 4-9 summarizes the design and operating parameters for the lagoon sites. For the dairy sites, WA5A is the largest operation with 5,600-cow capacity, which is a large farm for the industry according to the 2007 USDA Census of Agriculture. Average animal weight across the dairies is comparable.

For the swine breeding/gestation farms, IN4A is the smallest operation with a capacity of 1,400 sows, while OK4A has the largest capacity at 2,784 sows. All three sites represent some of the larger breeding/gestation operations, compared to other farms in the industry. Average sow weight at the farms is comparable.

The swine grow/finish operations have more variation in size with both IA3A and OK3A having just over 3,000-head capacity and NC3A with a capacity of 8,000 head. The average animal weight for these site represents the average weight over the entire growing cycle, where the animal starts out as an approximately 14 pound piglet and final market weight of 250 pounds or more.

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Table 4-9. Design and Operating Parameters of the NAEMS Swine and Dairy Lagoon Sites

Site	Farm Capacity (hd)	Animal Sector	Average Animal Weight (lb)	Confinement Description
IN4A	1,400 (sows)	Swine	475 (sows)/ 8 (piglets)	Sow
OK4A	2,784	Swine	490	Sow
NC4A	2,000 (sows)	Swine	433 (sows)	Gestation, farrowing, and breeding
IA3A	3,840	Swine	150	Grow/finish
NC3A	8,000	Swine	135	Grow/finish
OK3A	3,024	Swine	170	Grow/finish
IN5A	2,600	Dairy	1,500	Milking Operation
WA5A	5,600	Dairy	1,400	Milking Operation
WI5A	1,700	Dairy	1,400	Milking Operation

*Weight information not provided

4.3.2 Comparison of Local Meteorological Conditions

Table 4-10 summarizes the reported site-specific ambient and confinement conditions for each monitoring site. Ambient temperature varied greatly across the sites, with a minimum temperature at IN5A of -29.20 °C (-20.57 °F) and a maximum observed temperature of 41.37 °C (106.47 °F). NC4A had the highest average temperature at 18.07 °C (64.52 °F) and IN5A had the lowest average temperature at 4.47 °C (40.04 °F). The relative humidity observed during the study ranged from 5.05 to 100 percent. Site NC3A had the highest average humidity at 76.35 percent and WA5A had the lowest reported average humidity at 43.13 percent.

Lagoon liquid temperatures ranged from -0.51 °C (31.08 °F) at IN4A to 21.95 °C (95.01 °F) at IN5A. Lagoon temperature data were not available for IA3A and WA5A for any of the NAEMS monitoring periods. Lagoon temperature values were also not available when the surface of the lagoon liquid froze, which explains why there few lagoon temperatures reported below 0 °C.

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Table 4-10. Site-Specific Ambient and Lagoon Conditions

Monitoring Site	Ambient				Lagoon	
	Temperature (°C)		Relative Humidity (%)		Temperature (°C)	
	Average	Range [Min, Max]	Average	Range [Min, Max]	Average	Range [Min, Max]
IN4A	11.33	[-20.32, 33.59]	75.31	[17.03, 100.00]	16.53	[-0.51, 34.11]
NC4A	18.07	[-10.68, 33.90]	74.34	[18.74, 100.00]	20.61	[2.34, 35.01]
OK4A	12.88	[-12.77, 40.97]	57.35	[6.00, 100.00]	19.81	[2.62, 34.59]
IA3A	9.72	[-21.58, 32.05]	75.55	[13.09, 100.00]	No data available	No data available
NC3A	15.10	[-7.30, 34.60]	76.35	[14.69, 100.00]	18.31	[5.59, 31.21]
OK3A	13.05	[-15.01, 41.37]	58.12	[5.05, 100.00]	16.19	[0.65, 30.47]
IN5A	4.47	[-29.20, 29.94]	72.63	[16.64, 99.22]	21.95	[10.32, 29.17]
WA5A	17.72	[-2.10, 38.58]	43.13	[8.04, 95.38]	No data available	No data available
WI5A	4.61	[-26.61, 29.10]	72.74	[17.41, 100.00]	18.30	[4.06, 33.89]

4.3.3 Emissions-Level Comparison

Table 4-11 summarizes the emissions values determined using the various measurement techniques for each of the lagoons monitored during the NAEMS. The data presented in the tables include all valid daily average values as reported in the final site reports.

Overall, dairies had the lowest average daily NH_3 emissions, and average daily H_2S emissions varied considerably within the animal types. Overall, OK4A had the highest NH_3 emission of all the sites monitored, for either measurement method. There is no obvious difference in this site from the other sites that would suggest a noticeable difference in NH_3 emissions (e.g., larger capacity or larger lagoon). For H_2S emissions, OK4A and IN5A have noticeably higher emission levels that the other sites. Again, there are no distinguishable characteristics that set these sites apart from the others, except that these two sites have the highest number of emissions values available for the bLS method.

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Table 4-11. Average Daily Emissions for by Site

Pollutant	Parameter	Site								
		IN4A	**NC4A**	**OK4A**	**IA3A**	**NC3A**	**OK3A**	**IN5A**	**WA5A**	**WI5A**
NH_3 RPM (kg/d)	No. of values	1	4	30	4	3	9	18	0	0
	Average	58.4	70.8	177.2	47.1	58.2	102.8	23.4	-	-
	Range	[58.4, 58.4]	[53.4, 102.8]	[65.0, 317.9]	[38.3, 52.8]	[28.3, 117.8]	[53.6, 184.4]	[13.3, 34.6]	-	-
NH_3 bLS (kg/d)	No. of values	37	16	46	32	8	50	73	1	22
	Average	24.8	62.4	171.8	9.9	28.3	55.4	17.1	16.7	9.9
	Range	[0.1, 67.9]	[20.3, 136.2]	[4.8, 375.4]	[1.0, 59.6]	[4.4, 50.0]	[0.6, 149.8]	[0.7, 75.3]	[16.7, 16.7]	[1.5, 34.9]
H_2S bLS (kg/d)	No. of values	15	12	24	6	6	24	24	0	6
	Average	0.4	0.3	8.4	2.2	2.0	6.3	0.0	-	0.4
	Range	[0.0, 2.2]	[0.0, 1.0]	[0.1, 25.3]	[0.0, 12.3]	[0.0, 10.4]	[0.1, 25.4]	[0.0, 42.9]	-	[0.0, 1.9]
H_2S Radiometric (kg/d)	No. of values	0	2	13	1	2	2	1	0	0
	Average	-	0.2	14.3	9.2	4.5	0.2	12.5	-	-
	Range	-	[0.1, 0.3]	[2.4, 37.8]	[9.2, 9.2]	[9.0, 9.0]	[0.2, 0.2]	[12.5, 12.5]	-	-

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5.0 OVERVIEW OF NH3 EEM

This section presents the statistical analysis and procedures followed by the EPA in developing EEMs for NH_3 emissions from lagoons at swine and dairy operations. The EEMs produces a point prediction of NH_3 emissions for a given half-hour period, given the values of predictor variables characterizing the farm and lagoon configuration and ambient meteorology. The EEMs can be used to obtain both a point prediction and a 95-percent prediction interval for the total daily and annual emissions for a lagoon.

The amount of time-varying data (e.g., nitrogen content, ammonia content, pH) available to characterize the lagoon liquid at each site was very limited and including these limited data as predictor variables would have significantly reduced the overall size of the dataset available for EEM development. To maximize the number of NH_3 emissions measurements used to develop the EEM, the EPA considered a suite of static, farm-based predictor variables as surrogates for the time-varying data. These farm-based predictor variables describe the total live mass of animals on the farm, the surface area of the lagoon, and other characteristics of the facility that might indirectly provide information about precursor loading and potential for conversion to NH_3 emissions. However, because this information is not time-varying, there are only nine data values (one for each site) for each of the farm-based predictor variables available for quantifying both the effects of these variables on emissions and the degree of uncertainty around those effects. To address this data limitation, the EPA decided to allow the EEMs to learn about effects of meteorological and farm-based predictor variables on NH_3 emissions simultaneously from swine and dairy.

In previous sections of this document, the terms “parameter” and “estimate” were used to describe the data and data collection methods used in the NAEMS. In this section, these terms are used in their formal statistical context. The term “parameter” refers to unknown constants (e.g., regression coefficients, variance components) whose values relate predictor variables to emissions and give the EEM its shape. In this section, parameters are designated using Greek letters. The term “estimate” refers to the best approximation of a parameter value by fitting the EEM to the NAEMS data. The estimate of a given parameter is designated using a “hat” symbol over the Greek letter. For example, the estimate for the intercept, β_0, would be denoted as $\widehat{\beta_0}$. The term “predict” refers to obtaining a value of emissions using the EEM, including the use of predictor variables and estimated parameters. Finally, the term “effect” does not imply a cause-effect relationship: rather, the phrase “the effect of *sa* on NH_3 emissions” refers to the regression coefficient applied to the variable *sa*.

Figure 5-1 shows the protocol that the EPA followed in developing the EEM. Phase 1 is the selection of the datasets to be used in EEM development. Dataset selection was based on the

predictor variables that were monitored under the NAEMS as well as other important factors that affect emissions such as lagoon surface area. The dataset selection was also based on analyses of data completeness.

Phases 2 through 6 involve development and validation of the mathematical form of the EEM. The EEM has three components: the probability distribution, the mean trend function, and the covariance function. Equation 5-1 provides the general form of the EEM, and Table 5-1 defines the symbols and terms used in the equation.

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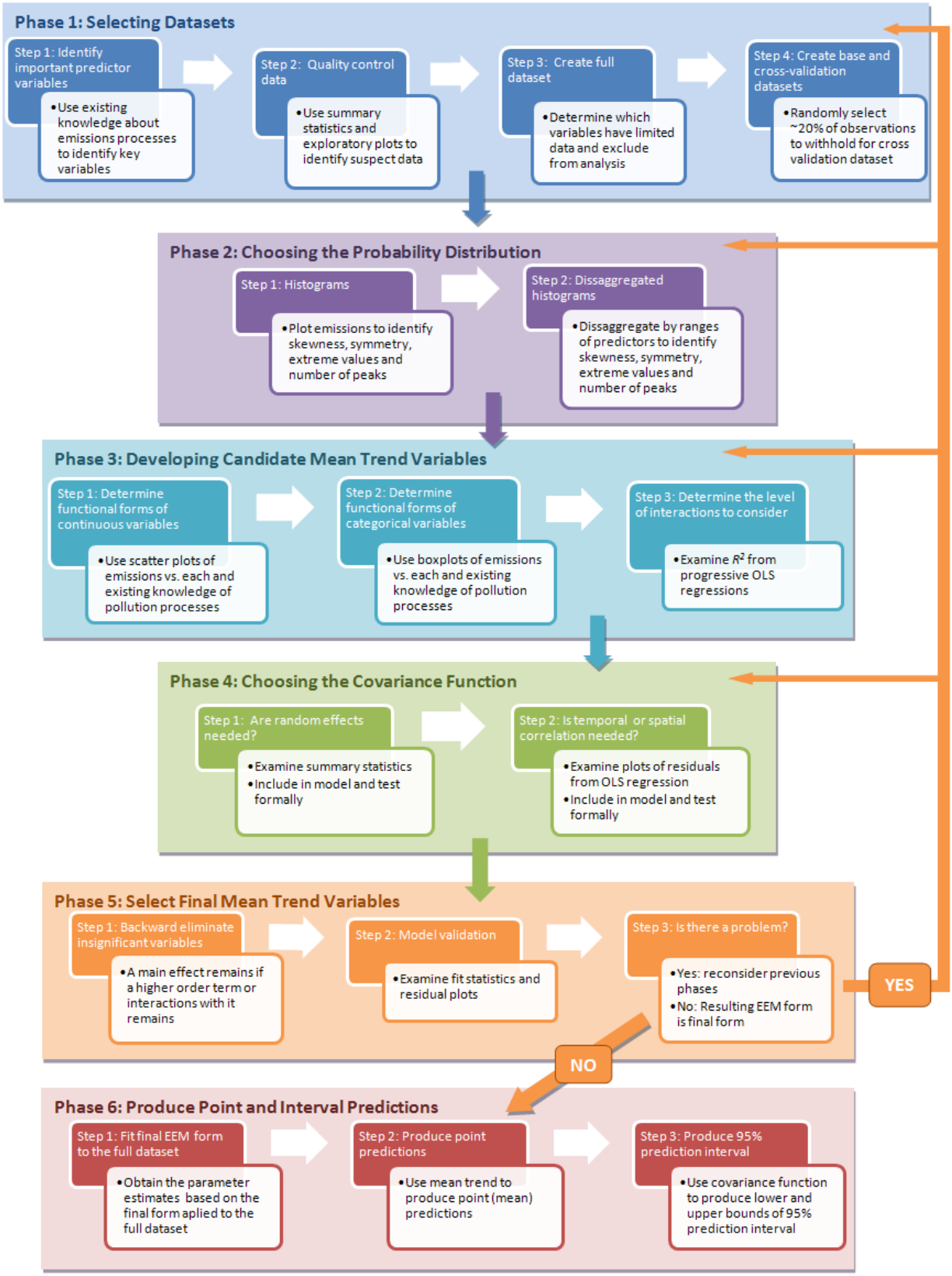

Figure 5-1. EEM Development Protocol

Table 5-1. Summary of Symbols and Terms Used in Equation 5-1

Description	Symbol
Index for sites	s
Index for dates	t
Mass of pollutant emitted from lagoon at site *s* on date *t*	Y_{st}
Index for regression coefficients, mean trend variables, and mean trend terms.	p
Number of mean trend variables, number of regression coefficients, number of mean terms minus one (the intercept is also a mean term).	P
Value of mean trend variable *p* for lagoon at site *s* on date *t*	x_{pst}
Regression coefficients	$\beta_p, \quad p = 1, \ldots, P$
Intercept	β_0
Mean trend terms	β_0 and $\beta_p x_{pht}$, $p = 1, \ldots, P$
Mean trend function— Three ways to write it.	$g(\mu_{st}) =$ $\beta_0 + \beta_1 x_{1st} + \cdots + \beta_p x_{pst} + \cdots + \beta_P x_{Pst}$ $= \boldsymbol{x}^T \boldsymbol{\beta}$
The $(P+1) \times 1$vector containing a place-holder for the intercept plus the mean trend variables	$\boldsymbol{x} = (1 \quad x_{1st} \quad \ldots \quad x_{pst} \quad \ldots \quad x_{Pst})^T$
The $(P+1) \times 1$vector containing the intercept and the regression coefficients	$\boldsymbol{\beta} = (\beta \quad \beta_1 \quad \ldots \quad \beta_p \quad \ldots \quad \beta_P)^T$
Deviation of emissions from lagoon at site *s* on date *t* from the value given by the mean trend function. A random variable. Optional for the gamma distribution.	e_{st}

$$\boldsymbol{Y_{st} \sim Gamma\{\mu_{st}, \phi\}; \quad s = 1, \ldots, 9; \quad t \text{ varies by site}}$$

$$\boldsymbol{g(\mu_{st}) = \beta_0 + \beta_1 x_{1st} + \cdots + \beta_p x_{pst} + \cdots + \beta_P x_{Pst} \underbrace{+ e_{st}}_{\text{optional}}} \qquad \text{Equation 5-1}$$

In the first line of Equation 5-1, the symbol Y_{st} represents pollutant emissions from the lagoon at site s and time t. The index, s, takes values 1 through 9, corresponding to the nine NAEMS sites. The index t identifies the date and time (in half-hour increments) associated with each half-hour NH_3 emissions value. Values of t are nested within values of s so that dates and times for different sites can be the same or different. Due to the rotating sampling schedule at 7 of the nine sites and the missing data, the dates were not always consecutive. Additionally, the half-hour values were not always consecutive for a given date.

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The notation $Y_{st} \sim Gamma\{\mu_{st}, \phi\}$ says that NH_3 emissions at site s and time t follow the asymmetric gamma probability distribution. The mean of the distribution is represented by the parameter μ_{st} and the scale parameter, ϕ, that also determines the shape of the distribution. The prediction of NH_3 emissions for a given site and time is represented by $\widehat{Y_{st}}$ which is equal to the estimated mean, $\widehat{\mu_{st}}$.

In the second line of Equation 5-1, the expression $g(\mu_{st}) = \beta_0 + \beta_1 x_{1st} + \cdots + \beta_p x_{pst} + \cdots + \beta_P x_{Pst}$ says that the mean of the gamma distribution, μ_{st}, is related to the mean trend function, $\beta_0 + \beta_1 x_{1st} + \cdots + \beta_p x_{pst} + \cdots + \beta_P x_{Pst}$ by the link function, $g(\ )$. The mean trend function describes the relationship between the predictor variables and the expected value of NH_3 emissions. In the mean trend function, x_{pst} represents the value of the pth mean trend variable at site s and time t. The symbol β_p denotes the regression coefficient for that variable and the symbol β_0 represents the intercept. The mean trend variables differ from the predictor variables in that they represent the functional form through which the predictor variables enter the EEM. Lower-case p is an index for regression coefficients β_p, mean trend variables, x_{pst}, and their products (the non-intercept mean trend terms, $\beta_p x_{pst}$). The index, p, takes values 1,⋯, P, so that upper-case P is the number of non-intercept mean trend terms. Because the formula for the mean trend function is cumbersome, the matrix multiplication version of the function, $x^T\beta$, is used in the remainder of this section. The term $\boldsymbol{x}$ represents the $(P+1) \times 1$ vector containing a placeholder for the intercept plus the mean trend variables, $x = (1 \quad x_{1st} \quad \ldots \quad x_{pst} \quad \ldots \quad x_{Pst})^T$, and the term $\boldsymbol{\beta}$ represents the $(P+1) \times 1$ vector containing the intercept and the regression coefficients, $\boldsymbol{\beta} = (\beta \quad \beta_1 \quad \ldots \quad \beta_p \quad \ldots \quad \beta_P)^T$.

Link functions allow the flexibility to compare the fits of EEMs with different mathematical forms to the NH_3 emissions data. For the gamma distribution, there are three commonly used link functions: the identity, the natural logarithm and the reciprocal. When the identity link function is used (i.e., $g(\mu_{st}) = \mu_{st}$), the mean of the distribution is exactly equal to the mean trend function. When the natural logarithm or reciprocal link functions are used, the natural logarithm or the reciprocal of the mean of the distribution is equal to the mean trend function. Link functions are discussed in more detail in Section 5.4.1.

The optional term, e_{st}, represents deviations from the mean trend function is needed when there is covariance (or correlation) of some kind between values of NH_3 emissions.

The choice of probability distribution, the variables included in the mean trend function, the link function and the form of the covariance function were all based on analyses of a subset of the NAEMS data called the "base" dataset, validated using another subset called the "cross-validation" dataset, and then modified and re-validated when necessary. After the final

mathematical forms were chosen, the EPA re-estimated the parameters using the "full" dataset (i.e., the combined base and cross-validation datasets).

The remainder of this section is organized as follows. Section 5.1 presents the selection of the candidate predictor variables and the base and cross-validation datasets. Section 5.2 explains why the gamma probability distribution was selected. Section 5.3 explains creation of candidate mean trend variables as functions of predictor variables. Section 5.4 discusses selection of the covariance function. Section 5.5 compares the fit statistics of three candidate EEMs with different mean trend variables. Section 5.6 describes how the EEMs are used to generate point and interval predictions for a half hour period and for sums of multiple half-hour periods. Section 5.6 also provides example predictions for each of the three EEMs discussed in Section 5.5. Section 5.7 discusses the challenges faced when developing the methodologies and offers additional analyses that may be considered by the EPA.

5.1 Selecting Datasets and Candidate Predictor Variables

The emissions and farm and lagoon data used to develop the NH_3 EEMs for lagoons were collected under the NAEMS from six swine sites (IA3A, IN4A, NC3A, NC4A, OK3A and OK4A) and three dairy sites (IN5A, WA5A and WI5A). The final reports submitted to the EPA contained daily lagoon emissions calculated based on measurements obtained using both the RPM model and the bLS model. In developing the NH_3 EEMs, the EPA used the measurements obtained using the RPM model. The EPA used the RPM data because these measurements were obtained using instrumentation and procedures that were similar to EPA's developmental test method OTM-10 (Optical Remote Sensing for Emission Characterization from Non-Point Sources). The EPA did not use the bLS emissions measurements because these data were collected under the NAEMS to conduct a validation study of the bLS model performance relative to the RPM model. Furthermore, because the RPM emissions dataset is much larger than the bLS dataset, including the bLS measurements in the EEM development dataset would not provide any additional information on lagoon emissions. Therefore, the EPA chose to only use the RPM emissions data as it represented the largest unique NH_3 emissions dataset available from the NAEMS.

Due to the very limited number of daily NH_3 emissions values reported, the EPA prepared a database of half-hour values by combining the 30-minute emissions data and 5-minute meteorological data provided by the NAEMS researchers. To obtain values for each meteorological variable for a given half-hour, the EPA averaged the 5-minute data values within that half hour, as long as at least one of the values was not missing. Because it is unlikely that the value of any of these meteorological variables would vary enough within the consecutive 5-minute periods that comprise a half hour to significantly change the mean value of the variable

during the half-hour, applying a completeness criterion to this aggregation would unnecessarily reduce an already limited data set. In the data aggregation, the EPA did not include any 30- or 5-minute data that had been flagged by the NAEMS researchers as invalid.

The resulting dataset contained a small number of negative NH_3 emissions (approximately 0.6 percent of the total values). Because such a small number of observations relative to the full dataset would be unlikely to provide information about variability in NH_3 emissions measurements, the EPA omitted these values from the EEM development dataset. Table 5-2 gives the number of 30-minute NH_3 emissions observations from each site after aggregation of the data, elimination of negative values, and evaluating completeness with meteorological variables. Table 5-3 shows the number of 30-minute values for the variables that were continuously monitored at each site after the EPA aggregated the 5-minute data to 30 minute values.

Table 5-2. Number of 30-Minute NH_3 Emissions Values by Site

Monitored Site		Site Number in EEM	No. of NH_3 Emissions Values
Swine breeding and gestation	IN4A	1	677
	NC4A	2	1,193
	OK4A	3	1,780
Swine grow/finishing	IA3A	4	1,048
	NC3A	5	1,074
	OK3A	6	1,600
Dairy	IN5A	7	2,593
	WA5A	8	507
	WI5A	9	312
All sites			10,784

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Table 5-3. Number of 30-Minute Data Values for Continuous Variables

Description	Units	Swine Breeding and Gestation Sites			Swine Grow/Finishing Sites			Dairy Sites			All Sites
		1	2	3	4	5	6	7	8	9	
		IN4A	NC4A	OK4A	IA3A	NC3A	OK3A	IN5A	WA5A	WI5A	
Ambient Meteorological Data											
Ambient temperature	^{o} C	677	1,193	1,780	1,048	1,078	1,600	2,593	507	312	10,788
Relative humidity	%	698	1,253	2,319	1,059	1,122	1,618	3,683	529	350	12,631
Atmospheric pressure	kPa	678	1,194	1,683	1,048	957	1,587	2,669	520	300	10,636
Dew point temperature	^{o} C	677	1,193	1,780	1,048	1,074	1,600	2,593	507	312	10,784
Solar radiation	W/m^2	522	924	2,007	841	991	1,297	2,837	440	293	10,152
Surface wetness	Resistance (Ω)	359	520	700	359	301	537	1,298	29	73	4,176
Wind speed	m/s	711	1,253	2,324	1,059	1,126	1,795	3,683	551	352	12,854
Lagoon Liquid Data											
pH	pH	357	1,191	1,836	0	983	1,211	1,330	0	12	6,920
Oxidation/ reduction potential	Millivolts (mV)	543	1,238	2,080	0	931	1,573	1,396	0	33	7,794
Temperature	^{o} C	581	1,237	2,077	0	888	1,571	1,422	0	73	7,849

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5.1.1 Candidate predictor variables

In addition to the continuous variables shown in Table 5-3, the EPA compiled the following information from the final reports for each site: type and presence of natural cover on the lagoon surface, lagoon liquid composition and animal inventory. This information was collected intermittently for select days during the NAEMS (see Section 4). For EEM development, the EPA assumed that the value of the intermittent data was constant for each 30-minute period of the day in which the information was collected. Table 5-4 shows the number of 30-minute values available for the intermittent data based on the EPA's approach.

To supplement the continuous and intermittent data, the EPA compiled information regarding the farms and lagoons at each monitoring site from the NAEMS open-source QAPP, SMPs and final reports. Table 5-5 shows the farm and lagoon information and whether the information was available for each monitoring site. The information listed in Table 5-5 consists of categorical specifications (e.g., animal type, impoundment type) where the value is constant and not expected to vary over time, and discrete specifications (e.g., animal weight, lagoon liquid depth) where the reported value is constant but the actual value was expected to change over time. As with the intermittent data, the EPA assumed that the values of the farm and lagoon information were constant throughout the NAEMS sampling period Therefore, the values were applied to all 30-minute periods.

In determining which of the data and information shown in Table 5-3, Table 5-4 and Table 5-5 would be selected as candidate predictor variables for EEM development, the EPA's primary consideration was data completeness. However, the EPA also considered whether or not the variable would be readily available to farmers. Table 5-6 shows the candidate predictor variables considered in the development of EEMs for lagoon NH_3 emissions.

Table 5-4. Number of 30-Minute Values Available for Intermittent Data by Site

Monitoring Site		Lagoon Cover	Lagoon Liquid Composition			Animal Inventory
			Nitrogen Content	Solids Content	NH_3 Content	
Swine Breeding and Gestation	IN4A	83	0	0	0	0
	NC4A	97	48	0	0	0
	OK4A	149	48	0	0	2,234
Swine grow/finishing	IA3A	122	96	144	144	1,059
	NC3A	31	144	0	0	1,126
	OK3A	136	96	96	96	1,795
Dairy	IN5A	300	0	0	0	3,683
	WA5A	11	0	0	0	551
	WI5A	24	0	0	0	352
All sites		953	432	240	240	10,890

Table 5-5. Farm and Lagoon Information by Site

Variable Description		Units	Variable Type[a]	Swine Breeding and Gestation Sites			Swine Grow/Finishing Sites			Dairy Sites		
				IN4A	NC4A	OK4A	IA3A	NC3A	OK3A	IN5A	WA5A	WI5A
Lagoon site ID	NAEMS site ID.	NA[b]	Cat.	Y[c]	Y	Y	Y	Y	Y	Y	Y	Y
Animal type	Swine or dairy.	NA	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Farm animal capacity	Average animal inventory contributing manure to the monitored lagoon.	head	Cont.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Average animal weight	Average weight of animals at swine and dairy farms.	kg	Cont.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Average animal weight (piglet)	Average weight of piglets at swine breeding and gestation farms.	kg	Cont.	Y	N	N	NA	NA	NA	NA	NA	NA
Number of confinement structures on the farm	Design specification for the number of confinement structures that contributed manure to the lagoon.	structures	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Farm manure management system	Design specification for the type of system (e.g., pull-plug pit) used to remove manure from the confinement structure.	NA	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solids separation	Design specification to indicate whether the site separates solids from manure before it is discharged to the lagoon.	NA	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Odor control	Design specification to indicate whether the site used a lagoon additive that suppresses NH_3 emissions.	NA	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Farm age	Date of farm construction (or since major renovation)	years	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y

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Table 5-5. Farm and Lagoon Information by Site

Variable Description		Units	Variable Type[a]	Swine Breeding and Gestation Sites			Swine Grow/Finishing Sites			Dairy Sites		
				IN4A	NC4A	OK4A	IA3A	NC3A	OK3A	IN5A	WA5A	WI5A
Impoundment type	Lagoon or basin.	NA	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lagoon configuration	Design specification for the lagoon configuration (e.g., single stage, multiple stage).	NA	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lagoon volumetric loading rate	Design specification for the volumetric loading rate of organic material, defined as the mass of volatile solids (VS), added to the lagoon daily.	lb VS/d-1,000 ft^3	Cat.	Y	Y	Y	N	Y	N	N	N	Y
Lagoon surface loading rate	Design specification for the surface loading rate of organic material added to the lagoon each day.	lb VS/d-ac	Cat.	Y	Y	Y	N	Y	N	N	N	N
Lagoon volume	Design specification for the volumetric capacity of the lagoon to store liquid and accumulated sludge.	ft^3	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lagoon surface area	Design specification for the total surface area of the lagoon.	1,000 ft^2	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lagoon liquid depth	Design specification for the average depth of the liquid above the layer of accumulated sludge at the bottom of the lagoon.	ft	Cat.	Y	Y	Y	Y	N	Y	Y	Y	Y
Lagoon sludge depth	Design specification for the depth of accumulated sludge at the bottom of the lagoon.	ft	Cat.	N	Y	N	Y	Y	Y	Y	N	Y
Number of manure inlets to the lagoon	Design specification for the number of inlets that discharge manure to the lagoon.	inlets	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y

Table 5-5. Farm and Lagoon Information by Site

Variable Description		Units	Variable Type[a]	Swine Breeding and Gestation Sites			Swine Grow/Finishing Sites			Dairy Sites		
				IN4A	NC4A	OK4A	IA3A	NC3A	OK3A	IN5A	WA5A	WI5A
Manure discharge schedule	Design specification for the frequency of manure removal from confinement structures	days	Cat.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lagoon pump-out frequency	Design specification that indicates the frequency that liquid is removed from the lagoon.	days	Cat.	Y	N	Y	Y	N	Y	N	N	Y
Lagoon agitation prior to pump-out	Activity indicator to note that the farm agitated the lagoon contents prior to pump-out.	1 = activity 0 = no activity	Cat.	Y	Y	Y	Y	Y	Y	N	N	N
Manure discharge to lagoon event	Activity indicator for a given date to note when manure was removed from the confinement structure	1 = varies[d] 0 = no activity	Cat.	Y	Y	N	Y	N	N	N	N	Y

[a] Cont. = Continuous, the value of the variable can change over time. Cat. = Categorical, the value of the variable is constant over time. Disc. = Discrete, the value is constant, but can change over time.
[b] NA = Not applicable.
[c] Y = data is available, N = data is not available.
[d] 0 = no removal; 1 = pit agitation and pump out; 2 = drained/pumped; 3 = scrape; 4 = pump to solids separation, excess to lagoon; blank = not reported.

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Table 5-6. Selected Candidate Predictor Variables

Category	Description	Predictor Variable	Units
Ambient	Temperature	*ta*	^{o}C
	Relative humidity	*ha*	%
	Wind Speed	*ws*	m/s
	Hour of the day	*hour*	hour
	Julian day (day of the year)	*jday*	day
Farm and lagoon	Animal type (Dairy or Swine indicator)	*animal*	NA[a]
	Capacity of farm (number of animals)	*capacity*	head
	Average adult animal weight	*adultwt*	lb
	Number of confinement structures	*barns*	barns
	Manure management system	*mms*	NA
	Surface area	*sa*	1000 ft^2
	Number of manure inlets into lagoon	*inlets*	inlets
	Whether an odor control agent was used on a given day	*odorctrl*	NA

[a] NA = Not applicable.

5.1.1.1 *Ambient Meteorology*

The NH_3 emissions rate from lagoons is affected by air temperature, wind speed across the lagoon surface and relative humidity (NAS, 2002). The ambient air temperature determines the temperature of the lagoon liquid, particularly near the surface of the lagoon. With increasing ambient air temperature, the resulting increase in liquid temperature is expected to increase NH_3 emissions. This positive relationship between liquid temperature and NH_3 emissions from swine lagoons was modeled by Aneja *et al.* (2001) and Harper *et al.* (1998). Values for ambient temperature were available for all swine and dairy sites. Consequently, the EPA included ambient temperature as a candidate predictor variable.

With regard to wind speed, the EPA expected that, in general, higher wind speeds would increase NH_3 emissions. As the wind sweeps across the lagoon surface, the concentration gradient between the lagoon liquid and the liquid-air boundary layer at the surface decreases, thereby increasing diffusion of NH_3 to the atmosphere. Also, high winds can increase surface agitation, thereby effectively increasing the surface area available for diffusion of NH_3 to the atmosphere. The positive relationship of wind speed on NH_3 emissions was noted in the model for swine lagoons developed by Harper *et al.* (1998). Values for wind speed were available for

all swine and dairy sites. Consequently, the EPA included wind speed as a candidate predictor variable.

The EPA expected that increases in relative humidity above the lagoon surface would tend to decrease the diffusion of gas molecules from the liquid/gas interface. Values for ambient relative humidity were available for all swine and dairy sites. Therefore, the EPA included relative humidity as a candidate predictor variable.

The EPA also expected that increases in atmospheric pressure above the lagoon surface would tend to decrease NH_3 emissions. Higher atmospheric pressure will decrease the gradient between the partial pressure of NH_3 gas dissolved in the lagoon liquid and the atmosphere above the lagoon surface, thereby reducing diffusion of gas molecules from the liquid. However, the EPA did not use atmospheric pressure as a predictor variable because to do so would have significantly reduced the size of the dataset.

The dew point is the temperature at which moisture in the atmosphere condenses to liquid water. This condensed moisture could reabsorb NH_3 released from the lagoon and potentially reduce NH_3 emissions. The condensed water could also reduce NH_3 emissions by reducing the concentration gradient between NH_3 in the bulk lagoon liquid and the boundary layer near the lagoon surface. Dew point is a function of temperature and humidity. Based on exploratory data plots, the EPA determined that the interaction effect of ambient temperature and relative humidity would be more effectively captured using the product of ambient temperature and relative humidity, rather than dew point values. Consequently, the EPA did not include dew point temperature as a candidate predictor variable.

Because rainfall incident to the lagoon could dilute the concentration of NH_3 near the lagoon surface, the EPA expected that wet conditions would result in lower NH_3 emissions. An electrical resistance grid was used to indicate the presence of wet or dry conditions on the ground near the lagoons; however, the amount of precipitation received by each site was not collected under the NAEMS. The number of wetness data values available for all sites was very limited (4,176 30-minute values for all sites) and incorporation of this data would reduce the size of the dataset available to develop the EEMs by approximately 67 percent. Consequently, the EPA did not include data for wet/dry conditions as a candidate predictor variable.

Because solar radiation affects ambient air temperature and the temperature of the liquid on the surface of the lagoon, increases in solar radiation were expected to increase NH_3 emissions. However, the EPA chose not to use solar radiation as a predictor variable because this information is not expected to be readily available. While temperature, humidity, and wind speed are recorded routinely at a network of meteorological sites, solar radiation is not. To capture the

effect of the annual solar radiation cycle on NH_3 emissions, the EPA used the Julian day (*jday*) corresponding to the measurement time stamps as a predictor variable. The Julian day is the day of the year, so that *jday* can take values 1 through 365 or 366, depending on whether or not the day falls in a leap year. The EPA believed that interactions of *jday* with *ta* and *ha* should account for reduced solar radiation due to cloud cover. Also, to account for the effect of the diurnal solar radiation cycle, the EPA used a function of *hour*.

5.1.1.2 ***Lagoon Liquid Data***

The NAEMS collected continuous monitoring data for pH, oxidation/reduction potential (ORP), and liquid temperature and intermittent data for the nitrogen, ammoniacal nitrogen and solids content of the liquid.

The concentration of NH_3 at the lagoon surface depends on the total concentration of ammoniacal nitrogen [i.e., NH_3 plus ammonium ion (NH_4^+)] in the liquid. The balance between NH_3 gas and highly-soluble NH_4^+ is a function of pH and temperature of the lagoon liquid. At a constant pH, the concentration of NH_3 relative to NH_4^+ increases, thereby increasing NH_3 emissions. At a constant temperature, the concentration of NH_3 relative to NH_4^+ also increases, thereby increasing lagoon NH_3 emissions potential (NAS, 2002). As noted in Section 5.1.1.1, previous studies [Aneja *et al.* (2001) and Harper *et al.* (1998)] have shown a positive relationship between liquid temperature and NH_3 emissions from swine lagoons. Consequently, the EPA expected that increasing pH or lagoon liquid temperature or both would result in higher NH_3 emissions.

The ORP measures the activity of electrons in a liquid and indicates whether the liquid is an oxidizing or reducing environment. However, because the mineralization of organic nitrogen to NH_3 occurs in both oxidizing and reducing environments, the ORP value only indicates if the potential exists for the reduction of NH_3 emissions due to nitrification. Therefore, the EPA expected that NH_3 emissions would decrease with positive ORP values indicating an aerobic and oxidizing environment.

Although the pH, ORP and temperature of the lagoon liquid were expected to affect NH_3 emissions from lagoons, the EPA did not include these data as candidate predictor variables due to the limited number of data values and because data were not provided for sites IA3A and WA5A.

Because the organic and ammoniacal nitrogen present in the lagoon liquid are precursors to NH_3 emissions, the EPA expected that NH_3 emissions would be higher at lagoons with higher total nitrogen concentrations. Nitrogen compounds can be bound to lagoon solids thereby preventing the release of ammonia precursors into the bulk lagoon liquid; therefore, the EPA also

considered using the solids content of lagoon liquid in EEM development. However, the EPA did not include data for the nitrogen or NH_3 content of the lagoon liquid as candidate predictor variables due to the limited number of data values (see Table 5-4).

At higher volumetric loading rates, the concentrations of total solids will be higher as will the concentration of total nitrogen, which is comprised of organic and ammoniacal nitrogen. Thus, the potential for NH_3 emissions also will be higher because the concentration of free NH_3 is a function of the ammoniacal nitrogen concentration with the latter a function of the readily mineralizable fraction of organic nitrogen. However, the EPA did not include data for total solids as candidate predictor variables due to the limited number of data values (see Table 5-4).

5.1.1.3 *Farm and Lagoon Information*

For animal type, the EPA included an indicator variable to designate whether the lagoon was located at a swine or dairy farm as a candidate predictor variable to consider the possible effect on lagoon NH_3 emissions due to the different type of animal. The EPA did not include a variable to distinguish between swine breeding/gestation and grow/finish farms. Although the swine industry includes farms that have breeding/gestation and grow/finish production stages on the same site, the NAEMS did not measure emissions at any farrow-to-finish operations. Consequently, including a variable to distinguish farm type in the EEM development dataset would have limited the applicability of the EEM to either a breeding/gestation or a grow/finish farm.

Because organic nitrogen in excreted manure is the precursor to NH_3 emissions from the lagoon, farms that generate more manure were expected to have larger lagoons and subsequently higher NH_3 mass emissions. To account for the relative size of the farms at each monitoring site, the EPA considered using the farm animal capacity, average daily animal inventory, average animal weight and the number of confinement structures as candidate predictor variables. Values for animal capacity, average animal weight and the number of confinement structures were available from the NAEMS documentation for each site; therefore, these data were used as candidate predictor variables. However, daily animal inventory values were not reported for sites IN4A and NC4A. Consequently, the EPA did not include animal inventory as a candidate predictor variable. In addition, the average animal weight for growing/finishing houses was the average weight over the lifetime of the pig, and therefore fall between the initial weight of the piglet (approximately 14 lb) and the final market weight of the pig (approximately 247 lb).

The swine and dairy sites used a variety of methods (e.g., pull-plug pit, flushing, scraping) to remove manure from the confinement houses. The EPA included the type of manure collection system used at each site as a candidate predictor variable to determine whether the

manner in which manure was removed from the houses was related to NH_3 emissions from lagoons.

Dairies typically use some form of solids separation step to remove solids and inorganic material (e.g., sand used for bedding) prior to discharging manure to the lagoon and all of the NAEMS dairy sites use solids separation. Conversely, none of the swine sites used solids separation which is typical of swine operations due to the consistency of excreted manure. Because the presence of solids separation at the sites does not vary within animal type, the effect on lagoon NH_3 emissions attributable to the presence or absence of solids separation cannot be assessed using this information. Consequently, the EPA did not include these data as a predictor variable.

Because increased mixing of the lagoon liquid could increase NH_3 emissions due to exposure of more concentrated liquid to the lagoon surface, the EPA considered including the following information to characterize the potential for turbulence in the lagoon in the list of candidate predictor variables: number of lagoon manure inlets, manure discharge schedule and lagoon liquid pump-out frequency. The EPA also considered using an indicator variable to designate days when the lagoon liquid was agitated prior to a pump-out event. Data values for the manure discharge schedule and the number of lagoon inlets were available for all sites; therefore, the EPA included these data as candidate predictor variables. The EPA did not include the frequency with which liquid was pumped out of the lagoon or indicator variables to denote specific events in the list of candidate predictor variables because these data were not reported for all sites.

The EPA considered using the following design specifications as predictor variables to assess whether lagoon design was related to NH_3 emissions: impoundment type (i.e., lagoon or basin), configuration, loading rates, volume, surface area, liquid depth and sludge depth. However, the EPA did not include lagoon loading rates, liquid depth and sludge depth because these data were not available for all sites. Also, the EPA did not consider using a predictor variable for single- or multiple-stage lagoons. Only site WI5A had a multi-stage lagoon, based on the descriptions provided in the SMP and final report. However, the emissions from each of the three stages were not measured independently. The monitoring equipment was located such that the total emissions from stages 1 and 2 were measured. Emissions from the 3rd stage, which was used to supply flush water, were not measured under the NAEMS. Consequently, the EPA decided to use the total emissions and total surface area from stages 1 and 2 as representative of a single-stage lagoon, rather than exclude site WI5A due to the different lagoon configuration. Therefore, a predictor variable for lagoon stages was not used.

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The presence of a natural cover (i.e., crust, scum or ice) on the lagoon surface tends to reduce emissions because the cover inhibits diffusion of NH_3 from the lagoon liquid to the atmosphere. Observations regarding the type (e.g., crust, ice) and degree of cover (percent of surface area) were provided for select days at each site. Although the presence of natural lagoon cover (i.e., crust, scum or ice) was expected to affect NH_3 emissions, the EPA did not use it as a candidate predictor variable because of the limited number of recorded observations.

One of the sites reportedly used an additive that reduces odor emissions from the lagoon. Consequently, the EPA included a predictor variable to note whether the grower used an odor control additive in the lagoon.

The EPA also did not use the type of impoundment (i.e., lagoon or basin), as a predictor variable. For impoundment type, the QAPP, SMPs and the final reports do not define the design and operational differences between a "lagoon" and "basin" and the documents tend to use the terms interchangeably. Based on discussions with the NAEMS Science Advisor, dairies tend to use basins which have a lower degree of microbial activity than lagoons. Using this information, all of the dairy sites would be assigned a basin for impoundment type and all of the swine sites would be assigned a lagoon. However, because the type of impoundment at the sites does not vary within animal type, the effect on lagoon NH_3 emissions attributable to the type of impoundment cannot be assessed using this information. Consequently, the EPA did not include impoundment type as a predictor variable.

5.1.2 Full, Base and Cross-validation Datasets

To ensure that the data selected for EEM development were representative of more than one of the monitored sites, the EPA limited the dataset for use in EEM development to those records for which data values were available for all selected predictor variables.

The number of 30-minute observations for which NH_3 emissions and all of the selected candidate predictor variables were available was 10,783. This dataset is referred to as the "full" dataset. From the full dataset, the EPA withheld a cross-validation dataset for use in testing the EEMs and ensuring that any relationships predicted by the EEMs would apply generally, rather than being attributable to anomalies that might be present in the data. To create the cross-validation dataset, the EPA randomly selected 2,191 (approximately 20 percent) of the 10,783 observations in the full dataset. The remaining 8,592 observations comprised the "base" dataset.

Ideally, 20 percent of the observations representing different combinations of conditions would be withheld to ensure that neither the cross-validation dataset nor the base dataset over or under-represents any one set of conditions. Because there are so many predictor variables for the NH_3 lagoon dataset, sub-dividing the data into many different sets of conditions would result in

subsets with few observations, and it would be difficult to ensure that 20 percent of any one set is actually withheld.

To ensure that the cross-validation and base datasets selected initially did not disproportionately over- or under-represented one or more sets of conditions, the EPA created two additional cross-validation datasets and corresponding base datasets by randomly selecting approximately 20 percent of the observations to withhold. Although this report presents results for the first base and cross-validation datasets only, the EPA checked for notable aberrations in results for the other two cross-validation datasets as well.

5.2 Selecting the Probability Distribution

Identifying the appropriate probability distribution allows for production of accurate prediction intervals that quantify uncertainty in the point estimate of NH_3 emissions. Selection of the correct distribution also ensures the validity of the p-values used to determine the statistical significance of regression coefficient estimates.

To determine the probability distribution, the EPA produced a series of histograms of NH_3 emissions, beginning with a histogram of the full dataset. The histogram in Figure 5-2 shows that the empirical distribution of NH_3 emissions is unimodal and is skew right. Note that the empirical distribution is increasing and then decreasing, rather than strictly decreasing.

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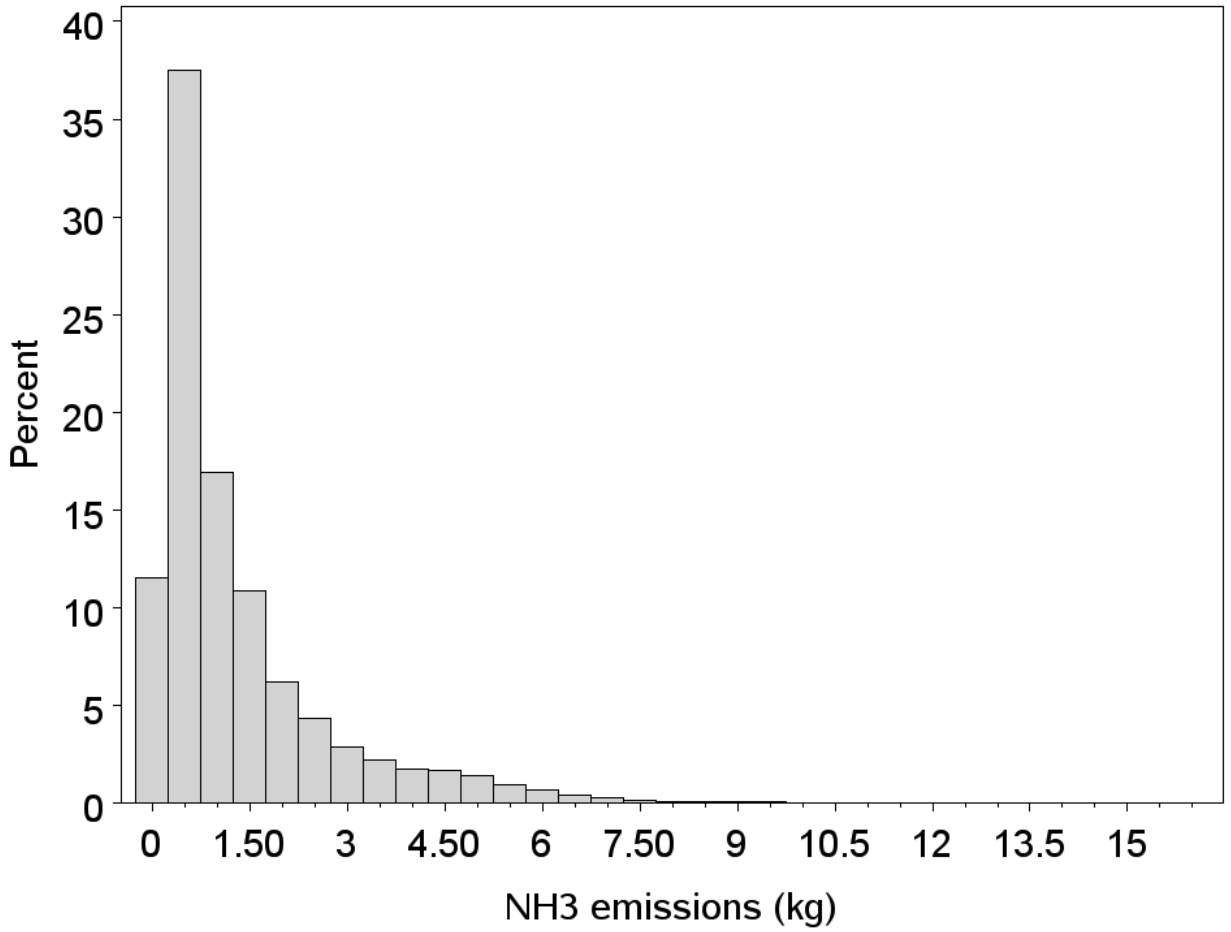

Figure 5-2. Histogram of NH_3 Emissions

This figure makes it appear that a skew-right distribution would be appropriate, but aggregating NH_3 emissions resulting from many different sets of conditions into a single histogram could mask differences in the distribution under different conditions, and could make a symmetric distribution appear skew. The EPA therefore disaggregated the dataset into bins based on values of the meteorological predictor variables. The EPA created three new variables (*tabin*, *habin* and *wsbin*) to identify eight ranges of values of ambient temperature, humidity and wind speed, respectively. These meteorological variables were used because they had a wide range of values that provided varying conditions to examine the distribution. These variables also displayed a significant ability to predict NH_3 emissions based on initial tests. These meteorological bins will also be used later in the analysis to allow for a closer examination of the data to verify that a wide range of meteorological conditions are covered by the dataset, as well as the emissions trends for combinations of these conditions (e.g., cold, moist and windy conditions versus hot, dry and calm conditions). The bin cut-off values for each are given in Table 5-7. In the first temperature bin, *tabin* = 1, for example, the values of temperature fall between -29 and -20 ^{o} C.

Table 5-7. Meteorological Variable Bin Cut-Offs

Ambient Temperature (° C)				Relative Humidity (%)				Wind Speed (m/s)		
tabin	**min**	**max**		***habin***	**min**	**max**		***wsbin***	**min**	**max**
1	-29	-20		1	0.0	12.5		1	0.00	2.25
2	-20	-11		2	12.5	25.0		2	2.25	4.50
3	-11	-2		3	25.0	37.5		3	4.5	6.75
4	-2	7		4	37.5	50.0		4	6.75	9.00
5	7	16		5	50.0	62.5		5	9.00	11.25
6	16	25		6	62.5	75.0		6	11.25	13.50
7	25	34		7	75.0	87.5		7	13.50	15.75
8	34	43		8	87.5	100.0		8	15.75	18.00

Figure 5-3 shows histograms of NH_3 emissions disaggregated by *tabin*. Within the eight different ranges of temperatures, bins 2 through 8 have enough data to draw conclusions. The distribution of NH_3 emissions is still primarily increasing then decreasing, unimodal and primarily skew right. Figure 5-4 shows a further disaggregation into combinations of *tabin* and *wsbin*. The temperature and wind speed were used for this disaggregation because preliminary plots showed that NH_3 emissions had the strongest relationship with these two variables. Because not all of the 64 combinations of *tabin* and *wsbin* contain many observations, the 25 combinations in Figure 5-4 are those with the most observations. Notice that the predominant shape of the distribution for these subsets of the data is again unimodal and skew right, although some plots are somewhat symmetric and others are skew left.

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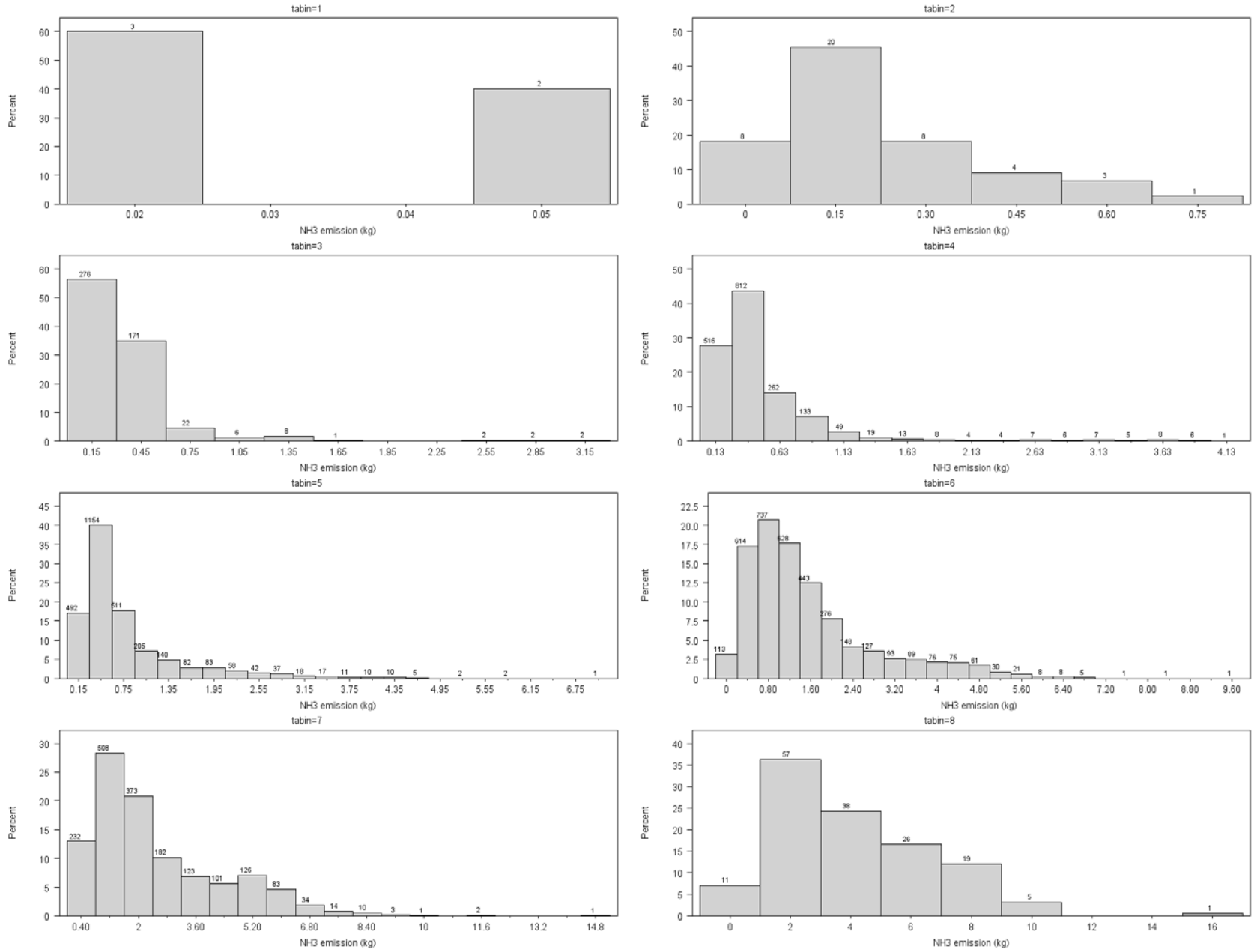

Figure 5-3. Histogram of NH_3 Emissions by Temperature Bin

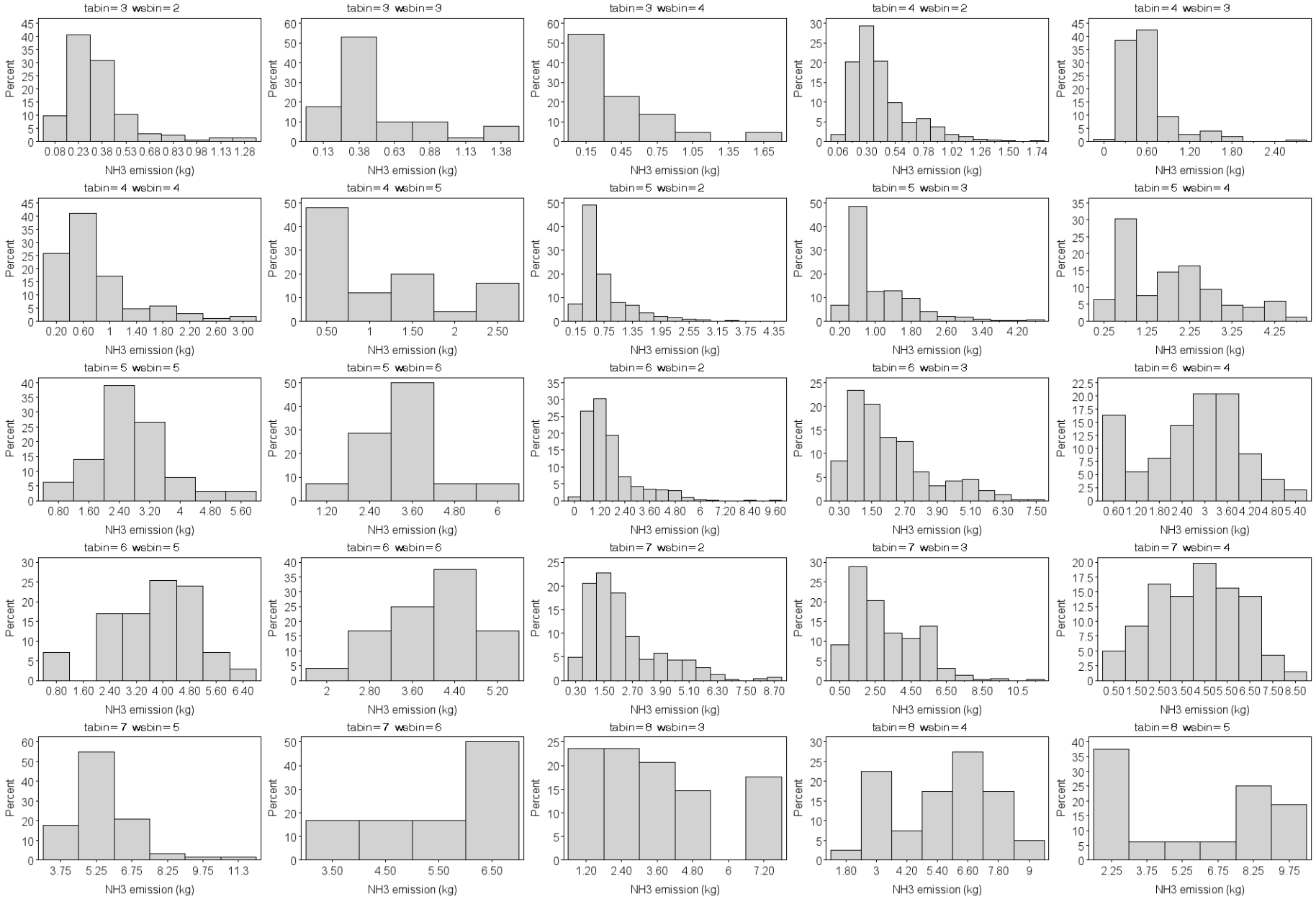

Figure 5-4. Histogram of NH_3 Emissions by Temperature and Wind Speed Bins

The EPA concluded that using a normal distribution for the NH_3 emissions was inappropriate for EEM development. To capture the skew-right nature of the NAEMS NH_3 emissions data, the EPA chose the gamma distribution. An advantage of using the gamma distribution as opposed to the often-used lognormal distribution is that use of the gamma distribution allows the flexibility of relating the mean of NH_3 emissions to predictor variables via a link function. The lognormal distribution relates mean NH_3 emissions to the mean trend function only by way of the natural log.

The gamma distribution is a skew-right distribution parameterized by the mean parameter, μ, and the parameter ϕ, which must be greater than 0 and describes the degree of skewness in the distribution. Figure 5-5 shows the different shapes the gamma distribution takes for different values of ϕ when $\mu = 1.5$, which is a typical value of NH_3 emissions from lagoons. When ϕ falls between 0 and 1, the distribution is increasing and then decreasing, unimodal and skew right, like most of the histograms in Figure 5-2, Figure 5-3 and Figure 5-4. When ϕ is greater than 1 (yellow line in Figure 5-5), the distribution is strictly decreasing, like a ski slope, and like some of the histograms in Figure 5-4. When ϕ approaches 0 (the blue line in Figure 5-5), the distribution is symmetric and bell-shaped, like some of the histograms in Figure 5-4.

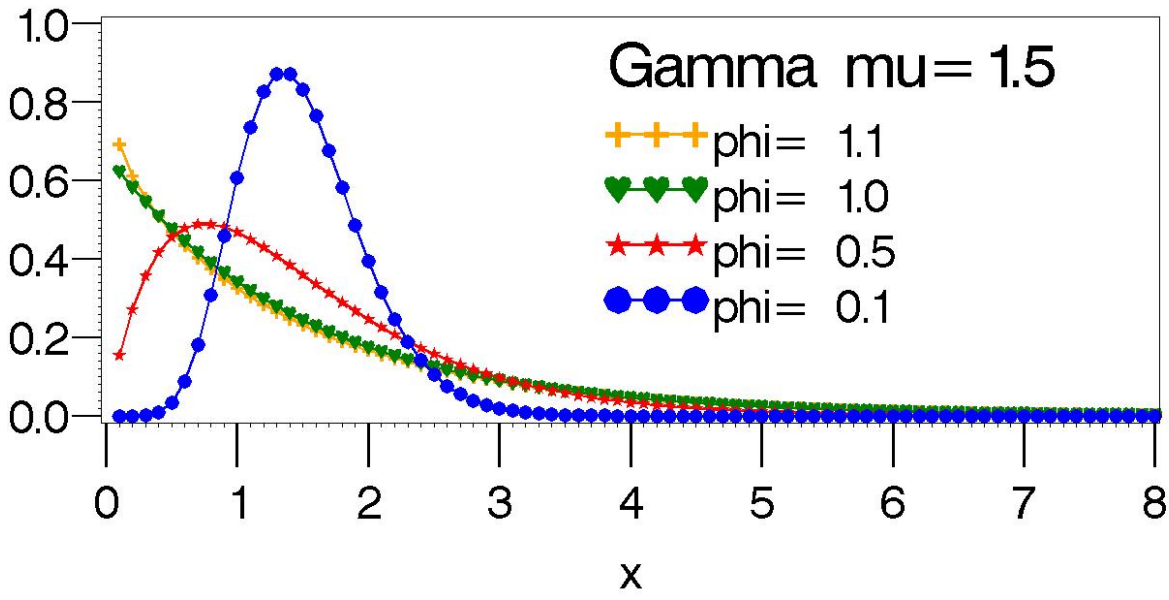

Figure 5-5. Shapes of Gamma Distribution for Different Parameter Values

5.3 Developing Candidate Mean Trend Variables

The mean trend function quantifies the relationship between the expected value of NH_3 emissions and the predictor variables. When combined with the link function, the mean trend

function provides the formula that is used to obtain the point estimate. Section 5.1.1 discusses the challenges of deciding how many and which of the static farm-based predictor variables to include, and shows how unbalanced coverage of meteorological conditions from site-to-site presents an obstacle to using the NAEMS data to learn about the effects of any of the farm-based variables on NH_3 emissions. Sections 5.3.1 through 5.3.5 describe how functional forms were chosen to represent effects of the continuous predictor variables on NH_3 emissions. Section 5.3.7 explains the selection of a working mean trend function, based on the continuous predictors, which will be used in Section 5.4 to make decisions regarding the covariance and link functions.

Table 5-8 presents the summary statistics for NH_3 emissions and the ambient meteorological variables. These summary statistics provided the context within which decisions regarding the form of the mean trend function were made. The mean value of NH_3 emissions was 1.3 kg, with a standard deviation of 1.4 kg. The minimum value is 0 kg, and the maximum observed half-hour emissions value was 16 kg. Notice that the median, 0.77 kg, is less than the mean, which is always the case for skew-right distributions. The middle 50 percent of emissions fall between the lower and upper quartiles, 0.38 and 1.7 kg, respectively.

Table 5-8. Summary Statistics for NH_3 and Meteorological Variables

Variable[a]	Description	Mean	Std Dev	Min	Lower Quartile	Median	Upper Quartile	Max
nh3	NH_3 emissions (kg)	1.30	1.42	0.00	0.38	0.77	1.66	16.09
ta	Temperature (^{o} C)	15.35	10.13	-23.29	8.33	16.40	22.94	41.37
ha	Relative humidity (%)	62.35	22.21	6.58	44.58	63.91	81.43	100.00
ws	Wind speed (m/s)	3.34	2.36	0.10	1.70	2.80	4.30	17.40

[a]Summary statistics for *hour* and *jday* are not included.

Ambient temperature in the NAEMS data ranges from -23 to 41 ^{o}C, with the middle 50 percent of values falling between 8 and 23 ^{o}C. The distribution of temperature is more symmetric than the distribution of NH_3 emissions, and if it is skew, it is skew to lower temperatures (meaning there are a few extreme low temperatures that would pull a tail to the left.) Notice that the mean is slightly less than the median.

Relative humidity can only take values from 0 to 100, and in this dataset it ranges from 6.6 to 100, with the middle 50 percent of values falling between 45 and 81 percent. The mean and median are close together, and the distribution is somewhat symmetric. Wind speed values range from 0 to 17 m/s. The distribution of wind speed is quite skew right; 75 percent of the values fall below 4.3 m/s, but there are a handful of extreme values such as 17 m/s.

Table 5-9 summarizes the candidate mean trend variables chosen as the functional forms through for each predictor variable in the EEM.

Table 5-9. Summary of Main Effect Mean Trend Variables

Main Effect	Original Predictor Variable(s)[a]	Functional Form Chosen	Centering Value	Scaling Value
animal	*animal*	Same as original variable	NA[b]	NA
size	*capacity**	*size** = *(capacity*)(adultwt*)*, Linear	1,977,855	1,845,378
	*adultwt**			
ta	*ta**	Linear	16	10
ha	*ha**	Linear	61	22
ws	*ws**	Linear	3.2	2.2
sa	*sa**	Linear	160	89
sh	*Solar radiation via hour*	As defined in Equation 5-2	NA	NA
ch				
sd	*Solar radiation via jday*	As defined in Equation 5-3	NA	NA
cd				

[a] An asterisk (*) is used to note that these predictor variables are the original values reported in the data submitted to the EPA before centering and scaling.
[b] NA = Not applicable.

5.3.1 Temperature

To determine the functional form through which the predictor variable for ambient temperature, *ta*, should enter the mean trend function, the EPA plotted $\ln(NH_3)$ versus *ta* for each animal type. The plots use $\ln(NH_3)$ on the y-axis rather than NH_3 because the log link function was chosen to represent the relationship between the mean of the gamma distribution and the mean trend function: $\ln(\mu_{st}) = x^T\beta$. Because the log function is a strictly increasing function, if $\ln(NH_3)$ is an increasing function of any predictor variable, then so is NH_3. Therefore conclusions based on $\ln(NH_3)$ emissions are directly applicable to NH_3 emission trends. Section 5.4.1 shows why this decision was made and makes it clear that the EEM development process involves a nonlinear decision-making process, as illustrated in Figure 5-1, in which decisions are re-evaluated based on results of the EEM validation analyses.

Figure 5-6 shows that $\ln(NH_3)$ increases with increasing temperature. This pattern is consistent across animal types and sites, except for the points at the bottom of the graphs that form horizontal lines where $\ln(NH_3)$ is approximately -3. These points correspond to very low NH_3 emissions (near zero), and the fact that they do not follow the same pattern with respect to the relationship to *ta* brings their validity into question.

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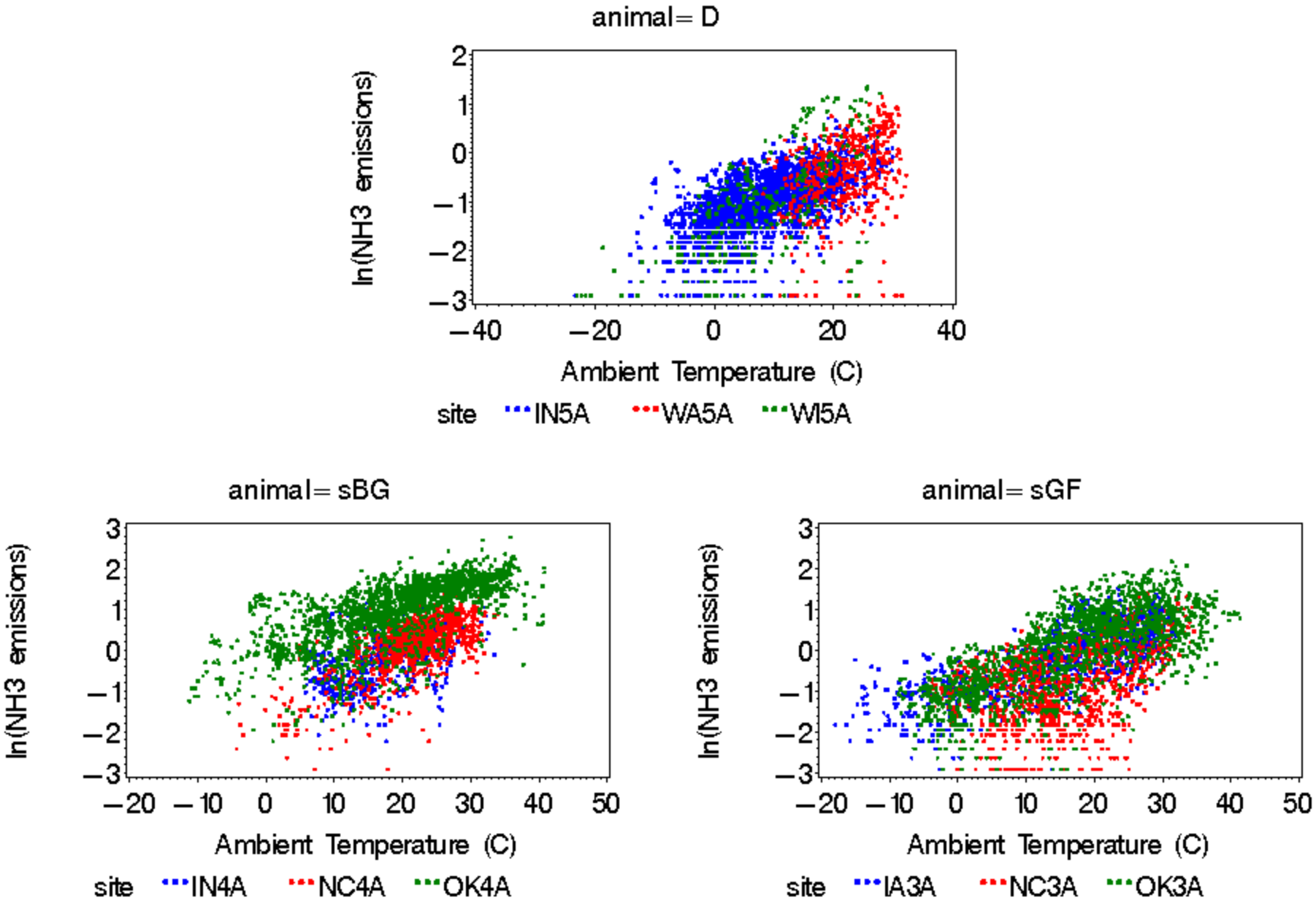

Figure 5-6. NH_3 Emissions vs. Temperature, by Animal Type (color-coded by site)

The axes in three plots of Figure 5-6 were scaled to fit the data for the different animal types. This scaling makes it clear that the range of NH_3 emissions is quite different for the different animal types. It also highlights differences in the range of temperature values covered at the three different types of farms. There are very few temperature values beyond 33 ^oC for the dairy sites, while there are quite a few at the swine sites.

To examine the need for an interaction between *ta* and the other meteorological variables, the EPA produced graphs of $\ln(NH_3)$ versus *ta* disaggregated by *wsbin* and *habin*. Figure 5-7 shows plots of NH_3 emissions versus *ta* for each of the eight *ws* bins given in Table 5-7. Each bin plot shows a linear regression line with a light blue band indicating the confidence limits for the mean of $\ln(NH_3)$ for the given temperature, and dark blue lines for the prediction limits for an individual prediction of $\ln(NH_3)$ for the given temperature. These plots allow examination of the change in the slope as *ws* increases. In bins 1 through 5, which are the only bins with sufficient data for trends to be examined, the slope of $\ln(NH_3)$ versus *ta* increases with increasing *ws*. Thus, the EPA expected an interaction term formed by multiplying *ws* and some function of *ta* to be helpful in describing variability in NH_3 measured emissions.

Figure 5-8 shows plots of $\ln(NH_3)$ versus *ta* for each of the eight *ha* bins given in Table 5-7. Ignoring bin 1, which does not contain sufficient data for drawing conclusions, the slope of $\ln(NH_3)$ versus *ta* decreases as *ha* increases. This observation is consistent with the expected result that as *ha* increases, NH_3 emissions from the lagoon decrease.

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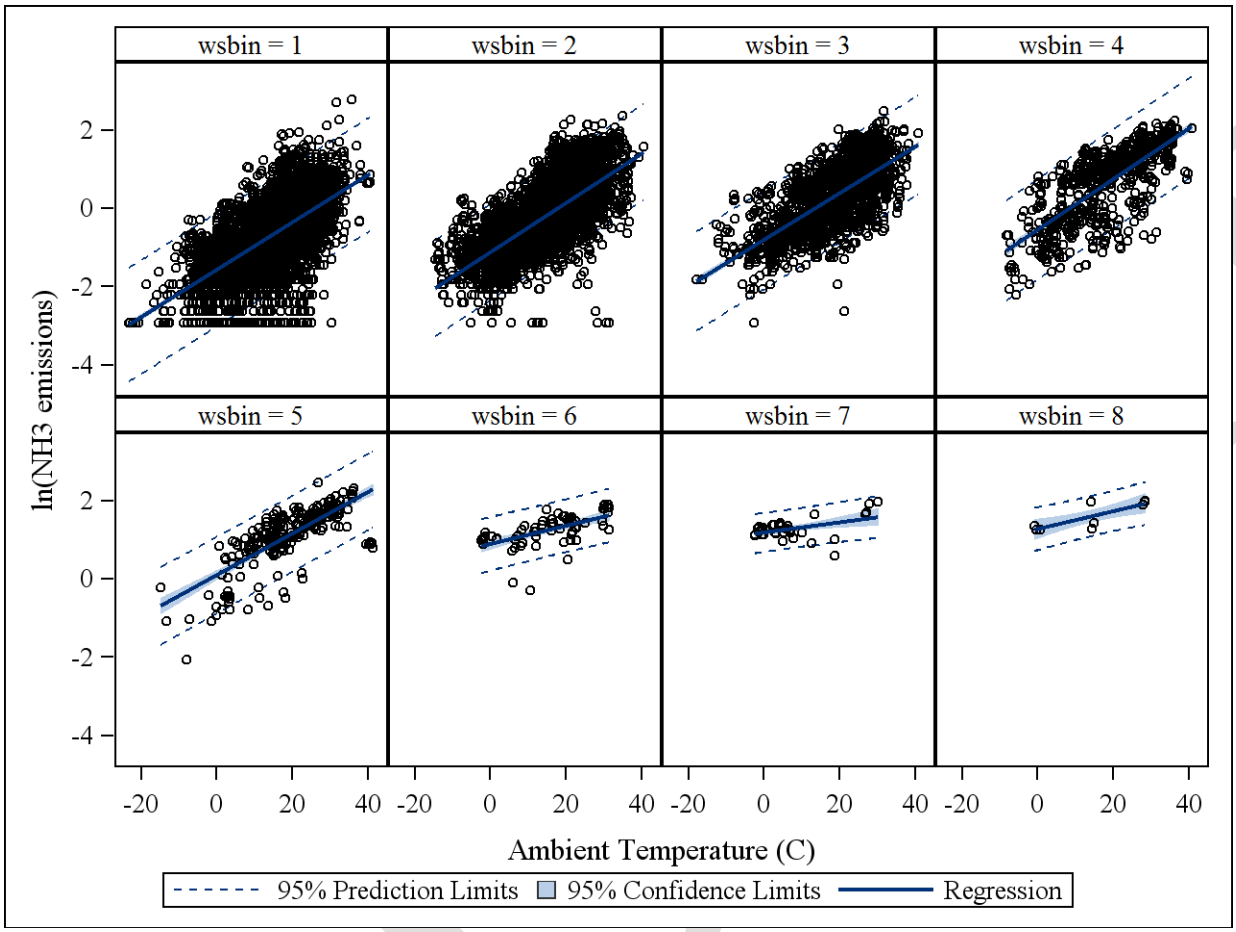

Figure 5-7. Scatter Plots of NH_3 Emissions vs. Temperature, by Wind Speed Bin (*wsbin*)

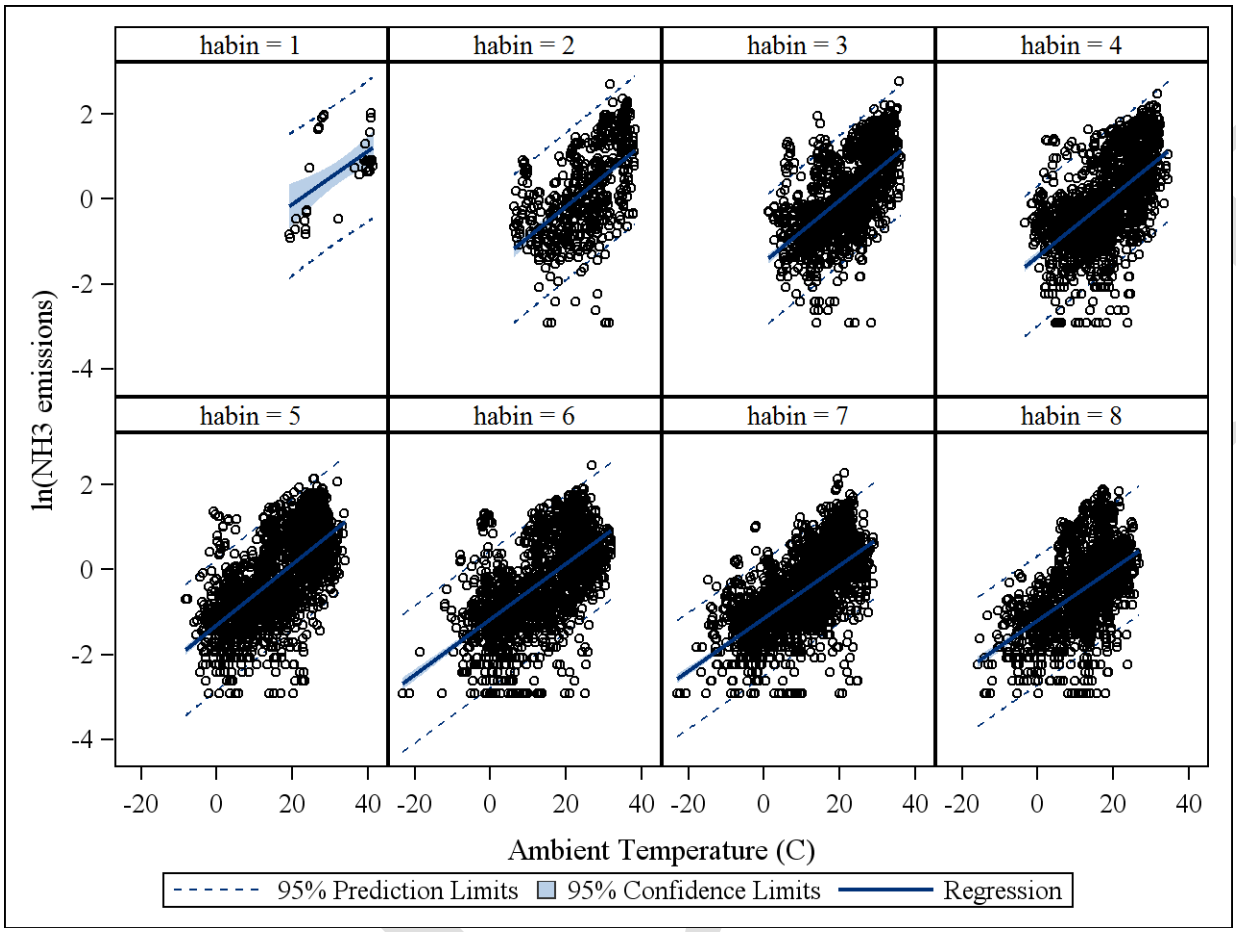

Figure 5-8. Scatter Plots of NH_3 Emissions vs. Temperature, by Relative Humidity Bin

5.3.2 Relative humidity

Figure 5-9 shows that the relationship between ln(NH_3) and *ha* for each of the three animal types is linear. This figure shows that ln(NH_3) decrease slightly with increasing relative humidity. This pattern is consistent across animal types and sites, except for the points at the bottom of the graphs that form horizontal lines where ln(NH_3) is approximately -3. These points correspond to very low NH_3 emissions (near zero), and the fact that they do not follow the same pattern with respect to the relationship to *ha* brings their validity into question.

Coverage of humidity is different for dairy and swine sites. The dairy sites have few values below 15 percent and none below 10 percent, while the swine sites have several values in both ranges.

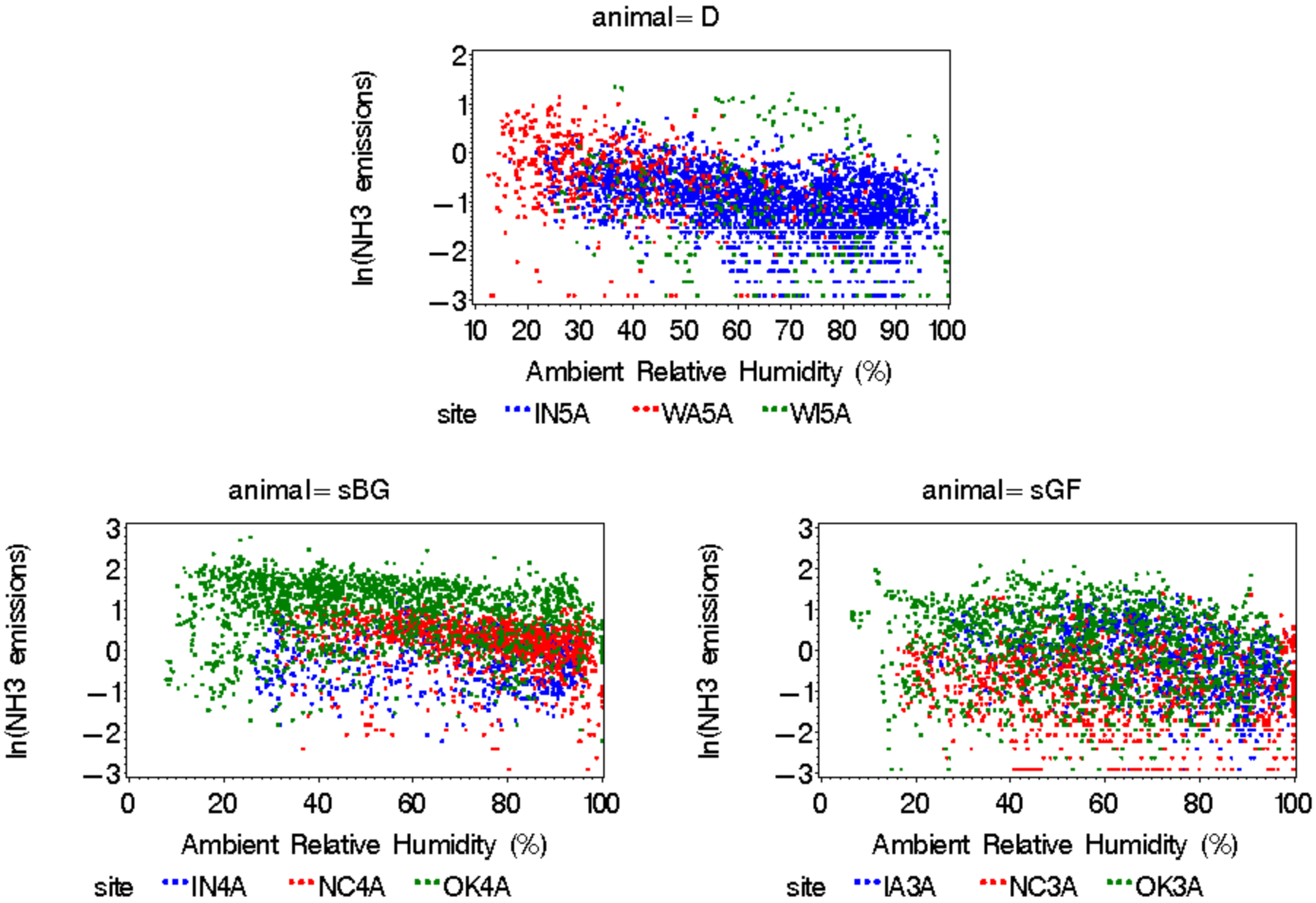

Figure 5-9. NH_3 Emissions vs. Relative Humidity, by Animal Type (color-coded by site)

The EPA investigated the need to include an interaction between NH_3 and *ha* in the mean trend function using scatter plots disaggregated by *ta* and *ws* bins. Figure 5-10 shows ln(NH_3) versus *ha* for the *ta* bins given in Table 5-7. Bins 3 through 7 have sufficient data to examine trends. In bins 3 to 6, the slope describing the relationship between ln(NH_3) and *ha* progresses from a negative slope, to a slope approximating zero, and to a positive slope. The relationship between the slope of *ha* and *ta* from bins 3 through 6 is consistent with the expectation that emissions increase with increasing values of temperature. Based on this analysis, the EPA expected that an interaction between *ha* and *ta* would help explain variability in measured NH_3 emissions. The negative slope shown in bin 7 may be due to a lack of data for the higher values of *ha* in that bin, combined with the effect of the low outliers at the higher values of *ha*.

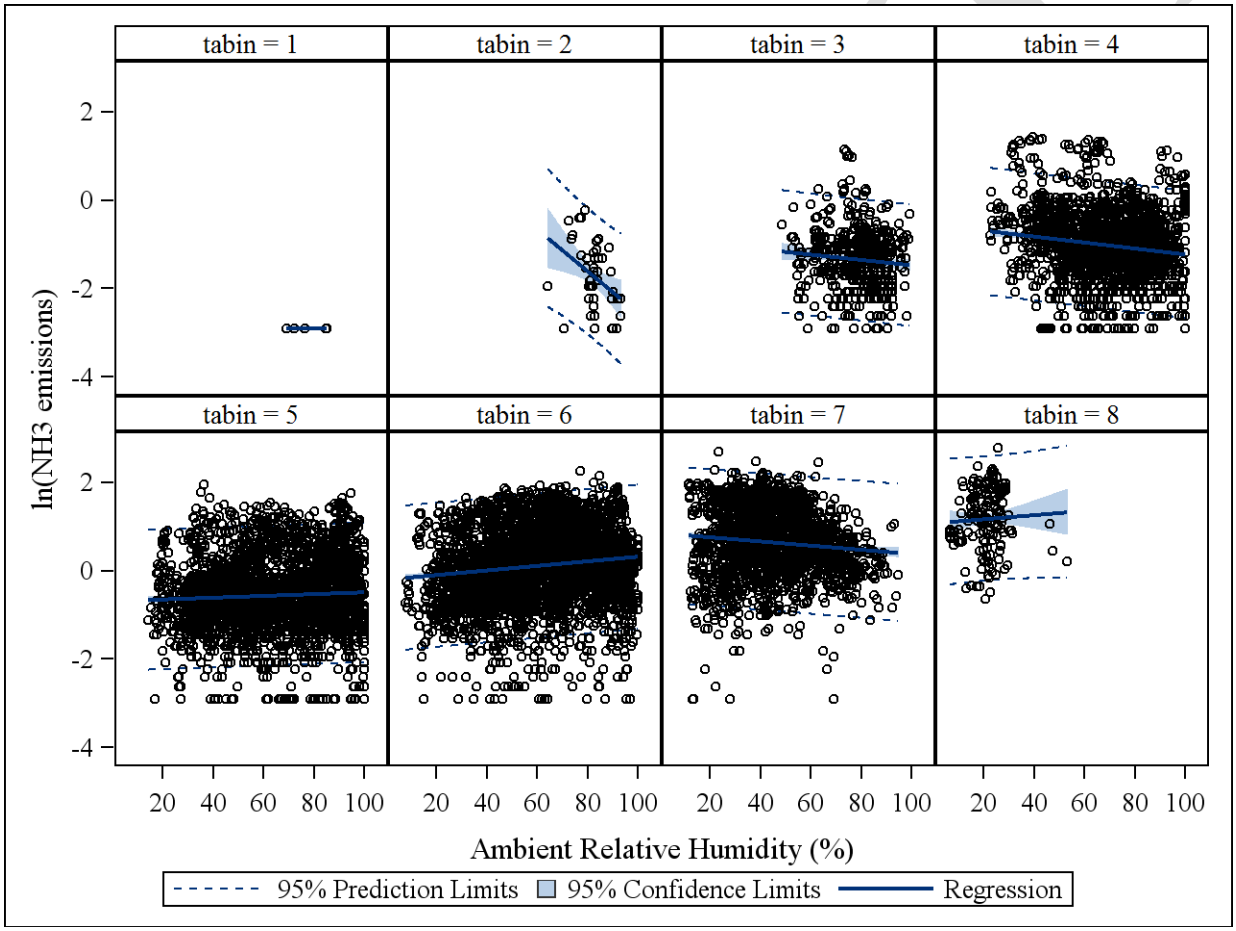

Figure 5-10. NH_3 Emissions vs. Relative Humidity, by Temperature Bin

Figure 5-11 shows ln(NH_3) versus *ha* for each of the *ws* bins given in Table 5-7. In all plots, the effect of *ha* on ln(NH_3) is negative. Bins 1 through 5 have sufficient data to examine trends in *ha*. As the plots progress from lower to higher wind speeds, the steepness of the slope increases (i.e., the slope becomes more negative with increasing *ws*). Notice that there are fewer values of high humidity when *ws* takes higher values, and the suspect near-zero NH_3 emissions

that form the horizontal lines at the bottoms of some plots do not occur at the higher values of *ws*. Thus, the EPA expected an interaction between *ha* and *ws* to help explain variability in emissions. Based on this analysis, the candidate mean trend variable that the EPA used for the effect of *ha* on NH_3 emissions is simply a linear function of *ha*. The EPA expected the effect of *ha* to be negative when the values of all other variables are held equal.

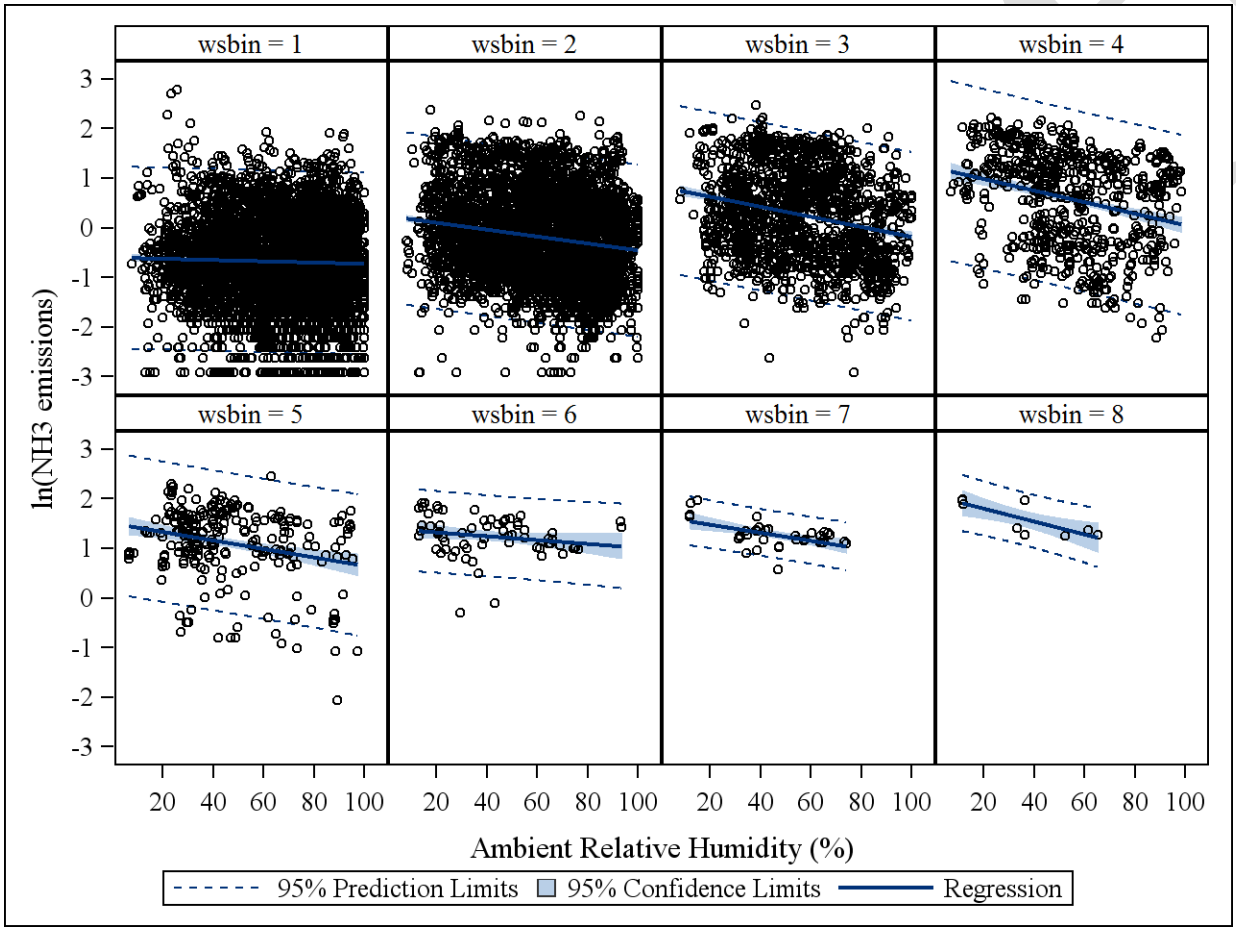

Figure 5-11. NH_3 Emissions vs. Relative Humidity, by Wind Speed Bin

5.3.3 Wind speed

In Figure 5-12, the plots of $\ln(NH_3)$ versus wind speed for each animal type and site show that at all sites, $\ln(NH_3)$ increases with increasing wind speed via an upward sloping curve that is quite steep at low winds speeds, but flattens out as wind speed increases. Notice that the curves are shifted to higher values of $\ln(NH_3)$ for some sites and to lower values for others. Because the meteorological conditions covered by sites WA5A and WI5A are quite different, with WA5A covering more high-temperature conditions and WI5A more low-temperature conditions, the first subplot suggests that the shifts in the curves result from different conditions with respect to other predictor variables.

The four high outliers at low wind speeds for site OK4A occur on days where temperature is very high and humidity very low. Thus, while high wind speed may increase emissions, it is not a necessary condition for high emissions. The expectation that NH_3 emissions would increase as a function of *ws* up to a threshold value, at which they will drop off dramatically is not supported in general, but when these plots are further disaggregated by site, this phenomenon does appear in the scatter plot (not shown) for swine site IA3A. For all observations at site IA3A for which *ws* is high but emissions are low, however, *ta* is less than 20 degrees C, and for many of those observations, *ha* is high. Thus, even for high values of *ws*, high humidity and low temperature can suppress emissions of NH_3.

The differences in the wind speed ranges for dairy sites versus swine sites are even more dramatic than the differences in the ranges of temperature and humidity. The dairy sites do not have wind speed values greater than 10 m/s, while the swine sites have many, especially the breeding and gestation facilities. Because the relationship between NH_3 emissions and wind speed is strong, these differences may have important implications for the ability of the EEMs to learn about the effects of high wind speeds for dairy sites.

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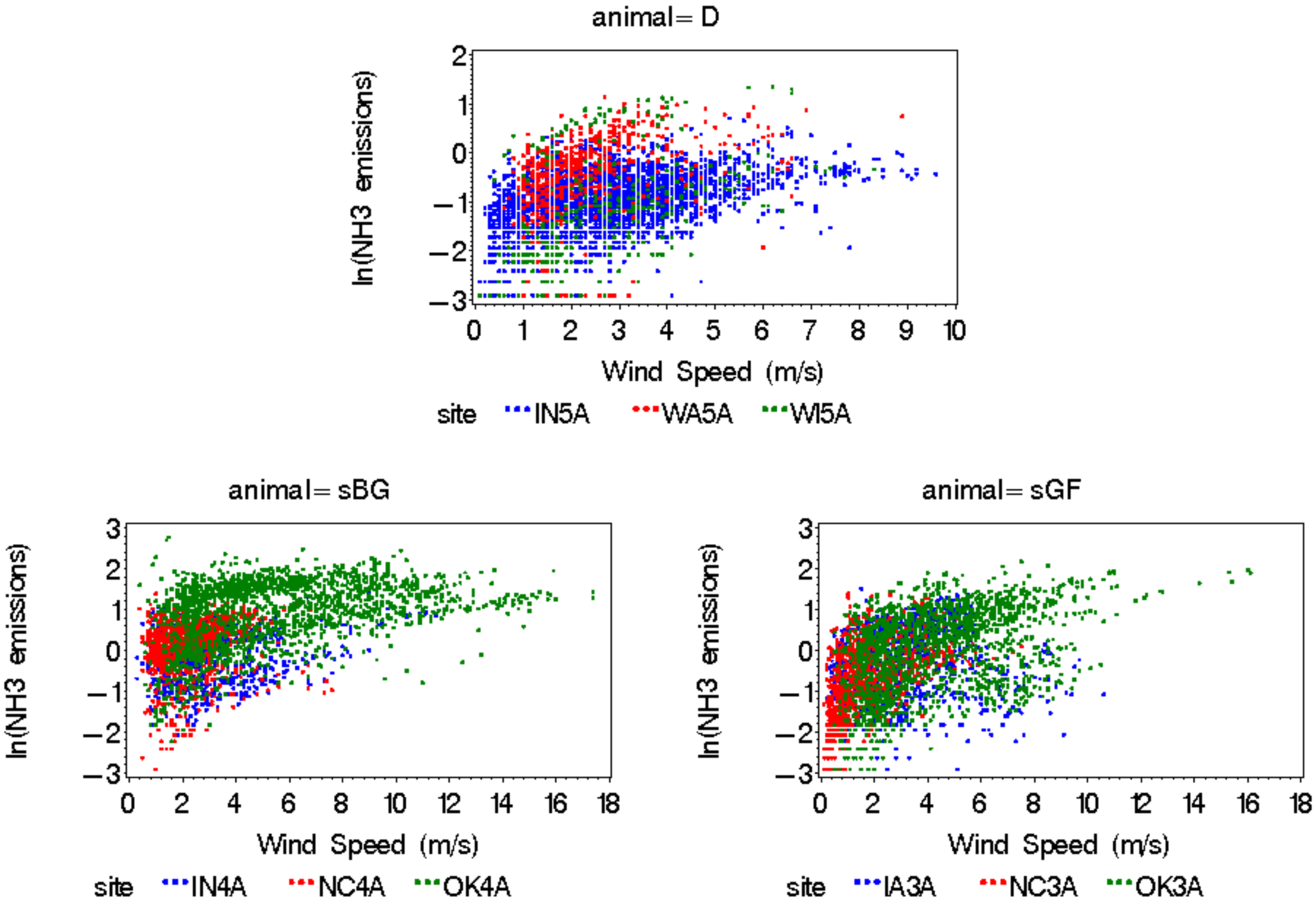

Figure 5-12. NH_3 Emissions vs. Wind Speed, by Animal Type (color-coded by site)

Figure 5-13 shows ln(NH_3) versus *ws* for the *ta* bins given in Table 5-7. Bins 3 through 8 provide sufficient data to determine trends in *ws*. Although these plots do not show changes in the slope describing NH_3 emissions versus wind speed for increasing ranges of *ta*, the EPA still considered an interaction between *ws* and *ta*.

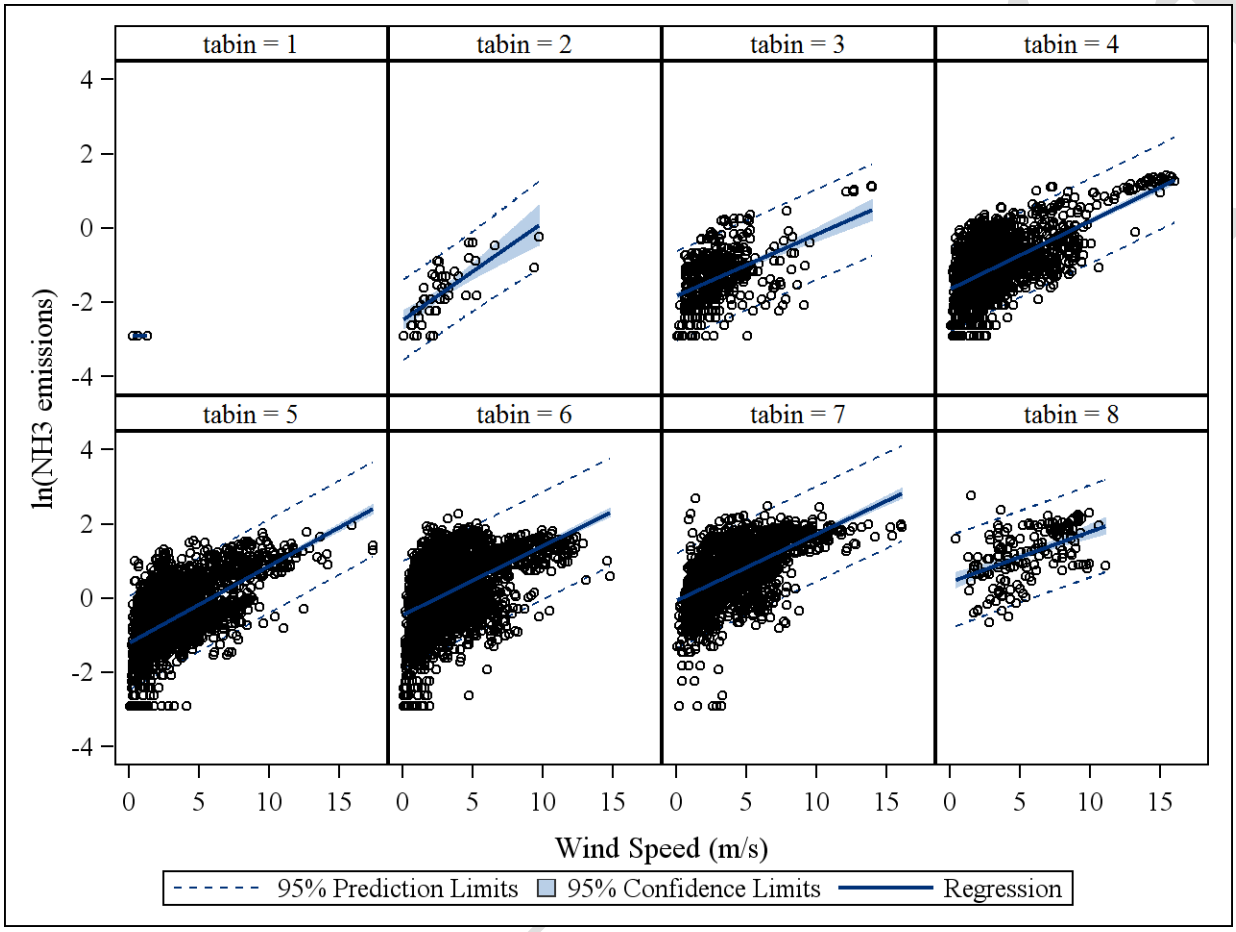

Figure 5-13. NH_3 Emissions vs. Wind Speed, by Temperature Bin

Figure 5-14 shows ln(NH_3) versus *ws* for the *ha* bins given in Table 5-7. The fact that the slope of the regression line decreases slightly with each successive *ha* bin is consistent with the expectation that higher humidity levels block emissions. Despite the curvature in the relationship between ln(NH_3) and *ws*, when the EPA used an exponential function of *ws*, the regressions did not fit as well as when a linear function was used. Therefore, the candidate mean trend variable the EPA used for the effect of wind speed was a linear function of *ws*.

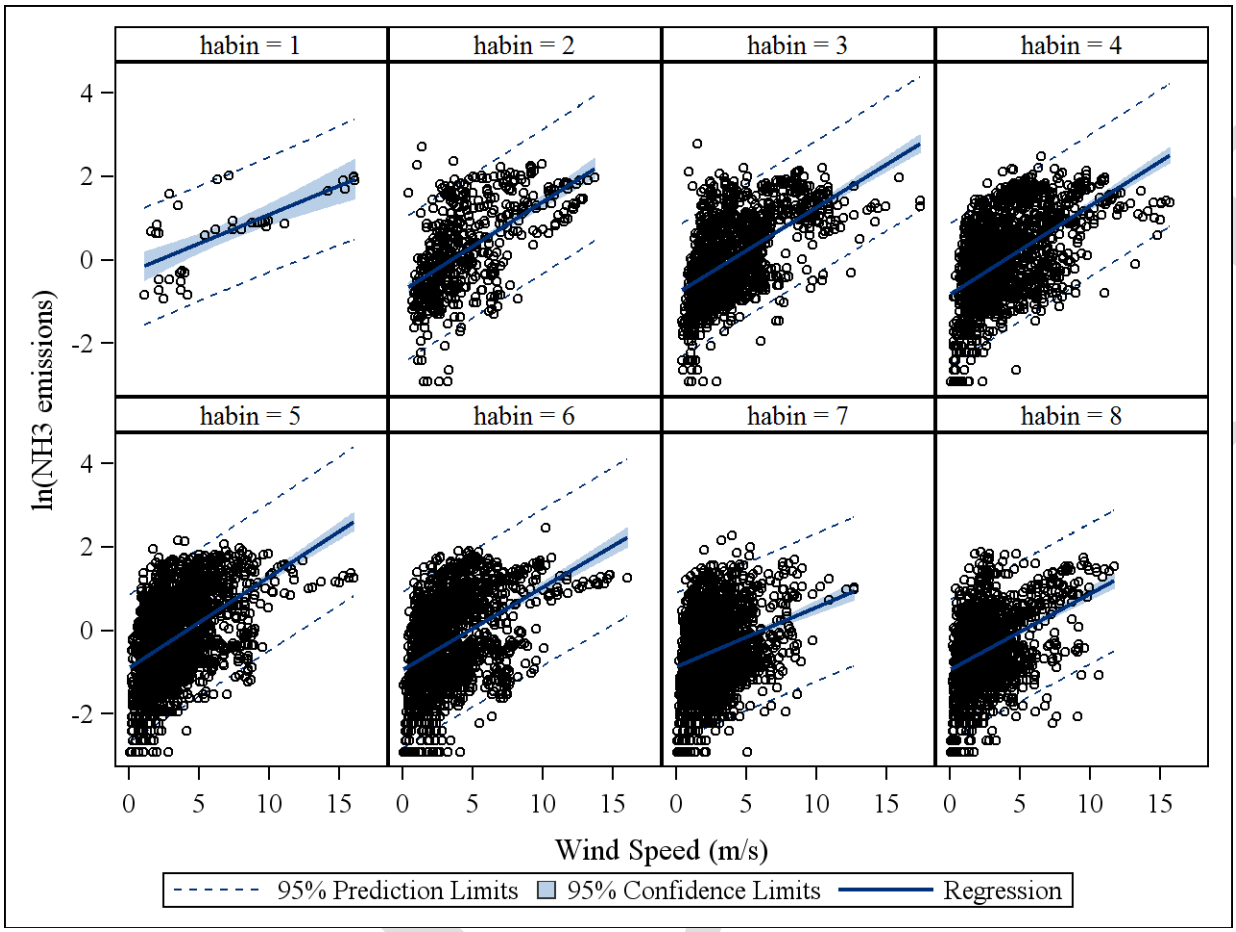

Figure 5-14. NH_3 Emissions vs. Wind Speed, by Relative Humidity Bin

5.3.4 Solar radiation via the diurnal cycle

When the EPA produced exploratory plots to determine what function of *hour* should be used to capture the effect of the diurnal solar-radiation cycle, some data issues became apparent. The box plots in Figure 5-15 show the distributions of $\ln(NH_3)$ for each hour of the day from hour 0 (midnight) to hour 23 (11 pm). For all sites, the time of day was reported in local standard time (LST) to mitigate any effect of one state observing daylight savings while another did not. This analysis showed that the highest of the $\ln(NH_3)$ maxima occur during the low- or no-sunlight hours of 1, 2 and 21 (1 a.m., 2 a.m. and 9 p.m.), and the lowest occurs at 11 am. This pattern was not consistent with the EPA's expectation that the maximum lagoon NH_3 emissions would occur during daytime hours.

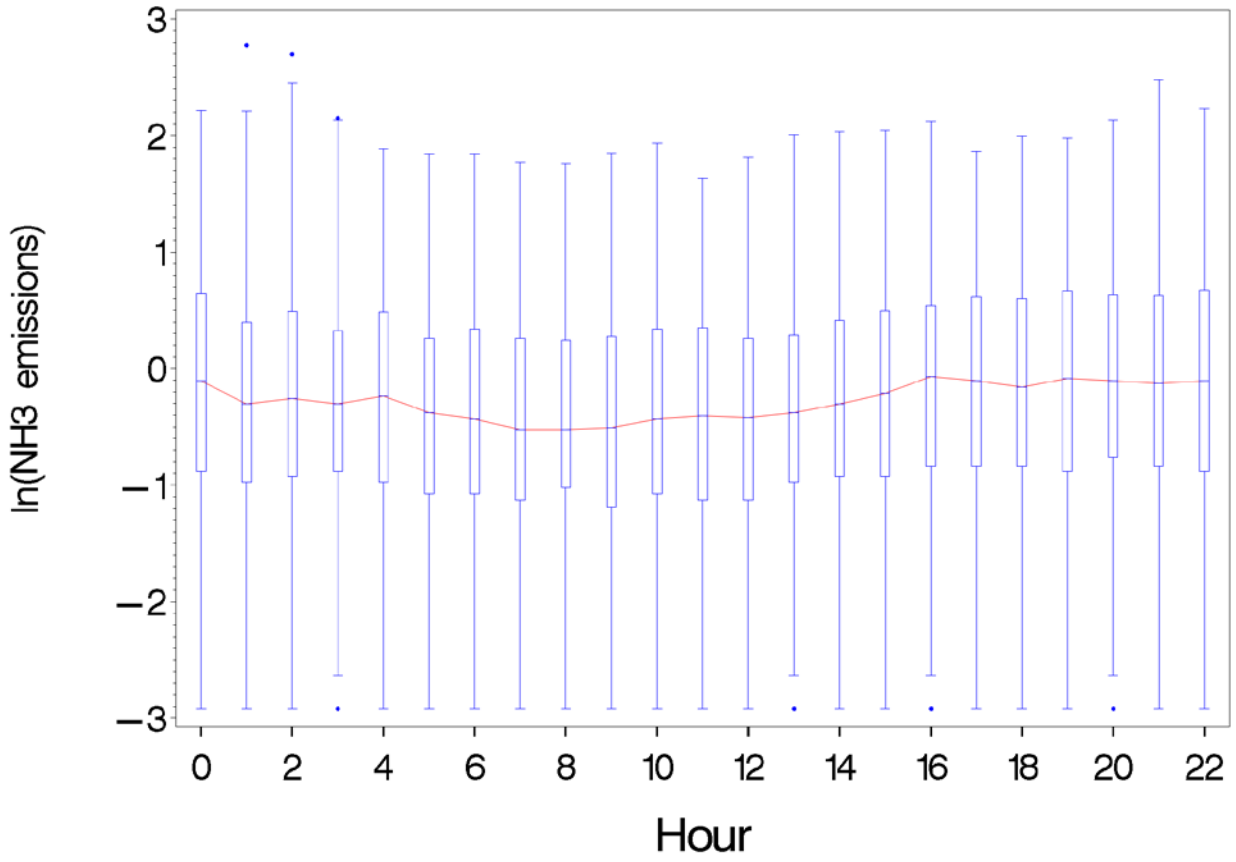

Figure 5-15. Box Plots of NH_3 Emissions vs. Hour

To investigate diurnal patterns more closely, and to keep the effects of extreme outliers from driving conclusions regarding trends, the EPA produced plots of other summary statistics for each hour: the mean, first quartile, median, third quartile, and 90th and 95th percentiles of ln(NH_3) (see Figure 5-16). All of these statistics demonstrate a similar periodic diurnal cycle for which the curvature appears sinusoidal. The hours with the lowest values for each statistic fall between 7 and 13 (7 am to 1 pm), and the hours with the highest fall between 20 and 0 (8 pm and midnight). This analysis was also not consistent with the expectation that effect of *hour* on NH_3 emissions would be due to the effect of solar radiation on lagoon temperature. Although the peaking of emissions at night might be due to a lagged effect of solar radiation on lagoon temperature, the EPA plotted other variables as a function of *hour* to investigate.

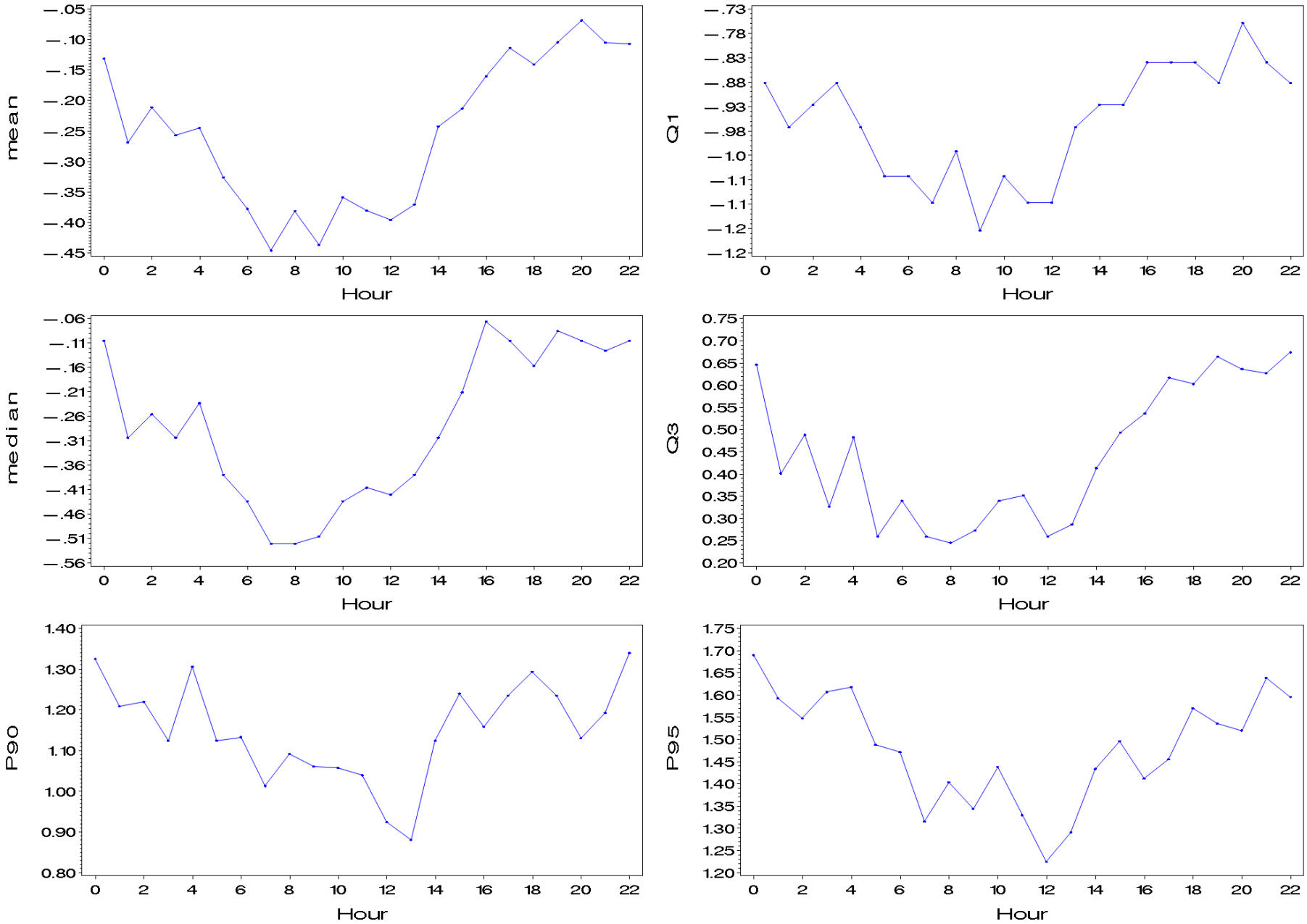

Figure 5-16. Summary Statistics for NH_3 Emissions vs. Hour

Figure 5-17 and Figure 5-18 show the distributions of *ta* and *ha* by *hour*, respectively. These plots show that the peak temperature values occurred over night and the peak humidity values occurred in the middle of the day. These patterns are counter intuitive and might indicate that there is an issue related to the time values in the data submitted to the EPA. The EPA continued using the values of *hour* as reported in the data submitted to the EPA. The EPA plans on resolving this issue with the NAEMS researchers. Correcting the values of *hour*, if needed, will be a minor change, and if the values of *hour* are shifted by 12, that will not affect the selection of functional form through which *hour* should enter the mean trend function, but it will affect the final regression coefficient estimates. Thus, if the values of *hour* change, the EPA will simply refit the EEM to the revised data to obtain the appropriate regression coefficient estimates.

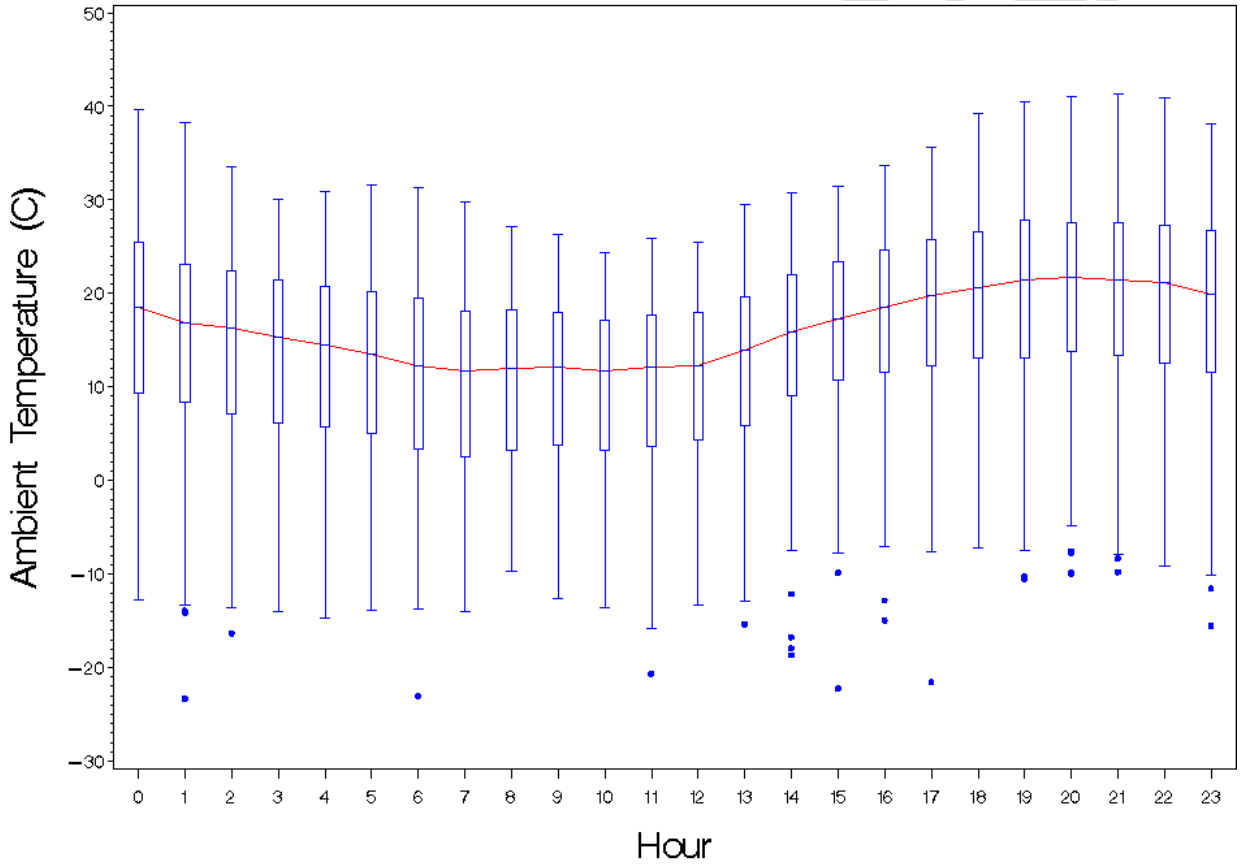

Figure 5-17. Box Plots of Temperature vs. Hour

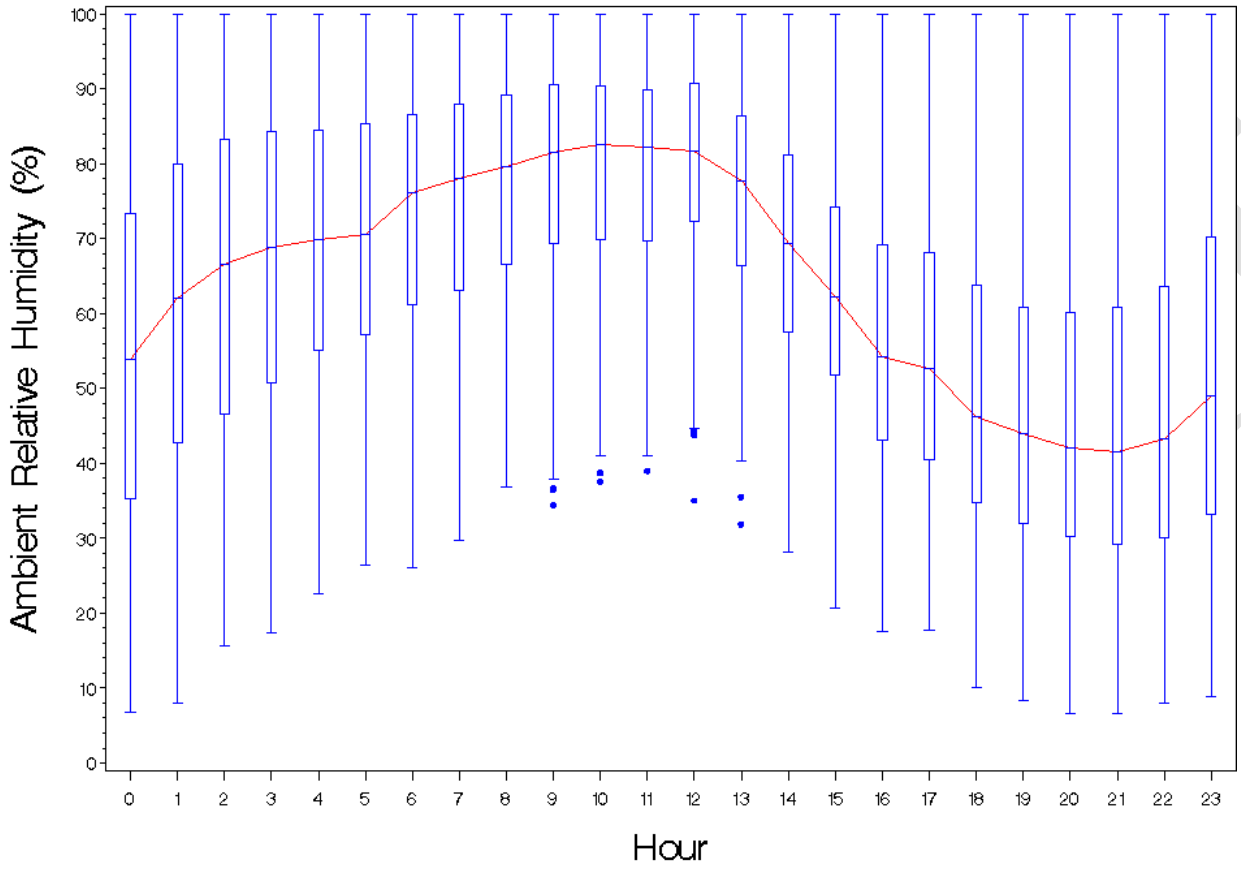

Figure 5-18. Box Plots of Humidity vs. Hour

Because representing a sinusoidal function of *hour* with a 24-hour period requires a sine and a cosine term, the EPA created the two new variables, *sh* and *ch*, where:

$$sh = \sin\left(\frac{2\pi\ (hour)}{24}\right) \quad \text{and} \quad ch = \cos\left(\frac{2\pi\ (hour)}{24}\right) \qquad \text{Equation 5-2}$$

The EPA used *sh* and *ch* as the variable names to indicate that these are hourly sine and cosine terms, as opposed to the daily sine and cosine terms *sd* and *cd* used to model an annual cycle, as explained in the next section. Thus, the candidate mean trend variables the EPA used for the effect of a diurnal solar radiation effect on NH_3 emissions were *sh* and *ch*.

5.3.5 Solar radiation via the annual cycle

To capture the effect of the annual solar radiation cycle on NH_3 emissions, the EPA used the variable *jday*, defined as the Julian day, which takes values 1 through 366 in leap years, and 1 through 365 otherwise. The plot of NH_3 emissions versus *jday* in Figure 5-19 at first makes it appear that not only is there an annual cycle; there is also a semi-annual cycle. There is a peak in

NH_3 emissions for the days corresponding to summer months and a minimum for days corresponding to winter months, but there are also smaller peaks for days corresponding to spring and fall months.

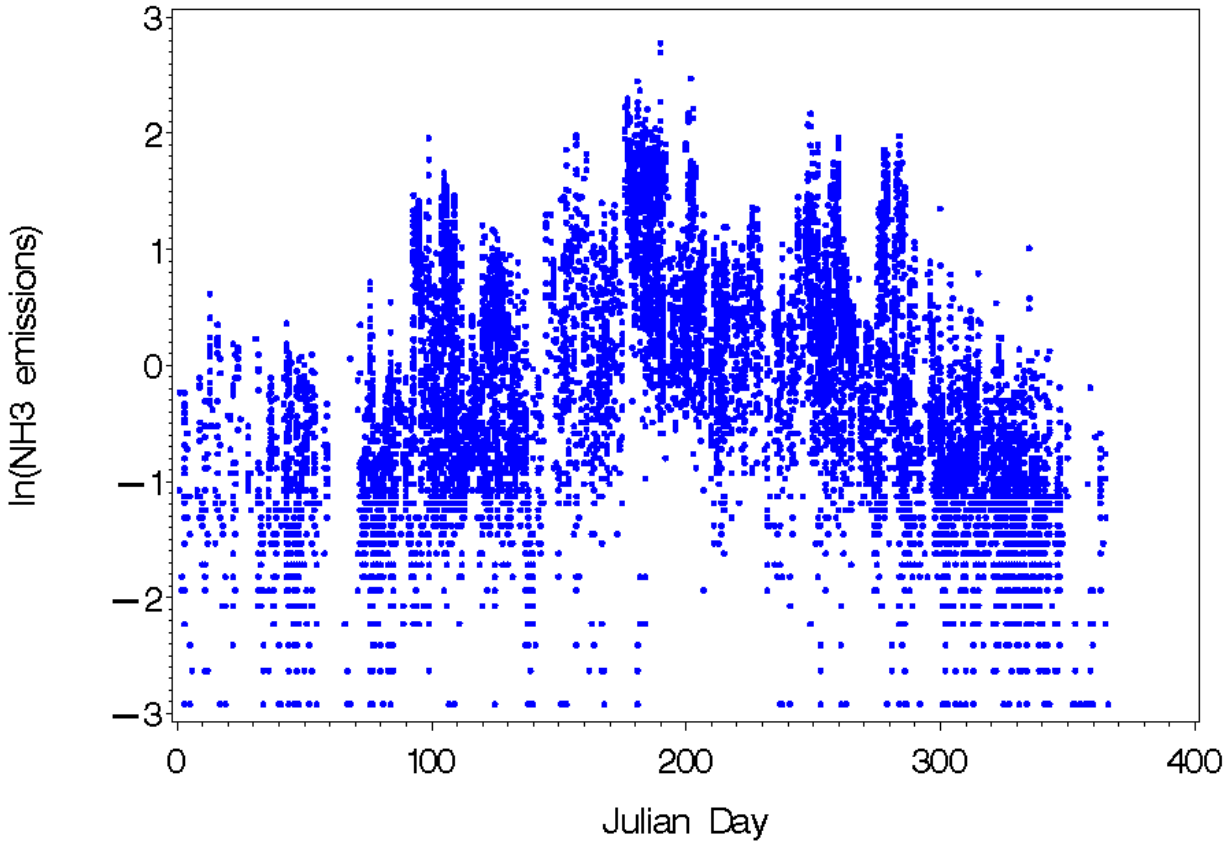

Figure 5-19. NH_3 Emissions vs. Julian Day

A histogram of the value of the variable *month* (Figure 5-20) shows that one explanation for the secondary peaks is that the majority of NH_3 emissions observations occur in the spring and fall. Because there are more observations during these seasons, there are more opportunities to see extreme values.

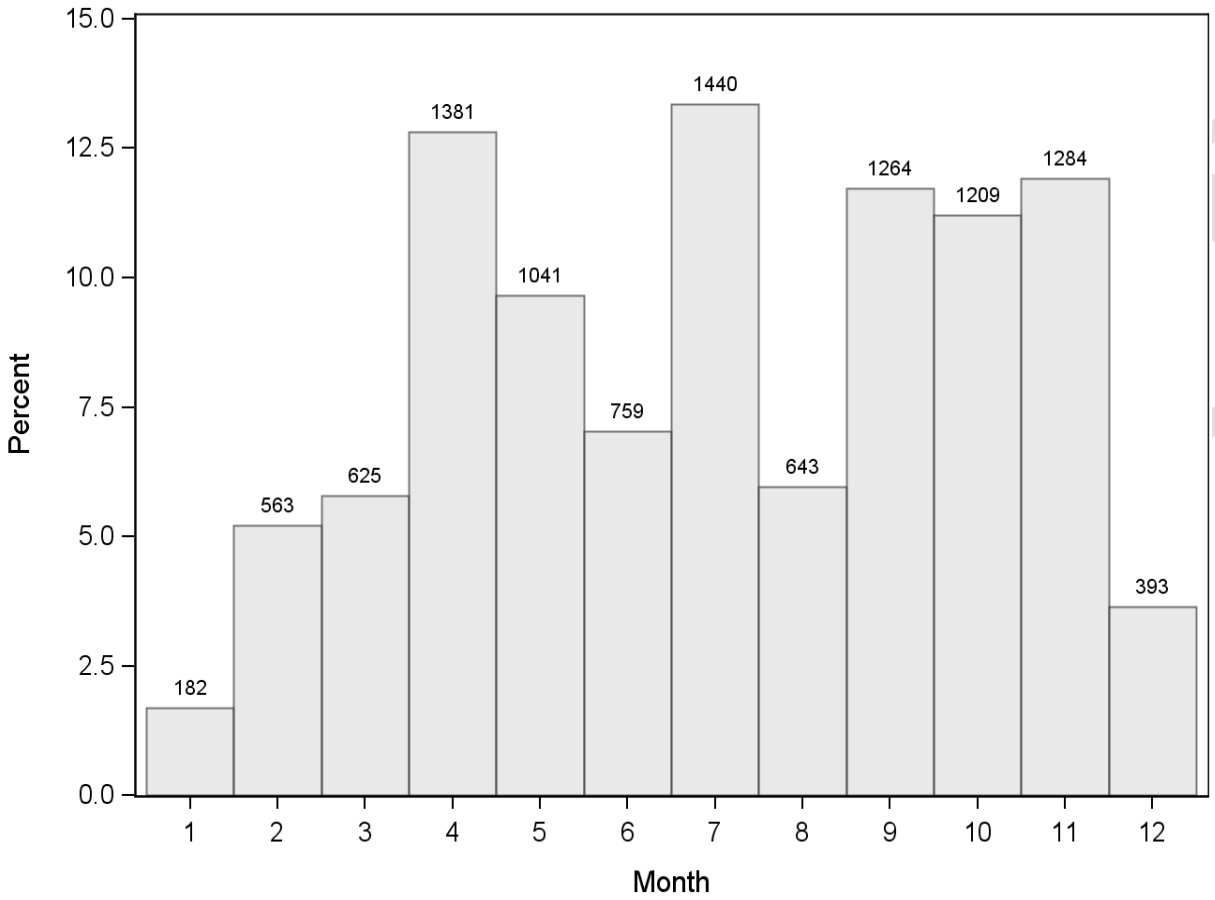

Figure 5-20. Percent and Number of Observations per Month

Based on the patterns shown in Figure 5-19 and Figure 5-20, the EPA chose to represent the annual effect of solar radiation on NH_3 emissions as a sinusoidal periodic function of *jday* with a period of 365.25 days. Therefore, the EPA created the two new variables, *sd* and *cd*, where:

$$sd = \sin\left(\frac{2\pi\ (jday)}{365.25}\right) \quad \text{and} \quad cd = \cos\left(\frac{2\pi\ (jday)}{365.25}\right) \qquad \text{Equation 5-3}$$

To ensure that additional harmonics were not needed, the EPA also created variables to represent a semi-annual cycle of solar radiation. These variables are the same as those in Equation 5-2, except that the denominator is 182.625. An ordinary least squares regression of NH_3 emissions on the first two terms (i.e., *sd* and *cd* on an annual basis) produced an R^2 of 0.2334. A regression on all four terms (i.e., *sd* and *cd* on annual and semi-annual bases) produced an R^2 of 0.2450. Because the semi-annual cycle explained less than two percent of variability beyond what was explained by the annual cycle, the EPA did not include the two

semi-annual cycle terms as mean trend variables. Thus, the candidate mean trend variables used for the effect of the annual solar radiation cycle NH_3 emissions were *sd* and *cd*.

5.3.6 Farm-Based Variables

In Section 5.1, the EPA's initial decisions regarding what farm-based variables to include as candidate predictor variables were made based on availability and the potential for the variable to influence NH_3 emissions. This section discusses the decisions regarding variable selection that the EPA made based on the ability of the EEMs to discern the effects of a variable on NH_3 emissions. This section also presents two challenges that were encountered in this analysis.

Table 5-10 shows the farm-based predictor variables values that describe the farm and lagoon configuration. Each of the variables is designated as being a static categorical or continuous/discrete predictor variable. The variables labeled continuous/discrete were treated as continuous variables in developing the EEMs, but were available as discrete numeric variables obtained from the NAEMS supporting documentation (e.g., SMPs). The continuous/discrete variables can take, at most, nine different values (i.e., one value for each site). However, because the EEMs must apply to lagoons other than those that participated in the NAEMS, a continuous function of these variables must be used in the EEMs.

Table 5-10. Summary of Farm-Based Predictor Variables

Variable [a]	Variable Type	Dairy Sites			Swine Sites					
		IN5A	WA5A	WI5A	IA3A	NC3A	OK3A	IN4A	NC4A	OK4A
animal[b]	Categorical	1	1	1	-1	-1	-1	-1	-1	-1
mms	Categorical	S	FS	FS	PP	PPR	PPR	PP	PPR	PPR
odorctrl	Categorical	N	N	N	N	N	Y	N	N	N
inlets	Categorical	1	1	1	2	1	1	1	1	2
*capacity**	Cont/Disc	2,600	5,600	1,700	3,840	8,000	3,024	1,400	2,000	2,784
*adultwt**	Cont/Disc	1,500	1,400	1,400	150	135	170	475	433	490
*barns**	Cont/Disc	4	6	6	4	5	3	9	9	3
*sa**	Cont/Disc	106	141	77	25	204	121	121	250	242

[a] For the variable *mms*: S = scrape, = FS = free-stall flush, PP = pull-plug pit, PPR = pull-plug w/pit recharge. An asterisk (*) indicates that the variable has not yet been centered and scaled.
[b] For the variable *animal*: 1 is used for dairy sites and -1 is used for swine sites.

5.3.6.1 *Challenges due to small number of NAEMS sites*

The first challenge is that there are only nine sites, or nine data points, but there are eight farm-based predictor variables. Although there are many observations of the continuous variables over time at each of the nine sites, the value of the farm-based predictor variables is the same for a given site over all time points. Effectively, this means that there are only nine data points available from which to learn about the effects of farm-based predictor variables on NH_3 emissions. It is impossible to learn about the effect of eight variables on NH_3 emissions with only nine data points. The following example demonstrates the challenge.

The example assumes that the predictor variable of interest is surface area, *sa,* and that only one half-hour period is being considered. For the example, the assumptions were made that the meteorological conditions are exactly the same at all sites and that data are available for only two sites. The surface area at Site 1 is 121,000 ft^2 and 200,000 ft^2 at Site 2. The NH_3 emissions from Site 1 are 1.0 kg and 1.5 kg from Site 2.

Equation 5-1 can be modified for this simplified example by omitting the subscript t, not including the optional term e_s and using the identity link function. The simplified equation is given in Equation 5-4.

$$\boldsymbol{Y_s \sim Gamma\{\mu_s, \phi\};\ \mu_s = \beta_0 + \beta_1 sa_s; s = 1, 2} \qquad \text{Equation 5-4}$$

Using the example values for surface area and NH_3 emissions, the simplified equation (i.e., EEM) can be written as Equation 5-5 and Equation 5-6, respectively.

$$\boldsymbol{1.0 \sim Gamma\{\mu_s, \phi\};\ \mu_s = \beta_0 + \beta_1 121} \qquad \text{Equation 5-5}$$

$$\boldsymbol{1.5 \sim Gamma\{\mu_s, \phi\};\ \mu_s = \beta_0 + \beta_1 200} \qquad \text{Equation 5-6}$$

As illustrated in these site-specific equations, there are three unknown parameters to be estimated from this dataset of two observations: $\beta_0, \beta_1,$ and ϕ. Three unknowns cannot be solved using only two equations. In this example, the number of parameters to be estimated (i.e., the model degrees of freedom), exceeds the number of observations in the dataset (i.e., total degrees of freedom). Consequently, it is impossible to estimate the parameters in the EEM.

The purpose of the scaling parameter ϕ can be thought of as quantifying variability around the mean. It determines how wide or narrow a curve like those in Figure 5-5 would be. Ignoring ϕ, solving for β_0 and β_1, and using the resulting EEM would be equivalent to saying that there is a 100 percent probability that all sites have the emissions given by this linear function under the same meteorological conditions. The emissions from different sites, however, will be different even if the meteorology is the same and the values of the variables in the mean

trend function are the same because there are different characteristics of each farm that have not been accounted for in the EEM that result in different emissions.

If the example included additional data for Site 3 (surface area = 121,000 ft^2 and NH_3 emissions of 1.1 kg), the three unknowns could be resolved. However, the EEM would perfectly fit these three data points, and thus these three sites. In this instance, although an estimate for the parameter that quantifies variability could be determined, it would not be a good estimate, because there are simply not enough data values from which to learn about variability. If such an EEM were to be applied to sites other than these three (for the same meteorological conditions), the variability quantified by ϕ would likely not be large enough for the 95-percent prediction intervals to contain 95 percent of the true the emissions values.

The difference between the total degrees of freedom and the model degrees of freedom is called the "error degrees of freedom." The error degrees of freedom must be large enough to adequately quantify variability of emissions around the mean. In other words, for any given set of values of predictor variables, the value of emissions will not be the same. Instead, there will be a distribution of values, and the EPA uses the gamma distribution to quantify the range of values of emissions for the chosen predictor variables. This variability is the source of uncertainty when the EEM is applied to sites outside the study. The estimated value of parameters must be based on many observations to quantify the spread of this distribution. The intercept, β_0, uses one degree of freedom, and the scale parameter, ϕ, uses one degree of freedom. One continuous mean trend variable requires one degree of freedom for its slope. The number of degrees of freedom used by each categorical variable is one less than the number of values the variable can take. For example, the categorical variable *mms*, which takes four possible values, uses three degrees of freedom.

With only nine NAEMS sites, there are nine total degrees of freedom with which to learn about farm-based variables. After using two degrees of freedom with the intercept and scale parameter, there are only seven degrees of freedom left. The EPA decided to use two additional degrees of freedom in the mean trend function and allow five error degrees of freedom for quantifying variability. The decision as to how many error degrees of freedom are sufficient is a judgment call, and was assessed by evaluating the percentage of NH_3 emissions in the cross-validation dataset that fall inside the 95-percent prediction interval.

In developing the EEMs from the NAEMS data, if the EPA were to attempt to develop a separate EEM using only data from the dairy sites, there would be only three data points. Consequently, at most, only one farm-based predictor variable could be used. The resulting EEM would perfectly fit the three dairy sites, with no degrees of freedom for error, but it would be

inappropriate to use it for predicting other sites due to the inability to adequately quantify uncertainty.

Because these obstacles would restrict individual dairy and swine EEMs to being functions of too few predictor variables, the EPA decided to use data from both dairy and swine lagoons to develop the EEM. The differences in NH_3 emissions from different animals are driven by differences in the contribution of precursors of NH_3 to the lagoon, differences in farm/lagoon management practices and/or differences in the physical and chemical processes that convert precursors to actual emissions. Of all the candidate predictor variables discussed in Section 5.1.1, those describing the lagoon liquid, for which the effects on NH_3 emissions were detailed in Section 5.1.1.2, are the variables whose effects on emissions come closest to representing the quantity of precursors and potential for conversion of precursors to emissions. Unfortunately, as shown in Table 5-3 and Table 5-4, the availability of this information was too restrictive to allow its use in EEM development. Thus, the EPA chose to use the farm-based predictor variables in Table 5-9 as surrogates for those describing differences in the lagoon liquid and thereby accounting for any difference in emissions from dairy and swine lagoons

Because the EPA allowed for five error degrees of freedom to quantify variability, only two degrees of freedom remain for the farm-based variables The EPA decided to compare three candidate EEMs, each using two of three variables chosen to represent differences in precursor content and potential for conversion of precursors to emissions. Using the variable *animal* (i.e., swine or dairy) might account for a broad range of differences in the contribution of precursors due to differences in feed, nitrogen excretion and differences in manure management. The variables *capacity* and *adultwt* would also provide information about contribution of precursors to the lagoon. However, because using both of these variables would use up two degrees of freedom, the EPA created the variable *size*, which was defined as the product of *capacity* and *adultwt*. This compound variable quantifies the average live animal mass on the farm while using only one degree of freedom. The NH_3 emissions might also be greater when surface area is larger due to more interaction of the surface of the lagoon with the atmosphere providing more opportunities for desorption of NH_3. Thus, the three variables chosen were *animal*, *size* and *sa;* and the three candidate EEMs each contain two of these three variables.

5.3.6.2 ***Challenges due to unbalanced coverage of meteorological conditions***

In addition to the challenges posed by having only nine data points from which to draw conclusions, the unbalanced representation of meteorological conditions at the different sites may also confound the ability of the EEM to discern effects of farm-based predictor variables. Figure 5-21 shows histograms of NH_3 emissions disaggregated by the three animal types: dairy, swine breeding and gestation, and swine growing and finishing. The number of observations per

bar are labeled to make it easier to see the outliers. Notice that the highest value of emissions for any dairy site is around 4 kg, but both swine sites have many values above 4 kg. The highest value of emissions for any swine growing and finishing site is around 9 kg, but the values for the breeding and gestation sites go as high as 16 kg.

Figure 5-21 gives histograms of NH_3 emissions further disaggregated by both animal type and site. Within each animal type, the mean and variation of emissions tend to be driven by a single site and the differences among sites were due primarily to different seasonal monitoring patterns at each site. Figure 5-22 gives the number of observations per month for each site, with a numerical summary provided in Table 5-11. Figure 5-21 shows that the greatest number of high emissions values among all sites was measured at swine breeding-gestation site OK4A, and Figure 5-22 shows that this site had far more measurements for June and July than any other site. Also, at all three of the breeding-gestation sites, relatively few measurements were made during the colder months, and at IN4A no measurements were taken from November through March. Accordingly, the swine breeding-gestation sites are more representative of lagoon emissions during the warmest six months of the year. In contrast, the great majority of measurements at two of the dairy sites (WI5A and IN5A) were made in the colder months of October through April. At dairy site IN5A, which had the lowest emissions of all sites, no measurements were taken in June, July or August. The highest dairy emissions were at WA5A where almost all of the measurements were taken between June and September.

At this point, no conclusion can be drawn from plots or summary statistics regarding differences in NH_3 emissions from lagoons for different animal-types because the meteorological conditions under which the data were collected for the different sites are so different. The emission differences among animal type appear to be driven by the differences in the NAEMS sampling schedule across the sites, with higher emissions occurring in the summer months and lower emissions in the colder months across all animal types. While the seasonal data availability is different among sites, the NAEMS data collectively provide coverage of all the seasons when all sites are combined, though the data are quite sparse for January.

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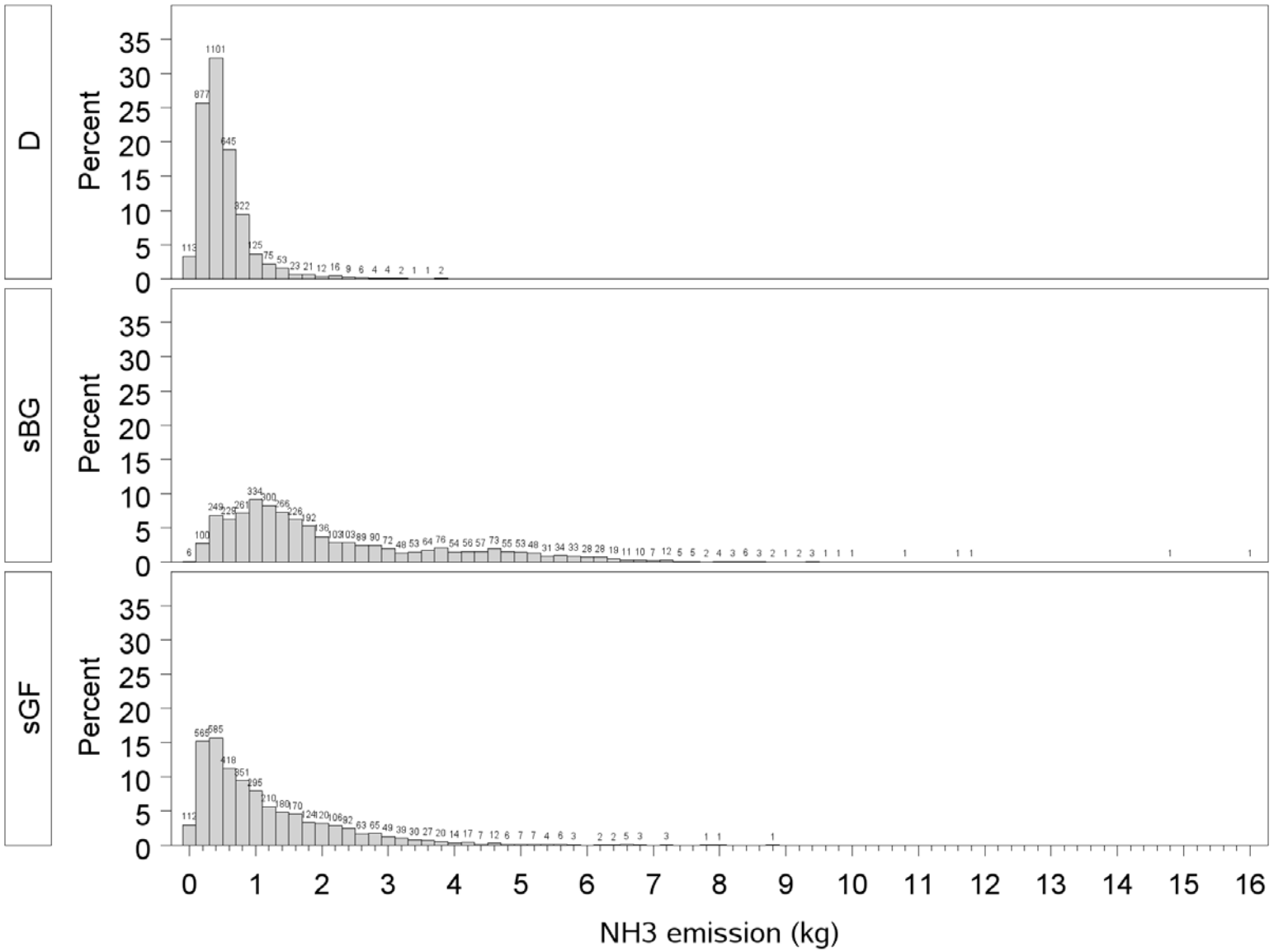
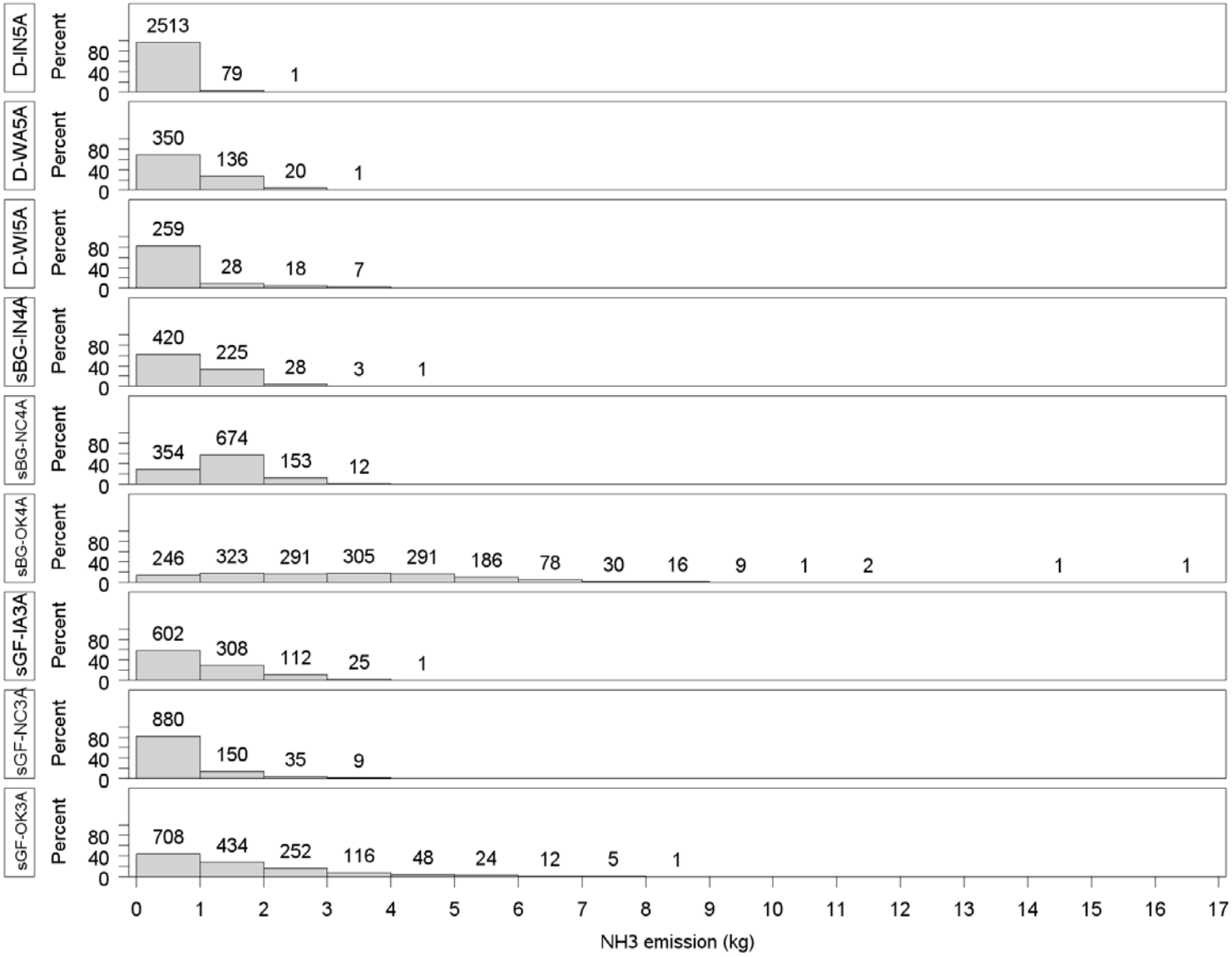


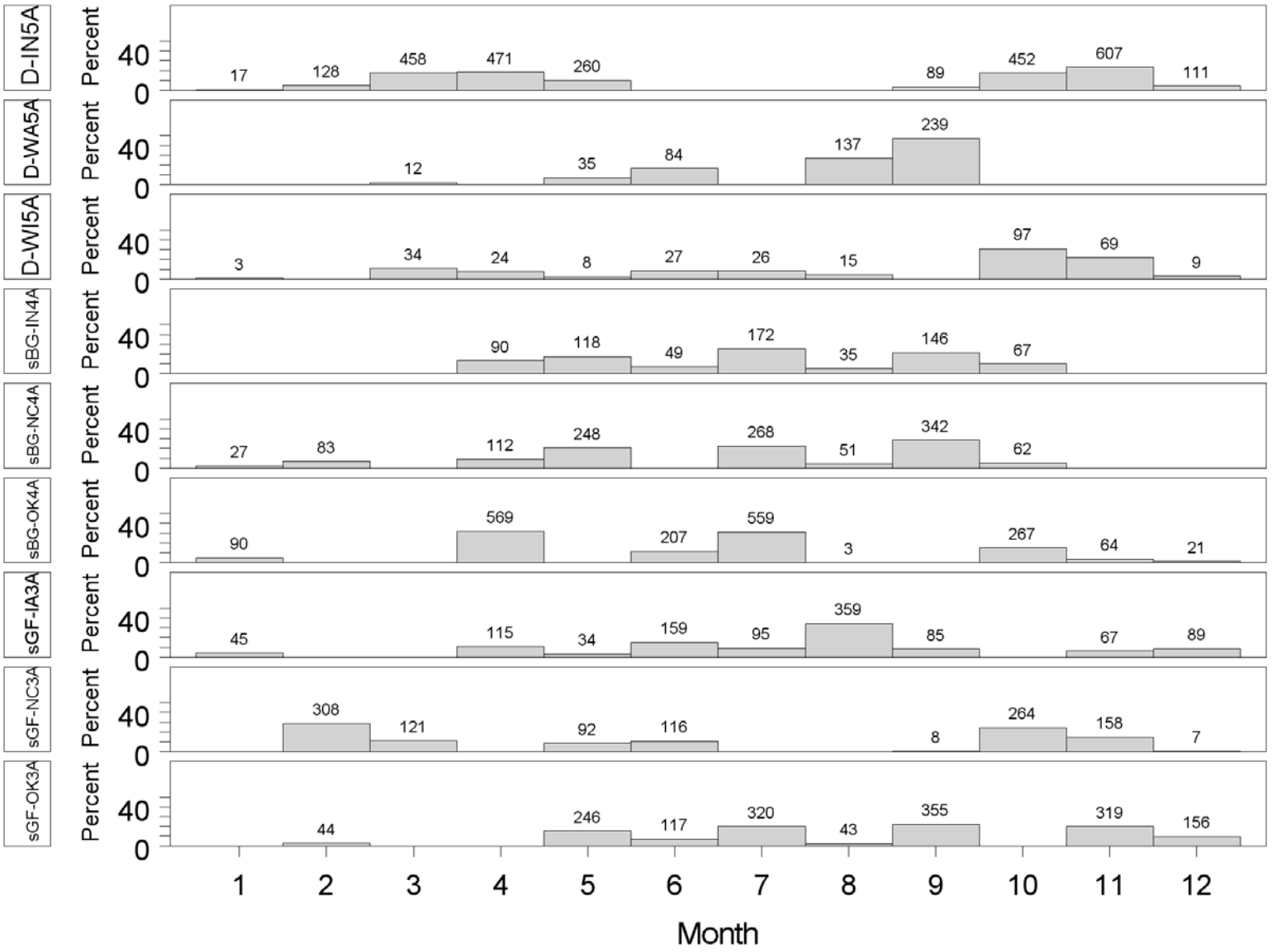
D= Dairy sites; sBG = Swine breeding/gestation sites, sGF = Swine grow/finish sites

Figure 5-21. Histogram of NH_3 Emissions by Animal Type



D= Dairy sites; sBG = Swine breeding/gestation sites, sGF = Swine grow/finish sites

Figure 5-22. Histogram of NH_3 Emissions by Animal Type and Site



D= Dairy sites; sBG = Swine breeding/gestation sites, sGF = Swine grow/finish sites

Figure 5-23. Histogram of Month by Animal Type and Site

Table 5-11. Summary of Data Available by Month and Site

Month	All Sites	IN5A	WA5A	WI5A	IN4A	NC4A	OK4A	IA3A	NC3A	OK3A
1	182	17	-	3	-	27	90	45	-	-
2	563	128	.	.	-	83	-	-	308	44
3	625	458	12	34	-	-	-	-	121	.
4	1381	471	-	24	90	112	569	115	-	-
5	1041	260	35	8	118	248	-	34	92	246
6	759	-	84	27	49	-	207	159	116	117
7	1440	-	-	26	172	268	559	95	-	320
8	643	-	137	15	35	51	3	359	-	43
9	1264	89	239	-	146	342	-	85	8	355
10	1209	452	-	97	67	62	267	-	264	-
11	1284	607	-	69	-	-	64	67	158	319
12	393	111	-	9	-	-	21	89	7	156

Note: Dashes indicate no data was available for the site for the month.

5.3.7 Working mean trend function

To obtain a working mean trend function, the EPA evaluated the relative importance of the meteorological mean trend variables. The EPA fit a model using the gamma distribution and the log link function to: (1) the individual meteorological variables, (2) two pairs of time-based variables representing the main effects of the annual solar radiation cycles, (3) all of these variables simultaneously, and (4) to all two-way interactions among this collection of variables. Table 5-12 presents the fit statistics for each of the four variable combinations. The first row of Table 5-12 gives the estimated slope of the individual meteorological variables. As expected, the slopes of *ta* and *ws* are positive and the slope of *ha* is negative.

Predictions of NH_3 emissions corresponding to the cross-validation dataset were produced for each of the four variable combinations. The rows labeled "% in PI" and "Width" present diagnostics that describe the quality of uncertainty quantification of the EEM. Ideally, 95 percent of the observed NH_3 emissions in the cross-validation dataset should fall inside the 95 percent prediction intervals. For all of the EEMs, the value exceeds 95 percent which means that the intervals are somewhat conservative. The width of the 95 percent prediction intervals gives some notion of their usefulness. For example, an interval with width 4 kg is more useful than one with width of 7 kg, if both had the same "% in PI."

Table 5-12. Fit Statistics for Subsets of Mean Trend Variables

Fit Statistic	Mean Trend Variables[a]						
	Individual Met Variables			Solar Radiation Variables		All Main Effects	Two-Way Interactions
	ta	*ha*	*ws*	*sh, ch*	*sd, cd*		
Slope	0.53	-0.27	-0.38	NA[b]	NA	NA	NA
% in PI	97	100	96	99	96	99	99
Width (kg)	4.0	7.6	3.9	6.5	3.9	4.3	4.4
R^2_{Test}	0.33	0.06	0.21	0.01	0.27	0.58	0.59
RMSE (kg)	1.2	1.4	1.3	1.4	1.2	0.93	0.91
γ_0 (kg)	-0.32 x	0.10 ✓	0.25 x	0.06 ✓	-0.24 x	-0.11 x	-0.00 ✓
γ_1	1.4 x	0.83 x	0.95 ✓	0.87 ✓	1.4 x	1.2 x	1.0 x[c]

[a] A check mark (✓) in the column for γ_0 indicates that the estimate is not significantly different from zero at the $\alpha = 0.05$ significance level, while an "x" indicates that it is significantly different from zero. Similarly, a check mark or an "x" in the column for γ_1 indicates whether the estimate is significantly different from one.
[b] NA = Not applicable.
[c] This value was significantly different than one when additional decimals places were considered.

The fit statistics shown in the last four rows of Table 5-12 result from a linear regression of measured NH_3 emissions in the cross-validation dataset on the point predictions of NH_3 emissions. The correlation coefficient, R^2, tells what proportion of the variability of emissions in the cross-validation dataset was explained by the EEM. Table 5-12 shows that the EEMs that used *ta*, *ws*, and the *sd*, *cd* combination, respectively, explained the most variability. When all main effects were included, 58 percent of the variability in the cross-validation dataset emissions was explained. When all main effects and two-way interactions were included, 59 percent of the variability was explained. Because the increase in variability explained by progressing from main effects only to including two-way interactions was only 1 percent, the EPA did not consider three-way interactions among meteorological variables.

The root mean squared error (RMSE), in kg NH_3, is defined in Equation 5-7. The RMSE provides a measure of the typical deviation of an NH_3 emissions value in the cross-validation dataset from the point prediction of NH_3 emissions. Thus, smaller values of RMSE indicate a better fit. Notice that of the EEMs including individual predictor variables, those containing *ta* and the *sd, cd* combination resulted in the lowest RMSE (1.2 kg). The EEM including all main effects reduced the RMSE to 0.93 kg and including all two-way interactions further reduced the RMSE value to 0.91 kg.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(Y_{ht} - \hat{Y}_{ht}\right)^2} \qquad \text{Equation 5-7}$$

If the EEM fit the cross-validation dataset perfectly, the intercept of this linear regression, γ_0, would equal zero and the slope, γ_1, would equal one. If γ_0 or γ_1 is significantly different from 0 or 1, respectively, the EEM has systematic bias. A check mark (✓) beside either γ_0 or γ_1 indicates that it is not significantly different from zero or one, respectively. Adding the two-way interactions to the main effects resulted in the intercept being closer to 0 and the estimated slope became 1 when rounded to the nearest tenth. Despite the fact that the difference between the intercept and 1 is statistically significant when additional decimal places were considered, the difference does not have practical significance.

5.4 Choosing the Covariance Function

Although the link function is not part of the covariance function, this section begins by showing how the EPA chose the log link using the working mean trend function. After this decision was made, the EPA used an EEM with the log link function to evaluate different covariance function components.

5.4.1 Selecting the link function

As mentioned in Section 5.2, three link functions can be used to relate the mean trend function to the expected value of NH_3 emissions under a given set of conditions: the identity, the natural logarithm, and the reciprocal. If the link function is the identity, then the mean of the distribution is exactly equal to the mean trend function. If the link function is the natural logarithm, then the natural log of the distribution mean is equal to the mean tread function. Finally, if the link function is the reciprocal, then the inverse of the distribution mean is equal to the inverse of the mean trend function.

To compare the three link functions, the EPA fit an EEM with the working mean trend function and each of the link functions, and recorded the fit statistics in Table 5-13. Notice that while the proportions of variability in the cross-validation dataset emissions explained by the identity and log link EEMs were similar, the 95 percent prediction intervals produced when the identity link was used were so narrow as to not contain any of the emissions in the cross-validation dataset. Thus, the quantification of uncertainty resulting from the use of the identity function was inaccurate.

The reciprocal link EEM explains only 48 percent of the variability in emissions of the cross-validation dataset, compared to the 59 percent explained by the log link EEM. The conservative 100 percent coverage probability of the prediction intervals produced by the

reciprocal link EEM was achieved by prediction intervals with mean width 5.8 kg. The 99 percent coverage probability of the log link prediction intervals have a narrower, and thus more useful mean width of 4.4 kg.

Table 5-13. Fit Statistics for Identity, Log and Reciprocal Link Functions

Fit Statistic[a]	Link functions		
	Identity	Log	Reciprocal
R^2	0.57	0.59	0.48
% in PI	0	99	100
Mean width PI's (kg)	0.042	4.4	5.8
RMSE (kg)	0.94	0.91	1.0
γ_0 (kg)	0.027 ✓	-0.00 ✓	0.25 x
γ_1	53 x	1.0 ✓	0.61 x

[a] A check mark (✓) in the column for γ_0 indicates that the estimate is not significantly different from zero at the $\alpha = 0.05$ significance level, while an "x" indicates that it is significantly different from zero. Similarly, a check mark or an "x" in the column for γ_1 indicates whether the estimate is significantly different from one.

5.4.2 Serial correlation

A possible source of correlation in the deviations from the mean trend function, e_{st}, is serial correlation, which is usually present in time series data. Failure to account for serial correlation can result in prediction interval widths that are overly optimistic and biased regression coefficient estimates for finite sample sizes. Accounting for serial correlation can be accomplished by: using a function of time in the mean trend function, using a parametric covariance function such as the AR(1) or using a nonparametric covariance structure such as a radial smoother.

Normally, diagnosis of the covariance structure involves plotting lagged residuals as a function of current time residuals, but the large number of large gaps in the hourly NH_3 emissions values made such plots uninformative. The EPA tried a parametric AR(1) structure, but the autoregressive parameter was not statistically significant. The EPA also used a radial smoother as a nonparametric covariance structure, but the numerical algorithm designed to compute basis functions required for such a structure returned an error.

Thus, the EPA used the functions of time already included in the mean trend function to account for relationships between NH_3 at one time and NH_3 at an adjacent time. The diurnal and annual cycles account for two different units of time and they interact with one another and with all other mean trend variables. As the fit statistics in Table 5-13 indicated at this point in the analysis, the prediction interval widths for the EEM with the working mean trend function and the log link account for enough variability for the coverage probability to exceed 95 percent. This result shows that not accounting for serial correlation beyond use of the periodic functions

of hour and day in the mean trend did not result in intervals that were too narrow. Therefore, the EPA did not use serial correlation.

5.4.3 Random effect of site

If conditions not captured by the mean trend function cause different sites to have different NH_3 emissions, a random effect of site might account for the additional prediction uncertainty caused by this site-specific variability. A fixed effect of site, as opposed to a random effect, is not appropriate because the EEM will be used to estimate emissions from sites that did not participate in the NAEMS.

The difficulty of including a random effect is that while it is not part of the mean trend function, it would have to replace the use of one of the static farm-based predictor variables. Site is a static farm-based variable also, and its use as a random effect would add another parameter to the EEM, using up one of the degrees of freedom available to learn about the static farm-based variables.

Despite this difficulty, the EPA examined fit statistics resulting from the inclusion of a random effect in the EEM that used the log link and the working mean trend function. The EPA fit an EEM with a random effect of site to the base dataset, and then tested the null hypothesis that the variance component associated with a random effect of site, σ_S^2, was equal to zero using a Wald test and a chi-squared test. For the Wald test, the p-value was an unconvincing 0.06. The chi-squared test produced a p-value of 0.0001, which seemed to suggest that a random effect of site allowed the EEM to better fit the base dataset. This EEM, however, does not contain another farm-based variable to describe site-to-site variability. Consequently, at this phase of the analysis, the random effect of site was accounting for any site-to-site differences, regardless of their source.

Table 5-14 gives the fit statistics that describe how well the EEM with a random effect of site fit the cross-validation dataset. Including the random effect in the EEM resulted in a coverage probability that was further away from 95 percent than that achieved by the EEM that did not include a random effect. Also, the mean width of the prediction intervals increased by 3.1 kg. The percent of variability in emissions in the cross-validation dataset that was explained increased from 59 percent to 60 percent upon inclusion of the random effect and the RMSE value decreased. The intercept of the regression of cross-validation emissions on the point predictions moved further from 0 to become significantly different from 0. Additionally, the slope moved further from 1. Because most of the fit statistics for the cross-validation dataset did not improve when the random effect of site was added to the EEM, the EPA concluded that this version of the EEM over-fit the base dataset.

As a final test of the usefulness of including a random effect of site in the EEM, the EPA progressively added each of the three chosen farm-based predictor variables to the working mean trend function of the random effect-EEM. Even when only one farm-based predictor variable was added at a time to the EEM, the fitting algorithm did not converge. This result suggested that when a static, farm-based predictor variable that was expected to inform variability in NH_3 emissions was included in the EEM, the random effect of site provided redundant information. Consequently, the fitting algorithm oscillated between different optimal values of the parameters.

Based on the poor fit to the cross-validation dataset and the lack of convergence of the fitting algorithm, the EPA did not consider a random effect of site in development of the EEM.

Table 5-14. Fit Statistics With and Without a Random Effect of Site

Fit Statistic[a]	Random Effect of Site Included in EEM?	
	No	Yes
% in PI	99	100
Mean width PI's (kg)	4.4	7.5
R^2	0.59	0.60
RMSE (kg)	0.91	0.90
γ_0 (kg)	-0.00 ✓	-0.29 x
γ_1	1.0 ✓	1.5 x

[a] A check mark (✓) in the column for γ_0 indicates that the estimate is not significantly different from zero at the $\alpha = 0.05$ significance level, while an "x" indicates that it is significantly different from zero. Similarly, a check mark or an "x" in the column for γ_1 indicates whether the estimate is significantly different from one

5.5 Comparison of EEMs With Different Mean Trend Variables

To choose the final EEM, the EPA evaluated the performance of three EEMs. Each of the EEMs contained two of the three candidate farm-based predictor variable (i.e., *animal*, *sa* and *size*), and the interactions between those variable pairs and the main effects and 2-way interactions of the meteorological and time-based variables. Table 5-15 shows the fit statistics calculated for each EEM on the cross-validation dataset. All three versions of the EEM had a coverage probability of 99 percent, and while the prediction interval widths differ by at most 0.1 kg, the optimal width of 4.5 kg is that of the *animal/size* EEM. The *animal/sa* EEM explained the most variability in cross-validation emissions, at 74 percent, with a large gap separating it from the other two EEMs. The *sa/size* EEM is the second best at 68 percent, and the *animal/size* EEM explained 66 percent. The optimal value of RMSE, 0.73 kg, was again achieved by the *animal/sa* EEM, and again a large gap separates it from the others. The *sa/size* EEM again has the second best value, at 0.80 kg, followed by the *animal/size* EEM at 0.83 kg.

For the *animal/sa* EEM, neither the slope nor the intercept of the regression of cross-validation NH_3 emissions on predictions of them was significantly different from the optimal

values of 0 and 1, respectively. For the other two EEMs, both the slope and intercept are significantly different from the optimal values. Based on these fit statistics, it seems clear that of these three EEMs, the one that best fits the data is the *animal/sa* EEM.

Table 5-15. Fit Statistics for Three Combinations of Two Farm-Based Variables

Fit statistic	Farm-Based Predictor Variable Pair		
	animal/sa	***animal/size***	***sa/size***
% in PI	99	99	99
Width (kg)	4.6	4.5	4.6
R^2	0.74	0.66	0.68
RMSE (kg)	0.73	0.83	0.80
γ_0 (kg)	-0.00 ✓	-0.11 x	0.11 x
γ_1	1.0 ✓	1.1 x	0.92 x

[a] A check mark (✓) in the column for γ_0 indicates that the estimate is not significantly different from zero at the $\alpha = 0.05$ significance level, while an "x" indicates that it is significantly different from zero. Similarly, a check mark or an "x" in the column for γ_1 indicates whether the estimate is significantly different from one

5.6 NH_3 EEM Summary, Use and Implications

This section presents the calculations using the three candidate EEMs presented in Section 5.5 for several example swine and dairy farms. For this analysis, the parameter estimates for each EEM were obtained from fitting each to the full dataset (i.e., combined base and cross-validation datasets).

Table 5-16 shows the values of the example predictor variables and the corresponding mean trend variables. The values of the mean trend variables were obtained from the values of the predictor variables as follows.

- *sd* and *cd*: These values are the sinusoidal periodic functions of Julian day, as defined in Equation 5-2, for this example, *jday* is equal to 243, co *sd* = -0.86169 and *cd* = -0.50743.

- *sh* and *ch*: These values are the sinusoidal periodic functions of hour of the day, as defined in Equation 5-3. For this example, *hour* is equal to for 6:00 p.m., which corresponds to *sh* = -1 and *ch* = -1.84E-16 .

- *ta, ha, ws, sa* and *size*: For these variables, the value of the predictor variable was centered and scaled by subtracting from it the "centering value" and dividing by the "scaling value" (Table 5-9 presents the centering and scaling values).

Table 5-16. Variables Values Used In Example Calculations

Predictor Variable			Mean Trend Variable	
Description	**Value**	**Unit**	**Description**	**Value**
Julian day (*jday*)	243	day	*sd*	-0.86
			cd	-0.51
Hour of the day (*hour*)	18	hour	*sh*	-1
			ch	0
Temperature (*ta**)	29	°C	*ta*	1.3
Humidity (*ha**)	40	%	*ha*	-1.0
Wind speed (*ws**)	4.1	meters/second	*ws*	0.41
Animal type (*animal*)	1	Dairy	*animal*	1
	-1	Swine		-1
Surface area (*sa**)	121	1,000 ft^2	*sa*	-0.44
	200			0.45
Animal capacity * adult weigh (*size**)	1.9	million lb	*size*	-0.042
	0.68			-0.703

[a] An asterisk (*) is used to note that these predictor variables are the original values reported in the data submitted to the EPA before centering and scaling.

To obtain the point estimate (i.e., mean) for each of the three EEMs, the values of the mean trend variables and the estimated regression coefficients from Table 5-18, Table 5-20 or Table 5-22, respectively, were inserted into Equation 5-8.

$$\hat{Y} = e^{(\widehat{\beta_0}+\widehat{\beta_1}x_1+\cdots+\widehat{\beta_{80}}x_{80})} \qquad \text{Equation 5-8}$$

Equation 5-8 estimates the kilograms of NH_3 emitted from the lagoon during a half-hour period. The lower and upper bounds of the 95-percent prediction intervals were calculated by subtracting and adding the margin of error to the point estimate. Because the gamma probability distribution (see Figure 5-5) is not symmetric, the error margins that are added and subtracted from the mean are not equal.

5.6.1 Animal/surface area EEM

For the *animal/sa* EEM examples, the EPA chose lagoon surface areas of 121,000 $ft^2$and 200,000 ft^2. The smaller value of surface area is similar to swine sites OK3A and IN4A and the observed lagoons at IN5A, WA5A and WI5A. The larger surface area is representative of larger swine facilities similar to sites NC3A and NC4A and all the lagoons in a multi-stage system prevalent at dairy facilities.

Table 5-17 shows the point prediction estimates and the lower and upper bounds of the 95-percent prediction interval for each lagoon size at a swine and dairy farm. Table 5-18 presents the mean trend variables (x_{pst}), the values of the regression parameter estimates ($\widehat{\beta_p}$) and the values of each mean trend variable (x_p) for the four example farms.

Table 5-17. Results of the *animal/sa* EEM Examples

Example Number	Farm-Based Predictor Variables		Point Prediction, $\hat{\mu}$ (kg/30 min)	95% Prediction Interval Bounds (kg/30 min)	
	animal[a]	***sa**** (1,000 ft^2) [b]	$\hat{Y}$	**Lower**	**Upper**
1	-1	121	1.8	0.05	6.5
2	1	121	1.2	0.04	4.3
3	-1	200	2.2	0.07	7.8
4	1	200	1.4	0.04	5.1

[a] For the variable *animal*, 1 is dairy and -1 is swine.
[b] An asterisk (*) is used to note that these predictor variables are the original values reported in the data submitted to the EPA before centering and scaling.

While the fact that this prediction interval has width 6.5 – 0.55 = 5.95 kg may seem to render it not very useful, the quantities most of interest to the EPA are sums of NH_3 emissions. If individual half-hour emissions follow a gamma distribution, then according to the Central Limit Theorem, the sum of many half-hour emissions will follow a normal distribution. The mean of the normal distribution will be the sum of the means of the half-hour emissions. The variance of the normal distribution will be the sums of the variances of the half-hour emissions. The variance for the gamma distribution is $\mu^2\phi$. For the example above, the point prediction is the estimate of μ, and the estimate of ϕ is given in the last row of Table 5-18. The variance is thus 3.5 kg^2. As a simple example to understand how useful the prediction intervals for a sum would be, imagine 100 half-hour periods just like the one in Example 1. The sum of emissions for all 100 half-hours would have a normal distribution with approximate mean and variance of 180 kg and 350 kg^2, respectively. The point estimate for the total emissions for the 100 half-hour periods would be the mean, 180 kg. The 95 percent prediction interval would be obtained by adding and subtracting 1.96 multiplied by the standard deviation, which is the square root of the variance: $180 \pm 1.96\sqrt{350}$. Thus, the lower bound would be 143 kg and the upper bound would be 217 kg, and this prediction interval would have the same interpretation given above.

For the *animal/sa* EEM, the point predictions for swine are higher than for dairy at both example lagoon sizes. For Example 1 (swine lagoon), the mean emissions rate was 1.8 kg/30 minutes while the mean emissions rate for Example 2 (dairy lagoon) was 1.2 kg/30

minutes. Thus when meteorology and surface area are held constant, this EEM predicts that swine lagoons emit more NH_3. Examples 1 and 3, both represent swine facilities. The point prediction for a surface area of 121,000 ft^2 is 1.8 kg, and for 200,000 ft^2 is 2.2 kg. These predictions of NH_3 emissions are consistent with the expectation that greater surface area presents more opportunities for desorption of NH_3 from the lagoon liquid.

Table 5-18. Values of Mean Trend Variables for the *animal/sa* EEM Examples

p	Name of x_{pst}	$\hat{\beta}_p$	Value of x_p			
			Ex. 1	Ex. 2	Ex. 3	Ex. 4
0	Intercept	-0.1704	NA [a]	NA	NA	NA
1	*animal*	-0.1264	-1	1	-1	1
2	*sa*	0.166	-0.4382	-0.4382	0.4494	0.4494
3	*ta*	0.2238	1.30	1.30	1.30	1.30
4	*ha*	0.01534	-1.00	-1.00	-1.00	-1.00
5	*ws*	0.3378	0.41	0.41	0.41	0.41
6	*sh*	0.06782	-1	-1	-1	-1
7	*ch*	0.01614	-1.84E-16	-1.84E-16	-1.84E-16	-1.84E-16
8	*sd*	-0.1347	-0.86169	-0.86169	-0.86169	-0.86169
9	*cd*	-0.3046	-0.50743	-0.50743	-0.50743	-0.50743
10	*animal*ta*	0.0441	-1.3000	1.3000	-1.3000	1.3000
11	*animal*ha*	0.0528	1.0000	-1.0000	1.0000	-1.0000
12	*animal*ws*	0.03723	-0.4100	0.4100	-0.4100	0.4100
13	*animal*sh*	-0.08584	1.0000	-1.0000	1.0000	-1.0000
14	*animal*ch*	-0.0158	0.0000	0.0000	0.0000	0.0000
15	*animal*sd*	0.09038	0.8617	-0.8617	0.8617	-0.8617
16	*animal*cd*	0.2183	0.5074	-0.5074	0.5074	-0.5074
17	*sa*ta*	0.03896	-0.5697	-0.5697	0.5843	0.5843
18	*sa*ha*	-0.00087	0.4382	0.4382	-0.4494	-0.4494
19	*sa*ws*	0.1086	-0.1797	-0.1797	0.1843	0.1843
20	*sa*sh*	0.04138	0.4382	0.4382	-0.4494	-0.4494
21	*sa*ch*	-0.01069	0.0000	0.0000	0.0000	0.0000
22	*sa*sd*	0.03115	0.3776	0.3776	-0.3873	-0.3873
23	*sa*cd*	-0.04754	0.2224	0.2224	-0.2281	-0.2281
24	*ta*ha*	0.05177	-1.3000	-1.3000	-1.3000	-1.3000
25	*ta*ws*	0.04942	0.5330	0.5330	0.5330	0.5330
26	*ta*sh*	-0.05717	-1.3000	-1.3000	-1.3000	-1.3000
27	*ta*ch*	0.08774	0.0000	0.0000	0.0000	0.0000
28	*ta*sd*	-0.0417	-1.1202	-1.1202	-1.1202	-1.1202
29	*ta*cd*	-0.05216	-0.6597	-0.6597	-0.6597	-0.6597
30	*ha*ws*	0.07141	-0.4100	-0.4100	-0.4100	-0.4100
31	*ha*sh*	-0.02224	1.0000	1.0000	1.0000	1.0000
32	*ha*ch*	-0.00842	0.0000	0.0000	0.0000	0.0000
33	*ha*sd*	-0.04523	0.8617	0.8617	0.8617	0.8617
34	*ha*cd*	-0.06174	0.5074	0.5074	0.5074	0.5074
35	*ws*sh*	-0.04305	-0.4100	-0.4100	-0.4100	-0.4100

Table 5-18. Values of Mean Trend Variables for the *animal/sa* EEM Examples

p	Name of x_{pst}	$\hat{\beta}_p$	Value of x_p			
			Ex. 1	Ex. 2	Ex. 3	Ex. 4
36	*ws*ch*	-0.00906	0.0000	0.0000	0.0000	0.0000
37	*ws*sd*	-0.02067	-0.3533	-0.3533	-0.3533	-0.3533
38	*ws*cd*	0.01939	-0.2080	-0.2080	-0.2080	-0.2080
39	*sh*sd*	0.003985	0.8617	0.8617	0.8617	0.8617
40	*sh*cd*	0.01495	0.5074	0.5074	0.5074	0.5074
41	*ch*sd*	0.03812	1.58E-16	1.58E-16	1.58E-16	1.58E-16
42	*ch*cd*	0.07877	9.32E-17	9.32E-17	9.32E-17	9.32E-17
43	*animal*ta*ha*	-0.0058	1.30	-1.30	1.30	-1.30
44	*animal*ta*ws*	0.009751	-0.53	0.53	-0.53	0.53
45	*animal*ta*sh*	0.006322	1.30	-1.30	1.30	-1.30
46	*animal*ta*ch*	-0.03063	0.00	0.00	0.00	0.00
47	*animal*ta*sd*	0.07724	1.12	-1.12	1.12	-1.12
48	*animal*ta*cd*	-0.01519	0.66	-0.66	0.66	-0.66
49	*animal*ha*ws*	0.01062	0.41	-0.41	0.41	-0.41
50	*animal*ha*sh*	0.06862	-1.00	1.00	-1.00	1.00
51	*animal*ha*ch*	-0.01994	0.00	0.00	0.00	0.00
52	*animal*ha*sd*	-0.01027	-0.86	0.86	-0.86	0.86
53	*animal*ha*cd*	-0.1979	-0.51	0.51	-0.51	0.51
54	*animal*ws*sh*	0.01821	0.41	-0.41	0.41	-0.41
55	*animal*ws*ch*	0.01005	0.00	0.00	0.00	0.00
56	*animal*ws*sd*	-0.004	0.35	-0.35	0.35	-0.35
57	*animal*ws*cd*	0.022	0.21	-0.21	0.21	-0.21
58	*animal*sh*sd*	0.07842	-0.86	0.86	-0.86	0.86
59	*animal*sh*cd*	0.1134	-0.51	0.51	-0.51	0.51
60	*animal*ch*sd*	-0.05731	0.00	0.00	0.00	0.00
61	*animal*ch*cd*	-0.07813	0.00	0.00	0.00	0.00
62	*sa*ta*ha*	-0.01088	0.57	0.57	-0.58	-0.58
63	*sa*ta*ws*	0.005086	-0.23	-0.23	0.24	0.24
64	*sa*ta*sh*	-0.03341	0.57	0.57	-0.58	-0.58
65	*sa*ta*ch*	0.02372	0.00	0.00	0.00	0.00
66	*sa*ta*sd*	0.05193	0.49	0.49	-0.50	-0.50
67	*sa*ta*cd*	-0.04981	0.29	0.29	-0.30	-0.30
68	*sa*ha*ws*	0.03486	0.18	0.18	-0.18	-0.18
69	*sa*ha*sh*	0.0476	-0.44	-0.44	0.45	0.45
70	*sa*ha*ch*	-0.01861	0.00	0.00	0.00	0.00
71	*sa*ha*sd*	0.06239	-0.38	-0.38	0.39	0.39
72	*sa*ha*cd*	-0.08068	-0.22	-0.22	0.23	0.23
73	*sa*ws*sh*	0.01293	0.18	0.18	-0.18	-0.18
74	*sa*ws*ch*	0.01629	0.00	0.00	0.00	0.00
75	*sa*ws*sd*	0.02821	0.15	0.15	-0.16	-0.16
76	*sa*ws*cd*	-0.02738	0.09	0.09	-0.09	-0.09
77	*sa*sh*sd*	-0.03134	-0.38	-0.38	0.39	0.39
78	*sa*sh*cd*	-0.1219	-0.22	-0.22	0.23	0.23
79	*sa*ch*sd*	0.008813	-6.94E-17	-6.94E-17	7.11E-17	7.11E-17

Table 5-18. Values of Mean Trend Variables for the *animal/sa* EEM Examples

p	Name of x_{pst}	$\hat{\beta}_p$	Value of x_p			
			Ex. 1	Ex. 2	Ex. 3	Ex. 4
80	*sa*ch*cd*	-0.00419	-4.08E-17	-4.08E-17	4.19E-17	4.19E-17
	Scale parameter	1.061	NA	NA	NA	NA

[a] NA = Not applicable.

5.6.2 Animal/size EEM

For the *animal/size* EEM examples, the EPA chose values of farm size that represented plausible combinations of *size** for both swine and dairy facilities, as supported by the USDA Agricultural Census. The first value of *size** (i.e., *capacity** multiplied by *adultwt**) chosen by the EPA was 1.9 million pounds. Such a value would occur at a dairy facility slightly smaller than that at site WI5A, with total capacity equal to 1,357 head of milk cows at 1,400 pounds each. This value of *size** would also occur at a swine breeding-gestation farm slightly larger than site OK4A, with a *capacity** of 3,878 sows at 490 pounds each for the same value of *adultwt**. The second value of *size** selected was 0.68 million pounds. This value would occur at a dairy site with a total capacity of 486 head (similar to site WI5A); or at a swine site with 1,388 pigs (similar to sites IA3A and IN4A) for the same value of *adultwt**. This value of *size** is also representative of swine operations similar to those at sites IA3A and IN4A.

The point prediction estimates and the lower and upper bounds of the 95-percent prediction interval for each farm size example at both a swine and a dairy operation are shown in Table 5-19. Table 5-20 presents the mean trend variables (x_{pst}), the values of the regression parameter estimates ($\widehat{\beta_p}$) and the values of each mean trend variable for the four examples

Table 5-19. Results of the *animal/size* EEM Examples

Example Number	Farm-Based Predictor Variables		Point Prediction (kg/30 min)	95% Prediction Interval Bounds (kg/30 min)	
	animal[a]	*size** (lbs) [b]	$\hat{Y}$	Lower	Upper
1	-1	1,900,000	2.4	0.07	8.6
2	1	1,900,000	0.95	0.03	3.4
3	-1	680,000	1.9	0.06	6.9
4	1	680,000	0.8	0.02	2.8

[a] For the variable *animal*, 1 is dairy and -1 is swine.
[b] An asterisk (*) is used to note that these predictor variables are the original values reported in the data submitted to the EPA before centering and scaling.

The point prediction for the swine site is 2.4 kg/30 minutes, while that for the dairy site is 0.95 kg/30 minutes. These predictions of NH_3 emissions are comparable to the daily emissions values contained in the final reports (see Section 3).

For the dairy Examples 1 and 3, the point prediction when *size** = 1.9 million pounds is 2.4 kg/30 minutes, and the point prediction when *size** = 0.68 million pounds is 1.9 kg/30 minutes. The swine emission pattern is similar. These predictions of NH_3 emissions are consistent with the expectation that greater live animal mass should result in more precursors supplied to the lagoon, which should result in more NH_3 emissions.

Table 5-20. Values of Mean Trend Variables for *animal/size* EEM Examples

			Value of x_p			
p	**Name of x_{pst}**	$\hat{\beta}_p$	**Ex. 1**	**Ex. 2**	**Ex. 3**	**Ex. 4**
0	Intercept	-0.3005	NA [a]	NA	NA	NA
1	*animal*	-0.5471	-1	1	-1	1
2	*size*	0.4147	-0.0422	-0.0422	-0.7033	-0.7033
3	*ta*	0.1932	1.30	1.30	1.30	1.30
4	*ha*	-0.00455	-1.00	-1.00	-1.00	-1.00
5	*ws*	0.2161	0.41	0.41	0.41	0.41
6	*sh*	0.05094	-1	-1	-1	-1
7	*ch*	0.04161	-1.84E-16	-1.84E-16	-1.84E-16	-1.84E-16
8	*sd*	-0.2406	-0.86169	-0.86169	-0.86169	-0.86169
9	*cd*	-0.3591	-0.50743	-0.50743	-0.50743	-0.50743
10	*animal*ta*	-0.2149	-1.3000	1.3000	-1.3000	1.3000
11	*animal*ha*	0.000272	1.0000	-1.0000	1.0000	-1.0000
12	*animal*ws*	-0.3289	-0.4100	0.4100	-0.4100	0.4100
13	*animal*sh*	-0.2317	1.0000	-1.0000	1.0000	-1.0000
14	*animal*ch*	0.08868	0.0000	0.0000	0.0000	0.0000
15	*animal*sd*	-0.287	0.8617	-0.8617	0.8617	-0.8617
16	*animal*cd*	-0.1205	0.5074	-0.5074	0.5074	-0.5074
17	*size*ta*	0.2064	-0.0548	-0.0548	-0.9143	-0.9143
18	*size*ha*	0.02935	0.0422	0.0422	0.7033	0.7033
19	*size*ws*	0.4158	-0.0173	-0.0173	-0.2884	-0.2884
20	*size*sh*	0.1528	0.0422	0.0422	0.7033	0.7033
21	*size*ch*	-0.1077	0.0000	0.0000	0.0000	0.0000
22	*size*sd*	0.3486	0.0364	0.0364	0.6060	0.6060
23	*size*cd*	0.2875	0.0214	0.0214	0.3569	0.3569
24	*ta*ha*	0.04663	-1.3000	-1.3000	-1.3000	-1.3000
25	*ta*ws*	0.007551	0.5330	0.5330	0.5330	0.5330
26	*ta*sh*	-0.01768	-1.3000	-1.3000	-1.3000	-1.3000
27	*ta*ch*	0.1057	0.0000	0.0000	0.0000	0.0000
28	*ta*sd*	-0.07326	-1.1202	-1.1202	-1.1202	-1.1202
29	*ta*cd*	0.01755	-0.6597	-0.6597	-0.6597	-0.6597
30	*ha*ws*	0.005272	-0.4100	-0.4100	-0.4100	-0.4100
31	*ha*sh*	-0.06899	1.0000	1.0000	1.0000	1.0000

Table 5-20. Values of Mean Trend Variables for *animal/size* EEM Examples

p	Name of x_{pst}	$\hat{\beta}_p$	Value of x_p			
			Ex. 1	Ex. 2	Ex. 3	Ex. 4
32	*ha*ch*	-0.00278	0.0000	0.0000	0.0000	0.0000
33	*ha*sd*	-0.04194	0.8617	0.8617	0.8617	0.8617
34	*ha*cd*	0.0573	0.5074	0.5074	0.5074	0.5074
35	*ws*sh*	-0.0395	-0.4100	-0.4100	-0.4100	-0.4100
36	*ws*ch*	-0.02627	0.0000	0.0000	0.0000	0.0000
37	*ws*sd*	-0.08146	-0.3533	-0.3533	-0.3533	-0.3533
38	*ws*cd*	-0.01699	-0.2080	-0.2080	-0.2080	-0.2080
39	*sh*sd*	0.003667	0.8617	0.8617	0.8617	0.8617
40	*sh*cd*	0.06681	0.5074	0.5074	0.5074	0.5074
41	*ch*sd*	0.08076	1.58E-16	1.58E-16	1.58E-16	1.58E-16
42	*ch*cd*	0.1565	9.32E-17	9.32E-17	9.32E-17	9.32E-17
43	*animal*ta*ha*	-0.08574	1.3000	-1.3000	1.3000	-1.3000
44	*animal*ta*ws*	-0.1486	-0.5330	0.5330	-0.5330	0.5330
45	*animal*ta*sh*	0.05419	1.3000	-1.3000	1.3000	-1.3000
46	*animal*ta*ch*	0.02732	0.0000	0.0000	0.0000	0.0000
47	*animal*ta*sd*	-0.03565	1.1202	-1.1202	1.1202	-1.1202
48	*animal*ta*cd*	0.3233	0.6597	-0.6597	0.6597	-0.6597
49	*animal*ha*ws*	-0.146	0.4100	-0.4100	0.4100	-0.4100
50	*animal*ha*sh*	-0.04517	-1.0000	1.0000	-1.0000	1.0000
51	*animal*ha*ch*	-0.00081	-1.84E-16	1.84E-16	-1.84E-16	1.84E-16
52	*animal*ha*sd*	-0.1607	-0.8617	0.8617	-0.8617	0.8617
53	*animal*ha*cd*	0.04089	-0.5074	0.5074	-0.5074	0.5074
54	*animal*ws*sh*	0.009941	0.4100	-0.4100	0.4100	-0.4100
55	*animal*ws*ch*	-0.00194	7.53E-17	-7.53E-17	7.53E-17	-7.53E-17
56	*animal*ws*sd*	-0.2062	0.3533	-0.3533	0.3533	-0.3533
57	*animal*ws*cd*	-0.1885	0.2080	-0.2080	0.2080	-0.2080
58	*animal*sh*sd*	0.06039	-0.8617	0.8617	-0.8617	0.8617
59	*animal*sh*cd*	0.2116	-0.5074	0.5074	-0.5074	0.5074
60	*animal*ch*sd*	0.005975	-1.58E-16	1.58E-16	-1.58E-16	1.58E-16
61	*animal*ch*cd*	0.04529	-9.32E-17	9.32E-17	-9.32E-17	9.32E-17
62	*size*ta*ha*	0.09349	0.0548	0.0548	0.9143	0.9143
63	*size*ta*ws*	0.2109	-0.0225	-0.0225	-0.3749	-0.3749
64	*size*ta*sh*	-0.04622	0.0548	0.0548	0.9143	0.9143
65	*size*ta*ch*	-0.06496	1.01E-17	1.01E-17	1.68E-16	1.68E-16
66	*size*ta*sd*	0.06439	0.0473	0.0473	0.7878	0.7878
67	*size*ta*cd*	-0.3927	0.0278	0.0278	0.4639	0.4639
68	*size*ha*ws*	0.1765	0.0173	0.0173	0.2884	0.2884
69	*size*ha*sh*	0.1073	-0.0422	-0.0422	-0.7033	-0.7033
70	*size*ha*ch*	-0.02489	-7.75E-18	-7.75E-18	-1.29E-16	-1.29E-16
71	*size*ha*sd*	0.1429	-0.0364	-0.0364	-0.6060	-0.6060
72	*size*ha*cd*	-0.2447	-0.0214	-0.0214	-0.3569	-0.3569
73	*size*ws*sh*	0.01065	0.0173	0.0173	0.2884	0.2884
74	*size*ws*ch*	0.008559	3.18E-18	3.18E-18	5.30E-17	5.30E-17
75	*size*ws*sd*	0.2204	0.0149	0.0149	0.2485	0.2485

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Table 5-20. Values of Mean Trend Variables for *animal/size* EEM Examples

p	Name of x_{pst}	$\hat{\beta}_p$	Value of x_p			
			Ex. 1	Ex. 2	Ex. 3	Ex. 4
76	*size*ws*cd*	0.3026	0.0088	0.0088	0.1463	0.1463
77	*size*sh*sd*	0.009514	-0.0364	-0.0364	-0.6060	-0.6060
78	*size*sh*cd*	-0.0549	-0.0214	-0.0214	-0.3569	-0.3569
79	*size*ch*sd*	-0.071	-6.68E-18	-6.68E-18	-1.11E-16	-1.11E-16
80	*size*ch*cd*	-0.1125	-3.93E-18	-3.93E-18	-6.56E-17	-6.56E-17
	Scale parameter	1.061	NA	NA	NA	NA

[a] NA = Not applicable.

5.6.3 Surface area/size EEM

The *sa/size* EEM estimates emissions based on farm size and surface area irrespective of animal type. For the *sa/size* EEM, the four examples use the same parameter values as the previous two examples: surface areas of 121,000 ft^2 and 680,000 ft^2 with a farm size of 1,900,000 pounds and 680,000 pounds for each surface area. The point prediction estimates and the lower and upper bounds of the 95-percent prediction interval for each example are shown in Table 5-21. Table 5-22 presents the mean trend variables (x_{pst}), the values of the regression parameter estimates ($\widehat{\beta_p}$) and the values of each mean trend variable for the four examples.

Table 5-21. Results of the *sa/size* EEM Examples

Example Number	Farm-Based Predictor Variables [a]		Point Prediction (kg/30 min)	95% Prediction Interval Bounds (kg/30 min)	
	*sa** (1,000 ft^2)	*size** (lbs)	$\hat{Y}$	Lower	Upper
1	121	1,900,000	1.6	0.05	5.8
2	121	680,000	1.8	0.05	6.5
3	200	1,900,000	2.0	0.06	7.2
4	200	680,000	2.2	0.07	8.0

[a] An asterisk (*) is used to note that these predictor variables are the original values reported in the data submitted to the EPA before centering and scaling.

For the same farm size, the point prediction for surface area of 121,000 ft^2 is 1.6 kg/30 minutes, and the prediction for surface area of 200,000 ft^2 is 2.0 kg/30 minutes. These predictions of NH_3 emissions are consistent with the expectation that greater surface area allows for greater desorption of NH_3 from the lagoon liquid.

For the same surface area, the point prediction for farm size of 1.9 million pounds is 1.6 kg/30 minutes, and the point prediction farm size is 680,000 pounds is 1.8 kg/30 minutes.

These predictions of NH_3 emissions are not consistent with the expectation that greater live animal mass should result in more precursors supplied to the lagoon, which, in turn should result in more NH_3 emissions.

Table 5-22. Values of Mean Trend Variables for the *sa/size* EEM Examples

p	x_{pst}	$\hat{\beta}_p$	Value of x_p			
			Ex. 1	Ex. 2	Ex. 3	Ex. 4
0	Intercept	-0.1122	NA[a]	NA	NA	NA
1	*size*	-0.09511	-0.0422	-0.7033	-0.0422	-0.7033
2	*sa*	0.2358	-0.4382	-0.4382	0.4494	0.4494
3	*ta*	0.2059	1.30	1.30	1.30	1.30
4	*ha*	-0.02163	-1.00	-1.00	-1.00	-1.00
5	*ws*	0.3208	0.41	0.41	0.41	0.41
6	*sh*	0.1078	-1	-1	-1	-1
7	*ch*	0.01653	-1.84E-16	-1.84E-16	-1.84E-16	-1.84E-16
8	*sd*	-0.1791	-0.8617	-0.8617	-0.8617	-0.8617
9	*cd*	-0.4074	-0.5074	-0.5074	-0.5074	-0.5074
10	*size*ta*	0.05834	-0.0548	-0.9143	-0.0548	-0.9143
11	*size*ha*	0.01868	0.0422	0.7033	0.0422	0.7033
12	*size*ws*	0.03671	-0.0173	-0.2884	-0.0173	-0.2884
13	*size*sh*	-0.05563	0.0422	0.7033	0.0422	0.7033
14	*size*ch*	-0.02925	7.75E-18	1.29E-16	7.75E-18	1.29E-16
15	*size*sd*	0.0874	0.0364	0.6060	0.0364	0.6060
16	*size*cd*	0.2198	0.0214	0.3569	0.0214	0.3569
17	*sa*ta*	0.01243	-0.5697	-0.5697	0.5843	0.5843
18	*sa*ha*	-0.04419	0.4382	0.4382	-0.4494	-0.4494
19	*sa*ws*	0.09624	-0.1797	-0.1797	0.1843	0.1843
20	*sa*sh*	0.08891	0.4382	0.4382	-0.4494	-0.4494
21	*sa*ch*	-0.01693	8.05E-17	8.05E-17	-8.26E-17	-8.26E-17
22	*sa*sd*	-0.00556	0.3776	0.3776	-0.3873	-0.3873
23	*sa*cd*	-0.1107	0.2224	0.2224	-0.2281	-0.2281
24	*ta*ha*	0.06729	-1.3000	-1.3000	-1.3000	-1.3000
25	*ta*ws*	0.04473	0.5330	0.5330	0.5330	0.5330
26	*ta*sh*	-0.071	-1.3000	-1.3000	-1.3000	-1.3000
27	*ta*ch*	0.1068	-2.39E-16	-2.39E-16	-2.39E-16	-2.39E-16
28	*ta*sd*	-0.06093	-1.1202	-1.1202	-1.1202	-1.1202
29	*ta*cd*	-0.0533	-0.6597	-0.6597	-0.6597	-0.6597
30	*ha*ws*	0.06418	-0.4100	-0.4100	-0.4100	-0.4100
31	*ha*sh*	-0.05328	1.0000	1.0000	1.0000	1.0000
32	*ha*ch*	-0.00199	1.84E-16	1.84E-16	1.84E-16	1.84E-16
33	*ha*sd*	-0.01954	0.8617	0.8617	0.8617	0.8617
34	*ha*cd*	0.04567	0.5074	0.5074	0.5074	0.5074
35	*ws*sh*	-0.05145	-0.4100	-0.4100	-0.4100	-0.4100
36	*ws*ch*	-0.01092	-7.53E-17	-7.53E-17	-7.53E-17	-7.53E-17
37	*ws*sd*	-0.01849	-0.3533	-0.3533	-0.3533	-0.3533
38	*ws*cd*	0.02467	-0.2080	-0.2080	-0.2080	-0.2080
39	*sh*sd*	-0.03892	0.8617	0.8617	0.8617	0.8617
40	*sh*cd*	-0.05384	0.5074	0.5074	0.5074	0.5074
41	*ch*sd*	0.0603	1.58E-16	1.58E-16	1.58E-16	1.58E-16
42	*ch*cd*	0.1102	9.32E-17	9.32E-17	9.32E-17	9.32E-17
43	*size*ta*ha*	0.004222	0.0548	0.9143	0.0548	0.9143

Table 5-22. Values of Mean Trend Variables for the *sa/size* EEM Examples

p	x_{pst}	$\hat{\beta}_p$	Value of x_p Ex. 1	Ex. 2	Ex. 3	Ex. 4
44	*size*ta*ws*	0.02358	-0.0225	-0.3749	-0.0225	-0.3749
45	*size*ta*sh*	0.008542	0.0548	0.9143	0.0548	0.9143
46	*size*ta*ch*	-0.0444	1.01E-17	1.68E-16	1.01E-17	1.68E-16
47	*size*ta*sd*	0.07121	0.0473	0.7878	0.0473	0.7878
48	*size*ta*cd*	-0.04238	0.0278	0.4639	0.0278	0.4639
49	*size*ha*ws*	0.01138	0.0173	0.2884	0.0173	0.2884
50	*size*ha*sh*	0.04908	-0.0422	-0.7033	-0.0422	-0.7033
51	*size*ha*ch*	-0.01311	-7.75E-18	-1.29E-16	-7.75E-18	-1.29E-16
52	*size*ha*sd*	0.006304	-0.0364	-0.6060	-0.0364	-0.6060
53	*size*ha*cd*	-0.1493	-0.0214	-0.3569	-0.0214	-0.3569
54	*size*ws*sh*	0.01724	0.0173	0.2884	0.0173	0.2884
55	*size*ws*ch*	0.009766	3.18E-18	5.30E-17	3.18E-18	5.30E-17
56	*size*ws*sd*	0.005532	0.0149	0.2485	0.0149	0.2485
57	*size*ws*cd*	0.07122	0.0088	0.1463	0.0088	0.1463
58	*size*sh*sd*	0.06257	-0.0364	-0.6060	-0.0364	-0.6060
59	*size*sh*cd*	0.09059	-0.0214	-0.3569	-0.0214	-0.3569
60	*size*ch*sd*	-0.0596	-6.68E-18	-1.11E-16	-6.68E-18	-1.11E-16
61	*size*ch*cd*	-0.08964	-3.93E-18	-6.56E-17	-3.93E-18	-6.56E-17
62	*sa*ta*ha*	0.00001	0.5697	0.5697	-0.5843	-0.5843
63	*sa*ta*ws*	0.009156	-0.2336	-0.2336	0.2396	0.2396
64	*sa*ta*sh*	-0.031	0.5697	0.5697	-0.5843	-0.5843
65	*sa*ta*ch*	0.03959	1.05E-16	1.05E-16	-1.07E-16	-1.07E-16
66	*sa*ta*sd*	0.0384	0.4909	0.4909	-0.5035	-0.5035
67	*sa*ta*cd*	-0.02103	0.2891	0.2891	-0.2965	-0.2965
68	*sa*ha*ws*	0.03982	0.1797	0.1797	-0.1843	-0.1843
69	*sa*ha*sh*	0.01147	-0.4382	-0.4382	0.4494	0.4494
70	*sa*ha*ch*	-0.01552	-8.05E-17	-8.05E-17	8.26E-17	8.26E-17
71	*sa*ha*sd*	0.07496	-0.3776	-0.3776	0.3873	0.3873
72	*sa*ha*cd*	-0.00376	-0.2224	-0.2224	0.2281	0.2281
73	*sa*ws*sh*	0.002782	0.1797	0.1797	-0.1843	-0.1843
74	*sa*ws*ch*	0.01562	3.30E-17	3.30E-17	-3.39E-17	-3.39E-17
75	*sa*ws*sd*	0.03416	0.1548	0.1548	-0.1588	-0.1588
76	*sa*ws*cd*	-0.02964	0.0912	0.0912	-0.0935	-0.0935
77	*sa*sh*sd*	-0.06139	-0.3776	-0.3776	0.3873	0.3873
78	*sa*sh*cd*	-0.148	-0.2224	-0.2224	0.2281	0.2281
79	*sa*ch*sd*	0.03324	-6.94E-17	-6.94E-17	7.11E-17	7.11E-17
80	*sa*ch*cd*	0.03199	-4.08E-17	-4.08E-17	4.19E-17	4.19E-17
	Scale parameter	1.061	NA	NA	NA	NA

[a] NA = Not applicable.

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5.7 Conclusion

Due to limitations on the available degrees of freedom for the static, farm-based predictor variables, the EPA developed three alternative EEMs. These three EEMs used the paired combinations of three farm-based variables (i.e., animal type, surface area and farm size) and the continuous variables representing meteorological conditions (i.e., ambient temperature, ambient humidity, wind speed and solar radiation).

After initial evaluation of the three alternatives, the EPA has concluded that additional analysis is needed to develop the lagoon EEMs due to some confounding factors in the available data. Emissions from dairy lagoons during the summer when lagoon emissions are typically higher than the rest of the year are under-represented in the NAEMS. This factor likely causes dairies to appear to have lower emissions than swine. Also, during our evaluation of the three draft EEMs, we concluded that the emissions and surface areas at two of the dairy sites were likely under-represented because all stages of the multi-stage treatment systems at each site were not monitored. This factor likely contributed to the prediction by the *size/sa* EEM that for two farms with the same lagoon surface area, NH_3 emissions are higher for the smaller sized farm. We also observed that the *animal/sa* EEM for both dairy and swine that NH_3 emissions from the farm with 190,000 lbs of animal weight is only 25 percent higher than the farm with 680,000 lbs of animal weight, even though animal weight is 2.8 times as large. Additionally, the reported surface area for swine site IA3A is much smaller than for the other swine sites. The EPA plans to investigate how this disparity in surface area values affects the predictive ability of the EEMs.

The EPA is considering conducting additional analysis to develop the lagoon EEMs that produce emissions more consistent with expectations regarding relationships between the emissions and the predictor variables.

The types of additional analysis under consideration are as follows:

1. Re-examine some suspect data values to determine if they are representative.
2. Consider altering the mathematical form that quantifies interactions between the farm-based variables with meteorological variables.
3. Consider using a weighting scheme whereby some emissions observations are given more weight than others in EEM development. The weighting would account for situations in which the value of a predictor variable for one site falls far from the values for all other sites and has a disproportionate influence on the relationships between that variable and emissions.
4. Consider developing a single static variable that can represent NH3 loading and lagoon surface area. This variable could be constructed using the ratio of nitrogen excretion rates from the Natural Resource Conservation Service (NRCS) to lagoon surface area.

The EPA is seeking recommendations from SAB on the additional proposed analyses.

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Appendix A

Quality Assurance Project Plan for the National Air Emissions Monitoring Study (Open Source Emissions Component) QAPP Category #1

Prepared by

Purdue Applied Meteorology Laboratory

Department of Agronomy, Purdue University

Quality Assurance Project Plan[1,2]
for the
National Air Emissions Monitoring Study
(Open Source Emissions Component)
QAPP Category #1

Prepared by
Purdue Applied Meteorology Laboratory
Department of Agronomy, Purdue University

A. Project management
1. Approvals

Richard Grant, Purdue University Project Manager	Date
Albert Heber, Purdue University Science Advisor	Date
Juan Carlos Ramirez, Purdue University Quality Assurance Manager	Date
William Schrock, USEPA OAQPS Project Manager	Date
Joseph Elkins, USEPA OAQPS QA Manager	Date

[1] This QAPP was drafted according to:
USEPA. 2002. *EPA Guidance for Quality Assurance Project Plans*. Office of Research and Development, United States Environmental Protection Agency, Washington, D.C. EPA QA/G-5, and
USEPA. 2001. *EPA Requirements for Quality Assurance Project Plans*. Office of Research and Development, United States Environmental Protection Agency, Washington, D.C. EPA QA/R-5.
[2] Principal author: Richard H Grant, Purdue University, West Lafayette, IN 47907-2054.

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Acronyms and Abbreviations

AARC	Agricultural Air Research Council
ABE	Agricultural and Biological Engineering Department
abl	Above berm level
ACA	Air Consent Agreement
AFOs	Animal Feeding Operations
agl	Above ground level
AGRY	Agronomy Department
ARM	Atmospheric Radiation Measurement Program
ASOS	Automated Surface Observation Stations
ASTM	American Society for Testing and Materials
AWOS	Automated Weather Observation Stations
bLS	Backward Lagrangian Stochastic method
CAA	Clean Air Act
CCF	Concordance correlation factor
CD	Compact disk
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Chain of custody
C_6H_6	Benzene
CH_4	Methane
DM	Data Manager
DOAS	Differential optical absorption spectrometer
DQI	Data Quality Indicators
DQO	Data Quality Objectives
DVD	Digital Video Disk
EA	Explained absorbance
FA	Filtered absorbance
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EtOH	Ethanol
FT-IR	Fourier Transform Infrared
FOS	Field Operations Staff
GC/MS	Gas Chromatography combined with a Mass Spectrometer
GPS	Global Positioning System
GSS	Gas Sampling System
HAc	Acetic Acid
H_2S	Hydrogen sulfide
HD	Computer hard drive
Hg	Mercury
hPa	Hectopascal
IHF	Integrated Horizontal Flux
IR	Infrared waveband
LAN server	Local Area Network server computer

m	Meter
mb	Millibar
MDL	Minimum Detectable Limit
MeOH	Methanol
MQO	Measurement Quality Objective
mV	Millivolt
NA	Not Applicable
NAEMS	National Air Emissions Monitoring Study
NAS	National Academy of Sciences
NELAP	National Environmental Laboratory Accreditation Program
NH_3	Ammonia
NIST	National Institute of Standards and Technology
NMi	Netherlands Measurement Institute
nm	Nanometer
NMHC	Non-Methane Hydrocarbons
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
N_2	Nitrogen
OP	Optical path
PAAQL	Purdue Agricultural Air Quality Lab
PAML	Purdue Applied Meteorology Lab
PAS	Photoacoustic IR Spectroscopy
PC	Personal computer
PDC	Path length-defining components
PDM	Project Data Manager
pH	Measure of activity of hydrogen
PF	Pulsed Fluorescence
PI	Principle investigator
PI-ORS	Path integrated optical remote sensing
PIC	Path integrated concentration
PM	Program manager
ppm	Parts per million
PP	Pull plug
PPR	Pull plug with recharge
PQAM	Project Quality Assurance Manager
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
RH	Relative humidity
RMS	Root mean square
RMSE	Root Mean Square Error
RPM	Radial plume mapping method
SA	Science advisor
SBFM	Smooth Basis Function Minimization

SMP	Site Monitoring Plan
SSE	Sum of squared errors.
S-OPS	Synthetic Open-Path System
SOP	Standard operating procedures
SO_2	Sulfur dioxide
SPS	Sponsored Program Services
SVD	Singular Value Decomposition
TBD	To be determined
TDLAS	Tunable Diode-Laser Absorption Spectroscopy
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UV	Ultraviolet waveband
UV-DOAS	Ultraviolet Differential Optical Absorption Spectrometer
VOC	Volatile Organic Compounds
WAAS	Wide Area Augmentation System
WMO	World Meteorological Organization

3. QAPP Distribution List

Albert Heber	Purdue University	heber@purdue.edu
Richard Grant	Purdue University	rgrant@purdue.edu
Jiqin Ni	Purdue University	jiqin@purdue.edu
Bill Bogan	Purdue University	bogan@purdue.edu
Juan Carlos Ramirez	Purdue University	jramirez@purdue.edu
Alfred Lawrence	Purdue University	ajlawren@purdue.edu
Matthew Boehm	Purdue University	mboehm@purdue.edu
Jenafer Wolf	Purdue University	jmwolf@purdue.edu
Scott Cortus	Purdue University	scortus@purdue.edu
Deb Dimmitt	Purdue University SPS	ddimmitt@purdue.edu
Ann Louise Sumner	Battelle Laboratories	sumnera@battelle.org
John Thorne	Agriculture Air Research Council	JThorne@crowell.com
Allan Stokes	National Pork Producers Council	Allan.Stokes@porkboard.org
Jim Tillison	National Milk Producers Federation	jtillison@nmpf.org
All individual producers		
William Schrock	US Environmental Protection Agency	Shrock.William@epa.gov
Joseph Elkins	US Environmental Protection Agency	Elkins.Joseph@epa.gov
Bruce Fergusson	US Environmental Protection Agency	Fergusson.Bruce@epa.gov

Complete copies of the QAPP will be stored in the computers at the PAML and PAAQL and at each mobile instrument trailer for ready access at any time. Paper copies will be provided to any future field operator or analyst associated with the project but not listed above. In addition, copies of the EPA-approved QAPP will be made available to any organization or individual upon request. Any changes to the QAPP will be reported to all participants listed above via email.

4. Project/Task Organization and Schedule

4.1. Personnel and agencies involved

Albert Heber	Purdue Univ./ Agricultural and Biological Engineering	(765) 494-1214
Jiqin Ni	Purdue Univ./ Agricultural and Biological Engineering	(765) 496-3994
Teng Lim	Purdue Univ./ Agricultural and Biological Engineering	(765) 494-1195
Bill Bogan	Purdue Univ./ Agricultural and Biological Engineering	(765) 494-9005
Juan-Carlos Ramirez	Purdue Univ./ Agricultural and Biological Engineering	(765) 494-1731
Richard Grant	Purdue Univ./ Agronomy	(765) 494-8048
Matthew Boehm	Purdue Univ./ Agronomy	(765) 496-9604
Alfred Lawrence	Purdue Univ./ Agronomy	(765) 496-1865
Jenafer Wolf	Purdue Univ./ Agronomy	(765) 496-1866
Scott Cortus	Purdue Univ./ Agronomy	(765) 496-6339
Deb Dimmitt	Purdue Univ./ Sponsored Program Services	(765) 494-8434
John Thorne	Agricultural Air Research Council	(202) 508-8962
Allan Stokes	National Pork Board	(515) 223-3447
Jim Tillison	National Milk Producers Board	(703) 243-6111
Kenneth Casey	Texas A&M University	(806) 677-5600
Project Manager	US Environmental Protection Agency OAQPS	TBD
Joseph Elkins	US Environmental Protection Agency OAQPS	(919) 541-2408
Bruce Harris	US Environmental Protection Agency OAQPS	(919) 541-7807
Robin Dunkins	US Environmental Protection Agency OAQPS	(919) 541-5335
Bill Schrock	US Environmental Protection Agency OAQPS	(919) 541-5032
Larry Elmore	US Environmental Protection Agency OAQPS	(919) 541-5433
Bruce Fergusson	US Environmental Protection Agency OECA	(919) 541-1261
Confidential	Producer- Farm 1	Confidential
Confidential	Producer- Farm 2	Confidential
Confidential	Producer- Farm 3	Confidential
Confidential	Producer- Farm 4	Confidential
Confidential	Producer- Farm 5	Confidential
Confidential	Producer- Farm 6	Confidential
Confidential	Producer- Farm 7	Confidential
Confidential	Producer- Farm 8	Confidential
Confidential	Producer- Farm 9	Confidential
Confidential	Producer- Farm 10	Confidential

4.2. Personnel responsibilities/ Project organization

Roles of each individual or group of individuals in the project follow:

- The Science Advisor (SA) has overall supervision of all aspects of the National Air Emissions Monitory Study (NAEMS) and has final approval authority for the release of

study data and reports of scientific results. The SA is responsible for selecting the external corral PI and implementing the subcontract with the PI's university, comprehensive NAEMS study design, selecting measurement locations, and overseeing all extensive technical aspects of the Barns Component of the NAEMS. The SA is the primary point of contact with the commercial laboratory.

- The Project Manager (PM) is responsible for the development of standard operating procedures (SOPs) and establishment of all measurement sites as well as ensuring that staff members are trained in site operation and sample handling. The PM assists the SA in the selection of Open Source emissions measurement locations. The PM is responsible for the specification and selection of all project instrumentation and equipment. The PM manages all aspects of the NAEMS Open Source Emissions Component, has the overall responsibility of field operations and activities, instrument calibrations, data validation, and ensures successful outcomes. All Open Source Emissions staff report to the Project Manager. The Project Manager reports to the SA. The PM is also responsible for all internal audits of measurement systems and instrument/ sensor performance.
- The Quality Assurance Manager (QAM) is responsible for the quality assurance of both the Barn and Open Source components of the NAEMS. The QAM will perform 'external' system and performance audits, document the adherence to measurement quality objectives (MQOs) and data quality indices (DQIs), and manage data quality assessment.
- The Data Manager (DM) is responsible for the data management of both the Barn and Open Source components of the NAEMS and will review and archive data reported from the PDM. The Data Manager also assists in the data reviews and preparation of periodic reports.
- The Data Analysis Manager (DAM) is responsible for the combined data analysis of both the Barn and Open Source components of the NAEMS and will correlate the data reported from the DM and PDM and develop linkages between the measured emissions and farm characteristics.
- The Project Data Manager (PDM) assists in the development and revision of SOPs for data processing and management and is responsible for the data management of the reported compound concentrations, emissions, and meteorological data from all monitoring locations in this project. The PDM receives and archives all data transferred from the field (by ftp download and physical delivery of electronic media) and the commercial laboratory, assists in the data reviews and with the PM evaluates the evidence for data invalidation, and preparation of periodic reports.
- The Project Quality Assurance Manager (PQAM) assists in the development and revising of SOPs, development and validation of automated quality assurance programs and documents the adherence to measurement quality objectives (MQOs) and data quality indices (DQIs), and is responsible for reviewing the accuracy of automatically invalided data, coordinates the routine assessment of data quality, and with the PM evaluates the evidence for data invalidation. The PQAM assist in the preparation of periodic reports. The PQAM is responsible for verifying and documenting the acceptance of all instruments and equipment.

- The Field Operations Staff (FOS) are responsible for on-site quality assurance checks, collecting and deploying samples, and retrieving open path analyzer, lagoon/ basin and meteorological data at each non-corral monitoring location. Manure samples collected at the swine basin location will be collected by the FOS and shipped by them to the designated commercial laboratory for analysis. When not at a measurement location, they also are involved in the data validation checks (coordinated by the PQAM) and data analysis for all locations.

Because the supported project staff is limited, some individuals have multiple roles. The individuals assigned to each role are indicated in Table 4.1.

Table 4.1 Roles of key personnel in the study.

Position	Location	Training	Name
Science Advisor (SA)	ABE	PhD	A Heber
Project Manager (PM)	AGRY	PhD	R Grant
Quality Assurance Manager (QAM)	ABE	PhD	J C Ramirez
Data Manager (DM)	ABE	PhD	J-Q Ni
Project Data Manager (PDM)	AGRY	PhD	A Lawrence
Project Quality Assurance Manager (PQAM)	AGRY	PhD	M Boehm
Field Operations Staff (FOS)	AGRY	PhD	M Boehm A Lawrence

The FOS will consist of two mobile teams and an additional technician. The ‘East’ team, consisting of a technician and scientist, will travel between eastern and Midwestern US monitoring locations, and a ‘West’ team of a technician and scientist will travel between Midwestern and western US monitoring locations. An additional technician will be responsible for maintenance of a continuous measurement location. An organizational chart of the staffing for this project is illustrated in Figs. 4.1 and 4.2.

Purdue University, the Agricultural Air Research Council (AARC), the US Environmental Protection Agency (EPA), and producers/farm managers have specific responsibilities:

- Purdue University will have specific fiduciary, communications and technical responsibilities. Purdue will oversee the expenditures of project funds and equipment purchases to ensure that federal check-off funding requirements and applicable tax laws are followed. Purdue University will report on the conduct of the study to the EPA and AARC. Purdue University will establish a project-specific website for the public dissemination of project progress and results.

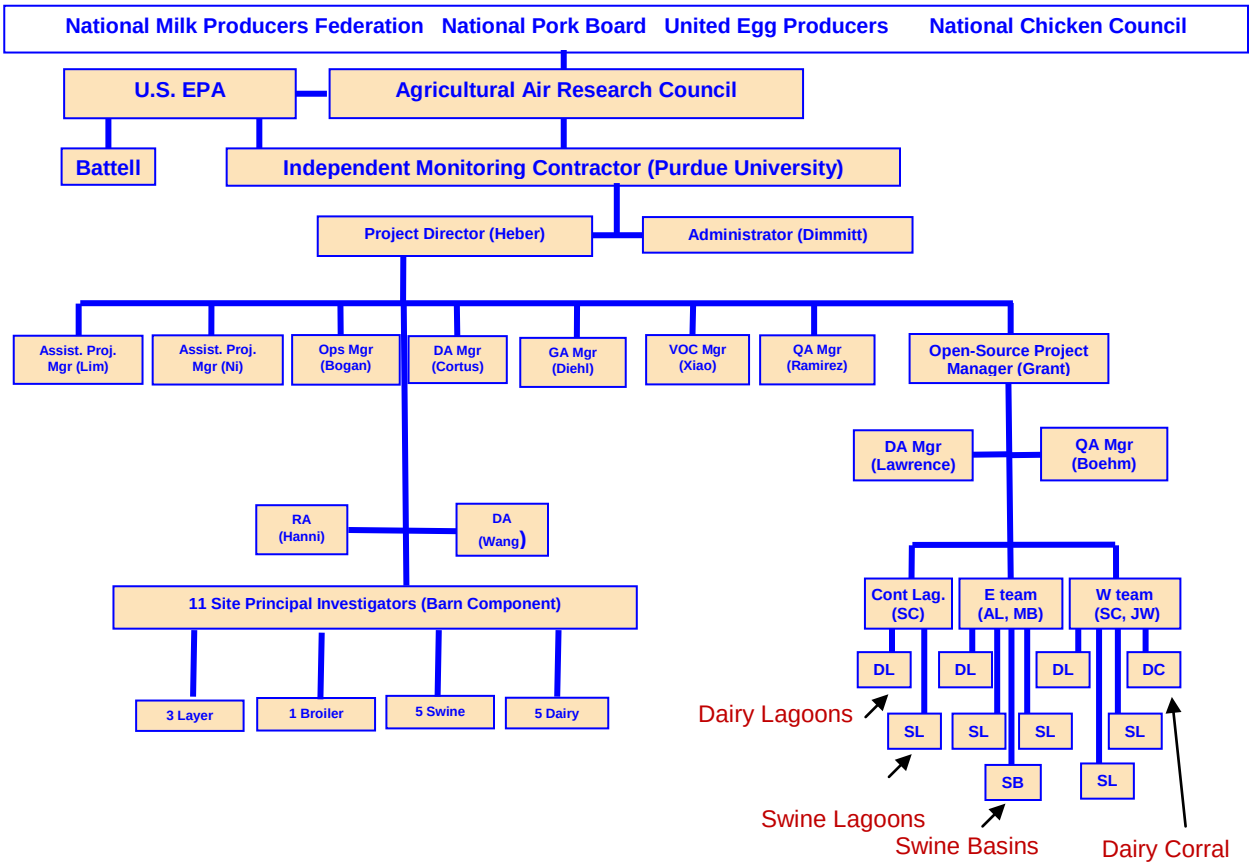

Figure 4.1 Responsibility & Authority Flow Chart for the NAEMS.
(GA = Gas Analyzer; RA = Research Assistant; DA = Data Analyst; DL = Dairy Lagoon; SL = Swine Lagoon; SB = Swine Basin; DC = Dairy Corral)

- The AARC will fund the study and receive regular progress reports on the project. The AARC is responsible for the holding and dispersing to Purdue University the funds necessary for the completion of the project. The AARC will approve the budget and review expenditures. The AARC also will provide the communication mechanism between the project personnel, Purdue University, and the livestock producers, media, and other interested parties (Fig. 4.1).
- The EPA will oversee the scientific issues of the project and provide external quality assurance that the approved protocols are being used throughout the study. EPA will receive regular interim reports including validated data and data summaries (Fig. 4.1).
- Producers/farm managers providing measurement locations for the project must be willing to: 1) attend a training session, 2) make minor changes in normal operating procedures to accommodate the project, and 3) maintain and share certain production and other records to facilitate data analysis and interpretation.

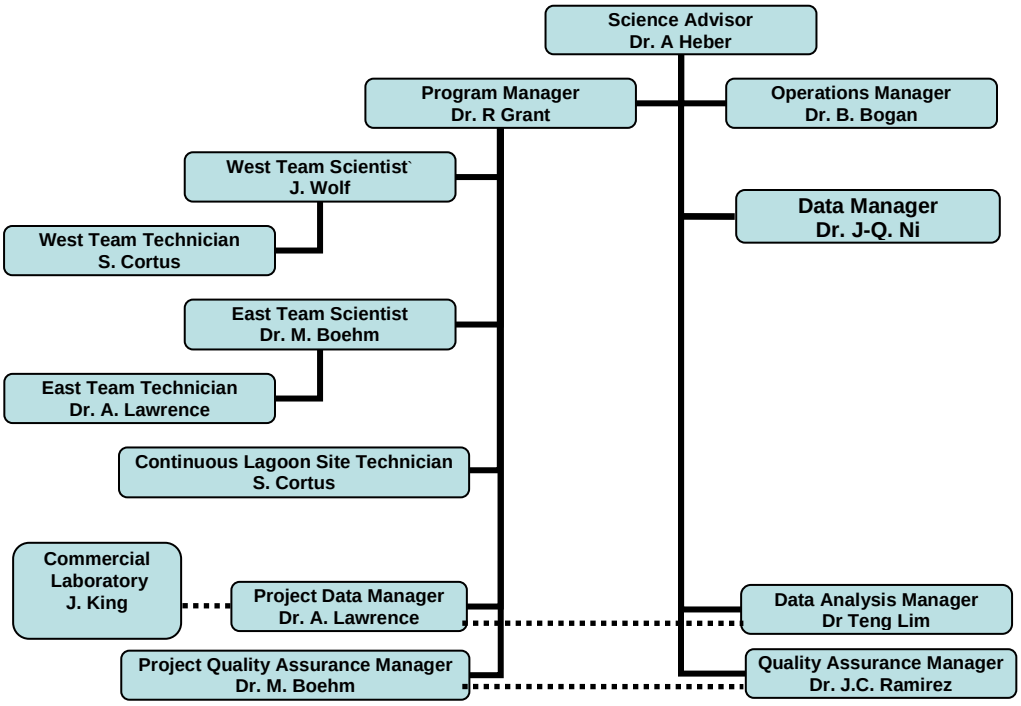

Figure 4.2 Organizational chart- Open Source Component
Non-authoritative communication linkages are indicated by dashed lines

4.3. Project schedule 2006-2009

The project schedule is partially defined by the Air Consent Agreement (EPA, 2005). There is a six-month spin-up time to establish the continuous monitoring locations, the permanent fixtures at all measurement locations, train the staff, and accept and prepare the equipment. Measurements will continue for 2 years. Subsequent to the measurement period, there will be a three month period for closing locations and writing the final reports. A general timeline follows (Quarters are indicated by boxes):

In the six months prior to beginning of data collection at any location:

- A backward Lagrangian Stochastic (bLS) emissions model validation study (described in section 10.7) will be conducted.
- A Cerex UVSentry UV-DOAS H_2S measurement characterization and validation study (described in section 10.8) will be conducted.
- A synthetic open-path sampling system validation study (described in Section 10.9) will be conducted.
- The infrastructure necessary for the conduct of the project for most locations will be established by the FOS in cooperation with each producer (rotating and continuous measurement locations). This includes the establishment of electricity, phone (where applicable), fixed measurement towers, and locations for all portable masts, and tripods.

- Training for operational staff, the FOS, PM, PDM, and PQAM will be conducted.
- All equipment and instruments will be ordered, received, accepted, configured, and integrated in the measurement systems for the project data collection.

Table 4.2 Project schedule

Year	2006						2007					
Month	D	J	F	M	A	M	J	J	A	S	O	N
Equipment procurement and testing	X	X	X									
Complete personnel hiring, conduct training	X	X	X	X					X			
Establish measurement locations	X	X	X	X	X	X	X					
UV-DOAS H_2S validation study					X	X						
Collect measurement data							X	X	X	X	X	X
Analyses						X	X	X	X	X	X	X
Interim reports										X		

Year	2007			2008								
Month	D	J	F	M	A	M	J	J	A	S	O	N
Establish measurement location					X	X						
Collect measurement data	X	X	X	X	X	X	X	X	X	X	X	X
bLS validation study							X	X				
Analyses	X	X	X	X	X	X	X	X	X	X	X	X
Interim reports	X			X			X			X		

Year	2008			2009							
Month	D	J	F	M	A	M	J	J	A	S	O
Collect measurement data	X	X	X	X	X	X					
Analyses	X	X	X	X	X	X	X	X	X	X	X
Interim reports	X			X			X				
Publish study results								X	X	X	X
Close measurement locations							X	X	X	X	

Given the relatively severe conditions during the winter months for the establishment of the measurement infrastructure at many farms, it is anticipated that the establishment of

infrastructure at some locations will occur after the beginning of the routine measurement data collection at the previously established locations.

During the measurement data collection phase, the FOS will rotate between eight measurement locations each quarter for two years, spending between eight and twenty days at a location. One corral location will be monitored continuously for the entire two years. Two measurement locations will each be monitored for one year continuously. In the three months after the end of data collection:

- Infrastructure at the measurement locations will be dismantled unless follow-on studies are to be conducted.
- Data analysis will be completed and final report written

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5. Problem Definition/Background

Air pollutants emitted from livestock manure storages may represent a significant source of pollution to the wider environment. Aerial pollutants of particular interest are ammonia (NH_3) and hydrogen sulfide (H_2S). At present, however, insufficient data exists to accurately model exactly how much pollution is emitted by livestock facilities, and how much emissions may be influenced by local climate, animal species, facility configuration, and/or management practices.

The NAEMS was developed in response to a 2003 National Academy of Sciences (NAS) report which highlighted potential air pollution problems arising from animal feeding operations (AFOs), and discussed the insufficiency of existing data. The study was designed by the Air Quality Group of the USDA's Natural Resources Conservation Service (NRCS) to address the issues in the NAS report, and to determine whether AFOs were likely to have compliance issues regarding the Clean Air Act and/or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The EPA offered AFOs in the swine, dairy, broiler chicken, egg, and turkey industries a one-time opportunity to participate in a legal agreement that would provide protection from prosecution from past federal law violations which may have occurred at those operations. In return, those industries would agree to participate in an extensive nationwide study which would generate data for determining emissions from major types of farms in geographic areas where they are located. NAEMS is the culmination of that agreement.

The goals of this component of NAEMS are:

- Determine whether individual farms are likely to emit volatile organic compounds (VOCs) in excess of applicable Clean Air Act (CAA) thresholds.
- Determine whether individual farms are likely to emit NH_3 and/or H_2S in excess of applicable CERCLA and Emergency Planning and Community Right-to-Know Act (EPCRA) reporting requirements.
- Form a database with which additional studies of air emissions and effectiveness of control technologies can be compared, and from which emission factors can be developed.
- Promote a national consensus on methods and procedures for estimating emissions from livestock operations.

In addition, it is expected that this project will result in a database with which additional studies of air emissions and effectiveness of control technologies can be compared and from which emission factors can be developed. As such, the results of this project will be useful to state and federal regulatory agencies, the livestock industry, researchers, consultants, and the general public.

NAEMS consists of two components: a barn component and an open source component. This QAPP addresses the details of the open source component only. A separate QAPP documents the details of the barn component. To meet the goals of the open source project, micrometeorological

techniques in combination with open-path gas measurements will be used to estimate the emissions of ammonia (NH_3) from open sources of swine and dairy lagoons or basins and dairy corrals. Emissions of VOCs will be estimated based on synthetic open-path sampling and either micrometeorological techniques or the relationship of the VOC to NH_3 concentrations measured near the open sources. Fundamentally, the emission calculations of NH_3 will use absorption spectroscopy of the air along an open path of at least 100 m length downwind and upwind of the open source (a path-integrated concentration or PIC) in conjunction with one to three (depending on emissions calculation method) 3-dimensional (3D) wind velocity measurements near the source. The emission of H_2S will use either direct open path absorption spectroscopy or a synthetic open-path system (S-OPS) in conjunction with a gas sampling system (GSS), analyzer, and one to three 3D wind velocity measurements near the surface. The emission of VOCs will use a synthetic open-path system (S-OPS) in conjunction with a gas sampling system (GSS), photoacoustic spectroscopy (PAS), and one to three 3D wind velocity measurements near the surface.

None of the gas concentration or emissions calculation methods are EPA-approved. The methods used in the project are however likely to result in defensible concentration measurements and emissions calculations through careful quality assurance and control.

Assessment of the capabilities of the TDLAS gas measurement system and bLS method in determining emissions from the lagoon/basin environment: Several studies have used TDLAS concentration measurements in combination with backward Lagrangian stochastic (bLS) modeling to calculate the emission rates for a variety of gases. Although this particular combination will not be used in our measurements, these studies demonstrate the validity of both the TDLAS measurement system and the bLS method inverse dispersion technique. There have been several studies of methane (CH_4) emissions from open sources using an open-path TDLAS measurement system in combination with bLS modeling. An evaluation of CH_4 emissions from a defined 6 m x 6 m area source made over 11 roughly two hour periods over 6 d indicated the bLS method error for a given 15-min period varied with stability; with a mean 12% overestimation under near neutral conditions, 13% underestimation under unstable conditions, and 38% overestimation under stable conditions (Flesch et al., 2004). The standard deviation of the bLS-estimated emission was 20%. A problem with this study was the low CH_4 signal/noise ratio of only 2 to 4, which probably resulted in high emission estimation errors. Another evaluation of the combination of TDLAS and bLS inverse dispersion modeling was made using CH_4 emissions from a 3 m x 3 m grid measured by an open-path laser and turbulence data from a three dimensional sonic anemometer (McBain and Desjardins, 2005). Under conditions when Monin Obukhov similarity theory is valid, the calculated emission rate was on average within 6% of the actual value with a standard deviation of 16%. In addition, obstructions upwind from the sensors were determined to have little impact on the Q estimates, so long as the distance between the sensors and the obstructions was at least 25 times the height of the obstructions. Finally, an evaluation of CH_4 emissions from grazing dairy cows over a 3 week period in winter and summer indicated the bLS method overestimated the emission (relative to the IHF method) by between 5% to 17% when averaging emissions estimates from five TDLAS beamlines (Laubach

and Kelliher, 2005). Due to the limited validation of the bLS method of determining lagoon or basin emissions, a validation study (Section 10.7) will be conducted as part of the project.

This same combination (TDLAS and bLS) has also been used to measure emissions of NH_3. An evaluation of NH_3 emissions using TDLAS gas measurements and the backward Lagrangian Stochastic (bLS) emissions model was made from a lagoon over 6 d with 15-min measurement periods (Flesch et al. 2005). Periods with u_*<0.15 m/s were excluded, and two different exclusion criteria for the Monin Obukhov length (L) were used. When periods with |L|< 2 m were excluded, the mean emission rate was 1.69 g/s (SD 1.23 g/s), while when periods with |L|< 10 m were excluded, the mean emission rate dropped to 1.44 g/s (SD 0.57 g/s). The emission rate dropped to 1.27 g/s (SD 0.49 g/s) when actual turbulence data were used. Since there was no measure of actual emissions, the reduction in emissions estimate after excluding measurements made outside of the defined meteorological conditions may or may not have caused a greater accuracy of the estimate. The calculated NH_3 emissions from a 3.1-m diameter (1.1-m high) manure pile using the bLS emissions calculation method with five individual TDLAS beamlines and the Integrated Horizontal Flux emissions calculation method (IHF) with passive gas samplers over 24 h were within 15% (after assumption concerning the differences in sampling times) (Sommer et al., 2004). It is however important to note that the IHF method cannot be assumed to be a standard method to which all other methods should be compared.

Assessment of the capabilities of the RPM emissions calculation method in determining emissions from the lagoon/basin environment: In simulation and controlled release studies, Hashmonay and Yost (1999) and Hashmonay et al. (2001) demonstrated that the application of VRPM configuration can be used to reconstruct the smoothed concentration field in a plane. In these studies, a series of measurements were made using open-path instruments. These studies showed that the fluxes carried by the plumes reconstructed by the RPM method generally agree within 10% of the emission rates from a controlled source. The accuracy of this method will depend on the specifics of the source and measurement configuration; for the studies mentioned, it was found that results were accurate so long as the wind direction was within about 30° of perpendicular to the measurement path. In addition, best results were obtained when several measurement periods were combined, with the dwell time for any particular PIC measurement as short as practically possible for obtaining an accurate reading above the background.

Assessment of the capability of UV-DOAS gas measurement systems to determine emissions from lagoon/basin environments: Mount et al. (2001) describe a method for using UV-DOAS in combination with a Gaussian plume model to calculate NH_3 emission rates near a lagoon. Most of the results presented are of NH_3 concentrations measured using the UV-DOAS, and not of emission rates, *per se.* They showed that the concentration measurements increase in a sensible manner with wind direction and also with time of day. Preliminary calculations of emission rate gave values of between 30 and 75 $\mu g/m^2/s$. Thoma (2006) describes use of a UV-DOAS system for measuring NO concentration near a road. These results demonstrate the ability of UV-DOAS to measure gas concentrations at high temporal resolution. Due to the lack of validation of measurements of H_2S using UV-DOAS measurement systems in lagoon environments, a validation study (Section 10.8) will be conducted as part of the project.

Assessment of the capabilities of the S-OPS/PFA gas measurement system and bLS method in determining H_2S emissions from the lagoon/basin environment: The measurement of H_2S using pulsed-fluorescence (PF) is an approved EPA method (EQSA-0486-060, EMTIC TM-006C). The synthetic open-path sampling system used to collect the air sample for analysis has not been validated. Due to the lack of validation, a validation study using a synthetic line emission of SO_2 using both the PF analyzer and a UV-DOAS measurement system (Section 10.9) will be conducted.

Assessment of emissions of NH_3 from lagoon/basins: Efforts to measure NH_3 emissions from open sources have been made. Measured emission rates of NH_3 from lagoons vary from 5.3 kg/h to 83.5 kg/h. Measurements by Aneja et al. (2000) using a dynamic chamber in the lagoon and Todd et al. (2001) showed a strong seasonal effect on emissions with emissions lower during the winter and higher during the spring and summer. An evaluation of NH_3 emissions using TDLAS gas measurements and the backward Lagrangian Stochastic (bLS) emissions model was made from a lagoon over 6 d (Flesch et al, 2005). Results indicated a mean emission rate of 1.27 g/s (SD 0.49 g/s). Considering only a 72-h period in March, the mean emission rate was 0.9 g/s corresponding to 6.5 g / (animal·d). Similar estimation during July (extrapolated from 15.5 h of measurement) resulted in a mean emission of 2.2 g/s corresponding to 16 g / (animal·d).

Assessment of emissions of VOC from lagoon/basins**:** There have been few reported measurements of VOC emissions of gases other than CH_4 from open lagoon sources. Bicudo et. al. (2001) studied VOCs on three swine production sites in Southwest Minnesota using SPME (Solid Phase Micro Extraction) methodology and found mean values equivalent to 9.0, 17.1 and 15.8 g/(m^2 d) respectively. Hobbs et. al. (1999) determined average daily and annual emissions rates for different VOCs from stirred pig slurry and found the largest emission to be acetic acid (HAc) (1.49 g/(m^2 d)) over propanoic acid, 2-methyl propanoic acid, butanoic acid, 3-methyl butanoic acid, 2-methylbutanoic acid, pentanoic acid, phenol, 4-methyl phenol, and 4-ethyl phenol. The emission factor for ethanol (EtOH) was estimated at 0.89 g/(cow·d) for a dairy lagoon slurry (sorbent tubes, cold trap, GC/MS; Filipy et al., 2006). The emission factor for total VOC except volatile fatty acids and amines from dairy lagoons and storage ponds was estimated at approximately 1.0 lb/(cow·yr) (method TO-15; San Joaquin Valley APC, 2005).

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6. Project/Task Description

6.1. Project objectives

NAEMS consists of two components: emissions from open sources and emissions from barns. This QAPP addresses the open source component to NAEMS. A companion QAPP addresses the barn emissions component to NAEMS. The objectives of this component of NAEMS are to:

- Quantify aerial pollutant emissions from open source manure storage areas.
- Provide valid baseline data on aerial emissions from typical U.S. livestock open source manure storage areas to regulators, producers, researchers, students, and other stakeholders.
- Determine long-term characteristics of H_2S and NH_3 emissions from representative types of livestock manure storage areas.

6.2. Project description

Gaseous emissions of NH_3, H_2S and various volatile organic compounds (VOCs) from open sources will be measured at a number of farm operations with a range of characteristics. The emissions from open sources, including lagoons, basins, and corrals, will be measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions will be measured using models that rely on concentration and wind flow measurements. All gas measurements will be corrected for barometric pressure, temperature and humidity using measurements described in Table 6.2

At the lagoon, basin and corral sites, the atmospheric concentration of NH_3 will be measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS) with a MDL of 50 ppb for a 100 m pathlength, broad bandwidth open path ultraviolet differential optical absorption spectroscopy (UV-DOAS) systems with a MDL of 5 ppb for a 100-m pathlength (if validated) and from air sampled by a synthetic open-path manifold of inlets using photoacoustic spectroscopy with a MDL of 200 ppb (Table 6.1). Prior studies indicate ranges in NH_3 concentration of between 250 and 810 parts per billion (ppb) over a swine lagoon surface (Todd et al., 2001), 500 to 700 ppb at the berm of a swine lagoon (Childers et al., 2001), and 0.4 to 130 ppb at 100 m from the berm of a swine lagoon (McCulloch, 1998). Similar concentrations are reported for a dairy lagoon, with concentrations varying from 100 to 500 ppb NH_3 over the course of 22 d of intermittent measurements during the summer (Rumberg et al., 2004). Measurements of NH_3 concentrations 50 and 200 m from dairy corrals indicate concentrations of 300 to 400 ppb (Sheffield, unpublished). Given the range in NH_3 concentrations reported in the literature and the 50 to 150 m pathlengths to be used in this study, the concentration measurements will be at least 3 times the MDL for the UV-DOAS and TDLAS under most conditions but may frequently be below the MDL of the photoacoustic multigas analyzer.

At the lagoons, basins, and open corral measurements of H_2S concentrations (as well as NH_3 concentrations) will be made using broad bandwidth open path ultraviolet differential optical absorption spectroscopy (UV-DOAS) systems (if method validated) with a MDL of 2000 ppb-m

(Table 6.1) or using pulsed fluorescence (PF) of air sampled by a synthetic open-path manifold system (if UV-DOAS method not validated) with an MDL of 2 ppb. Prior studies have shown that H_2S concentrations vary from 5 to 700 ppb near a swine lagoon surface (Lim et al, 2003), 1000 to 5000 ppb over a swine manure tank (Chénard et al., 2003), to 23,000 ppb directly over wet manure (Chénard et al., 2003). Measurements of H_2S concentrations 50 m and 200 m from dairy corrals indicate concentrations of 20 to 40 ppb (Sheffield, unpublished). Given the range in H_2S concentrations reported in the literature and the 50 to 150 m pathlengths to be used in this study, the concentration measurements will be above the nominal MDL (20 ppb over 100 m pathlength) for the UV-DOAS under some conditions. Further characterization of the UV-DOAS system performance in the matrix of gases found near lagoons or manure basins will be made (Section 10.8) to verify the suitability of the instrument for detecting and measuring the H_2S.

At the lagoons, basins, and open corral, measurements of methane (CH_4), ethanol (EtOH), methanol (MeOH), and residual VOC concentration (as well as NH_3 and water vapor concentration and barometric pressure) will be made using photoacoustic spectroscopy (Table 6.1). The instrument MDL for the measurement of CH_4 is 20 ppb, MeOH is 80 ppb, EtOH is 60 ppb, and total hydrocarbons (THC) is 20 ppb (depending on wavelength of measurement) with corrections for barometric pressure, temperature and humidity made using measurements described in Table 6.2. Very little is known about VOC concentrations near lagoons. Prior studies indicate there are very low concentrations of total VOCs in the air around lagoons, and there have been few prior studies in which VOC concentrations have been speciated. Childers et al. (2001) measured CH_4 concentrations ranging from 2.1 ppm to 11.0 ppm near swine production facilities. Rabaud et. al. (2003) identified and quantified volatile organic compounds emitted from dairy farms in NC using sorbent tubes and thermal-desorption GC/MS and found that HAc concentrations ranged between 15 ppb and 170 ppb, EtOH between 16 ppb and 90 ppb and a number of other VOCs between 0.1 and 100 ppb. Measurements of the headspace of waste collected as it enters a dairy lagoon in Washington (Filipy et al., 2006) suggest upper bounds on the EtOH concentrations of 14.3 to 58 ppb (sorbent tubes, cold trap). Total volatile organic carbon concentrations comprised of the accumulated concentration of 26 GC/MS-speciated compounds was 3-70 ppm in swine lagoons in Colorado (Method TO-15; Walker, 2001). Given the range in HAc concentrations reported in the literature and the photoacoustic analyzer MDL, the concentration at the lagoon will often be below the MDL. Given the range in CH_4 concentrations reported in the literature and the photoacoustic analyzer MDL, the concentration at the lagoon will rarely be below MDL. Given the range in MeOH+EtOH concentrations reported in the literature and the photoacoustic analyzer MDL, the concentration at the lagoon will often be below MDL. Given the range in total VOC concentrations reported in the literature and the photoacoustic analyzer MDL, the concentration at the lagoon will rarely be below MDL.

Emissions of NH_3 will be determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems and a Gaussian plume fit approach (Radial Plume Mapping: RPM). Emissions of H_2S will be determined using UV-DOAS open-path systems or PF with synthetic open path sampling systems (if the UV-DOAS measurement H_2S is not validated) and a Lagrangian Stochastic approach.

Table 6.1 Study critical measurements.

Measurement	Method/ Instrument	Reporting Units	Required Operating range	MDL	Locations	Minimum sample frequency	Final Data-Aggregation	Completeness
Location of sensors	Garmin GPS 76 w/ WAAS	M	0-300 m	3 m	1 m	1/ meas. period	1/ meas. period	100%
Optical Pathlengths	Nikon Monarch Gold Laser 1200	M	0-300 m	0.5 m	Each optical path	1/ meas. period	1/ meas. period	100%
Ammonia and Hydrogen Sulfide Concentration Measurements								
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder2	$\mu g/m^3$	1-800 ppb	5 ppm-m	retroreflectors at 1 m abl, 7 m, 15 m agl and 0 m to 10 m from berm	0.5 s beamlines	30 min & 24 h	75% of 10 d each quarter
NH_3	INNOVA 1412 multi-gas analyzer	$\mu g/m^3$	1-800 ppb	200 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
H_2S	UV-DOAS/ Cerex Inc. UV Sentry	$\mu g/m^3$	1-800 ppb	2000 ppb– m	1 m abl, 10 m from berm	100 ms integration 60 s avg	30 min & 24 h	75% of 10 d each quarter
H_2S	PF/Thermo Environmental 450i analyzer	$\mu g/m^3$	1-800 ppb	2 ppb	1 m abl, 0-2 m from berm	60 s avg	30 min & 24 h	75% of 10 d each quarter
VOC Concentration Measurements								
MeOH	PAS/ INNOVA 1412 multigas analyzer	$\mu g/m^3$	0-90+ ppb	80 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
EtOH	PAS/ INNOVA 1412 multigas analyzer	$\mu g/m^3$	0-90+ ppb	60 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
CH_4	PAS/ INNOVA 1412 multigas analyzer	$\mu g/m^3$	2000-11000 ppb	40 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
THC (reference propane)	PAS/ INNOVA 1412 multigas analyzer	$\mu g/m^3$	3000-70000 ppb	20 ppb	1 m abl, 0-2 m from berm	60 s	30 min & 24 h	75% of 10 d each quarter
Meteorological Measurements					Tower			
Wind Speed	3D Sonic anemometer/ RM Young 81000	m/s	0-60 m/s	0.01 m/s	2 m abl, 4, 16 m agl, 0- 10 m from berm	160 Hz sampling/ 16 Hz averaging	30 min & 24 h	75% of 10 d each quarter
Wind Direction	3D Sonic anemometer/ RM Young 81000	Degrees	0° -360°	0.1^o	2 m abl, 4, 16 m agl, 0- 10 m from berm	160 Hz sampling/ 16 Hz averaging	30 min & 24 h	75% of 10 d each quarter
Lagoon Measurements								
Length	Nikon Monarch Gold Laser 1200	m	0-300 m	0.5 m	1 m	1 time	1 time	100%
Width	Nikon Monarch Gold Laser 1200	m	0-300 m	0.5 m	1 m	1 time	1 time	100%
Volume	Calculation	m^3		1 m^3		1 time	1 time	100%
Turbulence Measurements					Tower			
3D Turbulence wind components	3D Sonic anemometer/ RM Young 81000	m/s	0-40 m/s	0.01 m/s	2 m abl, 4, 16 m agl, 10 m from berm	160 Hz sampling/ 16 Hz ave.	30 min	75% of 10 d each quarter
Temperature Variability	3D Sonic anemometer/ RM Young 81000	^oC	-50 to $+50^oC$	0.01^oC	2 m abl, 4, 16 m agl, 10 m from berm	160 Hz sampling/ 16 Hz ave.	30 min	75% of 10 d each quarter

Table 6.1 Study critical measurements (cont.)

Measurement	Method/ Instrument	Reporting Units	Required Operating range	MDL	Locations	Minimum sample frequency	Final Data-Aggregation	Completeness
S-OPS/GSS Air Sampling								
Sample flow rate	GSS/SOP-S	L/min	10	0.1	GSS	30 s	30 min	75% of 10 d each quarter
Sampling manifold pressure	GSS/SOP-S	Pa	±20,000	±500	GSS	30 s	30 min	75% of 10 d each quarter
Emissions Calculations								
NH_3 emissions	Radial Plume Mapping Model	g $m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	~ 3 min	30 min, 24 h	75% of 10 d each quarter
H_2S emissions	Backward Lagrangian Stochastic Model	g $m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
NH_3 emissions	Backward Lagrangian Stochastic Model	g $m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
MeOH emissions	Ratiometric to RPM Model	g $m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
EtOH emissions	Ratiometric to RPM Model	g $m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
CH_4 emissions	Ratiometric to RPM Model	g $m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter
THC emissions	Ratiometric to RPM Model	g $m^{-2}s^{-1}$	NA	NA	Lagoon/ Basin	30 min	30 min, 24 h	75% of 10 d each quarter

Table 6.2 Study non-critical measurements

Measurement	Method/ Instrument	Reporting Units	Required Operating range	MDL	Locations	Minimum sample frequency	Final Data-Aggregation	Completeness
Meteorological Measurements					Tower			
Ambient Temperature	Thermistor/ Campbell Scientific Inc HMP45C(Vaisala)	°C	-40 to 50 ° C	0.1 ° C	1 m abl, 0-10 m from berm	5 s	5 min, 30 min & 24 h	90% of 10 d each quarter
Relative Humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	%	0-100%	5%	1 m abl, 0-10 m from berm	5 s	5 min, 30 min & 24 h	90% of 10 d each quarter
Barometric Pressure	Aneroid barometer/ Setra 278	hPa	600 to 1100 hPa	600 hPa	1 m abl, 0-10 m from berm	5 s	5 min, 30 min & 24 h	90% of 10 d each quarter
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	(binary)	<2 m abl, 0- 10 m from berm	5 min	5 min, 30 min & 24 h	90% of 10 d each quarter
Solar Radiation	Silicon pyranometer/ LiCOR 190SB	W/m^2	0- 1200 W/m^2	10 W/m^2	<2 m abl, 0- 10 m from berm	5 s	5 min, 30 min & 24 h	90% of 10 d each quarter
Atmospheric pressure	PAS/ INNOVA 1412 multigas analyzer	mbar	600 to 1100 mbar	1 mbar	2 m abl, 0-2 m from berm	1 min	30 min & 24 h	75% of 10 d each quarter
Water vapor	PAS/ INNOVA 1412 multigas analyzer	°C	0 to 40 °C	0.1 °C	2 m abl, 0-2 m from berm	1 min	30 min & 24 h	75% of 10 d each quarter

Table 6.2 Study non-critical measurements (Cont.)

Measurement	Method/ Instrument	Reporting Units	Required Operating range	MDL	Locations	Minimum sample frequency	Final Data-Aggregation	Complete-ness
Lagoon/ Basin Measurements								
Lagoon solids depth	Sludge level detector/ SludgeGun 10HD, Markland Specialty Eng.	m	0-10 m	0.05 m	0-10 m depth in lagoon	1/ meas. Period	1 time	75% of meas. Periods
Years in service	Questioning lagoon/ basin owner	Years	NA	NA	Farm	1 time	1 time	100%
Lat & Long	Garmin GPS 76 w/ WAAS	degrees	-90 °- +90 ° latitude -180 - +180 ° longitude	0.00005 °	100 m	1 time	1 time	100%
Lagoon/ basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	pH units	0-14 units	0.2 unit	0.3 m lagoon depth	5 min	30 min & 24 h	75% of 10 d each quarter
Lagoon/ basin Redox potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	mV	-800 - +1100 mV	20 mV	0.3 m lagoon depth	5 min	30 min & 24 h	75% of 10 d each quarter
Lagoon/ basin Temperature	Thermistor/ Campbell Scientific Inc 107-L	°C	-35 - +50 °C	0.5 °C	0.3 m lagoon depth	5 min	30 min & 24 h	90% of 10 d each quarter
Manure NH_4	Micro Kjeldahl+ titrometric	mg/L	0.5-10 mg/L (diluted)	0.05 mg/L	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Manure Total Kjeldahl Nitrogen	Micro Kjeldahl+ titrometric	mg/L	0.5-10 mg/L (diluted)	0.05 mg/L	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Manure pH	KCl pH electrode	pH units	0-14 units	0.02	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Manure total solids content	Dry at 103-105 °C	mg/L	0-50 g sample	3 mg/L	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Manure volatile solids content	Heat to 550 °C	mg/L	0-50 g sample	7 mg/L	Basin/ Corral	1/ meas. period or 90 d	1/ meas. period or 90 d	75%
Map of topography and structures	Satellite imagery, topo-graphic maps, on-site survey, photographs	m	NA	1m elev. 10 m hor.	Farm	1 time	1 time	100%

The Gaussian plume fit approach, based on mapping of the radial shape of the plume, will be used to estimate the emissions of NH_3 from concentration measurements made using the TDLAS open path system. The approach (RPM method) uses a fitted Bi-Gaussian function and a fitted wind profile (from the three 3D sonic anemometers) to define the plume. The domain of the plume is based on PIC measurements made along two elevated paths and three horizontal paths. The Lagrangian approach, based on an inverse dispersion analysis using a backward Lagrangian stochastic method (bLS), will be used to estimate the emissions of NH_3 (using TDLAS open path systems), H_2S (using S-OPS and PF analyzer or UV-DOAS systems) and VOC (using S-OPS and PAS). The Lagrangian approach uses horizontal PIC measurements and turbulence statistics derived from the lowest (2 m height abl at lagoons/ basins and 2-m height agl at the corral) sonic anemometer.

An intercomparison between the RPM and bLS methods, with the goal of validating the bLS method using methodologies similar to EPA Method 301, will be conducted at two farms, which will each have their emissions measured continuously for one entire year.

Table 6.3 Description of sites.

Farm	Species	Phase[1]	Code	Location	Manure Collection	Source Type
1	Swine	Sow	NC4A	Duplin Co., NC	Flush	Lagoon[2]
2	Swine	Finisher	NC3A	Bladen Co., NC	Flush	Lagoon
3	Swine	Sow	IN4A	Clinton Co., IN	PPR[3]	Lagoon
4	Swine	Finisher	IA3A	Greene Co., IA	PP[4]	Basin
5	Swine	Sow	OK4A	Texas Co., OK	PPR	Lagoon
6	Swine	Finisher	OK3A	Texas Co., OK	PPR	Lagoon
7	Dairy	Lactation	WA5A	Yakima Co., WA	Flush	Lagoon
8	Dairy	Lactation	WI5A	Rock Co., WI	Flush	Lagoon[2]
9	Dairy	Lactation	IN5A	Cass Co., IN	Flush	Lagoon
10	Dairy	Lactation	TX5A	Deaf Smith Co., TX	Dry lot	Corral

[1] Characterizes type of farm.
[2] Lagoon can be single or double stage.
[3] PPR = pull plug with recharge
[4] PP= pull plug

Emissions will be measured at a total of 10 farms (Table 6.3) over the course of two years with the intent of representing the dominant manure management schemes for each animal species. Swine manure basin or lagoon emissions will be measured continuously at one farm (Farm 3) for one year and for up to 21 d each season over two years at five farms (Farms 1, 2, 4, 5, and 6). Dairy lagoon emissions will be measured continuously at one farm (Farm 9) for one year and for up to 21 d each season for two years at two farms (Farms 7 and 8). Dairy corral emissions will be measured for up to 21 d each season at one corral farm over two years (Farm 10). The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. By setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d), instrumentation problems associated with unfavorable weather conditions will not prevent meeting the completeness DQO for each measurement period. This is further explained in section 7.

Sites for monitoring are selected based on the location (relative to climate and typical practice), method of manure collection, type of manure storage, availability of power and communications, and physical configuration of buildings and lagoons/ basins. A general profile of the sites is found in Table 6.3. Further details of the site selection protocol are listed in the Producer Collaborations at Area Source Monitoring Sites Standard Operating Procedure (SOP S7).

Emissions measurements on Rotation Farms. Gaseous emissions of NH_3, H_2S, THC, CH_4, MeOH, and EtOH from lagoon/ basins will be measured over up to 21-d periods at eight farms each during each season of the year (Table 6.4; Fall= September, October, November; Winter=

December, January, February; Spring= March, April, May; Summer= June, July, August). The gaseous emissions of H_2S will be measured using a PF analyzer from air continuously sampled from upwind and downwind S-OPS or UV-DOAS systems in conjunction with the bLS emission model. The gaseous emissions of NH_3 will be measured continuously using upwind and downwind TDLAS systems in conjunction with the RPM emission model from a swine manure basin during the first year of measurements. Gaseous emissions of NH_3, THC, CH_4, MeOH and EtOH will also be determined from S-OPS near each lagoon/basin using the ratio of the point measurement of NH_3 concentration to TDLAS measurement of NH_3 concentration multiplied by the RPM measured NH_3 emission. Speciation of non-methane hydrocarbon (NMHC) emissions will include only MeOH and EtOH emissions. Samples of manure will be collected at the beginning of each measurement period at the basin and analyzed for pH, total and ammoniacal nitrogen, and total and volatile solids by a commercial laboratory (Midwest Laboratories, Inc.). Lagoon/basin emissions will be related to characteristics of the atmosphere and lagoon/basin including atmospheric stability, wind direction, lagoon/ basin temperature, pH and redox status, lagoon/basin loading and sludge depth (Table 6.2).

Two FOS teams (designated ‘E’ and ‘W’ in Table 6.4), each consisting of a scientist and technician will move sequentially from farm to farm to conduct the 20-d measurement periods at each of four farms each during each season of the year (Table 6.4). Each FOS team will set up instrumentation, conduct calibrations and quality assurance checks over two days, then leave the farm for up to 16 d (residing at PAML) until at latest 19 d into the measurement period. At that time they will return to the farm, conduct final quality assurance checks and take-down the equipment at the farm. They will then travel with all equipment to the next farm to begin the routine of set up and quality assurance checks for the next measurement period. Since the completeness objective is 75% of 10 d each quarter, some of the measurement periods could be as short as 8 d. The measurement sequence for the rotation around these farms for the ‘E’ and ‘W’ measurement teams are indicated in Table 6.4. Farm 4 may be measured by the ‘E’ or ‘W’ team depending on logistics at the planned time of measurement. To reduce possible bias in the climatic conditions associated with the measurements at a given farm, the sequence of measurements is the opposite in the second year as compared with the first year. The farm being measured at the end of one season will generally be continuously measured through the beginning of the next season for a measurement period of around 4 weeks (indicated in Table 6.4 by bold type). This provides for quality assurance visits that will not interfere (adding extra days in travel) with the rotation schedule as well as a period of extended measurement at each location. For the purposes of representation of individual seasons, the extended measurement period will be broken into two periods with an unused 5-7 d period of measurements at the end of one season or the beginning of the next.

Continuous lagoon/ basin emissions measurements. Gaseous emissions of NH_3 and H_2S from lagoon/ basins will be measured continuously for one year at two locations (Table 6.4). The equipment and methodologies at the continuous measurement locations will be identical to the rotation farms. The gaseous emissions of H_2S will be measured using a PF analyzer from air continuously sampled from upwind and downwind S-OPS systems or UV-DOAS systems in conjunction with the bLS emission model. The gaseous emission of NH_3 will be measured

continuously using upwind and downwind TDLAS systems in conjunction with the RPM emission model from a swine lagoon during the first year of measurements (Farm 3, Table 6.3 and Table 6.4) and from a dairy lagoon during the second year of measurements (Farm 9, Table 6.3 and Table 6.4). These continuous emissions measurements will provide information towards defining how well the annual emission is characterized by the short-duration measurement periods each quarter at the eight rotation farms. The gaseous emissions of NH_3, THC, CH_4,

Table 6.4 Project measurement and calibration schedule.

	Year	2007		2008				2009		
	Season[1]	U	F	W	S	U	F	W	S	U
Farm 1: NC4A	EAST[2]		2	3	2	3	4	1	3	
Farm 2: NC3A	EAST		3	4	1	4	3	2	4	
Farm 4: IA3A	EAST		1	2	4	1	2	4	1	
Farm 8: WI5A	EAST	1	4	1	3	2	1	3	2	
PAML calibration	EAST			X		X		X		X
Farm 5: OK4A	WEST[3]	1	3	1	3	3	4	1	3	
Farm 6: OK3A	WEST		1	3	4	1	2	2	2	
Farm 7: WA5A	WEST			4	1	4	1	4	1	
Farm 10: TX5A	WEST		2	2	2	2	3	3	4	
PAML calibration	WEST			X		X		X		X
Farm 3: IN4A	FIXED[4]									
Farm 9: IN5A	FIXED									

Notes:
1: Seasons; F=Fall (September, October, November), W=Winter (December, January, February), S=Spring (March, April, May), U=Summer (June, July, August)
2: East team
3: West team
4: Continuous operation

MeOH and EtOH will also be determined from air sampled using S-OPS upwind and downwind of the lagoon/basin using the ratio of the synthetic open-path line measurements of THC, CH_4, MeOH and EtOH to the line measurement of NH_3 concentration multiplied by the RPM-calculated NH_3 emission. Non-methane hydrocarbon (NMHC) emissions will be calculated by adding the MeOH and EtOH emissions to the THC emissions. Lagoon emissions will be related to characteristics of the atmosphere and lagoon/ basin including atmospheric stability, wind direction, lagoon/ basin temperature, pH and redox status, lagoon loading and sludge depth (Table 6.2).

Rotation dairy corral emissions measurements. Gaseous emissions will also be measured over periods up to 21 d long during each season of the year from an open corral facility (Farm 10, Table 6.3 and Table 6.4). The backward Lagrangian stochastic method (bLS) will be used to estimate the emissions of NH_3 from path-integrated concentration measurements made using

TDLAS systems. The backward Lagrangian stochastic method (bLS) will also be used to estimate the emissions of H_2S from path-integrated concentration measurements made using UV-DOAS or S-OPS/PFA systems. The gaseous emissions of NH_3, THC, CH_4, MeOH, and EtOH will also be determined for synthetic open paths near each lagoon/basin using the ratio of the S-OPS line measurement of CH_4, THC, MeOH, and EtOH to line measurement of NH_3 concentration multiplied by the bLS-measured NH_3 emission. Non-methane hydrocarbon (NMHC) emissions will be calculated by adding the MeOH and EtOH emissions to the THC emissions. Samples of manure will be collected every 90 d at the corral and analyzed for pH, total and ammoniacal nitrogen, and total solids (Table 6.2) by a commercial laboratory (Midwest Laboratories, Inc.). Corral emission will be related to characteristics of the atmosphere and corral surface including atmospheric temperature, stability and humidity, and wind speed and direction (Table 6.2).

The choice of open-path gaseous concentration measurements in combination with wind measurements and emissions modeling was based on the need to use a methodology that provided for measuring the emissions with minimal measurement interference to the emission processes, measuring the emissions resulting from all transport processes from liquid/solid to 'fenceline' air, measuring the emissions from the entire lagoon rather than a small section of the lagoon, measuring using 'fenceline' and not within-lagoon equipment, measuring continuously and calculating the emissions from both unmitigated and mitigated (such as straw or other covers) lagoons. The choice of TDLAS for the NH_3 measurements was based on cost and ability to make relatively long path measurements with a monostatic system configurable with a scanner. The choice of PF for the H_2S measurements over the UV-DOAS will be based on the performance of the UV-DOAS system. The PF method for H_2S measurements is EPA approved and will be used if the UV-DOAS does not meet specifications for H_2S measurement. The S-OPS was chosen to comparably sample the air along the path of the open-path TDLAS system. The choice of the photoacoustic multi-gas analyzer for the VOC measurements was chosen based on the ability to make continuous accurate measurements of multiple VOCs in combination with NH_3,

The study is largely in line with the original protocol reported in the Federal Register Air Consent Agreement (EPA, 2005). A comparison of the agreement between the Air Consent Agreement (ACA) and the project follows:

- The ACA identified the need for the manure storage at six swine facilities to be monitored. This matches the designated project monitoring locations.
- The ACA identified the need for the manure storage at four dairy facilities to be monitored. This matches the designated project monitoring locations.
- The ACA proposed the use of open-path Fourier Transform Infrared Spectrometers and the RPM model for the measurement of NH_3 emissions. The project is now using TDLAS systems in conjunction with the RPM model for this measurement.
- The ACA proposed the use of open-path UV-DOAS systems for the measurement of NH_3 and H_2S with emissions measured using the bLS model. A validation study of the UV-DOAS H_2S measurements will be conducted to determine if the measurement method meets the desired accuracy and MDL. If the UV-DOAS method does not meet the

performance criteria, the UV-DOAS will not be used to measure H_2S and the EPA-approved PF method of measuring H_2S will be used.

- The ACA proposed the use of water analyses and the WATER9 model for the measurement of VOC emissions. Due to difficulties in validating the WATER9 model, the project is using PAS in conjunction with a ratiometric VOC to NH_3 concentration and NH_3 emissions at that time to measure the VOC emissions.

Since the methods indicated in the ACA and adopted or changed for the project are not EPA standard methods, the project will provide an opportunity to evaluate the methods for possible future designation as Standard Methods. Efforts are currently underway to approve the RPM emissions measurement method as a Standard Method. The validation study of the bLS model that will occur before the routine data collection begins is an effort to determine if the method has promise of becoming a Standard Method for open path emissions calculation. A similar UV-DOAS measurement system has been evaluated and a draft standard operating procedure developed by the EPA ORD for the measurement of nitric oxide (USEPA, 2006). The TDLAS measurement system less the scanner has been evaluated by the Environmental Technology Verification Program for the measurement of NH_3 (Meyers et al., 2000).

6.3. Biosecurity

The movement of bacteria and viruses from farm to farm is a major issue. Biosecurity at each farm will be maintained by procedures outlined in SOP S7. The overarching biosecurity procedures are to be defined by each participating producer. These procedures may include:

- Using disposable boot covers and overalls if needing to meet with the farmer in his building.
- Avoiding contact with livestock and areas that the farmer has designated as off-limits.
- Avoiding driving across feed delivery lanes to reach the lagoon/ basin.
- Parking vehicle away from buildings.
- Avoiding contact with dead animals.
- Washing vehicle and trailer in a car wash between farms.

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7. Quality Objectives and Criteria for Measurement Data

7.1 Data Quality Objectives (DQOs)

The normal procedure for determining DQOs cannot be followed because there is a paucity of sequential long-term emission measurements that can be used to determine accuracy or completeness criteria. Since CERCLA and EPCRA reporting requirements are based on daily emissions and Clean Air Act (CAA) permit thresholds are based on annual emissions, both must be considered. Of the chemical emissions to be calculated in the study, the NH_3 and H_2S emissions are regulated by CERCLA and EPCRA while the VOC are regulated by the CAA. Since the normal procedure for determining accuracy and completeness is not possible due to lack of information, limitations on the completeness must be based on a best-estimate of the optimum instrumentation operation under outdoor weather conditions. Ignoring instrument failures, there are emission model limitations for both the RPM and bLS methods due to wind speed and wind direction variability.

The first overall DQO is to **provide mean daily lagoon/ basin emission calculations for each farm waste storage area under study that are within 30% of the true values for each measurement period**. This DQO is derived from the emissions model errors associated with the measurements used in the study and not from statistical analysis of previous measurements due to the very limited duration of previous lagoon/ basin emissions measurements. As previously stated, emissions of NH_3 are calculated in this study using two methods: the RPM method and the bLS method. Emissions of H_2S are calculated using the bLS method or the ratio of H_2S measured by PF from air sampled by the S-OPS to the nearest equivalent NH_3 PIC measured by TDLAS multiplied by the NH_3 emissions measured by RPM method. Emission of the VOCs (CH_4, THC, MeOH and EtOH) are calculated using the bLS method or the ratio of VOC measured by PAS from air sampled by the S-OPS to the nearest equivalent NH_3 PIC multiplied by the RPM-calculated emissions of NH_3. Non-methane hydrocarbon (NMHC) emissions will be calculated by adding the MeOH and EtOH emissions to the THC emissions. An evaluation of the emission calculation errors follows.

bLS emissions calculation
The model errors for the bLS emissions calculation method (21%) include: (1) 10% error for the estimate of the Monin-Obukov Length (L) derived from measurements, (2) 5% error in turbulence statistics: 10% error for the normalized variability statistics in the x and y directions (U and V) and 5% in the z direction (W) where the error in w is the most critical, (3) 15% error associated with the roughness length (z_o) estimate, and (4) 10% error due to stochastic methodology (Laubach and Kelliher, 2005).

Emissions of NH_3, H_2S, and VOCs at the corral are based on the bLS emission calculation method. In addition, emissions of H_2S and VOCs at some of the lagoon sites are based on the bLS emission calculation method. VOC concentrations are measured using the INNOVA multi-gas analyzer. The measurement precision error of the INNOVA is 1% except for EtOH and

MeOH (2%) while the calibration errors are 1% for NH_3 (1% due to diluter and 1% associated with the calibration gas), 1% for CH_4 (1% due to diluter and 1% associated with the calibration gas), 10% for THC (1% due to diluter and 10% associated with the propane calibration gas), 2% for MeOH (1% due to diluter and 2% associated with the calibration gas), and 1% for EtOH (1% due to diluter and 1% associated with the calibration gas). The H_2S measurement precision error of the PFA is 1% while the calibration error is approximately 3% (1% due to diluter and 3% associated with the calibration gas). The path-integrated concentration (PIC) measurement errors for H_2S using PFA or UV-DOAS are 5% and 10% respectively, while the calibration errors associated with the concentration of the calibration gas are 3% H_2S and 1% associated with the diluter (for the multipoint calibration).

Additional errors associated with the bLS emissions calculations include wind measurement errors of 3% in each direction. We also assume that non-ideal atmospheric and site conditions (such as limited fetch, variations in surface roughness, inhomogeneous non-stationary turbulence, and local variability in atmospheric mixing due to land-water temperature contrasts) introduce an error of approximately 20%. The overall bLS NH_3 and H_2S emissions calculation error is theoretically approximately 31%. This is consistent with empirically-estimated errors of the bLS emission calculation method, when constrained by the data quality indicator (DQI), of between 5% and 36%.

RPM emissions calculation
The model errors for the RPM emissions calculation method include errors in interpolation and extrapolation of the plume concentration map and errors associated with the interpolation of wind speeds through the concentration map domain. Prior studies indicate the method results in a 20% error when the entire plume is measured and mapped (this includes errors in wind speed measurement and PIC measurements described above). Extrapolation errors made when the plume is not entirely mapped could be as high as 20%. We assume that there is less error associated with non-ideal atmospheric and site conditions since the mean airflow adjusts to changes in surface roughness and heating more quickly than the turbulent structure of the flow and arbitrarily assume an error of 10% for these effects. As with the bLS emissions calculation, the TDLAS measurement error of 10% must also be included. Calibration errors associated with the concentration of the NH_3 calibration gas (1%) and diluter (1%) contribute little to the TDLAS error. The overall theoretical RPM NH_3 emissions calculation error is then approximately 30%.

Ratiometric emissions calculation
Emissions of H_2S and VOCs at some of the lagoon sites are based on the ratiometric emission calculation method. This method relies on the RPM-calculated NH_3 emission, the NH_3 concentration nearest the location of H_2S and VOC measurements, and the H_2S and VOC concentration measurements at all locations except the corral (where it is based on the bLS emissions calculation method in the absence of RPM methodologies). The RPM-calculated NH_3 emission error is approximately 30% while the individual TDLAS NH_3 concentration measurements have a combined error of approximately 10%. The combined errors (described above) of the INNOVA are 1% for NH_3, 1% for EtOH, 2% for MeOH, 1% for CH_4, and 10% for THC. The combined H_2S measurement error (described above) of the PFA is 3%. The errors of

estimating the emissions of the various VOCs are therefore approximately 35%. The error of estimating the emissions of H_2S is approximately 30%.

Adherence to the DQI for the critical measurements of the TDLAS, PFA, UV-DOAS, PAS multi-gas analyzer, 3D sonic anemometers, and RPM and bLS emissions calculations will assure the successful fulfillment of the first DQO.

A second DQO of critical interest is the completeness criteria for the study. **A valid sample of NH_3 and H_2S emissions during each quarter will consist of 75% of 10 d of valid measurements or 7.5 d of valid daily measurements**. The rationale for this DQO follows:

- NH_3 emissions calculations rely on NH_3 concentration measurements and the 2 m abl, 4 m agl, and 16 m agl 3D sonic anemometer measurements. It is expected that the NH_3 concentrations at the lagoon/basin and corral will be at least 3 times the MDL for the TDLAS. Therefore the 75% completeness DQO for NH_3 emissions calculations will likely be met provided the DQI for the emissions calculation methods are met. An analysis of the expected completeness of emissions calculations is below.
- H_2S emissions calculations rely on H_2S concentration measurements and either the 2 m abl 3D sonic anemometer measurements or the NH_3 concentration and RPM NH_3 emissions measurement. H_2S concentrations at the lagoons, basin and corral will typically be at least 3 times the MDL for the UV-DOAS or PF under most conditions. Therefore the 75% completeness DQO for H_2S emissions calculations will likely be met provided the DQI for the emissions calculation methods are met. An analysis of the expected completeness of emissions calculations is below.

A valid sample of CH_4, THC, EtOH and MeOH emissions during each quarter will consist of 75% of 10 d of valid measurements or 7.5 d of valid daily measurements. The rationale for this DQO follows:

- VOC emissions calculations rely on VOC concentration measurement of the photoacoustic multi-gas analyzer and either the 2-m abl 3D sonic anemometer measurements or the TDLAS NH_3 concentration measurement and RPM NH_3 emissions measurement. Although the NH_3 PIC measurements of the TDLAS will rarely be below MDL, the concentrations measured by the PAS at the lagoons, basin and corral may frequently be below the MDL of the photoacoustic multi-gas analyzer. These measurements will be set to ½ MDL.
- CH_4 and THC concentrations at the lagoons and basin will rarely be below MDL. Consequently, the EtOH and MeOH concentrations calculated from these measures will also be possible most of the measurement time. However since the NH_3 concentrations will often be below MDL for the photoacoustic multi-gas analyzer, it is expected that the emissions of CH_4, EtOH and MeOH will be 75% complete but the setting of NH_3 concentrations to ½ MDL for those measurements below detection limits will provide completeness but likely underestimate total emissions.

The MeOH and EtOH concentrations at the lagoons, basin and corral will often be below MDL. No emissions completeness criteria can be established for these chemical species- they will be considered only as supporting evidence of the composition of the NMHC.

The periods of valid NH_3 emissions will be limited in part due to TDLAS scanner failures and TDLAS errors associated with severe weather conditions. Periods of valid VOC and H_2S emissions will be limited by the orientation of the winds relative to the orientation of the two S-OPS paths. Further limiting the fraction of each measurement period resulting in valid emission are the criteria for valid RPM or bLS computations. The emissions computation methods used in the study do not generally perform adequately under very light winds (less than 1 ms^{-1}) or very high winds (greater than 8 ms^{-1}), and very stable or unstable atmospheric conditions (valid conditions indicated by the respective method's DQI). It was estimated from an analysis of CASTNet monitoring locations (Converse Station, CA, Centennial CO, Cherokee Nation, OK, Bondville, IL, and Candor, NC) that low winds occur up to 25% of the time in some parts of the country, high winds occur up to 14% of the time in some parts of the country, and very stable atmospheres occur up to 40% of the time in some locations. Since the co-occurrence of these conditions is expected, it is reasonable to assume that there will be invalid emissions calculations 30-40% of the time, with a greater fraction invalidated during the night time. Consequently, for any given fixed period of time the measurement completeness may be less than 75%.

A valid day of measurements will consist of 75% of the 30-min intervals in the day. To accomplish a 75% completeness for 10 d of data in a quarter (representing the weather during that quarter), it is expected that measurements will be made at a given farm location in the measurement rotation for up to 21 d of measurements. The need for 21 d of measurements to accomplish a 75% completeness of 10 d of emissions measurements is due to the complexity of the instrumentation and the necessity of having multiple measurements be valid (atmospheric concentration, winds, barometric pressure, relative humidity, and emissions calculation) for a valid emission measurement.

A 10-d period is needed to represent the within-season emissions variability. Within a season, most extratropical storms systems are spaced in time by approximately 3-4 d with weather associated with the storm lasting one to two days. A representative sample in a given season (quarter of the year) must span several weather systems and consequently represent about 10 d. Variability across the year is assessed by measurement periods occurring at each location during each season of the year. Three of the four quarters each year must attain the 75% 10 d completeness criteria for the year to be adequately represented in the study results.

If the second DQO for any gas emissions is not met within the 21 d period of sampling, there is no remediation possible; the mobile team will still need to move on to the next measurement location. There is no means of extending the measurement period to satisfy the second DQO for a given measurement location without impacting the potential successful completion of subsequent measurement periods and locations.

A result of the project will be the accumulation of sufficient measurements and calculated emissions to define the variability found at manure storage facilities and consequently provide the information needed to establish preliminary DQO for at least NH_3 and H_2S emission from lagoons. The measurement at only one corral and one swine basin will limit the validity of DQO established for these situations.

7.2 Data Quality Indicators

DQIs are goals established to assure the quality of measurements to meet the DQO. Failure to achieve any of the acceptance criteria described below triggers an immediate examination of sampling and/or analytical practices in order to correct the problem.

7.2.1 TDLAS NH_3 Measurements.

The scanning path-integrated concentration (PIC) measurements of NH_3 will be measured using Boreal Laser GasFinder2® instruments. The quality of the 15-s TDLAS spectra is defined by the instrument quality control tests described in the Standard Operating Procedure for Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS) (SOP C2). System accuracies of the Boreal Laser GasFinder2® were assessed in 2000 by the Environmental Technology Verification Program. The Environmental Technology Verification Program was established by the EPA to verify performance characteristics of innovative environmental technology. Results of this study are found in Table 7.1. The DQIs are established at a lower accuracy and precision for this study to allow for non-ideal environmental conditions. The DQIs are set at 10% accuracy and 10% precision for the PIC measurements. Measurement MDL, linearity, accuracy and precision DQI are met by calibration/verification and quality assurance audits. These are critical measurements.

Table 7.1.- Reported system accuracy, precision and DQIs for NH_3 concentration using the Boreal Laser GasFinder2®.

Parameter	**Measure**	**DQI**
MDL	5.32 ppm-m at 220 m pathlength	< 10 ppm-m
Linearity (r^2)	0.99	$\geq$ 0.9 r^2
Accuracy	1-10% at 220 m pathlength	Within 10%
Precision	3.14% at 475 ppm	< 10% at 100 ppm
Interferences	No consistent	

7.2.2 UV-DOAS NH_3 and H_2S Measurements.

The PIC measurements of NH_3 and H_2S will be made using Cerex UVSentry® instruments. The quality of the 15-min UV-DOAS spectra is defined by the instrument quality assurance tests described in the Standard Operating Procedure for Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer (UV-DOAS) (SOP C1). The Cerex UVSentry® instrument has not been assessed by the Environmental Technology Verification Program, so manufacturer-provided measures of

the accuracy and precision are found in Table 7.2. The instrument provides 10% accuracy and 10% precision for the PIC measurements. MDL values are a combination of laboratory tests made by the manufacturer and a field test made by the PAML. Since the UV-DOAS has not been validated for the measurement of H_2S, a validation study will be conducted. This study is described in section 10.8. Measurement MDL, accuracy, and precision DQI are met by calibration/ verification and quality assurance audits. These are critical measurements.

Table 7.2.- Manufacturer-reported system accuracy, precision and DQIs for NH_3 and H_2S concentrations using the Cerex Environmental Systems UVSentry®

Parameter	**NH_3 Measure**	**NH_3 DQI**	**H_2S Measure**	**H_2S DQI**
MDL	0.14-0.5 ppm-m	Within 0.5 ppm-m	0.32-1.9 ppm-m	Within 2.0 ppm-m
Accuracy	2-10%	Within 10%	3-10%	Within 10%
Precision	4-10%	Within 10%	3-10%	Within 10%
Interferences	H_2S		NH_3, HAc	

7.2.3 PAS VOC Measurements.

The VOC measurements will be made using an INNOVA 1412 Photoacoustic multi-gas analyzer following the Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer (SOP G7). VOCs to be measured include MeOH, EtOH, CH_4, and THC. The manufacturer-reported instrument performance for each parameter given the specified wavelength of detection are indicated in Table 7.4. Of these, CH_4 and THC are critical measurements while MeOH and EtOH are non-critical measurements. Measurement accuracy and precision DQI are met by calibration/verification and quality assurance audits.

Table 7.3.- Manufacturer-reported system accuracy, precision and DQIs for VOC concentrations using the INNOVA 1412 multi-gas analyzer.

Parameter	**Detection wavelength nm**	**Accuracy (%)**	**MDL, ppm**	**Precision % full scale**	**Interferences**	**DQI (% accuracy)**
NH_3	976	±1	0.2	±1	Ethanol	±1
CH_4	968	±1	0.2	±1	Acetic acid, Methanol, Ethanol	±1
THC	987	±1	0.2	±1	Methane, Methanol, Ethanol	±1
MeOH	971	±2	0.03	±1	Ammonia, Ethanol	±2
EtOH	974	±2	0.06	±1	Ammonia, Methanol	±2

The calculation of NMHC (THC + MeOH + EtOH) will have an accuracy of approximately 1% and a precision of ±1% of full scale.

7.2.4 Sonic Anemometer Measurements.

Turbulent wind components (u′, v′, w′) are derived from the measured instantaneous orthogonal wind components (u, v, w) according to:

$$u' = U - u$$
$$v' = V - v \qquad \text{(Equation 7.1)}$$
$$w' = W - w$$

where u, v, and w are the time-averaged mean wind components in the northerly, easterly, and upwards directions. Wind speed along the axis of the emission plume will be calculated as a resultant over the period of measurement. The orthogonal components of wind (u, v, w) and virtual temperature (T_v) will be measured using RM Young 81000 sonic anemometers following the Standard Operating Procedure for the Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer (SOP W2). Mean wind speed and wind direction will be calculated for 2-s measurement intervals at 2, 4, and 16 m agl heights to match the scan of five sequential TDLAS PIC measurements (section 7.2.1) for RPM plume reconstructions (Section 7.2.8). Turbulence (u′, v′, w′) and deviations in virtual temperature (T_v' where T_v'=instantaneous measured T_v – period-averaged T_v) will be derived from 30-min averaging periods at 2-m height abl at the lagoons and basin and 3-m height agl at the corral to match the UV-DOAS PIC measurements (Section 7.2.2) for bLS plume emissions calculations (section 7.2.5).

The desired accuracies and resolution of the sonic anemometer sensors are shown in Table 7.4. Also shown in the table are measurement resolutions and DQIs. Measurement resolutions are attained by the selection of measurement instruments. Measurement accuracy DQIs are met by calibration/verification and quality assurance audits. These are critical measurements.

Table 7.4. System accuracy, resolutions and DQIs for sonic anemometer measurements

Meteorological Parameter	**Intercomparison Bias**	**Measurement Resolution**	**DQI**
Orthogonal wind velocities U, V, and W	± 0.2 m/s	0.01 m/s	Within 0.2 m/s
Sonic temperature (T_v) calculated from V_o	±2 ^oC[1]	0.02^oC	Within 2 ^oC
Wind speed (horizontal)	± 0.2 m/s	0.01 m/s	Within 0.2 m/s
Wind direction (azimuth)	± 5 degrees	1 degree	N/A (computation from orthogonal components)

1: Sonic temperatures (T_v) will not be utilized in the project but is a measureable quantity to determine sensor performance. T_v' will be used to compute the Monin Obukov Length (*L*).

7.2.5 bLS Plume detection.

The bLS emissions methodology, calculated by the WINDTRAX® software, are assessed for quality using range limits for input variables. There is at present no explicit measure of the emission measurement accuracy. In general, low wind speeds and highly unstable or stable conditions result in poor performance of the method. These conditions are expressed by *L* and the friction velocity (u_*) (Table 7.5). The Method 301 Validation Study described in section 10.7

Table 7.5 Data Quality Indices for the bLS Methodology

Measurement Parameter	Analysis Method	DQI
U,V,W wind components	Side-by-side comparison of two wind monitors	<0.2 m/s
UV-DOAS [NH_3]	Comparison with primary standard gas	Within 10%
TDLAS [NH_3]	Comparison with primary standard gas	Within 10%
UV-DOAS [H_sS]	Comparison with NIST-certified standard gas	Within 10%
PF [H_2S]	Comparison with NIST-certified standard gas	Within 10%
PAS [MeOH]	Comparison with NIST-certified standard gas	Within 10%
PAS [EtOH]	Comparison with NIST-certified standard gas	Within 10%
PAS [THC]	Comparison with NIST-certified standard gas	Within 10%
PAS [CH_4]	Comparison with NIST-certified standard gas	Within 10%
bLS	u_*	>0.15m/s
bLS	$\|L\|$	> 2 m

will provide a better external measurement of the method accuracy. Details of the DQIs for the method are found in the Emissions Estimation Using the Thunder Beach Scientific Windtrax® Backward Lagrangian Stochastic (bLS) Model (SOP O1). These are critical measurements.

7.2.6 RPM Plume Reconstruction.

The RPM emissions methodology plume reconstructions are assessed for quality using three statistical parameters: Concordance Correlation Factor (CCF) that indicates the goodness of fit between measured and predicted PIC (similar to Pearson correlation coefficient), the plume positioning parameter (A) that is a correction factor to describe the shift in magnitude and location of the measured and predicted PIC vectors, and a plume capture parameter that described the fraction of the predicted plume cross-section that was based on measured concentrations by the scanning measurement system. Details of these DQIs (listed in Table 7.6) are found in the Standard Operating Procedure for Emissions Estimation Using the Arcadis Radial Plume Mapping (RPM) (SOP O2). These are critical measurements.

Table 7.6 Data Quality Indices for the RPM Methodology

Measurement Parameter	Analysis Method	DQI
TDLAS [NH_3]	Comparison with lab-checked standard gas	Within 10%
Wind Speed	Side-by-side comparison of two wind monitors	<0.2 m/s
Plume Reconstruction	CCF	≥0.8[a]
Total Mass Positioning	A	≥0.9[b]
Plume capture	Fractional change in vertical gradient of PIC	Topmost PIC ≤0.8 mid-height PIC

a The calculated CCF value associated with the RPM algorithm must be ≥0.8 for the reconstruction to be considered valid.

b The calculated CCF value associated with the RPM algorithm must be ≥0.9 for the reconstruction to be considered valid.

7.2.7 Non-critical Meteorological Measurements.

Meteorological measurements are used to characterize weather conditions during the measurement period(s). Measurements include solar radiation using LiCor silicon photodiode pyranometers following the Standard Operating Procedure for the Measurement of Solar Radiation with the LiCOR Model 200SL or 200SZ Silicon Pyranometer (SOP E3), ambient air temperature and humidity using capacitive hygrometers following the Standard Operating Procedure for Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield (SOP W1), barometric pressure using Setra resonant silicon aneroid barometers following the Standard Operating Procedure for the Measurement of Barometric pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer (SOP W5), and surface wetness using resistance-grid surface wetness sensors following the Standard Operating Procedure for the Measurement of Wetness with the Campbell Scientific Model Resistance Grid (SOP W3). Measurements will be made every 5 min and stored on a data logger following the Standard Operating Procedure for Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware (SOP W6). Configuration of the sensors is indicated in SOP W6. These are non-critical measurements.

Desired system accuracies are shown in Table 7.7. Also shown in the table are measurement resolutions, defined as the smallest parameter measurement that can be distinguished. All recommendations are from the On-Site Meteorological Program Guidance for Regulatory Application (USEPA, 2000) or from the Atmospheric Radiation Measurement Program (Atmospheric Radiation Measurement Program, 2004b). Measurement resolutions are attained by the selection of measurement instruments. Measurement accuracy DQIs are met by calibration/verification and quality assurance audits. Since surface wetness is a binary measure of wet or dry condition, accuracy of condition is verified by application of water. The corresponding DQI is the sensor responding to a wet and dry condition with appropriate resistance documented in SOP W3.

Table 7.7. Required system accuracy, resolution and DQIs for meteorological measurements.

Meteorological Parameter	Accuracy	Measurement Resolution	DQI
Ambient Temperature	± 0.5^{o}C	0.1^{o}C	Accuracy within 0.5^{o}C
Humidity	± 3%	0.3%	Accuracy within 5%
Barometric Pressure	± 3 hPa or 0.09 inches of Hg	0.5 hPa or 0.015 inches of Hg	Accuracy within 0.5 hPa
Radiation	± 5% of observed	10 Wm^{-2}	Accuracy within 5%

7.2.8 Non-Critical Lagoon/ basin Characterization Measurements.

Lagoon/ basin measurements will be used to characterize conditions during the measurement period(s). The pH and redox state will be measured using submersible plunger-style pH glass electrodes with a Teflon liquid junction according to the Standard Operating Procedure for the Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor (SOP L1) and the Standard Operating Procedure for the Measurement of Lagoon redox potential with Innovative Sensors Model CSIM11 Sensor (SOP L3). The redox probe has a platinum band wrapped around the glass electrode to cause response to the electron density of the fluid. The temperature will be measured using a thermistor probe according to the Standard Operating Procedure for the Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor Standard Operating Procedure (SOP L2). A measurement platform will be used to place the pH, temperature, and redox state probes at a depth of 0.3 m. Measurements will be made every 5 min and stored on a data logger (SOP W6). Measurement resolutions are attained by the selection of measurement instruments. Measurement accuracy DQIs are met by calibration/verification and quality assurance audits (Table 7.8).

Samples of manure will be collected at the corral and manure basin every measurement period (four times per year) according to the Manure Sampling Standard Operating Procedure (SOP M1). The composition of manure in the basin and corral will be used to characterize the emission source. Manure will be analyzed for pH, total and ammoniacal nitrogen, and total and volatile solids content. These measurements will be made by Midwest Laboratories, Inc. using procedures based on the same EPA Methods on which the Standard Operating Procedure for Conducting pH Measurements on Manure Samples (SOP M2), the Standard Operating Procedure for Determining Solids Content of Manure Samples (SOP M3), the Standard Operating Procedure for Determining Total (Kjeldahl) Nitrogen Content of Manure Samples (SOP M4) and the Standard Operating Procedure for Determining Ammonia Content of Manure Samples Standard Operating Procedure (SOP M5) are based. DQI associated with the analyses conform to the applicable EPA Method (see individual SOP). Measurement DQIs are based on measurement accuracy for pH and total and ammoniacal nitrogen content and on measurement precision for volatile and total solid content (Table 7.8).

Table 7.8. Required system accuracy, resolution and DQIs for lagoon/ basin measurements.

Parameter	Accuracy	Measurement Resolution	DQI
Lagoon/basin wastewater temperature	± 0.9°C	0.1°C	Accuracy within 0.9°C
Lagoon/basin pH	± 0.2 pH	0.01 pH	Accuracy within 0.2 pH
Lagoon/basin redox state	± 10 mV	0.1 mV	Accuracy within 20 mV
Sludge depth	± 0.05 m	0.01 m	Accuracy within 0.05 m
Manure pH	0.05 pH	0.01 pH	Accuracy within 0.05 pH units
Manure total nitrogen	0.02 mg/L	0.05 mg/L	Accuracy within 0.02 mg/L
Manure ammoniacal nitrogen	0.02 mg/L	0.05 mg/L	Accuracy within 0.02 mg/L
Manure total solids content	Non stated	3 mg/L	Precision and recovery 80% to 110%
Manure volatile solids content	Non stated	7 mg/L	Precision and recovery 70% to 110%

The lagoon/ basin loading will be calculated based on the volume and the sludge depth. The lagoon sludge solids depth will be measured using a liquid visibility depth finder probe at the beginning of each measurement period at the rotation farms and every three months at the continuous measurement lagoons.

7.2.9 PFA H_2S Measurements.

The synthetic PIC measurements of H_2S will be conducted using a Thermo Electron Corporation Pulsed-Fluorescence H_2S analyzer. The quality of the measurements is defined by the instrument quality assurance tests described in the Standard Operating Procedure for Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450i Pulsed- Fluorescence Analyzer (SOP G5). The manufacturer-provided measures of the accuracy and precision are provided in Table 7.2. The instrument will collect samples from the synthetic open-path sampling system described in the Standard Operating Procedure for the Synthetic Open-Path Sampling System (SOP C4), and provides 5% accuracy and 5% precision for single samples and an unknown accuracy for PIC measurements. MDL values are based on laboratory tests made by the manufacturer. Since the PF/S-OPS has not been validated, a validation study will be conducted. This study is described in Section 10.8. Measurement MDL, accuracy, and precision DQIs are met by calibration/verification and quality assurance audits. These are critical measurements.

Table 7.9.- Manufacturer-reported system accuracy, precision and DQIs for H_2S concentrations using the Thermo 450i Pulsed Fluorescence Analyzer

Parameter	H_2S Measure	H_2S DQI
MDL	1.0 ppm	
Accuracy	5%	Within 10%
Precision	5%	Within 10%
Interferences	Methyl mercaptan: 0.8 ppm increase per 1 ppm of CH_3SH Dimethyl disulfide: 0.5 ppm increase per 1 ppm of CH_3SSCH_3 Dimethl sulfide: < 0.1 ppm increase per 1 ppm of CH_3SCH_3 NO: Increase of < 3 ppb at 500 ppb NO *m*-xylene: Increase of < 1 ppb at 200 ppb *m*-xylene Water: < 2% of reading per 2% humidity ratio	

7.2.5 Ratiometric emission calculation.

The ratiometric emissions methodology relies on a good RPM plume reconstruction and valid concentration measurements of the gas of interest (H_2S, MeOH, EtOH, CH_4, or THC). Consequently, the DQI for the calculation method are those for the respective components (Table 7.10). These are critical measurements.

Table 7.10 Data Quality Indices for the Ratiometric Methodology

Measurement Parameter	Analysis Method	DQI
U,V,W wind components	Side-by-side comparison of two wind monitors	Within 10%
TDLAS [NH_3]	Comparison with primary standard gas	Within 10%
Wind speed	Side-by-side comparison of two wind monitors	<0.2 m/s
Plume reconstruction	CCF	≥0.8[a]
Total mass positioning	A	≥0.9[b]
Plume capture	Fractional change in vertical gradient of PIC	Top PIC ≤0.85 mid-height PIC
PFA [H_2S]	Comparison with NIST-certified standard gas	Within 10%
PAS [MeOH]	Comparison with NIST-certified standard gas	Within 10%
PAS [EtOH]	Comparison with NIST-certified standard gas	Within 10%
PAS [THC]	Comparison with NIST-certified standard gas	Within 10%
PAS [CH_4]	Comparison with NIST certified standard gas	Within 10%

7.3 Measurement Quality Objectives (MQOs)

Measurement data will undergo quality control (QC) review, which will assess, among other things, representativeness, completeness, comparability, bias and precision. Data quality is evaluated by inspecting QC flags and variables in processed data as described below.

Data representativeness will be assured by the overall sampling design, which includes high frequency and multi-location sampling. Each facility will be monitored 24 hours a day for approximately 21 d every three months (quarter) for two years. Since most mid-latitude extratropical weather systems have a periodicity of about 3-4 d through much of the country, at least 9- 10 d of measurements are needed to represent a given season's weather patterns. Locations to be measured will be chosen to represent the range in typical farm operations in the industry and a range of climatic conditions.

Data completeness will be achieved by assuring that valid data obtained from the measurement system will be no less than 75% of 10 d within the measurement period any quarter of the year. Also, at least seven of the eight scheduled sampling runs will be conducted.

Data comparability will be maintained by consistent use of the same analytical methods defined in the applicable SOP.

Accuracy and precision of all measurements will be assured through the use of regular quality assurance/ quality control procedures (described in the respective sensor or instrument SOP) so that the data quality objectives will be met. Details of the accuracy and precision of each measurement are found in the tables of Appendix A.

Individual MQOs for the critical measurements, including NH_3 PIC by the Boreal Laser GasFinder2®, H_2S PIC by UV-DOAS or S-OPS/PF, NH_3, CH_4 and THC concentrations by S-OPS/PAS and u', v', w' and T_v' and non-critical measurements including air temperature, relative humidity, atmospheric pressure, lagoon/ basin pH, lagoon/ basin redox potential, lagoon/ basin temperature, CH_4, MeOH, and EtOH concentrations by PAS, lagoon depth to solids, manure pH, manure total and volatile solids content, manure total and ammoniacal nitrogen content are described in Appendix A.

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SOP C4. 2006. Standard Operating Procedure for the Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP E3. 2006. Measurement of Solar Radiation with the LiCOR model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

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8. Special Training Requirements/Certification

TDLAS and other ambient air monitoring must be performed by qualified personnel. Supervisors must be experienced in the operation of the open path TDLAS, UV-DOAS, PAS and PFA monitors and knowledgeable in open-path TDLAS, UV-DOAS, PAS and PF theory as well as the theory and operation of the sonic anemometer. The site operators and staff must be thoroughly familiar with all SOPs for this project and the reference manuals supplied by all instrument manufacturers. A record of SOPs read and understood and training completed will be kept by each FOS.

Training for the open-path TDLAS and UV-DOAS (if method is validated for H_2S measurement) will consist of a group training session conducted by factory representatives or their designate prior to the measurements. Training for the PAS multigas and PFA (if H_2S measurement method is not validated) analyzers will consist of a group training session conducted by the PM or his designate. Training on the use of the emissions models will be conducted by the PM in conjunction with the model authors. Training on the meteorological and data communications equipment will be conducted by the PM or his designate. Basic training for medical emergencies will be conducted by certified staff. Additional training will occur as needed on the job by either communication with manufacturer representatives or the PM. To maximize operational efficiencies and minimize lost data due to illness, all personnel in the project excluding the SA will take part in the training.

Records of the date, type of training, and satisfactory completion of training for each individual and each instrument and method will be ensured by the QAM with documentation of completion maintained by the PM. All personnel will follow Standard Operating Procedures (SOPs) when carrying out their duties. Appendix A contains all SOPs used in this study.

Training of the laboratory analysts at the commercial laboratory (Midwest Laboratories, Inc., 13611 B St., Omaha, NE; Lab ID E87918) is conducted by the Midwest Laboratories Laboratory Supervisor according to their Quality Assurance Manual. Certification of the laboratory to conduct the analyses to the EPA methods indicated in this study is conducted by the Environmental Laboratory Certification Program of the Florida Department of Health. Certification Certificates are provided by the laboratory to the SA on request. The Certification will be requested regularly from the Laboratory by the SA or his designate based on the expiration date of the previous certificate.

References

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9. Documents and Records

Field and laboratory documentation is necessary for the successful completion of the project. The various types and levels of documentation required for this study are described below.

9.1 Field operations documentation

Manure samples will be collected at the corral and at the basin location by the FOS at the beginning of each measurement period. Three composited samples will be stored on ice and transported to the commercial laboratory for analysis at the time of each manure sampling event. Details of the sampling protocol are found in SOP M1. A chain of custody form (example in Appendix D) will be transmitted with the samples to the laboratory.

Each site visit by the FOS/PI (typically at the beginning and end of each measurement period for the rotating farm locations and at least every 21 d for the continuous monitoring locations) will involve physical inspections, QC checks and calibration verifications. At the end of each measurement period, the FOS/PI will collect from the producer any production and activity records for the measurement period. The PM will receive by email all updated logs on a daily basis while personnel are on site. Listed below is a summary of the field documentation required:

- Activity log book (as Adobe Acrobat pdf files) maintained at each monitoring site.
- Production and activity records provided by the producer- including the documentation of animal inventories and weights, feed compositions, water quality tests, lagoon water/basin manure removal events, land manure application events, agitation periods, power failures, etc.
- Daily monitoring notes (as Adobe Acrobat pdf files) including equipment physical inspections, calibrations, audits, QC checks, repairs or other corrective actions, weather conditions, power failures.
- Results of in-field QC checks on instruments during the beginning and end of measurement periods and any non-routine equipment investigations (as Adobe Acrobat pdf files and Microsoft EXCEL® files; examples in Appendix D)
- Chain of custody forms for manure (for basin location) and manure, feed, milk, and bedding samples (for corral locations) (example in Appendix D).
- Chain of custody forms for data CD and DVD transfers (example in Appendix D).
- Analytical instrument and analysis log books (as Adobe Acrobat pdf files and Microsoft EXCEL® files) for QC checks and reanalysis (examples in Appendix D).
- Inventory control spreadsheets (in Microsoft EXCEL®) for the timely replacement of expendable supplies.
- Meteorological equipment logbook and checklist for operations, repairs, QC checks, and audits (example in Appendix D).
- Site drawings (found in SMPs in Appendix C).
- Site installation QC checksheets (example in Appendix D).
- Amendments and/or deviations from this QAPP and the appended SOPs and SMPs.

Unless indicated otherwise, all forms are appended to the individual applicable SOPs

In general, documents will be electronic in form, although two printed copies of the completed documents will be made at the completion of each sampling period, with one stored on site and a second hand-carried to Purdue by field operations staff. Paper forms will be filled out in indelible ink and scanned and stored in a project file on the LAN server computer (Management of Open-Source, Weather, and Lagoon Characterization Data Standard Operating Procedure, SOP D1). Corrections to paper documents will be made in indelible ink with deletions struck by single line. All corrections will be initialed by the author of the correction and form rescanned and stored in a project file on the LAN server computer with a suffix in the filename of '–cor'. A printer will be located at each measurement location to create paper forms on demand and a scanner will be located at each location to scan images of hand-written notes and drawings for electronic storage.

All forms and logs for a given measurement location will be stored by site/measurement period. The DM will maintain the validated, quality-coded meteorological and analytical data by site and measurement period (SOP D1) on a dedicated computer for their particular portion of the study. Additionally, the DM will place this data on a computer network so that the data will be available in a timely manner to the personnel for ready distribution to inquiries for information. Copies of these validated, raw data will be maintained on the PDM and DM computers throughout the study period, as long as deemed necessary by the SA.

Data management is described in SOP D1. Raw data files represent files of data as received at the instrumentation trailer from the meteorological and lagoon/ basin measurement data logger, the GSS data logger, the two TDLAS systems, two UV-DOAS systems (if H_2S measurement method is validated), the PF analyzer (if H_2S measurement method is not validated) and the PAS analyzer. These data are already provided in standard units from their respective control and processing software. The files are then evaluated according to the quality assurance protocols defined in their respective instrument SOP and QA flags are added to each data value. All instruments will have calibration data files associated with calibrations conducted on-site and at Purdue. The emissions calculations resulting from the use of the RPM and bLS models with corresponding QA evaluations (indicated by a flag for each value) will be done at PAML. A summary of the types of files and storage devices used to store the files developed by each major measurement component of the project are listed in Table 9.1.

Any files in which data is corrected will be stored in the same directory as the original data file with the suffix '-cor' to the filename and the nature of the correction(s) documented in an EXCEL spreadsheet.

Table 9.1 Electronic data records.

File characterization	Turbulence	Meteorology	Lagoon/ basin/corral[1]	PAS	PFA or UV-DOAS	TDLAS	S-OPS, GSS
Raw data	DVD	Memory card CD	Memory card CD	CD	CD	CD	CD
Post process w/flags	HD	HD	HD	HD	HD HD	HD HD	HD HD
Calibration files		CD,HD	CD,HD	CD,HD	CD,HD	CD,HD	CD,HD
Emission w/flags					CD, HD	CD, HD	CD, HD

[1]Measurements characterizing the lagoon/basin or corral

9.2 Laboratory operations documentation

The commercial laboratory will document the person receiving the samples, number of samples, temperature of the samples, integrity of the sample containers, and time of receipt on arrival of the samples to the laboratory on the chain of custody form. The laboratory report on each sample set (specific location and sample date) will include:

- Name of submitter of the sample
- Sample origin location, date, time, type, and replicate number
- Date and time of receipt at laboratory
- Name of individual receiving sample
- Condition of sample on receipt
- Analyses requested
- Number of sample containers
- Time of analysis for each analyte.
- Measured values for each analyte in samples (pH, total nitrogen, ammoniacal nitrogen, total solids, total volatile solids)
- Initials of the analyst for the measurement
- Measured blanks, spikes, and replicates of samples.
- Results of instrument calibrations
- Corrective actions if instrument fails any performance check
- Deviations in procedures from those indicated in SOPs M2 through M5

Copies of all above field and laboratory documents will be maintained by the PM.
Copies of this QAPP, all SOPs, software, and instrument manuals will be kept with each team on-site. Copies of all log sheets, forms, and checklists will be maintained in the project files throughout the study period and for six years after the completion of the study.

Changes to the QAPP or SOPs will be made as necessary, with approval by the QA Manager, PM, and SA in consultation with the USEPA Quality Assurance Manager. Changes will be reported by email to all participants listed in section 3. Copies of any changed QAPP sections and SOPs will be routed to the same list defined in section 3.

The interim and final reports for the study will include summaries of validated data, documentation of invalidated data fractions, summary measurement statistics, charts of validated data if appropriate, and a discussion of quality assurance audits.

All validated data for the reporting period will be provided in electronic form to EPA at the time of each report. Records resulting from this project will be retained for a period of not less than six years by the SA and PM.

References

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SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

B. Data Generation and Acquisition

10. Sampling Process Design (Experimental Design)

The experimental design outlines the configuration of equipment to be used in the study, the sampling and averaging intervals to be used in the study, and the manner in which the study integrates the sampling-related information. The general protocol used in the study has been reviewed by a scientific panel of some 30 scientists between 2003 and 2006. Specifics associated with most SOPs have been evaluated by leading scientists in the respective fields associated with each measurement. No further review of methodologies is planned.

Siting criteria: The primary objective of instrument siting is to place the instrument in a location where it can make precise measurements that are representative of the general state of the atmosphere upwind or downwind of the storage facility that is consistent with the objectives of the data collection program. AFO lagoons and basins are not located with consideration for potential gaseous and air flow measurements. Trees are often used to reduce visibility of the lagoons and the distance between barns and lagoons are often too close to separate the barn emissions from the exhaust fans from the lagoon or basin. In addition, lagoons are often built up from the surrounding ground by the soil removed to form the lagoon, especially in areas with high water tables, creating a substantial berm height. Consequently, great care has been taken in locating the best possible ten farms for the study measurements and deviations from the preferred lagoon surroundings have been minimized. Specific locations chosen for the study are documented in the SMPs in Appendix C. Additional site photographs (beyond those in the respective SMP) will be taken at each site location. Latitude and longitude coordinates along with site elevation will also be measured by GPS and documented. Details of the siting criteria are found in the Installation of Open Source Measurement Equipment Standard Operating Procedure (SOP U5). Guidelines for the siting of equipment, and hence the choice of farms to be measured follow.

10.1. Meteorological measurements

Meteorological stations will be established at each site location to collect data to support the study. The parameters to be measured at all of the sites are the turbulent components of the wind, horizontal wind speed, wind direction, temperature, relative humidity, and barometric pressure. Meteorological parameters at the lagoon/ basin sites will be measured at 2 m above berm height (abl), 4 m above ground level (abl), and 16 m abl. The meteorological equipment will be located adjacent to the waste storage areas under study according to SOP U5 and SOP W6. The siting criteria for the wind speed, direction, temperature, relative humidity, solar radiation, and barometric pressure sensors are generally in accordance with the Quality Assurance Handbook for Air Pollution Measurement Systems: Volume 4. The desire is to locate sensors in areas of open terrain to comply with the assumptions used in the emission models. Open terrain is defined as an area where the horizontal distance between the instrument and any obstruction (building, hill, trees and other vegetation) is at least ten times the height of that obstruction.

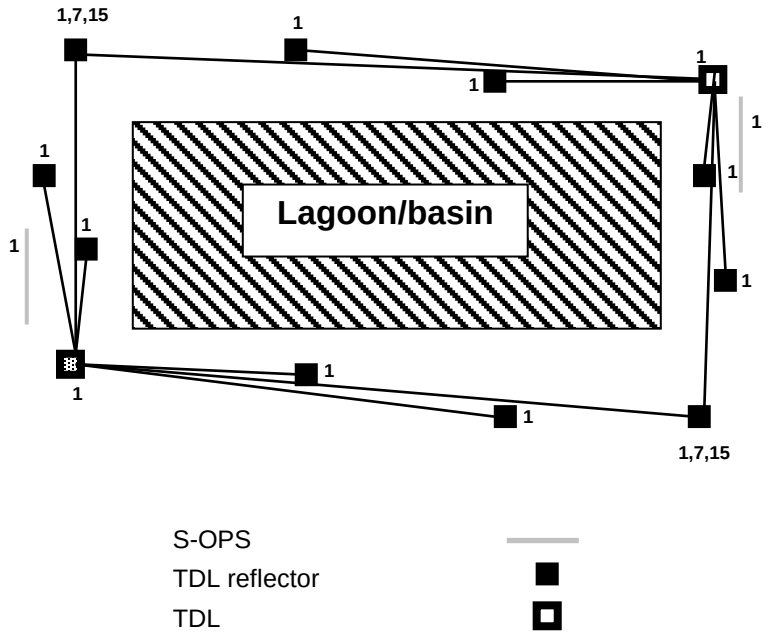

Figure 10.1- Example of lagoon/basin open path sampling plan. Labels represent height of instrument or retro-reflector in meters above lagoon/ basin berm.

Meteorology Towers: Meteorology towers will be located near the lagoon or basin or in an open level area such that instruments will be downwind of the lagoon or basin (based on prevailing wind direction) and unaffected by local obstructions or objects such as buildings, building exhaust fans and have minimal effects from hills and valleys. The towers will be located at a distance away from the obstruction of at least ten times the nearest upwind obstruction's height and three times the nearest downwind obstruction height. These protocols may be difficult to accomplish at all locations. Deviations from these protocols will be documented. Orientation and positioning of the towers at a lagoon or basin measurement location is detailed in SOP U5 (Figure 10.1). Orientation and positioning of the towers at a corral measurement location is detailed in the Installation of Open Source Measurement Equipment (Corrals) Standard Operating Procedure (SOP U7).

Wind Speed and Wind Direction Sensor (sonic anemometer): The locations of the wind sensors differ by type of measurement location; lagoon/ basin or corral. According to the World Meteorological Organization (WMO), the standard height for wind instruments over level, open terrain is 10 m above the ground. All lagoon/ basin measurement locations will have sensors at 2

m above berm level (abl) and 4 m and 16 m abl to provide wind profile information for the RPM emission measurements (described later) (SOP U5). Wind sensors will be 0 to 10 m from the edge of the berm at the lagoon and basin sites, more than 10 times the fan diameter away from building exhaust fans for mean wind measurements associated with the RPM emissions model (for 4 ft diameter fans, 40 ft) and 30 times the fan diameter away from the building exhaust fans for turbulence measurements associated with the bLS emissions model (for 4 ft diameter fans, 120 ft). Preferably, wind measurements will be made downwind of the lagoon or basin (based on prevailing wind direction). In general, the lagoon berms of the study locations are less than 1 m high. Consequently the distance from the anemometers to an obstruction will be at least 10 times the difference in height of the sensor and the nearest obstruction. The close proximity of the sensors to the measurement plane of the TDLAS beam paths is desired to reduce RPM emissions calculation error (RPM method described later). A 3D sonic anemometer will be securely mounted on the top of a 2-m mast and a 15-m corner tower. One additional 3D sonic anemometer will be mounted on a corner tower on a boom projecting at least two tower diameters away from the tower at 4-m height. This boom will be in a direction that provides the least wind distortion due to the tower structure for the most important wind direction or the prevailing wind direction. In this study, the wind speed and direction sensors will be combined using the 3D sonic anemometers. This is a critical project measurement.

Wind sensors will be at least 100 m from the edge of the feedlot at the corral sites to minimize roughness changes associated with the corral, providing a fetch of at least 10 times the height of the nearest obstruction. The anemometers will be securely mounted at the top of 2-m masts within 10 m of TDLAS paths along the sides of the corral.

Temperature and Humidity Sensors: The On-Site Meteorological Program Guidance for Regulatory Applications indicates temperature sensors must be housed in a ventilated radiation shield to protect the sensor from thermal radiation and should be mounted over a plot of open level ground at least 9 m in diameter. The ground surface should be covered with non-irrigated or un-watered short grass or, in areas where grass does not grow, natural earth. The surface must not be concrete or asphalt. The standard height for recording surface temperature and humidity is 2 m agl. Guidelines indicate that the sensors should not be closer to obstructions such as trees and/or buildings than a distance equal to four times their height. While guidelines indicate the sensors should be at least 30 m from large paved areas and not close to steep slopes, ridges, or hollows, in this study, the sensors will be between 0 m and 10 m from the lagoon/ basin berm and 1 m abl (SOP U5). The proximity of the sensor to the water body is consistent with it's use as a means to correct the measured gas concentration for ambient temperature and water vapor. At the lagoon/ basin sites in this study, the temperature and relative humidity instrument will be mounted in an unventilated radiation shield at 1 m abl. At the corral sites, the temperature and relative humidity instrument will be mounted in an unventilated radiation shield at 2 m agl at a distance of 100 m from the corral. The error induced in the gas law correction for temperature by not ventilating the sensor is small since a $2^{o}C$ error (typical difference between a non-ventilated to ventilated temperatures) induces an error of approximately 1% in the gas law correction to a gas concentration measurement. This is a non-critical project measurement.

Solar Radiation Sensors : On-Site Meteorological Program Guidance for Regulatory Applications indicates that solar radiation measurements should be taken throughout the year in a location free from any obstruction that could cast a shadow over the sensor. The sensor should not be located near light colored walls or artificial sources of radiation. In this study, the solar radiation sensor will be mounted on a beam off the south side of the meteorology mast/tower (SOP U5). This is a non-critical project measurement.

Wetness sensors: Guidelines derived from numerous studies indicate that the wetness sensor should be oriented off horizontal. Because the purpose of this sensor is to estimate whether there has been rain or dew to wet the ground or add to the lagoon, sensor height is not critical provided it is above vegetation and not under obstructions. For this study the sensors will be mounted at approximately 30° slope on the meteorology mast/tower near the height of the lowest sonic anemometer (SOP U5). This is a non-critical project measurement.

Barometric Pressure Sensors: Sensor height is not critical, however, 2 m agl is generally considered acceptable. The sensor should be protected from wind by placement within an enclosure. In this study the sensor will be mounted within a NEMA 4 box at 1 m abl on the meteorology mast/tower (SOP U5, SOP W6). This is a non-critical project measurement.

Sampling plan: All measurements except wind measurements will be made every 5 s with statistics calculated at 5-min intervals on a data logger (SOP W6). Wind measurements will be made at 100 Hz, filtered to 16 Hz (SOP W2) with statistics calculated on 100-s intervals and recorded on the LAN server computer in the instrumentation trailer (SOP D1).

10.2. Open path TDLAS

Siting criteria: The general site configuration is found in SOP U5. Two scanning open path TDLAS instruments will be mounted on opposite corners of the monitored lagoon or basin (Figure 10.1). Each open path system will be oriented approximately parallel to the (assumed rectangular) lagoon or storage area side and between 0 m and 10 m from the lagoon/ basin edge to minimize edge-of-source problems. Each of two monostatic TDLAS systems, located on opposite corners of the lagoon or basin, will scan five retro-reflectors on each of two adjacent sides of the lagoon or storage area: three at 1 m abl equally subsecting the length of the lagoon/ basin and two at 7 m agl and 15 m agl on a tower located at the corner down the adjacent sides of the lagoon or storage area (Figure 10.2). This will result in scan lines down each of the four sides of the lagoon/ basin. The locations of the corner towers and scanners will be determined after considering the prevailing wind direction(s) and wind obstructions such as trees, buildings, and building exhaust fans.

TDLAS Source/Receiver: The source/receiver will be located up to 10 m from the corner of the lagoon or storage facility in an open level area such that instruments will be unaffected by local obstructions or objects such as buildings and paved parking lots and minimizing the effects of hills and valleys. The instrument will be mounted at least 1 m above the top of any berm on a

scanner that will move the TDLAS laser beam to aim at each of the ten retro-reflectors in sequence.

TDLAS retro-reflectors: For each side of the lagoon or basin, three retro-reflectors will be located at 1 m height above the berm at 0.3W, 0.7W and approximately 1.1W distance across the width of the lagoon or basin (W) and up to 10 m away from the lagoon berm (Figure 10.2). Two additional retro-reflectors will be mounted at 7 m agl and 15 m agl on a tower located approximately 1.1W from the TDLAS. (Figure 10.2). Assuming a lagoon with no elevation of the berm, the resulting mean scan path height associated with the highest retro-reflector (15 m agl) across the width of the lagoon is 7.5 m agl. This height is approximately the σ_z of a Gaussian plume under the slightly-unstable Pasquill stability class C. All retro-reflectors will be located such that an unobstructed view of the source/receiver is possible. In addition, every effort will be made to locate beamlines such that:

- Retro-reflector towers are in the direction of the prevailing winds and more than their height away from power lines.
- Beamlines are more than 10 times the diameter of the fan away from barn fans.
- Retro-reflectors and scanners are more than 1 m away from on-farm vehicular traffic, 3 m away from off-farm vehicular traffic, and 5 m away from irrigation equipment.

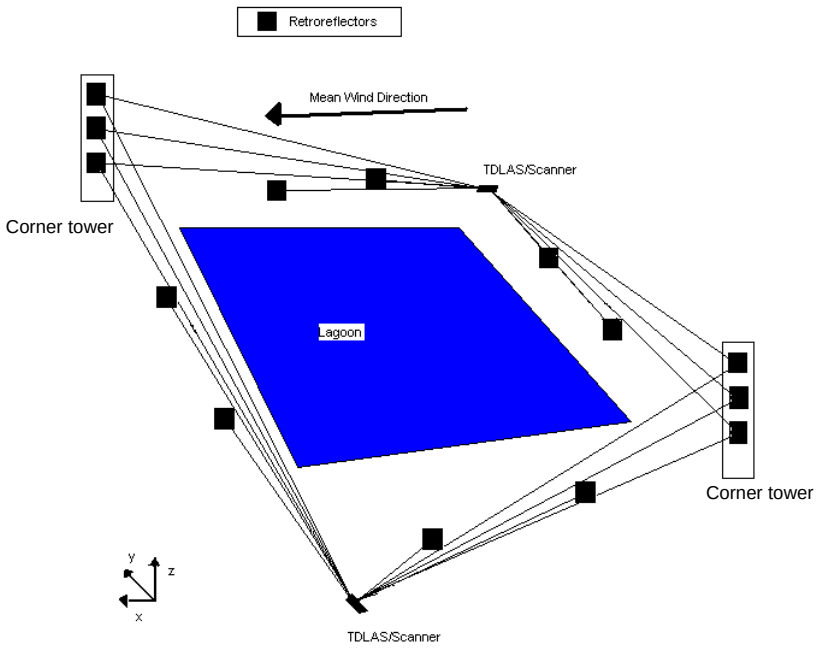

Figure 10.2 Example of a TDLAS Setup. Filled squares represent retro-reflectors. Lines represent optical paths

Specific configurations for the farms to be studied are found in the SMPs in Appendix C. These are critical project measurements.

Sampling plan: A complete set of measurements per TDLAS instrument consists of ten beamline PICs. Samples of each beamline will be sequential and continuous. The ten beamlines represent two sets of five beamlines that each define a vertical measurement plane along adjacent sides of the lagoon/ basin. Each vertical measurement plane is measured along five beamlines sequentially sampled over approximately100 s (15 s dwell time with approximately 5 s time for moving to new OP position for each of 5 OP). On completion of the series of five beamlines along one vertical measurement plane, the instrument will align with the second measurement plane and measure the PIC along five beamlines over the next approximately 100 s (Figure 10.3). An emission rate using the RPM method will be calculated after each complete cycle (approximately 100 s).

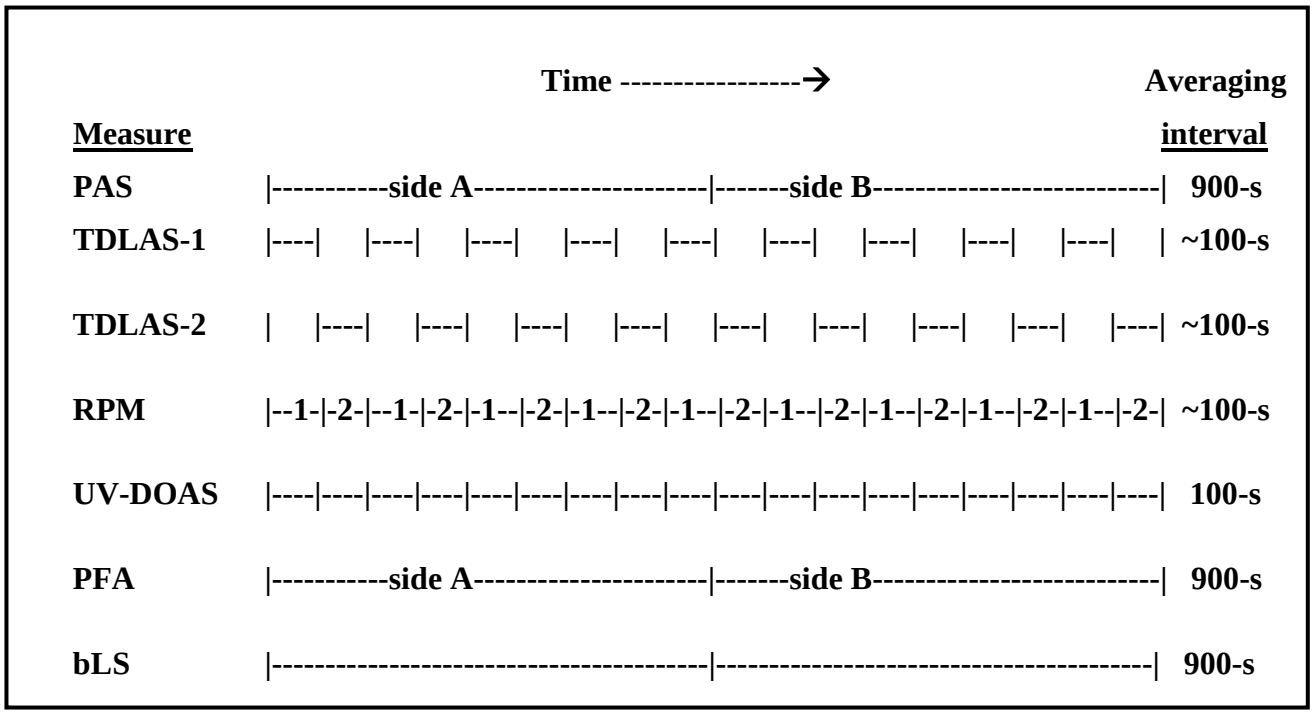

Figure 10.3 Coordination of sampling times at lagoon/basin locations. Each dash represents 20-s. Vertical lines indicate last 20-s for averaging (or integrating) time.

Siting criteria - corrals:
The general site configuration is presented in SOP U7. Two scanning open-path TDLAS instruments will be mounted on opposite corners of the monitored corral (Figure 10.4) with beamlines at 1 m abl along all sides of the corral (Figure 10.4). The locations of the retro-

reflectors and scanners will be determined after considering the prevailing wind direction(s) and wind obstructions such as trees, wind structures, and buildings.

TDLAS Source/Receiver: The source/receiver will be located up to 100 m from the corner of the corral facility in an open level area, such that instruments will be unaffected by local obstructions or objects such as buildings and paved parking lots, and minimizing the effects of hills and valleys. The instrument will be mounted at least 1 m agl on a scanner that will move the TDLAS laser beam to aim at each of the retro-reflectors in sequence.

TDLAS retro-reflectors: For each side of the corral system, one retro-reflector will be located at 1 m height near or beyond the length of the corral and up to 100 m away from the corral (Figure 10.4). All retro-reflectors will be located such that an unobstructed view of the source/receiver is possible. In addition, every effort will be made to locate beamlines such that retro-reflectors and scanners are more than 1 m away from on-farm vehicular traffic, 3 m away from off-farm vehicular traffic, and 5 m away from irrigation equipment. Specific configurations for the farms to be studied are found in the SMPs in Appendix C. These are critical project measurements.

Sampling plan: A complete set of TDLAS measurements consists of two to three beamline PIC measurements per TDLAS instrument. Samples of each beamline will be sequential and continuous. Each beamline will be sampled over 15-s dwell time (Figure 10.3). After twenty complete cycles (approximately 600 s or 10 min), the average PIC of each beamline and corresponding emission rate will be calculated.

10.3 Synthetic Open path System with PAS and PFA or open path UV-DOAS

Siting criteria - lagoon/basin sites: Two synthetic open-path systems (S-OPS) will be mounted on opposite sides of the monitored lagoon (Figure 10.1). Each S-OPS will be mounted approximately 2-4 m from the edge of the lagoon and within 2 m of a TDLAS path, 1 m height above the lagoon berm. The S-OPS will be approximately 50 m long. A multipoint air sampling system in the shelter will draw air sequentially from the nominally upwind and downwind S-OPS and deliver selected streams to a manifold, from which on-line PFA and PAS gas monitors draw their sub samples. Previous experience (Heber et al, JAWMA, 2006) has shown that the residence time for gas in a 300-ft long, ¼″ diameter sampling line of the type used here, flowing at 4 L/min, is approximately 45 s. Tubing connecting the S-OPS to the gas sampling system (GSS) will be approximately 500 to 1000 m long, resulting in a residence time in the tubing of 192 to 382 s when the flow is at least 5 L/min flow rate (Table 10.1). Each S-OPS is sampled for 15 min, using the first 3 min to allow the source air to reach the analyzer and the next 8 min to allow the gas analyzers to reach and maintain equilibrium. The distance from the analyzer manifold of the GSS to the analyzers themselves will never exceed 3 m (10 ft), which is well within the sample-drawing capabilities of each analyzer. Sample flow will always exceed the total draw of the gas analyzers by at least 25%.

Sampling plan: The GSS sampling manifold pressure and analyzer manifold flow rate and flow direction will be sampled continuously every 30 s. The PF analyzer will measure H_2S

concentrations of air coming from the GSS every minute. The PAS analyzer will measure NH_3 and VOCs in the air coming from the GSS every minute. The samples (omitting the first four minutes and last minute of each 15-min interval) will be averaged every 15 min. Each S-OPS will be sampled sequentially every 15 min, resulting in an upwind and downwind average pair every 30 min. Emission rates for the H_2S and VOC will be calculated for each 30-min period.

Table 10.1. Residence time in sampling lines, as a function of sampling line length and flow rate.

	Flow rate (L/min)	
Tube length, m	**5**	**10**
0 (GSS only)	2 s	1 s
50	21 s	10 s
100	40 s	20 s
200	78 s	39 s
500	192 s	97 s
1000	382 s	191 s

Notes:
Tubing ID = 0.25 in (0.0064 m) Tubing internal volume = 0.97 L/100 ft
Sampling manifold is 20 in long, with a 3/8″ ID, for a volume of 0.036 L; Sampling pump has a volume of 0.06 L.

If the UV-DOAS measurement of H_2S is validated, the UV-DOAS systems will be located as follows:

- *UV-DOAS Receiver*: The UV-DOAS receiver will be located within 10 m of the TDLAS source/receiver and at least 10 m from the lagoon edge.
- *UV-DOAS Source*: The UV-DOAS source will be located at least 10 m from the lagoon edge and 1 m above the lagoon berm at a distance of between 50 and 150 m from the UV-DOAS receiver.

Every effort will be made to locate beamlines such that they are within 1 m of berm height, more than 30 times the diameter of the fan away from barn fans, more than three times the height of the nearest downwind obstruction away from the downwind obstruction, and more than ten times the height of the nearest upwind obstruction away from the upwind obstruction. In addition, the siting of receiver and source will be more than 1 m away from on-farm vehicular traffic, 3 m away from off-farm vehicular traffic, and 5 m away from irrigation equipment.

Specific configurations for the farms to be studied are found in the SMPs in Appendix C. These are critical project measurements.

Sampling plan - lagoon/basin sites: If the UV-DOAS method for H_2S measurement is validated, the UV-DOAS will sample the ambient air concentration of NH_3 and H_2S at approximately 100-ms integration times with values averaged every 100-s and 5 min (Figure 10.3). Two 5-min integrations will be averaged to 10-min intervals in matching periods of 10-min intervals of valid wind measurements for NH_3 and H_2S emissions calculations.

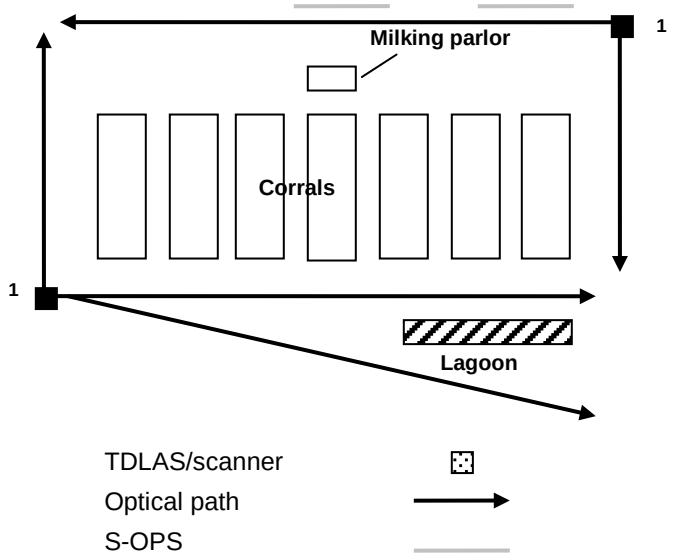

Figure 10.4- Example of corral open path sampling plan. Labels indicate height of instrument in meters.

If the UV-DOAS method for H_2S measurement is not validated, the S-OPS will sample the ambient air for analysis using PFA with values averaged for each 15-min interval (Figure 10.3). Regardless of the validation of the UV-DOAS, the S-OPS will sample the ambient air for VOC analysis using PAS with values averaged for each 15-min period (Figure 10.3). Each 15-min interval will be paired with the 15-min average of periods of valid wind measurements for VOC (and H_2S emissions if the UV-DOAS is not validated) calculations.

Siting criteria - corral site: Two open-path S-OPS paths will be mounted at least 100 m away from the predominant upwind side of the dairy corral operation to provide at least a 50:1 fetch (Figure 10.4). If the UV-DOAS method is validated for H_2S, UV-DOAS paths will be mounted at least 100 m away from the predominant upwind and downwind sides of the corral operation to provide at least a 50:1 fetch (Figure 10.4). Each S-OPS or UV-DOAS system will be mounted at 1 m agl. The S-OPS will be located within 5 m of a TDLAS path. The locations of the S-OPS and/or UV-DOAS will be determined after consideration of the prevailing wind(s) and terrain. Every effort will be made to locate paths that are more than 1 m away from on-farm vehicular traffic, more than 3 m away from off-farm vehicular traffic, and more than 5 m away from irrigation equipment. Specific configuration for the farm to be studied is found in the respective SMP in Appendix C.

Sampling plan - corral site: If validated for H_2S measurement, the UV-DOAS will measure H_2S in ambient air, and the S-OPS will sample the ambient air for measurement of VOC. If the UV-DOAS is not validated for H_2S measurements, the S-OPS will sample the ambient air for

measurement of H_2S. H_2S and VOC measurements will be averaged in 15-min periods for reported concentration measurements.

10.4 Photoacoustic multi-gas analyzer

(section deleted)

10.5 Lagoon/basin characterization

Lagoon or basin parameters to be recorded on site will include dimensions, volume and years in service. At lagoons, the pH (SOP L1), redox potential (SOP L3), depth of solids (Markland Sludge Gun Standard Operating Procedure; SOP L5) and temperature (SOP L2) will be continuously recorded during each measurement period. At the basin, the manure will be sampled and laboratory measurements of pH (SOP M2), total nitrogen (SOP M4), ammonia nitrogen (SOP M5) and total and volatile solids content (SOP M3) will be made. These are non-critical project measurements.

Sampling plan: Lagoon pH, redox potential, and temperature will be sampled every 5 min at 0.3 m depth on a data logger (SOP D1). Depth of solids will be manually determined by optical transmission at the beginning or end of each measurement period (SOP L5). Manure samples at the basin will be collected from three random locations near the basin rim or berm (SOP M1) at the beginning or end of each measurement period) with specifics addressed in SMP IA3A. A record of the sample number codes and any deviations in sampling protocol resulting from inaccessibility will be documented in the Field Notes for the sampling day. Samples will be shipped to Midwest Laboratories, Inc. within one day of collection by overnight shipping. Total transit time will not exceed two days. If a sample is lost or sample integrity compromised, the samples will be retaken at the conclusion of the measurement period. All manure samples will be analyzed at Midwest Laboratories, Inc. within 2 weeks of receipt.

10.6 Corral characterization

Manure will be sampled at the corral. Samples will be sent to Midwest Laboratories, Inc. where measurements of pH (SOP M2), total nitrogen (SOP M4), ammonia nitrogen (SOP M5) and total and volatile solids content (SOP M3) will be made. These are non-critical project measurements..

Sampling plan: Manure samples at the corral will be collected at some point during each measurement period from mixed slurries of manure collected from the corrals, the scraping lanes, the deposited manure piles, and the milking parlor (SOP M1), with specifics addressed in SMP TX5A. All manure samples will be analyzed at the designated laboratory. A record of the sample number codes and any deviations in sampling protocol resulting from inaccessibility will be documented in the Field Notes for the sampling day. Samples will be shipped to Midwest Laboratories, Inc. within one day of collection by overnight shipping. Total transit time will not exceed two days. If a sample is lost or sample integrity compromised, the samples will be

retaken and resent within one week. All manure samples will be analyzed at Midwest Laboratories, Inc. within 2 weeks of receipt.

10.7 bLS method validation

The bLS method has not been validated to measure the emissions from open sources and consequently cannot be used without qualification. To validate the method, it must be compared to a validated method. There is no method that has been validated for such a measurement. Although there is no method that is validated to measure emissions from open sources, the RPM method is in the process of validation. Consequently the bLS method validation must be against the RPM method. H_2S and VOC emissions calculations can be conducted using either the ratiometric method or the bLS method. Under a situation in which not all PIC values on a RPM measurement plane are valid, emissions will be calculated using time-averaged PICs and the bLS method. Therefore the bLS method must be validated. Ideally, the validation of the bLS method should use the same measurements that the RPM method uses to reduce method errors associated with the concentration measurements. Consequently, since the TDLAS system is unable to measure H_2S or the VOCs of interest but is used in the RPM method of NH_3 emission measurement, and the S-OPS does not have sufficient paths for the RPM method; the validation of the bLS method must be through the measurement of NH_3 emissions using the TDLAS.

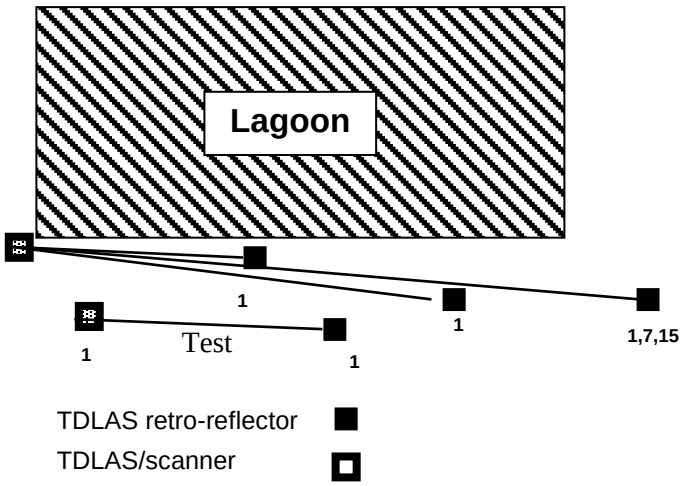

Figure 10.5 bLS Method Validation study instrument configuration. Labels represent heights of instrument or retro-reflector above lagoon berm.

Two validation studies will be conducted: (1) to validate the use of the bLS method by the RPM method for continuous PIC measurements along the single path used for the bLS method, and 2) to validate the use of the bLS method by the RPM method for intermittent PIC measurements along one of the five possible paths usually used for the RPM method:

- *Continuous PIC measurement bLS method validation*: A validation study of the bLS method will be conducted in accordance with EPA Method 301 ("Comparison with a validated method", Sections 5.2 and 6.2). One downwind side of a continuous monitoring lagoon will be instrumented with an additional TDLAS beamline (designated 'Test') according to Figure 10.5 with an established TDLAS system measuring PIC along five beamlines downwind of the lagoon. Measurements of NH_3 emissions will be made for several days using the bLS method and the single added TDLAS path and using the RPM method and the existing five TDLAS paths in conjunction with the sonic anemometers and meteorological characterization measurements described previously. From the measurement period, at least nine sets of paired 30-min measurement periods will be chosen such that the wind direction is less than 20° off the perpendicular of the measurement plane. The final paired dataset will be used for method validation statistics based on bracketed classifications of meteorological conditions (as a function of mean wind speed and atmospheric stability). Validation and QA/QC criteria for the measurements will be identical to that for the overall study.

- *Intermittant PIC measurement bLS method validation*: The bLS method will also be used to determine the emission rate from the five individual established scan lines during the sets of 30 min measurement periods when the wind direction is less than 20° off the perpendicular of the measurement plane. This will result in one measurement of the emissions by RPM paired with five measurements of emissions by the bLS method for each period of valid TDLAS and wind measurements. The final paired dataset will be used for method validation statistics based on bracketed classifications of meteorological conditions (as a function of mean wind speed and atmospheric stability). Validation and QA/QC criteria for the measurements will be identical to that for the overall study.

The precision of the bLS method for each individual bLS measurement will be assessed, assuming the RPM method is accurate. Since the RPM method is assumed to be accurate, the DQI associated with the RPM method will be used to restrict the measurement periods used in the validation. Since multiple independent measures of the bLS emissions calculation are possible for comparison with a single RPM measurement, a further result of the precision determination will be a collective precision estimation and possibly criteria defining optimal beamline location for bLS emissions calculations. The F-test will be used to determine if the precision of the bLS method is significantly different from that of the RPM method under a range of meteorological conditions. The experimental *F*-value is calculated according to.

$$F = \frac{S_{bLS}^2}{S_{RPM}^2} \qquad \text{(Equation 10.1)}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from a single PIC, and S^2_{RPM} is the variance of the RPM measurement method determined from the five PICs on a given side for the paired 30-min measurement periods. The experimental *F*-value will be compared to the critical range of *F* at a 95 percent confidence level for the appropriate degrees of freedom

associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* is above the critical range, the precision of the bLS method is significantly greater than the RPM method and the bLS method precision is unacceptable. If the experimental *F* is below the critical range, the precision of the bLS method will be accepted as equivalent to the RPM method.

The bias of the bLS method will be determined from the measurement periods and beamlines used in the precision determination. Bias will be determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval will be used (t=1.397). If the difference is significant, then the correction factor is calculated. The correction factor must fall within the range of 0.90 to 1.10 for the bLS method to be valid for measuring the emissions under the given meteorological conditions. If the correction factor is more than 1.10 or less than 0.90 then the bLS method will be used differently for lagoon/ basin and corral measurements. At the lagoon/ basin locations, the bLS model will not be considered valid for H_2S emissions estimates, and emissions of H_2S will be estimated from the ratio of PFA or UV-DOAS concentration measurements to nearby NH_3 concentration and RPM-calculated NH_3 emissions using

$$Q(H_2S) = Q_{RPM}(NH_3)\frac{\left[C_{x,j}(H_2S) - C_{x,bg}(H_2S)\right]}{\left[C_{x,j}(NH_3) - C_{x,bg}(NH_3)\right]} \qquad \text{(Equation 10.2)}$$

where the subscripts TDLAS, RPM, and x (UV-DOAS or S-OPS) refer to the instrument or method of determination, *bg* and *j* refer to the upwind and downwind path of the S-OPS, UV-DOAS, and H_2S (or VOC) and NH_3 refer to the measured gas. At the corral location, all bLS emission estimates will be considered valid but qualified at a reduced accuracy in accordance with that calculated from the validation experiment.

10.8 UV-DOAS H_2S measurement characterization and validation

The UV-DOAS instrument has not been validated for the measurement of H_2S in lagoon/manure storage environments and consequently cannot be used in the study until characterized and validated.

Characterization of the UV-DOAS H_2S measurement precision, accuracy, stability, sensitivity, and interferences in the lagoon environment will be conducted according to procedures outlined in the ETV “Generic Verification Protocol for Optical Open-Path Monitors” document. Initial characterization documented in Tables 6.1, 7.2, and A13 will be confirmed or modified in accordance with the characterization study results. The characterization will utilize a 1-m long function cell (provided by E. Thoma of USEPA) and N_2 dilutions of H_2S EPA protocol gas. The dilution system will be a calibrated Environics Inc. Model 4040 diluter operated according to SOP G11. The diluted gas streams will be introduced into the function cell while the cell is in the beam line along the lagoon edge so that characterization is in the presence of the other, potentially interfering gases emitted by the lagoon, such as acetic acid.

Validation of the UV-DOAS H_2S measurement (including precision, accuracy or bias, and stability) in the lagoon environment will be conducted according to procedures described in EPA Method 301. In this validation study, the UV-DOAS will be compared to a synthetic open-path system (S-OPS) using the Standard Operating Procedure for the Synthetic Open-Path Sampling System (SOP C4) in conjunction with Pulsed-Fluorescence H_2S Analyzers (USEPA Method EQSA-0486-060 and EMTIC TM-006C) using Standard Operating Procedure for the Measurement of Hydrogen Sulfide with the Thermo Electron Corporation Model 450I Pulsed-Fluorescence Analyzer (SOP G5) as suggested by EPA OAQPS personnel. The S-OPS consists of the measurement of gas concentration from a gas sample drawn uniformly from multiple points along a sampling line simulating the beamline of an open-path measurement. The H_2S measurements made with two UV-DOAS systems will be compared to those obtained with the two S-OPS over a period of 21 d (the maximum duration of continuous unattended operation at the Rotation farm lagoons/ basin) at the dairy lagoons of the Purdue University Animal Sciences Research and Education Center in Montmorenci, Indiana. The study will be conducted prior to the initiation of the routine measurements (Table 4.2) The precision, bias, and stability of the UV-DOAS gas measurement system in the measurement of H_2S will be evaluated in this study.

The validation study will consist of two UV-DOAS systems and two synthetic open-path systems (S-OPS) measuring the H_2S concentrations downwind of a lagoon and synthetic H_2S source (Figure 10.6). Each S-OPS consists of ten Teflon inlet nozzles spaced 5 m apart along Teflon tubing connected to calibrated pulsed fluorescence (PF) H_2S analyzers according to SOP G5. To avoid potentially biased plume sampling due to unequal inlet flows along the entire sampling system, each nozzle will have a flow of 1 L/min that is balanced using calibrated flow meters. To minimize biased sampling due to lags in flow associated with varying distances to each air intake, the S-OPS will operate under a 10 L/min flow rate, resulting in a lag time of only 20 s for the air drawn in at the furthest inlet nozzle. To minimize the differences in sampled air volume during the study, the two UV-DOAS optical paths will be located as close together as possible, and the two S-OPS systems will be located as close as possible to the UV-DOAS beamlines without obstructing the beams. The two S-OPS will be staggered by 2.5 m so that the lateral sampling distance of the combined two S-OPS will be only 2.5 m (Figure 10.6).

To assure measurable concentrations of H_2S in the measurement volume, the lagoon will be agitated to maximize the area emission of H_2S and a synthetic line source will be used at intervals during the study. The line source will be composed of tubing with five nozzles spaced 5 m apart at 1 m agl distributing H_2S from a 10% H_2S tank, and will be located upwind of the gas measurement systems (Figure 10.6) such that the PIC along the measurement path is at least 60 ppb-100m (3 x MDL of UV-DOAS system). The synthetic line source will only be activated during 3 h per day (representing one complete tank of gas under winds less than 4 m/s and flow of 20 L/min) for at least several days when the wind is blowing in the direction of the sensors and the stability is such to assure adequate concentrations at the measurement paths (Pasquill Stability Classes A through D). Measurements and QA data from each instrument will be recorded using 30-min averages, identical to the averaging period for the study (Section 10.3). Wind conditions and stability will be monitored using the 3D sonic anemometer (SOP W2) and validation will be based on only measurements made under meteorological conditions in which

the emissions methods are valid. Validation and QA/QC criteria for the measurements will be identical to those for the overall NAEMS (SOP C1, SOP G5).

The stability of the UV-DOAS gas measurement system under field conditions will be evaluated by assessing the variation in integration time and maximum peak emission over the entire study period. Analysis of the variation will include evaluation of the variations associated with sun location, temperature, winds and other weather fluctuations.

The sampling effectiveness of the S-OPS inlet spacing will be evaluated by comparing the time-varying statistics of H_2S concentration for the individual S-OPS (with 10 inlets spaced at 5 m) and the combined S-OPS (20 inlets spaced at 2.5 m).

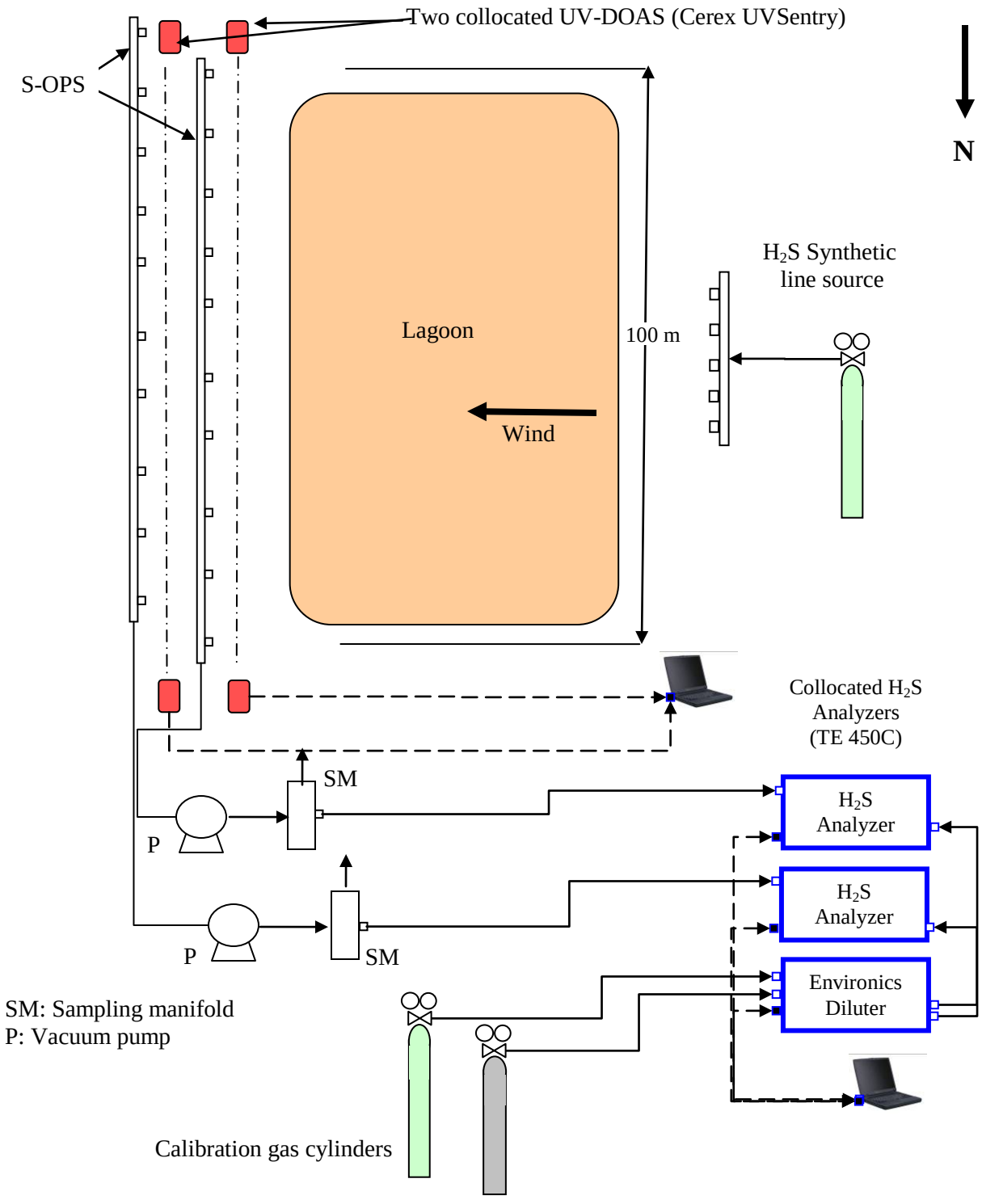

Figure 10.6. Configuration of sampling equipment and emission sources for the UV-DOAS verification study.

The average concentration of valid measurements from the two S-OPS measurement systems and the two UV-DOAS measurement systems will be used for the assessment of precision and bias of the UV-DOAS method.

The F test will be used to determine if the precision of the UV-DOAS H_2S measurement method is significantly different from that of the S-OPS H_2S measurement method. The experimental *F*-value is calculated according to:

$$F = \frac{S_p^2}{S_v^2} \qquad \text{(Equation 10.3)}$$

where S^2_p = the variance of the UV-DOAS measurement method from *p* 100-s measurement periods and S^2_v = the variance of the S-OPS measurement method from *v* 100-s measurement periods.

The experimental *F* value will be compared to the critical range of *F* at a 95 percent confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* is above the critical range, the precision of the UV-DOAS H_2S measurement method is significantly greater than the S-OPS measurement method and the UV-DOAS H_2S measurement is unacceptable. As a result, the S-OPS measurement system will be substituted for the UV-DOAS measurement system for the measurement of H_2S at all locations in the NAEMS.

The bias of the UV-DOAS H_2S measurement system from the S-OPS measurement system will be determined for selected measurement periods (100-s) used in the previously-described measurement system precision comparison. Bias will be determined by t-test of the mean differences between the mean of the two UV-DOAS measurement systems and the mean of the two S-OPS measurements. An 80% confidence interval will be used (t=1.397). If the difference is significant, then the correction factor is calculated. The correction factor must fall within the range of 0.90 to 1.10. If the correction factor is more than 1.10 or less than 0.90 then the UV-DOAS measurement method cannot be used in the study and the S-OPS measurement system will be substituted for the UV-DOAS system for the measurement of H_2S at all locations in the NAEMS.

10.9 S-OPS sampling validation

The S-OPS consists of the measurement of gas concentration from a gas sample drawn uniformly from multiple points along a sampling line, simulating the beamline of an open-path measurement. The S-OPS method of sampling the line concentration of a gas has not been validated, and consequently cannot be used in the study until characterized and validated.

Validation of the S-OPS sampling system (including precision, accuracy or bias, and stability) will be assessed in an open-field environment in accordance with procedures described in EPA

Method 301. In this validation study, the open path UV-DOAS measurement of SO_2 using Standard Operating Procedures for the Open-Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UVSentry Ultraviolet Differential Optical Absorption Spectrometer (SOP C1) (substituting SO_2 for NH_3) will be compared with a synthetic open path system (S-OPS) using the Standard Operating Procedure for the Synthetic Open-Path Sampling System (SOP C4) in conjunction with Pulsed-Fluorescence H_2S Analyzers (USEPA Method EQSA-0486-060 and EMTIC TM-006C) using Standard Operating Procedure for the Measurement of Hydrogen Sulfide with the Thermo Electron Corporation Model 450C Pulsed-Fluorescence Analyzer (SOP G5), as suggested by EPA OAQPS personnel. The S-OPS consists of a manifold of 10 orifices spaced 5 m apart with air drawn through the manifold at 10 L/min. The SO_2 measurements of the air sampled from the S-OPS and the SO_2 PIC measured with the UV-DOAS will be averaged for 1 min. The S-OPS and UV-DOAS will be positioned approximately 20 m downwind of a 5-orifice 25-m line source of 10% SO_2 (Figure 10.7) such that the PIC along the measurement path is at least 30 ppb-100m (3 x MDL of UV-DOAS and PFA instruments).

Measurements from both the PFA and UV-DOAS instruments will be made for at least five (5) half-hour periods of emission with 10 min of ambient air measurements made between emissions. Instruments will be calibrated prior to and after the study. Validation and QA/QC criteria for the measurements will be identical to those for the overall NAEMS (SOP C1, SOP C4, SOP G5). SO_2 concentrations measured by the two instruments will be compared in accordance with EPA Method 301.

The average concentration of valid measurements from the S-OPS/PFA measurement system and the UV-DOAS measurement systems will be used for the assessment of precision and bias of the S-OPS sampling method.

The F-test will be used to determine if the precision of the UV-DOAS SO_2 measurement method is significantly different from that of the S-OPS/PFA SO_2 measurement method. The experimental *F*-value is calculated according to

$$F = \frac{S_p^2}{S_v^2} \qquad \text{(Equation 10.4)}$$

where S^2_p equals the variance of the UV-DOAS measurement method from *p* 100-s measurement periods, and S^2_v is the variance of the S-OPS/PFA measurement method from *v* 100-s measurement periods.

The experimental *F*-value will be compared to the critical range of *F* at a 95 percent confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* is above the critical range, the precision of the UV-DOAS SO_2 measurement is significantly greater than the S-OPS/PFA SO_2 measurement method and the S-OPS sampling method as a surrogate for a

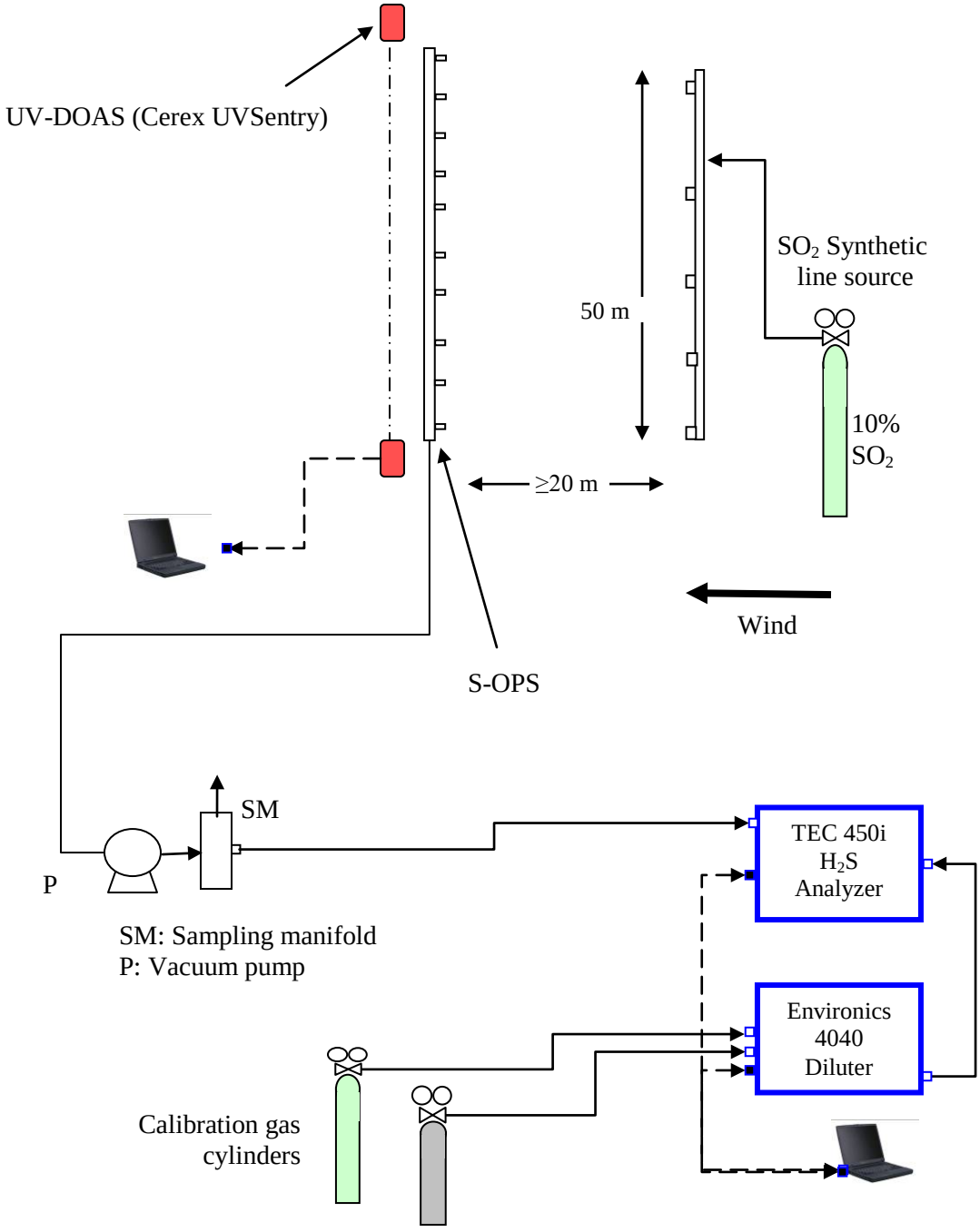

Figure 10.7. Configuration of sampling equipment and emission sources for the S-OPS validation study.

open-path measurement is unacceptable and measurements made of air collected through the S-OPS will consequently be considered as a line sample.

The bias of the UV-DOAS SO_2 measurement system from the S-OPS/PFA measurement system will be determined for selected measurement periods (30-min) used in the previously-described measurement system precision comparison. Bias will be determined by t-test of the mean measurement period differences of the UV-DOAS and S-OPS/PFA SO_2 measurements. An 80% confidence interval will be used (t=1.397). If the difference is significant, then the correction factor is calculated. The correction factor must fall within the range of 0.90 to 1.10. If the correction factor is more than 1.10 or less than 0.90 then the S-OPS measurement method cannot be used in the study as a surrogate for open-path measurement and will consequently be considered as a line sample in the NAEMS.

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SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Standard Operating Procedure G7. Purdue Ag Air Quality Lab.

SOP G11. 2006. Standard Operating Procedure for the Operation of the Environics Model 4040 Diluter. Standard Operating Procedure G11. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L

Thermistor. Standard Operating Procedure L2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11 ORP Sensor. Standard Operating Procedure L3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.
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11. Sampling Methods Requirements

The only sampling in this study involves the sampling of manure at the corral and basin measurement locations (Standard Operating Procedure for Manure Sampling; SOP M1) and the sampling of feed, bedding, and milk at the corral location. At the corral location, surface manure sampling will be conducted during every measurement period. Surface samples will be collected at random locations in the corrals themselves, as well as the scraping lanes, the deposited manure piles, and the milking parlor. At the basin, manure will be sampled from three locations near the basin rim at the beginning or end of each measurement period.

Extensive measurements, however, are made in this study, including: (1) wind measurements at three heights described in SOP W2, (2) ambient air temperature, humidity, and barometric pressure described in SOPs W1 and W5, (3) incident solar radiation described in SOP E3, (4) surface wetness described in SOP W3, (5) lagoon/basin pH, redox state and temperature at 0.3 m depth described in SOPs L1, L2, and L3, (6) path-integrated concentrations of NH_3 along many beamlines described in SOP C2 (and SOP C1 if UV-DOAS is validated for H_2S measurement), (7) synthetic path-integrated concentrations of H_2S along two paths described in SOP G5 and C4 or path-integrated concentrations of H_2S along two paths described in SOP C1 if UV-DOAS is validated for H_2S measurement, (8) synthetic path-integrated concentrations of NH_3, CH_4, THC (referenced to propane), MeOH, and EtOH described in SOP G7 and C4, (9) NH_3 emissions described in SOP O1 and O2, (10) H_2S emissions described in SOP O1, and (11) lagoon sludge depths described in SOP L5. The respective SOP documents define method summaries, interferences, safety issues, necessary supplies, acceptance, installation, operation, calibration, and troubleshooting procedures as well as QA/QC procedures for each instrument.

Facilities in support of the measurements are described in SOP D1 and SOP U4. Site installation, operation, and take-down for lagoons and basins are described in SOP U5. Site installation, operation, and take-down for corrals are described in SOP U7.

Requests for changes in protocols and any occurrences of deviations from approved protocols must be documented on a ‘Document Deviation Report’ Form (Appendix D). The PQAM in consultation with the QAM, PM and SA will determine the resolution of the deviation. Possible resolutions of a deviation include: accept deviation and revise a section of the QAPP or SOP, accept revision (minor) no changes necessary, reject deviation and data, reject deviation but retain data (for instance incomplete replication). All changes in operating protocol must be approved by the EPA prior to activation.

References

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SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

SOP C4. 2006. Standard Operating Procedure for the Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

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SOP G5. 2006. Standard Operating Procedure for the Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

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SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

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SOP U5. 2006. Installation of Open Source Measurement Equipment. Standard Operating Procedure U5. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP U7. 2006. Installation of Open Source Measurement Equipment (Corrals). Standard Operating Procedure U7. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Viasala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W5. 2006. Measurement of Barometric pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

12. Sample Custody

Physical manure samples are collected in this study. Manure, feed, bedding, and milk samples will be collected from the basin and corral locations according to the respective SMP and SOPs M1 and S6 and shipped to the analytical laboratory (Address: Midwest Laboratories, Inc., 13611 B St., Omaha, NE) on ice (maintaining $<4^{o}$C temperature) with a chain of custody form. A copy of the chain of custody form will be made and retained on-site and scanned into the computer records in the directory for the site. Samples will be labeled using indelible markers with the sample number code, sealed in two plastic bags, and shipped with the chain of custody form in foam freezer boxes sealed using duct tape or shipping tape. The integrity of the sample bag and the temperature of the shipping container will be determined on receipt at the laboratory and documented on the chain of custody form (Appendix D).

The chain of custody form (example in Appendix D) includes:

- Name of submitter of the sample
- Sample origin location, date, time, type, and number code.
- Date and time of receipt at laboratory
- Name of individual receiving sample
- Condition of sample on receipt
- Analyses requested
- Number of sample containers

The sample number code will be coded according to: Location code (Table C1)/ Day-Month-Year / Sample type (Manure) / replicate #.

Electronic measurement data are collected in this study. Raw data are stored in multiple places prior to transfer to PAML. PF, GSS and PAS raw data are stored on the LAN computer HD. UV-DOAS (if validated for H_2S measurements) raw data will be stored on flash memory drives of each instrument, as well as being stored on the LAN computer HD. TDLAS raw data (Figure 12.2) are stored on the TDLAS data acquisition computer HD, LAN computer and associated external HD. Meteorological/Lagoon Datalogger raw data (excluding wind measurements) are stored on a Compact Flash memory card attached to the data logger, the memory of the on-site data logger, the LAN server HD and the associated external HD. Wind data are stored on the LAN server HD and associated External HD.

All field data will be transferred to PAML by multiple means: ftp downloads and courier data pouches (carried at two different times). A daily ftp download will occur that will include daily raw and processed files from the two UV-DOAS systems (PIC values of NH_3 and H_2S), the two TDLAS systems (PIC values of NH_3), the meteorological (ambient air temperature, relative humidity, barometric pressure, solar radiation, surface wetness, wind components) and lagoon/basin (pH, temperature and redox state) characterization measurements. After each measurement location has been established, the returning Scientist in the FOS will bring with them a data pouch containing flash memory drives, CDs, and DVDs. The pouch will include:

For latest measurement period:

Two 4Gb UV-DOAS flash memory drives (if UV-DOAS method validated).

Two CDs with copies of UV-DOAS flash memory drives (if UV-DOAS method validated).

One DVD with 16-Hz sonic anemometer wind data

One CD with TDLAS, PF, PAS, GSS, wind (except 16-Hz data), and weather and lagoon/basin data (if using PFA and S-OPS measurements).

One 64Mb flash memory chip of weather and lagoon/basin data.

One 256Mb memory stick with field notes, calibration data and control charts.

For the previous measurement period (material previously stored in on-site data vault in environmentally-controlled instrumentation trailer):

Two CDs with copies of UV-DOAS flash memory drives (if UV-DOAS method validated).

One CD with TDLAS, PF, PAS, GSS, wind (except 16-Hz data), and weather and lagoon/basin data (if using PFA and S-OPS measurements).

Electronic data transfer forms for both recently-completed and previous measurement periods (Appendix D) with the upper section filled out.

The data pouch will be carried back to PAML and delivered to the PDM. Receipt of raw and post-processed data at PAML will be logged on the electronic data transfer forms and data transferred to the project database by the PDM. The Electronic data transfer forms will be filed by the DM. Additional detail in the process of sample handling are described in SOP D1.

Example forms used in the instrument calibration and quality assurance checks, data collection, and sample custody, and data transfer are included in Appendix D.

References

SOP D1. 2006. Management of Open-Source, Weather, and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

13. Analytical and Calculation Methods

Approved analytical methods will be used in all experiments. Analytical data will be generated in accordance with the Standard Operating Procedures and instrument manufacturer's manuals.

13.1. Meteorological measurements

Meteorological measurements will be used to monitor the atmosphere during the PIC and S-OPS concentration measurements by TDLAS, UV-DOAS (if validated), PF (if UV-DOAS not validated), and PAS described below. Air temperature, relative humidity, pressure, and solar radiation will be measured every 5-s and averaged over 5-min intervals. Wind profiles will be derived from the 2-s averaging of 16-Hz sampling of the instantaneous orthogonal wind components. Atmospheric stability and other characteristics of the atmosphere will be derived from the wind information and 5-s sampling of air temperature, relative humidity, and barometric pressure. Turbulence characteristics will be derived from 16 Hz sampling of the instantaneous orthogonal wind components and the virtual temperature will be derived from the speed of sound. Mean wind speed and direction will be determined from 100-s records. Wetness plates will be sampled at 5 min intervals and used to assess rain or dew at the site. Analysis of the meteorological data is covered in the SOPs in Appendix B.

AFO lagoons and basins are not located with consideration for potential gaseous and air flow measurements. Trees are often used to reduce visibility of the lagoons and the distance between barns and lagoons are often too close to separate the barn emissions from the exhaust fans from the lagoon or basin. In addition, lagoons are often built up from the surrounding ground by the soil removed to form the lagoon, creating a substantial berm height. Computational methods used below for the determination of stability, aerodynamic roughness, and turbulence characteristics assume that measurements are made over homogeneous surfaces and that the turbulence is stationary. Clearly this is not always true at AFOs or for all periods of time at a given AFO. Consequently, great care has been taken in locating the best possible ten farms for the study measurements so that deviations from the preferred terrain conditions have been minimized and tests of homogeneity and stationarity of turbulence are made in the validation of all turbulence measurements. Exclusion zones and invalidated methods are identified in the respective SMP where upwind or downwind conditions will clearly violate siting criteria designed to minimize location homogeneity problems.

Corrective action by the on-site teams will be necessitated by any deviation from published procedure or instruction manual direction.

13.2. Open path TDLAS

Narrowband open path TDLAS spectroscopy in the near infrared (1512 nm) will be used to monitor NH_3 in the atmosphere. Each of two TDLAS systems per waste storage location will scan along 10 OPs (five on each of two adjacent sides of the waste storage area). Concentration measurements along the individual OPs are sampled for approximately 15 s (integration or dwell

time) with up to 5 s provided to move to the next OP. A full scan set (one complete cycle of two sides of the open source) will require approximately 200 s. Concentration measurements along one side of the open source will require approximately 100 s. Three cycles over a period of approximately 600 s will constitute one complete set of measurements to be used in the RPM emissions model (Figure 10.3). Details of the measurement are found in SOP C2. Corrective action by the on-site teams will be necessitated by any deviation from published procedure (SOP C2) or the instrument instruction manual direction.

It is anticipated that during the winter months, lagoons at a number of locations will be frozen over during the measurement period, resulting in sub-MDL gaseous concentrations at the lagoon berm. Rather than set the measurements below MDL to ½ MDL concentrations, the poor accuracy of the measurement will be indicated by the corresponding r^2 value.

13.3. Open path UV-DOAS

Broadband UV-DOAS spectroscopy, if validated for H_2S measurement, will be used to monitor NH_3 and H_2S concentrations in the atmosphere over the 190 to 230 nm waveband (Figure 13.1). Two UV-DOAS instruments will be located on opposite sides of a waste storage area. Each measurement will consist of a spectrum with a 100-s integration time (Figure 10.3). Once spectra are generated, the spectra are filtered, aligned with a reference NH_3 spectrum, and analyzed using a classic least squares technique to quantify the NH_3. The absorption spectrum associated with the quantified NH_3 concentration is subtracted from the measured/filtered spectrum and the remaining absorption spectrum is analyzed for H_2S using partial least squares techniques. The FT-IR Open-Path Monitoring Guidance Document is used to provide guidance in the techniques used to acquire valid spectra. Details of the procedures are found in SOP C1. Corrective action by the on-site teams will be necessitated by any deviation from published procedure (SOP C1) or the instrument instruction manual direction.

It is anticipated that during the winter months, lagoons at a number of locations will be frozen over during the measurement period, resulting in sub-MDL gaseous concentrations at the lagoon berm. Measurements below MDL will be assigned ½ MDL concentrations.

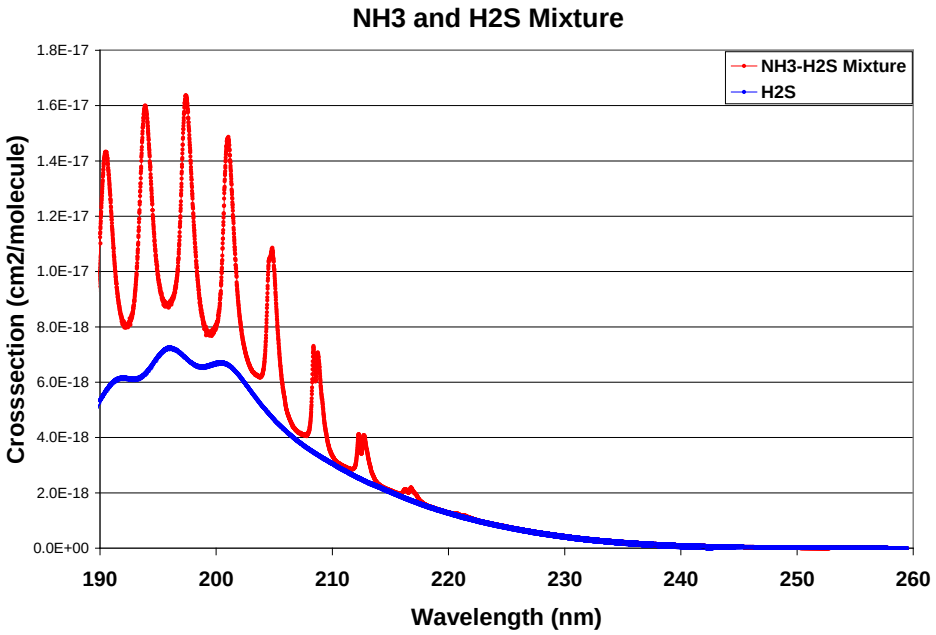

Figure 13.1 Typical broadband spectrum of the UV-DOAS instrument showing NH_3 and H_2S features.

13.4 Photoacoustic Spectroscopy

Photoacoustic IR spectroscopic techniques will be used to measure NH_3 and various VOCs including CH_4, MeOH, and EtOH (SOP G7). Measurements will be made from air sampled along two synthetic open-paths: up- and downwind of the lagoon or basin. Measurements will only be made one side of the corral. Air will be sampled on 1-min intervals for 15 min, with the mean of the equilibrated measurements used as the 15-min concentration per S-OPS. Measurements will be continuous with sequential sampling from the two S-OPS. The time required for equilibration will be experimentally determined from the measurement time history.

It is anticipated that during the winter months, lagoons at a number of locations will be frozen over during the measurement period resulting in sub-MDL gaseous concentrations at the lagoon berm. Measurements below MDL will be assigned ½ MDL concentrations.

13.5 Pulsed-fluorescence measurements

Pulsed-fluorescence techniques will be used to measure H_2S (SOP G5). Measurements will be made from air sampled along two synthetic open-paths: up- and downwind of the lagoon, basin, or corral. Air will be sampled at 1-min intervals for 15 min, with the mean of the equilibrated measurements used as the 15-min concentration. Measurements will be continuous with sequential sampling from the two S-OPS. The time required for equilibration will be experimentally determined from the measurement time history.

It is anticipated that during the winter months, lagoons at a number of locations will be frozen over during the measurement period resulting in sub-MDL gaseous concentrations at the lagoon berm. Measurements below MDL will be assigned ½ MDL concentrations.

13.6 Gas concentration data transformation

The open path TDLAS and UV-DOAS operating programs process the raw spectra data files into files containing PIC measurements in parts per billion (ppb) (UV-DOAS instrument) or parts per million (ppm) (TDLAS instrument). The PF and PAS produce files containing concentration measurements in ppm. Validated concentration measurements are reported in units of parts per billion (ppb), consequently the TDLAS and UV-DOAS PIC values are divided by the corresponding path lengths. The ideal gas law (*PV = nRT)* is used to convert volumetric gas concentrations to actual and standardized mass concentrations (moist) with eqns 13.1 and 13.2 respectively.

The emissions models calculate emissions based on the 'wet' (air including water vapor) concentrations computed from the measurements as:

$$C = \frac{PcM}{R(273.15 + T)} \qquad \text{(Equation 13.1)}$$

Where:

c	Volumetric concentration, ppb
C	Actual mass concentration, mg/m^3 or µg/m^3
M	Molecular weight, M=17.03 g/mol and 34.08 g/mol for NH_3 and H_2S respectively
P	Pressure at sampling location, atm
T	Temperature at sampling location, °C
R	Universal Gas Constant: 0.08206 L-atm/mol-°K

The reported gas concentrations are reported as if in 'dry' air at standard pressure (1 atm) and temperature (20°C). The volumetric gas concentration of any pollutant is converted to the standard mass concentration C′ according to:

$$C' = \frac{P'cM}{R(273.15 + T')} \qquad \text{(Equation 13.2)}$$

where:

c volumetric concentration, ppb
C′ Standard mass concentration moist basis, µg/m^3
P′ Standard pressure, 1 atm
T′ Standard temperature, 20°C

and to the dry standard concentration according to:

$$C'' = \frac{C'}{(1-W)} \qquad \text{(Equation 13.3)}$$

where:

C″ Dry standard mass concentration dry basis, µg/m^3, and
W Humidity ratio (kg/kg), is calculated as:

$$W = 0.62198 \frac{e^{f(T)}\varphi}{P_a - e^{f(T)}\varphi} \qquad \text{(Equation 13.4)}$$

where:

P_a = barometric pressure at the sampling location (Pa)
φ= relative humidity at the sampling location, decimal, and

$$f(T) = \frac{C_1}{T} + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln T \quad \text{for T < 273K.} \qquad \text{(Equation 13.5)}$$

$$f(T) = \frac{C_8}{T} + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln T \quad \text{for T > 273.16K}$$

C_1= -5.675x10^3, C_2= 6.392, C_3= -9.678x10^{-3}, C_4= 6.222x10^{-7},
C_5= 2.075x10^{-9}, C_6= -9.484x10^{-13}, C_7= 4.163, C_8= -5.800x10^3,
C_9= 1.391, C_{10}= -4.864x10^{-2}, C_{11}= 4.176x10^{-5}, C_{12}= -1.445x10^{-8}, and
C_{13}= 6.545.

13.6 Meteorological data transformations

Turbulence measures will be derived from 5-min averaging of 16-Hz sampling of instantaneous wind components u′, v′, w′ and the virtual temperature T_v′, derived from the speed of sound (V_o). Detailed procedures are found in SOP W2. In general, raw component wind speed measurements (*u, v, w* in m/s; T_v in K) are evaluated for extreme value spikes (with spike data omitted and measurements used in computations if fewer than 160 in 5 min of data), and period statistics are computed (mean and variance of *u, v, w,* and T_v and covariances between all signal pairs). Support frame wake corrections are made on the measurements internally in the instrument.

From the 2-m wind instruments (or 4-m if no 2-m measurements are available), the friction velocity will be calculated according to

$$u_* = \sqrt[4]{\overline{u'w'}^2 + \overline{v'w'}^2} \qquad \text{(Equation 13.6)}$$

the characteristic temperature will be calculated according to

$$T_* = \overline{w'T_v'}/u_* \qquad \text{(Equation 13.7)}$$

and the Obukov length (L) will be calculated according to

$$1/L = \frac{-kg\overline{w'T_v'}}{\overline{T_v}u_*^{\,3}} \qquad \text{(Equation 13.8)}$$

where k is von Karman's constant and g is the gravitational acceleration. Mean values of L and u_* will be calculated for the two heights, and will be flagged if they fall outside of acceptable limits for the bLS emissions model.

T_v is calculated from the relative humidity, air temperature, and atmospheric pressure measurements according to:

$$T_v = (1+0.614W)(T+273.14) \qquad \text{(Equation 13.9)}$$

for air at temperature T. Values are flagged if the period-averaged T_v derived from the speed of sound and the T_v (calculated from the relative humidity, air temperature, and atmospheric pressure measurements) differ by more than 2°C (DQI).

Since the terrain is not ideal for homogeneous turbulence measurements, the stationarity and homogeneity of the time series are evaluated using the 2-m (or 4-m if 2-m values are not available) wind measurements. The stationarity is evaluated by comparing the 5-min covariances of u′ and w′ and w′ and T_v′ to the 30-min averaged covariances (where i and j are different variables) using:

$$\left[\frac{\sum_{1}^{6}\left(\overline{u'_i\,u'_j}\right)_{5\,\mathrm{min}}}{6} - \left(\overline{u'_i\,u'_j}\right)_{30\,\mathrm{min}}\right] \Big/ \left(\overline{u'_i\,u'_j}\right)_{30\,\mathrm{min}} \qquad \text{(Equation 13.10)}$$

where u has been rotated into the mean wind direction. Turbulence is not stationary for any 30-min interval when the difference between the average 5-min and 30-min values are greater than 30%, and data will be correspondingly flagged. The homogeneity of turbulence is evaluated by comparing the theoretically derived and measured integral turbulence scales of w′, u′ (where u has been rotated into the mean wind direction) and T_v′ (u_* and T_{v*}) to the standard deviation of w′ and T_v′ as:

$$\frac{\sigma_w}{u_*} = 2.00(-z/L)^{1/6}, 2.00(-z/L)^{1/8}, 1.41, 1.25 \text{ for } z/L \text{ of } <-1,\ -1..-0.0625,\ -0.0625..<0$$

and ≥0 respectively

$\frac{\sigma_u}{u_*} = 2.83(-z/L)^{1/6}, 2.83(-z/L)^{1/8}, 1.99, 2.4$ for z/L of <-1, -1..-0.0625, and -0.0625..<0 and ≥0 respectively

$\frac{\sigma_T}{T_*} = 1.00(-z/L)^{1/3}, 1.00(-z/L)^{1/4}, 0.50(-z/L)^{1/2}$ for z/L of <-1, -1..-0.0625, and -0.0625..<0 respectively

(Equation 13.11)

Turbulence data is inhomogeneous when the measured and derived values differ by more than 30% (data will be correspondingly flagged).

The bLS emissions method can compute the roughness length (z_o) from single-height wind information it is provided or can be provided previously-calculated site-specific input information derived from multiple heights. The average value of z_o will be computed from the three heights of wind measurements (2 m abl, 4 m agl, 16 m agl), each calculated as:

$$z_o = \frac{(z-d)}{e^{kS/u_* + \psi_m}} \qquad \text{(Equation 13.12)}$$

where:
ψ_M= -4.7 $(z\text{-}d)/L$ for z/L>0.0001
ψ_M= 0 for 0.0001>z/L>0.0001
ψ_M= 2 $ln[(1+x^2)/2 \cdot (1+x)^2/4]$- $2\tan^{-1} x$ and x=$(1\text{-}15(z\text{-}d)/L)^{1/5}$ for z/L>0.0001

The dissipation rate (ε) is calculated using the 2-m and 4-m wind measurements according to:

$$\varepsilon = \frac{u_*^3}{kz}\varphi_\varepsilon \qquad \text{(Equation 13.13)}$$

where:
$\varphi_\varepsilon = 1 + 5z/L$ for L>0
$\varphi_\varepsilon = \frac{b_w^4(1-3z/L)^{1.33}+1}{(b_w^4+1)(1-3z/L)^{0.33}(1-6z/L)^{0.25}}$ for L<0.

QA Flags associated with each condition are described in SOP W2.

13.7 Emissions calculation transformations

The 15-min averages of turbulence, meteorological data, and OP spectra (if the UV-DOAS is validated) will be used in conjunction with the backward Lagrangian Stochastic (bLS) method to

determine NH_3 and H_2S emissions for that 15-min period. Emissions will be reported at 30-min intervals.

Since the S-OPS-sampled air from the two sides of the area source are each measured for 15 min, a complete set of measurements around the area source takes 30 min. Consequently, the VOC and H_2S (if UV-DOAS is not validated) measurements of the S-OPS sampled air represent 30-min intervals that will be matched with 30-min averages of turbulence and meteorological data to determine emissions with either the backward Lagrangian Stochastic (bLS) method or the ratiometric method. The 2-s averages of wind speed will be aligned with each set of five PIC for use in the RPM method to determine the NH_3 emission for each approximately 100-s period. The approximately 100-s emissions measurements will be averaged to the 30-min reporting periods. Emissions will be calculated based on the difference between downwind and background PICs. The background PIC (PIC_{bg}) will be the lowest concentration PIC among upwind beamlines. Both models will be uniquely configured for each measurement location prior to sampling.

Since the RPM emissions calculation for each side of the area source requires five valid PIC values for each side of the area source, there is a significant likelihood that at least one of the paths may be invalid sometimes due to various causes. Under these conditions, a bLS emissions calculation will be made using the 30-min average PIC for the (less than five) valid paths. The mean value of the calculated emissions for each valid PIC will represent the calculated emissions for that period of time.

13.7.1 bLS emissions calculation transformations

The bLS method is based on an inverse dispersion analysis. The WINDTRAX® model will be used to estimate the emissions of NH_3, H_2S, and various VOCs from 15- or 30-min average concentration measurements. The model uses turbulence data from the sonic anemometers and barometric pressure and air temperature measurements from the barometric pressure sensor and hygrometer respectively. WINDTRAX® simulates short-range atmospheric dispersion (for horizontal distances within about 1 km of the source) using a Lagrangian stochastic particle model. The simulation elements are represented by icons on a graphical interface showing a plan-view map with the location of sources and sensors at each location. Data files and the underlying numerical models are also represented by icons on the map. The model assumes that:

- The ground surface is horizontally homogeneous. Lagoons are water bodies of 100 m to 300 m on a side (criteria in this study) generally surrounded on two to three sides by cropland and one side by barns. Therefore the terrain does not have a homogeneous surface type. The location of the 2 m anemometer and meteorological tower are chosen when possible to be downwind of the lagoon (capturing the conditions of the modified air from the lagoon). As previously discussed, the upwind fetch is maximized but at least 1:10 (rise:run) for the 2 m above berm anemometer measurement height. The downwind fetch must be at least 1:3. A lagoon inner berm is usually at least approximately 1 m high while outer berms vary from flat with surrounding land to up to 3 m. These conditions will result in non-horizontal flow that will likely decrease the accuracy of the model and will be assessed in a verification study at the beginning of the project. Shifting wind

direction will change the turbulence characteristics as the incidence angle changes between the berm and the wind. This however should be measurable at least at the 2 m sonic anemometer location and will be partially expressed in the turbulence statistics used by the model. In addition, the measures of homogeneity and stationarity will provide useful information concerning these effects on the model emissions estimates. Changes in roughness will also influence the model estimates. As winds shift in direction, the upwind roughness will vary over the lagoon and basin relative to the upwind fetch conditions. These changes with direction will be consistent by location and over time may be resolvable from the wind profile information. This will be explored during the study but will be viewed as a source of error for the model estimates. While the distribution of cows will be variable in the corral, the dominant roughness components are not the animals but the shade structures and fences. Therefore it is anticipated that the roughness at the corral will be relatively constant.

- The source strength is homogeneous across the source area. Crusting and scum layers on the lagoon surface, manure intakes from the barns, and agitation associated with removal of waste for land application all will result in inhomogeneity of emission strength within the lagoon. Crusting and scum layers cannot be avoided and consequently introduce errors in the model emissions estimate. Inhomogeneities associated with the intakes are reduced by avoiding measuring the PIC near the intakes. Inhomogeneities associated with agitation are reduced by making measurements when manure removal events are not being made or excluding periods of time when the removals are made.
- Turbulence is homogeneous and stationary. These two conditions are tested using Equations 13.10 and 13.11.
- PIC measurements are contemporaneous. This condition is not strictly met, but can be assumed approximately true when considering individual 20-s PIC sampling intervals being averaged over the 30-min reporting periods.

Inputs to the model include each measured PIC, barometric pressure, air temperature and calculated statistics of the wind (σ_u/u_*, σ_v/u_*, σ_w/u_*) and mean u, v, w for each 15 or 30 min sampling period. Detailed description of the model is found in SOP O1.

In general, the program calculates the emission rate (Q_{obs}) corresponding to the measured background ($C_{obs,bg}$) and downwind (C_{obs}) beamline-averaged concentrations based on the assumption that ($C_{obs} - C_{obs,bg}$) / Q_{obs} is only a function of atmospheric conditions. For the measured atmospheric conditions, this ratio is determined by using the bLS model to simulate the flight path of air parcels backwards from the beamline until each parcel intersects the ground (a 'touchdown'). The modelled ratio is given as C_{sim} / Q_{sim} , where C_{sim} is the simulated averaged beamline concentration and Q_{sim} is the simulated source strength corresponding to this simulated concentration. The actual emission rate (Q_{obs}) is calculated using:

$$Q_{obs} = \frac{(C_{obs} - C_{obs,bg})}{\left[C_{sim} / Q_{sim}\right]} \qquad \text{(Equation 13.14)}$$

To determine the relationship between C_{sim} and Q_{sim}, the model simulates the flight path of air parcels backwards from the beamline until each parcel intersects the ground (a 'touchdown'). The velocity of each air parcel is varied during each modeling time step Δt according to:

$$\Delta u_k = \alpha_k \Delta t + \beta_k P_k \qquad \text{(Equation 13.15)}$$

where k is a directional indicator, $\beta_k = (4.41\varepsilon)^{0.5}$ implying a Schmidt number of 0.64 at neutral stability, P_k is a Gaussian random number from a population with mean zero and variance Δt, and α_k is a function of turbulence statistics. The location of each parcel ($x_k(u_1, u_2, u_3)$ = x, y, z directions) is then calculated as:

$$\Delta x_k = u_k \Delta t \qquad \text{(Equation 13.16)}$$

iteratively for a large number of cycles. At some time, all parcels will impact the surface. The location of intersection of the parcel with the surface is determined and the vertical velocity at impact with the surface (w_0) is recorded. Parcels rebound from the surface. If the parcel impacts the surface within the source domain area, then it contributes to the flux. If it does not impact the surface within the source domain, then the parcel does not contribute to the flux.

The model calculates "touchdown catalogs" of x, y, and w_0 for each concentration measurement point j along the beamline. The number of impacts within the source domain, weighted by w_0 and divided by the number of parcels (n) released from P equidistant points along each beamline, each with concentration C_{sim}, provides the ratio C_{sim} / Q_{sim} for the concentration measurement height:

$$a_{sim} = \frac{\mathrm{C_{sim}}}{\mathrm{Q_{sim}}} = \frac{1}{P}\sum_{j=1}^{P}\left(\frac{1}{\mathrm{n}} \sum_{\text{within source area}} \frac{2}{|w_0|}\right) \qquad \text{(Equation 13.17)}$$

The PIC values (units of ppm-m) are converted to beamline-averaged volume concentrations (c_{obs} and $c_{obs,bg}$, with units of ppm) by dividing by the corresponding instrument pathlength. Mass concentrations (C_{obs} and $C_{obs,bg}$ with units of mg/m^3) are obtained by taking into consideration the molecular weight of the target gas, atmospheric pressure and the ambient temperature(Equations. 13.1- 13.3). The final emission rate, (Q_{obs}) , in units of kg/m^{2}s, is calculated as:

$$Q_{obs} = \frac{C_{obs} - C_{obs,bg}}{a_{sim}}\left(\frac{1\,kg}{1{,}000{,}000\,mg}\right) \qquad \text{(Equation 13.18)}$$

13.7.2 RPM emissions calculation transformations

The Radial Plume Mapping (RPM) method of measuring NH_3 emission from an open source maps the vertical and horizontal shape of the downwind plume through the measurement plane. The NH_3 PIC used in the plume cross-section reconstruction are made using the TDLAS open path system. The model assumes that:

- The ground surface is horizontally homogeneous. Lagoons are water bodies of 100 m to 300 m on a side (criteria in this study) generally surrounded on two to three sides by cropland and one side by barns. Therefore the terrain does not have a homogeneous surface type. The locations of the 2 m anemometer and meteorological tower are chosen when possible to be downwind of the lagoon (capturing the conditions of the modified air from the lagoon). As previously discussed, the upwind fetch is maximized but at least 1:10 (rise:run) and a downwind fetch of at least 1:3 for the minimum 2 m above berm PIC and 2 m above berm height anemometer measurement height. A lagoon inner berm is usually at least approximately 1 m high while outer berms vary from flat with surrounding land to up to 3 m. This results in non-horizontal flow that will likely decrease the accuracy of the model and will be assessed in a verification study at the beginning of the project. Since the flow is not expected to be horizontal but is assumed horizontal, the deviation from horizontal flow is an uncontrollable source of error in the RPM model.
- PIC measurements are contemporaneous. The PIC measurements are sequential, requiring approximately 100 s for a complete vertical plane scan along one side of the lagoon.

Inputs to the model include the coordinates for each beamline path, the 2-s mean horizontal wind components at three heights (from sonic anemometers: SOP W2), and mean PICs for each measurement plane over the approximate 100-s sampling period (Figure 10.3). The horizontal wind component measurements will be matched to the time required for each scan cycle.

The RPM configuration reconstruction technique utilizes a two-dimensional smooth basis function minimization (SBFM) to reconstruct the smoothed mass equivalent concentration map (bivariate Gaussian). Because our interest is in the plane-integrated concentration, and subsequently the flux through the plane and not the exact map of concentrations in the plane, only one smoothed basis function (one bivariate Gaussian) is fitted to reconstruct the smoothed map. For the beam geometry, it is convenient to express the smooth basis function *G* in polar coordinates (pathlength *r* and inclination angle θ) as:

$$G(r,\theta)=\frac{A}{2\pi\sigma_y\sigma_z\sqrt{1-\rho_{12}^2}}\exp\left\{-\frac{1}{2\left(1-\rho_{12}^2\right)}\left[\frac{(r\cdot\cos\theta-m_y)^2}{\sigma_y^2}-\frac{2\rho_{12}\left(r\cdot\cos\theta-m_y\right)\left(r\cdot\sin\theta-m_z\right)}{\sigma_y\sigma_z}+\frac{\left(r\cdot\sin\theta-m_z\right)^2}{\sigma_z^2}\right]\right\} \quad \text{(Equation 13.20)}$$

with six unknown independent parameters:

A= normalizing coefficient which adjusts for the peak value of the bivariate surface;

ρ_{12}=correlation coefficient which defines the direction of the distribution-independent variations in relation to the Cartesian directions y and z (ρ_{12}=0 means that the distribution variations overlap the Cartesian coordinates);

m_y and m_z= peak locations in Cartesian coordinates; and

σ_y and σ_z = standard deviations in Cartesian coordinates. To fit the unknown parameters of the smooth basis function to the PIC data, one has to define an error function for minimization.

The bivariate Gaussian function can be resolved with four independent beam paths when we assume: (1) that the reconstructed bivariate Gaussian is limited only to changes in the vertical and crosswind directions (forcing the correlation parameter ρ_{12} equal to zero), and (2) that the height of the peak concentration is at the ground level making m_z zero.

A two-phase SBFM approach to solving the reduced bivariate Gaussian is used. First a one-dimensional SBFM reconstruction procedure is applied to reconstruct the smoothed ground level and crosswind concentration profile. Then, the reconstructed parameters are substituted into the bivariate Gaussian function before applying the two-dimensional SBFM procedure. The one dimensional SBFM reconstruction is applied to the ground level segmented beam paths (Figure 10.1) of the same beam geometry to find the cross wind concentration profile (Hashmonay and Yost 1999b). A Gaussian function is fitted to measured PIC ground level values as a univariate function. The error function for the Simplex minimization procedure is the Sum of Squared Errors (SSE) function defined as:

$$SSE(B, m_y, \sigma_y) = \sum_i \left(PIC_i - \frac{B}{\sqrt{2\pi}\sigma_y} \int_0^{r_i} \exp\left[-\frac{1}{2}\left(\frac{m_y - r}{\sigma_y} \right)^2 \right] dr \right)^2 \qquad \text{(Equation 13.21)}$$

where B is equal to the area under the one dimensional Gaussian distribution (integrated concentration), r_i is the pathlength of the ith beam, m_y is the mean peak location and σ_y is the standard deviation of the Gaussian function. PIC_i is the measured path integrated concentration value of the ith path.

Substituting the solved values of the standard deviation σ_y and peak location m_y of the above one-dimensional SBFM procedure into the bivariate SBFM simplified by the assumptions yields:

$$G(A, \sigma_z) = \frac{A}{2\pi\sigma_y\sigma_z} \exp\left\{ -\frac{1}{2}\left[\frac{(r \cdot \cos\theta - m_y)^2}{\sigma_y^2} + \frac{(r \cdot \sin\theta)^2}{\sigma_z^2} \right] \right\} \qquad \text{(Equation 13.22)}$$

which is solved by minimizing the SSE using the simplex procedure with PIC values for the one long beam along the ground level and the two elevated beams that sample the vertical concentration gradient according to:

$$SSE(A, \sigma_z) = \sum_i \left(PIC_i - \int_0^{r_i} G(A, \sigma_z) dr \right)^2 \qquad \text{(Equation 13.23)}$$

Once the parameters of the function are found for a specific run, the RPM procedure calculates the concentration values for every square elementary unit in a vertical domain. Then, the RPM procedure integrates the values, incorporating wind speed data at each height level to compute the flux according to Equation 13.24. The emission rate Q in units of g/(s m^2) is computed using linear interpolations and extrapolations of the wind profile from the surface to 20 m derived from the three wind sensors (SOP W2 and SOP U5) as:

$$Q = \frac{\sum_{y=0}^{pathlength} \sum_{z=0}^{20m} (C_{y,z})\hat{u}_z}{S} \qquad \text{(Equation 13.24)}$$

where S is the source surface area (m^2).

The flux across each measurement plane is calculated separately with fluxes away from the source (downwind plane) as positive values and fluxes towards the source (upwind plane) as negative values. The net flux from or to the source area is determined by adding the fluxes computed for the four measurement sides of the area source. More than one side may represent an upwind or downwind plane.

When the upwind plane is at ambient background concentration (C_{bg}), the concentrations derived from the measured PICs are likely to be nearly identical. Under these conditions, the flux across the upwind plane will not be computed by the RPM method (since the lack of a gradient in concentration will fail the DQI for the method), and the emission rate will be computed according to:

$$Q = \frac{\sum_{y=0}^{pathlength} \sum_{z=0}^{20m} (C_{y,z} - C_{bg})\hat{u}_z}{S} \qquad \text{(Equation 13.25)}$$

where the computed RPM plane is downwind of the source.

13.7.3 Ratiometric VOC emissions computation

The VOC emissions of THC, MeOH, EtOH, and CH_4 will be estimated based on the respective PAS VOC concentration measurements in conjunction with the NH_3 emission measurement derived from the RPM method (Figure 10.3). The NH_3 PIC values (units of ppm-m) are converted to beamline-averaged volumetric concentrations by dividing by the corresponding instrument pathlength. These concentrations are then converted to units of mg/m^3 by taking into consideration the molecular weight of the target gas, atmospheric pressure and the ambient temperature. The emission of a given VOC is determined from these values according to:

$$Q(VOC) = Q_{RPM}(NH_3)\frac{C_{S-OPS/INNOVA}(VOC)}{C_{TDLAS}(NH_3)} \qquad \text{(Equation 13.26)}$$

where C_{TDLAS} refers to concentration associated with the shortest TDLAS beamline nearest the S-OPS. Emissions of total non-methane VOC will be determined by addition of *Q(EtOH)* and *Q(EtOH)* to *Q(THC).*

13.7.4 Ratiometric H_2S emissions computation

If the bLS emissions method is invalidated (not meeting DQI) and the RPM emissions calculation is not invalidated, the NH_3 emissions calculation from the RPM method will be used to estimate H_2S emissions. The H_2S emissions will be estimated based on the respective S-OPS/PFA H_2S concentration measurement and nearest TDLAS NH_3 PIC measurement in conjunction with the emission measurement derived from the RPM method (Figure 10.3). The PIC values (units of ppm-m) are converted to beamline-averaged volumetric concentrations by dividing by the corresponding instrument pathlength. These concentrations are then converted to units of mg/m^2 by taking into consideration the molecular weight of the target gas, atmospheric pressure and the ambient temperature. The emission is determined according to:

$$Q(H_2S) = Q_{RPM}(NH_3)\frac{C_{S-OPS/PFA}(H_2S)}{C_{TDLAS}(NH_3)} \qquad \text{(Equation 13.27)}$$

Restrictions on the use of the ratiometric model utilizing S-OPS-sampled air and open path integrated air sampling are:

1) The S-OPS path and corresponding TDLAS path are equivalent such that the path along which the NH_3 PIC values are measured and the S-OPS air is sampled are equal. This requires that the two paths are separated by a distance much less than the averaging period divided by the mean wind speed perpendicular to the paths.
2) The S-OPS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. Sampling of the upwind and downwind S-OPS paths will be sequential with each path sampled over a 30-min interval, with each 30-min period synchronized with the corresponding TDLAS path measurements.

13.8 Lagoon/basin characterization

In situ measurements of the lagoon/basin will be used to monitor the conditions during the broadband (UV-DOAS) and narrowband (TDLAS) spectroscopy described above. Measurements will be averaged over 30-min intervals. Waste storage temperature (SOP L2), redox state (SOP L3), and pH (SOP L1) will be measured. No corrections or transformations to the measurements are needed. Basin manure pH (SOP M2), total nitrogen (SOP M4), ammonia nitrogen (SOP M5) and total and volatile solids content (SOP M3) will be determined by a

commercial laboratory (Midwest Laboratories, Inc.) from samples collected at the beginning or end of each measurement period. Specifics for the manure sampling procedures are found in SOP M1 and the appropriate SMP. Samples will be stored and shipped at <4°C with sample to analysis time of at most one week. During each site visit, photographs of the lagoon/basin will be taken to document the extent and locations of scum and crust.

The number and types of QC samples used by the laboratory are documented by the Laboratory QA/QC Manual. Laboratory SOPs align with Methods 9040C (pH measurement), 1684 (total and volatile solids), 1687 and 350.2 (total and ammonia nitrogen).

13.9 Corral characterization

Manure from the corral will be collected and tested for pH, total solids content, and ammonia nitrogen every measurement period. Manure pH (SOP M2), ammonia nitrogen (SOP M5) and total and volatile solids content (SOP M3) will be determined by a commercial laboratory (Midwest Laboratories, Inc.). Specifics for the manure sampling procedures are found in SOP M1 and the appropriate SMP. Samples will be stored and shipped at <4°C with sample to analysis time of at most one week.

The number and types of QC samples used by the laboratory are documented by the Laboratory QA/QC Manual. Laboratory SOPs align with Methods 9040C (pH measurement), 1684 (total and volatile solids), 1687 and 350.2 (Total and ammonia nitrogen).

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14. Quality Control Requirements

In order to insure the validity of the data generated from the study and meet the data quality objectives set forth by the study it is imperative to establish quality assurance and quality control measures in each aspect of the study. Quality control involves the evaluation of instrument performance by comparison to measurement standards or through the use of QC checks. Quality assurance includes the use of properly maintained and reliable instrumentation, approved analytical methodologies and standard operating procedures and well-trained analysts. Copies of QC records, including control charts (Standard Operating Procedure for Use of Control Charts for Performance Monitoring of Gas Analyzers and Analytical Instruments; SOP Q1) for gas analyzers, will be added as appendices to the final report as well as the interim quarterly reports as appropriate.

14.1 QC checks of meteorological measurements

QC checks vary by measurement and are specified in detail in the corresponding SOP. The frequency of each check described in the applicable SOP is summarized in Table 14.1. The results of these checks are documented on forms illustrated in the respective SOP (and Appendix D). The criteria for QC check acceptance and corrective actions are also documented in the respective SOP and the appropriate Tables A1 through A6 in Appendix A. All 100 s and 5-min checks are conducted within the sensor with results included in the data stream. 30-min and daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS and documented on forms similar to those at the end of each respective SOP (and in Appendix D). Checks made every 180 d are made at PAML by FOS and documented on forms similar to those at the end of each respective SOP (and in Appendix D). Where applicable, control charts will be maintained for the calibration verification and calibration of each sensor.

Spikes in the wind speed measurements are defined as instantaneous values that exceed three standard deviations from the 100-s running mean value. Checks on the turbulent components of the wind and the temperature fluctuations cannot be made directly. The quality of the wind turbulence will be checked daily through evaluating the spectral structure of the turbulence near solar noon and intercomparisons of the measurements made at the three heights. The quality of T_v' will likewise be checked using the spectral structure.

Table 14.1 Quality control (QC) checks for meteorological sensors.

Meteorological variable	100 s	5 min	30 min	Daily	Beginning and end of each measurement period	180 d	Annual	SOP
Wind speed (horizontal)	Spikes, Path obstruction check	Spikes, Path obstruction check	Comparison with NWS measurement	NA	In-field intercomparison Zero check	Unused triad inter-comparison		W2
Turbulent wind components u', v', w	Spikes, Path obstruction check	Spikes, Path obstruction check	Stationarity check Homogeneity check	Spectral structure check	In-field intercomparison Zero check	Unused triad inter-comparison		W2
'Sonic' air temperature	Spikes, Path obstruction check	Spikes, Path obstruction check	Comparison with computed T_v	NA	In-field intercomparison	Unused triad inter-comparison		W2
Temperature fluctuations in 'sonic' temperature	Spikes, Path obstruction check	Spikes, Path obstruction check	Stationarity check Homogeneity check	Spectral structure check	In-field intercomparison	Unused triad inter-comparison		W2
Ambient temperature	NA	NA	Comparison of computed T_v with 'sonic' air temperature and NWS measurement	NA	NA		Lab calibration with NIST-traceable standard	W1
Ambient humidity	NA	NA	Comparison with NWS measurement	NA	NA		Lab calibration with NIST-traceable standard	W1
Barometric pressure	NA	NA	Comparison with NWS measurement	NA	NA	Lab calibration with NIST-traceable standard		W5
Solar radiation	NA	NA	NA	NA	NA		Lab calibration with NIST-traceable unused sensor	E3

14.2 QC checks of lagoon/basin characterization

QC checks vary by measurement and are specified in detail in the corresponding SOP. The frequency of each check described in the applicable SOP is summarized in Table 14.2. Control charts will be maintained for the calibration verification and calibration of each sensor. Acceptance criteria and corrective actions are documented in the respective SOP and Tables A7 through A10 in Appendix A.

Table 14.2 Quality control (QC) checks for lagoon/basin characterization sensors.

Sensor	Beginning and end of each measurement period	180 d	Annual	SOP
Redox state	Calibration verification		Lab calibration with NIST-traceable standard	L3
Temperature	NA	Lab calibration with NIST-traceable standard		L2
pH	Calibration verification		Lab calibration with NIST-traceable standard	L1
Depth finder		Lab calibration		L5

The NIST-traceable pH and redox probe standards will be purchased at the same concentration as is used in the respective calibration procedures (SOP L1, L3). No dilutions or solution preparation is necessary.

Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. Results of beginning/end of measurement period and 180-d checks are documented on forms illustrated in SOP L1, L2, L3, and L5 and illustrated in Appendix D.

14.3 QC checks of Open Path UV-DOAS

Currently there are no EPA guidance documents available that specifically address QC checks for broadband UV spectroscopy. But because these systems operate in a similar manner as infrared air monitoring systems, we can borrow from the vast array of documentation for these air monitors. The open path UV-DOAS to be used is a bistatic broadband spectral absorption instrument designed to measure the concentration of various constituents (for this study, primarily NH_3 and H_2S) in the open air along a path of at least 50 m.

QC procedures, acceptance criteria and corrective actions for the UV-DOAS are documented in SOP C1 and Table A12 and A13 of Appendix A. They include the following:

- *Dark Current Correction Check*: Charged diode array spectrometers build up a charge over time that is independent of the actual light being detected. This charge buildup is defined as “dark current” and must be subtracted from each single beam spectra before data is analyzed. This performance audit is automatically conducted by the Cerex UVS software.
- *Baseline stability check*
- *Single beam ratio test*: The single beam ratio test for an open-path UV system is a fast and easy check on whether the UV Source is adequate for gas measurement. A weak UV source will produce data with low signal to noise ratios.
- *Precision and accuracy checks using single point calibration checks in the field and multiple point calibration checks in the lab.* TO-16 does not give a definitive test method

for determining the precision and accuracy of open-path instruments. However, the document does suggest that if an instrument is designed in a manner that all of the light beam can pass through an external cell that is placed in the instrument's beam path, a flow-through cell can be used to measure precision and accuracy. The UV-DOAS system precision and accuracy are determined using an external calibration cell in its beam path. Calibration verifications will be made using 50 ppm NH_3 in N_2 (±1% traceable to NMi standard) and 50 ppm H_2S in N_2 (±1% traceable to NIST). Zero and span are also checked.

- *Spectral Feature Match Check*: Comparison of reference table and measured peak location of Benzene calibration 'lollipop'.

The frequency of each QC procedure is listed in Table 14.3. All results of end of measurement period and 180 d QC checks are reported on a form illustrated in SOP C1. Control charts will be maintained for the calibration verification and calibration of each sensor.

All checks made throughout the sampling duration will be conducted within the sensor and reported in the output data stream for inspection at PAML on the day following the measurements. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. Results of beginning/end of measurement period and 180 d checks are documented on forms illustrated in SOP C1.

Table 14.3 QC checks for open-path concentration measurement sensors.

Sensor	Every Sample	Daily	Beginning and end of each measurement period	180 days	SOP
UV-DOAS- NH_3 and H_2S	Baseline stability Obstruction check Dark current	Single beam ratio Baseline stability	Spectral feature check with NIST traceable (H_2S) or vendor-certified FTIR-checked standards. Single point calibration verification with NMi-traceable gases.	Multipoint calibration with NIST traceable (H_2S) or vendor-certified FTIR-checked standards.	C1
TDLAS- NH_3	Obstruction check Linearity (every 100 samples)		Single point calibration verification with lab-checked gases.	Multipoint calibration with lab-checked gases	C2

14.4 QC checks of Open Path TDLAS

Currently there are no EPA guidance documents available that specifically address QC checks for TDLAS systems. However, as with the UV-DOAS systems, the TDLAS system operates in a similar manner as infrared air monitoring systems, so we can borrow from the documentation established for these air monitors. The open path TDLAS to be used is a monostatic narrowband

spectral absorption instrument designed to measure the concentration of NH_3 in the open air along a path of at least 50 m. The instrument is mounted on a scanner and tripod with data processing and control through a computer.

Quality control procedures, acceptance criteria and corrective actions for the TDLAS are documented in SOP C2 and Table A11 in Appendix A. They include the following:

- *Single point calibration check:* Precision and accuracy can be checked using an external calibration cell. Calibration verifications will be made using 100 ppm NH_3 in N_2 (±1%, verified with FTIR). A zero and span check of the instrument is possible using the permanent stable calibration cell by tuning the instrument off and on the NH_3 absorption line following procedures described in the SOP.
- *Multipoint calibration check:* Because the anticipated gas concentrations are expected to span a few orders of magnitude, the assumptions of Beers Law do not hold and a calibration curve needs to be generated to compensate for the large differences between the reference spectra and the data spectra (as suggested by TO-16). Thus a three-point calibration spanning the anticipated concentration range is needed.
- Internal performance audits performed by the software include:
  - *Internal linearity check*: The internal linearity check involves a comparison of the sample waveform and the reference waveform. The sample waveform is of the returning laser signal after it has passed through the sample gas, the receiver converts it to the shape of a specific waveform or curve. These waveforms are digitized and compared (Figure 14.1) using Least Squares Regression analysis.

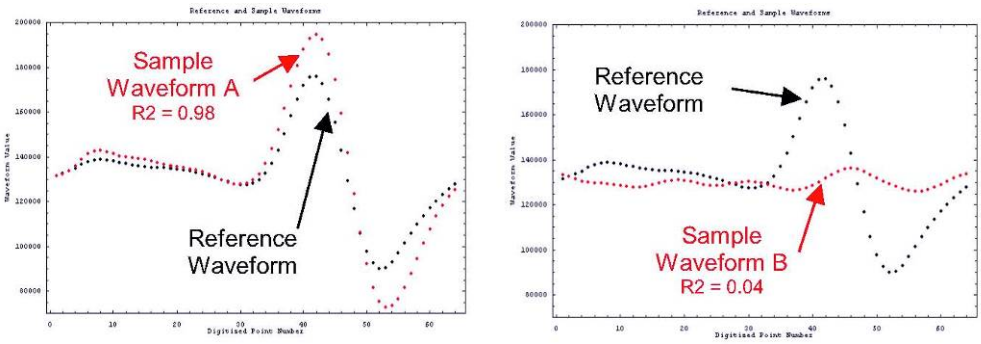

Figure 14.1 Waveform alignment of TDLAS. A good (left) and poor (right) fit of the reference gas and sample gas are illustrated.

The regression, indicated in Figure 14.2, illustrates the fit of the sample gas to reference gas. With low levels of sample gas, the R^2 between concentration and sensor response decreases, and equal zero when there is no gas present. As the signal from the gas becomes stronger, the effect of noise, both electronic and optical, is reduced and the R^2 will increase (i.e., the signal to noise ratio will increase). Based on company-derived data generated in the laboratory under controlled conditions, measurement accuracy has been found to correspond to the R^2 values- an R^2 of about 0.83 corresponds to a +/-10% accuracy (Table 14.3.1).

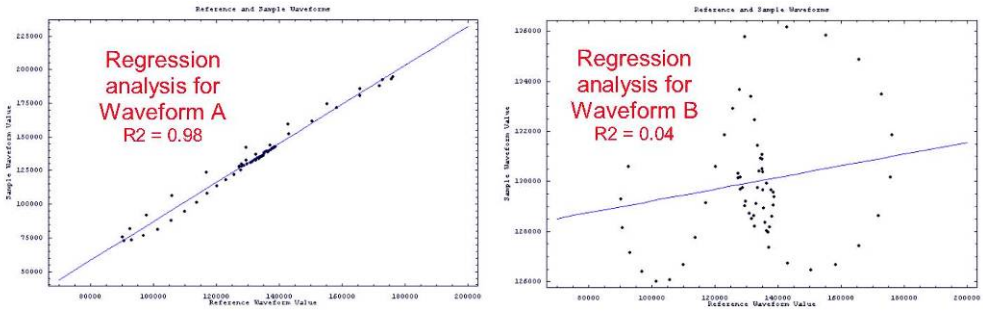

Figure 14.2 Regression analysis of TDLAS waveform measurements in Figure 14.1. The blue line represents the Linear Least Squares fit of the data.

Table 14.3.1 Correspondence of R^2 to measurement accuracy for NH3.

R^2	Accuracy
>90	+/- 2 %
80	+/- 13 %
70	+/- 24 %
60	+/- 35 %
50	+/- 46 %
40	+/- 57 %
30	+/- 67 %
20	+/- 78 %
10	+/- 89 %
0	+/- 100 %

The frequency of each QC procedure is listed in Table 14.3. Sampling Duration checks are made internally and reported in the data stream for evaluation at PAML on the day following the measurement day. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. Results of beginning/end of measurement period and 180-d QC checks are reported on a form illustrated in SOP C2. Control charts will be maintained for the calibration verification and calibration of each sensor.

14.5 QC checks of photoacoustic spectrometer method

All QC checks and acceptance criteria for the INNOVA 1412 photoacoustic multi-gas analyzer are documented in SOP G7 and itemized in Table 14.4. Acceptance criteria and corrective actions are also documented in Tables A14 through A18 in Appendix A. Value reasonableness is

assessed initially by the range of values documented in the literature. As measurements progress and histories of each parameter at each location are developed, the reasonableness of the value will be based on the value falling within the 95th percentile of the record at that location. If values fall outside the reasonable range, careful inspection of other measurements at that time will be conducted.

Calibration verifications will be made using NIST-certified EPA Protocol grade (EtOH, MeOH, methane, propane) or vendor-certified Primary Standard grade (NH_3) gases. The compositions of NH_3 cylinders used for gas analyzer calibrations will be checked using Fourier Transform Infrared (FTIR) spectroscopy, in accordance with SOP G12. If the NH_3 concentrations obtained by the FTIR check are not within ±5% of those certified by the gas provider, the gas provider will be contacted for further verification or re-certification, if necessary. Calibration verification gases include: 500 ppm NH_3 in N_2 (±1) diluted to 50 ppm, 1 ppm MeOH and 1 ppm MeOH in N_2 (± 10% accuracy), 50 ppm propane and 10 ppm methane in N_2 (±1% accuracy traceable to NIST standard) diluted to 5 ppm propane and 1 ppm methane.

Table 14.4 QC checks for photoacoustic spectrometer measurements.

Parameter	Every Sample	Beginning and end of each measurement period	180 days
NH_3 concentration		Single point calibration verification with primary standard gas	Multi-point calibration with primary standard
MeOH concentration		Single point calibration verification with lab-certified standard gas	Multi-point calibration with NIST-certified gases
EtOH concentration		Single point calibration verification with NIST-certified standard gases.	Multi-point calibration with NIST-certified gases
Methane concentration		Single point calibration verification with NIST-certified standard gases	Multi-point calibration with NIST-certified gases
THC concentration		Single point calibration verification with NIST-certified standard gases	Multi-point calibration with NIST-certified gases
Water vapor		Single point calibration verification	NIST-certified humidity calibrator
Response time			Measure using NIST-certified gases
Inlet flow rate	Measure		Measure with NIST-traceable flow meter
Perform leak check			Sample line, flow components and fittings

With every sample, checks are made internally and reported in the data stream for evaluation at PAML on the day following the measurement day. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d

are made at PAML by FOS. The frequency of each QC check is indicated in Table 14.4. Control charts will be maintained for the calibration verification and calibration of each sensor.

14.6 Lineage of Traceable Standards

All gases used in verification and calibration procedures are traceable to either a NIST standard reference material, or to EPA primary standard grade gases verified by FTIR, through a Certified Reference Material. All blending of the analytical gas with N_2 is traceable to a NIST standard by weight. NIST traceable calibration/verification gases include:

- 300 ppm and 4 ppm H_2S in N_2 or air at 3% accuracy
- 10 ppm methane and 50 ppm propane in N_2 at 1% accuracy
- 1 ppm MeOH and 1 ppm EtOH in N_2 at 10% (0.1 ppm) accuracy
- 40 ppm SO_2 in air at 2% accuracy

Primary standard calibration/verification gases include 500 ppm NH_3 in N_2 at 1% accuracy and 1000 ppm NH_3 in N_2 at 2% accuracy.

Standard solutions for pH and redox potential measurements will be traceable to certified NIST standards: pH solutions include pH 4 (potassium biphthalate using Standard Reference Material 185h), pH 7 (potassium phosphate using Standard Reference Material 186-I-g) and pH 11 (sodium borate using Standard Reference Material 187d) standards traceable to NIST, and 230 mV ZoBell's solution standard.

One of the two calibration check methods for the relative humidity sensor (SOP W1) require lithium chloride and potassium sulfate salt packets certified by the Vaisala Oy's Measurement Standards Laboratory which is accredited by Finnish Accreditation Service (FINAS), a member of the European Cooperation for Accreditation of Laboratories.

Table 14.5 QC checks for pulsed-fluorescence H_2S analyzer measurements.

Parameter	**Every sample**	**Beginning and end of each measurement period**	**180 days**
H_sS concentration		Single point calibration verification with NIST-traceable standard gas Multi-point calibration with NIST-certified gases if verification test shows zero deviation of > ±5% full scale from baseline zero or precision shows deviation of > ±10% from baseline	Multi-point calibration with NIST-certified gases
Inlet flow rate	Sample flow rate	Filter check	Leak check
Lamp function	Sample intensity and voltage		

14.7 QC checks of pulsed fluorescence method

All QC checks and acceptance criteria for the TEC 450i pulsed fluorescence H_2S analyzer are documented in SOP G7 and itemized in Table 14.5. Acceptance criteria and corrective actions are also documented in Table A25_in Appendix A. Value reasonableness is assessed initially by the range of values documented in the literature. As measurements progress and histories of each parameter at each location are developed, the reasonableness of the value will be based on the value falling within the 95th percentile of the record at that location. If values fall outside the reasonable range, careful inspection of other measurements at that time will be conducted. Calibration verification gas is 4 ppm H_2S in N_2 or air (±3% traceable to NIST standard) in trailers and at PAML.

With every sample, checks are made internally and reported in the data stream for evaluation at PAML on the day following the measurement day. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. The frequency of each QC check is provided in Table 14.5. Control charts will be maintained for the calibration verification and calibration of the analyzer.

14.8 QC checks of S-OPS and GSS sampling method

All QC checks and acceptance criteria for the S-OPS and GSS system are documented in SOP C4 and itemized in Table 14.6. Acceptance criteria and corrective actions are given in SOP C4.

With every sample, checks are made internally and reported in the data stream for evaluation at PAML on the day following the measurement day. Daily checks will be conducted using computers at PAML on the day following measurements. Checks at the beginning and end of each measurement period (or 21 d) are conducted on-location by FOS. Checks made every 180 d are made at PAML by FOS. The frequency of each QC check is indicated in Table 14.6.

Table 14.6 QC checks for S-OPS and GSS sampling.

Parameter	**Every Sample**	**Beginning and end of each measurement period**	**180 days**
Chamber pressure	Measure		
Chamber flow direction	Measure		Flow direction test
Sampling flow rate	Measure	S-OPS flow check	
Sample integrity		S-OPS and GSS leak checks	

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15. Instrument/Equipment Testing, Inspection, and Maintenance

All equipment will be purchased new. Each site visit will start with a physical inspection of the instrument conditions. Particular attention will be made to looking for damage to wires, dirt and dust on sensors, lightning and other surge damage to sensors, moisture penetration into instruments, and ice and wind damage to instruments and platforms. The results of the physical inspection will be documented in a logbook and scanned for ftp transmission. Acceptance criteria and corrective actions for equipment inspections are indicated in the respective SOP. An example maintenance list for an entire measurement site is in Appendix D and documented in SOP W6, SOP U5, and SOP U7.

15.1 *Meteorological and lagoon/basin characterization equipment*

At each site visit (at least at the beginning and end of each measurement period), the field operator will conduct visual inspections of the meteorological equipment according to SOP W6. Preventive maintenance will occur at the beginning or end of each measurement period (approximately every 21 d) with appropriate documentation and reporting. Particular attention will be made to the lagoon/basin measurement sensors as they will routinely become fouled by wastewater. See SOP L1, L2, and L3 for procedures related to cleaning measurement sensors.

15.2 *Open path UV-DOAS and TDLAS*

At each site visit (at least at the beginning and end of each measurement period) the field operator will conduct visual inspections of the alignment of each beamline and each mirror will be checked for water condensate and dried as needed. All equipment will be properly maintained and tested at the beginning and end of each approximately 20-d sampling period to ensure they are functioning properly in accordance with the manufacturer's recommended intervals and acceptance parameters. Maintenance procedures related to keeping windows and optics clean, replacing lamps, cleaning filters and other aspects of maintaining instrument upkeep are itemized in the respective manuals and SOPs C1 and C2.

15.3 *Photoacoustic multi-gas analyzer*

At each site visit (at least at the beginning and end of each measurement period) the field operator will conduct a visual inspection of the gas sampling head, pump, and analyzer. Obstruction to air flow will be cleared, All equipment will be properly maintained and tested at the beginning and end of each approximately 20-d sampling period to ensure they are functioning properly in accordance with the manufacturer's recommended intervals and acceptance parameters. Maintenance procedures related to cleaning air inlet filter and other aspects of maintaining instrument upkeep are itemized in the respective manuals and SOP G7.

15.4 *Pulsed fluorescence analyzer*

At each site visit (at least at the beginning and end of each measurement period), the FOS will conduct a visual inspection of the gas sampling tube filter, pump, and analyzer. Obstructions to air flow will be cleared, and all equipment will be properly maintained and tested at the beginning and end of each approximately 20-d sampling period to ensure they are functioning properly in accordance with the manufacturer's recommended intervals and acceptance parameters. Maintenance procedures related to replacing air inlet filters and other aspects of maintaining instruments are itemized in the respective manuals and SOP G5.

15.5 *GSS and S-OPS*

At each site visit (at least at the beginning and end of each measurement period), the FOS will conduct a visual inspection of the gas sampling tubes, inlet filters, and pumps. Obstructions to air flow will be cleared and filters replaced as indicated. All equipment will be properly maintained and tested at the beginning and end of each approximately 20-d sampling period to ensure they are functioning properly in accordance with SOP C4. Maintenance procedures for replacing air inlet filters and other aspects of maintaining instruments are itemized in SOP C4.

References

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SOP U7. 2006. Installation of Open Source Measurement Equipment (Corrals). Standard Operating Procedure U7. Purdue Applied Meteorology Lab.

SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

16. Instrument / Equipment Calibration and Frequency

Quality assurance of the measurements includes performance and technical systems audits. Calibration and performance audits are needed to maintain the quality of measurements and will be carefully tracked for each instrument. Calibration and performance audit records will document: date, instrument, serial number of instrument being calibrated and standard instrument being calibrated against, name of person performing calibration, calibration procedure used, problems encountered and the statistics of the before and after measurements made during the calibration. No adjustments to the instrument will be made in response to the calibrations. All calibration records will be maintained by the PQAM. Logbooks indicating the calibration activity are maintained in each trailer and images of the pages will be stored by the PDM in location-specific data directories.

16.1 *Meteorological equipment*

On receipt from the manufacturer, the wind, solar radiation, relative humidity, liquid temperature, air temperature and atmospheric pressure sensors will have their calibration verified in the laboratory using the performance audit procedures described in the respective SOP and summarized Table 16.1.

Table 16.1 Performance audit procedures for the meteorological equipment.

Meteorological sensor	**Audit performed**	**Method**
Wind speed (horizontal)	Signal	Comparison with three NIST-traceable (mean wind speed only) collocated *in-situ* sensors
Wind direction	Response	Comparison with three NIST-traceable (mean wind speed only) collocated *in-situ* sensors
Wind direction	Mounting configuration	Comparison with compass direction
Ambient temperature	Response	Comparison with NIST-traceable mercury thermometer in confined air
Humidity	Response	Salt solutions or dew point generator
Barometric pressure	Response	Comparison with Fortin barometer
Solar Radiation	Response	Comparison with NIST-traceable unused sensor under ambient environmental conditions

Relative humidity sensors (SOP W1) will be audited either using saturation salts according to procedures defined in ASTM E104 or using a dew point generator at PAML. Temperature sensors (SOP W1) will be audited at PAML. Atmospheric pressure sensors (SOP W5) will be audited against a Fortin barometer at PAML according to procedures stated in the *Manual of*

Barometry. Solar radiation sensors (SOP E3) will be intercompared with an unused sensor at PAML.

In general, the quality of sonic anemometer turbulence measurements can only be assessed by side by side comparisons. Wind tunnel calibration (which is NIST traceable and provided by the manufacturer) provides only an evaluation of the mean wind and not the turbulent components and the turbulence in a wind tunnel is not sufficient to evaluate the response of the sonic anemometer to turbulence. Therefore all performance audits of sonic anemometers will rely on intercomparisons (Table 16.1). The three-dimensional sonic anemometers will be inter-compared with three NIST-traceable unused sensors (termed a triad) at the Purdue Weather Station open field facility every six months. Details concerning the intercomparison are documented in SOP W2.

Field performance audits will be performed prior to installation of the equipment at each location and only units that "pass" the performance audits will be installed. The "fail" unit will then be returned to the manufacturer for repair. The equipment at the sites utilizing established meteorological monitoring equipment and procedures according to SOP will be audited by the PM and the QAM (technical systems audit). These meteorological equipment audit reports will be generated and archived by QAM.

16.2 *Lagoon/basin characterization equipment*

On receipt from the manufacturer, the pH, redox, and temperature sensors will be calibrated in the laboratory using performance audit procedures outlined in Table 16.2 below.

Table 16.2. Performance audit procedures for the lagoon/basin characterization equipment.

Sensor	Audit performed	Method
pH		Comparison with NIST-traceable standard buffer solutions
Temperature	Response	Comparison with NIST-traceable mercury thermometer in water bath
Redox state	Response	Comparison with calibration solutions
Depth finder	Response	Comparison with resin bed depth

16.3 *Open path UV-DOAS*

Although the UV-DOAS does not require a multi-point calibration as long as the range of measurement does not exceed the range of spectra stored in the PLS reference library, a multi-point calibration check will be conducted. On receipt from the manufacturer, the UV-DOAS calibration will be checked in the laboratory at multiple concentrations using certified calibration gases of H_2S (500 ppm) and NH_3 (500 ppm) according to procedures outlined in SOP C1. Calibration concentrations of each gas will bracket the range of in-field measurements. Calibration records will be maintained in accordance with SOP D1.

For all 21-d rotation locations, field performance audits consisting of a single-point calibration check will be performed prior to installation of the equipment at each location and measurement period. Certified calibration gases for the single-point check include H_2S (4 ppm, 3% accuracy, NIST certified) and NH_3 (50 ppm, 1% accuracy, lab certified). Only units that "pass" the performance audits will be installed. For all continuous measurement locations, field performance audits consisting of a single-point calibration check will be performed every 21 d and only units that "pass" the performance audits will be reinstalled. All "fail" units will be returned to the manufacturer for repair or recalibration. Records of the calibration checks will be maintained in accordance with SOP D1.

Multi-point calibrations of the UV-DOAS will be conducted every six months in the laboratory with calibration records maintained in accordance with SOP D1 and SOP C1. Procedures to troubleshoot the instrument and possibly resolve the cause for failure are defined in SOP C1. Units that fail the multi-point calibration and cannot be remediated to the point of passing the calibration will be returned to the manufacturer for repair or recalibration. Units that pass will return to the field.

16.4 *Open-path TDLAS*

The TDLAS is shipped already calibrated at the factory, however it will be calibrated using a vendor-certified primary standard 100 ppm NH_3 calibration gas (1% accuracy) according to procedures outlined in SOP C2. The TDLAS does not require any calibration in the field but will be calibration checked with single point calibrations.

During operation, the TDLAS internal reference cell is compared with this stored waveform at frequent intervals. Any significant deviation generates a status code to alert the user to a potential calibration problem (linearity check). The TDLAS software can be used to check the reference cell, as well as to download sample, reference and calibration waveforms to verify that the internal calibration system is functioning correctly. Manual checks of the waveforms can be made on-site using the TDLAS controller program.

Calibration records will be maintained in accordance with SOP D1. Field performance audits of single-point calibration verifications will be performed prior to installation of the equipment at each location and only units that "pass" the performance audits will be installed. The "fail" unit will then be evaluated and adjusted if possible. If it is not possible to remediate, the unit will be returned to the manufacturer for repair or recalibration. Multi-point calibrations of the TDLAS will be conducted every six months in the laboratory with calibration records maintained in accordance with SOP D1 and SOP C2. Calibration concentrations of each gas will bracket the range of in-field measurements. Procedures to troubleshoot the instrument and possibly resolve the cause for failure are defined in SOP C2. Units that fail the multi-point calibration and cannot be remediated to the point of passing the calibration will be returned to the manufacturer for repair or recalibration. Units that pass will return to the field.

16.5 *Photoacoustic multi-gas analyzer*

The Photoacoustic multi-gas analyzer is shipped already calibrated from the factory. However, on receipt from the manufacturer, the photoacoustic multi-gas analyzer will be single-point calibrated (SOP G7) using calibration gases of 10 ppm Methane (10% accuracy traceable to NIST),1 ppm MeOH (10% accuracy traceable to NIST), 50 ppm Propane (1% accuracy traceable to NIST), and 50 ppm NH_3 (lab-checked 1% accuracy). Calibration records will be maintained in accordance with SOP D1. Field performance audits of single-point calibration verifications will be performed prior to installation of the equipment at each location (approximately every 21 d) and only units that "pass" the performance audits will be installed. The "fail" unit will be further evaluated and adjusted if possible. If it is not possible to remediate, the unit will be returned to the manufacturer for repair or recalibration if necessary. Multi-point calibrations of the PAS will be conducted every six months in the laboratory with calibration records maintained in accordance with SOP D1 and SOP G7. Calibration concentrations of each gas will bracket the range of in-field measurements. Specifications for accuracy and precision are documented in SOP G7 and Tables A14 through A18. Specifications for linearity are documented in SOP G7. Procedures to troubleshoot the instrument and possibly resolve the cause for failure are defined in SOP G7. Units that fail the multi-point calibration and cannot be remediated to the point of passing the calibration will be returned to the manufacturer for repair or recalibration. Units that pass will return to the field.

16.6 *Equipment used in the analysis of manure*

The commercial laboratory to conduct these analyses (Midwest Laboratories, Inc.) has defined the audit and calibration frequency and associated documentation of audits and calibrations necessary for the analyses of total solids content, volatile solids content, pH, total nitrogen, and ammonia nitrogen. These are documented in individual SOPs of the laboratory referred to the laboratory’s Quality Assurance Manual.

16.7 *Pulsed Fluorescence H_2S Analyzer*

The Pulsed Fluorescence H_2S analyzer is shipped already calibrated from the factory. However, on receipt from the manufacturer, the analyzer will be multi-point calibrated (SOP G5) using calibration gases of 300 ppm and 4 ppm hydrogen sulfide (3% accuracy traceable to NIST). Calibration records will be maintained in accordance with SOP D1. Field performance audits of single-point calibration verifications will be performed prior to installation of the equipment at each location (approximately every 21 d) and only units that "pass" the performance audits will be installed. Any failing unit will be further evaluated and adjusted if possible. If it is not possible to remediate, the unit will be returned to the manufacturer for repair or recalibration if necessary. Multi-point calibrations of the PF analyzer will be conducted every six months in the laboratory, with calibration records maintained in accordance with SOP D1 and SOP G5. Calibration concentrations of each gas will bracket the range of in-field measurements. Specifications for accuracy and precision are documented in SOP G5 and Table A25.

Specifications for linearity are documented in SOP G5. Procedures to troubleshoot the instrument and possibly resolve the cause for failure are defined in SOP G5. Units that fail the multi-point calibration and cannot be remediated to the point of passing the calibration will be returned to the manufacturer for repair or recalibration. Units that pass will return to the field.

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SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

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SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Applied Meteorology Lab.

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SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.

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17. Inspection/Acceptance of Supplies and Consumables

Supplies and consumables for this project consist primarily of calibration supplies. A PAML FOS technician is responsible for accepting, tracking distribution, and maintaining supplies and consumables. Perishable consumables will be labeled on receipt and stored at normal room temperatures both in the PAML laboratory and at the measurement locations in the Instrument Trailer (SOP U4). A FOS technician will maintain a record of the labeling, manufacture date, replacement date, and shelf-life of consumables (using a "Perishable Consumables" EXCEL spreadsheet similar to that in Appendix D), verify that the perishable consumables are kept at normal room temperature, and replace perishable supplies as necessary. The PQAM is responsible for maintaining certification records of all calibration and calibration verification standards. Calibration checks of the TDLAS (SOP C2), pulsed fluorescence (SOP G5), and multi-gas analyzer (SOP G7) instrument measurements (critical measurements) will be completed using certified standard gases. All atmospheric gaseous measurements will be traceable to dual-analyzed and certified standards from a reputable supplier. Gases will be received according to SOP G2, and NH_3 concentrations will be checked according to SOP G12. Calibration gases for the TDLAS, PFA and PAS include: nominal 4 ppm H_2S (2% accuracy, NIST-traceable) and 50 ppm NH_3 (1% accuracy, NMi-traceable) for single-point in-field calibration checks and 4 ppm H_2S (2% accuracy, NIST-traceable) and 500 ppm NH_3 (1% accuracy, lab-checked according to SOP G12) for multiple-point in-lab calibrations. The shelf life of the NH_3 standard gases is six months. The shelf life of the H_2S standards is one year. Calibration gases for the multi-gas analyzer measurements include:

- 10 ppm methane (1% accuracy traceable to NIST), balance N_2, shelf life 36 months.
- 1 ppm MeOH (2% accuracy traceable to NIST), balance N_2, shelf life 12 months.
- 1 ppm EtOH (1% accuracy traceable to NIST), balance N_2, shelf life 12 months.
- 50 ppm propane (10% accuracy traceable to NIST), balance N_2, shelf life 36 months.
- 500 ppm NH_3 (10% accuracy, checked according to SOP G12), balance N_2, shelf life 6 months.
- 300 ppm and 4 ppm H_2S (3-4% accuracy traceable to NIST), balance air or N_2, shelf life 12 months.

A pure N_2 gas cylinder and CEM zero air cylinder will also be used in the multi-point calibrations as a diluter gas. This gas will be received according to SOP G2 but not concentration checked.

Calibration checks for pH (SOP L1) and redox potential measurements (SOP L3) (non-critical measurements) will be completed using solutions traceable to certified standards from a reputable supplier. Solutions will be received with manufacturer's calibration assumed to be valid. pH solutions include pH 4 (potassium biphthate), pH 7 (potassium phosphate) and pH 11 (sodium borate) standards traceable to NIST. An additional solution to evaluate the pH probe requires thymol ($C_{10}H_{13}OH$). Redox potential solution is the 230 mV ZoBell's solution standard. The shelf life of these standards is six months. Water softener resin, with a shelf life of greater than five years, is used to verify the calibration of the sludge depth sensor (SOP L5).

Calibration checks for the relative humidity sensor (SOP W1) require either lithium chloride and potassium sulfate salt packet certified by the Finnish Accreditation Service (shelf life of the packaged salts is six months) or the use of a LiCOR 610 portable dew point generator traceable to NIST standards (NIST, 1996).

In addition, Styrofoam coolers, sealable quart plastic bags, 'Authorized Return Shipment' ground shipment labels, 'blue ice' for maintaining 4°C sample temperature for manure samples during shipment to the analytical laboratory (SOP M1) will be stocked and tracked to assure adequate supplies for the Corral and Manure Basin locations.

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18. Data Acquisition Requirements (Non-Direct Measurement)

US National Weather Service Automated Surface Observation Stations (ASOS) and Automated Weather Observation Stations (AWOS) will be used to substitute for missing or invalid non-critical measurements of air temperature, humidity, barometric pressure and surface wetness (Table 18.1). In addition nearby National Weather Service Doppler Radar (WSR-88D) estimates of precipitation distribution and amount will be used to support project surface wetness measurements. In addition some missing or invalidated measurements may be substituted by valid measurements specified within the NAEMS Barn component QAPP.

Table 18.1 Locations of Supporting NWS Weather Observations

Farm	ASOS/AWOS location code	WSR 88-D Radar Location code
1	KDPL	RAX
2	KLBT	RAX
3	KLAF	IND
4	KCIN & KBNW	DMX
5	KGUY	AMA
6	KGUY	AMA
7	KPSC & KYKM	PDT
8	KJVL	MKX
9	KLAF	IND
10	KAMA	AMA

NWS data will be extracted from either a web-based source such as http://www.uswx.com/ and http://radar.weather.gov/ or from the continuous records collected at PAML by a Local Data Manager program as part of the Internet Data Distribution project of the UNIDATA program University Center for Atmospheric Research (Domenico, 2003). Data provided by the NWS have been quality assured through procedures defined in Federal Meteorological Handbook Nos. 1 and 11 Part A, therefore all measurements made available will be considered valid. On occasion supplementary values of the surface weather are reported on the same hour of the original measurement and if these supplemental reports are replacements of a prior measurement report, they will be used in place of the original reported values where applicable.

References

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19. Data Management

The data management program involves collecting, entering, transferring, verifying, validating, summarizing, and reporting the data gathered in this study. These data include descriptive and historical information about each site (e.g. log books and sheets, etc.), all analytical and meteorological data, and summaries and reports. The objective of the data management program is to ensure that the data gathered in the field and laboratory are and remain valid and are not altered (other than appropriate unit conversions) as they are transferred from the field to the periodic and final reports..

Quality assurance of the measurements includes data quality audits. The PQAM will conduct a data quality audit on the data management system at least monthly. Auditing will involve comparing the processed meteorological and analytical data in the spreadsheets with the raw data obtained from the field to ensure that the data are being processed correctly and that invalidated data are not being used incorrectly. Any findings or concerns from the data quality audits will be addressed to the SA and PM. PM is responsible for conducting or assigning the task of conducting the data validation. Data will be assessed for representativeness, completeness, comparability, accuracy and precision as outlined in Section 4.

The DM will distribute only validated, quality-coded data as directed by the SA. All personnel involved in collecting and transferring of measurement and processed data will be trained in all procedures prior to participating in the field operations.

19.1 *Data Analysis*

Emissions calculations using both the RPM and bLS models will be conducted at PAML after careful inspection of the data for validity. Computations of stability, turbulence, and dissipation (among others) will also be conducted at PAML. In addition, data analysis procedures will include statistical representations of the probability distributions for NH_3, H_2S, and VOC concentrations and emissions during varying periods of time defined both temporally and in terms of typical climatological conditions. Concentrations and emissions of NH_3, H_2S, and VOC will be correlated with atmospheric conditions such as stability, wind direction and wind speed. Concentrations and emissions of NH_3, H_2S, and VOC near the lagoons will be correlated with lagoon characteristics such as temperature, pH, redox state, and air-lagoon temperature difference. Concentrations and emissions of NH_3, H_2S, and VOC near the lagoons will be correlated with basin characteristics such as pH, total and volatile solid content, ammonia nitrogen and total nitrogen content. Concentrations and emissions of NH_3, H_2S, and VOC near the corral will be correlated with surface wetness. General techniques to be used include calculation of:

- Means, medians, standard deviations, probability distributions, and standard errors of measurements segregated by ranges of atmospheric or surface conditions.
- Correlations and linear and non-linear regressions between measurement variables with appropriate goodness-of-fit statistics.

- Analysis of variance to determine sources of variability in measurements.
- Significance of differences between probability distributions of measurements.
- Time series analysis of measurements.

It is important to remember however that statistical associations or lack of associations do not indicate causative relationships and provide only supporting evidence for process-based models. At the completion of each quarter, the results of the prior quarter will be presented to the NAEMS participants for review and comment. This will assure that the choices in data reduction are consistent with the needs of the NAEMS researchers.

19.2 *Data tracking*

Data files from each rotating measurement location and the PAML-managed continuous measurement locations will be transferred from field to PAML at the end of each 8 to 20-d sampling period by FOS hand delivery in a 'data pouch' with the associated Electronic Data Transfer Form (Appendix D). The data pouch contains two sets of data (that of the most recently-completed measurement period and that of the previous measurement period) to minimize risk of data loss through any accident of raw data files. The 'data pouch' includes:

- A set of data for the latest measurement period, including one CD with copies of TDLAS, sonic anemometer (except 16-Hz data), weather, lagoon, GSS, PFA and PAS data from recently-completed measurement period, one 64 Mb flash memory chip with weather/lagoon data, one 256Mb memory stick with field notes, calibration data and control charts from the recently-completed measurement period, one DVD with 16-Hz sonic anemometer data..
- A set of data for the previous measurement period, including one CD with copies of TDLAS, sonic anemometer (except 16-Hz data), weather, lagoon, GSS, PFA and PAS data from previous measurement period.

On arrival at PAML, the PDM will log the data into the laboratory and compare the files received by 'data pouch' to those received earlier by ftp. Inconsistencies will be followed up and the data files in the PAML computer will be corrected if indicated. After comparison and inconsistency resolution, the disks will be stored off-site to prevent loss from fire or other accident at PAML. Calibrations, control charts and field notes will be downloaded from the memory stick in the 'data pouch' to the appropriate directory.

Data files of chemical analysis of the manure samples from Midwest Laboratories, Inc will be received via email or the World Wide Web (128 bit encrypted) as comma-delineated data that has been verified at the Laboratory according to their Quality Assurance Plan.

19.3 *Data storage on-site and retrieval*

Raw data from the two TDLAS systems at each site (providing PIC values of NH_3) are collected on their respective control and data acquisition computers and daily transferred to the LAN server (Figure 19.2). At the end of each measurement period, the data collected on the two TDLAS computers will be copied onto one CD according to SOP D1.

Raw data from the PAS multigas analyzer at each site are collected on the LAN server computer using hard-wired serial communications and custom software (Figure 19.4). At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Raw data from the UV-DOAS units (if validated) at each site will be collected on the LAN server computer using hard-wired serial communications and custom software (Figure 19.1.1). Raw data from the PF analyzer (if UV-DOAS not validated) at each site will be collected on the LAN server computer using hard-wired serial communications and iPort® software (Figure 19.1.2). At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Raw data from the 3D sonic anemometers at each site are collected on the LAN server computer. Statistical representations of the raw data (SOP W2) will be computed and stored on the LAN server (Figure 19.2). At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Raw data from the GSS (pressure, flow rate, and flow direction) at each site will be stored on the GSS data logger (Campbell Scientific, Inc. CR800). Data will be in comma-delimited format. Measurements will be downloaded every 10 min to the LAN server (Figure 19.1, 19.4). At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Table 19.1 On-site computers and data loggers specifications

Computer/ data logger	Use	Input/Output	Storage	Memory	Number
LAN server 3.2 GHz dual processor	Data acquisition of PF, PAS and wind sensors Data transfer from CR1000 and CR800 data loggers Overall database manager DSL communications Runs LoggerNet, iPort, custom sensor communications programs	4-RS232 1-16X DVD+/-RW 3-USB, Ethernet Scanner, Printer CF card reader	200 Gb external HDD 2-120 Gb internal SCSI HDD	1 Gb	1
TDLAS 3.2 GHz dual processor	Data acquisition and control of TDLAS and scanner	3-USB 1-RS232 1-16X DVD+/-RW	120 Gb internal HDD 200 Gb external HDD	1 Gb	2
CR800 data logger	Data acquisition and control of GSS	6 Analog inputs 2 Pulse inputs Serial comm.	4 Mb	4 Mb	1
CR1000 data logger	Data acquisition of weather/lagoon data	16 Analog inputs 2 Pulse inputs Serial comm.	64 Mb flash	2 Mb	1

The meteorological stations at each site will operate according to SOP W6. The meteorological data (excluding wind data) and lagoon/basin characterization data will be collected and stored on the on-site data logger (Campbell Scientific, Inc. CR1000 with compact flash card extended memory) every 5 min. Data will be in comma-delimited format. Raw meteorological (ambient air temperature, relative humidity, barometric pressure, solar radiation, surface wetness, wind components) and lagoon/basin (pH, temperature and redox state) characterization data are stored on the data logger, the data logger compact flash card, and the LAN server (Figure 19.3). The compact flash card from the data logger will be replaced according to SOP W6 and the 'used' one will be downloaded at PAML. At the end of each measurement period, the data will be downloaded onto CD according to SOP D1.

Within the instrument trailer, the LAN server computer hard drive will be copied (backed-up) each night onto an attached external hard drive. All raw and processed data for the given day will be automatically ftp-transferred four times a day to a PAML computer. General specifications for the computers in the instrumentation trailer are documented in Table 19.1.

19.4 *Data storage at PAML*

Data received by email or ftp and verified by files transferred at the end of measurement periods on physical disks will be stored on a daily backed-up external hard disk drive. The PAML database computer is a 2.8-GHz dual-processor capable of holding approximately 1 Tb of data: two complete images of the complete database on RAID 6 or RAID 50 Arrays (Table 19.2). A separate computer is attached to the internet to receive daily ftp file downloads from the individual measurement locations (19.2). The post-processing bLS modeling and RPM modeling will be run on at least three additional computers (19.2). The PDM will manage the raw and processed data files. A large portion of the data (meteorological, TDLAS, GSS, PF, PAS, manure analyses) will be maintained electronically in the form of comma-delimited ASCII data. Access to raw or processed file directories will be password or user-group controlled according to need.

Table 19.2 PAML computer specifications.

Computer	Use	Input/Output	Storage	Memory	Number
ftp server 3.2 GHz dual processor	DSL communications	1-16X DVD+/-RW 4-USB, Ethernet, Scanner, Printer	120 Gb internal HDD 200 Gb external HDD	1 Gb	1
3.2 GHz dual processor	Runs all calibration equipment	4-USB, Ethernet 16X DVD+/-RW	120 Gb internal HDD	1 Gb	1
3.2 GHz dual processor	Runs bLS model for all locations	4-USB, Ethernet 16X DVD+/-RW	120 Gb internal HDD	1 Gb	1
3.2 GHz dual processor	Runs RPM model for all locations	4-USB, Ethernet 1-16X DVD+/-RW	120 Gb internal HDD	1 Gb	1
2.8 GHz dual processor	Overall database manager	4-USB, Ethernet 1-16X DVD+/-RW	1 Tb RAID 6 Array or RAID 50 Array (6-8 HDD)	1 Gb	1

Raw tables or graphs used in quality assurance of the data will be printed out and stored in a loose-leaf notebook in the laboratory. PAML staff will collectively keep the following logs: daily notes including site drawings, data analyses conducted and other notations. The logs will also contain measurement activities and monitoring notes. PQAM will keep all calibrations, certifications, results from QC checks and QA documents in a separate filing area. The PQAM will maintain logs of deviations from QA, data validations, records of invalidated data investigations, audit documents and documentation of other QA investigations in a separate loose-leaf notebook. Any other necessary records for documenting the operation of monitoring instruments will also be kept by the PQAM. A third party witness will acknowledge readability and clarity of all site log notes by email. All notes will be contained in a centralized notebook.

All hand entries in any document completed as part of the data collection and validation process will be in indelible ink with any changes or corrections indicated by single line cross-out with initials of individual making the change or correction and date of change or correction indicated. All documents with hand entries will be stored in the appropriate notebook and scanned into image format for electronic storage on completion of document and after any change or correction. All data transferred from hand-written documents to the electronic database (such as sludge depths measured on location, sensor location mapping and path distance determinations) will be entered into the database by duplicate entry with errors revealed by comparison of entries resolved by the PQAM.

Routine analyses of the data will be logged (including names of original files, processing done, and final files created) with results stored in the same directories as the raw and processed data and, where appropriate, notes concerning the results stored in loose-leaf notebooks accessible to all FOS and other staff.

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SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

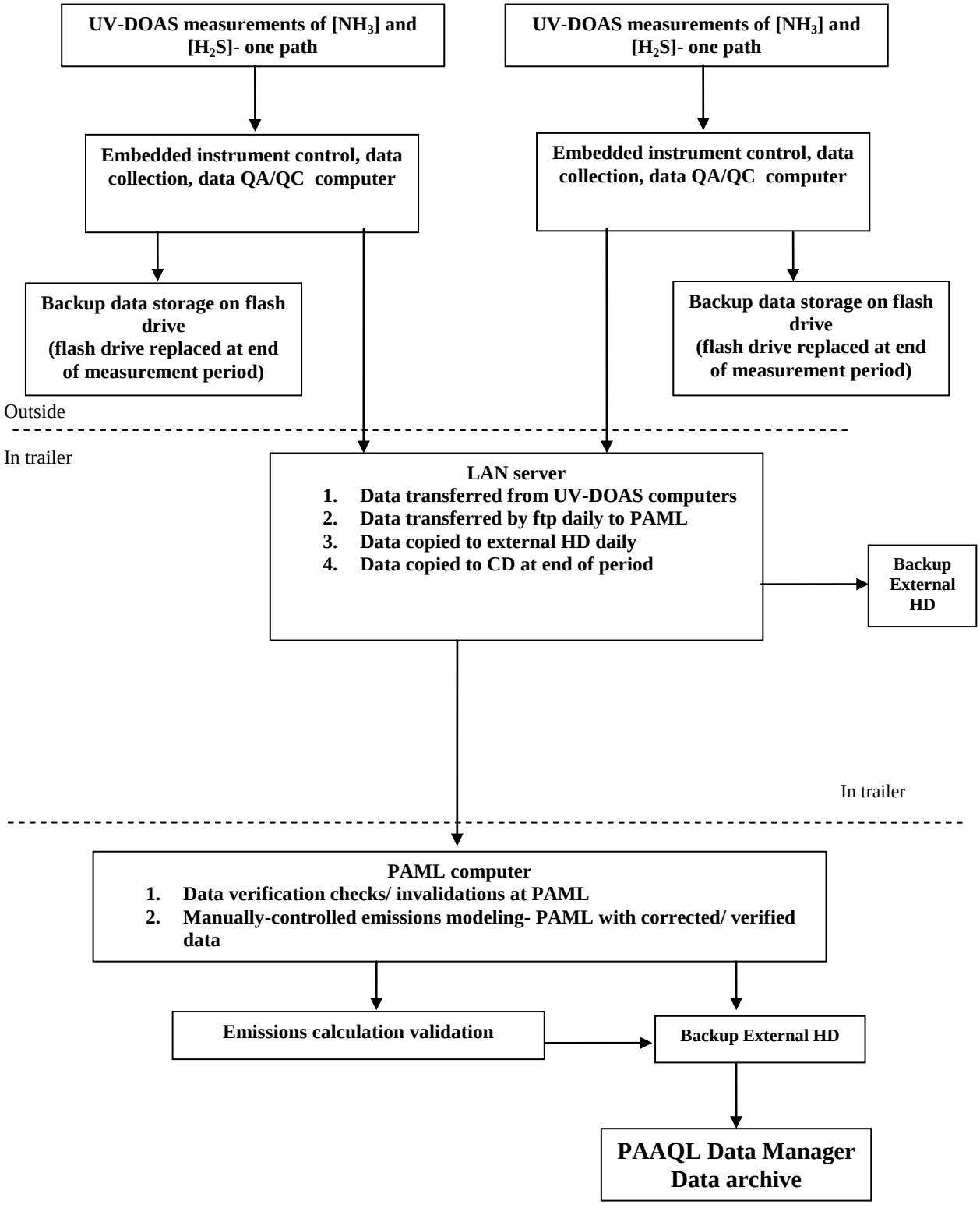

Figure 19.1.1. Data processing and management: UV-DOAS data.

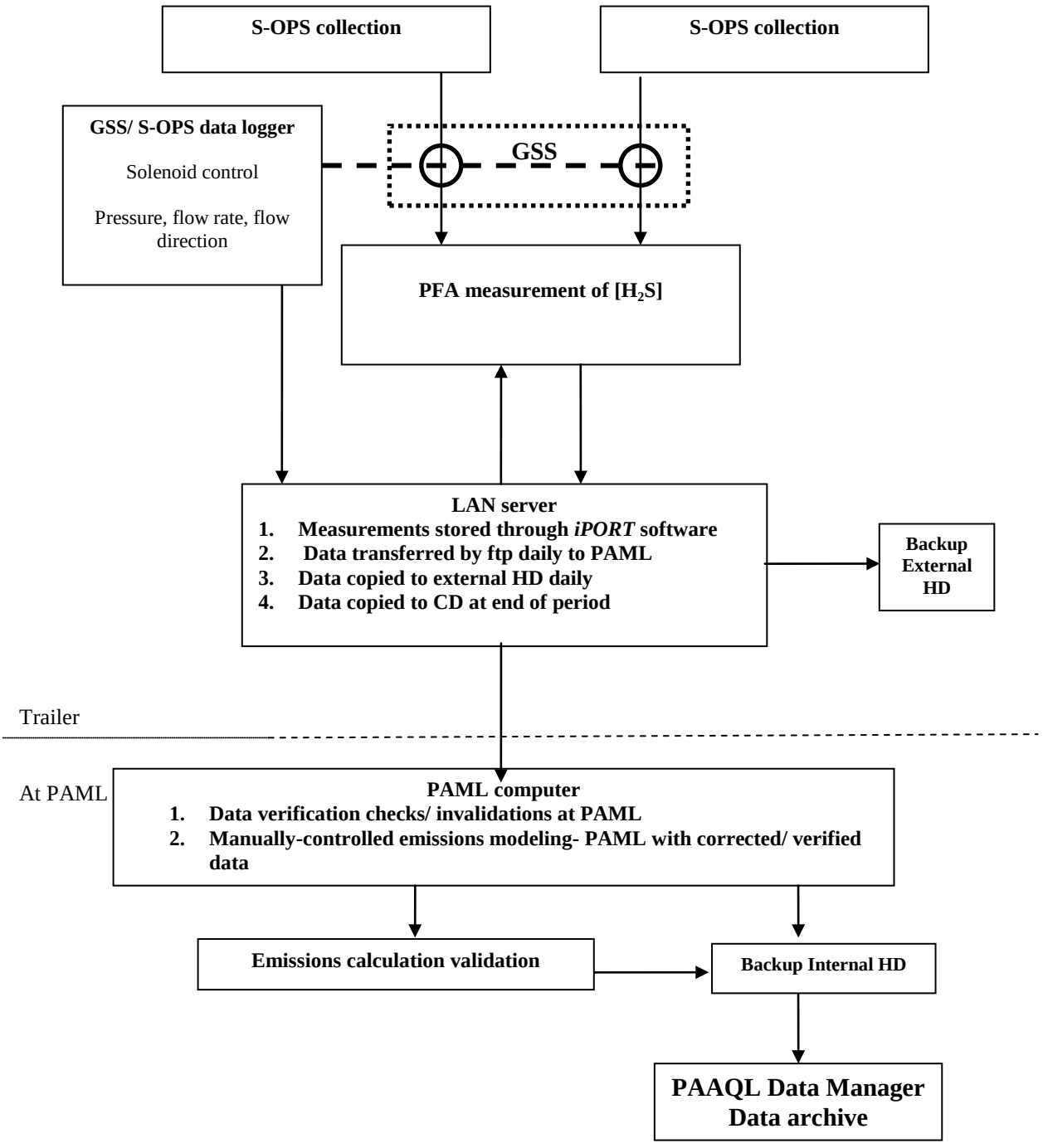

Figure 19.1.2. Data processing and management: PFA data.

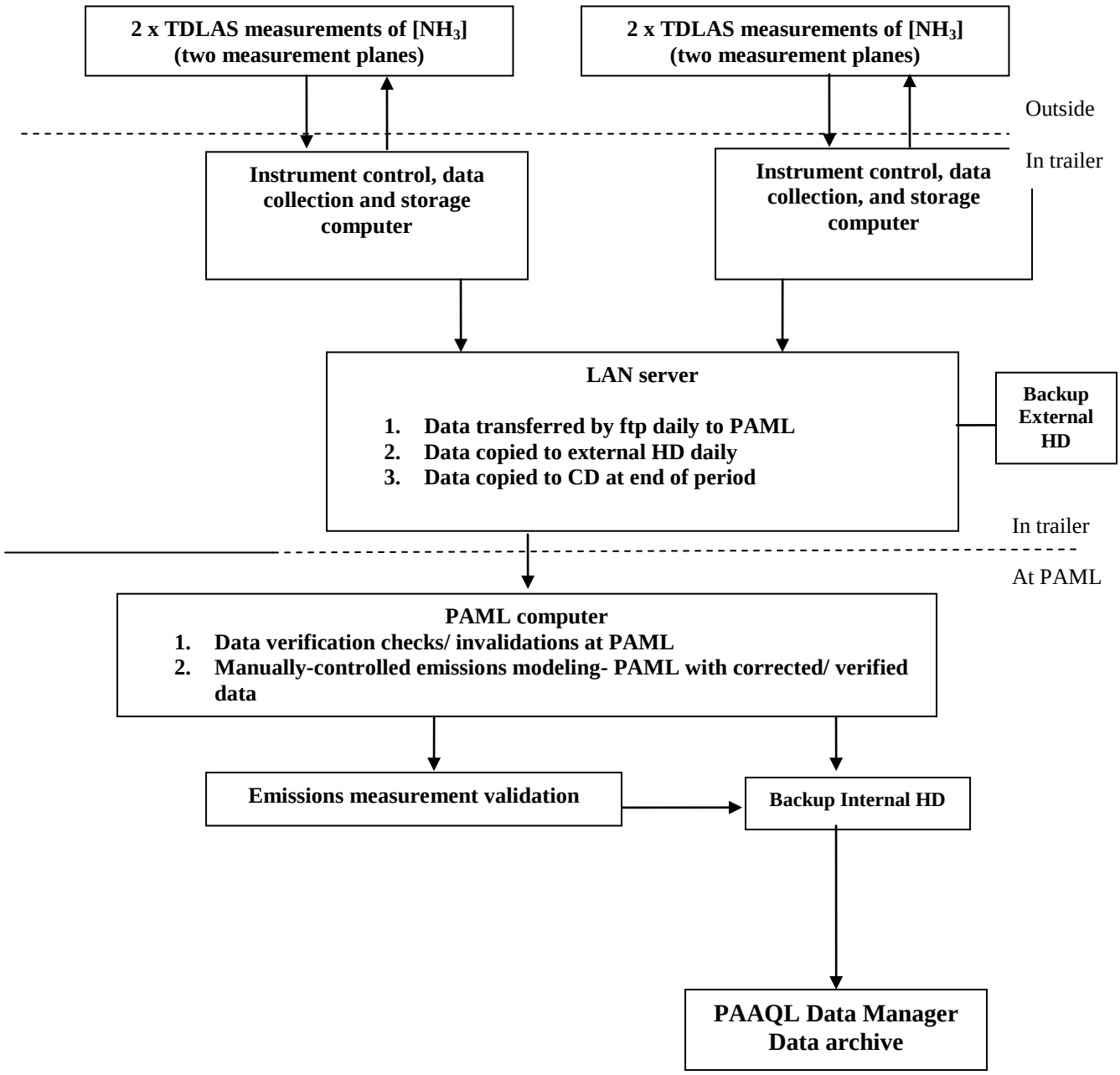

Figure 19.2. Data processing and management: TDLAS data.

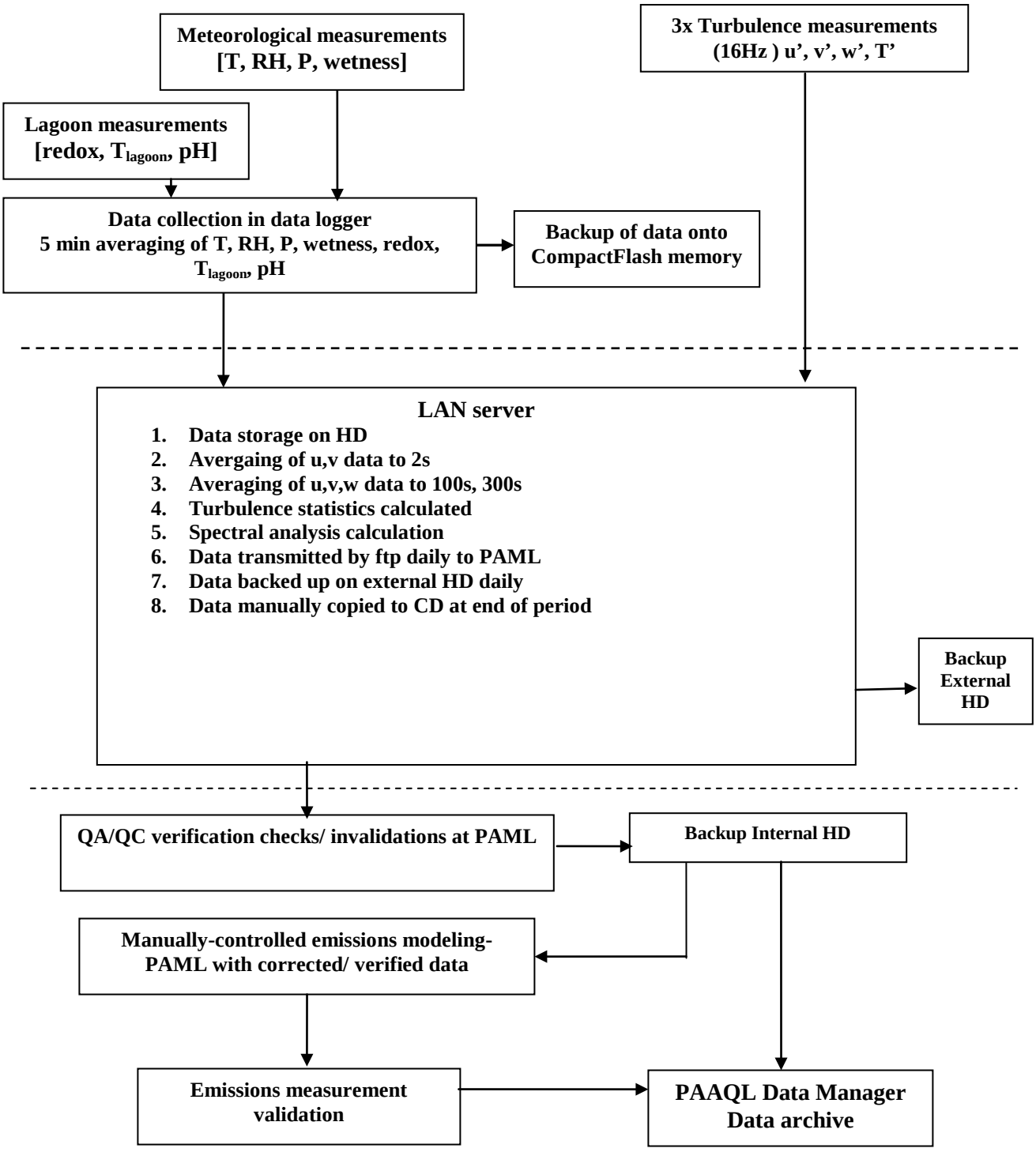

Figure 19.3. Data processing and management: meteorological and lagoon/basin data.

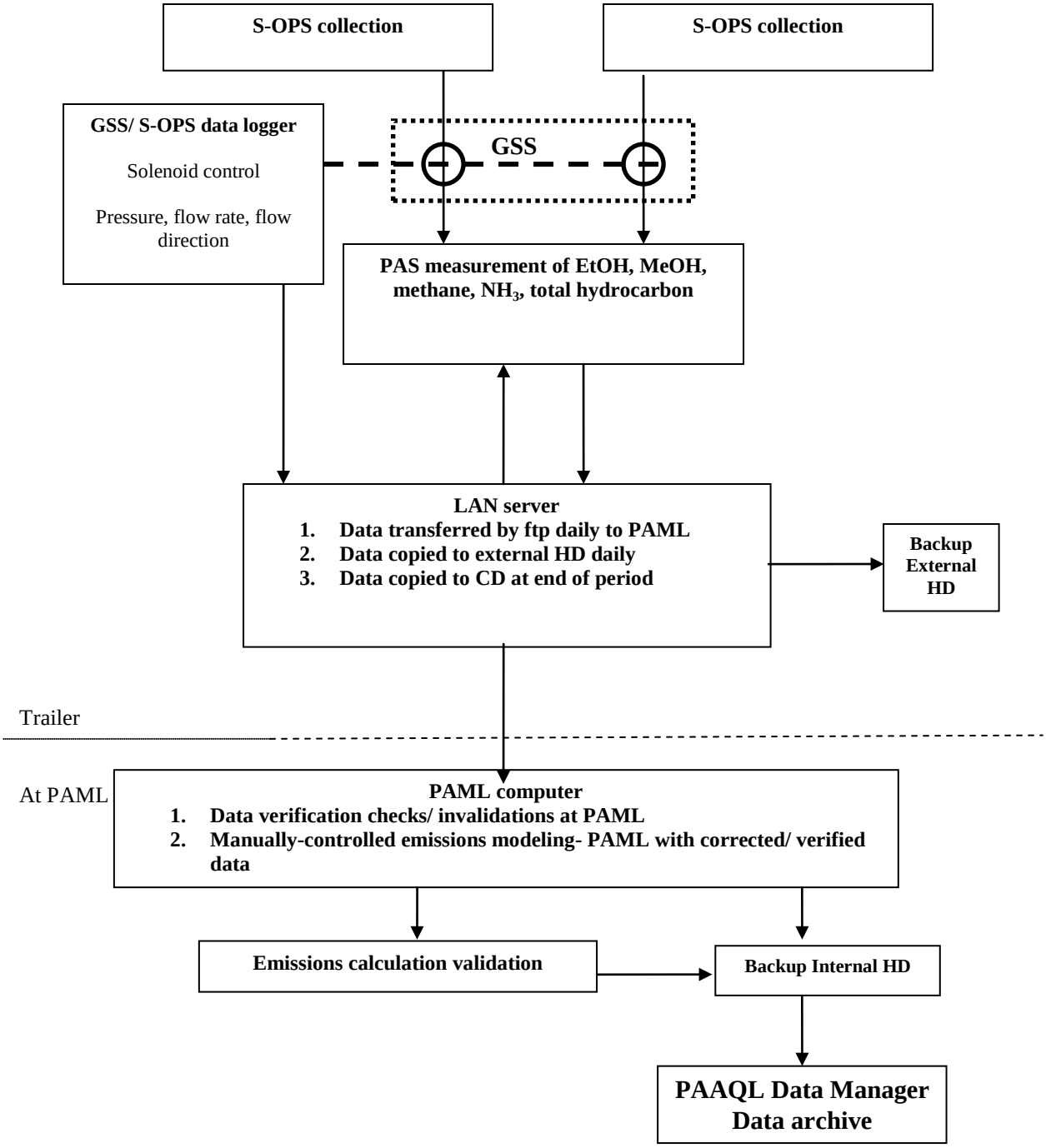

Figure 19.4. Data processing and management: VOC data.

C. Assessment/Oversight

20. Assessments and Response Actions

Quality assurance of the measurements is conducted by external validation of data, performance and technical systems audits, data quality audits, and documentation. New equipment should arrive from the manufacturer in a field-ready state. However, all equipment will be tested for acceptance at PAML according to procedures outlined in the respective SOP. In addition, performance and technical system audits are required to ensure the quality of the measurements throughout the period of the project. A general schedule for the performance, data quality, and technical systems audits is indicated below, however more frequent audits may occur if recurring problems with an instrument are detected.

External technical systems audits will be performed by the EPA or their designate on a schedule coordinated with the PM.

Internal data quality audits will be conducted on data collection, data validation, and data processing. Data will be assessed for representativeness, completeness, comparability, accuracy and precision as outlined in Section 7. The PQAM will perform data quality audits of the data management system at least monthly. Auditing will involve comparing the processed meteorological and analytical data in the spreadsheets with the raw data obtained from the field to ensure that the data are being processed correctly.

The QAM will conduct one internal technical systems audit at each location over the course of the two years in coordination with the PM. The PM will conduct internal technical systems audits at each location each year (due to the PQAM being part of a measurement team). During technical systems audits, the PM or QAM will observe sample collection, equipment operation and calibration verifications of all equipment at the location to verify that the procedures documented in this QAPP are being followed and that any corrective actions previously initiated are being continued. Field documentation will also be reviewed. A checklist identifying items to be included in the technical systems audit are documented in Appendix D. The audit will be documented using forms similar to those in Appendix 15, section 2 of the *USEPA Quality Assurance Handbook for Air Pollution Measurement* (August 1998). Any issues identified during these audits will be documented on the “Audit Finding Form” (Appendix D) and discussed with the appropriate FOS and addressed immediately. If any response actions are taken, the PM will inform the QAM of the reason for the actions and the results, documenting the response on an “Audit Finding Response Form” (Appendix D). Any findings or concerns from the audits will be addressed to the SA and PM. Any necessary response actions will be determined by the SA and PM. Invalidated data may result from a technical systems audit finding. It is not anticipated that immediate shutdown of operations will be needed unless the technical systems audits reveal serious protocol deviation which the FOS cannot correct immediately following the audit. Authority to stop work rests with the SA in consultation with the PM and USEPA Program Manager.

The QAM will be responsible for preparing the portions of any report concerning the results from the internal QAM audits. The PQAM will be responsible for preparing the portions of any report concerning the results from the internal PM audits. The Audit Forms, Audit Finding Form (if applicable), and Audit Finding Response Form (if applicable) must be delivered to the QAM, SA, and PM (as appropriate) within 30 d of audit completion. The generator of the completed forms will retain one copy of the completed forms for his/her file. The QAM will review the audit results and determine if changes to the QAPP (including SOPs) are warranted. If changes are warranted, the QAM will contact the PM and the PM in consultation with the SA and the EPA QAM will determine what changes are appropriate. Field performance audit routines, described below, are also described in each instrument's SOP.

Open-path gas concentration instruments

During the field audits of the performance of open-path concentration instruments (CEREX UVSentry UV-DOAS and Boreal GasFinder2.0 TDLAS), the instruments will be temporarily removed from the lagoon/basin measurement location and positioned near the trailer for alignment with the calibration chambers. Methods and associated SOP for a given audit are indicated in Table 20.1. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and each respective SOP.

Table 20.1 Performance audit methods for open-path gas concentration instruments.

Sensor	Frequency and location of audit	Audit performed	Method	SOP
UV-DOAS NH_3 concentration	Semiannually in field	System response	Single point calibration with primary standard NH_3 gas concentration; accuracy and precision check	C1
UV-DOAS H_2S concentration	Semiannually in field	System response	Single point calibration with NIST-certified H_2S gas concentration; accuracy and precision check	C1
TDLAS NH_3 concentration	Semiannually in field	System response	Single point calibration with primary standard NH_3 gas concentration; accuracy and precision check	C2

PAS multi-gas analyzer

During the field performance audits of the INNOVA 1413 Multigas Analyzer, the sampling system and analyzer will be audited together by applying the calibration gas at the gas sampling inlet. Methods for the field performance audits to be performed are identified in Table 20.2. The single point calibration verification method is described in SOP G7. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and SOP G7.

Table 20.2 Performance audit methods for INNOVA 1413 photoacoustic multi-gas analyzer.

Parameter	Frequency and location of audit	Audit performed	Method
NH_3 concentration	Semiannually in field	System response	Single-point calibration verification with primary standard gas concentration
MeOH concentration	Semiannually in field	System response	Single-point calibration verification with NIST-traceable EPA protocol gas concentration
EtOH concentration	semiannually in field	System response	Single-point calibration verification with NIST-traceable methane gas concentration
Water vapor concentration	Semiannually in field	System response	Single-point calibration verification with NIST-traceable dew point generator
CH_4 concentration	Semiannually in field	System response	Single-point calibration verification with NIST-traceable propane gas concentration
THC concentration	Semiannually in field	System response	Single-point calibration verification with NIST-traceable propane gas concentration

Manure characterization sensors

During field performance audits of the manure characterization sensors, the sensors will be temporarily removed from the lagoon and audited in the instrumentation trailer. Field performance audits listed in Table 20.3 will be performed on a semi-annual basis alternating with annual audits at Purdue so that an audit is occurring on each sensor approximately every six months. Methods for the performance auditing of the manure/lagoon sensing equipment are found in SOP L1, L2, L3 and L5. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and in the respective SOP.

Table 20.3. Performance audit methods for lagoon/basin characterization sensors.

Sensor	Frequency and location of audit	Audit performed	Method	SOP
Redox state	Annually at Purdue	Response	Comparison with certified ZoBell's solution	L3
Temperature	Annually at Purdue	Response	Comparison with unused collocated standard	L2
pH	Annually at Purdue	Response	Comparison with NIST-certified standard buffer solutions	L1
Depth finder	Annually at Purdue	Response	Resin bed test solution	L5

Meteorological sensors

Performance audits of meteorology stations and meteorological sensing equipment are required to ensure the collection of quality meteorological data. Field performance audits listed in Table 20.4 are to be performed on an annual basis alternating with annual performance audits at Purdue so that a performance audit occurs on each sensor approximately every six months. More frequent performance auditing may be conducted when suggested by unusual data.

During the field performance audits of these sensors, the sensors may or may not be temporarily removed from the towers for connection with audit devices. If the sensors are not removed from the towers, a collocated sensor will be used for intercomparisons (as indicated in Table 20.4). Standard Operating Procedures associated with the performance auditing of meteorological sensing equipment are indicated in Table 20.4. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in each respective SOP. Field performance audits results will be distributed among appropriate PAAQL personnel and included with the final report.

Assurance of parameter accuracy will be determined through performance audits of the meteorological equipment. Performance audits of meteorology stations and meteorological sensing equipment are required to ensure the collection of quality meteorological data. Meteorology stations will be evaluated on a quarterly basis through intercomparisons with unused standard sensors to determine status with respect to the siting criteria previously mentioned in this document. During field performance audits, sensors will be collocated with intercomparison instruments or temporarily removed from the towers for connection with audit devices. Standard Operating Procedures for performance auditing meteorological sensing equipment are described in the individual SOPs. The following performance audits are to be performed on an annual basis. All field performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and in the respective SOP.

Table 20.4. Summary of performance audit methods for meteorological sensors.

Meteorological sensor	Frequency and location of audit	Audit performed	Method	SOP
Wind Speed (horizontal)	Annually at Purdue	Signal	Comparison with other collocated NIST-traceable wind speed sensors	W2
Ambient Temperature	Annually at Purdue	Response	Comparison with other collocated NIST-traceable sensor	W1
Humidity	Annually at Purdue	Response	Comparison with NIST-traceable sling psychrometer	W1
Solar Radiation	Annually at Purdue	Response	Comparison with other collocated sensor with NIST-traceable calibration	E3
Barometric Pressure	Annually at Purdue	Response	Comparison to NIST-traceable calibrated Fortin barometer	W5

Performance audit samples for the analysis of manure for pH, total and ammonia nitrogen, total solid, and total volatile solids (SOP M2, M3, M4, and M5) will be prepared annually by the QAM and shipped to the commercial laboratory as blind samples.

PF gas analyzer

During the field performance audits of the TFS 450i pulsed fluorescence gas analyzer, the sampling system and analyzer will be audited together by applying the calibration gas at the gas sampling inlet. Methods for the field performance audits to be performed are identified in Table 20.5. The single-point calibration verification method is described in SOP G5. All field or lab performance auditing activities will be documented in the monitoring site logbooks using forms provided in Appendix D and SOP G5.

Table 20.5. Performance audit methods for TFS 450i pulsed fluorescence H_2S analyzer.

Parameter	Frequency and location of audit	Audit performed	Method
H_2S concentration	Semiannually at Purdue	System response	Single-point calibration verification with NIST-certified gas concentration
SO_2 concentration	Semiannually at Purdue	System response	Single-point calibration verification with NIST-certified gas concentration

S-OPS/GSS

Performance audits of the synthetic open-path gas collection and gas sampling system are required to ensure the collection of quality PFA and PAS gas concentration and emission data. Field performance audits listed in Table 20.6 are to be performed on an annual basis, alternating with annual performance audits at Purdue so that a performance audit occurs on each sensor approximately every six months. More frequent performance auditing may be conducted when suggested by unusual data.

Table 20.6. Summary of performance audit methods for S-OPS/GSS.

Sensor	Frequency and location of audit	Audit performed	Method	SOP
GSS mass flow	Annually at Purdue	Response	Comparison with NIST-certified flow meter	C4
GSS air leakage	Annually at Purdue	Response	GSS vacuum test	C4
S-OPS inlet balance	Annually in field	Response	S-OPS inlet flow rate measurement with NIST-certified flow meter	C4
S-OPS air leakage	Annually at Purdue	Response	S-OPS vacuum test	C4

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SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Laser Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Applied Meteorology Lab.

SOP C4. 2006. Standard Operating Procedure for the Synthetic Open-Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab/Purdue Applied Meteorology Lab.

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SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.

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21 Reports to Management

The Quality Assurance Manager will summarize the results of all audits into audit reports that will be documented and archived by the QAM in either hardcopy or electronic formats. These audit reports will include internal technical systems audits conducted by PM and QAM for the field sampling operations, the meteorological data collection, and data quality audits conducted by the PQAM to test the analytical procedures, and data management procedures.

The semi-annual internal technical systems audit reports produced by the PQAM and QAM will include:

- Date of audit
- Location of audit
- Team being audited
- Instruments audited
- Results of each audit
- Signature of auditor and those audited
- Response of team being audited to audit results
- Remediation and corrective actions (if any)

The PM and PDM will summarize the measurement results for the quarterly draft and final reports. Summaries of the audits will be included in the appropriate quarterly report. The quarterly draft and final project reports will contain:

- All valid monitoring data expressed as 30-min and daily values.
- Graphical representations of the location of all measurements taken.
- Numerical and qualitative results of all quality control measures on all measurement systems and will compare them to the applicable acceptance criteria.
- Summaries of the invalidated data and the reason for invalidation as well as the resultant corrective action.

Review drafts of the semi-annual internal technical systems audit reports and quarterly reports will be distributed to the following individuals or agencies:

William Schrock	EPA
Albert J. Heber	PU/ABE
Richard H. Grant	PU/AGR

The final report will contain the following information:

- The report introduction and the monitoring objectives for the project,
- Background information relating the purpose of the monitoring project.
- Descriptions and maps indicating the monitoring location(s).
- Information related to the monitoring methods employed at the monitoring site, the instrumentation used at the site and QA/QC results,
- Field observations during monitoring.

- Data analysis report and meteorological report.
- Emissions calculations by site, time of year, atmospheric conditions, and handling operations.
- Project conclusions.
- Attachments with open path TDLAS and UV-DOAS reprocessing and analysis results, site meteorological data, the initial sampling plans, and a health and safety plan.
- All spectral files and results will be backed up on recordable read only media.

Review drafts of the final report will be distributed to the following individuals or agencies:

William Schrock	EPA
Albert J. Heber	PU/ABE
Juan Carlos Ramirez	PU/ABE
Jiqin Ni	PU/ABE
Richard H. Grant	PU/AGR

The following individuals or agencies will receive final versions of the quarterly and final report.

OAQPS Project Manager	EPA
Albert J. Heber	PU/ABE
Jiqin Ni	PU/ABE
Richard H. Grant	PU/AGR
John Thorne	AARC

D. Data Validation and Usability

22. Data Review, Verification, and Validation

All analytical and meteorological data are reviewed by the PM, PQAM, QAM and the SA to determine if these data meet the QAPP objectives. Decisions to reject or qualify data are made by the PM and the PQAM. The QAM has oversight responsibilities for the PQAM activities.

All manure analysis data received by email or ftp from the commercial laboratory will be provided by the laboratory after verification following the laboratory Quality Assurance Plan. At the time of receipt of each set of analytical results and sample integrity information provided by the commercial laboratory, the chain of custody information documented by FOS and the information from the laboratory are reviewed by the PQAM to verify sample integrity and acceptable sample handling conditions (temperature, time between sampling and analysis, etc.)

All data received overnight by ftp from each monitoring site will be stored in an 'Unchecked data' subdirectory of the directory associated with the measurement period until quality-assured by staff scientists at PAML. Data files that have completed quality assurance (described in Section 23) and are validated will be inserted into a 'Validated data' directory. Validation of meteorology, lagoon/basin conditions, turbulence, GSS, NH_3 (TDLAS and UV-DOAS) PIC data, VOC (PAS) data and H_2S (PFA or UV-DOAS) PIC data will be conducted and data flags (Section 23) attached. All data will have a data flag associated with it. After validation procedures, data with non-zero data flags need to be assessed to determine the cause of flagging by staff scientists at PAML, in collaboration with similar staff at PAAQL. If flagged values are believed to be mis-flagged (a result of legitimate variability in the sensor response that is erroneously identified as evidence of sensor problems): (1) the filename, erroneous flag(s), cause for removing the flag condition, scientist initials, and date of assessment will be logged into a 'Data change' database maintained by the PDM, (2) the PQAM evaluates the legitimacy of the evidence for change in data status from invalid to valid. If after review by the PQAM and PM, the initial assessment is confirmed, then the flags will be changed and the changed data file is renamed with a "-cor" at the end of the file name and placed in the 'Validated data' directory.

Comparisons between the measured range of concentration measurements and the range of calibration for the UV-DOAS or PFA, TDLAS, and PAS instruments will be made to assure that the measurements fall within the range of the instrument multi-point calibration. Measurements falling outside the range of calibration concentrations will be verified by the PQAM and flagged as invalid and will not be used for further analysis.

Missing or invalid turbulence, NH_3, VOC and H_2S data values will not be estimated to complete a time series. Meteorological measurements (air temperature, barometric pressure) will be estimated to complete a time series if there is a continuous record of NH_3, VOC and H_2S data values since these measurements are needed to run the RPM, bLS and ratiometric models. All other meteorological and lagoon/basin characterization measurements will not be estimated or

substituted with nearby barn measurement values (if available at the location) or adjusted NWS values.

Emissions estimates via RPM, bLS, or ratiometric models will be run only on validated data with results containing the appropriate QA flags. The validity of the final emissions calculations will be assessed by the QA flags.

All data received by the data pouch (outlined in Table 9.1) will be stored as backup to the ftp data. This backup data will be compared after the end of the measurement period to the data files received by daily ftp. Comparisons will be initially by file size. If the ftp file and the data pouch file sizes differ for a given day, then the two files will be compared by timestamp record then data value (if necessary) to determine the cause for the difference in file sizes. If the difference is more than a result of end-of-file and beginning of file markers or differences in the number of records included in the file, the discrepancy will be documented reporting the filenames, cause for discrepancy, scientist initials, and date of assessment into a discrepancy database maintained by the PDM. The PDM and DM, in consultation with the SA and PM, will determine if the ftp version of the data file or the backup data file should be used in emissions estimates.

All data transferred from FOS hand-written documents to the electronic database (such as sludge depths measured on location, sensor location mapping and path distance determinations, and chain of custody sheets) will be entered into the database by duplicate entry with errors revealed by comparison of entries and the original document resolved by the PQAM.

Failures in daily QA procedures that indicate a problem with an instrument will be addressed by the PQAM in accordance with the respective SOP and outlined in section 23. Data flags are identified in Section 23 for each measurement. Instrument problems associated with critical measurements will be addressed on-site within three days as outlined in section 23. Instrument problems associated with non-critical measurements will be addressed on-site within one week.

QC checks occurring approximately every 21 d (discussed in section 14) and audits occurring approximately every six months (discussed in sections 16 and 20) provide the basis for data validation. The results of the internal and external technical systems audits, performance audits (Section 20) and QC checks (Section 14) assure proper sample collection, handling, and analytical procedures are being performed according to the QAPP. The records documenting the audits and QC checks will be used to further explain un-resolvable invalidated data and define the interval of valid data from a given instrument. If the performance audits do not explain invalidated data and a trip to the measurement location is needed to resolve the identified problem, the instrument must undergo another performance audit (if equipment repaired) or acceptance check (if equipment replaced). Failures in QC checks of any instrument result in an investigation for evidence for the time of failure in prior data QA flags. If no indication of time of failure is evident, all measurements using the instrument will be flagged invalid back to the last time the instrument was QC checked. If there is an indication of the time of failure from the QA flags, the PQAM in conjunction with the PM will determine the interval of invalid data. All

instruments failing a QC check will be removed from the field and sent to the manufacturer for repair on replacement.

All deviations in QAPP or SOP will be documented on a 'Document Deviation Report' Form (Appendix D). The PQAM in consultation with the QAM, PM and SA will determine the resolution of the deviation. Possible resolutions of a deviation include: accept deviation and revise a section of the QAPP or SOP, accept revision (minor) no changes necessary, reject deviation and data, reject deviation but retain data (for instance incomplete replication). All changes in operating protocol must be approved by the EPA prior to activation."

The DM will distribute only validated, quality-coded data as directed by the PM and SA. In this way, the data will be available in a timely manner to appropriate persons. All personnel involved in the study will have the opportunity to review these data before they are incorporated into the final report. Purdue will maintain records of rejected or qualified data for EPA review and must not delete any data without written EPA approval. Invalid data will also be maintained throughout the study period, until as long as deemed necessary by EPA. No data shall be destroyed without EPA's permission.

References

Midwest Laboratories, Inc. 2004. Quality Assurance Manual. Ver 6, Midwest Laboratories, Inc, Omaha, NE, 138 p.

SOP D1. 2006. Management of Open-Source, Weather, and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.

23. Validation and Verification Methods

The purpose of data validation is to detect any data values that may not represent actual conditions at the sampling locations. The PDM will electronically back up all data that are obtained from the field and the laboratory. These backup copies will be maintained until the data are transferred to the dedicated computer and verified. Verification entails a review to ensure that all the data for the collection period are accounted for. Data will be validated and verified by

- comparison with instrumental performance parameters as identified in the applicable SOP or instrument operation manual.
- checking the operations records and changes in the building environment.
- compliance with stated objectives for representativeness, precision, and accuracy defined in section 7 using basic statistical methods (calculation of mean values, standard deviations of the sample, standard error of the means, and coefficient of variation) as well as temporal and spatial analyses.

However, the evaluation process used to find and correct an error may not be defined in this QAPP because not all possible errors and corrections can be anticipated.

If data is determined to be invalid, the person with primary data review responsibilities will inform the PM and a record of the invalid data will be prepared. Both the data reviewer and the supervisor are required to sign the form. Verified, raw data will be maintained on the dedicated computer throughout the study period and for six years after the end of the study by the SA. Purdue will maintain records of rejected or qualified data for EPA review and must not delete any data without written EPA approval. Invalid data will also be maintained throughout the study period, until as long as deemed necessary by EPA. No data shall be destroyed without EPA's permission."

23.1 *Validation of meteorological data*

The meteorological data is validated to ensure that the quality goals of the study are met. Computers are used to assist in validation of meteorological data by determining if the values fall outside a specified range. Validation of each individual measurement is outlined in the respective instrument SOP. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the meteorological data. Validation guidelines for many of the meteorological parameters are provided in USEPA (2000). Invalid flags will be attached to each variable below under the following conditions:

The QA flagging codes for the measurement of wind speed (Table 23.1) and wind direction (Table 23.2) documented in SOP W2 are indicated. If any values of these measurements are flagged with a non-zero data flag, evaluate associated barn measurement location (if available) or nearest NWS weather station for reasonableness: If unreasonable, substitute value from associated barn measurement location (if available) or nearest NWS weather station, if reasonable, document reason for validation of value (with the invalidation flag retained) and retain value for further processing. An unresolved non-zero flag code will result in an

unscheduled repair/replacement trip by FOS to the location of the measurement within 2-3 d. These are project critical measurements used in the RPM emissions model.

Table 23.1. Wind speed QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or communications failure, substitute value from one of the two other anemometers if appropriate.
2	Value < 0 m/s or > 50 m/s or value is ±infinity	Check computations, connections, cable condition, lightning damage; repair or replace
4	Spike count >160.	Check connections, cable condition, lightning damage; repair or replace
8	Standard deviation over 24 h > 9 m/s.	Check connections, cable condition, lightning damage; repair or replace
16	5 min value does not vary by 0.5 m/s (1.1 mph) for 12 consecutive hours	Check connections, cable condition, lightning damage; repair or replace
32	5 min value does not vary by 0.1 m/s (0.2 mph) for 3 consecutive hours	Check connections, cable condition, lightning damage; repair or replace
64	> 10% of sampling interval has path obstruction	Check weather conditions (icing), farm activity; repair or replace

Table 23.2. Wind direction QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or communications failure, substitute value from one of the two other anemometers if appropriate
2	Value >360° or less than 0°	Check connections, cable condition, lightning damage; repair or replace
4	Spike count >160.	Check connections, cable condition, lightning damage; repair or replace
8	Standard deviation over 24 h < 0 ^{o} or > 90 ^{o} (bound of computation method).	Check connections, cable condition, lightning damage; repair or replace
16	5 min value does not vary by more than 10° for 18 consecutive hours	Check connections, cable condition, lightning damage; repair or replace
32	5 min value does not vary by more than 1° for 3 consecutive hours	Check connections, cable condition, lightning damage; repair or replace
64	> 10% of sampling interval has path obstruction	Check weather conditions (icing), farm activity; repair or replace

The QA data flagging codes and associated corrective actions for the measurement of air temperature (Table 23.3), relative humidity (Table 23.4), and barometric pressure (Table 23.5) documented in SOP W1 and SOP W5 are indicated. If any values of these measurements are

flagged with a non-zero data flag, evaluate associated barn measurement location (if available) or nearest NWS weather station for reasonableness. The location-adjusted NWS barometric pressure (according to SOP W5) and ambient temperature are corrected for altitude differences between location and NWS station and location adjusted ambient humidity is corrected for temperature differences between location and NWS station (according to SOP W1). The reasonableness of the sonic air temperature (SOP W2) at all three heights will be determined by comparison to the ambient virtual temperature determined from the ambient air temperature and the ambient relative humidity. If values are unreasonable, substitute value from associated barn measurement location (if available) or nearest NWS weather station, if reasonable, document reason for validation of value (with the invalidation flag retained) and retain value for further processing.

An unresolved non-zero data flag for these measurements will not result in an unscheduled repair/ remediation trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. These are project non-critical measurements used in the temperature, water vapor, and pressure correction of gas measurements.

Table 23.3. Temperature QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure
2	Value < -40°C or > +50°C (bounds of sensor calibration)	Check weather conditions and time series for inconsistencies. Check sensor mount, wiring, casing. Repair or replace.
4	Value > 7°C (16°F) change from the previous hour	Check sensor mount, wiring, casing. Repair or replace.
8	Value does not vary by more than 0.5°C (0.9°F) for 12 consecutive hours	Check sensor mount, wiring, casing. Repair or replace.
16	Value > local record high or < the local low on a monthly average	Check sensor mount, wiring, casing. Repair or replace.
32	Value differs by more than 5°C from the altitude-corrected air temperature from the nearest National Weather Service (NWS) weather station	Check weather conditions and time series for inconsistencies. Check sensor mount, wiring, casing. Repair or replace.
64	No NWS data for nearby stations is available for comparison	None

Table 23.4. Relative humidity QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure (measurements of other sensors also missing?), sensor wiring.
2	Value < -2% or > 104% (range of the sensor calibration and uncertainty)	Check sensor mount, wiring, casing. Repair or replace.
4	Value standard deviation over one hour> 20%	Check weather conditions and time series for inconsistencies. Check sensor mount, wiring, casing. Repair or replace.
8	Value differs by more than 15% from the temperature-corrected relative humidity from the nearest National Weather Service (NWS) weather station	Check sensor mount, wiring, casing. Repair or replace.
16	No NWS data for nearby stations is available for comparison	None

Table 23.5. Barometric pressure QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure
2	Value < 600 hPa or > 1100 hPa (i.e. outside the range of the sensor)	Check sensor mount, wiring, casing. Repair or replace as necessary.
4	Difference between the sampling site and local weather station is more than 8 hPa	Check sensor mount, wiring, casing.. Check weather conditions/ time series for inconsistencies. Repair or replace as necessary.
8	No NWS data for nearby stations is available for comparison	None

Table 23.6. Sonic temperature QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or data logger communications failure
2	Value <-40°C or >+50°C	Check connections, cable condition, lightning damage; repair or replace
4	Spike count >160.	Check connections, cable condition, lightning damage; repair or replace
8	Difference between value and calculated T_v >5°C	Check sensor mount, wiring. Repair or replace as necessary.
16	No weather station data available	Repair or replace humidity and temperature probe.

The QA data flagging codes for the measurement of solar radiation documented in SOP E3 are indicated in Table 23.7. No corresponding measurement is made at NWS weather stations. If any values of these measurements are flagged with a non-zero data flag, evaluate associated barn measurement location (if available): If unreasonable, substitute value from associated barn measurement location, if reasonable, document reason for validation of value (with the invalidation flag retained) and retain value for further processing. An unresolved non-zero data flag for these measurements will not result in an unscheduled repair/replacement trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. This is a project non-critical measurement used in the assessment of general weather conditions.

Table 23.7. Solar radiation QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure. Check sensor wiring, casing. Repair or replace as necessary.
2	Ratio of sensor measurement to potential irradiance is greater than 0.9	Check sensor wiring. Repair or replace as necessary.
4	Measurements between 10 AM and 2 PM are less than 10% of potential irradiance	Check sensor mount, wiring, casing. Repair or replace as necessary.

The QA data flagging codes and associated corrective actions for the measurement of wetness documented in SOP W3 are indicated in Table 23.8. If flagged with a non-zero data flag, evaluate conditions reported at the nearest NWS weather station for reasonableness: If unreasonable substitute value corresponding to expected state based on weather conditions of nearest NWS weather station, if reasonable document reason for validation of value (with the invalidation flag retained) and retain value for further processing. An unresolved non-zero data flag for these measurements will not result in an unscheduled repair/replacement trip by FOS

staff, but the sensor repair/replacement will be addressed in the next routine site visit. This is a project non-critical measurement used in the determination of dew or rain events.

Table 23.8 Wetness QA flagging codes

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or data logger communications failure
2	Values for day and prior day are not consistent with at least one of the past two day's weather conditions	Inspect sensor, repair or replace.

23.2 *Validation of sonic anemometer data*

The QA flagging codes for the sonic anemometer measurements at each height (2 m, 4 m, and 16 m) are indicated in Table 23.9.1. If the value of the 2 m sensor is flagged with a non-zero code, substitute value from the 4 m sensor for the bLS model input. If both the 2 m and 4 m sensor have a non-zero code, then no value is substituted. No equivalent measurements are made at either any associated barn measurement location or a NWS weather station. A non-zero flag code for all wind sensors will result in an unscheduled repair/replacement trip by FOS to the location of the measurement with 2-3 d. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the sonic anemometer data. These are project critical measurements used in the bLS emissions model.

Table 23.9.1 QA flagging codes for individual sonic anemometer components (u′, v′, w′, T_v′).

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of records in 5-min period)	Check for power or communications failure
2	Value below minimum or above maximum or value is ±infinity	Check connections, cable condition, lightning damage; repair or replace
4	Spike count >160	Check connections, cable condition, lightning damage; repair or replace
8	Value has variance >10 m^2/s^2 (u, v, w) or 10 C^2 (T)	Check connections, cable condition, lightning damage; repair or replace
16	> 10% of sampling interval has path obstruction	Check weather conditions (icing), farm activity; repair or replace

The individual components of turbulence are inter-correlated. The conditions influencing the validity of the bLS model will be assessed from: 1) checking for stationarity in the time series by comparing the 5-min covariances of u′ and w′ and w′ and T_v′ to the 30-min averaged covariances, with invalid data indicated by differences of greater than 30% between the 5-min and 30-min

values (Foken and Wichura, 1996), and 2) checking for inhomogeneity by comparing the theoretically derived and measured integral turbulence scales of w' and T_v' (u_* and T_{v*}) to the standard deviation of w' and T_v', with invalid values when the measured and derived values differ by more than 30% (Foken and Wichura, 1996). The QA flagging codes associated with these criteria are found in Table 23.9.2. These are project non-critical measurements used to qualify the bLS model accuracy.

Table 23.9.2 QA flagging codes for combinational components (u', v', w', T_v').

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	> 10% of sampling interval has path obstruction	Check weather conditions (icing), farm activity; repair or replace
2	$u'w'$ not stationary (30-min period)	Check weather conditions, stability and wind directions
4	$w'T'$ not stationary (30-min period)	Check weather conditions, stability and wind directions
8	σ_u inhomogeneous turbulence in 30-min period	Check weather conditions, stability and wind directions
16	σ_w inhomogeneous turbulence in 30-min period	Check weather conditions, stability and wind directions
32	σ_T inhomogeneous turbulence in 30-min period	Check weather conditions, stability and wind directions

23.3 *Validation of lagoon/basin characterization data*

The lagoon/basin wastewater characterization data is validated to ensure that the quality goals of the study are met. Computers are used to assist in validation of the data by determining if the values fall outside a specified range. Validation of each individual measurement is outlined in the respective sensor SOP.

The QA data flagging codes for the measurement of lagoon pH (Table 23.10), redox potential (Table 23.11), and wastewater temperature (Table 23.12) documented in SOP L1, SOP L2, and SOP L3 are indicated. No value substitution is possible as there are no equivalent measurements made at the measurement location. A non-zero data flag for these measurements will not result in an unscheduled repair/replacement trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the lagoon/basin characterization data. These are project non-critical measurements used to describe the lagoon condition.

Table 23.10. pH QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or communications failure
2	Value > 8.5 or < 6.5	Check connections, cable condition, clogged probe, low solution.; recalibrate
4	Changes by more than 0.5 in 1 h	Check for data flag 4 in lagoon temperature and redox measurements. If yes, ask associated barn measurement team (if applicable for the location) or producer to check if the sensor float is still right side up. If yes then schedule wiring and sensor troubleshooting for next site visit. If no, then ask barn measurement team to right probe float (if applicable).
8	Does not vary from 5.8 to 6.2 over 3 h	Check probe for crack; if yes, repair or replace
16	Does not vary from 7.0 over 3 h	Check cable for damage; if yes, repair of replace

Table 23.11. Redox potential QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (>10% of possible values in period)	Check for power or communications failure
2	Value > -20 mV or < -800 mV	Check for contamination or damage; clean or repair
4	Value ≥ 1100 mV	Check for damaged cables, loose connections, clogged or coated probe; repair or clean
8	Value= 0 mV	Check cable for damage, repair or replace

Table 23.12. Wastewater temperature QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or communications failure
2	Value < -40 °C or > +50°C (bound of sensor calibration)	Check cable and connections; repair or replace
4	Value > 5°C (9°F) change from the previous hour	Check for data flag 4 in lagoon pH and redox measurements. If yes, ask associated barn measurement team (if applicable for the location) or producer to check if the sensor float is still right side up. If yes then schedule wiring and sensor troubleshooting for next site visit. If no, then ask barn measurement team to right probe float (if applicable).

The QA data flagging codes for the measurement of lagoon sludge depth documented in SOP L5 are indicated in Table (23.13). These measurements are made manually by the FOS. Values with non-zero data flags cannot be substituted but since eight to nine measurements of sludge depth are made, the invalidated measurements will likely not result in a significant loss of data. It is anticipated that failures of the sensor will be evident by the FOS at the time of measurement and the instrument will be returned to PAML at the time that the FOS return. At that time, the instrument will be tested and a decision for repair or replacement made.

Table 23.13. Sludge depth QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Verify with FOS that the measurement was made.
2	Value > depth of lagoon	Verify with FOS that procedures were adhered to and that sensor has returned with FOS for repair/replacement.

Validation of the manure analyses for pH, total solids content, volatile solids content, ammonia nitrogen and total nitrogen conducted by the commercial laboratory (Midwest Laboratories, Inc.) is certified by the National Environmental Laboratory Accreditation Program (NELAP) to conduct the methodologies on which SOP M2 through SOP M5 are based: Method 9040C (USEPA, 2004), Method 1684 (USEPA, 2001a; Draft version), Method 1687 (USEPA, 2001b) and Method 350.2 (USEPA, 1974).

23.4 *Validation of UV-DOAS data*

The UV-DOAS data will be validated to ensure that the quality goals of the study are met. The UV-DOAS instrument control and data processing control computer will be used to assist in validation of meteorological data by determining if the values fall outside a specified range.

Data will be reviewed and validated by comparison with instrumental performance parameters. Three data validation techniques will be used to assess the validity of data prior to data interpretation and reporting: (1) light levels, (2) signal-to-noise ratio, and (3) lowest acceptable concentration for proper analyzer performance. The procedures outlined in SOP C1 will be followed. Data for each 5-min measurement period also will be evaluated for compliance with stated objectives for representativeness (75% valid measurements during sample period), precision, and accuracy.

Analyzer function and performance procedures found in SOP C1 must be performed to confirm that the measuring system is operating correctly. If function and performance tests indicate the instrument is not operating correctly, data must be flagged with an explanation of the quality issue and a discussion of the impact the deviations have on the quality of the data. Data validation analysis must be applied to each individual pollutant parameter in each field test application since the light levels, standard deviations, and detection limits vary with field test conditions, differences in path lengths, monitoring times, and detection limits.

The minimum requirements for QA and data validation include the following:

1. Valid initial reference and multipoint span calibration;
2. Span/offset check prior to the measurement period;
3. Normal system performance during the measurement campaign as determined by system tests and light levels;
4. Span/offset check following the conclusion of measurements that is within the acceptance parameters;
5. Signal strength and relative single beam intensity;
6. Acceptable correlation coefficient of filtered absorption spectrum to the calculated spectrum (greater than 0.75),
7. Pixel shift of one (approx. 0.07 nm) or less for the alignment of an NH_3 absorption peak from the measured/filtered absorption spectra to the NH_3 reference spectra (for H_2S QA),
8. Low spectrum analysis residual (the un-explained RMS residual from the analytical characterization of the measured/filtered spectrum):

   RMS residual= $\frac{\sum_{waveband}(FA-EA)^2}{\sum_{waveband}(FA-\overline{FA})^2}$ <0.25, and
9. Other validation checks in accordance with operating manuals.

Table 23.14. UV-DOAS NH_3 and H_2S QA flagging codes for each beamline.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or communications failure
2	Value zero	Check alignment; contact PM if aligned for replacement/repair
4	Maximum peak emission<2500 counts	Check for obstructions, check weather records of site and nearby NWS weather station for heavy fog, freezing rain,
8	Integration time >500 ns	Check alignment; contact PM if aligned for replacement/repair
16	Total drift at 270 nm < ±0.002 AU	Contact PM; if flag unresolved- replace/repair
32	Signal at 210 nm > 205 signal at 250 nm	Contact PM; if flag unresolved- replace/repair
64	Dark current ≤±5 counts	Contact PM; if flag unresolved- replace/repair
128	Pixel shift > 1	Check QC spectral feature pixel shift of measurement period, Check alignment, Check spectrum for below MDL NH_3 concentration, check abnormal shape, reprocess spectrum, contact PM if flag unresolved- replace/repair
256	Spectrum correlation coefficient < 0.75	Check alignment, Check spectrum for below MDL NH_3 concentration , Check spectrum for abnoramal shape, Check alignment, Contact PM; if flag unresolved- replace/repair
512	Analysis residual > 0.25	Check spectrum for below MDL NH_3 concentration, Check spectrum for abnormal shape, Check alignment, Contact PM; if flag unresolved- replace/repair

Any data not meeting the data quality objectives will be flagged as invalid for comparison to screening level criteria. Data flags associated with the QA checks are documented in Table 23.14. Subsequently, the root cause of the invalidation will be explored. No equivalent measurements are made at the location. A non-zero flag code will result in an unscheduled repair/replacement trip by FOS to the location of the measurement within 2-3 d. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the UV-DOAS data. These are project critical measurements used in the bLS emissions model.

23.5 *Validation of TDLAS data*

The TDLAS data will be validated to ensure that the quality goals of the study are met. The open path TDLAS instrument control and data processing computer will be used to assist in validation of the TDLAS data by determining if the values fall outside a specified range.

Data will be reviewed and validated by comparison with instrumental performance parameters. Three data validation techniques will be used to assess the validity of data prior to data interpretation and reporting: (1) light levels, (2) signal-to-noise ratio, and (3) lowest acceptable concentration for proper analyzer performance. The procedures outlined in the SOP C2 will be followed. Data for each 10-min measurement period also will be evaluated for compliance with

stated objectives for representativeness (75% valid measurements during each sample period), precision, and accuracy.

Analyzer function and performance procedures found in SOP C2 must be performed to confirm that the measuring system is operating correctly. If function and performance tests indicate the instrument is not operating correctly, data must be flagged with an explanation of the quality issue and a discussion of the impact the deviations have on the quality of the data. Data validation analysis must be applied to each individual pollutant parameter in each field test application since the light levels, standard deviations, and detection limits vary with field test conditions, differences in path lengths, monitoring times, and detection limits.

The minimum requirements for QA and data validation include the following:

1. Valid initial reference and multipoint span calibration;
2. Span/offset check prior to the measurement period;
3. Normal system performance during the measurement campaign as determined by system tests and light levels;
4. Span/offset check following the conclusion of measurements that is within the acceptance parameters;
5. Other validation checks in accordance with operating manual

Any data not meeting the MQO will be flagged as invalid. Internally-derived status codes are indicated in the data-logging program data stream output. Data flags associated with these QA checks are documented in Table 23.15. No equivalent measurements are made at the location. The cause for the non-zero data flag will be explored by comparisons of all data flags. An unresolved non-zero flag code will result in an unscheduled repair/replacement trip by FOS to the location of the measurement with 2-3 d. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the TDLAS data. These are project critical measurements used in the bLS emissions model.

Table 23.15. TDLAS NH_3 QA flagging codes for each beamline.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for power or communications failure
2	Return beam intensity <500 or >12000	Check alignment, clean windows and invalidate measurement.
4	Internal reference linearity $r^2 \leq 0.9$	Contact PM, if unresolved, return for repair/replacement
8	Internal calibration failure	Contact PM, if unresolved, return for repair/replacement
16	Internal temperature <15°C above ambient temperatures	Check for power failure, contact PM; if unresolved, return for repair/replacement

23.6 *Validation of PAS data*

The PAS data is validated to assure that the DQOs of the study are met. Computers are used to assist in validation of the data by determining whether the values fall outside a specified range. Validation of each individual measurement is outlined in SOP G7. The PAS data consists of measurements that are both project critical and project non-critical. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the PAS data.

The project critical measurements include methane and NH_3. The NH_3 is needed (in conjunction with TDLAS NH_3 PIC measurement and the corresponding RPM-calculated NH_3 emissions) to estimate the VOC emissions of methane. The QA data flagging codes for the measurements are indicated in Table 23.16. A non-zero data flag for these measurements will result in an unscheduled repair/replacement trip by FOS staff. No value substitution is possible as there are no equivalent measurements made at the measurement location.

Table 23.16. PAS measurement QA flagging codes.

Data Flag	Analyte	Reason	Corrective action
0	All	Value not suspect	None
1	All	Event mark “R1” from instrument	Power failure and restarted, no action
2	All	Value missing	Check for power or communications failure: other values also missing.
4	All	Value varies < 2 MDL over 1 h	Check for plugged gas sampling line or filter; clean or repair, invalidate measurement if due to plugged lines/filter
8	All	Event mark “F” from instrument	Filter out of alignment, realign filter wheel, invalidate measurement.
16	All	Event mark “X1” from instrument	Operational error; contact manufacturer for repair/replacement, invalidate measurement.
32	All	Event mark “A” from instrument	Over-range of instrument, check other measurements by instrument
64	NH_3	NH_3 value > MDL and > 10 x NH_3 value of corresponding TDLAS path	Check inlet filter for cleanliness, filterwheel for motion/sequence. Replace filter if needed. If filter wheel failure, contact manufacturer for repair/replacement
128	GSS sampling flow rate	Sampling flow rate less than combined analyzer flow (2 L/min) demand	Check S-OPS and GSS inlet filters for cleanliness. Replace filter if needed.
256	GSS pressure	Sample manifold pressure < -50 kPa	Check S-OPS and GSS inlet filters for cleanliness. Replace filter if needed.

The minimum requirements for QA and data validation include the following:

1. Valid initial reference and multipoint span calibration;

2. Span/offset check prior to the measurement period;
3. Normal system performance during the measurement campaign as determined by system tests;
4. Span/offset check following the conclusion of measurements that is within the acceptance parameters;
5. Other validation checks in accordance with operating manual

The project non-critical measurements include the concentration of MeOH and EtOH, used to partially define the composition of NMHC. The QA data flagging codes for these measurements are indicated in Table 23.16. A non-zero data flag for either of these measurements will not result in an unscheduled repair/replacement trip by FOS staff, but the sensor repair/replacement will be addressed in the next routine site visit. No value substitution is possible, as there are no equivalent measurements made at the measurement location.

23.7 *Cross-validation of UV-DOAS and TDLAS data*

Analysis of validated UV-DOAS and TDLAS data files that have been transferred to PAML by ftp will have *four* components. *All* data analysis components provide a higher level of data quality assurance and data reduction. By data, we mean the PIC of air pollutant gases measured by the UV-DOAS and TDLAS. For each set of 24 h of measurements and analysis, a daily check of the prior days measurements will be conducted (by the lead operator at PAML):

1. Determine the statistical properties of the daily data of downwind 30-min [H_2S] and [NH_3] (mean, median, 10th percentile, 90th percentile) and compare to the statistics of the prior records for the same location.
    a. Compare values of open path TDLAS and UV-DOAS when applicable (due to wind direction). Data comparability for NH_3 will be assessed by the collocated UV-DOAS and TDLAS instrumentation. Agreement between the monitoring methods will be considered acceptable if the respective 30-min data agree to within a coefficient of determination of 80%.
    b. Explore causes for extreme values with respect to temperature, wind direction, stability (L), and turbulence.
    c. Identify outliers on log (by 30 min of record) and specify conclusions.
2. Determine the statistical properties of the daily data of upwind 30-min [H_2S] and [NH_3] (mean, median, 10th percentile, 90th percentile) and compare to the statistics of the prior records for the same location.
    a. Compare to values from upwind open path TDLAS when applicable (due to wind direction)
    b. Explore causes for extreme values with respect to temperature, wind direction, stability (L), and turbulence.
    c. Identify outliers on log (by 30-min period) and specify conclusions.
3. Verify that the higher concentrations (mean, median, 90th percentile) occur for the downwind instrument.
4. Verify that the 10th percentile concentrations of upwind and downwind instruments are similar.

Based on these steps, additional data flag values are defined for both TDLAS and UV-DOAS measurements defined in Tables 23.14 and 23.15 according to Table 23.17.

Table 23.17. UV-DOAS / TDLAS cross-validation QA flagging codes.

Data flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (either UV-DOAS or TDLAS)	None, previously documented in individual measurement data flags
2	UV-DOAS value below MDL for TDLAS.	None, previously documented in individual measurement data flags
4	UV-DOAS value suspect - inexplicably below 10th or above 90th percentile of daily TDLAS.	None, track over time and look for trends
8	TDLAS value suspect - inexplicably below 10th or above 90th percentile of daily UV-DOAS.	None, track over time and look for trends

23.8 *Validation of bLS emissions estimates*

Emissions estimates from the WINDTRAX model (SOP O1) will be quality assured by evaluation of two DQI: the calculated Monin Obukov length (L) and the friction velocity. The bLS emissions calculations are made at PAML and DQI values calculated for each 30-min measurement interval. Plots of the apparent plume are saved on the on-site computer. Visual

Table 23.18 bLS QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for missing UV-DOAS or 2 and 4 m wind measurements
2	Inhomogeneity of turbulence at wind measurement height	None, results of low quality
4	Non-stationarity of turbulence at wind measurements height	None, results of low quality
8	$\|L\|<2$ m	None, results invalid
16	$u_* < 0.15$ m/s	None, results invalid
32	2-m wind substituted with 4-m wind	None
64	Value represents mean of multiple PIC measurements	None

inspection of the plots and measurement period DQI failures will be conducted. After inspection of plots, measurements made during unusual plume plots will be inspected and their validity

assessed. The bLS model will be rerun for all measurement periods at PAML using weather-specific conditions to create the touchdown tables. Periods that fail the DQI will be run, but flagged as invalid. Subsequently, the cause of the invalidation will be explored. Modeling will proceed even when the 5-min data acquisition atmospheric turbulence criteria are not met (Table 23.9), however the model measurement will be flagged for poor data quality (Table 23.18).

Prior studies indicate the emissions estimate is ±36% when period $|L|<2$ m and/or $u_* < 0.15$ m/s (Flesch et al., 2004). Emissions estimates will be classified as invalid when the mean period $|L|<2$ m and/or $u_* < 0.15$ m/s (Table 23.18). See SOP O1 for details. Further validation against the RPM emissions estimates will be conducted according to Method 301 (Section 10.5).

23.9 *Validation of RPM emissions estimates*

Emissions estimates from the RPM model (SOP O2) will be quality assured by evaluation of three DQI: the measured fraction of the plume, the Concordance Correlation Factor (CCF), and the correction factor (A). The RPM emissions calculations will be made on-site as an automated routine with DQI values calculated for each 10-min measurement interval (three complete cycles of the TDLAS scanning system). Plots of the reconstructed plumes will be saved on the on-site computer. The data and plots will be downloaded daily to PAML by ftp (SOP D1) and visual inspection of the plots and measurement period DQI failures will be done. Unusual plume plots and periods which failed the DQI will be manually rerun if the situation indicates a shift in cycles per measurement or shift in measurement period may result in successful emissions calculations.

Modeling will proceed even when only one 10-min mean wind speed measurement height is valid, however the model measurement will be flagged for poor data quality (data flag 1 in Table 23.19). Modeling will also proceed if there are only three valid PIC measurements (the longest pathlength), however the model measurement will be the flagged for poor data quality (Data flag 1 in Table 23.19). Modeling will not proceed if there are no valid TDLAS PIC measurements.

Calculated emission rates will be considered valid when the topmost PIC is less than or equal to 90% of the midlevel PIC (Table 23.19). Under these cases, the measurement plane contains 70% or more of the plume. Prior studies indicate that the emissions error is ±20% when the emissions estimate is based on measurements of the ‘entire’ plume (Hashmonay and Yost, 1999). The Concordance Correlation Factor (CCF) indicates the goodness of fit between measured and predicted PIC. CCF is defined as $CCF = rA$ where r is the Pearson correlation coefficient, and A is a correction factor for the shift in population and location. This shift is a function of the relationship between the averages and standard deviations of the measured and predicted PIC vectors:

$$A = \left[\frac{1}{2} \left(\frac{\sigma_{PIC_P}}{\sigma_{PIC_M}} + \frac{\sigma_{PIC_M}}{\sigma_{PIC_P}} + \left(\frac{\overline{PIC_P} - \overline{PIC_M}}{\sqrt{\sigma_{PIC_P} \sigma_{PIC_M}}} \right)^2 \right) \right]^{-1} \qquad \text{(Equation 23.1)}$$

where σ_{PIC_P} and σ_{PIC_M} are the standard deviations of the predicted and measured PIC vectors respectively, and $\overline{PIC_P}$ and $\overline{PIC_M}$ are the means of the predicted and measured PIC vectors respectively. An A≥ 0.9 verifies that the plume positioning is a reasonable fit of the raw data. If A<0.9, a longer grouping of measurement cycles should be used (4 instead of the nominal 3) and the algorithm rerun (Table 23.18). A CCF ≥0.8 indicates that the surface concentration plot is a reasonable fit with the raw data. If the CCF <0.8, a longer grouping of measurement cycles should be used (4 instead of the nominal 3) and the algorithm rerun (Table 23.18). These changes in the grouping of measurement cycles will be a post-processing procedure for RPM emissions calculations that fail the A and/or CCF DQI of the automated routine but pass the plume capture fraction DQI. Emissions estimates will be classified as invalid when any of the DQIs are not met. Subsequently, the cause of the invalidation will be explored.

Table 23.19. RPM QA flagging codes.

Data Flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing	Check for missing wind or TDLAS measurements, results of poor quality
2	CCF<0.8	Invalidate results, increase number of cycles included in PIC and wind averaging and rerun model.
4	A<0.9	Invalidate results, increase number of cycles included in PIC and wind averaging and rerun
8	15 m TDLAS PIC > 8 m TDLAS PIC or 8 m TDLAS PIC > 1 m TDLAS PIC	No calculation, Invalid plume conditions
16	15 m TDLAS PIC > 0.9 of 8 m TDLAS PIC	No calculation, Invalid plume conditions
32	2 m wind invalid, substituted 4 m wind	None
64	4 m wind invalid, substituted 16 m wind	None
128	16 m wind invalid, substituted 4 m wind	None
512	2 of 3 wind measurements invalid	Invalidate results, no wind profile

23.10 *Reconciliation of Validated RPM and bLS emissions estimates*

If the UV-DOAS and TDLAS systems are used to measure NH_3, it is anticipated that validated emissions calculations from the RPM method and the bLS method will not be the same. Consequently, a means of evaluating the 'true' emission must be made. If the correction factor for the bLS emission calculation is between 1.10 and 0.90 that of the RPM calculation method,

as determined in the validation study (Section 10.7), then the bLS and RPM calculations will both be considered of equal accuracy. Consequently:

- If there is a significant difference between the validated RPM and bLS NH_3 emissions; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S emissions will be determined using the ratio of H_2S to NH_3 concentrations determined by the UV-DOAS measurements multiplied by the RPM NH_3 emissions calculation.
- If the difference between the validated RPM and bLS NH_3 emissions is not significant; the NH_3 emissions for the basin will be the average of the two emissions calculations and the H_2S emissions will be based on the bLS model results. If the RPM emissions calculation of NH_3 is valid but the bLS calculation is invalid; the NH_3 emissions for the basin will that computed from the RPM model and the H_2S emissions will be determined using the ratio of H_2S to NH_3 concentrations determined by the UV-DOAS measurements multiplied by the RPM NH_3 emissions calculation.

Emission measurements will be weighted according to the results of the bLS/ RPM comparison study described in Section 10.7 and a statistical representation (mean and standard deviation) of the emission estimates made. Using these statistics, outlying emissions calculations can be identified and evaluated as to cause, and emission measurement confidence can be determined.

If the correction factor for the bLS emission measurement is more than 1.10 or less than 0.90 that of the RPM measurement method, then the bLS method will be used differently for lagoon/ basin and corral measurements. At the lagoon/ basin locations, the bLS model will not be considered valid even when the DQI for the bLS method are satisfied. The RPM emission rate for NH_3 will be the true emission while the emission rate of H_2S will be based on the ratio of UV-DOAS NH_3 and H_2S PIC measurements will be used in combination with the TDLAS NH_3 PIC and RPM measured emission using Equation 10.1. Since only bLS emissions calculations are made at the corral location, all bLS emission estimates that pass the DQI will be considered valid and will be qualified at a reduced accuracy in accordance with the validation experiment.

23.11 *Validation of PFA data*

The PFA data is validated to assure that the DQOs of the study are met. Computers are used to assist in data validation by determining whether the values fall outside a specified range. Validation of each individual measurement is outlined in SOP G5. The PFA data consists of H_2S measurements that are project critical. The minimum requirements for QA and data validation include the following:

1. Valid initial reference and multipoint span calibration
2. Span/offset check prior to the measurement period
3. Normal system performance during the measurement campaign as determined by system tests and light levels
4. Span/offset check following the conclusion of measurements that is within the acceptance parameters
5. Other validation checks in accordance with operating manual

The H_2S measurements are needed (in conjunction with TDLAS NH_3 PIC measurement and the corresponding RPM-calculated NH_3 emissions) to estimate the H_2S emissions. The QA data flagging codes for the measurements are indicated in Table 23.20. A VisualBasic program will build an Excel® spreadsheet, assisting in the validation of the PF data. A non-zero data flag for these measurements will result in an unscheduled repair/replacement trip by FOS staff. No value substitution is possible as there are no equivalent measurements made at the measurement location.

Table 23.20. PF measurement QA flagging codes.

Data Flag	Analyte	Reason	Corrective action
0	All	Value not suspect	None
1	All	Value missing	Check for power or communications failure: other values also missing.
2	Reaction chamber and converter	Reaction chamber out of range (43-47°C) or converter temperature out of range (300-400°C)	Operational error. Contact manufacturer for repair/replacement, invalidate
4	H_2S and SO_2	Does not vary more than 2 ppb over 1 h	Check other measurements by instrument, contact manufacturer for repair/replacement, invalidate
8	Pressure	Pressure outside of range (400-1000 mmHg)	Check for plugged gas sampling line or filters or inlet filters; clean or repair, invalidate measurement if due to plugged line/filter.
16	Sample flow rate	Flow rate outside of range (0.35-1.4 L/min)	Check for plugged gas sampling line or filters or inlet filters; clean or repair, invalidate measurement if due to plugged line/filter.
32	Lamp intensity or voltage	Lamp voltage outside of range (20-100) Lamp intensity outside of range (500-1200)	Operational error. Contact manufacturer for repair/replacement, invalidate
64	GSS sampling flow rate	Sampling flow rate less than 2 L/min	Check S-OPS and GSS inlet filters for cleanliness. Replace filter if needed.
128	GSS pressure	Sample manifold pressure < -50 kPa	Check S-OPS and GSS inlet filters for cleanliness. Replace filter if needed.

23.12 *Cross-validation of PAS and TDLAS data*

Analysis of validated PAS and TDLAS data files that are transferred to PAML by ftp will have four components. All data analysis components provide a higher level of data quality assurance and data reduction. By data, we mean the PICs of air pollutant gases measured by the TDLAS that are nearest to the S-OPS system on the two sides of the source, and the PAS measurements from the S-OPS-sampled air. For each set of 24 h of measurements and analysis, a daily check of the prior day's measurements will be conducted (by the lead operator at PAML). Cross-validation will consist of the calculation of the statistical properties of the daily data of valid 30-min [NH_3] concentrations (mean, median, 10th percentile, 90th percentile) and a comparison of resulting values. Agreement between the monitoring methods will be considered acceptable if the respective PAS 30-min data agree to within a coefficient of determination of 80% of the TDLAS data. Where agreement is not indicated, data analysts will explore causes for extreme values with respect to temperature, wind direction, stability (L), and turbulence and identify outliers on log (by 30 min of record) and specify conclusions. Based on these steps, additional data flag values are defined for both TDLAS and PAS measurements according to Table 23.17.

Table 23.17. PAS / TDLAS cross-validation QA flagging codes.

Data flag	Reason	Corrective action
0	Value not suspect	None
1	Value missing (either TDLAS or PAS values missing)	None- previously documented in individual measurement data flags
2	TDLAS value below MDL for PAS	None
4	TDLAS value suspect - inexplicably above daily 90th percentile or below daily 10th percentile.	None, track over time and look for trends
8	PAS value suspect - inexplicably above daily 90th percentile or below daily 10th percentile.	None, track over time and look for trends

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24. Reconciliation with User Requirements

Since there are no specific DQOs for the study, explicit evaluation of the meeting of the DQOs is not possible. The two general DQO identified in section 7 provide the criteria to evaluate how well the project has met the intended use as specified by the ACA. Data (measurement or calculation) are flagged as invalid based on data validation checks, performance audits, technical system audits, or QC checks. All data is retained.

The first DQO for the study is to provide mean daily lagoon/ basin emission calculations for each farm waste storage area under study that are within 30% of the true values for each measurement period. This DQO is derived from the emissions model errors associated with the measurements used in the study and not from statistical analysis of previous measurements due to the very limited duration of previous lagoon/ basin emissions measurements. The quality of the measurements and calculated emissions of NH_3, H_2S and VOCs (THC, methane, MeOH and EtOH) will be assessed by:

- A review of the data including the review of systematic invalidation of data as indicated in the quality assurance reports.
- Inspection of summary statistics (number of samples, mean concentration, median concentration, standard deviation, coefficient of variation, and probability distributions) generated for all measurements within a day of a measurement period and for each quarter of year for emissions characteristics of the area sources.
- Statistically compare the daily emissions by operation type to determine influence of season, climate/operation type on emissions. Determine the typical daily emissions for each operation type and season using the predefined measurement errors.

The second DQO is the completeness criteria for the study: Valid samples of NH_3, H_2S, THC, methane, MeOH and EtOH) emissions during each quarter will consist of 75% of 10 d of valid measurements or 7.5 d. Since there is no way to rerun the periods of measurement, invalid data directly impacts the final completeness DQO. An evaluation of the completeness of the data for the determination of typical emissions for the represented operations will qualify the analyses of daily emissions above.

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Appendix A- Measurement Quality Objectives

Tables reporting the MQO for each parameter needed in the study follow.

Table A1. Measurement Quality Objectives - Ambient temperature (Thermistor in CSI Model HMP45C hygrometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Degrees C		
Shelter temperature	Daily	-40 - +60°C		Sensor mounted in solar radiation shelter and kept at ambient environmental conditions
Equipment -thermistor	Purchase specification	Accuracy ±0.5 °C across -40 - +60°C	USEPA 454/R-99-005	Sensor is part of a instrument.
Detection	Purchase specification	0.1 °C	Manufacturer manual	Platinum resistance thermistor
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling for approx. 21 d/quarter to assure 90% of 10 d
Local primary standard	Purchase specification	±0.01 °C	Manufacturer calibration certificate	NIST certified standard immersion thermometer
Calibration	On receipt Annual	Accuracy ±0.5 °C across -40 - +60°C, NIST traceability	USEPA 454/R-99-005 SOP W1	Invalidate data to last acceptable calibration. Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.
Performance evaluation	Daily	-40 to +60°C , 1) hourly SD > 2°C, 2) < 5°C change from previous hour 3) varies > 0.5°C over 12 consecutive hours 4) within 3°C of nearby NWS measurement	SOP W1	Data automatically flagged, assess weather conditions Check sensor mount, wiring, casing; repair or replace
Precision	Annual	0.3 °C	Manufacturer manual	Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.
Accuracy	Annual	Accuracy ±0.5 °C across -40 - +60°C	SOP W1	Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.

Table A2. Measurement Quality Objectives- Parameter: Relative Humidity of ambient air (Hygrometer in Campbell Scientific, Inc. CSI HMP45C hygrometer; Vaisala, Inc.).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Percent relative humidity		Determined from temperature measurements.
Shelter temperature	daily	-40 - +60°C	Manufacturer manual	Sensor mounted in solar radiation shelter and kept at ambient environmental conditions
Equipment -RH sensor	Purchase specification	±2% over 10-90% RH; ±3% over 90-100% RH	Manufacturer manual	Sensor is part of an instrument.
Detection	Purchase specification	0.3%	Manufacturer manual	Capacitive chip
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Transfer standard	Purchase specification	Less than one year old	Batch purity certified by FINAS	Salts
Calibration - Salt solution calibration check	On receipt Annual	RH within 3% of theoretical values	ASTM E104 Manufacturer manual	Invalidate data to last acceptable calibration. Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.
Performance evaluation	Daily Hourly Hourly	-2%<RH≤104% Standard deviation< 20% within 10% of nearby NWS measurement	SOP W1	Data flagged
Accuracy	Annual	5%	USEPA 454/R-99-005 SOP W1	Contact PM for replacement of sensor head with HMP 41 sensing element and recalibrate. If continued problems, decommission and return to manufacturer for repair and contact PM for replacement or repair.

Table A3. Measurement Quality Objectives- Parameter: Barometric pressure of ambient air (Campbell Scientific, Inc. CS110 aneroid barometer, Setra, Inc.).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	hPa		
Shelter temperature	daily	-40 - +60°C	Manufacturer manual	Instrument kept in a un-conditioned enclosed box.
Equipment -pressure sensor	Purchase specification	800-1100 hPa Accuracy ±3 hPa	USEPA 454/R-99-005	
Detection	Purchase specification	0.5 hPa	USEPA 454/R-99-005	
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Local primary standard		NIST traceability	Fortin barometer	
Calibration -multipoint	On receipt Annually	≤2 hPa ≤2 hPa	USEPA 454/R-99-005 SOP W5	Return to manufacturer for repair Back-correct data record for shift (>2 to ≤6 hPa) Back-correct data record for shift, Contact PM for replacement, repair (>6h Pa) Invalidate data to last acceptable calibration. Contact PM for replacement, repair
Performance evaluation	Daily	600 to 1100 hPa within 4 hPa of NWS measurement	SOP W5	Data flagged
Accuracy	Semi-annual	±2 hPa	SOP W5	

Table A4. Measurement Quality Objectives- Parameters: Wind speed and direction (Model 81000 RM Young ultrasonic anemometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Speed: m/s Direction: deg.		
Shelter temperature	Daily	-50 - +50°C	Manufacturer manual	Instrument mounted un-enclosed in the ambient environment
Equipment -3D sonic anemometer	Purchase specification	Speed: ±0.2 m/s + 5 % observed Direction: ±5 degrees	USEPA 454/R-99-005	
Detection	Purchase specification	Speed: 0.1 m/s Direction: 1 degree	USEPA 454/R-99-005	
Completeness 5 min data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Calibration Intercomparison of three sensors Intercomparison of at least three sensors	 Beginning/end of meas. period or 20d, whichever comes first On receipt / Every six months	 Difference between sensors <0.2 m/s Difference between sensors <0.2 m/s Sensor calibration with NIST traceability	SOP W2	Invalidate data to last acceptable calibration or evident failure in data record. Contact PM for replacement Return to manufacturer for repair
Performance evaluation - zero check - range and variability	Daily Beginning/end of meas. period or 20d, whichever comes first Daily	Zero check yields <0.3 m/s <u>Wind speed</u>: 0 - 45 m/s, varies by >0.1 ms^{-1} in 3 consecutive hours, varies by > 0.5 ms^{-1} in 12 consecutive hours, SD < 9 m/s <u>Wind direction</u> : 0° -360°, SD between 0 and 90 degrees.	SOP W2 USEPA 454/R-99-005	Data flagged Documented on calibration form Data flagged
Accuracy		Speed: ±0.2 m/s Direction: ±5 degrees		

Table A5. Measurement Quality Objectives- Parameter: Surface wetness (AC resistance grid plate).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Wet or Dry		
Equipment - wetness grid	Purchase specification	Detect wetness with resistance change	Manufacturer manual	Instrument mounted un-enclosed in the ambient environment
Detection		threshold of visual wetness	Manufacturer manual	
Completeness 5 min data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Verification	On receipt At end of study	Resistance change on wetting	Manufacturer manualSOP W3	Return to manufacturer for repair
Performance evaluation (Wetting)	At beginning of each measurement period Daily Daily	Resistance change on wetting Dry condition: <0.3124 mVDC Wet condition: >6.1881 mVDC Must match wetness state from NWS or other external source in at least one of the past 2 d	SOP W3	Invalidate data to last acceptable evaluation. Substitute with external weather information. Data flagged Check continuity of sensor and cleanliness of surface and retest -Sensor cleaned if dirty -if continued problem, contact PM for replacement/ return to manufacturer for repair
Accuracy	On receipt At end of study	Resistance change on wetting	SOP W3	Check continuity of sensor and cleanliness of surface Return to manufacturer for repair

Table A6. Measurement Quality Objectives- Parameter: Solar radiation (LiCOR 200SB silicon photodiode radiometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	W/m^2		
Equipment - radiometer	Purchase specification	±5% of observed	USEPA 454/R-99-005	
Detection	Purchase specification	10 W/m^2	USEPA 454/R-99-005	
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Calibration	On receipt Annual	±5% response of unused sensor, NIST traceability	USEPA 454/R-99-005 Intercomparison with unused sensor SOP E3	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement or repair and PM for replacement.
Performance evaluation - Ratio of measured to potential values - Value check - Zero check	Daily Daily between 10AM-2PM At beginning of each measurement period or 21 d whichever comes first	<0.9 of potential irradiance >100 W/m^2 <0.01 mV	SOP E3 SOP E3	Data flagged. Invalidate data to last acceptable measurements. Inspect sensor and cable and clean sensor at next visit to site. If problem persists, decommission and contact manufacturer for replacement or repair and PM for replacement. Inspect sensor and cable. If problem persists, decommission and contact manufacturer for replacement or repair and PM for replacement.
Accuracy	Annual	±5% of unused sensor	SOP E3	Check for cleanliness of surface Return to manufacturer for repair

Table A7. Measurement Quality Objectives- Parameter: pH of lagoon/basin (Campbell Scientific, Inc. CSIM11 pH sensor; Innovative Sensors, Inc).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	pH unit		Correction using lagoon/basin temperature measurement
Shelter temperature	daily	0°C to +80°C	Manufacturer specification	
Equipment -pH sensor	Purchase specification	0 – 14 pH units accuracy 0.1%, ±0.1 pH unit	Manufacturer specification	
Completeness 1/2h data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Transfer Standards at pH 4.01, 7, 11 buffers	Every 6 mos.	NIST traceability	Manufacturer specification	Replace
Calibration 2-point Probe stability 2-point Probe stability	 On receipt Beginning/end of meas. period or 20d, whichever comes first	 ±0.1 pH units. ±0.05 pH units ±0.3 pH units ±0.05 pH units.	 APHA 4500-H+ Manufacturer specification SOP L1 Manufacturer specification	Return to manufacturer for replacement Invalidate data to last acceptable calibration, Return to manufacturer for repair or replacement
Performance evaluation	Beginning/end of meas. period or 20d, whichever comes first Daily	Accuracy ±0.3 pH units. Probe stability: ±0.05 pH units. Abrupt changes	SOP L1 Manufacturer specification	Data flagged; if at beginning of period, replace probe, if at end of period, invalidate data to last acceptable calibration check. Data flagged, check sensor
Accuracy	Every six months	±0.2 pH units.	SOP L1	Check for cleanliness Return to manufacturer for repair

Double junction Response time 95% of reading in 10s
Drift < 2 mV/week

Table A8. Measurement Quality Objectives- Parameter: Redox potential of lagoon/basin (Campbell Scientific, Inc. CSIM11-ORP sensor; Innovative Sensors, Inc).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	mV		Correction using lagoon/basin temperature measurement
Shelter temperature	daily	0° to +70°C		
Equipment -redox sensor	Purchase specification	-800 to +1100 mV	Manufacturer manual	
Completeness ½ h data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Transfer standard 230mV	Every 6 mos.	NIST traceability	Manufacturers specification SOP L3	
Calibration (standard solution-230mV)	On receipt Beginning/end of measurement period	≥ |10 mV| ≥ |30 mV| ≥ |50 mV|	APHA 2580 SOP L3	Return to manufacturer Data flagged; if at beginning of meas. period replace sensor, if at end correct values throughout period Invalidate data to last acceptable calibration. Contact PM for replacement / return to manufacturer for repair
Performance evaluation (standard solution)	Beginning/end of measurement period Daily	≥ |30 mV| ≥ |50 mV| Abrupt changes	SOP L3	Data flagged; if at beginning of meas. period replace sensor, if at end correct values throughout period Data flagged, Replace sensor Data flagged, check sensor
Accuracy	Every six months	±0.1% of full range	SOP L3	Check for cleanliness Return to manufacturer for repair

Table A9. Measurement Quality Objectives- Parameter: Temperature of lagoon/basin (Thermistor).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Degrees C		
Shelter temperature	daily	-35° to +50°C		Sensor is exposed in ambient wastewater
Equipment -submersible thermistor	Purchase specification	-38 ^{o}C to 53 ^{o}C Accuracy ±0.9 ^{o}C.	Manufacturer manual	
Detection	Purchase specification	0.1 ^{o}C	Manufacturer manual	
Completeness 1/2h data	10 d within quarter	90%	USEPA 454/R-99-005	No remediation possible Sampling will occur for approx. 21 d to assure 90% of 10 d in each quarter
Local primary standard	Purchase specification	±0.01 ^{o}C	Manufacturer calibration certificate	NIST certified standard immersion thermometer
Calibration	On receipt Every 6 mos.	±0.5 ^{o}C ±0.5 ^{o}C	USEPA 454/R-99-005 Water bath SOP L2	Invalidate data to last acceptable calibration. Contact PM for replacement, replace sensor
Performance evaluation	Daily	>5 ^{o}C change from prior ½ h period	SOP L2	Data flagged
Precision		±0.2 ^{o}C	SOP L2	
Accuracy		±0.9 ^{o}C	SOP L2	

Table A10. Measurement Quality Objectives- Parameter: Lagoon solids depth (acoustic depth finder).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	m		
Shelter temperature	daily	-20 °C - +50°C	Manufacturer specification	
Equipment -submersible acoustic depth finder	Purchase specification	Accuracy: ±0.001 m	Manufacturer specification SOP L5	
Detection	Purchase specification	0.001 m- 0.01 m	Manufacturer specification	Dependent on resolution of length measure used.
Completeness	Each site visit	90%		
Calibration: Test solution	On receipt Annually	±0.001 m	Manufacturer specification SOP L5	Calibration in a water+resin solution with visual depth indication Contact PM for replacement Return to manufacturer for repair
Performance evaluation -Calibration check	Bi-annual	+/- 0.5% full scale	SOP L5	Data flagged Dependent on resolution of length measure used.
Precision		±0.01 m	SOP L5	Dependent on resolution of length measure used.
Accuracy		±0.2% full scale	SOP L5	Dependent on resolution of length measure used.

Table A11. Measurement Quality Objectives for the TDLAS measurement of NH_3 (Boreal Laser, Inc. GasFinder2®).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard units	All data	Ppm		
Shelter temperature	Daily	-40 - +50°C	Manufacturer specification	Maintain instrument case at above dew point temperature. Record temperature of case. Flag all measurements made when instrument case temperature is less than the dew point temperature
Equipment -open path tunable diode laser	Purchase spec.	Accuracy: +/-10%	Manufacturer specification	Current operational limits of open-path technology
Detection	Purchase spec.	NH_3: 5ppm-m	Manufacturer spec.	
Completeness 10 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	500 ppm NH_3 EPA Protocol Gas Mixture N_2	CFR 40 Pt 75 App. A Section 5.1.4 EPA-600/R-97/121.	
Calibration -single point -multipoint	On receipt Beginning/end of meas. period or 21 d, whichever is first. Every 6 mos.	10% NH_3	EPA/625/R-96/010b SOP C2	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement or repair
Performance evaluation -return beam intensity -background check -linearity	Daily Daily Daily	Signal strength Zero values r^2>0.9	EPA/625/R-96/010b SOP C2	Data flagged Clean windows or align Decommission and contact manufacturer for replacement or repair Decommission and contact manufacturer for replacement or repair
Precision -Direct assay of calibration gas	Beginning/end of meas. period or 20d, whichever is first	10%	EPA/625/R-96/010b Myers, et al. (2000) SOP C2	Contact PM or manufacturer for remediation and repeat calibration. If problem unresolved, decommission and contact manufacturer for replacement or repair
Accuracy -Direct assay of calibration gas	Beginning/end of meas. period or 20d, whichever is first	10%	EPA/625/R-96/010b Myers, et al. (2000) SOP C2	Contact PM or manufacturer for remediation and repeat calibration. . If problem unresolved, decommission and contact manufacturer for replacement or repair

Table A12. Measurement Quality Objectives for the UV-DOAS measurement of NH_3 (Cerex UVSentry®).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppb		
Shelter temperature	daily	-40 - +50°C	Manufacturer spec.	Maintain transmitter and receiver instrument cases at above dew point temperature.
Equipment -open path UV-DOAS	Purchase spec.	Accuracy: +/-10%	Manufacturer spec.	Current operational limits of open-path technology
Detection	Purchase spec.	500 ppb m	Manufacturer spec.	
Completeness 5 min data	10 d within quarter	75%		No remediation possible. Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Transfer standards		C_6H_6 and SO_2 in 'lollipop' H_2S, NH_3 cylinders	EPA/625/R-96/010b SOP C1	
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	50 ppm, 500 ppm NH_3 in N_2,(primary standard) 50 ppm, 500 ppm H_2S in N_2 (NIST certified EPA protocol gases	CFR 40 Pt 75 App. A Section 5.1.4 EPA-600/R-97/121.	
Calibration -single point with interference -Spectral feature match -multipoint with interference	On receipt Beginning/end of meas. period or 20d, whichever is first Every six months Every six months	Within 10% of NH_3 conc. (alone and with H_2S) Peaks of C_6H_6 and SO_2 in 'lollipop' 2 pixels or less, corr. Coeff>0.9. Within 10% of NH_3 conc. (alone and with H_2S)	 EPA/625/R-96/010b SOP C1	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation -Baseline stability -Single beam ratio -Dark current correction	 Daily Daily Daily	 Total drift at 270 nm < ±0.002 AU Signal at 210 nm > 205 signal at 250 nm +/-5 counts	 EPA/625/R-96/010b SOP C1	 Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of meas. period or 20d, whichever is first	10%	EPA/625/R-96/010b SOP C1	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay ,calibration gas	Beginning/end of meas. period or 20d	10%	EPA/625/R-96/010b SOP C1	Decommission and contact manufacturer for replacement and repair

Table A13. Measurement Quality Objectives for the UV-DOAS measurement of H_2S (Cerex UVSentry).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppb		
Shelter temperature	daily	-40 - +50°C	Manufacturer spec.	Keep transmitter, receiver cases > dew point.
Equipment -open path UV-DOAS	Purchase spec.	Accuracy: ±10%	Manufacturer spec.	Current operational limits of open-path technology
Detection	Purchase spec.	2000 ppb-1m	Manufacturer spec., experimental result	
Completeness 5 min data	10 d within quarter	75%		No remediation possible. Sampling occurs for up to 21 d to assure 75% of 10 d in each quarter
Transfer standards		C_6H_6 and SO_2 in 'lollipop' H_2S , NH_3 cylinders	EPA/625/R-96/010b SOP C1	
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	50 ppm and 500 ppm NH_3 in N_2 (primary standard, 1% acc.), 50 ppm and 500 ppm H_2S in N_2: EPA protocol NIST-certified, 1% acc.	CFR 40 Pt 75 App. A Section 5.1.4 EPA-600/R-97/121.	
Calibration -single point with interference -Spectral feature match -multipoint with interference	On receipt Beginning/end of meas. period or 20d, whichever is first Every six months Every six months	Within 10% of H_2S conc. (alone and with NH_3) Shift in peaks of C_6H_6 and SO_2 in 'lollipop' ≤ 2 pixels, correlation coeff>0.9. Within 10% of H_2S conc. (alone and with NH_3)	 EPA/625/R-96/010b SOP C1	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation -Baseline stability -Single beam ratio -Dark current correction	Daily Daily Daily	Total drift at 270 nm < ±0.002 AU Signal at 210 nm > 205 signal at 250 nm +/-5 counts	 EPA/625/R-96/010b SOP C1	Data flagged Contact PM for remediation Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of meas. period or 20d, whichever is first	10%	EPA/625/R-96/010b SOP C1	Contact PM for remdiation, If unresolvable, decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of meas. period or 20d,	10%	EPA/625/R-96/010b SOP C1	Contact PM for remdiation, If unresolvable, decommission and contact manufacturer for replacement and repair

Table A14. Measurement Quality Objectives for the INNOVA 1412 measurement of NH_3.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppm	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±1%	Manufacturer spec.	
Detection	Purchase spec.	0.2 ppm	Manufacturer spec.	On 977 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	100 ppm NH_3 in N_2, ±1% traceable to NMi standard N_2	NMi standard	
Calibration Single point- Multi Point-	On receipt Span gas calibration, beginning/end of every meas. period. After every 6 months	100 ppm NH_3 in N_2 100 ppm NH_3 in N_2 0.5, 1, 10 and 100ppm NH_3 in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, RS 232, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period.	5% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period.	±5%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A15. Measurement Quality Objectives for the INNOVA 1412 measurement of MeOH.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Ppm		All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±2%	Manufacturer spec.	
Detection	Purchase spec.	0.08 ppm	Manufacturer spec.	On 936 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	1 ppm MeOH in N_2, ±2% accuracy. N_2		
Calibration Single point- Multi Point-	On receipt Span gas calibration Beginning/end of every meas. period After every 6 months	1ppm MeOH in N_2 1ppm MeOH in N_2 0.1, 0.5 and 1ppm MeOH in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period	5% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period	±5%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A16. Measurement Quality Objectives for the INNOVA 1412 measurement of EtOH.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppm	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±2%	Manufacturer spec.	
Detection	Purchase spec.	0.06 ppm	Manufacturer spec.	On 974 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	1 ppm EtOH in N_2, ±2% accuracy. N_2		
Calibration Single point- Multi Point-	On receipt Span gas calibration Beginning/end of every meas. period After every 6 months	1ppm EtOH in N_2 1ppm EtOH in N_2 0.1, 0.5 and 1ppm EtOH in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period	5% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period	±5%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A17. Measurement Quality Objectives for the INNOVA 1412 measurement of THC (referenced to propane).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppm	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±1%	Manufacturer spec.	
Detection	Purchase spec.	0.02 ppm	Manufacturer spec.	On 987 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	50 ppm propane in N_2, ±1% accuracy, traceable to NIST standard. N_2		
Calibration Single point- Multi Point-	On receipt Span gas calibration Beginning/end of every meas. period After every 6 months	50ppm propane in N_2 50ppm propane in N_2 0.1, 1, 10 and 50 ppm propane in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period	1% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period	±1%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A18. Measurement Quality Objectives for the INNOVA 1412 measurement of methane.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	ppm	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	-25 ˚C to 55˚C	Manufacturer spec.	Operating temperature: 5˚C -40 ˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±1%	Manufacturer spec.	
Detection	Purchase spec.	0.4 ppm	Manufacturer spec.	On 969 nm wavelength
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	10 ppm Methane in N_2, ±1% accuracy, traceable to NIST standard. N_2		
Calibration Single point- Multi Point-	On receipt Span gas calibration Beginning/end of every meas. period After every 6 months	10ppm Methane in N_2 10ppm Methane in N_2 0.5, 1, 10 ppm Methane in N_2	SOP G7	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source, sample filter, pump, measurement chamber, chopper and filter wheel.	SOP G7	Data flagged Contact PM for remediation
Precision -Direct assay of calibration gas	Beginning/end of every meas. period	5% of the Full scale	SOP G7	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period	±5%	SOP G7	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Table A19. Measurement Quality Objectives- Parameters: 3D turbulence components (Model 81000 RM Young ultrasonic anemometer)

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	m/s		
Shelter temperature	daily	-50 - +50°C	Manufacturer spec.	Sensor is exposed to ambient weather conditions
Equipment -3D sonic anemometer	Purchase spec.	U,V,W =0.2 m/s	Manufacturer spec.	
Detection	Purchase spec.	W, V, W: 0.01 m/s	Manufacturer spec.	
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Calibration Intercomparison with two other used sensors Intercomparison with unused sensor	On receipt Beginning/end of meas. period or 20d, whichever comes first. Every 6 mos.	Deviation in value from mean of three sensors of 0.2 m/s	SOP W2	Return to manufacturer for repair or replacement
Performance evaluation 1) spikes 2) obstructions 3) stationarity 4) homogeneity 5) spectral turbulence structure	 30 min 5 min 5 min 15 min daily	1) If spike <100 values/30 min, substitution with mean value 2) Internally flagged 3) invalidated if diff. betw. 5 min and 30 min values >30% 4) theoretical and derived values differ by >30%, data invalidate 5) Numerous tests	Foken and Wichura (1996) SOP W2	1)Data flagged as spiked 2) Data already flagged 3 and 4)Data flagged invalid 5)Data flagged suspect
Precision		0.05 m/s for 0 to 5 m/s, 1% of reading from 5 to 30 m/s, 3% of reading from 30 to 40 m/s.	Manufacturer spec.	This value is not measurable for turbulent flow. Value represents steady mean flow.
Accuracy		0.02 m/s	Manufacturer spec.	This value is not measurable for turbulent flow. Value represents steady mean flow.

Table A20. Measurement Quality Objectives- Parameters: Sonic Temperature (Model 81000 RM Young ultrasonic anemometer).

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	^{o}C		
Shelter temperature	Daily	-50 - +50°C	Manufacturer specification	Sensor is exposed to ambient weather conditions
Equipment -3D sonic anemometer	Purchase specification	±2°C	Manufacturer specification	
Detection	Purchase specification	0.01^{o}C	Manufacturer specification	
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Calibration	On receipt Yearly	±2°C ±2°C	Intercomparison with air temperature, SOP W2	Return to manufacturer for repair
Performance evaluation -Path obstruction -Spikes -mean value	 30 min 15 min 15 min	Values < 5 standard deviations of the mean Value < 3 ^{o}C from hygrometer value	SOP W2	Data flagged
Precision			Manufacturer spec.	
Accuracy		±2°C	Manufacturer specification	Sensor accuracy is low but not critical since deviations in temperature are of interest

Table A21. Measurement Quality Objectives for pH measurements of manure samples.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	pH units		Correction using sample temperature measurement.
Shelter temperature	Daily	0˚C to +100˚C	Manufacturer spec.	
Equipment	Purchase spec.	0 – 14 pH units, Accuracy = ±0.02%	Manufacturer spec.	
Detection	Purchase spec.	0.02 pH units	Manufacturer spec.	
Completeness	Per sample period or 90 d (corrals)	75%		
Transfer Standards: pH 4, 7 and 10	Purchase spec.		Manufacturer spec.	Replace
Calibration -(2 points)	Before and after each batch of samples	±0.05 pH units	SOP M2 USEPA 9040C, Rev. 3, November 2004.	Contact PM for replacement Return to manufacturer for repair or replacement.
Performance evaluation -calibrations - time between collection and analysis - temperature of sample in shipping	 Before and after each batch of samples Each shipped sample Each shipped sample	 ±0.05 pH units Duration of sample to analysis < 1 weeks Samples shipped at <4°C	 SOP M2 SOP M2 SOP M2	If yes ,Correct measured pH values If No, measure the pH of the sample Verification by chain of custody document If exceeded, invalidate sample If exceeded, invalidate sample
Precision				
Accuracy		±0.05 pH units	USEPA 9040C, Rev. 3, November 2004.	Check for cleanliness Return to manufacturer for repair

Table A22. Measurement Quality Objectives for determining total solids contents of manure samples.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	mg/L		
Shelter temperature	Daily	4 ˚C	USEPA Method 1684, Draft – January 2001	Refrigerate the sample at 4˚C up to the time of analysis to minimize microbiological decomposition. Make the sample at room temperature before analysis.
Detection Limits	Method Spec.	Approx. 3 mg/L,	USEPA Method 1684, Draft – January 2001	
Completeness	Per sample period or 90 d (corrals)	75%		
Calibration -analytical Balance		±10% (i.e. ±0.2 mg at 2 mg) and ±0,5% (i.e. ±5 mg at 1000 mg)	USEPA Method 1684, Draft – January 2001	If it does not match the acceptance criteria, recalibrate.
Performance evaluation -Initial Precision and Recovery (IPR) - Ongoing Precision and recovery (OPR) - time between collection and analysis - temperature of sample in shipping	Before and every ten samples Each shipped sample Each shipped sample	Compare the values with the corresponding limits for initial precision and recovery in the mentioned table Duration of sample to analysis < 1 weeks Samples shipped at <4°C	USEPA Method 1684, Draft – January 2001 SOP M3 SOP M3	If the values do not match with the mentioned tables, system performance is unacceptable, correct the problem and repeat the test. Verification by chain of custody document If exceeded, invalidate sample If exceeded, invalidate sample
Precision -KHP spike[1]		80-110% of KHP spike	USEPA Method 1684, Draft – January 2001	If the values do not match with the mentioned tables, system performance is unacceptable, correct the problem and repeat the test.
Accuracy		Unstated	USEPA Method 1684, Draft – January 2001	

1: KHP spike: NaCl-potassium hydrogen phthalate solution with 200 mg/l total solid, 81.0 mg/L volatile solids.

Table A23. Measurement Quality Objectives for determining total Kjeldahl nitrogen (TKN) content of manure.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	mg N/gram (wet weight basis)	SOP M4	
Shelter temperature	daily	4 ˚C	USEPA Method 1687 Draft January 2001	Samples should be kept at 4 ˚C and should not be hold for more than 28 d.
Detection	Purchase spec.	Approx 0.05 mg/L	40 CFR part 136, SOP M4	The method has a working range of approximately 0.5 – 10 mg N/gram. Concentration value that corresponds to the instrument signal in range of 2.5 to 5
Completeness	Per sample period or 90 d (corrals)	75%		
Calibration Standards Nicotinic acid spikes Balance Calibration (2 mg and 1000 mg using class "S" weights)	Purchase spec.	 ±10% at 2 mg and ±0.5% at 1000mg	SOP M4 USEPA Method 1687 Draft January 2001	Five concentrations of nicotinic acid in 5g of blank sand with 250 mL NH_3-free water such that the organic nitrogen concentration of the precision and recovery is one to five times the MDL If values are not within these limits, recalibrate the balance.
Calibration verification standard solution	Once per every ten analysis	100% ±5%	SOP M4	If standard does not meet acceptance criteria, identify problem and correct, including possible recalibration of the system.
Performance evaluation - Initial Precision and Recovery (IPR) - Ongoing Precision and recovery (OPR) - Matrix spikes (MS)	Before and one sample in 10 analyzed)	check for residual chlorine 90% - 110% 80% to 120% with Relative percentage difference (RPD) ≤ 20%	USEPA Method 1687 Draft January 2001	Samples should be checked for residual chlorine and treated with sodium thiosulfate, if necessary, during collection. Samples should be preserved with 2 mL Conc. H_2SO_4. If OPR outside range, resolve. If % recovery or RPD of TKN in the MS samples falls outside designated range while the % recovery in the Precision and recovery sample is within acceptable range- problem is matrix-related.
Precision	Beginning of analysis	±10%, 0.2 mg N/liter	SOP M5, USEPA method # 350.2	Based on 24 analysts at 16 laboratories
Accuracy	Beginning of analysis	±0.02 mg N/ liter	USEPA method # 350.2	Based on 24 analysts at 16 laboratories

Table A24. Measurement Quality Objectives for determining ammonia content of manure.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	mg NH_3/gram (wet weight basis)	SOP M5	
Shelter temperature	daily	4 ˚C	USEPA method # 350.2	Samples should be kept at 4 ˚C with 2 mL of Conc. H_2SO_4, and should not be hold for more than 28 d.
Detection	Purchase spec.	Approx 0.05 mg/L	40 CFR part 136, SOP M5	The method has a working range of approximately 0.5 – 10 mg NH_3-N/L. Concentration value that corresponds to the instrument signal in range of 2.5 to 5
Completeness	Per sample period or 90 d (corrals)	75%		
Calibration Standards Ammonium chloride spikes Balance Calibration (2 mg and 1000 mg using class "S" weights)	Purchase spec.	 ±10% at 2 mg (i.e. ±0.2mg) and ±0.5% at 1000mg (i.e. ±5mg).	SOP M5	Five concentrations of ammonium chloride in 5g of blank sand with 250 mL NH_3-free water such that the ammonia concentration of the precision and recovery is one to five times the MDL If values are not within these limits, recalibrate the balance.
Calibration verification standard solution	Once per every ten analysis	100% ±10%	SOP M5	If standard does not meet acceptance criteria, the problem must be identified and corrected, including possible recalibration of the system.
Performance evaluation -If Aqueous Sample - Ongoing Precision and Recovery (OPR) - Matrix spikes (MS)	 10% (one sample in 10 analyzed)	check for residual chlorine 90% - 110% 80% to 120% with Relative percentage difference (RPD) ≤ 20%	USEPA Method 1687 Draft January 2001 SOP M5 SOP M5	Samples should be checked for residual chlorine and treated with sodium thiosulfate, if necessary, during collection. Samples should be preserved with 2 mL Conc. H_2SO_4. If OPR outside range, resolve. If % recovery or RPD of TKN in the MS samples falls outside designated range while the % recovery in the Precision and recovery sample is within acceptable range- problem is matrix-related.
Precision	Beginning of every analysis	±10%, 0.2 mg N/liter	SOP M5 USEPA method # 350.2	Based on 24 analysts at 16 laboratories
Accuracy	Beginning of every analysis	±0.02 mg N/ liter	USEPA method # 350.2	Based on 24 analysts at 16 laboratories

Table A25. Measurement Quality Objectives for the TEC 450i measurement of H_2S.

Requirement	Frequency	Acceptance criteria	Reference	Information/ Action
Standard reporting units	All data	Ppb	Manufacturer spec.	All data will be in engineering units
Shelter temperature	daily	0 ˚C to 45˚C	Manufacturer spec.	Operating temperature: 15˚C -35˚C, the instrument will be inside the trailer maintaining a temperature of 21˚C±3˚C
Equipment	Purchase spec.	Accuracy: ±1%	Manufacturer spec.	
Detection	Purchase spec.	2.0 ppb	Manufacturer spec.	
Completeness 5 min data	10 d within quarter	75%		No remediation possible Sampling will occur for approx. 21 d to assure 75% of 10 d in each quarter
Compressed gases Gas standards Dilution gas	Purchase spec. Purchase spec.	4 ppm H_2S in N_2, ±2% traceable to NIST CEM Zero gas- air	NIST standard	
Calibration Single point- Multi Point-	Span gas calibration, beginning/end of every meas. period. On receipt After every 6 months	0.5 ppm H_2S in N_2 or air 0, 0.5, 1, 2 and 3 ppm H_2S in N_2 or air	EQSA-0486-060 EMTIC TM-006C SOP G5	Invalidate data to last acceptable calibration. Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair
Performance evaluation Flags (errors) on the data Screen Change of Filter paper	Daily In the beginning of every monitoring period.	Checks will refer to source lamp, sample flow and pressure, instrument temperatures, RS 232.	EQSA-0486-060 EMTIC TM-006C SOP G5	Data flagged Contact PM for remediation
Precision -Direct assay of zero gas	Beginning/end of every meas. period.	5% of full scale	EQSA-0486-060 EMTIC TM-006C SOP G5	Decommission and contact manufacturer for replacement and repair
Accuracy -Direct assay of calibration gas	Beginning/end of every meas. period.	±10%	EQSA-0486-060 EMTIC TM-006C SOP G5	Contact PM or manufacturer for remediation and repeat calibration If problem persists, decommission and contact manufacturer for replacement and repair

Appendix B
Standard Operating Procedures

Table B1. List of NAEMS Open-source SOPs.

Code	Title
C1	Open-Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UV Sentry Ultraviolet Differential Optical Absorption Spectrometer
C2	Measurement of Ammonia with the Boreal Laser GasFinder Tunable Diode Laser Absorption Spectrometer (TDLAS)
C3	Operation of the Thermo Electron Model 146C Multi-gas Diluter
C4	Synthetic Open Path Sampling System
D1	Management of Open-source, Weather, and Lagoon-characterization Data
E3	The Measurement of Solar Radiation with the Licor Model 200SL or 200SZ Silicon Pyranometer
G2	Compressed Gas Cylinders
G5	Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed Fluorescence Analyzer
G7	Use of the INNOVA 1412 Photoacoustic Multi-Gas Monitor
G11	Operation of the Environics® Computerized Gas Dilution System
G12	FTIR Verification of Gas Cylinder Concentration
L1	Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor
L2	Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor
L3	Measurement of Lagoon Redox State with the Campbell Scientific CSIM11 ORP Sensor
L5	Measurement of Lagoon Sludge Depth with Markland Model 10 Portable Sludge Gun
M1	Manure Sampling
M2	Conducting pH Measurements on Manure Samples
M3	Determining Solids Content of Manure Samples
M4	Determining Total (Kjeldahl) Nitrogen Content of Manure Samples
M5	Determining Ammonia Content of Manure Samples
O1	Emissions Estimation Using the Thunder Beach Scientific Windtrax Backward Lagrangian Stochastic Model
O2	Emissions Estimation Using the ARCADIS Radial Plume Mapping Model
Q1	Use of Control Charts for Performance Monitoring of Gas Analyzers and Analytical Instruments
S7	Producer Collaborations at Open-source Monitoring Sites
U4	Open-source Instrument Trailer
U5	The Installation of Open-source Measurement Equipment for Lagoon Sites
U6	The Powerware 9125 Uninterruptible Power Supply
U7	The Instrument Trailer and Installation of Open-Source Measurement Equipment (Corrals)

W1	Measurement of Atmospheric Temperature and Humidity with the Vaisala Model HMP45C Sensor and Solar Shield
W2	Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer
W3	Measurement of Wetness with the Campbell Scientific Model Resistance Grid
W5	The Measurement of Barometric Pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer
W6	Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware

Appendix C
Site Monitoring Plans

Table C1. List of NAEMS Site Monitoring Plans.

Farm No. (Table 6.3)	Location Code	Location Classification
1	NC4A	Southeast Swine Sow Lagoon
2	NC3A	Southeast Swine Finisher
3	IA3A	Midwest Finisher Basin
4	IN5A	East Dairy Lagoon
5	OK3A	West Swine Finisher Lagoon
6	OK4A	West Swine Sow Lagoon
7	WA5A	Northwest Dairy Basin
8	WI5A	Midwest Dairy Lagoon
9	IN4A	Midwest Swine Sow Lagoon
10	TX5A	West Dairy Corral

Appendix D
Forms

Perishable Consumables Tracking Form

Material	Use	Shelf Life (months)	Manufacture date	Dispose-of date	Container labeled date	FOS responsible
4.01 pH buffer (potassium biphthalate)	pH sensor calibration	6				
7.00 pH buffer (potassium phosphate)	pH sensor calibration	6				
10.00 pH buffer (sodium borate/sodium carbonate)	pH sensor calibration	6				
Potassium biphthalate (KHP)	pH sensor calibration	36				
Thymol ($C_{10}H_{13}OH$)	pH sensor calibration	24				
1M KCl solution or reagent grade KCl	Redox sensor calibration	6				
ZoBell's Solution Redox Standard	Redox sensor calibration	6				
A Gas cylinder: Pure N_2 (or equivalent)	UV-DOAS, TDLAS, PAS sensor calibration	36+				
A58L Disposable gas cylinder: 50 ppm H_2S (1% accuracy traceable to NIST), balance N_2 (or equivalent)	UV-DOAS sensor calibration	6				
A58L Disposable gas cylinder: 50 ppm NH_3 (1% accuracy traceable to NMi), balance N_2 (or equivalent)	UV-DOAS, TDLAS sensor calibration	6				
CL Gas cylinder: 50 ppm Propane (1% accuracy traceable to NIST), balance N_2 (or equivalent)	PAS sensor calibration	*36*				
CL Gas cylinder: 10 ppm Methane (1% accuracy traceable to NIST), balance N_2 (or equivalent)	PAS sensor calibration	36				
CL Gas cylinder: 1 ppm EtOH (2% accuracy traceable to NIST), balance N_2 (or equivalent)	PAS sensor calibration	12				

CL Gas cylinder: 1 ppm HAc (2% accuracy traceable to NIST), balance N_2 (or equivalent)	PAS sensor calibration	12				
CL Gas cylinder: 500 ppm H_2S in N_2 (or equivalent)	UV-DOAS sensor calibration	12				
CL Gas cylinder: 500 ppm NH_3 in N_2 (or equivalent)	UV-DOAS, TDLAS sensor calibration	12				
CL Gas cylinder: 50 ppm NH_3 (1% accuracy traceable to NMi), balance N_2 (or equivalent)	PAS sensor calibration	12				
Lithium chloride salt	Humidity sensor calibration	6				
Potassium sulfate salt	Humidity sensor calibration	6				

Maintenance List for NAEMS Open Source Measurements

Location: _____ Date:_____

	Interval (d)	Notes[1]
Check integrity of trailer antenna cable feed-through	Start of period	
Check cable connections at antennae	Start of period	
Check cable connections at computers	Start of period	
Check cable connections at GSS/CR580 datalogger /computer	Start of period	
Check cable connections at TEC 450i/switch/computer	Start of period	
Check cable connections at TEC 146i/computer	Start of period	
Check trailer power feed cable connections	Start of period	
Check trailer ground rod connections	Start of period	
Check UPS, GFCI trips	Start of period	
Check ground rod connection at weather station	Start of period	
Check ground rods at towers	Start of period	
Check power connection at 15-m tower retroreflectors, GFCI OK on outlets	Start of period	
Check power connection at 7-m tower retroreflectors, GFCI OK on outlets	Start of period	
Check power connection at 2-m tower retroreflectors, GFCI OK on outlets	Start of period	
Check power connection at 2-m ground retroreflectors, GFCI OK on outlets	Start of period	
Check ground rods at towers	Start of period	
Replace dessicant in NEMA box	Start of period	
Lagoon cable floats: intact and spaced correctly?	Start of period	
Flag cable path for lagoon sensors	Start of period	
Flag tubing path for S-OPS extension tubing	Start of period	
Check power cable connections at TDLAS modem/power units	Start of period	
Check sonic cable integrity and connector connections	Start of period	
Check sonic power unit connections	Start of period	

Check under road tubing path for integrity and uncrushed tubing	Start /End of period	
Check integrity of calibration cylinder/analyzer/diluter/chamber tubing	Start /End of period	
Check tubing connections of calibration cylinders/diluter/analyzers/chamber	Start /End of period	
Check cable integrity of all meteorological sensors	Start /End of period	
Check cable integrity of lagoon sensors	Start/End of period	
Check connections in NEMA box to datalogger	Start /End of period	
Check signal cable connections at TDLAS units (rubber seal present)	Start/End of period	
Check cable connections from scanner units (weather-tight seal at connectors)	Start/End of period	
All towers, tripods, & mast look vertical?	Start/End of period	
All towers, tripods, & mast intact?	Start/End of period	
Sonic anemometers mounted & oriented correctly?	Start/End of period	
Check tower: bolts all present & tight?	End of period	
All tools & equipment put away?	End of period	
S-OPS and S-OPS extension tubing intact?	End of period	
Clean/Check Retro-reflector windows	End of period	
Check integrity of NEMA box	End of period	
Clean sonic heads	As needed	
Replace inlet filters (inlet flow test check)	As needed	
Check/Replace gas sampling filters	As needed	
Check/Clean pyranometer	As needed	
Check/Clean T/RH shield	As needed	
Check/Clean wetness grid	As needed	
Replace pH probe reference sol	6 mos	
Replace pH probe QCCS sol	3 mos	
Replace redox probe reference sol (if needed)	6 mos	
Replace redox probe ZoBell's sol	3 mos	
Replace redox probe 0.1M KCl sol	3 mos	

1: If additional space needed, use back of page, then attach additional pages.

Name(FOS): _____

Example Chain of Custody Form

Midwest Laboratories, Inc.

13611 "B" Street • Omaha, Nebraska 68144-3693 • (402) 334-7770 • FAX (402) 334-9121 • www.midwestlabs.com

ACCOUNT NUMBER _____

MANURE, SLUDGE AND COMPOST SUBMITTAL FORM

REPORT & BILL TO	IDENTIFICATION	COPY TO
ZIP		ZIP
PHONE ( )		

TESTS DESIRED (See Bottom of Page)	SAMPLE NUMBER	SOURCE OF SAMPLE	LAB USE ONLY	SPECIAL REPORTING	MOISTURE	COMMENTS
☐ BASIC ☐ CHLORIDE ☐ NITRATE-N ☐ OTHER _____		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT _____		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # _____ SAMPLE # _____ DATE _____	RAINFALL _____ IRRIGATION TYPE _____	
☐ BASIC ☐ CHLORIDE ☐ NITPATE-N ☐ OTHER _____		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT _____		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # _____ SAMPLE # _____ DATE _____	AVERAGE ANNUAL RAINFALL _____ IRRIGATION TYPE _____	
☐ BASIC ☐ CHLORIDE ☐ NITRATE-N ☐ OTHER _____		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT _____		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (dude soil submittal form) ☐ USE MIDWEST REPORT # _____ SAMPLE # _____ DATE _____	AVERAGE ANNUAL RAINFALL _____ IRRIGATION TYPE _____	
○ BASIC ☐ CHLORIDE ☐ NITRATE-N ☐ OTHER _____		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT _____		☐ SPECIFIC APPLICATION RECOMMENDATIONS REQUESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # _____ SAMPLE # _____ DATE _____	AVERAGE ANNUAL RAINFALL _____ IRRIGATION TYPE _____	
☐ BASIC ■ CHLORIDE ☐ NITRATE-N ☐ OTHER _____		☐ SLUDGE ☐ COMPOST ☐ ORGANIC FERTILIZER ☐ MANURE (check below) ☐ DAIRY ☐ CHICKEN ☐ HOG ☐ TURKEY ☐ FEEDLOT _____		☐ SPECIFIC APPLICATION RECOMMENDATIONS REWESTED ☐ SOIL SAMPLE ENCLOSED (include soil submittal form) ☐ USE MIDWEST REPORT # _____ SAMPLE # _____ DATE _____	AVERAGE ANNUAL RAINFALL _____ IRRIGATION TYPE _____	

BASIC: Manure & Sludge Test: Moisture/Total Solids, Total Nitrogen, Ammonia Nitrogen, Organic Nitrogen, Phosphate, Potash, Sulfur, Calcium, Magnesium, Sodium, Iron, Manganese, Copper, Zinc, Organic Nitrogen, pH

SUBMIT TO: MidwestLaboratories,Inc.
13611 "B" Street, Omaha, NE 68144-3693

Rev.3/02

NAEMS Site Audit Form: Open sources

Site: Auditor(s):
Date:
Researchers present during visit:

Characteristics of producer collaboration and cooperation:
Is producer providing the following data?
Animal inventory and weight Yes _____ No _____
Animal diet? Yes _____ No _____
Record of production (e.g. wt of marketed animals, milk) Yes _____ No _____
Record of sludge removals Yes _____ No _____
Record of pump outs Yes _____ No _____
Record of water consumption Yes _____ No _____
Occurrence of special activities, e.g., generator tests, building cleaning, power failures, etc.? Yes _____ No _____

Installed equipment:

Instrument	Serial number	Instrument	Serial number
TDLAS-1		Solar Radiation	
TDLAS-2		T/RH probe	
PAS		2 m Sonic	
CR1000 Data logger		4 m Sonic	
Barometer		16 m Sonic	
Wetness sensor		Lagoon temp.(1)	
CR800 Data logger		Lagoon pH (1)	
GSS Mass flow controller		Lagoon redox (1)	
GSS temperature		Lagoon temp. (2)	
GSS flow direction		Lagoon pH (2)	
CR Relay driver		Lagoon redox (2)	
NH_3 regulator		H_2S regulator	
Zero air regulator		Organics regulator	

Gas cylinders:

	Cylinder number	Date of expiration	Remaining Pressure
Zero Air			
Nom. 500 ppb NH_3			
Nom. 1 ppm MeOH, 1 ppm EtOH			
Nom. propane_____, methane _____			
Nom. 4 ppm H_2S			

Data Management

Is manual entry log book being maintained? Permanent ink?

Are electronic field notes being maintained?

All files under one folder in the LAN Server PC?

Automatic data and files backup system functioning?

Computer	Last external backup	Errors in backup?
LAN server		
TDLAS-1		
TDLAS-2		

Are the second set of data from prior measurement period stored in fireproof box or stored away from instrument shelter (e.g. on campus)?

Instrument Trailer

Cleanliness and orderliness:

SOPs up to date and available? Yes _____ No _____

Trailer environmental control: Temp. _____, RH _____
Security:

Electrical power protection:

Gas Sampling System:

Gas sampling inlet clean and oriented correctly?
Date of last leak test:
Visual appearance:
Mass flow sensor:
Flow rate (minimum = 3.6 L/min) = _____ L/min
Has response time been tested? Yes _____ No _____

Towers and tripods:
Tall towers secure and stable?

Retro tripods secure and stable?

Meteorology mast secure and stable?

Layout Inspection:

Check location of sensors match SMP and site setup records:

Vulnerability of sampling lines to mechanical damage:

Vulnerability of power lines to mechanical damage:

Equipment protection (from animals, workers):

Maintenance:

	Frequency	Most recent	Notes
Replace dessicant in NEMA box	Each period		
Clean sonic heads	As needed		
Replace gas sampling filters	As needed		
Clean Pyranometer	As needed		
Clean T/RH shield	As needed		
Clean wetness grid	Each period		
Clean Retroreflector windows	As needed		
Clean TDLAS windows	As needed		
Check tubing and connections	Each period		
Clean pH probe	Each period		
Clean redox probe	Each period		
Check integrity of NEMA box	Each period		
Check integrity of trailer antenna cables feed-through	Each period		
Check cable connections at CR1000 datalogger	Each period		
Check cable connections at CR800 datalogger			
Check cable connections at computers	Each period		
Check cable connections at antennae	Each period		
Check RF antennae	Each period		
Check UPS connections at TDLAS/scanner units	Each period		

Inspect cables and cable connectors for damage

	Power	Signal	Notes
TDLAS<>scanner			
Scanner<>power/ modem box			
TDLAS/scanner computer			
TDLAS/scanner modems inside			
CR1000			
CR1000 modem inside			
CR1000 modem outside			
Sonic modems inside			
Sonic modems outside			
Pyranometer			
T/RH			
wetness grid			
Retroreflectors			
TEC 450i			
Innova 1412			
Lagoon pH probe			
Lagoon redox probe			
Lagoon temp.			
2 m sonic			
4 m sonic			
16 m sonic			
LAN computer			
Internet connection			
Trailer power			
CR800			
GSS Pressure sensor			
GSS T/RH			
GSS MFC			
GSS flow direction			

Communications

Instrument	Serial/Ethernet communications OK?	Notes
Powerware UPS		
Power switch		
Internet modem		
Innova 1412		
TEC450i		
TDLAS-1		
TDLAS-2		
CR1000 Datalogger		
2 m Sonic		
4 m Sonic		
16 m Sonic		
CR800 Datalogger		

Calibration Verification Records:

Are all cal. gas cylinders valid (not expired?) Yes ____ No _____
Regulators operational? Yes ____ No _____

Instrument	Last calibration verification date		Results of most recent verification	Notes
	QAPP	Actual		
TEC450i H_2S	Period start/end			
TDLAS-1 NH_3	Period start/end			
TDLAS-2 NH_3	Period start/end			
PAS NH_3	Period start/end			
PAS Methane	Period start/end			
PAS MeOH	Period start/end			
PAS EtOH	Period start/end			
PAS THC	Period start/end			
Lagoon redox	Period start/end			
Lagoon pH	Period start/end			
Lagoon temp	Period start/end			

Instrument	Last calibration verification date		Results of most recent verification	Notes
	QAPP	Actual		
Solar radiation	Period start/end			
RH	6 mos.			
Temperature	6 mos.			
Barometer	Period start/end			
Wetness	Period start/end			
2 m sonic	Period start/end			
4 m sonic	Period start/end			
16 m sonic	Period start/end			
Mass flow meter				

Control charts available for gas analyzers?

TDLAS-1	Yes ____	No _____
TDLAS-1	Yes ____	No _____
Innova 1412	Yes ____	No _____
TEC 450i	Yes ____	No _____

Calibration verification records available in shelter?

TDLAS-1	Yes ____	No _____
TDLAS-1	Yes ____	No _____
Innova 1412	Yes ____	No _____
TEC 450i	Yes ____	No _____
Sonic -1	Yes ____	No _____
Sonic -2	Yes ____	No _____
Sonic -3	Yes ____	No _____
pH probe-1	Yes ____	No _____
redox probe-1	Yes ____	No _____
pH probe-2	Yes ____	No _____
redox probe-2	Yes ____	No _____

NAEMS Audit Finding Form: Open sources

Site Audited: _____

Audit Date: _____

Audit Title: _____Audit #:_____Finding #_____

Finding:

Discussion:

QA Lead Signature:_____ Date: _____

Audited site

Signature: _____ Date: _____

NAEMS Audit Finding Response Form: Open Sources

Site Audited: _____

Audit Date : _____

Audit Title: _____Audit #:_____Finding #_____

Finding:

Cause of the Problem:

Actions taken or planned for correction:

Responsibilities and timetable for the above actions:

Prepared by:_____ Date: _____

Signed by: _____ Date: _____

QA officer

Reviewed by: _____ Date_____

Remarks:

Is this audit finding closed?_____when?_____

File with QA coordinator. Sent copy to auditee.

Document(s) Deviation Report Form

Date: Author:

Deviation in (SOP / QAPP / SMP)?

Description of Deviation:

Resolution:

Accept deviation, minor, do not modify document	Accept deviation, major, modify document
Reject deviation, invalidate results	Reject deviation, modify document

If document modification, Document(s) modified : _____

Date of modification(s) : _____

Initials: PQAM: _____, QAM: _____, PM: _____, SA: _____

EPA Approval: _____Date: _____

SOP C1

UV-DOAS Calibration Sheet

UV-DOAS Serial Number _____

		Certified Gases		Measured Analyte				
Date	**Time**	**Analyte: Gases present**	**Conc.**	**Mean**	**SD[1]**	**Accuracy[2]**	**RSD**	**Operator**
mm/dd/yy	**hh:mm**		**ppm-m**	**ppm-m**	**ppm-m**	%	%	
		NH_3						
		H_2S						
		NH_3: NH_3+H_2S						
		H_2S: NH_3+H_2S						

[1]Standard deviation

[2]Accuracy = 100% * (Measured concentration – Certified concentration) / (Certified concentration)

SOP C1

UV-DOAS QA Sheet

UV-DOAS Serial Number _____

Date	Time	Dark current correction check	±5 counts?	Spectral feature match	<2 pixels?	R[1]	>0.90?	Baseline stability drift at 270 nm	<+/- 0.002AU?	Beam energy at 250 nm	Beam energy at 210 nm	210 nm energy /250 nm energy	<20%?	Operator
mm/dd/yy	**hh:mm**	**# counts**	Y/N	**pixels**	Y/N			AU						

1: R is correlation coefficient

If <u>No</u> is answer any of the above questions, Remediation is needed.

SOP C2

TDLAS Single Point Calibration Verification Log

Trailer: (EAST/WEST/FIXED)
Site: _____

TDLAS Serial number _____ Operator_____
Date (MM/DD/YYYY):_____
Calibration verification filename ():_____

Calibration cylinder# (_____) concentration: _____ppm
Diluted chamber calibration gas concentration: _____ppm

Trail[1]	TEST	Valid measurement times[2]		TDLAS mean measurement			
		Start	End	Mean	SD	RSD	Bias
	Background						
1	Calibration gas						
	Background						
2	Calibration gas						
	Background						
3	Calibration gas						
	Background						
4	Calibration gas						
	Background						

1: Only one good trial is needed (comments needed if more that one is conducted)
2: Valid measurement times represent the time after 10 min of flow.

Comments:

SOP C4 Appendix B NAEMS open GSS Acceptance Form

GSS S/N _____ Date: _____

Operator: _____

	Solenoid 2	Solenoid 3	Solenoid 5	Solenoid 7
Sample flow test				
Outlet Mass Flow (L/min)				
Pressure (kPa)				
Pass/Fail				
GSS Leak test				
Mass Flow (L/min)				
Corrected Mass flow (L/min)				
Pressure (kPa)				
Corrected Pressure (kPa)				
Pass/Fail				
No flow test				
Mass Flow (L/min)				
Pressure (kPa)				
Max flow test				
Outlet Mass Flow (L/min)				
Pressure (kPa)				

Comments:

SOP C4 Appendix C

NAEMS open S-OPS Acceptance Form

Date: _____/____/_____ GSS S/N _____

Location: _____ FOS: _____

	Solenoid 2	**Solenoid 3**	**Solenoid 5**	**Solenoid 7**
Max flow test				
Inlet Mass Flow (L/min)				
Outlet Mass Flow (L/min)				
Pressure (kPa)				
Pass/Fail				
S-OPS/ GSS Leak test				
Mass Flow (L/min)				
Corrected Mass flow (L/min)				
Pressure (kPa)				
Corrected Pressure (kPa)				
Pass/Fail				
S-OPS S/N				

Comments:

SOP C4 Appendix D
Synthetic Open-Path System Inlet Flow Verification Form

S-OPS S/N _____ Date: _____/_____/_____

FOS: _____

Inlet	S-OPS inlet flow rate (L/min)	Deviation[1]	Action (clean, replace..)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

1: Deviation= (Inlet flow-Mean flow)/Mean flow

SOP C4 Appendix E

S-OPS/ GSS Bag Test (System Adsorption)

S-OPS: _____ Date: ____/_____/_____

GSS S/N: _____ FOS: _____

Gas: H2S Analyzer: TFS 450i s/n:						
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Methane Analyzer: Innova 1412 s/n:						
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

SOP C4 S-OPS/ GSS Bag Test (System Adsorption) (Continued)

S-OPS: _____ Date: _____/_____/_____

GSS S/N: _____ FOS: _____

Gas: Methanol		Analyzer: Innova 1412 s/n:				
			Diluter/Cylinder	Analyzer	Average from	
Time		Sampling	Reading	Reading	Data File	Percent
Start	Stop	Location	ppm	ppm	ppm	Difference
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Ethanol		Analyzer: Innova 1412 s/n:				
			Diluter/cylinder	Analyzer	Average from	
Time		Sampling	Reading	Reading	Data File	Percent
Start	Stop	Location	ppm	ppm	ppm	Difference
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

SOP C4 S-OPS/ GSS Bag Test (System Absorption) (Continued)

S-OPS: _____ Date: _____/_____/_____

GSS S/N: _____ FOS: _____

Gas: Propane		Analyzer: Innova 1412 s/n:				
			Diluter/cylinder	Analyzer	Average from	
Time		Sampling	Reading	Reading	Data File	Percent
Start	Stop	Location	ppm	ppm	ppm	Difference
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Ammonia		Analyzer: Innova 1412 s/n:				
			Diluter/cylinder	Analyzer	Average from	
Time		Sampling	Reading	Reading	Data File	Percent
Start	Stop	Location	ppm	ppm	ppm	Difference
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

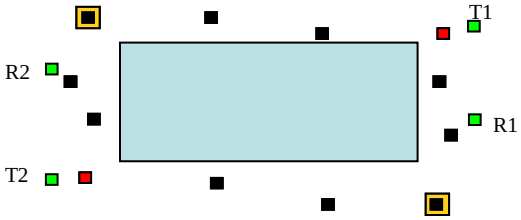
SOP C4 Appendix F

Lagoon/Basin Site Open-path Sensor Installation Report

Location: _____

Date: _____/_____/_____

FOS: _____



NEAR S-OPS extension tubing

S-OPS Path #1 start location (T1) _____Deg (N) _____._____Min Lat.

_____Deg (N) _____._____Min Long.

S-OPS Path #1 end location (R1) _____Deg (N) _____._____Min Lat.

_____Deg (N) _____._____Min Long.

Distance between Path #1 outlet tube and GSS manifold (extension tubing): _____ m

Height of path#2 above lagoon berm : _____ m

FAR S-OPS extension tubing

S-OPS Path #2 start location (T2) _____Deg (N) _____._____Min Lat.

_____Deg (N) _____._____Min Long.

S-OPS Path #2 end location (R2) _____Deg (N) _____._____Min Lat.

_____Deg (N) _____._____Min Long.

Distance between Path #2 outlet tube and GSS manifold (extension tubing): _____ m

Height of path #2 above lagoon berm : _____ m

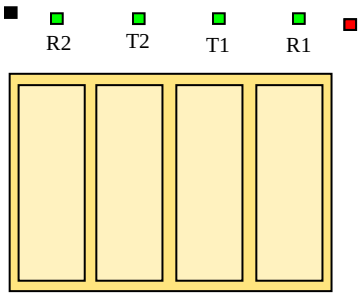
Notes:

Corral Site Open-path Sensor Installation Report

Location: _____

Date: _____/_____/_____

FOS: _____



NEAR S-OPS extension tubing

S-OPS Path #1 start location (T1) _____Deg (N) _____._____Min Lat.

_____Deg (N) _____._____Min Long.

S-OPS Path #1 end location (R1) _____Deg (N) _____._____Min Lat.

_____Deg (N) _____._____Min Long.

Distance between Path #1 outlet tube and GSS manifold (extension tubing): _____ m

Height of path#2 above lagoon berm : _____ m

FAR S-OPS extension tubing

S-OPS Path #2 start location (T2) _____Deg (N) _____._____Min Lat.

_____Deg (N) _____._____Min Long.

S-OPS Path #2 end location (R2) _____Deg (N) _____._____Min Lat.

_____Deg (N) _____._____Min Long.

Distance between Path #2 outlet tube and GSS manifold (extension tubing):_____ m

Height of path #2 above lagoon berm: _____ m

Notes:

Appendix F **Flow Direction Sensor Calibration**

GSS S/N _____ Date: _____

Operator: _____

	Solenoid 2	**Solenoid 3**	**Solenoid 5**	**Solenoid 7**
Flow				
Sample flow rate (L/min)				
Reverse Flow rate (L/min				
Δ Flow (L/min)				
Sensor Response				
Sample flow				
Reverse Flow				
Δ response				
Pass/Fail				

SOP D1
Electronic Data Chain of Custody form

Location of measurements: _____

Period represented: From Date (MM/DD /YYYY) _____ time (GMT: 24h clock) _____: _____

To Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

Data preparation/ copying done by: _____

Calibration conducted during period

TDLAS1: s/n _____ Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____
Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

TDLAS2: s/n _____ Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____
Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

TEC 450i: s/n _____ Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____
Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

Innova 1412: s/n _____ Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____
Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

Notes:

Data Receipt

Received: Date (MM/DD/YYYY) _____ *time (GMT: 24h clock)* _____: _____

Physical condition of TDLAS1/TDLAS2/WXL/H2S/GSS data CD	(Excellent / Good / Fair / Poor)
Physical condition of WXL flash memory chip	(Excellent / Good / Fair / Poor)
Physical condition of 16Hz sonic data DVD	(Excellent / Good / Fair / Poor)
Physical condition of Backup DVD (excl 16Hz data)	(Excellent / Good / Fair / Poor)
Physical condition of memory stick	(Excellent / Good / Fair / Poor)

Received by: _____

SOP G2 and G11: Gas Cylinder Labels

Gas _____
Concentration _____
Initial Pressure _____psi
CGA No. _____
Cylinder No. _____
Date Received _____
Expiration Date _____
Date:_____Pressure:_____psi
Date:_____Pressure:_____psi
Date:_____Pressure:_____psi
Date:_____Pressure:_____psi
Date:_____Pressure:_____psi

Return To: General Stores

From: Rich Grant
Department of Agronomy
215 LSPS

Date:

Return label for gas cylinders:

Calibration date:_____
Next calibration due date:_____
Calibrated by:_____

Sample calibration label.

SOP L1

Inspection and Maintenance Log
INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial Number _____

Date (DMY)	Condition		Action taken	Calibration done?	Acceptance done?	Person assessing
	Glass electrode	Cable				

SOP L1

Acceptance Log

INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial Number _____

Date (DMY)	Condition		T (°C)	QCCS reference check (mV)	Time to stable QCCS reading (min)[1]	pH reading in QCCS check		Calibration done?	Action taken	Analyst
	Glass electrode	Porous junction				30-s	2-min			

[1]Should be ±1 mV in less than 1 min

[2]Both 30-s and 2-min readings should be 4.00±0.05 pH units (at 25°C) and agree within ±0.05 pH units.

SOP L1

pH Quality Assurance Log

INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial number _____

Beginning or end of measurement period?	Date (DMY) & Time	T (^{o}C)	Buffer pH	Nernst temp comp. (mV)	Expected potential of pH buffer (mV)	Probe measurement		pH Error (Expected vs. calculated)	Action (Adjust, Replace)	Analyst
						mV	Calculated pH			
			7							
			4							
			10							
			7							
			4							
			10							
			7							
			4							
			10							

SOP L2

Model 107 Thermistor Calibration Form

Serial Number _____

Calibration Date D-M-Y	Calibration Time hh:mm		Temperature(^{o}C)			Action (Adjust, Replace)	Analyst
	Begin	End	Expected	Measured	Offset (Table 1)		

SOP L3

Acceptance Log

INNOVATIVE SENSORS MODEL CSIM11 ORP SENSOR

Serial Number _____

Date & Time	Condition		KCl reference check (mV)	Time to stable reading (min)[1]	Calibration done?	KCl reference check (mV)	Action	Analyst
	Pt sensing element	Porous junction						

[1]Should be stable within ±1 mV in less than 10 min

SOP L3

Calibration form

Redox Sensor - CSIM11-ORP sensor for SOP L3

Serial Number _____

Date & Time	T (°C)	Redox standard ORP (mV)			Action (Retest, Replace)	Analyst
		(Expected)	Measured	Error (Expected-measured)		

SOP L5

Markland Model 10 Sludge Gun Calibration Form

Serial Number _____ Date (DD-MM-YYYY) _____

Person Calibrating _____ Action: (Accept / Adjust / Replace)

Actual depth of resin layer (mm)	Measured Depth (mm)
	Trial #1
	Trial #2
	Trial #3
	Trial #4
	Trial #5
	Trial #6
	Trial #7
	Trial #8
	Trial #9
Mean	
Standard Deviation (Precision)	
Accuracy (Measured depth – Actual depth)	

SOP L5

Sludge Depth Field Data Form

Location: _____ Sensor serial number _____

Date (D-M-Y)	Time (EST)	**Bottom Depth (m)**			**Sludge Depth (m)**			Comments	Persons measuring
		Avg Cable Marker # (A)	Avg Distance to Waterline (B)	Avg Bottom Depth (A – B)	Avg Cable Marker # (C)	Avg Distance to Waterline (D)	Avg Depth to Sludge Layer (C – D)		
									/
									/
									/
									/
									/
									/

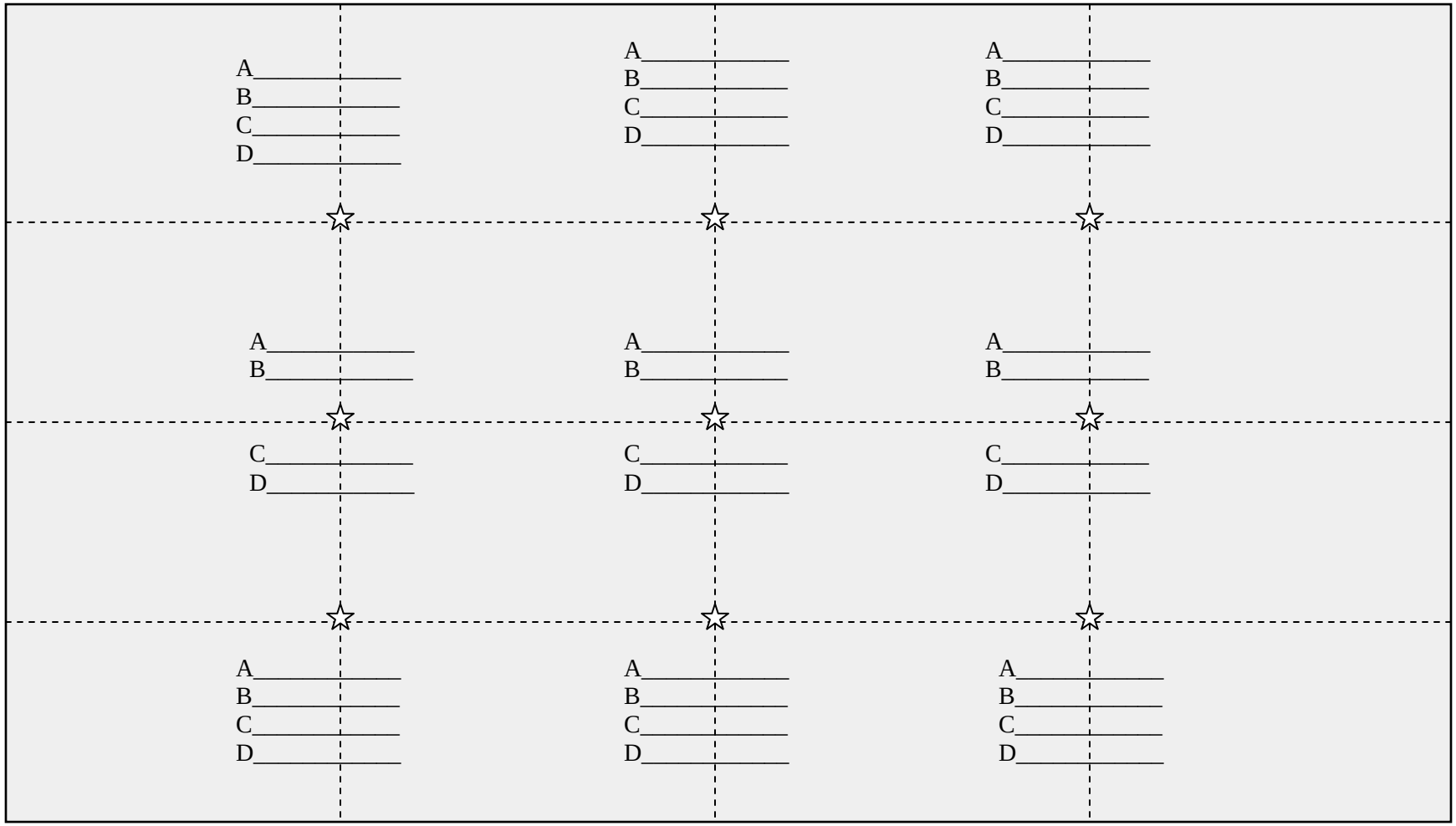
SOP L5

Depth Plot Worksheet

Location: _____ Date: _____ Operator: _____

Sensor serial number _____

☆ Denotes approximate measurement locations



Site Information Form for Lagoons and Basins SOP S7 (Table 1)

Category	Information
Farm name	
Address, phone	Contact Person:
Livestock Producer	Biosecurity: time since farm visit, d:
	Willing to provide production information?
	Cooperative and enthusiastic participant?
	How long has the farm been in operation under current owner?
	Able to provide feed and water consumption data? Sample analysis records?
	Willing to possibly test abatement technologies after the NAEMS?
	Describe management style (tools used, etc.):
Convenience	Distance from university, miles:
	Phone, internet, and electric power available? 240 VAC?
	Lodging nearby for research team?
Facilities	Generally describe rations:
	Animal breed:
	Describe feed delivery system
	Describe waste collection, handling, treatment and storage systems
	Rate lagoon maintenance from 1 to 5 (1 is cleanest):
	Any emission control measures at facility?
Surroundings	Describe surrounding landscape and topography (hills, flat, etc.)
	Describe other pollution sources within one mile:
	Distance to nearest land application sites
	Distance from public road. Type of road (gravel or paved).

Site Information Form for Lagoons and Basins SOP S7 (Table 2)

Descriptive parameters	Unit 1	Unit 2	Unit 3
Livestock type			
Year of facility construction			
Separation distance from barn fans, ft			
Type of storage (basin, lagoon or tank)			
Stage of lagoon (1st, 2nd, 3rd)			
Manure contributors to unit			
Animal 1 type (sows, cows, etc.)			
Animal 1 average weight (lb)			
Animal 1 inventory (# head)			
Animal 2 type (sows, cows, etc.)			
Animal 2 average weight (lb)			
Animal 2 inventory (# head)			
Animal 3 type (sows, cows, etc.)			
Animal 3 average weight (lb)			
Animal 3 inventory (# head)			
Manure collection (flush, scrape, PPR)			
Source flush or recharge water (if any)			
Lagoon loading frequency, hours			
Minimum space surrounding unit, ft			
Volumetric loading rate, lb/d-ft^3			
Surface loading rate, lb/d-ft^2			
Obstructions within 3X height of unit?			
If yes, what kind? (e.g. trees, barns)			
Height of worst obstruction, ft			
Distance from worst obstruction, ft			
Type of cover (crust, straw, none, etc.)			
Are solids separated from influent?			
Odor control: (digester, additives)			
Sludge removal cycle, years			
Last time sludge removed (e.g., 1999)			
Agitation prior to pumpout?			
Manure removal frequency, d			
Pump out (contractor or producer)			
Type of liner (clay, plastic, etc.)			
Volume, cubic ft			
Surface area, square feet			
Berm slope (e.g. 3:1, 3.5:1, 4 :1, etc.)			
Maximum side length, ft			
Minimum side length, ft			
Actual freeboard, ft			
Inner berm height, ft			
Outer berm height, ft			
Liquid depth, ft			
Sludge depth, ft			
Number of inlets (show on drawings)			
Shape (rectangular, oval, etc.)			

Dairy Corral Site Information Form SOP S7

(Email to Al Heber, Purdue University: heber@purdue.edu)

Table 1. Dairy Corral Site Selection Criteria

Category	Information
Farm name	
Address, phone	
Livestock Producer	Provide production and herd management information (DC305)?
	Cooperative and enthusiastic about study?
	Willing to make some nonconsequential changes for the test?
	Willing to train herdspersons about importance of test?
	Able to provide feed and water consumption data per cow group?
	Willing to possibly test abatement technologies after the NAEMS?
	Describe management style (tools used, etc.):
Convenience	Distance to site from university, miles:
	Cell phone signal?
	Phone, internet, electric power available?
	Lodging nearby for research team?
corrals	Generally describe rations (including forages and purchased feeds)
	Describe feed delivery system.
	Describe waste collection, handling, treatment and storage systems
	Rate corral hygiene from 1 to 5 (1 is cleanest).
Surroundings	Describe surrounding landscape and topography.
	Describe other pollution sources within one mile of site;
Farm	Describe all facilities on the site (# hd, size, age);
	Distance to nearest land application sites.
	On-site heifer growing program?

Table 2. Characteristics of test site and corrals **SOP S7**

Descriptive parameters.	Type 1	Type 2	Type 3
Breed			
Inventory (cow capacity)			
Average mass, lb			
Year(s) of construction			
Overall site width (E-W dist), ft			
Overall site length (N-S dist), ft			
Heifer growing program?			
Corrals			
Type (yearlings, lactation, hosp, etc.)			
Number			
Corral orientation			
Corral width, ft			
Corral length, ft			
Corral area, ft^2			
Apron width, ft			
Apron length, ft			
Apron cleaning (flush, scrape, vac)			
Maintenance technique (scr, harrow)			
Maintenance frequency (d)			
Shade height, ft			
Shade length, ft			
Shade width, deg.			
Side slope, %			
Cross slope, %			
Cow lane width, ft			
Cow lane length, ft			
Windbreak			
Height, ft			
Length, ft			
Lagoon			
Length, ft			
Width, ft			
Depth, ft			
Berm height, ft			
Number of stockpiles			
Weeping pad area, ft^2			
Number of separators			
Number of silage bunkers			
Number of hay barns			
Parlor			
Width, ft			
Length, ft			
Sidewall height, ft			
Roof ridge height, ft			
Type of ventilation			

Number of air outlets in ridge			

Table 2. Characteristics of test site and corrals (continued) **SOP S7**

Descriptive parameters.	**Type 1**	**Type 2**	**Type 3**
Type of sidewall inlets			
Air circulation fans in ceiling			
Misting?			
Exit lane drenching?			
Holding time, min			
Wash cows?			
Milking frequency, times daily			
Parlor occupancy, # cows			
Holding pen			
Manure removal (flush, hand wash)			
Manure removal frequency			
Width, ft			
Length, ft			
Sidewall height, ft			
Roof ridge height, ft			
Type of ventilation (NV, MV)			
Number of air outlets in ridge			
Type of sidewall inlets			
How is feed weighed?			
How is manure loads weighed?			
How are animals weighed?			
Number of pumps to monitor			
Access around property for sensors?			

Producer Event/Change Form SOP S7

In order for the Purdue Air Quality group to do its job, they need to know about events/changes around the lagoon, basin, or corral that affect airflow or air emissions. A few jotted notes here will help them not make mistakes when analyzing the data. Thank you for your cooperation!

[Examples of changes include (but are not limited to): major water leaks, power interruptions, sludge removal, pump outs, and diet changes.]

Description of event/change	Start time/date	End time/date	Contact person

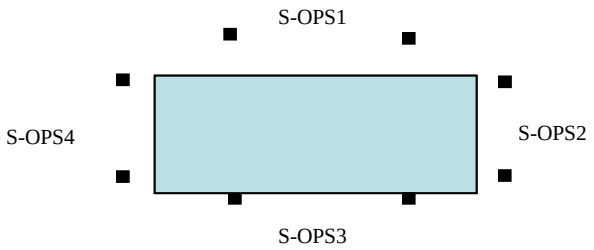
Research staff contact information:

Name(s):_____

Office phone: _____

Cell phone: _____

Synthetic Open-Path System (S-OPS) Placement Form SOP C4



Location: _____

Date: _____/_____/_____

FOS: _____

Indicate North direction on map

Synthetic Open Path system (S-OPS1) End of line:_Deg (N) _____Min_____Sec

Synthetic Open Path system (S-OPS2) End of line:_Deg (N) _____Min_____Sec

Synthetic Open Path system (S-OPS3) End of line:_Deg (N) _____Min_____Sec

Synthetic Open Path system (S-OPS4) End of line:_Deg (N) _____Min_____Sec

S-OPS	Height above berm (m)	Distance from berm (m)	Length of path (m)	Number of inlets	Length of sampling line from S-OPS to pump (m)	Orientation of path (N-S, NE-SW, etc.)
1						
2						
3						
4						

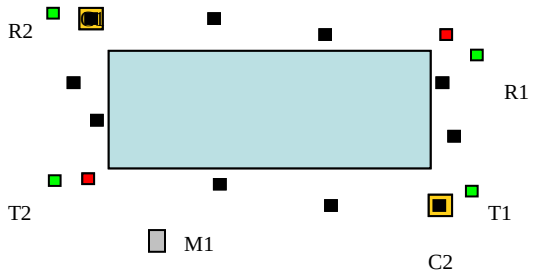
Notes:

Site Open-path Sensor Installation Report SOP U5

Location: _____

Date: _____/_____/_____

FOS: _____



Crank-up tower 1 location (C1) _____Deg (N) _____Min_____Sec

Crank-up tower 2 location (C2) _____Deg (N) _____Min_____Sec

Mast location (M1) _____Deg (N) _____Min_____Sec

UV-DOAS 1 transmitter location (T1) _____Deg (N) _____Min_____Sec

UV-DOAS 1 receiver location (R1) _____Deg (N) _____Min_____Sec

Distance between transmitter and receiver: _____ m

Height of path 1 above lagoon berm : _____ m

UV-DOAS 2 transmitter location (T2) _____Deg (N) _____Min_____Sec

UV-DOAS 2 receiver location (R2) _____Deg (N) _____Min_____Sec

Distance between transmitter and receiver: _____ m

Height of path 2 above lagoon berm : _____ m

Notes:

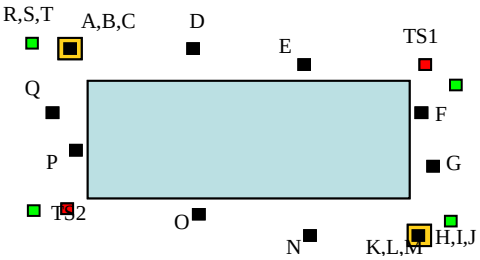
Site Open path sensor Installation Report SOP U5

(Continued)

Location: _____

Date: _____/_____/_____

FOS: _____



TDLAS/scanner 1 location (TS1) _____Deg (N) _____Min_____Sec

---------- Location ----------

Retro-reflector	Deg (N)	Min	Sec	Distance from TDLAS (m)	Actual height above berm (m)
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					

Inspection Checklist Form SOP U5

(Cables)

Date: _____

Item	All OK	One Bad	Repaired or Replaced Unit # or Description	Note #
Retro-reflector Cables (15-m/Tower)				
Retro-reflector Cables (7-m/Tower)				
Retro-reflector Cables (1- m/Tower)				
Retro-reflector Cables (1-m 2/3)				
Retro-reflector Cables (1-m 1/3)				
UV-DOAS Power Cable (Transmitter)				
UV-DOAS Power Cable (Receiver)				
TDLAS Power Cable				
Meteorological Unit Power Cable				
Lagoon Sensor Data Cables				
Sonic Anemometer Cables (16-m)				
Sonic Anemometer Cables (4-m)				
Sonic Anemometer Cables (1-m)				

All notes to be documented on back of form and note # referenced to the appropriate entry!

Name: _____

Inspection Checklist Form SOP U5

(Continued)

(Hardware)

Date: _____

Item	OK	Problem	Note #
GFCI Trip and Power OK?			
Lightning Rod OK?			
Ground Wire OK?			
Mast Stakes			
Crank Up Tower Guys Wires Tight?			
Crank Up Tower Base Bolts All Present & Tight?			
All Towers, Tripods, & Mast Look Vertical?			
All Towers, Tripods, & Mast Intact?			
Sonic Anemometers Mounted & Oriented Correctly?			
Lagoon Cable Floats Intact And Spaced Correctly?			
All Heater Cables Look OK, Mounted Securely?			
All Other Sensor Cables Look Intact			
Meteorological Boxes Weather Tight?			
Desiccant Fresh In Meteorological Boxes?			

All notes to be documented on back of form and note # referenced to the appropriate entry!

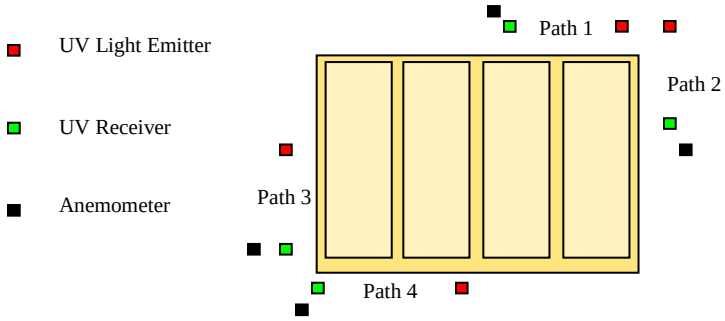
Name: _____

SOP U7

Site Open path sensor Installation Report (Corrals)

Location: _____

Date: _____/_____/_____



Path #1

UV-DOAS light emitter location (T1) _____Deg (N) _____Min_____Sec

UV-DOAS receiver location (R1) _____Deg (N) _____Min_____Sec

Sonic Anemometer location (A1) _____Deg (N) _____Min_____Sec

Distance between transmitter and receiver: _____ m

Path#2

UV-DOAS light emitter location (T2) _____Deg (N) _____Min_____Sec

UV-DOAS receiver location (R2) _____Deg (N) _____Min_____Sec

Sonic Anemometer location (A2) _____Deg (N) _____Min_____Sec

Distance between transmitter and receiver: _____ m

Path#3

UV-DOAS light emitter location (T3) _____Deg (N) _____Min_____Sec

UV-DOAS receiver location (R3) _____Deg (N) _____Min_____Sec

Sonic Anemometer location (A3) _____Deg (N) _____Min_____Sec

Distance between transmitter and receiver: _____ m

Path#4

UV-DOAS light emitter location (T4) _____Deg (N) _____Min_____Sec

UV-DOAS receiver location (R4) _____Deg (N) _____Min_____Sec

Sonic Anemometer location (A4) _____Deg (N) _____Min_____Sec

Distance between transmitter and receiver: _____ m

Name:

Inspection Checklist Form

Date: _____

Item	All OK	One Bad	Repair or Replaced Unit # Or Description	Note #
GFCI Trip and Power OK?				
Lightning Rod OK?				
Ground Wire OK?				
Mast Stakes				
UV-DOAS Power Cable (Transmitter)				
UV-DOAS Power Cable (Receiver)				
Meteorological Unit Power Cable				
Sonic Anemometer Cables				
All Other Sensor Cables Look Intact				
Meteorological Boxes Weather Tight?				
Desiccant Fresh In Meteorological Boxes?				
Tower Bolts All Present & Tight?				
All Towers, & Mast Look Vertical?				
All Towers, & Mast Intact?				
Sonic Anemometers Mounted & Oriented Correctly?				
All Tools & Equipment Put Away?				

All notes to be documented on back of form and note # referenced to the appropriate entry!

Name: _____

SOP W2

AUDIT FORM

SOP W2 RM YOUNG MODEL 81000 3-DIMENSIONAL SONIC ANEMOMETER

Date/time Yymm/dd hhmm	Bias in U (m/s)	Bias in V (m/s)	Bias in W (m/s)	Auditor

SOP W3

Calibration Check Form: Campbell Scientific Resistance Grid Wetness Sensor

Instrument Serial Number:_____ Location:_____

Date (D-M-Y)	Time		Resistance (ohms)		Action Taken (Adjust, Replace)	Analyst
	Begin	End	Dry	Wet		

Calibration Record: Setra 278 Barometric Pressure Sensor SOP W5

Instrument Serial Number:_____ Location:_____

Date (D-M-Y) Time: Begin- End	Temp. (^{o}C)	Manometer pressure (in. Hg)	Hg Temp. correction (in. Hg)	Pressure					Difference		Action*	Analyst
				Corrected			Measured		mb	hPa		
				in. Hg	mb	hPa**	mb	hPa				

* Sensor adjustment or replacement made after the measurement, if necessary. If action is taken, next entry should show result of re-calibration following that action.

**1hPa = 0.02953 in Hg

SOP W6
CR1000 Data logger Calibration Form

Instrument Serial Number:_____

Date (MM/DD/YYYY): ____/_____/_____ Calibrator: _____

Begin time (HrHr:MinMin) _____ End time (HrHr:MinMin) _____

For 5VDC input, factory accuracy: ±6.3 mV

SE Channel	Recorded voltage Mean value	Error (5-mean)	Within factory accuracy (±6.3 mV)? (Y/N)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
12			
13			
14			
15			
16			

Appendix B

SMPs

SMP IA3A
SITE MONITORING PLAN FOR FINISHER SWINE BASIN IN IOWA

SMP IA3A
SITE MONITORING PLAN FOR FINISHER SWINE BASIN IN IOWA

The Midwestern finisher basin facility is located in Greene County, IA. The elevation at the farm is 351 m (1151 ft). The magnetic compass variation at this location is 03°E. The farm consists of two barns and a manure basin (Fig. 1). The facility has a capacity of 3840 finishers in four units. The construction of the facility was completed in 1998.

Logistics

Measurements will be made once per quarter for two years by one of the rotating measurement teams from Purdue Applied Meteorology Laboratory in W. Lafayette, IN. The farm is located 75 km (47 mi) – an approximately 1.5-h drive – NW of the nearest airport (Des Moines, IA).

Climate (Table 1)

The climate for the area is represented by the Des Moines, IA National Weather Service weather station, which is approximately 75 km (47 mi) SE of the farm. The area typically receives an annual average of 783 mm (31 in) of precipitation (NCDC, 1981). The prevailing winds are from the S from May through October, and NW from November through April (Table 1, Fig. 2). The maximum chances of days with precipitation are during the spring (Table 1). Mean monthly wind speeds range from 4 m/s (9 mph) to 6 m/s (13 mph) (NCDC, 1998). Relative humidity (RH) ranges from 79% in the morning to 60% in the afternoon, while air temperatures range from 18°C (58°F) to 6°C (40°F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is given in Table 1.

Farm Operations Characteristics (Table 2)

Manure from the 2-ft deep pits in each of the four barns is transferred approximately once every ten weeks to the basin, through two inlets (Fig. 2). The basin is W of the barns (Fig. 3). The concrete circular basin has a diameter of 55 m (180 ft). The basin sides are approximately 1.5 ft above ground level (agl), and extend 6.5 ft below ground level. While the basin is circular, the measurements are described below as on the N, E, S, and W ‘sides’ of the basin, referring to measurements made to the N, E, S and W. Manure is surface-applied on adjacent fields every other year, and on fields up to 2 mi from the basin on the alternate years.

Surrounding Sources

The nearest identifiable NH_3 or H_2S emission source is a two-barn finisher farm two miles to the W of the farm site. No other basin, lagoon, or barn sources of NH_3 or H_2S emission are within one mile of the farm. Manure is surface-applied in alternating years on adjacent fields, and on fields up to 2 mi from the basin.

Monitoring Plan

The NH_3 emissions from the basin will be monitored using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1). VOC emissions will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4) and analyzed by the INNOVA (SOP G7). Data will be collected on the LAN server in the trailer (SOP D1, SOP U5).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes around the basin. Two towers will be located at the NW and SE "corners" of the basin (SOP U5) (Fig. 4). The scanning TDLAS instruments will be mounted at 1-m height above the basin rim on anchored tripods (SOP U5) at the NE and SW corners. The 1.5-ft (approx 0.5-m) height of the basin rim results in the TDLAS/scanners being about 1.5 m abl. Retro-reflectors at the approximate 1/3 and 2/3 distance down the basin 'sides' will also be mounted at 1 m above basin rim height on anchored tripods (SOP U5) (Fig. 4). The TDLAS laser beam is eye-safe.

Two S-OPS paths will be used to measure the synthetic PIC of VOC and H_2S near the basin rim height on two sides of the basin. Since the prevailing winds are S or NW depending on the time of year, the S-OPS will be positioned to the N and S of the basin (Fig. 4).

Volatile organic compounds, including methane, methanol, ethanol, and total VOC, will be measured using an INNOVA 1412 multi-gas photoacoustic analyzer (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the basin (Fig. 4).

Hydrogen sulfide will be measured using pulsed-florescence (SOP G5) from air sampled through the S-OPS paths upwind and downwind of the basin (Fig. 4).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located 10 m to the SW of the basin and 66 m W of the barns (Fig. 4). The meteorological measurement data will be collected on the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height, and on the NW corner tower (Fig. 4) at 4-m and 16-m heights abl (Fig. 4) (SOP U5).

The farm is located in rolling terrain (Fig. 5). The barns 12 m to the E of the basin have an approximate ridge height of 5 m (16 ft) agl, resulting in a fetch ratio (rise: run) to the E for the nearest TDLAS beamline of 1:3 or better. Crops are grown to the N, S and W of the basin. The area to the N alternates between corn and soybeans, while that to the W and S varies between wheat, soybean, and corn. Crops approximately 10 m (currently) to the N, S, and W of the basin will have a height ranging from 1 m (soybeans, wheat) to 3 m (corn). Since measurements are at

1.5 m abl or higher, the soybean and wheat crops would not affect the air flow at beamline or anemometer measurement heights. The fetch for the TDLAS and S-OPS beamlines to the S of the basin is 1:17 or better when cropped with corn. The fetch for TDLAS beamlines to the W of the basin is 1:6 or better when cropped with corn. The fetch for the S-OPS and TDLAS to the N of the basin is 1:3 or better when cropped with corn. To the N, the current year crop is soybeans, so under typical rotation 2007 will be in corn and 2008 in soybeans. The 2-m anemometer has a prevailing wind upwind fetch of 1:36 and 1:33 for the NW and S winds, respectively, and 1:22 for the E winds coming from the barns. The 4-m anemometer fetch in all directions except E winds is greater than 1:100; for the E wind, fetch is 1:78. Consequently, all wind measurements should be relatively unaffected by upwind conditions.

Configuration specifics:

The TDLAS/ scanners are located to the NE and SW of the basin, mounted at 1 m above basin height on anchored tripods (Fig. 4). The tower-mounted TDLAS retro-reflectors are mounted on fixed towers located SE and NW of the basin (Fig. 4). A description of the position of each measurement path, with photographs showing the views corresponding to the locations and directions indicated in Fig. 1 follows:

N side of basin

- TDLAS/scanner 9 m S of fenceline and 12 m NW of NW corner of northernmost barn.
- Three retro-reflectors mounted on a tower 23 m S of the fenceline and 79 m W of the barns, with a path length of 75 m.
- TDLAS retro-reflectors will be located 25 m and 45.5 m W of the TDLAS/ scanner on the NE corner, mounted at 1 m above basin rim height using anchored tripods.
- Beam paths are approximately 3 m from the basin at their closest point.
- 50-m length S-OPS path beginning at the TDLAS/scanner and ending 19 m S of the fence and 59 m W of the northernmost barn.
- Nearest point from S-OPS path to basin is 3 m.

Location of N side TDLAS beam path looking W towards the 15-m TDLAS retro-reflector tower. Basin rim is on left.

E side of basin

- TDLAS/scanner 9 m S of fenceline, 12 m NW of NW corner of northernmost barn.
- Three retro-reflectors mounted on a tower 12 m W of the barns and 84 m S of the fenceline (halfway between barns 3 and 4) with an 80.5-m path length.
- TDLAS retro-reflectors will be located 27 and 48 m S of the TDLAS/ scanner at the NE corner and mounted at 1 m above basin

Location of E side TDLAS beam path, looking N towards the location of the 15-m TDLAS retro-reflector tower. Basin rim is on right.

rim height using anchored tripods. Retro-reflectors are located halfway between barns 2 and 3, and 3 and 4.
- Beam paths are approximately 1 m from the berm at their closest point.

S side of basin

- 50 m length S-OPS path E-W along the TDLAS path lines with closest point 9 m S from the basin.
- S-OPS path begin 11 m W of barns.at 1 m above basin rim height and ends along the TDLAS path lines 62 m W of the barns.
- TDLAS/scanner at the SW basin corner, 79 m W of the barns and 75 m S of fenceline.

S side of basin. Basin rim is on left.

- TDLAS retro-reflectors will be located 22 m and 44 m E from the TDLAS/scanner. The retro-reflectors are mounted at 1 m above basin rim height on anchored tripods.
- Three retro-reflectors are mounted on a tower 11 m W of the barns and 84 m S of the fenceline (halfway between barns 3 and 4) with a 71 m path length.
- TDLAS beam paths are approximately 9 m from the basin at their closest point.

W side of basin

- TDLAS/scanner is located 79 m W of the barns and 75 m S of the fenceline.
- Three retro-reflectors are mounted on a tower 23 m S of the fenceline and 79 m W of the barns with a 60.5-m path length.
- TDLAS retro-reflectors will be located 18 m and 36 m N from the TDLAS/scanner. The retro-reflectors are mounted at 1 m above basin rim height on anchored tripod.

W side of basin. Basin rim is on left.

- TDLAS beam paths are approximately 12 m W of basin rim.

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the three sonic anemometers (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above rim height) are less than 1 m/s. The wind speeds (at a 7-m height) at Des Moines, IA were 1.1 m/s or less 2.8% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m abl) are greater than 11 m/s. Wind speeds (at 7-m height) at

Des Moines, IA were 11.1 m/s or more 1.4% of the time between 1981 and 1990 (NCDC, 1998).

3) The TDLAS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane on all four 'sides' of the basin ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

It is anticipated that the TDLAS upwind concentration measurements will be valid even when the winds are from the NNE to SSE, since the fetch is better than 1:3 and the distance to the beam line is ten times the diameter of the fan. We expect channeling of the flow along the barn axis, causing many of the NNE to SSE winds to align to an E wind.

VOC and Hydrogen sulfide emissions from the lagoon will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4, Fig. 4) and analyzed by PF (SOP G5). Restrictions on the use of the model are as follows:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid, although the surrounding area of the farm is open cropped land. The crop rotation is generally corn followed by soybean, but this is not strictly adhered to. The corn crop may have a canopy height of up to 3 m, while the soybean or wheat canopy height is approximately 1 m. The farm has additional roughness elements of buildings (to the E) of approximately 5 m (16 ft) height. Given prevailing winds from the NW, the buildings are downwind with at least a 1:3 fetch. For the prevailing southerly winds, the buildings are 11 m to the E of the flow. If the winds are from the NNE to SSE, the 1:3 fetch to the beamlines is inadequate and consequently emissions measurements will be invalidated (Fig. 2).
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period with the exception of when the winds are coming from the NNE to SSE (exclusion zone of Fig. 2). The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan.
3) The S-OPS concentration measurements are at upwind and downwind locations and are synoptic. This is essentially true when ½ hour averaging periods are used. Valid upwind and downwind paths will be when winds are from the N, NW and S; the prevailing winds during most of the year. It will not be true for winds from other directions.
4) Emission measurements will be invalidated when the friction velocity is less than 0.15 m/s, which corresponds approximately with winds of 1.1 m/s at 7-m height. The wind speeds at 7-m height at Des Moines, IA were 1.1 m/s or less 2.8% of the time between 1981 and 1990 (NCDC, 1998).

Surface manure sampling (SOP M1) will be conducted at the beginning or end of every measurement period when sufficient crusting exists in the basin. Surface samples will be collected at random locations in the basin. A minimum of three samples will be taken from separate locations in the basin to composite for each sample required. The composited piles will then be sampled using a corer (SOP M1). These samples will be analyzed for pH (SOP M2),

moisture content (SOP M3), total nitrogen (SOP M4), ammonia (SOP M5), and total and volatile solids (SOP M3). Results will provide the basis for correlating these properties with emissions from the basin.

Communications

The instrumentation trailer (SOP U4) will be located between the center two barns (barns 2 and 3) at the W end of the barns, approximately 15 m from the basin (Fig. 3). Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/basin characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source. All wiring will be buried directly in the ground from the producer-supplied source, and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS

model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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SOP E3. 2006. The Measurement of Solar Radiation with the Licor Model 200SL Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab.

SOP G5 2006. Standard Operating Procedure for Measurement of Hydrogen Sulfide (H2S) with the Thermo Electron Corporation Model 450C Pulsed- Flourescence Analyzer Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

SOP M1. 2006. Manure Sampling. Standard Operating Procedure M1. Purdue Ag Air Quality Lab.

SOP M2. 2006. Conducting pH Measurements on Manure Samples. Standard Operating Procedure M2. Purdue Ag Air Quality Lab.

SOP M3. 2006. Determining Solids Content of Manure Samples. Standard Operating Procedure M3. Purdue Ag Air Quality Lab.

SOP M4. 2006. Determining Total (Kjeldahl) Nitrogen Content of Manure Samples. Standard Operating Procedure M4. Purdue Ag Air Quality Lab.

SOP M5. 2006. Determining Ammonia Content of Manure Samples. Standard Operating Procedure M5. Purdue Ag Air Quality Lab.

SOP O1. 2006. Emissions Estimation Using Backward Lagrangian Stochastic (bLS) Model. Standard Operating Procedure O1. Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Applied Meteorology Lab.

SOP U4. 2006. Open Source Instrument Trailer. Standard Operating Procedure U4. Purdue Applied Meteorology Lab.
SOP U5. 2006. Installation of Open Source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.
SOP W1. 2006. Humidity and Temperature Probe. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.
SOP W2. 2006. Ultrasonic Anemometer for Wind Velocity. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.
SOP W3. 2006. Wetness Grid for Measuring Precipitation. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.
SOP W5. 2006. Barometric Pressure Sensor. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.
SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

Figure 1. Overall view of farm and basin. Basin is fenced-in area to the left of the barns. Compass directions are indicated. Courtesy of Ron Myers, USEPA.

Table 1. Monthly climate description (Des Moines, IA).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days ≥0.01 precip[1]	8	7	10	10	11	11	9	9	9	7	6	7
Wind speed (mph) [2]	12	11	13	13	11	10	9	9	10	10	12	11
Wind direction[2]	NW	NW	NW	NW	S	S	S	S	S	S	NW	NW
Morning RH (%)[1]	75	78	78	78	78	79	81	84	84	78	78	79
Afternoon RH (%)[1]	68	67	62	56	55	56	56	58	59	54	63	70
Maximum temp (°F) [1]	27.5	32.5	42.5	59.7	70.9	79.8	84.9	83.2	74.6	64.9	46.4	32.8
Minimum temp (°F) [1]	11.3	15.8	25.2	39.2	50.9	61.1	65.3	63.4	54.0	43.6	29.2	17.2

[1] NCDC (1981)
[2] NCDC (1998)

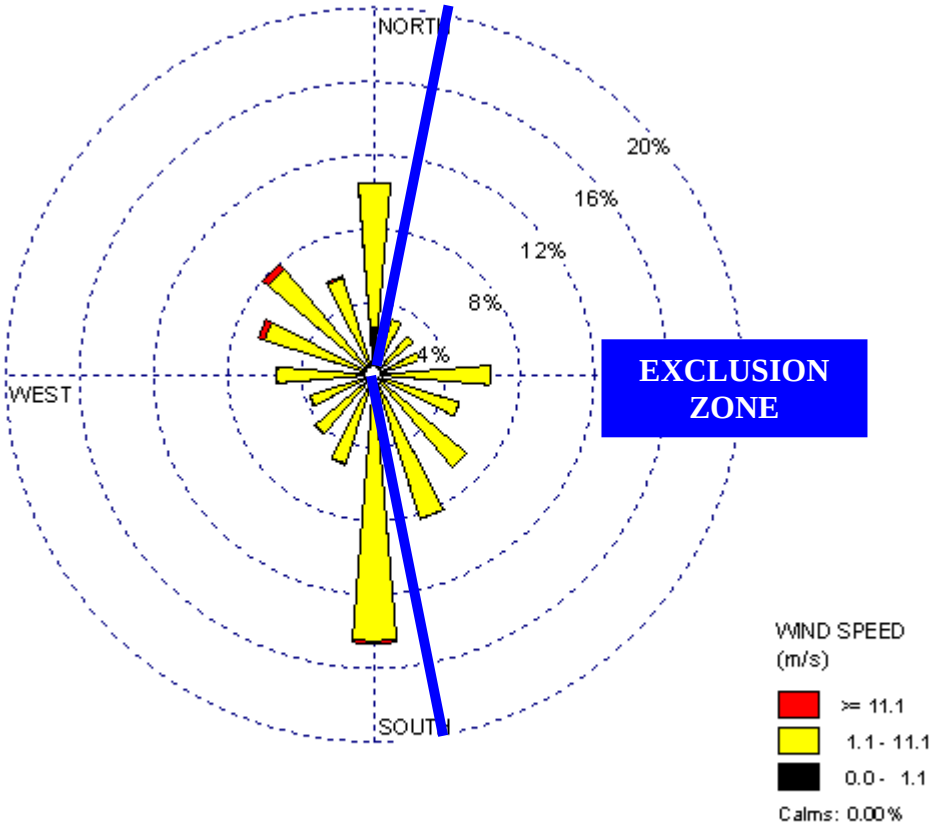

Figure 2. Des Moines, IA Windrose: 1981-1990. bLS based emissions measurements will be invalidated when the winds are in the wind direction exclusion zone indicated. Note that winds of <1.1 m/s are assigned to a nominal N direction, as they are below the threshold of the NWS anemometers.

Table 2. Characteristics of basin at the site.

Descriptive parameters	Unit 1
Livestock type	Swine Finisher
Year of facility construction	1998
Separation distance from barn fans, ft	45 (min)
Type of storage (basin, lagoon or tank)	Basin
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Finisher hogs
Animal 1 average weight (lb)	150
Animal 1 inventory (# head)	3840
Manure collection (flush, scrape, PPR)	PP
Source flush or recharge water (if any)	None
Lagoon loading frequency	Once every 10 wks
Minimum space surrounding unit, ft	
Volumetric loading rate, lb/d-ft^3	
Surface loading rate, lb/d-ft^2	
Obstructions within 3X height of unit?	None
If yes, what kind? (e.g. trees, barns)	
Height of worst obstruction, ft	
Distance from worst obstruction, ft	
Type of cover (crust, straw, none, etc.)	Crust
Are solids separated from influent?	No
Odor control	None
Sludge removal cycle, years	None
Last time sludge removed (e.g., 1999)	N/A
Agitation prior to pumpout?	Yes
Manure removal frequency, d	365
Pump out (contractor or producer)	Producer
Type of liner (clay, plastic, etc.)	Concrete
Volume, ft^3	203,537
Surface area, ft^2	25,442
Berm slope	Vertical
Maximum side length, ft	180 ft dia
Minimum side length, ft	
Actual freeboard, ft	1 ft
Inner berm height, ft	
Outer berm height, ft	
Liquid depth, ft	7 ft maximum
Sludge depth, ft	1 ft
Number of inlets	2
Shape	Round

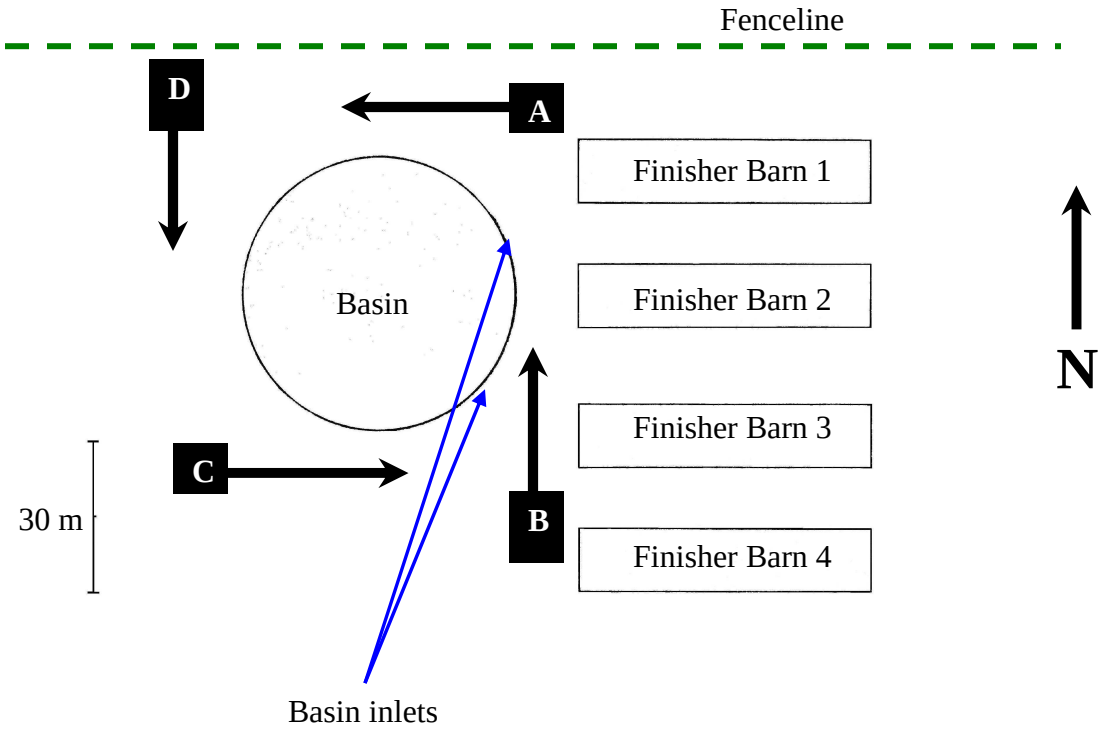

Figure 3 – General configuration of barns and basin. The direction of view of each photograph described in the measurement plan is indicated by letters (A: N view; B: E view; C: S view; D: W view).

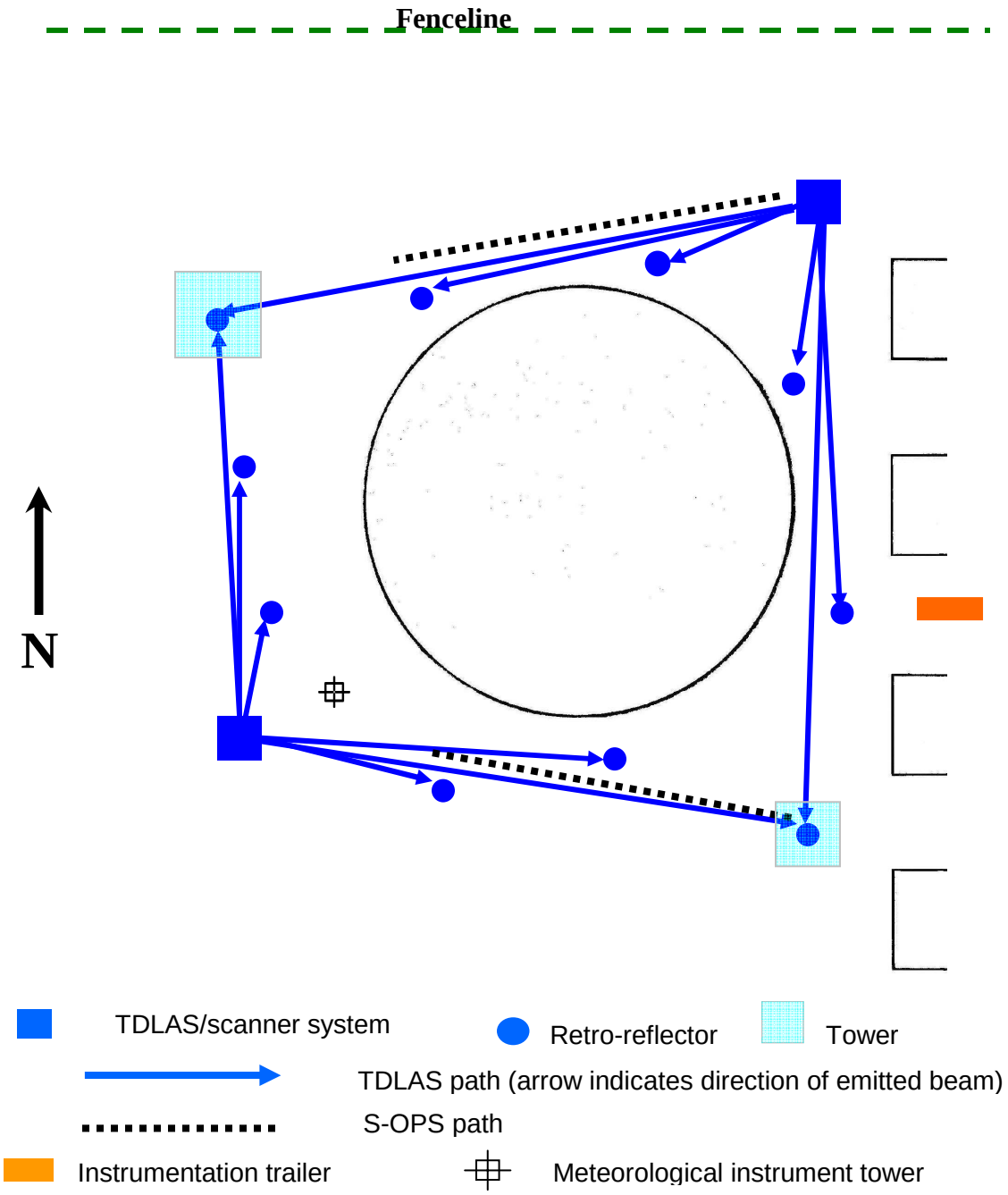

Figure 4. Measurement plan for the basin.

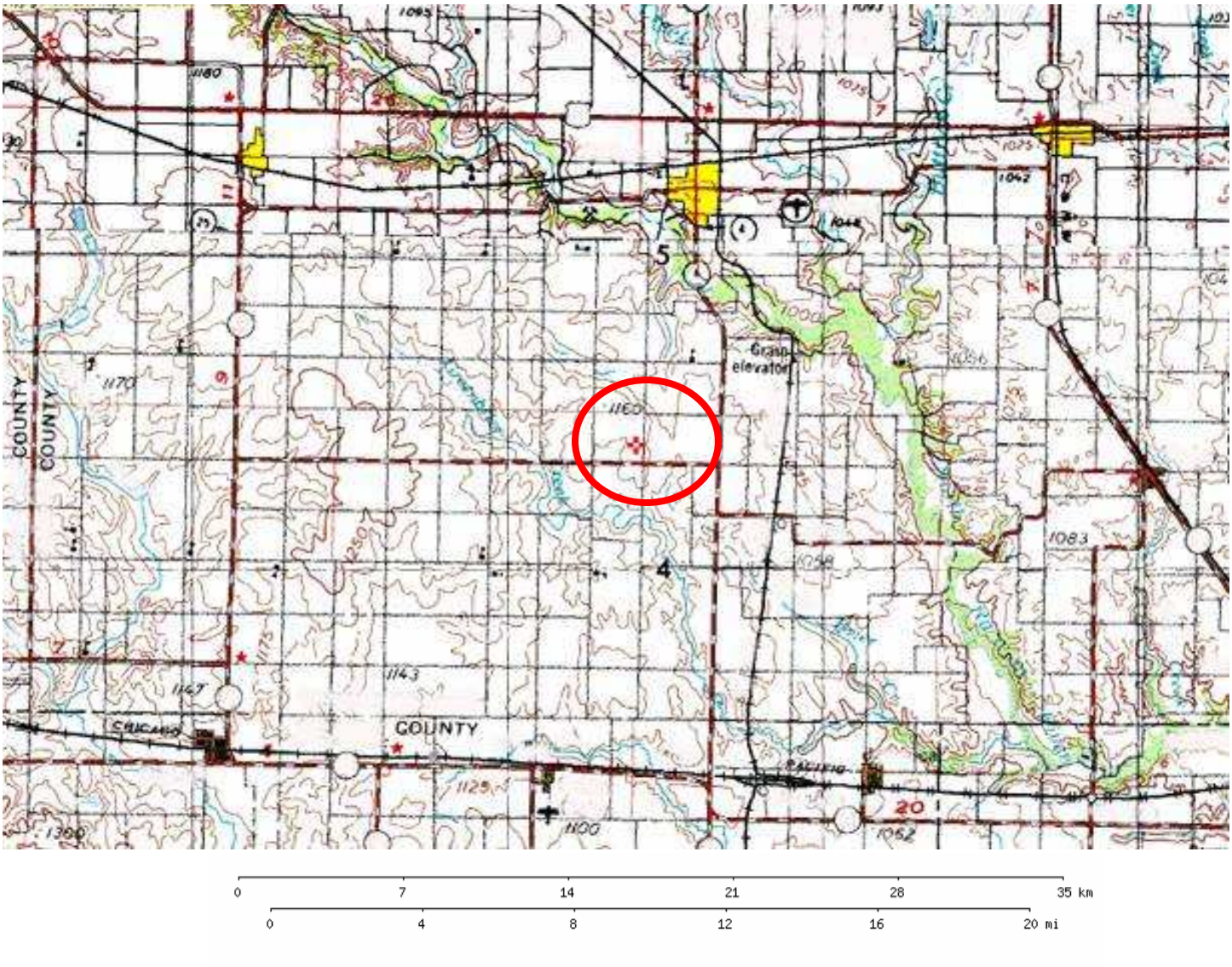

Figure 5. Terrain of surrounding area. Farm is indicated by the circle.

SMP IN4A
SITE MONITORING PLAN FOR SOW LAGOON IN INDIANA

SMP IN4A
SITE MONITORING PLAN FOR SOW LAGOON IN INDIANA

The Midwestern sow lagoon facility is located in Clinton County, Indiana. The elevation at the farm is 264 m (866 ft). The magnetic compass variation at this location is 04°W. The farm consists of nine barns (Fig. 1) and a lagoon (Fig. 2), and has a capacity of 1400 sows. The facility has been added to for many years, starting operations in 1968, while the last building addition was done in 1992. Eight years ago (1998), the facility was changed from a finisher operation to farrow-to-wean operation.

Logistics

Measurements will be made continuously for one year by staff at the Purdue Applied Meteorology Laboratory in West Lafayette, IN. The farm is located 58 km (35 mi) S of West Lafayette, for a one-way driving time of approximately 45 min.

Climate (Table 1)

The climate for the area is represented by the Indianapolis, IN National Weather Service weather station approximately 56 km (35 mi) S of the farm. The area typically receives an average of 984 mm (38.7 inches) of precipitation (NCDC, 1981). The prevailing winds are from the SW (Fig. 3, NCDC, 1998). Maximum chances of days with precipitation are during the spring (NCDC, 1981). Mean monthly wind speeds range from 3 m/s (7 mph) to 5 m/s (12 mph) (NCDC, 1998). Average relative humidity (RH) ranges from 84% in the morning to 62% in the afternoon, while air temperatures range from 19°C (62°F) to 6°C (42°F) (NCDC, 1981).

Farm operations characteristics (Table 2)

Liquid waste from the deep pits of the barns is transferred once every two weeks to the lagoon by a single inlet on the E side of the lagoon (Fig. 4). A manure composting pile is present within 5 m (16 ft) of the base of the N berm. This will be moved for the study. The lagoon is S from the barns (Fig. 3). The lagoon berm is 2-3 m (7-10 ft) high, and the lagoon itself is 112 m (365 ft) by 115 m (378 ft).

Surrounding sources

There are no identifiable fixed ammonia or hydrogen sulfide emission sources within one mile of the farm (Fig. 2). Once per year, manure from the lagoon is spread on the surrounding fields to the S, E and W via piping laid on the ground. The fields are at least 10 m from the lagoon berm in all directions.

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions

model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes around the lagoon. Fixed triangular towers will be located off the SW and NE corners of the lagoon berm (SOP U5) (Fig. 5). The scanning TDLAS instruments will be mounted at 1-m height above the berm at the NW and SE corners. The TDLAS/scanners will be mounted at 1-m height on anchored tripods (SOP U5). Retro-reflectors at the ⅓ and ⅔ distances down the berm sides will also be mounted at 1 m above berm height on anchored tripods (SOP U5) (Fig. 5). The TDLAS laser beam is eye-safe.

Two S-OPS air collection systems will be used to sample air from which measurements of VOC and H_2S will be made. The S-OPS will be near the berm height on two sides of the lagoon. Since the prevailing winds are from the SW throughout the year (Table 1), the S-OPS systems will be positioned to the N and S of the lagoon. It is expected that the southerly S-OPS system will usually be the upwind sensor system, while the northerly system will usually be the downwind system (Fig. 5).

Volatile organic compounds, including methane, methanol, ethanol, and total VOCs, will be measured using the INNOVA Model 1412 (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 2).

Hydrogen sulfide will be measured using pulsed-florescence (SOP G5) form air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 2).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located on the berm 15 m to the E of the lagoon's SW berm corner (Fig. 5). The meteorological measurement data will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height and on the SW corner tower (Fig. 4) at 4-m and 16-m heights above berm level (Fig. 5) (SOP U5).

The barns 469 m (1540 ft) to the N of the lagoon have an approximate ridge height of 6 m (19 ft) agl, resulting in a fetch ratio to the N of better than 1:100 for all measurements. Crops approximately 10 m (currently) surrounding the lagoon can be less than 1 m (soybeans) to 3 m (corn) tall, on alternating years. The current year is corn; so, under typical rotation, 2007 will be in soybeans and 2008 in corn. Since measurement are at 2 m abl, the soybean crop would not affect the air flow at measurement height, and the corn would have at least a 5:1 fetch at the lowest (2 m) measurement height (assuming cropped land is kept 5 m from the tripods and towers). Consequently, all wind measurements should be relatively unaffected by upwind conditions.

Configuration specifics:
The TDLAS/scanners are located on the berm at the SE and NW berm corners; mounted at 1 m above the berm height on anchored tripods (Fig. 5). The TDLAS retro-reflector towers are located approximately 12 m N and 12 m E from the NE berm corner on a fixed 18-m (59-ft) triangular tower and 12 m S and 12 m W of the SW triangular tower (Fig. 5).

A description of the position of each measurement path, with photographs showing the views corresponding to the locations and directions indicated in Fig. 4 follows:

N side of lagoon

- 50 m length S-OPS path due E-W 3 m N of lagoon berm mounted 1 m abl. and starting 37 m E of NW TDLAS/scanner.
- TDLAS retro-reflectors will be located 42.5 m and 87 m E along the berm from the NW corner. The retro-reflectors are mounted at 1 m above the berm using anchored tripods.
- Three TDLAS retro-reflectors are mounted on the NE corner tower 12 m E and 12 m N of the NE berm corner, each with a 144.5-m path length.

N side of lagoon looking W. Lagoon is to the right.

E side of lagoon

- TDLAS retro-reflectors will be located on the berm, 41.5 m and 83 m N of the SE corner. The retro-reflectors are mounted at 1 m above the berm using anchored tripods.
- Three TDLAS retro-reflectors are mounted on the NE corner tower 12 m E and 12 m N of the NE berm corner, with a 146.5-m path length.

E side of lagoon looking N. Lagoon is to the right.

S side of lagoon

- 50 m length S-OPS path due E-W 3 m S of lagoon berm at 1 m abl. starting 32 m W of SE TDLAS/scanner.
- TDLAS retro-reflectors will be located 42 m and 81.5 m W along the berm from the SE corner. The retro-reflectors are mounted at 1 m above the berm, using anchored tripods.

S side of lagoon looking E. Lagoon is on right.

- Three TDLAS retro-reflectors are mounted on the SW corner tower 12 m W and 12 m S of the SW berm corner, with a 141-m path length.

W side of lagoon

- TDLAS retro-reflectors will be located on the berm 41.5 m and 83.5 m N of the SW corner. The retro-reflectors are mounted at 1 m above the berm using anchored tripods.
- Three TDLAS retro-reflectors are mounted on the NW corner tower 12 m W and 12 m N of the NW berm corner, with a 141-m path length.

W side of lagoon looking N. Lagoon is on right. Barns can be seen in the distance.

The NH_3 PIC measurements and VOC and H_2S S-OPS measurements are not expected to be strongly influenced by the flow conditions surrounding the relatively high-bermed lagoon. The high upwind outer berms of the lagoon contribute to regions of vertical flow convergence at the berm top, with a mean vertical flow between 10 and 20 degrees upward (PAML, 2006a). This upward flow on the upwind berm is not anticipated to cause problems in the emissions calculations, since the upwind conditions provide the background concentrations for the emissions calculations. The high downwind berm results in a recirculation at heights lower than the berm height; however, smoke tests conducted in September of 2006 (PAML, 2006a), demonstrated that the berm did not change the mean, nearly horizontal flow of air above the berm height.

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the three sonic anemometers (SOP W2) and TDLAS measurements (SOP C2). Modeling and storage of results on-site will be accomplished by the individual instrument controlling computer (SOP O2, SOP D1). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. Wind speeds (at 7-m height) at Indianapolis, IN were ≤1.1 m/s 4.4% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds (at 7 m height) at Indianapolis, IN were ≥11.1 m/s 0.6% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS PIC measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

VOC and hydrogen sulfide emissions from the lagoon are calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1) with the 2-m height sonic anemometer (SOP W2). Modeling and storage of results on-site will be accomplished by the bLS computer (SOP O1, SOP D1). Restrictions on the use of the model are:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid, although the surrounding area of the farm is open cropped land. The crop rotation is corn followed by soybean. The corn crop may have a canopy height of up to 3 m, while the soybean canopy height is approximately 1 m. Smoke and wind measurements indicate that the corn crop contributes to very complex downwind flow conditions (PAML, 2006a). Therefore, to minimize the impact of the crops on the flow around the lagoon, measurements will be made during 2007-2008 when the surrounding crops will be soybeans to the S, E, and N, and winter wheat to the W of the lagoon. The farm has additional roughness elements (buildings) to the N, with a height of approximately 6 m (19 ft). With the barns 1540 ft (469 m) to the N and the prevailing winds from the SW, there is minimal influence of the buildings to the flow at the PIC height of 1 m above berm height.
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006b). Smoke and wind measurements showed a persistent upward motion as the flow transitioned from the lagoon to the downwind berm, as well as when the flow encountered the upwind outer berm of the lagoon (PAML, 2006a). Berm wind measurements will be made in the center of the berm top to minimize upward motion from either the outer berm rise (for winds coming up the berm side) or the inner berm rise (for winds coming across the lagoon).
3) The S-OPS PIC sampling for measurements of upwind and downwind components are synoptic. This is approximately true when averaged over ½ hr periods. Given that the prevailing winds are from the SW for the entire year, the placement of S-OPS planes along the S and N sides of the lagoon should provide valid synoptic PICs for most measurement periods.
4) Emission measurements will be invalidated when the friction velocity is less than 0.15 m/s. This corresponds approximately with winds of 1.1 m/s. The wind speeds (at 7-m height) at Indianapolis, IN were ≤1.1 m/s 4.4% of the time between 1981 and 1990 (NCDC, 1998).

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the S and 3 m from the W shore at the SW corner of the lagoon (SOP U5). The lagoon characterization measurement data will be collected by the data logger (SOP W6). Lagoon sludge depth measurements (SOP L5) will be made at nine locations in the lagoon (approximate locations indicated in Fig. 3), at approximately 20-d intervals.

Communications

The instrumentation trailer (SOP U4) will be located 10 m E and 30 m S of the NE berm corner (Fig. 3). Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via wireless DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the separate transformer installed at the street for use by the project. All wiring will be buried directly in the ground and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather- proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006b) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the

ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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Figure 1. View of the buildings at the farm.

Figure 2. Satellite image of the farm and its surroundings. Lagoon is indicated by the circle.

Table 1. Monthly climate description for the site (Indianapolis, IN).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	12	10	13	12	12	10	9	9	8	8	10	11
Wind speed (mph) [2]	11	11	12	12	10	9	8	7	8	9	11	11
Wind direction[2]	WSW	WSW	SW	SW	WSW	WSW	SW	SW	SW	SW	SW	SW
Morning RH (%)[1]	81	80	80	78	82	83	87	91	91	87	85	83
Afternoon RH (%)[1]	70	67	63	56	56	57	60	62	59	57	66	73
Maximum temp (°F) [1]	36.0	39.3	49.0	62.8	72.9	82.3	85.4	84.0	77.7	67.0	50.5	38.7
Minimum temp (°F) [1]	19.7	22.1	30.3	41.8	51.5	61.1	64.6	62.4	54.9	44.3	32.8	23.1

[1] NCDC (1981)
[2] NCDC (1998)

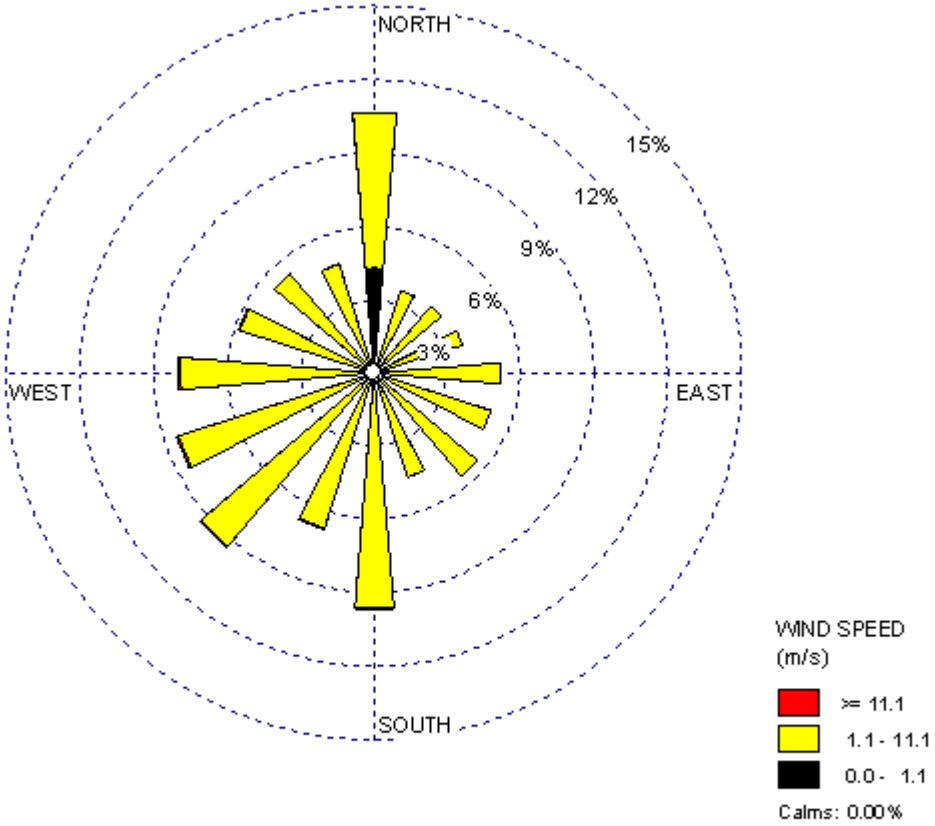

Figure 3. Indianapolis, IN Windrose: 1981-1990. Note that winds of <1.1 m/s are assigned to a nominal N, direction, as they are below the threshold of the NWS anemometers.

Table 2. Characteristics of the lagoon at the site.

Descriptive parameters.	Unit 1
Livestock type	Sows
Year of facility construction	1968-1992
Separation distance from barn fans, ft	1760
Type of storage (basin, lagoon or tank)	Lagoon
Stage of lagoon (1st, 2nd, 3rd)	1st
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Sows
Animal 1 average weight (lb)	475
Animal 1 inventory (# head)	1400
Animal 2 type (sows, cows, etc.)	Baby pigs
Animal 2 average weight (lb)	8
Animal 2 inventory (# head)	
Manure collection (flush, scrape, PPR)	Deep pits
Source flush or recharge water (if any)	
Lagoon loading interval, h	Every 2 wks
Minimum space around unit, ft	
Volumetric loading rate, lb VS/d-1000ft^3	2.11 to 2.56
Surface loading rate, lb VS/d-acre	1001 to 1073
Obstructions within 3X height of unit?	No
If yes, what kind? (e.g. trees, barns)	
Height of worst obstruction, ft	n/a
Distance from worst obstruction, ft	n/a
Type of cover (crust, straw, none, etc.)	None
Are solids separated from influent?	No
Odor control	None
Sludge removal cycle, yr	Never
Last time sludge removed (e.g., 1999)	Never
Agitation prior to pumpout?	No
Manure removal frequency, d	365
Pump out (contractor or producer)	Producer
Type of liner	Clay
Volume, ft^3	1,200,000
Surface area, ft^2	121,000
Berm slope	3 :1
Maximum side length, ft	378
Minimum side length, ft	365
Actual freeboard, ft	4
Inner berm height, ft	4
Outer berm height, ft	12
Liquid depth, ft	12
Sludge depth, ft	Unknown
Number of inlets	1
Shape	Rectangular

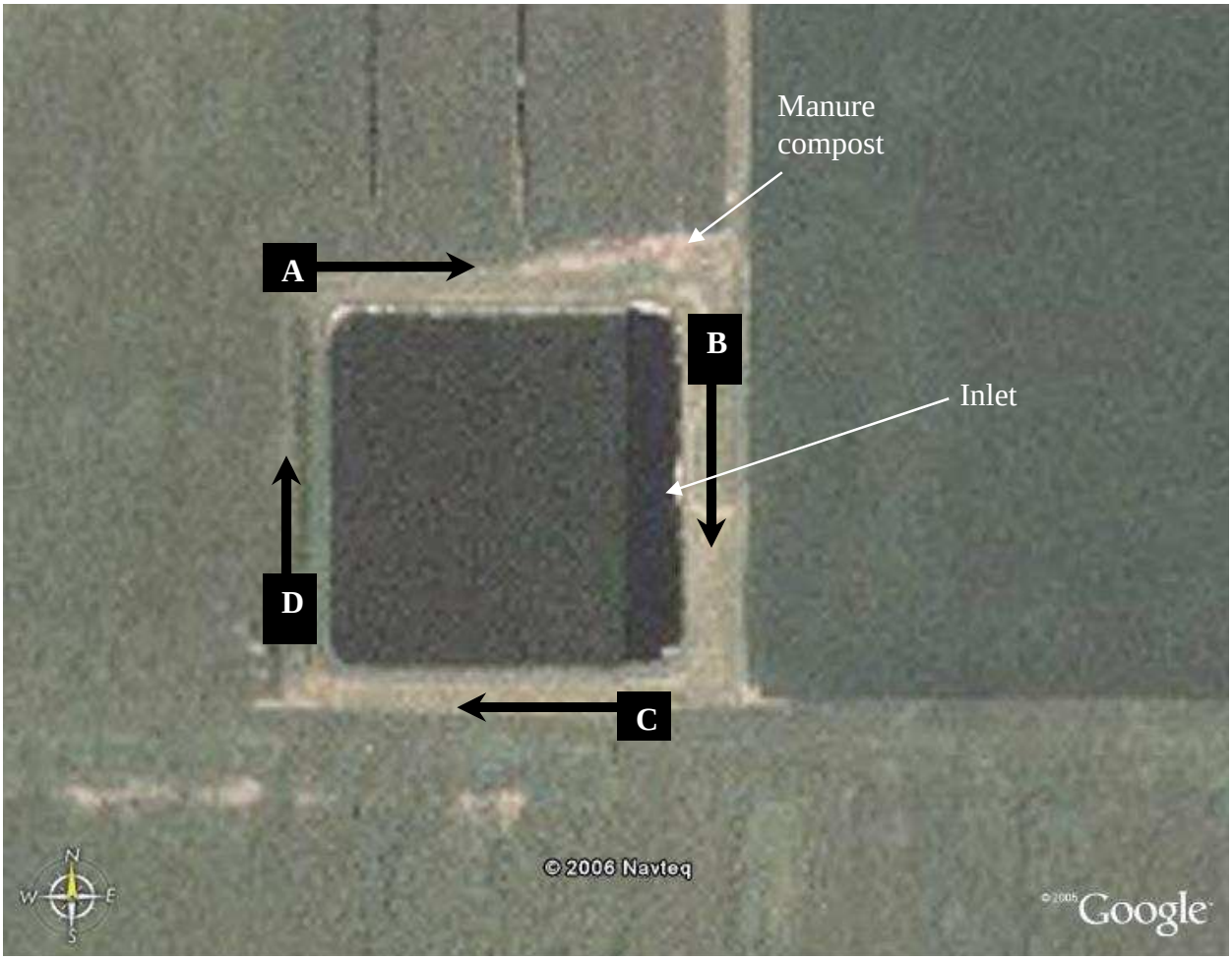

Figure 4. General configuration of the lagoon. The location and direction of view of each photograph described in the measurement plan is indicated by letters (A: N view; B: E view; C: S view; D: W view). Lagoon inlet is indicated, along with an existing manure compost pile that will be moved for the purpose of the study.

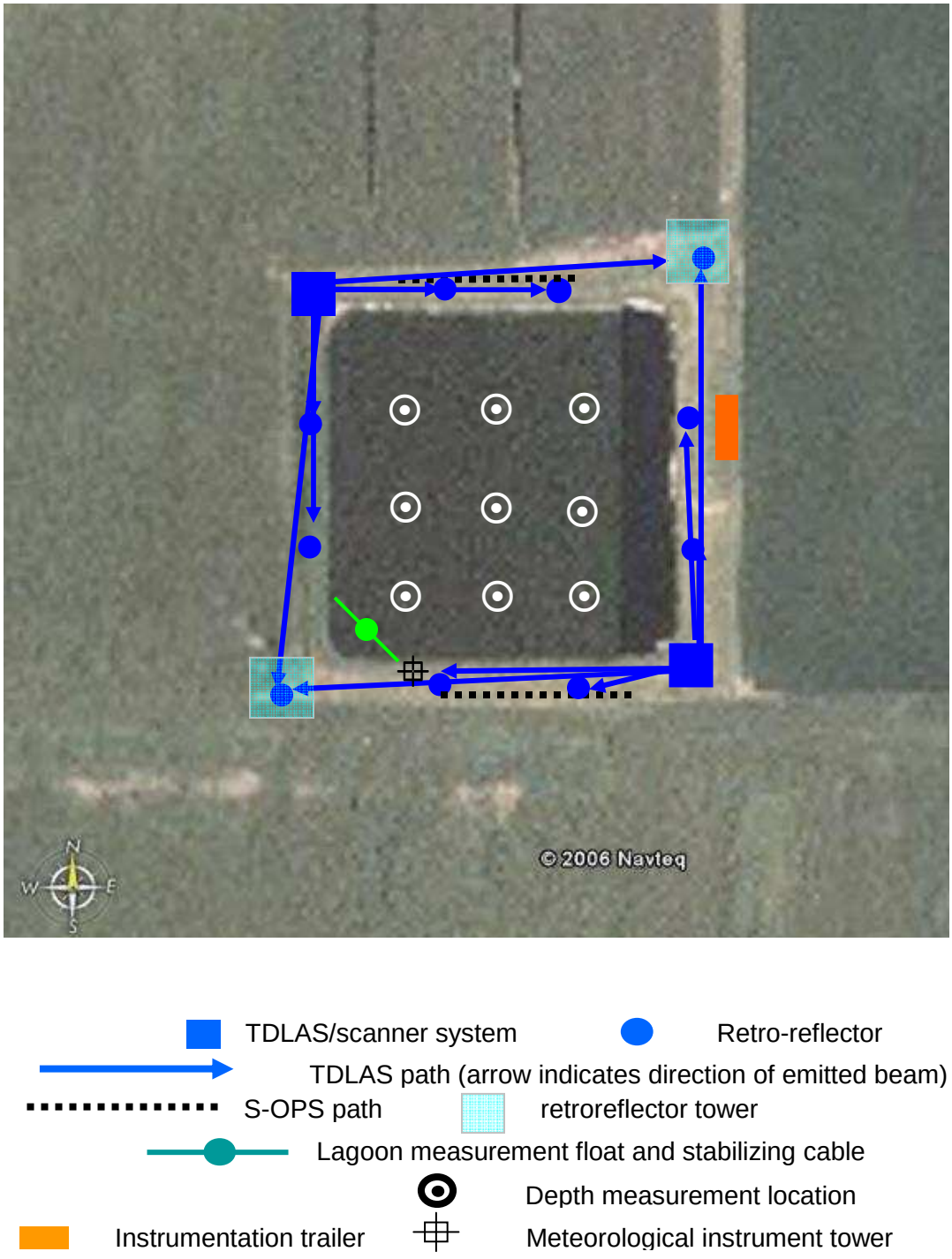

Figure 5. Measurement plan for the lagoon.

SMP IN5A
SITE MONITORING PLAN FOR DAIRY LAGOON IN INDIANA

SMP IN5A
SITE MONITORING PLAN FOR DAIRY LAGOON IN INDIANA

The facility that includes the Midwestern dairy lagoon is located in Cass County, IN. The elevation at the farm is 238 m (781 ft). The magnetic compass variation at this location is 02°E. The dairy consists of three barns, a feed storage area, special needs barn, milking parlor, and an office and tool and repair shops (Fig. 1). The facility as a whole has a capacity of 2600 cows. Construction of the dairy was completed in 2002.

Logistics

Measurements will be made continuously for one year by the continuous lagoon measurement team from Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. The farm is 86 km (54 mi) N of West Lafayette, with a one-way driving time of approximately 1¾ hours.

Climate (Table 1)

The climate for the area is represented by the Fort Wayne, IN National Weather Service weather station, which is approximately 93 km (58 mi) NE of the farm. The area typically receives an average of 883 mm (34.75 inches) of precipitation annually (NCDC, 2001); this is fairly evenly distributed through the year (Table 1). The prevailing winds are from the W to S (Peru, IN; Table 1, Fig. 2). Mean monthly wind speeds range from 2 m/s (5 mph) to 5 m/s (12 mph) (Peru, IN; NCDC, 1998). Average relative humidity (RH) ranges from 37% in the morning to 37% in the afternoon, while air temperatures range from 23.3 ^{o}C (74.0 ^{o}F) to -5.1 ^{o}C (22.9 ^{o}F) (NCDC, 2001). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure is vacuumed from the lactating cow barns and special needs barn every 12 hours, and placed in basins near the barns (Fig. 1). Manure is flushed from the holding area and milking parlor every ½ hour. A small fraction of waste is held in a slurry tank. Wastewater (flush) from the holding area and milking parlor goes to a rectangular settling basin S of the road, then into the waste lagoon S of the road. The clay-lined waste lagoon is 85 m (280 ft) wide and 116 m (380 ft) long, and is oriented N-S. The lagoon bank has a berm slope of 2.5:1. Liquid depth is approximately 5 m (16 ft). Sludge has never been removed from the lagoon.

Surrounding sources

There are no identifiable continuous NH_3 or H_2S emission sources within 1 mi of the measurement location (Fig. 5). Wastewater is spread on a field 250 ft to the S of the waste lagoon (through irrigation) (Fig 1).

Monitoring Plan

Emissions from the lagoon will be monitored continuously for one year using a Synthetic Open Path System (S-OPS) (SOP C4). The NH_3 concentrations will be determined using a photoacoustic spectrometer (PAS) (SOP G7) and scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments (SOP C2), while the H_2S concentrations will be monitored using pulsed-florescence (PF) (SOP G5). NH_3 data, 3-dimensional (3D) sonic anemometer data (SOP W2), and meteorological measurements will be input into the radial plume mapping (RPM) emissions model (SOP O2) to determine NH_3 emissions. H_2S emissions will be generated through radial plume mapping (RPM) (SOP O2), using concentration data, 3-dimensional (3D) sonic anemometer data (SOP W2), meteorological measurements and ratiometric relationships of concentrations.

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3 so as to create vertical measurement planes on each side of the lagoon. Two 15-m (51-ft) towers (SOP U5) will be located at the NE and SW corners of the lagoon. The scanning TDLAS instruments will be mounted at 1 m height above the lagoon berm at the NW and SE corners. The NW corner TDLAS/scanner will be mounted on an anchored tripod at 1 m height (SOP U5). The retro-reflectors on the NE corner tower will be at 1 m, 8 m, and 15 m heights. Retro-reflectors at the 1/3 and 2/3 distance down the lagoon sides will be mounted on anchored tripods (SOP U5) on the respective berm (Fig. 4). The retro-reflectors on the SW corner tower will also be at 1 m, 8 m and 15 m height. The TDLAS laser beam is eye-safe, and presents no hazard to farm workers.

Two S-OPS will be used to collect air along linear paths at 1 m above berm level (abl) along the lagoon berm on two sides of the lagoon for the measurement of VOCs (SOP G7) and H_2S (SOP G5). Each 50-m S-OPS consists of ten orifices spaced at a 5 m interval along the line. S-OPS lines will sample parallel to the N and S sides of the lagoon. The S-OPS along the S side of the lagoon will primarily act as the upwind station, while the S-OPS on the N side of the lagoon will primarily act as the downwind measurement path (Fig. 4).

Meteorological measurements, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3) will be located 10 m W and 30 m S from the NW berm corner (Fig. 4). The data from these meteorological measurements will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2 m height, and on the SW corner tower (Fig. 4) at 4 m and 16 m heights above ground level (Fig. 4) (SOP U5).

The barns 245 m (803 ft) to the N have ridge heights of approximately 8.5 m (28 ft) agl. and therefore a fetch ratio of 27:1 for the lowest TDLAS paths. A single line of trees (approximately 10 m or 30 ft) are 145 m (475 ft) to the W and 77 m to the S, resulting in upwind fetches of 16:1 and 8.5:1 for the TDLAS paths. Fetch to the E is better than 1:100, with the upwind conditions consisting primarily of irrigated crops (Figs. 1 & 5). A description of the position of each measurement path, including a photograph view taken in the directions and locations indicated by the black arrows and letter code in Fig. 3 follows:

N side of lagoon

- 50-m long S-OPS path parallel to and 5 m N of berm beginning 5 m N of NW berm corner extending 50 m E parallel to the berm.
- Retro-reflectors at 33 m, 66 m, and 3 at approx. 99 m on corner tower. The 33-m and 66-m retro-reflectors are mounted on the berm at 1 m height above berm on anchored tripods.
- TDLAS paths approximately parallel to and 5 m N of berm.

Location of N side S-OPS and TDLAS beam path, looking E TDLAS/scanner.

E side of lagoon

- TDLAS paths approximately parallel to the E berm of the lagoon, with retro-reflectors at 42 m, 84 m, and 3 at approx.124 m on the corner towers. The 42-m and 84-m retro-reflectors are mounted on anchored tripods along the berm at 1 m height above berm.
- TDLAS paths 1 - 5 m from berm.

Location of E side TDLAS beam path, looking S towards the location of the 15-m TDLAS retro-reflector tower. Lagoon berm is on right.

S side of lagoon

- 50-m long S-OPS path 1 m above, parallel to, and 5 m S of lagoon berm starting 5 m S of SW corner of berm (in the drainage swale) and running E parallel to the berm.
- Retro-reflectors at 31 m, 63 m, and 3 at approx. 95 m on the corner tower. The 31-m and 63-m retro-reflectors are mounted on the berm at 1 m height above berm on anchored tripods.

Location of S side TDLAS beam path, looking W towards the location of the 15-m TDLAS retro-reflector tower. Lagoon berm is on right.

W side of lagoon

- Retro-reflectors at 42 m, 84 m, and 3 at approx. 125 m on the corner tower.
- The 42 m and 84 m retro-reflectors are mounted on the berm at 1 m height above berm on anchored tripods. TDLAS paths 1 - 5 m from berm.

Location of W side TDLAS beam path, looking N towards the TDLAS/scanner system. Lagoon berm is on right

In addition:

- TDLAS scanner located 1 m E and 5 m S of SE berm corner on an anchored tripod at 1 m height abl.
- TDLAS scanner located 5 m W and 5 m N of NW corner of lagoon mounted at 1 m height abl on an anchored tripod.
- TDLAS tower located 5 m E and 5 m N of NE corner of berm.
- TDLAS tower located 5 m W and 1 m S of SW corner of berm.

Ammonia emissions from the lagoon will be calculated using the RPM model (SOP O2) with data from the three sonic anemometers (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are as follows:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are < 1 m/s. Wind speeds (7 m height) at Peru, IN were ≤ 1.1 m/s 3.2% of the time between 1981 and 1990 (NCDC, 2007).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are > 11 m/s. Wind speeds (7 m height) at Peru, IN were ≥ 11.1 m/s or more 2.6% of the time between 1995 and 2006 (NCDC, 2007).

Volatile organic compounds (VOC), including methane, methanol, ethanol, and total VOCs, will be measured using the INNOVA Model 1412 Multi-gas photoacoustic analyzer (SOP G7) from the air sampled using the S-OPS (SOP C4) upwind and downwind of the lagoon (Fig. 4). Measurement data will be collected on the LAN server in the trailer (SOP D1, SOP U4).

The single line of trees to the W and S have upwind fetches of 16:1 and 8.5:1, respectively, which may result in a increased turbulence on the S berm, and the sonic anemometer from which the turbulence statistics for the bLS are derived has a fetch of only 10:1 with the S trees. Thus, the bLS emissions model cannot be used. VOC and H_2S emissions from the lagoon will be calculated using the ratiometric method. The ratio of VOC measured by the S-OPS/PAS or H_2S measured by the S-OPS/PF to the to ammonia measured by TDLAS and the emission of ammonia by the lagoon measured by the RPM method will be used to estimate the VOC and H_2S emission according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). Restrictions on the use of the model are:

1) The S-OPS path and corresponding TDLAS path are equivalent, such that the NH_3 PIC values can be assumed to represent that along the S-OPS path.

2) The S-OPS air samples from upwind and downwind locations are synoptic. This can be assumed since concentrations will be averaged over ½-hr intervals. The synoptic measurements will provide the ability to determine the ammonia, VOC, and hydrogen sulfide concentration change for the air crossing over the lagoon.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float that is positioned 3 m N and 3 m W from the SE corner of the lagoon (SOP U5). The lagoon characterization measurement data will be collected on the data logger (SOP W6). Lagoon sludge depth (SOP L5) measurements will be taken at eight locations in the lagoon (Fig. 4) at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted, or if winds prohibit being able to keep the boat stationary for the measurements.

Animal inventory will also be obtained from the producer, and will be verified every six months by the study personnel (SOP S7).

Communications

The instrumentation trailer (SOP U4) will be located 10 m N of the SE corner of the lagoon (Fig. 4). Telemetry of TDLAS, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All data telemetered to the trailer will be sent to Purdue nightly via wireless DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source at the S side of the lagoon. All wiring will be buried directly in the ground from the producer-supplied (transformer-reduced 480 VAC 3 phase) source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather-proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be minimal due to location on the farm. Furthermore training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of the initial setup, and as needed during the year/measurement period.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be chewed or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals, and will be inspected and repaired or replaced if necessary after each measurement period. .

Power cables are not anticipated to be damaged by animals. All cables and tubing will be inspected at the beginning and end of the measurement periods, and repairs made as needed.

Emissions determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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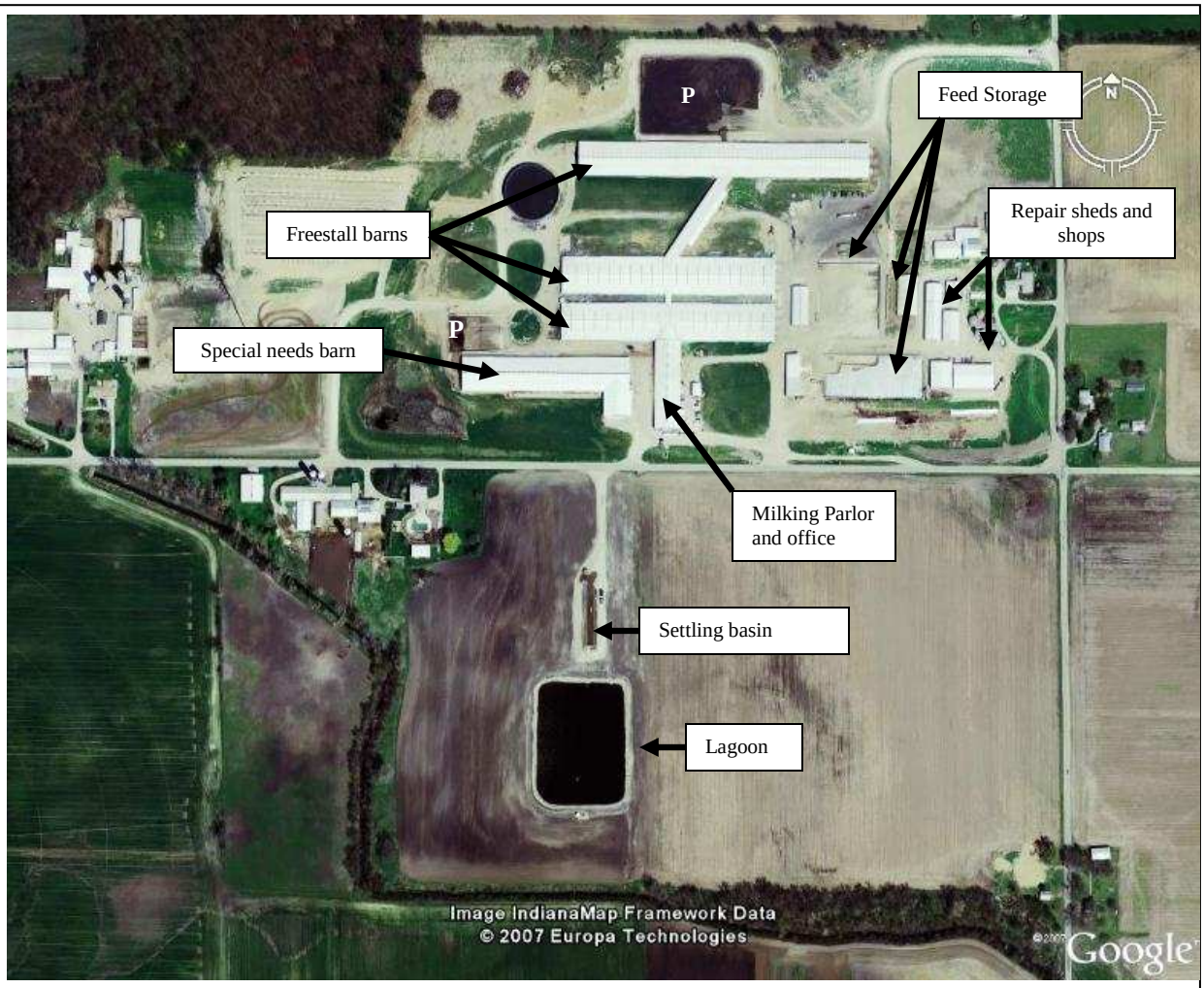

Figure 1. Aerial view of the Indiana dairy lagoon site. Image shows the relationship of the lagoon (lower center) to the freestall barns and the milking parlor (upper center). The areas marked P are the scrapping pits from the barns.

Table 1. Monthly climate description for the site (from Fort Wayne/Peru, IN).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	12	10	13	13	12	10	10	9	9	9	11	13
Wind speed (mph)[2]	12	10	10	10	8	7	6	5	6	8	9	10
Wind direction[2]	W	W	W	W	N	S	W	S	S	S	W	W
Morning RH (%)[1]	81	81	80	79	79	81	85	89	89	85	83	83
Afternoon RH (%)[1]	72	69	63	56	55	55	56	59	57	58	68	75
Maximum temp (°F)[1]	30.4	34.0	46.3	59.8	71.2	80.9	84.6	82.2	75.6	63.1	49.1	35.5
Minimum temp (°F)[1]	15.3	17.8	28.8	38.5	49.1	59.3	63.2	60.9	54.2	42.5	33.5	21.6

[1] NCDC (2001); Fort Wayne, IN
[2] NCDC (1998); Grissom Air Force Base, Peru, IN

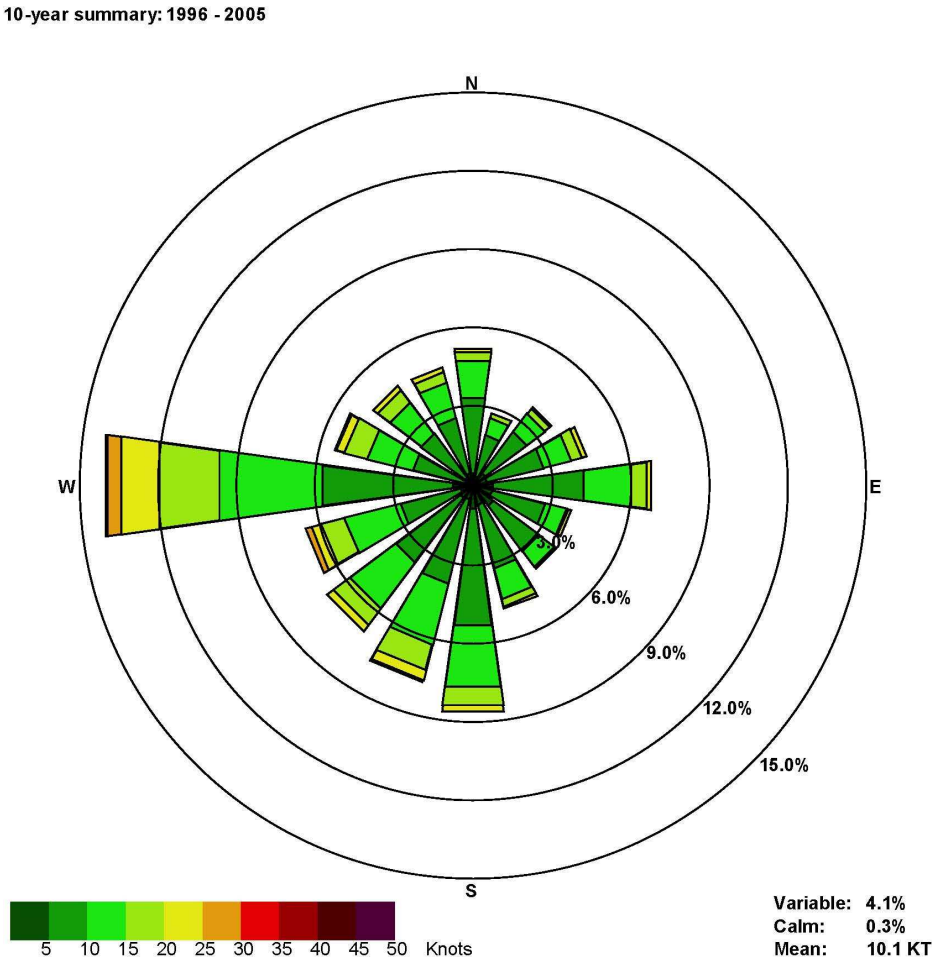

Figure 2. Grissom Air Force base, Peru, IN Windrose: 1996-2005.

Table 2. Characteristics of the manure storage units at the Indiana dairy lagoon site.

Descriptive parameters.	**Unit 1**	**Pits**
Livestock type	Dairy cattle	Dairy cattle
Type of storage	Dirt lagoon	Concrete lagoon
Number of units		
Year of facility construction	2003	2003
Separation distance from barn fans, ft	1000	750
Stage of lagoon (1st, 2nd, 3rd)	1st	2nd
Manure contributors to unit		
Animal 1 type	Cows	Cows
Animal 1 average weight (lb)	1500	1500
Animal 1 inventory (# head)	2600	2600
Manure collection	Flush, Vacuum	Flush, Vacuum
Source flush or recharge water (if any)	Holding pen & milking parlor	Holding pen & milking parlor
Lagoon loading interval, h	2/hr	2/hr
Minimum space around unit, ft		
Volumetric loading rate, lb vs/d-ft^3		
Surface loading rate, lb vs/d-ft^2		
Obstructions within 3X height of unit?	Yes	No
If yes, what kind?	Trees	
Height of worst obstruction, ft	35	
Distance from worst obstruction, ft	200	
Type of cover	None	Crust
Are solids separated from influent?	Yes	
Odor control	None	None
Sludge removal cycle, years	None	10x/yr
Last time sludge removed	Never	11/2007
Agitation prior to pumpout?	Yes	No
Manure removal frequency, days	Irrigation during growing season	Every 40d
Pump out (contractor or producer)	Producer	Both
Type of liner	Clay	Concrete
Volume, ft^3	1,702,400	15,888
Surface area, ft^2	280 x 380	24 x 180
Berm slope	2.5 :1	None
Maximum side length, ft	380	180
Minimum side length, ft	280	24
Actual freeboard, ft	5	3
Inner berm height, ft	10	7
Outer berm height, ft	5	7
Liquid depth, ft	16	4
Sludge depth, ft	0	4
Number of inlets	1	1
Shape	Rectangular	

Figure 3. Closeup of lagoon, showing the locations and directions of the four photos illustrating the measurement paths.

(A – N path view; B – E path view; C – S path view; D – W path view)

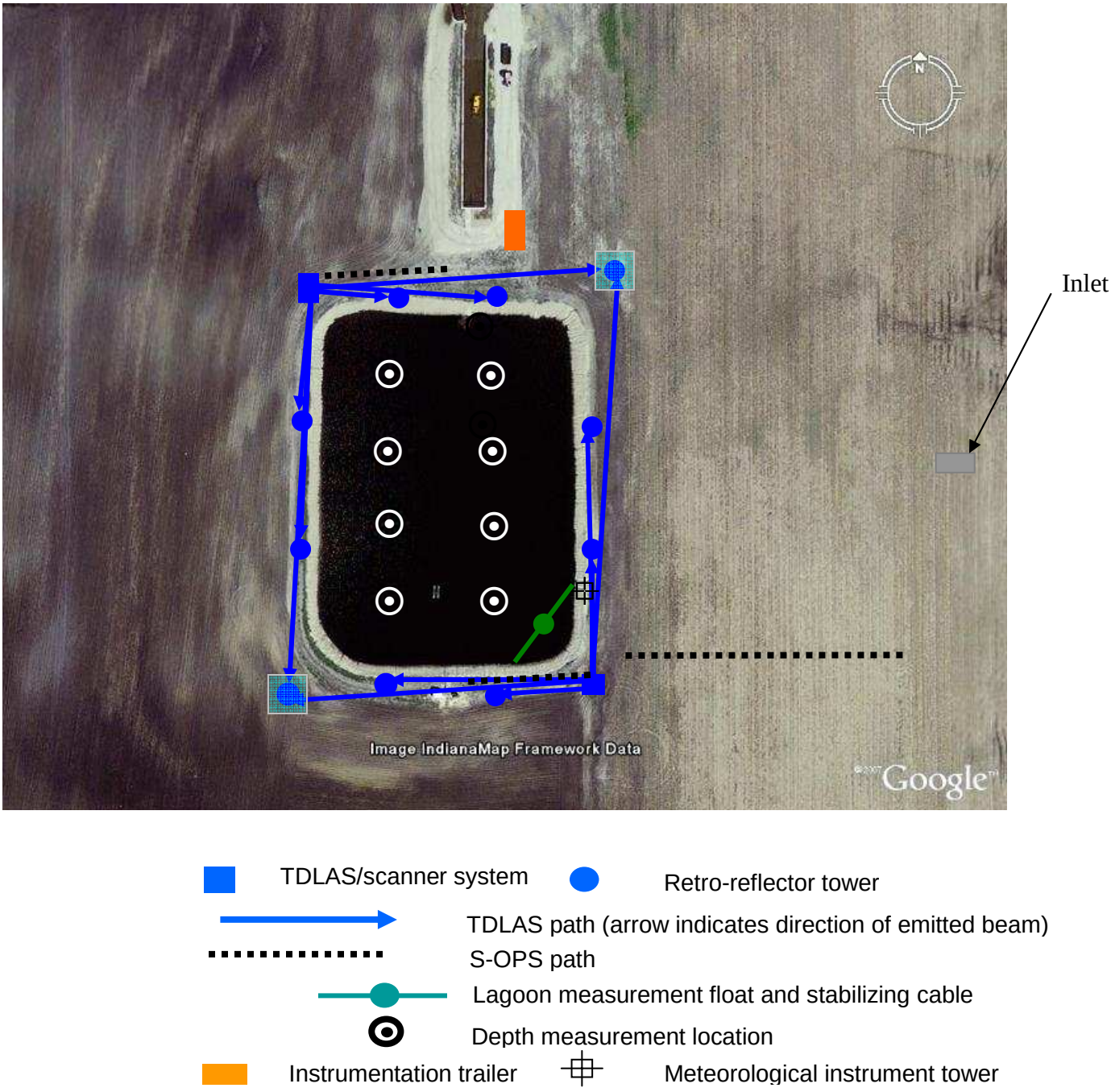

Figure 4. Dimensional plan of the lagoon.

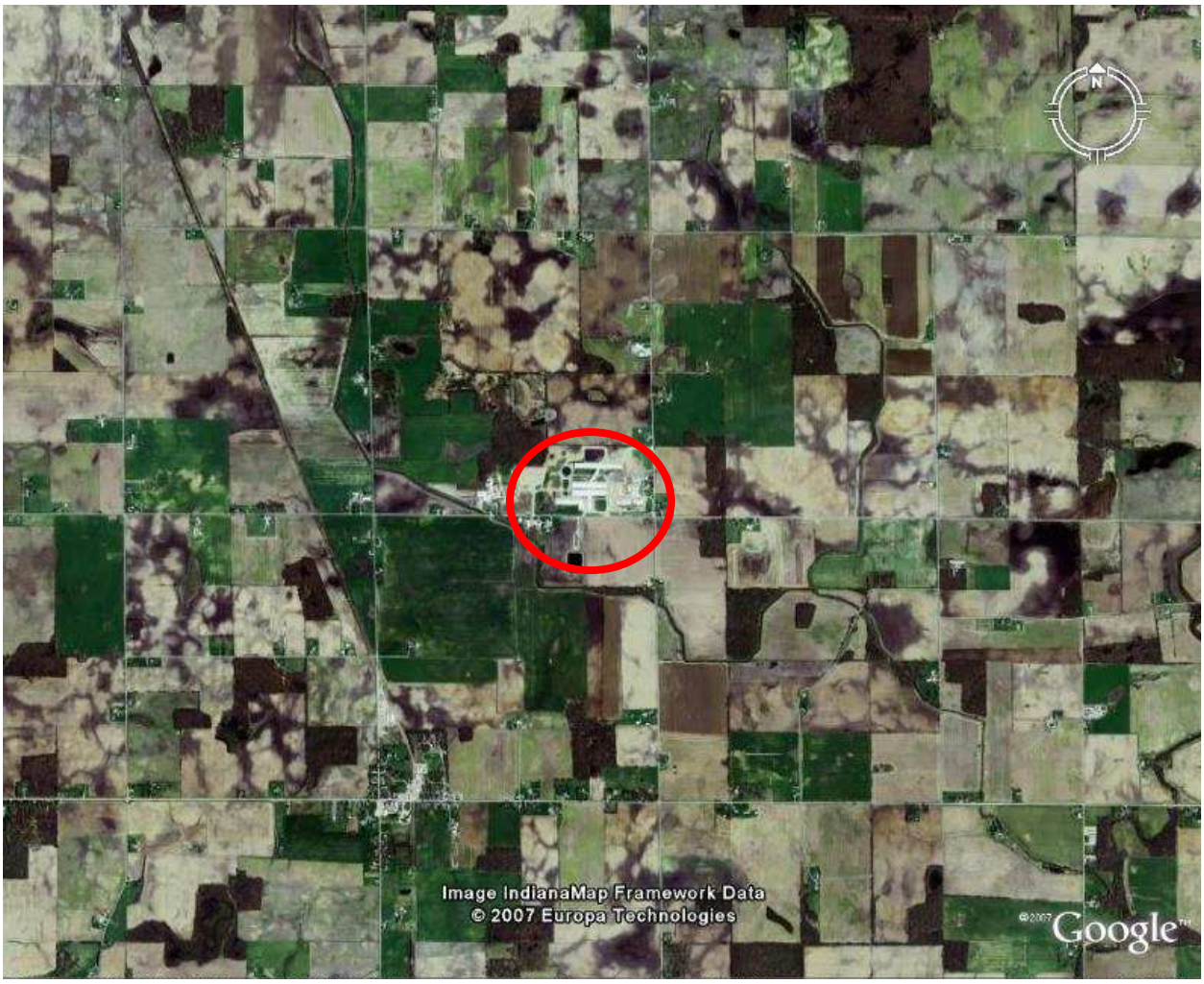

Figure 5. Satellite image of the farm's surroundings.
The farm that will be monitored is indicated by a red circle.

SMP NC3A
SITE MONITORING PLAN FOR FINISHER SWINE LAGOON IN NORTH CAROLINA

SMP NC3A
SITE MONITORING PLAN FOR FINISHER SWINE LAGOON IN NORTH CAROLINA

The Southeastern finisher lagoon facility is located in Bladen County, North Carolina. The elevation at the farm is 36 m (119 ft). The magnetic compass variation at this location is 07°W. The farm consists of five barns (Fig. 1) and an office, in addition to the lagoon itself. The facility has a capacity of 8000 finishing pigs in five units. Construction of the farm was completed in 1996.

Logistics

Measurements will be made by one of the rotating measurement teams from Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. The nearest airport is located at Raleigh/Durham, NC. The farm is located 132 km (79 mi) S of the Raleigh/Durham airport, for a one-way driving time of approximately 2 h.

Climate (Table 1)

The climate for the area is represented by the Fayetteville and Raleigh, NC National Weather Service weather stations. The wind climatology is from the Fayetteville station, approximately 32 km (20 mi) NW of the farm. The precipitation, humidity, and temperature climatology is from the Raleigh station, approximately 127 km (79 mi) NW of the farm. The area typically receives an average of 1080 mm (42.5 in) of precipitation (NCDC, 1981). The variation in winds over the year is illustrated in Fig. 2. The prevailing winds are from the SW to WSW during winter, spring, and summer, and N in fall (Table 1). Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 2 m/s (5 mph) to 3 m/s (7 mph) (NCDC, 1998). Relative humidity (RH) ranges from 85% in the morning to 55% in the afternoon, while air temperatures range from 21°C (70°F) to 7°C (48°F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure from the barns is transferred daily to the lagoon by pull plug and lagoon water recharge. Waste water combines into one inlet (Fig. 1). The rectangular waste lagoon is located to the N and separated by a drainage swale from the barns. The clay-lined lagoon is 113 m (370 ft) wide and 173 m (568 ft) long, and is oriented E-W. Liquid depth is variable, and is removed as weather permits. Sludge from the lagoon has not been removed since construction (15-year sludge removal cycle).

Surrounding sources

There are no identifiable NH_3 or H_2S emission sources within one mile of the farm site. The area immediately surrounding the farm is approximately ¾ woodlands and ¼ agricultural fields (Fig. 3).

Biosecurity Requirements

The producer requires that all visitors to the farm meet the following requirements:

- A minimum of 48 hours of downtime from any other swine contact
- No contact with swine in a foreign country in the last 7-10 d.
- No visit to any location with any live birds, or contact with other poultry or domestic birds (including parakeets, parrots, etc) within 48 hours prior to the farm visit.

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) using a ratiometric emissions calculation method (PAML 2006a). VOC emissions will be monitored using S-OPS sample collection (SOP C4) and INNOVA Photoacoustic spectroscopy (SOP G7) using a ratiometric emissions calculation method (PAML 2006a).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Two 15-m (51-ft) towers will be located at the NW and SE corners of the lagoon. The scanning TDLAS instruments will be mounted at 1 m height above the lagoon berm on the berm at the NE and SW corners on anchored tripods (SOP U5). Retro-reflectors at the approximate ⅓ and ⅔ distances down the lagoon sides will also be mounted on the berm at 1 m height on anchored tripods on the respective berm (Fig. 3) (SOP U5). The TDLAS laser beam is eye-safe.

Two S-OPS air collection systems will be used to sample the air along a linear path from which measurements of VOC and H_2S near lagoon berm height on two sides of the lagoon. S-OPS will be mounted at 1 m height parallel to the N and S sides of the lagoon. The S-OPS along the S side of the lagoon will primarily act as the upwind station, while the S-OPS on the N side of the lagoon will primarily act as the downwind measurement path (Fig. 4).

Volatile organic compounds, including methane, methanol, ethanol, and total VOCs, will be measured using the INNOVA Model 1412 (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 4).

Hydrogen sulfide will be measured using pulsed-florescence (SOP G5) from air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 4).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located on the berm 30 m W of the NE berm corner (Fig. 4). The meteorological

measurement data will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height and the SE corner tower (Fig. 3) at 4-m and 16-m heights above berm level (Fig. 4) (SOP U5).

The barns 20 m (67 ft) to the S of the lagoon berm have an approximate ridge height of 6 m (19 ft) agl (above ground level), resulting in a fetch ratio to the W of 3:10 to the lagoon. Fetch to the E for the wind measurements is 3.5:1 for the 16-m measurement height, 1.3:1 for the 4-m measurement height, and 2.8:1 for the 2-m measurement, with the obstruction to the E of a 23-m (75 ft) deciduous forest canopy. The W obstruction for the 2-m wind measurement is a similar forest at 140 m (460 ft) distance, with a fetch of 6:1. Obstructions to the SW for the other wind measurements are the 5.5-m (18-ft) high farm barns at 50 m (165 ft) distance. The 16-m measurement height should be unaffected by the barns, while the fetch is 33:1 for the 4-m measurement height, indicating a small influence on the westerly flow by the buildings.

The barn exhausts to the S of the lagoon will likely contribute to the upwind NH_3 PIC values under SW winds. The S TDLAS measurement plane and the S berm S-OPS PIC values will be the upwind measurements for the SW flow NH_3 emissions measurements.

Configuration specifics:
A TDLAS/ scanner is located at the NE and SW corners of the lagoon berm, each mounted at 1 m agl on an anchored tripod (Fig. 4). Fixed triangular retro-reflector towers are located 25 m N of the NW berm corner and 15 m S and 18 m E of the SE berm corner (Fig. 4).

A description of the position of equipment on each measurement path follows:

N side of lagoon

- 50 m S-OPS path 1m abl.
- S-OPS path begins at the NE berm corner and extends W 50 m.
- TDLAS retro-reflectors will be located at 60.5 m and 112 m down the berm from the scanner at the NE corner for the berm. The 60.5-m and 112-m retro-reflectors are mounted on anchored tripods on the berm at 1 m height above berm.
- Three retro-reflectors are mounted on a tower off the NW berm corner at 207.5 m from the scanner at the NE corner.

E side of lagoon

- TDLAS retro-reflectors will be located at 40.5 m and 77.5 m along the berm from the NE corner scanner, and 3 at approximately 130 m path length to the

N berm looking W towards NW retro-reflector tower location.

E berm looking S towards SE retro-reflector tower location.

SE corner tower. The 40.5-m and 77.5-m retro-reflectors are mounted on the berm at 1-m height on anchored tripods.

S side of lagoon

- 50 m S-OPS path 1m abl.
- S-OPS path begins at the SW berm corner and extends E 50 m.
- TDLAS retro-reflectors will be located at 57.5 m and 110 m E along the berm from the SW corner scanner, and 3 retro-reflectors with a 183 m path length to the SE corner tower.
- The 57.5-m and 110-m retro-reflectors are mounted on the berm at 1 m abl, using an anchored tripod.

S berm looking W towards TDLAS/ scanner location.

W side of lagoon

- TDLAS retro-reflectors will be located at 53 m and 89.5 m N along the W berm from the scanner, and 3 retro-reflectors at a 135.5 m path to the fixed tower from the TDLAS/scanner.
- The 53-m and 89.5-m retro-reflectors are mounted on the berm at 1 m above berm.

W berm looking S towards SE retro-reflector tower location.

Ammonia emissions from the lagoon are calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the sonic anemometer (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. Wind speeds at Raleigh, NC (at 7-m height) were ≤1.1 m/s 6.9% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds at 7-m height at Raleigh, NC were ≥11.1 m/s 0.1% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

VOC and H_2S emissions from the lagoon will be calculated using the ratiometric method. The ratio of VOC measured by the S-OPS/PAS or H_2S measured by the S-OPS/PF to the to ammonia measured by TDLAS and the emission of ammonia by the lagoon measured by the RPM method will be used to estimate the VOC and H_2S emission according to the National Air Emissions

Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). Restrictions on the use of the model are:

1) The S-OPS path and corresponding TDLAS path are equivalent such that the NH_3 PIC values can be assumed to represent that along the S-OPS path.
2) The S-OPS air samples from upwind and downwind locations are synoptic. This can be assumed since concentrations sampled from the S-OPS sampled air will be averaged over ½ hr intervals. The synoptic measurements will provide the ability to determine the ammonia and hydrogen sulfide concentration change for the air crossing over the lagoon.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the E shore of the NE corner of the lagoon (SOP U5). The lagoon characterization measurement data will be collected by the data logger (SOP W6). Lagoon sludge depth measurements (SOP L5) will be made at nine locations in the lagoon (locations shown in Fig. 4) at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or if winds prohibit being able to keep the boat stationary for the measurements.

Communications

The instrumentation trailer (SOP U4) will be located approximately10 m W and 10 m S of the SE corner of the lagoon (Fig. 4). Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source. All wiring will be buried directly in the ground from the producer-supplied source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and periodically during the year/measurement period as needed.

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Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eated or

otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. The H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

Figure 1. Aerial view of lagoon, showing relationship to the barns. Red lines indicate soils delineations, and not a physical property boundary.

Table 1. Monthly climate description (Fayetteville/Raleigh, NC).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	10	10	11	9	10	9	11	10	8	7	8	9
Wind speed (mph)[2]	5	6	6	6	5	5	3	3	3	3	3	5
Wind direction[2]	WSW	WSW	W	SW	SW	WSW	SW	SW	NE	N	N	WSW
Morning RH (%)[1]	79	76	81	81	87	88	91	93	93	90	85	81
Afternoon RH (%)[1]	56	50	50	45	55	58	59	60	60	54	52	55
Maximum temp (°F)[1]	51.0	53.2	61.0	72.2	79.7	85.6	87.7	86.8	81.5	72.4	62.1	51.9
Minimum temp (°F)[1]	30.0	31.1	37.4	46.7	55.4	63.1	67.2	66.2	59.7	48.0	37.8	30.5

[1] NCDC (1981)
[2] NCDC (1998)

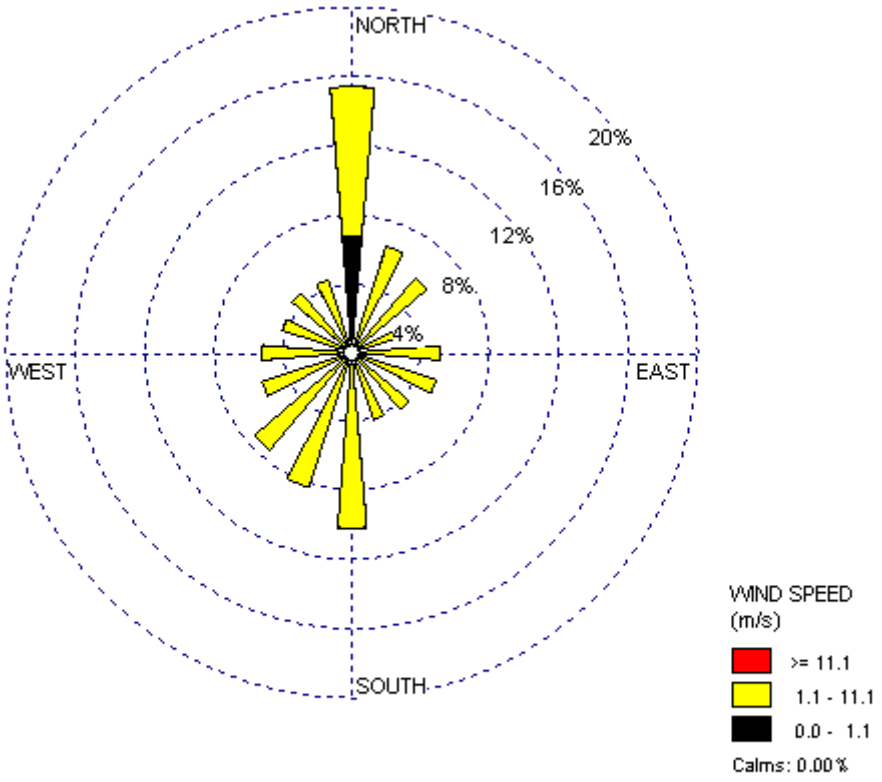

Figure 2. Raleigh Windrose, 1981-1990. Note that winds of <1.1 m/s are assigned to a nominal N, direction, as they are below the threshold of the NWS anemometers.

Table 2. Characteristics of lagoon at the NC finisher site.

Descriptive parameters.	Unit 1
Livestock type	Finishing
Year of facility construction	1996
Separation distance from barn fans, ft	60
Type of storage	Lagoon
Stage of lagoon (1st, 2nd, 3rd)	1st
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Finishing swine
Animal 1 average weight (lb)	135
Animal 1 inventory (# head)	8000
Manure collection (flush, scrape, PPR)	Pit recharge
Source flush or recharge water	Lagoon
Lagoon loading interval, h	24
Minimum space around unit, ft	?
Volumetric loading rate, lb/d-1000ft^3	5.7
Surface loading rate, lb VS/d-acre	2006
Obstructions within 3X height of unit?	Yes
If yes, what kind?	Trees
Height of worst obstruction, ft	75
Distance from worst obstruction, ft	150
Type of cover (crust, straw, none, etc.)	None
Are solids separated from influent?	No
Odor control	
Sludge removal cycle, yr	15
Last time sludge removed (e.g., 1999)	Never
Agitation prior to pumpout?	No
Manure removal frequency, d	As weather permits
Pump out (contractor or producer)	Producer
Type of liner	Clay
Volume, ft^3	1,623,326
Surface area, ft^2	204,386
Berm slope	3:1
Maximum side length, ft	567.5
Minimum side length, ft	370
Actual freeboard, ft	-
Inner berm height, ft	-
Outer berm height, ft	-
Liquid depth, ft	-
Sludge depth, ft	1.9
Number of inlets	1
Shape	Rectangular

Figure 3. Satellite image of surroundings. Red lines indicate soils delineations, and not a physical property boundary.

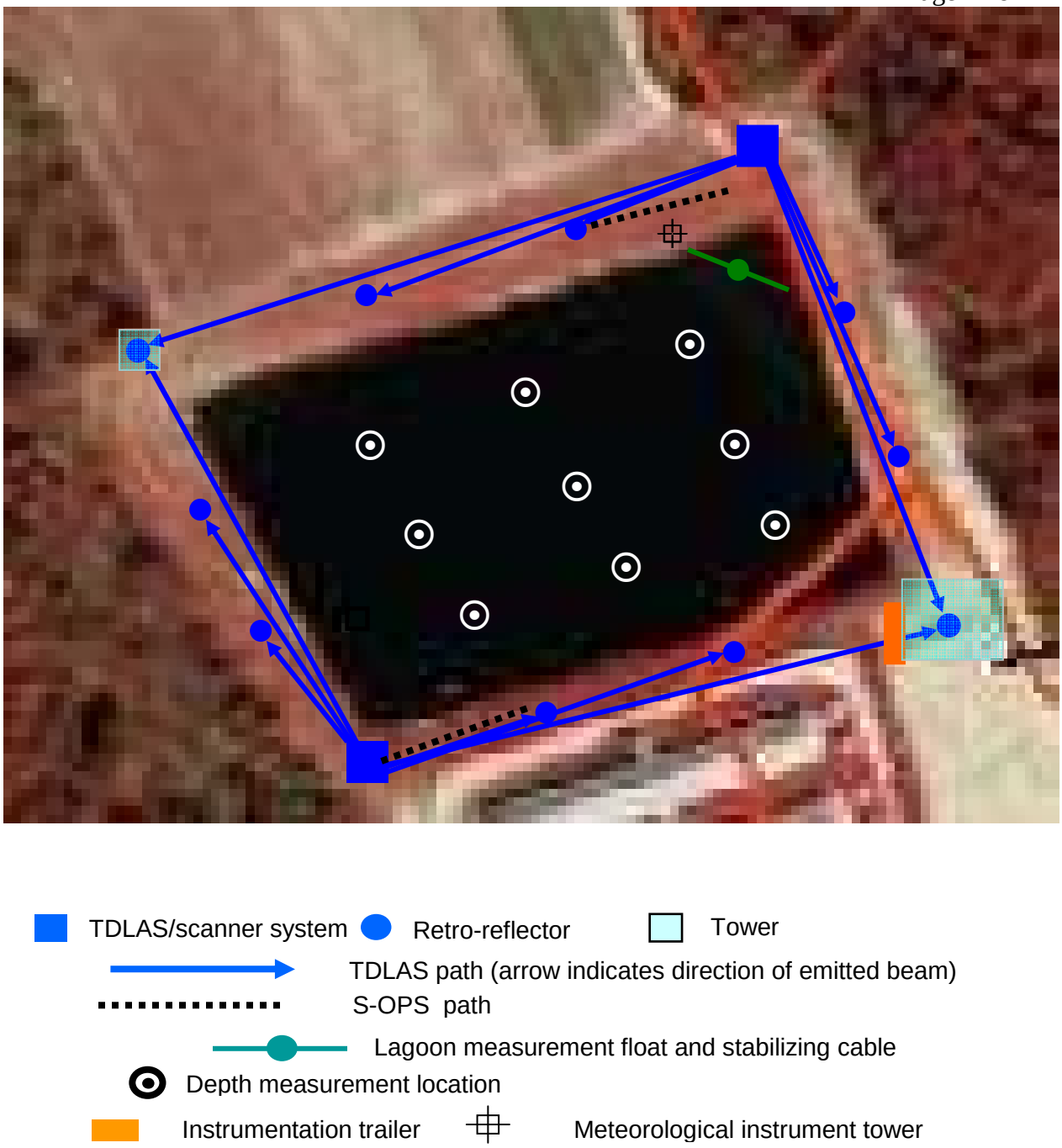

Figure 4. Dimensional plan of the lagoon.

SMP NC4A
SITE MONITORING PLAN FOR SOW FARM LAGOON IN NORTH CAROLINA

SMP NC4A
SITE MONITORING PLAN FOR SOW FARM LAGOON IN NORTH CAROLINA

The Southeastern sow facility is located in Duplin County, North Carolina. The elevation at the farm is 59 m (170 ft). The magnetic compass variation at this location is 08°W. The farm consists of three barns – one each of gestation, breeding, and farrowing – and an office (Fig. 1). The facility has a capacity of 2000 sows in three units. Construction of the farm was completed in 1994.

Logistics

Measurements will be made by one of the rotating measurement teams from Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. The nearest airport is located at Raleigh/Durham, NC. The farm is located 108 km (65 mi) SE of the Raleigh/Durham airport, with a one-way driving time of approximately 1 h.

Climate (Table 1)

The climate for the area is represented by the Goldsboro and Raleigh, NC National Weather Service weather stations. The wind climatology is from the Goldsboro station, which is approximately 32 km (20 mi) N of the farm. The precipitation, humidity, and temperature climatology is from the Raleigh station, approximately 104 km (65 mi) N of the farm. The area typically receives an average of 1080 mm (42.5 in) of precipitation (NCDC, 1981). The variation in winds over the year is illustrated in Fig. 2. The prevailing winds are from the S during spring and summer, and N during the fall and winter (Table 1). Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 2 m/s (5 mph) to 3 m/s (7 mph) (NCDC, 1998). Relative humidity (RH) ranges from 85% in the morning to 55% in the afternoon, while air temperatures range from 21°C (70°F) to 7°C (48°F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure from the barns is transferred once a week from the gestation, farrowing, and breeding barns to the lagoon by pull plug and lagoon water recharge. Waste water from all three buildings combines into one inlet (SW corner of lagoon- Fig. 1). The waste lagoon is located to the N of the barns. The clay-lined trapezoidal-shaped lagoon is 123 m (410 ft) wide and 187 m (624 ft) long, and is oriented E-W. The lagoon bank is clay, with a berm slope of 3:1. Liquid depth is approximately 2.5 m (8 ft), while the sludge depth is approximately 0.7 m (2 ft). Liquid is removed as weather permits. Sludge from the lagoon has not been removed since construction (15-yr sludge removal cycle).

Surrounding sources

There are no identifiable NH_3 or H_2S emission sources within one mile of the farm site (Fig. 3).

Biosecurity Requirements

The producer requires that all visitors to the farm meet the following requirements:

- A minimum of 48 hours of downtime from any other swine contact
- No contact with swine in a foreign country in the last 7-10 days
- No visit to any location with any live birds, or contact with other poultry or domestic birds (including parakeets, parrots, etc) within 48 hours prior to the farm visit.

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1). VOC emissions will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4) and analyzed by the INNOVA (SOP G7). Measurement data will be collected on the LAN server in the trailer (SOP D1, SOP U4).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Two fixed 15-m (51-ft) towers (SOP U5) will be located at the NW and SE corners of the lagoon (Fig. 4). The scanning TDLAS instruments will be mounted at 1 m height above the lagoon berm on the berm at the NE and SW corners. The TDLAS/scanners will be mounted at 1 m height on anchored tripods (SOP U5). Retro-reflectors at the approximate ⅓ and ⅔ distance down the lagoon sides will also be mounted on the berm at 1 m height on anchored tripods (SOP U5) on the respective berm (Fig. 3). The TDLAS laser beam is eye-safe.

Two S-OPS systems (SOP C4) will collect the gas along linear paths at 1 m abl on opposite sides of the lagoon for the measurement of the synthetic PIC of H_2S and various VOC. Each 50-m S-OPS consists of ten orifices spaced 5 m apart. Since the prevailing winds are N or S, the S-OPS will usually be positioned to the N and S of the lagoon (Fig. 4). Changes in anticipated wind direction will result in the use of the alternate E and W paths (Fig. 4).

Volatile organic compounds, including methane, methanol, ethanol and total VOCs, will be tentatively measured using an INNOVA 1412 multi-gas photoacoustic analyzer (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the basin (Fig. 4).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located on the berm 30 m S of the NE berm corner (Fig. 4). The meteorological measurement data will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2 m height and on the SE corner tower (Fig. 4) at 4 m and 16 m heights above berm level (Fig. 4) (SOP U5).

The barns 20 m (67 ft) to the S of the lagoon berm have an approximate ridge height of 6 m (19 ft) agl, resulting in a fetch ratio to the S of 10:3 to the surface of the lagoon. Fetch for winds from the E (cropland) for the wind measurements is 1:100 for the all measurement heights. Fetch to the W for the wind measurements is limited by a 23-m (75-ft) deciduous tree line. The fetch to the W for the 2-m wind measurement is 1:14. Fetch to the W for the 4-m wind measurement (influenced by the 5.5-m (18-ft) high breeding building) is 1:15. Fetch to the W for the 16-m height wind measurement (influenced by the 23-m (75-ft) high tree line at a 287-m (950-ft) distance) is 1:41. Consequently, all wind measurements should be relatively unaffected by upwind conditions. The fan exhaust from the northernmost barn is to both the E and W. The fan exhaust from the middle barn is to the W.

Configuration specifics:
The TDLAS/ scanners are located on the NE and SW corners of the lagoon berm, mounted at 1 m above berm height on anchored tripods (Fig. 4). TDLAS retro-reflectors are mounted on two 15-m (51-ft) fixed triangular towers located 16 m N of the NW berm corner and 10 m S and 17 m E of the SE berm corner (Fig. 4).

A description of the position of each measurement path, with photographs showing the views corresponding to the locations and directions indicated in Fig. 1 follows:

N side of lagoon

- 50 m length S-OPS path 1 m abl.
- S-OPS beginning at NE berm corner extending W.
- TDLAS retro-reflectors will be located 59 m and 116 m W of the TDLAS/ scanner on the NE berm corner.
- Three retro-reflectors are mounted on the tower at the NW corner with a 184-m path length. The 59-m and 116-m retro-reflectors are mounted on the berm at 1 m height using anchored tripods.

N of N berm looking SW. Lagoon is between berm and barns.

E side of lagoon

- TDLAS retro-reflectors will be located 44 m and 83 m S of the TDLAS/ scanner at the NE berm corner. The 44-m and 83-m retro-reflectors are mounted on the

berm at 1 m height using anchored tripods.
- Three retro-reflectors are mounted on the SE corner tower 135 m S of the TDLAS/ scanner on the NE berm corner.

Location of E side TDLAS beam path, looking S towards the location of the 15-m TDLAS retro-reflector tower. Lagoon berm is on right.

S side of lagoon
- 50-m long S-OPS path 1 m abl
- S-OPS beginning 62 m E of the SW berm corner extending E.
- TDLAS retro-reflectors will be located at 62 m and 126 m E from the TDLAS/scanner at the SW berm corner. The 62-m and 126-m retro-reflectors are mounted on the berm at 1 m height on anchored tripods.
- Three retro-reflectors are mounted on the tower in the SE corner of the lagoon with a path length of 210 m E of the scanner.

S berm looking from the NE berm corner.

W side of lagoon
- TDLAS retro-reflectors will be located 46 m and 90 m N from the TDLAS/scanner located at the SW berm corner. The 46-m and 90-m retro-reflectors are mounted on the berm at 1 m height using an anchored tripod.
- Three retro-reflectors are mounted on the NW corner tower, approximately 150 m N of the scanner.

Location of W side TDLAS beam path, looking N towards the TDLAS tower location. Lagoon berm is on right.

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the three sonic anemometers (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. Wind speeds at Raleigh, NC (at 7-m height) were ≤1.1 m/s 6.9% of the time between 1981 and 1990 (NCDC, 1998).

2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds at 7-m height at Raleigh, NC were ≥11.1 m/s 0.1% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

VOC and hydrogen sulfide emissions from the lagoon will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and gaseous measurements of air collected through the S-OPS (SOP C4). Restrictions on the use of the model are as follows:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid; although the surrounding area of the farm is open cropped land, the farm has additional roughness elements (a building to the S, and a tree line to the W of the lagoon). The aerodynamic roughness of the 19-ft high barns contributes to non-homogeneous surface roughness. The barns and other buildings are 20 m (67 ft) to the S of the lagoon berm (Fig. 4), and the prevailing winds are W, SW, or N (Table 1). This will reduce the impact of the buildings on airflow around the lagoons.
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). The breeding barn exhaust is 20 m (65 ft) from the S berm TDLAS measurement plane, and 27 m (90 ft) from the S S-OPS sampling path that is 10 m S of the berm, and therefore is not expected to strongly influence emissions into the lagoon.
3) The concentration (PIC) measurements of upwind and downwind air sampled by the S-OPS must be synoptic. This can be assumed since concentrations sampled from the S-OPS sampled air will be averaged over ½ hr intervals. There will be loss of emission measurements when the winds do not provide an upwind and downwind pair of PIC measurements.
4) Emission measurements will be invalidated when the friction velocity is <0.15 m/s. This corresponds approximately with wind speeds of 1.1 m/s. For wind measurements made at Raleigh (at the 7-m height), this occurred only 6.9% of the time between 1981 and 1990 (NCDC, 1998).

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the E shore of the NE corner of the lagoon (SOP U5). The lagoon characterization measurement data will be collected by the data logger (SOP W6). Lagoon sludge depth measurements (SOP L5) will be made at nine locations in the lagoon (approximate locations indicated in Fig. 4) at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or when winds are too high to keep the boat stationary during measurements.

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All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be

computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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SOP W3. 2006. Wetness Grid for Measuring Precipitation. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.
SOP W5. 2006. Barometric Pressure Sensor. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.
SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

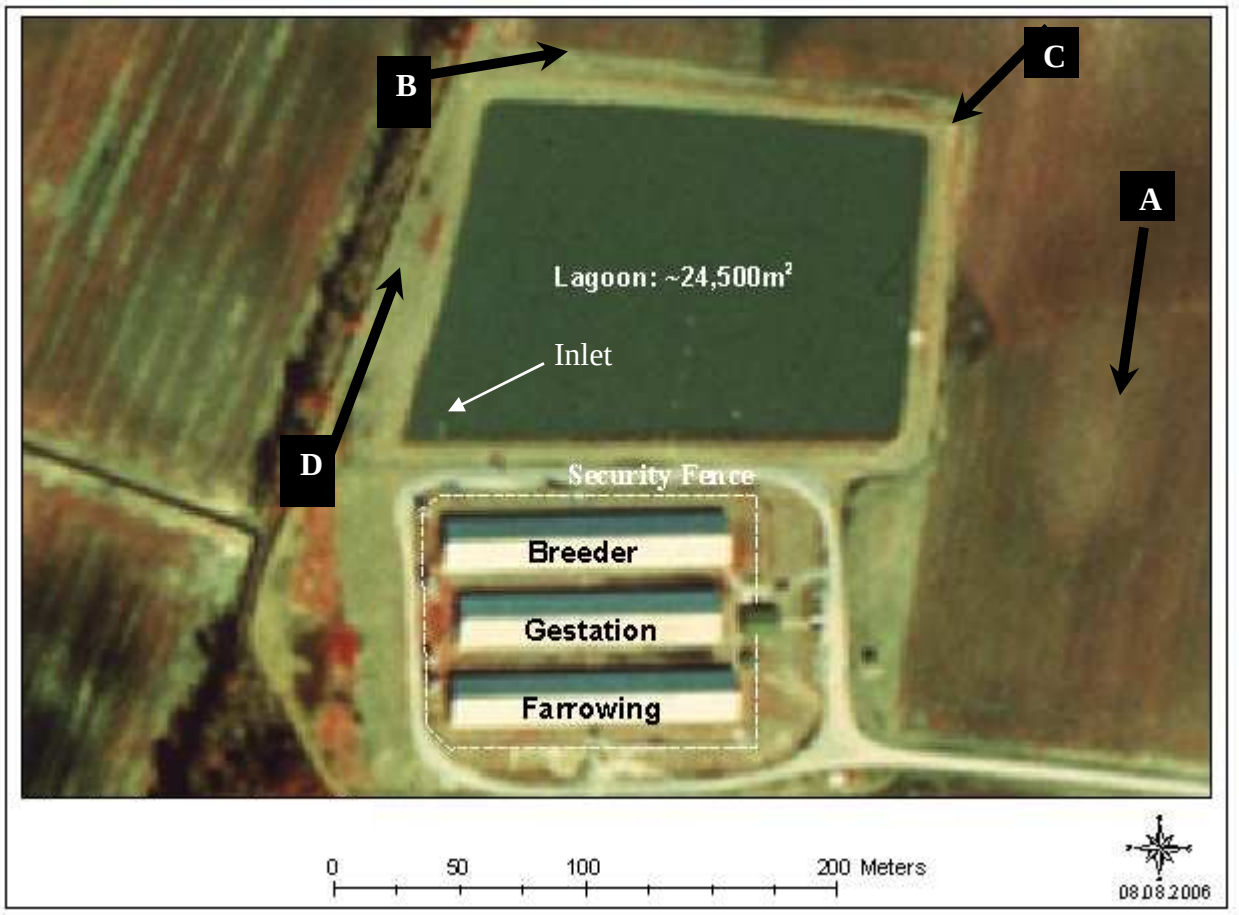

Figure 1. General layout of the farm and configuration of the lagoon. The location and direction of view of each photograph described in the measurement plan is indicated by letters (A: N view; B: E view; C: S view; D: W view).

Table 1. Monthly climate description for the NC sow site (Goldsboro/Raleigh, NC).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	10	10	11	9	10	9	11	10	8	7	8	9
Wind speed (mph) [2]	6	7	7	7	6	5	5	5	5	5	5	6
Wind direction[2]	N	N	N	SW	S	S	S	S	NNE	N	N	W
Morning RH (%)[1]	79	76	81	81	87	88	91	93	93	90	85	81
Afternoon RH (%)[1]	56	50	50	45	55	58	59	60	60	54	52	55
Maximum temp (°F) [1]	51.0	53.2	61.0	72.2	79.7	85.6	87.7	86.8	81.5	72.4	62.1	51.9
Minimum temp (°F) [1]	30.0	31.1	37.4	46.7	55.4	63.1	67.2	66.2	59.7	48.0	37.8	30.5

[1] NCDC (1981)
[2] NCDC (1998)

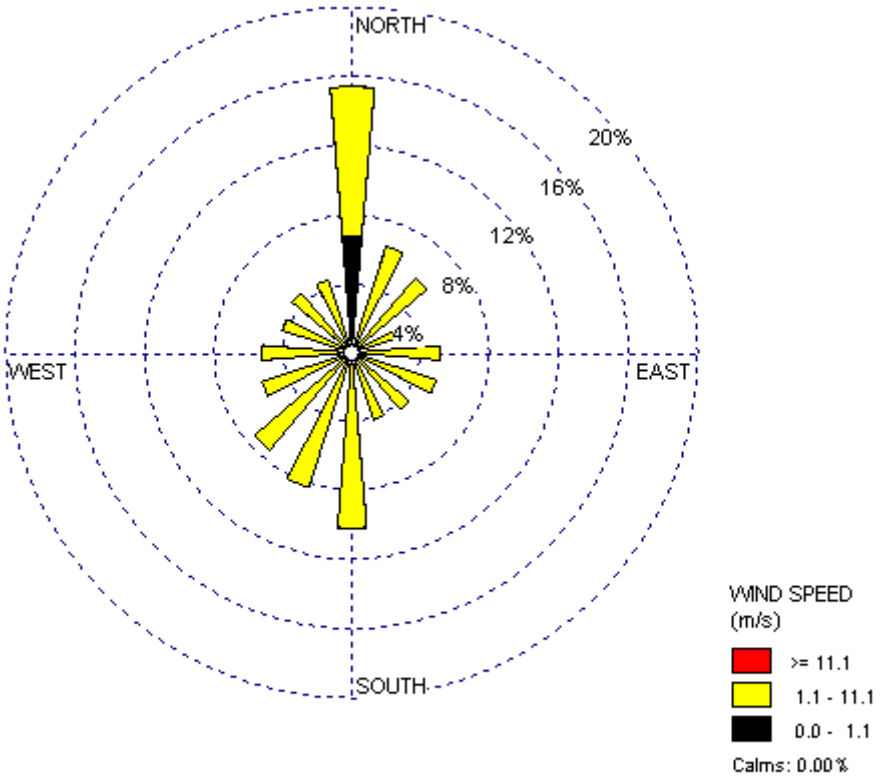

Figure 2. Raleigh Windrose, 1981-1990. Note that winds of <1.1 m/s are assigned to a nominal N, direction, as they are below the threshold of the NWS anemometers.

Table 2. Characteristics of the lagoon at the NC sow farm.

Descriptive parameters.	Unit 1
Livestock type	Sow (farrow-wean)
Year of facility construction	1994
Separation distance from barn fans, ft	100
Type of storage (basin, lagoon or tank)	Lagoon
Stage of lagoon (1st, 2nd, 3rd)	1st
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Sows (farrow-wean)
Animal 1 average weight (lb)	433
Animal 1 inventory (# head)	2000
Manure collection (flush, scrape, PPR)	Pit recharge
Source flush or recharge water (if any)	Lagoon
Lagoon loading interval, hr	1X per week
Minimum space around unit, ft	?
Volumetric loading rate, lb VS/d-1000ft^3	1.82
Surface loading rate, lb VS/acre-d	692
Obstructions within 3X height of unit?	Yes
If yes, what kind? (e.g. trees, barns)	Trees
Height of worst obstruction, ft	75
Distance from worst obstruction, ft	150
Type of cover (crust, straw, none, etc.)	None
Are solids separated from influent?	No
Odor control: (digester, additives)	None
Sludge removal cycle, yr	15
Last time sludge removed (e.g., 1999)	Never
Agitation prior to pumpout?	No
Manure removal frequency, d	As weather permits
Pump out (contractor or producer)	Producer
Type of liner (clay, plastic, etc.)	Clay
Volume, ft^3	2007450
Surface area, ft^2	249672
Berm slope (e.g. 3:1, 3.5:1, etc.)	3:1
Maximum side length, ft	624
Minimum side length, ft	410
Actual freeboard, ft	-
Inner berm height, ft	-
Outer berm height, ft	-
Liquid depth, ft	10 total
Sludge depth, ft	2.33
Number of inlets (show on drawings)	?
Shape (rectangular, oval, etc.)	Rectangular

Figure 3. Satellite image of the farm's surroundings.

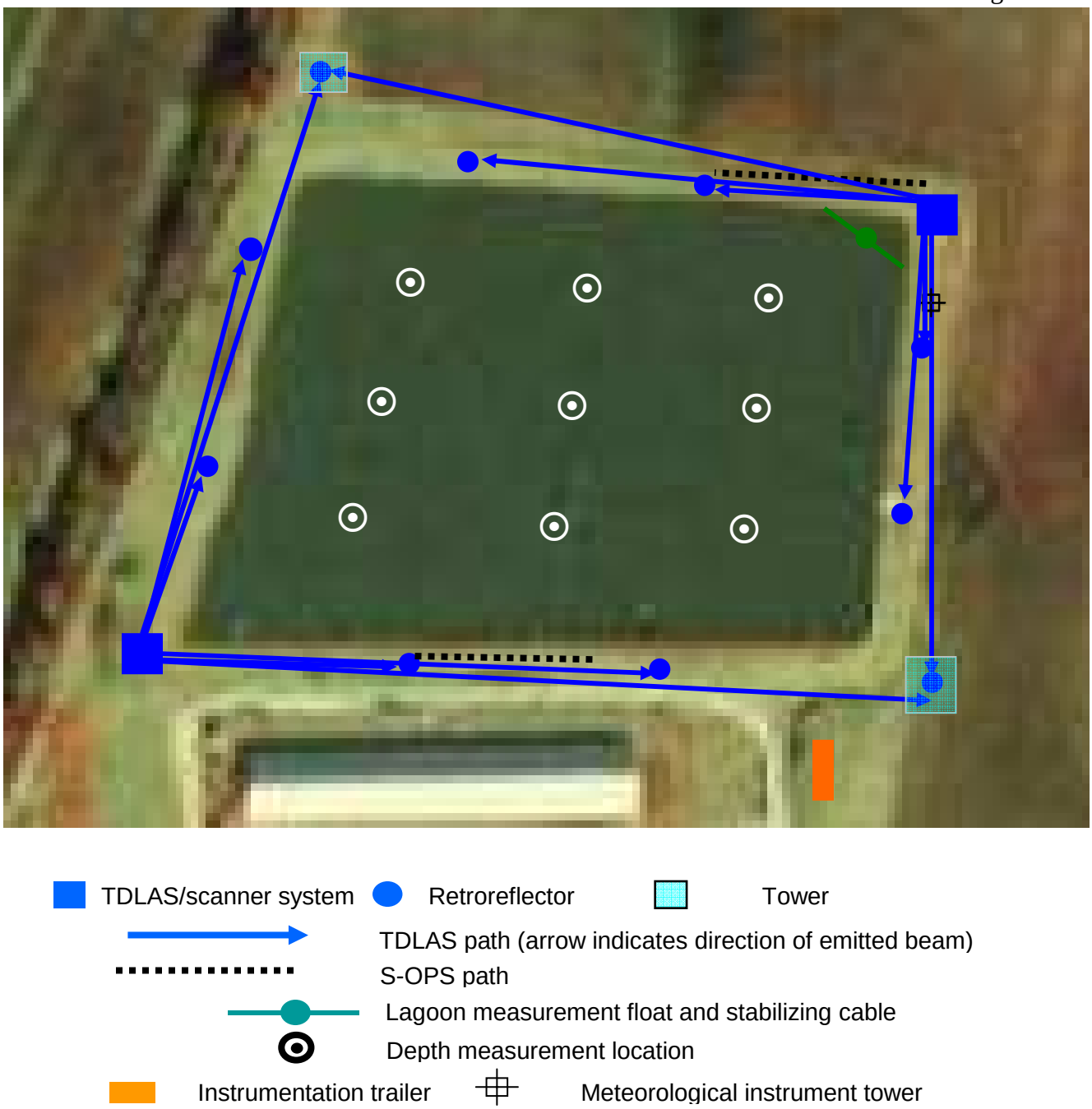

Figure 4. Measurement plan for the lagoon. The exact location of S-OPS depends on wind direction; both seasonally-dependent locations are indicated.

SMP OK3A
SITE MONITORING PLAN FOR WEST FINISHER LAGOON SITE

SMP OK3A
SITE MONITORING PLAN FOR WEST FINISHER LAGOON SITE

The Western finisher facility is located near Guymon, Oklahoma. The elevation at the farm is 927 m (3051 ft), the magnetic compass variation at this location is 09°E. The farm consists of three barns (Fig. 1). The facility has a maximum capacity of 3,024 finishing pigs. Construction was completed in 1997.

Logistics

Measurements will be made by one of the rotating measurement teams from Purdue Applied Meteorology Laboratory in West Lafayette, IN. Airports are located in both Amarillo, TX and Liberal, KS. The farm is located 200 km (120 mi) N of Amarillo, TX and 67 km (40 mi.) SE of Liberal, KS. Driving times from the two airports are approximately 2 h and 1 h, respectively.

Climate (Table 1)

The climate for the area is represented by the Amarillo, TX, National Weather Service weather station, which is approximately 188 km (117 mi) S of the farm. The area typically receives an average of 515 mm (20.28 inches) of precipitation (NCDC, 1981). The prevailing winds are from the S to SW during summer, fall and winter and N in spring (NCDC, 1998). Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 6 m/s (13 mph) to 7 m/s (16 mph) (NCDC, 1998). Average relative humidity (RH) ranges from 72% in the morning to 45% in the afternoon, while average air temperatures range from 22°C (71°F) to 7°C (44°F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure from the barns is transferred three times a week to the lagoon by a pull plug system with lagoon water recharge. Waste water from all three units combines into one inlet. The waste lagoon is rectangular and is located to the W of the barns (separated by a drainage swale). The clay-lined lagoon is 59 m (195 ft) wide and 210 m (689 ft) long, and is oriented N-S. The lagoon bank is clay, with a berm slope of 3.8:1. Liquid depth is approximately 6 m (20 ft) with an inner berm-to-water distance of 0.6 m to 1.2 m (2 to 4 ft). Liquid is removed approximately every six months. Sludge from the lagoon has not been removed since construction (20-yr sludge removal cycle).

Surrounding sources

The nearest sources of identifiable NH_3 or H_2S emission are four different farrow-to-finish swine farms; 1 mi to the E, ½ mi to the N, S, SE and SW. A cattle stockyard is 1 ½ mi S of the site. There are more than 20 farms within a 5-mi radius of the site.

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1). VOC emissions will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4) and analyzed by the INNOVA (SOP G7). Measurement data will be collected on the LAN server in the trailer (SOP D1, SOP U4).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Two 17-m (56-ft) towers will be located at the NE and SW corners of the lagoon, while maintaining an approximately 4-m right-of-way from the county roads. The scanning TDLAS instruments will be mounted at 1-m height above the lagoon berm at the NW and SE corners. Since the berm is less than 1 m high all around the lagoon, the TDLAS/scanners will be mounted at 1-m height on anchored tripods. Retro-reflectors at the 1/3 and 2/3 distance down the lagoon sides will also be mounted at 1-m height on anchored tripods on the respective berm (Fig. 2). The TDLAS laser beam is eye-safe, and presents no hazard to farm workers.

Two S-OPS systems (SOP C4) will be used to collect the gas for the measurement of the synthetic PIC of H_2S and various VOC near lagoon berm height on two sides of the lagoon. Since the prevailing winds are N, SSW, S, and SW, a S-OPS will be positioned to the N of the N berm of the lagoon and another S of the S berm. The S-OPS along the S side of the lagoon will primarily act as the upwind station, while the S-OPS on the N side of the lagoon will primarily act as the downwind measurement path (Fig. 1). Each 50 m S-OPS will sample air at 1-m height and have 10 orifices spaced at 5 m intervals.

Volatile organic compounds, including methane, methanol, ethanol, and total VOCs, will be measured, using the INNOVA Model 1412 (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the basin (Fig. 2).

Meteorological measurements (barometric pressure (SOP W5), air temperature and relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3)) will be located 10 m S of the NW berm corner (Fig. 2). The 3D sonic anemometers will be located on the meteorological tower at 2-m height and on the SW corner tower (Fig. 2) at 4-m and 16-m heights above berm level (Fig. 2). All fans exhaust on the E side of the barns and therefore will not influence the lagoon PIC measurements, except under easterly winds (which are not the prevailing wind at any time of the year).

Setup and configuration of the trailer and site power, towers, and instrumentation are discussed in SOPs U4, U5, and W6, respectively.

The barns 10 m (33 ft) to the E of the lagoon berm have an approximate ridge height of 19 ft agl, resulting in a fetch ratio of 6:10 to the east side of the lagoon. A region of wind conditions from E to SE will be excluded from emissions calculation due to this poor fetch (Fig. 1). The impact of this exclusion region is expected to be small, since the prevailing winds do not come from the direction of the buildings at any time of the year. Fetch in all other directions is better than 1:100, with the upwind conditions being primarily center-pivot irrigation of crops (Fig. 1). A description of the position of each measurement path, including a photograph view corresponding to the paths indicated by black arrows and letters in Fig. 1 follows:

N side of lagoon

- 50 m length S-OPS path parallel to and 5 m N of berm. County road is 5 m N and parallel to path.
- S-OPS begins at the NW corner of the lagoon and extends E with orifices mounted at 1 m abl.
- TDLAS paths of 21 m, 42 m, and 3 at 63 m length, approx. parallel to the berm. The 21-m and 42-m retro-reflectors are mounted on the berm at 1 m abl.
- TDLAS and scanner located 1 m N and 1 m W of NW corner of berm. The TDLAS and scanner are mounted at 1 m abl on an anchored tripod.
- TDLAS tower located 5 m N and 10 m E of NE berm corner. Distance to road is approximately 5 m to N.

Location of N side S-OPS path, looking W towards the location of the 15-m TDLAS retro-reflector tower.

E side of lagoon (Photo B)

- TDLAS paths of 69, 138, and approx.215.5 m length, approx. parallel to the E berm of the lagoon. The 69-m and 138-m retro-reflectors are mounted on the berm, at 1 m abl.
- TDLAS paths 1 to 3 m from berm.
- TDLAS scanner located 1 m S and 55 m E from SE berm corner.
- TDLAS tower located 5 m N and 10 m E of NE berm corner.

Location of E side TDLAS beam path, looking N towards the location of the 15-m TDLAS retro-reflector tower. Lagoon is on left.

S side of lagoon

- 50 m S-OPS path at 1 m abl starting at the SE corner of the lagoon extending W.

- TDLAS paths of 20 m, 40 m, and 3 at 68 m length. The 20-m and 40-m retro-reflectors are mounted on the berm, at 1 m abl.
- TDLAS tower located 8 m S and 8 m W of SW berm corner.

Location of SW side S-OPS and TDLAS beam path, looking E towards the TDLAS/scanner. Lagoon berm is on left.

W side of lagoon

- TDLAS paths of 70, 144, and approx. 220 m length, parallel to the W berm of the lagoon. The 70-m and 144-m retro-reflectors are mounted on the berm, at 1 m abl.
- TDLAS paths approx. on the berm and 7 m from a farm access road.
- TDLAS scanner located 1 m W and 1 m N of NW berm corner.
- TDLAS tower located 8 m S and 8 m W of SW berm corner

Location of W side TDLAS beam path, looking S towards the TDLAS tower location. Lagoon berm is on left.

VOC and hydrogen sulfide emissions from the lagoon are calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1). Restrictions on the use of the model are:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid; although the surrounding area of the farm is open cropped land, the farm has additional roughness elements. The aerodynamic roughness of the barns (19 ft high) contributes to non-homogeneous surface roughness. However, the barns and other buildings are 33 ft (10 m) to the E of the lagoon berm (Fig. 2), and the prevailing winds are S, SW, or N (Table 1). This will reduce the impact of the buildings on airflow around the lagoons. However, as discussed above, the proximity of the buildings does result in an exclusion region for winds from the E to SE (Fig. 1).
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. Inhomogeneous flow is expected for winds coming from the direction of the exclusion region (Fig. 1), because of the presence of the barns. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). The fan exhaust from the three barns is directed to the E, and therefore is not expected to influence the determination of lagoon emissions.
3) The S-OPS PIC measurements for upwind and downwind components must be synoptic. There will be loss of emission measurements when the winds do not provide an upwind and downwind pair of PIC measurements. An averaging time of ½ hr for the S-OPS gas measurements will assure near-synoptic measurement pairs.

4) Emission measurements will be invalidated when the friction velocity is less than 0.15 m/s. This corresponds approximately with winds of 1.1 m/s; at the 7-m height for wind measurements made at Amarillo, this occurred only 1.5% of the time between 1981 and 1990 (NCDC, 1998).

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2). Restrictions on the use of this model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are less than 1 m/s. For Amarillo, this occurred 1.5% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m abl) are greater than 11 m/s. The wind speeds recorded (at a 7-m height) at Amarillo, TX were 11.1 m/s or more 3.3% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS PIC measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the W shore of the NW corner of the lagoon. Lagoon sludge depth sampling (SOP L5) will be made at eight (8) locations in the lagoon at the beginning or end of each measurement period; the approximate locations of these sampling points are indicated in Fig. 2. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or winds are too high to keep the boat stationary during measurements.

Communications

Telemetry of TDLAS/scanners, 3D anemometers, and meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP D1). All measurements telemetered to the trailer will be sent to Purdue nightly via DSL cellular service.

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source (SOP S7) from the southern barn or the meter on the power pole south of the barns and directly buried underground to the trailer, which will be located approximately 10 m S of the SE corner of the southernmost barn. The line routed around the lagoon will be buried directly in the ground from the producer-supplied source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weatherproof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the

ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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SOP C4. 2006. Standard Operating Procedure for the Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Ag Air Quality Lab.

SOP D1. 2006. Management of Open-source, Weather, and Lagoon-characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.

SOP E3. 2006. The Measurement of Solar Radiation with the Licor Model 200SL Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab.

SOP G5 2006. Standard Operating Procedure for Measurement of Hydrogen Sulfide (H2S) with the Thermo Electron Corporation Model 450C Pulsed- Florescence Analyzer Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

SOP G7. 2006. Operation of the INNOVA 1412 Photoacoustic Multi-gas Analyzer. Standard Operating Procedure G7. Purdue Ag Air Quality Lab.

SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Applied Meteorology Lab.

SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.

SOP L3. 2006. Measurement of Lagoon Redox State with the Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Applied Meteorology Lab.

SOP L5. 2006. Measurement of Lagoon Sludge Depth with Markham Model 10 Portable Sludge Gun. Standard Operating Procedure L5. Purdue Applied Meteorology Lab.

SOP O1. 2006. Emissions Estimation Using the Thunder Beach Scientific Windtrax Backward Lagrangian Stochastic Model. Standard Operating Procedure O1. Purdue Applied Meteorology Lab.

SOP O2. 2006. Emissions Estimation Using the Arkadis Radial Plume Mapping Model. Standard Operating Procedure O2. Purdue Applied Meteorology Lab.

SOP U4. 2006. Open-source Instrument Trailer. Standard Operating Procedure U4. Purdue Applied Meteorology Lab.

SOP U5. 2006. The Installation of Open-source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.

SOP S7. 2006. Producer Collaborations at Open-source Monitoring Sites. Standard Operating Procedure S7. Purdue Applied Meteorology Lab.

SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Vaisala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.

SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.

SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.

SOP W5. 2006. The Measurement of Barometric Pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.

SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

Table 1. Monthly climate description (from Amarillo, Texas).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	4	4	4	5	8	8	8	8	6	5	3	4
Wind speed (mph)[2]	13.1	14.2	15.6	15.5	14.7	14.4	12.5	12.2	12.9	13.0	13.1	13.0
Wind direction[2]	SW	SW	SW	N	N	N	SSW	SSW	SSW	S	S	S
Morning RH (%)[1]	70	71	66	67	73	76	73	76	79	70	73	68
Afternoon RH (%)[1]	51	49	41	38	42	44	42	45	49	41	48	47
Maximum temp (F)[1]	49.4	53.0	60.0	70.9	79.2	88.0	91.4	90.4	82.9	72.9	60.0	51.5
Minimum temp (F)[1]	22.5	26.4	31.2	42.1	51.9	61.2	65.9	64.7	56.7	46.1	32.5	25.5

[1] NCDC (1981)
[2] NCDC (1998)

Table 2. Characteristics of the lagoon at the Oklahoma finisher site.

Descriptive parameters.	Unit 1
Livestock type	Finishing
Type of storage (basin, lagoon or tank)	Lagoon
Number of units	1
Year of facility construction	1997
Separation distance from barn fans, ft	50
Stage of lagoon (1st, 2nd, 3rd)	Single
Manure contributors to unit	Finishing pigs
Animal 1 type (sows, cows, etc.)	Finishing pigs
Animal 1 average weight (lb)	170
Animal 1 inventory (# head)	Approx 3,000/site, 1,000/barn
Manure collection (flush, scrape, PPR)	PPR
Source flush or recharge water (if any)	Fresh recharge
Lagoon loading interval, h	3x/week
Minimum space around unit, ft	50
Volumetric loading rate, lb VS/d-ft^3	
Surface loading rate, lb VS/d-ft^2	
Obstructions within 3X height of unit?	Yes
If yes, what kind?	Barn
Height of worst obstruction, ft	19
Distance from worst obstruction, ft	30
Type of cover (crust, straw, none, etc.)	None
Are solids separated from influent?	No
Odor control	Micro-Aid
Sludge removal cycle, years	20 (Est.)
Last time sludge removed (e.g., 1999)	Not yet
Agitation prior to pumpout?	No
Manure removal frequency, days	Every 6 mos.
Pump out (contractor or producer)	Producer
Type of liner	Clay
Volume, ft^3	1,011,463
Surface area, ft^2	120,600
Berm slope	3.8 :1
Maximum side length, ft	683’
Minimum side length, ft	193’
Actual freeboard, ft	2’
Inner berm height, ft	4’
Outer berm height, ft	5’
Liquid depth, ft	20
Sludge depth, ft	2 (Est.)
Number of inlets	1
Shape	Rectangle

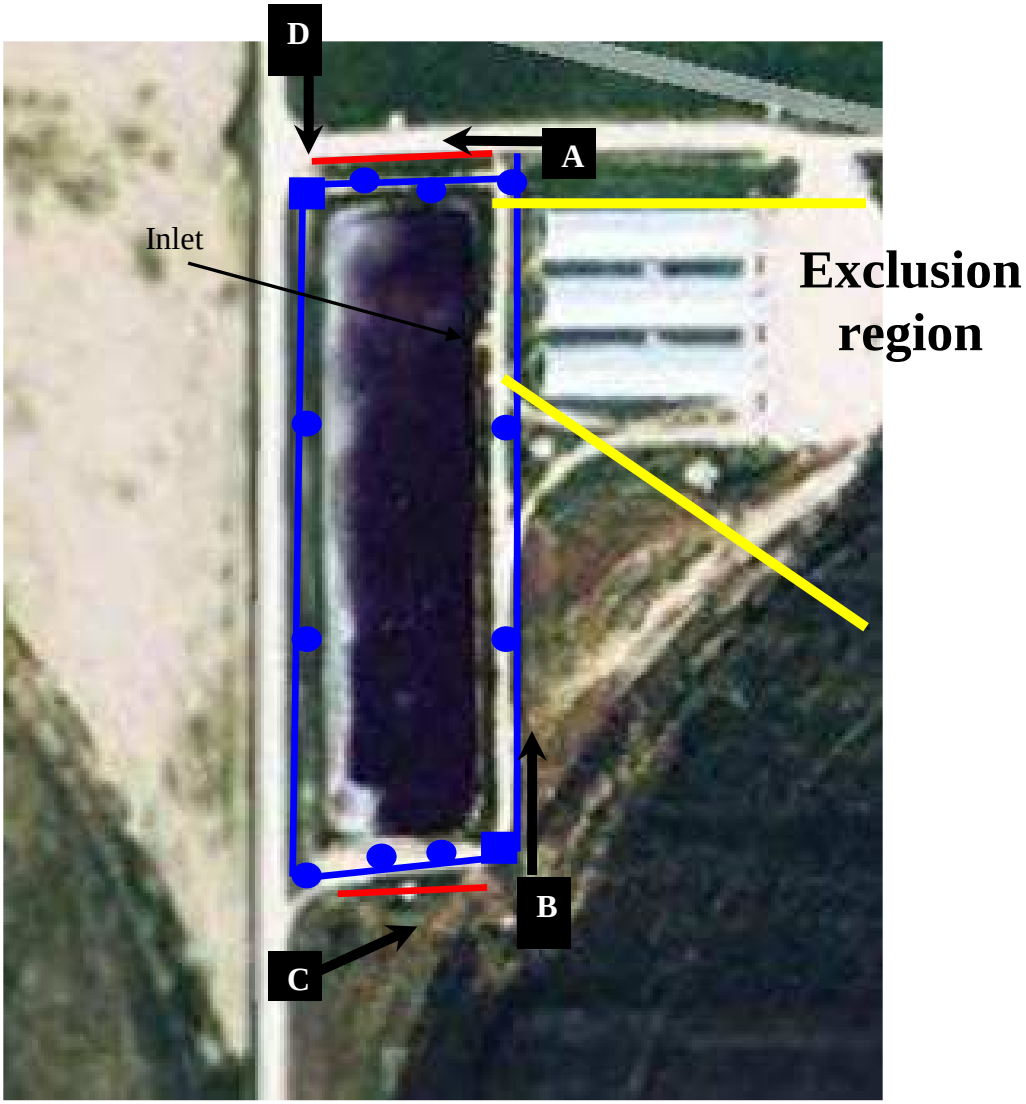

Figure 1. Plan layout of lagoon.

The S-OPS paths (red lines), TDLAS/ scanner (blue squares) instruments and retro-reflector locations (blue circles) are indicated with the scan beam lines/ planes indicated by letter. Blue lines indicate the planes of the TDLAS scanner and retro-reflector pairs. A wind direction exclusion region for emissions calculations (due to flow disruption caused by the barns) is indicated in yellow. Black boxes A,B,C, and D, and black arrows correspond to the locations and lines of sight for the N, E, SE, and W lagoon side photos above.

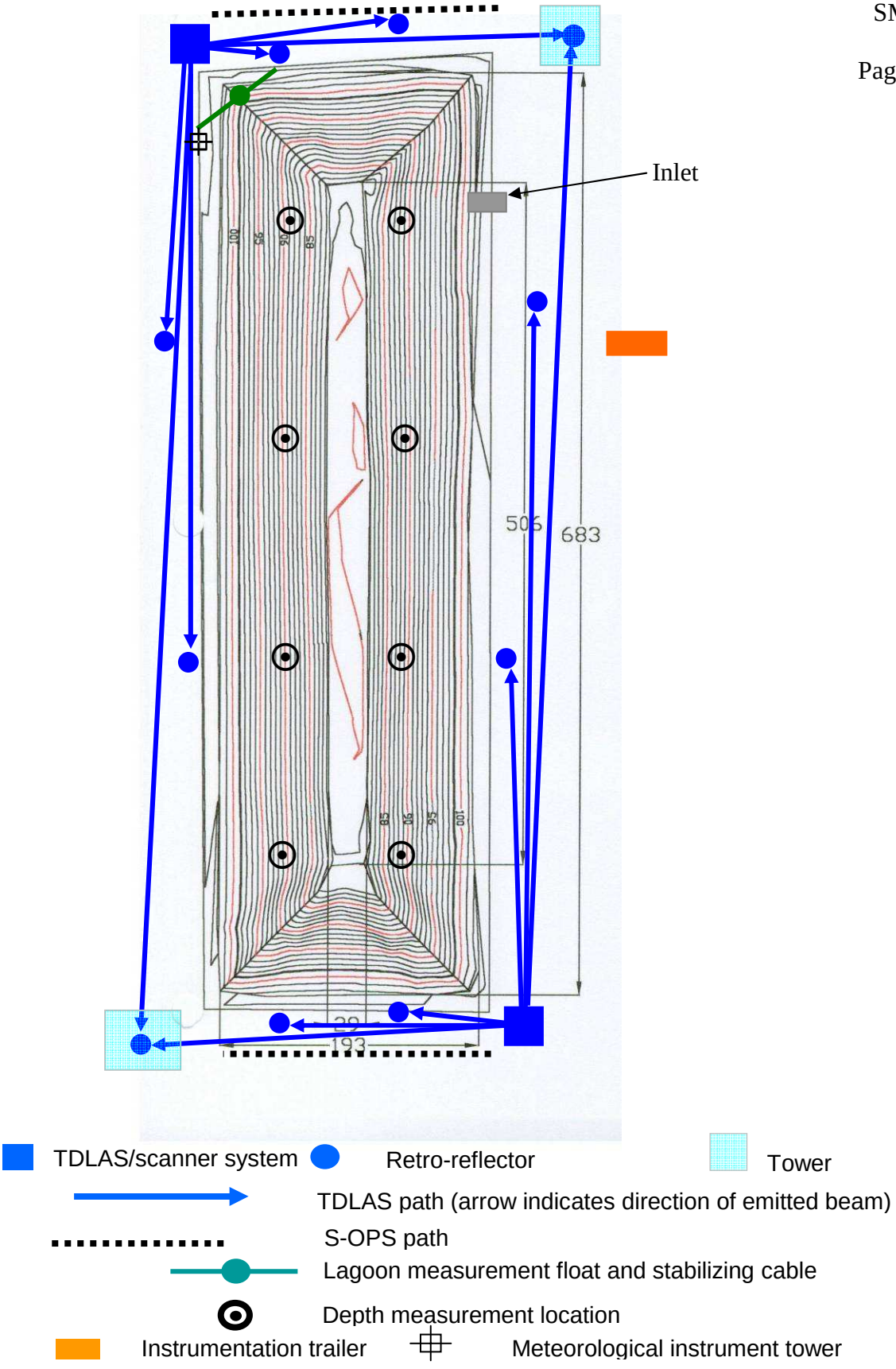

Figure 2. Dimensional plan of the lagoon.

Figure 3. Satellite image of the farm's surroundings.
Farm location indicated by yellow circle

SMP OK4A
SITE MONITORING PLAN FOR WEST SOW SITE
(LAGOON COMPONENT)

SMP OK4A
SITE MONITORING PLAN FOR WEST SOW SITE
(LAGOON COMPONENT)

The Western sow facility is located near Hooker, Oklahoma. The elevation at the farm is 905 m (2968 ft), with a magnetic compass variation at this location is 09°E. The sow farm consists of three barns and one office (Fig. 1). The facility has a capacity of 1225 breeding and gestation sows in each of two breeding and gestation units, and 384 farrowing sows in one farrowing unit. Construction of the sow farm was completed in 1994.

Logistics

Measurements will be made by one of the rotating measurement teams from Purdue Applied Meteorology laboratory in West Lafayette, IN. Airports are located in both Amarillo, TX and Liberal, KS. The farm is located 210 km (125 mi) N of Amarillo, TX and 33 km (20 mi.) SE of Liberal, KS. Driving times from the two airports are approximately 2 hr, and 40 min, respectively.

Climate (Table 1)

The climate for the area is represented by the Amarillo, TX, National Weather Service weather station, which is approximately 188 km (117 mi) S of the farm. The area typically receives an average of 515 mm (20.28 inches) of precipitation (NCDC, 1981). The prevailing winds are from the S to SW during summer, fall and winter and N in spring (NCDC, 1998). Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 5.6 m/s (12.5 mph) to 7 m/s (15.6 mph) (NCDC, 1998). Relative humidity (RH) ranges from 72% in the morning to 45% in the afternoon, while air temperatures range from 22°C (71°F) to 7°C (44°F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

Manure from the barns is transferred weekly from the two gestation units and every 2.5 weeks from the farrowing unit to the lagoon by pull plug and lagoon water recharge. Waste water from the two gestation units combines into one inlet (the southerly inlet in Fig. 2), while wastewater from the farrowing unit enters the lagoon from the northerly inlet (Fig. 2). The rectangular waste lagoon is located to the E and separated by a drainage swale from the barns. The clay-lined lagoon is 119 m (390 ft) wide and 193 m (634 ft) long, and is oriented N-S. The lagoon bank is rocky with a berm slope of 4:1. Liquid depth is approximately 5.5 m (18 ft), with an inner berm-to-water distance of 1.2 to 3 m (4 to 10 ft). Sludge from the lagoon has not been removed since construction (20-yr sludge removal cycle).

Lagoon liquid analysis is contracted by the producer every year for all nitrogen components. Lagoon liquid is applied through center-pivot irrigation when liquid levels reach maximum lagoon capacity (minimum freeboard). Additional liquid analyses for all nitrogen compounds occur at the time of field applications (0-2 times annually based on rainfall).

Surrounding sources

There is one identifiable NH_3 or H_2S emission source (a farrow-to-finish swine farm), which is 2 km (1.2 mi) N of the measurement location, one identifiable NH_3 or H_2S emission source (another farrow-to-finish swine farm) 3 km (2 mi) E of the measurement location, and two identifiable NH_3 or H_2S emission sources (one farrow-to-finish and one sow swine farm) 4 km (2.5 mi) SW of the measurement location (Fig. 3).

Monitoring Plan

The NH_3 emissions from the basin will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the basin during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, and the backward Lagrangian Stochastic model (SOP O1).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Two 15-m (51-ft) towers will be located at the NW and SE corners of the lagoon, while maintaining an approximately 4-m right-of-way from the county roads. The scanning TDLAS instruments will be mounted at 1-m height above the lagoon berm at the NE and SW corners. The NE corner TDLAS/ scanner will be mounted on an anchored tripod at 2-m height as a result of the 1 m N berm height. The retro-reflectors on the NW corner tower will be at 2-m, 7-m, and 15-m heights. Retro-reflectors at the approximate 1/3 and 2/3 distance down the lagoon sides will be mounted on anchored tripods on the respective berms (Fig. 2). The retro-reflectors on the SW corner tower will be at 2-m, 7-m and 15-m heights. The laser beam is eye-safe, so these heights will not create a hazard.

Two S-OPS air collection systems will be used to sample the air from which measurements of VOC and H_2S near lagoon berm height on two sides of the lagoon. S-OPS will be mounted at 1 m height parallel to the N and S sides of the lagoon. The S-OPS along the S side of the lagoon will primarily act as the upwind station, while the S-OPS on the N side of the lagoon will primarily act as the downwind measurement path (Fig. 2).

Volatile organic compounds, including methane, methanol, ethanol, and total VOCs, will be measured using the INNOVA Model 1412 (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 2).

Hydrogen sulfide will be measured using pulsed-florescence (SOP G5) form air sampled through the S-OPS paths upwind and downwind of the lagoon (Fig. 2).

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature and relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3) will be located 5 m W from the NE berm corner, on the berm (Fig. 2). The 3D sonic anemometers

will be located on the meteorological tower (SOP U5) at 2-m height and the NE corner tower (Fig. 2) at 4-m and 16-m heights above berm level (Fig. 2).

110 VAC power for equipment is provided by the farm (SOP S7) from a central power distribution point, which will be installed at the trailer location, approximately 25 m (83 ft) from the NW corner of the lagoon berm. Setup and configuration of the trailer and site power, towers, and instrumentation are discussed in SOPs U4, U5, and W6, respectively.

The barns 53 m (173 ft) to the W of and 1.2 m (4 ft) above the lagoon berm have a ridge height of 5.8 m (19 ft) agl. Therefore, the nearest building obstruction is 7 m (23 ft) above the berm, resulting in a fetch ratio to the W of 8:100. Fetch in all other directions is better than 1:100 (Fig. 1). A description of the position of each measurement path, including a photograph view corresponding to the paths indicated by black arrows and letters in Fig. 1 follows:

N side of lagoon

- 50 m length S-OPS path at 1 m abl.
- S-OPS begins at NE berm corner extending W along the berm.
- TDLAS paths of 44 m, 80 m, and 3 at 125 m length, approx. parallel to and 10 m N of berm. The 44-m and 88-m retro-reflectors are mounted on the berm at 1 m height above berm.
- TDLAS and scanner located 10 m N and 10 m W of NW corner of berm. The TDLAS and scanner are mounted at 1 m height on a anchored tripod.
- TDLAS 15 m tower located 10 m N of NE berm corner. Distance to road is 15 m to E

Location of N side TDLAS beam path, looking E towards the location of the TDLAS/scanner. Lagoon berm is on right.

E side of lagoon

- TDLAS paths of 66, 132, and 209 m length, approx. parallel to the E berm of the lagoon. The 66- and 132-m retro-reflectors are mounted on the berm at 1 m height above berm.
- TDLAS paths 5 m from berm and 10 m from county road.
- TDLAS scanner located due E of NE berm corner.
- TDLAS tower located 5 m E and 5 m N of NW berm corner.

Location of E side TDLAS beam path, looking S towards the location of the 15-m TDLAS retro-reflector tower. Lagoon berm is on right.

S side of lagoon

- 50 m length S-OPS path 1 m abl.

- S-OPS begins at SW berm corner and extends to the E along the berm.
- TDLAS paths at 54 m, 82 m, and 3 at approx. 131 m lengths. The 54-m and 82-m retro-reflectors are mounted on the berm at 1 m height above berm.

Location of S side UV-DOAS and TDLAS beam paths, looking W towards the location of the TDLAS/scanner and the UV-DOAS receiver. Lagoon berm is on right side of photo.

W side of lagoon

- TDLAS paths of 66, 132, and approx 210 m lengths parallel to the W berm of the lagoon. The 66-m and 132-m retro-reflectors are mounted on the berm at 1 m height above berm.
- TDLAS paths 5 m from berm and 10 m from county road.
- TDLAS scanner located due W of SW corner of lagoon.
- TDLAS tower located 5 m W and 5 m N of the NW berm corner.

Location of W side TDLAS beam path, looking S towards the TDLAS/scanner system. Lagoon berm is on left.

VOC and hydrogen sulfide emissions from the lagoon will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1). Restrictions on the use of the model are as follows:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid; although the surrounding area of the farm is open cropped land, the farm has additional roughness elements. The aerodynamic roughness of the barns is 5.8 m (19 ft) high, and other miscellaneous buildings contribute to non-homogeneous surface roughness. However, the barns and other buildings are more than 50 m (164 ft) to the W of the lagoon (Fig. 2) and the prevailing winds are S, SW, or N (Table 1). This will reduce the impact of the buildings on airflow around the lagoons.
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006).
3) The S-OPS PIC sampling for measurements of upwind and downwind components must be synoptic. This is approximately true when averaged over ½ hr periods. There will be

loss of emission measurements when the winds do not provide an upwind and downwind pair of PIC measurements.

4) Emission measurements will be invalidated when the friction velocity is less than 0.15 m/s. This corresponds approximately with winds of 1.1 m/s at the 7 m height for wind measurements made at Amarillo. This occurred only 1.5% of the time between 1981 and 1990 (NCDC, 1998).

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are less than 1 m/s. The wind speeds recorded at a 7-m height at Amarillo, TX were 1.1 m/s or less 1.5% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m above ground level) are greater than 11 m/s. The wind speeds recorded at a 7-m height at Amarillo, TX were 11.1 m/s or more 3.3% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS PIC measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. The locating of a TDLAS scan plane for all four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the E shore of the NE corner of the lagoon. Lagoon sludge depth sampling (SOP L5) will be made at nine (9) locations in the lagoon at the beginning of each measurement period; the approximate locations of these sampling points are indicated in Fig. 2. Lagoon sludge depth measurements (SOP L5) will be made at nine locations in the lagoon (approximate locations indicated in Fig. 4) at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or if winds prohibit being able to keep the boat stationary for the measurements.

Communications

Telemetry of TDLAS/scanners, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP D1). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL. Trailer power will be wired from the barns (Fig. 1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied source. All wiring will be buried directly in the ground from the producer-supplied source and routed to small wooden

posts with the proper style of connection point for each station mounted to the post in weather proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and periodically during the year/measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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Table 1. Monthly climate description (from Amarillo, Texas).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	4	4	4	5	8	8	8	8	6	5	3	4
Wind speed (mph)[2]	13.1	14.2	15.6	15.5	14.7	14.4	12.5	12.2	12.9	13.0	13.1	13.0
Wind direction[2]	SW	SW	SW	N	N	N	SSW	SSW	SSW	S	S	S
Morning RH (%)[1]	70	71	66	67	73	76	73	76	79	70	73	68
Afternoon RH (%)[1]	51	49	41	38	42	44	42	45	49	41	48	47
Maximum temp (^{o}F)[1]	49.4	53.0	60.0	70.9	79.2	88.0	91.4	90.4	82.9	72.9	60.0	51.5
Minimum temp (^{o}F)[1]	22.5	26.4	31.2	42.1	51.9	61.2	65.9	64.7	56.7	46.1	32.5	25.5

[1] NCDC (1981)
[2] NCDC (1998)

Table 2. Characteristics of the lagoon at the Oklahoma sow facility.

Descriptive parameters.	**Unit 1**
Livestock type	Swine
Type of storage	Lagoon
Number of units	1
Year of facility construction	1994
Separation distance from barn fans, ft	173
Stage of lagoon (1st, 2nd, 3rd)	1st
Manure contributors to unit	
Animal 1 type (sows, cows, etc.)	Sows
Animal 1 average weight (lb)	230-750
Animal 1 inventory (# head)	2784
Manure collection	PPR
Source flush or recharge water (if any)	Lagoon (Recharge)
Lagoon loading interval, h	24
Minimum space around unit, ft	173 ft
Volumetric loading rate, lb VS/d-ft^3	0.0048
Surface loading rate, lb VS/d-ft^2	0.0597
Obstructions within 3X height of unit?	None
If yes, what kind?	--
Height of worst obstruction, ft	--
Distance from worst obstruction, ft	--
Type of cover	None
Are solids separated from influent?	No
Odor control	None
Sludge removal cycle, years	20
Last time sludge removed	Never
Agitation prior to pumpout?	None
Manure removal frequency, days	180-365
Pump out (contractor or producer)	Producer
Type of liner	Clay
Volume, cubic ft	234,133
Surface area, square feet	242,056
Berm slope	4 :1
Maximum side length, ft^3	632
Minimum side length, ft^2	383
Actual freeboard, ft	1.5
Inner berm height, ft	4-10
Outer berm height, ft	0-2
Liquid depth, ft	18
Sludge depth, ft	Unknown
Number of inlets	2
Shape	Rectangular

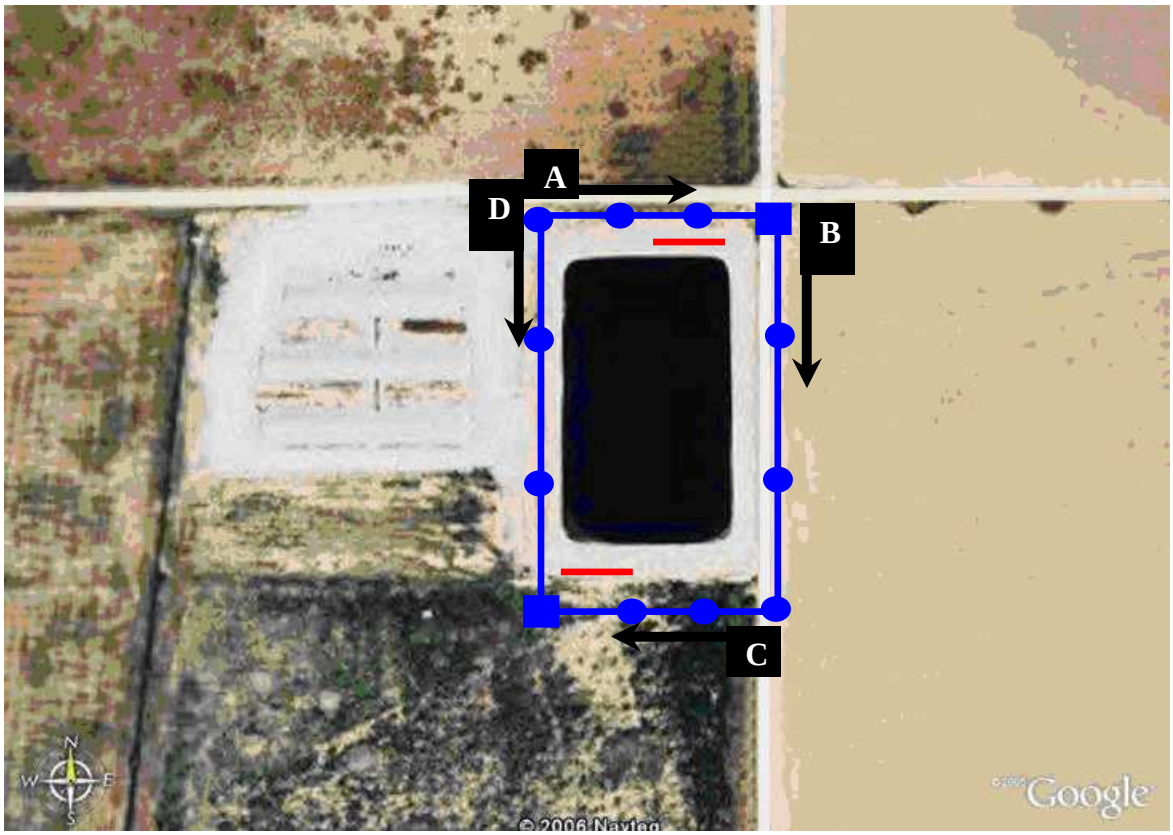


Figure 1. Plan layout of lagoon.

The S-OPS (red lines), TDLAS/ scanner (blue squares) instruments and retro-reflector locations (blue circles) are indicated, with the scan beam lines/planes indicated by letter. Blue lines indicate the planes of the TDLAS scanner and retro-reflector pairs. Black boxes A,B,C, and D, and black arrows correspond to the locations and lines of sight for the N, E, S, and W lagoon side photos above.

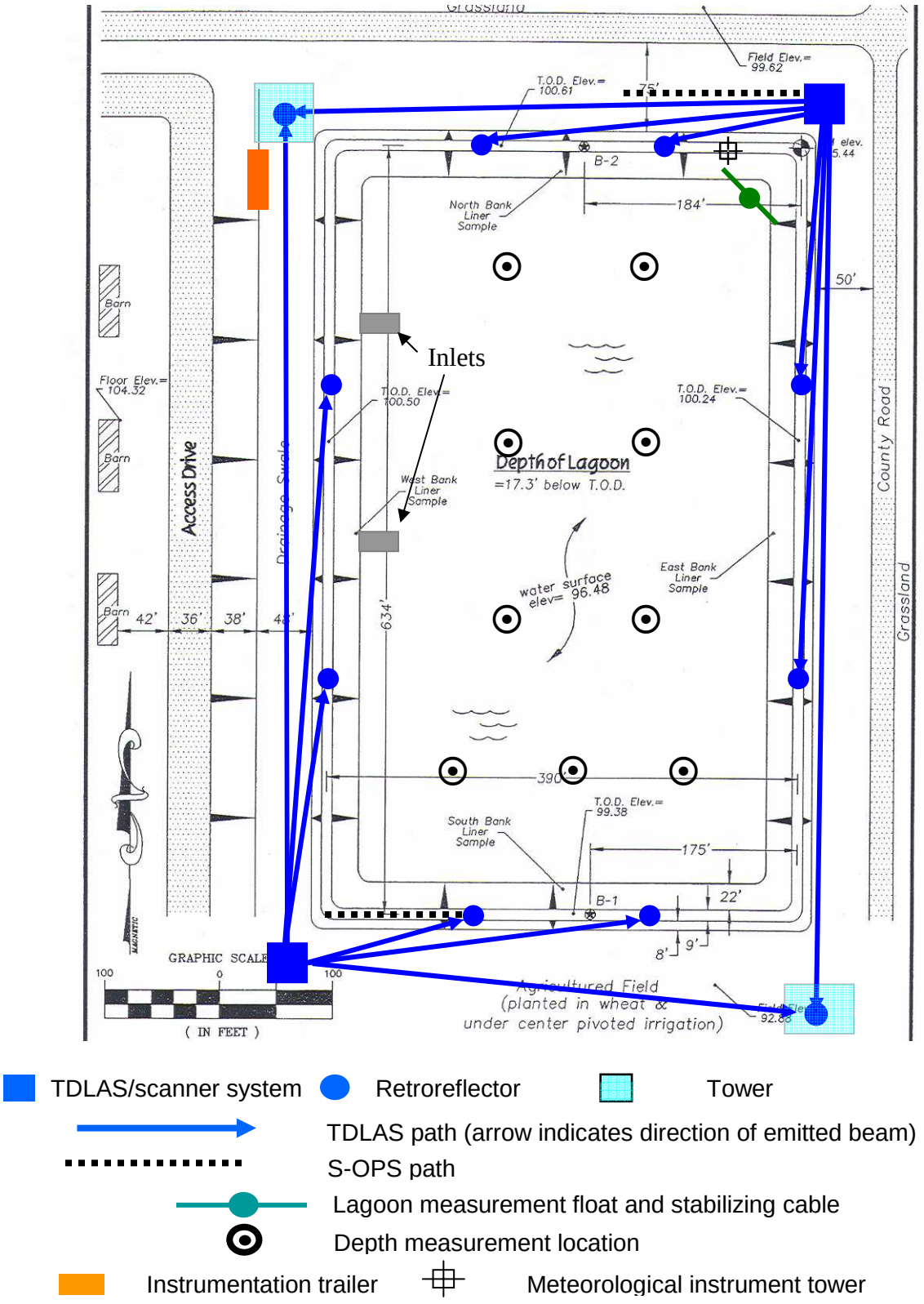


Figure 2. Dimensional plan of the lagoon, including locations of structures and roads. Berm along S side is 6 ft from ground. Berm along N side is 1 ft above ground. Drainage swale W of lagoon varies from 1 ft to 6 ft deep from N to S.

Figure 3. Satellite image of surroundings.

SMP WA5A
SITE MONITORING PLAN FOR DAIRY SITE IN WASHINGTON STATE
(LAGOON COMPONENT)

SMP WA5A
SITE MONITORING PLAN FOR DAIRY SITE IN WASHINGTON STATE (LAGOON COMPONENT)

The Western freestall dairy facility is located in Yakima County, Washington. The elevation at the farm is approximately 244 m (800 ft). The magnetic compass variation at this location is 17°E. The farm consists of six barns, a milking parlor, and an office (Fig. 1). The facility has a capacity of 4400 milking cows and 1200 dry cows in three units. Construction of the dairy was completed in 2002.

Logistics

Measurements will be made by one of the rotating measurement teams from the Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. Airports are located in Yakima, WA and Pasco, WA. The farm is located 68 km (42 mi) SE of Yakima, WA, with a one-way driving time of less than one hour.

Climate (Table 1)

The climate for the area is represented by the Yakima, WA, National Weather Service weather station, which is approximately 59.45 km (37 mi) NW of the farm. The area typically receives an average of 203.15 mm (8.00 in) of precipitation (NCDC, 1981). The prevailing wind information, taken from the 'Mabton' weather station of the Washington State University *AgWeatherNet* network, indicates a generally SW wind all year, but with distinct diurnal slope wind influences. A monthly breakdown of the winds is indicated in Fig. 2. Maximum chances of days with precipitation are during the summer (NCDC, 1981). Mean monthly wind speeds range from 1 m/s (2 mph) to 3 m/s (6 mph) (*AgWeatherNet*, 2006). The average relative humidity (RH) ranges from 53% in the morning to 44% in the afternoon, while air temperatures range from 19°C (63°F) to 5.5^{o}C (36°F) (NCDC, 1981). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm operations characteristics (Table 2)

The farm has freestall style barns, with automated flushing four times daily. Manure is transferred to the upper lagoon/settling basins (to be measured in this study) from a sand separation pit. Liquids are skim separated and returned as flush to the barns. Settled solids are removed yearly. Remaining solids are strained through Agpro screens and centrifugal/screw presses, and liquid transferred to large serpentine concrete basins for secondary settling. Solids are then dried for bedding. Removed water is stored in a large clarified water storage basin for dilution of barn flush water. Sludge is applied on land, utilizing underground pressurized pipes and a no-till soil injector. Wastewater enters the initial lagoon/basin from the N, near the NW corner of the lagoon (Figs. 3 & 4).

The two upper earthen-lined lagoon/settling basins are located to the S of the barns, and are used in alternate years. Consequently, the positioning of sensors for 2007/8 (Spring 2007 through

Winter 2008) differs from that of 2008/9. One of the lagoons is rectangular (East lagoon), with dimensions of 183 m (600 ft) by 72 m (235 ft.). The West lagoon is five-sided with dimensions of approximately 183 m (600 ft). long and 83 m (271 ft) wide with the SW corner of the lagoon cut off (Fig. 3). The berm on the W side drops from 2 m (6 ft) high to 4 m (12 ft) high from S to N, flat along the S side, and dropping 50 ft or more to the north toward the serpentine basins. The berm on the E side drops about 1 to 2 m (3 to 6 ft), then rises approximately 2 m (6 ft) to fields to the E.

Surrounding sources

On-farm sources of potential NH_3 or H_2S emissions include the land application areas approximately 50 m (164 ft) to the W, settling basins 20 m (65 ft) to the S, and an open lot for heifers 60 m (198 ft) to the N. The nearest identifiable off-farm sources of NH_3 or H_2S emissions are a small open lot dairy located to the N on the valley floor, a seasonally-used sheep lambing camp ¼ mile to the W, and a calf operation ⅓ mile to the W.

Monitoring Plan

The NH_3 emissions from the two upper lagoons/settling basins will be monitored for 8 to 20 d each quarter of the year for two years, using scanning TDLAS open-path instruments (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements and the radial plume mapping (RPM) (SOP O2). H_2S emissions from the same lagoons/settling basins over the same periods of time will be monitored using pulsed-florescence (PF) (SOP G5) sampled through a Synthetic Open Path System (S-OPS) (SOP C4) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements and backward Lagrangian Stochastic (bLS) emissions models (SOP O1). VOC emissions including methane, methanol, ethanol, and total non-methane VOC will be calculated using the backward Lagrangian Stochastic (bLS) model (SOP O1), with data from the 2-m height sonic anemometer (SOP W2) and air sampled using the S-OPS (SOP C4) and analyzed by the INNOVA (SOP G7). Measurement data will be collected on the LAN server in the trailer (SOP D1, SOP U4).

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, so as to create vertical measurement planes on each side of the lagoon. Fixed sheet metal towers will be used to withstand the reported 90-mph winds associated with Chinooks. Two towers (SOP U5) will be located at the NW and NE corners of the lagoons. One 15-m (51-ft) tower will be placed at the center point of the two lagoons, approximately 15 m S of the south berms. The scanning TDLAS instruments will be mounted at 1-m height above the lagoon berm at the NW and SE corners of the E lagoon for 2007 and at the NE and SW corners of the W lagoon for 2008. The TDLAS/scanners will be mounted at 1-m height above berm on an anchored tripod (SOP U5). Retro-reflectors at approximately ⅓ and ⅔ of the distance down the lagoon sides will also be mounted at 1-m heights above berm level (abl) on anchored tripods (SOP U5) on the berms (Fig. 4A/B).

Two S-OPS systems (SOP C4) will collect the gas along linear paths on opposite sides of the lagoon for the measurement of the synthetic PIC of H_2S and various VOC. Since the prevailing winds are SW, S-OPS paths will be positioned to the N ends of the E and W lagoons. The S-OPS along the SW side of the lagoon will primarily act as the upwind station. The S-OPS on the northern end of the E side of the E lagoon will primarily act as the downwind measurement path in 2007 (Fig 3), while the S-OPS on the N side of the W lagoon will act as the prevailing downwind measurement path in 2008 (Fig. 3).

Meteorological measurements, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be located 19 m S and 5 m East of the NE berm corner of the West lagoon (Fig 4A/B) for both years. The meteorological measurements will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height above berm level. Two 3D sonic anemometers will be located at 4-m and 16-m heights above ground level (agl) (SOP U5) on the centrally located S fixed sheet metal tower for both years.

Fetch to the W is better than 1:100 before terrain rises. Fetch to the E, towards the center-pivot irrigation system, is interrupted by a 3- to 6-m (10- to 20-ft) deep and 30- to 45-m (100- to 150-ft) wide gulley (Fig. 1) to be filled in in the near future. A description of the position of each measurement path by photo and by year of operation (Figs. 3 & 4A/B) follows:

2007/8: East Lagoon Measurements

W side of East lagoon

- Retro-reflectors at 67 m and 132 m, and 3 on SW fixed tower at approx. 259 m from NW corner TDLAS scanner. The 67-m and 132-m retro-reflectors are mounted on anchored tripods on the berm at 1 m abl.
- Met tower will be placed on the East lagoon side of the dividing berm between the lagoons, 23 m S of the N berm.

W side of East lagoon (right) and E side of West lagoon (left) looking N.

N side of lagoon

- S-OPS path parallel to the berm and 50 m long beginning 10 m N of the NW berm corner
- Retro-reflectors at 29 m and 52 m along berm from NW corner TDLAS/scanner and 3 at approx. 83 m on fixed tower at NE berm corner.
- TDLAS paths approximately parallel to the N berm of the lagoon. The 29-m and 52-m retro-reflectors are mounted on the berm on anchored tripods at 1 m abl height.

N side of East lagoon from NE corner looking W. Lagoons on left.

E side of lagoon

- Retro-reflectors at 70 m and 135 m from SE corner TDLAS/scanner and 3 on NE corner fixed tower at approximately 206 m from the scanner. The 70 m and 135 m retro-reflectors are mounted on the berm (West side of road) at 1 m abl.
- Instrument trailer is located at SE bermcorner and just E of the road.

NE corner of East lagoon, looking S along E edge.

S side of lagoon

- 50-m long S-OPS path south of road beginning 10 m S of berm SE corner.
- Retro-reflectors at 32 and 57 m W along berm from TDLAS/scanner at SE corner, and 3 on a SW corner fixed tower at approximately 100 m. The 32 m and 57 m retro-reflectors are mounted on anchored tripods on the berm at 1 m abl.

In addition:

- SW fixed tower located 67 m S and 4 m W of SW berm corner of East lagoon.
- SE TDLAS/scanner located 4 m E and 14 m S of SE berm corner (S and E of road) mounted at 2 m agl on an anchored tripod.
- NE fixed tower located 4 m E and 4 m N of NE berm corner (N and E of road).
- NW TDLAS/scanner located 4 m W and 4 m N of NW berm corner mounted at 2 m agl on an anchored tripod.

S side of East lagoon in distance. Lagoon is to left.

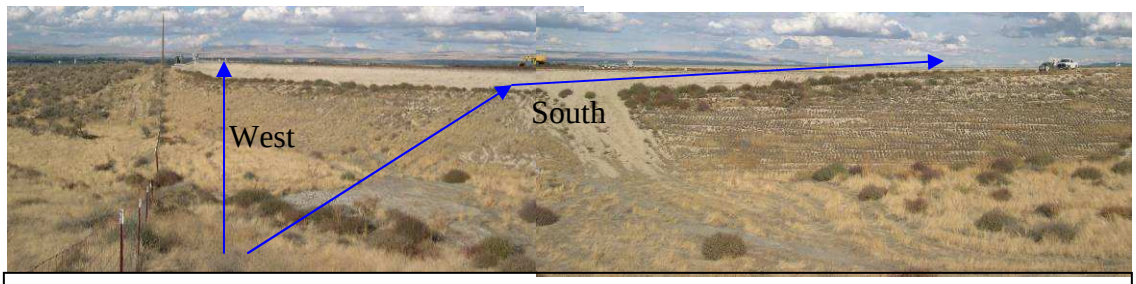
2008/9: West Lagoon Measurements

S side of lagoon

- 50-m long S-OPS path parallel to and 5 m from S berm.
- S-OPS path 1 m S of southerly SW side corner of berm extending E to SE berm corner.
- Instrument trailer will be located near the SE corner, just E of the center road between the two lagoons.
- Retro-reflectors at 60.5 m, 84 m and 3 on the SE corner tower 111 m from SW corner TDLAS/scanner. The 60.5 m, 84 m retro-reflectors are on berm mounted on an

SW side of West lagoon to right. Location of SW TDLAS/scanner indicated by blue arrow

anchored tripod at 1 m abl.



SW side of West lagoon looking N from TDLAS/scanner position. Lagoon is center and right in image. Paths for west side of lagoon and south side of lagoon indicated by labeled

W side of lagoon

- Retro-reflectors 93.5 m and 160 m, and 3 on the NW corner fixed tower at approx. 237 m from SW corner TDLAS/scanner. The 93.5-m and 160-m retro-reflectors are mounted on the berm on anchored tripods at 1 m abl.

N side of lagoon

- Retro-reflectors at 27 m and 60 m along berm from the NE berm corner TDLAS/scanner and 3 at approx. 95 m from the fixed tower at the NW corner.
- The 27-m and 60-m retro-reflectors are mounted on the berm at a height of 1 m abl.
- 50-m S-OPS path located on the northernmost edge of the berm 10 m E of the NW corner of the East lagoon.

N side of lagoons (West lagoon nearest to right). NW corner of West lagoon, looking E along N edge.

E side of West lagoon (center road)

- TDLAS/scanner located on the outside of the road at the NE berm corner.
- Retro-reflectors at 65 m and 130 m down the side of the lagoon, and 3 on a fixed tower approximately 300 m from the scanner. The 65-m and 130-m retro-reflectors are mounted at 1 m abl on anchored tripods.
- Met tower will be placed on the East lagoon side of the dividing berm, approximately 23 m S of the N berm.

E side of West lagoon looking N along center road towards TDLAS/scanner location..

In addition:

- NE TDLAS scanner 4 m N and 4 m E of NE berm corner of West lagoon mounted on anchored tripod at 1 m abl (N of berm road at center lane in between lagoons).

- SE fixed tower located 67 m S and even with SE berm corner of West lagoon (same location as for East lagoon measurements).
- SW TDLAS/scanner 4 m W of SW berm corner (W of berm road).
- NW fixed tower located 4 m W and 4 m N of NW berm corner.

VOC and hydrogen sulfide emissions from the lagoon will be calculated either using the backward Lagrangian Stochastic (bLS) model (SOP O1) with the 2-m height sonic anemometer (SOP W2) and measurements from the S-OPS/PAS (SOP C4, G7) and S-OPS/PF (SOP C4, G5) or by ratio of VOC and hydrogen sulfide to NH_3 and the emissions of NH_3 determined from the RPM emissions model method.. Restrictions on the use of the bLS model are:

1) The ground surface around the source is assumed to be horizontally homogeneous. This is not strictly valid, since the dairy is located on a shelf about 23 m (75 ft) above the main Yakima Valley floor, with sloping ground to the S. The area surrounding the farm slopes gently 2 to 3 degrees upward to the S (Figs. 5 & 6). Fetch to the W is better than 1:100 before terrain rises. Winds are fairly steady down the valley from the W (Fig. 2). Fetch to the E, towards the center-pivot irrigation system, is interrupted by a 3- to 6-m (10- to 20-ft) deep and 30- to 45-m (100- to 150-ft) wide gulley (Fig. 3) to be filled in in the near future. The barns, another source of roughness, are 172 m (563 ft) to the N of the N lagoon berm (Fig. 1), and should not significantly influence wind flow, since winds are from the N less than 5% of the time (Fig. 2).
2) Turbulence is assumed to be homogeneous and stationary. This will likely be valid during much of the measurement period, since winds are consistent in direction and speed much of the year. However, weak valley/slope winds driven by temperature gradients in the Yakima Valley will likely cause changes in turbulence (through changes in stability) through the course of the day. The homogeneity and stationarity will be monitored using the statistical tests described in the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006).
3) The S-OPS measurements for upwind and downwind components must be synoptic. This will be approximately true over an averaging period of ½ hour.
4) Emission measurements will be invalidated when the friction velocity is <0.15 m/s. This corresponds approximately with winds of 1.1 m/s. At the 7-m height, this occurred only 0.8% of the time at Yakima, WA from 1981-1990 (NCDC, 1998).

Ammonia emissions from the lagoon will be calculated using the radial plume mapping (RPM) model (SOP O2) with the three sonic anemometer (SOP W2) and TDLAS measurements (SOP C2). Restrictions on the use of the model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. The wind speeds at 7-m height at Yakima, WA were ≤1.1 m/s 10.2% of the time between 1981 and 1990. (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds at 7-m height at Yakima, WA were ≥11.1 m/s 0.8% of the time between 1981 and 1990 (NCDC, 1998).

3) The TDLAS PIC measurements for upwind and downwind components must be synoptic. This is maintained in the measurement plan.

Communications

The instrumentation trailer (SOP U4) will be located just E of the road on the SE corner of the East lagoon for 2007/8 and just off the S side of the road on the SE corner of the West lagoon for 2008/9 (Fig. 4A/B). Telemetry of TDLAS, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer supplied source. Piping (2″ schedule 40 PVC conduit) will be run underground from an existing 600-amp 480-V 3-phase service located at the SW corner of the lagoon to the trailer location. A total of 3 #6 THHN copper conductors (2 ungrounded, 1 grounded) will be run through the conduit. A 25-kva 480-V primary 120-V secondary transformer will be provided at the trailer location to supply the required 120-V 50-amp circuit.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use. Furthermore, training sessions will be held with the farm staff about the project, its instruments, and requirements; these will be held at the time of initial setup and as needed during the study period.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions Determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be computed based on the results of the validation of the bLS model. If the bLS model is not validated; the H_2S and VOC emissions will be determined using

the ratio of H_2S or VOC S-OPS measurements to NH_3 concentrations determined by the nearest corresponding TDLAS scan path multiplied by the RPM NH_3 emissions calculation. If the bLS model is validated, the H_2S and VOC emissions will be based on the H_2S or VOC concentration by the S-OPS/PF method and the bLS model results. If the RPM emissions measurement of NH_3 is valid but the bLS model conditions are not met; the NH_3 emissions for the basin will be computed from the RPM model and the H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

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SOP O2. 2006. Emissions Estimation Using Radial Plume Mapping (RPM). Standard Operating Procedure O2. Purdue Applied Meteorology Lab.

SOP U4. 2006. Open Source Instrument Trailer. Standard Operating Procedure U4. Purdue Applied Meteorology Lab.

SOP U5. 2006. Installation of Open Source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.

SOP W1. 2006. Humidity and Temperature Probe. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.
SOP W2. 2006. Ultrasonic Anemometer for Wind Velocity. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.
SOP W3. 2006. Wetness Grid for Measuring Precipitation. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.
SOP W5. 2006. Barometric Pressure Sensor. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.
SOP W6. 2006. Weather Data Acquisition and Control Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

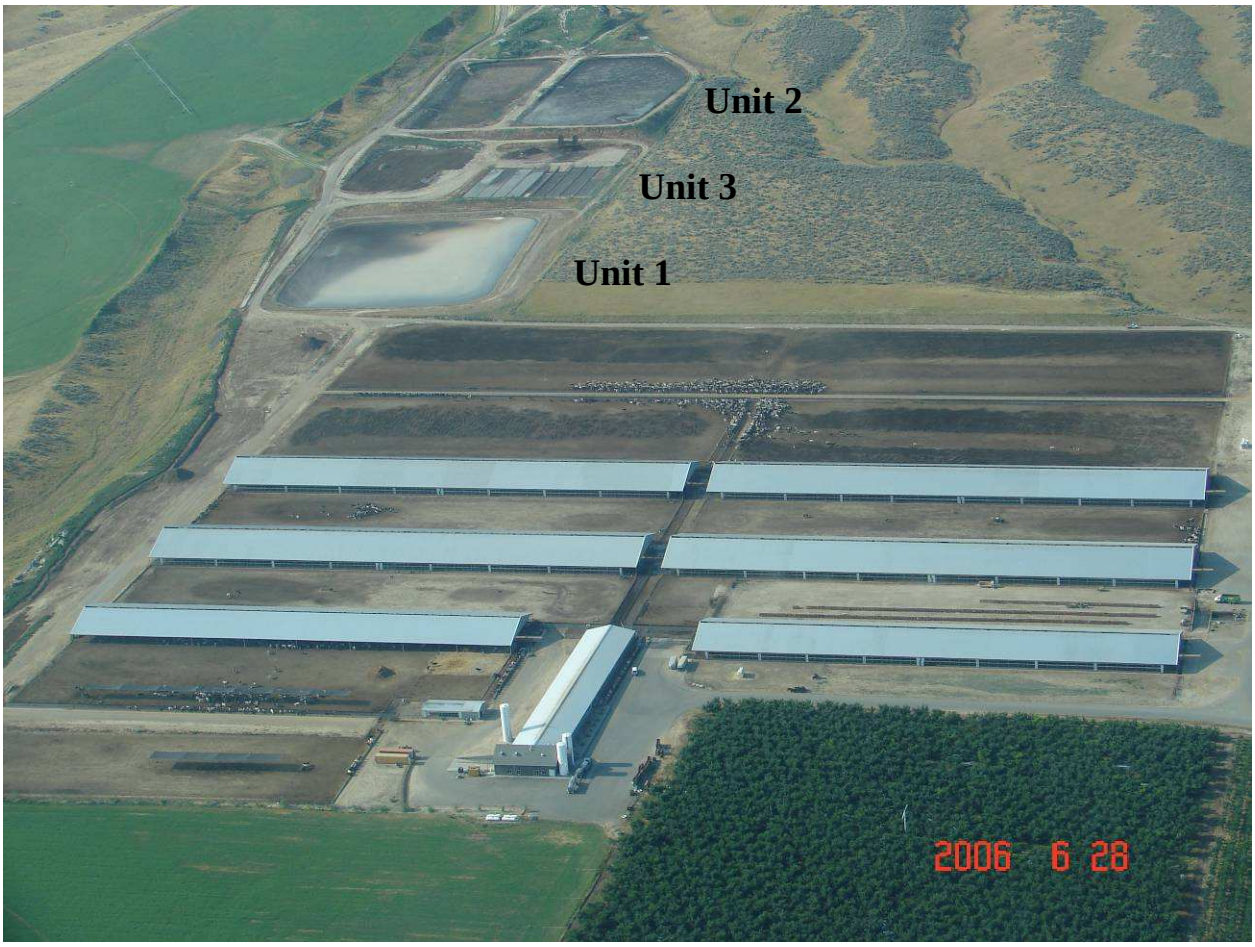

Figure 1. Overall layout of farm, as viewed from the NNW.
Photograph courtesy of Stewart Turner, CPAg.

Table 1. Monthly climate description for the site (from Yakima, WA and Mabton, WA).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with ≥0.01 precip[1]	10	7	6	4	5	5	2	3	3	5	8	10
Morning RH (%)[1]	77	70	52	40	37	38	35	39	44	55	72	80
Afternoon RH (%)[1]	70	58	41	32	30	30	25	28	32	43	63	74
Maximum temp (°F)[1]	36.4	46.1	54.8	64.1	73.1	79.7	88.1	85.9	78.3	64.1	51.1	41.0
Minimum temp (°F)[1]	18.6	25.2	28.8	34.8	42.6	49.3	53.3	51.2	44.3	35.4	28.3	23.5
Wind speed (mph)[2]	6.0	5.2	5.7	5.5	4.5	4.9	4.8	4.3	4.1	3.7	3.2	2.3

[1] Yakima, WA: NCDC (1981)
[2] Mabton, WA: U. of Wash. Automated Weather Network *AgWeatherNet*, Sept 2005-Aug 2006.

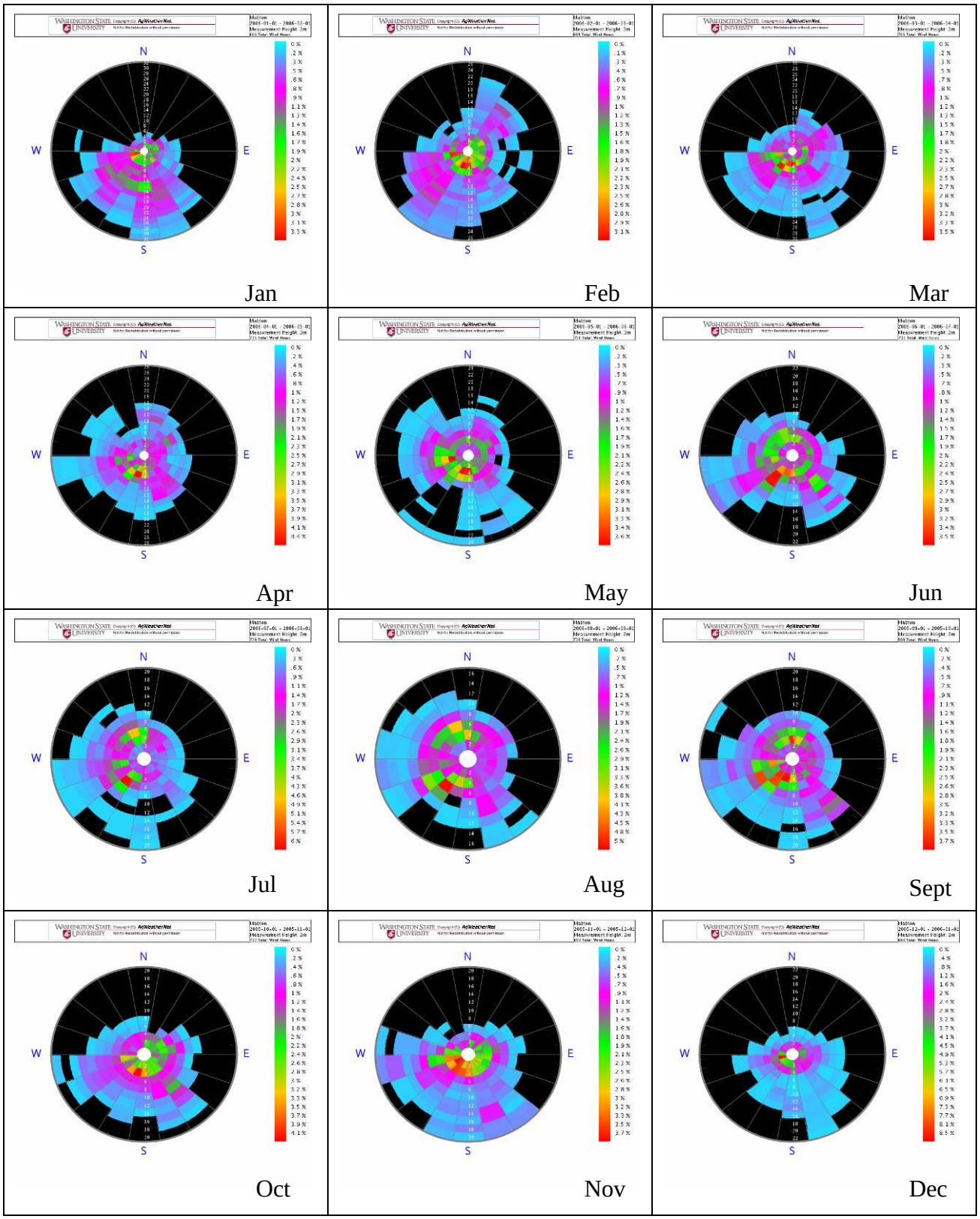

Figure 2. Wind Rose Maps from Washington State University (Sept 2005- August 2006).

Table 2. Characteristics of the lagoons and basins at the site.

Descriptive parameters	Unit 1	Unit 2	Unit 3
Livestock type	Dairy cows	Dairy cows	Dairy cows
Type of storage	Main storage basin	Drying ponds	Serpentine basins
Number of units	1	2	2
Year of facility construction	2002	2002	2002
Volume (each) (Mgal)	25	15	1
Volume, ft^3	3,342,500	2,005,500	133,700
Stage of lagoon (1st, 2nd, 3rd)	1st	-	-
Distance from barn fans, ft	About 600	About 1600	About 1200
Manure contributors to unit			
Animal 1 type	Milking cows	Milking cows	Milking cows
Animal 1 average weight (lb)	1400	1400	1400
Animal 1 inventory (# head)	4400	4400	4400
Animal 2 type	Dry cows	Dry cows	Dry cows
Animal 2 average weight (lb)	1400	1400	1400
Animal 2 inventory (# head)	1200	1200	1200
Manure collection	Flush/alley scraping	Flush/alley scraping	Flush/alley scraping
Source flush or recharge water	Well	Well	Well
Lagoon loading interval, hours	Continuous	Continuous	Continuous
Minimum space around unit, ft	65	50	40
Volumetric loading rate, lb vs/d-ft^3	-	-	-
Surface loading rate, lb vs/d-ft^2	-	-	-
Obstructions within 3X height?	No	No	No
Type of cover	-	-	-
Are solids separated from influent?	Yes	Yes	Yes
Odor control	None	None	None
Sludge removal cycle, years	-	2 for each pond (alternating use 1 yr)	-
Last time sludge removed	-	2006 (E), 2005 (W)	-
Agitation prior to pumpout?	Yes	-	-
Manure removal frequency, days	Varies	Varies	Varies
Pump out (contractor or producer)	Producer	Producer	Producer
Type of liner	PVC	Clay	Concrete
Berm slope	3 :1 – 4 :1	3 :1 – 4 :1	3 :1 – 4 :1
Maximum side length, ft	563	600 (E), ≈ 600 (W)	180
Minimum side length, ft	368	235 (E), 271 (W)	70
Surface area, ft^2	207,184	141,000 (E) 163,200 (W)	12,600
Actual freeboard, ft	2	-	-
Inner berm height, ft	-	Varies	-
Outer berm height, ft	11.5 (max)	12 (max)	
Liquid depth, ft	17 (max)	16-18	
Sludge depth, ft	Varies	Varies	Varies
Number of inlets	1	1	1
Shape (rectangular, oval, etc.)	Rectangular	Rectangular and Trapezoidal	Rectangular

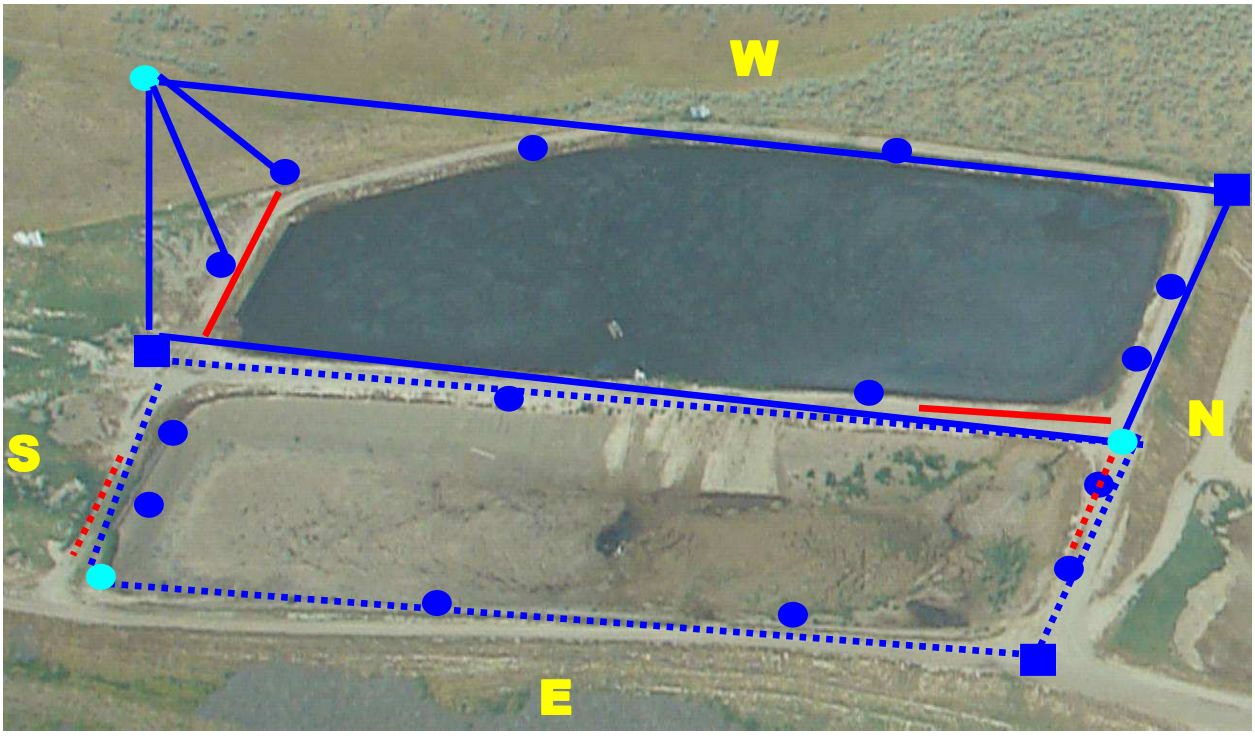

Figure 3. Plan layout of lagoon.

The S-OPS (red), TDLAS/ scanner (light blue circles) instruments and retro-reflector locations (blue circles) are indicated, retro-reflector towers (blue squares) and the scan beam lines/ planes (blue lines) are indicated by letter. Dashed lines correspond to 2007/8 measurement; solid lines to 2008/9. Photograph courtesy of Stewart Turner, CPAg.

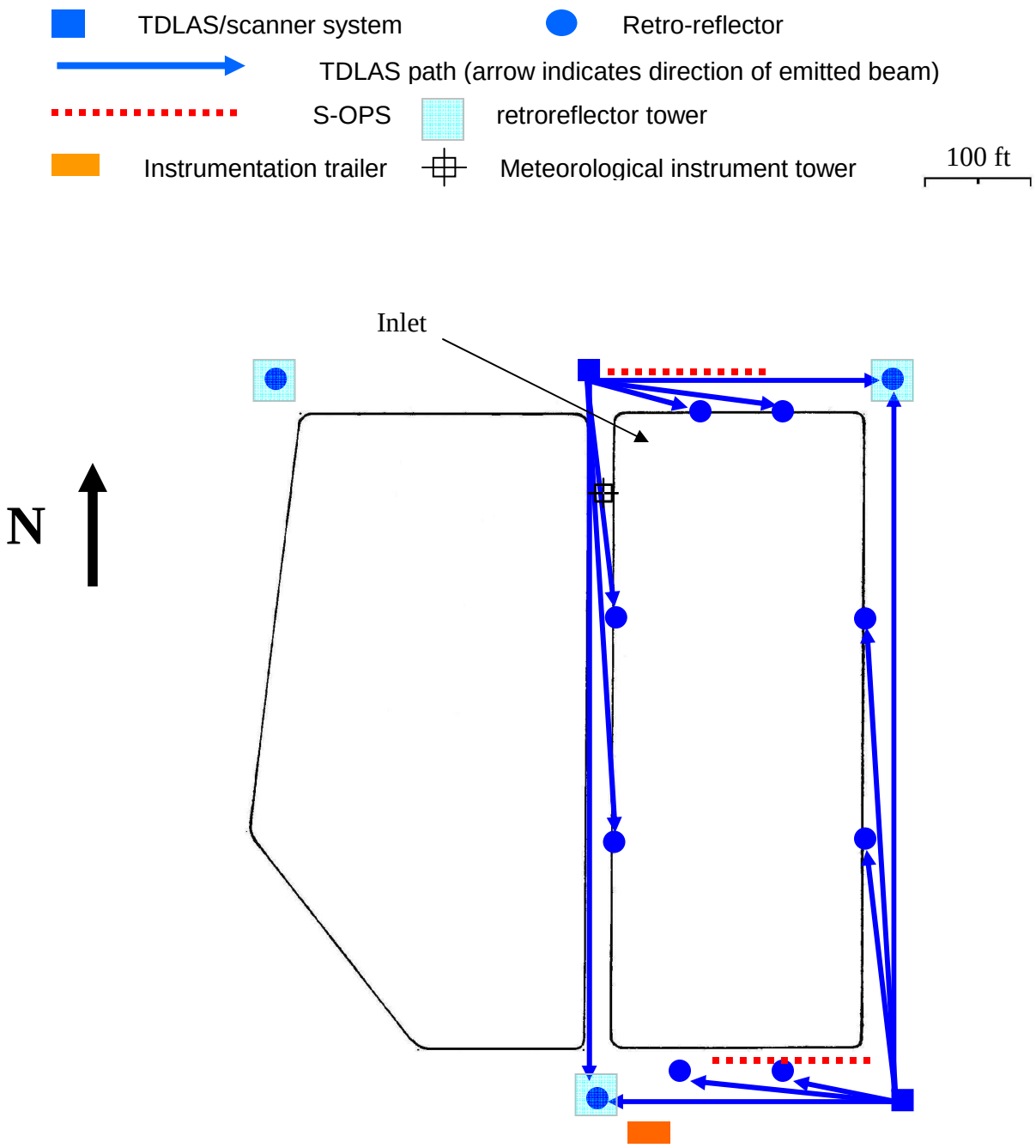

Figure 4A. Dimensional plan of the lagoon (2007/8).

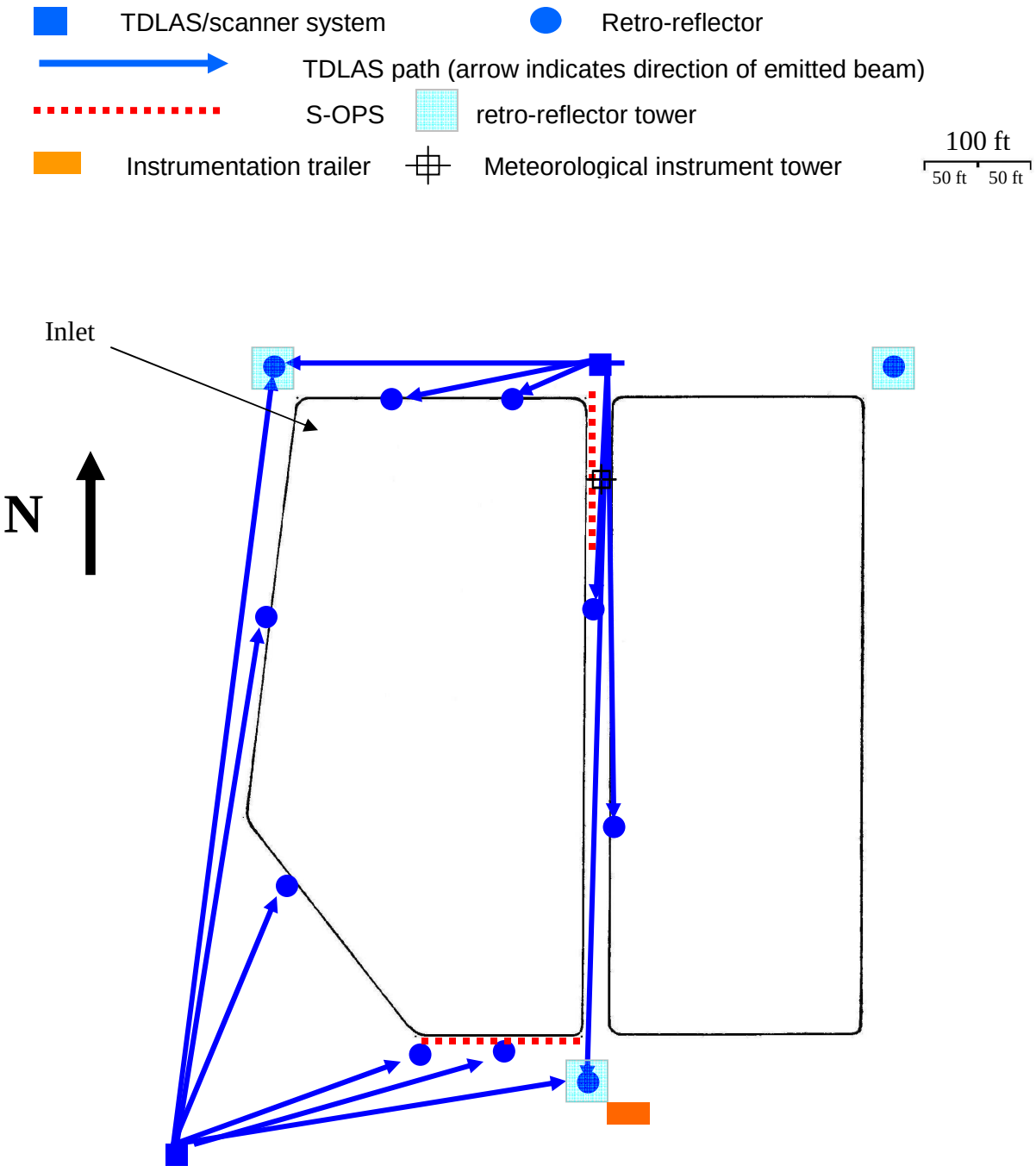

Figure 4B. Dimensional plan of the lagoon (2008/9).

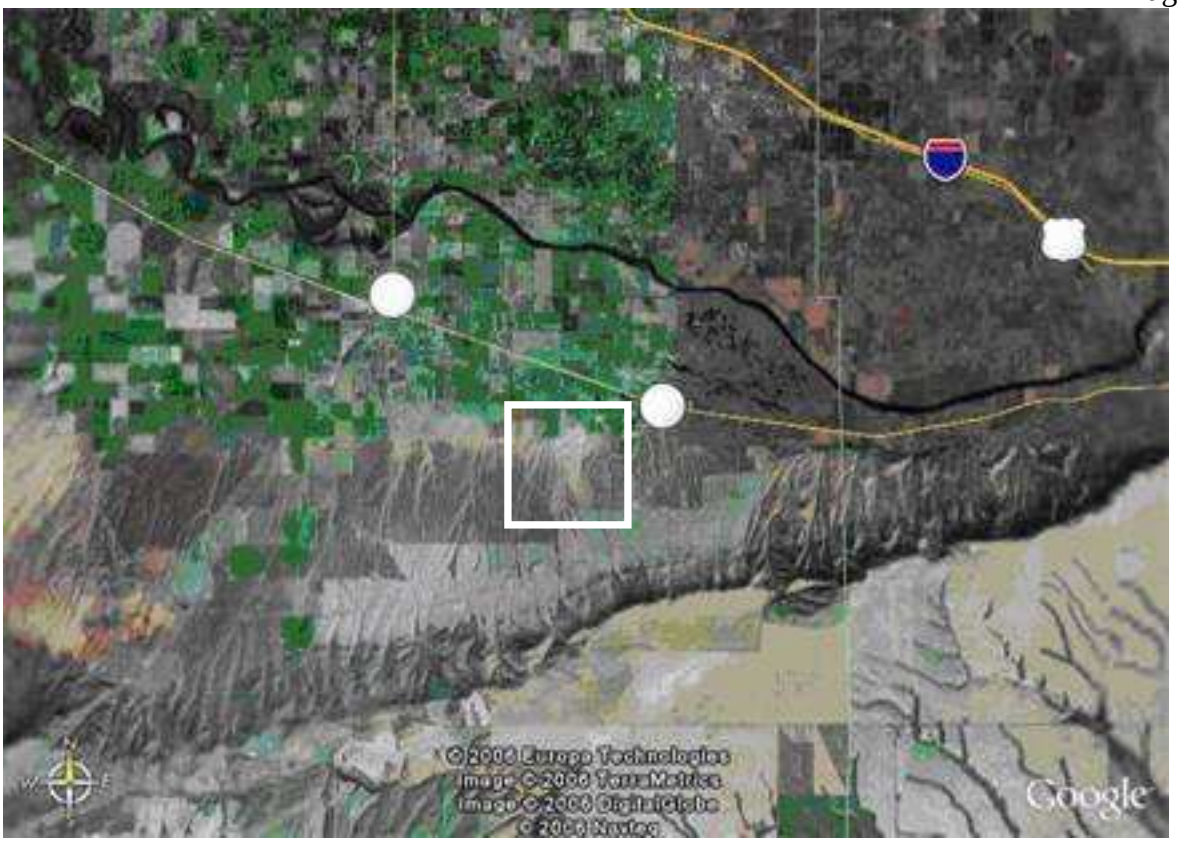

Figure 5. Satellite image of the farm's surroundings.
Location of farm, which was still under construction at the time of the imagery, is indicated by the square.

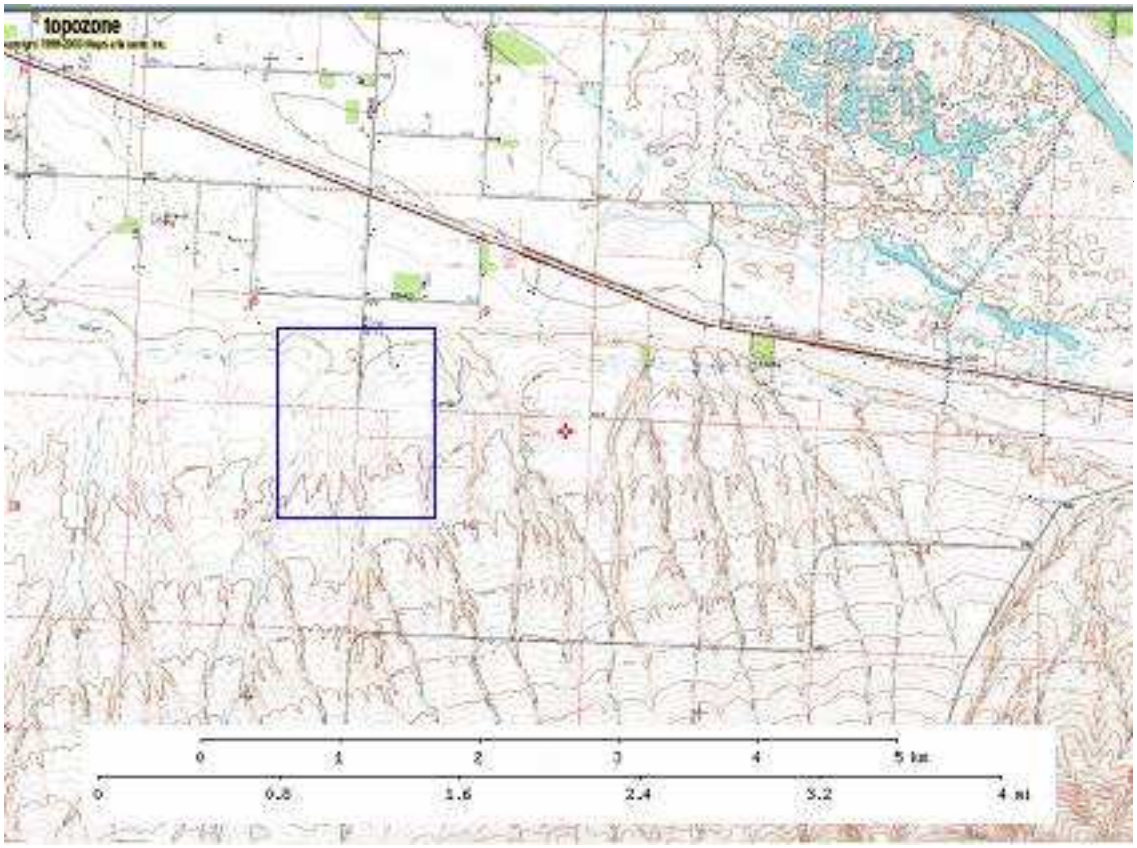

Figure 6. USGS Topographic Map of area.
Height interval is 10 ft Location of farm is indicated by blue rectangle. Prevailing winds are from the SW.

SMP WI5A
SITE MONITORING PLAN FOR DAIRY FARM IN WISCONSIN
(LAGOON COMPONENT)

SMP WI5A
SITE MONITORING PLAN FOR DAIRY FARM IN WISCONSIN
(LAGOON COMPONENT)

Site Description

The Midwest freestall dairy facility is located in St Croix County, WI (Fig. 1) on the side of a river valley (Fig 2). The elevation at the farm is approximately 332 m (1088 ft). The farm has a total of 6 barns, a milking parlor with holding pen, and a special needs area. The farm has a capacity of 1700 Holstein cows.

Logistics

Measurements will be made by one of the rotating measurement teams from the Purdue Applied Meteorology Laboratory (PAML) in West Lafayette, IN. The nearest airport is located in Minneapolis/St. Paul, MN, an approximately one-hour drive of 79 km (49 mi) W of the site.

Climate (Table 1)

The climate for the area is approximated by the Minneapolis/St Paul National Weather Service weather station, which is approximately 79 km (49 mi) W of the farm. The area typically receives an average of 659 mm (26 in) of precipitation (NCDC, 1981). Over the course of the year, the prevailing winds vary from N in April, ESE during May and June, S from July through September, and NW from October through March (Fig. 3, Table 1). Maximum chances of days with precipitation are during the summer. Mean monthly wind speeds range from 4 m/s (9 mph) to 5 m/s (12 mph). Average relative humidity (RH) ranges from 78% in the morning to 60% in the afternoon, while average air temperature ranges from 12.1 ºC (53.8 ºF) to 1.2 ºC (34.3 ºF). A more detailed description of the mean monthly climate of the region is in Table 1.

Farm Operations Characteristics (Table 2)

Manure from the freestall barns and the milking parlor complex is removed by flushing three times daily. The manure flushed from the parlor, holding pen, and freestall barns flows to a solids separator, from which the solids are removed and stacked on a pad until they are spread on fields (the nearest of which is approximately 100 m from the barns). The liquid effluent from the solids separator is pumped back into vertical tanks for reuse to flush the barns. Once a week, enough water is removed from the third stage of the three-stage lagoon and added to the flush tanks to makeup for water lost in the recycled flush system. The three-stage lagoon receives effluent from the two freestall barns (Barns 1 and 2) that are being measured by the barn component of the National Air Emissions Monitoring Study (NAEMS), as well as the other barns and milking parlor. The lagoons are pumped out into trucks twice yearly. The first and second stages of the three-stage lagoon system will be monitored in this study. These lagoons have an outer berm height of 6 m to the W, and between 1 and 6 m to the N.

Surrounding Sources

The nearest identifiable NH_3 or H_2S emission sources include: Three barns 30 m E of the three-stage lagoons, 2 barns approximately 200 m SE of the lagoons, a lagoon about 110 m S, the manure stacking pad which is about 130 m S of the three-stage lagoons (Fig 4), manure spread on nearby fields 30 m W and approximately 100 m to the N, a swine farm 1.6 km to the W, and an open heifer lot 300 m to the NE.

Monitoring Plan

The NH_3 emissions from the lagoon will be monitored for 8 to 20 d each quarter of the year for two years using TDLAS open path instrumentation (SOP C2) and 3-dimensional (3D) sonic anemometers (SOP W2), in conjunction with meteorological measurements, the RPM emissions model (SOP O2). H_2S emissions from the lagoon during the same periods will be monitored using S-OPS sample collection (SOP C4) and PF equipment (SOP G5) in conjunction with NH_3 emissions calculated by the RPM emissions model (SOP O2) by ratiometric methods (PAML 2006a). VOC emissions from the lagoon during the same periods will be monitored using S-OPS sample collection (SOP C4) and PAS equipment (SOP G7) in conjunction with NH_3 emissions calculated by the RPM emissions model (SOP O2) by ratiometric methods (PAML 2006a).

The NH_3, H_2S and VOC PIC measurements are not expected to be strongly influenced by the flow conditions surrounding the relatively high berm of the lagoon. In a study of a slightly lower (4 m high) berm the upwind outer berm of a lagoon contributed to region of vertical flow convergence at the berm top at a height of 2 m, with a mean vertical flow between 10 and 20 degrees upward (PAML, 2006b). This upward flow on the upwind berm was not anticipated to cause problems in the emissions calculations from PIC measurements, since the upwind conditions provide the background concentration for emissions calculations. The high downwind berm results in a recirculation at heights lower than the berm height, but did not appear to change the mean, nearly horizontal flow above the berm height (PAML, 2006b). The positioning of the S-OPS systems at 1 m abl should represent the concentration of gases in the air from over the lagoon.

Two TDLAS systems will be used to measure multiple path-integrated concentrations (PIC) of NH_3, creating vertical measurement planes on each side of the two lagoon complex (Fig. 5). Fixed towers will be located at the SE corner of the 2nd stage lagoon and at the NW corners of the 1st stage lagoon. The scanning TDLAS instruments will be mounted at 1-m height above berm level (abl) on anchored tripods at the NE berm corner of the 1st stage lagoon and off the SW berm corner of the 2nd stage lagoon. Retro-reflectors at the approximate ⅓ and ⅔ distance down the lagoon sides will be mounted at 1-m abl on anchored tripods located on the berms (Fig. 5). Fetch from the TDLAS beamline along the N berm of the 1st stage lagoon is 1:2.5 (42 m distance, 16 m tree height) (Fig. 5). Fetch to the S from the TDLAS beamline on the S berm of the 2nd stage lagoon is greater than 1:100 while that to the N is 1:8.6. Fetch to E from the TDLAS

beamline along the E of the three lagoons is 1:4.6 (7 m high at a distance of 31 m) with the 2nd barn, 1:3.1 (6 m high at a distance of 20 m) with the 1st barn and 1:3.5 (4 m high at a distance of 14 m) with the 3rd barn. Due to poor fetch to the E of the beamlines, there will be no monitoring when winds are from the N through SE (Fig. 3), as typically prevails during May and June (Table 1), and represents about 35.6% of the year overall (Fig. 3). The TDLAS laser beam is eye-safe, so no special safety precautions are necessary.

Two S-OPS will be used to collect air along linear paths at 1 m abl along the lagoon berm on two sides of the lagoon for the measurement of H_2S and VOC. Each 50-m S-OPS consist of ten orifices spaced at a 5 m interval along the line. Since the prevailing winds are NW, N, and ESE, the S-OPS will be positioned on the N berm of the 1st stage lagoon and off the S berm of the 2nd stage lagoon (Fig. 5) at 1-m height above berm height. Fetch from the S-OPS path along the N berm of the 1st stage lagoon is 1:3 (42 m distance, 16 m tree height) (Fig. 5). Fetch to the S from the S-OPS path S of the S berm of the 2nd stage lagoon is greater than 1:100, while that to the N is 1:8.6.

Volatile organic compounds, including methane, methanol, ethanol and total VOCs, will be measured using an INNOVA 1412 multi-gas photoacoustic analyzer (SOP G7) from air sampled through the S-OPS paths upwind and downwind of the basin.

Meteorological measurement sensors, including barometric pressure (SOP W5), air temperature (SOP W1), relative humidity (SOP W1), solar radiation (SOP E3), and surface wetness (SOP W3), will be mounted on the meteorological tower located on the berm between the 1st and 2nd stage lagoons, 20 m to the E of the 2nd lagoon NW corner (Fig. 5). The meteorological data will be collected by the data logger (SOP W6). The 3D sonic anemometers (SOP W2) will be located on the meteorological tower at 2-m height between the 1st and 2nd stage lagoons (Fig. 5), and at 4-m and 16-m heights above berm level (abl) on the SE corner tower (SOP U5).

Configuration specifics:
The TDLAS/scanners will be located on the lagoon berm at the NE corner of the 1st stage lagoon and SW corner of the 2nd stage lagoon, and will be mounted at 1 m abl on anchored tripods (Fig. 5). The TDLAS retro-reflector towers are located 12 m SE of the SE berm corner and located 20 m NW of the NW berm corner are fixed triangular towers (Fig. 5). For the northernmost beamlines on the 1st stage lagoon, the fetch to the trees and buildings to the N is 1:2.2 (42.6m distance, 16.2m height). Details of the position of each measurement path associated with the paths indicated in Fig. 5 follows:

N side of 1st stage lagoon

- 50 m length S-OPS path beginning 2.5 m NE of the NE lagoon corner and running W parallel to the berm.
- TDLAS retro-reflectors will be located 31 m and 60 m west from the TDLAS/scanner on the NE berm

N side of lagoon looking E along the berm . Lagoons are on right.

corner, and mounted at 1 m abl using anchored tripods.

- Three retro-reflectors are mounted on the NW tower at 1 m abl, 7 m abl, and 15 m abl, with an approximate pathlength of 111 m.

E side of lagoons

- TDLAS retro-reflectors will be located along the berm at 34 m and 73 m south of the TDLAS/ scanner at the NE corner. Retro-reflectors will be mounted at 1 m abl using anchored tripods.
- Three retro-reflectors will be mounted on the SE corner tower located off the berm and W of the fenceline at 1 m abl (approx. 2 m agl) at 7 m agl, and 15 m agl, with a pathlength of 102 m.

E side of lagoons looking S along W side of fenceline. 1st stage lagoon is on right.

E side of lagoon looking N along the berm E of the fenceline. Lagoons are on left.

S side of 2nd stage lagoon

- 50 m length S-OPS path on the lagoon berm between the 2nd and 3rd stage lagoons.
- S-OPS begins at the SW berm corner of the 2nd stage lagoon and extends E.
- TDLAS retro-reflectors will be located at 25 m and 54 m east along the berm from the TDLAS/scanner on the platform 3 m SW of the SW berm corner of the 2nd stage lagoon. The retro-reflectors will be mounted at 1 m abl on anchored tripods.
- Three TDLAS retro-reflectors will be mounted on the SE tower with an approximate path length of 83 m.

S side of lagoon looking E along the berm. 2nd stage lagoon is on right.

W side of lagoons

- TDLAS retro-reflectors will be located 60 m and 108 m north of the TDLAS/scanner located at the SW corner. Retro-reflectors will be

mounted at 1 m abl on anchored tripods.

- Three retro-reflectors will be mounted on the NW tower, with a path length of approximately 110 m.

W side of lagoon looking S. 1st stage lagoon is on left.

Ammonia emissions from the lagoon will be calculated using the Radial Plume Mapping (RPM) model (SOP O2), with data from the three sonic anemometers (SOP W2) and TDLAS data (SOP C2). Restrictions on the use of the RPM model are:

1) Emission measurements will be invalidated when the winds across the plane of measurement (down to 1 m above berm height) are <1 m/s. Wind speeds (at 7-m height) at St. Paul, MN were ≤1.1 m/s 4.4% of the time between 1981 and 1990 (NCDC, 1998).
2) Emission measurements will be invalidated when the winds across the plane of measurement (up to 15 m agl) are >11 m/s. Wind speeds (at 7-m height) at St. Paul, MN were ≥11.1 m/s 1.3% of the time between 1981 and 1990 (NCDC, 1998).
3) The TDLAS path-integrated concentration (PIC) measurements for upwind and downwind components are synoptic. This is maintained in the measurement plan. Locating a TDLAS scan plane on each of the four sides of the lagoon ensures the synoptic measurement of an upwind PIC, as well as at least one downwind PIC.
4) Sufficient fetch upwind and downwind. Fetch from the east beamlines to the E is 1:4.3 (6 m high barn at 80 m distance) to the N is 1:61 (195m distance, 3.2m height) (Fig. 5). The barns are approximately 30 m (100 ft) to the E of the lagoons (Fig. 5), and should not significantly influence wind flow under most winds (Fig. 3), since winds are usually from the NW and S. For the 4-m and 16-m wind sensors, fetch to the N is 1:74 at 16 m and 1:10 at 4 m. For the 2-m wind sensor, fetch to the N is 1:5.6. For winds from the E, the 2-m wind sensor has a fetch of 1:13, the 4-m sensor has a fetch of 1:6.5, and the 16-m sensor is above the buildings to the E. Measurements during winds from the E, which typically prevail in May and June (Table 1) and represent 35.6% of the year overall (Fig. 3) will not be included in any analysis. Careful choice of measurement periods will be needed to avoid easterly winds commonly associated with stormy weather.

VOC and H_2S emissions from the lagoon will be calculated using the ratiometric method. The ratio of VOC measured by the S-OPS/PAS or H_2S measured by the S-OPS/PF to the to ammonia measured by TDLAS and the emission of ammonia by the lagoon measured by the RPM method will be used to estimate the VOC and H_2S emission according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006). Restrictions on the use of the model are:

1) The S-OPS path and corresponding TDLAS path are equivalent such that the NH_3 PIC values can be assumed to represent that along the S-OPS path.
2) The S-OPS air samples from upwind and downwind locations are synoptic. This can be assumed since concentrations sampled from the S-OPS sampled air will be averaged over ½ hr intervals. The synoptic measurements will provide the ability to determine the ammonia and hydrogen sulfide concentration change for the air crossing over the lagoon.

The three-stage lagoon system included in the measurement area will not each emit NH_3 , VOC, or H_2S only in proportion to the lagoons' surface areas, but will vary due to their differences in composition. To sample only one lagoon of the three does not provide enough pathlength for good sensitivity.

Animal inventory will also be obtained from the producer, and will be verified every six months by the study personnel (SOP S2).

Communications

The instrumentation trailer (SOP U4) will be located just E of the road between the 1st and 2nd stage lagoons (Fig. 5). Telemetry of TDLAS, 3D anemometers, and the meteorological/lagoon characterization measurements will be by radio modem to the instrumentation trailer (SOP U4). All measurements telemetered to the trailer will be sent to Purdue nightly via cellular DSL (SOP D1).

Electrical Supply

All electrical supply needs will be fed from the producer-supplied sources already located between the 1st and 2nd stage lagoons and the 2nd and 3rd stage lagoons. All wiring will be buried directly in the ground from the producer-supplied source and routed to small wooden posts with the proper style of connection point for each station mounted to the post in weather proof boxes.

Mechanical Equipment, Human Interference Prevention

Human interference for the project /instruments will be avoided by placing warning flags near the equipment in use and furthermore by training sessions to be held with the farm staff about the project, its' instruments, and requirements at the time of initial setup, and periodically during the measurement period as needed.

Animal Interference Prevention

Animal interference to the proper function of the equipment will largely consist of bird droppings and chewing by mammals. Solar radiation and wetness sensors will be cleaned of droppings before and after measurement periods. All signals from the instruments are transferred to the instrument shelter by RF modem, minimizing signal wiring that could be eaten or otherwise damaged by animals. Teflon tubing used in the S-OPS may be damaged by animals

and will be inspected and repaired or replaced if necessary after each measurement period. . Power cables are not anticipated to be damaged by animals. All cables will be inspected at the beginning and end of the measurement periods and repairs made as needed.

Emissions determination

All measurements will be quality assured at Purdue according to the National Air Emissions Monitoring Study Open Source Quality Assurance Project Plan (PAML, 2006) prior to the emissions calculations. The NH_3 emissions for the basin will be computed from the RPM model. The H_2S and VOC emissions will be determined using the ratio of H_2S or VOC concentration by the S-OPS/PF method and NH_3 concentration determined by the TDLAS measurements along the nearest TDLAS scan path multiplied by the RPM NH_3 emissions calculation.

Lagoon pH (SOP L1), redox potential (SOP L3) and water temperature (SOP L2) will be measured from a float positioned 3 m from the N and 3 m from the W shore at the SW corner of the 1st stage and from a float positioned 3 m S and 3 m E from the NW corner of the 2nd stage lagoon (SOP U5) (Fig. 5). The lagoon characterization measurement data will be collected by the data logger (SOP W6). Lagoon sludge depth measurements (SOP L5) will be made at nine locations: six locations in the 1st stage lagoon and three locations in the 2nd stage lagoon (approximate locations indicated in Fig. 5), at the beginning or end of each measurement period. Sludge depth measurements will not be made when more than 50% of the lagoon is crusted or if winds prohibit being able to keep the boat stationary for the measurements.

Analyses of the lagoon effluent is conducted bi-annually for the producer by an external laboratory at the time of each lagoon sludge removal. This information, as well as the time of removals and other pertinent operations events will be provided by the producer according to SOP S7, and will be utilized in assessing the relationship of lagoon composition and emissions.

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Figure 1. Overall layout of farm lagoons and nearby barns (looking N).

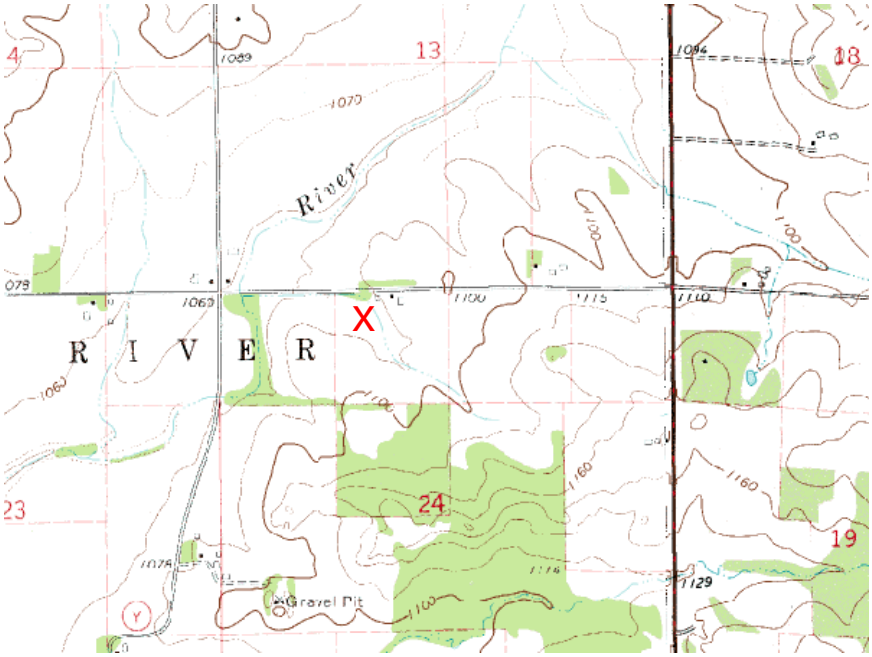

Figure 2. Terrain of surrounding area. Farm is indicated by the red cross.

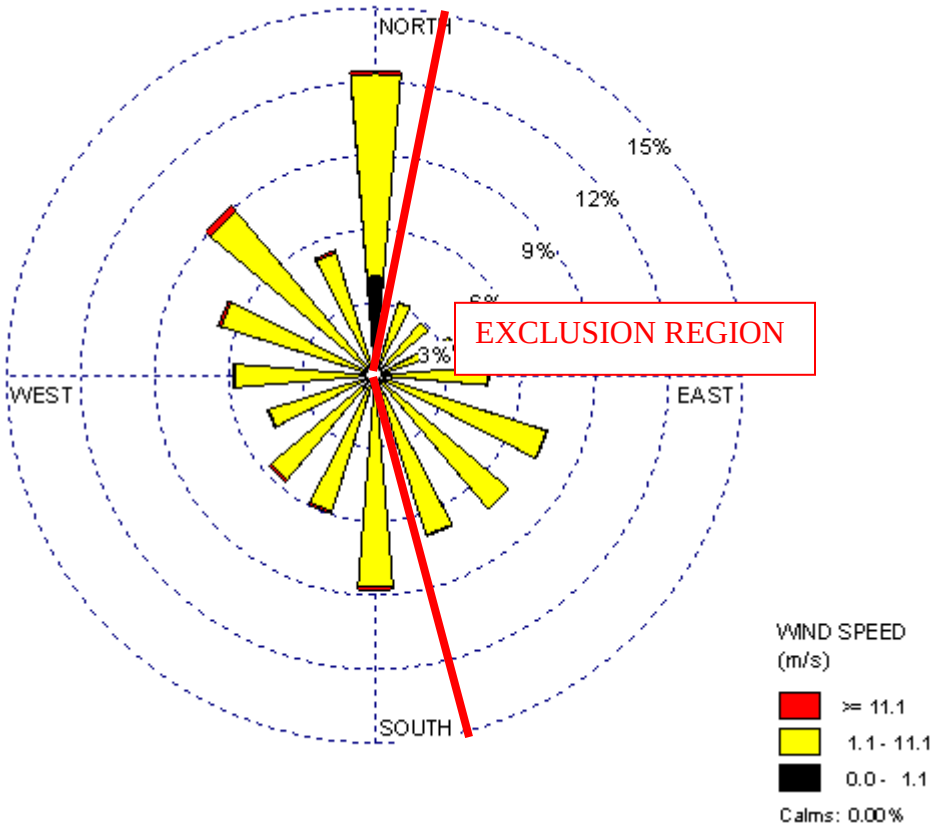

Figure 3. Wind Rose for Minneapolis/St. Paul NWS weather station.
Measurement exclusion region is bounded by red lines. Wind speeds below 1.1 m/s are below the range of the NWS anemometers, and are all assigned a northerly direction.

Table 1. Monthly climate description for St. Paul, MN.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days with >=0.01 in of precipitation[1]	9	7	10	10	11	12	10	10	9	8	8	9
Wind speed (mph) [2]	11	10	11	12	11	11	10	9	10	11	11	10
Wind direction[2]	NW	NW	NW	N	ESE	ESE	S	S	S	NW	NW	NW
Morning RH (%)[1]	72	73	76	75	76	79	81	84	86	81	80	77
Afternoon RH (%)[1]	66	64	63	54	51	54	54	56	60	58	65	69
Maximum T (°F) [1]	21.2	25.9	36.9	55.5	67.9	77.1	82.4	80.8	70.7	60.7	40.6	26.6
Minimum T (°F) [1]	3.2	7.1	19.6	34.7	46.3	56.7	61.4	59.6	49.3	39.2	24.2	10.6

[1] NCDC (1981)
[2] NCDC (1998)

Table 2. Characteristics of lagoons and Basins at the Wisconsin dairy site.

Descriptive parameters.	**Unit 1**	**Unit 2**	**Unit 3**
Livestock type	Dairy Cows	Dairy Cows	Dairy Cows
Type of storage (basin, lagoon or tank)	Lagoon	Lagoon	Lagoon
Number of units			
Year of facility construction	1991	1991	1994
Separation distance from barn fans, ft	200	200	200
Stage of lagoon (1st, 2nd, 3rd)	1st	2nd	3rd
Manure contributors to unit			
Animal 1 type (sows, cows, etc.)	Dairy cows	Dairy cows	Dairy cows
Animal 1 average weight (lb)	1400 #	1400 #	1400#
Animal 1 inventory (# head)	650	650	650
Manure collection (flush, scrape, PPR)	Flush	Flush	Flush
Source flush or recharge water (if any)	Recycled	Recycled	Recycled
Lagoon loading interval, h	Every hour	Every hour	Every hour
Minimum space around unit, ft	100	100	100
Volumetric loading rate, lb VS/d-ft^3	350,000	350,000	350,000
Surface loading rate, lb VS/d-ft^2	None	None	None
Obstructions within 3X height of unit?	None	None	None
If yes, what kind? (e.g. trees, barns)	Barns, 4th Lagoon, Stacking pad	Barns, 4th Lagoon, Stacking pad	Barns, 4th Lagoon, Stacking pad
Height of worst obstruction, ft	28.3	27.3	20
Distance from worst obstruction, ft	98	92	104
Type of cover	None	None	None
Are solids separated from influent?	Yes	Yes	Yes
Odor control	None	None	None
Sludge removal cycle, years	2x/year	2x/year	None
Last time sludge removed (e.g., 1999)	2006	2006	None
Agitation prior to pumpout?	Yes	Minimum	No
Manure removal frequency, days	180	180	180
Pump out (contractor or producer)	Producer	Producer	Producer
Type of liner (clay, plastic, etc.)	Clay	Clay	Clay
Volume, ft^3	373,000	226,700	226,700
Surface area, ft^2	45,900	31,200	30,400
Berm slope (e.g. 3:1, 3.5:1, 4 :1, etc.)	2 :1	2 :1	2 :1
Maximum side length, ft	270	260	190
Minimum side length, ft	170	120	160
Actual freeboard, ft	1	1	1
Inner berm height, ft	12	12	12
Outer berm height, ft	12	13	14
Liquid depth, ft	11	11	11
Sludge depth, ft	1	1	2
Number of inlets	1	1	2
Shape	rectangular	rectangular	rectangular

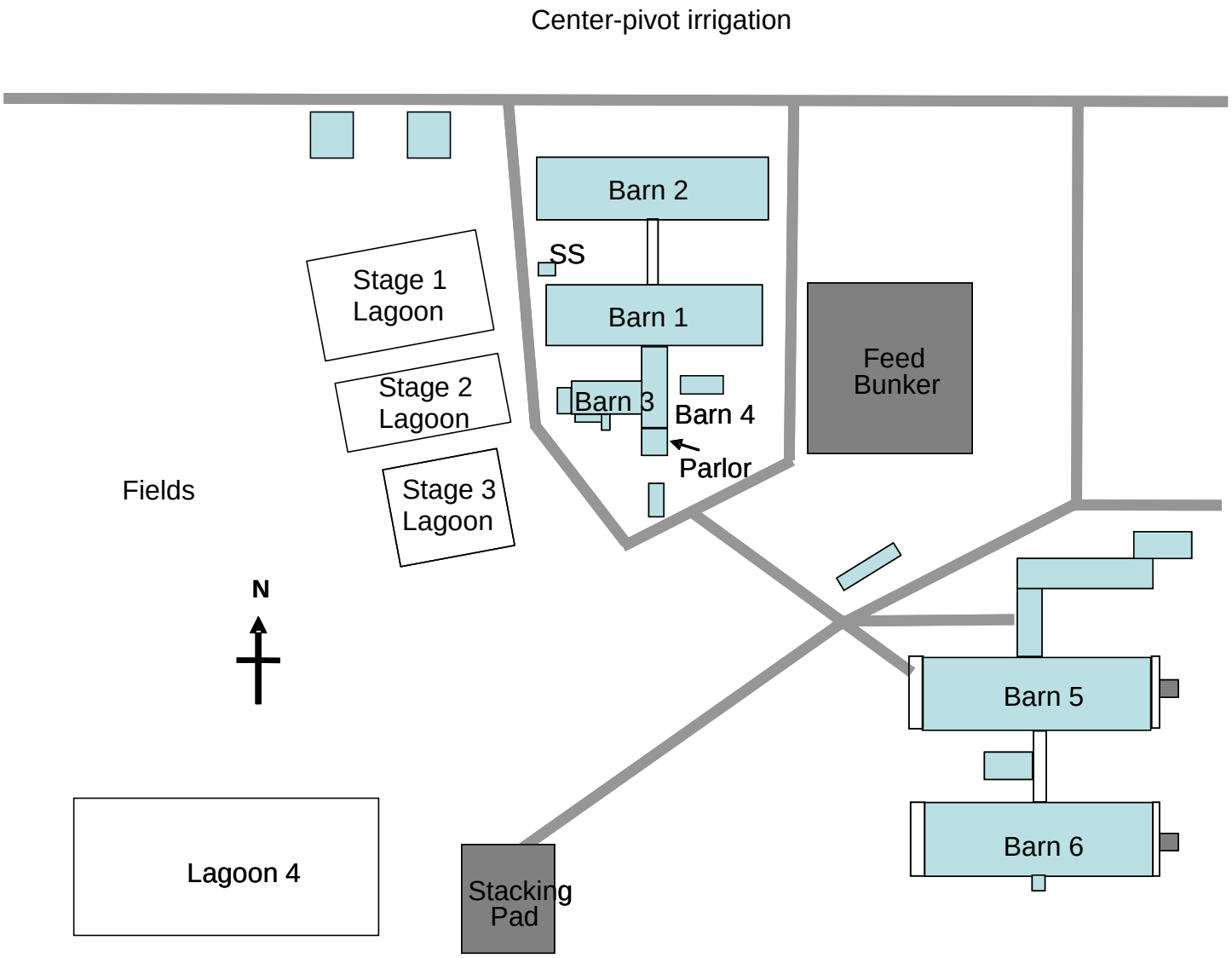

Figure 4. Diagrammatic overall layout of farm.
Stage 1 and 2 Lagoons will be monitored. SS = sand separator.

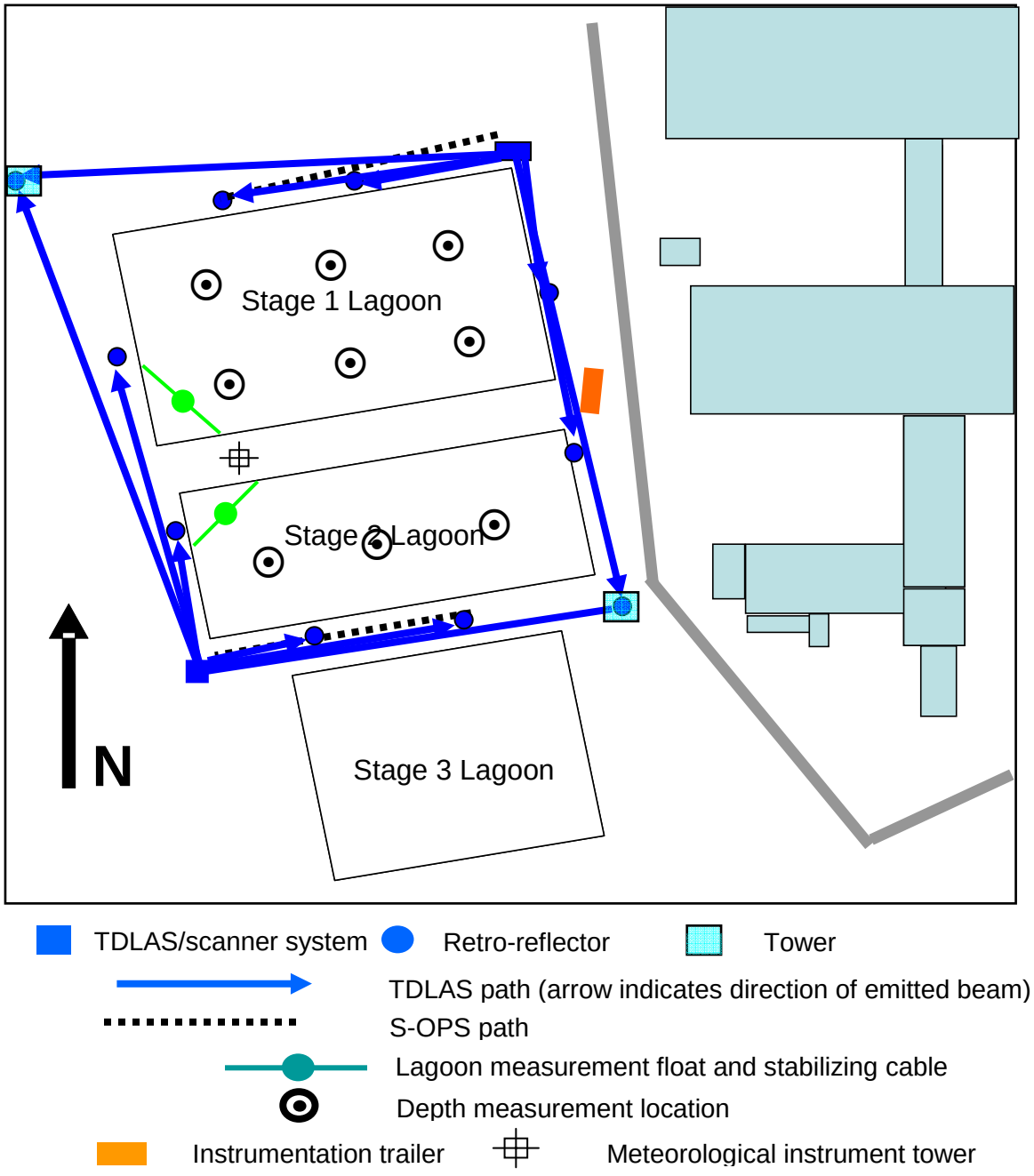

Figure 5. Dimensional plan of the lagoon

Appendix C

SOPs

OPEN PATH MEASUREMENT OF AMMONIA AND HYDROGEN SULFIDE WITH THE CEREX UVSENTRY ULTRAVIOLET DIFFERENTIAL OPTICAL ABSORPTION SPECTROMETER

Standard Operating Procedure (SOP) C1

OPEN PATH MEASUREMENT OF AMMONIA AND HYDROGEN SULFIDE WITH THE CEREX UVSENTRY ULTRAVIOLET DIFFERENTIAL OPTICAL ABSORPTION SPECTROMETER

Standard Operating Procedure (SOP) C1

Prepared by

Richard H. Grant

Reviewed by

Bill W. Bogan, Juan Carlos Ramirez, and Albert J. Heber

Effective Date: November 9, 2006

PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. This method involves open-path spectral measurements of NH_3 and H_2S made with a UV-DOAS instrument (UV Sentry, Cerex Environmental Services, Atlanta, GA).
1.2. The purpose of the method is to measure NH_3 and H_2S upwind and downwind of area sources at livestock production facilities.
1.3. One UV Sentry can measure multiple gases.
1.4. The path length is 50 to 150 m long.
1.5. The minimum detection limit for $NH_3$is 500 ppb-m in lagoon air matrix.
1.6. The minimum detection limit for H_2S is 2000 ppb-m in lagoon air matrix.
1.7. The concentration range when used at manure storage facilities is 1 to 800 ppb.

2. Summary of Method

The Open Path UV-DOAS is a bi-static, broadband, spectral absorption instrument designed to measure the concentration of various constituents in the open air along a path that is at least 50 m long. The instrument is built around a CCD spectrometer. The spectrometer and UV light source (emitter) are mounted on tripods or other stable platforms. Data processing is computerized. Ammonia is characterized by multiple sharp peaks with relatively small absorbance between the peaks, which is known as "fine feature structure", while H_2S is characterized by a broad absorbance band (peak absorbance at 196 nm with secondary peaks at 192 and 200 nm) that shows no fine feature structure, and therefore is known as a "broad absorber" (Fig. 1).

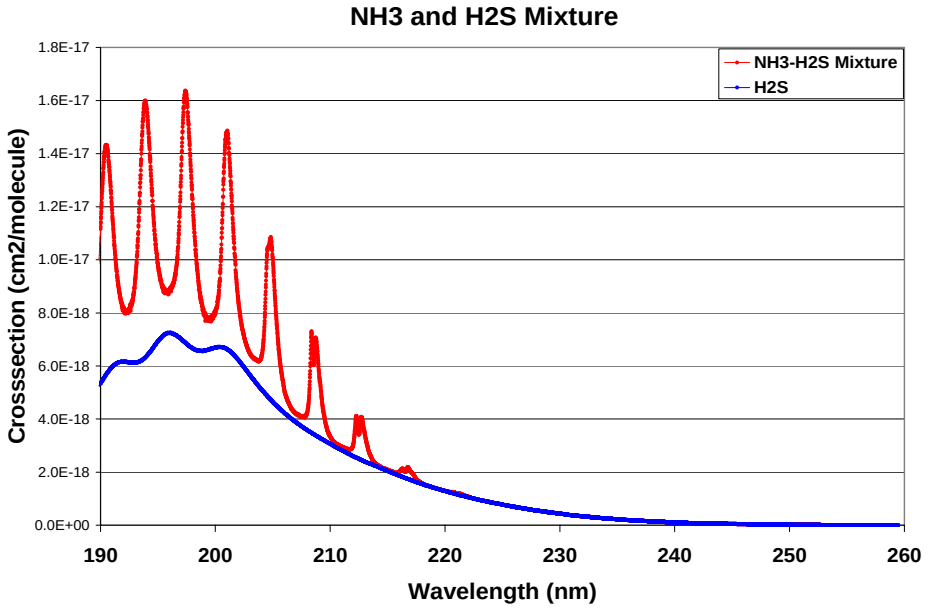

Figure 1. Absorbance characteristics: broad band and fine feature structures.

3. Definitions

3.1.	AU	Absorbance units
3.2.	CLS	Classic least squares
3.3.	CCD	Charge-coupled device
3.4.	EA	Explained Absorbance
3.5.	FA	Filtered Absorbance
3.6.	FOS	Field operations staff
3.7.	HD	Computer hard drive
3.8.	lollipop	A sealed cell that contains a stable calibration gas
3.9.	MDL	Minimum detection limit
3.10.	DOAS	Differential optical absorption spectrometer
3.11.	ppb	parts per billion (volume basis)
3.12.	PC	Personal computer (laptop)
3.13.	PIC	Path-integrated concentration
3.14.	PLS	Partial least squares
3.15.	PM	Program Manager
3.16.	QAPP	Quality Assurance Project Plan
3.17.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.18.	PAML	Purdue Applied Meteorology Laboratory
3.19.	RSD	Relative standard deviation
3.20.	RMS	Square root of a mean squared error
3.21.	USB	Universal serial bus
3.22.	UV	Ultraviolet
3.23.	UVS	UV Sentry

4. Health and Safety

4.1. The transmitter contains a UV-irradiating deuterium lamp. Within 10 ft of the casing, do not look directly at the light source unless wearing UV-filtering eyewear. It can cause permanent damage to eyesight and even blindness.

4.2. Use proper care with the electrical components of the sensor.

5. Interferences

5.1. General interferences that obscure light beam

5.1.1. Dirty windows (loss of sensitivity and possible interruption)

5.1.2. Dirty or deteriorated optical bench components (loss of sensitivity and possible interruption).

5.2. Degradation of backgrounds

5.2.1. The characteristic output of a UV light source degrades over time so beware of older backgrounds (Section 8.2.4.2) because inaccuracies may be introduced to the analytical process when a recent sample is compared to an older sample.

5.2.2. Program the UVS Control to automatically update backgrounds so that if an acquisition is less contaminated than the current background, it will begin using the latest acquisition as background.

5.3. Weather interferences that obscure light beam
  5.3.1. Heavy fog (temporary loss of sensitivity and possible interruption)
  5.3.2. Heavy rain (temporary loss of sensitivity and possible interruption)

5.4. Independent analysis of NH_3 and H_2S is not possible. Because both gases are analyzed together, it must be calibrated using mixtures of the two gases. Otherwise, each gas is an interferent for the other gas (Figure 1), causing inaccuracies.

5.5. Acetic acid is an interferent (Figure 2; broad band absorber with peak absorption at 202 nm) for H_2S analysis but anticipated to be at concentrations below the MDL of the instrument. The acetic acid absorption characteristic are stored in the UVS software and the acetic acid concentration are determined in combination with H_2S using a Partial Least Squares (PLS) analysis method.

5.6. Oxygen is an interferent for NH_3 and H_2S; however, the instrument's software is programmed to account for oxygen at atmospheric levels.

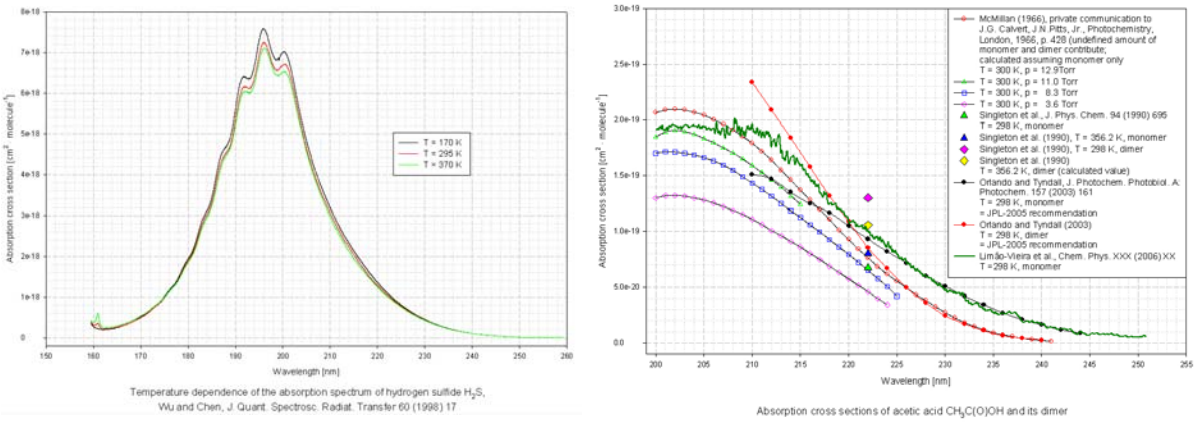

Figure 2. Absorbance spectra of Hydrogen Sulfide and Acetic Acid
Note that the maximum absorbance cross-section for H_2S is $8x10^{-18}$ cm^2 / molecule and for acetic acid is $2x10^{-19}$ cm^2 / molecule. (reproduced from Hannelore Keller-Rudek, Geert K. Moortgat, *MPI-Mainz-UV-VIS Spectral Atlas of Gaseous Molecules*,www.atmosphere.mpg.de/spectral-atlas-mainz)

6. Personnel Qualifications

6.1. Personnel must be trained to use the handheld multimeter, which takes 10 min.

6.2. Field staff members must read and understand the instrument instruction manual and this SOP, and have undergone specific training for the UVS.

6.3. Personnel must be trained in the use of the TEI Model 146 diluter (SOP C3).

7. Equipment and Supplies

7.1. UV-DOAS (UV Sentry, CEREX Environmental Services, Atlanta, GA)
7.2. XStream® RS-232/485 RF Modem
7.3. TEI Model 146 diluter
7.4. Environics Series 4040 Gas diluter
7.5. Laptop computer
7.6. DB9 modem cable
7.7. Nitrogen (N_2) gas cylinders with pressure regulators (SOP G2)
7.8. H_2S gas cylinders with pressure regulators (SOP G2)
  7.8.1. One disposable aluminum cylinder with regulator and about 50 ppm H_2S
  7.8.2. One aluminum cylinder with regulator and about 500 ppm H_2S
7.9. NH_3 gas cylinder with pressure regulator (SOP G2)
  7.9.1. One disposable aluminum cylinder with regulator and about 50 ppm NH_3
  7.9.2. One aluminum cylinder with regulator and about 500 ppm NH_3
7.10. "Lollipop" with benzene (C6H6) gas at a concentration greater than 100 ppm
7.11. 6 in x 4 in flow-through calibration cell to contain the H_2S gas
7.12. Tripods (2) to mount the 6" flow-through cells
7.13. Various lengths of tubing to connect the tanks to the cells
7.14. Adjustable wrench
7.15. Electrical tape

8. Procedures

8.1. Instrument acceptance
  8.1.1. Single-point checks of the NH_3 and H_2S calibrations are made using separate external chambers filled with known quantities of gas.
  8.1.2. Conduct single-point check with interference calibration (Section 8.4.4).
8.2. Instrument installation
  8.2.1. Field setup
    8.2.1.1. Set up tripods at the desired distance, and adjust legs until they are level according to bubble level at the head mount.
    8.2.1.2. Attach UVS by sliding the mounting bracket into the tripod head.
    8.2.1.3. Roughly align UVS using sighting scopes with crosshairs focused on opposing unit's silver hood.
  8.2.2. Hardware setup
    8.2.2.1. Connect power and USB cables to the UV Sentry Receiver.
    8.2.2.2. Connect USB to the monitoring computer.
    8.2.2.3. Start the UVS Software.
    8.2.2.4. If the status window at bottom shows "Not Connected"
      8.2.2.4.1. Go to: Setup → Hardware
      8.2.2.4.2. Click "Manually Select"
      8.2.2.4.3. Under *USB Serial Number*, select: USBxxxxxx
      8.2.2.4.4. Click: *OK*, then *OK* again to return to the main program screen.
    8.2.2.5. Check alignment by clicking *Align*.
    8.2.2.6. Physically align UVS until maximum signal strength is reached..

8.2.2.7. Finally, adjust integration time so that peak value of the curve is between 2500 and 3500 counts, which is indicated by Done button turning green. Click Done to return to the main program screen.

8.2.3. Sampling interval

8.2.3.1. Adjust the sample interval of the UVS to obtain 30-s, 1-min, or 5-min average according to the QAPP specifications.

8.2.3.2. Go to: Setup → Analysis.

8.2.3.3. Choose a sampling interval.

8.2.3.4. Make sure "Dynamically adjust integration period" is selected.

8.2.3.5. Set *Boxcar Smoothing* to 0.

8.2.3.6. Select "Automatically update background".

8.2.4. Backgrounds

8.2.4.1. The ideal background is one free of potential contaminants, if the winds change so that you are upwind of an emission source, a new background may be desirable. To acquire a new background:

8.2.4.1.1. Go to: Acquire → Single Acquisition

8.2.4.1.2. At end of sample period, select: Acquire→Background→Last Acquisition

8.2.4.2. In many situations, a background is available that is known to be clean. To use a stored background:

8.2.4.2.1. Select: Acquire → Background → From File…

8.2.4.2.2. A menu will appear that will enable you to select a UVS xxxxx YYYY-MM-DD.csv file that you know to be a valid background.

8.2.5. Site names and file logging

8.2.5.1. By default, the system logs samples to a directory corresponding to the site name entered at the left of the main program screen.

8.2.5.2. Site Name is predefined (SOP D1) (Do not use dashes, '-',in file name.)

8.2.5.3. Insert the correct distance between tripods in the *Path length* field.

8.2.5.4. Double clicking on the *File Count* in the status bar resets count to 0.

8.2.6. Monitoring

8.2.6.1. The system has two monitoring settings: *Single* and *Continuous*.

8.2.6.1.1. In *Single Acquisition* mode, one data collection is performed and the system stops monitoring. Select *Acquire → Single Acquisition*.

8.2.6.1.2. In *Continuous Acquisition* mode, the system will acquire data until user manually stops monitoring. Select Acquire → Continuous Acquisitions or click *Start Monitoring*. Click *Stop Monitoring* after enough samples have been obtained.

8.3. Communications installation

8.3.1. Connect serial cable from XStream Modem to laptop computer COM port.

8.3.2. Using PC Windows Hyperterminal program on PC, verify configuration of Modem (8 data bits, 1 stop bit, no parity, 19200 baud) (SOP U5).

8.3.3. Connect serial cable from XStream Modem serial output connector to UV-DOAS using 1/8"slotted screwdriver (Fig. 3).

8.3.4. Connect antenna coaxial cable to RF modem.

8.3.5. Verify destination address of Modem (SOP U5).

8.3.6. Provide power to UV-DOAS.

8.3.7. Provide power to radio modem by connecting power cable to power connector and switching on power switch (Fig. 3).
8.3.8. Verify power to radio modem by checking red light (Fig. 3).

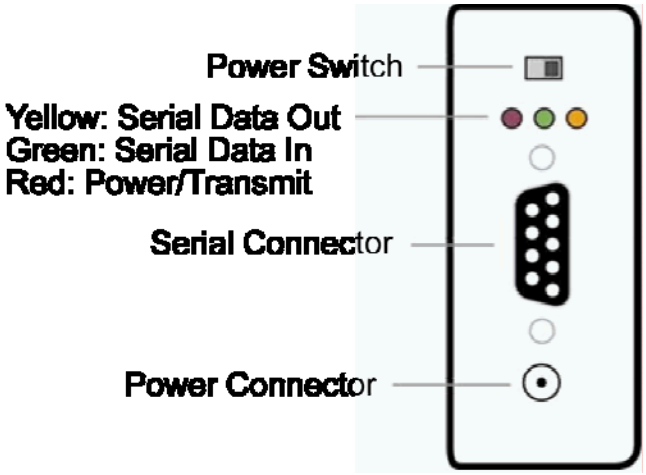

Figure 3. Diagram of radio modem.

8.3.9. Test communication link to PC in trailer.
8.4. Instrument calibration
8.4.1. External calibration chambers
8.4.1.1. Utilize two 6″ x 10 cm flow-through calibration cells.
8.4.1.2. The 6″ cell has a ¼″ Swagelok tubing connection
8.4.2. Calibration gas cylinder with 50 ppm NH_3 in N_2
8.4.2.1. Verify concentration with FTIR (SOP G12).
8.4.2.2. Calibration gas flowing through 10-cm long chamber is at 1% of inlet concentration per meter: 5 ppm-m.
8.4.3. Calibration gas cylinder with 50 ppm H_2S in N_2
8.4.3.1. Verify concentration with FTIR (SOP G12) or fluorescence (SOP G5)
8.4.3.2. Calibration gas flowing through 10-cm long chamber is at 10% of inlet concentration per meter: 5 ppm-m.
8.4.4. Single Point with Interference Calibration Procedure
8.4.4.1. Single point calibrations will be performed in the field but next to the instrumentation trailer.
8.4.4.2. Remove instruments from their respective support structures and mount on portable tripods next to trailer.
8.4.4.3. Set path length between transmitter and receiver at 3 m.
8.4.4.4. Use calibration gases defined in 8.4.2 and 8.4.3.
8.4.4.5. Mount calibration cells on portable tripods next to trailer.
8.4.4.6. Record cylinder reference numbers and chemical concentrations on calibration sheet for calibration cylinders (see verifications in SOP G2).
8.4.4.7. Place the two calibration cells on tripods in beam path as close as possible to the receiver.
8.4.4.8. Align the system to achieve best integration time: 20 – 25 ms for 3000+ counts. Use the UV-DOAS to monitor the alignment and ensure a sustained high signal strength.

8.4.4.9. Make background scan

8.4.4.9.1. Purge first calibration cell with N_2 and cover inlet and outlet ports when finished. This should take anywhere from 1 – 5 min, depending on the flow rate.

8.4.4.9.2. Purge second calibration cell with N_2 at a low flow rate.

8.4.4.9.3. Begin taking a background scan while N_2 is flowing through the cell.

8.4.4.9.4. Set to 30-s averaging and uncheck auto-update integration time and auto-background update. Do not use boxcar smoothing (Fig. 4).

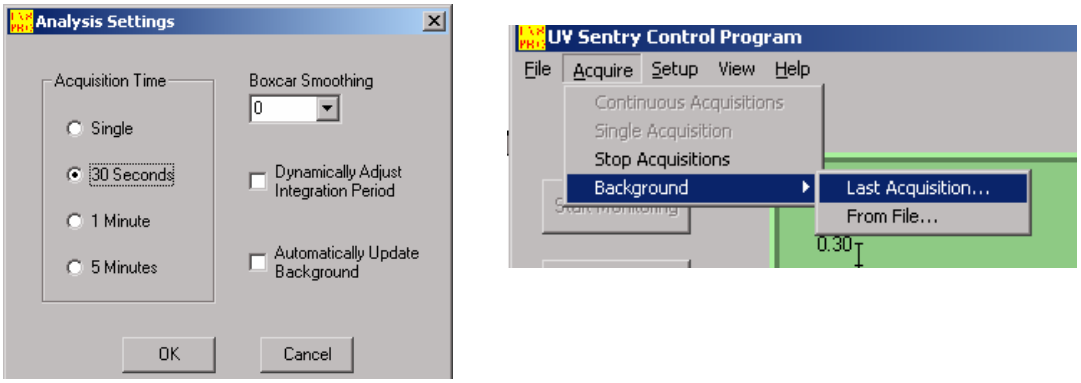

Figure 4. Configuring UVS Analysis Settings and setting a background with the Background → Last Acquisition feature.

8.4.4.9.5. Set this acquisition as the background for UV-DOAS (Fig. 4).

8.4.4.10. NH_3 Calibration Point

8.4.4.10.1. Continue N_2 flow through second cell. Start *Continuous Acquisitions*. [Do not stop *Continuous Acquisitions* until end of test].

8.4.4.10.2. Acquire four 30-s data sets, then shut off the N_2.

8.4.4.10.3. Connect the NH_3 to the cell inlet port and begin flowing gas at 0.2 L/min.

8.4.4.10.4. Acquire fifteen 30-s data sets.

8.4.4.10.5. Calculate mean NH_3 concentration from recorded data in MS Excel.

8.4.4.10.6. Record mean NH_3 concentration on MS Excel Single Point Calibration Data Sheet (Appendix A).

8.4.4.10.7. Purge cell with N_2 for 2 min and cover ports with tape to retain N_2.

8.4.4.11. H_2S Calibration Point

8.4.4.11.1. Remove tape covering the ports to the first calibration cell.

8.4.4.11.2. Connect H_2S tank to the Inlet port of the calibration cell.

8.4.4.11.3. Begin flowing H_2S gas at 0.2 L/min.

8.4.4.11.4. Acquire fifteen 30-s data sets, then shut off the H_2S.

8.4.4.11.5. Calculate mean H_2S concentration from recorded data in MS Excel.

8.4.4.11.6. Record H_2S concentration on MS Excel Single Point Calibration Data Sheet (Appendix A).

8.4.4.11.7. Purge cell with N_2 for 2 min and cover ports with tape to retain N_2.

8.4.4.12. NH_3 and H_2S Combined Calibration Point

8.4.4.12.1. Connect NH_3 to the first cell and begin flowing gas.

8.4.4.12.2. Connect H_2S to the second cell and begin flowing gas.
8.4.4.12.3. Acquire fifteen 30-s data sets with this combined gas configuration.
8.4.4.12.4. Shut off NH_3 gas first. Purge the first cell with N_2.
8.4.4.12.5. Acquire fifteen 30-s data sets with only H_2S again.
8.4.4.12.6. Calculate mean NH_3 and H_2S concentrations from recorded data in MS Excel.
8.4.4.12.7. Record NH_3 concentrations on Calibration Data Sheet (Appendix A).
8.4.4.13. Evaluate measurement accuracy by calculating percent error:

$$\% \text{ Error} = \frac{[(\text{Mean of 15 readings}) - (\text{Gas cylinder concentration})]}{(\text{Gas cylinder concentration})} \times 100\%$$

Use MS Excel. (Example results found in Appendix B)
8.4.4.13.1. Calculate percent error for NH_3 alone, and for NH_3 with H_2S present.
8.4.4.13.1.1. If accuracy <10%, the system is working properly.
8.4.4.13.1.2. If accuracy >10%:
8.4.4.13.1.2.1. Verify placement of flow-through cells in beam path.
8.4.4.13.1.2.2. Verify proper operation of N_2 gas cylinder.
8.4.4.13.1.2.3. Verify proper operation of NH_3 and H_2S gas cylinders.
8.4.4.13.1.2.4. Repeat test.
8.4.4.13.1.2.5. If the system fails twice, pull it from the field.
8.4.4.13.2. Calculate percent error for H_2S alone, and for H_2S with NH_3 present.
8.4.4.13.2.1. If accuracy <10%, the system is working properly.
8.4.4.13.2.2. If accuracy >10%:
8.4.4.13.2.2.1. Verify placement of flow-through cells in beam path.
8.4.4.13.2.2.2. Verify proper operation of N_2 gas cylinder.
8.4.4.13.2.2.3. Verify proper operation of NH_3 and H_2S gas cylinders.
8.4.4.13.2.2.4. Repeat test.
8.4.4.13.2.2.5. If the system fails twice, pull it from the field.
8.4.4.14. Reinstall instruments on their respective support structures.
8.4.5. Multipoint Calibration with Interference Procedure
Because NH3 and H2S concentrations are expected to span several orders of magnitude, verify linear system response with a 4-point calibration that spans the expected range.
8.4.5.1. Multipoint calibrations will be performed at PAML.
8.4.5.2. Calibration of NH_3 with 500 ppm calibration gas
8.4.5.2.1. Verify concentration with FTIR (SOP G12).
8.4.5.2.2. Dilute gas to 5 and 50 ppm using N_2 using a diluter (SOP C3).
8.4.5.2.3. Calibration gas flows through 10-cm long chamber, resulting in an effective path-integrated calibration concentration for the sensor of 10% of that for a 1-m pathlength: Calibration gas inlet concentrations of 5 ppm and 50 ppm correspond to effective path integrated concentrations of 500 ppb-m and 5 ppm-m, respectively.
8.4.5.2.4. Document results on MS Excel Multipoint Calibration Data Sheet (Appendix C).

8.4.5.3. Calibration of H_2S with 500 ppm calibration gas
8.4.5.3.1. Verify concentration with FTIR (SOP G12).
8.4.5.3.2. Dilute gas to 5 and 50 ppm with N_2 using a diluter (SOP C3).
8.4.5.3.3. Effective path integrated concentrations are 500 ppb-m and 5 ppm-m (Section 8.4.5.2.3).
8.4.5.3.4. Document results on MS Excel Multipoint Calibration Data Sheet (Appendix C).
8.4.5.4. Conduct calibration at zero concentration (pure N_2) and at each concentration in isolation and in combination. Follow procedures outlined in Section 8.4.4.9.
8.4.5.4.1. Document results on MS Excel Multipoint Calibration Data Sheet (Appendix C).
8.4.5.5. *Linearity*: Reference spectra are included in the data analysis matrix that span the expected minimum and maximum concentrations. In order to ensure that non-linearity effects do not come into play, the field data must be within the highest and lowest gas concentrations within the analytical matrix. Because the PLS algorithm uses multiple concentrations for each gas, there are no issues associated with non-linearity of absorbance spectra. There is no need for adjustments for non-linearity due to Beer's Law.

8.5. Instrument operation
8.5.1. Setup
8.5.1.1. Connect serial cable from XStream Modem to PC COM port.
8.5.1.2. Using PC Windows HyperTerminal program, verify configuration of Modem (8 data bits, 1 stop bit, No parity, 19200 baud) (SOP U5.
8.5.1.3. Connect serial cable from XStream Modem to UVS COM port.
8.5.1.4. Test communication link to PC in trailer.
8.5.1.5. Locate appropriate input serial channel on PC in trailer (SOP U4) and evaluate output for reasonable values.
8.5.1.6. Generate a background spectrum according to Section 8.2.4.
8.5.1.7. Depending on wind direction and overall monitoring situation, obtain a single beam spectra for the path length of interest when there is no contribution of the target gases from a source upwind.
8.5.1.8. Check maximum peak emission for counts between 2500 and 3000.
8.5.1.9. Set measurement scans for every ~0.5 s averaged to 5 min for each of two instruments.

8.6. Troubleshooting
8.6.1. Communications
8.6.1.1. Verify communications link between radio modems (Yellow and Green lights on modems (Fig. 2).
8.6.1.2. If no communications, verify firm connections for power, signal, and antenna for serial communications. Correct as needed.
8.6.1.3. Verify power to modems by red light (see Fig. 2).
8.6.1.4. Correct as needed.

8.6.2. UV Sentry

8.6.2.1. Integration time of 3500 counts at maximum signal strength should be less than 500 ms, in accordance with Table 1. If not:

8.6.2.1.1. Check system alignment. Correct as necessary

8.6.2.1.2. If alignment is good, either the source needs to be replaced or the optics may have become damaged. In either case, contact PM at PAML: the system should be returned to PAML for instrument check and calibration.

Table 1. Troubleshooting based on integration time.

Integration Time, ms	Deuterium Source (100-m path)
Less than 150	Factory Specification
150 – 500	Data is reliable
500 – 700	Source is degrading
Greater than 700	Replace source

8.7. Data acquisition, calculations & data reduction requirements

8.7.1. Store 5-min averaged spectra as individual 48K (a0) files in Flash memory

8.7.2. Analyze spectra in real time for NH_3 and stored in sequential record file containing scan #, background scan #, NH_3, background NH_3.

8.7.3. Utilize a partial least squares (PLS) data analysis routine to quantify gases that absorb UV light. The method (incorporated into the UVS software) minimizes effects of baseline shifts, cross interference of target gases, and interference of other gases. Key elements of the method are as follows:

8.7.3.1. A data analysis matrix is created that includes all of the target analytes. The matrix includes reference spectra containing gases of interest, as well as interfering species.

8.7.3.2. Absorption spectra are generated by ratioing the field data to a clean air background reference.

8.7.3.3. The absorbance spectra are then smoothed using a Savinski-Golay smoothing filter resulting in the filtered absorbance (FA) spectra. The filter eliminates high frequency noise in the absorbance spectra while maintaining target analytes' sharp spectral features.One peak of the NH_3 absorption feature in the FA spectra is aligned in frequency (pixel shifting for the CCD spectrometer detector) to the reference spectra. Maximum allowable pixel shift is ±1 pixel.

8.7.3.4. The ammonia concentration is determined from the relationship of the FA NH_3 absorption peak and the corresponding peak of the absorption reference spectra using a classical least squares (CLS) technique.

8.7.3.5. The entire ammonia absorption spectra corresponding to the CLS-determined concentration is subtracted from the FA spectra.

8.7.3.6. The remaining portion of the FA spectra is analyzed for H_2S and acetic acid using a PLS analysis method resulting in the determination of the concentration of all compounds found in the PLS calibration matrix.

8.7.3.7. The correlation coefficient between the original FA spectra and the combined explained H_2S, NH_3, and acetic acid (or other analyte) absorption spectra (EA spectra) is calculated

8.7.3.8. The root mean squared (RMS) residual from the regression, representing the unexplained variability in the measured absorption spectra is calculated based on the determined concentrations of NH_3, H_2S (and acetic acid, etc.) according to:

$$\text{RMS residual} = \sqrt{\frac{\sum_{waveband}(FA - EA)^2}{\sum_{waveband}(FA - \overline{FA})^2}} \qquad \text{(Equation 1)}$$

8.8. Computer hardware & software

8.8.1. The instrument is controlled by an embedded computer, which is linked to the LAN.

8.8.2. Record and store data using a second PC (termed 'bLS computer').

9. Data and Records Management

9.1. 5-min integration spectra are stored as individual 48k (a1) files.

9.2. Format of file is: (background PIC, SignalStrength, IntegrationTime, PIC NH3, NH3 measurement error, PIC H2S, H2S measurement error, PixelShift, CorrelationCoeff., RMSresidual).

9.3. Store spectra for each instrument in separate directories (SOP D1).

9.4. Send spectra for each instrument to Purdue through ftp (SOP D1).

9.5. Receipt of raw and post-processed data at PAML will be logged on the transmittal sheet and transferred to the database (SOP D1).

9.6. WINDTRAX/ bLS Emissions measurement method

9.6.1. Measured NH3 PIC is passed from UVS to WINDTRAX program for on-site flux estimation using BLS method (SOP O1) on 'bLS' PC (SOP D1).

10. Quality Control and Quality Assurance

10.1. Precision and accuracy

10.1.1. While TO-16 (USEPA, 1999a) gives no definitive test method for determining precision and accuracy of open-path sensors, it states that a flow-through cell is appropriate for measuring precision and accuracy if the entire light beam passes through an external cell in the beam path.

10.1.2. The UV-DOAS system's precision and accuracy are determined by using an external flow-through cell in its beam path (Appendix B).

10.1.2.1. Determine accuracy according to Section 8.4.4.

10.1.2.2. Determine precision according to Sections 8.4.4.1 through 8.4.4.10.

10.1.2.2.1. Calculate RSD the computed analyte concentration from 15 measurement spectra.

10.1.2.2.2. Precision = RSD of 15 measurements.

10.1.2.2.2.1. If RSD <10% of the difference between the cylinder and average measured values, the system is working properly.

10.1.2.2.2.2. If RSD >10% of the difference between the cylinder and average measured values.

10.1.2.2.2.2.1. Verify the external flow through cells are correctly placed in the beam path.

10.1.2.2.2.2.2. Verify the N_2 gas cylinder is operating correctly.

10.1.2.2.2.2.3. Verify the NH_3 and H_2S gas cylinders are operating correctly.

10.1.2.2.2.2.4. Perform test again.

10.1.2.2.2.2.5. If the system fails the test a twice, replace it.

10.2. Dark Current Correction Check

10.2.1. Charged diode array spectrometers build up a charge over time that is independent of the actual light being detected. This charge buildup is defined as "dark current", and must be subtracted from each single-beam spectrum before data analysis can occur. Although the system can be setup in a manner where the dark current is measured and then manually subtracted out of each individual spectrum, the UVS software performs this task automatically.

10.2.2. Examine the first 15 pixels of a single beam spectrum to determine whether the UVS software is performing this function properly.

10.2.3. Record results on QA sheet (Appendix D).

10.2.4. The average of these pixels should fall within ± 5 counts. Dark current is shown in the bracketed rows of Fig. 4.

10.3. Spectral Feature Match Check

10.3.1. Check is guided and results documented by the "Q-Soft System Calibration Software"

10.3.2. Use absorption peaks of benzene.

10.3.3. Insert a 'lollipop' containing benzene and SO_2 into beam path.

10.3.4. Collect a data spectrum and compare the locations of the measured benzene absorption peaks with the location in the standard benzene peak found in the set of QA reference spectra that are matched to the spectrometer. The QA reference spectra output files are denoted by the letters QA.

10.3.5. Record results on QA sheet (Appendix D).

10.3.6. Difference in peak location should be <2 pixels. If >2 pixels, contact manufacturer for remediation or repair.

10.3.7. Correlation coefficient should be ≥ 0.90. If <0.90, contact manufacturer for remediation or repair.

10.4. Single point calibration check (procedures found in section 8.4.4)

10.4.1. Check is guided and results documented by the "Q-Soft System Calibration Software"

10.4.2. Set path length between transmitter and receiver at 3 m.

10.4.3. Fill first external cell with a known concentration of NH_3.

10.4.4. Fill second external cell with a known concentration of H_2S.

10.4.5. Set signal strength to 3000 counts.

10.4.6. Collect a background scan.

10.4.7. Insert calibration cell in path.

10.4.8. Verify that signal strength is between 2700 and 3300 counts.

10.4.9. Collect five consecutive data sets and observe reported concentrations.
10.4.10. Record results on MS Excel Single Point Calibration Data Sheet (Appendix A).
10.5. Multipoint Calibration Check
10.5.1. Procedures for this are found in Section 8.4.5.
10.5.2. Record results on MS Excel Multipoint Calibration Data Sheet (Appendix C).
10.6. Baseline Stability Test
10.6.1. Set the following system parameters:
10.6.1.1. Integration Time: < 500 ms
10.6.1.2. Sample Time: 30-s average
10.6.1.3. Number of Samples: 12
10.6.2. Collect background spectrum.
10.6.3. Collect designated number of samples.
10.6.4. Convert samples to absorbance spectra.
10.6.5. Open the UVS absorbance viewing software.
10.6.6. Record results on QA sheet (Appendix D).
10.6.7. The total drift at 270 nm should be less than ± 0.002 AU.
10.7. Single Beam Ratio Test.
The single beam ratio test checks the adequacy of the UV Source. A weak UV source that is weak will produce data with low signal-to-noise ratios.
10.7.1. Align instrument at the shortest path length of the study.
10.7.2. Adjust integration time until maximum signal strength is 3500 counts.
10.7.3. For a deuterium source, the maximum peak energy should be near 250 nm. Compare the signal value at 250 nm to the signal value at 210 nm. Record the two signal values and ratio the value at 210 nm to the value at 250 nm.
10.7.4. Record results on QA sheet (Appendix D).
10.7.4.1. The signal value at 210 nm should be greater than 20% of the signal at 250 nm.
10.7.4.1.1. If the signal value at 210 nm is equal to or less than 20% of the signal at 250 nm, contact PM at PAML for remediation.
10.8. Spectral alignment
10.8.1. Alignment of the measured spectrum to the reference spectrum is determined using one peak of the NH_3 absorption feature (Figure 1). This alignment consists of a pixel shift in the spectrometer array. Maximum allowable pixel shift is 1 pixel.
10.8.1.1. If the pixel shift > 1 and NH_3 PIC < MDL, set NH_3 PIC to ½ MDL and the H_2S PIC is indeterminate by automated processing.
10.8.1.1.1. Post-process FA for H_2S using PLS assuming NH_3 is zero. If still no H_2S quantified, set to ½ MDL.
10.8.1.2. If the pixel shift > 1 and NH_3 PIC > MDL, compare pixel shift against the spectral feature alignment check (paragraph 10.3)
10.8.1.2.1. If the spectral feature alignment check < 2, set H_2S PIC to ½ MDL.

10.9. Correlation coefficient

10.9.1. The correlation coefficients of the measured spectra compared to the spectral quantification of H_2S, NH_3 and acetic acid absorption spectra is calculated. Values must be greater than 0.75.

10.9.1.1. If $r^2 < 0.75$ and NH_3 PIC < MDL, set NH_3 and H_2S PIC to ½ MDL.

10.9.1.2. If $r^2 < 0.75$ and the NH_3 PIC > MDL, set H_2S PIC to ½ MDL.

10.10. Analysis residual

10.10.1. The residual of the spectral quantification, or unexplained variability in the absorption spectra, is calculated based on the determined concentrations of NH_3, H_2S and acetic acid. Values must be less than 0.25.

10.10.1.1. If residual > 0.25 and the NH_3 PIC < MDL, set the NH_3 and H_2S PIC to ½ MDL.

10.10.1.2. If residual > 0.25 and the NH_3 PIC > MDL, set H_2S PIC to ½ MDL.

10.11. If the instrument records no measured PIC, set PIC to ½ MDL.

11. References

11.1. Hannelore Keller-Rudek, Geert K. Moortgat, 2006. *MPI-Mainz-UV-VIS Spectral Atlas of Gaseous Molecules,*www.atmosphere.mpg.de/spectral-atlas-mainz.

11.2. SOP C3. 2006. Operation of the Thermo Electron Model 146C Multi-gas Diluter. Standard Operating Procedure C3. Purdue Ag Air Quality Lab.

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11.4. SOP G2. 2006. Compressed Gas Cylinders. Standard Operating Procedure G2. Purdue Ag Air Quality Lab

11.5. SOP G5. 2006. Measurement of Hydrogen Sulfide (H2S) with the Thermo Electron Corporation Model 450C Pulsed-Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab.

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11.17. Xstream Model Manual. 2005. XStream-PKG-R RS-232/485 RF Modem. Product Manual v4.2B, Maxstream, Lindon, UT.

12. Contacts

12.1. UV-DOAS Manufacturer: CEREX Environmental Services Inc., 739 Trabert Avenue, N.W., Building 2, Suite D, Atlanta, GA 30318 USA
12.1.1. Phone: 404-352-0210
12.1.2. Fax: 801-858-7844
12.1.3. e-mail: don@cerexenv.com
12.2. Modem Manufacturer: Maxstream, Inc., 355 South 520 West, Suite 180, Lindon, UT 84042
12.2.1. Phone: 801-765-9885
12.2.2. Fax: 801-765-9895
12.2.3. e-mail: rf-xperts@maxstream.net

	A	B	C
1	UVS File F	2	
2	Site	South Park #1a	
3	Pathlength	72	
4	File Count	9935	
5	Integration	600	
6	Averages	100	
7	Date	11/24/2004 8:37:51 AM	
8	Operator	Walter	
9	Reference	South Park #1a-9933	
10	Signal Stre	2476.594248	
11	Reference	11/24/2004 8:29:00 AM	
12			
13			
14	176.11	0	
15	176.1851	0	
16	176.2603	-4.595752869	
17	176.3354	-6.910064392	
18	176.4106	-2.425752869	
19	176.4857	-4.460064392	
20	176.5608	-0.145752869	
21	176.636	2.379935608	
22	176.7111	3.834247131	
23	176.7862	14.09993561	
24	176.8613	5.064247131	
25	176.9364	2.259935608	
26	177.0116	5.364247131	
27	177.0867	6.019935608	
28	177.1618	5.274247131	

Figure 4. Dark current rows.

Appendix A:Single point UV-DOAS Calibration Sheet

UVDOAS Serial Number _____ Date (MMDDYY) _____ Time (HH:MM) _____

NH_3 cylinder reference number _____ H_2S cylinder reference number _____

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Certified Gases			**Measured Analyte**				
Analyte: Gases present	**Conc.**	**Conc.**	**Mean**	**SD[1]**	**Accuracy[2]**	**RSD**	**Operator**
		ppm-m	**ppm-m**	**ppm-m**	%	%	
NH_3							
H_2S							
NH_3: NH_3+H_2S ppm-m							
H_2S: NH_3+H_2S							

[1]Standard deviation

[2]Accuracy = 100% * (Measured concentration – Certified concentration) / (Certified concentration)

Appendix B
Assessments of Detection Limits, Precision, and Accuracy

1) Detection Limits

Laboratory (negligible sources of NH_3 or H_2S):

The procedure for determining the detection limits for ammonia (NH_3) and hydrogen sulfide (H_2S) with a 2 m physical pathlength was:

- Generate 16 sequential spectra using a UVS.
- Create 15 absorption spectra using the back to back spectra.
- Quantify the target analytes using the standard PLS matrix for NH_3 and H_2S,
- Calculate the standard deviation of the 15 quantifications.
- Calculate the MDL by multiplying the standard deviation by three.

Results from CEREX, Inc laboratory test, Spring 2006:
The MDL for NH_3 was 138 ppb-m.
The MDL for H_2S was 317 ppb-m.

Field (lagoon environment with acetic acid, NH_3, H_2S):

The procedure for determining the detection limit for hydrogen sulfide (H_2S) with a 100 m physical pathlength with negligible H_2S present was:

- Generate 10 sequential spectra using a UVS.
- Create 10 absorption spectra using the back to back spectra.
- Quantify the NH_3 using CLS technique.
- Subtract quantified NH_3 from absorption spectra and quantify H_2S using the standard PLS matrix.
- Calculate the standard deviation of the 10 quantifications.
- Calculate the MDL by multiplying the standard deviation by three.

Results from three replicates under field conditions on 10-9-2006 indicated the MDL for H_2S was 1903 ppb-m.

2) Precision and Accuracy:

The laboratory precision and accuracy of the UVS for H_2S and NH_3 was determined using:

- 50 ppm H2S calibration gas cylinder with 15-cm flow through cell
- 311 ppm NH3 calibration gas cylinder with 1-cm flow through cell

The procedure for determining the precision and accuracy of a target analyte in the field was as follows:

- Place the external cell in the 2-m beam path of the open-path UV system
- Flow N2 through the cell until three volume changes occurred
- Collect a data spectrum.
- Flow the target analyte through the cell for a total of three volume changes
- Collect fifteen data spectra

- Purge the system with N2 and obtain another data spectrum

Example results from CEREX, Inc laboratory test, Spring 2006:
Determination of Accuracy:

Gas	Reference	n	Mean	Accuracy
	ppm-m		ppm-m	%
NH_3	31	15	31.77	1.7
H_2S	75	15	77.60	2.6

Determination of Precision

Gas	n	Mean	St. Deviation	Precision
		ppm-m	ppm-m	%
NH_3	15	31.77	1.34	4.23
H_2S	15	77.60	2.64	3.39

Appendix C: Multipoint UV-DOAS Calibration Sheet

UVDOAS Serial Number _____ Date (MMDDYY) _____ Time (HH:MM) _____

NH_3 cylinder reference number _____ H_2S cylinder reference number _____

Certified Gases							Measured Analyte				
Nominal NH_3 Inlet Conc.	Dilution	Actual NH_3 Inlet Conc.	Nominal H_2S Inlet Conc.	Dilution	Actual NH_3 Inlet Conc.	Analyte: Gases present	Mean	SD[1]	Accuracy[2]	RSD	Operator
ppm			ppm				ppm-m	ppm-m	%	%	
500			0			NH_3:NH_3					
50			0			NH_3:NH_3					
5			0			NH_3:NH_3					
0						NH_3:NH_3					
0						H_2S:H_2S					
0						H_2S:H_2S					
0		0				H_2S:H_2S					
0		500				$_2S$:H_2S					
500		50	500			NH_3: NH_3+H_2S					
50		5	500			NH_3: NH_3+H_2S					
5		0	500		H	NH_3: NH_3+H_2S					
500			50			NH_3: NH_3+H_2S					
50			50			NH_3: NH_3+H_2S					
5			50			NH_3: NH_3+H_2S					
500			5			NH_3: NH_3+H_2S					
50			5			NH_3: NH_3+H_2S					
5			5			NH_3: NH_3+H_2S					

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[1]Standard deviation [2]Accuracy = 100% * (Measured concentration – Certified concentration) / (Certified concentration)

Appendix D:UV-DOAS QA Sheet

UVDOAS Serial Number _____

Date	Time	Dark current correction check	+/- 5 counts?	Spectral feature match	<2 pixels?	R[1]	>0.90?	Baseline stability drift at 270 nm	<+/- 0.002AU?	Beam energy at 250 nm	Beam energy at 210 nm	210 nm energy /250 nm energy	<20%?	Operator
mm/dd/yy	**hh:mm**	**# counts**	Y/N	**pixels**	Y/N			AU						

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1: R is correlation coefficient

If <u>No</u> is answer any of the above questions, Remediation is needed.

SOP C2. STANDARD OPERATING PROCEDURE FOR MEASUREMENT OF AMMONIA WITH THE BOREAL LASER GASFINDER TUNABLE DIODE LASER ABSORPTION SPECTROMETER (TDLAS)

SOP C2. STANDARD OPERATING PROCEDURE FOR MEASUREMENT OF AMMONIA WITH THE BOREAL LASER GASFINDER TUNABLE DIODE LASER ABSORPTION SPECTROMETER (TDLAS)

Prepared by

Richard H. Grant and Jenafer M. Wolf

Reviewed by

Bill W. Bogan and Albert J. Heber

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The absorption of a laser tuned to 1512 nm will be used to measure ammonia gas concentrations upwind and downwind of open manure storage areas and lagoons.
1.2. The open-path concentration data will be obtained with a Tunable Diode Laser Absorption Spectrometer (TDLAS).
1.3. This procedure applies only to the Boreal Laser GasFinder2.0 TDLAS, which can measure only one gas at a time.
1.4. The stated detection limit for ammonia using this TDLAS is 5.3 ppm-m at 100 m (the test length used in this SOP).
1.5. The reported range of NH3 concentrations in the atmosphere around agricultural open-source manure storages is 1 to 800 ppb.
1.6. The path length of this TDLAS is 10 to 1000 m long.

2. Summary of Method

The open-path TDLAS is a monostatic narrowband spectral absorption instrument designed to measure the concentration of various constituents (here NH_3) in the open air along a path of at most 1 km. The TDLAS consists of an integrated transmitter/receiver unit and a remote, passive retro-reflector array. The transceiver houses the laser diode source, the transmitter and receiver electronics, the detector module, and microcomputer subsystems. The laser light emitted from the transceiver unit propagates through the atmosphere to the retro-reflector and returns to the instrument, where it is focused onto a photodiode detector. A portion of the laser beam is passed through an onboard reference cell to provide a continuous calibration update. These two optical signals are converted into electrical waveforms, which the microcontroller processes to determine the actual concentration of gas along the optical path.

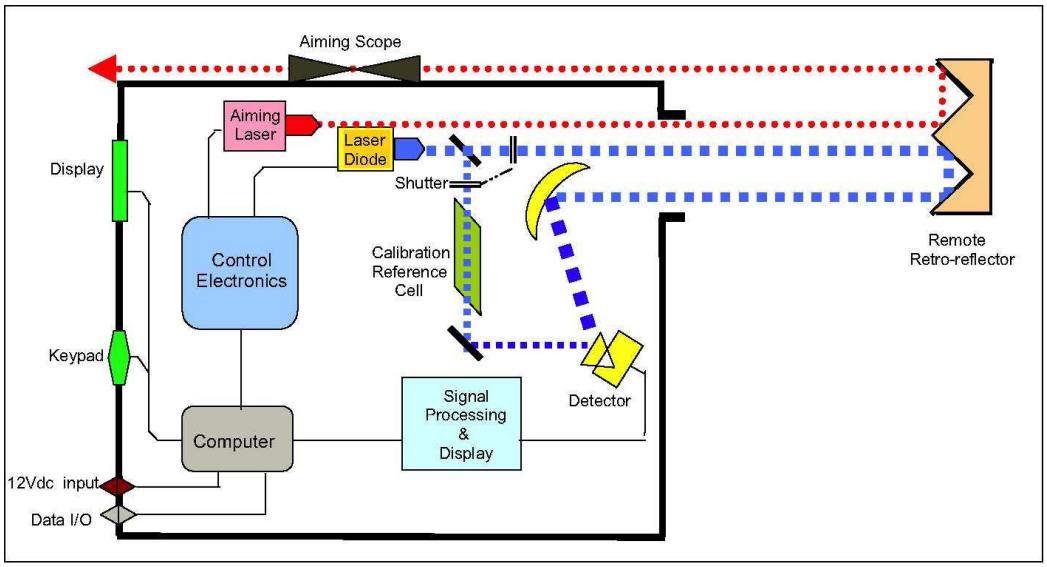

Figure 1. Schematic representation of the GasFinder2.0 TDLAS.

The computed gas concentration is then displayed on the back panel of the instrument. The TDLAS is controlled by a laptop computer linked by hard-wire or radio modem. The TDLAS is mounted on a scanner, which is controlled by the same computer and by the same communications method, and which provides lateral scanning of at least 90° and vertical scanning of at least 15°. The scanner is stepper motor controlled, with a resolution of 0.02^{o}. The concentration data from the TDLAS data, along with the associated scanner position data, is processed by a computer.

3. Definitions

3.1.	FOS	Field operations staff
3.2.	HD	Computer hard drive
3.3.	TDLAS	Tunable Diode Laser Absorption Spectrometer
3.4.	MDL	Minimum detection limit
3.5.	PIC	Path integrated concentration
3.6.	ppm	Parts per million by volume
3.7.	QAPP	Quality Assurance Project Plan
3.8.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.9.	PAML	Purdue Applied Meteorology Laboratory
3.10.	PC	Personal computer
3.11.	Retro-reflector	A reflector composed of a number of reflecting corner cubes resulting in reflections that always return in the same direction as the incoming light.
3.12.	SMP	Site Monitoring Plan

4. Health and Safety

4.1. The Boreal Laser GasFinder 2.0 Instrument contains both visible and invisible (infrared) laser sources. Both sources conform to Class 3a as per ANSI Z136.1-1993, and do not require the use of protective eyewear, protective equipment or special safety measures. There is no optical ignition hazard presented by lasers of this type.

4.2. Misuse or mishandling of electrical equipment may cause electrocution, severe burns, injury, or death.

5. Cautions

5.1. The sensors have electrical components, and proper care should be used as with all electrical equipment.

5.2. The TDLAS outer window is a thin plastic membrane that can tear if mishandled.

5.3. Optical components in the equipment may be damaged if the equipment is dropped.

5.4. The scanner is made of precision mechanical components that may be damaged if dropped.

5.5. Failure to tightly secure the scanner and TDLAS to its tripod can result in damage to the scanner and/or the TDLAS, and possible injury or death.

6. Interferences

6.1. General interferences
  6.1.1. Dirty windows (loss of sensitivity and possible interruptions)
  6.1.2. Dirty retro-reflectors (loss of sensitivity and possible interruptions)
6.2. Weather interferences that obscure light beam
  6.2.1. Heavy fog (temporary loss of sensitivity and possible interruptions)
  6.2.2. Heavy entrained dust (temporary loss of sensitivity and possible interruptions)
  6.2.3. Heavy precipitation (temporary loss of sensitivity and possible interruptions)
6.3. Gases that interfere with NH_3 concentration measurements include CO_2 and H_2O (ETV report, Reference 12.4):

7. Personnel Qualifications

7.1. Personnel must be trained in use of the handheld multimeter. Training takes 10 min.
7.2. Field staff members must read and understand the sensor instruction manual and this SOP, and undergo specific training on this instrument, before operating the TDLAS equipment.

8. Equipment and Supplies

8.1. (2) Boreal Laser GasFinder 2.0 Tunable Diode Laser Absorption Spectrometers with scanner heads
8.2. Distilled water
8.3. Anti-static spray solution
8.4. Tissues
8.5. NH3 calibration gas cylinder and pressure regulator (SOP G2)
  8.5.1. One disposable aluminum cylinder with regulator and about 500 ppm
  8.5.2. One aluminum cylinder with regulator and about 1000 ppm
8.6. CEM Zero nitrogen (N_2) or CEM zero air gas cylinder with regulator (SOP G2)
8.7. Environics Series 4040 Gas diluter (SOP G11)
8.8. TEI Model 146 diluter (SOP C3)
8.9. Lumitek International Model Q-32-R IR Sensor Card
8.10. Calibration chamber
8.11. XStream® RS-232/485 RF Modems
8.12. Laptop computer
8.13. D300 test cable
8.14. D300 interface cable (Model D300AC-CAB-25BO).
8.15. 24-VDC power supply (Model D300AC-APS-30V).
8.16. 12-VDC power supply
8.17. DB9 modem cables
8.18. (2) Short-haul radio telephones
8.19. Tripod

9. Procedures

9.1. TDLAS acceptance

9.1.1. Connect to a 12-VDC, 3-A power supply and switch on (Figure 2).

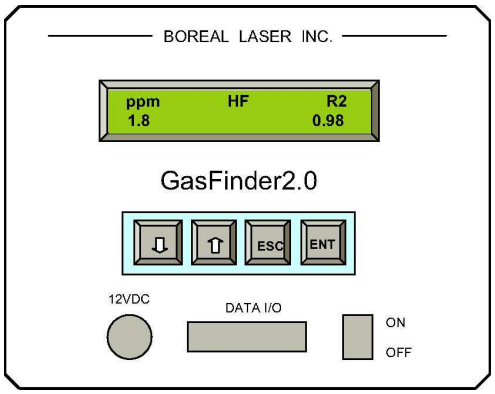

Figure 2. Back panel of TDLAS.

9.1.2. Warm-up cycle lasts approximately 3 min. The display will read:

After the warm-up cycle, the following display may appear:

This indicates that the TDLAS is off-target and requires alignment with the reflector tape.

9.1.3. Press the ENT key twice on the keypad, then the ⇩ key once, and the Light Value display will appear:

This indicates a pre-set default distance of 10 m, and a minimum returning light value of 64 (a light value of < 100 indicates a no-light situation).

9.1.4. Align TDLAS with the visible red aiming laser to point at piece of reflective tape at least 3 m away. Verify the Light Value ranges from 2000-12000. Light level can be decreased by tilting the reflector or rotating the calibration chamber.

9.1.4.1. Verify the distance in the GasViewMP program reads 1.0 meter.

9.1.4.1.1. If the distance is a value other than 1.0 meter, change the value to 1.0 meter in the Aim menu and click OK.

9.1.5. Press the ESC key twice on the TDLAS to return to the normal operating mode. After the computer checks the calibration, the display will read something like:

ppm	HF	R2
4		0.99

9.1.5.1. This indicates a measured path-averaged hydrogen fluoride (HF) concentration of 4 ppm with an R^2 of 0.99 (99%). Note that the actual value for ppm will be displayed in the GasViewMP program if the path length (distance) is set correctly.

9.1.6. The TDLAS instrument is shipped already calibrated.

9.1.7. The TDLAS will undergo an internal calibration check on power-up (See Section 9.3.2).

9.1.8. Check calibration with single-point calibration according to Section 9.3.4.

9.2. Scanner acceptance

9.2.1. Mount scanner on provided tripod.

9.2.2. Connect scanner at D300 base connector (Figure 3) to computer serial COM port and 24-VDC, 2.3-A power supply using the D300 interface cable.

Figure 3: Scanner cable connections.

9.2.3. Using HyperTerminal, set computer port to 9600 baud, 1 start bit, 8 data bits, 1 stop bit, and no parity or handshaking.

9.2.4. Power up the scanner. If power is working, the unit may go through a power-up calibration as soon as power is supplied (not all scanners are programmed to do so).

9.2.5. At power up, the scanner defaults to providing splash text on the computer screen that

will identify the unit configuration. The scanner should go through a reset cycle (pan and tilt axes will cycle through their full range of motion). This reset is completed when an asterisk ('*') appears.

9.2.5.1. If the unit does not reset properly, recheck the power source and cables.

9.2.5.2. If the unit went through its reset procedure, but no text or garbled text appears on the screen, then:

9.2.5.2.1. Check that the host RS-232 host port settings are correct.

9.2.5.2.2. Check that the RS-232 cable is correct for the host computer.

9.2.6. Test scanner motion under TDLAS load.

9.2.6.1. Attach TDLAS to the scanner as a side mount using provided bracket and bolts.

9.2.6.1.1. Test the pan axis: Move the pan axis through its range using the following sequence of commands in HyperTerminal (HT):

Enter in HT	System response in HT	Scanner physical response
dr_	*	
Pp1000_	*	Moves approx. 6° to right
pp-1000_	*	Moves approx..6° to left
pp_	"current pan position is -1000"	

Note: Underline indicates a "space"

9.2.6.1.1.1. A load that is too heavy or moved too quickly will cause unit to lose synchrony, resulting in an audible "rrrr" sound from the pan-tilt unit motors. If this occurs, contact Boreal Laser for remediation.

9.2.6.1.2. Test the tilt axis. Move the tilt axis through its range of motion to test whether the pan-tilt can handle the load using the following sequence of commands in HyperTerminal (HT):

Enter in HT	System response in HT	Scanner physical response
dr_	*	
tp1000_	*	Moves approx. 12° down
tp-1000_	*	Moves approx. 12° up
pp_	"current tilt position is -1000"	

9.2.6.1.2.1. A load that is too heavy or moved too quickly will cause the unit to lose synchrony, which will be accompanied by an audible "rrrr" sound from the scanner. If this occurs, contact Boreal Laser for remediation.

9.3. TDLAS calibration

9.3.1. The factory calibration data are stored in the instrument's software as a standard reference waveform.

9.3.2. At system startup

9.3.2.1. When powered up, the GasFinder automatically centers the laser frequency using the internal reference cell and precise control over the internal laser diode temperature and drive current. The system will display "Calibrating" while it is

calibrating, and the associated GasFinder data status code (Appendix A) will display 2001.

9.3.2.1.1. Upon completion, the GasFinder will be in a standard operating mode displaying gas data and R2 values on the front panel (Figure 2). If the GasFinder automatic calibration fails, the display will read "CAL_ERR" and the status code within the GasFinder serial data string will display a value other than 1. If the system fails this calibration, contact Boreal Laser Inc. for further instructions.

9.3.2.1.2. Verify that the units setting is 'ppm-m'. If set on 'ppm', change to 'ppm-m'.

9.3.3. During operation

9.3.3.1. The internal reference cell scan is compared with the stored waveform at specified intervals with significant deviations generating a QA status code to alert the user to a potential calibration problem.

9.3.3.2. The drift in the absolute absorption of the reference cell is assessed periodically and recorded in the instrument. The sample, reference and calibration waveforms are used to verify that the internal calibration system is functioning correctly.

9.3.4. A single-point calibration check is made using an external chamber filled with a known quantity of gas and measured.

9.3.4.1. Record the gas concentration (50 ppm) of the calibration cylinder (verified as below) on the calibration sheet.

9.3.4.1.1. Concentration of the calibration gas should be directly checked by FTIR (SOP G12), or checked against that of a cylinder which has been checked by FTIR.

9.3.4.1.2. Calibration gas can be mixed with zero air or zero N_2 using an Environics Model 4040 diluter (SOP G11) or a TEI Model 146 diluter (SOP C3) to achieve the desired concentration, if other than 50 ppm. The calibration concentration, either directly from the cylinder or as indicated by the diluter, is the 'Expected concentration'.

9.3.4.2. Insert external calibration chamber in laser path.

9.3.4.2.1. 50-cm chamber made of Teflon tube with Lexan® windows at Brewster's angle.

9.3.4.3. Attach zero air/zero N_2 cylinder to a rotameter, open gas cylinder to a pressure of 20 psi, and adjust the flow control 0.5 L/min (flow verified by rotameter). Once verified, remove tubing connection to rotameter and attach to calibration chamber.

9.3.4.4. Align GasFinder through the calibration chamber according to Sections 9.1.4-9.1.5.

9.3.4.5. Flow zero air into chamber for 5 min.

9.3.4.6. Collect background scans over 1 min while flowing zero air/zero N_2 through the chamber.

9.3.4.7. Attach tubing from zero air/zero N_2 cylinder to the TEI 146I diluter's zero air port, and the calibration cylinder to port A (or other programmed Port).

9.3.4.8. Open both gas cylinders (calibration gas and zero air) to a pressure of 20 psi

9.3.4.9. Connect output port to calibration gas to chamber with tubing.

9.3.4.9.1. Effective concentration of the calibration gas flow through 50-cm chamber is 50% of inlet concentration per meter. For example, 50 ppm concentration calibration gas yields 25 ppm-m path.

9.3.4.9.1.1. Dilute calibration gas with zero air/zero N_2 as necessary with diluter.
9.3.4.9.1.2. Verify flow rate through diluter.
9.3.4.9.2. Allow three exchanges of the chamber volume prior to measurement.
9.3.4.9.3. Rotate calibration cell until the linear correlation r^2 is maximized and concentrations are stabilized. This should occur when the reflected light off the incoming light window is near a minimum.
9.3.4.10. Collect 5 min of consecutive NH_3 measurements.
9.3.4.10.1. In Microsoft Excel, determine the accuracy [(expected-measured)/expected] based on the valid measurements (r2>0.84), and determine the standard deviation of the five (5) 1-min mean measured concentrations. Calculate the relative standard deviation (RSD) based on the measured mean concentration of gas supplied to the external chamber. Results are stored on form similar to Appendix B.
9.3.4.10.2. The ETV Report for TDLAS (Ref. 12.4) documented an MDL of TDLAS for NH_3 is 5.3 ppm-m with dwell time of 1 minute. Accuracy was 1.3% to 9.8% for a 220-m pathlength.
9.3.4.10.3. If the calculated accuracy (RSD) is greater than 10%, then further evaluation of the instrument is indicated.
9.3.4.10.3.1. Repeat calibration verification with 5 min of measurements using NH_3 calibration gas diluted to 200 ppm and recalculate RSD.
9.3.4.10.3.2. If the accuracy (RSD) of this test is less than 10%, the diluter may be introducing noise in the response. Repeat calibration verification with 5 min of measurements using NH_3 calibration gas undiluted (at the full concentration of the calibration gas cylinder) and recalculate the RSD.
9.3.4.10.4. If the accuracy (RSD) continues to be greater than 10% regardless of concentration of supplied calibration gas to the chamber, decommission the instrument. The ETV Report documented an RSD precision of 3.14%.
9.3.4.10.5. If the calculated precision (RSD) is greater than 5% then further evaluation of the instrument is indicated.
9.3.4.10.5.1. Repeat calibration verification with 5 min of measurements using NH_3 calibration gas diluted to 200 ppm and recalculate RSD.
9.3.4.10.5.2. If the RSD is greater than 5%, the diluter may be introducing noise in the response. Repeat calibration verification with 5 min of measurements using NH_3 calibration gas undiluted (at the full concentration of the calibration gas cylinder) and recalculate RSD.
9.3.4.10.5.3. If the RSD continues to be greater than 5% regardless of concentration of supplied calibration gas to the chamber, decommission the instrument is and send to the manufacturer for repair.
9.3.5. Multipoint calibration check. Because the anticipated gas concentrations are expected to span several orders of magnitude, a linear system response should be verified. Thus, perform a three-point calibration spanning the anticipated concentration range.

9.3.5.1. Align TDLAS to have laser reflect off reflector tape at an approximate 3-m distance.

9.3.5.2. Insert 50-cm external calibration chamber into the laser path.

9.3.5.2.1. Use calibration gas concentration of about 1000 ppm (exact value determined following Section 9.3.4.1).

9.3.5.2.2. Dilutions of the 1000-ppm calibration gas can be made using an Environics Model 4040 diluter (SOP G11) or a TEI Model 146 diluter (SOP C3) to achieve the desired concentration.

9.3.5.2.3. Make all dilutions with CEM zero air or CEM zero N_2.

9.3.5.2.4. Calibrations should be made at inlet concentrations of 1000 ppm (undiluted), 500 ppm, and 200 ppm.

9.3.5.2.5. Corresponding integrated path concentrations are 500 ppm-m, 250 ppm-m, and 100 ppm-m. Adjust these values as necessary based on the verified composition (Section 9.3.4.1) of the calibration gas cylinder.

9.3.5.3. For each calibration gas concentration:

9.3.5.3.1. Insert external chamber into laser path.

9.3.5.3.2. Verify signal strength is within 2000 – 12000 range.

9.3.5.3.3. Open zero air/zero N_2 flow into chamber at 0.5 L/min for 5 min and collect background scans as in Sections 9.3.4.3 – 9.3.4.6..

9.3.5.3.4. Collect measurements for 1 min.

9.3.5.3.5. Introduce calibration gas (or dilution thereof) into the cell.

9.3.5.3.6. Adjust orientation and position of the calibration cell until r^2 is maximized and concentrations are stabilized.

9.3.5.3.7. Collect measurements for 5 min according to Section 9.3.4.9.

9.3.5.4. In Microsoft Excel, determine the standard deviation of the discrepancy between actual and measured concentrations at each point of the multipoint calibration. Calculate the percent relative accuracy at each concentration as the absolute value of the difference between the monitor response and the reference gas concentration, divided by the reference gas concentration. Calculate the average accuracy by averaging the percent accuracy at all of the individual calibration concentrations.

9.3.5.4.1. The ETV Report documented an accuracy of 1.3 to 9.8% for a 220-m pathlength.

9.3.5.4.2. If the calculated accuracy (RSD) is greater than 10%, decommission the instrument and send to the manufacturer for repair.

9.3.5.5. Calculate instrument linearity in Microsoft Excel using the regression function, making sure to only use measurements with the same integration time and pathlength.

9.3.5.5.1. The ETV Report documented a linearity of 0.99.

9.3.5.5.2. If the linearity is less than 0.95, decommission the instrument and send to the manufacturer for repair.

9.4. Scanner calibration

9.4.1. The scanner is controlled by step motors, and their proper function dictates proper movement.

9.4.2. The scanner may be configured to reset both the pan and tilt axes automatically upon

power up or when the reset command is issued. If necessary, transmit a manual rest using the GasViewMP program.

9.4.2.1. The reset calibration allows the pan-tilt unit to determine axis coordinates, hence the pan-tilt axis should be reset every time the scanner is powered up (default).

9.5. TDLAS and scanner installation

9.5.1. Power and communication with the TDLAS and scanner can either be directly through a laptop computer (with separate power supplies for each component), or through a combined power supply/RF modems.

9.5.2. Serial communications configuration: 8 data bits, 1 stop bit, No parity, No handshaking, 9600 baud

9.5.3. If using separate power supplies and direct serial connection to laptop:

9.5.3.1. Connect the TDLAS serial/power cable from the TDLAS DATA I/O connector and power connector. Connect the D300 test cable from the TDLAS/scanner D300 base connector to the laptop COM port and USB COM port, the TDLAS power supply, and the scanner power supply.

9.5.3.2. Connect the two power supplies to line power (110VAC).

9.5.3.3. In the field, connect the power/communications unit to the scanner's D300 base connector (Fig. 3) and the payload connector (Fig. 3).

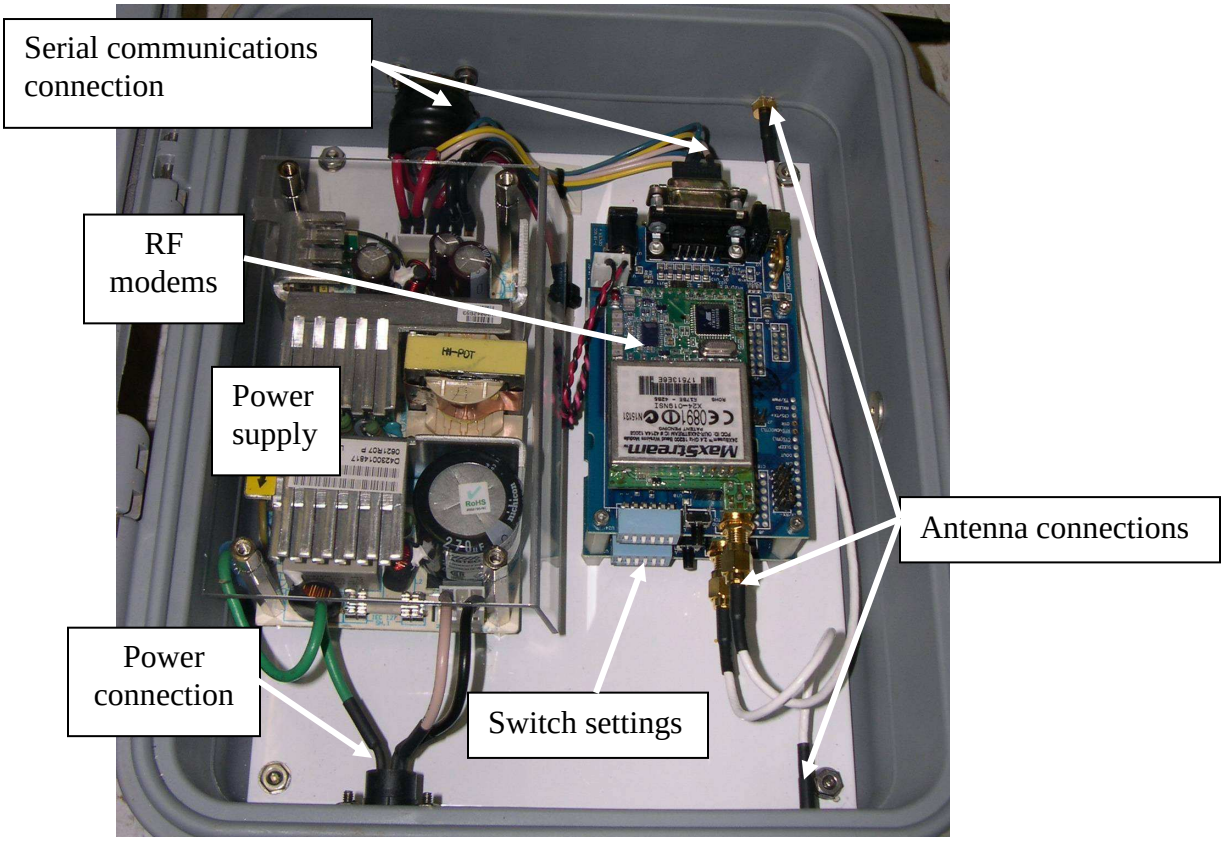

Figure 4. Combined power supply/RF modem unit. Top modem is for the TDLAS, and bottom modem is for the scanner.

9.5.4. If using combined power supply/RF modems:

9.5.4.1. Install laptop in trailer and connect the serial cable from the TDLAS RF modem (Fig. 4) in the instrumentation trailer to first laptop computer COM port and connect the serial cable from the scanner RF modem in the instrumentation trailer to the second laptop COM port (a USB port).

9.5.4.2. Verify that the switch settings on the two RF modems in the TDLAS/scanner power/communications unit (Fig. 4) are identical to the paired modems (one for the scanner and one for the TDLAS) attached to the laptop computer in the trailer.

9.5.4.3. Attach antennae from the trailer roof to the two RF modems in the trailer using coaxial cables.

9.5.4.4. Attach wall power transformers to RF modems in trailer and connect wall power transformers to 110 VAC power.

9.5.4.5. Verify power to radio modems by checking red lights on the modems (Fig. 5).

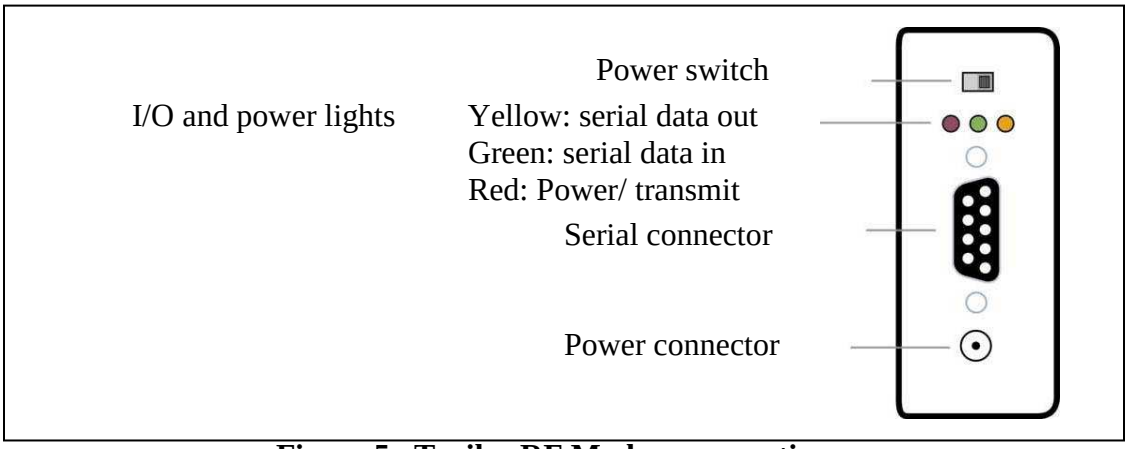

Figure 5. Trailer RF Modem connections.

9.5.4.6. In the field, connect the cable from the power/communications unit (Fig. 6) to the scanner's D300 base connector (Fig. 3), and the TDLAS serial/power cable from the TDLAS DATA I/O connector and power connector.

9.5.4.6.1. Use PC Windows HyperTerminal program on the laptop computer to verify configuration of modem in accordance with SOP U6.

9.5.4.7. Attach both antennae to the power/communications unit.

9.5.4.8. Connect power cord from power/communications unit to 120-VAC line power.

9.5.4.9. Verify power to radio modem by checking red lights on the modems in the power/communications unit (Fig. 6).

9.5.4.10. Test communication link to PC in trailer.

9.5.5. Switch on the TDLAS instrument (the scanner has no start switch but starts on provision of power). The TDLAS requires a 3-min warmup period.

9.5.5.1. Switch power on at TDLAS. Warm up cycle for TDLAS takes about 3 min.

9.5.5.2. Establish communications according to Section 9.5.

9.5.5.3. Locate appropriate input serial channel on computer in trailer (SOP U4) and evaluate output for reasonable values. If TDLAS does not indicate reasonable values, refer to Section 9.8.

9.5.6. Scanner operation

9.5.6.1. Establish communications according to Section 9.5.

9.5.6.2. Warm up consists of scanner going through a reset cycle where pan and tilt axes will cycle through their full range of motion. If scanner does not reset properly, refer to Section 9.10.

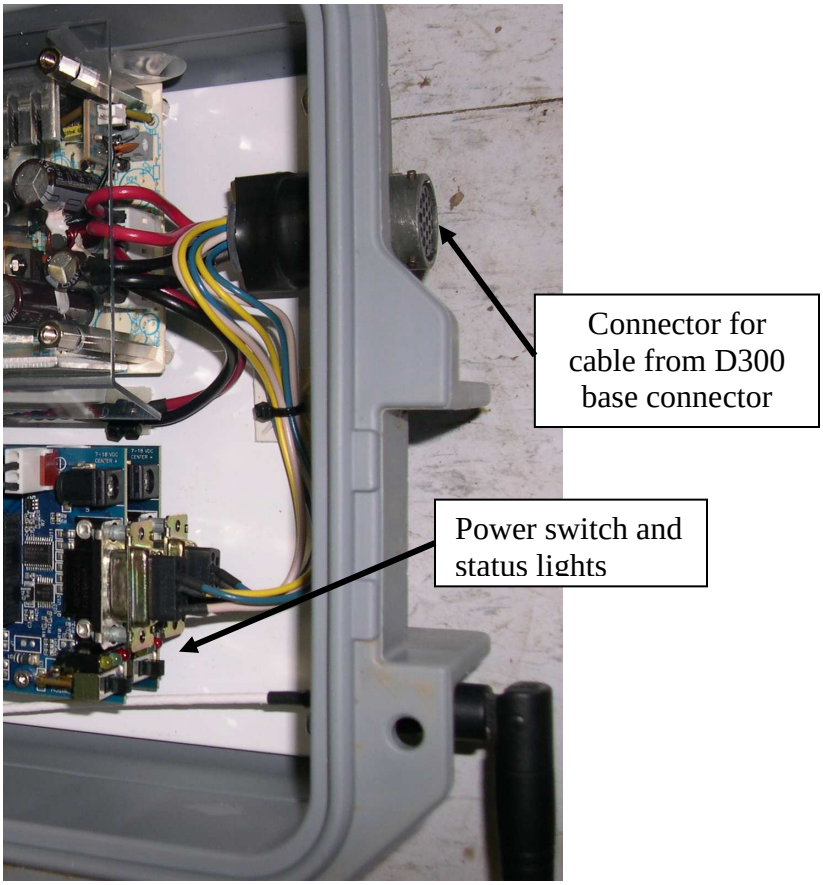

Figure 6. Connections on the combined power supply/RF modem unit.

9.5.7. Start GasViewMP software program on the laptop computer in the trailer.

9.5.7.1. Set number of retro-reflectors to be scanned by the scanner under ‘Options‘, ‘Pan-Tilt Unit’ dropdown menu. Setting is in upper left-hand corner.

9.5.7.1.1. Set scanner parameters as:

9.5.7.1.1.1. Pan and Tilt Hyst to 100

9.5.7.1.1.2. Minimum Acceptable to 3000, Maximum Acceptable to 11000, and Optimum Level to 8000

9.5.7.1.1.2.1. Exceptions will occur at sites with longer or shorter than typical path lengths.

9.5.7.1.1.3. Obstruction Level to 100

9.5.7.1.1.4. Size to 2

9.5.7.1.1.5. Maximum Cross Excursion to 0 and Spiral Excursion to 5

9.5.7.1.1.6. Timeout to 900 sec

9.5.7.2. Click on ‘optimize enable’ under ‘Options‘ dropdown menu.

9.5.8. Sequentially align the retro-reflectors configured according to SOP U5 with the laser head. At 250-m path length, the diameter of the beam is about 375 mm, so the beam area is larger than the area of the retro-reflector (260 mm x 229 mm).

9.5.8.1. Procedure generally requires two people: one at the computer and one at the TDLAS/scanner.

9.5.8.2. Enter “light meter” mode on back of TDLAS as per Section 9.1.3. The red aiming laser will be visible.

9.5.8.3. Position retro-reflectors according to SOP U5.

9.5.8.4. Use alignment routine accessed from ‘AIM’ radio button to center the TDLAS aiming scope crosshairs on a retro-reflector target. The software will have an adjustment for movements of 1-500 steps/move.

9.5.8.5. With the crosshair centered on the retroreflector, you should be able to see a large reflection of the visible laser back through the GasFinder aiming scope. Using the light value displayed on the GasFinder front panel, maximize the GasFinder return light signal using approximately 1 step/move. There is a 1 measurement time delay (roughly 1 sec) associated with a position move and the resulting change of light level.

9.5.8.6. Fine-tune the adjustment so that the displayed light value is near maximum level (16368) or as high as possible.

9.5.8.6.1. If the light value is below 2000, the system is in a low-light situation, and may fail to make a correct measurement. When the light value drops below a factory set value of 500, the system will give a status message on the display indicating “low light -no reading” and an error code will be stored in the instrument (termed ‘checksum’ in Appendix A). To increase the light value, move the crosshairs closer to the center of the retroreflector array or increase the number of retroreflectors.

9.5.8.6.2. If the light value is above the optimal range, the receiver electronics may saturate and spurious readings may be displayed (e.g., unrealistically high concentration values and low confidence factors). Program will optimize light level if optimization has been enabled.

9.5.8.7. Set Dwell Time for 15 sec.

9.5.8.8. Indicate path length next to ‘Distance’ setting. Distance between scanner and retro-reflector is documented in appropriate SMP.

9.5.8.9. Record settings with ‘APPLY’ radio button.

9.5.8.9.1. Record the coordinates of the retro-reflector on paper.

9.5.8.10. Repeat Sections 9.5.8.5 through 9.5.8.8 for each retro-reflector to be scanned by the scanner.

9.5.8.11. Manually perform one full cycle between targets by stepping down through path numbers and record GasFinder light values. If light values are not greater than 2000, return to Sections 9.5.8.4 through 9.5.8.6 for alignment.

9.5.8.12. Verify that each path is aiming at its own designated location.

9.5.8.13. Once complete, click radio button ‘OK’

9.5.8.14. Under ‘Options’, ‘LogFile’ dropdown menu, check “By Clock” and place checkmarks next to 00:00, 06:00, 12:00, and 18:00. Check “Append Timestamp”.

9.5.8.15. Under ‘File’, ‘OpenLogFile’ dropdown menu, browse to find the appropriate directory for storing the new data. If necessary, create this new directory. Name the output file, e.g., TDL1_OH1A.

9.5.8.16. Exit “light meter” mode on back of TDLAS by pressing ESC key twice. The screen on the TDLAS should appear similar to Fig. 2.

9.5.8.17. Initiate scanning by clicking radio button ‘RUN’

9.5.8.17.1. Be sure that the Alarm output on the main GasViewMP screen says 1 when valid light levels are present. If not, then be sure that the instrument is out of alignment mode

9.6. Power up the pan-tilt unit and test its operation according to Section 9.2.6.

9.7. Instrument operation

9.7.1. Two configurations of the TDLAS and scanner are used. Both configurations will scan ten retro-reflectors per cycle (SOP U5).

9.7.1.1. TDLAS and scanner communicating with the control and data acquisition computer in the trailer (SOP U4) by hard-wired D300 interface cable.

9.7.1.2. TDLAS and scanner communicate with the control and data acquisition computer in the instrumentation trailer (SOP U4) by RF modems.

9.7.2. Ensure that the power cables for the TDLAS and scanner on the D300 interface cable are connected to the 12VDC power supply (TDLAS) and 24VDC power supply (scanner). Ensure that the TDLAS Data I/O and 12V power cables are connected to the scanner payload cable (Fig. 3).

9.7.3. Ensure that the scanner and TDLAS serial data connectors on the D300 interface cable are connected to their respective RF radio modems or directly to the COM ports of the control and data acquisition PC.

9.7.4. TDLAS operation

9.7.4.1. Switch power on at TDLAS. Warm up cycle for TDLAS takes about 3 min.

9.7.4.2. Establish communications according to Section 9.5.

9.7.4.3. Locate appropriate input serial channel on computer in trailer (SOP U4) and evaluate output for reasonable values. If TDLAS does not indicate reasonable values, refer to Section 9.8.

9.7.5. Scanner operation

9.7.5.1. Establish communications according to Section 9.5.

9.7.5.2. Warm up consists of scanner going through a reset cycle where pan and tilt axes will cycle through their full range of motion. If scanner does not reset properly, refer to Section 9.10.

9.7.5.3. From the GasViewMP software program running on the laptop computer in the trailer, perform the following:

9.7.5.3.1. Perform one full cycle between targets and record GasFinder light values. If light values are not in the range of 2000-12000, return to Section 9.5 for alignment.

9.7.5.3.2. Initiate scanning.

9.7.5.3.3. Verify that each path is aiming at its own designated location.

9.8. Communications troubleshooting

9.8.1. Verify communications link between radio modems (Yellow and Green lights on modems (Fig. 5).

9.8.1.1. If no communications:

9.8.1.1.1. Verify firm connections for power, signal, and antenna for serial communications.

9.8.1.1.2. Verify power to modems.

9.8.1.1.3. Verify Destination Address of radio modems in accordance SOP W6.

9.8.1.1.4. Check that the correct baud rate is selected (See Serial Communications section).

9.9. TDLAS troubleshooting

9.9.1. If the system is not operating:

9.9.1.1. Check power supply integrity. Verify that the unit is plugged in, and that the fuse and power cable are intact.

9.9.2. If the status message: “Low Light -No Reading” appears:

9.9.2.1. Check that open path is clear, and that no obstruction (vehicle, personnel, etc) is interfering with the signal.

9.9.2.2. Check for dirty windows, and clean as necessary (Section 11.1).

9.9.2.3. Check alignment (Section 11.2)

9.9.2.4. If trying to operate the unit in heavy fog or heavy rain, it may be necessary to wait for improved weather conditions.

9.9.2.5. Verify optical alignment (see Operating Instructions)

9.9.3. If a problem develops with the internal thermoelectric cooler or the associated electronics, the system will protect the laser diode by shutting the laser off. Contact Boreal Laser to resolve this problem.

9.9.4. If the signal being analyzed by the onboard electronics falls below a certain set value, and the returning light level is within the acceptable bounds, this may indicate a problem with the internal receiver electronics. Contact Boreal Laser to resolve this problem.

9.9.5. If the voltage of the portable battery or power supply falls below 11.5V, a ‘B’ will appear in the top right corner of the display. If the voltage falls below 10.0V, the instrument will shut down and enter a “low power” mode after saving all the system variables. In this mode, internal logging of the data will be suspended. After a voltage greater than 11.5V is applied, the instrument will resume normal operations.

9.9.6. If a constant measurement is recorded for more than 1 min

9.9.6.1. Check for clicking sound of shutter changing position of laser path between internal reference cell and outside retro-reflector.

9.9.6.1.1. If there is no clicking sound, contact manufacturer for possible repair.

9.9.7. If no data is being transmitted to the storage computer:

9.9.7.1. Check that the correct handshaking option is selected. (See Section 9.5.2).

9.9.7.2. Check that the TDLAS is on line in the GasView MP program (TDLAS serial number indicated at the top of the graph), and that the data communications cable(s) is (are) connected.

9.10. Scanner troubleshooting

9.10.1. If scanner does not show an introduction page (In HyperTerminal) and go through a reset cycle (pan and tilt axes will cycle through their full range of motion):

9.10.1.1. Recheck power source and cabling, unplug power and replug power to scanner.

9.10.1.2. If problems continue, contact Boreal Laser.

9.10.2. If the scanner went through its reset procedure, but no text or garbled text appears in HyperTerminal:

9.10.2.1. Check that the host RS-232 host port communications settings are correct.

9.10.2.2. Check that the RS-232 cable is correct for the host computer.

9.10.2.3. If problems continue, contact Boreal Laser.

9.10.3. If there is an audible "rrrr" sound from the pan-tilt unit motors during movement, contact Boreal Laser.

9.10.4. If scanner is operating properly but no TDLAS measurements are indicated on either the TDLAS itself or the GasViewMP program, realign retro-reflector.

9.10.4.1. A record of the coordinates of the retro-reflector is beneficial as it provides a good starting point for re-alignment.

9.11. Data acquisition, calculations & data reduction requirements

9.11.1. The data are transmitted as a comma-delimited ASCII string. The format of the string is as follows:

$GFDTA, scanline#,Conc, R^2,dist,light,date_time,ser_num,status_code,* checksum

such as: $GFDTA,3,8.9,18,125.0,6292,2007/12/10 08:05:42, NH3OP-1029,1*52

9.11.1.1. $GFDTA indicates a data value

9.11.1.2. scanline: ranging from 1 to 10, integer

9.11.1.3. Conc: concentration in ppm-m (parts per million meter), real number

9.11.1.4. R2 : value between 0 and 99, Integer

9.11.1.5. dist: user set distance to reflector in meters, real number

9.11.1.6. light: returning light level, Integer

9.11.1.7. date_time: current date and time, YYYY/MM/DD hh:mm:ss

9.11.1.8. ser_num: identification number of the system, String

9.11.1.9. status_code: code giving system operation parameters, Integer. QA status codes are described in Appendix A of this SOP.

9.11.1.10. An asterisk (*) signifies end of string. Each string is terminated by a carriage return and a line feed.

9.11.1.11. checksum: check summing option to verify data integrity, String.

9.11.2. The [NH_3] PIC values are stored as individual files on laptop hard drive according to SOP D1.

9.12. Computer hardware & software

9.12.1. The instrument is controlled internally and communicates with a computer by two serial modems. The computer will record and store the data.

10. Data and Records Management

10.1. Store the measurements of each scan path as individual record strings as (a1) files.
10.1.1. Store measurements for each instrument in separate directories on the HD as specified in SOP D1.
10.1.2. Send data from each instrument to Purdue through ftp according to SOP D1.
10.1.3. Receipt of raw data at Purdue will be logged automatically, and the data will be transferred to a directory for daily quality assurance checks.

11. Quality Control and Quality Assurance

Currently there are no EPA guidance documents that specifically address Quality Assurance (QA) for TLDAS spectroscopy. However, because these systems operate in a similar manner as infrared air monitoring systems, we can borrow from the vast array of QA documentation that has been established for the air monitors.

11.1. Cleaning windows
11.1.1. The instrument relies on a clear optical path to obtain readings of gas concentration. Dust settling on the instrument's window and/or the window of the retroreflector enclosure must be cleaned off whenever it degrades the instrument's performance. The average value for the light level should be kept between 2,000 and 10,000.
11.1.2. Many dusts are very abrasive and care must be taken not to scratch the windows when cleaning them. Follow the recommended procedure for cleaning in the manual.
11.1.3. The need for cleaning will be indicated by a consistent loss of light, which may result in poor gas concentration readings. Cleaning intervals may vary from once per week to once per year.
11.2. Alignment
11.2.1. Difficulty in obtaining an adequate light level after cleaning the windows may indicate that the instrument has moved out of alignment. This may be caused by movement of the base due to vibration or other factors. Details of the alignment procedures can be found in the Operation Manual.
11.2.1.1. Alignment is automatically adjusted within the GasViewMP program optimization routine if optimization has been enabled.
11.2.1.1.1. Scanner moves in search pattern defined by setup parameters (Section 9.5.7.1.1).
11.2.1.2. Optimization routine begins when light level is above obstruction light level and below minimum acceptable light level. GasViewMP reports each position in the optimization routine (resulting from low light level) as a $GFDTA measurement (Section 9.11.1). After specified number of trial positions, the optimized position value is reported as:

$GFMPO, opt_channel, opt_light, opt_status, opt_pan, opt_tilt, opt_date_time ', Checksum

A typical optimization sequence on path #1 is illustrated below:

$GFDTA,1,0.0,0,44.0,6736,2007/12/10 07:50:00, NH3OP-1029,30001*5F
$GFDTA,1,0.0,0,44.0,80,2007/12/10 07:50:03, NH3OP-1029,30010*50
$GFDTA,1,0.0,0,44.0,80,2007/12/10 07:50:05, NH3OP-1029,30010*56
$GFDTA,1,0.0,0,44.0,80,2007/12/10 07:50:06, NH3OP-1029,20010*54
$GFDTA,1,0.0,0,44.0,14067,2007/12/10 07:50:06, NH3OP-1029,20001*68
$GFMPO,1,12165,3,6533,-229,2007/12/10 07:50:08*5A
$GFDTA,1,0.0,0,44.0,12165,2007/12/10 07:50:08, NH3OP-1029,1*61
$GFDTA,1,0.0,0,44.0,9799,2007/12/10 07:50:09, NH3OP-1029,70001*58
$GFDTA,1,0.0,0,44.0,16368,2007/12/10 07:50:11, NH3OP-1029,60001*64
$GFDTA,1,0.0,0,44.0,6103,2007/12/10 07:50:13, NH3OP-1029,60001*58
$GFMPO,1,5227,3,6535,-229,2007/12/10 07:50:14*62

11.2.1.2.1. channel, opt indicates channel being optimized
11.2.1.2.2. opt_status values indicate:
0 – minimum light level not met (keep coordinates)
1 – new path coordinates accepted
2 – Low light detected and optimizing
3 – High light detected and optimizing
4 – Pan-tilt movement error/timeout during optimization(see status code n20 from $GFDTA line).
11.2.1.2.3. opt_pan and opt_tilt are the optimized pan and tilt coordinates

11.3. Internal linearity check
11.3.1. During operation, the instrument's internal reference cell is periodically compared with the stored waveform at specified intervals with significant deviations generating a QA status code to alert the user to a potential calibration problem.
11.3.2. The drift in the absolute absorption of the reference cell is assessed periodically and recorded in the instrument.
11.3.3. Internal check indicated as:
$GFDBG, internaltemp, centerlinedutycycle, refcellquality, refR2, refstatus, supplyvoltage, gain1, gain2, Date_Time, Checksum

For example:
$GFDBG, 12.6, 165, 10344, 97, 0, 1341, 1, 0,2007/12/10 08:06:02*64

11.3.3.1. "internaltemp" is the TDLAS internal temperature (^{o}C)
11.3.3.2. "centerlinedutycycle" is the output of an internal pulse-width modulator that generates a small DC offset current to make adjustments to the laser diode drive current in order to compensate for changes in laser wavelength due to temperature changes. The value is adjusted by the microcontroller by measuring the peak position of the LD wavelength and comparing it to a pre-set value.
11.3.3.3. "refcellquality" is a comparison of the current, live reference cell waveform with the factory-stored calibration waveform. A comparison of 100% would be shown as 10000.

11.3.3.4. "refR2" is the correlation coefficient of the linear regression of the reference cell to the stored waveform of the reference cell on installation

11.3.3.5. "refstatus" value "0" is the normal operation code. Additional codes are given in Appendix A.

11.3.3.6. "supplyvoltage" is the voltage into the GasFinder, in 1/100^{ths} of a volt

11.3.3.7. "gain1" and "gain2" are internal circuit gain values, and are used primarily during setup of the instrument at the factory. Values range from 0 to 3, with 0 being a maximum gain (lowest attenuation) and 3 being lowest gain (maximum attenuation). These values are not necessarily indicative of any particular problem or status of the instrument.

11.3.4. Comparison of repeated measured concentrations in reference cell to actual: Coefficient of Determination (r^2) should be greater than 0.96.

11.4. Each reported measurement has corresponding QA status codes (Appendix A) indicating instrument performance.

11.4.1. Comparison of structure of internal reference cell absorption spectrum to measured spectrum, as evaluated by Coefficient of Determination (r^2), provides a measure of accuracy of measurement.

11.4.2. Company-provided relationship of NH_3 measurement accuracy to r^2:

r^2	Accuracy
>90	+/- 2 %
80	+/- 13 %
70	+/- 24 %
60	+/- 35 %
50	+/- 46 %
40	+/- 57 %
30	+/- 67 %
20	+/- 78 %
10	+/- 89 %
0	+/- 100 %

11.5. Determination of Root Mean Square noise

11.5.1. RMS noise is used to determine the inherent noise of the system. This is an important QA element, as it determines the MDL for the gases of interest.

11.5.1.1. The procedure to measure RMS noise is to collect successive single-beam spectra. The spectra should simulate the standard field setup, including a typical path length for the equipment (100 m), typical integration time for the data collection (1 sec), and typical sample time for each spectrum.

11.5.1.2. Measure concentrations for 15 sec.

11.5.1.3. In Microsoft Excel, determine the standard deviation of the measurements where the r^2 value is greater than 0.90. The MDL is two times the standard deviation.

11.5.1.3.1. The stated detection limit for ammonia is 0.79 ppm-m at 100 m.

11.5.1.3.2. The ETV Report documented a MDL of 5.32 ppm-m for ammonia.

11.6. The sample, reference and calibration waveforms are used to verify that the internal calibration system is functioning correctly.
11.7. If light levels range from 100-3000 or above 11000 on a particular retro-reflector path, the instrument conducts an automatic re-alignment routine to maximize signal strength on that individual path. New pan/tilt coordinates are passed to the GasViewMP program.
11.8. If light levels are between 2000 and 10,000, but r^2 is less than 0.10, no PIC value can be resolved; set PIC to a value one-half the MDL.

12. References

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12.9. SOP G8. 2007. General calibration of Gas analyzers. Standard Operating Procedure G8, v. 1.0. Purdue Ag Air Quality Lab
12.10. SOP G11. 2007. Operation of the Environics Computerized Gas Dilution System. G11, v. 1.0. Purdue Ag Air Quality Lab.
12.11. SOP U4. 2008. Open Source Instrument Trailer. Standard Operating Procedure U4, v. 1.0. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.
12.12. SOP U5. 2008. Installation of Open Source Measurements. Standard Operating Procedure U5, v. 1.0. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

13. Contacts

13.1. TDLAS manufacturer: Boreal Laser, Inc., #13, 51127 RR 255, Spruce Grove, AB, Canada T7Y 1A8
13.1.1. Phone: (780) 987-4382
13.1.2. Fax: (780) 987-2418

13.2. Modem manufacturer: Maxstream, Inc., 355 South 520 West, Suite 180, Lindon, UT 84042
13.2.1. Phone: (801) 765-9885
13.2.2. Fax: (801) 765-9895
13.2.3. email: rf-xperts@maxstream.net

Appendix A- GasFinder2.0 Status Codes

The GasFinder data stream output after the '$GFDTA,scanline#,' is as follows:

122.8,99,235,8835,2002/03/01 10:21:25,HF-1015,2800,*(2F)

122.8	99	235	8835	2002/03/01	10:21:25	HF-1015	**2800**	*	(2F)
ppmm	R^2	Distance	Light Level	Date	Time	Serial Number	**Status Code**	End Of String	Checksum

Status Code **2** **8** **0** **0**

Hex	n_{15}	n_{14}	n_{13}	n_{12}	Hex	n_{11}	n_{10}	n_9	n_8	Hex	n_7	n_6	n_5	n_4	Hex	n_3	n_2	n_1	n_0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1
2	0	0	1	0	2	0	0	1	0	2	0	0	1	0	2	0	0	1	0
3	0	0	1	1	3	0	0	1	1	3	0	0	1	1	3	0	0	1	1
4	0	1	0	0	4	0	1	0	0	4	0	1	0	0	4	0	1	0	0
5	0	1	0	1	5	0	1	0	1	5	0	1	0	1	5	0	1	0	1
6	0	1	1	0	6	0	1	1	0	6	0	1	1	0	6	0	1	1	0
7	0	1	1	1	7	0	1	1	1	7	0	1	1	1	7	0	1	1	1
8	1	0	0	0	8	1	0	0	0	8	1	0	0	0	8	1	0	0	0
9	1	0	0	1	9	1	0	0	1	9	1	0	0	1	9	1	0	0	1
A	1	0	1	0	A	1	0	1	0	A	1	0	1	0	A	1	0	1	0
B	1	0	1	1	B	1	0	1	1	B	1	0	1	1	B	1	0	1	1
C	1	1	0	0	C	1	1	0	0	C	1	1	0	0	C	1	1	0	0
D	1	1	0	1	D	1	1	0	1	D	1	1	0	1	D	1	1	0	1
E	1	1	1	0	E	1	1	1	0	E	1	1	1	0	E	1	1	1	0
F	1	1	1	1	F	1	1	1	1	F	1	1	1	1	F	1	1	1	1

n_{15}	n_{14}	n_{13}	n_{12}	n_{11}	n_{10}	n_9	n_8	n_7	n_6	n_5	n_4	n_3	n_2	n_1	n_0

n_{15} - CAL_ERR: calibration line center error
n_{14} - WAVG_ENAB: averaging enabled
n_{13} - NOT_CALIB: calibration not verified
n_{12} – LOW_BAT: low battery indication
n_{11} - MENU_MODE: unit is currently in menu system
n_{10} - CALIB_ERR: reference cell out of factory calibration
n_9 - OVERFLOW: gas concentration >8 digits
n_8 - OVERRANGE: receiver signal beyond gain switch control

n_7 - LD_COLD: TE Failure, laser diode off line
n_6 – Lt_Lv_ERR: turbulence, timed out
n_5 - NOLOCKDET: receiver unlocked, low signal
n_4 - LOW_LIGHT: laser path blocked, low light
n_3 - R2_LOW: R^2 lower than set minimum value
n_2 - NOT_CTRD: laser not centered on gas wavelength
n_1 - GAS_HIGH: concentration higher than set maximum
n_0 - NO_ERROR: normal operation, no errors

The above sample status code of "2800" corresponds to "0010_1000_0000_0000". This indicates an instrument status of: **n13 - NOT_CALIB, n11 - MENU_MODE**

The following is another example: Code "A42E" would correspond to "1010_0100_0010_1110" and indicate an instrument status of:
n15 -CAL_ERR, n13-NOT_CALIB, n10 -CALIB_ERR, n5 -NOLOCKDET, n3 - R2_LOW, n2 -NOT_CTRD, n1 -GAS_HIGH

Under normal operating conditions, the most common status code is "1". This is actually 0001, but the software ignores the leading zeros and indicates a status code of "1". This corresponds to "0000_0000_0000_0001", and indicates an instrument status of: **n0 - NO_ERROR.**

Appendix B
TDLAS Single Point Calibration Verification Log

Trailer: (EAST/WEST/FIXED)
Site: _____

TDLAS Serial number _____ Operator_____
Date (MM/DD/YYYY):_____
Calibration verification filename ():_____

Calibration cylinder# (_____) concentration: _____ppm
Diluted chamber calibration gas concentration: _____ppm

Trail[1]	TEST	Valid measurement times[2]		TDLAS mean measurement			
		Start	End	Mean	SD	Bias	RSD
	Background						
1	Calibration gas						
	Background						
2	Calibration gas						
	Background						
3	Calibration gas						
	Background						
4	Calibration gas						
	Background						

1: Only one good trial is needed (comments needed if more that one is conducted)
2: Valid measurement times represent the time after 10 min of flow.

Comments:

OPERATION OF THE THERMO ELECTRON MODEL 146C MULTI-GAS DILUTER
Standard Operating Procedure (SOP) C3

OPERATION OF THE THERMO ELECTRON MODEL 146C MULTI-GAS DILUTER

Standard Operating Procedure (SOP) C3

Prepared by

Congna Li

Reviewed by

Bill W. Bogan and Richard H. Grant

Effective Date: November 6, 2006

PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Precise dilution of manufacturer-supplied gases is required during the calibration of the open-path monitoring instruments that are used to monitor emissions from confined animal feeding operations (such as corrals) and open sources (such as lagoons) at livestock facilities.

1.1.1. Typical dilution ratios needed to calibrate open-source monitoring instruments, such as UV-DOAS (SOP C1) and TDLAS (SOP C2) systems are approximately 100:1 to 1000:1.

1.2. This procedure describes the setup and operation of the Thermo Electron Corporation Model 146C Dynamic Gas Calibrator.

1.2.1. The Model 146C can handle zero air flows of 0.2-10 L/min, and span gas flows of 1.0-50 sccm.

1.2.2. The accuracy of each mass flow measurement is 2% of reading or 1% of full scale, whichever is less.

1.2.3. Linearity of mass flow measurement is 0.5% of full scale.

1.2.4. Repeatability of mass flow measurement is 2% of reading or 1% of full scale, whichever is less.

1.2.5. Permeation oven temperature stability is 0.1°C.

2. Summary of Method

The Thermo Environmental Model 146C Multigas Calibrator precisely dilutes calibration gases, which can then be used for precision and Level I span checks, audits, and multipoint calibration of various instrumentation. The Model 146C integrates mass flow controllers, an ozone generator, a permeation tube oven, power supplies, and solenoid valves into a single microprocessor-controlled unit, which can also be controlled remotely using a datalogger or computer. The calibrator uses either permeation tubes (optional add-on) or standard gases as calibration gas sources. The standard Model 146C hardware/plumbing configuration mixes gas and zero air flows. The basic unit can handle three gas standards, which are controlled by individual solenoids and regulated by mass flow controllers; the zero air controller is high-flow, while the gas flow controller is low-flow. The desired concentration is produced in a Teflon mixing chamber. When a permeation gas source is used in conjunction with the gas dilution system, permeation dilution concentration is calculated based on the permeation rate and the flow rate of zero air controlled by the gas dilution system. The permeation oven heats a permeation tube that supplies an internal source of calibration gas. A small amount of zero-air flows through the permeation tube oven and is mixed with the remainder of the zero-air flow in the mixing chamber. Accuracy is achieved through precise control of the release rate of the permeation tube gas and the flow of zero air through the zero-air mass flow controller, as well as maintenance of a stable permeation tube temperature. When only the permeation oven is activated, up to five gas concentration levels (ppm) can be set.

3. Definitions

3.1.	LED	Light-emitting diode
3.2.	MFC	Mass flow controller
3.3.	NIST	National Institute of Standards and Technology
3.4.	QAPP	Quality Assurance Project Plan
3.5.	sccm	Standard cubic centimeters per minute
3.6.	TDLAS	Tunable diode laser acoustic spectroscopy
3.7.	UV-DOAS	Ultraviolet differential optical absorption spectroscopy

4. Health and Safety

4.1. Be careful when connecting the precision standard and dilution gas cylinders to the diluter, especially in the case of toxic, reactive, or otherwise hazardous gases. See SOP G2 for more information on handling gas cylinders.
4.2. Avoid mixing gases that may produce an explosion or other hazardous reaction.
4.3. Be careful when making electrical connections, disconnecting and connecting connectors and making voltage measurements in the instrument as high voltage or current can injure or kill.
4.4. Disconnect power before servicing the unit.

5. Cautions

5.1. Verify that the scheduled calibration date is prior to the expiration date specified on the EPA protocol calibration gas cylinder. Do not use expired cylinders.
5.2. Leave the power on at all times when a permeation tube has been installed. The zero air-air supply should also be connected and active to allow a small flush flow across the permeation tube.
5.3. When determining the actual flow through the mass flow controller, use the LED reading, and not the value set on the potentiometer.

6. Interferences

6.1. Reactive compounds can be lost in this instrument. Follow the procedure to verify that reactive compounds are not lost in the gas dilution system, especially in Methods 15*, 16, and, 25A and 25B (40 CFR part 60, appendix A) when using a gas other than propane.

7. Personnel Qualifications

7.1. Each operator must read and understand this SOP and SOP G2 before working with the instrument. Any operator using this instrument to calibrate the UV-DOAS and/or TDLAS instruments must also read and understand SOP C1 and/or C2, respectively.

7.2. Each operator must be trained in the use of the handheld multimeter, the barometer, water bath, and mass balance before initiating the procedure.

8. Equipment and Supplies

8.1. Model 146C Dynamic Gas Calibrator (Thermo Electron Corporation, Waltham, MA)
8.2. Permeation tube oven and permeation tube(s) containing appropriate gas(es) (optional)
8.3. Internal ozone generator (optional)
8.4. Teflon tubing
8.5. Zero air and span gas cylinders (EPA protocol standard, 1% certification)
8.6. Stainless steel dual-stage gas cylinder regulators as appropriate for the particular gas(es) (SOP G2)
8.7. Wrench to manipulate gas cylinder connections
8.8. NIST-traceable flow calibrator
8.9. NIST-traceable thermometer with a range of 0-45°C
8.10. Water bath (heatable to 45°C)
8.11. Barometric pressure sensor
8.12. Balance with 0.01 mg accuracy
8.13. Ambient air temperature sensor
8.14. 4.369-KΩ Resistor or resistance box capable of providing 4.369 KΩ
8.15. Wire leads with clips to connect to resistance box
8.16. Multimeter

9. Procedure

9.1. Instrument Setup
9.1.1. Connect a source of zero air to the inlet port labeled “ZERO AIR” (Fig. 1).
9.1.2. The zero air source must be capable of supplying the full-scale flow required by the zero air controller (up to 10 L/min) at a pressure between 10 and 40 psi.
9.1.3. Connect the standard gas cylinders to the ports labeled A, B and C (Fig. 1).

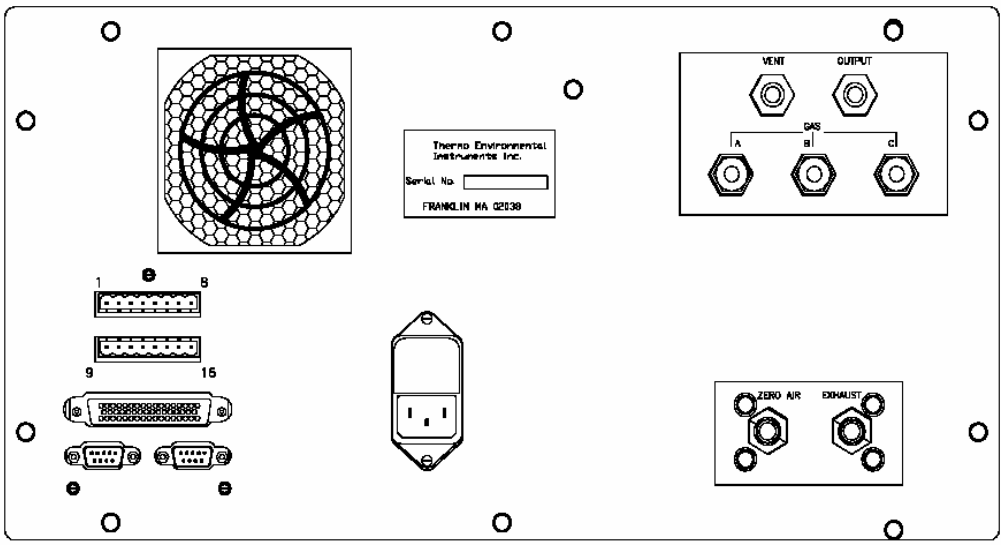


Figure 1. Model 146C Rear Panel.

9.1.4. Install the permeation tube using the following procedure (applicable only if the permeation option is installed):

9.1.4.1. Remove the instrument cover and locate the permeation oven (Fig. 2).

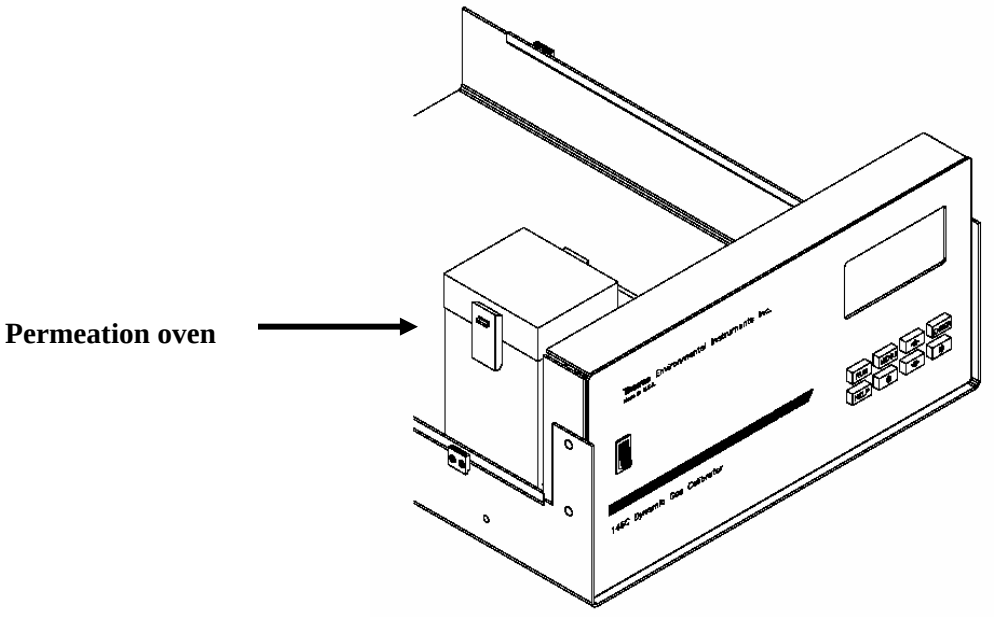


Figure 2. Removing cover of the TEI 146C to access the permeation oven.

9.1.4.2. Release the latches on the sides of the oven cover, and remove the cover.
9.1.4.3. Remove glass chamber assembly by loosening (not removing) knurled screw, located at the top of the chamber, and gently pulling assembly upward. Completely remove assembly from oven (Fig. 3).
9.1.4.4. Separate the glass chamber from the top assembly by twisting and gently pulling glass away from top. Keep glass clean by using Kimwipes or similar material to handle glass.
9.1.4.5. Place permeation tube in chamber.
9.1.4.6. Attach glass chamber to top assembly by gently pushing together with a slight twisting motion.
9.1.4.7. Replace glass chamber assembly into oven until top of assembly is flush or slightly below oven top (Fig. 4).
9.1.4.8. Tighten knurled screw with finger. Do not use tools to tighten.
9.1.4.9. Replace oven cover, being careful to place tubing and wire in slot of cover.

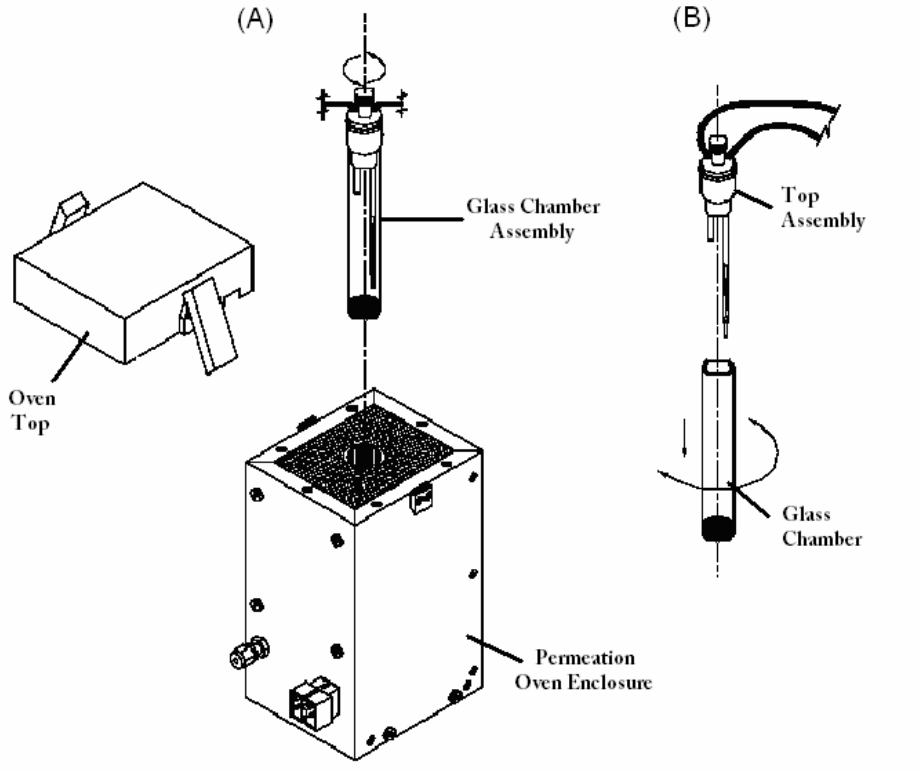


Figure 3. Removing glass chamber from permeation oven (A) and removing top assembly (B).

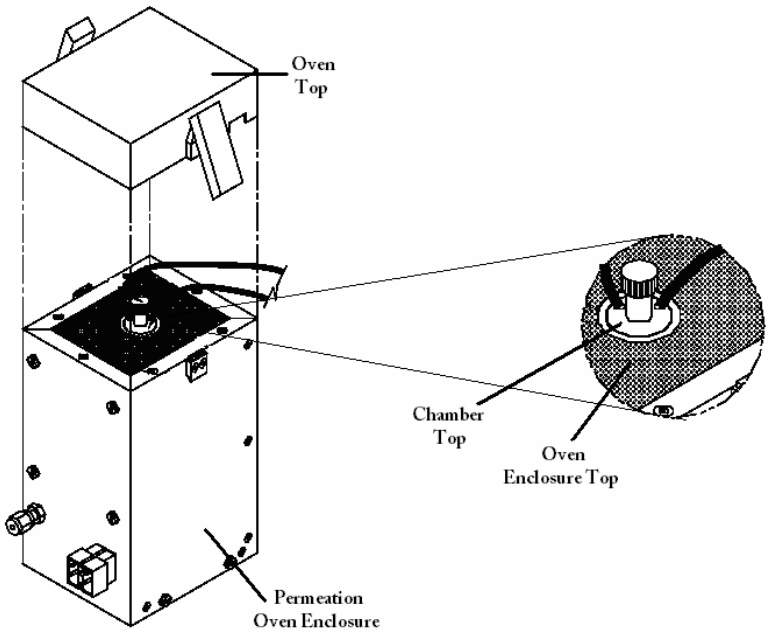


Figure 4. Replacing glass chamber. Inset shows chamber top flush with oven enclosure top.

9.2. Operation

9.2.1. Gas dilution using a gas cylinder

9.2.1.1. Press the "RUN" pushbutton, choose "Run Screen 1", press the "MENU" pushbutton, select the "Local" mode using the ↑ and ↓ pushbuttons, and press "ENTER". Press "MENU" to return to the Main menu.

9.2.1.2. From the "Main Menu", move to Gas A, B, or C by using the ↑ and ↓ pushbuttons. Press "ENTER" to select.

9.2.1.3. Select "Name", move the underscore to select a character, using the ← and → pushbuttons. Select a new character using the ↑ and ↓ pushbuttons. Press the "ENTER" pushbutton to save the selection.

9.2.1.4. Select "Tank Conc", enter the gas concentration using the ← and → and the ↑ and ↓ pushbuttons. Press "ENTER" to save the selection.

9.2.1.5. Select "Span 0 Flow", enter the value of the zero-air flow using the ← and → and the ↑ and ↓ pushbuttons. Press "ENTER" to save the selection.

9.2.1.6. Use the ← and → pushbuttons to select the desired span level (Span 1 to 5, or manual).

9.2.1.7. Select "Span", select the span gas concentration and total flow rate (sum of zero-air and span gas flow) using the ↑ and ↓ pushbuttons. Press "ENTER" to switch to the corresponding screen.

9.2.1.8. Under the “Span” menu, select “Conc PPM”, enter the value of the diluted gas concentration using the ← and → and the ↑ and ↓ pushbuttons. Press “ENTER” to save your selection.

9.2.1.9. Under the “Span” menu, select “Span Flow”, enter the value of the span gas flow rate using the ← and → and the ↑ and ↓ pushbuttons. Press “ENTER” to save your selection.

9.2.1.10. To manually set the zero-air and gas flows, select “Manual” after selecting Gas A, B, or C, use the ↑ and ↓ pushbuttons to select zero-air and gas flow. Press “ENTER”. Then select “ZERO AIR SCCM” to display and modify the zero air flow setting manually, or select “Gas SCCM” to display and modify the span gas flow setting manually using the ← and → and the ↑ and ↓ pushbuttons. Press “MENU” to return to the upper menu or press “ALT” to return to the “Run” screen.

9.2.1.11. Computation of diluted gas concentrations

9.2.1.11.1.

$$\text{Model 146C output (ppm)} = \frac{F_{gas}}{F_{gas} + F_{zero\ air}} \times C_{cyl}$$

Where:

F_{gas} = Flow measured for cylinder gas, sccm.
$F_{zero\ air}$ = Flow measured for zero air, sccm.
C_{cyl} = Concentration of gas in cylinder, ppm

9.2.2. Gas dilution using the permeation tube oven

9.2.2.1. Allow 24 h for permeation tube temperature to stabilize after turning the unit on. If a permeation tube is purchased with a certified rate, R2, at a given temperature, T2, it is possible to calculate the approximate temperature T1 that is needed to achieve permeation rate R1, by using the following equation:

9.2.2.1.1.

9.2.2.1.2. Log R1=logR2-2950(1/T1-1/T2)

Where:

R_1 = Permeation rate in ng/min at T_1,
R_2 = Permeation rate in ng/min at T_2.

9.2.2.2. From Run Screen 1, use the ↑ and ↓ pushbuttons to scroll to the ozone/perm line.

9.2.2.3. Use the ← and → pushbuttons to select the desired permeation level (Perm Levels 1 through 5). Press “ENTER”.

9.2.2.4. Set the flow of zero air in the manual settings screen of the flow controls menu.

9.2.2.5. Allow 24 h for the permeation tube temperature to stabilize.

9.2.2.6. Calculate the permeation rate, R, following Section 9.3.2.3.

9.2.2.7. Computation of diluted permeation gas concentrations

9.2.2.7.1. Model 146C output (ppm) = RK/Q_0

Where:

R = Permeation rate, ng/min
Q_o = Zero air flow rate, sccm
K = Constant for specific permeant = 24.45/MW
MW = Molecular weight of specific permeant

9.3. Calibration

9.3.1. Calibration of mass flow controllers

9.3.1.1. Connect a source of clean, dry air to the inlet of the mass flow controller.

9.3.1.2. Measure barometric pressure and room temperature.

9.3.1.3. Connect a suitable flow meter (NIST-traceable calibrator) to the mass flow controller outlet.

9.3.1.4. Set the Model 146C to “Gas Drive” or “Zero Air Flow Calibration”.

9.3.1.5. Enter the flow meter reading using the flow input screen.

9.3.1.6. Repeat the above two steps for the remaining flow settings.

9.3.1.7. If difficulty is encountered due to a malfunction of the flow controller, contact Thermo Environmental Instruments.

9.3.2. Calibration of permeation tube oven

9.3.2.1. Setting water bath to the desired temperature

9.3.2.1.1. Unplug the connector at J3, from the Oven Controller Board (Fig. 5). Place a 4.369-KΩ resistor across pins 3 and 4 of J3 on the Oven Controller Board.

9.3.2.1.2. From the Permeation Oven Menu, select Cal Oven Thermistor. Adjust R2 on the Oven Controller Board until the oven drive voltage is 5.000 volts. Press MENU to return to the Permeation Oven Menu.

9.3.2.1.3. Remove the thermistor from the permeation tube oven. Leave the thermistor connected to the Oven Controller Board. Insert the thermistor into a water bath next to the NIST-traceable thermometer.

9.3.2.1.4. Turn on the power to the water bath. Using a NIST-traceable thermometer with a resolution of ±0.01°C, adjust water bath to 45.00±0.02°C.

9.3.2.1.5. From the Permeation Oven Menu, select Cal Gas Thermistor. Adjust R4 on the Oven Controller Board until the permeation gas temperature reading is 45.00°C.

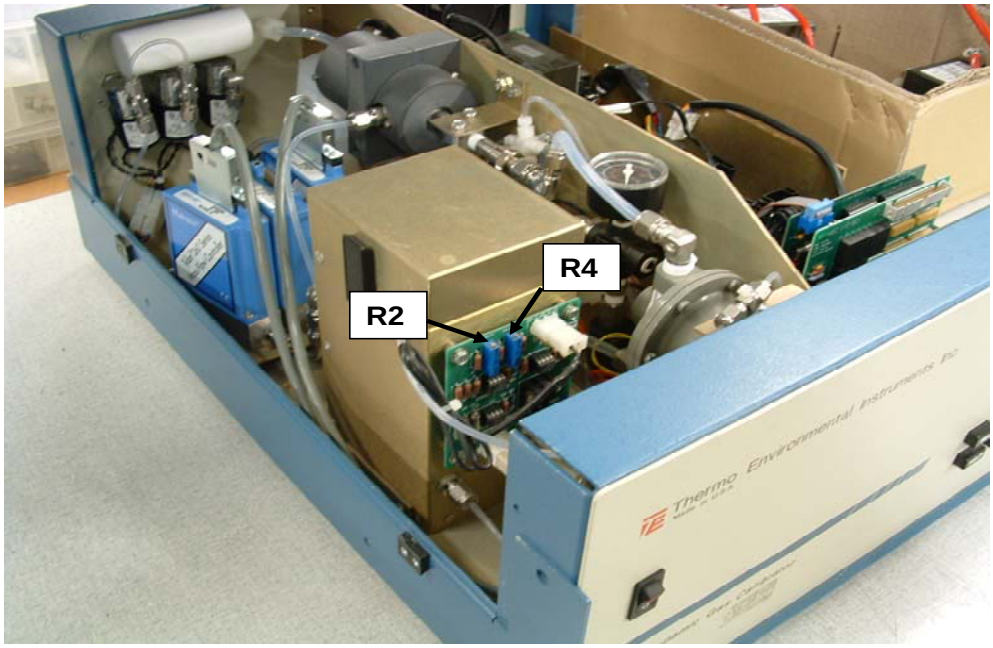
9.3.2.1.6. Remove thermistor from the water bath, dry, and replace into the permeation tube oven.

9.3.2.1.7. Wait for the permeation gas temperature reading to stabilize.

9.3.2.1.8. From the Permeation Oven Menu, select Set Gas Temperature. Adjust R2 until the Perm Gas reading displayed on the first line is 45.00°C. Wait at least 10 min between adjustments.

9.3.2.2. Setting measure temperature with accurately known oven temperature (as an alternative approach to that described in Section 9.3.2.1)

9.3.2.2.1. Unplug the connector at J3, from the Oven Controller Board. Place a 4.369 KΩ resistor across pins 3 and 4 of J3 on the Oven Controller Board.



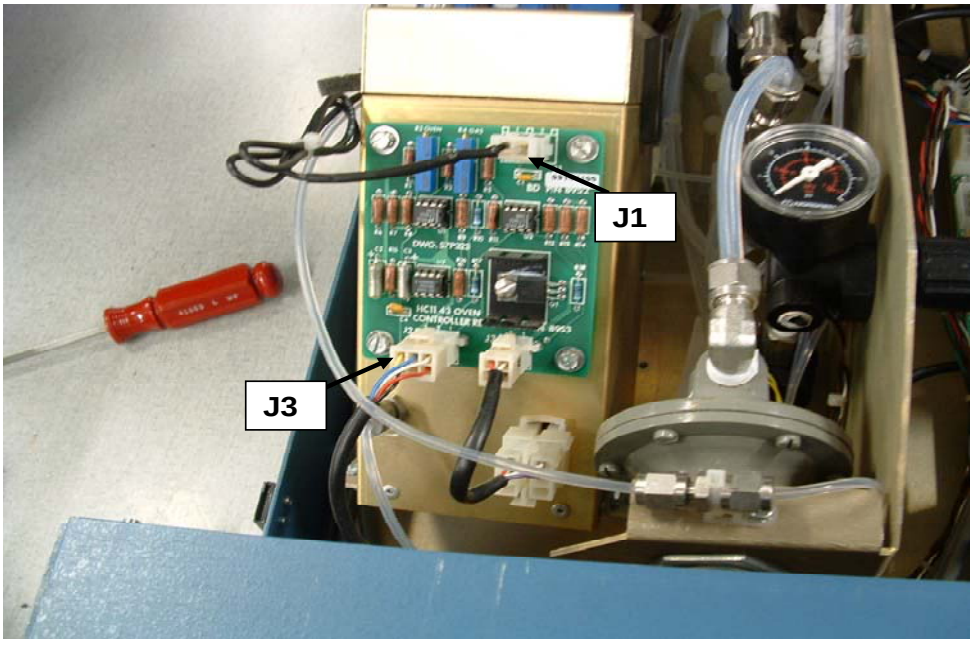


Figure 5. The permeation oven controller board, showing the board's location, the locations of R2, R4, J1 and J3 on the board, and the pin layouts of J1 and J3.

9.3.2.2.2. From the Permeation Oven menu, select Cal Oven Thermistor. Adjust R2 on the Oven Controller Board until the oven drive voltage is 5.000 volts. Press MENU to return to the Permeation Oven menu.
9.3.2.2.3. Unplug the thermistor from J1 on the Oven Controller Board.
9.3.2.2.4. Connect a resistance of 4.369 KΩ across pins 1 and 2 of J1.
9.3.2.2.5. From the Permeation Oven menu, select Cal Gas Thermistor. Adjust R4 on the Oven Controller Board until the permeation gas temperature reading is 45°C.
9.3.2.2.6. Reconnect the thermistor to J1.
9.3.2.2.7. Wait for the permeation gas temperature reading to stabilize.
9.3.2.2.8. From the permeation oven menu, select Set Gas Temperature. Adjust R2 until the Perm Gas reading displayed on the first line is 45.00°C. Since it takes several minutes for the permeation oven temperature to stabilize, wait 10 min between adjustments.

9.3.2.3. Determination of permeation rate by weight loss

9.3.2.3.1. Make sure the oven has been calibrated as described above.
9.3.2.3.2. Gently insert the permeation tube using clean tweezers or similar tool. Never touch the tube with your fingers.
9.3.2.3.3. Turn on the Model 146C.
9.3.2.3.4. Wait 48 to 72 hours for the permeation tube temperature to stabilize.
9.3.2.3.5. Carefully remove the permeation tube from the oven and weigh permeation tube to nearest 1 mg. Perform this measurement as quickly as possible.
9.3.2.3.6. Return permeation tube to the oven.
9.3.2.3.7. Allow permeation tube to permeate at constant temperature with gas flow over tube for a period sufficient to generate a measurable weight loss (usually a minimum of 72 h).
9.3.2.3.8. Reweigh permeation tube to nearest 1 mg.
9.3.2.3.9. Compute the permeation rate, R, in terms of ng/min as:

R = (Initial weight-Final weight)/Time.

9.3.2.3.10. Use the permeation tube in the same oven that was used to determine the permeation tube’s weight loss.

9.3.2.4. Determination of release rate by use of transfer standard

9.3.2.4.1. To perform this procedure, one Model 43C and two Model 146Cs are needed.
9.3.2.4.2. Ensure that the ovens in both of the Model 146Cs have been calibrated.
9.3.2.4.3. Determine permeation rate for permeation tube in Model 146C being used as calibration standard, or install a certified permeation tube.
9.3.2.4.4. Allow the permeation tubes in both Model 146Cs to stabilize at least 48 h.
9.3.2.4.5. Carefully calibrate an analyzer, such as a Thermo Environmental Model 43C, using the Model 146C with the calibrated permeation tube. Follow the instruction for calibration in the 43C instrument manual.
9.3.2.4.6. Connect calibrated analyzer to Model 146C with permeation tube whose permeation rate is to be determined.

9.3.2.4.7. Adjust flow of the Model 146C so that the analyzer reads close to full scale. Note flow and measured concentration.

9.3.2.4.8. Compute permeant concentration from the following equation:

$$\text{Model 146C output (ppm)} = \frac{R \times K}{Q_o}$$

Where:

R = Permeation rate, ng/min

Q_o = Flow rate, sccm

K = Constant for specific permeant $= \frac{24.45}{MW}$

MW = Molecular weight of specific permeant

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this instrument. Supplement this electronic record by a record book designated for this instrument, which should contain copies of the electronic record.

10.2. Manage all data according to SOP B5.

10.3. Document all data and information on field data sheets, and within site logbooks with permanent ink, or in electronic field notes. Overstrike all errors in writing with a single line. Initial and date all such corrections.

10.4. A copy of the manufacturer' instructions for the operation of the instrument, as well as the most recent calibration documentation shall be made available for the project auditor's inspection upon request.

10.5. A label (Fig. 6) shall be affixed at all times to the gas dilution system listing the date of the most recent calibration, the due date for the next calibration, and the person or manufacturer who carried out the calibration.

Calibration date:_____
Next calibration due date:_____
Calibrated by:_____

Figure 6. Sample calibration label.

11. Quality Control and Quality Assurance

11.1. Check and recalibrate the mass flow controller, using a NIST-traceable flow calibrator, whenever the target and actual flow (within the range of 20 to 100% of full scale) deviates greater than ±2% of reading or 1% of full scale, whichever is less. The QAPP for the particular project may have additional requirements.

11.2. Calibrate the permeation tube oven whenever the temperature indicator deviates by 0.2°C (an error of about 0.1°C corresponds to an error of 1% in release rate).

11.3. Calibrate the flow calibrator, thermometer, water bath, barometric pressure sensor, balance and ambient air temperature sensor at the initiation of the study and annually thereafter, unless the QAPP specifies otherwise.

12. References

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12.3. SOP B5. 2006. Data Management for Barns. Standard Operating Procedure B5. Purdue Ag Air Quality Lab.
12.4. SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UV Sentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Applied Meteorology Lab.
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SYNTHETIC OPEN-PATH SAMPLING SYSTEM
Standard Operating Procedure (SOP) C4

SYNTHETIC OPEN-PATH SAMPLING SYSTEM

Standard Operating Procedure (SOP) C4

Prepared by

Juan Carlos Ramirez, Richard H. Grant, Bill W. Bogan, Scott Cortus, and Sam M. Hanni

Reviewed by

Albert J. Heber

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. This method is used for continuous real-time sampling of airborne gases, for example, those downwind of an open source area, and provides a path-integrated concentration, comparable to open-path techniques.
  1.1.1. This method allows the use of analyzers that can measure gases not measurable by standard open-path techniques, e.g. TDLAS (SOP C2).
  1.1.2. Any gas for which a suitable detector can be configured for real-time, unattended operation can be measured with this method.
  1.1.3. Any gas for which adsorption/desorption in tubing does not prohibit real-time measurements given the sampling intervals of the technique can be measured with this method.
1.2. The maximum practical length of the path that can be sampled with this method is approximately 1000 ft (330 m).
1.3. The sensitivity of the measurement does not depend on path length.
1.4. The desired residence time for an air sample in the tube is approximately 20% of the sampling period. The flow rate of the sampling pump should be adjusted to achieve this.
1.5. This procedure applies only to single-tube sampling lines, with multiple inlets spaced along their length to sample across a plume.
1.6. The GSS draws air through long sampling lines from one or more sampling points, and provides a mixed sample for analysis by gas analyzer(s) or auxiliary manual (bags, sorbent tubes, impingers, and canisters) collection. Delivery of calibration gases to the analyzer(s) is also facilitated with the GSS.
1.7. The minimum detection limit (MDL) for this method is determined by the detection limit of the detector being used.
  1.7.1. This method does not cover the analyzer or detector. Consult the relevant SOP for the detector in question for that information.
1.8. Data generated using this method is analyzed using the Backward Lagrangian Stochastic (bLs) method (SOP O1) or a ratiometric method referenced to a path-integrated concentration measurement.

2. Summary of Method

2.1. The synthetic open-path method consists of a long section of tube (Teflon or other suitable material) that samples along a line intersecting a plume resulting from gases emanating from a contaminant source. Multiple air inlets are spaced at equal distances along the tube to draw air samples from several discrete locations within the plume. The inlet flow rates through the air inlets are adjusted using flow restricting orifices and measured using a mass flow meter to ensure equal flows and avoid biased sampling of the plume. The tube functions as a combining manifold, blending the incoming sample streams as they are drawn through the tube by the sampling pump. Suitable flow rates are calculated based on a single diameter tubing and the assumption that the outlet of the system will be located at one extreme end of the main tube. The maximum inlet air residence time and the variance of inlet air residence times in the system can be reduced by using multiple tube diameters in the main line. After passing through the tube, the

blended air sample is subsampled in the GSS for the target gas(es). The GSS and analyzers are generally contained in a suitable instrument shelter at the site to allow for long-term, continuous, unattended operation.

2.2. The GSS was developed by the Purdue Agricultural Air Quality Laboratory (PAAQL) in 2006, and supersedes the GSS described by Heber et al. (2006, in press). It has sampling and bypass manifolds that are arranged in a parallel configuration on a sloped mounting board (Fig. 4). Compared to the previous design, it has better gas leakage/blockage prevention, lower gas adsorption/desorption time, and more convenient operation and maintenance. A schematic diagram of the GSS, as it is integrated with the other components at a site (gas analyzers, DAC system) is presented in Fig. 5.

2.3. A sampling pump draws air from a S-OPS at 4-7 L/min, while a bypass pump composites all unsampled S-OPS lines and purges them simultaneously with a total flow of about 10 L/min. The sample air is continuously delivered to a slightly positive-pressure analyzer manifold, from which each gas analyzer draws continuous subsamples. The sample air is optionally delivered to a manually operated valve for collecting samples for offline analysis.

2.4. A data acquisition and control (DAC) system controls the automatic or manual sequential gas sampling through an array of independently-controlled 3-way solenoid valves in the GSS. Typically, air from only one sampling location at a time is provided to the sampling and analyzer manifolds. The GSS has built-in continuous sensors that measure pressure (positive or negative) in the sampling manifold and the flow rate of the sampling air. Sensor data is recorded by the DAC system.

2.5. This GSS is enclosed and is heated by thermal energy dissipated by the pumps and solenoids. The increased GSS temperature reduces adsorption/desorption of gases and helps to prevent condensation.

3. Definitions

3.1.	AI	Analog input
3.2.	bLs	Backward Lagrangian stochastic
3.3.	DAC	Data acquisition and control
3.4.	DAQ	Data acquisition
3.5.	DO	Digital output
3.6.	GSS	Gas sampling system
3.7.	TDLAS	Tunable diode laser absorption spectrometry
3.8.	M_a	Analyzer manifold
3.9.	M_b	Bypass manifold
3.10.	M_c	Calibration manifold
3.11.	MDL	Minimum detection limit
3.12.	M_s	Sampling manifold
3.13.	NC	Normally closed (air normally directed to bypass manifold)
3.14.	NO	Normally open (air normally directed to sampling manifold).
3.15.	PIC	Path-integrated concentration
3.16.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.17.	PAML	Purdue Applied Meteorology Laboratory

3.18. PC Personal computer
3.19. PM Particulate matter
3.20. QAPP Quality Assurance Project Plan
3.21. SMP Site Monitoring Plan
3.22. S-OPS Synthetic Open Path System

4. Health & Safety

4.1. Check with the producer to make sure the area is free of underground wires, pipes, etc before digging post holes or driving the support stakes for the sampling line.
4.2. The GSS has two 120-VAC vacuum pumps. Follow electrical safety rules when working on the pumps.
4.3. Air sampled from the open-area sources may contain air pollutants with high concentrations that could cause negative health effects. Properly exhaust excess sample air to the outside of the trailer, and keep the trailer well ventilated.

5. Cautions

5.1. Plugging of individual inlets by ice, dust, insects, or other debris will lead to biased sampling of the plume, and may produce inaccurate results. Install suitable in-line filters to avoid plugging and monitor inlet flow using a mass-flow meter.
5.2. Water in the sampling line can trap water-soluble gases in the sample stream, and lead to underestimates of these. The filter at the inlet has a large aperture and is pointed with its opening downward to shed water away from the inlet (Fig. 1).
5.3. Minimize exposure of the sampling line to external contamination (water, dust or other material) during the installation process by sealing each end of the tube, and the open ends of the tees that will connect to the inlets, properly with electrical tape (or equivalent). Remove the seal only when the inlet filters are in place, and the line is ready to be connected to the sampling pump.
5.4. Place the sampling line in an area where it will not interfere with animal, vehicle, or foot traffic.
5.5. Flow rates that are too high for the tube used in the sampling line may cause the tube to collapse. Consult the manufacturer’s specifications on any tube before setting the sampling flow rate.
5.6. The sampling line should be kept straight. Use multiple supports and anchors along the distance of the line.
5.7. Handle the GSS with care to avoid dropping it to the floor.
5.8. When transporting the GSS or storing it for a long time, seal all the openings of the solenoid valves and tubes to avoid contamination.
5.9. Only hand-tighten fittings inside the GSS to avoid over tightening them.
5.10. Each compression fitting inside the GSS has a gripper (seal) and a ferrule. Use these correctly to avoid air leakage.

5.11. Use a filter (Section 8.16) with about 1 mm x 1 mm mesh holes at the end of the GSS exhaust to prevent flies from entering the exhaust tubes. Make sure that the filter does not create excessive (>10 Pa) pressure drop in the exhaust.
5.12. Verify all power and signal connections and make sure that they are correct before using the GSS.
5.13. A 47-mm Teflon filter does not always stay flat when taking it out of the box. When inserting filters into the filter holders, carefully check the filter and make sure that it does not leave part of the surface area uncovered before tightening the holder. Always tighten the filter holder with the special filter holder wrenches.

6. Interferences

6.1. Off-gassing of the sampling tube could introduce interferents into the gas stream, depending on the target gas(es), the tube material, and the detection method. If off-gassing does occur from the sampling line, the magnitude of this interference will increase with longer residence times and temperature.
6.2. Any obstruction between the source and the sampling line (e.g. trees or bushes, uneven ground) can interfere with air flow, and cause biased sampling. Make sure no inlets are located directly downwind of any significant obstruction.
  6.2.1. Do not position the instrument shelter between the source and the sampling line, or within 4 m downwind from the sampling line.
6.3. Narrow “hotspots” within a plume could potentially pass between sampling inlets, and not be drawn into the line. This should be minimized over time due to fluctuations in wind direction making it unlikely that even a narrow hotspot would always pass entirely between the inlets. This problem is minimized with more inlets into the sampling line.
  6.3.1. If the source is significantly heterogeneous and hot spots within the plume are a concern, inlets should not be spaced further apart than 10% of the total path length.
6.4. Any specific interferences inherent to the detector that is used to quantify the gas(es) in the sample must also be addressed. Consult the SOP and instrument manual for the particular detector in question for this information (e.g. SOP G5 for hydrogen sulfide).
6.5. Air leaks into the GSS can dilute the sample gas. Maintain the GSS and perform leak checks when suspicions arise. Correct all problems discovered during leak checks.
6.6. Condensation in sampling air will not only introduce measurement error, but also may damage the analyzers. Stop the GSS if condensation is found in the tubes that provide sampling air to the GSS until the problem is solved.
6.7. Particulate matter in the sample can cause malfunctions of the solenoids and the mass flow meter. Verify proper installation of the in-line Teflon filter in all sampling inlets.
6.8. Improper conditioning of the Tedlar bags for the bag test (Section 9.19) can cause inaccurate results. Strictly follow the procedures in Section 9.19.4 to condition each bag,

7. Personnel Qualifications

7.1. Field staff members must read and understand this SOP, the SOP for any detector(s) used with the sampling system, and any additional documentation required by those SOPs, before performing this method.

7.2. The operator should be trained to change air filters, to check sensors (relative humidity, temperature, and pressure), and to perform leak checks.

8. Equipment and Supplies

8.1. 1500′ of 3/8″ OD Teflon sampling tubing
8.2. (2) 3/8″ Stainless steel unions
8.3. 3/8″ OD Teflon sampling tube, with 3/8″ tees for connecting inlets
8.4. Inlet tubings (Fig. 3)
8.5. 1/8″ OD Teflon tubing for making flow-restricting orifices for each inlet
8.6. Miniature Bunsen burner
8.7. 3/8″ 25-mm inlet filter holders for each inlet
8.8. 3/8″ – 1/4″ 47-mm in-line filter holders for each S-OPS
8.9. Storage/feeder device for extension tubing
8.10. #3 Rubber stoppers for plugging each sampling inlet
8.11. Gas sampling #3 rubber stopper with tubing/connector
8.12. 1.5-m high metal fenceposts. Enough fenceposts are needed to place one every 5 m (or less) along the sampling line.
8.13. Small sledge hammer to drive stakes.
8.14. Cable ties
8.15. ‘Reverse flow’ sampling pump
8.16. Teflon filters (1-µm pore size and 47-mm diameter) used in the in-line filter holders
8.17. Teflon filters (1-µm pore size and 25-mm diameter) used in the inlet filter holders
8.18. Electrical tape to seal the ends of the tubes to prevent their contamination during maintenance, testing, transportation or storage
8.19. Gas Sampling System
8.20. 0-10 L/min rotameter with 1/4″ connector (termed 10 L/min rotameter)
8.21. 100-1000 cc/min rotameter with 1/4″ connector (termed 1 L/min rotameter)
8.22. Approximately 10′ of Teflon tube (1/4″ OD x 1/8″ ID) for connecting the GSS to the 47-mm Teflon filters (Fig. 3)
8.23. Approximately 15′ of PVC tube (3/16″ ID) for connecting bypass exhaust air from the GSS to outdoors
8.24. Approximately 15′ of PVC tube (5/8″ ID) for connecting excess sample air from the GSS to outdoors
8.25. Digital signal cable (16-conductor 22-gage shielded or unshielded cable) for connecting the solenoid control receptacle in the GSS to the DO channels in the DAC hardware.
8.26. Analog signal cable (14-conductor 22-gage shielded cable) for connecting the sensor power/signal receptacle in the GSS to the AI channels in the DAC hardware.
8.27. Standard filter holders (2″ dia), with discs of air conditioner filter foam (“NaturalAire” filters, or equivalent) to keep flies out of sampling lines
8.28. Multimeter to check electrical connections
8.29. Tedlar bags for the bag test. The size of the Tedlar bag depends on the sampling flow rate. An 80-L Tedlar bag will work in most all cases.
8.30. DAC system (Campbell Scientific CR800 data logger)
8.31. Software programs for CR800 Data logger

8.31.1. Program for system testing ‘NAEMS_GSS-test.CR8’
8.31.2. Program for system operation ‘NAEMS_GSS.CR8’
8.32. Relay controller for solenoid control (Campbell Scientific A21Rel-12).
8.33. 24-VDC power supply for solenoid control (from TEC 450I Pulsed Florescence H_2S Analyzer).
8.34. 12-VDC power supply for DAC (Campbell Scientific CR800 and A21Rel-12).

9. Procedures

9.1. Consult applicable SMP to determine the location(s) for the sampling line(s), and for the posts and supports.
9.1.1. Check with landowner to be sure that posts/ support stake locations are free of underground wires, pipes, etc.
9.2. Setup of support stakes and synthetic open path sampling line (in field)
9.2.1. Cable and support stakes or posts
9.2.2. Supports
9.2.2.1. Using the cable as a guide to make sure all supports are in a line, drive support stakes every 5 m or less along the path of the sampling line
9.2.2.2. Determine coordinates of start and end of S-OPS using GPS
9.2.2.3. Record on “Open-Path Sensor Installation Report” (Appendix F).
9.2.3. Sampling line
9.2.3.1. Use a suitable feeder device to protect and guide the tubing from the reel, while laying it along the ground next to the fence posts, beginning with the closest one to the trailer.
9.2.3.1.1. Uncoil the tubing correctly when there is no feeder device available. Turn the coil while feeding the tubing. Do not pull the tubing from the coil when the coil lays flat on the ground.
9.2.3.2. If necessary, turn the tube so that the openings of the tees (taped) are facing upward
9.2.3.3. Insert the sampling tubes (Fig. 2) with the attached inlets and filter holders (and taped rubber stopper plugs) into the corresponding tees (the sampling tubes are numbered 1-10; 1 is closest to extension tubing connector). Remove tape covering on tee connections
9.2.3.4. Hand-tighten connections as tight as possible. Do not use wrench to tighten.
9.2.3.5. Using 4″ cable ties, secure the sampling tubes and inlets to the fence posts with the 180-degree bend in the tube pointing the inlet downwards (Fig. 1).
9.2.3.6. Keep all tees plugged with taped rubber stoppers while placing the tube.
9.3. Setup of sample line extension tubing (in field)
9.3.1.1. Use a suitable feeder device to protect and guide the tubing from the reel, while laying it along the ground outside the trailer to the end of the sampling line closest to the trailer. Leave at least 6 m at trailer end for feed-through into trailer and attachment to GSS.
9.3.1.1.1. Uncoil the tubing correctly when there is no feeder device available. Turn the coil while feeding the tubing. Do not pull the tubing from the coil when the coil lays flat on the ground.

9.3.1.2. Two sections of 500′ extension tubing are needed for the most distant synthetic open-path sampling line. One section of 500′ extension tubing is needed for the near synthetic open-path sampling line.
9.3.1.2.1. Connect extension tubing sections with stainless steel union connectors (Fig. 2) using wrenches.
9.3.1.2.2. Connect the synthetic open-path sampling line with the extension tubing with stainless steel connectors (Fig. 2) using wrenches.
9.3.1.3. Connect extension tubing sections to the GSS with Teflon connectors according to Fig. 2. Hand-tighten as tight as possible. Do not use wrench to tighten.
9.3.1.4. Attachment of extension tubing to GSS with Teflon connector
9.3.1.4.1. Feed extension tubing through tubing pass-thru in trailer floor
9.3.1.4.2. Connect 500′ (corresponding to nearest S-OPS) S-OPS extension to 47-mm filter holder inlet feeding solenoid 2 (normally open).
9.3.1.4.3. Connect 1000′ (corresponding to farthest S-OPS) S-OPS extension to 47-mm filter holder inlet feeding solenoid 3 (normally closed).
9.3.1.4.4. Hand-tighten all connections as tight as possible. Do not use wrench to tighten..

9.4. Setup of S-OPS and GSS (in field)
9.4.1. Connect each S-OPS to the S-OPS extension tubing with a Stainless steel union connector
9.4.1.1. Connect nearest S-OPS (S-OPS #1) to 500′ S-OPS extension tubing.
9.4.1.2. Connect farthest S-OPS (S-OPS #2) to 1000′ S-OPS extension tubing.
9.4.2. Connect a piece of 3/16″ ID PVC tube to the bypass exhaust (Fig. 7), and lead the other end of the tube to outside the trailer trough tubing pass-thru on floor.
9.4.3. Insert a piece of 5/8″ ID PVC tube through the sample exhaust hole (Fig. 7) and connect it to the barbed fitting on the top of the analyzer manifold (Fig. 7), and run the other end of the tube to outside the trailer through tubing pass-thru on floor.

9.5. Inlet flow verification (in field)
9.10.1 Measure flow at each inlet using 1 L/min rotameter
9.10.2 Check flow rate of line with each installed inlet and record on Inlet Flow Verification Form (Appendix D).
9.10.3 Adjust inlet as necessary to maintain constant flow rate across all inlets (5% accuracy)

9.6. Power up GSS (in field)
9.6.1. Verify that all the completed connections are correct.
9.6.2. Plug the GSS power cord into a 115-VAC power outlet to power up the GSS.
9.6.3. Turn on the sampling pump and the bypass pump.

9.7. Initial setup of single-inlet gas sampling system (GSS) (in lab)
9.7.1. Cut a 3′ section of 1/4″ OD Teflon tubing with a sharp tube cutter.
9.7.2. Connect one end of the 1/4″ Teflon tube to the outlet of the Teflon filter holder. Tighten it with a wrench (this is different type of compression fitting that does not have ferrules).

9.7.3. Place a 47-mm filter holder and 1-µm pore membrane filter at one end of each 3′ 1/4″ OD tube to be used to connect the S-OPS extension tubing to the GSS solenoids. This prevents PM from entering the air tubing, GSS, and gas analyzers.

9.7.3.1. Install a Teflon filter with 1-µm pore size in the 47-mm in-line filter holder and tighten the holder with the special filter holder wrenches.

9.7.4. Insert the other end of the 3′ piece of 1/4″ OD Teflon tube through the tube holder on the top of the GSS (Fig. 4) and align it with the solenoid port that faces upwards (Fig. 4). Connect the tube to the Teflon adapter in the solenoid by hand tightening the nut (Fig. 4). Hand-tighten the adapter (tube holder) on the top panel so that the tube does not move.

9.7.5. Connect the inlet of the filter holder to the 3/8″ OD extension tubing for a S-OPS using Teflon connectors.

9.7.6. Repeat Sections 9.7.4 to 9.7.5 to connect all the sampling tubes to the GSS.

9.7.7. Connect the inlet tubes of the gas analyzers to the gas ports (Fig. 7), and hand-tighten the Teflon fittings.

9.8. Cable connections

9.8.1. There are two cable connection receptacles in the GSS. One has 16 pins, and is for solenoid control. Another has 14 pins, and is for sensor power and sensor signals.

9.8.1.1. Connect the solenoid (digital) control cable to the A21REl-12 Relay controller (Table 1).

9.8.1.2. Connect the analog cable to the DAC (CR800 Data logger) (Table 2).

9.8.2. Connections for the A21Rel-12 Relay Controller (Table 3)

9.8.2.1. Connect the positive of the 24VDC power supply from the TEC 450i Terminal I/O connector terminal 24 to ‘REL 1 COM’ and the ground of the TEC 450I digital output connector terminal 24 to the ‘GRND’ on the relay controller.

9.8.2.2. Connect the blue wire from the GSS digital cable to ‘REL 1-NC’ on the relay controller

9.8.2.3. Connect the Black/spotted red and white wire from the GSS digital cable to ‘GRND’ on the relay controller .

9.8.2.4. Connect the positive and ground/common of the 12-VDC power supply to the CR800 data logger. Power for the A21REL-12 Relay Controller comes from the data logger.

9.8.2.5. Connect the Green wire from ‘C1’ on the CR800 data logger to ‘CTRL1’on the relay controller.

9.9. Construction of S-OPS sampling manifold (at laboratory)

9.9.1. Choose length of sampling manifold

9.9.2. Cut 3/8″ OD Teflon tubing into section no longer than 10% of the manifold length or 5 m, whichever is smaller

9.9.2.1. The last 5-m section should have additional length for bending tubing to sample height of 1-2 m.

9.9.3. Connect lengths of tubing with 3/8″ Teflon Tees

9.9.4. Put stainless steel connector on tubing to connect with S-OPS extension tubing and seal with tape.

9.9.5. Cut inlet tubing to length corresponding to desired sampling height. Assume tees will be at ground level.
9.9.6. Connect inlet tubing to tees (last inlet tubing is bent section) and hand tighten
9.9.7. Connect inlet tubing to 25-mm filter holders and hand tighten tubing connectors.

9.10. Static balancing of S-OPS inlet flows (at laboratory)
9.10.1. Construct flow-restricting orifices out of 1/8″ OD Teflon tubing
9.10.2. Cut tubing into 5″ sections
9.10.3. While rotating tubing pieces, hold middle of tubing over small Bunsen burner and stretch tubing to decrease inside diameter to a very small hole
9.10.4. Cut stretched piece of tubing in half to make 2 orifices
9.10.5. Repeat procedure to make the required number of orifices (with many extras).
9.10.6. Initial flow testing
9.10.6.1. Connect spare pump to a controlling flow valve to a section of tubing in which each orifice can be inserted (Fig. 3) for flow testing.
9.10.6.2. Plug inlet of 25-mm filter holder (with 1-μm pore filter installed) with rubber stopper pre-fit with 1/4″ OD Teflon tubing section. Attach Gillian flow meter (or equivalent) to 1/4″ Teflon tubing extending from stopper.
9.10.6.3. Insert flow restrictor in tubing at filter holder outlet, turn on pump, and measure flow with meter.
9.10.6.4. Orifices should measure a flow of approximately 0.5 L/min

9.11 Dynamic balance inlets in S-OPS sampling manifold (at laboratory)
9.11.1 Attach 1000′ of 3/8″ Teflon tubing to S-OPS manifold to determine the flow rate (use 1000′ because this should be about the maximum amount of tubing needed to reach the S-OPS sampling manifold from the GSS)
9.11.2 Use a Gillian flow meter (or equivalent) to measure the flow rate at the end of the 1000′ of tubing (about 6.7 L/min).
9.11.3 Using a spare pump and ball valve, establish a flow rate equal to this flow (6.7 L/min) and attach the spare pump (with 1/4″ OD tubing to the S-OPS sampling manifold (with 3/8″ OD tubing) with reducing union. Lay out orifices in a straight line
9.11.4 Insert flow restrictors into sampling manifold at the filter holder inlet (with 1-μm pore filter installed) of each inlet tube.
9.11.5 Attach the rubber stopper with pre-fit 1/4″ tubing into the filter inlet of the inlet to be flow-tested. Keep all other inlets of the S-OPS open.
9.11.6 Turn on pump and measure flow at the 1/4″ OD Teflon tubing using a Gillian flow meter (or equivalent).
9.11.7 Progressing from inlet 1 to 10, balance inlets to 0.67 L/min (±5%) by cutting off small amounts of the ends of the orifices as needed.

9.12 Software configuration
9.12.1 The GSS is designed to have one solenoid normally open to the sampling manifold and the others normally open to the bypass manifolds (Fig. 4). This is to avoid choking the pumps in case that all solenoids shut off (e.g. computer shut-down or DAC power failure) while the pumps are still running.

9.12.2 The GSS is controlled by the DAC hardware (CR800 and A21REL-12 Relay Controller) and program in data logger.

9.13 GSS initial tests in field

9.13.1 Verify GSS sensor operation

9.13.1.1 Using the LoggerNet software, connect to the CR800 and upload the GSS program 'NAEMS_GSS_test.CR8'. After uploading, access measurements at "Data displays/Numeric/1" by the radio button on the screen.

9.13.1.1.1 Add to the Numeric listing: PortStatus(1) from 'Status' Table and Pressure, Mass Flow, and Flow direction from 'Public' Table.

9.13.1.2 The pressure sensor should have values in the range between -20 kPa and -50 kPa at normal sampling. If it is not in this range, there may be either a leakage or a blockage in the sampling tube anywhere from the sampling location to the sampling pump.

9.13.1.3 The sampling flow rate should be between 4 and 7 L/min. If it is not in this range, check the sampling tubes, the sampling pump, and the mass flow meter.

9.13.1.4 Record readings under 'Sample flow test' on the GSS Acceptance Form (Appendix B).

9.13.2 Verify solenoid control

9.13.2.1 Listen for clicking sound from inside the GSS, indicating that the solenoids are switching. Check PortStatus(1), which will change from 'True' to 'False' in "Data displays/Numeric/1"

9.13.2.2 If clicking sound is heard, the solenoids are being controlled.

9.13.2.3 If no clicking sound is heard, check power to relay controller and signal lines between DAQ and relay controller and GSS to DAQ and relay controller according to Tables 1 and 3.

9.13.3 Verify sampling air flow in the GSS and gas sampling filter.

9.13.3.1 Check the airflow using the mass flow meters at the outlet of the sampling system.

9.13.3.2 Disconnect extension S-OPS tubing from 47-mm sampling filters.

9.13.3.3 Record readings under 'Max flow test' on the GSS Acceptance Form (see Appendix B).

9.13.4 Verify bypass air flow

9.13.4.1 Make sure that the bypass pump has about 4 L/m flow rate and is running.

9.13.4.2 Disconnect S-OPS manifold from S-OPS extension tubing and connect the 10 L/min rotameter to inlet of S-OPS extension tubing

9.13.4.3 Measure the airflow rate at the inlet of the S-OPS extension tubing when the line is not being sampled. An airflow rate of > 0.5 L/m should be detected, depending on the total sampling locations in the system.

9.13.4.4 If airflow rate is too low, check the flow restrictor inside the 1/4″ OD Teflon tube between the bypass manifold and the solenoid connected to this particular S-OPS extension line (Fig. 7). If necessary, pull out the flow restrictor from the 1/4″ OD Teflon tube and cut it a little shorter (enlarge the orifice) before inserting it back into the 1/4″ OD Teflon tube. Because there is a balance of bypass airflow among all sampling lines, be cautious not to enlarge the orifice of the flow restrictor too much.

9.13.4.5 Repeat 9.13.4.1 to 9.13.4.4 for each S-OPS extension line.

9.14 GSS leakage test (in field)

9.14.1 Connect the GSS to the DAQ hardware and software so that the solenoids can be controlled, and the pressure and airflow rate can be monitored.

9.14.2 Check all air passage connections. Hand-tighten fittings inside the GSS if loose.

9.14.3 Make sure that the GSS pressure and airflow rate measurement are correct.

9.14.3.1 When the sampling pump inside the GSS is shut off, both pressure and airflow rate should read near zero.

9.14.3.2 Record readings under 'No flow test' on the GSS Acceptance Form (see Appendix B). These values are used to 'correct' measurements for sensor offsets.

9.14.4 Plug inlet side of 47-mm filter at inlet of solenoid passing air into the sampling manifold.

9.14.5 Watch the readings of the sampling pressure and sampling flow rate in the data logger measurements. Both of them should drop down quickly.

9.14.6 Do not leave the vacuum status too long because the GSS is "over loading" during this test.

9.14.6.1 Record readings under 'Leakage test' on the GSS Acceptance Form (see Appendix B)

9.14.7 Repeat 9.14.4 – 9.14.6 for all actively-used solenoids

9.14.8 Correct all flow and pressure readings for sensor offsets by subtracting the no-flow values from the measured pressure and flow measurements. Record calculated values under "Corrected Mass flow" and "Corrected Pressure" on the GSS Acceptance Form (see Appendix B).

9.14.9 If the sampling airflow drops to less than 0.1 L/m within about one minute, the GSS is leak-free starting from the solenoids. Indicate a 'Pass' on the GSS Acceptance Form if this is true.

9.14.10 If the sampling airflow is more than 0.1 L/m Check integrity (tightness) of the filter holder, tube connections of the filter holder and in the GSS (in that order) and repair as needed. Indicate a 'Fail' on the GSS Acceptance Form if this is true and indicate in the comments the remediation and results of remediation.

9.15 Sampling system (GSS + S-OPS) leakage test (in field- requires two persons and a pair of walkie-talkies)

9.15.1 Plug all inlets of an S-OPS with rubber stoppers

9.15.2 Record the sampling pressure and sampling airflow rate from the data logger measurements.

9.15.3 If the sampling line is leak-free, the sampling airflow will drop down to about 0.7 L/min within several minutes, depending on the length of the tube.

9.15.3.1 Record the test results under "S-OPS/GSS Leak test" on the NAEMS open S-OPS Acceptance Form (Appendix C).

9.15.4 Do not leave the vacuum status too long because the GSS is "over loading" during this test

9.15.5 Correct all flow and pressure readings for sensor offsets by subtracting the "No-Flow" values on GSS Acceptance Form (Appendix B) from the measured pressure and flow measurements in 9.15.2. Record calculated values under

"Corrected Mass flow" and "Corrected Pressure" on the S-OPS Acceptance Form (Appendix C).

9.15.5.1 If the airflow is below 10% of the total sampling air flow (0.7 L/min for a 7-L/min sampling airflow), the sampling system should be considered normal. Indicate a 'Pass' on the S-OPS Acceptance Form if this is true.

9.15.5.2 If the airflow is more than 10% of the sampling air flow, the sampling system has a leak. Check integrity of the 25-mm filter holders, connections to 25-mm filter holder, tees in S-OPS manifold, extension S-OPS tubing to S-OPS connection, and connection of S-OPS extension tubing to 47-mm filter holder in trailer (in that order) and repair as needed. Apply or replace Teflon tape to nylon screw joints (especially 25-mm filter) to enhance seal.

9.15.5.3 If failure continues, indicate a 'Fail' on the S-OPS Acceptance Form, and indicate in the comments the attempted remediation and results.

9.16 Sampling system (GSS/ S-OPS) flow balance test (in field)

9.16.1 Requires two persons and a pair of walkie-talkies

9.16.2 Disconnect S-OPS manifold from S-OPS extension tubing and connect 10 L/min rotameter to inlet of S-OPS extension tubing.

9.16.3 Connect the outlet of the airflow meter or rotameter to the end of the S-OPS 3/8″ extension tubing using a short piece of 1/4″ tube coming from the suction-side of the meter inserted into the 3/8″ tubing.

9.16.3.1 The mass flow meter inside the GSS can serve as the outlet airflow meter. Use another airflow meter or a rotameter as the inlet measurement device. Make sure that the two meters are calibrated together before the test.

9.16.4 Record mass flow at end of extension tubing (from rotameter) and mass flow measured at the inlet to the Analyzer manifold (from mass flow meter measurement reported in GSS data logger data record).

9.16.5 Correct the mass flow meter measurements as in 9.15.5, and record under "Max Flow Test" on S-OPS Acceptance Form (Appendix C)

9.16.6 Compare the airflow readings from the inlet air flow meter with that from the mass flow meter in the GSS. A positive difference in readings (difference = inlet - outlet) indicates a possible air leakage.

9.16.6.1 The difference between the two mass flow measurements should be less than 0.2 L/min. Indicate a 'Pass' on the S-OPS Acceptance Form if this is true.

9.16.6.2 If the difference in flow is greater than 0.2 L/min, there is a leak in the sampling system. Check integrity of the extension S-OPS tubing, connections and the GSS (in that order) and repair as needed. Indicate a 'Fail' on the S-OPS Acceptance Form if this is true and indicate in the comments the remediation and results of remediation.

9.17 Initial GSS acceptance tests in laboratory

9.17.1 Verify GSS sensor operation

9.17.1.1 Using the LoggerNet software connect to the CR800 and upload the GSS program 'NAEMS_GSS_test.CR8'. After uploading, access measurements at "Data displays/Numeric/1" by the radio button on the screen.

9.17.1.1.1 Add to the numeric listing: PortStatus(1) from ‘Status’ Table and Pressure, Mass Flow, and Flow direction from ‘Public’ Table.

9.17.1.2 The pressure sensor should have values in the range between -20 kPa and -50 k Pa at normal sampling. If it is not in this range, there may be either a leak or a blockage in the sampling tube anywhere from the sampling location to the sampling pump.

9.17.1.3 The sampling flow rate should be between 4 and 7 L/min. If it is not in this range, check the sampling tubes, the sampling pump, and the mass flow meter.

9.17.1.4 Record readings under ‘Sample flow test’ on the GSS Acceptance Form (Appendix B).

9.17.2 Verify solenoid control

9.17.2.1 Listen for clicking sound from inside the GSS, indicating that the solenoids are switching and PortStatus(1) which will change from ‘True’ to ‘False’ in “Data displays/Numeric/1”

9.17.2.2 If clicking sound is heard, the solenoids are being controlled.

9.17.2.3 If no clicking sound is heard, check power to relay controller and signal lines between DAQ and relay controller and GSS to DAQ and relay controller according to Tables 1 and 3.

9.17.3 Verify sampling air flow balance to check for leaks in the GSS itself and in its immediate connections.

9.17.3.1 This method can be used prior to leak testing of the entire sampling system (Section 9.15). It requires two persons to work together.

9.17.3.2 Check the airflow balance using two airflow (mass flow) meters, one at the inlet and another at the outlet of the sampling system.

9.17.3.3 The mass flow meter inside the GSS can serve as the outlet airflow meter. Use another airflow meter or a rotameter as the inlet measurement device. Make sure that the two meters are calibrated together before the test.

9.17.3.4 Connect the outlet of the airflow meter or rotameter to the end of 500′ of S-OPS 3/8″ extension tubing using a short piece of 1/4″ tube coming from the suction-side of the meter inserted into the 3/8″ tubing.

9.17.3.5 Compare the airflow readings from the air flow meter with that from the mass flow meter in the GSS. A positive difference in readings (difference = inlet - outlet) indicates a possible leak.

9.17.3.6 Record readings under ‘Max flow test’ on the GSS Acceptance Form (Appendix B).

9.17.3.7 If there is leakage indicated, the leak should be identified and removed.

9.17.3.8 This procedure can be combined with that of solenoid testing (Section **Error! Reference source not found.**) to save testing time.

9.17.4 Test flow direction sensor

9.17.4.1 Plug all analyzer ports.

9.17.4.2 Be sure that sample and bypass pumps are on.

9.17.4.3 Note sample flow rate and flow direction sensor response and record on Flow Direction Sensor Calibration Form (Appendix G) for each solenoid used.

9.17.4.4 Turn off sample and bypass pumps and disconnect lower connection of tee between sample pump and analyzer manifold (Fig. 7).

9.17.4.5 Using a spare sampling pump (reverse flow pump) of the same design as the GSS pumps, connect 5/8″ ID PVC to 1/4″ Teflon reverse flow adapter to sample manifold exhaust to positive flow side of spare pump.

9.17.4.6 Start reverse flow pump and verify flow from open analyzer port (verify that flow is exhausting from the disconnected tubing at sample pump tee.

9.17.4.7 Note reverse flow rate and flow direction sensor response and record on Flow Direction Sensor Calibration Form (Appendix G) for each solenoid used. Value should be negative

9.17.4.7.1 If there is no difference in values, look for leaks in the analyzer manifold. Repair and retest.

9.18 GSS leakage test

9.18.1 Connect the GSS to the DAQ hardware and software so that the solenoids can be controlled, and the pressure and airflow rate can be monitored.

9.18.2 Check all air passage connections. Hand-tighten fittings inside the GSS if loose.

9.18.3 Make sure that the GSS pressure and airflow rate measurement are correct.

9.18.3.1 When the sampling pump inside the GSS is shut off and the analyzer manifold and exhaust are plugged, both pressure and airflow rate should read near zero.

9.18.3.2 Record readings under ‘No flow test’ on the GSS Acceptance Form (Appendix B). These values are used to ‘correct’ measurements for sensor offsets.

9.18.4 Disconnect 47-mm filter on inlet tube. Plug tube entering sampling solenoid.

9.18.5 Turn on pumps and watch the readings of the sampling pressure and sampling flow rate in the data logger measurements. Both of them should drop down quickly.

9.18.5.1 Do not leave the vacuum status too long because the GSS is “over loading” during this test.

9.18.5.2 Record readings under ‘Leakage test’ on the GSS Acceptance Form (Appendix B)

9.18.6 Repeat 9.16.1 – 9.16.5 for all actively-used solenoids

9.18.7 Correct all flow and pressure readings for sensor offsets by subtracting the no-flow values from the measured pressure and flow measurements. Record calculated values under “Corrected Mass flow” and “Corrected Pressure” on the GSS Acceptance Form (Appendix B).

9.18.8 If the sampling airflow drops to less than 0.1 L/min within about one minute, the GSS is leak-free starting from the solenoids. Indicate a ‘Pass’ on the GSS Acceptance Form if this is true.

9.18.9 If the sampling airflow is more than 0.1 L/min, check integrity/tightness of the filter holder, tube connections of the filter holder and in the GSS (in that order), and repair as needed. Indicate a ‘Fail’ on the GSS Acceptance Form if this is true and indicate in the comments the remediation and results of remediation.

9.19 Bag test (system adsorption test done in lab)

9.19.1 Conduct this test once for each gas sampled through the GSS

9.19.2 Connect 3 m (10′) of 1/4″ Teflon tubing to the output of the TEC 146i diluter or the cylinder regulator (as appropriate).

9.19.3 Program the diluter (SOP C3) to produce a concentration significantly different from that which is currently being measured at the sampling location, or utilize a calibration tank of concentration significantly different from that which is currently being measured at the sampling location.

9.19.3.1 Selecting a different concentration from that which is being measured allows the operator to easily see that a particular location is being tested, and to visualize differences from one sampling location to another during the bag test.

9.19.4 Conditioning of Tedlar bags

9.19.4.1 Check the Tedlar bags for damage that might cause leaks (holes, cuts, a bad or loose valve, etc.)

9.19.4.2 Using flexible (i.e. vinyl) tubing, connect the first Tedlar bag to a vacuum pump. Evacuate the bag, then disconnect it and evacuate the other 5 bags.

9.19.4.3 Fill 1/3 full with gas of a known concentration for the bag test.

9.19.4.4 Repeat Sections 9.19.4.2 - 9.19.4.3 two more times.

9.19.4.5 Completely fill the Tedlar bag with gas of a known concentration.

9.19.4.6 Repeat Sections 9.19.4.2 - 9.19.4.5 for the other 4 Tedlar bags

9.19.5 Test the integrity of each inlet on the S-OPS as follows:

9.19.5.1 Plug all inlets to the S-OPS with rubber stoppers

9.19.5.2 Sample each location on each S-OPS for a minimum of 5 min before attaching the Tedlar bag with the known concentration.

9.19.5.3 Change rubber plug at inlet of interest with stopper with tubing insert.

9.19.5.4 Using flexible (i.e. vinyl) tubing, attach Tedlar bag to the sampling location that is being measured. Use a reducing union, and make sure that the connection is a tight connection to avoid any leaks.

9.19.5.5 Open valve on Tedlar bag with 3 turns. Do not open any further than this, because the valve will come apart.

9.19.5.6 Sample the Tedlar bag for 10 min.

9.19.5.7 Monitor the data on the analyzer.

9.19.5.8 Save a print screen of the data logger in a PowerPoint file.

9.19.5.9 Record the sampling time (start & stop), sampling location, concentration readings from the diluter (cylinder specification) and the analyzer, and the analyzer serial number in the field notes, using the form in Appendix E.

9.19.5.10 Switch to the next location.

9.19.5.11 Repeat steps 9.19.5.3 to 9.19.5.10 until all sampling locations have been tested. If necessary, refill empty Tedlar bags with the known gas concentration again until all the locations have been tested.

9.19.6 Average analyzer concentrations

9.19.6.1 Go to computer data file containing measurements from the analyzer of interest.

9.19.6.2 Copy and paste the copy of the current 1-min data file in the data file

9.19.6.3 Open the copy of current 1-min data file with Excel.

9.19.6.4 Locate the start and stop times for each location during the bag test in the 1-min data file.
9.19.6.5 Average the concentration readings for the last two minutes of the Tedlar bag sampling.
9.19.6.6 Enter the average concentrations for each S-OPS into the form (Appendix E).
9.19.6.7 Close the copy of the 1-min data file without saving.
9.19.6.8 Calculate the percent difference from average concentration reading from all sampling locations for each sampling location.
9.19.6.9 If the percent difference is greater than 5 % for any sampling location, take the following corrective action(s), and retest that sampling location (repeat Sections 9.19.5.4 to 9.19.5.10), until the percent difference is less than 5 %.
9.19.6.9.1 Check and tighten all connections for the sampling line that has a leak.
9.19.6.9.2 Check for holes or damage to the sampling line.
9.19.6.9.3 Check to make sure that the filter holder is closed tightly
9.19.6.9.4 Check the GSS for leakage or loose connections
9.19.6.9.5 Check Tedlar bag for leaks
9.19.6.9.6 Check the connects between the GSS and the gas analyzers
9.19.6.9.7 Check the connection between the sampling location and the Tedlar bag
9.19.6.10 Check the Tedlar bags for damage that might cause leaks (holes, cuts, a bad or loose valve, etc.).
9.19.6.11 Evacuate Tedlar bags and store in a safe place until needed again.

9.20 GSS operation
9.20.1 Using the LoggerNet software connect to the CR800 and upload the GSS program ‘NAEMS_GSS.CR8’. After uploading, access measurements at “Data displays/Numeric/1” by the radio button on the screen.
9.20.1.1 Add to the Numeric listing: PortStatus(1) from ‘Status’ Table and Pressure, Mass Flow, and Flow direction from ‘Public’ Table.
9.20.1.2 The pressure sensor should have values in the range between -30 kPa and -80 k Pa at normal sampling. If it is not in this range, there may be either a leak or a blockage in the sampling tube anywhere from the sampling location to the sampling pump.
9.20.1.3 The sampling flow rate should be between 4 and 7 L/min. If it is not in this range, check the sampling tubes, the sampling pump, and the mass flow meter.
9.20.1.4 If results differ from those on the GSS Acceptance Form, address problem following Section 9.21.

9.21 Troubleshooting
9.21.1 Contamination
9.21.1.1 If moisture is observed in the line, remove the end cap and flush the interior of the line with dry air for a minimum of 5 min.
9.21.1.2 If dust, PM or other debris is observed in the line, remove the end cap, plug the sampling inlets, and flush with water for 5 min, and then air for 30 min.
9.21.2 Air sampling tubing failure
9.21.2.1 While pumping air through the tubing with all inlets plugged except for the inlet at the opposite end of the tube, use rotameters or similar devices to

measure airflow rate at both ends. If the two flow rates do not agree, inspect the tube for damage or leaks.

9.21.2.2 While pumping air through the tubing with all inlets open, measure all inlet and exhaust flows with rotameters or mass flow meters. If the sum of the inlet flows disagrees with the total pump flow, inspect tubing for damage or leaks.

9.21.2.3 If tubing is found to be damaged or chewed through by rodents, cut out and replace the section (if necessary) and connect using stainless steel union(s). Flush the whole tube from the trailer with pressurized N_2 zero air, and inspect for trapped particles. Measure flow rates again to guard against leakage.

10. Data and Records Management

10.1. Maintain all records on appropriate worksheets of the electronic field notes designated for this method. Supplement this electronic record by documentation in the open site field notes.

10.2. Manage all data according to SOP D1.

10.3. On initial set-up for a given location, use the Synthetic Open-Path Placement Form (Appendix F) in conjunction with the SMP to record the position and configuration of each sampling line.

10.4. Document all data and information (e.g., sample collection method used) on field data sheets, and within site field notes with permanent ink, or in electronic field notes.

10.5. Overstrike all errors in writing with a single line. Initial and date all such corrections.

11. Quality Control and Quality Assurance

11.1. Inspect S-OPS and S-OPS extension tubing for physical damage, firm connections, and sampling line contamination at the beginning and end of each sampling period or every 20 d, whichever is less

11.2. Inspect filters at S-OPS inlets for physical damage, firm connections, and filter contamination at the end of each sampling period or every 20 d, whichever is less.

11.3. Test S-OPS and extension tubing for leakage (Section 9.15) at the beginning and end of each sampling period or every 20 d, whichever is less.

11.4. Test S-OPS inlets for flow rates at the end of each sampling period or every 20 d, whichever is less.

11.4.1. Use 1 L/min rotameter attached to 1/4″ OD tubing inserted through rubber stopper.

11.4.2. Insert rubber stopper in inlet leaving all other inlets un-obstructed. Test all 10 inlets of each S-OPS. Record flow results on Synthetic Open Path Inlet Flow Verification Form (Appendix D).

11.4.3. Calculate mean flow of all 10 inlets.

11.4.4. Calculate deviation of inlet from the mean flow of all other inlets. To avoid biased sampling of the plume, the flow through each inlet must be within 5% of the average flow through all inlets.

11.4.5. If an inlet has a flow deviation greater than 5% low, check inlet filter for accumulated dirt. Replace as needed and retest flow.

11.4.6. Mass flow meters measuring the air flow must be calibrated (SOP A9) at least once per year.

11.5. Keep minimum sampling airflow about 0.5 L/min higher than the maximum sample airflow drawn by all analyzers and the manual port. If additional analyzers are connected to the GSS, and cause increased sample air demand, adjust the flow restrictor between the sampling pump and the mass flow meter to increase the sample flow.

11.6. Review the daily measurement data for the GSS sampling pressure and flow rate to identify abnormal readings. Some common problems that can be identified by the pressure and airflow data are listed in Table 4.

12. References

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Table 1. GSS digital solenoid control connections to A21REL-12 relay controller

Solenoid #	Pin #	Cable wire color	A21REL-12 Terminal	Sampling location
S2	2	Blue	REL1 NC	Near S-OPS
S3	3	Black/spotted red	NC	Far S-OPS
S5	5	White/spotted red	NC	
S7	7	Blue/spotted red	NC	
Ground	22	Blue/spotted black	GROUND	

Table 2. GSS sensor connections to DAC (CR800).

Sensor	Pin #	Wire color	DAC Terminal #
Pressure transducer, signal	1	Black	2H
Pressure transducer, ground	2	Green	2L
Mass flow meter, signal	5	Red	3H
Mass flow meter, ground	6	Black/White stripe	Ground -⏚
Flow direction +	7	Green/Black stripe	1H
Flow direction -	8	Orange	1L
Cooling fan, +24 DVC	22	Black	

Table 3. A21REL-12 Relay controller connections.

Cable/Instrument	Terminal	Wire color	Signal	A21REL-12 Terminal #
GSS digital cable		Black/spotted red&white	Ground	GRND
GSS digital cable		Blue	C2+	REL1-NC
TEC 450I digital output connector	24	White	+24VDC	REL1 COM
TEC 450I terminal I/O connector	24	Black	Ground	GRND
CR800	12V	Red	+12V	+12V
CR800	GND	Black	Ground	GRND
CR800	C1	Green	Digital 5VDC	CTRL1

Table 4. Possible sampling system problems related to GSS pressure and airflow data.

Pressure[1]	Airflow	Number of locations to check for problems	Possible problem and solution
Low	Low	One or several	An overloaded air filter or a blockage in the sampling line. Change the filter and clean the blockage.
High	Low	All locations	Sampling pump loses vacuum. Replace worn diaphragm and fix loose check valves inside pump. Check filters at inlets, and replace if heavily loaded.
High	High	One or a few	Leakage in the sampling line or GSS.
Low	High	All	Leakage in the GSS.
Unstable	Unstable	One	Solenoid not receiving stable power due to relay control problem. Check PortStatus(1) and power supply at connection terminals of solenoid.

1: Low= larger negative pressure

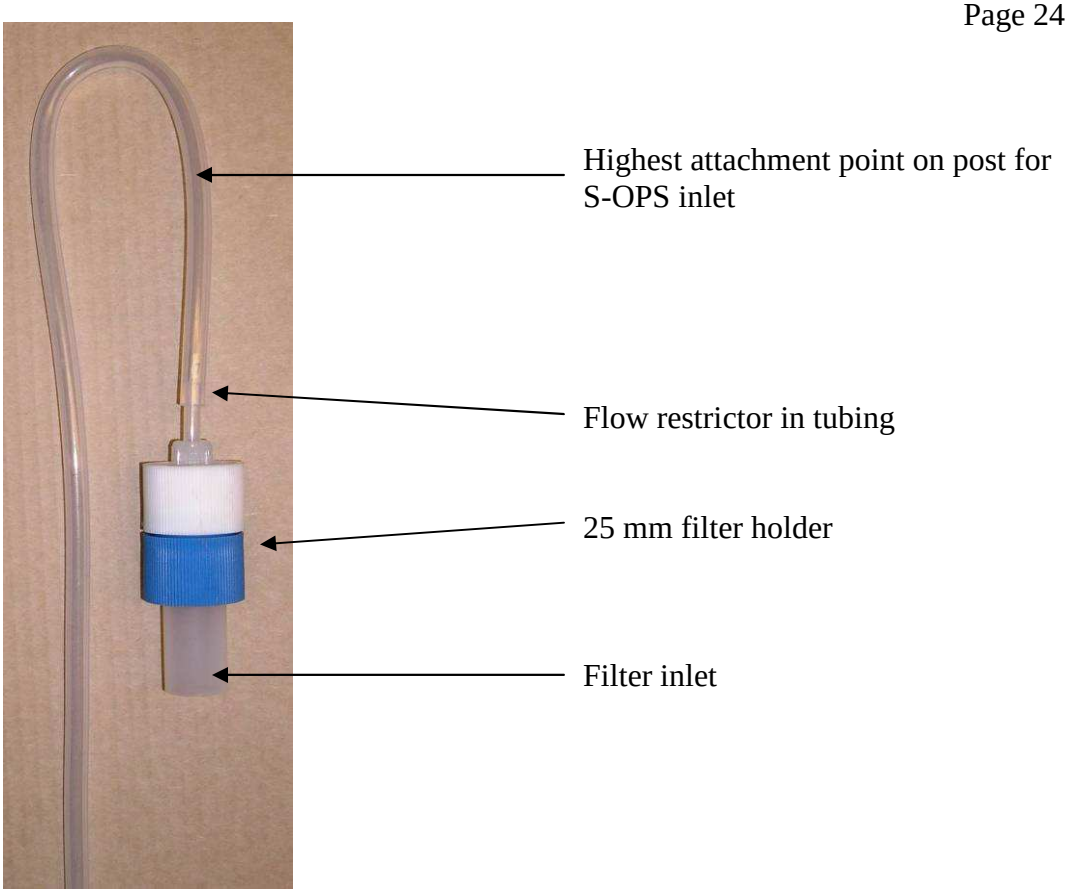


Figure 1. Synthetic open path sampling tube inlet construction.

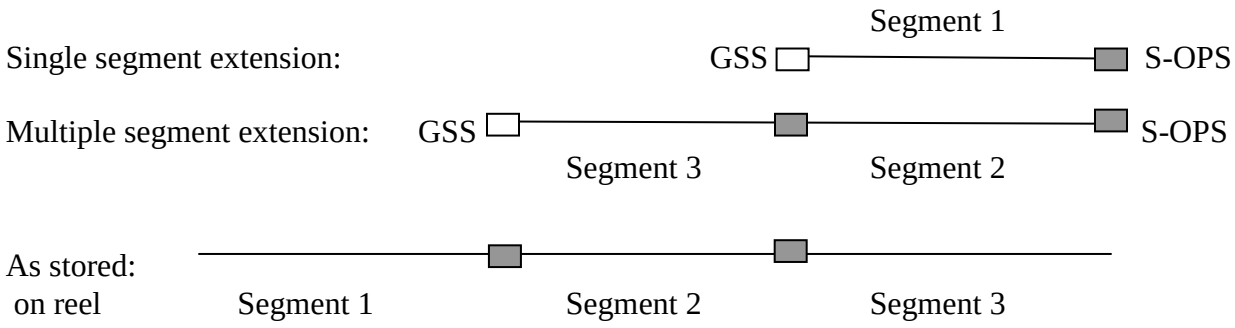


Figure 2. Extension tubing configuration.

Connector material: Stainless steel (▬) and Teflon (▭). Extension tubing is stored on the reel with Stainless Steel unions connecting segments together. An additional union is needed to attach both the single and multiple segment extension lines to the two S-OPS.

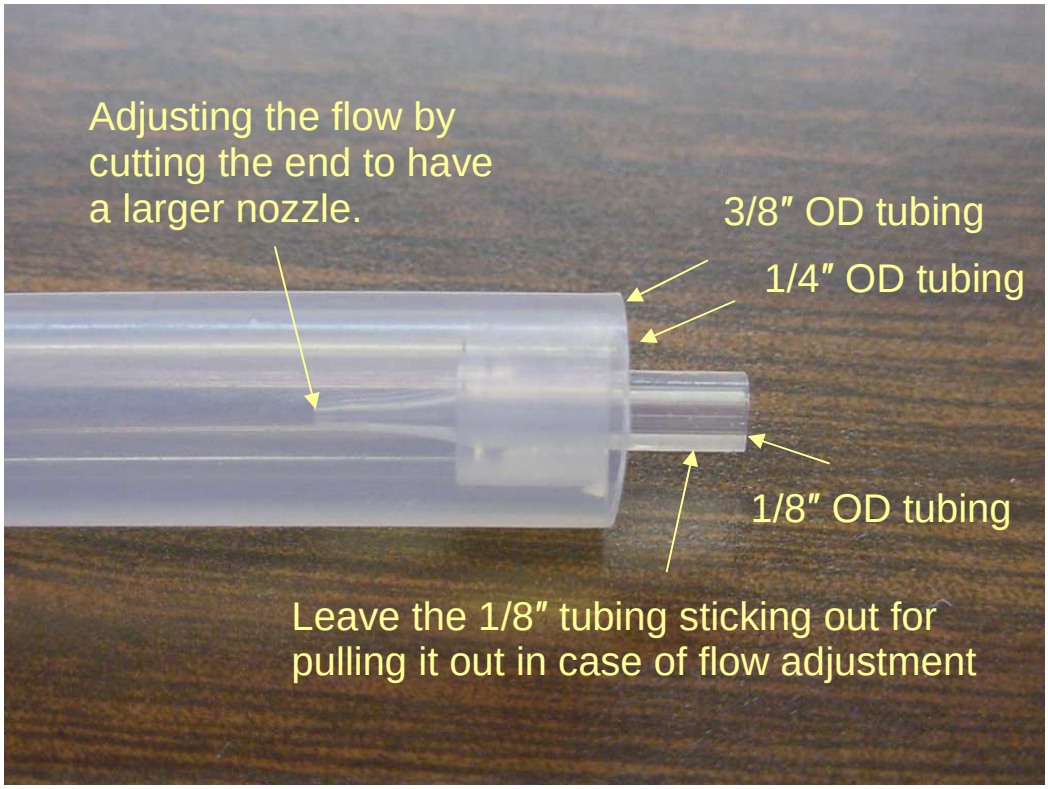


Figure 3. Configuration of flow restrictor in sampling inlet.

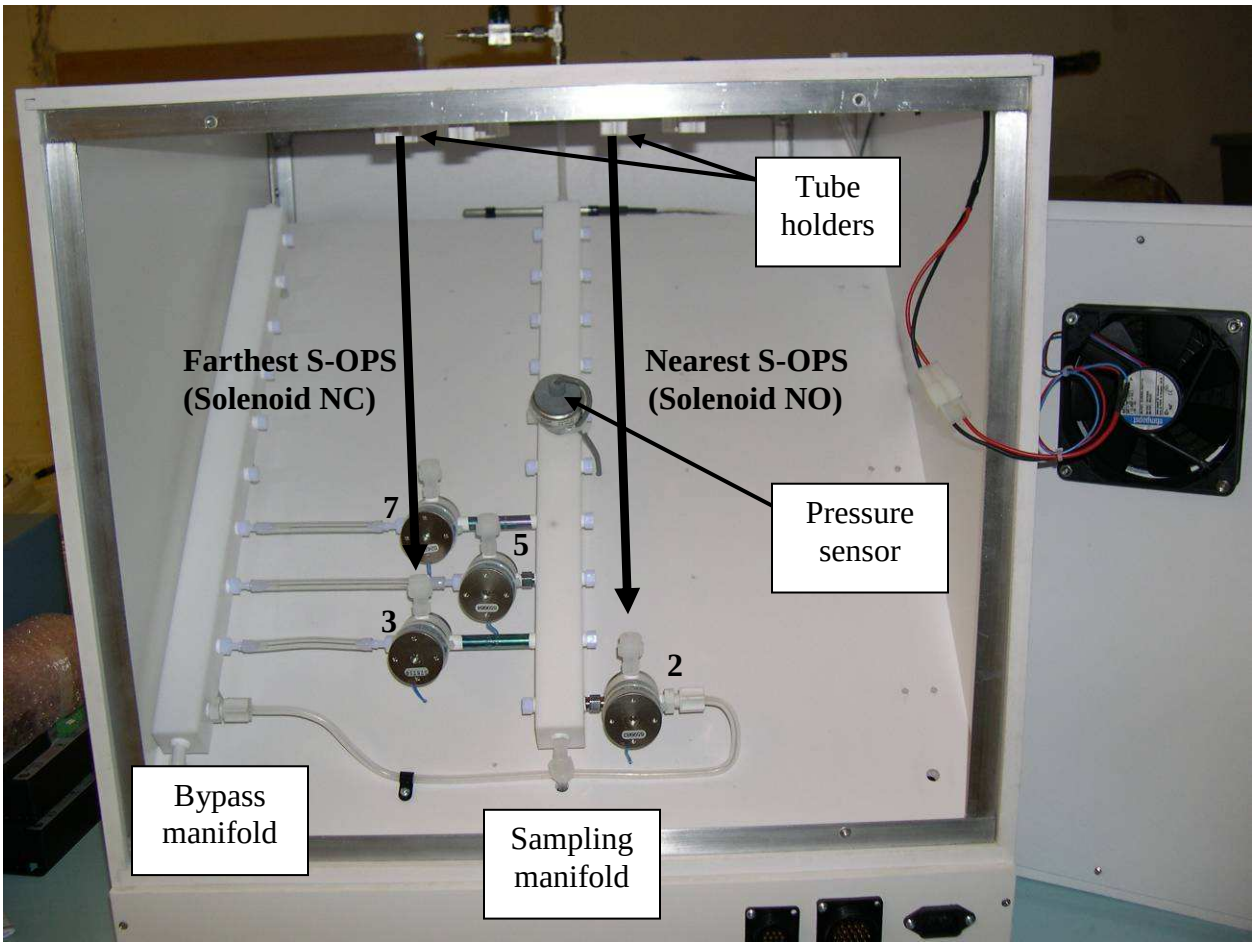


Figure 4. Open-cover view of the multi-point Gas Sampling System (front). Solenoid numbers are indicated as well as first two solenoids to be used with S-OPS configuration. NC= Normally closed (air normally directed to bypass manifold),NO=Normally open (air normally directed to sampling manifold).

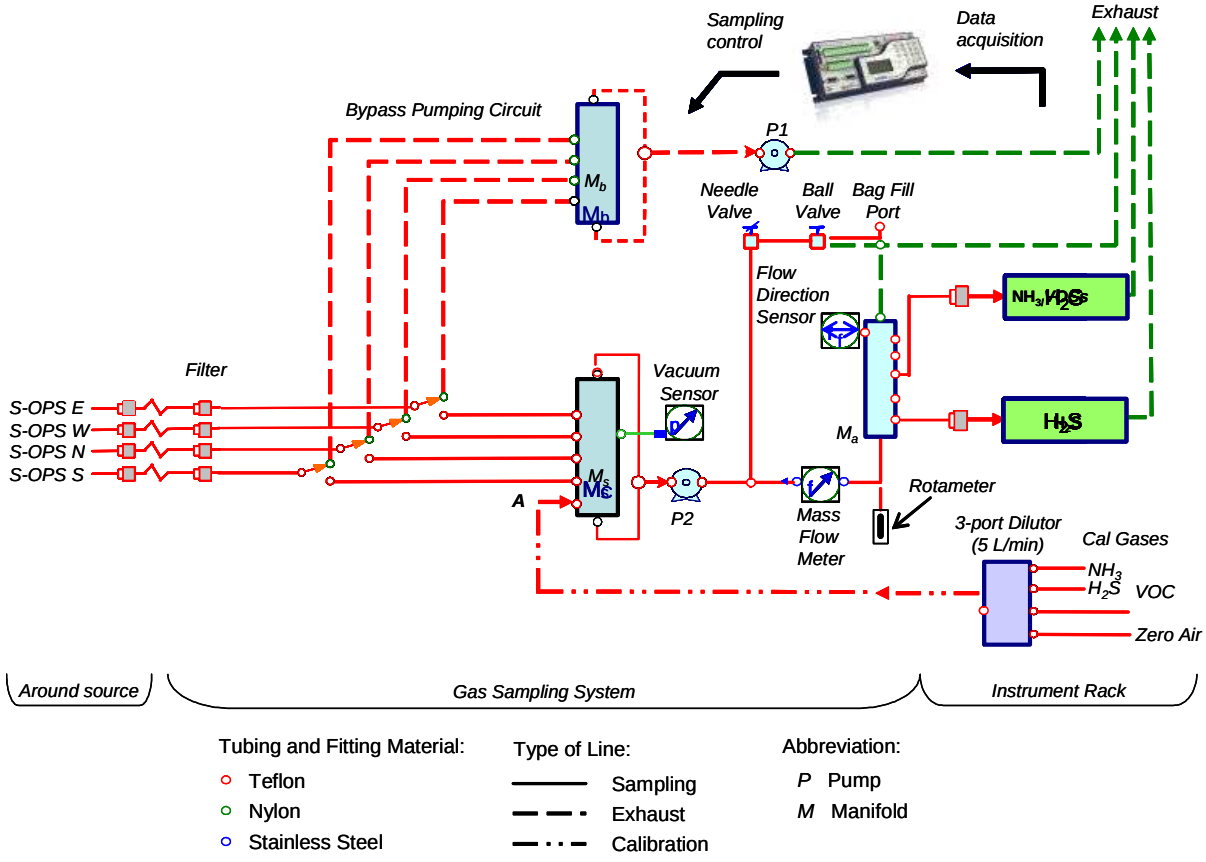


Figure 5. Schematic of Gas Sampling System.

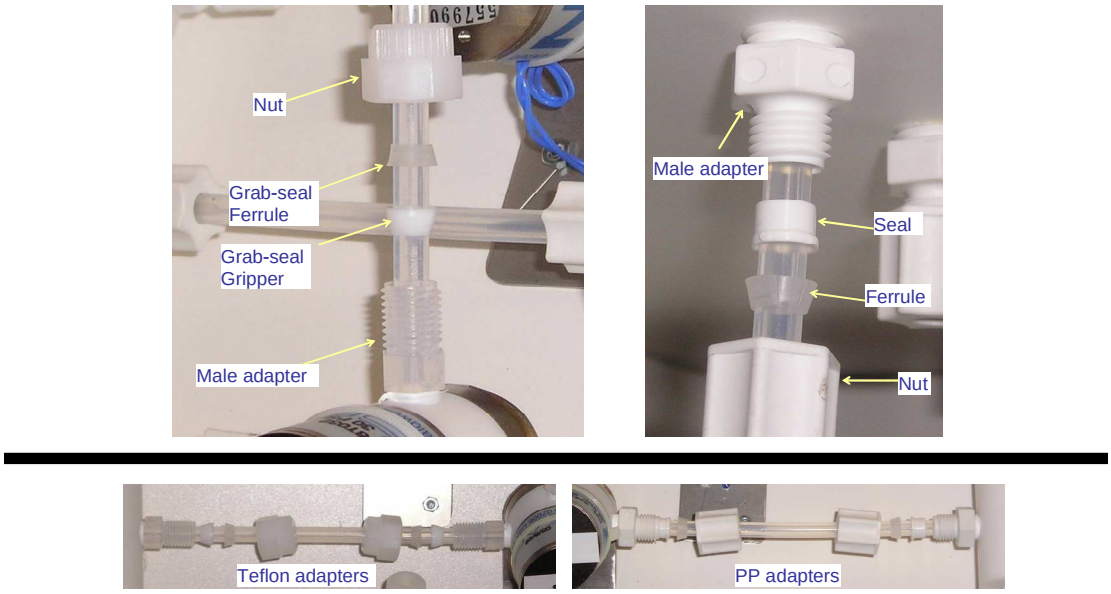


Figure 6. Connection of sampling tube to the Grab-seal Teflon fitting (left) at the solenoid and through the white polypropylene (right) fitting as the tube holder on top panel of the GSS.

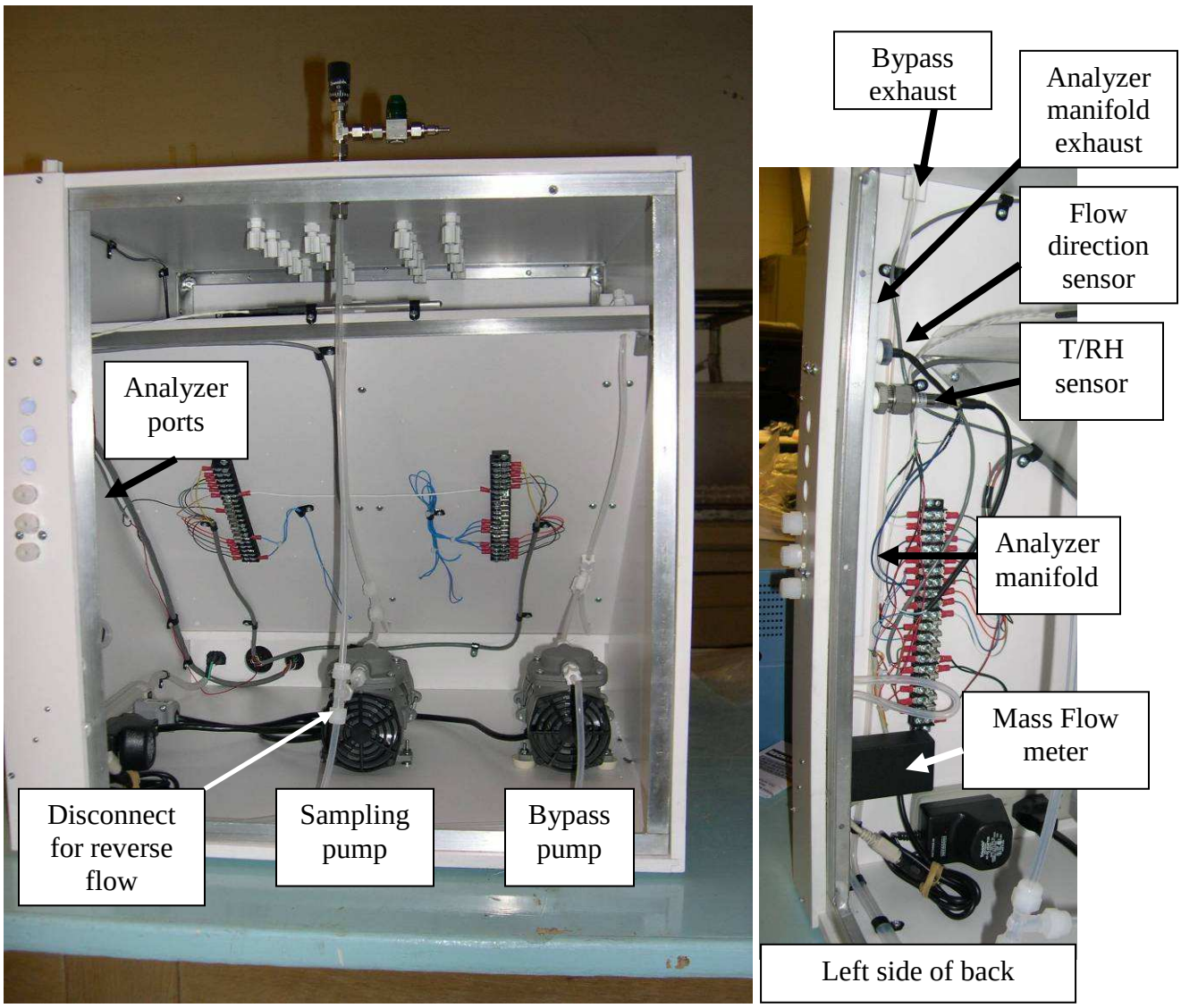


Figure 7. Open-cover view (back) of the multi-point gas sampling system.

Appendix A. Residence Time Calculations.

The residence time (ti) was calculated using the following equations:

$t_i = L_i / V_i$

Where:
L_i: length of tubing between inlet ni and next inlet.
V_i: velocity of gas in tubing segment Li.

$V_i = q_i / C_d * A_i$

Where:
q_i: gas flow in tubing segment L_i
A_i: internal cross area of tubing segment L_i.

Table A1 show the gas residence time and pressure loss as a function of the sampling volume per inlet . The pressure loss includes only the friction pressure loss, not the pressure drop due to the inlet filter and the needle valve used to regulate the inlet flow. Table A2 shows the residence time for a sample of air to travel through the S-OPS and S-OPS extension tubing given flow rates at the GSS.

Table A1. Gas residence time and pressure loss as a function of inlet sampling volume.

Inlet flow q_i, L/min	Residence time, t_i, s		Pressure loss at 20°C	
	Maximum, i=1	Minimum, i=10		
			Pa	Psi
1	55	0.19	5,113	0.73
2	27	0.95	17,223	2.4
3	18	0.63	35,070	5.0
4	13	0.47	58,106	8.3
5	11	0.38	85,990	12.2

Tubing diameter: 0.63 cm (0.25 in.); tubing length: 100 m; number of inlets: 10; inlet i=10 is closest to the sampling pump.

Table A2. Gas residence time for sampling through S-OPS extension tubing.

	Residence time (s)	
Tube length, m	**5 L/min flow**	**10 L/min flow**
0 (GSS only)	1.9	1.0
50	21	20
100	40	20
200	78	39
300	116	58

Appendix B **NAEMS Open GSS Acceptance Form**

GSS S/N _____ Date: _____

Operator: _____

	Solenoid 2	**Solenoid 3**	**Solenoid 5**	**Solenoid 7**
Sample flow test				
Outlet mass flow (L/min)				
Pressure (kPa)				
Pass/Fail				
GSS leak test				
Mass flow (L/min)				
Corrected mass flow (L/min)				
Pressure (kPa)				
Corrected pressure (kPa)				
Pass/Fail				
No flow test				
Mass flow (L/min)				
Pressure (kPa)				
Max flow test				
Outlet mass flow (L/min)				
Pressure (kPa)				

Comments:

Appendix C

NAEMS Open S-OPS Acceptance Form

Date: _____/____/_____ GSS S/N _____

Location: _____ FOS: _____

	Solenoid 2	**Solenoid 3**	**Solenoid 5**	**Solenoid 7**
Max flow test				
Inlet mass flow (L/min)				
Outlet mass flow (L/min)				
Pressure (kPa)				
Pass/Fail				
S-OPS/ GSS Leak test				
Mass flow (L/min)				
Corrected mass flow (L/min)				
Pressure (kPa)				
Corrected pressure (kPa)				
Pass/Fail				
S-OPS S/N				

Comments:

Appendix D

Synthetic Open-Path System Inlet Flow Verification Form

S-OPS S/N _____ Date: _____/_____/_____

FOS: _____

Inlet	**S-OPS inlet flow rate (L/min)**	**Deviation[1]**	**Action (clean, replace..)**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

1: Deviation = (Inlet flow-Mean flow)/Mean flow

Appendix E
S-OPS/ GSS Bag Test (System Adsorption)

S-OPS: _____ Date: ____/_____/_____

GSS S/N: _____ FOS: _____

Gas: H2S Analyzer: TFS 450I s/n:						
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Methane Analyzer: Innova 1412 s/n:						
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

S-OPS/ GSS Bag Test (System Adsorption) (Continued)

S-OPS: _____ Date: _____/_____/_____

GSS S/N: _____ FOS: _____

Gas: Methanol		**Analyzer: Innova 1412 s/n:**				
			Diluter/Cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Ethanol		**Analyzer: Innova 1412 s/n:**				
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

S-OPS/ GSS Bag Test (System Absorption) (Continued)

S-OPS: _____ Date: _____/_____/_____

GSS S/N: _____ FOS: _____

Gas: Propane		**Analyzer: Innova 1412 s/n:**				
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

Gas: Ammonia		**Analyzer: Innova 1412 s/n:**				
			Diluter/cylinder	**Analyzer**	**Average from**	
Time		**Sampling**	**Reading**	**Reading**	**Data File**	**Percent**
Start	**Stop**	**Location**	**ppm**	**ppm**	**ppm**	**Difference**
		S-OPS 1				
		S-OPS 2				
		S-OPS 3				
		S-OPS 4				
		S-OPS 5				
		S-OPS 6				
		S-OPS 7				
		S-OPS 8				
		S-OPS 9				
		S-OPS 10				
		Ambient				
Average						

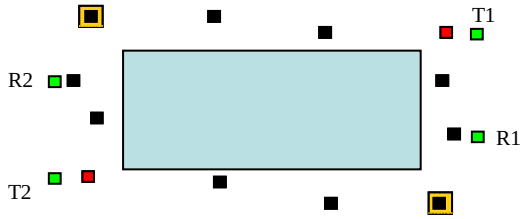
Appendix F

Lagoon/Basin Site Open-path Sensor Installation Report

Location: _____

Date: _____/_____/_____

FOS: _____



NEAR S-OPS with 500' extension tubing

S-OPS Path #1 start location (T1) _____Deg (N)____.____Min Deg (W)_____.__ Min

S-OPS Path #1 end location (R1) _____Deg (N)____.____Min Deg (W)_____.__ Min

Distance between Path #1 outlet tube and GSS manifold (extension tubing): _____ m

Height of Path #1 above lagoon berm : _____ m

FAR S-OPS with 1000' extension tubing

S-OPS Path #2 start location (T2) _____Deg (N)____.____Min Deg (W)_____.__ Min

S-OPS Path #2 end location (R2) _____Deg (N)____.____Min Deg (W)_____.__ Min

Distance between Path #2 outlet tube and GSS manifold (extension tubing):_____ m

Height of Path #2 above lagoon berm : _____ m

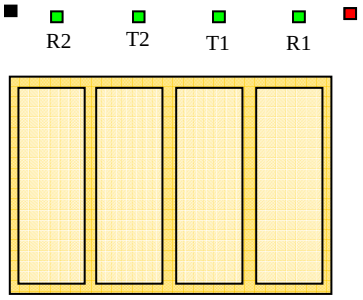
Notes:

Corral Site Open-path Sensor Installation Report

Location: _____

Date: _____/_____/_____

FOS: _____



NEAR S-OPS with 500' extension tubing

S-OPS Path #1 start location (T1) _____Deg (N)____.___Min Deg (W)_____.__ Min

S-OPS Path #1 end location (R1) _____Deg (N)____.___Min Deg (W)_____.__ Min

Distance between Path #1 outlet tube and GSS manifold (extension tubing): _____ m

Height of Path #1 above corral: _____ m

FAR S-OPS with 1000' extension tubing

S-OPS Path #2 start location (T2) _____Deg (N)____.___Min Deg (W)_____.__ Min

S-OPS Path #2 end location (R2) _____Deg (N)____.___Min Deg (W)_____.__ Min

Distance between Path #2 outlet tube and GSS manifold (extension tubing):_____ m

Height of Path #2 above corral: _____ m

Notes:

Appendix G

Flow Direction Sensor Calibration

GSS S/N _____ Date: _____

Operator: _____

	Solenoid 2	**Solenoid 3**	**Solenoid 5**	**Solenoid 7**
Flow				
Sample flow rate (L/min)				
Reverse flow rate (L/min				
Δ Flow (L/min)				
Sensor Response				
Sample flow				
Reverse flow				
Δ response				
Pass/Fail				

MANAGEMENT OF OPEN-SOURCE, WEATHER, AND LAGOON-CHARACTERIZATION DATA
Standard Operating Procedure (SOP) D1

MANAGEMENT OF OPEN-SOURCE, WEATHER, AND LAGOON-CHARACTERIZATION DATA

Standard Operating Procedure (SOP) D1

Prepared by

Richard H. Grant

Reviewed by

Bill W. Bogan, Ji-Qin Ni, and Albert J. Heber

Effective Date: November 6, 2006

PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Careful management of open-source, weather, and lagoon-characterization data is required to ensure that these data are all accurately documented and preserved.

1.1.1. Data generated with the Tunable Diode Laser Absorption Spectrometer (TDLAS) is needed to properly apply the radial plume mapping method, and thus to document the changing ammonia concentrations of the air surrounding the open-air source.

1.1.2. Data generated by Ultraviolet Differential Optical Absorption Spectroscopy (UV-DOAS) is needed to properly apply the backward Lagrangian Stochastic emissions model, and thus to document the changing ammonia and hydrogen sulfide concentrations of the air surrounding the open-air source

1.1.3. Data generated by INNOVA Model 1412 Photoacoustic Multi-gas Monitor (SOP G7) to quantitate total and individual volatile organic compounds (VOCs) from the air surrounding the open-air source needs to be properly documented.

1.1.4. Data on meteorological and lagoon conditions are needed for valid modeling of the effect of weather and microclimate on emissions.

1.2. The data management regime must be capable of managing data collected during multiple measurement periods, and at multiple study locations.

2. Summary of Method

The objective of data management is to ensure data security, easy data identification and retrieval, and efficient publication. All project-related files and data must be classified and organized in the computerized research data storage system. The tools to deliver, backup, inspect, analyze and present data must be available and kept current with the latest updates.

3. Definitions

3.1.	bLS	Backward Lagrangian Stochastic
3.2.	CD	Compact disk
3.3.	DM	Data Manager
3.4.	DVD	Digital video disk
3.5.	Flash memory	Non-volatile rewritable memory
3.6.	FOS	Field operations staff
3.7.	HD	Computer hard drive
3.8.	ODBC	Open data base connectivity
3.9.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.10.	PAML	Purdue Applied Meteorology Laboratory
3.11.	PIC	Path-integrated concentration
3.12.	PM	Project Manager
3.13.	ppb	Parts per billion (by volume)
3.14.	QAM	Quality Assurance Manager
3.15.	QAPP	Quality Assurance Project Plan

3.16. RPM	Radial Plume Mapping method of emissions measurement
3.17. Site PI	Site Principal Investigator
3.18. SMP	Site monitoring plan
3.19. LAN Server	Local Area Network Sever computer
3.20. TDLAS	Tunable Diode Laser Absorption Spectrometer/Spectroscopy
3.21. UV-DOAS	Ultraviolet Differential Optical Absorption Spectrometer/ Spectroscopy
3.22. VOC	Volatile organic compounds
3.23. WXL	Weather and lagoon

4. Personnel Qualifications and Responsibilities

4.1. Most of these procedures assume a familiarity with the use of personal computers and general computer application software (e.g. MS Office), as well as the following:
- 4.1.1. UV-DOAS procedures (SOP C1) and the WINDTRAX bLS software (SOP O1)
- 4.1.2. The RPM software (SOP O2) and the TDLAS procedures (SOP C2)
- 4.1.3. INNOVA 1412 Photoacoustic Multi-gas Monitor procedure (SOP G7)
- 4.1.4. The data analysis software programs which are used to perform the transformations described in SOPs W1-W5
- 4.1.5. The data acquisition and control software described in SOP W6

4.2. The site PI will follow an orderly system of data recording, organization, and safeguards, and will ensure that all members of the research team (including appropriate administrative personnel) understand and follow the system.

4.3. Data access management will be controlled according to Purdue University (Information Technology at Purdue) procedures defined for sensitive data (Appendix A). Those authorized to access research data will use strong passwords that are difficult to crack, according to Appendix B. Passwords will not be written down or shared with others. Passwords will be changed on a regular basis (every two months at a minimum).

4.4. Only those people explicitly authorized to access the research data will be allowed to write to the files (Appendix A).

5. Equipment and supplies

5.1. Data transfer pouch
5.2. UV-DOAS 4-Gb flash memory drives (2 per measurement period)
5.3. 64Mb CompactFlash® memory card (1 per measurement period)
5.4. 256Mb flash memory sticks (3 per measurement period)
5.5. Blank CDs
5.6. Fire-proof data vault
5.7. Innova Gas Monitor Software (Version 7304)

6. Procedures

6.1. Classification of electronic files

- 6.1.1. Classify all electronic files according to the following four categories:

6.1.1.1.Research information and data. These files, if lost, cannot be rebuilt or recovered.
- 6.1.1.1.1. Measurement data
- 6.1.1.1.2. Data acquisition configuration data
- 6.1.1.1.3. Calibration data forms
- 6.1.1.1.4. Data logged by instruments (TDLAS and UV-DOAS) with internal data storage
- 6.1.1.1.5. Calibration data recorded by TDLAS and UV-DOAS systems, and electronic calibration forms
- 6.1.1.1.6. Data recorded by INNOVA 1412 Photoacoustic multi-gas monitor
- 6.1.1.1.7. Field notes
- 6.1.1.1.8. Email messages
- 6.1.1.1.9. Image files (digital photos or graphs)

6.1.1.2.Project-specific configurations that could be rebuilt or recovered, if lost
- 6.1.1.2.1. Hardware configuration files
- 6.1.1.2.2. Configurations of firewalls, virus protection, etc
- 6.1.1.2.3. Email accounts, address books, message rules
- 6.1.1.2.4. Favorite lists

6.1.1.3.Project-specific software and documents
- 6.1.1.3.1. Thunder Scientific WINDTRAX
- 6.1.1.3.2. Boreal Laser GasView2
- 6.1.1.3.3. Arcadis RPM
- 6.1.1.3.4. INNOVA Gas Monitor Software 7304
- 6.1.1.3.5. Campbell Scientific LoggerNet data logger programming and collection software
- 6.1.1.3.6. National Instruments LabVIEW
- 6.1.1.3.7. Files provided by vendors, such as instrument manuals and application notes
- 6.1.1.3.8. Instrument communication software

6.1.1.4.General PC Software
- 6.1.1.4.1. Microsoft Windows XP
- 6.1.1.4.2. Microsoft Office
- 6.1.1.4.3. WS_FTP server and ftp encryption software
- 6.1.1.4.4. PC Anywhere
- 6.1.1.4.5. Network Associates Enterprise
- 6.1.1.4.6. Spybot S&D
- 6.1.1.4.7. Genie Backup Manager

6.2. Data acquisition of UV-DOAS PIC spectra (SOP O1) for NH_3 and H_2S concentration calculation is conducted by the on-site ‘bLS’ computer (Fig. 1).

6.2.1. Data is stored in a 4Gb flash memory drive on each UV-DOAS receiver. After 20 days, memory used is approximately 500Mb.

6.3. Data acquisition of TDLAS PIC spectra (SOP O2) for NH_3 concentration calculations is conducted by each of the on-site ‘TDLAS/scanner’ computers (Fig. 2).

6.3.1. Data is stored in the HD of each TDLAS/scanner computer. After 20 days, memory used is approximately 3.3Mb.

6.4. Data acquisition using INNOVA 1412 Photoacoustic multi-gas monitor (SOP G7) for total and individual VOC concentrations stored directly in the HD of the LAN computer (Fig. 3).

6.5. Data acquisition of lagoon temperature, pH, and redox state (SOPs L1, L2 and L3), barometric pressure, air temperature, relative humidity, solar radiation, surface wetness, and data logger power supply voltage (SOPs E3, W1, W3, and W5) is conducted by a datalogger (SOP W6) (Fig. 4).

6.5.1. Data is stored in a first in first out (FIFO) memory, and on a 64Mb CompactFlash® memory card. After 20 days, memory used is approximately 64Kb.

6.6. Data acquisition of wind components at three heights (SOP W2) is conducted by the on-site LAN Server computer (Fig. 4).

6.7. Data processing for the parameters listed in Section 6.2 is conducted by the on-site 'bLS' computer, which is connected to the UV-DOAS system by radio communications (Fig. 1).

6.8. Data processing for the parameters listed in Section 6.3 is conducted by the on-site LAN server computer, which is connected to the two 'TDLAS/scanner' computers by Ethernet (Fig. 2).

6.9. Data processing for the parameters listed in Section 6.4, and control of the INNOVA Multi-gas Monitor, are conducted by the Gas Monitoring Software 7304 running in the on-site LAN Server computer, which is connected by RS 232 cable to the INNVOA 1412 (Fig. 3).

6.10. Data processing for the parameters listed in Section 6.5 is conducted by the on-site Network Server computer, which is connected to the datalogger by radio communications.

6.11. File organization

6.11.1. All project-specific files on computers will be in folders called *YY*farm*n*, where *YY* is a two-letter abbreviation for the state and *n* is the farm identifier within the state. For example, two farms in Missouri would be identified as MOfarm1 and MOfarm2.

6.11.2. The flash memory drive of each UV-DOAS instrument (Fig. 1) contains:

6.11.2.1. Raw 5-min average PIC spectra [MinMinHrHr, PIC NH_3, PIC H_2S]

6.11.2.2. Spreadsheet of 5-min PIC averages (filename 'C'MMDDYY [MinMinHrHr] containing: background PIC, SignalStrength, IntegrationTime, PIC NH_3, NH_3 measurement error, PIC H_2S, H_2S measurement error, RMSnoise)

6.11.3. The datalogger flash memory (Fig. 4) contains:

6.11.3.1. Raw data files (named by MMDDYY, containing farm number, MMDDYY, HrHrMinMin, 5-min averages of lagoon temperature, pH, and redox state, barometric pressure, air temperature, relative humidity, solar radiation, surface wetness, and power supply voltage) (SOP W6)

6.11.4. In the on-site computer associated with both UV-DOAS systems (Fig. 1), termed the 'bLS computer', store all project date-specific measurement files in folders called MMDDYY where MM is numerical month, DD is numerical day in month, and YY is a two-letter abbreviation for the year in which the WINDTRAX bLS program was started. Organize the subfolders as:

6.11.4.1. Program. WINDTRAX bLS software

6.11.4.2. Config. Contains configuration files for bLS at location *YY*farm*n*.

6.11.4.3. Touchdown tables (See SOP O1) for *YY*farm*n*
6.11.4.4. 5-min 2-m height wind turbulence statistics (SOP W2) for *YY*farm*n* so that statistics coincide with periods of PIC measurements according to SOP O1.
6.11.4.4.1. Wind data is transferred from the LAN server computer to the UV-DOAS systems through the Ethernet connection.
6.11.4.5. UV-DOAS Instrument 1 data for location *YY*farm*n*
6.11.4.5.1. Raw 5-min average PIC spectra [MinMinHrHr, PIC NH_3, PIC H_2S
6.11.4.5.2. Spreadsheet of 5-min PIC averages (filename 'C'MMDDYY [MinMinHrHr] containing: background PIC, SignalStrength, IntegrationTime, PIC NH_3, NH_3 measurement error, PIC H_2S, H_2S measurement error, RMS noise)
6.11.4.6. UV-DOAS Instrument 2 data for location *YY*farm*n*
6.11.4.6.1. Raw 5-min average PIC spectra [MinMinHrHr, PIC NH_3, PIC H_2S
6.11.4.6.2. Spreadsheet of 5-min PIC averages (filename 'C'MMDDYY [MinMinHrHr] containing: background PIC, SignalStrength, IntegrationTime, PIC NH_3, NH_3 measurement error, PIC H_2S, H_2S measurement error, RMSnoise)
6.11.4.7. WINDTRAX input spreadsheet for location *YY*farm*n*
6.11.4.7.1. 5-min average difference in PICs and wind data (filename MMDDYY [MinMinHrHr]; containing: turbulence statistics, PIC NH_3, PIC H_2S)
6.11.4.8. WINDTRAX output file for location *YY*farm*n* (filename MMDDYY [MinMinHrHr]
6.11.5. In the on-site data acquisition computer associated with each TDLAS/scanner system (each of 2 computers and associated systems, located according to Fig. 2), The two TDLAS/scanner systems are designated TDLAS1 and TDLAS2. All date-specific measurement files are in folders called MMDDYY where MM is numerical month, DD is numerical day in month, and YY is a two-letter abbreviation for the year in which the RPM program was started. Organize the subfolders as:
6.11.5.1. Config1. Contains all files associated with first plane of measurement for RPM analysis of TDLAS
6.11.5.1.1. Config. Contains geometry configuration file
6.11.5.1.2. Input file. Includes PIC values for each time period of averaging
6.11.5.1.2.1. Format according to SOP O2.
6.11.5.1.3. Plume map graphs. Contains each averaging period plume map from the RPM program (See SOP O2) as a jpeg file (70Kb/image)
6.11.5.1.4. Flux output file. Contains flux measurements with QA/QC checks on the RPM measurement according to SOP O2
6.11.5.1.5. Valid raw wind data
6.11.5.1.5.1. Format according to SOP W2.
6.11.5.1.5.2. Data is transferred from the LAN server computer through the Ethernet connection.
6.11.5.1.6. Parsed wind data so that the measurement period of wind data coincides with the measurement period of each complete cycle of PIC measurements.
6.11.5.1.7. Raw PIC measurements from TDLAS
6.11.5.1.7.1. Beam1. PIC values along beamline 1 with QA/QC flags (SOP C2).
6.11.5.1.7.2. Beam2. PIC values along beamline 2 with QA/QC flags (SOP C2).

6.11.5.1.7.3. Beam3. PIC values along beamline 3 with QA/QC flags (SOP C2).
6.11.5.1.7.4. Beam4. PIC values along beamline 4 with QA/QC flags (SOP C2).
6.11.5.1.7.5. Beam5. PIC values along beamline 5 with QA/QC flags (SOP C2).
6.11.5.2. Config2. Contains all files associated with second plane of measurement for RPM analysis of TDLAS
6.11.5.2.1. Config. Contains geometry configuration file
6.11.5.2.2. Input file. Includes PIC values for each time period of averaging
6.11.5.2.2.1. Format according to SOP O2.
6.11.5.2.3. Plume map graphs. Contains each averaging period plume map from the RPM program (SOP O2) as a jpeg file (70Kb/image)
6.11.5.2.4. Flux output file. Contains flux measurements with QA/QC checks on the RPM measurement according to SOP O2
6.11.5.2.5. Valid raw wind data
6.11.5.2.5.1. Format according to SOP W2.
6.11.5.2.5.2. Data is transferred from the LAN server computer
6.11.5.2.6. Parsed wind data so that the measurement period of wind data coincides with the measurement period of each complete cycle of PIC measurements
6.11.5.2.7. Raw PIC measurements from TDLAS
6.11.5.2.7.1. Beam6. PIC values along beamline 6 with QA/QC flags (SOP C2).
6.11.5.2.7.2. Beam7. PIC values along beamline 7 with QA/QC flags (SOP C2).
6.11.5.2.7.3. Beam8. PIC values along beamline 8 with QA/QC flags (SOP C2).
6.11.5.2.7.4. Beam9. PIC values along beamline 9 with QA/QC flags (SOP C2).
6.11.5.2.7.5. Beam10. PIC values along beamline10 with QA/QC flags (SOP C2).
6.11.6. In the on-site INNOVA data acquisition computer (which is also the on-site LAN server) organize the subfolders in the C drives as :
6.11.6.1. C:\INNOVA (for all single point data acquisition and control)
6.11.6.2. \Data acquisition program (Gas Monitoring Software7304)
6.11.6.3. \Configuration file (common for all measurement locations)
6.11.6.4. Data collected from the Gas Monitor Software 7304 (SOP G7) by the LAN server will be saved in the directory [C:\INNOVA\Farm number\MMDDYY\ODBC] (SOP G7).
6.11.6.5. 5-min raw sample values will be stored on the LAN server in MS-access format (ODBC).
6.11.6.6. Data includes: Measurement times, measurement sequence numbers, Error and user flags, atmospheric pressure, water vapor, NH_3 concentration, acetic acid concentration, methanol concentration, ethanol concentration.
6.11.7. In the <u>on-site weather data acquisition computer (which is also the on-site LAN Server)</u> organize the subfolders in the C drive as:
6.11.7.1. LabVIEW files (for wind sensor data acquisition and control)
6.11.7.1.1. Data acquisition program
6.11.7.1.2. Configuration file (common for all measurement locations)
6.11.7.1.3. Wind data files for *YY*farm*n* (See SOP W2)
6.11.7.1.3.1. File with 30 min of raw 16-Hz data for spectral analysis (including U, V, W, T_v)
6.11.7.1.3.2. 5-min average statistics

6.11.7.1.3.3. 30-min average statistics

6.11.7.2. LoggerNet® datalogger software directories and subdirectories according to LoggerNet manual (page 2-3) for data collection and datalogger control of weather and lagoon characterization sensors (Section 5.2 of manual).

6.11.7.2.1. Communication logs

6.11.7.2.2. System. Includes binary files, configuration files and raw data downloads collected by the data acquisition program named as [MMDDYY-*YY*farm*n*]

6.11.7.2.3. PakBusGraph. Contains daily plots of raw data.

6.11.7.2.3.1. Data files for *YY*farm*n* (named by date MMDDYY, containing HrHrMinMin, 5-min averages of lagoon temperature, pH, and redox state, barometric pressure, air temperature, relative humidity, solar radiation, surface wetness, and power supply voltage)

6.11.7.3. Datalogger configuration and program editors

6.11.7.4. Library directory containing compilers and definition files

6.11.7.5. Calibration. Contains calibration sheets, gas cylinder logs, control charts, and other records

6.11.7.6. QAPP. The latest copy of the Quality Assurance Project Plan

6.11.7.7. SOP. Latest copies of all relevant Standard Operating Procedures

6.11.7.8. SMP. Site monitoring plan

6.11.7.9. Certifications

6.11.7.10. Measurement period records. Indicates dates and locations

6.11.7.11. Field Notes

6.11.7.11.1. Typed logs of activities and observations (All notes must include name and date of the person making the note)

6.11.7.11.2. Producer Event forms and updated farm specific information (layout drawings etc) other farm lagoon management data (information on animals, weight, feed, etc) collected from the farm manager (SOP S7)

6.11.7.12. Photos. Digital pictures of field setup and observations

6.11.7.13. Email. Contains email messages and attachments. Name the email account yyfarmn@zzz.zzz where zzz.zzz is the internet service provider's domain. Outlook Express is the preferred email program.

6.11.7.14. Miscellaneous

6.11.7.14.1. Site equipment inventory including gas cylinders, etc

6.11.7.14.2. Transported equipment inventory

6.11.8. The administrative server at PAML contains the following folders and information, and operates various personal computers:

6.11.8.1. Weather data from outside sources for each day and every location that measurements are taken. Example of an outside source might be; http://www.wunderground.com/us/nc/elizabethtown.html.

6.11.8.2. Data ftped from *YY*farm*n*

6.11.8.3. UV-DOAS and bLS data and configuration files

6.11.8.4. TDLAS and RPM data and configuration files

6.11.8.5. Excel files of text data exported from bLS and RPM directories during processing

6.11.8.6. LoggerNet configuration files

6.11.8.7. INNOVA Gas Monitor Software 7304 configuration files
6.11.8.8. LabVIEW configuration files
6.11.8.9. Excel files of data exported from LoggerNet during processing
6.11.8.10. Excel files of data exported from LabVIEW during processing.
6.11.8.11. AutoCad drawings of lagoon and equipment
6.11.8.12. Data tables for reports and manuscripts
6.11.8.13. Farm production data
6.11.8.14. Reports
6.11.8.15. ftp transfer logs

6.12. Data security

6.12.1. The on-site computer associated with the UV-DOAS (Fig. 1) is linked through an Ethernet local area network to the Network Server computer.

6.12.2. Each on-site data acquisition computer linked with each TDLAS instrument is linked to the Network server computer in the trailer through an Ethernet local area network (SOP U4).

6.12.3. Datalogger

6.12.3.1. Three 5-digit security passwords are needed to change the data acquisition program, download data, or change the clock.

6.12.3.1.1. FOS will each have all security codes.

6.12.3.2. Replace 1Mb flash memory at the end of each measurement period (identified here as WXL).

6.12.3.2.1. Put flash memory into the zippered Data pouch.

6.12.4. LoggerNet will be operated as a service on the on-site computer, so that the program will restart after power failures.

6.12.5. Innova Gas Monitoring Software 7304 shortcut will be placed in the start up folder so the program will restart after power failure or restart.

6.12.6. Program Windows “Scheduled Tasks” to ftp the 24-h data files from the on-site weather data acquisition computer, Innova Gas Monitoring software, and the data acquisition computers linked to the TDLAS instruments and UV-DOAS instruments to the PAML computer at midnight.

6.12.6.1. All ftp file transfers are encrypted.

6.12.7. Collect archived raw data from flash drives in each UV-DOAS instrument (approximately 500MB of data on each of the 4GB flash drives) at the conclusion of the measurement period.

6.12.7.1. Replace the flash drive in each instrument.

6.12.7.2. Copy content of each UV-DOAS flash drive onto two CDs.

6.12.7.2.1. Identify CD with location (*YY*farm*n*), measurement period (MM-DD-YY to MM-DD-YY), “UVDOAS1” for “UVDFlash1” and “UVDOAS2” for “UVDFlash2” and label “vault” or “carry”.

6.12.7.2.2. Copy using LAN Server computer

6.12.7.2.3. Put one copy of each of the two CDs into the fire-proof data vault in the trailer.

6.12.7.2.4. Put the other copy of each CD in Data pouch.

6.12.7.3. Store all data-containing UV-DOAS Flash drives in Data pouch.

6.12.8. Field notes
- 6.12.8.1. Notes are stored on the HD of the LAN server computer, and are (automatically) backed up daily on an external HD.
- 6.12.8.2. Email field notes to PM and DM at the end of each work day in the field, before leaving the site.
- 6.12.8.3. Download field notes onto flash memory stick.
- 6.12.8.4. Store memory stick in the zippered Data pouch.

6.12.9. FOS copies of calibration data and control charts
- 6.12.9.1. Email to PM, DM, and QAM after each 20-day measurement period.
- 6.12.9.2. Retain one paper copy in trailer.
- 6.12.9.3. Download onto flash memory stick with field notes.
- 6.12.9.4. Store memory stick in the zippered Data pouch.

6.12.10. Send (by ftp) configuration files to DM whenever they are updated.

6.12.11. File backups by field staff
- 6.12.11.1. Back up project folders and subfolders *YY*farm*n* of each onsite computer onto an external hard drive at 1:00 a.m. each night during the measurement period.
- 6.12.11.2. Back up data files onto DVD at the conclusion of every measurement period.
  - 6.12.11.2.1. Two copies each of UVDOAS1, UVDOAS2 from LAN server.
  - 6.12.11.2.2. Two copies each of TDLAS 1 and TDLAS 2 from respective Data Acquisition computers.
  - 6.12.11.2.3. Two copies of INNOVA data files from LAN server
  - 6.12.11.2.4. Two copies of WXL data from LAN server
  - 6.12.11.2.5. Identify each CD with data type (above), location (*YY*farm*n*) and measurement period (MM-DD-YY to MM-DD-YY). Label one copy of each DVD as “vault”, one copy as “carry”.
  - 6.12.11.2.6. Put “vault” copy of DVD into the fire-proof data vault.
  - 6.12.11.2.7. Put “carry” copy of DVD in the data pouch.
- 6.12.11.3. Manually back up the operating system of any computer onto an external HD whenever significant changes are made to the system.

6.12.12. Automatically back up filesystem of the LAN server onto an external HD every day at 2:00 a.m.

6.12.13. Carry Data pouch in hand luggage upon returning to PAML.
- 6.12.13.1. Data pouch includes:
  - 6.12.13.1.1. For latest measurement period:
    - 6.12.13.1.1.1. One pair of 4-Gb UV-DOAS flash memory drives (UVDFlash1 and UVDFlash2)
    - 6.12.13.1.1.2. One pair of CDs with copies of UV-DOAS flash memory drives (UVDOAS1 and UVDOAS2)
    - 6.12.13.1.1.3. Two CDs with TDLAS data (TDLAS1 and TDLAS2)
    - 6.12.13.1.1.4. One CD with weather,and lagoon (WXL) and INNOVA data from recently-completed measurement period
    - 6.12.13.1.1.5. One 64-Mb flash memory chip of weather and lagoon (WXL) data from recently-completed measurement period
    - 6.12.13.1.1.6. One 256-Mb memory stick with Field notes, calibration data and control charts from recently-completed measurement period

6.12.13.1.1.7. One DVD with *YY*farm*n* backup of all *YY*farm*n* directories
6.12.13.1.2. For previous measurement period (material previously stored in data vault):
6.12.13.1.2.1. One pair of CDs with copies of UV-DOAS flash memory drives (UVDOAS1 and UVDOAS2)
6.12.13.1.2.2. Two CDs with TDLAS data from the previous measurement period (TDLAS1 and TDLAS2)
6.12.13.1.2.3. One CD with weather, lagoon (WXL) and INNOVA data from previous measurement period
6.12.13.1.2.4. One DVD with *YY*farm*n* backup of all *YY*farm*n* directories
6.12.13.1.3. Electronic data transfer forms for both recently-completed and previous measurement period (Appendix C) with upper section filled out.
6.12.13.2. Deliver Data pouch to DM on arrival.
6.12.13.2.1. Document delivery of data to DM with Electronic Data Transfer Forms (Appendix C).
6.12.13.2.1.1. Forms to be stored in the folder marked 'Electronic data Transmittal records' under the control of the DM.
6.12.14. DM archives files on the PAML computer onto an external HD drive every day at 5:00 a.m.
6.12.15. DM downloads all flash memory to a separate directory on PAML computer for backup.
6.12.16. DM stores all received CDs in an off-campus location.
6.12.17. DM archives files on the PAAQL server., which is backed up daily on the Purdue University backup system.
6.13. Retention of data
6.13.1. Keep all data files for at least six (6) years.

7. Quality Control and Quality Assurance

7.1. Verify that the following software are included in their respective computers' startup menus, for automatic recovery after power failure.
7.1.1. LoggerNet, Gas Monitor Software 7304, and LabVIEW (in the on-site, LAN server, computer)
7.1.2. WINDTRAX program (in the bLS computer)
7.1.3. RPM program (in each TDLAS/scanner data acquisition computer)
7.2. Verify that all data acquisition computers log power failures, and that emails are sent to the QAM and DM upon restart.
7.3. Check field computer and relevant software, and take immediate measures to solve related problems, if the daily data file ftp, and/or emails with other files are not received.
7.4. Multiple means of irreplaceable data transfer to PAML
7.4.1. Daily ftp of files
7.4.2. Hand delivery of data from each measurement period at end of measurement period and at the end of the next sequential measurement period (stored in the data vault)
7.5. Raw data stored in multiple places prior to transfer to PAML
7.5.1. UV-DOAS raw (Fig. 1)
7.5.1.1. Flash memory drive of each UV-DOAS instrument

7.5.1.2.bLS computer HD
7.5.2. TDLAS raw and RPM processed data (Fig. 2)
7.5.2.1.TDLAS data acquisition computer HD
7.5.2.2.External HD
7.5.3. bLS computer filesystems (including wind measurements and bLS input files and results) (Fig. 1)
7.5.3.1.bLS computer HD
7.5.3.2.External HD
7.5.4. INNOVA raw data (Fig. 3)
7.5.4.1.LAN server HD
7.5.4.2.External HD
7.5.5. Datalogger raw data (excluding wind measurements) (Fig. 4)
7.5.5.1. CompactFlash memory card
7.5.5.2. On-site datalogger
7.5.5.3. LAN server HD
7.5.5.4. External HD
7.5.6. LAN Server computer filesystems (including wind measurements) (Figs. 1-4)
7.5.6.1. HD of on-site computer
7.5.6.2. External HD

7.6. DM tracks all modifications to electronic files. This includes tracking the original data entered, tracking who and when an individual or system viewed or changed any data, and recording why data was changed.
7.6.1. Save and archive all raw data in their original form.
7.6.2. Use a “notes” worksheet in Excel files to describe modifications.
7.6.3. Include date at the end of file name in the following format: MM-DD-YY, ex: 01-09-06. Leading zeros in day and month can be omitted, ex. 1-9-06.
7.6.4. Utilize electronic audit trails as much as possible.

8. References

8.1. Campbell Scientific Inc. 2005. LoggerNet Instruction Manual, v. 3.2, Campbell Scientific Inc., Logan UT.
8.2. Campbell Scientific Inc. 2006. CR1000 Measurement and Control System Operators Manual. v. 3/06, Campbell Scientific Inc., Logan, UT
8.3. Information Technology at Purdue. 2006. Electronically Stored (Computer-based) Information. Available at: http://www.itap.purdue.edu/security/procedures/dataHandling/electrStored.cfm. Accessed 2-28-2006.
8.4. Information Technology at Purdue. 2006. Password Guidelines. Available at: http://www.itap.purdue.edu/security/procedures/passGuidelines.cfm. Accessed 2-28-2006.
8.5. SOP C1. 2006. Open Path Measurement of Ammonia and Hydrogen Sulfide with the Cerex UV Sentry Ultraviolet Differential Optical Absorption Spectrometer. Standard Operating Procedure C1. Purdue Applied Meteorology Lab.

8.6. SOP C2. 2006. Measurement of Ammonia with the Boreal Laser GasFinder Tunable Diode Laser Absorption Spectrometer (TDLAS) Standard Operating Procedure C2. Purdue Applied Meteorology Lab.
8.7. SOP E3. 2006. The Measurement of Solar Radiation with the Licor Model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab.
8.8. SOP G7. 2006. Use of the INNOVA 1412 Photoacoustic Multi-gas Monitor. Standard Operating Procedure G7. Purdue Ag Air Quality Lab.
8.9. SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Applied Meteorology Lab.
8.10. SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.
8.11. SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Applied Meteorology Lab.
8.12. SOP O1. 2006. Emissions Estimation Using the Thunder Beach Scientific Windtrax Backward Lagrangian Stochastic Model. Standard Operating Procedure O1. Purdue Applied Meteorology Lab.
8.13. SOP O2. 2006. Emissions Estimation Using the ARCADIS Radial Plume Mapping Model. Standard Operating Procedure O2. Purdue Applied Meteorology Lab.
8.14. SOP S7. 2006. Producer Collaborations at Area Source Monitoring Sites. Standard Operating Procedure S7. Purdue Applied Meteorology Lab.
8.15. SOP U4. 2006. Open-source Instrument Trailer. Standard Operating Procedure U4. Purdue Applied Meteorology Lab.
8.16. SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Vaisala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.
8.17. SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.
8.18. SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.
8.19. SOP W5. 2006. The Measurement of Barometric Pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.
8.20. SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware.. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

Figure 1. Data Processing and Management: UV-DOAS and bLS Data.

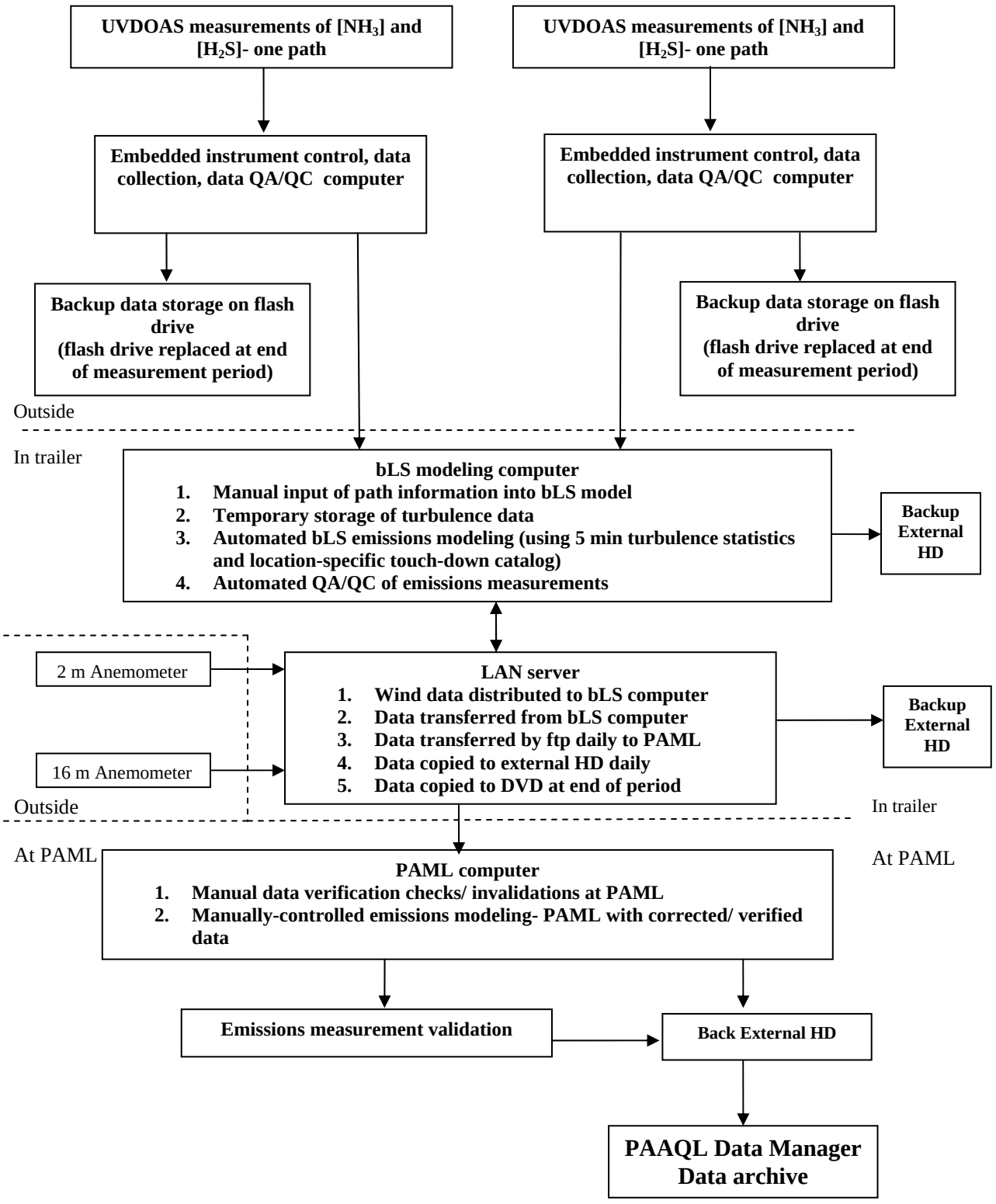


Figure 2. Data Processing and Management: TDLAS and RPM Data.

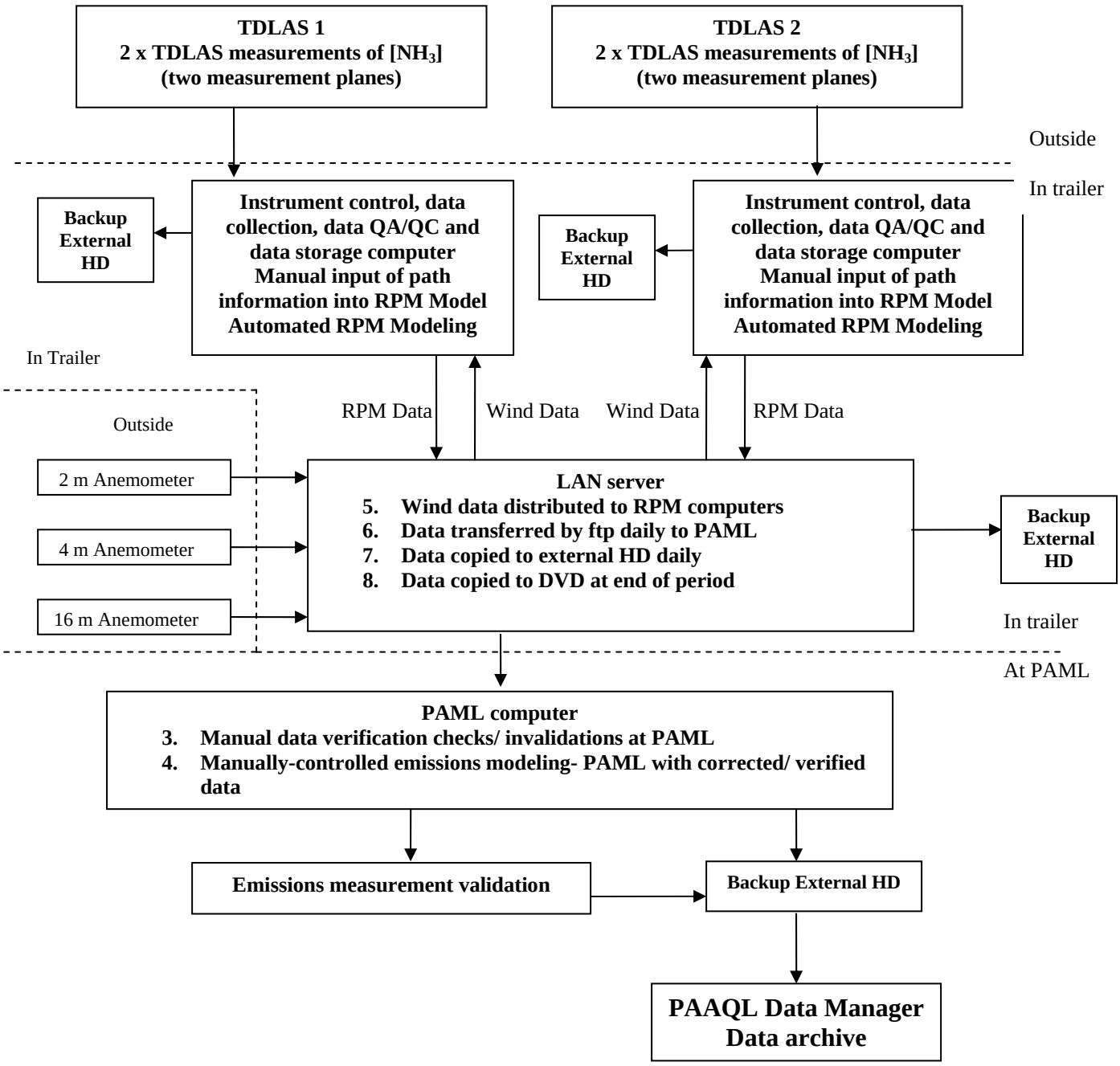


Figure 3. Data Processing and Management for INNOVA 1412.

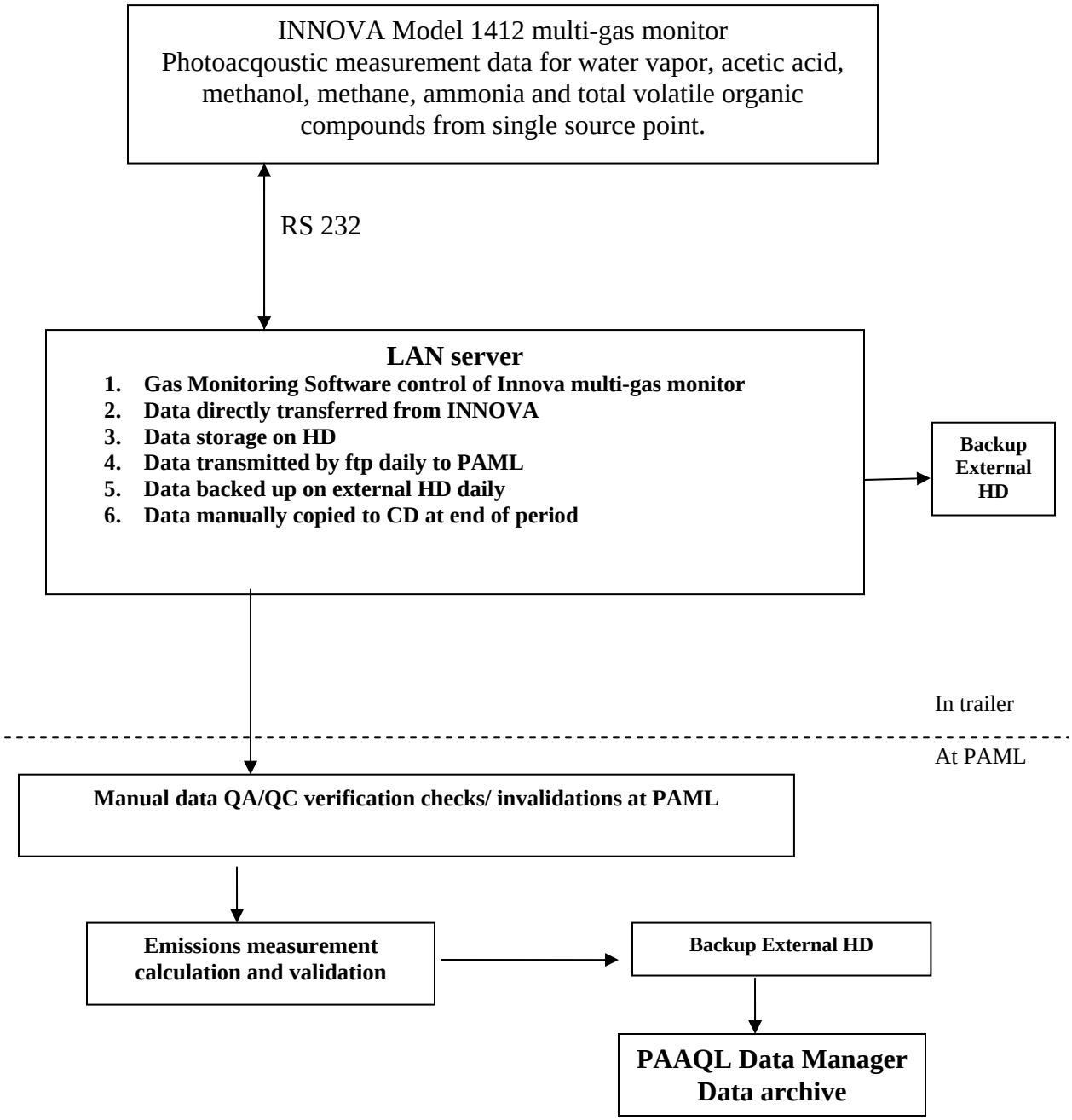
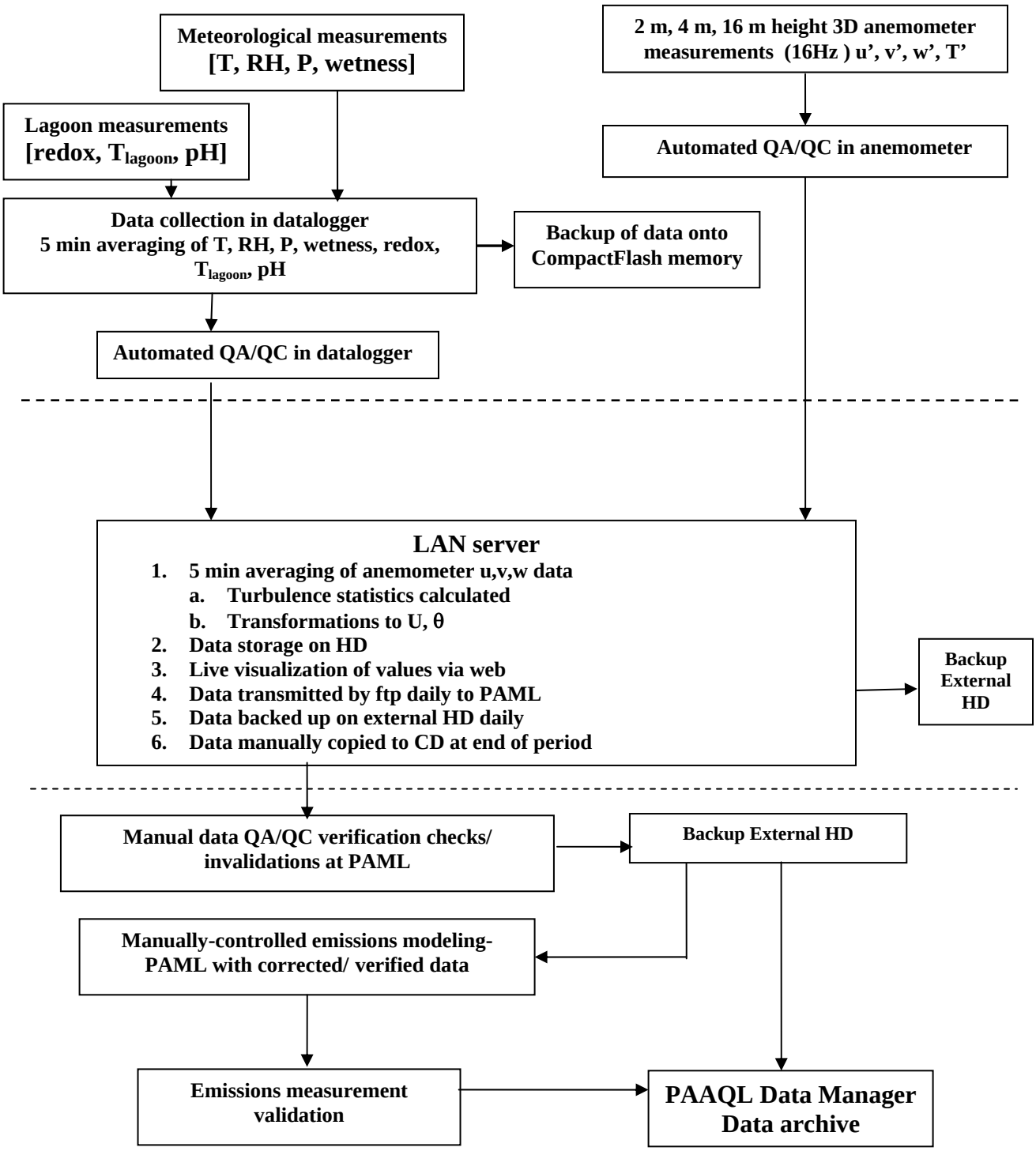


Figure 4. Data Processing and Management: Meteorological and Lagoon Data.



Appendix A
Guidelines for Managing Electronically-stored Sensitive Information[1]

Action	Sensitive Information
Storage on fixed media with access controls	No encryption required
Storage on fixed media without access controls, but accessible via the web	Not advised. If you must store data via this media, it must be encrypted.
Storage on fixed media without access controls, but not accessible via the web	No encryption required
Storage on removable media	No encryption required
Read access to information (includes duplication)	Access is based on roles defined by QAPP
Create / Update access to information	Access is based on roles defined by QAPP
Delete access to information	Access is based on roles defined by QAPP
Print hard copy report of information	Unattended printing permitted only if physical access controls are used to prevent unauthorized viewing.
Internal labeling of information at the application or screen/display level	No special requirement
Disposal of the physical electronic media device (diskettes, tapes, hard disks, etc.)	Physical destruction beyond ability to recover.
Disposal of information	Delete files through normal platform delete command, option or facility.
Data Manager & Information Owner review Data Confidentiality for continued applicability	Review annually

1: modified from Information Technology at Purdue:

http://www.itap.purdue.edu/security/procedures/dataHandling/electrStored.cfm,

Appendix B
Purdue University Password Requirements

- Passwords must contain at least 1 letter.
- Passwords must contain at least 1 number or punctuation mark.
- Passwords must be at least 8 characters long.
- Passwords must contain more than 4 unique characters.
- Passwords may not contain easily guessed words (e.g. Purdue, itap, boiler).
- Passwords may not contain a name or parts of the name (e.g., Bill, Julie, Bob, or Susan).
- New passwords must be different than the previous password (re-use of the same password will not be allowed for 180 days).
- Passwords never should be stored on your computer or written down and stored in plain sight (e.g., taped to the bottom of your computer keyboard). If a password must be written down, it should be locked up and stored in a place that is difficult for others to access.
- Passwords may be used only by the authorized user. Do not share your password with anyone.
- All users must change their password at least once every 30 days.
- If you suspect your password has been compromised, it should be changed immediately.

Appendix C
Electronic Data Transfer Form

Location of measurements: _____

Period represented: From Date (MM/DD /YYYY) _____ time (GMT: 24h clock) _____: _____

To Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

Data preparation/ copying done by: _____

Calibration conducted during period

UVDOAS1: s/n _____ Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

UVDOAS2: s/n _____ Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

TDLAS1: s/n _____ Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

TDLAS2: s/n _____ Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

Notes:

Data Receipt

Received: Date (MM/DD/YYYY) _____ time (GMT: 24h clock) _____: _____

Physical condition of TDLAS1 data CD	(Excellent / Good / Fair / Poor)
Physical condition of TDLAS2 data CD	(Excellent / Good / Fair / Poor)
Physical condition of UVDOAS1 data CD	(Excellent / Good / Fair / Poor)
Physical condition of UVDOAS2 data CD	(Excellent / Good / Fair / Poor)
Physical condition of WXL and INNOVA data CD	(Excellent / Good / Fair / Poor)
Physical condition of WXL and INNOVA flash memory chip	(Excellent / Good / Fair / Poor)
Physical condition of UVDFlash1 memory drive	(Excellent / Good / Fair / Poor)
Physical condition of UVDFlash2 memory drive	(Excellent / Good / Fair / Poor)
Physical condition of Backup DVD	(Excellent / Good / Fair / Poor)
Physical condition of memory stick	(Excellent / Good / Fair / Poor)

Received by: _____

THE MEASUREMENT OF SOLAR RADIATION WITH THE LICOR MODEL 200SL OR 200SZ SILICON PYRANOMETER

Standard Operating Procedure (SOP) E3

THE MEASUREMENT OF SOLAR RADIATION WITH THE LICOR MODEL 200SL OR 200SZ SILICON PYRANOMETER

Standard Operating Procedure (SOP) E3

Prepared by

Juan Carlos Ramirez, Bill W. Bogan, and Richard H. Grant

Reviewed by

Albert J. Heber, Ji-Qin Ni, and Kenneth D. Casey (Texas A&M Univ.)

Effective Date: November 6, 2007

PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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Appendix B. Procedure to Calculate Potential Solar Radiation on a Horizontal Surface....11

1. Scope and Applicability

1.1. The method described in this SOP is to use the silicon photodiode to measure solar incident radiation in the 300 to 1200 nm wavelength band.

1.2. This procedure applies only to the LiCOR Model LI-200SL Pyranometer for monitoring solar radiation during barn air emissions measurements, or for atmospheric stability class determination. By default, these instructions apply to both measurement scenarios. If there are any differences between the two applications, this will be specified.

1.3. Detection limit is 10 W/m^2. Ambient range is 10 to 1300 W/m^2.

2. Summary of Method

A pyranometer is an instrument for measuring solar radiation. The Model LI-200SL Pyranometer (LiCOR, Lincoln, NE) includes a Model LI-200SA pyranometer sensor and a millivolt converter. The sensor is installed on a mounting and leveling fixture to receive solar radiation (Figure 1). It uses a silicon-based photodiode semiconductor that converts the solar energy into a microamp current proportional to the solar radiation. The current signal is provided to a converter through a BNC connector. The converter contains a variable resistor that is unique to the LI-200SA sensor, and that converts the current signal to a standardized output voltage, 10 mV per 1000 W/m^2. The ultimate termination of the converter consists of bare leads to be connected to the data acquisition system, which converts the voltage signal to solar radiation in W/m^2, displays it on a computer monitor, and saves it into data files.

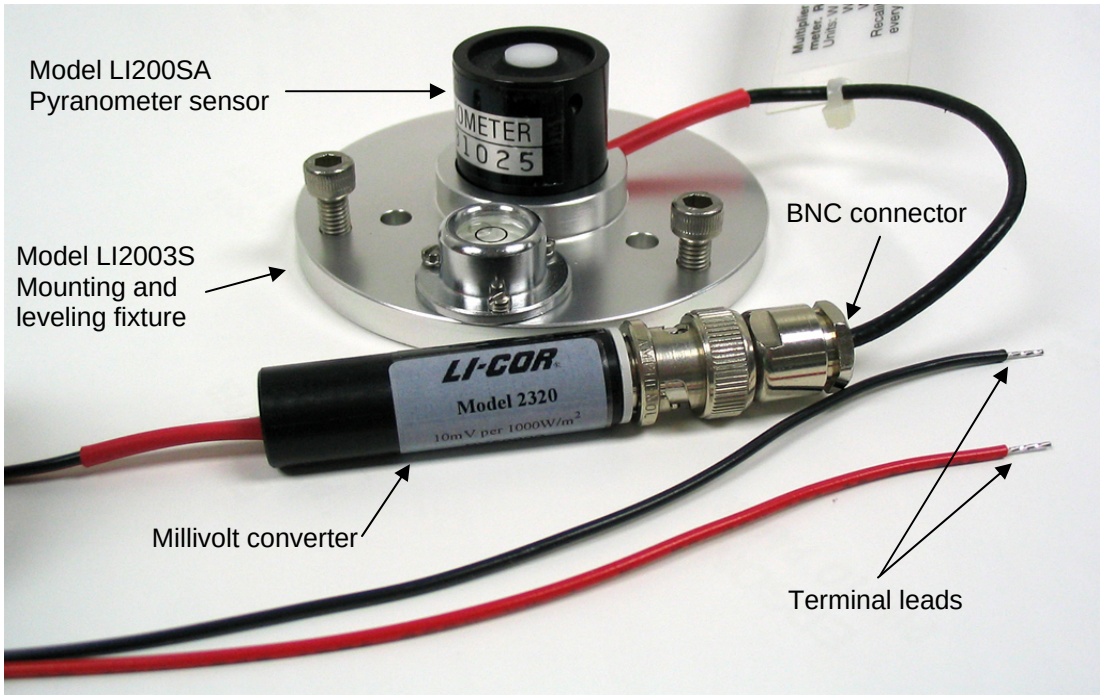

Figure 1. Model LI-200SL Pyranometer (including a LI-200SA Pyranometer sensor and a LI-2302 standardized millivolt adapter) and Model LI2003S Mounting and Leveling Fixture (adapted from LI-COR, 2006a).

3. Definitions

3.1. BNC Bayonet Neill Concelman connector (used with coaxial cables)
3.2. PAAQL Purdue Agricultural Air Quality Laboratory
3.3. QAPP Quality Assurance Project Plan

4. Health and Safety

4.1. The pyranometer only produces weak electric signal that does not pose a health concern.
4.2. The pyranometer is installed outdoors, usually several meters above the ground. Follow all relevant safety precautions during installation and maintenance. Locate the sensor where it can be reached safely by the operator during the periodic clean up procedures.

5. Cautions

5.1. The acrylic material used in LI-COR light sensors can be crazed by exposure to alcohol or organic solvents, which adversely affects the response of the sensor. Clean the diffuser element of the sensor only with water and mild soap such as dishwashing soap. Do not use alcohol, organic solvents, abrasives, or strong detergents. LI-COR has found that vinegar can also be used to remove hard water deposits from the diffuser element, if necessary.
5.2. The spectral response of the LI-200 does not include the entire solar spectrum. Therefore, use the pyranometer in the same lighting conditions as those under which it was calibrated. Use it only to measure unobstructed daylight, not reflected sunlight.
5.3. Remove and save the red protective cap from the sensor. This is used to protect the sensor when it needs to be calibrated or stored.
5.4. Be careful when connecting the sensor cable to the data acquisition system. Make sure the connections are tight, and are made according to SOP B1.
5.5. Each pyranometer sensor is used only with the millivolt converter that is supplied with it and the serial numbers must match in the Model LI200SL. Be sure to change both the sensor and the converter if the LI200SL needs to be replaced.
5.6. The millivolt converter is not weatherproof. Install it inside the instrument shelter or protect it in a weatherproof enclosure.

6. Interferences

6.1. Incorrect siting of the solar radiation sensors can lead to inaccuracies over the period of data collection. One example is installing the sensor where it receives the shadow of a building or other object. Another example is installing the sensor where it receives the reflection of a clear painted wall or other object. It should not be used under vegetation.
6.2. Particulate matter and bird droppings on the optical head will cause low readings. The risk of this interference is greater near livestock buildings.
6.3. The signal provided by the converter to the data acquisition is a weak voltage. To prevent excess signal noise pickup, avoid using long cable between the converter and the data acquisition system or running the cable close to power cords.

7. Personnel Qualifications

7.1. Personnel must be trained in the use of the handheld millivolt multimeter before initiating the procedure. Training requires 10 minutes.
7.2. Each member of the field staff must read the pertinent sections of the sensor instruction manual (pp 1-5, 10-13) and this SOP before operating this instrument.

8. Equipment and Supplies

8.1. For barn measurement locations:
  8.1.1. Model LI-200SL Pyranometer (LiCOR, Inc., Lincoln, NE), which includes a LI-200 SA pyranometer, a BNC connector and a millivolt adapter. The LI-200SL comes with a 15-ft cable.
8.2. For open source measurement locations:
  8.2.1. Model LI-200SZ Pyranometer (no BNC connector) with Model 2220 millivolt adaptor (LiCOR, Inc., Lincoln, NE)
  8.2.2. Weatherproofed NEMA 4X box
  8.2.3. Data logger (SOP W6)
8.3. Model LI2003S Mounting and Leveling Fixture (LiCOR, Inc.)
8.4. Sensor stand and mounting arm (Fig. 2) if they are not available in the weather tower.
8.5. Machine screws with nuts to mount the Mounting and Leveling Fixture to the sensor stand.
8.6. 3/64″ hex wrench to mount the pyranometer sensor to the Mounting and Leveling Fixture, and 1/8″ screwdriver to fasten the screws
8.7. Plastic cable ties to fix the sensor cable
8.8. Multimeter to check the pyranometer signal output, with a resolution of ≤ 0.01 mV
  8.8.1. Multimeter must be pre-calibrated for open-source applications. This is not necessary for barn applications.
8.9. Soft cloth, soap, water and soft toothbrush if the sensor needs cleaning
8.10. Electronic parts cleaner
8.11. Heat shrink tubing
8.12. Heat blower
8.13. Unused LiCOR LI-200 (to calibrate the sensor)

9. Procedures

9.1. Acceptance
  9.1.1. Verify that the serial number on the calibration certificate matches the serial number on the instrument.
  9.1.2. Verify that the serial numbers of the pyranometer sensor and the converter match.
  9.1.3. Response check:

9.1.3.1. Place pyranometer outside facing towards the sky on a sunny day.
9.1.3.2. Remove and save the red protective cap from the sensor.
9.1.3.3. Connect the sensor and the converter with the BNC connector.
9.1.3.4. Measure sensor response across the positive and negative wires with a multimeter.
9.1.3.4.1. The multimeter resolution should be better than 0.01 VDC. For atmospheric stability classification uses, the multimeter should be a calibrated model.
9.1.3.5. If sensor voltage is less than 1 mV, return sensor to supplier for replacement.
9.1.4. Zero check:
9.1.4.1. Obstruct all light from entering the optical window using a non-reflective cup or other means and measure the voltage with a millivolt multimeter across the sensor wires.
9.1.4.2. Value should be less than 0.01 mV. If value is greater than 0.01 mV, return the instrument to supplier for replacement.
9.1.5. Installation
9.1.6. Mount the Mounting and Leveling Fixture to the horizontal platform, 2 ft away from the S side of the Weather Station Tower (or the S side of a 10-ft mast, in open-path measurements) using a mounting arm or a cross arm stand (Fig. 2), such that no obstruction can cast a shadow over the sensor, according to SOP E5 (barn installation), SOP U5 (lagoon/basin installation), or U7 (corral installation).

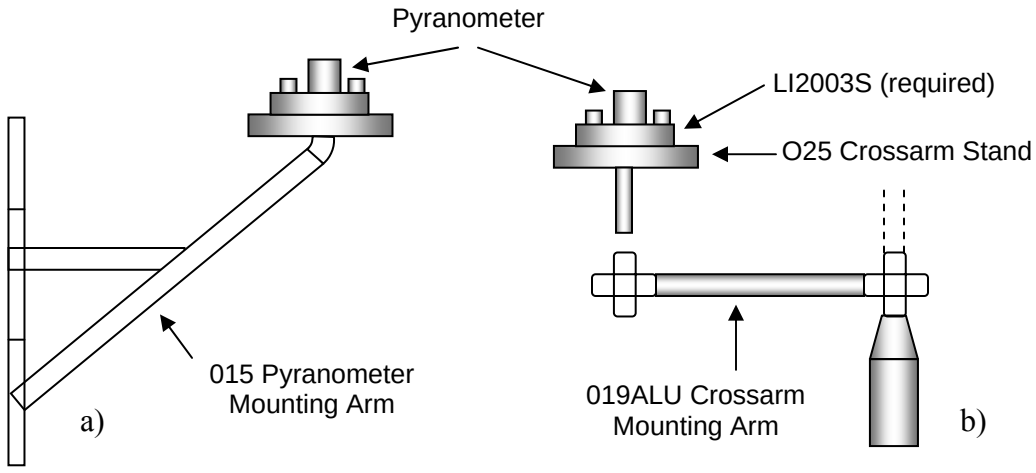

Figure 2. Pyranometer mounting arm (a) and cross arm stand (b) (LiCor Inc., 2006b).

9.1.7. Securely mount the pyranometer sensor onto the Mounting and Leveling Fixture using the 3/64″ hex wrench.
9.1.8. Adjust the level of the Mounting and Leveling Fixture.
9.1.9. If installing the sensor for open-source use, pass the coaxial cable through the appropriate knockout of the weatherproofed NEMA 4X box.

9.1.10. If installing the sensor for barn use, no NEMA 4X box is needed. Wrap the BNC connector, and its junction with the millivolt adapter, with electrical tape.
9.1.11. Run the cable from the pyranometer to the instrument shelter or trailer.
9.1.11.1. If a field datalogger is being used (i.e. during open-source applications), use the 1/8″slotted screwdriver to connect the positive signal wire to the single-ended measurement channel, and the black wire to ground according to SOP W6.
9.1.12. Connect the cable to the Millivolt Converter inside the instrument shelter.
9.1.13. Measure voltage across the two wires using a multimeter. On a sunny day, the voltage should be at least 1 mV.
9.1.14. Attach wires to data acquisition system according to SOP B1.
9.2. Calibration checks
9.2.1. Check the calibration of a pyranometer which is in use by comparing its readings with an unused pyranometer of the same model which is known to be accurate.
9.2.1.1. This can be done in the field or at Purdue. The QAPP for a particular project will state which option is to be used.
9.2.1.1.1. If these checks are to be done in the field, it is necessary to include an additional support and additional wiring for the collocated sensor, as well as the corresponding wiring, when installing the sensor. There must also be an available input channel in the data acquisition system for this collocated sensor.
9.2.1.1.2. This is not necessary if the instruments are to be sent to Purdue for calibration.
9.2.1.2. Measurements are made every 5 min for 2 d, using the same data acquisition system used in the study to collect data from both sensors.
9.2.1.3. The calibration check frequency will be specified in the QAPP.
9.2.1.3.1. The manufacturer recommends recalibrating this instrument every two years. A shorter interval can be chosen based on the QAPP's Quality Objectives.
9.2.2. Calculate the difference in each 5-min paired measurement, and compute the mean difference between the two sensors for the daylight hours over the two days.
9.2.3. If the mean difference between the sensor under calibration and the unused sensor is < ±5% of the unused sensor's reading, then the sensor being calibrated is assumed good. In this case, calculate a correction factor to apply to the in-field sensor.
9.2.4. If the mean difference between the sensor under calibration and the unused sensor is greater than ±5% of the unused sensor's reading, then check the cleanliness and the connections of the sensor that is being checked, and repeat the calibration check. If the difference persists, the sensor being checked is assumed to be defective, and must returned to the supplier for repair or replacement.
9.3. Troubleshooting
9.3.1. Low readings are often due to a dirty optical window. Clean surface of sensor with soap and water.
9.3.2. Erratic values are often due to poor connections. Check connections for tightness.
9.4. Data acquisition, calculations & data reduction requirements
9.4.1. The LI-200SL output is acquired by a data acquisition (DAQ) system (SOP B1 and SOP B2) at a frequency of 1 Hz.

9.4.2. The DAQ system converts the voltage signals to W/m^2, averages them every 15 s and 60 s, and saves the averaged data in data files.

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method, as well as in a bound record book designated for the method.
10.2. Manage all data according to SOP B5 (for barn measurements) SOP D1 (for open-source meteorological measurements).
10.3. Document all data and information on field data sheets and in site logbooks with permanent ink, or in electronic notes.
10.4. Strike out errors in writing with a single line. Initial and date all such corrections.

11. Quality Control and Quality Assurance

11.1. Do the following at the beginning and end of each measurement period, or as specified in the QAPP:
11.1.1. Check physical cleanliness of the pyranometer's optical window. If dirty, clean with soap and a wet cloth. Always use lens cloth to avoid scratching the glass surface.
11.1.2. Perform recalibration if the optical window shows any scratches, or discoloration that cannot be washed off.
11.1.3. Check physical cleanliness of connectors. If corroded, clean with electronic cleaner and toothbrush.
11.1.4. Check integrity of the plastic casing of the signal cable.
11.1.4.1. If damaged slightly, repair with heat-shrink tubing.
11.1.4.2. If damaged significantly, replace sensor and return sensor to manufacturer for repair.
11.1.5. Perform zero checks (Section 9.1.4).
11.1.6. Record results of each check in the calibration file (Appendix A) for open-source applications, or a similar table entry in the electronic field notes for barn applications.
11.1.7. Calibration checks against a collocated sensor (Section 9.2).
11.2. Do the following daily:
11.2.1. Compare the measurement with potential irradiance based on time of day, latitude and longitude of the location, and a solar constant of 1367 W/m^2 (Appendix B).
11.2.2. Ratio of sensor measurement to potential irradiance must be less than 0.9.
11.2.3. If ratio is greater than 0.9:
11.2.3.1. Flag data value as invalid.
11.2.3.2. Perform a calibration check against an unused pyranometer (Section 9.2). If the sensor fails this check (Section 9.3.4), replace sensor and return sensor to factory for repair.
11.2.4. Check measurements between 10 AM and 2 PM.
11.2.4.1. If measurements are less than 100 W/m^2:
11.2.4.1.1. Flag data values for day as invalid
11.2.4.1.2. Check wiring and optical window. Repair, clean, or replace as necessary.

12.

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12.16. Free Zip Code Lookup. Available at http://zipinfo.com/search/zipcode.htm. Accessed on 7/10/2006

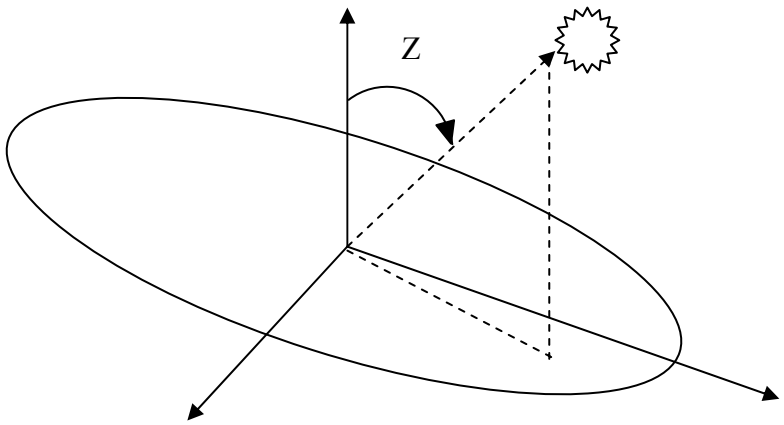
13. Contact Information

13.1. Distributor: Campbell Scientific, Inc., 815 West 1800 North, Logan, Utah, 84321. Technical support (435)-753-2342.

Appendix A. Calibration form: LI-200SL Solar Radiation Sensor
Instrument Serial Number: _____ Location: _____

Date (D-M-Y)	Time Begin	Time End	Mean irradiance (W/m^2)		Difference, (unused-measured)		Action Taken (Adjust, Replace)	Analyst
	AM/PM	AM/PM	Unused sensor	Sensor in use	W/m^2	%		

Appendix B. Procedure to Calculate the Potential Solar Radiation on a Horizontal Surface.



Calculate the vertical component of the potential solar radiation on a horizontal surface using the following equation:

$$\mathbf{Ho = Io * CosZ}$$

Where:

Ho = Potential extraterrestrial insolation on a horizontal surface (W/m^2)

Io = Extraterrestrial solar radiative flux (1367 W/m^2)

Z = zenith angle (from the vertical position to the position of the sun).

Obtain the site-specific Cosine of the Zenith angle (CosZ) from the National Oceanic and Atmospheric administration (NOAA) website (http://www.srrb.noaa.gov/highlights/sunrise/azel.html), by entering the geographic location of the monitoring site (latitude and longitude) and the time of day. The online calculator will determine the cosine of the zenith.

If unsure of the latitude and longitude of the specific monitoring site, this can be obtained through the website http://zipinfo.com/search/zipcode.htm, by checking the "latitude and longitude" box and the entering the ZIP code of the location.

COMPRESSED GAS CYLINDERS

Standard Operating Procedure (SOP) G2

COMPRESSED GAS CYLINDERS

Standard Operating Procedure (SOP) G2

Prepared by

Congna Li, Juan Carlos Ramirez, and Claude A. Diehl

Reviewed by

Bill W. Bogan and Albert J. Heber

Effective Date: November 6, 2006

PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Gas cylinders are used to transfer certified gas standards to research labs where gas concentration measurements are conducted. They are also used to supply fuel for flame ionization detectors, carrier gases for gas chromatographs, dilution gases for programmable diluters, and concentrated gases for gas injection systems. The following general facts about compressed gas cylinders are relevant to this SOP:

1.1.1. Gas standards typically have a defined, finite shelf life, and a specific expiration date.
1.1.2. Gas cylinders contain a finite volume of gas that may need to be replenished.
1.1.3. Gas cylinders are typically rented so money is saved by returning them promptly.
1.1.4. Gas cylinders generally look alike which challenges identification procedures.
1.1.5. Missing cylinders must be replaced at a significant replacement charge.
1.1.6. The time between purchase and delivery are relatively long.
1.1.7. The high pressure inside a gas cylinder represents a potential safety hazard.
1.1.8. The contents of a gas cylinder can range from very safe to extremely hazardous.
1.1.9. A gas-specific pressure regulator is required for each cylinder.
1.1.10. Managing gas cylinders requires a significant amount of labor.
1.1.11. They may be exposed to the extremes of indoor and outdoor temperatures.

2. Summary of Method

This SOP covers the necessary procedures, cautions and documentation for selecting, purchasing, receiving, transporting, storing, using, terminating, and returning gas cylinders. The compressed gas cylinder inventory will be scientifically selected, carefully controlled, and professionally handled to reduce cost, ensure safety, and improve data quality. Gas regulators will be properly selected and installed on each cylinder to prevent leakage and ensure safe delivery of the gases. Following this method will ensure proper documentation of the cylinders and the regulators that are used with the cylinders.

3. Definitions of Terms and Acronyms

3.1. ABE: Agricultural and Biological Engineering
3.2. CGA: Compressed Gas Association.
3.3. PAAQL: Purdue Agricultural Air Quality Laboratory
3.4. REM: Office of Radiation and Environmental Management at Purdue University
3.5. Compressed Gas: Any material or mixture having in the container either an absolute pressure exceeding 40 psia (3 bar) at 70°F (21°C).
3.6. Requested Concentration: The gas concentration requested by the customer when purchasing a standard gas.
3.7. Balance Gas: The material ("component") making up the majority of a mixture.
3.8. Blended Concentration: The concentration measured by the blending process. The numerical concentration assigned to a component based on the results of blending.

3.9. Blend Tolerance: The degree of agreement between the Blended Concentration and the Requested Concentration.
3.10. Crawl: Rise above a set delivery pressure during operation of a regulator.
3.11. Accuracy: The statistical agreement of a measured value with its true value
3.12. Expiration date: The stated date after which a gas concentration is no longer valid or legal to use for calibration purposes.
3.13. Traceability: Basis for establishing the true value of a standard or pathway back to the true value. For example, it is the relationship between a measured value and an established element of the National/International Measurement System.
3.14. Two-Stage Pressure Reducing Regulator: A regulator which reduces high-pressure to low pressure and controls the low or outlet pressure with two stages of pressure reduction. Used when more stability of operation is required.
3.15. Stability: The ability to maintain a constant concentration value over a defined time within statistical significance
3.16. Gas Mixture Grades
3.16.1. EPA Protocol Grade: EPA Protocol Gases are manufactured and analytically certified in strict accordance with the most recent EPA traceability guideline document entitled "EPA Traceability Protocol for Assay and Certification of Gaseous Standards". EPA protocol certified standards meet or exceed gas standards specified in U.S. regulations 40CFR60 and 40CFR75.
3.16.2. Primary Grade: Specialty gas, high resolution, gravimetric mixture with certification accuracy of either 1% relative, or 0.02% absolute, whichever is less. Often referred to as NIST-Traceable By Weight.
3.16.3. Certified Grade: Working standards prepared either by partial pressure or gravimetrically. Certification accuracies may range from ±2% to ±5%.
3.16.4. Unanalyzed Grade: The unanalyzed grade is used when the minor component accuracy does not have to be less than 10%.

4. Health and Safety

4.1. Always use the smallest size cylinder required to perform the work.
4.2. Cylinders of compressed gases must be handled as high potential energy sources.
4.3. Cylinders on wheeled carts must be capped and secured by an approved cylinder support strap or chain. The cart must be an approved cylinder cart. Do not attempt to take a loaded cylinder cart up or down a stairway.
4.4. Secure uncapped cylinders independently to a solid element of the lab structure. Do not "gang" cylinders behind a single chain, and do not use carts to support uncapped or in-use cylinders.
4.5. Transporting cylinders
4.5.1. Move cylinders by hand trucks or carts that are designed for this purpose. Always use a cylinder cart equipped with a chain restraint.
4.5.2. During transportation, properly secure cylinders to prevent them from falling or striking each other.
4.5.3. Do not move a cylinder with a regulator connected to it.
4.5.4. Never transport a gas cylinder without its valve protection cap firmly in place.

4.5.5. Keep both hands on the cylinder cart during transport.
4.5.6. Follow applicable federal and state regulations when transporting cylinders on open roads. Provided that no more than 440 lbs (>220lbs of flammable gas and >220lbs of other gases including container weights) are being transported, the gases are classified as “Materials of Trade”, and are not subject to placards and other restrictions that would normally be associated with transporting larger quantities of compressed gas.

4.6. Securing cylinders
4.6.1. Place cylinder in an upright position against a cylinder rack located against the wall.
4.6.2. Place the straps around the cylinder.
4.6.3. Insert the strap through the buckle and pull tight.

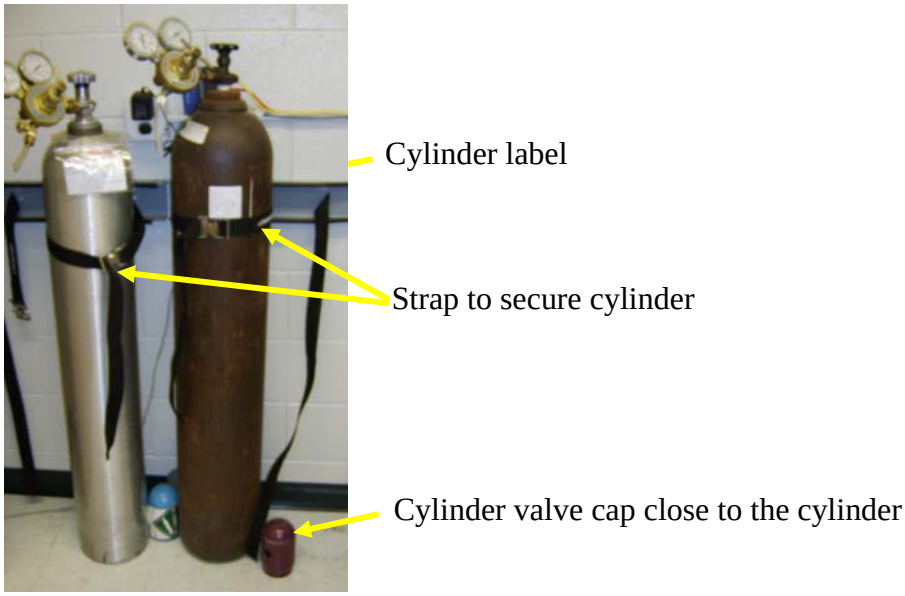


Figure 1. Gas cylinders safely located for use.

4.7. Storage of cylinders
4.7.1. Storage Area. Store gas cylinders in a ventilated and well-lit area, away from combustible materials. Store cylinders containing flammable gases away from oxygen cylinders and other oxidants. Separate by a fire-resistant wall, or locate them at least 20 feet apart from each other.
4.7.2. Storage Area Conditions. Storage areas should be located away from sources of excess heat, open flame or ignition, and not located in closed or subsurface areas. The area should be dry, cool and well-ventilated.
4.7.3. Securing Cylinders in Storage. Always hold cylinders in place with a chain or another type of fastener such as a bench or wall clamp. While in storage, cylinder valve protection caps must be firmly in place.
4.7.4. Cylinders may be stored flat on the ground, if vertical storage is not possible, provided they are secured as described in 4.7.3.
4.7.4.1. Note that this applies only to storage. Cylinders may not be transported or used while horizontal.

4.7.5. For cylinders at remote sites, the conditions in 4.7.1 and 4.7.2 will be followed as closely as possible. Sections 4.7.3 and 4.7.4 will be followed strictly, including at remote sites.

4.8. Never tamper with safety devices in valves or cylinders.

4.9. Use only a cylinder cap wrench to loosen and unscrew cylinder caps; do not strike cylinder caps when attempting to loosen them.

4.10. Oil or grease on the high pressure side of an oxygen cylinder can cause an explosion. Do not lubricate an oxygen regulator or use a fuel gas regulator on an oxygen cylinder.

4.11. Wear goggles or safety glasses with side shields when handling compressed gases.

4.12. Eyewash fountains, safety showers, gas masks, respirators, and/or resuscitators should be located nearby but out of the immediate area that is likely to become contaminated in the event of a large release of gas.

4.13. Fire extinguishers, preferably a combination of water- and CO_2-based types, should be kept close at hand, and should be checked periodically to ensure their proper operation.

4.14. Always use appropriate gauges, fittings, and materials compatible with the particular gas. Regulators must be compatible with gas cylinders (do not use adapters). Each cylinder and regulator have connection fittings that are designated by a CGA number. CGA numbers can be stamped on the cylinder and regulator and listed on the producer's label. CGA numbers are typically (but not always) stamped on the regulator just above the threads of the cylinder connection (Fig. 2). Table 1 shows some examples of CGA connection numbers and some examples of the gases used with these connections.

4.15. MSDS information sheets will be kept in a 3-ring binder located near the cylinders.

4.15.1. MSDS information will also be kept on-site for any gases which are stored and/or used at remote locations.

Table 1. Cylinder Valve Outlets and CGA Connections.

Examples of Gases	CGA Connection #
Ammonia	705
Carbon Dioxide	320
Butane, ethylene oxide, propane, propylene	510
Air (industrial grade)	590
Carbon monoxide, ethylene, methane, hydrogen	350
Hydrogen sulfide, hydrogen chloride	330
Nitrogen, helium, argon, noble gases	580
Nitrogen dioxide, sulfur dioxide	660
Oxygen	540

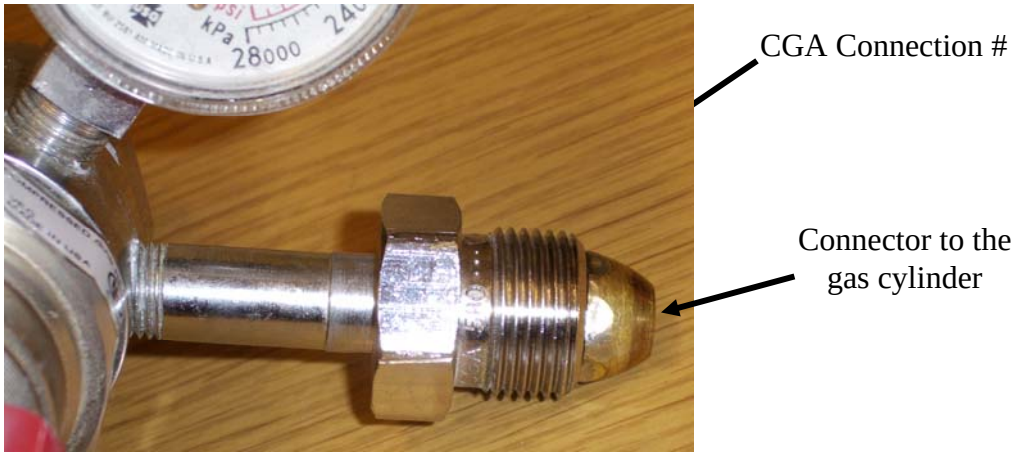


Figure 2. Photo of a gas pressure regulator (CGA 580) showing the connector to the gas cylinder. The CGA number can be found on the side of the nut closer to the regulator.

4.16. When work is planned with toxic, corrosive, or reactive gases, consult the MSDS and/or institutional safety office for information concerning specific handling requirements for the gas involved. Generally, these gases will need to be used and stored with local exhaust ventilation, such as a lab hood, gas cabinet, or a ventilated OFIS that is designed for that purpose.

4.17. Check the regulator and cylinder valve for evidence of damage or contamination.

4.18. Do not apply Teflon tape between the regulator and the cylinder connections. Bits of Teflon tape can get blown into the regulator, causing a leak, valve malfunction or erroneous reading.

4.18.1. If a leak-free connection cannot be established between the regulator and the cylinder, inspect the regulator and cylinders threads for possible damage or contamination. If regulator components (adapter threads, washers, and/or fittings) are damaged, they should be replaced. Any regulator which cannot be made leak-free should be replaced.

4.19. If an OFIS at a field site (farm) contains cylinders, notify the producer and/or appropriate staff that there are compressed cylinders within the OFIS and describe the contents of the compressed cylinders. This is especially important in case of a fire, so that the producer will stay away from the OFIS, and properly notify responding emergency personnel.

5. Cautions

5.1. Do not allow cylinder temperature to exceed 125°F (52°C), or to drop to -30°C or lower, since many types of steel will lose their ductility and impact strength at lower temperatures.

5.2. Store empty cylinders separately from full cylinders, and clearly identify them as such. Leave some pressure (>50 psi) in a depleted cylinder to prevent air backflow that would allow moisture and contaminants to enter the cylinder.

5.3. Flammable gases have reverse threads, meaning that the connection is tightened by turning the nut counterclockwise. You can always tell a reverse thread connection because the nut that you tighten has a line inscribed around its circumference.
5.4. Do not use an expired cylinder for a Level 1 Precision Check. In other words, never adjust an analyzer based on data obtained from an expired cylinder.

6. Personnel Qualifications

6.1. Personnel should be trained in the handling of cylinders and also in the updating of the web-based cylinder control file before initiating the procedure alone.
6.2. Personnel handling any compressed gas should be familiar with the potential hazards before using the gas.
6.3. Personnel should address potential emergencies and the safe and proper measures necessary to avoid these emergencies.
6.4. Personnel should identify several scenarios that could result in gas leaks or other emergencies to be totally prepared to respond adequately.

7. Equipment and Supplies

7.1. Gas cylinders
  7.1.1. EPA maintains a web site which documents the performance of major gas-cylinder vendors, based on the results of a round robin test conducted every two years.
  7.1.2. Consider the following parameters when selecting cylinders:
    7.1.2.1. Certification accuracy
    7.1.2.2. Blend tolerance
    7.1.2.3. Shelf life
    7.1.2.4. Delivery time
    7.1.2.5. Reanalysis tolerance
    7.1.2.6. Requested concentration
7.2. Gas regulators appropriate for each gas (Section 4.14)
7.3. Labels to identify each cylinder (Section 8.1.7)
7.4. An adjustable or combination cylinder wrench to connect and disconnect the regulator to the cylinder.
7.5. Cylinder hand truck
7.6. Cylinder brackets
7.7. Cylinder return labels (Section 8.8.4)

8. Procedures

8.1. Receiving gas cylinders (PAAQL)
  8.1.1. Cylinders are delivered to the ABE shop’s gas cylinder receiving station by Purdue’s Gas Cylinder Control Office.
  8.1.2. Upon delivery, the cylinders should be picked up by PAAQL staff, after verifying that there is a plastic seal on the cylinder valve. If there is no seal, make a note and contact the company.

8.1.3. Write the cylinder-stamped number on the form by the gas cylinder rack, and sign the form to indicate that the cylinder has been received.
8.1.4. A delivery sheet or packing slip is attached to every cylinder to verify that the proper cylinder is delivered (gas type, amount of gas, cylinder ID).
8.1.5. Sign and date the delivery sheet.
8.1.6. Place the original delivery sheet in the ABE Business Office's inbox and a copy of the delivery sheet in the loose leaf cylinder notebook in the section corresponding to the year received and the company that supplied the cylinder. This notebook is kept on top of the manual's file cabinet in room ABE-102E.
8.1.7. Attach a cylinder label (Fig. 3) to the cylinder upon receipt, with the following information filled out:

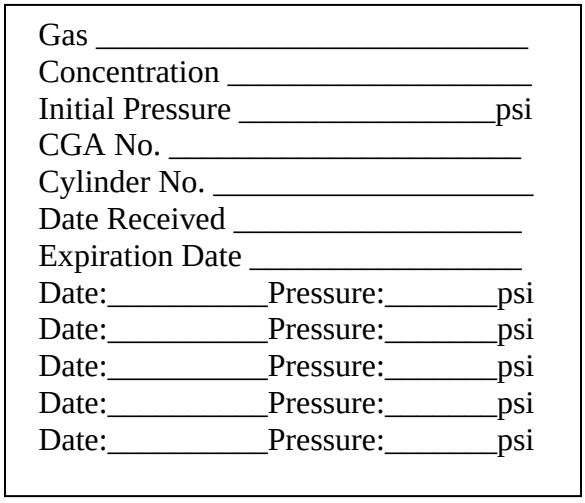


Figure 3: A cylinder label.

8.2. Receiving gas cylinders (Field sites)
8.2.1. Cylinders are delivered to a specified location (e.g. the field site itself, a subcontracting university or other entity, etc) by the supplier's local vendor/agent.
8.2.2. Upon delivery, the cylinders should be picked up by study personnel (PAAQL or otherwise), after verifying that there is a plastic seal on the cylinder valve. If there is no seal, make a note and contact the company.
8.2.3. If necessary, transport the cylinder to the field site, observing all cautions listed in Section 4.5.
8.2.4. Write the cylinder-stamped number on the form by the gas cylinder rack and sign the form to indicate that the cylinder has been received.
8.2.5. A delivery sheet or packing slip will be attached to every cylinder by the supplier to verify that the proper cylinder is delivered (gas type, amount of gas, cylinder ID).
8.2.6. Sign and date the delivery sheet.
8.2.7. File a copy of the delivery sheet on-site in a binder or loose-leaf notebook (Section 8.1.6).

8.2.8. Fill out a cylinder label (Fig. 3), and attach it to the cylinder.

8.3. Installing pressure regulators

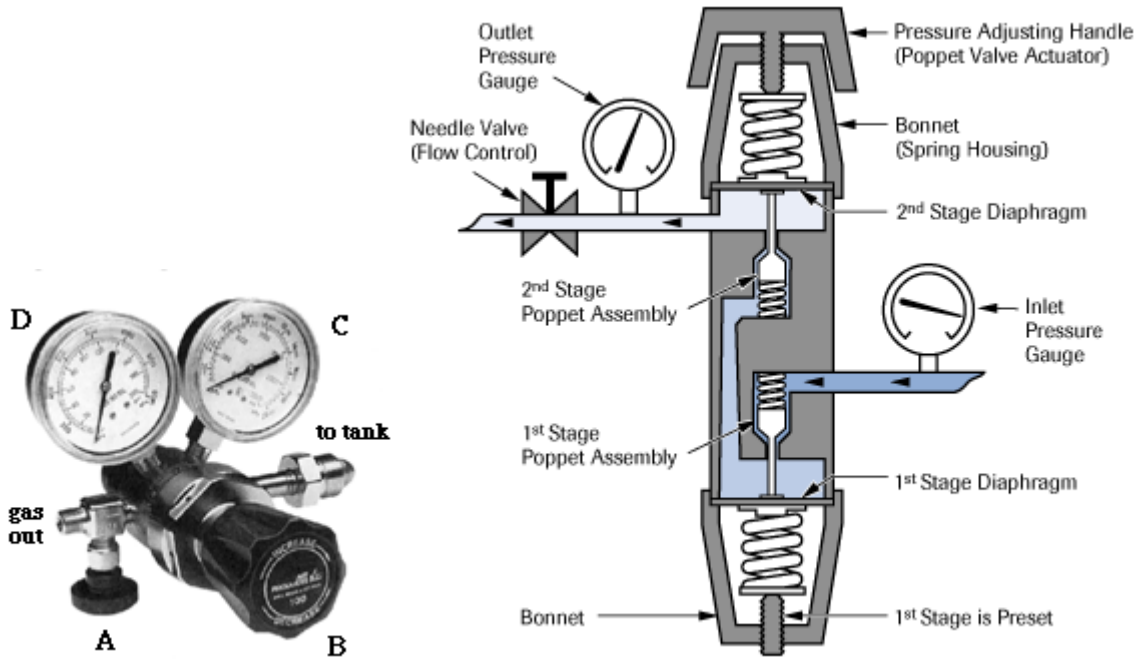
8.3.1. Make sure the cylinder is properly secured, and that the regulator is the correct one for the cylinder, and that any special hazards of the gas are known.

8.3.2. Remove the cylinder valve cap (counterclockwise). Place it somewhere nearby.

8.3.3. Some regulators (on lecture bottles and certain corrosive gases) require a Teflon washer to be inserted between the tank outlet and regulator. Check to see if this is required before continuing to the next step.

8.3.4. Make sure that the regulator's needle valve (A) (Fig. 4) is shut. Screw it clockwise until it seats. Do not over tighten it or you can damage the valve seat.

8.3.5. Make sure that the regulator's pressure adjusting handle (B) (Fig. 4) is shut. Turn it counterclockwise until it is almost completely unscrewed. If you unscrew it completely, just put it back in.



(a) (b)

Figure 4. (a) A two –stage pressure regulator and its components. A: Needle valve for outlet flow control. B: Pressure adjusting handle (Poppet Valve Actuator). C: Inlet pressure gauge. D: Outlet pressure gauge. (b) Schematic diagram of a two-stage pressure regulator.

8.3.6. Turn the regulator onto the tank by hand until it is almost finger tight.

8.3.7. Use an adjustable wrench or cylinder wrench to tighten the regulator onto the cylinder.

8.4. Operation of pressure regulator

8.4.1. Open the tank valve slowly (counterclockwise (CCW)). Watch the tank pressure on the regulator's inlet pressure gauge (C) (Fig. 4).

8.4.2. Slowly turn the pressure adjusting handle (B) on the regulator until the regulator's outlet pressure gauge (D) is at the desired pressure level (Fig. 4).
8.4.3. Open the regulator's needle valve (A) to regulate flow with this valve.
8.4.4. Check your system for leaks using Snoop (a commercial product) or some soapy water. Snoop is preferred since it leaves no residue.

8.5. FTIR validation of gas concentration

8.5.1. If the composition of the gas in a cylinder is to be checked by FTIR, this procedure should be conducted according to SOP G12 ("FTIR Verification of Gas Cylinder Composition").

8.6. Shut down of pressure regulator

8.6.1. Shut the tank valve on the gas cylinder.
8.6.2. Slowly open the needle valve (A) on the regulator.
8.6.3. Watch the pressure gauges C and D drop to zero.
8.6.4. Open the regulator's pressure adjusting handle (B) (turn it clockwise) to ensure that all pressure is released.
8.6.5. After relieving all the gas pressure, turn the regulator pressure adjusting handle (B) CCW as far as it will go to close the regulator, and also close the needle valve (A).

8.7. Disconnecting a pressure regulator

8.7.1. Use a wrench to disconnect the regulator from the gas cylinder.
8.7.2. Replace the protective cylinder cap immediately.

8.8. Cylinder return

8.8.1. Prior to returning the cylinder, place a return label on the cylinder and date it. (Fig. 5)
8.8.2. The cylinder should be returned to the cylinder collection rack in the ABE shop.
8.8.3. Place an "Empty Cylinder" ring on the cylinder.
8.8.4. Enter the returned cylinder number and date on the form.

Return To: General Stores

From: Al Heber
Department of Ag and Bio Engineering
1146 ABE

Date:

Figure 5: Return label for gas cylinders.

9. Troubleshooting

9.1. Check regulators periodically to ensure proper and safe operation. This periodic check will vary depending on gas service and usage. The procedure for checking out any regulator is as follows:

9.1.1. Be sure gauges read zero when all pressure is drained from the system.

9.1.2. Open the cylinder valve and turn the pressure adjusting handle counterclockwise; the inlet pressure gauge will read the cylinder pressure.

9.1.3. Starting at Section 9.1.1, close the cylinder valve after reading the cylinder pressure, if the pressure drops after one (1) hour of monitoring the inlet pressure, there is a leak between the inlet pressure gauge and the cylinder valve.

9.1.4. Starting at Section 9.1.1, close the regulator's outlet needle valve then wait 1 hour; the outlet pressure gauge should not indicate a pressure increase. A pressure increase would indicate leakage across the internal valve system.

9.1.5. Turn the pressure adjusting handle clockwise until a nominal delivery pressure is indicated. Inability to attain a proper delivery-pressure setting or abnormal adjustment of the screw indicates improper operation, which may be attributed to blockage of the gas passage or a leak in the low-pressure side of the regulator. Continued wear on a regulator valve-and-seat assembly will cause a rise above a set delivery pressure, termed *crawl*. A regulator exhibiting crawl should not be used.

9.1.6. Close cylinder valve and observe pressure on both inlet and delivery sides of the regulator after 1 h. A drop in the pressure reading after this period of time may indicate a leak in the system, possibly at the inlet or through the needle valve, safety devices, or diaphragm.

9.1.7. An excessive fall in delivery pressure under operating conditions and normal flow indicates an internal blockage.

9.1.8. Any deviation from the normal in the preceding checkout will require servicing by reputable repair personnel.

10. Data and Records Management

10.1. Use the information on the delivery sheet to update the PAAQL Cylinder Inventory webpage. To update this webpage you must:

10.1.1. Open the "odor" drive (permission to access this drive is required).

10.1.2. Open the "public-web" folder.

10.1.3. Open the "cylinder" folder

10.1.4. Open the "PAAQL Cylinder Inventory.htm" file.

10.1.5. To edit the "PAAQL Cylinder Inventory.htm" webpage:

10.1.5.1. Click on "File".

10.1.5.2. Click "Edit with Microsoft Excel".

10.1.5.3. Add the following data to the PAAQL Cylinder Inventory web page:

10.1.5.3.1. Gas name

10.1.5.3.2. Balance gas

10.1.5.3.3. Gas analyzer that cylinder is assigned for calibration

10.1.5.3.4. Cylinder number (this is the engraved number only)

10.1.5.3.5. Cylinder style
10.1.5.3.6. Cylinder volume
10.1.5.3.7. Supplier of the gas cylinder
10.1.5.3.8. Purchase order number
10.1.5.3.9. Person who requested the order
10.1.5.3.10. Date issued
10.1.5.3.11. Date received
10.1.5.3.12. Date tested
10.1.5.3.13. Date returned
10.1.5.3.14. Cylinder expiration date
10.1.5.3.15. Initial pressure, psi
10.1.5.3.16. Final pressure, psi
10.1.5.3.17. CGA number (this can be found on the cylinder valve)
10.1.5.3.18. Gas concentration,
10.1.5.3.19. Certified accuracy, %
10.1.5.3.20. Project
10.1.5.3.21. Location
10.1.5.3.22. Cylinder cost
10.1.5.3.23. Monthly cost
10.1.5.3.24. Total cost to date

10.1.5.4. Update the following data each month on the PAAQL Cylinder Inventory:
10.1.5.4.1. Location
10.1.5.4.2. Pressure test
10.1.5.4.3. Pressure test date
10.1.5.4.4. Monthly cost (see demurrage report)
10.1.5.4.5. Total cost to date (see demurrage report)

10.1.5.5. The PAAQL Cylinder Inventory web page is color coded.
10.1.5.5.1. The cylinders that have been recently returned have a purple color.
10.1.5.5.2. Cylinders that are in ABE are in yellow.
10.1.5.5.3. Cylinders that are on site are in dark blue.
10.1.5.5.4. Cylinders not currently in the inventory but still on the demurrage report are in red.
10.1.5.5.5. Cylinders that were apparently returned but yet cylinder rental charges are accruing are in green.

10.2. Initiate an order for a replacement cylinder well in advance of a cylinder's running out (i.e. dropping below 150 psi, as per Section 5.4).

10.2.1. Each time a cylinder is used, record the pressure remaining at the end of use. Keep a graph tracking pressure vs. date to allow projection of when pressure will reach the 150 psi minimum limit.

10.2.2. Allow sufficient time to meet the following requirements:
10.2.2.1. Replacement cylinders will be compared to the old cylinder using the applicable gas analyzer. Leave sufficient gas in the old cylinder to conduct this test.
10.2.2.2. If the replacement cylinder is outside the acceptable specifications, there must be sufficient gas remaining in the old cylinder to operate until an acceptable cylinder is received.

10.2.2.3. In general, a new purchase order should be initiated two months in advance before the current cylinder is empty or expires, if such gas is needed on a continuous basis.

10.2.3. Email notification of new order will be sent to the personnel responsible for the project.

11. Quality Control and Quality Assurance

11.1. Personnel handling any compressed gas will be trained to be aware of potential hazards before using the gas, to address potential emergencies and the safe and proper measures necessary to avoid these emergencies, and to identify several scenarios that could result in gas leaks or other emergencies to be totally prepared to respond adequately.

11.2. Regulators and cylinder valves should be checked periodically to ensure proper and safe operation.

11.3. The PAAQL Cylinder Inventory webpage will be used to update the information for all the cylinders in the current inventory and the most recent cylinders that have been returned.

11.4. Do not calibrate with a span gas if its cylinder pressure is below 150 psi.

12. References

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MEASUREMENT OF HYDROGEN SULFIDE (H2S) WITH THE THERMO ELECTRON CORPORATION MODEL 450I PULSED-FLUORESCENCE ANALYZER

Standard Operating Procedure (SOP) G5

MEASUREMENT OF HYDROGEN SULFIDE (H_2S) WITH THE THERMO ELECTRON CORPORATION MODEL 450I PULSED-FLUORESCENCE ANALYZER

Standard Operating Procedure (SOP) G5

Prepared by

Claude A. Diehl, Bill W. Bogan, Richard H. Grant and Matt T. Boehm

Reviewed by

Ji-Qin Ni and Albert J. Heber

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PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The purpose of this procedure is to present the methodology and instrumentation used to automatically and sequentially measure hydrogen sulfide (H_2S) emissions from barns, other buildings or open sources at confined animal feeding operations (CAFO).

1.2. This procedure applies only to the Model 450I Pulsed Fluorescence H_2S/SO_2 Analyzer (Thermo Electron Corporation, Franklin, MA).

1.3. The pulsed fluorescence method is useful for measuring hydrogen sulfide (H_2S) in air, due to its suitable detection limit, response time, and measurement range.

1.3.1. The detection limit of the method is:

1.3.1.1. 6 ppb (when using a 10-s averaging time)

1.3.1.2. 2 ppb (60-s averaging time)

1.3.1.3. 1.5 ppb (300-s averaging time)

1.3.2. The 90% response time to a step change in H_2S concentration is:

1.3.2.1. 80 s (10-s averaging time)

1.3.2.2. 110 s (60-s averaging time)

1.3.2.3. 320 s (300-s averaging time)

1.3.3. The measurement range of the Model 450I is from 0 to 10,000 ppb (10 ppm).

1.4. The stated precision of the 450I is 1% of reading or 1 ppb (whichever is greater).

2. Summary of Method

Hydrogen sulfide in sample air entering the 450I is converted to sulfur dioxide (SO_2) in a converter operating at 300-400°C (1).

$$H_2S \rightarrow SO_2 \quad (1)$$

The sample flows directly to the hydrocarbon kicker when the 450I measures SO_2, or flows through the converter first, then to the hydrocarbon kicker when the 450I measures H_2S (Fig. 1) Any hydrocarbon present in the sample permeates through the tube wall of the hydrocarbon kicker, and is removed from the sample. SO_2 passes through the hydrocarbon kicker into the fluorescence chamber (the L-shaped box at the center right of Fig. 1).

The sample containing SO_2 is pulsed with ultraviolet (UV) light by a high-intensity xenon lamp. SO_2 molecules absorb at one wavelength and become excited (SO_2^*); they then decay to a lower energy state by emitting UV light at a different wavelength (2).

$$SO_2 + h\nu_1 \rightarrow SO_2^* \rightarrow SO_2 + h\nu_2 \quad (2)$$

Emitted UV light is proportional to SO_2 concentration and is detected and converted to an electrical current by a PMT detector.

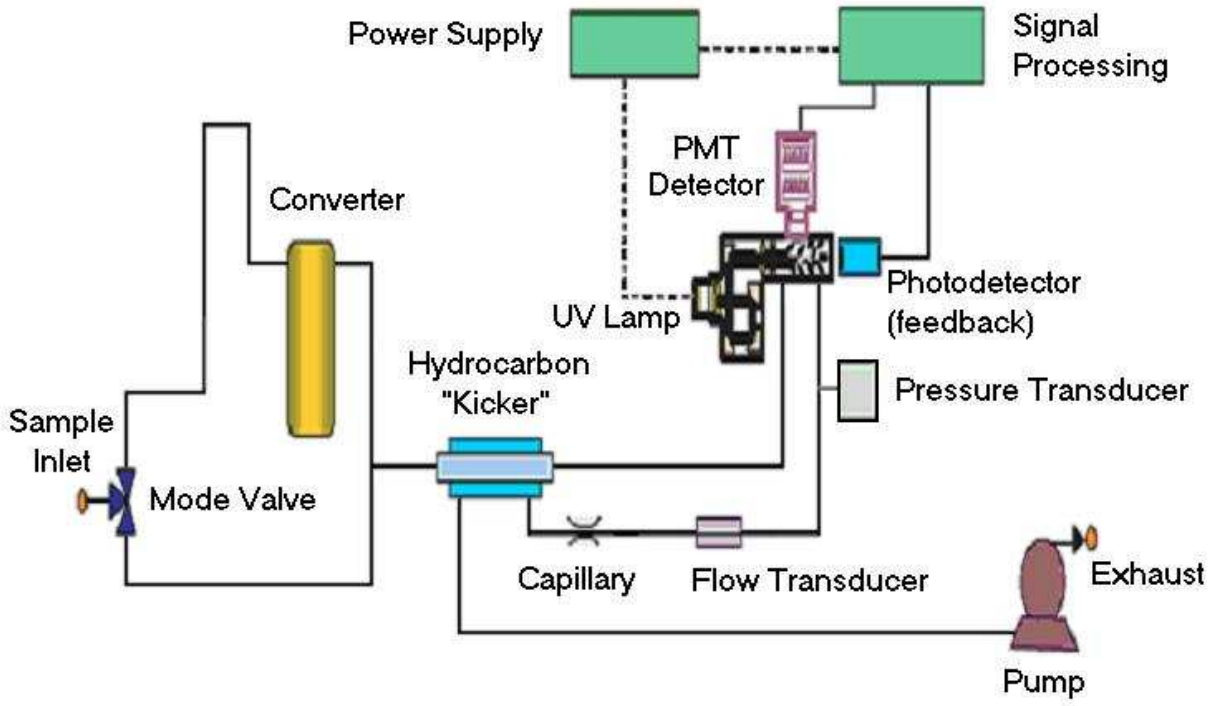

Figure 1. Flow schematic of the 450I.

3. Definitions of Terms and Acronyms

AirDAC	Data acquisition and control software for barn applications (SOP B2)
CS	Combined sulfur (H_2S + SO_2)
CAFO	Confined animal feeding operation
GSS	Gas sampling system (SOP G1)
Hydrocarbon kicker	A membrane tube in the 450I that removes aromatic hydrocarbons based on their ability to pass through the membrane. SO_2 molecules pass through the hydrocarbon kicker unaffected.
QAPP	Quality Assurance Project Plan
OFIS	On-farm instrument shelter (SOP U1)
PAAQL	Purdue Agricultural Air Quality Laboratory
PMT	Photomultiplier tube

4. Health and Safety

4.1. Be careful when working with the electrical power connection.
4.2. The converter of the Model 450I contains high-temperature elements (300-400°C), and should not be touched.
4.3. Properly vent analyzer exhaust to avoid exposure to noxious gases in the sample.
4.4. Prevent leaking of the calibration gases into the working environment.

5. Cautions

5.1. Use antistatic wrist strap or discharge your body's electrostatic charge to a grounded metallic frame before touching any internal components of the 450I to avoid damage of the electronics by static discharge. See Chapter 7 ("Servicing") of the 450I manual.

6. Interferences

6.1. Compounds that interfere with fluorescence-based H_2S measurements are as follows:

Interferences	Effect on H_2S Readings
Methyl mercaptan	0.8 ppm increase per 1 ppm of CH_3SH
Dimethyl disulfide	0.5 ppm increase per 1 ppm of CH_3SSCH_3
Dimethl sulfide	< 0.1 ppm increase per 1 ppm of CH_3SCH_3
NO	Increase of < 3 ppb at 500 ppb NO
m-xylene	Increase of < 1 ppb at 200 ppb *m*-xylene
Water	< 2% of reading per 2% humidity ratio

6.1.1. The effect of humidity will typically be less than 3% of reading. For example, the difference in humidity ratio between saturated air at 30°C (86°F) and saturated air at 0°C (32°F) is approximately 2.3%

6.1.2. H_2S is expected to be present at one or two orders of magnitude higher than dimethyl sulfide or dimethyl disulfide; thus, the relative magnitude of these interferences should be minor. Dimethyl sulfide and dimethyl disulfide can be monitored with the Innova Model 1412 Multi-Gas Monitor (SOP G7).

6.1.3. Concentrations of NO and *m*-xylene are expected to be negligible.

7. Personnel Qualifications

7.1. Personnel should be trained in the operation, maintenance and calibration of the analyzer before initiating the procedure. Training requires about three hours.

7.2. Each analyst must read and understand the entire analyzer manual and this SOP before operating the Model 450I.

7.3. Personnel should also be trained to interpret the analyzer output signal, converted concentration data, and correction of concentrations based on calibration.

8. Equipment and Supplies

8.1. Hydrogen sulfide analyzer (Model 450I, Thermo Electron Corporation)

8.2. H_2S-to-SO_2 converter (Model 340, Thermo Electron Corporation)

8.3. Keep the following spare parts at each site:

8.3.1. 20-mil capillary, Part No. 4126

8.3.2. O-ring capillary, Part No. 4800

8.3.3. Teflon tubing (1/4″ OD x 1/8″ ID) for connecting analyzer to GSS and exhaust port

8.3.4. 4-conductor cable (shielded, 22-gauge)

8.4. Keep the following spare parts in a central stock at PAAQL:
8.4.1. 20-mil capillary, Part No. 4126
8.4.2. O-ring capillary, Part No. 4800
8.4.3. Pump, 110 VAC, Part No. 8550
8.4.4. Pump repair kit, Part No. 8606
8.4.5. Flash lamp, Part No. 8666
8.4.6. Particulate filter assembly, Part No. 60100
8.4.7. Converter assembly, 120 VAC, Part No. 450P702-1
8.4.8. Power supply board, Part No. 10570
8.4.9. Trigger pak, Part No. 8774
8.4.10. Flash intensity board, Part No. 8884
8.4.11. Flasher supply board, Part No. 9681
8.4.12. Temperature control board, Part No. 8765
8.4.13. PMT high voltage power supply, Part No. 9901
8.4.14. Temperature control board (converter), Part No. 9889
8.4.15. Teflon tubing (1/4″ OD x 1/8″ ID) for connecting analyzer to GSS and exhaust port
8.4.16. 4-conductor cable (shielded, 22-gauge)
8.5. Calibration gas cylinders: Hydrogen sulfide (H_2S), sulfur dioxide (SO_2), zero gas (see the QAPP for exact specifications and compositions), with appropriate regulators (SOP G2)
8.5.1. In projects where SO_2 is not a primary measurement, it may still be used to check the converter efficiency (Section 9.3).

9. Procedure

9.1. Model 450I Analyzer setup
9.1.1. Check the exterior of the analyzer (Fig. 2) carefully to assure it is free of visible defects or damage.
9.1.1.1. Remove the instrument cover to expose the internal components (Fig. 3).
9.1.1.2. Remove any packing material, check for possible shipping damage and ensure that all connectors and circuit boards are firmly attached.
9.1.1.3. Replace the instrument cover.
9.1.2. Securely mount the analyzer in the instrument rack.
9.1.3. Connect the analyzer manifold in the GSS to the “SAMPLE” bulkhead (Fig. 2) on the instrument’s rear panel using ¼” OD (1/8” ID) Teflon tubing less than 10’ long. Allow enough slack to permit movement of the instrument rack.
9.1.4. For barn applications:
9.1.4.1. Connect the “EXHAUST” bulkhead to the OFIS air exhaust with 1/4″ OD (1/8″ ID) tubing less than 10′ long, which is unimpeded and free of kinks or blockages.
9.1.4.2. Connect a 4-conductor, 20- or 22-gage shielded cable to the designated channels of the FieldPoint analog input module (SOP B1). Properly ground the shield of the analog output cable.
9.1.4.3. Connect the other end of the 4-conductor cable to the analyzer’s analog outputs for SO_2 and H_2S (not to the CS analog output).
9.1.4.3.1. Remove about 1.8 cm of insulation from the other end of the cable. Fold back the shielding. If necessary, use electrical tape or shrink tubing to hold

shielding in place. Expose a minimum of 1.5 cm of shielding. Strip each signal wire and connect them to the terminals (1) through (4) of the 8-position header of the 450I (Fig. 4) according to the wire connection to the data acquisition hardware

9.1.5. For open source applications:

9.1.5.1. Connect the “EXHAUST” bulkhead to the GSS bypass air exhaust with 1/4″ OD (1/8″ ID) tubing such that total tubing length is less than 10′ long. Tubing must be unimpeded and free of kinks or blockages.

9.1.5.2. Connect a null modem RS232 cable from the RS232 connector of the data-collecting computer to the “RS232/485” connector at the back of the instrument.

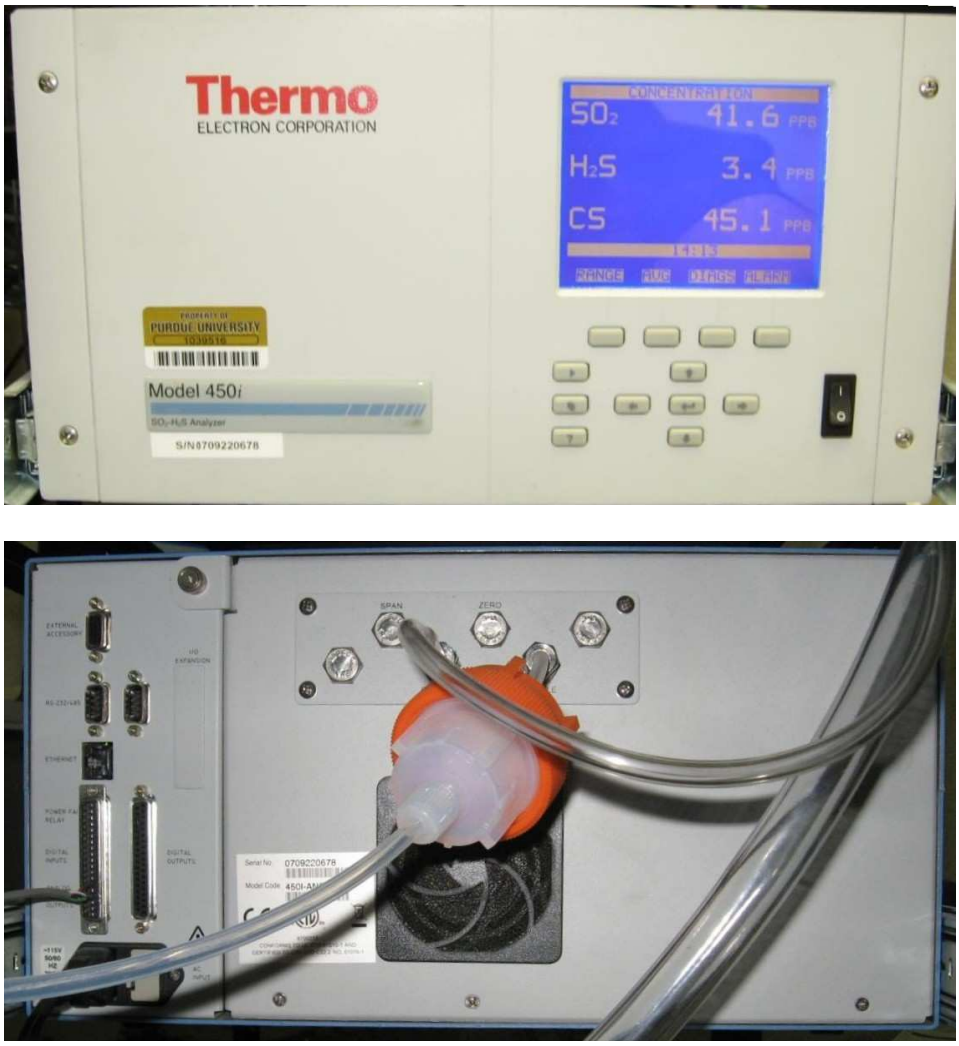

Figure 2. Front (top) and back (bottom) views of the TEC 450I.

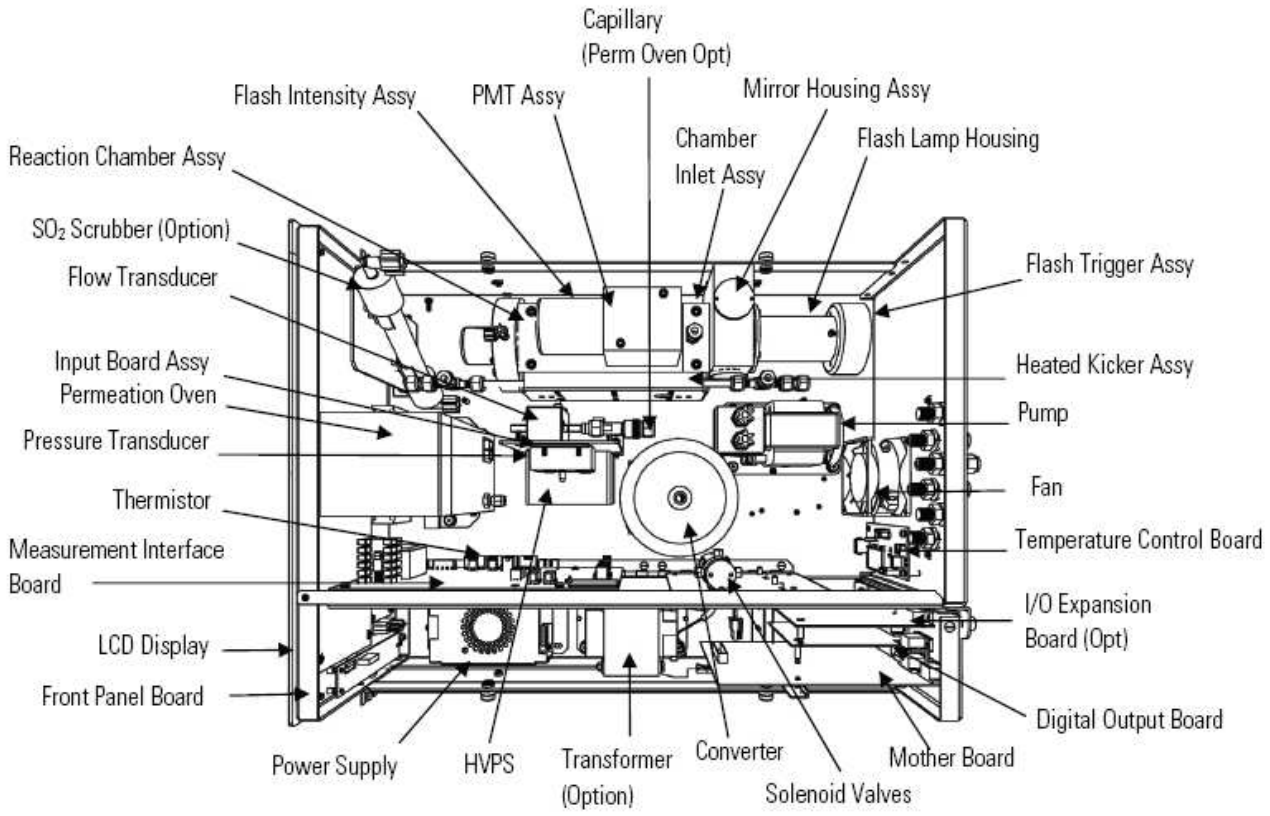

Figure 3. Internal schematic of the TEC 450I analyzer.

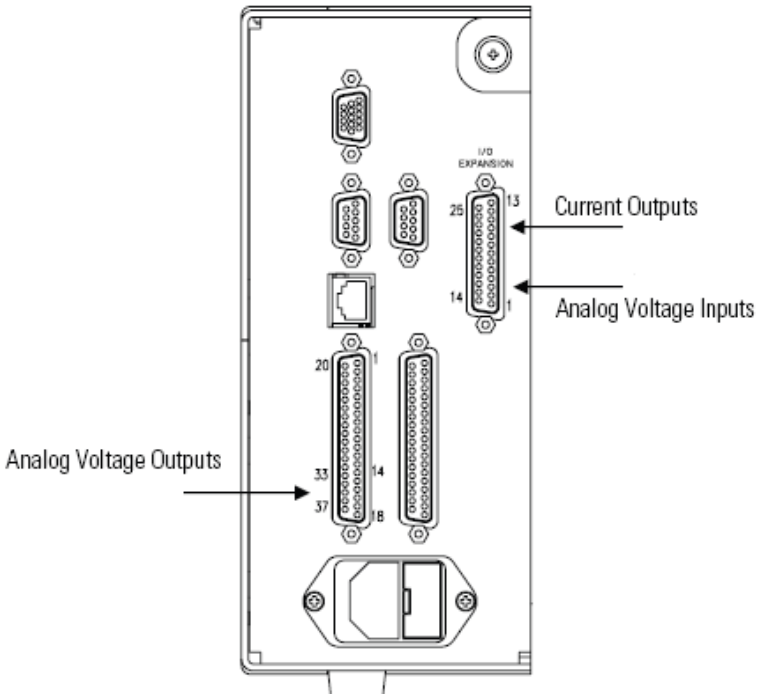

Figure 4. Connectors on the 450I rear panel (left side of Fig. 2 lower panel).

9.1.6. Plug the 450I power cord into a 110VAC power source, turn on its power, and allow a minimum of 90 min for the unit to warm up and stabilize before calibrating.

9.1.7. Operate the instrument menu (Fig. 5) to navigate to the screens necessary to set the instrument control settings (Table 1) and to check the operating parameters and ranges (Table 2), as described in detail in Chapter 3 of the instrument manual. An alarm message will appear in the screen on the front panel of the instrument when any of these parameters is operating outside the set limits.

Table 1. TEC 450I Instrument settings.

Parameter	Setting
Gas Units	ppb
Measurement Mode	Automatic Mode
Averaging Time	60 s
Temperature Correction	ON
Pressure Correction	ON
Flash Lamp	ON
Baud Rate	9600
Service Mode	OFF
Time	Current
Date	Current
Converter Temperature	352°F

Table 2. TEC 450I instrument operating parameters and ranges.

Parameter	Range
Pressure (mm Hg)	400 – 1000
Sample Flow (L/min)	0.350 – 1.400
Lamp Voltage (V)	500 – 1200
Lamp Frequency (Hz)	10,000 – 50,000
Converter Temperature (°C)	300 – 400
Internal Temperature (°C)	15 – 45
Chamber Temperature (°C)	43 – 47

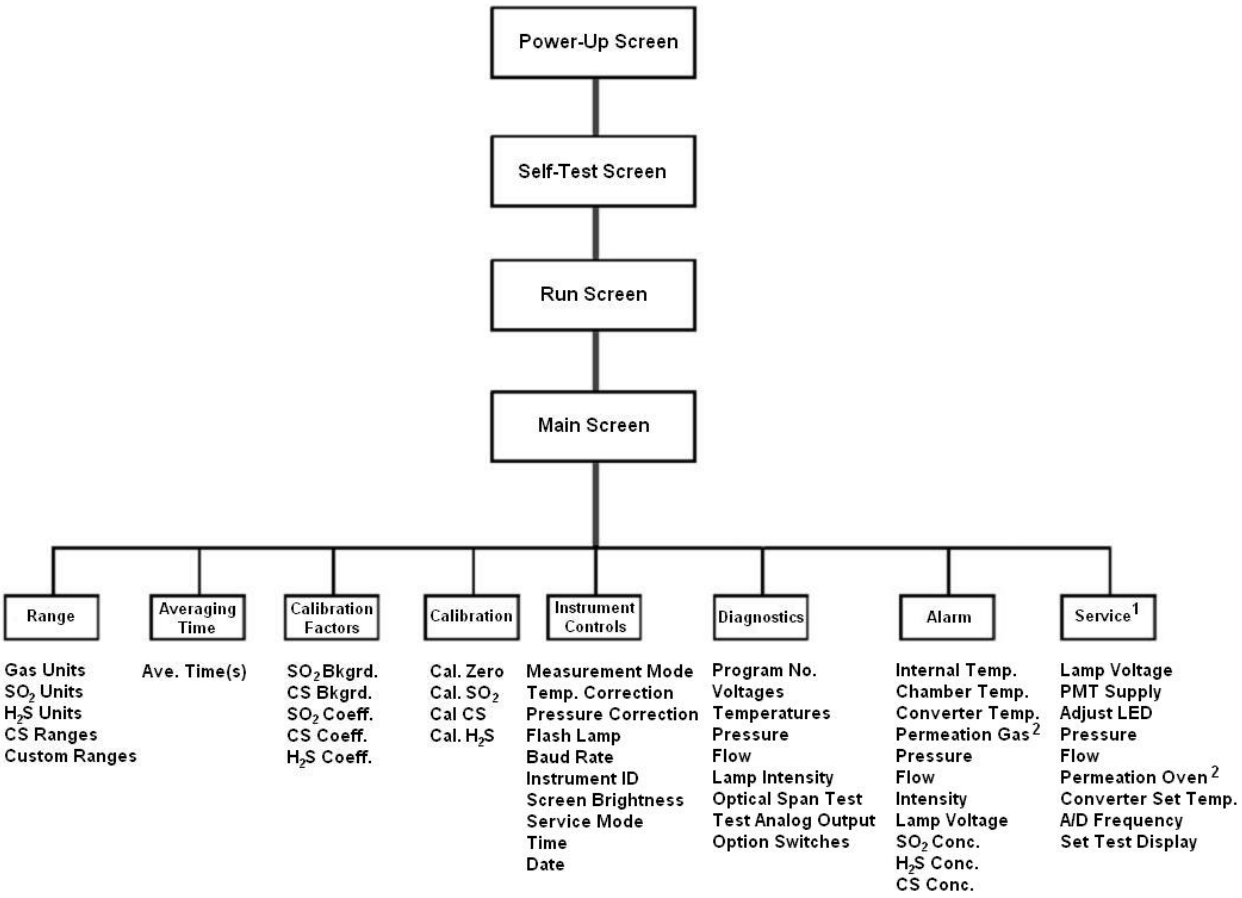

Figure 5. Partial flow chart of the TEC 450I menu from the instrument manual. Notes: 1 – Option only appears when the Service Mode is ON. 2 – Appears only when optional Permeation Oven is installed.

9.1.8. For barn measurements:

9.1.8.1. The analyte (H_2S, SO_2, CS) measurement ranges for the 450I are from 0 to 10,000 ppb. The analyte measurement range settings for each site are listed in the QAPP.

9.1.8.2. Enter the analyzer's analog signal ranges (0 to 10 VDC) and H_2S and SO_2 measurement ranges into the DAQ table in the AirDAC software (SOP B2) so that concentration reading can be displayed, converted and recorded.

9.1.9. For open source measurements:

9.1.9.1. Using iPort software, set data logging settings in instrument

9.1.9.1.1. Under "Main Menu->Instrument Controls->Datalogging settings":

9.1.9.1.1.1. Set "Select SREC/LREC" to "LREC"

9.1.9.1.1.2. Under “Select Content”, make sure the following appears

“FIELD 1	H2S”	
“FIELD 2	SO2”	
“FIELD 3	INTT”	(corresponds to INT TEMP)
“FIELD 4	RCTT”	(corresponds to CHAMBER TEMP)
“FIELD 5	CONVT”	(corresponds to H2S CNV TEMP)
“FIELD 6	PRES”	(corresponds to CHAMBER PRES)
“FIELD 7	SMPLFL”	(corresponds to SAMPLE FLOW)
“FIELD 8	PMTV”	(corresponds to PMT VOLTS)
“FIELD 9	LMPV”	(corresponds to FLASH VOLTS)
“FIELD 10	LMPI”	(corresponds to FLASH REF)
“FIELD 11	NONE”	
…….		
“FIELD 32	NONE”	

9.1.9.1.1.3. Select any fields that are incorrect and modify as necessary. The item type for fields 1 and 2 is “CONCENTRATIONS” while that for the remaining 8 fields is “OTHER MEASUREMENTS”

9.1.9.1.1.4. *If changes were made to any of the above fields and **if all data on the instrument have been saved to the LAN:*** Go to “Main Menu->Instrument Controls->Datalogging Settings->Commit Content”; You will be asked to confirm that you want to commit content. Only say “YES” if you are positive that all data logged on the analyzer have been saved

9.1.9.1.1.5. Check configuration of the data logging at “Main Menu->Instrument Controls->Datalogging Settings->Configure Data logging”
-LOGGING PERIOD, MIN should be set to 1 MIN
-MEMORY ALLOCATION SHOULD BE SET TO 100%
-DATA TREATMENT should be set to AVG

9.1.9.1.1.6. Check the time zone setting; “Main Menu->Instrument Controls->Timezone”; should be set to UTC(GMT).

9.1.9.1.1.7. Set Ethernet communications at “Main Menu->Instrument Controls->Communication Settings->TCP/IP Settings->”
->USE DHCP: OFF
->IP ADDR: 192.168.0.15
->NETMASK: 255.255.255.0
->GATEWAY: 192.168.0.1
->NTP Server: 132.239.1.6

9.1.9.1.1.8. If any value is modified, turn the instrument off and back on again.

9.1.9.2. Using the iPort software, prepare instrument for transmission and storage of the analyzer’s quality assurance and gas concentration measurements

9.1.9.2.1. Under “File->Preferences>instrument”:

9.1.9.2.1.1. Set “size” to FULL

9.1.9.2.1.2. Set “Data Record Loading” to “Save to File” and “Create”

9.1.9.2.2. Under “Comm->Connect”, assure settings are:
Location: H2Sanalyzer
Com: (set to correct value)

Baud Rate: 115200
Len: 8
Stop: 1
Parity: N
Handshake: None
Polling Config: 45 (this is the instrument ID)

9.1.9.2.3. Click on “OK” and respond “YES” to attach instrument.

9.1.9.2.4. Real-time data file save is set up under “Instrument->Load Records”: Click on “Real time” and click “Save to file”. Remove dash and spaces from the default file name (before the date and before the time compoents) and add the path and site code before the filename (e.g. C:\NAEMS\Data\OK4A\Period3\H2S\OK4A), and click “OK”

9.1.9.3. Verify that the output file is being produced in the desired location and check the contents by right clicking and opening with ‘Windows Notepad’. File should appear as:

```
;;
;; C:\NAEMS\Data\450I0103082156.dat Thu Jan 03 21:57:05 2008
;;
;; Model 450I- (prog iSeries 450I 01.05.06.165)
;;
Time   Date    Flags      h2s      so2     intt     rctt    convt     pres   smplfl     pmtv     lmpv     lmpi
14:53  01-03-08 LL------    1.052  9.36528  10.8132  32.8277   322.29  661.186  1.06992 -647.131  808.951       89
14:54  01-03-08 LL------  1.48701  8.50626  10.9028  33.1631  324.389  656.023  1.06526 -647.131   809.76       88
14:55  01-03-08 LL------  1.40748  7.61518  11.0148  33.4469  327.276  663.312  1.07233 -647.131  809.356       87
14:56  01-03-08 LL------ 0.247904  7.33171  11.1044  33.8854  326.751  658.149  1.06647 -647.131  810.973       88
14:57  01-03-08 LL------ 0.142362  7.49943  11.2164   34.066  323.865  663.312  1.07233 -647.131  808.143       88
14:58  01-03-08 LL------ 0.912892  7.91842  11.2612  34.1692  322.552  656.023  1.06492 -646.761  809.356       89
14:59  01-03-08 LL------ 0.957739  8.52361  11.3956  34.4788  325.177  661.186  1.07026 -647.131  808.547       89
15:02  01-03-08 LL---LL-        0        0   11.642   35.132  323.602  661.489  1.07164 -647.131  808.547       88
15:03  01-03-08 LL------        0        0   11.754   35.352  323.077  655.719  1.06544 -646.761  807.738       88
```

9.2. Gas Analyzer Calibration

9.2.1. Reference calibration gases

9.2.1.1. Sulfur Dioxide (SO_2) in N_2 - exact composition as specified in the QAPP.

9.2.1.2. Hydrogen Sulfide (H_2S) in N_2 or air - exact composition as specified in the QAPP.

9.2.1.3. Zero air, also referred to as Continuous Emission Monitoring (CEM) Zero Air.

9.2.2. For barn measurements, set AirDAC to “Gas Cal” (Gas Calibration) and calibrate the 450I following SOPs G8 and G9

9.2.3. For open source measurements:

9.2.3.1. Start the 450I gas analyzer and let it warm up for at least 30 minutes.

9.2.3.2. Use Environics Series 4040 Gas Dilution System or TEC 146I dilutor to dilute H_2S levels if necessary.

9.2.3.2.1. Install gas line from exhaust of 450I to vent into trailer or outside

9.2.3.2.2. Install gas line from output port of dilutor to sample port of 450I, with a tee in the line to vent excess to outside through a flowmeter; this prevents over-pressurizing the 450I and verifies sufficient flow for 450I sampling.

9.2.3.2.3. Open both gas cylinders (calibration gas and zero air) to a pressure of 20 psi, then

9.2.3.2.4. Initial calibration gas is 0 ppm H_2S.

9.2.3.2.5. If using the Environics dilutor:

9.2.3.2.5.1. Attach gas lines of H_2S cylinder and Zero Air cylinder to ports 2 and 1 (respectively) of Environics dilutor.

9.2.3.2.5.2. Set the H_2S concentration in the Environics dilutor program to the chosen concentration according to SOP G11.

9.2.3.2.6. If using the TEC 146I dilutor:

9.2.3.2.6.1. Attach gas lines from calibration cylinder to port A (or other programmed Port), and from the zero air cylinder to Zero Air Port.

9.2.3.2.6.1.1. Connect gas line from zero air cylinder (for 0 ppm H_2S) to sample port of 450I, with a tee in the line that vents exhaust (this prevents over-pressurizing the 450I).

9.2.3.2.6.2. Set the H_2S concentration on the diluter (not 0 ppm) to the chosen concentration according to SOP C3.

9.2.3.2.7. Open flow valve of regulator. Flow calibration gas through the 450I and wait 5-10 min. for the H_2S concentration reading on the 450I to stabilize.

9.2.3.2.8. Repeat sections 9.2.3.2.4, 9.2.3.2.6 (Environics diluter) or 9.2.3.2.5, 9.2.3.2.6 (TEC 146i diluter) using calibration gas at appropriate concentration.

9.2.3.2.8.1. Record pressure, flow rate, lamp intensity, and lamp voltage from 450I on a form similar to Table 3.

9.2.3.2.8.2. Once stabilized record H_2S output concentration from dilutor and H_2S concentration reading on the 450I.

9.2.3.3. If multipoint calibration, repeat section 9.2.3.2 for each target concentration, running a zero test in between span checks (the four concentrations are 3ppm, 2ppm, 1ppm, and 0.5ppm) in decreasing concentration and record results on form similar to Table 3.

9.2.3.3.1. Calculate linear regression of instrument response to concentration and apply to records as a post-process.

9.2.3.4. If calibration verification check, repeat section 9.2.3.2 for zero and 0.5 ppm concentrations respectively.

Table 3 – Example Multi-point calibration form for Open source instruments

450I Gas Analyzer Multi-Point Calibration

Serial #	Time	Pressure	Flow	Lamp Int.	Lamp Volt.	H2S cyl. Conc.	Dilutor Conc.	450I H2S reading
						0		
						3 0		
						0		
						2 0		
						0		
						1 0		
						0		
						0 5		
						0		

9.2.4. Recording information during a calibration or precision check

9.2.4.1. Record the analyzer's responses to both zero and reference (precision check) gases before and after adjusting the analyzer. The recorded responses before adjustment (as-found responses), are used to correct the data since the previous calibration or previous precision checks.

9.2.4.2. Record 450I pressure, sample flow, lamp intensity, and lamp voltage in the electronic field notes in a table like Table 4.

9.2.4.3. For barn measurements: Record the start / stop (read) times, analyzer, calibration gas, calibration gas concentration, analyzer reading, AirDAC concentration reading, and AirDAC signal in the field notes like in Table 5 (Precision Checks) or Table 6 (Calibration)

9.2.4.4. For open source measurements: Record the start / stop (read) times, analyzer, calibration gas, calibration gas concentration, analyzer reading, data file concentration reading in the field notes like in Table 7 (Calibration Verification/Precision Checks).

9.2.5. Introduce reference gas. The number of points and gas concentrations for multipoint calibrations and calibration verification/ precision checks are specified in the Quality Objectives of the QAPP.

9.2.5.1. Start flow of reference gas to the analyzer. See SOP G1 for delivery options

9.2.5.2. Record date and time in the electronic field notes in a table like Table 5.

9.2.5.3. Record pertinent gas delivery parameters (SOP G1).

9.2.5.4. Wait a minimum of 10 min for the display to stabilize (The minimum of 10 min corresponds with the sampling time used for each location).

9.2.5.5. Record the time and concentrations shown on the 450I display, and in AirDAC (barn measurements), on provided form and Excel® spreadsheet form (open area measurements) and in the electronic or paper field notes. Update the control chart in accordance with SOP Q1.

Table 4. Recording of TEC 450I operating parameters.

Date	TEC 450I Operating Parameters			
	Pressure,	Sample Flow	Lamp Intensity	Lamp Voltage
	mm Hg	L/min	Hz	V
3/07/2006	558.6	0.996	21173	1095
3/12/2006	557.5	1.040	20998	1094
“	“	“	“	“
“	“	“	“	“

9.2.5.6. If the stabilized concentration during a precision check deviates from the control chart baseline calibration value by 10% or more, conduct a multipoint calibration in accordance with SOP G9 (barn measurements) or Section 9.2.3.3 of this SOP (open area measurements).

9.2.5.7. Stop gas flow and record the time.

9.2.6. Repeat the steps in Section 9.2.5.for each reference gas.

9.2.7. Return analyzer's display back to the run screen by pressing run.

9.2.8. For barn measurements, return the GSS back to normal sampling mode by setting AirDAC to auto sample.

9.3. Converter Efficiency Check

9.3.1. Following Section 9.2, calibrate the SO_2 and CS channels with the SO_2 calibration gas. Then, calibrate the H_2S channel with the H_2S calibration gas.

9.3.2. Navigate to the "Calibration Factors" Menu (Fig. 5). The H_2S coefficient shown here is the converter efficiency.

9.3.2.1. For example, if the H_2S coefficient is 0.905, the converter efficiency is 90.5%.

9.4. Maintenance

9.4.1. Preventive maintenance is covered in Chapter 5 of the 450I Instrument Manual.

9.4.1.1. Clean the dust filters on the back of the analyzer and converter on a regular basis. This can range from weekly to monthly, depending on the dust level in the OFIS.

9.4.1.2. If the lamp voltage is equal to or greater than 1200 V, lower the voltage by adjusting the potentiometer (R28) on the lamp power supply board (See Chapter 7 of the Instrument Manual for Servicing), or replace the lamp.

9.4.1.3. Run a leak test if the sample flow rate, as reported by AirDAC (barn measurements) or iPORT (open area measurements), is < 0.9 L/min.

9.4.1.3.1. Block the bulkhead labeled "SAMPLE" on rear panel with a leak-tight cap then wait 5 to 10 min.

9.4.1.3.2. Check the sample flow and pressure readings. There should be zero flow and less than 160 mm Hg pressure. If not, check to see that none of the fittings or threads of the input lines are cracked or broken.

9.4.1.4. Check the capillary tubes for particulate deposits within the bore. Clean or replace as necessary.

9.4.1.5. Conduct a zero & precision span check before and after any maintenance, except for cleaning of the dust filter.

9.5. Troubleshooting

9.5.1. Troubleshooting guidelines are in Chapter 6 of the 450I manual.

9.5.1.1. Check wiring, power connections, and fuses if there is no signal or power.

9.5.1.2. Check flow path integrity if span concentration cannot be attained, or if flow rate is low.

9.5.1.3. If there is no or low flow, check the capillary tube or internal pump.

9.5.1.4. Replace lamp if the lamp intensity is varying widely (ranging quickly from 10,000 to 50,000 Hz).

9.6. Data acquisition, calculations & data reduction requirements

9.6.1. Barn measurements: Monitor a 0-10 VDC analog output signal using AirDAC (SOP B2).

9.6.2. Open area measurements: Monitor measurements using iPort software.

9.6.3. Report all data with 3 significant digits.

9.6.4. Follow SOP B4 to correct gas concentrations for calibration and air density.

9.7. Computer hardware & software

9.7.1. Barn measurements:

9.7.1.1. DAQ hardware (SOP B1)

9.7.1.2. AirDAC (SOP B2)

9.7.1.3. ARDIS (SOP B3)

9.7.1.4. CAPECAB (SOP B6)
9.7.2. Open area measurements:
9.7.2.1. LAN server (SOP U4)
9.7.2.2. iPort software

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method. Supplement this electronic record by a bound record book designated for the method, which should contain copies of the electronic record.
10.2. Manage all data according to SOP B5 (barn measurements) or SOP D1 (open area measurements).
10.3. Document all data and information (e.g., sample collection method used) on field data sheets, and within site logbooks with permanent ink, or in electronic field notes.
10.4. Overstrike all errors in writing with a single line, and initial and date all such corrections.
10.4.1. Open area measurements:
10.4.1.1. LAN server (SOP U4)
10.4.1.2. iPort software

11. Quality Control and Quality Assurance

11.1. Conduct zero and one or more precision checks at the QAPP-specified frequency.
11.2. Conduct multipoint calibrations at the QAPP-specified frequency
11.3. Conduct a multipoint calibration whenever a precision check indicates a drift of > ±10% from the baseline calibration value, unless otherwise stated in the QAPP for a particular project.
11.4. Conduct a multipoint calibration whenever the zero check is > ±5% of full scale different than the baseline zero, unless otherwise stated in the QAPP for the particular project.
11.5. Check response time every month for barn measurements, and every six months for open area measurements.
11.6. In cases where SO_2 is not a primary measurement, weekly zero/precision checks with SO_2 are not necessary. In these cases, the QAPP will dictate the frequency of converter efficiency checks, and the converter efficiency that must be maintained.
11.7. Perform preventative maintenance every six months, according to the schedule provided in Chapter 5 of the 450I manual.
11.7.1. Visually inspect for obvious visible defects (loose connections and/or fittings, cracked or clogged Teflon lines, and excessive dust accumulation.
11.7.2. Inspect the fan filter located on the back of the instrument weekly; clean as needed.
11.7.3. The schedule for replacing the sample particulate filter is found in the QAPP.
11.7.4. Measure the gas analyzer inlet flow rate every six months.
11.7.5. Check the lamp voltage under the diagnostics menu. If the lamp voltage is 1200 V or higher, replace the lamp or adjust its voltage.
11.7.6. Leak check the sample line and flow components and fittings every six months.

11.8. If troubleshooting of the analyzer reveals particulate deposits in the capillaries, these must be replaced.

12. References

12.1. iPort Instruction Manual. 2007. *i*Port Instruction Manual. Communications software for iSeries and C Series Instruments. Part#102606-00. Thermo Fisher Scientific, Franklin, MA.
12.2. TFS 450I Manual. 2006. Model 450I Pulsed Fluorescence SO_2- H_2S-CS Analyzer Instruction Manual. Part #103258-00. Thermo Fisher Scientific, Franklin, MA.
12.3. SOP B1. 2007. Data Acquisition and Control Hardware. Standard Operating Procedure B1, v. 1.0. Purdue Ag Air Quality Lab.
12.4. SOP B2. 2007. Data Acquisition and Control Software (AirDAC). Standard Operating Procedure B, v. 1.02. Purdue Ag Air Quality Lab.
12.5. SOP B3. 2006. Air Data Pre-Processing Software. Standard Operating Procedure B3, v. 0.0. Purdue Ag Air Quality Lab.
12.6. SOP B5. 2006. Data Management for Barns. Standard Operating Procedure B5, v. 0.0. Purdue Ag Air Quality Lab.
12.7. SOP B6. 2007. Data Processing Software (CAPECAB). Standard Operating Procedure B6, v. 1.0. Purdue Ag Air Quality Lab.
12.8. SOP G1. 2006. The PAAQL Gas Sampling System. Standard Operating Procedure G1, v. 0.0. Purdue Ag Air Quality Lab.
12.9. SOP G2. 2006. Compressed Gas Cylinders. Standard Operating Procedure G2, v. 0.0. Purdue Ag Air Quality Lab.
12.10. SOP G7. 2008. Use of the INNOVA 1412 Photoacoustic Multi-Gas Monitor. Standard Operating Procedure G7, v. 1.0. Purdue Ag Air Quality Lab.
12.11. SOP G8. 2007. Multi-Point Calibration of Gas Analyzers. Standard Operating Procedure G8, v. 1.0. Purdue Ag Air Quality Lab.
12.12. SOP G9. 2006. Zero and Precision Checks of Gas Analyzers. Standard Operating Procedure G9, v. 0.0. Purdue Ag Air Quality Lab.
12.13. SOP G11. 2007. Operation of the Environics® Computerized Gas Dilution System. Standard Operating Procedure G11, v. 1.0. Purdue Ag Air Quality Lab.
12.14. SOP Q1. 2007. Use of Control Charts for Performance Monitoring of Gas Analyzers and Analytical Instruments. Standard Operating Procedure Q1, v. 1.0. Purdue Ag Air Quality Lab.

13. Contact Information

13.1. Manufacturer: Thermo Fisher Scientific (www.thermo.com), 8 West Forge Parkway, Franklin, MA 02038, Technical Support: 1-866-282-0430
13.2. PAAQL: odor@purdue.edu, heber@purdue.edu, http://www.AgAirQuality.com.

Table 5. TEC 450I Analyzer Precision Check - Barn Measurements.

Precision Checks							
3/12/2006				Concentration	Instrument	Lab View	Signal
Started	Stopped	Instrument	Gas	ppb	Reading	ppm /ppb	vdc or mA
4/28/2006 14:05	4/28/2006 14:15	TEC 450I (H2S)	CEM Zero	0	-3.1	2.55	0.0005
4/28/2006 14:05	4/28/2006 14:15	TEC 450I (SO2)	CEM Zero	0	0	0.98	0.0008
4/28/2006 14:16	4/28/2006 14:26	TEC 450I (H2S)	H2S	2080	2090	2101.22	2.090
4/28/2006 14:16	4/28/2006 14:26	TEC 450I (SO2)	H2S	2080	10	10.78	0.011
4/28/2006 14:27	4/28/2006 14:37	TEC 450I (H2S)	SO2	1900	-106	-107.74	-0.109
4/28/2006 14:27	4/28/2006 14:37	TEC 450I (SO2)	SO2	1900	1907	1904.71	1.912

Table 6. TEC 450I Analyzer Calibration Check- Barn Measurements.

Calibration (H2S)							
8/9/2005				Concentration	Instrument	Lab View	Signal
Started	Stopped	Instrument / Comments	Gas	ppb	Reading	ppb	vdc
8/9/2005 8:55	8/9/2005 9:10	TEC 450I	CEM Zero	0	-33	-38	0.059
8/9/2005 9:11	8/9/2005 9:22		H2S	4370	4570	4551	9.091
8/9/2005 9:23	8/9/2005 9:35	Recorded reading	CEM Zero	0	-25.7	-33	-0.049
	8/9/2005 9:37	Zero-ed instrument		0			
	8/9/2005 9:39	Recorded reading (9:39:19)		0	0	0	0.001
8/9/2005 9:11	8/9/2005 9:22	Recorded reading	H2S	4370	4540	4536	9.071
	8/9/2005 9:52	Adjusted instrument to H2S span of 4370 ppb					
	8/9/2005 9:53	Recorded reading (9:53:08)			4370	4371	8.741
8/9/2005 9:54	8/9/2005 10:06		CEM Zero	0	3.6	5.0	0.011
8/9/2005 10:06	8/9/2005 10:17		H2S	4370	4370	4376	8.751
8/9/2005 10:17	8/9/2005 10:28		CEM Zero	0	0.4	0	0.001
8/9/2005 10:28	8/9/2005 10:39		H2S	4370	4420	4416	8.831
8/9/2005 11:19	8/9/2005 11:29	Baseline	CEM Zero	0	-1.6	-2	0.001
8/9/2005 11:29	8/9/2005 11:39	Baseline	H2S	4370	4380	4361	8.771

Table 7. TEC 450I Analyzer Calibration Verification Check- Open Area Measurements.

3/12/2006			Concentration	Instrument Reading	Deviation from baseline	Site FOS
Started	Stopped	Gas	ppb			
4/28/2006 14:05	4/28/2006 14:15	CEM Zero	0	-3.1		
4/28/2006 14:05	4/28/2006 14:15	CEM Zero	0	0		
4/28/2006 14:16	4/28/2006 14:26	H2S	2080	2090		
4/28/2006 14:16	4/28/2006 14:26	H2S	2080	10		

USE OF THE INNOVA 1412 PHOTOACOUSTIC MULTI-GAS MONITOR

Standard Operating Procedure (SOP) G7

USE OF THE INNOVA 1412 PHOTOACOUSTIC MULTI-GAS MONITOR

Standard Operating Procedure (SOP) G7

Prepared by
Congna Li and Bill W. Bogan

Reviewed by
Claude A. Diehl, Jerry Rutherford (California Instruments),
and Albert J. Heber

Effective Date: November 6, 2006

PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)
Agricultural and Biological Engineering, Purdue University
West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The purpose of this procedure is to present the methodology and instrumentation used to automatically and sequentially measure concentrations of various gases at confined animal feeding operations (CAFO), specifically, within the barns and other buildings, and around open sources such as corrals, manure lagoons, or storage basins.

1.2. The method described in this SOP is suitable for measurement of any gas which absorbs infrared (IR) radiation. Gas selectivity is achieved through the use of optical filters. Gases which can be measured through this method, and which are relevant to CAFOs, include:

1.2.1. Ammonia (NH_3)
1.2.2. Ethanol/methanol (total alcohols)
1.2.3. Acetic acid
1.2.4. Acetaldehyde
1.2.5. Dimethyl sulfide
1.2.6. Carbon dioxide
1.2.7. Methane
1.2.8. Phenol
1.2.9. Total VOC

1.3. The QAPP for a particular project will specify which gases will actually be measured.

1.4. This procedure applies only to the INNOVA Model 1412 Photoacoustic Monitor.

1.4.1. The minimum detection limit (MDL) of this instrument is gas-dependent, but is typically in the ppb region. It is often below 100 ppb, with the exception of ammonia, which has a minimum detection limit of 200 ppb.

1.4.2. The range is also gas-specific. The linear range for a given gas is typically from 1 to 10,000 times the MDL.

1.4.2.1. For example, the Model 1412's linear range for ammonia is from 0.2 ppm (the MDL) to 2000 ppm.

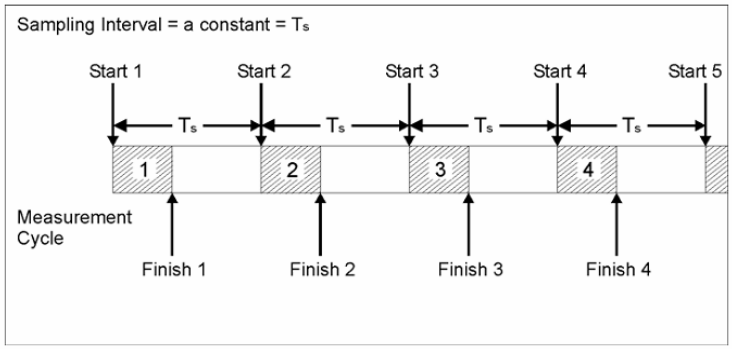
1.4.3. The stated precision of the Model 1412 is 1% of measured value.

1.4.4. The instrument's stated response time (97%) to a step change in concentration is 12 s.

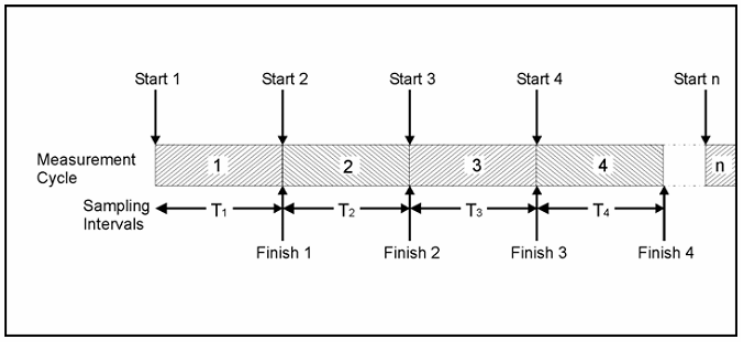
2. Summary of Method

The multi-gas monitor (INNOVA Model 1412, Innova AirTech Instruments, Ballerup, Denmark) is based on the photoacoustic infrared detection method. As shown in the schematic diagram in Fig. 1, a gas sample is drawn at a constant flow rate (in the case of the barns, from the GSS analyzer manifold), and introduced into an acoustic cell where it is exposed to pulsing infrared light of specific wavelength. If the sample contains the gas of interest, it will absorb an amount of infrared light that is proportional to the analyte gas concentration in the sample. When a gas absorbs infrared light, its temperature rises as its molecules increase in kinetic energy; this causes a pressure wave inside the photoacoustic cell. Pressure pulses, which are also proportional to the concentration of the analyte gas, thus correspond to the light pulses, and are detected by two sensitive microphones located inside the chamber. Almost any gas that absorbs infrared light can be measured by this method.

Gas analysis with the Model 1412 can be conducted either using set sampling intervals, or in continuous mode. Sampling interval is a measure of the time between the start of one measurement cycle and the start of the next measurement cycle. Therefore, if a measurement cycle (including readings of all gases being measured) takes 27 s, and the sampling interval is 1 min, then there will be 33 s before the next measurement cycle starts, as follows:



In continuous sampling mode, each measurement cycle is followed immediately by another similar measurement cycle, as below:



In either mode, a measurement cycle consists of the following steps:

- Measurement of the gas sample with each chosen individual optical filter (up to 5)
- Measurement of the gas sample with the water vapor optical filter
- Flushing the chamber & tubing and filling the chamber with the next gas sample

Gas selectivity is achieved through the use of optical filters. The Innova 1412's optical filter carousel can hold 5 optical filters for target gases, plus one for water vapor, thus allowing measurement of up to 5 gases and water vapor in a given air sample. Each individual optical filter rotates in front of the photoacoustic chamber, and pauses for the set sample integration time (SIT) before moving to the next filter. All filters rotate through once every measurement cycle. The MDL is gas-specific and filter wavelength-specific; examples include:

Acetic acid	40 ppb	Total TOC (reference propane)	20 ppb
Ammonia	200 ppb	Methane	100 ppb
Carbon dioxide	1500 ppb	Sulfur dioxide	300 ppb

Measurement accuracy is ensured by the Model 1412's ability to compensate for temperature and pressure fluctuations, water-vapor interference and interference from other IR-absorbing gases that are known to be present. Reliability of measurement results can be ensured by regular self-tests. The analysis time is dependent on the physical properties of the gas of interest, the number of gases being measured, the set-up of the instrument, the gas sampling system, and the sampling location. When a gas or a gas mixture is introduced to the analyzer, the response time can vary from approximately 13 s for one gas (or water vapor) to approximately 150 s if five gases plus water vapor are measured. The following table indicates in more detail the effect of analyzer configuration on analysis time:

Sample integration time, s	1	1	5	5	20
Water vapor measured?	no	yes	no	yes	yes
Number of gases	1	5	1	5	5
Flushing time, s	4	4	Auto (tube 1 m)	Auto (tube 1 m)	Auto (tube 1 m)
Analysis Time, s	**~13**	**~27**	**~25**	**~60**	**~150**

3. Definitions of Terms and Acronyms

AirDAC	Data Acquisition and Control software (SOP B2)
Analysis Time	The total time required to measure each gas's response to infrared light (SIT) and to flush the photoacoustic cell.
GSS	Gas sampling system (SOP G1)
IR	Infrared
LAN	Local area network
MDL	Minimum detection limit
NIST	National Institutes of Science and Technology
NMi	Netherlands Measurement Institute
PAAQL	Purdue Agricultural Air Quality Laboratory
PAML	Purdue Applied Meteorology Laboratory
PC	Personal computer
ppb	Parts per billion
ppm	Parts per million
QAPP	Quality Assurance Project Plan
SIT	Sample integration time

4. Health and Safety

4.1. Be careful when working with the analyzer's electrical power connection.
4.2. The IR source and analysis cell are very hot when the analyzer is operating. Do not attempt to service any internal components without allowing adequate cool-down time.
4.3. If used indoors (such as inside the OFIS). Properly vent the analyzer's exhaust to avoid exposure to noxious gases in the sample.

5. Interferences

5.1. Water absorbs IR light at most wavelengths, and is nearly always present in air samples. Thus, water will essentially always contribute to the total acoustic signal. The Model 1412 is permanently fitted with a special water-selective filter, which enables it to compensate for this interference.

5.2. By selecting different filters, this technique can also be used to cross-compensate for known interferents (i.e. gases which are not target analytes, but which are known to absorb IR at the wavelength(s) used to quantify one or more target compounds.

5.2.1. Possible interferent gases relevant to livestock barns, anaerobic treatment lagoons, manure storages, and related facilities (Schmidt et al, 2005; Summers, 2005) include the following (levels are based on detection limits in Innova AirTech Instruments' "Detection Limits Wall Chart" (Reference 12.3) for these gases at the same wavelength used for quantifying the given primary analyte):

5.2.1.1. **Ammonia** can be quantified at either of two wavelengths – 974 μm or 976 μm. The stated detection limit at each of these wavelengths is 200 ppb. Some of these compounds will interfere more at one wavelength (indicated in parentheses) and less (but still possibly significantly) at the other wavelength. If VOC characterization of the site indicates that any of these compounds are present above the indicated thresholds, it may be necessary to compensate for them in order to obtain accurate NH_3 data.

5.2.1.1.1. 2-butanone ≥ 500 ppb (976 μm)
5.2.1.1.2. Ethanol ≥ 60 ppb (974 μm)
5.2.1.1.3. Ethanolamine ≥ 110 ppb (974 μm)
5.2.1.1.4. Methanol ≥ 80 ppb (974 μm)
5.2.1.1.5. Phenol ≥ 400 ppb (974 μm)

5.2.1.2. **Ethanol/methanol** is optimally measured at 974 μm, with a detection limit of 80 ppb. Interferents at this wavelength include:

5.2.1.2.1. Ammonia ≥ 200 ppb
5.2.1.2.2. Ethanolamine ≥ 110 ppb
5.2.1.2.3. Phenol ≥ 400 ppb

5.2.1.3. **Acetic acid** is optimally measured at 970 μm. Its stated detection limit is 40 ppb. Interferents at this wavelength include:

5.2.1.3.1. Methanol ≥ 500 ppb

5.2.1.4. **Acetaldehyde** is optimally measured at 986 μm, with a detection limit of 80 ppb. Interferents at this wavelength include:

5.2.1.4.1. Dimethyl sulfide ≥ 400 ppb
5.2.1.4.2. Dimethylamine ≥ 40 ppb
5.2.1.4.3. Formaldehyde ≥ 40 ppb
5.2.1.4.4. Trimethylamine ≥ 20 ppb

5.2.1.5. **Dimethyl sulfide** is optimally measured at 936 μm. Its detection limit is 600 ppb at this wavelength. Interferents at this wavelength include:

5.2.1.5.1. Methanol ≥ 80 ppb

5.2.1.6. No obvious relevant interferents for **CO_2** (quantified at 983 μm) are evident. The stated diction limit for CO_2 is 3.4 ppm

5.2.1.7. **Methane** can be quantitated at 968 μm or 969 μm; however, the former of these is much more sensitive to interference from water vapor. When methane is quantified at 969 μm, it has a detection limit of 400 ppb, with the following possible interferents:
5.2.1.7.1. $H_2S \geq 14$ ppm
5.2.1.7.2. Acetone ≥ 70 ppb
5.2.1.8. **Phenol** is optimally measured at 971 μm. Its detection limit is 8 ppb. Interferents at this wavelength include:
5.2.1.8.1. m-cresol ≥ 50 ppb
5.2.1.8.2. Dimethylamine ≥ 200 ppb
5.2.1.8.3. Methyl methacrylate ≥ 20 ppb
5.2.1.8.4. $SO_2 \geq 400$ ppb
5.2.1.8.5. Trimethylamine ≥ 200 ppb
5.2.1.9. Total VOC is best measured at 987 μm, with a detection limit of 20 ppb. Since it is intended to measure all volatile organic hydrocarbons, no individual hydrocarbons can be considered interferents. Some oxygenated VOC will absorb at this wavelength; others will not. Ammonia and H_2S have negligible absorptions at 987 μm.

5.3. Certain gases require humidification in order to generate accurate calibration readings. This is needed to speed the relaxation (energy release) of the analyte molecules after they are excited by the IR light, by mediating the dispensation of energy to bulk fluid (gas). Without humidification, there will be significant downward drifting of the reading of the calibration gas, leading to inaccurate readings. An inline Nafion-based humidifier (Section 8.5) must be used (Section 9.4.3.3.1.3) with these gases.
5.3.1. Humidification is required for any calibration or span check with CO_2.
5.3.2. Humidification is required for methane if air is used as the diluent.

6. Cautions

6.1. When installing the RS-232 cable to the back of the gas analyzer monitor, ensure that both the monitor and the PC are switched off at the mains. Failure to do so may result in equipment being damaged.
6.2. Blown fuses in the monitor can indicate a serious fault in the analyzer; therefore, it is advisable to contact the Innova representative before changing the fuse.
6.3. Do not pressurize the instrument above 250 Pa (1 in. of water).
6.4. Avoid water condensation in the analyzer.
6.5. Do not allow any liquid to enter the analyzer's photoacoustic chamber.

7. Personnel Qualifications

7.1. Personnel should be trained in the use of the analyzer before initiating the procedure. Training requires about three hours.
7.2. Each analyst must read and understand the entire analyzer manual and this SOP before operating the Model 1412.

7.3. Personnel should also be trained to interpret the analyzer output signal, converted concentration data, and correction of concentrations based on calibration.

8. Equipment and Supplies

8.1. Multi-gas Photoacoustic Monitor (Model 1412, Innova AirTech Instruments, Ballerup, Denmark), with appropriate optical filters (as defined in the particular project's QAPP):
- 8.1.1. UA0976 or 974 for ammonia
- 8.1.2. UA0974 for ethanol/methanol
- 8.1.3. UA0970 (or UA0971) for acetic acid
- 8.1.4. UA0986 for acetaldehyde
- 8.1.5. UA0936 for dimethyl sulfide
- 8.1.6. UA0983 for carbon dioxide
- 8.1.7. UA0968 for methane
- 8.1.8. UA0971 for phenol
- 8.1.9. UA0985 for nitrous oxide
- 8.1.10. UA0984 for carbon monoxide
- 8.1.11. UA0987 for total VOC (general hydrocarbon filter)

8.2. Rack and rack mounts

8.3. Data acquisition and control
- 8.3.1. Barn applications: PAAQL data acquisition and control hardware (SOP B1), and AirDAC (SOP B2) and proprietary custom software to allow communication between INNOVA and AirDAC (Nexus Solutions, London, Ontario, Canada)
- 8.3.2. Open-source applications: LAN Server computer in open-source trailer (SOP U5 or U7 for lagoon or corral sites, respectively), and LabVIEW software (National Instruments Corporation, Austin, TX)

8.4. Mounting post and post driver (for open-source applications – SOP U5 or U7)

8.5. Nafion humidifier (California Analytical Instruments Part # CAI-110-03-34)

8.6. Keep the following spare parts at each remote site and in central stocks at PAAQL and PAML:
- 8.6.1. Threaded nuts (2x YM 0652)
- 8.6.2. Swagelok stainless steel ¼" nuts and ferrules
- 8.6.3. Gas Monitoring Software 7304 for Photoacoustic Multi-gas monitors 1412
- 8.6.4. External filters
  - 8.6.4.1. (Recommended) stainless steel filter frit (10 μm, 25 mm)
  - 8.6.4.2. External fine air filters (CAII-F01) 100/pkg. (Millipore: Mitex Membrane Filter, PTFE, hydrophobic, 10 μm, 25 mm, white, plain; catalog number: LCW02500)
- 8.6.5. Cables
  - 8.6.5.1. Modem cable (9 pin)
  - 8.6.5.2. RS-232 null modem cable (25 pin female/9 pin male)
  - 8.6.5.3. Power cable (cord) for the analyzer
- 8.6.6. Tubing
  - 8.6.6.1. Teflon tubing (¼″ OD)
  - 8.6.6.2. UD 5037 Nafion tubing

8.6.7. Spare slow-blow (T) fuses with a rating of 2.5 A, 250 VAC, 5x20 mm, UL-approved (Innova Order Number: VF0087A)
8.6.8. Instruction manual, menu tree, and field guide for the Innova 1412 Photoacoustic Monitor
8.7. Keep the following spare parts in central stocks at PAAQL and PAML:
8.7.1. Optical filter locking springs (8x DL 3322)

9. Procedure

9.1. Installation
9.1.1. Check analyzer carefully to assure it is free of visible defects or damage.
9.1.2. Mounting options
9.1.2.1. For barn applications, securely mount the analyzer horizontally on the instrument rack in the OFIS.
9.1.2.2. For open-source applications, mount the instrument securely to a mounting post at a specified location downwind of the lagoon or other open source which is being monitored. See the Site Monitoring Plan to locate the exact location.
9.1.3. Install the gas monitoring software 7304 for the control of photoacoustic gas monitors 1412 and 1314, if it is not already installed.
9.1.4. Connect the gas analyzer monitor to the data acquisition PC.
9.1.4.1. Connect the 25-pin female cable (RS-232) to the RS-232 port on the Innova 1412. Connect the 9-pin modem cable to the RS-232 cable from the Innova 1412. Connect the null modem cable into the COM 1 port of the DAC computer.
9.1.4.2. Leave sufficient extra length to the tubing and cables such that the instrument rack can be moved a few feet to get access to the back of the analyzer.
9.1.5. Connect tubing to the Innova 1412
9.1.5.1. Connect the analyzer inlet to the gas source (e.g. the GSS analyzer manifold for barn applications) with the minimum length of ¼″ OD Teflon tube.
9.1.5.2. Connect the analyzer exhaust with a 3″ length of 4-mm tube that is connected to ¼″ ID PVC or other tubing. Connect the exhaust tube from the analyzer to the air exhaust of the OFIS.
9.1.6. Power up the analyzer, turn on its internal pump, switch to measurement mode and allow the analyzer to warm up for a minimum of 60 – 90 min before analysis. This is necessary to warm up the analysis cell, as conditions within the cell tend to stabilize more quickly (allowing stable readings) once the temperature inside the analysis cell is 15°C above the ambient room temperature.
9.2. Setting up Communication Parameters between the Model 1412 and PC
9.2.1. Using the push buttons on the front of the monitor and following the operation manual, set the communication parameters for the serial interface as follows:

Baud rate	9600
Stop bits	1
Data bits	7
Parity	Even
Hardwire mode	Leased line
Handshake type	Hardwire

9.2.2. Using the push buttons on the front of the monitor and follow the operation manual, set the text line terminator, print data log and print error log as follows to prevent communication errors:

Text line Terminator	CR-LF
Print Data Log	NO
Print Error Log	NO

9.2.3. Select the PC communication port

9.2.3.1. Start any one of the gas monitoring software 7304 options: Online, Offline, or Calibration.

9.2.3.2. Pull down the Task menu. Click on Communication. The analyzer can use COM port 1 through COM port 4.

9.2.3.3. Click on the radio push-button next to the correct port name. Refer to the PC manual if not sure which port the cable is connected to. COM Port 1 is used most of the time.

9.3. Set up and start a Monitoring Task using the gas monitor software 7304, and set the instrument parameters according to Table 1.

9.3.1. Measurement parameter set-up

9.3.1.1. Pull down the Task menu. Click on New to create a new database, or click on Open to use an existing database.

9.3.1.2. For a new database, click in the "Enter Name For" field of the database window and type in a desired name. For existing databases, click on the desired database name.

9.3.1.3. Click OK.

9.3.1.4. Pull down the Sequence menu. Click on Settings and the Setup window appears.

9.3.1.5. Click on the Sampling tab.

9.3.1.6. Click on the radio-button for the desired sampling mode. If Sampling Interval is selected, set the time to the correct value.

9.3.1.7. Click on the radio-button for the desired flushing mode.

9.3.1.7.1. If Auto is selected, set the correct tube length.

9.3.1.7.2. If Fixed Time is selected, set the desired chamber flushing time and the tube flushing time (recommended value: chamber flushing time, 8 s; tube flushing time, 3 s).

9.3.1.8. If water vapor and cross interference are required, check the appropriate box.

9.3.1.9. If average values are to be displayed on the gas monitor screen, click in the Average check box, and set the interval to the correct value.

9.3.1.10. Click on the Gas tab.

9.3.1.11. Click in the check box to the left of the desired filter.

9.3.1.12. Click in the field to the right of the selected filter and select the correct gas.

9.3.1.13. Repeat the above two steps until all the filters which are required for the measurements are selected and the correct names are displayed.

9.3.1.14. Click in the Sample Integration Time field and select the desired option.

9.3.1.15. Click on the Alarm tab and check to make sure that alarms are set to default.

9.3.1.16. Click on OK to complete the system setup.

Table 1. Appropriate settings for various instrument parameters for the INNOVA Model 1412.

Instrument Parameters	
Units	
Concentration Unit:	ppm
Length Unit:	ft
Temperature Unit:	°C
Pressure Unit:	mm Hg
Humidity Unit:	Tdew
Normalization Temperature	20.0°C
Sampling Mode	
Sample Continuously	Yes
Sampling Interval (If selected)*	1 min (barns), 200 s (open-source)
Flushing	
Auto	No
Tube Length	10 ft (barns), 0.5 ft (open-source)
Fixed Time	Yes
Chamber	8 s (barns), 13 s (open-source)
Tube	3 s
Compensation	
Water Interference	Yes
Cross Interference	Yes
Gas Monitor Display	
Average	No
Time (HH:MM)	00:10
Current Air Pressure	
Pressure	Measured by Instrument
Memory Use	
Store History	Yes
Gas Setup	
Gas	S.I.T.
Ammonia	2 s
Ethanol / Methanol	1 s
Acetic Acid	2 s
Acetaldehyde	2 s
Dimethyl Sulfide	1 s
Carbon Dioxide	1 s
Methane	1 s
Phenol	2-5 s
Total VOC	1s
Alarms	
All gases are set to “Default”	No Alarms Set

* Note: If “Sampling Interval” Mode is selected, set “Sample Continuously’ to “No”.

9.3.2. Start a monitoring task
9.3.2.1. Pull down the Sequence menu and click on Start.
9.3.2.2. In the "Enter Sequence Description" field, type in the name of the monitoring sequence. If no name is entered, the default name "Sequence 1" is used.
9.3.2.3. To start the measurement immediately, click on the Now radio-button in the Start Time group.
9.3.2.4. To delay the start, click on the Start At: radio-button, and define the start time in the Start Time group.
9.3.2.5. To manually stop the measurement later, click on the None radio-button in the Stop Time group.
9.3.2.6. To automatically stop the measurement by defining a stop time, click on the Stop at: radio-button in the Stop Time group and enter the time to stop.
9.3.2.7. Press OK to start the monitoring task.
9.3.3. Stop a monitoring task
9.3.3.1. If no pre-set monitoring period is defined, pull down the Sequence menu and click on Stop.
9.3.4. Displaying measurement results while monitoring
9.3.4.1. Using the Online program, measurement data are displayed on screen as soon as they are available from the monitor. The data can be displayed in both a graphic window and a numeric window, simultaneously. Refer to the manual for detailed procedures for defining the graphic window and numeric window.
9.3.5. Displaying measurement results from a stored monitoring task
9.3.5.1. Click on the Presentation program, and pull down the Task menu. Click on Open to view an existing database.
9.3.5.2. In the database window, click on the desired database name.
9.3.5.3. Click on OK. A window opens showing all the measurement values for the complete monitoring task. Refer to the manual for detailed procedures for defining the graphic window and numeric window.
9.3.6. Export measurement data as comma-delimited ASCII files
9.3.6.1. Click on the Presentation program. Open the database to be exported.
9.3.6.2. Pull down the Task menu and click on Export.
9.3.6.3. Use the standard Windows browser, which appears on screen, to define the destination for the exported data.
9.3.6.4. Type in the desired file name. All files have a .TXT extension.
9.3.6.5. Click on Save.
9.3.6.6. Use Microsoft Excel to open and process the saved file.
9.4. Gas Analyzer Calibration
9.4.1. The exact composition for each reference calibration gas is dependent upon the gases being monitored in a given project, and the concentrations expected at the site. Calibration gas compositions for a particular project will be specified in the QAPP for that project.
9.4.2. Calibrate Innova 1412 following SOPs G8 (multipoint calibrations) and G9 (zero/precision checks).

9.4.3. Calibrate the optical filters.

9.4.3.1. Calibrate the optical filters with the following steps: zero point calibration, humidity interference calibration, span calibration of CO_2 (if that filter is in the instrument), and span calibration of any other gases after the instrument has been dried with zero air or a clean dry source of nitrogen.

9.4.3.2. Before calibrating the optical filters:

9.4.3.2.1. Warm up the monitor for a period of 60-90 min in the measurement mode before a calibration task is started to reduce the time required for calibration.

9.4.3.2.2. Detach the air inlet tube from the existing sampling manifold. Close the gas sampling manifold with a plug.

9.4.3.2.3. Obtain a print-out of calibration data in the monitor by using the "Print Current Calibration" function. This will compare the "old" calibration factors with the "new" ones.

9.4.3.2.4. Check the calibration of each installed optical filter following the procedures described in the manual.

9.4.3.2.5. Verify that the installed optical filters have been entered correctly in the active set-up of the monitor.

9.4.3.3. Basic setup for calibration

9.4.3.3.1. Set up the calibration equipment according to Fig. 2. Connect three different lengths of Teflon tubing to a "Y"-piece.

9.4.3.3.1.1. Connect the tube attached to point 1 to the analyzer's air inlet.

9.4.3.3.1.2. Connect the tube attached to point 2 to a gas flow meter.

9.4.3.3.1.3. Connect the tube attached to point 3 to the cylinder of gas which is to be used during calibration. This connection should be direct if humidity is not to be included, or through a water bath (as shown in Fig. 3) if humidity interference calibration is being conducted. If the calibration is being done for CO_2 or methane, use a Teflon tube which has been cut into two segments, and with a Nafion humidifier inserted into it using the tubing couplers provided.

9.4.3.4. Preparation for humidity interference, zero, or span calibration

9.4.3.4.1. Verify the settings of the Model 1412's communication parameters are set to the values described in Section 9.2.1.

9.4.3.4.2. Make sure the text line terminator, print data log and print error log are set to the values described in Section 9.2.2.

9.4.3.4.3. Open the "Calibration" program and create a new calibration task.

9.4.3.5. Zero gas calibration

9.4.3.5.1. Close the regulator valve on the zero gas cylinder.

9.4.3.5.2. Open the main valve on the zero gas cylinder.

9.4.3.5.3. Open the "Calibration" program and choose "New" to create a new task.

9.4.3.5.4. Type in the desired task name and click "OK".

9.4.3.5.5. Pull down the "Sequence" menu and click "Settings".

9.4.3.5.6. Click on the "Calibration" tab, if it is not already at the front. Select the "Zero point" button.

9.4.3.5.7. Click on the "Gas" tab, click in the "Sample Integration Time" field, and make sure that SIT is set to the same as that used for monitoring (Section 9.3).

9.4.3.5.8. Click on the Sampling tab and set the flushing time. The flushing type and values should be set to the same as those used when monitoring. Click OK.

9.4.3.5.9. Insert the 1/4"-OD tubing from the zero gas cylinder into the flow meter mounted on the side of the instrument rack. Open the regulator valve to allow gas flow. Adjust regulator valve until vent airflow is about 2.5 L/min. Use the flow meter to measure the flow rate.

9.4.3.5.10. Pull down the "Sequence" menu, and click "Start". Record time and analyzer display in field notes.

9.4.3.5.11. After display has stabilized (typically 10 to 15 min), pull down the "Sequence" menu and click "Stop".

9.4.3.5.12. Close regulator and remove tubing from the zero gas cylinder.

9.4.3.6. Humidity interference calibration

9.4.3.6.1. Run the Teflon tube from the zero gas cylinder into a temperature-controlled water bath. The outlet tube from the water bath should flow into a separate, empty flask, which acts as a safety trap. The outlet line from this flask then enters the "Y" connector, and is split between the flow meter and monitor. See Fig. 3 for a diagram of this setup.

9.4.3.6.1.1. The temperature of the water bath and the safety flask should be at least 2°C below the ambient temperature of the room.

9.4.3.6.2. Pull down the "Sequence" menu and click "Settings".

9.4.3.6.3. Click on the "Calibration" tab, if it is not already at the front.

9.4.3.6.4. Click to select "Humidity Calibration" radio-button.

9.4.3.6.5. Only select Humidity Interference Calibration (All Filters). Do not select Perform Water Vapor Span Calibration.

9.4.3.6.6. Click on the "Gas" tab, click in the "Sample Integration Time" field, and select the desired time (Fast 1 s).

9.4.3.6.7. Click "OK".

9.4.3.6.8. Open the regulator valve to allow gas flow through the water bath and safety flask (Do not allow any liquid into the instrument).

9.4.3.6.9. Adjust regulator valve until vent airflow is about 2.5 L/min using a flow meter to measure the flow rate.

9.4.3.6.10. Pull down the "Sequence" menu and click "Start".

9.4.3.6.11. Allow the readout to stabilize (typically 10 to 15 min). Record time and analyzer display in field notes.

9.4.3.6.12. Pull down the "Sequence" menu; click on "Stop".

9.4.3.6.13. Close regulator and main valve and remove tubing from the zero gas cylinder.

9.4.3.7. Span gas calibration of CO_2 (if applicable)

9.4.3.7.1. Pull down the "Sequence" menu, and click "Settings".

9.4.3.7.2. Click on the "Calibration" tab, if it is not already at the front. Select the "Gas Span Calibration" button.

9.4.3.7.3. Click in the "Active Filter" field, select "Carbon Dioxide", or other gas as appropriate. Check "Perform Cross Interference Calibration". Input the concentration of the analyte in the gas which is being used.

9.4.3.7.4. Click on the "Gas" tab, click in the "Sample Integration Time" field, and select the desired time (the same as that used when monitoring). Click "OK".

9.4.3.7.5. Insert the ¼″ OD tubing from the gas cylinder into the flow meter mounted on the side of the instrument rack. Open the regulator valve to allow gas flow. Adjust regulator valve until vent airflow is about 2.5 L/min, using the flow meter to measure the flow rate.

9.4.3.7.6. Pull down the "Sequence" menu, and click "Start"**.** Record time and analyzer display in field notes.

9.4.3.7.7. After the display has stabilized (typically 10 to 15 min), pull down the "Sequence" menu and click "Stop".

9.4.3.7.8. Close regulator and remove tubing from the gas cylinder.

9.4.3.8. Span gas calibration for other gases

9.4.3.8.1. Set the analyzer to measure water vapor only

9.4.3.8.2. Flow dry nitrogen or CEM zero air through the analyzer until the water vapor measurement is reading -58 to -60 for Tdew°C.

9.4.3.8.3. Pull down the "Sequence" menu, and click "Settings".

9.4.3.8.4. Click on the "Calibration" tab, if it is not already at the front. Select the "Gas Span Calibration" button.

9.4.3.8.5. Click in the "Active Filter" field, select "Ammonia", or other gas as appropriate. Check "Perform Cross Interference Calibration". Input the concentration of the analyte in the gas which is being used.

9.4.3.8.6. Click on the "Gas" tab, click in the "Sample Integration Time" field, and select the desired time (have to be the same as those used when monitoring). Click "OK".

9.4.3.8.7. Insert the ¼″ OD tubing from the gas cylinder into the flow meter mounted on the side of the instrument rack. Open the regulator valve to allow gas flow. Adjust regulator valve until vent airflow is about 2.5 L/min using a flow meter to measure the flow rate.

9.4.3.8.8. Pull down the "Sequence" menu, and click "Start"**.** Record time and analyzer display in field notes.

9.4.3.8.9. After display has stabilized (typically 10 to 15 min), pull down the "Sequence" menu and click "Stop".

9.4.3.8.10. Close regulator and remove tubing from the gas cylinder (Repeat Sections 9.4.3.7.1 through 9.4.3.7.8 for the other gases).

9.4.3.9. Calculating and downloading Calibration Factors

9.4.3.9.1. While the raw measurement data are still displayed on the screen, open the "Cursor Values" dialogue box.

9.4.3.9.2. Use two cursors and the statistical data (displayed in the Cursor Values dialogue box) to locate a suitable range of data. All values in the selected interval should be very stable, and the temperature should be above 40°C.

9.4.3.9.3. When the desired region is between the cursors, pull down the "Sequence" menu, and click on "Mark Interval".

9.4.3.9.4. Select and mark all the intervals for every calibration.

9.4.3.9.5. Pull down the "Value" menu, and click on "Calculate". When the calculation(s) is complete, a "Calculation Finished" dialogue box is displayed.

9.4.3.9.6. Pull down the "Values" menu, and click on "Download". The "Download" dialogue box is displayed.

9.4.3.9.7. Select the "Zero Point" tab, and set ticks in the appropriate check boxes, depending on which gas (and/or water vapor) calibrations were just run.
9.4.3.9.8. Repeat the above two steps in the "Humidity" and "Gas" tabs.
9.4.3.9.9. Click "OK" to download the calibration factors to the monitor.
9.4.3.10. After calibration is complete, reattach the Model 1412 to the GSS, and close the main valves on all gas cylinders.

9.4.4. Data acquisition, calculations & data reduction requirements
9.4.4.1. Report data with three significant digits.
9.4.4.2. Follow SOP B4 to correct gas concentrations for calibration and air density.

9.4.5. Computer hardware & software
9.4.5.1. Barn applications:
9.4.5.1.1. AirDAC (SOP B2)
9.4.5.1.2. AirDAC Data Pre-Processing Software (SOP B3)
9.4.5.1.3. CAPECAB (SOP B6)
9.4.5.2. Open-source applications (SOPs D1, U4, and U5/U7):
9.4.5.2.1. LabVIEW
9.4.5.2.2. LAN Server computer

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method. Supplement his electronic record with a bound record book designated for the method, which should contain copies of the electronic record.
10.2. Manage all data according to SOP B5 or SOP D1 (barn or open-source applications), as appropriate.
10.3. Document all data and information (e.g., sample collection method used) on field data sheets, and within site logbooks with permanent ink, or in electronic field notes.
10.4. Overstrike all errors in writing with a single line. Initial and date all such corrections.

11. Quality Control and Quality Assurance

11.1. Conduct gas analyzer checks according to the QAPP for the particular project. This will include zero gas and one or more reference span concentrations.
11.2. Conduct gas analyzer calibration when the precision check is >±10% of baseline, unless the QAPP for the particular project specifies a different value.
11.3. Conduct gas analyzer calibration when the zero check is >±5% of full scale different than the baseline, unless the QAPP for the particular project specifies a different value.
11.4. The calibration gas should be certified using EPA protocol (1% certification), if this grade is available, unless the QAPP for the particular project specifies a different value.
11.5. Check the response time every six months, unless the QAPP for the particular project specifies a different value.
11.6. Measure the gas analyzer's inlet flow rate every six months.
11.7. Perform leak check in sample line and flow components and fittings every six months by measuring the inlet and exhaust flow rates with a flow meter.

11.8. Change the fine air-filter paper in the internal and external air-filtration units monthly. For analyzers that have the stainless steel 10 μm frit for the internal filter, clean the frit monthly. After cleaning or replacing filters, perform a leak check at the inlet sample port and the exhaust port by measuring the inlet and exhaust flow rates with a flow meter, to ensure that no leaks were introduced.
11.9. Clean the filter in the ventilation unit monthly.
11.10. Record any maintenance in the Instrument Performance Record File's worksheet labeled maintenance.

12. References

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12.3. Innova AirTech Instruments. 2000. Detection Limits Wall Chart. Online at www.innova.dk/uploads/media/Wall_Chart_PW_01.pdf. Accessed 2/15/2006.
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12.6. SOP B2. 2006. Data Acquisition and Control Software (AirDAC). Standard Operating Procedure B2. Purdue Ag Air Quality Lab.
12.7. SOP B3. 2006. Air Data Pre-Processing Software. Standard Operating Procedure B3. Purdue Ag Air Quality Lab.
12.8. SOP B4. 2006. Calculation and Reporting of Air Emissions from Barns. Standard Operating Procedure B4. Purdue Ag Air Quality Lab.
12.9. SOP B5. 2006. Data Management for Barns. Standard Operating Procedure B5. Purdue Ag Air Quality Lab.
12.10. SOP B6. 2006. Data Processing Software (CAPECAB). Standard Operating Procedure B6. Purdue Ag Air Quality Lab.
12.11. SOP D1. 2006. Management of Open-source, Weather, and Lagoon-characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.
12.12. SOP G8. 2006. General Calibration of Gas Analyzers. Standard Operating Procedure G8. Purdue Ag Air Quality Lab.
12.13. SOP G9. 2006. Zero and Precision Checks of Gas Analyzers. Standard Operating Procedure G9. Purdue Ag Air Quality Lab.

12.14. SOP U5. 2006. The Installation of Open-source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.
12.15. SOP U7. 2006. The Instrument Trailer and Installation of Open-source Measurement Equipment (Corrals). Standard Operating Procedure U7. Purdue Applied Meteorology Lab.

13. Contact Information

13.1. Distributor:
California Analytical Instruments
Tel: (714) 974-5560
Email: info@gasanalyzers.com

13.2. Manufacturer:
Innova AirTech Instruments (www.innova.dk)
Energivej 30, DK-2750 Ballerup, Denmark
Tel.: (+45) 44 20 0100, Fax: (+45) 44 20 0101, innova@innova.dk

13.3. PAAQL: odor@purdue.edu, heber@purdue.edu, http://www.AgAirQuality.com.

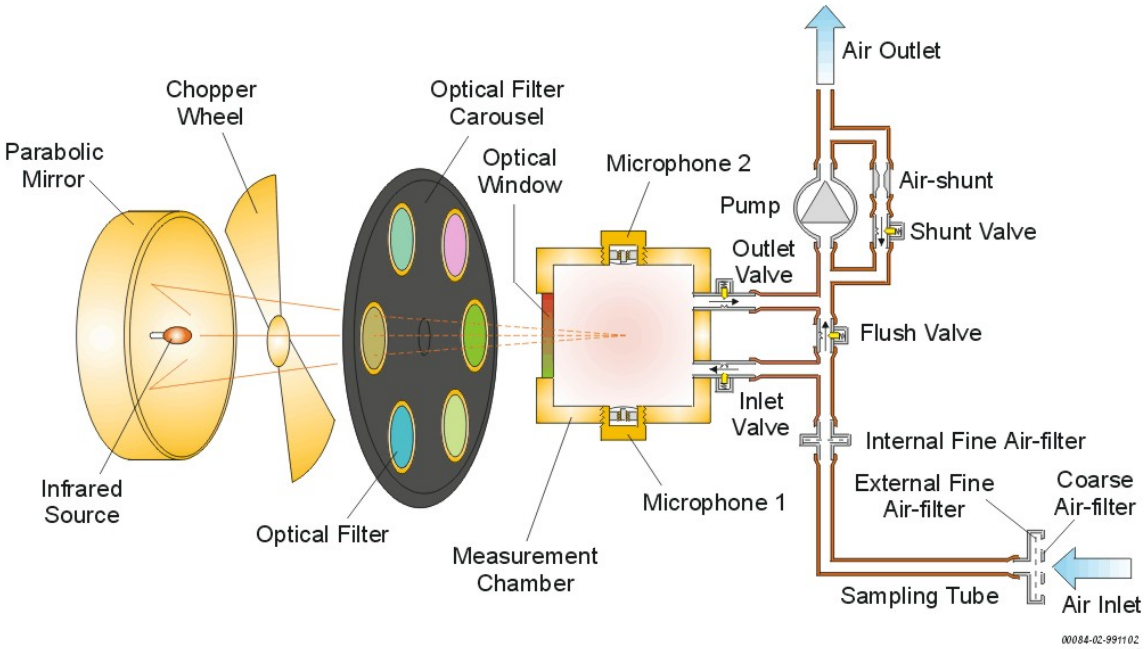

Figure 1. Schematic diagram of the major internal components of the INNOVA Model 1412 Photoacoustic Multi-gas Monitor.

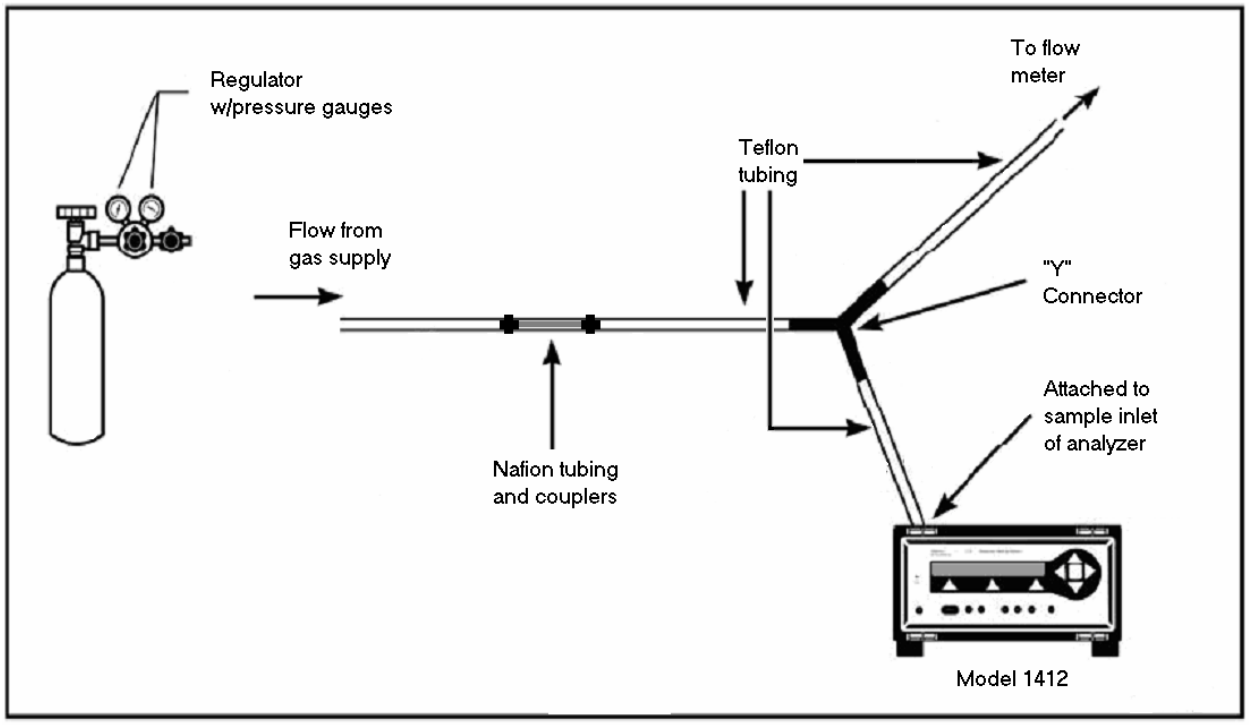

Figure 2. General equipment required for calibration of the Model 1412. Nafion tubing is coupled into the Teflon line from the cylinder during calibration of CO_2 or methane.

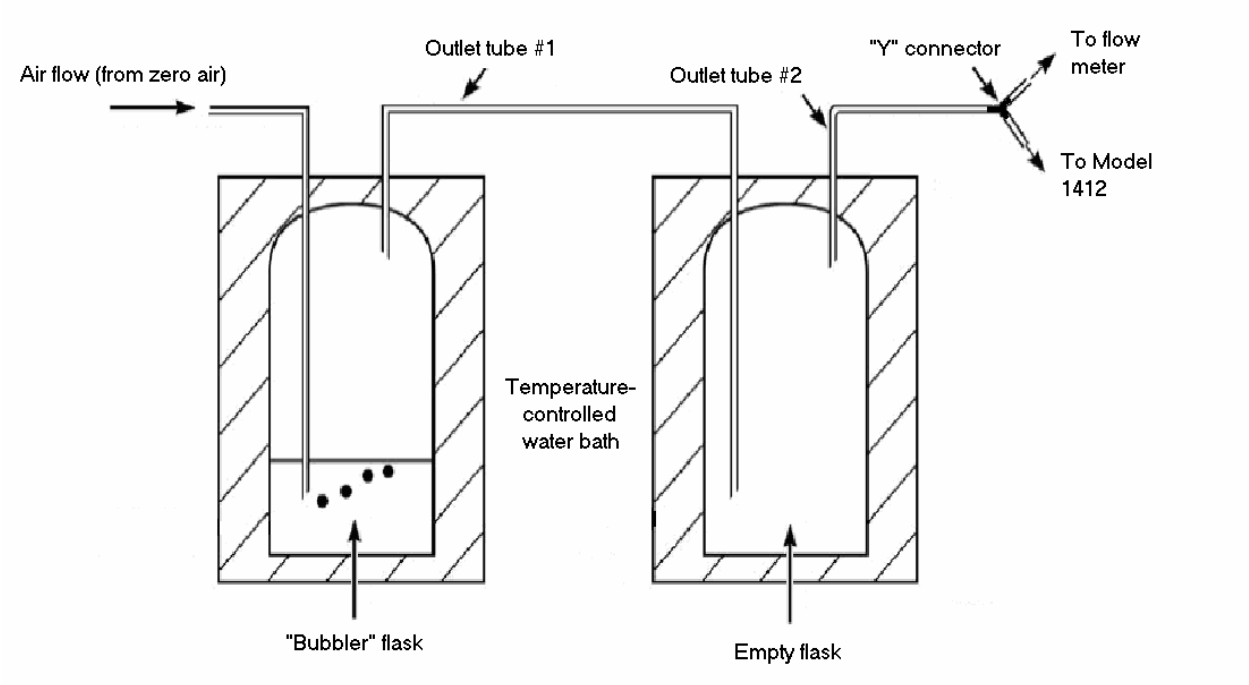

Figure 3. Schematic diagram of the equipment necessary to produce a supply of clean, wet air for humidity interference calibration.

OPERATION OF THE ENVIRONICS® COMPUTERIZED GAS DILUTION SYSTEM

Standard Operating Procedure (SOP) G11

OPERATION OF THE ENVIRONICS® COMPUTERIZED GAS DILUTION SYSTEM

Standard Operating Procedure (SOP) G11

Prepared by
Sam M. Hanni and Juan Carlos Ramirez

Reviewed by
Congna Li, Bill W. Bogan, and Albert J. Heber

Effective Date: December 28, 2007

PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)
Agricultural and Biological Engineering, Purdue University
West Lafayette, IN 47907

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1. Scope and Applicability

1.1. This method dilutes a compressed gas standard with a balance gas, allowing the resulting mixture to be used for calibrating the continuous gas analyzers which are used in monitoring barn emissions.

1.2. This method applies only to the Environics Series 4040 Computerized Gas Dilution System and its accompanying computer software.

1.2.1. The maximum flow rate of the gas mixture is 5 L/min.

1.2.2. The gas standard is diluted to concentrations that range from 10 to 99% of its original concentration.

1.2.3. The minimum concentration can be reduced to 1% of the original with the addition of one mass flow controller (MFC).

1.2.4. The minimum concentration can be reduced to 0.1% of the original with the addition of two MFCs.

1.2.5. The accuracy of each MFC is ±1% of its set flow rate.

1.2.6. The accuracy of the overall dilution ratio is an additive function of the errors of all MFCs involved in the dilution. For example, if two MFCs are used, the maximal error (if the individual errors of the two MFCs are in the same direction) is ±2%. If the errors of the individual MFCs are in the opposite directions, the overall dilution ratio error will be considerably lower than this.

1.2.7. The dilutor can be programmed to automatically deliver diluted standards on a schedule.

1.2.8. The diluter described and used in this SOP has all its gas-accessible internal surfaces passivated with a non-reactive (RESTEK) coating, which makes it suitable for use with reactive gases.

2. Summary of Method

The Environics® Series 4040 is a computerized gas dilution system that automatically generates precise gas calibration standards for single or multi-point calibration of analyzers. The system consists of two components: the Series 4040 Diluter and the user's PC. The user interface is a Microsoft® Windows application that communicates with the Environics system via a RS232 serial interface connected to any available COM port of the personal computer. The Series 4040 instrument has a single chassis supporting up to four mass flow controllers (MFC) having ranges of 5, 5, 0.5, and 0.05 L/min, respectively. This set of flow controllers allows accurate dilution of gas standards over a very wide range of dilution ratios, by selection of the appropriate flow controllers. The MFCs are factory-calibrated using a primary flow standard traceable to the National Institute of Standards and Technology (NIST). Each flow controller utilizes an 11-point calibration table with linear interpolation, to increase accuracy and reduce flow controller nonlinearity. During operation, the protocol gas concentration, inlet port, desired output concentration, and desired output flow rate are entered by means of the keypad of the personal computer used to operate the 4040 diluter, and the diluter then sets the required standard and diluents flow rates to produce the desired mixture. The 4040 diluter indicates on the computer’s display the actual concentration being produced, which in some cases differs very slightly from the nominal concentration requested. In all cases the actual

concentration produced is recorded as the concentration provided to the analyzers undergoing testing. To calibrate this instrument, it is necessary to choose a pre-calibrated gas analyzer to test the concentrations produced by the diluter.

3. Definitions

3.1.	FTIR	Fourier transform infrared spectroscopy
3.2.	GC/MS	Gas chromatography/mass spectrometry
3.3.	GSS	Gas sampling system
3.4.	K-factor	Gas correction factor
3.5.	MFC	Mass flow controller
3.6.	NIST	National Institute of Standards and Technology
3.7.	OGC	Output gas concentration
3.8.	PC	Personal computer
3.9.	QAPP	Quality Assurance Project Plan

4. Health and Safety

4.1. Avoid mixing gases that may produce an explosion or other hazardous reaction. Follow all other health and safety precautions related to gas cylinders (SOP G2).
4.2. Disconnect power before servicing the unit.
4.3. Make sure that replacement fuses are the correct size and rating (115 V).
4.4. Use only grounded outlet electrical outlets.

5. Cautions

5.1. Verify that scheduled calibration date is prior to the expiration date of the standard gas.
5.2. Verify that the instrument ambient temperature conditions are in the manufacturer's recommended range of 0°C to 50°C.
5.3. If the Environics software is not connected to the LabView (AirDAC) data acquisition software (SOP B2), adjust its time to agree with the time of the LabView computer.
5.4. Note all other cautions related to gas cylinders (SOP G2).
5.5. In any case where the Model 4040 is not under the control of the AirDAC program, make sure that the computer clock (used by the Environics system) is synchronized with the time in AirDAC. If the times are not synchronized, any task programmed on the Environics dilutor could be out of phase with other tasks controlled by the AirDAC program.
5.6. Use of any USB adapter other than the one described in Section 8.3 may cause communications problems between the PC and diluter. If such problems are suspected with a different adapter, replace with this one as a first measure.

6. Interferences

6.1. Do not operate the diluter at a flow lower than 10% of the working range of the flow controller selected (this instrument has four flow controllers for different working

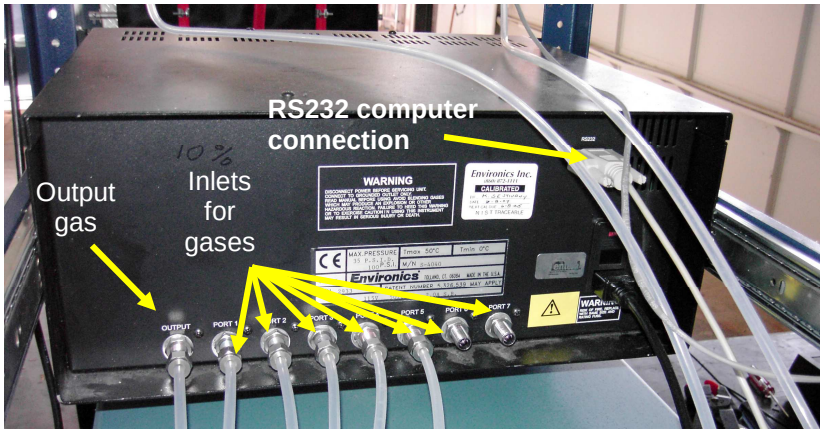
ranges), which is a flow region where flow control errors might be enhanced. The 4040 diluter provide warnings if a flow controller is being operated at this low range. Switching to another flow controller, if available, will minimize these uncertainties.

7. Personnel Qualifications

7.1. Each operator must read and understand this SOP, SOP G2, and the instrument manual before working with the instrument.

8. Equipment and Supplies

a)



b)

Figure 1. Front (a) and back (b) of the Environics Model 4040 Gas Diluter.

8.1. Environics Series 4040 Gas Dilution System
8.2. PC. Minimum recommended: 66-MHz 486 PC with 8 MB of RAM.
8.2.1. Operating system: Windows 3.1 or newer (including Windows 95/98/Me and Windows NT/2000/XP).

8.3. Communications cable/adapter: USB to Serial adapter DB9m, G-uc232a, Cyberguys.com.
8.4. Mass flow meter
8.5. Teflon tubing
8.6. 9/16″ box wrench

9. Procedure

9.1. Instrument setup
9.1.1. Hardware setup
9.1.1.1. Connect the diluter to the computer via an RS232 cable. Connect the cable to one of the COM ports (1-4) on the computer. COM 1 is the system's default port.
9.1.2. Software installation
9.1.2.1. Close all running window applications.
9.1.2.2. Install the Environics Series 4000 Software from the CD included with the instrument.
9.1.2.3. To start the software, double-click the Environics Series 4000 icon or select Environics Series 4000 from the START menu.
9.1.3. Data disk installation
9.1.3.1. Instrument Data Disk Installation installs instrument specific information into the Environics Instrument Data base.
9.1.3.2. Start the Environics Series 4000 Software.
9.1.3.3. From the Main Menu, select Configure – Instrument – Install.
9.1.3.4. Insert the Instrument Data Disk in the appropriate floppy disk drive.
9.1.3.5. When the Install Instrument box appears, select the appropriate Drive Icon (A or B) from the pull down box and click OK.
9.1.3.6. The instrument is now ready to use.
9.1.4. Creating desktop
9.1.4.1. From the Environics Series 4000 main window select File and then New.
9.1.4.2. In the DESKTOP box, enter a name for the Desktop.
9.1.4.3. In the INSTRUMENT box, click the drop down arrow to display the list of available instruments and select the serial number of the instrument you are using.
9.1.4.4. Click OK to save the new file.
9.1.5. Cylinder Configuration
9.1.5.1. Open Series 4000 main window click on Configure and then Cylinder to open the cylinder library. This will bring up the Cylinder Library form (Fig. 2).
9.1.5.2. Click Add and enter a name for the new cylinder at the prompt. The name of the cylinder will usually be the name of the gas of interest in the cylinder.
9.1.5.3. Click the OK button. This name will appear in the Name box.
9.1.5.4. K-Factor should be set to automatic.
9.1.5.5. Creation Date should be the current date.
9.1.5.6. If there is no expiration date on the cylinder then click on the box next to No Expiration Date. If there is an expiration date then unclick the box next to No Expiration Date and enter in the expiration date on the cylinder.
9.1.5.7. Type the cylinder serial number in the Information box.

9.1.5.8. Enter contents of the cylinder beginning with the balance gas. Using the pull-down box under Gas Name or Symbol in the Contents section, select the desired balance gas. The concentration will be automatically set at 1 million ppm.

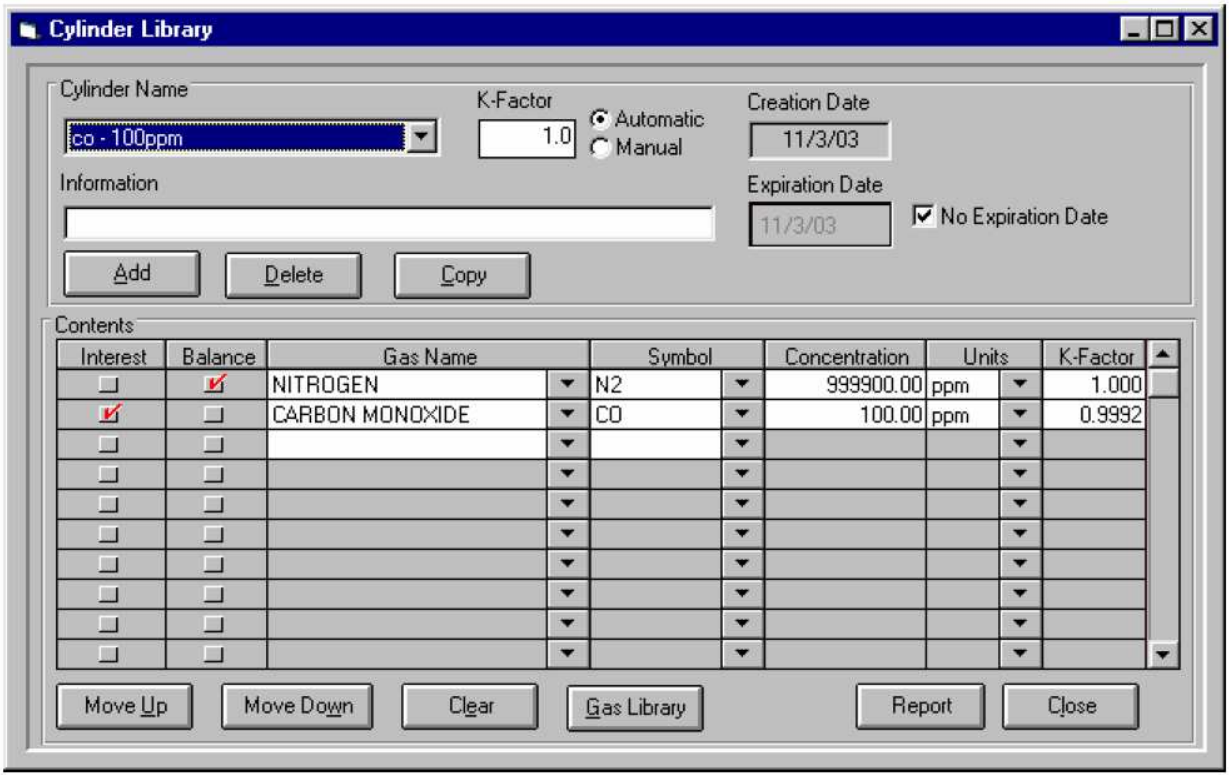


Figure 2. The Cylinder Library Screen.

9.1.5.9. Continue adding the remaining component gases by selecting them from the Gas Name or Symbol pull down box.

9.1.5.10. Select default gas of interest by clicking the Interest box next to the desired gas.

9.1.5.11. Once all gases have been added, enter the concentration of each component gas under the concentration box. The units can be changed from ppm to % using the pull down box under units. The concentration of each gas and the unit of gas will be identified on the side of the cylinder. If the gas is read in ppb then will need to be converted to ppm. The balance gas concentration will automatically be filled in as the difference so that all gases add up to 1 million ppm (100%).

9.1.5.12. As data is entered, the cylinder K-factor will automatically be computed based on the concentration of the individual gases in the cylinder.

9.1.5.13. When done, click Close to save the cylinder information and exit the Cylinder Library. The Program will display a prompt to allow the new cylinder to be saved. Click the Yes button to save.

9.1.5.14. Alternately, click Add to add a new cylinder without exiting the Cylinder Library.

9.1.6. Editing cylinder gas information

9.1.6.1. To move or delete a gas, click the name of the gas. The name box will turn red.

9.1.6.2. To move a gas, click on the Move Up or Move Down button to move the gas down one position on the list. Continue to click on the Move Down button until the gas is in the desired location on the list.

9.1.6.3. To delete the selected gas from the cylinder, click the Clear button.

9.1.7. Port configuration

9.1.7.1. To open the Port Configuration screen, select Configure – Port from the main menu. The desktop must be open to change the port configuration. If a desktop is not open, then Configure – Port will not be accessible.

9.1.7.2. The current cylinder assignments for the port configuration are displayed in the port configuration assignment table (Fig. 3). To assign a different cylinder to the port, uses the pull down box under cylinder, and select the desired cylinder from those listed in the cylinder library.

9.1.7.3. Once the cylinder is assigned, the default gas, symbol, concentration, and K-factor are automatically placed in the table from the cylinder library. It cannot be edited within the port configuration table. To edit this information, click on Cylinder Library and edit from within the library.

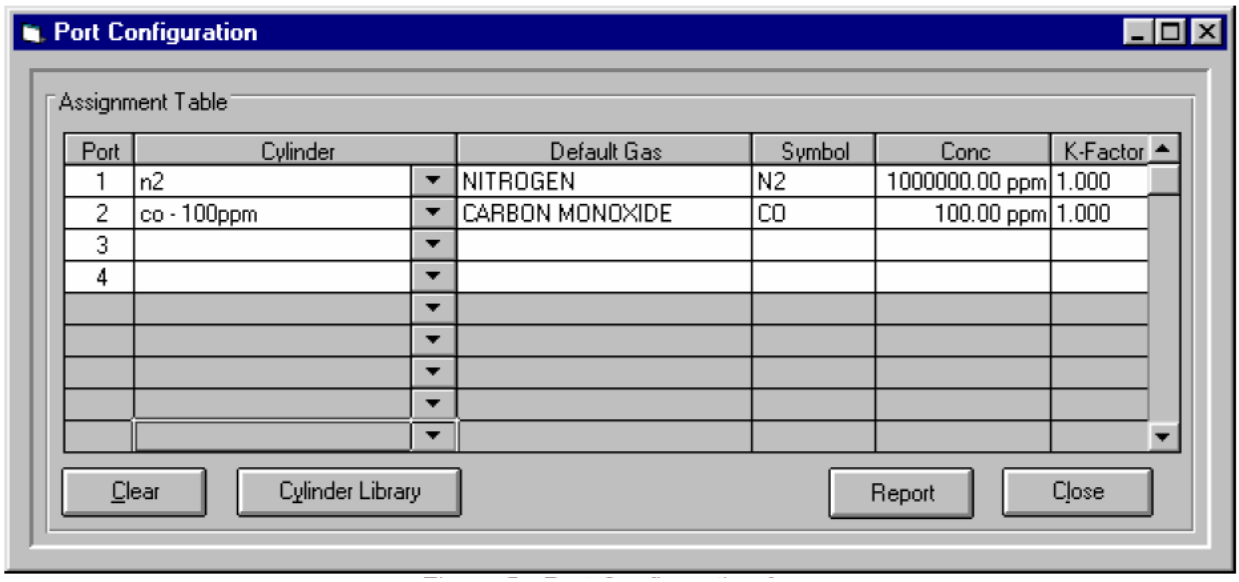


Figure 3. The Port Configuration Table.

9.1.7.4. 9.1.7.4. To save the cylinder/port assignments, click on Close, then click YES.

9.1.7.5. Using ¼″ Teflon tubing with a Gyrolok fittings provided with the instrument connect one end of the tubing to the Environics configured port and, with a Swagelok fitting connect the other end of the Teflon tubing to the regulator on the desired cylinder.

9.1.7.6. To remove cylinders from a port, select the cylinder by clicking on the cylinder name in the assignment table, and click the Clear button to remove the cylinder from the port configuration table.

9.2. Operating the instrument

9.2.1. Concentration Mode

9.2.1.1. To open the Concentration Mode (Fig. 4) screen, select Run – Concentration from the Series 4000 main window.

9.2.1.2. To add a Concentration Mode file click on Add.

9.2.1.3. Enter the file name and click OK.

9.2.1.4. A blank Concentration Mode table will appear.

9.2.1.5. Specify each desired source cylinder by using the pull down box in the concentration table under Cylinder. Select the cylinder by clicking on it. The port is automatically selected based on the current cylinder/port assignments. The port number is displayed in the Port box.

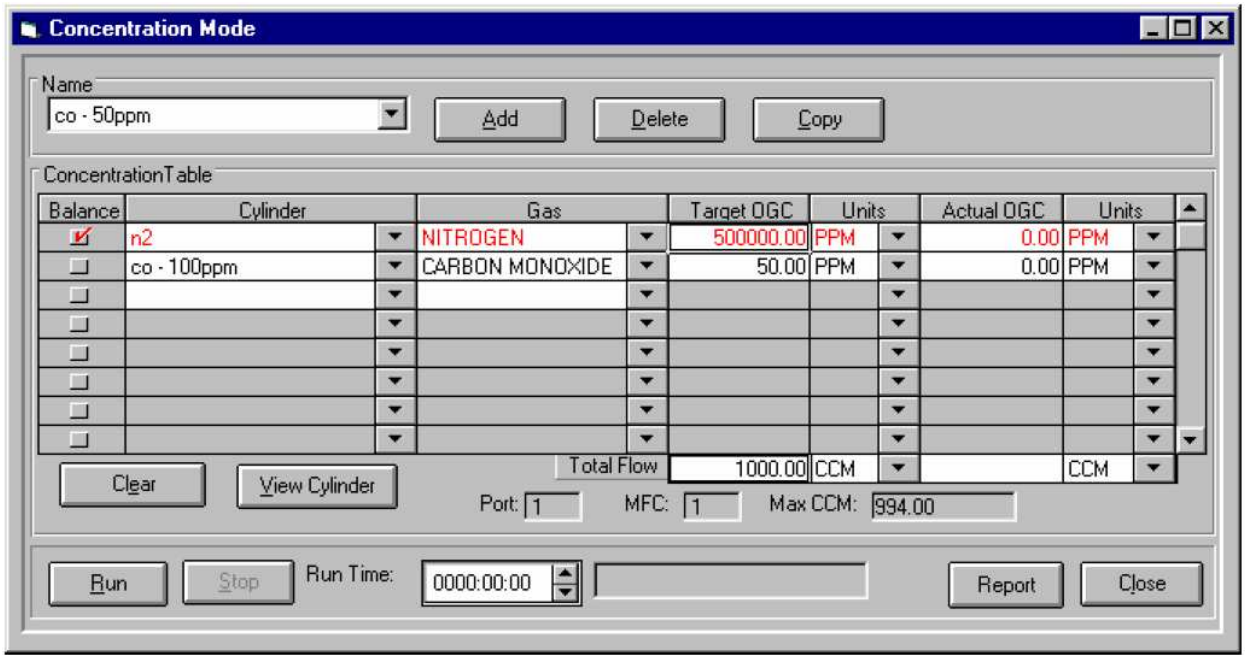


Figure 4. The Concentration Mode Screen.

9.2.1.6. Next, specify the gas of interest by using the pull down box under Gas next to the cylinder name. Select the component gas of interest by clicking on it. To see the contents of the cylinder, click on View Cylinder.

9.2.1.7. Once all of the cylinders are entered, select the balance gas by clicking the balance box beside the cylinder name.

9.2.1.8. Specify the desired output concentration for each cylinder. Type the value in the Target Output Gas Concentration (OGC) box. If desired, the units can be changed between ppm and % by using the pull down box under units.

9.2.1.9. Finally, enter the total flow by typing in its value. The units can be changed from ccm to L/min by using the pull down menu under units. The value entered is used by the system to compute the target concentration of the balance gas and the required flow of each controller.

9.2.2. Program Mode

9.2.2.1. To open the Program Mode screen (Fig. 5), select Run – Program from the Series 4000 main window.

9.2.2.2. To add a Program Mode file click on Add.

9.2.2.3. Click the Mode pull down box in the row of the desired step. Select the desired run mode which will be Conc.

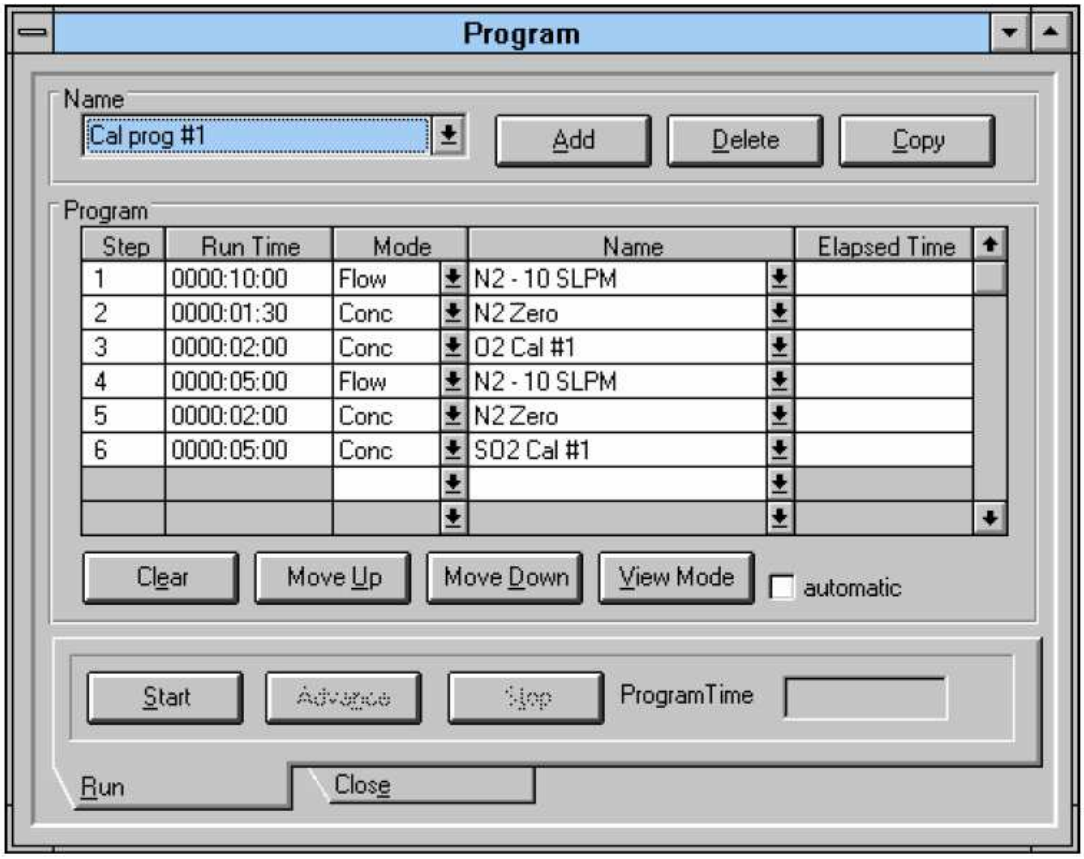


Figure 5. The Program Mode Screen.

9.2.2.4. The available saved mode names will appear in the Name box. Open the pull down box under Name; select the desired run mode file.

9.2.2.5. Click in the Run Time box to set the run time for the mode (HH:MM:SS).

9.2.2.6. Repeat until all desired steps have been entered.

9.2.2.7. Press the Start button to begin the current program. While the program is running, the Elapsed Time box indicates the elapsed time for the current step. In addition, the Program Time box indicates the total elapsed time.

9.2.2.8. To abort the current step and proceed to the next, press the Advance button.

9.2.2.9. To stop the program before completion, click the Stop button.

9.2.3. Schedule Mode

9.2.3.1. To open the Schedule Mode screen (Fig. 6), select Run – Schedule from the Series 4000 main window.

9.2.3.2. Click Add, enter a name for the file and click OK.

9.2.3.3. A blank Schedule Mode table will appear. Fill in the table with the desired values.

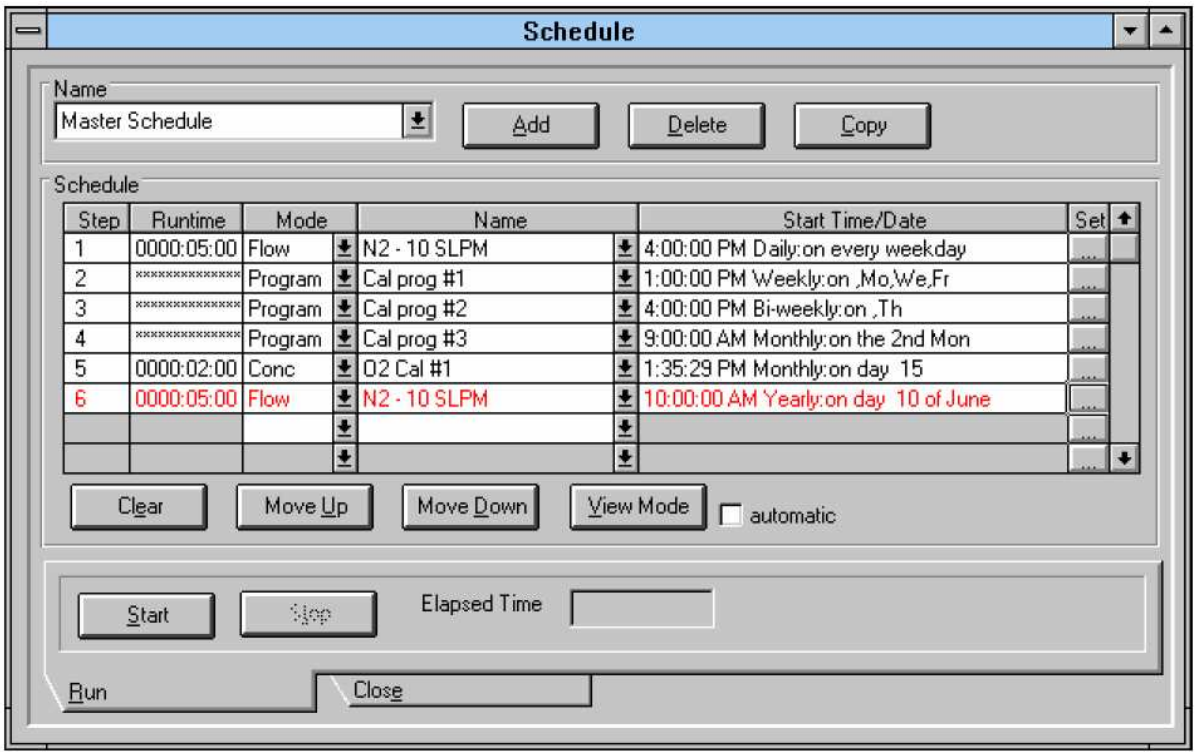


Figure 6. The Schedule Mode Screen.

9.2.3.4. Click the Mode pull down box in the row of the desired step. Select the desired run mode which will be Conc.

9.2.3.5. The available saved mode names will appear in the Name box. Open the pull down box under Name; select the desired run mode file.

9.2.3.6. Click in the Run Time box to set the run time for the mode (HH:MM:SS).

9.2.3.7. Click the SET button to set the time/date for this item. This will bring up the Time/Date editor (Fig. 7).

9.2.3.7.1. Select the type of event using the buttons on the left side of the screen. For an item that occurs only once, click the Specific Date button. For a repeating (Daily, Weekly, etc.) event, click the button for the desired frequency.

9.2.3.7.2. For a repeating event, fill out the appropriate options at the bottom of the screen. The options displayed will vary, depending on the type of repeat chosen. If an item is repeated weekly or biweekly, select the day(s) of the week that it is to be run by clicking in the appropriate square(s). For items repeated monthly, select the day of the month on which to repeat the item (such as every first of the month or every third Monday). For items repeated yearly, select the day and month on which to repeat the item (such as every January 1 or every third Monday in May).

9.2.3.7.3. Enter the desired start time, by clicking on the Start Time box and typing in the time, or by clicking the up/down arrows.

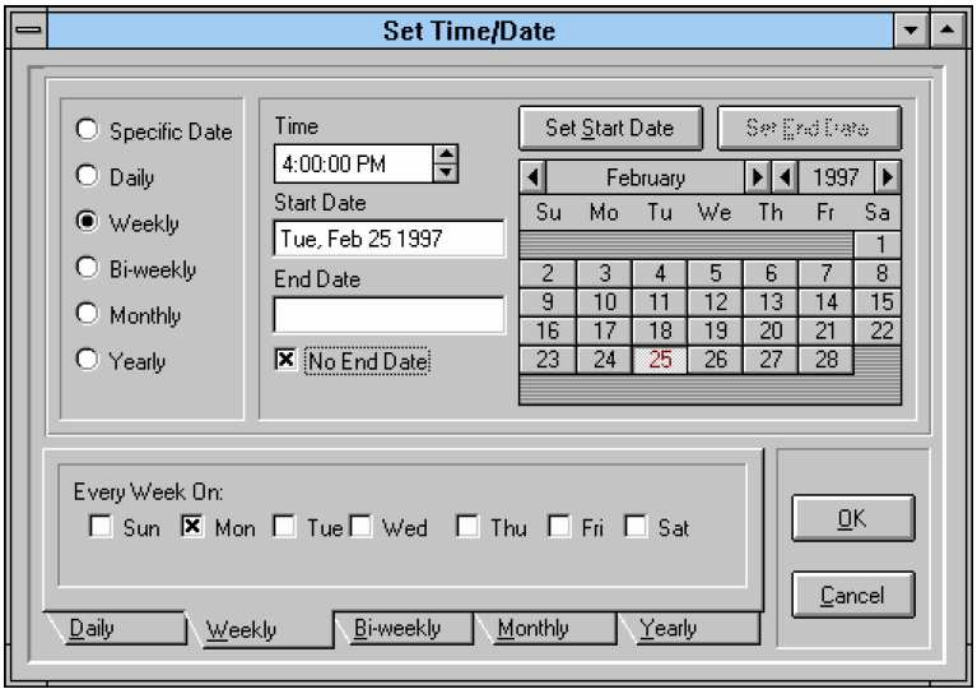


Figure 7. The Time/Date Editor within Schedule Mode.

9.2.3.7.4. Select the desired start date from the calendar by clicking on the day and then clicking the SET START DATE button. Use the left/right buttons to change the month or year. For a Specific Date event, this is the date the item will be run. For repeating events, it is the date the event will start to repeat.

9.2.3.7.5. For repeating events, select the desired end date from the calendar by clicking on the day and then clicking the SET END DATE button. This allows the repeating event to occur within a specific range of dates. Alternately, if this item is to be repeated indefinitely, click the NO END DATE box. End Date is not used for a Specific Date event.

9.3. 9.3. Generating reports

9.3.1. From the Main Menu, select Report and then the desired report type, or click the Report button directly from the Configure/Run Mode that is currently in use.

9.3.2. In the Reports dialog box (Fig. 8), click the Select Report dropdown box to select the desired report type. The types of available reports are given in Table 1.

9.3.3. Select the desired "Create Report For" and "Selection" options desired.

9.3.3.1. To limit the report to a specific item, click the "Current desktop, selection only" option, and select the desired item in the "Selection" box.

9.3.3.2. To limit the report to all items in the current desktop, click the "Current desktop, all items" option. The item shown in the "Selection" box is ignored.

9.3.3.3. To report on all items in all desktops, click the "All items" option. The item shown in the "Selection" box is ignored.

Figure 8. The Reports dialog box.

Table 1. Available report formats in the Environics software.

Gas Library	Lists all gases in the gas library
Cylinder Library	Shows cylinder name(s) and parameters (compositions and concentrations), for one or all cylinders
Cylinder Audit	Gives names, creation and expiration dates, and days until expiration for all cylinders
Physical Configuration	Gives configuration details for the MFCs, ports, and solenoids in the instrument
Instrument Calibration	Gives calibration tables for the MFC
Port Configuration	Gives cylinder assignments (name, gas and concentration) currently made to each port
Concentration Mode	Details one or more Concentration Mode files (cylinders, gas concentrations, total flow rate)
Programs	Details one or more Program Mode files
Schedules	Details one or more Schedule Mode files

9.3.4. Click Print to view the report on the screen. A sample Program Mode report is shown in Fig. 9.
9.3.5. Print the report and store it according to SOP B5.
9.3.6. Click the arrow buttons to move between pages. Click the Magnifying Glass Icon to change the view size.
9.3.7. Click the Printer icon to send the report to the printer.

9.3.8. When finished, click the Close button to return to the Reports menu.
9.3.9. Repeat Sections 9.6.2 through 9.6.8 to generate additional reports.
9.3.10. When done, click Close to return to the Main Menu.

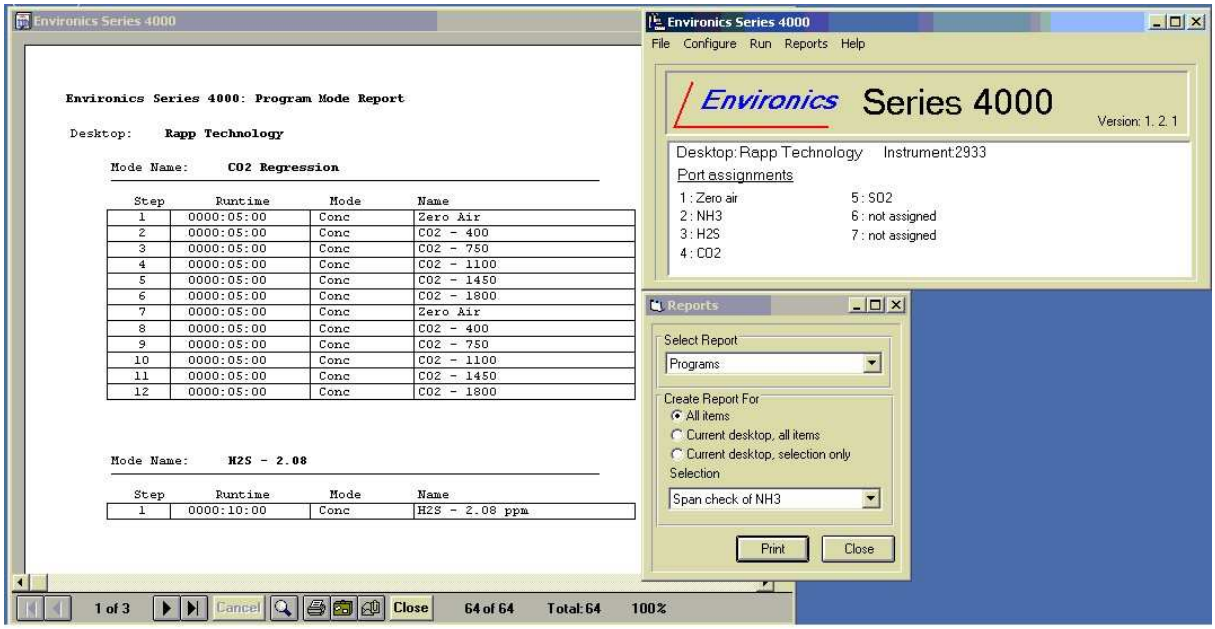


Figure 9. Screen capture showing a sample Program Mode report.

9.4. Troubleshooting
9.4.1. Perform the steps in Section 9.1.3 if a "no instruments registered" warning appears.
9.4.2. When opening a desktop, the software will try to communicate with the assigned instrument. If it is unable to communicate, a warning message will be displayed. There are two possible reasons for this:
9.4.2.1. The desktop's assigned serial number does not match the instrument being used.
9.4.2.2. The selected PC serial port on the Environics software might be configured to a COM different from the actual COM that is connected to the PC.
9.4.3. The only available cylinders listed are those assigned to ports. If the desired cylinder is not listed, modify the port settings.
9.4.4. The Program Mode cannot be set up unless either the Concentration, Flow, or Divider mode is set up.
9.5. Computer hardware & software
9.5.1. Store all applicable software in the data acquisition computer.
9.5.2. The dilutor can be controlled by, and input data to, the AirDAC program (SOP B2).

10. Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method. Supplement this electronic record by a bound record book designated for the method, which should contain copies of the electronic record.

10.2. Manage all data according to SOP B5.
10.3. Document all data and information (e.g., sample collection method used) on field data sheets, and within site logbooks with permanent ink, or in electronic field notes.
10.4. Overstrike all errors in writing with a single line. Initial and date all such corrections.

11. Quality Control and Quality Assurance

11.1. Flow Calibration (Initial)
11.1.1. Mass flow controller zero check
11.1.1.1. Some MFCs require the cover to be removed to make adjustments
11.1.1.2. Connect the (-) lead from a voltmeter to PC402 GROUND (TP2).
11.1.1.3. Connect the (+) lead to each MFC Response Test Point: MFC1 (TP9), MFC2 (TP11), MFC3 (TP13), and MFC4 (TP15).
11.1.1.4. Verify that the voltage at each test point is 0 V ±.025 V for a Tylan MFC and 0.01 V ±0.005 V for a Hastings MFC. If the "zero" is out of spec, adjust the MFC “zero” pot to bring it within these specified ranges.
11.1.1.5. After adjusting the “zero” pot, replace system cover.
11.1.1.6. After "zero" adjustment, wait at least one hour (1 h) for temperature to stabilize before proceeding to MFC calibration (Section 11.1.2).
11.1.2. Mass flow controller calibration
11.1.2.1. Connect calibration gas to the appropriate input ports for the MFCs being calibrated. The input pressure should be approximately 25 psig.
11.1.2.2. Connect a primary standard flow calibration device to the output of the system.
11.1.2.3. Be sure the instrument is connected to the PC and powered up.
11.1.2.4. Run the Environics Series 4000 software.
11.1.2.5. From the menu screen, select Configure.
11.1.2.6. Select Instrument.
11.1.2.7. Select Calibrate.
11.1.2.8. In the Reference Gas box, click the down arrow button and set this to match the calibration gas for that MFC.
11.1.2.9. In the Controller Instrument box, click the down arrow button, and select the serial number of the instrument to be calibrated.
11.1.2.10. In the MFC box, click the down arrow button, and select the desired Mass Flow Controller to enter data (start with MFC 1).
11.1.2.10.1. If the MFC has been changed, select Init Points, enter appropriate size in Max Flow, Table will initialize.
11.1.2.11. Click on the 100% calibration point and press Start. Wait at least 10 min for flow to stabilize before continuing.
11.1.2.12. Using a mass flow meter, take a flow measurement. Measured flow value must be between 100% and 110% of the MFCs rated full-scale flow. If flow value is out of this range, adjust the MFC “span” pot.
11.1.2.12.1. Some MFCs require the cover to be removed to make adjustments. In this case, after performing “span” adjustment, replace MFC cover. After adjusting “span” pot, replace system cover and wait at least 1 h for temperature to stabilize before continuing.

11.1.2.13. If measured flow value is acceptable, enter the measured value in the True Flow column. If not, repeat Step 9.3.11.
11.1.2.14. Click on the next calibration point, and press the Start button. Wait at least 2 min for flow to stabilize before continuing.
11.1.2.15. Take a flow measurement, and enter the value in the True Flow column.
11.1.2.16. Repeat Steps 9.3.14 to 9.3.15 until all calibration points have been completed.
11.1.2.17. Press Stop, then press Save to save the MFC calibration data. This will download the new calibration files to the instrument.
11.1.2.17.1. If a warning appears "CAL TABLE ERROR -3", click OK, then save again before exiting.
11.1.2.18. Repeat steps 9.3.10-9.3.17 until all MFCs have been calibrated.
11.1.2.19. Click Close to return to the main menu screen.

11.2. Flow Calibration (Periodic)

11.2.1. The FRM 205 recommends that the gas dilution system shall be recalibrated once per calendar year using NIST-traceable primary flow standards with an uncertainty of ≤ 0.25%. The QAPP may specify a more frequent calibration schedule. The manufacturer will conduct this recalibration.
11.2.2. Keep a label (Fig. 10) affixed at all times to the gas dilution system listing the date of the most recent calibration, and the due date for the next calibration.

Calibration date:_____
Next calibration due date:_____

Figure 10. Sample calibration label.

11.2.3. Before sending a unit to the manufacturer for re-calibration, record the existing (as-found) flow rate (if this is not automatically recorded by AirDAC), and the resultant dilution ratio based on that flow rate.

11.3. At each use of the Model 4040, document its delivered flow rate to ensure that it is at least 0.5 L/min higher than the GSS flow rate (SOP G1).
11.4. In any case where the Model 4040 is not under the control of the AirDAC program, make sure that the computer clock (used by the Environics system) is synchronized with the time in AirDAC.

12. References

12.1. Environics Model 4040 Manual. 2003. Series 4000/4040 Gas Mixing System/Gas Dilution System. Environics, Inc, Tolland, CT.
12.2. Environics Inc. 2003. Computerized Gas Dilution System Series 4040, Online at http://www.environics.com/4040.html. Accessed 10 January 2006.
12.3. SOP B2. 2006. Data Acquisition and Control Software (AirDAC) Standard Operating Procedure B2. Purdue Ag Air Quality Lab.
12.4. SOP B5. 2006. Data Management for Barns. Standard Operating Procedure B5. Purdue

Ag Air Quality Lab.
12.5. SOP G1. 2006. The PAAQL Gas Sampling System. Standard Operating Procedure G1. Purdue Ag Air Quality Lab.
12.6. SOP G2. 2006. Compressed Gas Cylinders. Standard Operating Procedure G2. Purdue Ag Air Quality Lab.
12.7. SOP G12. 2006. FTIR Verification of Gas Cylinder Concentration. Standard Operating Procedure G12. Purdue Ag Air Quality Lab.
12.8. SOP V6. 2006. GC/MS Analysis of VOCs Collected in Sampling Canisters. Standard Operating Procedure V6. Purdue Ag Air Quality Lab.
12.9. SOP V7. 2006. Cleaning, Certification and Pre-sampling Preparation of Sampling Canisters. Standard Operating Procedure V7. Purdue Ag Air Quality Lab.

13. Contact Information

13.1. Manufacturer:

Environics, Inc.
69 Industrial Park Road East
Tolland, CT 06084-2805
Phone: (860) 872-1111
Fax: (860) 870-9333
E-mail: info@environics.com
Web Page: http://www.environics.com

FTIR VERIFICATION OF GAS CYLINDER CONCENTRATION

Standard Operating Procedure (SOP) G12

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Prepared by

Congna Li

Reviewed by

Bill W. Bogan, Jacek A. Koziel (Iowa State Univ.), and Albert J. Heber

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PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. A method is needed which will accurately analyze the concentrations of certified standard gases in cylinders purchased from outside vendors. Such a method is needed to ensure that the gas cylinders which are used for calibrations and/or performance checks of gas analyzers and other analytical instruments do, in fact, contain gases at their stated concentrations.

1.2. Fourier Transform Infrared (FTIR) Spectroscopy provides a reliable method for verifying gas cylinder concentrations for vapor-phase organic or inorganic compounds that absorb energy in the mid-infrared spectral region, about 800-4000 cm-1. Compounds that can be checked using this method include ammonia, carbon dioxide, methane, hexane, n-butanol, acetone, ethylene, carbon monoxide, propane, and nitrous oxide.

1.3. Typically, the FTIR minimum detection limit is as low as 2-10 ppb. Analytical range and sensitivity depend on the frequency-dependent component absorptivity, instrument configuration, data collection parameters, and gas stream concentration.

1.3.1. Instrument factors that affect performance (range, sensitivity, etc.) include:

1.3.1.1. Spectral resolution

1.3.1.2. Interferometer signal averaging time

1.3.1.3. Detector sensitivity and response

1.3.1.4. Absorption path length

1.4. This procedure applies only to the Nexus 670 FTIR gas spectrometer (Thermo Electron Corporation, Palatine, IL).

2. Summary of Method

The FTIR gas spectrometer (Nexus 670, Thermo Electron Corporation, Palatine, IL) allows accurate analysis of concentrations of compounds that are delivered from gas cylinders. The FTIR analyzer consists of a KBr beamsplitter, a mercury cadmium telluride High D* (MCT-High D*) detector (cooled with liquid nitrogen), an IR source, a heated stainless steel gas absorption cell, an electronic package, and a computer. The sample gas can be delivered to the gas absorption cell either directly from the gas cylinder (continuous purge mode), or from a sample bag to the vacuumed gas cell (batch mode). The latter is used if the gas cylinder is not available onsite with the FTIR. The optical bench measures the intensity of a specially encoded infrared beam after it has been passed through a sample. The resulting signal, called an “interferogram”, contains information about all frequencies present in the beam. The computer reads the interferogram, uses Fourier transformation to decode the intensity information for each frequency, and presents the spectrum. Absorbance band intensities in the spectrum are related to sample concentrations by what is commonly referred to as Beer’s Law. The frequency-dependent relationship between absorptivity and concentration can be determined by taking standard spectra of samples of compounds at known concentrations. Unknown compounds can be detected by matching sample absorbance bands with bands in standard spectra, and their

concentrations can be calculated by comparing sample band intensities with standard band intensities. Using OMNIC QuantPad software (Thermo Nicolet Instrument Corporation, Madison, WI), quantitative analysis methods can be created which allow analysis of spectra from gas- or condensed-phase samples using the Classical Least-Squares (CLS) quantitative analysis algorithms.

3. Definitions of Terms and Acronyms

3.1. FTIR Fourier Transform Infrared (FTIR) spectrometer
3.2. PAAQL Purdue Agricultural Air Quality Laboratory
3.3. Analyte A compound that the method is required to measure.

4. Health and Safety

4.1. When filling the detector's Dewar flask, be careful not to contact the liquid nitrogen with your skin. Wear protective gloves and goggles, and follow standard laboratory safety practices.
4.2. Do not touch the infrared source housing; it may be very hot. It stays hot for up to 15 min after the spectrometer is turned off.
4.3. Always follow the safety information that is displayed on the spectrometer itself. Do not operate a spectrometer, or any accessory, without following the safety precautions described in the manual and the documentation that came with the spectrometer.
4.4. Laser light exposure is possible when a beam-deflecting accessory (for example, a diffuse reflectance accessory) is installed. Never stare into the sample compartment when a beam-deflecting accessory is installed.
4.5. Avoid exposure to hazardous compounds when delivered from gas cylinders. Ensure that the gases are properly vented and that the gas delivery system is leak-free.

5. Interferences

5.1. Background interference. This results from a change in throughput relative to single beam background. In routine sampling, throughput may degrade over several hours. Periodically a new background spectrum must be collected.
5.2. Interference occurs when other compounds in the sample have spectral features that overlap with those of the analyte(s). Water vapor and CO2 are common spectral interferents. The extent of interference depends on the interferent concentration, analyte concentration, and the degree of band overlap. Spectral interference can be minimized or avoided by choosing an alternate spectral region for analysis.
5.3. If the temperature in the gas cell is too low, condensation of the analytes and/or water vapor can occur. Set the temperature of the gas cell at 50°C to minimize condensation.

5.4. In addition to being a spectral interferent, condensed moisture removes soluble compounds from the gas phase by allowing them to dissolve into the separate liquid phase.
5.5. Ambient air can mix with the sample if the gas absorption cell valves are not leak-free when delivering the sample in batch mode from a sample bag.
5.5.1. When introducing sample from a sample bag, minimize the length of inlet tubing to reduce errors in gas concentrations.
5.6. Samples stored in sample bags should be analyzed as soon as possible (preferably within 24-48 hrs) to avoid potential contamination of chemicals released from the sample bag itself and the loss/uptake of gases via diffusion though walls.
5.6.1. If possible, controlled tests with sample bags should be performed prior to their use to collect samples, to establish that the analyte(s) of interest are not lost from the bags. See Section 11.9.

6. Cautions

6.1. Always ensure that the detector is cooled by liquid nitrogen before taking a spectrum.
6.2. The manufacturer recommends that the spectrometer power remain on, even when not in operation. Allow the spectrometer to warm up for one hour if the power has just been turned on, then align it before collecting spectra.
6.3. Collect a new background spectrum regularly, preferably once every 4 h during the operation of the FTIR.
6.4. Collect a new background spectrum if the software parameters have been changed.
6.5. Align the spectrometer daily for optimum performance. The spectrometer should also be aligned if the ambient temperature has changed by at least 5°C, or in such situations such as when a laser has been replaced, a beamsplitter has been installed, the spectrometer has just been moved, or the detector signal intensity has dropped significantly from its usual level.
6.6. Never use a flammable gas to purge a spectrometer bench. The purge gas must be free of moisture, oil and other reactive materials. Use dried air or nitrogen to purge the instrument. Other gases, even inert gases such as argon (Ar), can damage the spectrometer laser.
6.7. The FTIR operates reliably at ambient temperatures between 16°C and 27°C. Temperature changes may result in drift in the system response.
6.8. The sample spectra to be analyzed using a particular method must have the same data point spacing and the same spectral range (frequency limits) as the spectra used to calibrate the method.
6.9. The calibration spectra must be of pure components or pure components diluted with a solvent or gas that either doesn't absorb infrared energy or absorbs in a different region of the infrared spectrum.

7. Personnel Qualifications

7.1. Personnel should be trained in the use of the instrument before initiating the procedure. Training requires about three days.
7.2. Each analyst must read and understand the entire instrument manual and this SOP before operating it.
7.3. Personnel should also be trained in verifying the instrument is functioning properly, performing routine maintenance, making a calibration method for analyzing a specific component, and interpreting the analyzer output signal.

8. Equipment and Supplies

8.1. FTIR gas spectrometer (Model Nexus 670, Thermo Electron Corp., Palatine, IL).
8.2. Stainless steel gas absorption cell (Mars Model 8L/40V, Gemini Scientific Instruments, Buena Park, CA)
8.3. Purge gas generator (Model PCDA1112-122, MTI-Puregas, Westminster, CO).
8.4. Absolute pressure gauge (Automation Products Group, Logan, UT)
8.5. Temperature controller (Model 689-0005, Barnant Co., Barrington, IL).
8.6. Heat Jacket and Thermo Controller
8.7. Vacuum pump
8.8. Nitrogen gas
8.9. Liquid nitrogen, Dewar flask, and funnel
8.10. Teflon tubing
8.11. Calibration standard gas
8.12. Sample bags (if gas cylinder is offsite)
8.13. Diluter

9. Procedures

9.1. Take triplicate bag (#1, 2, and 3) samples from a gas cylinder, if the gas cylinder is offsite.
  9.1.1. Flush each bag thoroughly at least 3 times with ultra-high purity (UHP) grade nitrogen and vacuum completely before use. Bag volume should be ≥ 40 L.
  9.1.2. Turn on the gas cylinder following SOP G2.
  9.1.3. Connect Teflon tubing that is connected to the gas cylinder regulator to the hose connection of bag (#1) fitting (stem protruding from the side of the bag fitting).
  9.1.4. Open the shut-off valve of the bag (#1) by holding the side stem and turning the entire upper portion of the fitting counterclockwise one revolution. Gas from cylinder begins to fill the bag. Fill the bag to no more than 80% of its maximum volume.
  9.1.5. Turn the gas cylinder off and close the shut-off valve of the sampling bag (#1) by holding the side stem and turning the entire upper portion of the fitting clockwise until it is snug.
  9.1.6. Detach the Teflon tubing from the sample bag (#1).

9.1.7. Finish sampling for bags #2, and 3 by repeating the Sections 9.1.1 to 9.1.6.
9.1.8. Pack the filled sample bags in a rigid carton to prevent damage or discharge during shipping. Ship the samples to the laboratory by overnight delivery, but do not ship sample bags by air unless the cargo cabin of the aircraft is pressurized. Time shipping dates so that samples are received by the laboratory when someone is there to accept them.

9.2. Turning on the system components
9.2.1. Connect external power supply.
9.2.2. Turn on accessories such as the temperature controller.
9.2.3. Turn on the spectrometer by pressing the power switch (I/O).
9.2.4. Turn on the printer (if available).
9.2.5. Turn on the computer.
9.2.6. Allow at least 1 h after turn on of the spectrometer and wait until the temperature inside the gas cell stabilized at 50°C before collecting spectrum.
9.2.7. Keep spectrometer on at all times for stable operation.
9.2.8. If the system components are to be turned off, do so in the following order:
9.2.8.1. Turn off computer.
9.2.8.2. Turn off printer.
9.2.8.3. Turn off spectrometer.
9.2.8.4. Turn off accessories.

9.3. Checking the purge gas generator
9.3.1. Set the pressure regulator of the purge gas generator between 20 and 40 psi.
9.3.2. Set the flow meter to deliver around 30 scfh.
9.3.3. Use only nitrogen or compressed air to purge the system.

9.4. Starting OMNIC software
9.4.1. Double-click the OMNIC shortcut on the windows desktop.

9.5. Cooling the detector with liquid nitrogen
9.5.1. Before running any samples, check whether liquid nitrogen needs to be added.
9.5.1.1. Open OMNIC.
9.5.1.2. Select “Experiment Setup” from the “Collect” Menu.
9.5.1.3. Go to the tab labeled “Diagnostic”.
9.5.1.4. If the detector signal is a flat line, liquid nitrogen must be added to the system before spectra are collected.
9.5.1.5. Wait 15 min, or until the signal intensity is satisfactory before collection (the magnitude of signal changes as a function of resolution being used). A minimum signal intensity of 30% of maximum voltage is required if resolution is set at 1.
9.5.1.6. Liquid nitrogen will evaporate over time, even if the FTIR does not scan. As a rule of thumb, it should be replenished after 8-10 h, even if the system has been idle during that time.
9.5.2. Add liquid nitrogen
9.5.2.1. ALWAYS wear protective eye wear and gloves.
9.5.2.2. Fill the small liquid nitrogen Dewar cylinder 2/3 full from a large Dewar.
9.5.2.3. Open the lid on the left hand side of FTIR, and pour liquid nitrogen from the small Dewar into the top hole using the special funnel provided.

9.5.2.4. Close the lid and return gloves/goggles to the drawer.

9.6. Quant Pad set up prior to collecting spectrum

9.6.1. Open Quant Pad.

9.6.2. Click “Method” button on the Quant Pad button panel.

9.6.2.1. Click the “Select Method” button.

9.6.2.2. Select the file of the quant method you want to use for the gas cylinder concentration check and then choose “OK”. An analysis method can be made following the procedures described in Section 9.11. If the gas concentration being checked is outside the analysis range, dilute the gas (SOP G11).

9.6.3. Click “Collect” button on the Quant Pad button panel.

9.6.3.1. Set the number of scans for both background and sample at 64.

9.6.3.2. Click the “More” button at the bottom of the above dialog box to check the settings of the data collection parameters.

9.6.3.2.1. Make sure that Resolution, Apodization, Zero Filling, Final Format, and File Handling parameters are set properly according to Table 1.

9.6.3.2.2. If a new background is needed before taking the sample spectra (e.g., when the sample is going to be taken more than 4 h after the last background spectrum is taken), make sure the background setting is placed at the third option (“collect background after x minutes”).

9.6.3.2.3. Otherwise, make sure the background setting is placed at the fourth option (“use specified background file”), and that the latest background file is loaded.

9.6.3.2.4. Click “OK” when finished setting the collection parameters.

9.6.4. Align the optical bench by clicking “Align” in the Quant Pad button panel.

9.7. Perform FTIR gas absorption cell leak-check. Follow the procedures described in Section 11.8.

9.8. Collecting a background spectrum

9.8.1. Check the settings of the data collection parameters by clicking the “Collection” button on the Quant Pad button panel. Make sure the background setting is placed at “collect background after xx minutes”.

9.8.2. Flush the FTIR chamber with pure nitrogen, delivered directly from gas cylinders, for at least 10 min. Control delivery rate at 5-10 L/min. Continue to deliver nitrogen while the background spectrum is being collected.

9.8.3. Click the “Background” button on the Quant Pad button panel.

9.8.4. Click “OK”.

9.8.5. Wait until the specified number of scans has been collected. A typical background spectrum is depicted in Fig. 1.

9.8.6. Click “Yes” to add the background spectrum to the indicated spectral window.

9.8.7. Use the “Save As” command in the OMNIC File menu to save the background spectrum on the hard disk.

9.8.8. A new background should be taken at least once at the beginning of the day’s work, or preferably every 4 h during continuous scanning.

9.9. Collecting and analyzing a sample spectrum

9.9.1. Check the settings of the data collection parameters by clicking the "Collection" button on the on the Quant Pad button panel. Change the background setting to "use specified background file" option, and load the file where the most recent background spectrum is saved. When collecting sample spectra, use the same parameter settings that were used to collect the standard spectra (Table 1). Collect the sample and standard spectra at the same pressure and approximately the same temperature.

9.9.2. Introduce sample

9.9.2.1. Batch Sampling (offsite cylinder): Load bag sample into FTIR chamber using vacuum/fill step.

9.9.2.1.1. Purge the FTIR gas cell with nitrogen at 5-10 L/min for at least 10 min.

9.9.2.1.2. Close inlet valve on FTIR.

9.9.2.1.3. Attach vacuum pump to the outlet tubing connected to the FTIR.

9.9.2.1.4. Turn on the vacuum pump, open outlet valve on FTIR, and wait until the pressure drops to stable level (usually around 80-200 torr).

9.9.2.1.5. Close the outlet valve. Turn off vacuum pump.

9.9.2.1.6. Attach sample bag to the inlet tubing. Open the bag valve. Minimize the length of inlet tubing to reduce errors in gas concentrations.

9.9.2.1.7. Open the FTIR inlet valve partially and let the bag sample deliver to the FTIR gas cell, close the inlet valve until the pressure reading stabilizes to ambient pressure. Close the bag valve.

9.9.2.1.8. Repeat Steps 9.9.2.1.3 to 9.9.2.1.7 to deliver and purge the sample 3 times. Use the third-time sample as the representative sample delivered from the bag. Wait for at least 2 min for stabilization of gas delivered to the FTIR gas cell before taking the sample spectrum.

9.9.2.1.9. If the gas concentration from the gas cylinder is greater than the maximum analytical range of the current method, then a new method has to be established by incorporating a standard spectrum with a certified gas concentration greater than the gas cylinder concentration.

9.9.2.2. Continuous Sampling (onsite cylinder): Load sample directly from cylinder into FTIR.

9.9.2.2.1. Follow the procedures described in SOP G2 (Standard Operating Procedure for Compressed Gas Cylinders) to deliver gas directly from the gas cylinder.

9.9.2.2.2. If the gas concentration from the gas cylinder is greater than the maximum analytical range of the method, use Environics (See SOP G11) or TEI 146 diluter (See SOP C3) to dilute the gas concentration to below the maximum concentration level that the method can analyze accurately before taking the spectrum.

9.9.2.2.3. Flush the FTIR gas cell with nitrogen beforehand. Vacuum the FTIR gas cell before delivering standard gas to reduce the time before a stable concentration can be reached. Deliver the sample gas at a flow

rate of 5 L/min for at least 10 min to ensure delivery of a representative sample of the gas to be checked.

9.9.3. Click "Sample" button on the Quant Pad button panel. Scanning of the sample will begin immediately. The final spectrum displays when the specified number of scans have been collected.

9.9.4. Click "Save As" in the OMNIC File menu to save the displayed sample spectrum.

9.9.5. Click the "Quantify" button on the Quant Pad button panel. The Quantify window shows the title of the selected quantitative analysis method and the path length, temperature and pressure values it used to calculate the results, followed by the concentration value and confidence range for each component.

9.9.6. To analyze a spectrum already saved on the disk, click the "Open" button on the Quant Pad button panel. Click the "Quantify" button on the Quant Pad button panel to automatically display the gas sample concentration.

9.9.7. To save the concentration data in a file on the disk, click the "Save" button in the "Quantify" window. The concentration data will be saved in a file named with the current base name and the extension "CNC".

9.10. Calculating the gas cylinder concentration analyzed by the FTIR

9.10.1. Following procedures described in Section 9.9, collect spectra for samples from at least three sample bags filled with the specified gas to be checked, if the gas cylinder is offsite. If the sample is continuously delivered directly from a gas cylinder, collect at least three spectra, at an interval of every 2-3 min.

9.10.2. Average the concentration data. Apply dilution factor if diluted sample is used. Compare the averaged value with the specified span gas concentration. The accuracy of the gas cylinder is confirmed if the average measured concentration is within 5% of the specified span gas concentration.

9.11. To make a Single Gas Method:

9.11.1. Collect calibration standard, a known concentration sample spectrum, using Quant Pad (select any method file) following the procedures described in Steps 9.2 to 9.9. Examples of standard spectra for representative compounds are displayed in Fig. 2.

9.11.2. Click the "Save as Standard" button on the Quant Pad button panel. Click "OK" after entering the spectrum information displayed on the window.

9.11.3. Enter a file name for this standard in the "File Name" box and select the drive and directory where the standards should be stored.

9.11.4. Open Quant Setup.

9.11.5. Choose "New Method" from the "File" menu

9.11.5.1. Select your sample phase as gas and concentration units as ppm.

9.11.5.2. Click "OK".

9.11.6. Choose "Components" from the "Edit" Menu

9.11.6.1. Type in the component name.

9.11.6.2. Type an abbreviated name in the component code box.

9.11.6.3. Click "OK".

9.11.7. Choose “Standards” from the Edit Menu
9.11.7.1. Click “Browse”.
9.11.7.2. Find the file of the standard spectrum and click “OK”.
9.11.7.3. Once the file is specified to be used in a method, it can not be moved out of its specified directory or the method will fail. If you choose to move the file, the method must be modified to match.
9.11.7.4. Check that the concentration, temperature, and pressure are correct for your standard.
9.11.7.5. Click “OK”.
9.11.8. Choose “Regions/Windows” from the Edit Menu
9.11.8.1. Carefully study the calibration spectra and choose frequency ranges in which the component peak are clearly identifiable and can be used to quantify the component in a method. Avoid using regions which show high absorption for water vapor or CO_2. Do not choose a frequency range in which the absorbance units are greater than 1 for the component to be quantified. The recommended regions for certain representative compounds are listed in Table 2.
9.11.8.2. Click the “Region Add” button to add regions.
9.11.8.3. If you want Quant Setup to use only certain windows in this analysis region to calculate component concentrations, click in the “Window” box and then click the “Window Add” button to add windows.
9.11.8.4. Repeat the above two steps until all regions and windows have been specified.
9.11.9. Choose “Calculations” from the Edit menu
9.11.9.1. Type an “S” for the region of the spectrum that you wish to use to calculate the concentration of this component. For the other regions, type “I”.
9.11.9.2. Click “OK”.
9.11.10. Choose “Save Method As” from the File Menu
9.11.10.1. Enter a title for the method.
9.11.10.2. Click “OK”.
9.12. Validating the Method:
9.12.1. Once Quant Pad is running, select any method and collect at least one sample spectrum from a sample containing a known concentration of the component, using Quant Pad and the method described above. The concentration should be about one-tenth of the concentration of the corresponding standard used to make the above method.
9.12.2. Save spectrum as a standard with Quant Pad.
9.12.3. Create a validation sample set
9.12.3.1. From Quant Setup, choose “Sample Sets” from the Analyze menu.
9.12.3.2. Click “New”.
9.12.3.3. Click “Add” button.
9.12.3.4. Select file names of spectra you wish to add.
9.12.3.4.1. To change the information associated with the file, click the file name, then click in the appropriate text box and enter the correct value.

9.12.3.4.2. To display a spectrum, click “View Spectra” in the Samples dialog box.
9.12.3.5. Click “OK”.
9.12.3.6. Click “Save Set”.
9.12.3.7. Enter a unique title for the sample set.
9.12.3.8. Click “New” to add this sample set to the list of sample sets.
9.12.3.9. Click “OK” to close the Samples dialog box.
9.12.4. Quantify the validation sample set
9.12.4.1. Be sure the correct method is open.
9.12.4.2. Choose “Quantify” from the Analyze menu.
9.12.4.2.1. This will open a dialog box containing information about the sample set based on the method selected.
9.12.4.2.2. The calculated component concentrations will be displayed.
9.12.4.2.3. Click the next button to see results for the next sample in the set.
9.12.4.3. When finished click “OK”.
9.12.4.4. If the calculated component concentrations differ from the actual concentrations by more than an acceptable amount (usually 1 to 5%, depending on the application), and if the errors tend to change regularly as a function of concentration, the absorbance vs. concentration plot for that component may be curved instead of linear. In this case, follow the instructions below to calculate a correction curve for that component.
9.12.5. Calculate a correction curve:
9.12.5.1. Use Quant Pad Application to collect spectra from different known concentrations (preferably 4 to 6 different concentration levels) and save as standards using Quant Pad.
9.12.5.2. Open “Quant Setup” and click “Open Method” from the File menu.
9.12.5.3. Select the title of the method to be corrected in the drop down list box and choose “OK”.
9.12.5.4. Create the calibration sample set:
9.12.5.4.1. Choose “Sample Sets” from the analyze menu.
9.12.5.4.2. Click “New”.
9.12.5.4.3. Click the “Add” button.
9.12.5.4.4. Select file names of the spectra you want to add.
9.12.5.4.5. Check to be sure information for each spectrum is correct.
9.12.5.4.6. Click “OK”.
9.12.5.4.7. Click “Save Set”.
9.12.5.4.8. Enter a unique title for your new sample set.
9.12.5.4.9. Click “New” to add this sample set to the list of sample sets.
9.12.5.4.10. Click “OK” to close the Sample dialog box. This set automatically becomes the active sample set.
9.12.6. Calculate the correction curve coefficients and save the calibration sample set.
9.12.6.1. Click “Calibration” from analyze menu.
9.12.6.2. Select the component you want to correct by clicking its name in the “Component” list.

9.12.6.3. Press the correction button in the calibration dialog box to analyze the calibration sample set using the primary standard for the selected component.

9.12.6.3.1. To force the curve through zero, turn on the "Force Zero Intercept" Option. The accuracy of the method can be improved by forcing the correction curve through zero if the concentration of the analyte in the samples may approach zero. Do not force the curve through zero if the lowest expected concentration in the samples is higher than the lowest standard in the calibration set, especially when all of the spectra in the calibration set are taken at high concentration range.

9.12.6.4. Calculate the correction curve coefficient.

9.12.6.4.1. Click on the "Calculate" button in the calibration dialog box to calculate the correction curve coefficients.

9.12.6.4.2. To exclude a selected calibration spectrum from the curve calculation (in case the spectrum is suspected to be an outlier or out of the desired calibration concentration range), select its file name and then turn off the "Include This Sample" option. If necessary, re-run a standard spectrum at such concentration to guarantee the accuracy of the standard spectrum concentration, and reintroduce the new spectrum into the calibration sample set.

9.12.6.4.3. Click "Display" in the Correction Curve Selection dialog to see a graph of the actual vs. measured values.

9.12.6.4.4. Click "Results" in the Correction Curve Selection dialog to see detailed information about the fit of the selected polynomial function to the spectral data.

9.12.6.4.5. Click the up or down arrow button next to the selected order to examine a higher- or lower-order function.

9.12.6.4.6. Select the lowest curve order that fits the actual concentration to the calculated concentrations with the required degree of accuracy specified in the QAPP.

9.12.6.5. Transfer curve coefficients to the current method.

9.12.6.5.1. Display the Correction Curve Selection dialog box and make sure the correct polynomial order is selected.

9.12.6.5.2. Click the "Use" button. This transfers the current set of coefficients into the current method for use in correcting the concentrations of the selected component.

9.12.6.6. Save the Calibration sample set.

9.12.6.6.1. Press the "Return" button in the Correction Curve Selection dialog box. Calibration Data dialog box appears on screen.

9.12.6.6.2. Press "Save Set", then either click "Replace" or enter new title and click "New".

9.12.6.6.3. Press "Return" to get to Quant Setup menu.

9.12.7. Save the corrected method by clicking "Save Method" from File menu, or clicking "Save Method As" and enter a title for the method, and then choose "OK".

9.12.8. To run the corrected method, open Quant Pad and select the method. Then either open, quantify, or collect and quantify a spectrum.

9.13. Troubleshooting

9.13.1. Troubleshooting measures for software, hardware, and application problems are listed in the last three chapters of the ThermoNicolet Nexus 670 User's Guide.

9.13.2. If the above action does not solve the problem, call Thermo Nicolet Service office at 1-800-642-6538, 608-276-6100, or email them at techinfo@thermonicolet.com.

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method. Supplement this electronic record by a record book designated for the method, which should contain copies of the electronic record.

10.2. Manage all data according to SOP B5.

10.3. Document all data and information (e.g., sample collection method used) on field data sheets, and within site logbooks with permanent ink, or in electronic field notes.

10.4. Maintain gas certification records.

10.5. Store the quantitative analysis method and spectra (standard, background, and sample spectra) on a computer disk. Store a second backup copy on a separate disk.

11. Quality Control and Quality Assurance

11.1. The accuracy of any FTIR quantitative analysis is limited by the accuracy of the concentrations of the gas standards used in establishing the calibration method. Preferably the calibration gas should be certified using EPA protocol (1% certification).

11.2. The calibration spectra must be of pure components, or pure components diluted with a solvent or gas that either doesn't absorb infrared energy or absorbs in a different region of the infrared spectrum.

11.3. Check the FTIR calibration on a monthly basis by comparing the concentrations of the spectra taken from a reference span gas cylinder with its specified gas cylinder concentration that is guaranteed of accuracy. Recalibrate the instrument if the average measured concentration deviates more than 5% from the specified span gas concentration.

11.4. New background spectra should be collected regularly, preferably once every 4 h during the operation of the FTIR.

11.5. Align the spectrometer daily for optimum performance.

11.6. Keep the room temperature where the FTIR is installed at temperatures between 16°C and 27°C.

11.7. Verify that the detector is cooled by liquid nitrogen before taking any spectrum.

11.8. Perform FTIR gas absorption cell leak-check before taking sample spectra. Leak check the FTIR cell under both vacuum and pressurized (greater than ambient) conditions.

11.8.1. For the batch sampling technique, close the inlet valve to the FTIR cell, open the outlet valve and connect to a vacuum pump. Evacuate the absorption cell to the minimum absolute pressure P_{min}. Close the outlet valve, and determine the change in pressure P_v after 2 min.

11.8.2. For both the batch sampling and continuous purging techniques, pressurize the system to about 100 mmHg above atmospheric pressure. Determine the change in pressure P_p after 2 min.

11.8.3. Determine the percent leak volume $\%V_L$, calculated as P_{max} divided by atmospheric pressure and then multiplied by 100%, where P_{max} is the larger of P_v or P_p.

11.8.4. Leak volumes in excess of 4% of the FTIR system volume are unacceptable, and the tubing connection should be re-checked.

11.9. Prior to use of sample bags for storage of gas samples for subsequent FTIR analysis, perform tests to evaluate sample recoveries and/or contamination from sample bags under controlled conditions. This could be accomplished by comparing FTIR responses to gases in the purge mode and in the batch mode simulating bag materials (walls and fittings), storage times and storage temperatures. Choose the type of sample bag that has the least amount of gas loss and contamination.

12. References

12.1. EPA Test Method 320. Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive Fourier Transform Infrared (FTIR) Spectroscopy. www.midac.com/apnotes/Ap-139.PDF

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12.5. Nicolet Instrument Corporation. 1995.QuantPad User's Guide. Madison, WI.

12.6. SOP B5. 2006. Data Management for Barns. Standard Operating Procedure B5. Purdue Ag Air Quality Lab.

12.7. SOP G11. 2006. Operation of the Environics® Computerized Gas Dilution System. Standard Operating Procedure G11. Purdue Ag Air Quality Lab.

12.8. SOP G2. 2006. Compressed Gas Cylinders. Standard Operating Procedure G2. Purdue Ag Air Quality Lab.

13. Contact Information

13.1. Technical Support: 1-800-Nicolet (1-800-642-6538), 1-608-276-6373.
13.2. PAAQL: odor@purdue.edu, heber@purdue.edu, http://www.AgAirQuality.com.

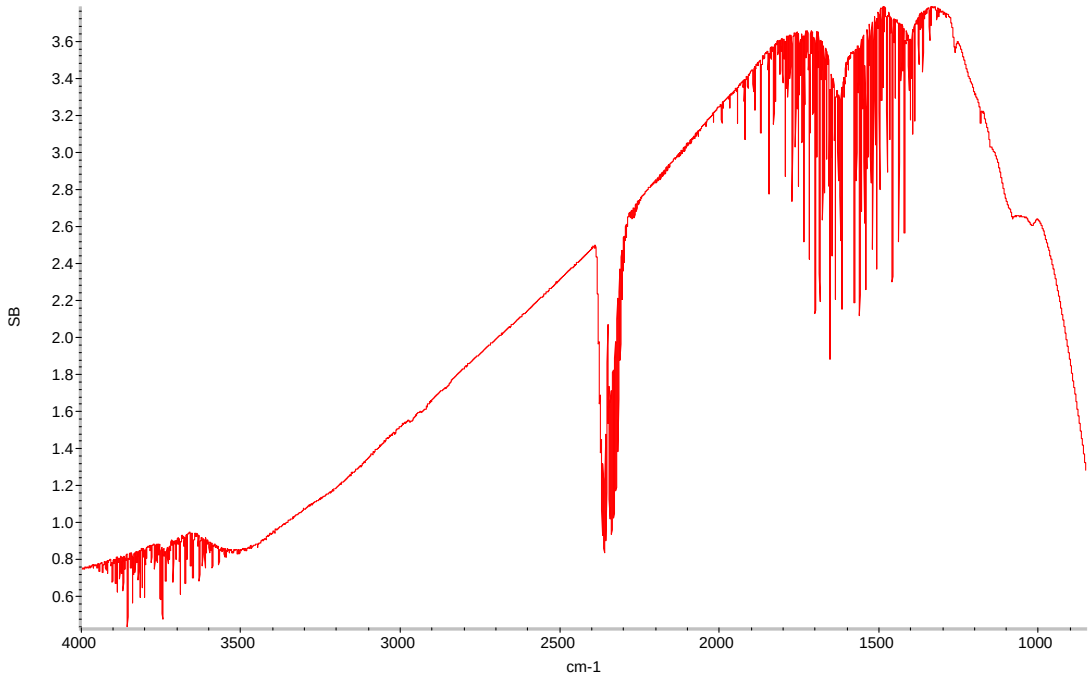

Figure 1. Example of a background spectrum.

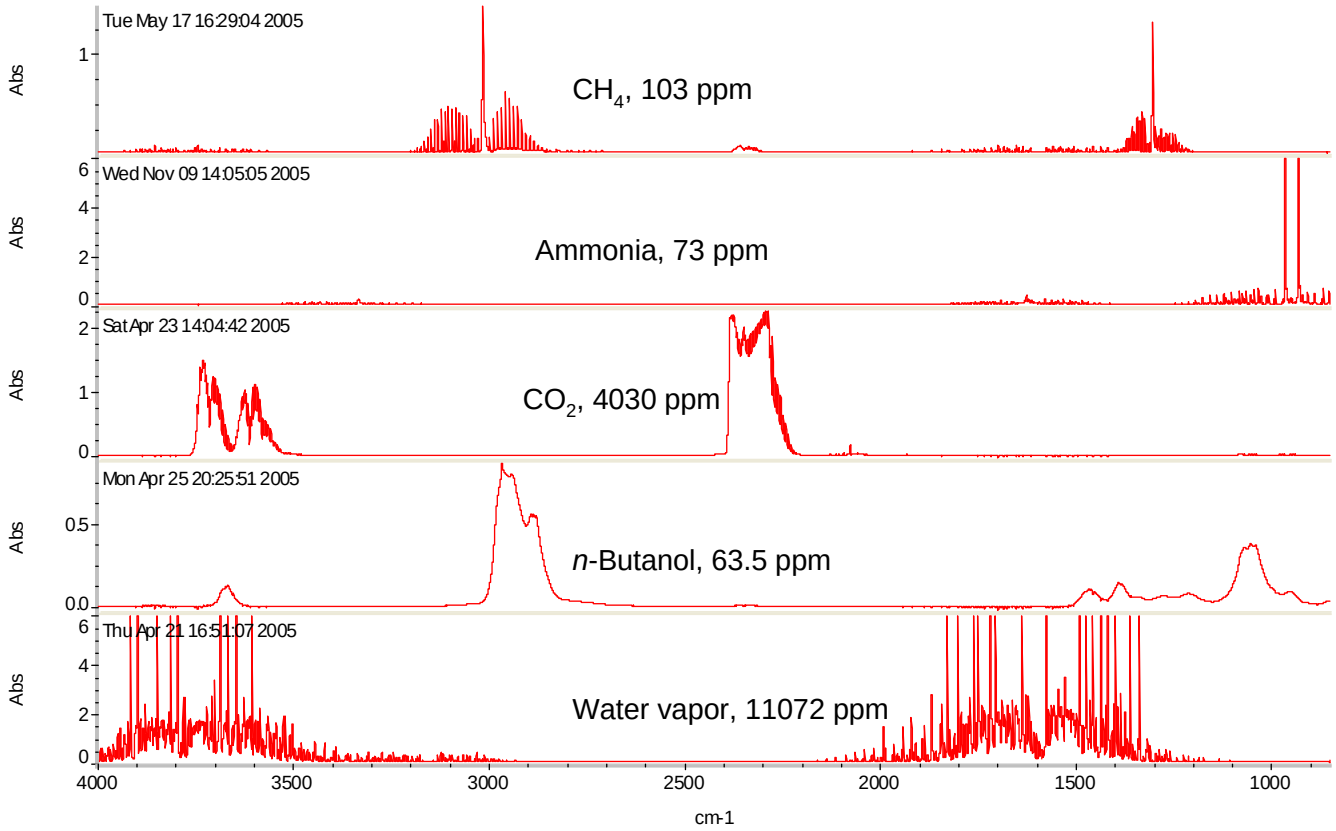

Figure 2. Standard spectra for representative compounds.

Table 1. Data collection and optical bench setup parameter for standard and sample spectra collection.

Parameter	**Setting**
Number of sample scans	64
Number of background scans	64
Resolution	1
Data spacing	0.482 cm-1
Spectral range	4000-850 cm-1
Mirror velocity	1.8988
Gain	1
Aperture	34
Level of zero filling	0
Apodization	Happ-Genzel
Phase correction	Mertz

Table 2. Preferred frequency ranges to be used as calculation regions for making the analysis methods for each compound.

Compound Name	Frequency Ranges (cm^{-1})
Carbon dioxide	2075.7-2080
Water vapor	3372.7-3405
Methane	3008.2-3019.6
n-Butanol	2809-3019
Ammonia	961.3-969

MEASUREMENT OF LAGOON pH WITH THE INNOVATIVE SENSORS MODEL CSIM11-pH SENSOR
Standard Operating Procedure (SOP) L1

MEASUREMENT OF LAGOON pH WITH THE INNOVATIVE SENSORS MODEL CSIM11-pH SENSOR

Standard Operating Procedure (SOP) L1

Prepared by

Alfred J. Lawrence and Richard H. Grant

Reviewed by

Wayne P. Robarge (N.C. State Univ.), Bill W. Bogan, and Albert J. Heber

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. A range of pH-dependent chemical and biological interactions and processes can affect the odor of, and overall chemical emissions from, manure stored in a lagoon.
  1.1.1. Emissions of ammonia (NH_3) increase as pH increases.
  1.1.2. Emissions of hydrogen sulfide (H_2S) decrease as pH increases.
1.2. Ion-specific probes with built-in preamplifiers are useful for accurate pH measurements.
  1.2.1. The pH measurement range of these probes is from 0 to 14.
  1.2.2. The pH in anaerobic lagoons typically ranges from 6.8 to 8.3.
1.3. This SOP applies only to the Campbell Scientific Model CSIM11 pH probe.

2. Summary of Method

The activity of hydrogen ion (H^+) in solution is measured as pH using an ion-selective probe with built-in preamplifier (Innovative Sensors Model 11 Process pH sensor purchased as Model CSIM11, Campbell Scientific). A porous Teflon liquid junction resists fouling while the probe is deployed in the lagoon, and a double-junction reference cell increases the service life of the probe. The sensor voltage output is proportional to pH. The probe will be 0.3 m below the lagoon surface and 9 m away from the lagoon berm. The probe will be connected to a styrofoam float, held in place with two nylon ropes and a ½" PVC raceway, which keeps the float in place and protects its lead cable. The raceway will pivot off two steel posts that support a weatherproof NEMA box, which will house the data logger.

3. Definitions

3.1.	Ag	Silver
3.2.	AgCl	Silver chloride
3.3.	APHA	American Public Health Association
3.4.	BNC	Bayonet Neill Concelman Connector
3.5.	CS	Campbell Scientific, Inc
3.6.	H^+	Hydrogen ion
3.7.	KHP	Potassium biphthalate
3.8.	QAPP	Quality Assurance Project Plan
3.9.	QCCS	Quality Control Check Sample
3.10.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.11.	PAML	Purdue Applied Meteorology Laboratory
3.12.	pH	Hydrogen activity, defined as $-log[H^+]$
3.13.	PVC	Polyvinylchloride
3.14.	NEMA	National Electrical Manufacturers Association
3.15.	SOP	Standard operating procedure

4. Health and Safety

4.1. Be careful when working with solutions. Buffers may cause eye and skin irritations and may be harmful if inhaled or swallowed. Maintain proper lab procedures when filling electrodes or calibrating. Wear eye protection, as eye damage may result from splash.
4.2. Wear gloves and face shields when handling manure (including lagoon) samples.

5. Cautions

5.1. Be careful when connecting the sensor cable to the datalogger, being sure that the connections are tight and are made according to SOP W6.
5.2. Avoid crimping electrical cables and connectors.
5.3. Stray sources of ions such as tap water, soil, dust etc. can contaminate the reference solution. Maintain good lab cleanliness when refilling probe.
5.4. Take proper care to avoid damaging the probe's glass reservoir
  5.4.1. Never wipe the pH bulb, since dust may scratch the delicate gel layer.
  5.4.2. Do not drop the probe.

6. Interferences

6.1. The depth of measurement must be maintained at 0.3 m.
6.2. Algae and other biological organisms will foul the probe, and/or physically block porous liquid junctions.

7. Personnel Qualifications

7.1. Each field staff member must read and understand the sensor instruction manual, the reference pH sensor manual, and this SOP before operating this instrumentation.
7.2. Personnel must be trained in the use of the handheld multimeter before initiating the procedure. Training requires 10 min.

8. Equipment and Supplies

8.1. #2 common head screwdriver
8.2. 1/8″ slotted screwdriver
8.3. Low-temperature oven (capable of temperatures to at least 125°C)
8.4. Deionized water
8.5. Mild (dish) soap for cleaning probe
8.6. Protective gloves and face shields
8.7. Stands and clamps for sensor and pH reference electrodes
8.8. Safety glasses
8.9. Teflon pipe tape
8.10. NIST- traceable pH buffers
  8.10.1. 4.01 pH (potassium biphthalate)
  8.10.2. 7.00 pH (potassium phosphate)

8.10.3. 10.00 pH (sodium borate/sodium carbonate)
8.11. Potassium biphthalate (KHP)
8.12. Thymol ($C_{10}H_{13}OH$)
8.13. Non-mercury thermometer
8.14. 50-mL beakers
8.15. High-input impedance multimeter.
8.16. Standard glass-body reference electrode (Ag/AgCl) with porous liquid junction and
8.16.1. BNC connector
8.17. 5-VDC power supply for preamplifier
8.18. Analytical balance (200 g range , 0.01 g resolution)
8.19. pH preamplifier kit for BNC connector-equipped electrodes, with leads to connect to
8.19.1. multimeter
8.20. pH probe. Model CSIM11, Campbell Scientific, North Logan, UT
8.21. Measuring tape
8.22. Reference solution
8.23. Drying oven

9. Procedures

9.1. Probe preparation
9.1.1. Electrodes are shipped with a wetting cap covering the measuring end. The cap contains a pH 4 buffer, which is saturated with potassium chloride (KCl) for single-junction combination electrodes and potassium nitrate (KNO_3) for double-junction electrodes.
9.1.1.1. Gently remove wetting cap by unscrewing the bottle from the cap and then sliding the cap and o-ring off the electrode body. Save the cap for storage.
9.1.1.2. During shipping or transit, some air may have moved into the bulb from inside the probe. Grasp the electrode near the cable and gently swing it through an arc to force the internal electrolyte into the pH bulb. Visually inspect to ensure that the internal surface of the porous junctions in the electrodes is in contact with internal reference solutions.
9.1.1.3. Rinse the electrode with distilled water.
9.2. Acceptance
9.2.1. Physically inspect pH probe, referring to the figure in Appendix D. Verify that the glass sensing bulb is intact and not scratched. Verify that the porous junction is not visibly leaking, and that the area around the porous junction is not cracked or otherwise damaged. Reject the probe if it fails any of these tests. Record assessment on Acceptance Log (Appendix B).
9.2.2. Prepare the pH Quality Control Check Sample (QCCS) solution inside the trailer.
9.2.2.1. Dry 10.5 g of KHP for 2 h at 110 °C. Dissolve 10.21 g of dried KHP in 1 L distilled/deionized water. Add a single thymol crystal per L for preservation. The pH of this solution is 4±0.05 pH units .
9.2.3. Connect the green lead from pH probe to one terminal of the high-input impedance multimeter. Connect the clear-cased reference lead from preamplifier kit for standard glass-bodied reference electrode to other terminal of multimeter. Connect black

ground lead from preamplifier (attached to the standard glass-bodied reference electrode) to the ground (brown) wire of the pH probe (Fig. 1).

9.2.4. Connect the three-wire preamplifier connector to the 5-VDC power supply. Connector cable has red to positive, black to negative, green to ground (Fig. 1).

9.2.4.1. Conduct this procedure inside trailer, where the temperature is maintained at 21˚ ±3˚C (SOP U4).

9.2.4.2. Place both pH probe and glass-bodied reference electrode into fresh QCCS solutions and measure voltage difference between the reference electrodes. Ideally, the measured voltage should be 0 ± 4 mV for two Ag/AgCl reference electrodes; however, internal construction differences, as well as liquid junction potentials, may result in a non-zero reading.

9.2.4.3. Record the voltage reading (millivolts) on the Acceptance Log (Appendix B) for future reference in assessing pH probe performance.

9.2.4.3.1. If the voltage reading is unstable after one min (±1 mV), the porous junction on the probe is likely either leaking or partially obstructed. According to the pH probe manual change internal reference solutions for the pH probe, and repeat measurements of the pH probe with standard glass-bodied reference electrode.

9.2.4.3.2. If the reading is still unstable, follow the procedure for cleaning clogged liquid junctions outlined in the manual (Section A.1.6 “Electrode Cleaning”), and repeat measurements of the pH probe with standard glass-bodied reference electrode.

9.2.4.3.3. If the readings are still unstable, reject pH probe and replace with a new one.

9.2.5. Calibrate the probe (Section 9.4).

9.2.6. Probe stability

9.2.6.1. Conduct procedure inside trailer, where the temperature will be maintained at 25˚ ±3˚C (SOP U4).

9.2.6.2. Place calibrated probe in fresh QCCS solution. Using Table 1 record its pH readings after 30 s, and after 2 min on the Acceptance Log (Appendix B). Both readings should agree within ±0.05 pH units or ±3mV.

9.2.6.2.1. If the 30-s reading is not 4.00±0.05 pH units, or if the 30-s and 2-min readings do not agree within ± 0.05 units, this may also indicate problems with the probe.

9.2.6.3. Check probe response with fresh QCCS solution. If the readings are still outside the acceptable range, clean the electrode, check for leakage at the junction and/or damage to the glass bulb. If neither is found, repeat Step 9.2.3. Retest with fresh QCCS solution; if the probe is still not functioning properly, replace it.

9.3. Installation (SOP U5, Section 9.6.7)

9.3.1. Locate the position on the lagoon corner (away from inlet) in which the sensor should be placed. Refer to the QAPP and/or Site Monitoring Plan.

9.3.2. Position the probe so that the sensor will be 0.3 m below the waterline of the float, and install all sensors in tri-sensor float.

9.3.3. Connect center of nylon guide rope to tri-sensor float and lift using rope. Rope has markers to indicate position to ensure the float will be 3 m from the edges of the lagoon in the corner.

9.3.4. Connect the probe cable from NEMA box to the indicated hole in the lagoon probe float.
9.3.5. Verify the waterline of the float matches to the 0.3 m mark on the Styrofoam float.
9.3.6. Attach wires to datalogger in NEMA box using the ⅛″ slotted screwdriver. Connect brown wire to ground and red and green wires to the differential-ended analog channel

9.4. Calibration (Beginning/end of measurement period or 20d, which ever comes first)
9.4.1. Conduct procedure inside trailer, where temperature will be maintained at 25˚±3˚C (SOP U4).
9.4.2. Based on APHA Standard Method 2580
9.4.3. Probes and buffers should be at temperature equilibrium before calibration.
9.4.4. Measure and record temperature from bulb thermometer on the Quality Assurance Log (Appendix C).
9.4.4.1. Calculate the Nernst temperature compensation (-0.2 pH/mV per ºC).
9.4.5. Connect red wire to positive post and green wire to negative post of multimeter.
9.4.5.1. Set multimeter to mV readings.
9.4.6. Rinse probe three times in distilled water
9.4.7. Place probe in pH 7.0 buffer
9.4.7.1. Record buffer pH, temperature compensation of probe, expected buffer mV (from Table 1), and measured mV on the Quality Assurance Log (Appendix C).
9.4.7.1.1. If the measured value, corrected for temperature, differs from the expected value by ±0.3 pH units (17.7 mV) or more, repeat Sections 9.4.5 and 9.4.6
9.4.7.1.1.1. If the error is still ≥ ±0.3 pH units (17.7 mV), contact vendor for replace/repair decision (Section 13.2).
9.4.8. Repeat Sections 9.4.6 and 9.4.7 using pH 4.01 buffer.
9.4.9. Repeat Sections 9.4.6 and 9.4.7 using pH 10.0 buffer.

9.5. Troubleshooting
9.5.1. If the probe reads pH 14 or higher:
9.5.1.1. Check for damaged cable. If damaged, replace or repair.
9.5.1.2. Check for loose connections at datalogger. Tighten if necessary.
9.5.1.3. Check for coating on bulb. If needed, clean according to Appendix A (Page A-3) of the probe manual.
9.5.1.4. Check for clogging of reference probe. If needed, clean according to manual. Check performance as specified in Section 9.6.
9.5.1.5. Check that bulb is full of solution. If not, gently swing it through an arc to force the internal electrolyte into the pH bulb. If still low, follow instructions in the probe manual (Pages 4-5) to refill.
9.5.2. Noisy or erratic readings
9.5.2.1. Check for coating or clogging of glass or reference electrode. Clean as needed according to Appendix A (Page A-3) of the probe manual. Check performance as specified in Section 9.2.3.
9.5.3. No response to changes in pH
9.5.3.1. If electrode reads between 5.8 and 6.2 in all pH solutions, visually inspect bulb for cracks. Replace probe if cracks are found.

9.5.3.2. If pH electrode reads pH 7 (or 0.0 mV) in all pH solutions, check cable for damage that might cause a short circuit. If damaged, replace and send for repair.

9.6. Conduct performance assessment and preventive maintenance at the beginning and end of each measurement period.

9.6.1. Remove pH probe from float and visibly inspect glass sensing bulb and liquid junction for damage or blockage. Record assessment on the Inspection Log Form (Appendix A).

9.6.1.1. If damaged, replace sensor and send damaged sensor to manufacturer for repair.

9.6.2. Rinse pH probe with copious amounts of distilled water to remove lagoon effluent.

9.6.2.1. Calibrate sensor (Section 9.4), indicating beginning or end of the measurement period on Quality Assurance Log (Appendix C).

9.6.2.2. If the temperature-corrected measured pH is within ±0.3 pH units (17.7 mV) of the buffer solution pH, the probe function is considered acceptable.

9.6.2.3. If the temperature-corrected measured pH differs from the buffer solution pH by > 0.3 pH units, the probe function has degraded. If this occurs at the beginning of a measurement period, do not use the probe, but replace it with a new one. If it occurs at the end of the measurement period, flag or correct the data collected during the period as follows:

9.6.2.3.1. If the temperature-corrected measured pH differs from the buffer solution pH by ≥ 0.5 pH units, flag the measurements during the period as questionable.

9.6.2.3.2. If the temperature-corrected measured pH differs from the buffer solution pH by < 0.5 pH units, age-correct the measurements made during the measurement period, based on a linear interpolation of the difference in measured and theoretical values across the time of the measurement period:

Corrected pH measurement = pH measurement + TM * (pHF – pHI)/(TP)

Where:

TM = Elapsed time into the measurement period when pH reading was taken, h
pHF = Probe pH reading at the end of the measurement period
pHI = Probe pH reading at the beginning of the measurement period
TP = Total length of the measurement period, h

9.6.3. Clean pH probe and sensor cable with mild soap and water, following Appendix A of the probe manual.

9.6.4. Inspect cable for damage and record assessment on the Inspection Log (Appendix A).

9.6.4.1. Repair or replace as necessary to maintain cable integrity and wire continuity.

9.6.5. Repeat Section 9.2.

9.6.5.1. If sensor meets acceptance criteria, store according to manufacturer’s guidelines in preparation for future use.

9.6.5.2. If sensor fails acceptance criteria, replace sensor and send to supplier for repair.

9.7. Data acquisition, calculations & data reduction requirements are given in the probe manual (Pages 3-4 and Appendix B)

9.7.1. Sensor output (-0.413 to 0.413 VDC) is monitored by the data logger.

9.7.1.1. Sensor response is 59 mV per pH unit at 25oC, with pH 7 equal to 0 mV.
9.7.2. Measurements will be recorded by the data logger every 5 min.
9.7.2.1. Temperature correction of pH measurement (Page 3 of probe manual) is:
1/(TempC+273)/298 * 59)
where TempC is the measured lagoon temperature (SOP L2) in oC.
9.7.2.2. Temperature correction is made in data logger, using the program described in SOP W6).
9.7.3. Report data to three significant digits
9.8. Computer hardware & software
9.8.1. Attach the sensors with electrical wires to a data logger (Section 9.3.5), which will extract data from the instruments and store it (SOP W6).
9.8.2. Data logger operates using on-board BASIC-like programming.
9.8.2.1. The general program for measurements is described in Appendix B of the probe manual

10. Data and Records Management

10.1. Maintain all lab records in a worksheet of the electronic field notes spreadsheet designated for this method, as well as in a bound record book designated for meteorological sensors.
10.2. Manage all data according to SOP D1
10.3. At the end of this SOP are forms to record the inspection and calibration information.
10.4. Document all data and information on field data sheets, sensor logs and in site logbooks with permanent ink, or in electronic notes.
10.5. Overstrike errors in writing on logs with a single line. Initial and date all corrections.

11. Quality Control and Quality Assurance

11.1. Check to be sure the probe is mounted 0.3 m below the waterline of the lagoon probe float.
11.2. Abrupt changes in the pH reading may indicate that the probe float has turned over. Daily checks of the data will provide a check against sudden changes that might indicate that the float has turned over or encountered other problems.
11.3. Replace reference solution in probe every six months (or as needed).
11.3.1. Clean the probe tip according to Appendix A of the probe manual.
11.3.2. Note how far the red refill plug is screwed into the probe body. Remove plug and place it where it will stay clean.
11.3.3. Rinse reservoir with deionized water repeatedly to remove old solution. Drain out all remaining water.
11.3.4. Completely fill the reservoir with the new reference solution. Make sure to keep the bottle tip clean, and replace bottle cap immediately after use.
11.3.5. Replace the red plug and apply new pipe tape. Make sure the plug is screwed back in as far as it was originally.
11.3.6. Because the reference solution is viscous, it may be necessary to invert the probe and wait for the reference solution to fill the glass bulb.

11.3.6.1. If necessary, take the probe in hand and GENTLY swing it in a downward arc to speed the flow of solution into the bulb.

11.4. Conduct the acceptance protocol (Section 9.2) and calibration (Section 9.4) on all new units, and at the beginning and end of each measurement period.

11.5. Conduct any preventative maintenance during the performance assessment (Section 9.6) at the beginning and end of each measurement period.

12. References

12.1. pH Probe Manual. 2003. Using CSIM11 pH and ORP Probes with Campbell Scientific Dataloggers, Campbell Scientific, Inc., North Logan, UT, 14 p.

12.2. APHA. 1995. Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 4500-H^+, A.D. Eaton, L.S. Clesceri, A.E. Greenberg (Eds.), AWWA, WEF.

12.3. Aneja, V.P.; B. Bunton, J.T. Walker, and B.P. Malik. 2001. Measurement and analysis of atmospheric ammonia emissions from anerobic lagoons. Atm. Env. 35:1949-1958.

12.4. Miller, W.J. 2003. Redox Chemistry of Six Anaerobic Swine Lagoons in Eastern North Carolina. MS Thesis, North Carolina State University, Raleigh, NC 167 p.

12.5. SOP D1. 2006. Management of Open-source, Weather and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.

12.6. SOP L2. 2006. Measurement of Lagoon Temperature with the Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.

12.7. SOP U4. 2006. Open-source Instrument Trailer. Standard Operating Procedure U4. Purdue Applied Meteorology Lab.

12.8. SOP U5. 2006. Installation for Open-source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.

12.9. SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

12.10. http://www.sensorex.com/support/education/pH_education.html

13. Contact Information

13.1. Distributor: Campbell Scientific, Inc., 815 West 1800 North, Logan, Utah, 84321

13.1.1. Technical support: 435-753-2342

13.2. Manufacturer: Innovative Sensors, Inc, 4123 E. La Palma Ave #200, Anaheim, California 92807

13.2.1. Telephone: 714-577-5600, 800-835-5474

13.2.2. Fax: 714-577-5688

Figure 1. Quality Control Check Sample (QCCS) connections.

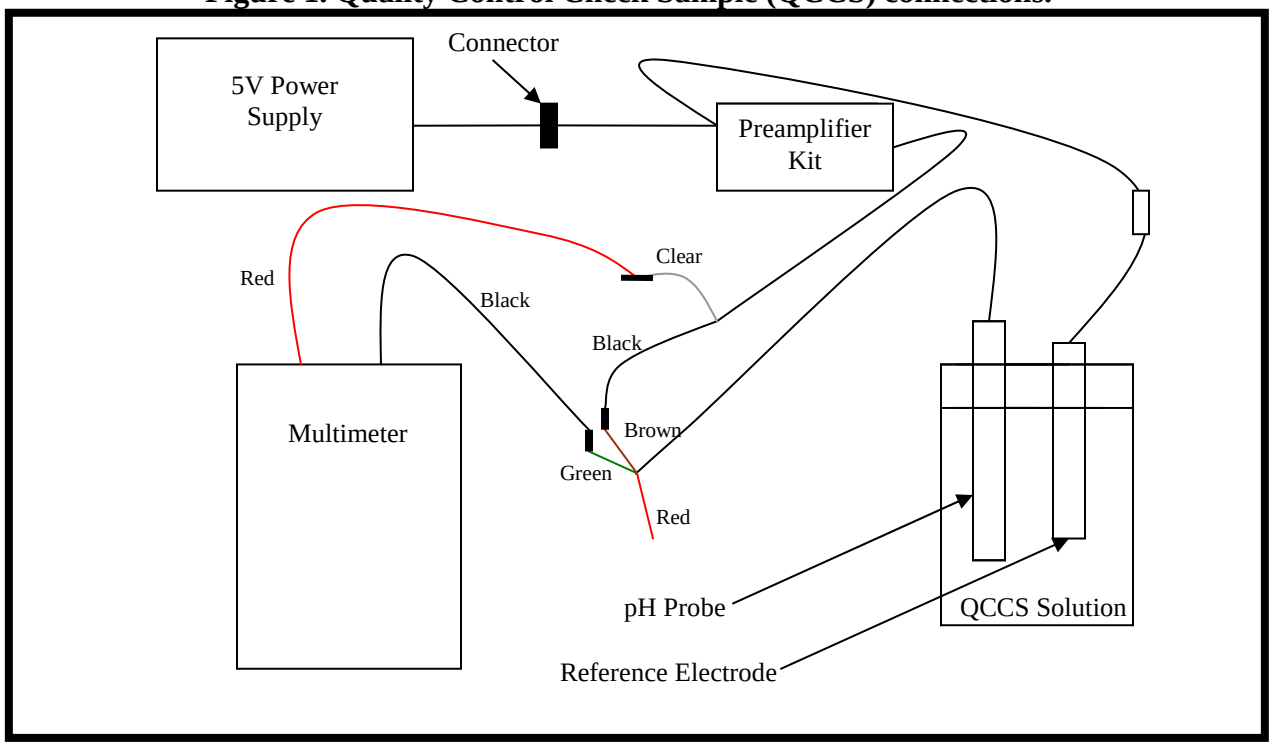


Table 1. pH units Vs mV

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
+414	+355	+296	+237	+177	+118	+59	00	-59	-118	-177	-237	-296	-355	-414

Zero mV = pH 7
59.2mV per pH unit change
mV are + for pH < 7 and mV are – for pH >7

Table 2.pH vs Temperature Error Chart

	pH2	pH	pH	pH5	pH6	pH7	pH8	pH9	pH10	pH11	pH12
5º	0.30	0.24	0.18	0.12	0.06	0	0.06	0.12	0.18	0.24	0.30
15º	0.15	0.12	0.09	0.06	0.03	0	0.03	0.06	0.09	0.12	0.15
25º	0	0	0	0	0	0	0	0	0	0	0
35º	0.15	0.12	0.09	0.06	0.03	0	0.03	0.06	0.09	0.12	0.15
45º	0.30	0.24	0.18	0.12	0.06	0	0.06	0.12	0.18	0.24	0.30
55º	0.45	0.36	0.27	0.18	0.09	0	0.09	0.18	0.27	0.36	0.45
65º	0.60	0.48	0.36	0.24	0.12	0	0.12	0.24	0.36	0.48	0.60
75º	0.75	0.60	0.45	0.30	0.15	0	0.15	0.30	0.45	0.60	0.75
85º	0.90	0.72	0.54	0.36	0.18	0	0.18	0.36	0.54	0.72	0.90

Note: Values in light blue are less than 0.1 errors, and may not require temperature compensation. Values in gray are temperature/pH combinations at which there is no error in pH from temperature.

Appendix A. Inspection and Maintenance Log
INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial Number ____________

Date (DMY)	Condition		Action taken	Calibration done?	Acceptance done?	Person assessing
	Glass electrode	Cable				

Appendix B. Acceptance Log

INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial Number _____

Date (DMY)	Condition		T (°C)	QCCS reference check (mV)	Time to stable QCCS reading (min)[1]	pH reading in QCCS check[3]		Calibration done?	Action taken	Analyst
	Glass electrode	Porous junction				30-s	2-min			
						mV pH units	mV pH units			
						mV pH units	mV pH units			
						mV pH units	mV pH units			
						mV pH units	mV pH units			
						mV pH units	mV pH units			
						mV pH units	mV pH units			
						mV pH units	mV pH units			

[1]Should be ±1 mV in less than 1 min

[2]Both 30-s and 2-min readings should be 4.00±0.05 pH units (at 25°C) and agree within ±0.05 pH units.

[3] pH readings in mV and pH units (according to Table 1)

Appendix C. Quality Assurance Log

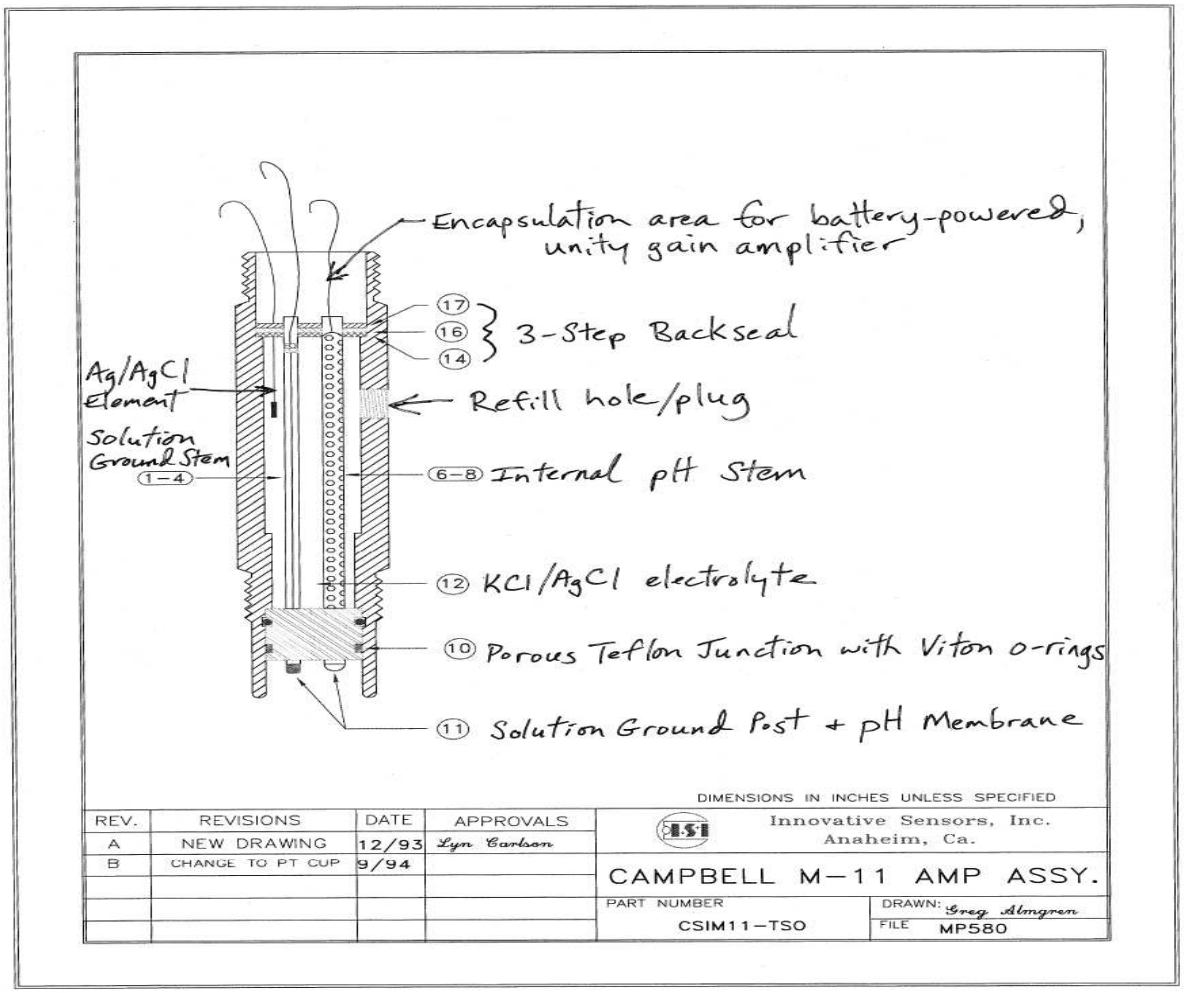
INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR

Serial number _____

Beginning or end of measurement period?	Date (DMY) & Time	T (^{o}C)	Buffer pH	Nernst temp comp. (mV)	Expected potential of pH buffer (mV)	Probe measurement		pH Error (Expected vs. calculated)	Action (Adjust, Replace)	Analyst
						mV	Calculated pH			
			7							
			4							
			10							
			7							
			4							
			10							
			7							
			4							
			10							

Appendix D. pH Probe Diagram

INNOVATIVE SENSORS MODEL CSIM11 pH SENSOR



MEASUREMENT OF LAGOON TEMPERATURE
WITH CAMPBELL SCIENTIFIC MODEL 107-L THERMISTOR
Standard Operating Procedure (SOP) L2

MEASUREMENT OF LAGOON TEMPERATURE WITH CAMPBELL SCIENTIFIC MODEL 107-L THERMISTOR

Standard Operating Procedure (SOP) L2

Prepared by

Richard H. Grant

Reviewed by

Wayne P. Robarge (N.C. State Univ.), Albert J. Heber and Bill W. Bogan

Effective Date: November 6, 2006

PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Lagoon temperature is a factor influencing emissions. For example, ammonia emissions vary with temperature because the acid-dissociation constant for ammonium (NH_4^+) is temperature-dependent (De Visscher et al 2002). However, lagoon temperature is not needed to measure the emission, and is therefore a secondary measurement.

1.2. Thermistors are useful for the accurate measurement of temperature over long distances without the need for reference measurements.

1.3. This procedure applies only to the Campbell Scientific Model 107 Temperature probe.

1.3.1. The temperature range of this sensor is -38°C to +53°C.

1.3.2. The accuracy is ±0.4°C over the range of -24°C to 48°C and ±0.9°C over the ranges of -38°C to -25°C and 48°C to 53°C.

1.3.3. The time constant of the sensor is less than 30 s.

2. Summary of Method

The Model 107 thermistor measures lagoon water temperature using a negative resistance coefficient semiconductor. The sensor is linearized by bridge resistors. The bridge resistors and thermistor are excited by a 2-VAC voltage, and the measured voltage is further linearized with a fifth-order polynomial (Model 107-LC Temperature Probe Manual, 2003). The probe will be located 0.3 m below the surface of the lagoon and 9 m from the where the liquid meets the berm of the lagoon. The probe will be connected to a styrofoam float, which will be held in place with nylon ropes, as described in SOP U5. A weatherproof NEMA box will house a datalogger that will store data from the probe.

3. Definitions

3.1.	AC	Alternating current
3.2.	ARM	Atmospheric Radiation Monitoring Network
3.3.	CS	Campbell Scientific, Inc
3.4.	mVDC	Millivolts direct current
3.5.	NEMA	National Electrical Manufacturers Association
3.6.	NIST	Natioanl Institute of Standards & Technology
3.7.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.8.	PAML	Purdue Applied Meteorology Laboratory
3.9.	PVC	Polyvinylchloride
3.10.	QAPP	Quality Assurance Project Plan
3.11.	Time constant	The amount of time required for a thermistor to indicate 63% of a new temperature value

4. Health and Safety

4.1. Be careful when working with electrical connections.

5. Cautions

5.1. Be careful when connecting the sensor cable to the datalogger, and make sure the connections (SOP W6) are tight.
5.2. Be careful not to overcrimp the sensors' electrical cables and connectors.
5.3. Be careful not to puncture the lagoon liner when driving in the post for the NEMA box.

6. Interferences

6.1. The probe should be 0.3 m below the surface of the lagoon to prevent being pulled to the surface by waves on windy days.

7. Personnel Qualifications

7.1. Each field staff member must read and understand the sensor instruction manual and this SOP before operating the sensor.
7.2. Personnel must be trained in the use of the handheld multimeter.

8. Equipment and Supplies

8.1. Model 107-LC temperature probe (Campbell Scientific, North Logan, UT) with 30 m of lead cable
8.2. #2 common head screwdriver
8.3. ⅛″ slotted screwdriver
8.4. Temperature calibrator
8.5. Multimeter
8.6. Dishwashing soap for cleaning sensor and cable
8.7. Styrofoam float (1′ x 1′ x 4″)
8.8. Post and post driver
8.9. NEMA box
8.10. NIST-traceable thermometer, accurate to within 1°C
8.11. Datalogger (SOP W6)
8.12. Measuring tape

9. Procedures

9.1. Initial inspection/acceptance of probe
9.1.1. Check resistance across red and purple wires with multimeter. Using Table 1, determine the temperature which would be output by the probe based on this resistance. Compare to the temperature reported on a NIST-traceable thermometer.
9.1.1.1. If the two values correspond to within +/- 2°C, the sensor is functioning properly.
9.1.1.2. If the two values differ by more than +/- 2°C, the sensor is defective and must be returned to the manufacturer.
9.2. Installation (Section 8.6.5 of SOP U5)
9.2.1. Locate position on lagoon corner (away from inlet) where sensor should be placed.

9.2.2. Position the probe so that the sensor will be 0.3 m below the waterline of the float.
9.2.3. Once all sensors are installed, connect center of nylon guide rope to sensor float and lift the float using the rope. Rope has markers to indicate position to ensure the float will be 3 m from the edges of the lagoon in the corner.
9.2.4. Connect probe cable from NEMA box to indicated hole in the lagoon probe float.
9.2.5. Verify the waterline of the float matches to the 0.3 m mark on the Styrofoam float.
9.2.6. Attach wires to datalogger in NEMA box using the ⅛″ slotted screwdriver. Connect black wire to the switched excitation channel, purple to ground, clear to ground, and red to the single-ended analog channel.

9.3. Calibration

9.3.1. Perform a single-point calibration every six months.
9.3.1.1. Single-point calibration determines the temperature offset in the polynomial equation. The value of the offset is chosen so that the probe outputs the temperature calculated by the polynomial, not the actual calibration temperature.
9.3.1.1.1. 9.3.1.1.1. For example, if probe is placed into a 0°C chamber, and reads 0.1°C, the offset is -0.16, because at 0°C the polynomial gives a value of -0.06°C (Table 1).
9.3.1.2. Connect sensor probe to datalogger (Section 9.2.15).
9.3.1.2.1. Set datalogger to real time measurement mode (SOP W6).
9.3.1.3. Insert sensor probe into calibration chamber. Record chamber temperature, indicated probe temperature, and computed offset on the Calibration Form (Appendix A).
9.3.1.3.1. If sensor offset exceeds +/- 0.5oC, replace sensor.

9.4. Preventive maintenance after each measurement period

9.4.1. Clean the sensor and sensor cable with soap and water.
9.4.2. Inspect the sensor cable for damage, and repair or replace as necessary to maintain cable integrity and continuity in the wires.

9.5. Troubleshooting

9.5.1. Repeated constant values indicate sensor failure.
9.5.1.1. Check connection at datalogger, and tighten with a screwdriver if necessary.
9.5.1.2. Check condition of Santoprene® jacket of cable for cracks and tears. Replace sensor if damaged.

9.6. Data acquisition, calculations & data reduction requirements

9.6.1. Temperature output (-35 to 50 mVDC) is monitored by the datalogger.
9.6.2. Measurements are recorded by the datalogger every 5 min.
9.6.3. The datalogger converts measured voltage (equation 1 below) to temperature using a 5th-order polynomial (equation 2 below). Data is reported to three significant digits.

$$X = Vs/Vx = 800 * mVDC \quad \text{Equation 1}$$

Where X is a ratio of voltage measured (Vs) to excitation voltage (Vx)

$$Temp = -53.4601 + 90.807X - 83.257X^2 + 52.283X^3 - 16.723X^4 - 2.211X^5 \quad \text{Equation 2}$$

9.7. Computer hardware & software
  9.7.1. A Campbell Scientific datalogger will extract data from the sensor, record the data, and store it.
  9.7.2. The datalogger operates using on-board BASIC-like programming.
    9.7.2.1. The general program for measurements is provided on pages 4 & 5 of the Model 107 Temperature Probe Instruction Manual (Probe Manual, 2004).

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method, as well as in a bound record book designated for meteorological sensors.
10.2. Manage all data according to SOP D1.
10.3. Appendix A of this SOP contains a form to record the calibration information.
10.4. Document the complete data and information in the field data sheets and in the site logbooks with permanent ink, or in electronic notes.
10.5. Overstrike errors in writing with a single line. Initial and date all corrections.

11. Quality Control and Quality Assurance

11.1. Check to be sure the probe is mounted 0.3 m below the waterline of the float.
11.2. Abrupt changes (>5oC within 5 min.) indicate the probe float has turned over. Check float and correct orientation.

12. References

12.1. Probe Manual. 2004. Model 107 Temperature Probe Instruction Manual. Campbell Scientific, Inc., North Logan, UT.
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12.5. SOP D1. 2006. Management of Open-Source, Weather and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.
12.6. SOP W6. 2006. Establishment, Data Acquisition and control of weather and lagoon characterization hardware. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.
12.7. SOP U5. 2006. Installation of Open-Source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.

13. Contact Information

13.1. Distributor: Campbell Scientific, Inc., 815 W 1800 N, Logan, UT, 84321 Technical support: 435-753-2342

Table 1. Correspondence between sensor resistance and measured and reported temperatures.

Temperature °C	Resistance OHMS	Output °C
-40.00	4067212	-39.18
-38.00	3543286	-37.55
-36.00	3092416	-35.83
-34.00	2703671	-34.02
-32.00	2367900	-32.13
-30.00	2077394	-30.18
-28.00	1825568	-28.19
-26.00	1606911	-26.15
-24.00	1416745	-24.11
-22.00	1251079	-22.05
-20.00	1106485	-20.00
-18.00	980100	-17.97
-16.00	869458	-15.95
-14.00	772463	-13.96
-12.00	687276	-11.97
-10.00	612366	-10.00
-8.00	546376	-8.02
-6.00	488178	-6.05
-4.00	436773	-4.06
-2.00	391294	-2.07
0.00	351017	-0.06
2.00	315288	1.96
4.00	283558	3.99
6.00	255337	6.02
8.00	230210	8.04
10.00	207807	10.06
12.00	187803	12.07
14.00	169924	14.06
16.00	153923	16.05
18.00	139588	18.02
20.00	126729	19.99
22.00	115179	21.97
24.00	104796	23.95
26.00	95449	25.94
28.00	87026	27.93
30.00	79428	29.95
32.00	72567	31.97
34.00	66365	33.99
36.00	60752	36.02
38.00	55668	38.05
40.00	51058	40.07
42.00	46873	42.07
44.00	43071	44.05
46.00	39613	46.00
48.00	36465	47.91
50.00	33598	49.77
52.00	30983	51.59
54.00	28595	53.35
56.00	26413	55.05
58.00	24419	56.70
60.00	22593	58.28

Appendix A. Model 107 Thermistor Calibration Form

Serial Number _____

Calibration Date D-M-Y	Calibration Time hh:mm		Temperature (^{o}C)			Action (Adjust, Replace)	Analyst
	Begin	End	Expected	Measured	Offset (Table 1)		

MEASUREMENT OF LAGOON REDOX STATE WITH THE INNOVATIVE SENSORS CSIM11-ORP SENSOR
Standard Operating Procedure (SOP) L3

MEASUREMENT OF LAGOON REDOX STATE WITH THE INNOVATIVE SENSORS CSIM11-ORP SENSOR

Standard Operating Procedure (SOP) L3

Prepared by

Alfred J. Lawrence and Richard H. Grant

Reviewed by

Wayne P. Robarge (N.C. State Univ.), Bill W. Bogan, and Albert J. Heber

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The redox state of a livestock waste lagoon is an important parameter that influences emissions from the lagoon.

1.1.1. For example, redox potentials above ~300 mV will inhibit the growth of methanogenic bacteria in a lagoon, which will lead to a buildup of organic alcohols, aldehydes, and acids (the metabolic products of acetogenic bacteria) (Zhang 2001). Many of these are volatile, and can contribute to odorous volatile organic compound (VOC) emissions from the lagoon.

1.2. Ion-specific probes with built-in preamplifiers are useful for the accurate measurement of Oxidation-Reduction Potential (ORP), a key measure of the redox state of a system.

1.3. This procedure applies only to the Campbell Scientific Model CSIM11 ORP probe.

1.3.1. The ORP measurement range is from -700 to +1100 mV.

1.3.2. The ORP range encountered in anaerobic livestock-waste lagoons is -20 to -300 mV.

2. Summary of Method

The density of electrons in solution is measured as the reduction-oxidation potential using an ion-selective probe with a built-in preamplifier (Innovative Sensors, Inc., Model 11 process ORP sensor purchased as Model CSIM11-ORP, Campbell Scientific). A platinum band around the glass electrode provides a surface for reaction and results in the response of the sensor to electron density. The band also reduces sensor drift. A porous Teflon liquid junction resists fouling in the solution and a double junction reference cell increase the service life of the probe. The voltage output of the sensor is proportional to electron density. The probe will be located 0.3 m below the surface of the lagoon and 9 m from where the liquid meets the berm of the lagoon. The probe will be connected to a styrofoam float, which will be held in place with two nylon ropes and a ½" PVC raceway. In addition to keeping the float in place, the PVC raceway will protect the lead cable coming from the probe. The raceway will pivot off of two steel posts which will also support a weatherproof NEMA box, which will house a datalogger that will store data from the probe.

3. Definitions

3.1.	APHA	American Public Health Association
3.2.	Ag/AgCl	Silver: Silver chloride
3.3.	BNC	Bayonet Neill Concelman Connector
3.4.	CSI	Campbell Scientific, Inc
3.5.	emf	Electro-motive force
3.6.	KCl	Potassium chloride
3.7.	NEMA	National Electrical Manufacturers
3.8.	ORP	Oxidation-reduction potential
3.9.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.10.	PAML	Purdue Applied Meteorology Laboratory
3.11.	PVC	Polyvinyl chloride

3.12. QAPP Quality Assurance Project Plan
3.13. SOP Standard operating procedure
3.14. VDC Voltage direct current
3.15. VOC Volatile organic compounds

4. Health and Safety

4.1. Be careful when working with solutions. Buffers may cause eye and skin irritations and may be harmful if inhaled or swallowed. Maintain proper lab procedures when filling electrodes or calibrating. Wear proper eye protection, as damage to eyes may result from splash.
4.2. Wear gloves and face shields when handling manure (including lagoon) samples.

5. Cautions

5.1. Be careful when connecting the sensor cable to the datalogger, being sure that connections are tight and are made according to SOP W6.
5.2. Avoid crimping electrical cables and connectors.
5.3. Stray sources of ions such as tap water, soil, dust etc. can contaminate the reference solution. Maintain good laboratory cleanliness when refilling probe.
5.4. Take proper care to avoid damaging the probe's glass reservoir
5.4.1. Never wipe the pH bulb, since dust may scratch the delicate gel layer.
5.4.2. Do not drop the probe.

6. Interferences

6.1. The depth of measurement must be maintained at 0.3 m.
6.2. Algae and other biological organisms will foul the probe, and/or physically block porous liquid junctions.

7. Personnel Qualifications

7.1. Each field staff member must read and understand the sensor instruction manual and this SOP before operating the instrumentation.
7.2. Personnel must be trained in the use of the handheld multimeter before initiating the procedure. Training requires 10 min.

8. Equipment and Supplies

8.1. #2 common head screwdriver
8.2. 1/8″slotted screwdriver
8.3. Bottle with deionized water
8.4. 250-mL and 500-mL beakers
8.5. 2 stands and clamps for sensor and pH reference electrodes
8.6. Protective gloves

8.7. Safety glasses
8.8. Teflon pipe tape
8.9. Multimeter
8.10. ZoBell's Solution Redox Standard (Source: Campbell Scientific, Inc.)
8.10.1. For Ag/AgCl in 4M KCl, the measured emf is +228 mV at 25˚C
8.10.2. For Ag/AgCl in saturated KCl, the measured emf is +229 mV at 25˚C
8.10.3. According to the manufacturer, the shelf life is typically 6 months; however, drifts of >10 mV over 30 d have been reported when solutions are stored at room temperature.
8.11. Standard glass-body reference electrode (Ag/AgCl) with porous liquid junction and BNC connector
8.12. pH preamplifier kit for BNC connector equipped electrodes with leads to connect to multimeter
8.13. 5-VDC power supply for preamplifier
8.14. Analytical balance (200 g range , 0.01 g resolution)
8.15. 1M KCl solution (or reagent grade KCl for preparing solution)
8.16. ORP probe Model CSIM11-ORP, Campbell Scientific, Inc., North Logan, UT
8.17. Stirring rod
8.18. Measure tape
8.19. Reference solution (KCl/AgCl + KNO_3)

9. Procedures

9.1. Probe preparation
9.1.1. All electrodes are shipped with a wetting cap covering the measuring end. This cap contains a pH 4 buffer saturated with potassium chloride (KCl) for single-junction combination electrodes and potassium nitrate (KNO_3) for double-junction electrodes.
9.1.1.1. Gently remove wetting cap by unscrewing the bottle from the cap and then sliding the cap and o-ring off the electrode body. Save the cap for storage.
9.1.1.2. During shipping some air may have moved into the bulb from inside the probe. Grasp the electrode near the cable and gently swing it through an arc to force the internal electrolyte into the pH bulb. Ensure that the internal surface of the porous junctions in the electrodes is in contact with internal reference solutions.
9.1.1.3. Rinse the electrode with distilled water.
9.2. Acceptance
9.2.1. Physically inspect ORP probe (Appendix C). Verify that the glass sensing bulb is intact and not scratched, that the porous junction is not visibly leaking, and that the area around the porous junction is not cracked or damaged. Reject the probe if it fails any of these tests. Record assessment on Acceptance Log (Appendix A).
9.2.1.1. If damaged, return probe to manufacturer for repair or replacement.
9.2.2. Make 1M KCl solution
9.2.2.1. Dissolve 74.55 g of reagent grade KCl in 1 L of distilled water.
9.2.2.2. This solution is stable for 6 months.
9.2.3. Place 100 mL of KCl solution in a 250-mL beaker.
9.2.4. Connect green lead from ORP probe to one terminal of the high-input impedance multimeter. Connect the clear-cased reference lead from preamplifier of standard

glass-bodied reference electrode to other terminal of multimeter. Connect ground of ORP probe (black wire) to ground lead from preamplifier of standard glass-bodied reference electrode (Fig. 1).

9.2.5. Connect the three-wire preamplifier connector to the 5-VDC power supply. Connector cable has red to positive, black to negative, green to ground. (Fig. 1).

9.2.6. Place both ORP and glass-bodied reference electrodes into the 1M KCl solution, and measure the voltage difference between them. The measured voltage should be 0±4 mV for two Ag/AgCl reference electrodes.

9.2.6.1. Use of 1M KCl solution is designed to minimize junction potentials for the two electrodes.

9.2.6.2. Record voltage reading (in mV) on the Sensor Acceptance Log (attached at the end of this SOP) for future reference of ORP probe performance and correction of readings if measured voltage is not zero.

9.2.6.2.1. If the voltage reading is unstable after one min (± 1mV), the porous junction on the probe is likely either leaking or partially obstructed. According to the ORP manual (page 5) change internal (reference) solutions for the ORP probe, and repeat measurements with standard glass-bodied reference electrode.

9.2.6.2.2. If the reading is still unstable, follow the procedure for cleaning clogged liquid junctions outlined in the manual (Section A.1.6 “Electrode Cleaning”), and repeat measurements of the ORP probe with the standard glass-bodied reference electrode.

9.2.6.2.3. If the readings are still unstable, reject ORP probe and replace with a new one.

9.2.7. Calibrate the probe (Section 9.4) using redox standard solution to verify acceptability.

9.3. Installation (SOP U5, Section 9.6.7)

9.3.1. Locate the position on the lagoon corner (away from inlet) in which the sensor should be placed. Refer to the QAPP and/or Site Monitoring Plan.

9.3.2. Position the probe so that the sensor will be 0.3 m below the waterline of the float and install all sensors in tri-sensor float.

9.3.3. Connect center of nylon guide rope to tri sensor float and lift using rope. Rope has markers to indicate position to ensure the float will be 3 m from the edges of the lagoon in the corner.

9.3.4. Connect the probe cable from NEMA box to the indicated hole in the lagoon probe float.

9.3.5. Verify the waterline of the float matches to the 0.3 m mark on the Styrofoam float.

9.3.6. Attach wires to datalogger in NEMA box using the ⅛″ slotted screwdriver. Connect brown wire to ground, and red and green wires to the differential-ended analog channel.

9.4. Calibration

9.4.1. Based on APHA Standard Method 2580.

9.4.2. Connect red wire to positive post and green wire to negative post of multimeter.

9.4.2.1. Set multimeter to mV readings.

9.4.3. Rinse probe with de-ionized water three times.

9.4.4. Make ZoBell's solution in the field by mixing 1.41 g $K_4Fe(CN)_6 \cdot 3H_2O$ (potassium ferrocyanide), 1.10 g $K_3Fe(CN)_6$ (potassium ferricyanide), and 7.46 g KCl (potassium chloride) in 1 L deionized water.

9.4.5. Place ZoBell's Solution in a 500 mL beaker (Section 8.10), and maintain a temperature of 25 ±3 ºC.

9.4.6. Measure and record the temperature of the redox standard solution on the calibration form (attached at the end of this SOP as Appendix B).

9.4.6.1. Determine potential of the ZoBell's solution from Table 1 and record on the calibration form under 'expected' (Appendix B).

9.4.7. Immerse probe in gently-stirred redox standard solution (ZoBell's Solution).

9.4.7.1. Record measured emf (mV) on the calibration form (Appendix B).

9.4.7.2. If measured emf differs from the expected value by less than ± 30 mV after 10 min, the ORP probe is functioning properly, and may be accepted for use.

9.4.7.3. If measured emf differs from the expected value by more than ± 30 mV after 10 min, replace with unused redox standard solution and repeat Step 9.4.5.

9.4.7.4. If measured emf again differs from the expected value by more than ± 30 mV, replace internal solution and clean platinum-sensing element according to page 5 of the probe manual. Rinse well with distilled water and repeat Step 9.4.4.

9.4.7.5. If measured emf continues to differ from expected value by more than ± 30 mV, the probe performance has degraded beyond acceptable levels. If this occurs at the beginning of a measurement period, replace the probe with a new one. If it occurs at the end of the measurement period, flag or correct the data collected during the period as follows:

9.4.7.5.1. If the measured emf differs from the expected value by ≥50 mV, flag the measurements during the period is invalidated.

9.4.7.5.2. If the measured emf differs from the expected value by less than ± 50 mV, age-correct the measurements made between the beginning and end of measurement period by linear interpolation of the difference in measured values across the time of the measurement period according to:

$$\text{Corrected ORP measurement} = \text{ORP measurement} + T_M * (ORP_F - ORP_I)/(T_P)$$

Where:

T_M = Elapsed time into the measurement period when ORP reading was taken, h
ORP_F = Probe ORP reading at the end of the measurement period
ORP_I = Probe ORP reading at the beginning of the measurement period
T_P = Measurement period duration, h

9.5. Performance assessment and preventive maintenance after each measurement period

9.5.1. Remove ORP probe from float and visibly inspect platinum-sensing ring and liquid junction for damage or blockage.

9.5.2. Rinse ORP probe with copious amounts of distilled water to remove lagoon effluent.

9.5.3. Calibrate according to Section 9.4.4.

9.5.4. Clean ORP according to the probe manual.

9.5.5. Clean sensor cable with mild soap and water.

9.5.6. Inspect sensor cable for damage and repair or replace as necessary to maintain integrity of the cable and continuity in the wires.
9.5.7. Repeat acceptance protocol (Section 9.2) to assess probe performance at the end of the measurement period and in preparation for future use.
9.5.8. If ORP probe meets acceptance criteria, store according to manufacturers guidelines in preparation for future use.
9.5.9. If the ORP probe fails acceptance criteria, contact PM for replacement probe.

9.6. Troubleshooting

9.6.1. If probe reads 1100 mV or higher:
9.6.1.1. Check for damaged cable. If damaged, replace or repair
9.6.1.2. If the cable is damaged and can't be repaired, contact PM for replacement.
9.6.1.3. Check for loose connections at datalogger; tighten if necessary.
9.6.1.4. Check for coating on platinum sensing element. If needed, clean according to Appendix A, page A3 of the probe manual.
9.6.1.5. Check for clogging of reference probe. If needed, clean according to Appendix A (Page A3) of the probe manual. Repeat acceptance protocol (Section 9.2).
9.6.1.5. Check the probe if filled with reference solution, according to the probe manual.
9.6.2. Noisy or erratic readings
9.6.2.1. Check for coating or clogging of reference electrode. If needed, clean according to Appendix A (Page A3) of the probe manual. Repeat acceptance (Section 9.2).
9.6.3. No response to changes in oxidation reduction potential
9.6.3.1. If electrode reads 0.0 mV when connected to the datalogger, check cable for damage (short circuit). If damaged, replace or repair.

9.7. Data acquisition, calculations & data reduction requirements (SOP D1)

9.7.1. Probe output (-0.413 to 0.413 VDC) is monitored by the datalogger.
9.7.2. Measurements will be recorded by the datalogger every 5 min.
9.7.3. Data is reported to three significant digits.

9.8. Computer hardware & software

9.8.1. Attach the sensors through electrical wires to a Campbell Scientific datalogger.
9.8.2. The Campbell Scientific datalogger will record the data and store it.
9.8.3. The datalogger operates using on-board BASIC-like programming.
9.8.3.1. The general program for measurements is described in the Appendix B of the CSIM11 ORP probe manual
9.8.3.2. Instructions for downloading data from the datalogger are provided in SOP D1.

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method, as well as in a bound record book designated for meteorological sensors.
10.2. Manage all data according to SOP D1.
10.3. Acceptance and Calibration Forms are attached at the end of this SOP as Appendix A and Appendix B, respectively.
10.4. Document all data and information on field data sheets and logs and in site logbooks with permanent ink, or in electronic notes.

10.5. Overstrike any errors in writing with a single line. Initial and date all corrections.

11. Quality Control and Quality Assurance

11.1. Verify that the probe is mounted 0.3 m below the waterline of the lagoon probe float.
  11.1.1. Conduct a daily remote check of the data for abrupt changes in measurements (more than ±10 mV in sequential values).
  11.1.2. Verify the correct placement of the probe at the end of each measurement period (up to 20 days).
11.2. Replace redox standard reference solution every 6 months.
11.3. Clean the probe tip according to the probe manual.
  11.3.1. Take note of how far the red refill plug is screwed into the probe body. Remove plug and place it where it will stay clean.
  11.3.2. Rinse reservoir with deionized water repeatedly to remove old solution. Drain out all remaining water.
  11.3.3. Completely fill the reservoir with the new reference solution (Section 13.1). Keep the bottle tip clean and replace bottle cap immediately after using the bottle.
  11.3.4. Replace the red plug and apply new pipe tape. Make sure the plug is screwed back in as far as it was originally.
11.4. Conduct the acceptance protocol (Section 9.2) and calibration (Section 9.4) on all new units, and at the beginning and end of each measurement period.
11.5. Conduct any preventative maintenance during the performance assessment (Section 9.5) at the beginning and end of each measurement period.

12. References

12.1. Probe manual. 2003. Using CSIM11 pH and ORP Probes with Campbell Scientific Dataloggers, Campbell Scientific, Inc., North Logan, UT, 14p
12.2. APHA, Standard Methods for the Examination of Water & Wastewater, 19th Edition, Method 4500-H^+, A.D. Eaton, L.S. Clesceri, A.E. Greenberg (Eds.), AWWA, WEF, 1995.
12.3. Aneja, V.P.; B. Bunton, J.T. Walker, and B.P. Malik. 2001. Measurement and analysis of atmospheric ammonia emissions from anerobic lagoons. Atm. Env. 35:1949-1958.
12.4. Miller, W.J. 2003. Redox Chemistry of Six Anaerobic Swine Lagoons in Eastern North Carolina. MS Thesis, North Carolina State University, Raleigh, NC, 167 p.
12.5. Zhang, R. 2001. Biology and Engineering of Animal Wastewater Lagoons. Online at ucce.ucdavis.edu/files/filelibrary/5049/678.pdf. Acessed 6/08/2006.
12.6. SOP D1. 2006. Management of Open-source, Weather and Lagoon Characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.
12.7. SOP U5. 2006. The Installation of Open-source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.
12.8. SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

13. Contact Information

13.1. Distributor: Campbell Scientific, Inc., 815 West 1800 North, Logan, Utah, 84321
13.1.1. Technical support: 435-753-2342
13.2. Manufacturer: Innovative Sensors, Inc, 4123 E. La Palma Ave #200, Anaheim, California 92807
13.2.1. Telephone 714-577-5600, 800-835-5474
13.2.2. Fax: 714-577-5688
13.3. Fisher Scientific
13.3.1. www.fishersci.com/Chemical
13.3.2. Rica Chemical No. : 9880-32
13.3.3. Telephone 1-800-766-7000.

Figure 1. Quality Control Check Sample (KCl) connections.

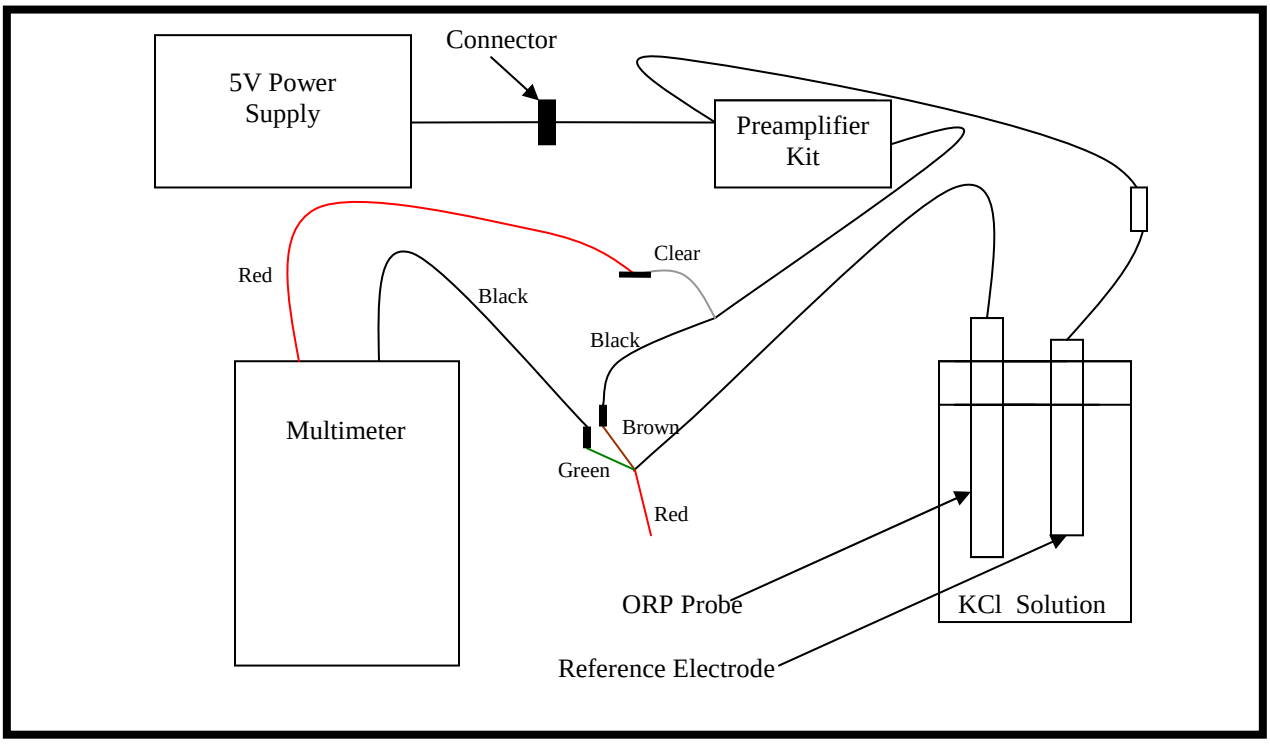


Table 1. Potential of ZoBell's Solution.

Standard Solution	Potentials of Pt Electrode Vs Ag/AgCl reference electrodes at 25 ºC in Standard Solution		
	KCl 1.00M	KCl 4.00M	KCl saturated
ZoBell's solution	+192	+228	+229

Appendix A. Acceptance Log
INNOVATIVE SENSORS MODEL CSIM11 ORP SENSOR

Serial Number _____

Date & Time	Condition		KCl reference check (mV)	Time to stable reading (min)[1]	Calibration done?	KCl reference check (mV)	Action	Analyst
	Pt sensing element	Porous junction						

[1]Should be stable within ±1 mV in less than 10 min

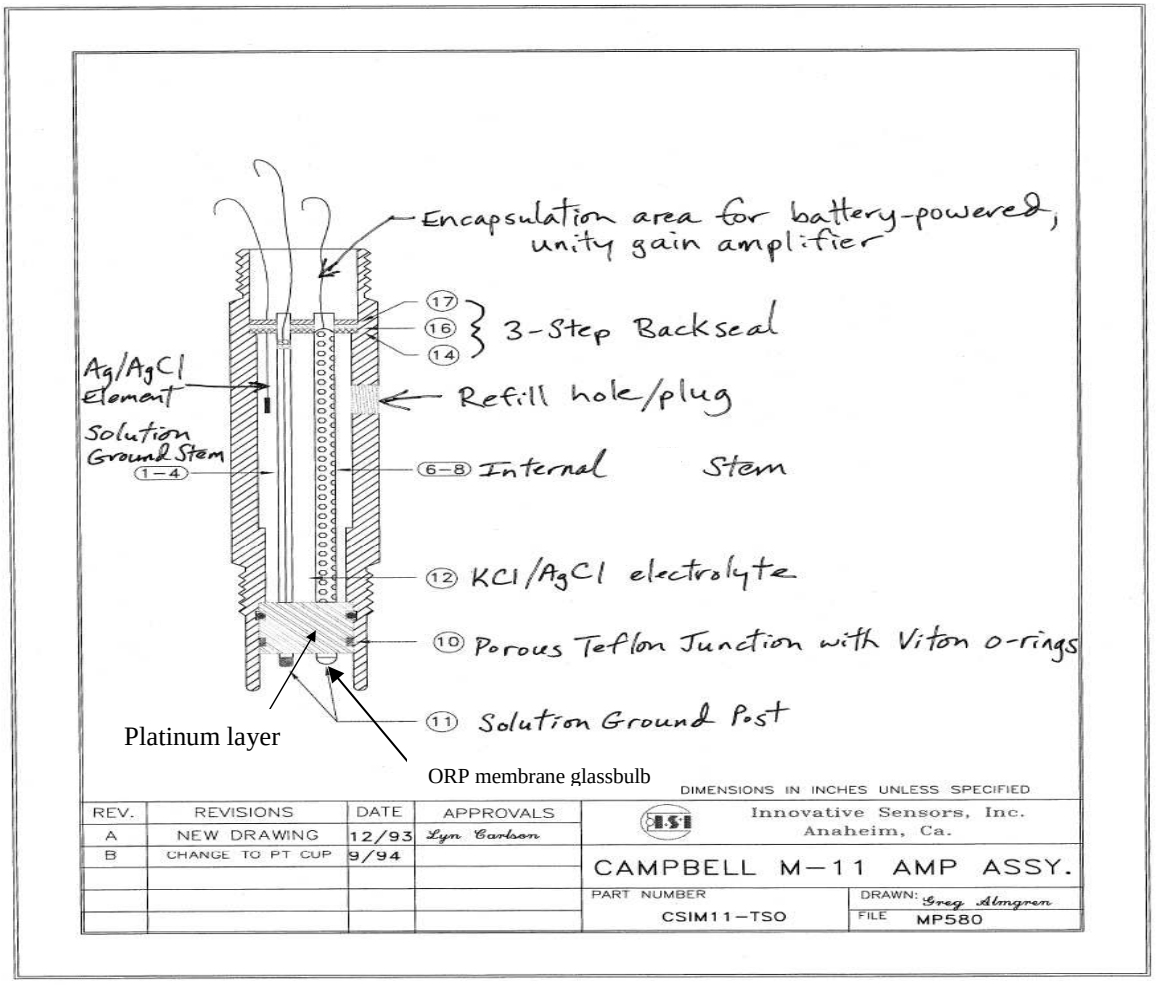
Appendix B**. Calibration Form**
INNOVATIVE SENSORS MODEL CSIM11 ORP SENSOR

Serial Number _____

Date & Time	T (°C)	Redox standard ORP (mV)			Action (Retest, Replace)	Analyst
		Expected	Measured	Error (Expected-measured)		

Appendix C. ORP Probe Diagram

INNOVATIVE SENSORS MODEL CSIM11 ORP SENSOR



MEASUREMENT OF LAGOON SLUDGE DEPTH
WITH MARKLAND MODEL 10 PORTABLE SLUDGE GUN
Standard Operating Procedure (SOP) L5

MEASUREMENT OF LAGOON SLUDGE DEPTH WITH MARKLAND MODEL 10 PORTABLE SLUDGE GUN

Standard Operating Procedure (SOP) L5

Prepared by

Chris D. Fullerton and Richard H. Grant

Reviewed by

Bill W. Bogan and Albert J. Heber

Effective Date: November 6, 2006

PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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Appendix A. Markland Model 10 Sludge Gun Calibration Form 9

Appendix B. Sludge Depth Field Data Form 10

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1. Scope and Applicability

1.1. The depth of a livestock waste lagoon can influence emissions from the lagoon.
1.1.1. The ratio of surface area to volume is an important parameter governing emission of NH_3 (Ullman and Mukhtar, 2004).
1.2. Optical transmission of infrared light can be used to detect changes in the solids content of a liquid.
1.3. This SOP document applies only to the Markland Model 10 Sludge Level Detector, or "Sludge Gun".
1.3.1. The measurement (depth) range of this instrument is 0 to 10 m.
1.3.2. Measurement accuracy (under laboratory conditions) is ±1 cm.
1.3.3. Measurement precision (under laboratory conditions) is ±0.5 cm.

2. Summary of Method

The Markland Model 10 Sludge Level Detector uses high-frequency pulses of a solid-state infrared light-emitting diode, received by a phototransistor, to detect the transmittance of infrared radiation through the liquid enclosed within an open chamber (such as a lagoon or basin). The sensor detects a noise as it receives these pulses; the pitch of this noise increases as the degree of infrared transmittance by the lagoon increases, indicating increasing solid content.

Once during each time the site is set up for a measurement period (one per season), nine individual measurements will be taken from specified areas of the lagoon using the pattern and approximate locations specified on the Depth Plot Worksheet (Appendix D) with the above-described probe. These will be averaged together, and recorded on the "Sludge Depth Field Data Form" (Appendix B). The original Depth Plot Worksheets will then be filed for scanning into the computer and retained according to SOP D1.

3. Definitions

3.1. SOP Standard operating procedure

4. Health and Safety

4.1. Wear proper Personal Protective Equipment
4.1.1. Use life jackets at all times when near the edge of the lagoon, and when using the sampling boat.
4.1.2. Always have the life-line rope attached to your waist and in reach of your field partner (on berm) when in the boat.
4.1.3. Do not attempt to take measurements from the lagoon or board the sampling boat if your field partner is not watching from the berm.

4.1.4. Do not attempt to take measurements from the lagoon or board the sampling boat if threatening weather is nearby or imminent.
4.1.5. Use safety glasses when near the lagoon water, and take care not to splash lagoon contents on clothes.
4.1.6. Use rubber gloves when handling the Markland sludge gun, the boat, or any other gear that may have come in contact with the lagoon contents.
4.2. Wash and dry gloves before storing
4.3. Wash hands after working in the lagoon or on anything that may come in contact with lagoon contents.
4.4. Notify your field partner and apply decontamination and correct field dressing if you accidentally cut yourself or puncture the skin in any manner while handling the sludge gun or any material that may have come into contact with the lagoon contents.
4.5. It is recommended to wait until close to the end of the day to take measurements from the lagoon if possible so you can proceed to change clothes and shower as soon as possible afterwards.
4.5.1. Have a spare change of clothes at the site with you at all times.
4.6. If you fall into the lagoon or become soaked with fluids from the lagoon:
4.6.1. Immediately notify your partner.
4.6.2. Immediately wash your face and hands.
4.6.3. Locate shower facilities and change clothing if your skin has become soaked.
4.6.3.1. If needed, arrange for transport to your hotel to change clothes and shower, return to work site as soon as possible afterwards.
4.6.3.1.1. Place plastic sheeting on the seats and floor of the work vehicle to avoid contaminating them.

5. Cautions

5.1. Twisting the cable will damage it.
5.2. If the probe is to be lowered in the vicinity of any moving rakes or scrapers, make sure these are stopped first.
5.3. Unwind and rewind cable slowly, to avoid stirring up a large ‘cloud’ of sludge, which would result in inaccurate readings.
5.4. Never drop the probe into any tank with a hard (e.g. concrete) bottom.

6. Interferences

6.1. Battery life is shortened in cold weather. For accurate readings, use new batteries during winter operation (i.e. if temperature is near or below freezing).

7. Personnel Qualifications

7.1. Each member of the field staff must read and understand this SOP before operating this instrument.

8. Equipment and Supplies

8.1. Model 10 Sludge Level Detector (Markland Specialty Engineering, Toronto, Canada)
8.2. Cloth and rubbing alcohol
8.3. Dish soap
8.4. 500-mL beaker to serve as a calibration chamber
8.5. Water softener resin
8.6. 50-ft tape measure with metric markings
8.7. 1-m ruler with float
8.8. 10-cm ruler
8.9. Heavy duty rubber gloves (2 pair)
8.10. (2) Safety glasses
8.11. (2) Life vests
8.12. 300-ft Life-line rope capable of lifting 300 lbs.
8.13. Roll of plastic sheeting (for protecting vehicle from contamination with fecal matter should transport be necessary with contaminated clothing)
8.14. AA alkaline batteries (sensor uses 6)
8.15. Heavy duty two man inflatable raft with oars
8.16. Portable 12-VDC inflation unit.

9. Procedures

9.1. Acceptance
9.1.1. Unpack the unit and check for visible damage or missing parts.
9.1.2. Clean the cable using the following method.
9.1.2.1. Unreel all the cable from the probe and lay it out in a straight line on a clean grassy area. Wipe the entire cable with a clean cloth saturated with rubbing alcohol. Allow a few minutes for the cable to dry.
9.1.3. Make sure the cable is clean and dry. Starting at the sensor end and working towards the "gun" body, string a 50-ft. tape measure beside the cable, with the zero end of the tape at the sensing window in the probe gap (see Fig. 1). Peel off the numbers provided with the instrument from the manufacturer and place the "1" at the 1-m mark on the cable, "2" at the 2-m mark, etc.
9.1.4. Calibrate sensor according to Section 9.2
9.1.4.1. If the sensor cannot be calibrated to within the accuracy and precision limits given in Sections 1.3.2 and 1.3.3, return sensor to manufacturer for repair or replacement.
9.2. Calibration
9.2.1. Set sensitivity on the Sludge Level Detector in midpoint of range, using the knob on the back of the handle (Fig. 1). Rotate the control knob so that, with the trigger depressed, there is no sound when the probe is in air or in the liquid at the top of the tank, and the high-pitched note sounds when the probe is in the sludge at the lagoon bottom.
9.2.2. Add 200 mL of resin and 200 mL of tap water to the 500-mL beaker.

9.2.3. Record water depth (in mm) to top of resin on calibration form (Appendix A).
9.2.4. Clamp sensor portion of the instrument to a stand at a height of < 1 m.
9.2.5. Place beaker below sensor.
9.2.6. Lower probe into water until sensor speaker makes a sound.
9.2.7. Holding the cable at the point where it reaches the water line, remove cable and record length of cable from waterline to sensor on calibration form.
9.2.8. Repeat Sections 9.2.4 through 9.2.8 eight additional times.
9.2.9. Calculate precision and accuracy from the 9 sets of measurements as indicated on the calibration form (Appendix A).

9.3. Determining average depth of sludge and water for the lagoon

9.3.1. Refer to Depth Plot Worksheet (Appendix D) for proper sampling locations.
9.3.1.1. Visualize a grid over the lagoon to be measured consisting of intersecting points by making vertical lines from one edge of the lagoon to the other, at approximately the ¼ point the ½ way point and the ¾ point, and doing the same in the horizontal direction.
9.3.2. Switch gun on. A short 'beep' indicates nominal operation.
9.3.3. Proceed to the first sampling point on the grid.
9.3.4. To unwind or rewind cable, point the gun downward and rotate the whole gun in a circular motion. The cable will come off the front of the spool. Unwind only as much cable as needed, then pass it through the pinch-groove at the front of the gun (Fig. 1). To get the cable back up onto the spool, guide the cable with one hand and rotate the whole gun with the other, so the cable comes back onto the spool.
9.3.5. Slowly lower the probe while squeezing the probe trigger.
9.3.5.1. If the sensitivity control is set correctly, there will be no sound.
9.3.5.2. If sound is heard, adjust sensitivity according to Section 9.2.1.
9.3.5.3. As the probe nears the sludge bed, the sensor emits a low-pitched sound.
9.3.5.4. The volume and pitch will increase as the solids concentration increases.
9.3.5.5. Keep the trigger depressed and slowly lower the probe to the bottom of the lagoon (the cable will go slack when on the bottom).
9.3.5.5.1. Record the first cable marker number above the waterline on the Depth Plot Worksheet as value "A" for the current location shown on the worksheet.
9.3.5.5.2. Using the one-meter ruler, measure the distance from this marker to the waterline, and record as value "B".
9.3.5.6. Slowly raise the sensor probe cable until the sound just stops.
9.3.5.6.1. Record the first cable marker number above the waterline as value "C"
9.3.5.6.2. Using one-meter ruler, measure distance from marker to waterline, and record as value "D".
9.3.6. Repeat Section 9.3.5 for each additional required measurement location, filling in all values on the Depth Plot Worksheet.

9.3.7. Determine averages for values A, B, C, and D by adding all the measurements for that value (A, B, C, or D) and dividing by the number of measurement locations (9). Enter the averaged values on the "Sludge Depth Field Data Form" (Appendix B) in the appropriate field. File the completed Depth Plot Worksheet to be scanned and saved according to SOP D1.

9.4. Preventive maintenance after each set of measurements at the field site

9.4.1. Clean sensor and sensor cable with water and soap and dry before storage.

9.4.1.1. Clean sludge depth gun by unwinding cable and lay cable out lengthwise in a clean grassy or snowy area and then wipe sensor and cable with cloth saturated with soap and water and rewind cable using a dry clean cloth.

9.4.2. Inspect sensor cable for damage. Repair or replace as necessary to maintain cable integrity and wire continuity.

9.4.3. Store indoors (i.e. in the open-source instrument trailer) when not in use.

9.5. Troubleshooting

9.5.1. With the probe in air, if a low-pitched ticking occurs as soon as the trigger is depressed, and does not stop upon turning the sensitivity control, this indicates that either the probe is dirty or the batteries need to be replaced.

9.5.1.1. Clean probe and retest.

9.5.1.2. If ticking persists, replace batteries. Remove two screws and take off rear speaker, pull down on the spring-loaded plunger, and slide out the Battery Pack. Insert new batteries, checking orientation against that shown on the pack.

9.5.2. Repeated constant values indicate sensor failure. Replace sensor.

10. Data and Records Management

10.1. Record original calibration and measurement data on appropriate forms (Appendices A and B, respectively), which are kept in a waterproof bound record book designated for lagoon sensors.

10.2. Transfer calibration and measurement data to worksheets of the electronic field notes spreadsheet designated for this method.

10.2.1. Reserve one worksheet for calibration data, and one for measurement data.

10.3. Document all written data and information in site logbooks with permanent ink.

10.4. Overstrike errors in writing with a single line. Initial and date all corrections.

10.5. Manage all data is managed according to SOP D1.

11. Quality Control and Quality Assurance

11.1. Calibrate (Section 9.2) the sensor quarterly.

11.2. Clean sensor and cable (Section 9.4.1) and inspect for damage (Section 9.4.2) after every use.

11.2.1. If damaged, repair wires and encase cable with waterproof heatshrink tubing.

12. References

12.1. Sludge Gun Manual. 2006. Markland Model 10 Sludge Gun Operating Instructions. Markland Specialty Engineering, Ltd., Toronto, Canada

12.2. SOP D1. 2006. Management of Open-source, Weather, and Lagoon-characterization Data. Standard Operating Procedure D1. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

12.3. Ullman, J.L. and S. Mukhtar. 2004. Implications on ammonia emissions from dairy facilities using dry-lot versus hybrid (free-stall) housing practices. ASAE Paper #044064. American Society of Agricultural Engineers, St. Joseph, MI.

13. Contact Information

13.1. Distributor: Markland Specialty Engineering, Ltd
48 Shaft Road, Toronto, Ontario, Canada M9W 4M2
Tel: 416-244-4980, Fax: 416-244-2287
email: markland@sludgecontrols.com

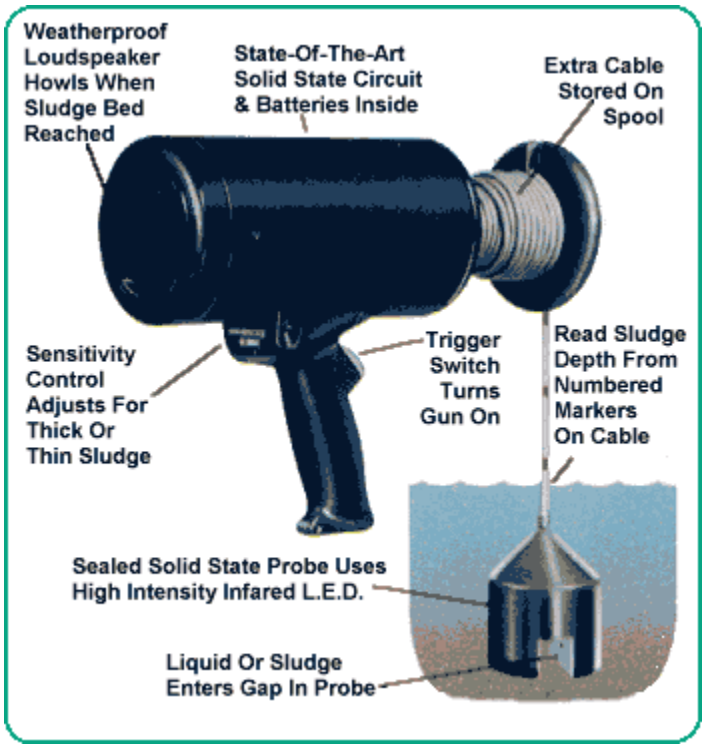


Figure 1. Markland Model 10 Sludge Gun.

Appendix A
Markland Model 10 Sludge Gun Calibration Form

Serial Number _____ Date (DD-MM-YYYY)

_____

Person Calibrating _____ Action:

(Accept / Adjust / Replace)

Actual depth of resin layer (mm)	Measured Depth (mm)
	Trial #1
	Trial #2
	Trial #3
	Trial #4
	Trial #5
	Trial #6
	Trial #7
	Trial #8
	Trial #9
Mean	
Standard Deviation (Precision)	
Accuracy (Measured depth – Actual depth)	

Appendix B
Sludge Depth Field Data Form

Location: _____ Sensor serial number _____

Date (D-M-Y)	Time (EST)	**Average Bottom Depth (m)**			**Average Sludge Depth (m)**			Comments	Persons measuring
		Cable Marker # (A)	Distance to Waterline (B)	Bottom Depth (A – B)	Cable Marker # (C)	Distance to Waterline (D)	Depth to Sludge Layer (C – D)		
									/
									/
									/
									/
									/

/

Appendix C

MARKLAND SPECIALTY ENGINEERING LTD.
OPERATING INSTRUCTIONS MODEL 10 SLUDGE GUN®

Cable Markers

Make sure the cable is *clean and dry*. String a 50 ft. tape measure beside the cable, with the zero end of the tape at the Probe. Carefully peel off the numbers and place the "1" at the 1ft. mark, "2" at the 2ft. mark, etc… Metric or any other units can also be used. Placing a strip of black vinyl electrical tape midway between the number markers permits more precision in reading the depth.

Sensitivity Adjustment

This thumb adjustable control is at the back of the handle. Rotate the control knob so that with the trigger depressed, there is no sound with the Probe in air or when it is in the liquid at the top of the tank, and the high pitch note sounds when the probe is down in the sludge. This setting is not critical. The sensitivity control is mainly needed for extremely thick or thin slurries, or for boosting the power as the batteries get weak.

Unwinding/Rewinding Cable

Point the Gun downward and rotate the whole Gun in a circular motion and the cable will come off the front of the spool like a fishing line coming off a reel. Unwind only as much cable as needed, then pass it through the pinch- groove at the front of the Gun. To get the cable back up onto the spool, guide the cable with one hand and again rotate the whole Gun with the other hand so the cable comes back onto the spool. ***Do not twist the cable!***

Finding The Sludge Blanket

Lower the Probe while squeezing the trigger. If the Sensitivity control is set right (see Sensitivity Adjustment) no sound will be heard. As the Probe nears the sludge bed a low pitch sound will come from the speaker. This will increase in volume and rise in pitch as the solids concentration increases. Keep the trigger depressed and lower the Probe to the bottom of the tank (the cable will go slack when on the bottom). Read the cable marker opposite the handrail (for example - 25ft.). The speaker will still be howling with the trigger depressed and the Probe in the sludge. *Slowly* raise the cable until the note starts to become lower pitched, and again read the marker opposite the handrail (for example - 20 ft.). Continue *slowly* raising the Probe until the sound stops and read the cable marker (for example - 18 ft.). In this example, you would have 5ft. of dense sludge, covered by 2 ft. of a partially settled sludge 'cloud'. Remember to move *slowly*, or you will stir up a large 'cloud' and confuse the reading.

Battery Replacement

Batteries will last about one year in normal service. With the Probe in air, if a low pitched ticking is heard as soon as the trigger is depressed, and this cannot be removed by turning the sensitivity control, this indicates that either the Probe is dirty and needs washing, or the batteries are weak and will soon need to be replaced. Ignore the short beep that is heard when the Gun is first switched on. This is normal. Battery life is shorter when the Gun is used at low temperatures. To change batteries, remove two screws and take off rear speaker, pull down on spring loaded plunger and slide out the Battery Pack. Replace with AA size Pencell Alkaline batteries, and be careful to install in the direction shown on the Battery Holder.

Appendix C (continued)

MARKLAND SPECIALTY ENGINEERING LTD.
OPERATING INSTRUCTIONS MODEL 10 SLUDGE GUN®

Cold Weather Operation

Battery output is greatly reduced at low temperatures. It is suggested that the Gun be fitted with new batteries if it is going to be used at temperatures near or below freezing. The Gun should be stored indoors when not in use.

Probe

The solid-state Probe is sealed and requires no maintenance other than washing. The cable is sealed at the Probe and can't be disconnected. If defective, the entire Probe/Cable assembly must be replaced. Care should be taken not to tangle the Probe in Rakes or Scrapers, which should be stopped before lowering the Probe into the tank. Do not drop the Probe onto the concrete tank bottom, lower it slowly. Quickly dropping the Probe stirs up the sludge bed making readings difficult, and could cause Probe damage.

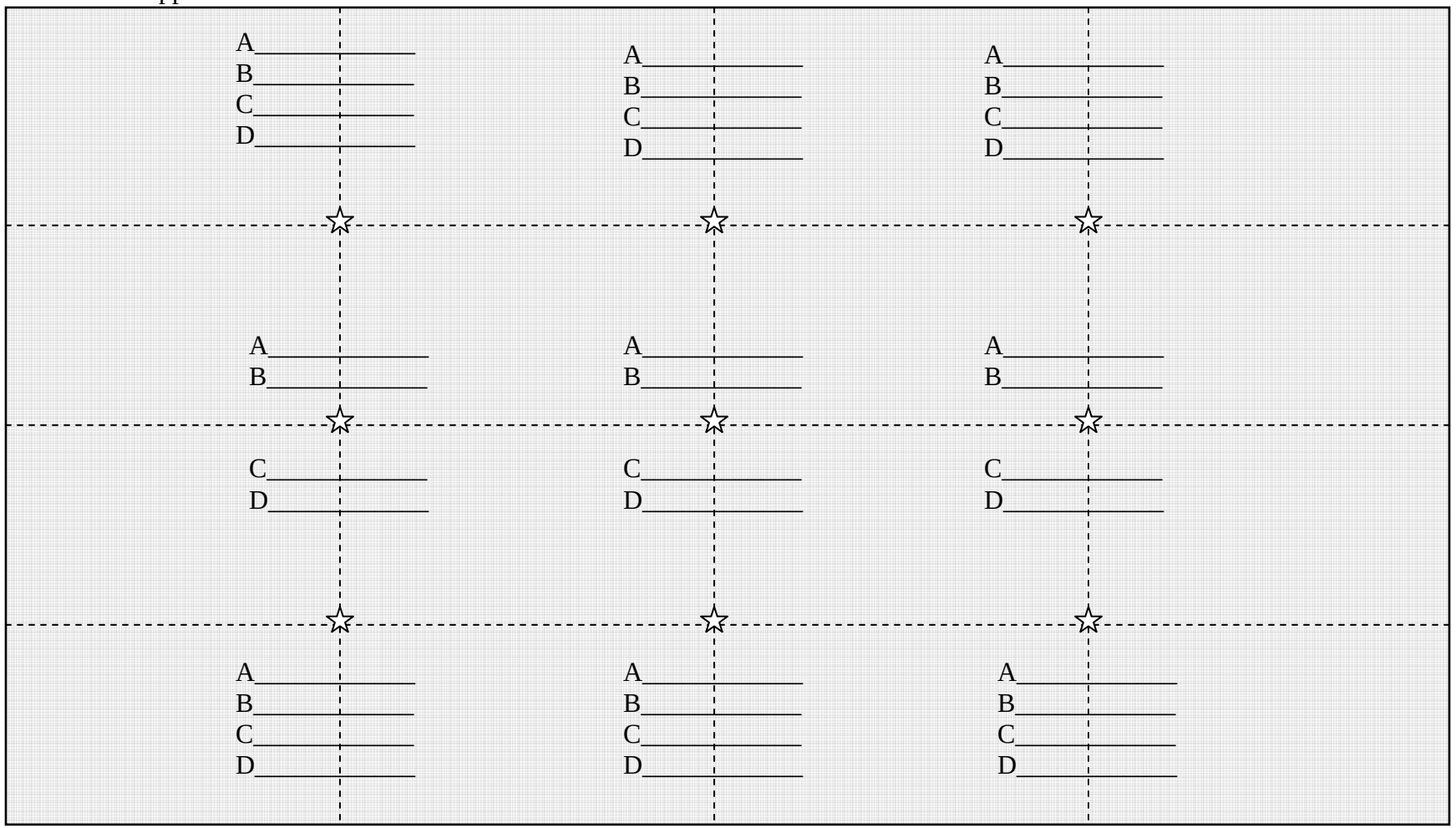
Appendix D

Depth Plot Worksheet

Location: _____ Date:_____Operator:_____

Sensor serial number _____

☆ Denotes approximate measurement locations



MANURE SAMPLING
Standard Operating Procedure (SOP) M1

MANURE SAMPLING

Standard Operating Procedure (SOP) M1

Prepared by
Sam M. Hanni and Bill W. Bogan

Reviewed by
Albert J. Heber and Teng Teeh Lim

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PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)
Agricultural and Biological Engineering, Purdue University
West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The release of ammonia from manure in livestock barns and storage areas is affected by manure pH, moisture content, and nitrogen and ammonia contents. Manure must be collected to determine these parameters.

1.2. Data on nitrogen content of manure at the end of its storage period is also needed to develop a N balance for the facility (SOP S5).

1.3. This SOP describes the procedures for collecting manure samples from broiler, layer, dairy, and swine barns, and from manure storage areas, during tests of air emissions.

1.3.1. Manure samples may need to be collected from various types of storage or treatment facilities, including deep pits under buildings, collection channels, drainage pipes, outdoor storage basins, lagoons, and storage piles.

1.4. This SOP provides information on selecting sampling locations and methods to capture representative samples.

1.5. The sampling methods described in this SOP are adapted from References 11.1 – 11.4.

2. Summary of Method

Different sampling equipment and techniques should be selected based on manure characteristics (liquid or dry samples) and the type of facility that is being sampled. Storage basins and lagoons can be sampled with either a conduit-mounted container sampler, a sampling tube with a stopper, or a telescoping ladle. The ladle is also well-suited to sampling collection channels or drainage pipes. Deep pits under slatted floors can be sampled with a sampling tube with a stopper, or with a manure/sludge sampling pump. Manure storage piles that do not contain significant litter, feathers, or other material can be sampled using a tube corer. If, however, litter and feathers are plentiful, sampling can be conducted using a shovel or spade. Several sub-samples can be taken to produce a composite sample. It is important to take a sufficient number of samples to be representative of the manure storage or treatment unit. The times at which manure is sampled will depend on the data required. For example, if the sample is intended to provide data on initial manure parameters (pH, moisture, N and/or NH_3 content) that may affect emissions, it may be desirable to collect fresh manure. If, on the other hand, the final N content of aged manure leaving a storage facility is needed for an N balance, sampling should coincide with the emptying of the storage unit. Exact sampling times for each site will be specified in the Site Monitoring Plans in the QAPP for the specific project.

3. Definitions

3.1.	COC	Chain of custody
3.2.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.3.	QAPP	Quality Assurance Project Plan

4. Health and Safety

4.1. When sampling manure, wear Tyvec suits, shoe covers, and gloves. Wear a respirator to prevent exposure to manure gases.
4.2. Sample, mix, and package all samples in a well-ventilated area.
4.3. Agitation of manure in storage facilities (e.g. deep-pit systems) may release gases that cause very strong odors, and high concentrations that are a severe (i.e. lethal) health hazard (Lorimor et al. 2004).
  4.3.1. If agitation is deemed necessary for accurate sampling, either remove all animals and persons from the facility before beginning agitation, or open or turn on all available ventilation sources (doors, windows, exhaust fans) throughout the agitation and sampling process.
4.4. Be aware of slippery surfaces.
4.5. When collecting samples from confined storage spaces, make sure there is someone watching from a safe area.
4.6. Do not attempt to take samples from manure piles that are too moist and soft to walk on. If the manure becomes too soft, wait to take samples until it is dry enough to walk on, or until it is removed from the building.
4.7. Keep manure sampling equipment and samples away from your mouth and face.
4.8. Be aware of aggressive livestock that may interfere with the sampling process.
4.9. If animals are interfering with the sampling procedure at a particular location, contact the farm manager so that the animals can be temporarily removed from the location.

5. Interferences

5.1. Clean all equipment thoroughly between samplings and sampling locations, using a scrub brush and a bucket of hot, soapy (antibacterial dish soap) water. Check all equipment visually and make sure there is no remaining manure attached.
5.2. Nutrient stratification can occur in non-agitated basins, pits, and lagoons. In these cases, it can be particularly important to collect subsamples from as wide a range of depths as possible, so they can be composited to obtain samples that are representative of the entire vertical profile.

6. Personnel Qualifications

6.1. Personnel should read and understand this SOP and be trained in the use of sampling equipment.
6.2. Personnel should be trained in proper handling and labeling of samples, and in the storage and shipping process.
6.3. The individual taking samples should be able to locate the place from which samples are to be taken.

7. Equipment and Supplies

7.1. Conduit-mounted container sampler (Fig. 1) for sampling basins and lagoons
  7.1.1. The container sampler consists of a long conduit, with a handle at one end and a container with a spring-loaded lid on the other. A cable is attached to the lid of the container, and runs up the conduit and through the handle. When pulled, the cable opens the lid of the container; when released, the spring closes the lid. This type of sampler is particularly useful for collecting samples below the surface of a storage basin or lagoon, if concurrent collection of the surface layer is not required.
7.2. Sampling probe or tube (Fig. 2) for sampling lagoons or deep pits
  7.2.1. Make the sampling tube from a PVC tube.
  7.2.2. For sampling a deep pit, choose a sampler that has an outside diameter smaller than the slot opening of the slats.
  7.2.3. For sampling open pit or lagoon, use a tube with a larger outside diameter (up to 6″) to reduce the sampling time.
  7.2.4. The sampling tube is equipped with a string running the length of the tube. One end of the string is attached to a rubber stopper or ball with a diameter larger than that of the tube; on the opposite end, the string is attached to the sampling tube.
7.3. Telescoping sampler for sampling collection gutters or channels
  7.3.1. CONBAR telescoping dipper, Enviro-Tech Services, Martinez, CA (or equivalent)
  7.3.2. Sampler consists of three nested 4.5′ metal conduit sections, which telescope out to a total length of 12′. The end of the sampler has a screw-tight mounting for a 600-mL polypropylene beaker.
7.4. Manure/sludge sampling pump and collection system for sampling deep pits under slatted floors
  7.4.1. Pump: ¼-horsepower, Gast Model 0523-V191Q-G588DX, or equivalent
  7.4.2. Erlenmeyer filtering flasks (2) 2-L or larger. Polypropylene is preferred over glass for safety reasons.
  7.4.3. Stoppers and tubing to connect the two flasks in series
  7.4.4. Sampling tubing – wall of tubing must be thick enough to withstand collapse under the vacuum from the pump.
  7.4.5. PVC pipe or similar rigid support to guide tubing into the pit and allow sampling at depth
  7.4.6. Cable ties
7.5. Metal tube corer (Fig. 3) for sampling manure piles
  7.5.1. The corer consists of a thin-walled metal tube with a solid metal handle.
7.6. Sledgehammer
7.7. Sharp spade for sampling of feather-containing manure piles
7.8. Five-gallon buckets, hand plungers, and mixing rods for sample homogenization
7.9. Tyvec suits, shoe covers and gloves
7.10. Bucket, scrub brush and antibacterial dish soap
7.11. Freezer for storage of manure samples prior to shipping
7.12. Shipping materials
  7.12.1. Insulated cooler
  7.12.2. One-quart plastic bottles or equivalent

7.12.3. 8″ x 10″ and 9″ x 12″ zip-lock plastic bags
7.12.4. Moisture-proof labels for sampling containers
7.12.5. Shipping peanuts and/or expandable shipping foam
7.12.6. “Blue ice” or other cooling agent
7.12.7. Duct tape or packing tape
7.12.8. Shipping and chain-of-custody (COC) forms

8. Procedures

8.1. Sampling basins or lagoons with container sampler
8.1.1. Immerse container portion of sampler below the surface of the basin.
8.1.2. Pull cable to open container lid and allow sample to fill the open container, then release to close. Avoid collecting floating debris, as these may bias the analysis.
8.1.3. Transfer collected sample into a five-gallon bucket.
8.1.4. Take multiple samples in order to make a composite sample.
8.1.4.1. If the composite sample is intended to represent the entire basin or lagoon, take each individual sample at a different location.
8.1.4.2. If the sample is intended to represent fresh manure, sample from the inlet as manure is entering the basin or lagoon.
8.1.4.3. The total number of samples needed from each basin or lagoon, and the number of different locations needed, will be specified in the QAPP for a specific project.
8.1.5. Mix the composite sample with a hand-held plunger (using an up-and-down motion) until it is well-mixed.
8.1.6. While mixing is maintained, withdraw sample using a cup or similar instrument.
8.1.7. Fill a one-quart plastic bottle not more than three-quarters full and cap tightly.
8.1.8. Log the sample (Section 10.1) and follow the shipping procedures in Section 8.7.
8.2. Sampling deep pits or lagoons with sampling tube
8.2.1. Insert sampling tube into the lagoon or deep pit until touching the bottom, with the stopper open.
8.2.2. Pull string attached to stopper to seal the end of the sampling tube. Retract the tube, being careful to avoid tipping the tube and spilling the sample.
8.2.3. Release the sample into a five-gallon bucket.
8.2.4. Take multiple samples to make a representative composite sample.
8.2.4.1. If the composite sample is intended to represent the entire deep pit or lagoon, take each individual sample at a different location.
8.2.4.2. If the sample is intended to represent fresh manure, sample from the inlet as manure is entering the lagoon, or from the top layer of the deep pit.
8.2.4.3. The total number of samples needed from each pit or lagoon, and the number of different locations needed, will be specified in the QAPP for the specific project.
8.2.5. Use a mixing rod to stir the contents of the bucket; this will resuspend settled solids.
8.2.6. While agitating the liquid, use a ladle to transfer the sample into a plastic bottle until the bottle is three-quarters full.
8.2.7. Securely fasten the lid onto the container.
8.2.8. Log the sample (Section 10.1) and follow the shipping procedures in Section 8.7.

8.3. Sampling lagoons or collection gutters with telescoping sampler

8.3.1. If not already attached, attach the polypropylene beaker to the end of the sampler. Extend the sampler to the desired length, and immerse container portion of sampler below the surface of the manure.

8.3.2. Transfer the collected sample into a five-gallon bucket. Follow Steps 8.2.4-8.2.8 above to collect and mix a composite sample and prepare it for shipping.

8.4. Sampling deep pits under slatted floors with a pump

8.4.1. Connect two filtering flasks in series with the sampling pump, as shown in Fig. 4.

8.4.2. Attach the sampling tubing to the PVC pipe or other support using cable ties. Slide the tubing/support into the manure in the pit to the desired depth. Unless it is specifically intended to sample the sludge layer that is most likely present at the bottom of the pit, it may be desirable to avoid lowering the sampling tube all the way to the bottom, as the sludge may block the tubing.

8.4.3. Turn on the sampling pump. Collect approximately 1 L of manure in the first flask (half full). The second flask should serve as a trap to keep manure from entering the pump.

8.4.4. Turn off the pump and disconnect the sample flask. Mix the contents, either with a stir bar or by swirling, and transfer (pour) the sample into a plastic bottle until the bottle is three-quarters full. Alternatively, if the sample is to be composited with others before taking the final sample, follow Sections 8.1.3–8.1.7.

8.4.5. Securely fasten the lid onto the container.

8.4.6. Log the sample (Section 10.1) and follow the shipping procedures in Section 8.7.

8.4.7. Discard the remainder of the manure from the sample flask, and rinse the flask before re-connecting to collect the next sample.

8.5. Sampling storage piles with a spade and/or scoop

8.5.1. With a scoop and a bucket, collect samples throughout the manure storage piles. Take multiple samples in order to make a representative composite sample.

8.5.1.1. If the composite sample is intended to represent the entire storage pile, take each individual sample at a different location.

8.5.1.2. If the sample is intended to represent fresh manure, sample from newest portion of the pile (if necessary, consult with farm personnel to identify this portion).

8.5.1.3. The total number of samples needed from each storage pile, and the number of different locations needed, will be specified in the QAPP for the specific project.

8.5.2. Once all of the samples have been collected, lay a piece of clean plastic on the ground and place the samples onto the plastic.

8.5.3. Using a shovel, continuously scoop the outside of the pile to the center of the pile, and mix the center, until the composite pile is thoroughly mixed.

8.5.4. Use a scoop to collect a composite sample from the mixed pile into a one-quart sealable bag. Fill the bag approximately halfway.

8.5.5. Squeeze excess air out of the bag, seal the bag, and place the bag into a second bag, which should be larger than one quart (e.g. 9″ x 12″) for ease of handling.

8.5.6. Log the sample (Section 10.1) and follow the shipping procedures in Section 8.7.

8.6. Use of core sampler for sampling storage pile

8.6.1. Insert the corer into the manure storage pile. If needed, use a sledgehammer to pound the tube portion of the corer into the manure, until it touches the bottom of the pile.

8.6.2. Remove the core sampler from the manure pile.
8.6.3. Using a long rod or broom handle, push sample from corer into a clean bucket.
8.6.4. Take multiple samples to make a composite sample. The total number of samples needed from each pile will be specified in the QAPP for the particular project.
8.6.4.1. If the composite sample is intended to represent the entire storage pile, take each individual sample at a different location.
8.6.4.2. If the sample is intended to represent fresh manure, sample from newest portion of the pile (if necessary, consult with farm personnel to identify this portion).
8.6.4.3. The total number of samples needed from each storage pile, and the number of different locations needed, will be specified in the QAPP for the specific project.
8.6.5. Once all of the samples have been collected, lay a piece of clean plastic on the ground and place the samples onto the plastic.
8.6.6. Using a shovel, break up any chunks that may be present. Continuously scoop the outside of the pile to the center of the pile, and mix the center, until the composite pile is thoroughly mixed.
8.6.7. Use a scoop to collect a composite sample from the mixed pile into a one-quart sealable bag. Fill the bag approximately halfway.
8.6.8. Squeeze excess air out of the bag, seal the bag, and place the bag into a second bag, which should be larger than one quart (e.g. 9″ x 12″) for ease of handling.
8.6.9. Log the sample (Section 10.1) and follow the shipping procedures in Section 8.7.
8.7. Handling and shipping samples
8.7.1. Label all samples with sample location, date and the name of the personnel who collected the samples. Include a completed COC form with each shipment. Enclose COC form in a zip-lock back to keep it dry and clean.
8.7.2. Load all samples into the cooler they will be shipped in. Add the desired amount of blue ice, ice-gel packs, or equivalent. If necessary, add sufficient packing material (such as packing peanuts or expandable packing foam) to keep the samples from shifting. Place the packed cooler in the freezer overnight (at minimum).
8.7.2.1. Make sure that the cooler is not contaminated with chemicals or manure, and that it can be properly sealed. Use duct tape or packing tape to keep the cooler closed during shipping.
8.7.3. Use overnight shipping. Arrange shipping and receiving to ensure that samples are not held over a weekend or holiday, and that they do not arrive at the lab on a weekend or holiday.

9. Data and Records Management

9.1. Maintain all records in a worksheet of the electronic field notes spreadsheet which is designated for this method. Supplement this electronic record with a bound record book designated for the method, which should contain copies of the electronic record.
9.2. Manage data according to SOP B5.
9.3. Document all data and information on field data sheets, and within site logbooks, with permanent ink, or in electronic field notes.

10. Quality Control and Quality Assurance

10.1. Log all samples. Identify all collected samples, both on their container and in the site logbook, with the sample name and/or number, location, collection method, and date.
10.2. Check all sampling equipment before each sampling trip to make sure they are functioning properly.

11. References

11.1. Lorimor, J., W. Powers, and A.L. Sutton. 2004. Manure Characteristics. Manure Management Systems Series #MWPS-18, Section 1. Second Edition. MidWest Plan Service, Ames, IA.
11.2. MidWest Plan Service. 1998. Livestock Waste Facilities Handbook. Third Edition. MidWest Plan Service, Ames, IA.
11.3. Peters, J., S. Combs, B. Hoskins, J. Jarman, J.L. Kovar, M. Watson, A. Wolf, N. Wolf. 2003. Recommended Methods Of Manure Analysis. American Society for Agronomy-Crop Science Society of America-Soil Science Society of America Annual Meeting Abstracts. University of Wisconsin Extension Service, Madison, WI.
11.4. Sonon, L., P. Vendrell, and D. Kissel. Manure and Soil Sampling Analysis. Online at http://www.engr.uga.edu/service/extension/agp2/resources/presentation/Manure%20and%20Soil%20Sampli179.ppt. Accessed February 1, 2006.
11.5. SOP B5. 2006. Data Management for Barns. Standard Operating Procedure B5. Purdue Ag Air Quality Lab.

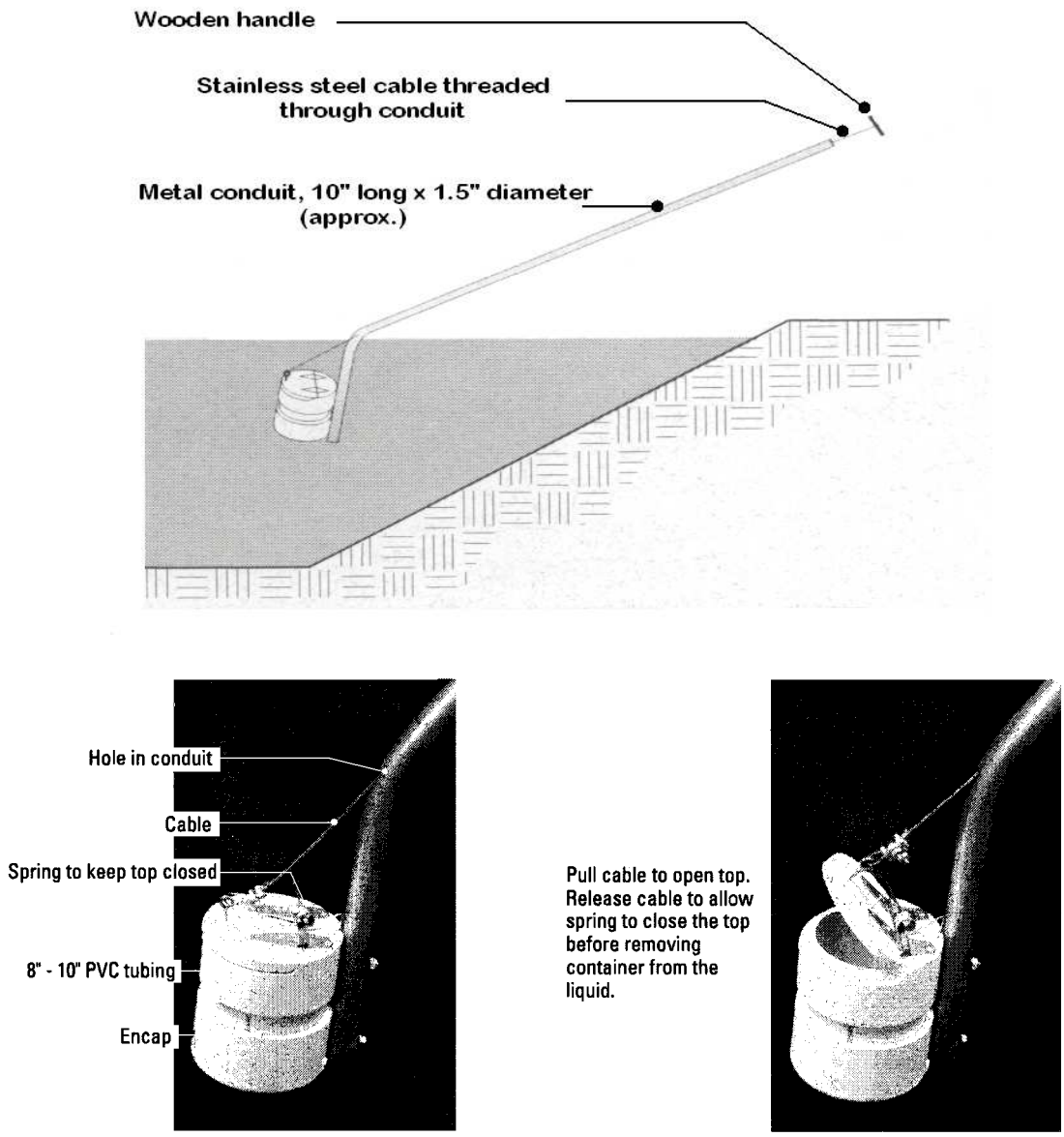

Figure 1. Conduit-mounted container sampler, with close-up showing the operation of the container lid (Lorimor et al, 2004).

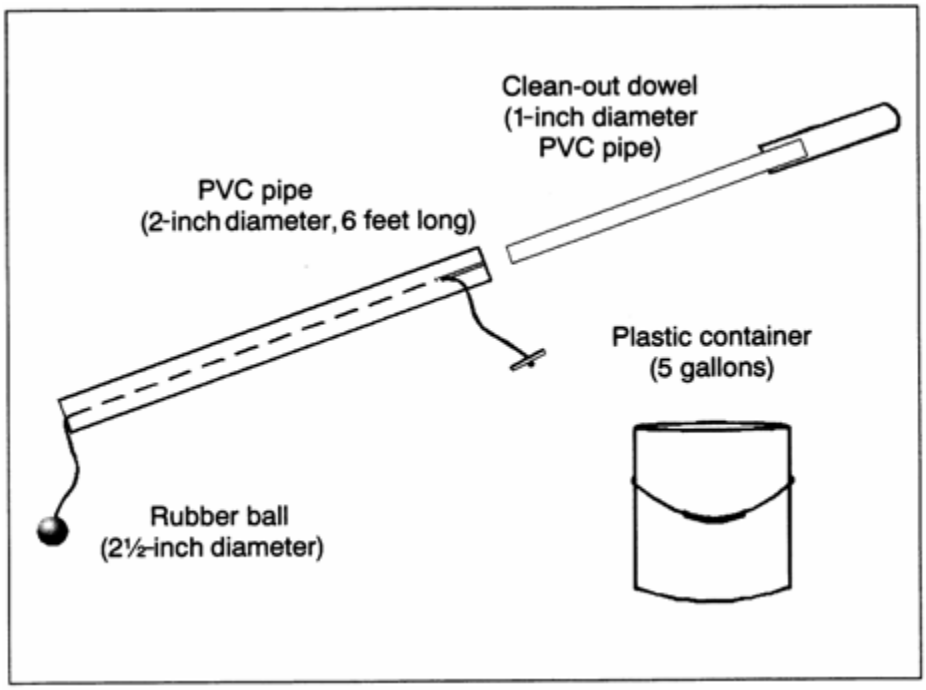

Figure 2. Liquid Slurry Sampling tube (Sonon et al., 2005). Sampler size shown is appropriate for sampling deep pits beneath slatted floors; larger diameters may be used for open lagoons.

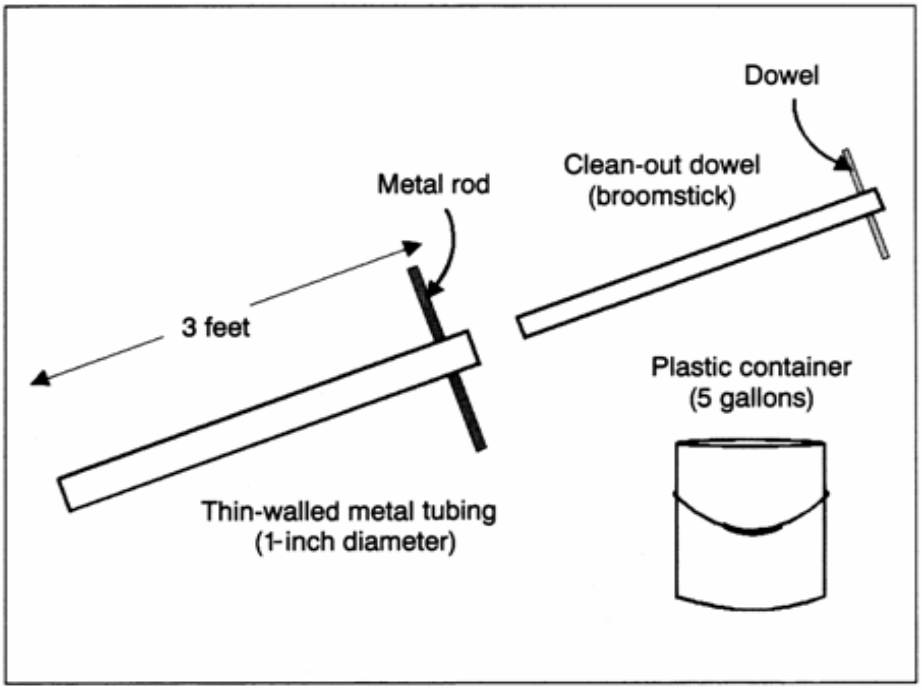

Figure 3. Core Sampler (Sonon et al., 2005).

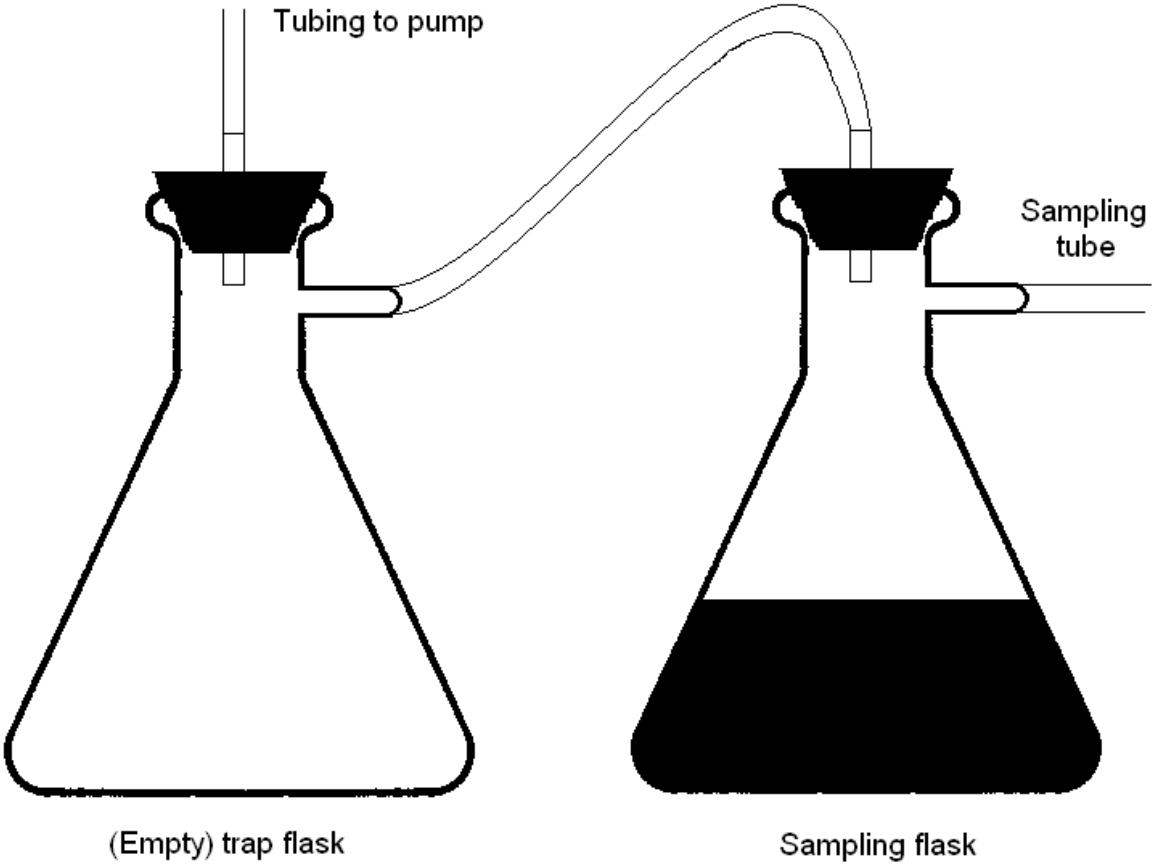

Figure 4. Sampling system for collecting manure from pits under slatted floors (e.g. from deep-pit swine barns).

CONDUCTING pH MEASUREMENTS ON MANURE SAMPLES
Standard Operating Procedure (SOP) M2

CONDUCTING pH MEASUREMENTS ON MANURE SAMPLES

Standard Operating Procedure (SOP) M2

Prepared by
Alan L. Sutton, Brian Richert, Scott Radcliffe, Dan Kelly and Bill W. Bogan

Reviewed by
Albert J. Heber, Harold M. Keener (Ohio State Univ.), and Jerome J. King (Midwest Laboratories, Inc)

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PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. A range of pH-dependent chemical and biological interactions and processes can affect the odor and overall composition of the manure.
  1.1.1. Emissions of ammonia (NH_3) increase as pH increases.
  1.1.2. Emissions of hydrogen sulfide (H_2S) decrease as pH increases.
1.2. The method detailed here is adapted from USEPA Method 9040C, "pH Electrometric Measurement", and is therefore suitable for use on aqueous wastes and those multiphase wastes (including manures) where the aqueous phase constitutes at least 20% of the total volume of the waste. Wastes which originally contain less than 20% water by volume are mixed with water, and allowed to equilibrate, prior to taking the pH measurement.
1.3. This procedure measures the pH of a manure sample using the Orion Model 310 pH meter, equipped with a KCl electrode.
  1.3.1. This instrument covers the pH range from 0.00 to 14.00.
  1.3.2. The instrument has a resolution of 0.01 pH units, and a stated accuracy of ±0.02 pH units.
  1.3.3. The Orion Model 310 can be used within the temperature range of 0°C to 100°C, and includes temperature correction over this range. Its temperature resolution is 0.1°C, with a stated relative accuracy of ±0.5°C.
  1.3.4. This instrument can be used in laboratory or on-site settings.
  1.3.5. This method allows for high-throughput analysis of samples, as analysis of one sample generally requires no more than 5 min.

2. Summary of Method

The pH of the sample is determined electrometrically using either a glass electrode in combination with a reference potential, or a combination electrode. The measuring device (pH meter) is calibrated using a series of standard solutions of known pH, which are chosen such that the calibration range brackets the samples whose pH is to be determined. Liquid samples are measured as collected, while solid samples are equilibrated with deionized water in order to obtain a reading. Because measurement of pH is sensitive to temperature, the Orion Model 310 pH meter and 82-02 electrode are equipped with a temperature-correction capability.

3. Health and Safety

3.1. Wear lab coats, gloves and face shields when handling manure samples.
3.2. Buffers may cause eye and skin irritations and may be harmful if inhaled or swallowed.

4. Cautions

4.1. Avoid rubbing or wiping electrode bulb, as this may introduce error due to polarization.
4.2. Do not let stirring bar hit the sensing bulb, as it may crack or break the electrode tip.

5. Interferences

5.1. Glass KCl electrodes, in general, are not subject to solution interferences from any of the following factors:
  5.1.1. Color
  5.1.2. Turbidity
  5.1.3. Colloidal matter
  5.1.4. Oxidizing or reducing agents
  5.1.5. Moderate (<0.1 M) salinity
5.2. Coatings of oily material or particulate matter on the electrode surface can impair its response, and should be removed as they arise. These coatings can usually be removed by gentle wiping with detergent, followed by rinsing with distilled water. An additional treatment with hydrochloric acid (1:10) may be necessary to remove any remaining film.
5.3. Temperature effects on pH measurement using this method arise from two sources:
  5.3.1. Change in electrode output at various temperatures. This interference is controlled by using a pH meter and electrode equipped with temperature compensation.
  5.3.2. Change of pH due to temperature-dependent changes in the sample itself. This error is sample-dependent and cannot be controlled. It should, therefore, be noted by reporting both the pH and temperature at the time of analysis.
5.4. Manures have considerable bacterial populations, and metabolic acids produced by these bacteria can cause rapid fluctuations (decreases) in pH. Keep manure samples cool during shipping (SOP M1), and freeze upon arrival in the lab to minimize bacterial growth and activity. Analyze samples as soon after thawing as possible. Observe the general holding times described in Section 10.1.3.

6. Personnel Qualifications

6.1. Personnel should be trained in the use of the analytical instruments, and in laboratory safety, before initiating the procedure.
6.2. Each analyst must read and understand the entire manuals for the pH meter and electrode, and this SOP, before operating the instruments.

7. Equipment and Supplies

7.1. Orion Model 310 pH meter (Thermo Electron Corp., Beverly, MA), or equivalent
7.2. Orion 82-02 PerpHecT ROSS Combination pH Electrode with automatic temperature compensation (Thermo Electron Corp., Beverly, MA)
7.3. Calibration buffers (VWR International, Chester, PA) - These commercially available solutions have been validated by comparison with NIST standards and are recommended by USEPA for routine use.
  7.3.1. pH 4 Buffer , Cat. No. 34170-127
  7.3.2. pH 7 Buffer, Cat. No. 34170-130
  7.3.3. pH 10 Buffer, Cat. No. 34170-133
7.4. Magnetic stirrer and Teflon-coated stirring bars

8. Procedures

8.1. Select the KCl electrode.
8.2. Lower the plastic band covering the hole on the electrode.
8.3. Set pH meter to “standby”.
8.4. Lift electrode from storage solution.
8.5. Using a wash bottle, rinse electrode with redistilled water into a waste beaker.
8.6. Instrument calibration
  8.6.1. Set meter to “pH” mode.
  8.6.2. Press “CAL” key to initiate calibration sequence. “CAL” is displayed for 2 s.
  8.6.3. Press the “YES” key to accept the last calibration range (7-4 or 7-10) or select one of these calibration ranges using the SCROLL keys. Press “YES” to accept.
    8.6.3.1. When measuring samples with acidic pH, use pH 4 buffer for the second calibration step (Choose 7-4 calibration).
    8.6.3.2. When measuring samples with alkaline pH, use pH 10 buffer for the second calibration step (Choose 7-10 calibration).
  8.6.4. “pH 7” will be displayed for 2 s. Place electrode in pH 7 buffer, using a sufficient volume of buffer in a 50-mL beaker to cover the sensing elements of the electrodes, and to give adequate clearance for the magnetic stirring bar. Reading will be displayed and updated as calibration continues. When the “READY” light comes on indicating electrode stability, press the “YES” key to accept.
  8.6.5. “pH 4” (or “pH 10”) will then be displayed for 2 s. Remove electrode from pH 7 buffer. Rinse with deionized water and place electrode in either pH 4 or pH 10 buffer (depending on calibration range that was selected). When the “READY” light comes on, press the “YES” key to accept buffer value. “SLP” (slope) will be displayed for 2 s, after which the calculated slope will be displayed.
  8.6.6. Meter will automatically go into the “MEASURE” mode, at which point the “READY” light will come on to indicate electrode stability.
8.7. Using a wash bottle, rinse electrode with redistilled water into a waste beaker.
8.8. If sample is a liquid, or a slurry with >20% water by volume, place approximately 30-40 mL of sample to be tested into a beaker and gently stir at a constant rate to provide homogeneity and suspension of solids.
  8.8.1. If sample is a solid, or a slurry with <20% water by volume, mix approximately 5 g of sample with water in a 1:1 ratio in a beaker. Gently stir at a constant rate to provide homogeneity and suspension of solids, and allow sample to equilibrate for 30 min before taking the measurement.
8.9. Submerge electrode; when readout is stable, note and record sample pH and temperature.
  8.9.1. If operating in the LogR mode or using an ATC (Automatic Temperature Compensation) probe, the temperature-corrected pH is displayed.
8.10. Rinse electrode between samples with distilled water into the waste beaker.
8.11. When finished, submerge electrode in storage solution and return pH meter to “standby”.

9. Data and Records Management

9.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method. Supplement this electronic record by a bound record book designated for the method, which should contain copies of the electronic record.
9.2. Manage all data according to SOP B5.
9.3. Document all data and information on field data sheets, and within site logbooks with permanent ink, or in electronic field notes. Overstrike all errors in writing with a single line. Initial and date all corrections.

10. Quality Control and Quality Assurance

10.1. Data integrity
10.1.1. A second person will verify that the analyses were conducted properly and provide a signature at the end of the data set run and/or at the end of the working day.
10.1.2. Record the temperature with each set of pH measurements, in accordance with Section 5.3.2.
10.1.3. In accordance with USEPA Method 9040C, analyze all samples as soon after collection as is feasible.
10.1.3.1. Hold refrigerated samples for no more than 7 days prior to conducting this analysis. Archived (frozen) samples can be maintained indefinitely.
10.2. Equipment handling and maintenance
10.2.1. Submerge electrode in storage buffer at all times when not in use.
10.2.2. Maintain the level of filling solution above the reference junction and at least one inch above the sample level when immersed. Add saturated KCl solution to the electrode if it falls below this level.
10.2.3. Calibrate the instrument (See Section 8.6) immediately before each batch of samples, and after each batch as a check of how much drift may have occurred.

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11.2. Thermo Electron Corporation. 2006. Orion 301 PerpHecT® pH/Temperature Meter – Product Specifications. Online at http://thermofinnigan.com/com/cda/product/detail/1,1055,10640,00.html. Accessed 3/13/2006.
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DETERMINING SOLIDS CONTENT OF MANURE SAMPLES
Standard Operating Procedure (SOP) M3

DETERMINING SOLIDS CONTENT OF MANURE SAMPLES

Standard Operating Procedure (SOP) M3

Prepared by
Alan L. Sutton, Brian Richert, Scott Radcliffe, Dan Kelly and Bill W. Bogan

Reviewed by
Albert J. Heber, Harold M. Keener (Ohio State Univ.) and Jerome J. King (Midwest Laboratories, Inc)

Effective Date: December 28, 2007

PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)
Agricultural and Biological Engineering, Purdue University
West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Manure composition significantly affects its emissions of odor and individual chemical components. The solids-to-liquids ratio is an important property.
1.2. This method determines the total solids, volatile solids and fixed solids contents of a manure sample.
1.3. The method described in this SOP is taken from USEPA Method 1684 (2001 Draft version), and is therefore also applicable to soils, sediments, and both raw and processed sludges.
1.4. The stated Method Detection Limits (MDLs) specified for this method are 3 mg/L total solids, 7 mg/L volatile solids, and 7 mg/L fixed solids.

2. Summary of Method

Well-mixed sample aliquots, having a wet weight of between 25 and 50 g, are dried at 103ºC to 105ºC in order to drive off all of the moisture in the sample. This step allows for the determination of total solids. Following cooling, the total-solids portion of the sample is heated to 550ºC, in a step that causes the volatile solids to be released. The sample is again cooled, and the remaining residue represents the fixed-solids portion.

3. Definitions

3.1.	IPR	Initial precision & recovery
3.2.	MDL	Method detection limit
3.3.	OPR	Ongoing precision & recovery
3.4.	QA	Quality Assurance
3.5.	QC	Quality Control
3.6.	Sample batch	All samples which are analyzed at the same time, up to a maximum of twenty (20). If more than 20 samples are analyzed at once, they must be assigned into more than one batch for the purposes of including blanks and OPR standards.

4. Health and Safety

4.1. Use gloves, tongs, and/or suitable sample holders when handling/moving hot sample vessels.

5. Cautions

5.1. When working with wet samples, weigh as quickly as possible after transferring to crucibles (Step 9.2.1), as these can lose water due to evaporation.
5.2. Unless extended drying times are required due to crusting (Section 6.3), do not exceed the drying times specified in this method. Overdrying can result in negative errors due to volatilization of certain salts (Section 6.5), volatilization of organic matter, or heat-

induced chemical decompositions, or to positive errors due to weight gain through sample oxidation.

5.3. Minimize the time that desiccators containing dried samples are open, as samples can adsorb moisture from the air. If strong desiccants are present in the sample (i.e. if weight gain occurs while samples are in the desiccator), use of a vacuum desiccator would be necessary. In all cases, do not remove samples from desiccators until immediately prior to weighing.

6. Interferences

6.1. Keep samples at or below 4°C after collection and during shipping (SOP M1), and prior to analysis, to minimize microbial degradation of sample solids. Analyze all samples within 7 days of collection. Frozen (archived) samples can be maintained indefinitely.

6.2. Samples must be kept homogeneous during the transfer of subsamples to drying vessels, as phase separation at this stage can be a source of considerable error.

6.2.1. Use a magnetic stirrer (See Step 9.2.1.1).

6.2.2. If the sample contains visible suspended solids, do not retrieve subsamples with a narrow-bore pipette. Use wide-bore pipettes, spoons or similar appropriate tools.

6.2.3. If part of the whole sample adheres to the sample container walls despite magnetic stirring, a more intensive homogenization method must be used for mixing. In these cases, sample will be transferred (including scraping of the sample which is adhering to the vessel walls) into a Waring blender and homogenized in this way.

6.2.4. Do not use a magnetic stirrer if magnetic particles are present in the sample.

6.3. If samples form a crust during the drying stage, this can inhibit further evaporation (either of water or volatile solids), and must be dealt with through special handling (either extended drying times or careful physical disruption (breakage) of the crust).

6.4. Following the initial drying step for total solids determination, some samples may retain small amounts of bound water, either as water of crystallization or interstitial water in crystals. Because the loss of this water is generally very slow, these samples may take longer to reach a constant weight.

6.5. Some samples may exhibit loss of CO_2 as bicarbonate is converted to carbonate. Loss of ammonium carbonate may also occur.

6.6. Samples with high levels of oil and grease may require particularly long drying times to reach a constant weight; it may therefore be difficult to obtain incontrovertible results for these samples.

6.7. Some dried samples may be highly hygroscopic, and contain stronger desiccants than are used in the desiccators themselves. Follow Section 5.3.

6.8. Use the same balance for all weighing steps involving a particular batch of samples.

7. Personnel Qualifications

7.1. Personnel should be trained in the use of the analytical instruments.

7.2. Each analyst must read and understand USEPA Method 1684 and this SOP before initiating these procedures, and must demonstrate the ability to generate acceptable data accuracy and precision as outlined in Section 11.2.

8. Equipment and Supplies

8.1. Drying oven
8.2. Muffle furnace
8.3. 15-100-mL crucibles or evaporating dishes made of porcelain or high-silica glass.
8.4. Watch glasses of suitable size to cover the crucibles/evaporating dishes
8.5. Analytical balance: Sartorius Model CP124S, Sartorius AG, Goettingen, Germany (or equivalent) (Capacity = 120 g; Accuracy =0.0001g).
8.5.1. Reference masses for calibration: 2-mg, 1000-mg, and 50-g class "S" weights
8.6. Magnetic stirrer
8.7. Spatulas
8.8. Desiccator and desiccant (Drierite, Anhydrous Calcium Sulfate)

9. Procedures

9.1. Preparation
9.1.1. If volatile solids are to be determined, heat crucibles/evaporating dishes and watch glasses to 550ºC for 1 h.
9.1.2. If only total solids are to be determined, heat crucibles/evaporating dishes and watch glasses to 103ºC to 105ºC for 1 h.
9.1.3. Cool and store all glassware in a desiccator.
9.1.4. Prior to use, weigh empty clean crucible and watch glass, and record value (to the nearest 0.01 g) of the two combined.
9.2. Sample handling
9.2.1. Obtaining subsamples
9.2.1.1. Fluid (i.e. free-flowing) samples: Stir to homogenize (either by magnetic stirrer or using a spatula). Taking care that the sample remains homogeneous (i.e. that no phase separation occurs), transfer a 25- to 50-g aliquot to a crucible/dish using a pipette, spoon, or other appropriate tool. Spread evenly over the crucible. Replace watch glass and re-weigh; record weight to the nearest 0.01 g.
9.2.1.2. Wet solid samples: Stir with a spatula to homogenize. Transfer a 25- to 50-g aliquot to a crucible/dish using a spatula, spoon, or other appropriate tool. Spread evenly over the crucible. Replace watch glass and re-weigh; record weight to the nearest 0.01 g.
9.2.1.3. Dry solid samples: Pulverize the entire sample by hand (using rubber gloves) on a clean surface. Mix, and transfer a 25- to 50-g aliquot to a crucible/dish using a spatula, spoon, or other appropriate tool. Spread evenly over the crucible. Replace watch glass and re-weigh; record weight to the nearest 0.01 g.
9.2.2. Include one blank (Section 11.8) and one Ongoing Precision and Recovery sample (Section 11.3) with each batch of samples.
9.2.3. Put in oven to dry for 12 h at 103°C to 105°C.
9.2.4. Remove from oven with tongs and place in the desiccator to cool to room temperature. Do not remove from desiccator until immediately prior to weighing. See Step 5.3 if working with highly hygroscopic samples.
9.2.5. Weigh cooled crucible/watch glass/sample, and record value to the nearest 0.01 g.

9.2.6. Place crucible in the (cool) muffle furnace and raise temperature to 550° C and hold for 2 h.
9.2.7. Remove crucible from the muffle furnace with tongs and place in the desiccator to cool to room temperature.
9.2.8. Weigh and record value of crucible/watch glass/ash residue to the nearest 0.01 g.
9.2.9. Return to muffle furnace for 30 minutes, cool and re-weigh. Repeat as necessary until weight change is less than 4% or 50 mg (whichever is less).
9.2.10. Record final value of crucible/watch glass/ash residue to the nearest 0.01 g.

9.3. Calculations

9.3.1. Wet sample weight:
Crucible/watch glass/wet sample (Step 9.2.1) – Crucible/watch glass (Step 9.1.4)
9.3.2. Dry sample weight:
Crucible/watch glass/dry sample (Step 9.2.7) – Crucible/watch glass (Step 9.1.4)
9.3.3. Ash weight:
Crucible/watch glass/ashed sample (Step 9.2.12) – Crucible/watch glass (Step 9.1.4)
9.3.4. % Total Solids = ((Dry sample weight)/(Wet sample weight)) * 100
9.3.5. % Fixed Solids = ((Ash weight)/(Dry sample weight)) * 100
9.3.6. % Volatile Solids = 100% - % Fixed Solids

10. Data and Records Management

10.1. Maintain all laboratory records in an electronic spreadsheet designated for this method. Supplement this electronic record by a bound record book designated for the method, which should contain copies of the electronic record.
10.2. Document all data and information on data sheets with permanent ink, or in electronic field notes.

11. Quality Control and Quality Assurance

11.1. Quality Control (QC) Solutions

11.1.1. One of the following solutions will be employed for QC checks of the procedures described in this SOP:

11.1.1.1. NaCl-KHP QC solution

11.1.1.1.1. Dissolve 0.10 g NaCl in reagent-grade (de-ionized) water.
11.1.1.1.2. Add 0.10 g potassium hydrogen phthalate (KHP), and mix to dissolve. Warm and stir if necessary to dissolve the KHP.
11.1.1.1.3. Dilute with de-ionized water to 1.0 L in a volumetric flask.
11.1.1.1.4. Store at 4°C
11.1.1.1.5. This solution contains 200 mg/L of total solids, 81 mg/L of volatile solids, and 119 mg/L fixed solids.

11.1.1.2. Commercially-obtained QC solution: Wibby Environmental Volatile Solids QC Standard (Catalog # QC-VSOL-WP), Wibby Environmental, Golden, CO (or equivalent).

11.2. Analyst Proficiency Demonstration

11.2.1. Initial Precision and Recovery (IPR): Analyst must demonstrate ability to generate acceptable precision and accuracy. Prepare at least four (4) replicate (50-mL) aliquots of a 12-fold dilution of the QC solution. Process all replicates through each step of the analytical method, and perform all calculations. Using the results of the four or more replicates, calculate the average and standard deviation for the concentrations of total, volatile and fixed solids. Compare to the following table:

Analyte	Expected value	Acceptable range	Acceptable S.D.
Total solids (mg/L)	16.7	14.2 – 18.4	10%
Volatile solids (mg/L)	9.92	7.44 – 10.91	30%
Fixed solids (mg/L)	6.75	5.06 – 7.42	20%

11.2.1.1. If averages and standard deviations do not fall within these acceptable ranges, analyst must identify his/her source(s) of error and repeat the IPR procedure.

11.3. Ongoing Precision and Recovery (OPR)

11.3.1. Prepare an OPR solution identical to the IPR solution described in Step 11.2.1 (i.e. a 12-fold dilution of the QC solution).

11.3.2. Include one (1) OPR sample (25-50 mL) with each sample batch, and subject it to all steps of the analytical method.

11.3.3. Concentrations determined from the OPR sample must fall within the following ranges (in mg/L):

- Total solids: 13.4 – 18.4
- Volatile solids: 6.94 – 10.91
- Fixed solids: 4.90 – 7.42

11.3.4. If recovery of any analyte falls outside the acceptable range for a given OPR sample, repeat analysis of that sample batch after appropriate troubleshooting and correction of the problem.

11.4. QC Charts

11.4.1. Track all IPR and OPR results to keep a graphical representation of continued laboratory performance.

11.5. Method Modifications & Re-validation

11.5.1. Each time any modification is made to this method, the analyst will verify that the modified method meets or exceeds the Method Detection Limit and Initial Precision and Recovery achieved by the same analyst using the original (unmodified) method.

11.5.2. Verify MDLs by diluting either the NaCl-KHP QC solution (Section 11.1.1.1) or the commercial standard (Section 11.1.1.2) to the extent(s) necessary to achieve the solids contents listed in Section 1.4. Analyze each of these diluted solutions by the modified method to verify that the analyte can be detected at that level.

11.5.3. The laboratory will maintain records of any modifications made to the method. At minimum, these records must include the following:

11.5.3.1. Names, titles, and contact information for analyst who initiated the modifications and for the QA officer who witnessed and approved the modifications.

11.5.3.2. Narrative stating reason(s) for the modification

11.5.3.3. Results from all QC tests comparing the modified method's performance to that of the original method:
- Initial Precision and Recovery
- Accuracy
- Blanks
- Ongoing Precision and Recovery

11.6. Data Integrity

11.6.1. A second person will be present to verify that analyses were conducted properly and provide a signature at the end of the data set run and/or the end of the working day.

11.7. Replication

11.7.1. Run at least 10% (one in ten) of the samples in each batch in duplicate, with at least one duplicate per batch. Initial masses (i.e. wet weights) of the duplicates will not differ by more than 10%. Replicates must agree to within 10% of their average (% total solids); if not, rerun this batch.

11.8. Blanks

11.8.1. One blank (25-50 mL of deionized water) must be included with each sample batch, and be subjected to all steps of the analytical method.

11.8.2. If material is detected in the blank at or above the MDLs stated in Section 1.4, stop analysis until the source of contamination is identified and eliminated (i.e. a new blank shows no evidence of contamination).

11.9. Instrument Calibration and Standardization

11.9.1. Analytical balance

11.9.1.1. Full calibration (annually at a minimum).

11.9.1.1.1. Calibrate at 2 mg and 1000 mg using class "S" weights.

11.9.1.1.2. Instrument readings must be within ±10% at 2 mg (i.e. ±0.2 mg) and ±0.5% at 1000 mg (i.e. ±5 mg). If these are not achieved, re-calibrate the balance.

11.9.1.2. Calibration check (daily before any samples are weighed)

11.9.1.2.1. Place a 50-g weight and the 2-mg weight on the balance together. Verify that the balance reads 50.002 g (±0.0002 g).

12. References

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DETERMINING TOTAL (KJELDAHL) NITROGEN CONTENT OF MANURE SAMPLES
Standard Operating Procedure (SOP) M4

DETERMINING TOTAL (KJELDAHL) NITROGEN CONTENT OF MANURE SAMPLES

Standard Operating Procedure (SOP) M4

Prepared by
Alan L. Sutton, Brian Richert, Scott Radcliffe, Dan Kelly and Bill W. Bogan

Reviewed by
Albert J. Heber and Jerome J. King (Midwest Laboratories, Inc)

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PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)
Agricultural and Biological Engineering, Purdue University
West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Manure composition can significantly affect its emissions, both in terms of general odor and individual chemical components. The total nitrogen content is an important manure property that affects emission of ammonia and other nitrogen-containing compounds. Thus, this parameter is important for both barn and open-source systems.

1.2. This method determines the total Kjeldahl nitrogen (TKN) content of a manure sample, Kjeldahl nitrogen being the sum of ammoniacal nitrogen and organic nitrogen.

1.3. The digestion method described in this SOP is taken from USEPA Method 1687 (2001 draft version), and is therefore also applicable to wastewaters, drinking water or groundwater, and industrial and other wastes.

1.4. The distillation and titrimetric procedures are described in USEPA Method 351.3.

1.4.1. This method has a working range of ca. 0.5-10 mg N/g manure (wet weight basis).

1.4.2. The stated detection limit for the method (Reference 12.4) is 0.01% (0.1 mg/g) N.

2. Summary of Method

Organic nitrogen in a manure sample is first converted to ammonia by metal-catalyzed acid digestion (with the exceptions listed in Section 6.7). The ammonia in the digested sample (the sum of nitrogen that was originally present in the ammoniacal form, plus that which is liberated from organic compounds) is then distilled away from the rest of the sample, at which point it is captured in a dilute sulfuric acid/boric acid solution containing bromocresol green/methyl red indicator. The ammonia concentration of the distillate is then determined by titration with sulfuric acid. Cupric sulfate/titanium dioxide ($CuSO_4/TiO_2$) is used as the sole catalyst in the digestion process. This avoids the toxicity and waste-disposal problems posed with mercury- and/or selenium-containing compounds. A QA/QC section is provided to discuss the calibration and periodic testing of the analytical method to ensure reliable data.

3. Definitions

3.1.	COD	Chemical oxygen demand
3.2.	CV	Calibration verification
3.3.	IPR	Initial precision and recovery
3.4.	MDL	Method detection limit
3.5.	MgO	Magnesium oxide
3.6.	MS	Matrix spike
3.7.	NaOH	Sodium hydroxide
3.8.	OPR	Ongoing precision and recovery
3.9.	QA/QC	Quality assurance/quality control
3.10.	Sample batch	A group of samples analyzed at the same time, up to a maximum of twenty (20). If more than 20 samples are analyzed at a time, divide them into multiple batches for the purpose of including blanks and CV and PR standards.
3.11.	SOP	Standard operating procedure
3.12.	TKN	Total Kjeldahl nitrogen

4. Health and Safety

4.1. Use gloves, tongs, and/or suitable sample holders when handling hot sample tubes.
4.2. Treat each chemical compound as a potential health hazard, and reduce exposure to chemicals to the lowest possible level.
  4.2.1. Wear protective clothing (gloves, lab coats, protective eyewear) when working with chemicals.
  4.2.2. Conduct all sample digestions in properly-ventilated fume hoods. Use a manifold to remove acid fumes.
  4.2.3. Keep analytical balances and other work areas clean; deal promptly with spills.
  4.2.4. When using concentrated acids and bases, keep a fully-stocked spill kit (including suitable neutralizers and absorbents) in the work area.
4.3. Maintain a current awareness file of Occupational Safety and Health Administration (OSHA) regulations pertaining to the chemicals specified in this method.
4.4. Maintain a reference file of material safety data sheets, which will be available to all personnel involved in these analyses.
4.5. Sulfuric acid digest is classified as a hazardous waste. Dispose of accordingly.

5. Cautions

5.1. Considerable heat is generated when dissolving sodium hydroxide (NaOH) in water (Step 8.7.2), or by mixing acids with water. Cool the container in an ice bath when preparing NaOH solutions or when mixing acid and water.
5.2. Excessive foaming during distillation can cause foam to pass into the condenser, which can contaminate the receiving flask and condenser with alkaline salts. Treat heavily-foaming samples with an anti-foaming agent.

6. Interferences

6.1. Keep samples at or below 4°C after collection and during shipping (SOP M1), and prior to analysis, to minimize microbial activity. Analyze all samples within 7 days of collection. Frozen (archived) samples can be maintained indefinitely.
6.2. Use only ammonia-free water, which can be prepared by passing reagent water through an ion-exchange column that is packed with a mixture of both strongly acidic cation- and strongly basic anion-exchange resins. Regenerate this column periodically according to the manufacturer's instructions.
6.3. Ammonia gas in the lab can deposit into the sample. Minimize sample exposure to air.
6.4. Nitrate in large quantities (>10 mg/L) will oxidize ammonia produced by the digestion and can introduce a substantial negative error. Although this interference cannot be prevented, its effect can be predicted and accounted for on the basis of preliminary nitrate determination of the sample. Whenever high nitrate levels are a potential issue, nitrate analyses of the sample should be conducted first.

Inorganic salts or solids will increase digestion temperature; however, conducting digestion at temperatures in excess of 400°C will cause pyrolitic loss of nitrogen. If high levels of salts and/or solids are suspected, adding extra H_2SO_4 can partially circumvent this problem. Approximately 1 mL H_2SO_4 per g of salt/solid will preserve the proper ratio, and allow digestion to proceed at the target temperature. Monitoring of digestion temperature will indicate if problems are occurring.

6.5. Large amounts of organic matter can consume the acid in the digestion reagent, causing the digestion temperature to rise above 400°C. Adding 10 mL H_2SO_4 per 3000 mg COD will prevent this. Monitor digestion temperature and pH if this correction is used.

6.6. Nitrogen occurring in certain organic compounds will not be measured by this method. These compounds include those in which the nitrogen occurs in the following forms:

- azide
- azine
- azo
- hydrazone
- nitrate
- nitrite
- nitrile
- nitro
- nitroso
- oxime
- semicarbazone

6.6.1. Levels of these compounds in manure are expected to be negligible.

7. Personnel Qualifications

7.1. Personnel should be trained in the use of the equipment before initiating the procedure.

7.2. Each analyst must read and understand this SOP, as well as USEPA Methods 1687 and 351.3, before initiating this procedure, and must show the ability to generate acceptable data accuracy and precision (Section 11.3).

8. Equipment and Supplies

8.1. Copies of USEPA Methods 1687 and 351.3

8.2. Tecator Instrument Model 2020 digester block and aspirator for sample digestion

8.3. Foss Kjeltec Model 2300 automated distillation and titration analyzer (FOSS Analytical, Hilleroed, Denmark), or equivalent

8.4. Flasks: 100-mL Kjeldahl and 50-mL Erlenmeyer flasks

8.5. Magnetic stirrer and Teflon-coated stir bars

8.6. Spatulas

8.7. Analytical balance (Capacity = 410 g; Accuracy = 0.001 g)

8.7.1. Reference weights for calibration: 2-mg, 1000-mg, and 50-g class “S” weights

8.8. Reagents

8.8.1. Sulfuric acid: Concentrated, 0.020N & 0.25N H_2SO_4, certified (Midland Scientific, Omaha, NE)

8.8.2. Sodium hydroxide: 40% NaOH solution, certified (Midland Scientific, Omaha, NE)

8.8.3. Digestion reagent: TT-43 Pro Pac Kjeldahl digestion tablets (Alfie packers, Inc, Omaha, NE)

8.8.4. Boric acid indicator

8.8.4.1. Add 0.10 g bromocresol green, 0.10 g methyl red, 100 g boric acid, and 20 mL of 0.10N NaOH to a 2-L flask that is half-full of NH_3-free water and dissolve all reagents

8.8.4.2. Add NH_3-free water to the 2-L mark on the flask.

8.8.4.3. Quantitatively transfer contents of the flask to the receiving solution reservoir below the Foss Kjeltech Model 2300.

8.8.4.4. Add 8 moreL of NH_3-free water to the reservoir, for a total of 10 L of solution.

8.9. Standards

8.9.1. Ammonia standards

8.9.1.1. Ammonia stock solution (1000 mg/L NH_3-N): Dissolve 0.382 g of anhydrous ammonium chloride (NH_4Cl), which should be dried at 105°C immediately prior to use, in NH_3-free water and dilute to 100 mL in a volumetric flask with NH_3-free water.

8.9.1.2. Ammonia working standard (10 mg/L NH_3-N): Dilute 10 mL of ammonia stock solution to 1 L in a volumetric flask with NH_3-free water.

8.9.2. Nicotinic acid standard (Contains 100 mg/L organic N): Dissolve 21.637 g nicotinic acid in ~ 150 mL NH_3-free water. Dilute to 200 mL with NH_3-free water.

8.9.3. Calibration standards

8.9.3.1. Prepare calibration standards by spiking 5-g aliquots of blank sand or diatomaceous earth (Section 8.10) directly with nicotinic acid standard solution (Section 8.9.2).

8.9.3.2. Prepare a minimum of five calibration standards, at five different concentrations to produce a calibration curve with at least five points.

8.9.3.3. At least one of the calibration standards should correspond to a sample concentration at or below that necessary to meet the data quality objectives of the project. The QAPP for a particular project will state the specific concentration needed for this standard.

8.9.3.4. The remaining standards should correspond to the concentration range found in actual samples, without exceeding the titration-based system’s working range.

8.9.4. Calibration Verification (CV) standard

8.9.4.1. Prepare the CV standard such that its N concentration approximates the midpoint of the calibration curve.

8.9.4.2. The source used to prepare the CV standard should be different from that used to prepare the calibration standards. Use either a different bottle of nicotinic acid, or a different compound altogether.

8.9.4.3. If a different ammonium compound is used for the CV stock, adjust the amount weighed according to the ratio of N weight to the molecular weight. Nicotinic acid has one atom of N per molecule and a formula weight of 123.11; it is, therefore 11.37% N by weight (14/123.11). If, for example, nicotinamide (2 N per molecule, formula weight 122.12, 22.93% N) is used as the CV standard, and X mg of nicotinic acid was needed to yield the desired N concentration, then (11.37/22.93) X, or 0.496 X g of nicotinamide would be needed.

8.9.5. Quality control sample (QCS): Standard Reference Material 1570a (Spinach Leaf). National Institute of Standards & Technology, Gaithersburg, MD.

8.10. Blank sand or diatomaceous earth

8.10.1. Bake 500 g diatomaceous earth or clean sand at 400°C for 8 h. Cool and store in a glass container with a sealing lid.

9. Procedures

9.1. Sample Preparation

9.1.1. In a fume hood, preheat the digestion block of the Model 2020 to 380ºC.

9.1.2. Obtain percent total solids of each sample to be analyzed, according to SOP M3.

9.1.3. Label digestion tubes as necessary to accommodate all samples, plus the various QA standards (Duplicates, Precision and Recovery Samples, Calibration Verification Standards, Quality Control Standards, Matrix Spikes, and/or Blanks) as required (See Sections 11.4 through 11.9 for the frequency that these must be included).

9.1.4. Bring samples to room temperature. Thoroughly homogenize the sample. Transfer 50 mL of sample into a digestion tube, and obtain and record the sample weight.

9.1.5. Add Kjeldahl digestion tablets (Section 8.8.3) and 20 mL of concentrated H_2SO_4, and place tube in the preheated digestion block.

9.2. Digestion

9.2.1. Immediately set up the exhaust system, and place the exhaust manifold so that it covers the mouth of each digestion tube. Turn water to vacuum on low.

9.2.2. Digest for 2 h.

9.2.2.1. Be sure that the manifold and hood fan are operating properly to remove the fumes released in the digestion process.

9.2.3. Remove tubes from digestion block with tongs and transfer to cooling tray to cool, leaving the exhaust manifold in place for a minimum of 30 min after the end of digestion. After 30 min, turn off water to vacuum, and remove exhaust manifold.

9.2.4. Add NH_3-free water to each tube to the level of the top horizontal support on the cooling rack (~50 mL). Place samples in the cooler and cool to <20 ºC.

9.3. Distillation

9.3.1. Place samples on the Model 2300 and select “Kjeldahl 5”. This selection ensures that the instrument will dispense a sufficient amount of NaOH to the sample.

9.3.1.1. Use 0.020 N H_2SO_4 for low-N samples, and 0.25 N for all others. Most samples associated with livestock manure, feed, and bedding are assumed to require 0.25 N H_2SO_4.

9.4. Calculations

9.4.1. Calculate TKN (in units of mg/g) in the sample as follows, correcting the amount of titrant (0.25N H_2SO_4) added to each sample by subtracting that needed to titrate a blank to endpoint:

$$\text{TKN} = \frac{\text{Titrant}_{\text{sample}}\,(\text{mL}) - \text{Titrant}_{\text{blank}}\,(\text{mL})}{\text{Sample wt (g)}} \times 3{,}500^{*}$$

*If 0.25N H2SO4 is used in the distillation/titration step. If 0.02 N acid is used, replace 3,500 with 280.

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method. Supplement this electronic record by a bound record book designated for the method, which should contain copies of the electronic record.
10.2. Manage all data according to SOP B5.
10.3. Document all data and information on field data sheets, and within site logbooks with permanent ink, or in electronic field notes. Overstirke errors in writing with single lines.
10.4. Initial and date all corrections.

11. Quality Control and Quality Assurance

11.1. Reagent Purity
11.1.1. Use only NH_3-free water in this method. See Step 6.1 for the methodology used to remove ammonia from water for use in these procedures.
11.1.2. All other reagents will be ACS Reagent Grade or better.
11.2. Instrument Calibration and Standardization
11.2.1. Calibrate analytical balance annually (at a minimum).
11.2.1.1. Calibrate at 2 mg and 1000 mg using class "S" weights.
11.2.1.2. Instrument calibration must be within ±10% at 2 mg (i.e. ±0.2 mg) and ±0.5% at 1000 mg (i.e. ±5 mg). If these limits are not achieved, the balance must be re-calibrated.
11.2.1.3. Place a 50-g weight and the 2-mg weight on the balance together. Verify that the balance reads 50.002 g (±0.0002 g).
11.3. Initial Demonstration of Analyst & Laboratory Proficiency
11.3.1. The following steps are to be followed by every new analyst performing this method, in order to assure the quality of his/her technique. No analyst may perform analyses of actual samples until he/she has passed all of the following:
11.3.1.1. Determine Method Detection Limit (MDL)
11.3.1.1.1. Prepare a group of at least seven (7) MDL determination samples by mixing 5-g aliquots of blank sand (or diatomaceous earth) (Section 8.10) with 10 mL NH_3-free water, and spiking each with nicotinic acid standard (Section 8.9.2) such that the organic N concentration of each MDL sample is one to five times the estimated detection limit (Section 1.4.2).
11.3.1.1.2. Using the seven replicates; process each through every step of the method. Calculate the N concentrations (Section 9.4.1) for each aliquot, and compare with the expected concentrations.
11.3.1.1.3. If, on average, the calculated concentrations are within 20% of the expected concentrations, analyst and system performance are acceptable .
11.3.1.2. Initial Precision and Recovery (IPR)
11.3.1.2.1. Prepare a group of at least four (4) IPR samples by mixing 5-g aliquots of blank sand (or diatomaceous earth) with 10 mL NH_3-free water, and spiking the slurries with nicotinic acid standard so that the organic N concentration of each PR sample is on the order of 1%. Process each sample through every step of the method. Perform the TKN calculations in Section 9.4.1, and determine

the percent recovery by comparing these to the known input amount.

11.3.1.2.2. Using the results of the set of four analyses, compute the average percent recovery (X) and the standard deviation (s) of the percent recovery for TKN.

11.3.1.2.3. The required performance specifications are $110\% \geq X \geq 90\%$, and $s \leq 5\%$.

11.3.1.2.4. If X and s meet the acceptance criteria, analyst and system performance are acceptable..

11.3.1.2.5. If s exceeds the precision limit (5%), and/or X falls outside the range for recovery, analyst and/or system performance is unacceptable. In this event, correct the problem, and repeat the test.

11.3.1.3. Blank

11.3.1.3.1. Include a minimum of one blank (Section 11.9) to verify that nitrogen is not detected in the blank at a concentration greater than the aqueous or solid MDL (Section 11.4.1.1).

11.3.1.4. Linearity of calibration curve

11.3.1.4.1. Analyst will prepare a five-point calibration curve (Section 8.9.3) to verify his/her ability to generate linear results over the concentration range of interest. If the linear correlation coefficient (r^2) of the calibration curve is $\geq$0.96, analyst and system performance are acceptable.

11.3.1.5. CV Standard

11.3.1.5.1. Include a minimum of one CV Standard (Section 8.9.4) to verify that the analyst can meet the acceptance criteria outlined in Section 11.6.1.1.

11.4. Ongoing Precision and Recovery (OPR)

11.4.1. MDL

11.4.1.1. Re-determine/verify MDLs annually.

11.4.1.2. Re-determine/verify MDLs whenever a modification is made to the method or analytical system.

11.4.2. Precision and Recovery (PR) samples

11.4.2.1. Each batch of samples (Section 3.10) must contain a minimum of one PR sample. Run solid samples with solid PR samples, and slurry samples with slurry PR samples.

11.4.2.1.1. Prepare a solid PR sample by spiking 5 g of blank sand (or diatomaceous earth) with nicotinic acid standard such that the organic N concentration of the PR sample is approximately five times the MDL (Section 1.4.2).

11.4.2.1.2. Prepare a slurry PR sample by mixing 5 g of blank sand (or diatomaceous earth) with 10 mL NH_3-free water, and spiking the slurry with nicotinic acid standard such that the organic N concentration of the PR sample is approximately five times the MDL (Section 1.4.2).

11.4.2.2. Carry the spiked PR sample through the entire analytical process, and calculate percent recovery.

11.4.2.2.1. If recovery falls within 90 to 110%**,** the system performance is acceptable.

11.4.2.2.2. If recovery falls outside 90% to 110%, system performance is unacceptable, and the problem must be identified and resolved prior to further analyses.

11.4.2.3. All samples must be associated with an acceptable PR standard before their results may be reported.

11.5. Calibration curves

11.5.1. Generate a new calibration curve (containing a minimum of five points as described in Section 8.9.3) whenever a new standard is obtained.

11.6. Calibration Verification (CV) standards

11.6.1. A Calibration Verification Standard (solid or slurry, as appropriate) must be run once per sample batch (every twenty analyses – Section 3.10).

11.6.1.1. Acceptance criteria for the CV Standard is 100% ± 5%.

11.6.1.2. If the CV does not meet acceptance criteria, the problem must be identified and corrected, including possible recalibration of the system if the problem cannot be corrected by other means.

11.6.1.3. All samples must be associated with an acceptable CV Standard before their results may be reported.

11.7. Quality Control standards

11.7.1. In accordance with Method 1687, analyze a QC standard with each day's distillations, or every 12 h, whichever is more frequent.

11.8. Matrix Spikes

11.8.1. To assess the performance of the method on a given sample matrix, spike (in duplicate) a minimum of 5% (1 sample in 20) of the samples from a given site.

11.8.2. Ensure that the concentration of nitrogen spiked into each MS sample is 1-5 times the background (i.e. existing) concentration expected for that particular sample.

11.8.2.1. The spiking level may be established *a priori* based on existing information (either analyst's previous experience or existing literature values) for N content of manures from the particular species.

11.8.3. The concentration added should be expressed as mg/kg, and should be calculated for a 1-g aliquot by multiplying the N concentration (mg/L) added (as nicotinic acid) by the conversion factor 100 (mg/L x 0.1L/0.001kg = 100).

11.8.4. Do not use blanks for MS analysis.

11.8.5. Assessing spike recovery

11.8.5.1. Calculate the percent recovery of TKN in the duplicate matrix spike samples (corrected for the background concentration measured in the corresponding unspiked sample which was used as the basis for the MS samples), as well as the relative percent difference (RPD) between the two values.

11.8.5.1.1. Percent recovery is calculated as follows:

$$\text{Percent Recovery} = \frac{(C_s - C_b)}{S} \times 100$$

Where:
C_s = Sample N concentration determined after spiking
C_b = Sample N concentration determined before spiking
S = Known concentration of the spike

11.8.5.1.2. RPD is calculated as follows:

$$\text{RPD} = \frac{(|D_1 - D_2|)}{D_1 + D_2} \times 100$$

Where:
D_1 = TKN concentration of MS sample #1
D_2 = TKN concentration of MS sample #2

11.8.5.2. Percent recoveries for the matrix spikes should be within three (3) standard deviations above or below the mean, with RPD ≤ 20%.

11.8.5.3. If either the percent recovery or the RPD of TKN in the MS samples falls outside the designated range, while the percent recovery in the PR sample is within the acceptable range, the problem encountered with the MS sample is judged to be matrix-related instead of method-related.

11.9. Blanks

11.9.1. Run a minimum of one blank with each batch of samples (Section 3.10).

11.9.2. Run aqueous (slurry) samples with an aqueous blank (10 mL NH_3-free water), and solid samples with a solid blank (a 5-g aliquot of blank sand).

11.9.3. If material is detected in the aqueous or solid blank at a concentration greater than the MDL (Section 1.4.2), halt analysis of samples until the source of contamination is eliminated and a new blank shows no contamination.

11.9.4. All samples must be associated with an uncontaminated laboratory blank before their results may be reported.

11.10. QC Charts

11.10.1. Track all IPR, OPR, Calibration Verification, QC Standard, MS and Blank results to provide graphical representations of continued laboratory performance.

11.11. Method modifications & re-validation

11.11.1. If any modification is made to this method, verify that the modified method meets or exceeds the Method Detection Limit (11.3.1.1) and Initial Precision and Recovery (11.3.1.2) achieved by the same analyst using the original (i.e. unmodified) method.

11.11.2. Maintain records of any modifications made to the method. At minimum, these records must include the following:

11.11.2.1. Names, titles, and contact information for analyst who initiated the modifications and for the QA Officer who witnessed and approved them

11.11.2.2. Narrative stating reason(s) for the modification

11.11.2.3. Results from all QC tests comparing the modified method's performance to that of the original method:

- Initial Precision and Recovery
- Ongoing Precision and Recovery
- Results with CV, QC Standard, MS samples and Blanks

11.12. Duplication

11.12.1. Run a minimum of 10% of samples (1 in 10) in duplicate, with a minimum of one duplicate per batch. Replicates must agree to within 10% of their average TKN content; if not, the batch of samples must be re-run.

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Prepared by

Alan L. Sutton, Brian Richert, Scott Radcliffe, Dan Kelly and Bill W. Bogan

Reviewed by

Albert J. Heber and Jerome J. King (Midwest Laboratories, Inc)

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PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The composition of manure can significantly affect its emissions, both in terms of general odor and individual chemical components. The ammonia content of a manure is generally a good indicator of readily available nitrogen, and therefore affects emission of both ammonia and other nitrogen-containing compounds.

1.2. This method determines a manure sample's total ammoniacal nitrogen (NH_3-N) content.

1.3. The distillation and titrimetric analyses are described in USEPA Method 350.2 and elsewhere (Bremner and Keeney 1965).

1.3.1. This method has a working range of approximately 0.5-10 mg NH_3 per g of manure (wet weight basis), and a minimum detection limit of approximately 0.1 mg/g.

1.3.2. The digestion and distillation method described in this SOP has been scaled down to "micro-Kjeldahl" scale in accordance with Reference 12.2.

2. Summary of Method

The ammonia in a manure sample is distilled away from the rest of the sample, at which point it is captured in a dilute boric acid solution which contains a bromocresol green methyl red indicator. The ammonia concentration of the distillate is then determined by titration with a known concentration of sulfuric acid. A quality assurance/quality control (QA/QC) section is provided to discuss the calibration and periodic testing of the analytical method to ensure that reliable data are collected.

3. Definitions

3.1.	CV	Calibration verification
3.2.	IPR	Initial precision and recovery
3.3.	MDL	Method detection limit
3.4.	MgO	Magnesium oxide
3.5.	MS	Matrix spike
3.6.	NaOH	Sodium hydroxide
3.7.	OPR	Ongoing precision and recovery
3.8.	PR	Precision and recovery
3.9.	QA/QC	Quality assurance/quality control
3.10.	RPD	Relative percent difference
3.11.	Sample batch	A group of sample analyzed at the same time, up to a maximum of twenty (20). If more than 20 samples are analyzed at a time, they must be divided into multiple batches for including blanks and QA standards.
3.12.	SOP	Standard operating procedure

4. Health and Safety

4.1. Treat each chemical compound as a potential health hazard, and reduce exposure to chemicals to the lowest possible level.

4.1.1. Wear protective clothing (gloves, lab coats, protective eyewear) when working with chemicals.
4.1.2. Conduct all operations involving solvents in properly-ventilated fume hoods.
4.1.3. Keep analytical balances and other work areas clean; deal with spills promptly.
4.1.4. When using concentrated acids and bases, keep a fully-stocked spill kit (including suitable neutralizers and absorbents) in the work area at all times.

4.2. Maintain a current awareness file of Occupational Safety and Health Administration (OSHA) regulations regarding the safe handling of the chemicals specified in this method.

4.3. Maintain a reference file of material safety data sheets (MSDS), which will be available to all personnel involved in these analyses.

5. Cautions

5.1. Considerable heat is generated when dissolving sodium hydroxide (NaOH) in water, or when mixing acid with water. Cool the container in an ice bath when preparing NaOH solutions, or when mixing acid with water.

5.2. Excessive foaming during distillation can cause foam to pass into the condenser, which can contaminate the receiving flask and condenser with alkaline salts. Treat heavily-foaming samples with an anti-foaming agent.

6. Interferences

6.1. Keep samples at or below 4°C after collection and during shipping (SOP M1), and prior to analysis, to minimize microbial activity. Analyze all samples within 7 days of collection. Frozen (archived) samples can be maintained indefinitely.

6.2. Use only ammonia-free water, prepared by passing reagent water through an ion-exchange column packed with strongly acidic cation- and strongly basic anion-exchange resins. Regenerate this column periodically according to the manufacturer's instructions.

6.3. Ammonia gas in the lab can deposit into the sample. Minimize sample exposure to air.

6.4. Nitrate in large quantities (>10 mg/L) can oxidize ammonia in the sample and introduce negative error. Although this interference cannot be prevented, its effect can be predicted and accounted for on the basis of preliminary nitrate determination of the sample. Whenever high nitrate levels are a potential issue, conduct nitrate analyses of the sample before attempting an ammonia analysis.

6.5. Volatile nitrogen-containing compounds such as hydrazine and some amines can cause overestimates of ammonia content. The levels of these in manure should be negligible.

6.6. Any residual Cl^- in the sample must be removed using sodium thiosulfate. This is most often associated with aqueous samples, or samples containing free water, and generally does not affect manure/biosolid samples.

7. Personnel Qualifications

7.1. Personnel should be trained in conducting these analyses before initiating the procedure.

7.2. Each analyst must read and understand this SOP, SOP M3, and USEPA Methods 351.3

and 1687 before initiating this procedure, and must show the ability to generate acceptable data accuracy and precision (Section 11.3).

8. Equipment and Supplies

8.1. Copies of PAAQL SOP M3 and USEPA Methods 351.3 and 1687
8.2. Foss Kjeltec Model 2300 automated distillation and titration analyzer (FOSS Analytical, Hilleroed, Denmark), or equivalent
8.3. Flasks: 100-ml Kjeldahl and 50-ml Erlenmeyer flasks
8.4. Analytical balance (Capacity = 410 g; Accuracy = 0.001 g)
8.4.1. Reference weights for calibration: 2-mg, 1000-mg, and 50-g class "S" weights
8.5. Reagents and buffers
8.5.1. Sulfuric acid: Concentrated, 0.020N & 0.25N H_2SO_4, certified (Midland Scientific, Omaha, NE)
8.5.2. Sodium hydroxide: 40% NaOH solution, certified (Midland Scientific, Omaha, NE)
8.5.3. Boric acid indicator:
8.5.3.1. Add 0.10 g bromocresol green, 0.10 g methyl red, 100 g boric acid, and 20 mL of 0.10N NaOH to a 2-L flask that is half-full of NH_3-free water. Dissolve all reagents
8.5.3.2. Add NH_3-free water to the 2-L mark on the flask.
8.5.3.3. Quantitatively transfer flask contents to the receiving solution reservoir below the Foss Kjeltech Model 2300.
8.5.3.4. Add 8 more liters of NH_3-free water to the reservoir, for a total of 10 L of solution.
8.6. Standards
8.6.1. Ammonia standards
8.6.1.1. Ammonia stock solution (1000 mg/L NH_3-N):
8.6.1.1.1. Dry anhydrous ammonium chloride (NH_4Cl) at 105°C immediately before use.
8.6.1.1.2. Dissolve 0.382 g of this dried NH_4Cl in NH_3-free water and dilute to 100 mL with NH_3-free water in a volumetric flask.
8.6.1.2. Ammonia working standard (10 mg/L NH_3-N): Dilute 10 mL of ammonia stock solution to 1 L in a volumetric flask with NH_3-free water.
8.6.2. Calibration standards
8.6.2.1. Prepare calibration standards by spiking 5-g aliquots of blank sand or diatomaceous earth (Section 8.7) directly with ammonia standard solution (Section 8.6.1).
8.6.2.2. Prepare a minimum of five calibration standards, at five different concentrations to produce a calibration curve with at least five points.
8.6.2.3. At least one of the calibration standards must correspond to a sample concentration at or below that necessary to meet the data quality objectives (DQOs) of the project. The QAPP for the particular project will state what concentration meets the DQOs.

8.6.2.4. The remaining standards should correspond to the concentration range found in actual samples, without exceeding the titration-based system's working range.

8.6.3. Calibration Verification (CV) standard

8.6.3.1. Prepare the CV standard so its NH_3 concentration approximates the midpoint of the calibration curve.

8.6.3.2. Prepare solid CV standards for use with solid samples, and slurry CV samples for use with slurry samples.

8.6.3.3. The source used to prepare the CV standard should be different from that used to prepare the calibration standards. Use either a different bottle of the same compound, or a different NH_3-containing compound altogether.

8.6.3.4. If a different ammonium compound is used for the CV stock, adjust the amount weighed according to the ratio of NH_3-N atomic weight to molecular weight. Ammonium chloride has one NH_4 group per molecule and a formula weight of 53.49; it is, therefore 31.78% NH_3 by weight (17/53.49). If, for example, dibasic ammonium phosphate (2 NH_4 per molecule, formula weight 132.06, 25.75% NH_3) is used as the CV standard, and X mg of ammonium chloride was needed to yield the NH_3 concentration at the midpoint of the calibration curve, then (31.78/25.75) X, or 1.23 X g of dibasic ammonium phosphate would be needed to yield the same NH_3 concentration.

8.6.4. Quality Control Sample (QCS): A prepared quality control sample from a standards vendor. Environmental Resource Associates (Arvada, CO) Catalog #545, or equivalent.

8.7. Blank sand or diatomaceous earth

8.7.1. Bake 500 g diatomaceous earth or clean sand at 400 °C for 8 h. Cool and store in a glass container with a sealing lid.

9. Procedures

9.1. Sample Preparation

9.1.1. Obtain percent total solids of each sample, according to SOP M3.

9.1.2. Label Kjeldahl distillation flasks as necessary to accommodate samples, in duplicate, as well as all necessary duplicates, Precision and Recovery Samples, Calibration Verification Standards, Quality Control Standards, Matrix Spikes, and/or Blanks (See Sections 11.4 - 11.9 for the frequency that these must be included).

9.1.3. Add sample.

9.1.3.1. Solid samples: Bring to room temperature. Thoroughly homogenize the sample. Weigh 1-2 g of sample into the Kjeldahl flask.

9.1.3.2. Slurry samples: Bring to room temperature. Mix the sample thoroughly. Transfer (by pipette or spatula) 1-2 mL (or 1-2 g) of sample to the distillation flask, and record the weight of the added sample.

9.2. Distillation

9.2.1. Place samples on the Model 2300 and select "Kjeldahl 5". This selection ensures that the instrument will dispense a sufficient amount of NaOH to the sample.

9.2.1.1. Use 0.020 N H_2SO_4 for low-N samples, and 0.25 N for all others. Most samples associated with livestock manure will require 0.25 N H_2SO_4.

9.3. Calculations

9.3.1. Calculate NH_3-N (in units of mg/g) in the sample as follows, correcting the amount of titrant (0.25N H_2SO_4) added to each sample by subtracting that needed to titrate a blank to endpoint:

$$NH_3\text{-}N = \frac{\text{Titrant}_{\text{sample}}\,(\text{mL}) - \text{Titrant}_{\text{blank}}\,(\text{mL})}{\text{Sample wt (g)}} \times 3{,}500^*$$

*If 0.25N H2SO4 is used in the distillation/titration step. If 0.02 N acid is used, replace 3,500 with 280.

10. Data and Records Management

10.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method. Supplement this electronic record by a bound record book designated for the method, which should contain copies of the electronic record.

10.2. Manage all data according to SOP B5.

10.3. Document all data and information on field data sheets, and within site logbooks with permanent ink, or in electronic field notes. Overstrike all errors in writing with a single line.

10.4. Initial and date all corrections.

11. Quality Control and Quality Assurance

11.1. Reagent Purity

11.1.1. All water used in this method must be NH_3-free. See Step 6.1 for the methodology used to remove NH_3 from water for use in these procedures.

11.1.2. All other reagents will be ACS Reagent Grade or better.

11.2. Instrument calibration and standardization

11.2.1. Calibrate the analytical balance annually (at a minimum).

11.2.1.1. Calibrate at 2 mg and 1000 mg using class “S” weights.

11.2.1.2. Instrument calibration must be within ±10% at 2 mg (i.e. ±0.2 mg) and ±0.5% at 1000 mg (i.e. ±5 mg). If these limits are not achieved, the balance must be re-calibrated.

11.2.1.3. Place a 50-g weight and the 2-mg weight on the balance together. Verify that the balance reads 50.002 g (±0.0002 g).

11.3. Initial demonstration of analyst & laboratory proficiency

11.3.1. The following steps are to be followed by every new analyst performing this method, in order to provide an assurance of the quality of his/her technique. No analyst may perform analyses of actual samples until he/she has passed all of the following:

11.3.1.1. Determine Method Detection Limit (MDL)

11.3.1.1.1. Prepare a group of at least seven (7) MDL determination samples by mixing 5-g aliquots of blank sand (or diatomaceous earth) (Section 8.7) with 10 mL NH_3-free water, and spiking each with ammonia standard (Section 8.6.1) such that the organic NH_3 concentration of each MDL sample is one to five times the estimated detection limit (Section 1.3.1).

11.3.1.1.2. Using the seven replicates; process each through every step of the method. Calculate the NH_3 concentrations (Section 9.3) for each aliquot, and compare with the expected concentrations.

11.3.1.1.3. If, on average, the calculated concentrations are within 20% of the expected concentrations, analyst and system performance are acceptable.

11.3.1.2. Initial Precision and Recovery (IPR)

11.3.1.2.1. Prepare a group of at least four (4) IPR samples by mixing 5-g aliquots of blank sand (or diatomaceous earth) with 10 mL NH_3-free water, and spiking the slurries with ammonia standard such that the NH_3 concentration of each PR sample is on the order of 1%. Process each sample through every step of the method. Perform the % NH_3 calculations in Section 9.3, and determine the percent recovery by comparing these to the known input amount.

11.3.1.2.2. Using the results of the four analyses, compute the average percent recovery (X) and the standard deviation (s) of the percent recovery for ammonia.

11.3.1.2.3. The required performance specifications for PR samples are a recovery of $110\% \geq X \geq 90\%$, and precision (s) $\leq 5\%$.

11.3.1.2.4. If s and X meet the acceptance criteria, analyst and system performance are acceptable.

11.3.1.2.5. If s exceeds the precision limit (5%), and/or X falls outside the range for recovery, system performance is unacceptable. In this event, correct the problem, and repeat the test.

11.3.1.3. Blank

11.3.1.3.1. Analyst will include a minimum of one blank (Section 11.9) to verify that he/she does not detect NH_3 in the blank at a concentration greater than the stated MDL (Section 1.3.1).

11.3.1.4. Linearity of calibration curve

11.3.1.4.1. Analyst will prepare a five-point calibration curve (Section 8.6.2) to verify his/her ability to generate linear results over the concentration range of interest. If the linear correlation coefficient (r^2) of the calibration curve is ≥ 0.96, analyst and system performance are acceptable.

11.3.1.5. CV Standard

11.3.1.5.1. Analyst will include a minimum of one CV Standard (Section 8.6.3) to verify that he/she can meet acceptance criteria (Section 11.6.1.1).

11.4. Ongoing Precision and Recovery (OPR)

11.4.1. MDL

11.4.1.1. Re-determine/verify method detection limits annually.

11.4.1.2. Re-determine/verify method detection limits whenever a modification is made to the method or analytical system.

11.4.2. Precision and Recovery (PR) Samples

11.4.2.1. Each batch (up to 20 samples) (Section 3.11) must contain a minimum of one PR sample. Run solid samples with solid PR samples, and slurry samples with slurry PR samples.

11.4.2.1.1. Prepare a solid PR sample by spiking 5 g of blank sand (or diatomaceous earth) with ammonia working standard such that the NH_3 concentration of the PR sample is approximately five times the MDL (Section 1.3.1).

11.4.2.1.2. Prepare a slurry PR sample by mixing 5 g of blank sand (or diatomaceous earth) with 10 mL NH_3-free water, and spiking the slurry with amoonia working standard such that the NH_3 concentration of the PR sample is approximately five times the MDL (Section 1.3.1).

11.4.2.2. Carry the PR sample through the entire analytical process, and calculate percent recovery.

11.4.2.2.1. If recovery falls within the range of 90% to 110%**,** the system performance is acceptable.

11.4.2.2.2. If recovery falls outside the range of 90% to 110%, the system performance is unacceptable, and the problem must be identified and resolved before performing any further analyses.

11.4.2.3. All samples must be associated with an acceptable PR standard before their results may be reported.

11.5. Calibration curves

11.5.1. Generate a new calibration curve (containing a minimum of five points as described in Section 8.6.2) whenever a new standard is obtained.

11.6. Calibration Verification Standards

11.6.1. Run a Calibration Verification Standard, either solid or slurry as appropriate based on the sample matrix, once per sample batch (every 20 analyses – Section 3.11).

11.6.1.1. Acceptance criteria for the CV Standard is 100 % ± 10%.

11.6.1.2. If the CV does not meet the acceptance criteria, the problem must be identified and corrected, including possible recalibration of the system if the problem cannot be corrected by other means.

11.6.1.3. All samples must be associated with an acceptable CV Standard before their results may be reported.

11.7. Quality Control (QC) Standards

11.7.1. In accordance with Method 1687, analyze a QC standard with each day's distillations, or every 12 h, whichever is more frequent.

11.8. Matrix Spikes (MS)

11.8.1. To assess the performance of the method on a given sample matrix, spike, in duplicate, a minimum of 5% (one sample in 20) of the samples from a given sampling site.

11.8.2. The concentration of NH_3-N spiked into each MS sample shall be 1-5 times the background concentration for the corresponding batch of samples.

11.8.2.1. The spiking level may be established *a priori* based on existing information (either analyst's previous experience or existing literature values) for NH_3 content of manures from the particular species.

11.8.3. The concentration added should be expressed as mg/kg, and should be calculated for a 1-g aliquot by multiplying the N concentration (mg/L) added (as ammonium chloride) by the conversion factor 100 (mg/L x 0.1L/0.001kg = 100).

11.8.4. Do not use blanks for MS analyses.

11.8.5. Assessing spike recovery

11.8.5.1. Calculate the percent recoveries of NH_3-N and relative percent difference (RPD) of the duplicate matrix spike samples (corrected for the background concentration measured in the corresponding unspiked sample which was used as the basis for the MS samples).

11.8.5.1.1. Calculate percent recovery as follows:

$$\text{Percent Recovery} = \frac{(C_s - C_b)}{S} \times 100$$

Where:

C_s = Sample NH_3-N concentration determined after spiking
C_b = Sample NH_3-N concentration determined before spiking
S = Known concentration of the spike

11.8.5.1.2. Calculate RPD as follows:

$$\text{RPD} = \frac{(|D_1 - D_2|)}{D_1 + D_2} \times 100$$

Where:

D_1 = NH_3-N concentration of MS sample #1
D_2 = NH_3-N concentration of MS sample #2

11.8.5.2. Percent recoveries for the matrix spikes should be within three standard deviations of the mean value, with RPD $\leq$ 20%.

11.8.5.3. If either the percent recovery or the RPD of NH_3-N in the MS samples falls outside the designated range, while the percent recovery in the PR sample is within the acceptable range, the problem encountered with the MS sample is judged to be matrix-related instead of method-related.

11.9. Blanks

11.9.1. Run a minimum of one blank with each batch of 20 samples (Section 3.11).

11.9.2. Suitable blanks are 10 mL of NH_3-free water, or 5 g of blank sand.

11.9.3. If NH_3-N is detected in the blank at a concentration greater than the MDL stated in Section 1.3.1, halt analysis of samples until the source of contamination is eliminated and a new blank shows no contamination.

11.9.4. All samples must be associated with an uncontaminated laboratory blank before their results may be reported.

11.10.QC Charts

11.10.1. Track all IPR, OPR, Calibration Verification, QC Standard, MS and Blank results to provide graphical representations of continued laboratory performance.

11.11. Method Modifications & Re-validation

11.11.1. Each time any modification is made to this method, the analyst will verify that the modified method meets or exceeds the Method Detection Limit and Initial Precision and Recovery achieved by the same analyst using the original (unmodified) method.

11.11.2. The laboratory will maintain records of any modifications made to the method. At minimum, these records must include the following:

11.11.2.1. Names, titles, and contact information for analyst who initiated the modifications and for the QA Officer who witnessed and approved them

11.11.2.2. Narrative stating reason(s) for the modification

11.11.2.3. Results from all QC tests comparing the modified method's performance to that of the original method:

- Initial Precision and Recovery
- Ongoing Precision and Recovery
- Results with Calibration Verification, QC Standard, MS samples and Blanks

11.12. Replication

11.12.1. Run duplicates of 10% of the samples in each batch, with a minimum of one duplicate per batch. Initial masses (i.e. wet weights) of the duplicates will not differ by more than 10%. Replicates must agree to within 10% of their average NH_3 content; if not, the batch of samples must be re-run.

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EMISSIONS ESTIMATION USING THE THUNDER BEACH SCIENTIFIC WINDTRAX® BACKWARD LAGRANGIAN STOCHASTIC MODEL
Standard Operating Procedure (SOP) O1

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Prepared by

Richard H. Grant

Reviewed by

Bill W. Bogan

Effective Date: November 6, 2006

PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. This protocol describes backward Lagrangian Stochastic (bLS) methods designed to estimate mass flux of air pollutants from an open source, based on concentrations measured along a horizontal line within a vertical plane downwind from the source

1.2. The bLS method has been evaluated, demonstrated, and peer-reviewed for measuring emissions of air pollutants from open sources (See Appendix B).

1.3. The bLS methodology is appropriate for characterizing ground-level area sources and non-point fugitive emission sources of NH_3 and H_2S, such as lagoons and manure storages.

1.4. The bLS method requires both downwind and upwind path-integrated concentrations (PICs) of the contaminants in question, turbulence, and other meteorological data to calculate emission rates.

1.4.1. The bLS methodology described here uses two open-path methods: Ultraviolet Differential Optical Absorption Spectroscopy (UV-DOAS) in a single beam configuration (SOP C1), and Tunable Laser Diode Absorption Spectroscopy (TLDAS) in multiple beam configurations (SOP C2), to obtain the PIC data.

1.4.2. Background PIC (PIC_{bg}) is defined as the lowest PIC measured among upwind beamlines.

1.5. The limitations of this methodology can be instrument- or geometry-based.

1.5.1. Instrument-Specific Limitations: The UV-DOAS and TDLAS systems' maximum pathlength, compounds which can be detected, and detection limits are described in SOP C1 (UV-DOAS) and SOP C2 (TDLAS).

1.5.2. Geometry Limitations: Plume emissions are assumed to originate near ground level (within 3 m from the ground).

1.6. The measurement data consists of 5-min averages, and the bLS models will be uniquely configured for each measurement location prior to sampling.

1.7. The level of acceptable uncertainty in emission rates is +/- 30%.

2. Summary of Method

The commercially-available program WindTrax® will apply the bLS method to determine emissions of H_2S and NH_3 from area sources (e.g. lagoons, corrals). WindTrax® simulates short-range atmospheric dispersion (for horizontal distances within about 1 km of the source) based on measured turbulence statistics. The model has an easy-to-use graphical interface for assessment of turbulence transport on the micro-meteorological scale using Lagrangian stochastic particle models. The simulation elements are represented by icons on a graphical interface showing a plan-view map with the location of sources and sensors at each location. Data files and the underlying numerical models are also represented by icons on the map. The turbulence statistics are based on 16-Hz measurements from the 2.0-m height sonic anemometer described in SOP W2 and SOP U5.

In applying the bLS method, the WindTrax® software makes three significant assumptions: 1) The ground surface around the source is assumed to be horizontally homogeneous; 2) Turbulence is assumed to be homogeneous and stationary; and 3) The PIC measurements for upwind and downwind components are assumed to be contemporaneous.

3. Definitions

3.1. Beamline	Path along which a PIC is determined
3.2. bLS	backward Lagrangian Stochastic. A Lagrangian modeling approach in which the position of a parcel of air is based on turbulence statistics backward in time.
3.3. c	Downwind volume concentration of a contaminant of interest (ppm)
3.4. c_{bg}	Upwind (background) volume concentration of a contaminant of interest (ppm)
3.5. C	Downwind mass concentration of a contaminant of interest (mg/m^3)
3.6. C_{bg}	Upwind (background) concentration of a contaminant of interest (mg/m^3)
3.7. DQI	Data quality indicator
3.8. L	Monin Obukov length, m
3.9. |L|	Absolute value of Monin Obukov length, m
3.10. PAML	Purdue Applied Meteorology Laboratory
3.11. PC	Personal computer
3.12. PIC	Path-Integrated Concentration. The integrated concentration of a gaseous pollutant measured along the beam path length, given in units of parts per million-meter (ppm-m).
3.13. PIC_{bg}	Upwind (background) PIC (ppm-m)
3.14. PI-ORS	Path-Integrated Optical Remote Sensing. Instrument system used to acquire gaseous PIC along open optical beam path.
3.15. ppm	Parts per million concentration by volume
3.16. Q	Emission rate, kg/m^2s
3.17. SMP	Site Monitoring Plan
3.18. SOP	Standard operating procedure
3.19. TDLAS	Tunable Diode Laser Absorption Spectroscopy
3.20. Tolerance parameter	A threshold value used to terminate iterative search algorithms of the bLS methodology.
3.21. u_*	Friction velocity, m/s
3.22. UV-DOAS	Ultraviolet Differential Optical Absorption Spectroscopy

4. Cautions

4.1. Take care when collecting turbulence and survey data, as the quality of this data will have a direct impact on the quality of the bLS method's calculations. Carefully follow the protocols given in SOP W2.

5. Interferences

5.1. Interferences for collecting UV-DOAS and TDLAS data, which can, in turn, affect the quality of bLS modeling, are given in SOPs C1 and C2, respectively.

6. Personnel Qualifications

6.1. Each analyst must read and understand the pertinent sections of the WindTrax® manual and this SOP before operating the software.
6.2. Basic knowledge of the UV-DOAS and TDLAS systems, and the ability to obtain quality PIC data from them, is assumed.

7. Equipment and Supplies

7.1. Computer hardware and software
7.1.1. The PC used for bLS modeling must have, at minimum, a 3-GHz CPU, 1 GB RAM, and a 40-GB hard drive.
7.1.2. Commercial bLS methodology software (WindTrax®, Thunder Beach Scientific, Nanaimo, BC) is used to analyze the acquired PIC and wind data.

8. Procedures

8.1. Setup
8.1.1. Physical configuration of each source location
8.1.1.1. The location of the UV-DOAS and TDLAS systems that provide PIC values are given in the QAPP and individual SMPs.
8.1.1.2. The location of the wind sensor used to define the turbulence and the elevation of the site is documented in SOP U5.
8.1.2. Meteorological measurements
8.1.2.1. Measurements of barometric pressure, air temperature, and turbulence are described in SOP W2 and SOP W6.
8.2. Data acquisition, calculations & data reduction requirements
8.2.1. The program calculates emission rates and downwind concentrations from the arbitrarily shaped lagoon or waste storage area sources using Lagrangian stochastic models for dispersion calculations in backward mode from PI-ORS PIC measurements.
8.2.1.1. The path-integrated concentration measured downwind of the source, *PIC,* and the background value measured upwind of the source, PIC_{bg}, are converted to beamline-averaged mass concentrations by dividing each *PIC* by the corresponding instrument pathlength to produce the volumetric concentrations, c_{obs} and $c_{obs,bg}$, respectively, and then substituting these values into Equation A.1 to obtain C_{obs} and $C_{obs,bg}$.
8.2.1.2. The model calculates the emission rate (Q_{obs}) corresponding to the measured background and downwind beamline-averaged concentrations based on the assumption that $(C_{obs} - C_{obs,bg}) / Q_{obs}$ is only a function of

atmospheric conditions. For the measured atmospheric conditions, this ratio is determined by using the bLS model to simulate the flight path of air parcels backwards from the beamline until each parcel intersects the gound (a 'touchdown'). The modeled ratio is given as C_{sim} / Q_{sim} , where C_{sim} is the simulated averaged beamline concentration, and Q_{sim} is the simulated source strength corresponding to this simulated concentration. The actual emission rate (Q_{obs}) is calculated using:

$$Q_{obs} = \frac{(C_{obs} - C_{obs,bg})}{\left[C_{sim} / Q_{sim}\right]} \qquad \text{(Equation 1)}$$

8.2.2. The velocity of each bLS-simulated air parcel is varied during each model timestep Δt according to

$$\Delta u_k = \alpha_k \Delta t + \beta_k P_k \qquad \text{(Equation 2)}$$

Where:
k is a directional indicator
$\beta_k = (4.41\varepsilon)^{0.5}$ (implying a Schmidt number of 0.64 at neutral stability)
P_k is a Gaussian random number from population with mean 0 and variance Δt
α_k is a function of turbulence statistics, which is given by

$$\alpha_u = -\frac{1}{2(\sigma_u^2\sigma_w^2 - u_*^4)}\beta_u^2[\sigma_w^2(u-U) + u_*^2 w] + w\frac{\partial U}{\partial z},$$

$$\alpha_v = -\frac{1}{2}\beta_v^2\frac{v}{\sigma_v^2},$$

$$\alpha_w = -\frac{1}{2(\sigma_u^2\sigma_w^2 - u_*^4)}\beta_w^2[u_*^2(u-U) + \sigma_u^2 w] + \frac{1}{2}\frac{\partial\sigma_w^2}{\partial z} + \frac{1}{2(\sigma_u^2\sigma_w^2 - u_*^4)}\left[u_*^2\frac{\partial\sigma_w^2}{\partial z}(u-U)w + \sigma_u^2\frac{\partial\sigma_w^2}{\partial z}w^2\right]$$

(Equation 3)

Where:
u_* is the friction velocity
U is the mean velocity in the streamwise direction over the measurement period
u, v and w are the instantaneous components of the wind in the streamwise, cross-stream, and vertical directions respectiuvely.

8.2.3. The location of each parcel ($x_k(u_1, u_2, u_3$ = x, y, z directions) is calculated as

$$\Delta x_k = u_k \Delta t \qquad \text{(Equation 4)}$$

iteratively for a large number of cycles. At some time, all parcels will impact the surface. The location of the intersection of the parcel with the surface is determined, and the vertical velocity at impact with the surface (w_0) is recorded. Parcels rebound from the surface. If the parcel impacts the surface within the source domain area, then it contributes to the flux. If it does not impact the surface within the source domain, the parcel does not contribute to the flux.

8.2.4. The model calculates "touchdown catalogs" of x, y, w_0 for each concentration measurement point *j* along the beamline. The number of impacts within the source domain, weighted by w_0, divided by the number of parcels (*n*) released from *P* equidistant points along each beamline, each with concentration C_{sim}, provides the ratio C_{sim} / Q_{sim} for each concentration measurement height:

$$a_{sim} = \frac{\mathrm{C_{sim}}}{\mathrm{Q_{sim}}} = \frac{1}{P}\sum_{j=1}^{P}\left(\frac{1}{\mathrm{n}} \sum_{\text{within source area}} \frac{2}{|w_0|}\right) \qquad \text{(Equation 5)}$$

.

8.2.4.1. The bLS model is run on-location and at PAML.

8.2.4.1.1. Automated on-site modeling will utilize generalized touchdown catalogs.

8.2.4.1.2. Model runs at PAML will be automated and utilize measurement period-specific touchdown catalogs.

8.2.5. Depending on stability and source/sensor geometry, all sensors might measure some part of the source emission, and none are sure to provide the correct background C_{bg}. WindTrax® calculates the actual background concentration, since the number of given concentrations (PIC values) is at least one greater than the number of unknown emission rates (lagoon).

8.2.6. The PIC values (units of ppm-m) are converted to beamline-averaged mass concentrations by dividing by the corresponding instrument pathlength to produce the volumentric concentrations, c_{obs} and $c_{obs,bg}$, respectively, and then substituting these values into Equation A.1 to obtain C_{obs} and $C_{obs,bg}$ (units of mg/m^2), taking into consideration the molecular weight of the target gas, atmospheric pressure and the ambient temperature.

8.2.7. The emission rate (Q_{obs}) , in units of kg/m^2s, is calculated using

$$Q_{obs} = \frac{C_{obs} - C_{obs,bg}}{a_{sim}}\left(\frac{1\,kg}{1{,}000{,}000\,mg}\right) \qquad \text{(Equation 6)}$$

8.3. Calibration and standardization

8.3.1. The bLS methodology relies on accurate PIC data provided by the UV-DOAS instruments (SOP C1).

8.3.2. The bLS methodology requires accurate turbulence measurements (SOP W2).

8.4. Computer hardware & software

8.4.1. This method uses the WindTrax® program.

8.4.2. Location-specific configurations, 5-min turbulence and meteorological data, and 5-min average PICs are stored on a desktop computer.

8.4.3. Software is run on a desktop computer according to SOP D1.

9. Data records Management

9.1. The individual 5-min emission rates determined from each beamline and corresponding QC flags (Section 11.3.2) will be written to a file. Manage all data according to SOP D1.

9.2. Document all data and information checked in the lab (PAML) on lab data sheets and in modeling logbooks with permanent ink, or in electronic notes.

9.3. Overstrike errors in writing with a single line. Initial and date all corrections.

10. Quality Assurance and Quality Control

10.1. Data quality indicator (DQI) goals are established to assess the quality of critical measurements. For PI-ORS systems, they depend on the wind measurements and the model specifics. These are summarized in Table 1.

10.1.1. DQIs for UV-DOAS are given in SOP C1.

10.1.2. No fully-documented DQI has been developed for the bLS method. Based on literature evaluations, values of u_* that are >0.15 m/s and values of |L| that are >2 m appear to provide the threshold of method accuracy needed to obtain emission rate measurements at the 30% uncertainty level.

Table 1. DQIs for the bLS Methodology.

Measurement Parameter	Analysis Method	DQI
U,V,W wind components	Side-by-side comparison of two wind monitors	Within 10%
UVDOAS [NH_3]	Comparison with standard gas	Within 10%
UVDOAS [H_2S]	Comparison with standard gas	Within 10%
bLS	u_*	>0.15 m/s
bLS	| L |	> 2 m

10.2. Meteorological measurements

10.2.1. The quality assurance of the wind component measurements from the 2-m height anemometer is described in SOP W2.

10.3. Reasonableness of the calculated flux

10.3.1. Verify that the generated result is reasonable based on the raw PIC data.

10.3.2. Assess plume emission measurements for quality using range limits for input variables.

10.3.2.1. Flag measurements with a "1" when $u_* < 0.15$ m/s (calculated from SOP W2). Flagged values are invalidated.

10.3.2.2. Flag measurements with a "2" when $|L| < 2$ m (calculated from SOP W2). Flagged values are invalidated.

10.4. Plume emission measurement accuracy

10.4.1. Plume emission measurement accuracy is expected to be ± 30%.

10.4.2. Accuracy is based in part on least-squares fit and the uncertainty inherent in the coefficients a_{ii} generated by the statistical LS model. Stochastic errors, related to the number of particles released in the model, are estimated at 7%.

10.4.2.1. Corral emission rates are modeled using 1 downwind PIC and 1 source.

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12. Contacts

12.1. Software manufacturer: Thunder Beach Scientific
12.1.1. Phone: (250) 753-5955
12.1.2. e-mail: Brian@thunderbeachscientific.com
12.2. Software adaptation: CEREX Environmental Services
12.2.1. e-mail: David Yu [dhy1332@yahoo.com]

Appendix A
Conversion of Volumetric Gas Concentrations to Gas Density Concentrations

Validated air pollutant concentration measurements are reported in units of parts per billion (ppb). Standard dry concentrations of all gas measurements will be reported but emissions will be calculated using the non-dry (including water vapor partial pressure) air concentrations. As emissions calculations require units of $\mu g/m^3$, all measurements will be converted from ppb to $\mu g/m^3$ at 20^oC.

The ideal gas law (*PV = nRT)* is used to convert volumetric gas concentrations to actual and standardized mass concentrations in non-dry air according to:

$$C = \frac{PcM}{R(273.15 + T)} \qquad \text{(Equation A.1)}$$

Where:

c	Volumetric concentration, ppb for mass concentration of $\mu g/m^3$
C	Actual mass concentration, mg/m^3 or $\mu g/m^3$
M	Molecular weight, M=17.03 and 34.08 for NH_3 and H_2S respectively
P	Pressure at sampling location, atm
T	Temperature at sampling location, °C
R	Universal Gas Constant: 0.08206 L-atm/mol-°K

The equation to standardize the volumetric gas concentrations of any pollutant to the standard mass concentration C' is as follows:

$$C' = \frac{P'C^*M}{R(273.15 + T')} \qquad \text{(Equation A.2)}$$

Where:

C'	Standard mass concentration moist basis, $\mu g/sm^3$
P'	Standard pressure, 1 atm
T'	Standard temperature, 20°C

The dry standard concentration is calculated as follows:

$$C'' = \frac{C'}{(1 - W)} \qquad \text{(Equation A.3)}$$

Where:

C''	Dry standard mass concentration dry basis, $\mu g/dsm^3$
W	Humidity mixing ratio

The humidity mixing ratio (W) is calculated as:

$$W = 0.62198 \frac{e^{f(T)}\varphi}{P_a - e^{f(T)}\varphi} \qquad \text{(Equation A.4)}$$

Where:

W Humidity mixing ratio, kg/kg

P_a Pressure at the sampling location

φ Relative humidity, decimal

$$f(T) = \frac{C_1}{T} + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln T \qquad \text{for } T < 273.15°K$$

$$f(T) = \frac{C_8}{T} + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln T \qquad \text{for } T > 273.16°K$$

$C_1 = -5.675 \times 10^3$
$C_2 = 6.392$
$C_3 = -9.678 \times 10^{-3}$
$C_4 = 6.222 \times 10^{-7}$
$C_5 = 2.075 \times 10^{-9}$
$C_6 = -9.484 \times 10^{-13}$
$C_7 = 4.163$
$C_8 = -5.800 \times 10^3$
$C_9 = 1.391$
$C_{10} = -4.864 \times 10^{-2}$
$C_{11} = 4.176 \times 10^{-5}$
$C_{12} = -1.445 \times 10^{-8}$
$C_{13} = 6.545.$

Appendix B
Evaluations of the Backward Lagrangian Stochastic Emissions Model

1. Accuracy Evaluations: Theoretical

a. Theoretical analysis of the bLS method versus the Integrated Horizontal Flux (IHF) method for estimating emissions from a lagoon under variable surrounding terrain and atmospheric conditions suggests that the bLS method can be expected to estimate the emissions between -14% to +44% of the IHF method under terrain situations of nearby buildings or woods (Wilson et al., 2001). Stability varied from L of -27 to 103 m.

2. Accuracy Evaluations: Field Trials

a. A comparison of calculated NH_3 emissions (passive gas samplers) from small field plots using the bLS method and the IHF method showed the bLS underestimated emissions by 16-24% compared to the IHF estimate, but were not statistically different (Sommer et al., 2005).
b. A comparison of calculated NH_3 emissions from a 3.1-m diameter (1.1-m high) manure pile using bLS (gas measurements by TDLAS) and IHF (passive gas sampler) methods over 24 h showed agreement to within 15% (after assumptions concerning differences in sampling times) (Sommer et al., 2004). Stability varied from z/L of 2.7 to -0.5 and L of 0.37 to -2 m. Sample averaging of 30 min was used.
c. An evaluation of CH_4 emissions from a defined 6 m x 6 m area source using bLS (gas measurements by TDLAS) method was made over 11 roughly two-hour periods over 6 d. Results indicated that bLS method error for 15-min periods ranged from 300% to 20%, while stability varied from L of -407 to 419 m. Two measurement periods during light winds and sunrise resulted in estimation errors of more than 100%. These measurement periods had the lightest winds of all periods, and appeared to indicate a breakdown of model assumptions. Conditions of strong instability (-2 m $\leq L \leq$ 2 m) and low winds ($u^* < 0.15$ m/s) resulted in model failure. Errors in emission estimates during measurement periods with the allowed stability range also varied with stability: A mean 12% overestimation under near-neutral conditions, 13% underestimation under unstable conditions, and 38% overestimation under stable conditions were observed (Flesch et al., 2004). The single best diagnostic for inaccurate Q estimates was found to be $u_* < 0.15$ m/s. When such cases were eliminated, the average value of the ratio $Q_{modeled}/Q_{actual}$ was 0.97, with a standard deviation over the 15-min averaging periods of 0.28. These results show that the bLS method is capable of calculating individual 15-min period values for Q within about 30%. This study also describes placement of the measurement platforms. They must be placed at least several instrument heights away from the upwind edge of the lagoon and other obstructions, but also near enough that the concentration rise over the background can be measured accurately. A problem with this study was the low CH_4 signal/noise ratio of only 2 to 4, which probably resulted in overestimations.
d. An evaluation of CH_4 emissions from a defined 6m x 6m area source surrounded by a 20 m x 20 m fence (flow disturbance) using bLS (gas measurements by TDLAS)

method was made over 10 roughly 2-h periods over 4 d. Results indicated an overestimate of emissions by the bLS model of an average of 10%, ranging from 80% overestimation to 49% underestimation. Errors in the near-field measurements (in front of the fence row) ranged from 40% underestimation to 30% overestimation. When the near-fence measurements were eliminated, the results improved so that on average the modeled *Q* values were within 2% of the actual values, with a standard deviation of about 20% for individual 15-min periods. Stability varied from L of -235 to -17 m (Flesch et al., 2005b). The results from this study show that the bLS technique provides reliable estimates for *Q*, even in the presence of some flow obstruction. It is recommended that ambient wind statistics, rather than disturbed, should be used to obtain the best results. A problem with this study is the low CH_4 signal/noise ratio of only 2 to 4, which probably resulted in overestimations.

e. An evaluation of CH_4 emissions (gas measurement by TDLAS) from grazing dairy cows for 3-week periods in winter and summer indicated that the bLS method overestimated the emission (relative to the IHF method) by 5% to 17% when averaging emissions estimates from five TDL scans. They approximated the sources of the error: 1) stochastic model errors were estimated at 1 to 7%, 2) measurement errors of the atmospheric conditions were estimated at 5%, and 3) the error associated with estimating the grazing animal 'surface roughness' was considered to be 15%. The model error was on average 19-23% greater for measurements made at high heights with the error of up to 35% when the measurement height was 5m. There was no tendency for the model error (bias) to vary with stability after filtering for $-2m \leq L \leq 2m$ or $u^* < 0.15$ m/s (Laubach and Kelliher, 2005).

f. An evaluation of NH_3 emissions (gas measurements by TDLAS) was made from a lagoon over 6 d. The 15-min measurement periods were filtered using the stability range of $-2\ m \leq L \leq 2\ m$ or $u^* < 0.15$ m/s (low winds) resulting in a mean emission rate of 1.69 g/s (SD 1.23 g/s). In this study, estimation problems due to trajectories rising above the measurement height resulted in an increase in the stability exclusion range to $-10m \leq L \leq 10m$ (extreme instability with measurements made far from the source) and a mean emission rate of 1.44 g/s (SD 0.57 g/s). Use of actual turbulence (as in this SOP) reduced the mean emission estimate 13% to 1.27 g/s (SD 0.49 g/s). Since there was no measure of actual emissions, the reduced emissions estimate may or may not have contributed to greater accuracy of the estimate. Considering only a 72-hr period in March in which no measurement intervals were removed by filtering resulted in a mean emission of 0.9 g/s, corresponding to 6.5 g/animal/day. Similar estimation during July (extrapolated from 15.5 hrs of measurement) resulted in a mean emission of 2.2 g/s, corresponding to 16 g/animal/day (Flesch et al., 2005a).

g. An evaluation of bLS modeling was made using CH_4 emissions from a 3 m x 3 m grid measured by an open-path laser with turbulence data from a three-dimensional sonic anemometer (McBain and Desjardins 2005). Under conditions when Monin Obukhov similarity theory is valid, the modeled Q value was, on average, within 6% of the actual value, with a standard deviation of 0.16. In addition, obstructions upwind from the sensors were determined to have little impact on the Q estimates, so long as the distance between the sensors and the obstructions was at least 25 times the height of the obstructions.

EMISSIONS ESTIMATION USING
THE ARCADIS RADIAL PLUME MAPPING MODEL
Standard Operating Procedure (SOP) O2

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Prepared by

Richard H. Grant

Reviewed by

Bill W. Bogan and Albert J. Heber

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. This SOP describes a method for characterizing gaseous emissions from non-point pollutant sources. The Radial Plume Mapping (RPM) methodology described here uses scanning Path-Integrated Open-Path Tunable Laser Diode Absorption Spectroscopy (TLDAS) in multiple beam configurations to measure emission fluxes. The RPM methodology has been well developed, evaluated, demonstrated, and peer-reviewed.

1.2. The Vertical Radial Plume Mapping (RPM) configuration described here is designed to measure mass flux of pollutants through a vertical plane, downwind from an emission source.

1.3. The PIC data will be generated by measurement with a scanning TDLAS (See SOP C2). The wind profile will be generated by measurements with sonic anemometers (See SOP W2).

1.4. The TDLAS system's maximum pathlength, compounds which can be detected, and detection limits are described in SOP C2.

1.4.1. TDLAS measurement and RPM mapping are appropriate for NH3 emissions.

1.4.2. The sensitivity of the TDLAS system is described in SOP C2.

1.5. The RPM methodology described here was developed from studies that concentrated on developing, evaluating, and demonstrating the various configurations of the RPM methodology. The RPM methodology (configurations, procedures, and algorithms) was patented as a technology for mapping air contaminants using a PI-ORS system with a non-overlapping, variable pathlength, radial beam geometry.

1.6. RPM methodology is appropriate for characterizing ground-level area sources and non-point fugitive emission sources, such as lagoons and manure storage areas. Its limitations can be instrument- or geometry-based.

1.6.1. The primary geometric limitation of this version of the RPM software is that plume emissions are assumed to originate within 3 m from the ground.

1.7. The level of acceptable uncertainty in emission fluxes determined using this method is ± 10%.

2. Summary of Method

This protocol describes application of an RPM method which is designed specifically for use with the TDLAS system. RPM utilizes multiple non-intersecting beam paths in a vertical plane downwind from the emission source to obtain a mass-equivalent plume map. This map, in conjunction with wind speed and direction, is used to obtain the flux of pollutants through the vertical plane. The measured flux is then used to estimate the emission rate of the upwind source being characterized. The TDLAS system collects spectra from airborne contaminants. There are no true "samples" that require preservation, storage, transport, extraction, digestion, or concentration. A vertical scanning plane, downwind of the source, is used to directly measure the gaseous flux (Section 8.3). The total length of the measurement area required depends on the size of the emission source, and is typically between 100 m and 300 m,

depending on location (SOP U5). The height of the scanning area is dependent on the 16 m tower and the lateral distance along the side of the manure storage area (SOP U5). It will nominally represent a rectangular area of approximately 200 m by 15 m. The chemical concentration of each gas species of interest, along each beam path, is obtained following the measurement and analysis procedures for the instruments being used. The PIC measurements along the elevated beam paths provide vertical concentration gradient information of the emitted plume. The beam paths on the ground indicate the approximate ground level concentration profile along the length of the RPM setup. Ground-level refers to the area as close to horizontal as possible, relative to the surface of the measurement area. A bivariate Gaussian function is assumed for the plume mass across the RPM plane, and the parameters of the mass-equivalent bivariate Gaussian function(s) are reconstructed from the measured PIC. These reconstructed parameters are then used to calculate the concentration values across the RPM plane at high resolution. The concentration values (in ppm) are converted to mass concentrations using the molecular weight of the monitored gas species, air temperature and atmospheric pressure. The products of the mass concentration and the wind speed normal to the measurement plane are integrated across the plane to calculate the mass flux through the plane. The physical range and sensitivity of the RPM methodology is determined by the limitations of the TDLAS to acquire the PIC data. The accuracy of results from the RPM method depends on the instrument accuracy as well as: 1) the quality control (QC) criteria of the algorithms, and 2) the accuracy and representativeness of the wind data. Because the estimation of the emission rate is dependent on the wind data, stable and measurable wind conditions are desired so that the source remains upwind of the RPM plane. Wind speed and direction measurements will be recorded at 2 m, 4 m, and 16 m (SOP W2).

3. Definitions

3.1. CCF	Concordance Correlation Factor. CCF is used to represent the quality of fit for the reconstruction in the path-integrated domain. CCF is similar to the Pearson correlation coefficient, but is adjusted to account for shifts in location and scale.
3.2. Cycle	One complete sequential data collection of the TDLAS system, through all PDCs in the setup.
3.3. Gaussian function	A normal distribution curve with a specified mean and standard deviation.
3.4. PDC	Pathlength-defining components. PDC is used to denote the component on the other end of the optical path from the PI-ORS instrument. Depending on the instrument selected, this could be a source, detector, mirror, or other reflecting object.
3.5. PIC	Path Integrated Concentration. PIC is the integrated concentration (ppm-m) of an analyte measured along an open optical beam path..

3.6. PI-ORS	Path-Integrated Optical Remote Sensing. An instrument system used to acquire PIC data.
3.7. ppm	Parts per million. Typical units of gas concentration for TDLAS, ratioed by volume.
3.8. Retro-reflector	A reflector that returns a beam of light in the same direction from which it came, regardless of the orientation of the reflector relative to the light source. This is the PDC for the TDLAS-based measurements.
3.9. RPM	Radial Plume Mapping. A methodology involving the acquisition of PIC data over multiple beam paths originating from a single, stationary PI-ORS instrument. Optimization algorithms are applied to give a time-averaged, mass-equivalent plume map (field of concentration) of air pollutants from an area source.
3.10. SBFM	Smooth Basis Functions Minimization. An algorithm used in the RPM methodology to fit the parameters of the Gaussian basis function(s) to the measured PIC data.
3.11. SMP	Site monitoring plan.
3.12. SSE	Sum of Squared Errors. The SSE is the sum of the squared differences between the measured and predicted PIC at each step of the iterative algorithm used in the RPM methodology.
3.13. TDLAS	Tunable diode laser absorption spectroscopy
3.14. TDLAS system	The TDLAS, and all associated components, e.g. mirrors, scanners, software, etc.
3.15. Tolerance parameter	A threshold value used to terminate iterative search algorithms of the RPM methodology.

4. Health and Safety

4.1. The hazards of performing the RPM methodology are those associated with any field event. Safety procedures should be established and implemented before using this protocol.

4.2. TDLAS system-specific safety protocols should be followed (SOP C2).

5. Cautions

5.1. The quality of the results generated with this method depends on the quality of the wind profile measurements (SOP W2), the survey measurements (SOP U5), and the TDLAS system PIC measurements (SOP C2).

6. Interferences

6.1. General Interferences
  6.1.1. Do not allow vehicle or pedestrian traffic to temporarily obstruct the beam path for any PIC measurement.
  6.1.2. Do not allow any physical obstruction of the beam path (e.g., by buildings, trees, and/or complex topography).
6.2. Weather Interferences
  6.2.1. Fog, rain, or snow obscures the light beam and affects the ability of the TDLAS to continuously measure gas concentrations (SOP C2).
  6.2.2. Wind conditions can greatly affect the results of field measurements.
    6.2.2.1. Optimal results are obtained in wind speeds between 1 and 8 m/s.
    6.2.2.2. In very low wind speeds (<0.5 m/s), the source plume may not be carried through the vertical plane.
    6.2.2.3. Very high wind speeds (>11 m/s) may displace or vibrate the optical alignment of various components of the TDLAS retro-reflectors, and affect the quality of the PIC acquired in multiple beam paths.
    6.2.2.4. Data collected in wind speeds between 8 and 11 m/s should be carefully checked for reliability.

7. Personnel Qualifications

7.1. Each member of the field staff must read and understand the pertinent sections of the RPM program instruction manual, SOP D1, and this SOP.
7.2. Specific training in the RPM software, by the software supplier, is required.
7.3. Basic knowledge of the TDLAS system and the ability to obtain quality path-integrated concentration (PIC) data is assumed.

8. Equipment and Supplies

8.1. Concentration Instrumentation. A TDLAS system (SOP C2) will provide the PIC data used in the RPM emissions rate characterization methodology.
8.2. Vertical Structure. Stable towers (SOP U5) are used to ensure reliable PIC data.
8.3. Computer Software
  8.3.1. Use specific software to control the TDLAS and obtain PIC data.
  8.3.2. Use commercial RPM software for post-analysis of PIC and wind data.
  8.3.3. Use custom software for the pre-processing of PIC data and post-processing of RPM data.
8.4. Meteorological Measurements. Wind measurements used in the RPM methodology (SOP W2). See QC checks described in SOP W2.
8.5. Survey Measurements. A GPS unit is used to measure latitude and longitude coordinates of each component. A laser rangefinder is used to measure each pathlength. Azimuth, and elevation angle of each PDC (SOP U5) is computed by the RPM program.

9. Procedures

9.1. RPM configuration setup. Four RPM planes will surround the lagoon or waste pile according to SOP U5 (Fig. 1).

9.1.1. The primary purpose of the RPM configuration is to calculate the fluxes through the vertical planes of each of the four sides of the lagoon.

9.1.2. Five retro-reflectors are used to create the vertical plane:

9.1.2.1. One at 1/3 the distance of the length of the RPM setup (1-m height)

9.1.2.2. One at 2/3 the distance of the length of the RPM setup (1-m height)

9.1.2.3. One the full length of the RPM setup (1 m height)

9.1.2.4. One positioned on the vertical structure at the full length of the RPM setup and at 8 m height

9.1.2.5. One positioned at the full length of the RPM setup at the top of the vertical structure (15 m)

9.1.2.6. Ground-level retro-reflectors refer to those defining optical beams as close to horizontal as possible given the terrain of the measurement site.

9.1.3. Background PIC will be measured from a measurement plane that is upwind during any given measurement period (one of the four RPM planes).

9.2. Data acquisition, calculations & data reduction requirements

9.2.1. Wind measurements

9.2.1.1. The orthogonal components to horizontal wind speed are measured at three heights (2 m, 4 m, 16 m) according to SOP W2 and SOP U5.

9.2.1.2. Wind component measurements are averaged to 2-s values.

9.2.1.3. The wind profile is interpolated linearly with height from these measurements by the RPM software for each complete cycle.

9.2.2. TDLAS data acquisition parameters

9.2.2.1. TDLAS dwell time per retro-reflector is 15 s.

9.2.2.2. TDLAS time to reposition scanner for next beam path is roughly 5 s.

9.2.2.3. TDLAS time per complete scan cycle: approximately100 s.

9.2.2.4. Data collection should proceed regardless of the wind conditions (if safety permits) until a minimum of 1/2 hour of total data is collected during times when the wind meets the criteria defined in Section 6.2.3.

9.2.3. RPM theory and algorithms: Once the PIC for all beam paths for each cycle of the gas species of interest are determined valid, the RPM model determines the corresponding wind measurements, reconstructs a plume map in the vertical plane, and determines the flux through the reconstructed plane. The RPM plume reconstruction technique utilizes a two-dimensional smooth basis functions minimization (SBFM) to reconstruct the smoothed mass equivalent concentration map (bivariate Gaussian).

9.2.3.1. A smooth basis function is assumed to describe the distribution of concentrations, and the search is for the unknown parameters of the basis function. Because the goal here is to determine the plane-integrated concentration, and subsequently the flux through the plane (and not the exact map of concentrations in the plane), only one smoothed basis function (one bivariate Gaussian function) is fitted to reconstruct the

smoothed map. For the beam geometry, it is convenient to express the smooth basis function G in polar coordinates r and θ:

9.2.3.2. Six independent beam paths are needed to determine one bivariate Gaussian function with six independent unknown parameters. However, some reasonable assumptions are made to reduce the number of unknown parameters to four.

$$G(r,\theta)=\frac{A}{2\pi\sigma_y\sigma_z\sqrt{1-\rho_{12}^2}}\exp\left\{-\frac{1}{2\left(1-\rho_{12}^2\right)}\left[\frac{(r\cdot\cos\theta-m_y)^2}{\sigma_y^2}-\frac{2\rho_{12}\left(r\cdot\cos\theta-m_y\right)\left(r\cdot\sin\theta-m_z\right)}{\sigma_y\sigma_z}+\frac{\left(r\cdot\sin\theta-m_z\right)^2}{\sigma_z^2}\right]\right\} \quad (1)$$

Where:

A = Normalizing coefficient, which adjusts for the peak value of the bivariate surface

ρ_{12} = Correlation coefficient, which defines the direction of the distribution-independent variations in relation to the Cartesian directions y and z (ρ_{12}=0 means that the distribution variations overlap the Cartesian coordinates)

m_y and m_z = Peak locations in Cartesian coordinates

σ_y and σ_z = Standard deviations in Cartesian coordinates.

9.2.3.2.1. To fit the unknown parameters of the smooth basis function to the PIC data, one has to define an error function for minimization.

9.2.3.2.2. Assume that the reconstructed bivariate Gaussian function is limited only to changes in the vertical and crosswind directions. This sets the correlation parameter (ρ_{12}) equal to zero.

9.2.3.2.3. Assume that the ground-level PIC is the largest of the vertical beams. The peak location in the vertical direction is then fixed to the ground level, setting m_z to zero.

9.2.3.3. A two-phase SBFM approach is used to solve the bivariate Gaussian function. First, a one-dimensional SBFM reconstruction procedure is applied to reconstruct the smoothed ground-level and crosswind concentration profiles. Then, the reconstructed parameters are substituted into the bivariate Gaussian function before applying the two-dimensional SBFM procedure.

9.2.3.4. The one dimensional SBFM reconstruction is applied to the ground-level segmented beam paths (Fig. 1) of the same beam geometry to find the crosswind concentration profile (Hashmonay and Yost 1999). A Gaussian function is fitted to measured PIC ground-level values as a univariate function. The error function for the Simplex minimization procedure is the Sum of Squared Errors (SSE) function:

$$SSE(B, m_y, \sigma_y) = \sum_i \left(PIC_i - \frac{B}{\sqrt{2\pi}\sigma_y} \int_0^{r_i} \exp\left[-\frac{1}{2}\left(\frac{m_y - r}{\sigma_y} \right)^2 \right] dr \right)^2 \quad (2)$$

Where:

B = Area under 1-D Gaussian distribution (integrated concentration)
r_i = Pathlength of the ith beam
m_y = Mean peak location
σ_y = Standard deviation of the Gaussian function
PIC_i = Measured path-integrated concentration value of the ith path

9.2.3.5. Substituting the solved values of the standard deviation (σ_y) and peak location (m_y) of the above one-dimensional SBFM procedure into the bivariate SBFM simplified by the assumptions in Section 9.2.4.2 yields:

$$G(A, \sigma_z) = \frac{A}{2\pi\sigma_y\sigma_z} \exp\left\{ -\frac{1}{2}\left[\frac{(r \cdot \cos\theta - m_y)^2}{\sigma_y^2} + \frac{(r \cdot \sin\theta)^2}{\sigma_z^2} \right] \right\} \quad (3)$$

which is solved by minimizing the SSE using the simplex procedure with PIC values for the one long beam along the ground level and the two elevated beams that sample vertical concentration gradients according to:

$$SSE(A, \sigma_z) = \sum_i \left(PIC_i - \int_0^{r_i} G(A, \sigma_z) dr \right)^2 \quad (4)$$

9.2.3.6. Once the parameters of the function are found for a specific run, the RPM procedure calculates the concentration values for every 2x2 m square elementary unit in the vertical (y,z) domain.

9.2.3.7. The concentration values are converted from ppm by volume to g/m^3, taking into consideration the molecular weight of the target gas, the atmospheric pressure and the ambient air temperature (Appendix A).

9.2.3.8. The wind speed component perpendicular to the vertical plane at each height z ($\hat{u}_z$) is computed by linear interpolations between the three wind sensors (SOP W2 and SOP U5) and setting a constant wind speed above the top wind sensor to 20 m.

9.2.3.9. If the upwind concentration C_{bg} derived from the upwind PIC (PIC_{bg}) is constant for all heights, the the upwind concentration is at ambient levels and the emission flux Q in g/s is determined by:

$$Q = \sum_{y=0}^{pathlength} \sum_{z=0}^{20m} (C_{y,z} - C_{bg}) \hat{u}_z \quad (5)$$

Where:

$C_{y,z}$ = Interpolated concentration in the RPM y,z plane
C_{bg} = Background concentration determined from the minimum PIC in an upwind RPM plane

9.2.3.10. If the upwind concentration C_{bg} is not constant with height, then the upwind concentration is not at ambient levels, and the emission flux (in g/s) across the *d* RPM plane of measurement (Q_d) is determined by:

$$Q_d = \sum_{y=0}^{pathlength} \sum_{z=0}^{20m} (C_{y,z})\hat{u}_z \qquad (5)$$

Where:

$C_{y,z}$ = Interpolated concentration in the *d* RPM y,z plane

The flux across each measurement plane is calculated separately with fluxes away from the source (downwind plane) as positive values and towards the source (upwind plane) as negative values. The net flux is computed as the sum of the fluxes. Note that the upwind and downwind RPM planes may consist of two planes each when winds are not perpendicular to a face of the area source.

9.2.3.11. The emission flux across each plane is written to a file.

9.3. Calibration and standardization

9.3.1. The RPM methodology relies on accurate PIC data provided by the TDLAS. Calibration of the TDLAS is described in SOP C2.

9.3.2. The RPM methodology relies on accurate wind speed measurements. Calibration of the wind sensors is described in SOP W2.

9.4. Computer hardware & software

9.4.1. This method utilizes a commercially-available, proprietary RPM emissions program in conjunction with custom software to pre-process the concentration data and post-process the emissions data.

9.4.2. This method uses location-specific configurations, 2-s mean wind speeds, and PIC values.

9.4.3. This method requires the use of proprietary dongles on the USB port of the processing computer.

10. Data and Records Management

10.1. Write the individual emission rates and DQIs (See Section 11.1) to files, as indicated in SOP D1.

10.2. Manage all data according to SOP D1.

10.3. Conduct all processing at PAML, and ensure that information is documented on lab data sheets and in modeling logbooks with permanent ink, or in electronic notes.

10.4. Overstrike any errors in writing with a single line in ink and initial.

11. Quality Control and Quality Assurance

Data Quality Indicator (DQI) goals for critical measurements: DQI goals are established to assess the quality of critical measurements. The DQI goals for this methodology are listed in Table 1.

Table 1. DQIs for the RPM Methodology

Measurement Parameter	Analysis Method	DQI
TDLAS [NH_3]	Comparison with standard gas	Within 10%
Wind speed	Side-by-side comparison of two wind monitors	Within 20%
Plume reconstruction	CCF	≥0.8[a]
Total mass positioning	A[c]	≥0.9[b]
Plume capture	Fractional change in vertical gradient of PIC	Topmost PIC <=0.9 mid-height PIC

[a] If CCF ≥ 0.8, then the reconstruction is considered valid.

b If CCF < 0.8, then check the A parameter. If A ≥0.9, the reconstruction is not a good fit to the Gaussian function, but the total mass prediction is valid.

[C] A is defined in Equation 6 below.

11.1. Specific QC checks on TDLAS measurements are discussed in SOP C2.
11.2. Specific QC checks on wind measurements are described in SOP W2.
11.3. Specific RPM QC checks:
11.3.1. RPM total mass positioning and reconstruction. The RPM methodology plume estimates are assessed for quality using the following:
11.3.1.1. Concordance Correlation Factor (CCF) (Lin, 1989), indicates goodness of fit between measured and predicted PIC. CCF is equal to rA, where r is the Pearson correlation coefficient, and A is a correction factor for the shift in population and location. This shift in total mass positioning is a function of the relationship between the averages and standard deviations of the measured and predicted PIC vectors:

$$A = \left[\frac{1}{2} \left(\frac{\sigma_{PIC_P}}{\sigma_{PIC_M}} + \frac{\sigma_{PIC_M}}{\sigma_{PIC_P}} + \left(\frac{\overline{PIC_P} - \overline{PIC_M}}{\sqrt{\sigma_{PIC_P}\sigma_{PIC_M}}} \right)^2 \right) \right]^{-1} \qquad (6)$$

Where:

σ_{PIC_P} = Standard deviation of the predicted PIC vector

σ_{PIC_M} = Standard deviation of the measured PIC vector

$\overline{PIC_P}$ = Mean of the predicted PIC vector

$\overline{PIC_M}$ = Mean of the measured PIC vector

where the measured PIC vector is of length five (number of scans) and consists of PIC values for each scan beamline. The predicted PIC vector of

same length represents the computed values along each beamline based on the modeled concentrations in the y,z plane plume.

11.3.1.2. A CCF ≥0.8 indicates a valid reconstruction.

11.3.1.3. An A≥ 0.9 verifies that the total mass positioning was a reasonable fit of the raw data.

11.3.2. Plume capture: For emission rate estimations using the RPM configuration, maximal plume capture is desired. Calculated emission rates are considered valid when the topmost PIC is less than or equal to 90% of the midlevel PIC. Under these cases, the measurement plane contains ≥ 70% of the plume.

11.3.3. Check for reasonableness of the calculated flux: Verify that the generated result is reasonable based on the raw PIC data and a visual plot of the concentration plane (a product of the model).

12. References

12.1. Hashmonay, R.A.; Yost, M.G. 1999. Innovative approach for estimating gaseous fugitive fluxes using computed tomography and remote optical sensing techniques. J. Air & Waste Manage. Assoc. 49, 966.

12.2. Lin, L. I-K. 1989. A Concordance Correlation Coefficient to evaluate reproducibility. Biometrics. 45, 255-68.

12.3. SOP C2. 2006. Open Measurement of Ammonia with the Boreal Laser GasFinder Tunable Diode Laser Absorption Spectrometer (TDLAS). Standard Operating Procedure C2. Purdue Applied Meteorology Lab.

12.4. SOP D1. 2006. Management of Open-source, Weather, and Lagoon-characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.

12.5. SOP U5. 2006. The Installation of Open-source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.

12.6. SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.

13. Contacts

13.1. ARCADIS

13.1.1. Phone: 919 544 4535

13.1.2. Email: Hashmonay, Ram [RHashmonay@arcadis-us.com]

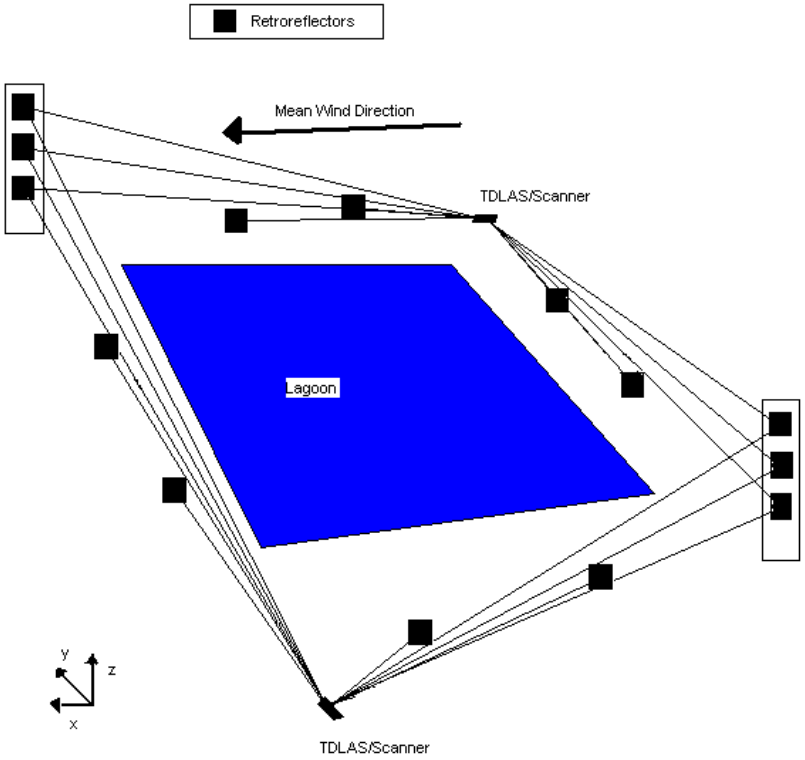

Figure 1. Example of RPM Configuration Setup.

Appendix A
Conversion of volumetric gas concentrations to gas density concentrations

Validated air pollutant concentration measurements are reported in units of parts per billion (ppb). Standard dry concentrations of all gas measurements will be reported, but emissions will be calculated on the non-dry (including water vapor partial pressure) air concentrations. As emissions calculations require units of $\mu g/m^3$ all measurements will be converted from ppm to $\mu g/m^3$ at 20^oC.

The ideal gas law (*PV = nRT)* is used to convert volumetric gas concentrations to actual and standardized mass concentrations in non-dry air according to:

$$C = \frac{PcM}{R(273.15+T)x10^3} \qquad \text{(Equation A.1)}$$

Where:

c Volumetric concentration, ppm
C Actual mass concentration, $\mu g/m^3$
M Molecular weight, M=17.03 and 34.08 for NH_3 and H_2S respectively
P Pressure at sampling location, atm
T Temperature at sampling location, °C
R Universal Gas Constant: 0.08206 L-atm/mol-°K

Table A.1. Physical constants.

	Ammonia	**Hydrogen sulfide**
Molecular weight	17.03	34.08
Density	0.771 g/L @ 760 mm	1.539 g/L
Solubility in cold water	89.9 g/100 mL	437 cm^3/100 mL

Source: Lide, D.R. ed. 1993. *CRC Handbook of Chemistry and Physics*. Boca Raton: CRC Press.

The equation to standardize the volumetric gas concentrations of any pollutant to the standard mass concentration C' is as follows:

$$C' = \frac{P'cM}{R(273.15+T')x10^3} \qquad \text{(Equation A.2)}$$

Where:

C' Standard mass concentration moist basis, $\mu g/sm^3$
P' Standard pressure, 1 atm
T' Standard temperature, 20°C

The dry standard concentration is calculated as follows:

$$C'' = \frac{C'}{(1-W)} \qquad \text{(Equation A.3)}$$

Where:
C'' Dry standard mass concentration dry basis, µg/dsm^3
W Humidity mixing ratio

The humidity mixing ratio (W) is calculated as:

$$W = 0.62198 \frac{e^{f(T)}\varphi}{P_a - e^{f(T)}\varphi} \qquad \text{(Equation A.4)}$$

Where:
W = humidity mixing ratio, kg/kg
P_a = pressure at the sampling location
φ = relative humidity, decimal

$$f(T) = \frac{C_1}{T} + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln T : \quad \text{(for T < 273.15°K)} \qquad \text{(Equation A.5)}$$

$$f(T) = \frac{C_8}{T} + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln T : \quad \text{(for T > 273.16°K)}$$

C_1= -5.675x10^3
C_2= 6.392
C_3= -9.678x10^{-3}
C_4= 6.222x10^{-7}
C_5= 2.075x10^{-9},
C_6= -9.484x10^{-13}
C_7= 4.163
C_8= -5.800x10^3
C_9= 1.391
C_{10}= -4.864x10^{-2}
C_{11}= 4.176x10^{-5}
C_{12}= -1.445x10^{-8}
C_{13}= 6.545.

Appendix B
Example application of methodologies described in this protocol using OP-FTIR

The methodologies described in this protocol are independent of the particular PI-ORS instrument. This appendix has been included to illustrate the application of the methodologies described in this protocol using a scanning open-path FTIR (OP-FTIR).[B1-4] The methodologies described in this protocol have been utilized for several other environmental monitoring programs.[B5-7]

B1.0 Examples of DQI goals and internal QC.

The Data Quality Indicator (DQI) goals for the OP-FTIR instrument are shown in Table B1. The DQI goals were developed based on analysis of the historical data obtained in similar studies and available guidance documents.

Table B1. Data Quality Indicators (DQIs) for OP-FTIR

Measurement Parameter	Analysis Method	Accuracy	Precision	% Complete
PIC determination	OP-FTIR: nitrous oxide conc.	±25%/15%/10%[a]	± 10%	90
Mid-IR absorbance	OP-FTIR: spectra quality	Acceptable[b]	NA	100

a The accuracy acceptance criterion is ±25 percent for pathlengths of less than 50 m, ±15 percent for pathlengths between 50 and 100 m, and ±10 percent for pathlengths greater than 100 m.

b Spectral quality must meet minimal quality (refer to instrumentation manuals and EPA methods for instrument-specific spectral quality criteria).

B1.1 *Procedures for Evaluating OP-FTIR DQIs*. The development and determination of DQIs for open-path measurements is an ongoing process. The following section details the procedure for assessing the OP-FTIR DQI goals presented in Table B1.

B1.1.1 *PIC Determination*. The accuracy and precision of the absorbance data may be verified by analyzing measured atmospheric nitrous oxide concentrations over time. This test is valid only if the background spectrum is void of nitrous oxide, and nitrous oxide is not used in the verification gas release. For the duration of the study, the calculated concentration results for nitrous oxide should be comparable to the natural ambient atmosphere level of 315 ppb ±25 percent for path lengths less than 50 meters, 315 ppb ±15 percent for path lengths between 50 and 100 meters, and 315 ppb ±10 percent for path lengths greater than 100.[B8] Refer to Section 11.3.1.1 of *ASTM Standard Practice E 1982-98* for more information on this procedure.[B2]

B1.1.2 *Mid-IR Absorbance*. The quality of the mid-IR absorbance data can be assessed by performing several qualitative and quantitative checks. These checks include assessing instrument noise, detector nonlinearity, detector saturation, and instrument response. These checks were developed based on *ASTM Standard Practice E 1982-98*. Additional details on how to perform these checks can be found

in the EPA document entitled, *ECPB Optical Remote Sensing Facility Manual*. [B9]

B1.2 *Internal Quality Control*. Traditional quality control (QC) samples are not applicable to OP-FTIR experiments. Instead, the analyses of IR-active ambient gases having relatively constant values are included in the quantification process. Examples include nitrous oxide and methane, which are found at relatively constant concentrations of 315 ppb and 1.7 ppm as global backgrounds, respectively. These must be used with caution, because a particular measurement area may prove to be a source of these gases. Methane, for example, is often emitted from hog waste lagoons and landfills.

B1.2.1 *Generation of a Background Spectrum*. As described in EPA Compendium Method TO-16 (1999),[B2, B3] the generation of a background spectrum, more precisely the I_0 spectrum, is best accomplished synthetically. The best approach to this depends upon the software being used for processing the data. Many commercially available software systems are compatible with the data format used by OP-FTIR instruments. However, all of the available software options require analyst input; therefore, there is some subjectivity involved in the process.

B1.2.2 *Data Integrity*. Spectra are analyzed for peaks of common atmospheric constituents, such as water vapor, carbon dioxide, and methane. If these peaks are located outside of their expected spectral region or exhibit any other abnormal characteristics, a spectroscopist should manually examine a select portion of the original data to determine the reason for these deviations and/or the usability of the collected data.

B2.0 RPM example

B2.1 *Introduction*. During the Fall of 2002 and Spring of 2003, the methodologies described in this protocol was evaluated using the controlled release of verification gases and a scanning monostatic OP-FTIR instrument. The experiment was performed at the Duke Forest Facility of Duke University, located in Chapel Hill, North Carolina. A nearly flat and square area of 14,400 m^2 was selected for the study. The verification gases released during the experiments included ethylene and acetylene. This example briefly describes the preliminary results obtained from this controlled demonstration study using the RPM methodology described in SOP O2.

B2.2 Experimental Setup. *This study was supported by the Environmental Security Technology Certification Program (ESTCP) of the Department of Defense (DoD) and audited by the Emissions Monitoring Center (EMC) of the EPA.*

In this study, an OP-FTIR mounted on a scanner and an array of mirrors (PDC) formed multiple, non-intercepting beam paths. Five mirrors were used. The OP-FTIR was scanned sequentially from mirror to mirror, acquiring spectra from each beam path. The OP-FTIR dwelling time on each mirror was 60 s. Ethylene was released and data were collected for 12 cycles. A total of 1.0 lb of ethylene was released over a period of 68 min, which resulted in an average release rate of 0.11 g/s.

B2.3 *Results and Discussion*. PIC data were derived from the collected spectra, and wind data were time-synchronized with the spectral data and averaged for the corresponding measurement cycle. Following this, the PIC data were sorted according to mirror number, and the expanded data matrix was then used as input to the

software developed by ARCADIS in Research Triangle Park, NC. The software provides spatial information on the homogeneity of the plume, and calculates the emission flux through the configuration.

B2.3.2 *Results*. Several verification gases were released in an "H" pattern upwind of the RPM configuration to simulate a small area source in Duke Forest (see Fig. B1).[B9] The verification gas cylinders were weighed before and after each release to calculate the actual release rate (in g/s). Spectral data were collected by sequentially scanning the OP-FTIR from mirror to mirror. This data were used to derive PIC data along each beam path, which were used as input to the RPM algorithm to determine a plane-integrated concentration. Wind data were simultaneously collected at two heights (2 and 10 m), and were incorporated with the plane-integrated concentration data to calculate the emission flux through the RPM configuration.

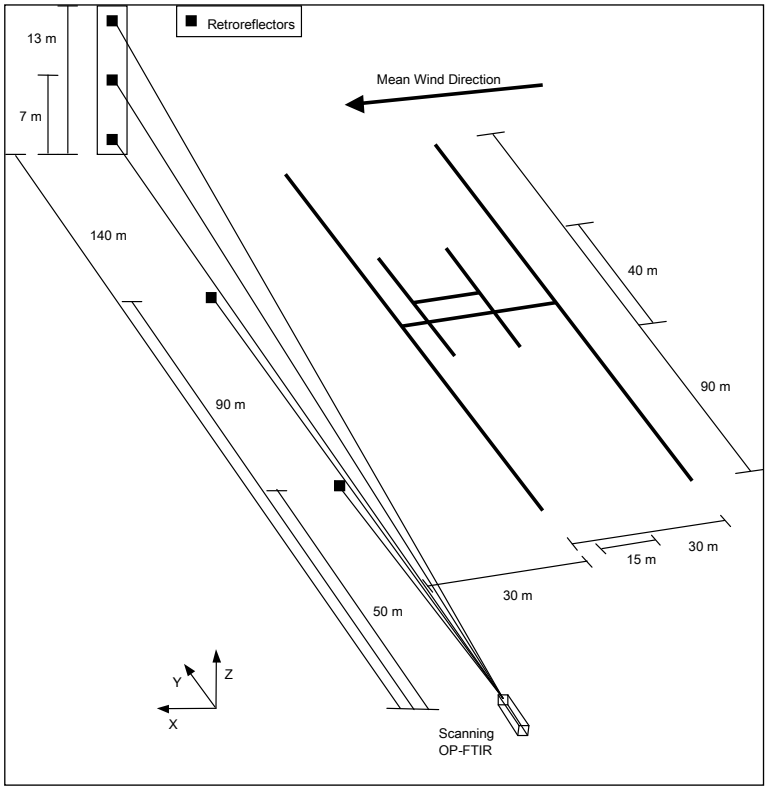

Figure B1. Schematic of the RPM configuration used for the ethylene release.

Table B2 presents the data matrix used to construct the mass-equivalent plume map. Fig. B2 shows the reconstructed mass-equivalent plume map constructed by averaging PIC data from all 12 cycles. The average calculated emission flux was 0.10 g/s.

B2.3.2.1 Average wind speed and direction data for each measurement cycle is shown in Table B2. Wind measurements were interpolated every 2 m between the 2- and 10-m heights. The average wind data for each cycle at 4 m above the ground are shown. The wind direction is measured clockwise from an axis perpendicular to the RPM configuration. In this convention, 0º is perpendicular to the vertical plane.

Table B2 Data matrix used to construct Figure B2.

Beam Path no.	**1**	**2**	**3**	**4**	**5**	**WS (m/s)**	**WD from Normal (deg)**
Physical Beam Path Length (m)	52.1	90.1	137	141.5	141.9		
Cycle 1 (ppm-m)	**2.7**	13.4	17.8	**3.8**	**5.1**	2.7	5
Cycle 2 (ppm-m)	6.4	28.0	19.4	9.0	**5.4**	2.6	1
Cycle 3 (ppm-m)	4.5	23.4	23.1	8.8	**7.9**	2.1	0
Cycle 4 (ppm-m)	**2.8**	28.3	20.4	10.0	**7.3**	2.1	14
Cycle 5 (ppm-m)	5.0	19.8	34.7	**4.2**	**5.3**	2.9	13
Cycle 6 (ppm-m)	**2.9**	27.9	14.4	11.1	**7.8**	2.9	3
Cycle 7 (ppm-m)	10.8	14.1	28.5	**4.7**	**7.9**	3.0	-11
Cycle 8 (ppm-m)	**2.7**	10.3	49.1	4.9	**5.8**	2.3	18
Cycle 9 (ppm-m)	**2.7**	23.1	25.8	23.3	**7.1**	1.8	-2
Cycle 10 (ppm-m)	6.7	11.6	18.7	**4.5**	11.1	1.7	-15
Cycle 11 (ppm-m)	14.4	20.2	36.0	15.7	**7.0**	2.0	-8
Cycle 12 (ppm-m)	**2.6**	**3.3**	30.9	8.3	**6.7**	2.2	14
12-Cycle Average (ppm-m)	5.4	18.6	26.6	9.0	7.0	2.35	3

BOLD values represent one-half the minimum detection limit.

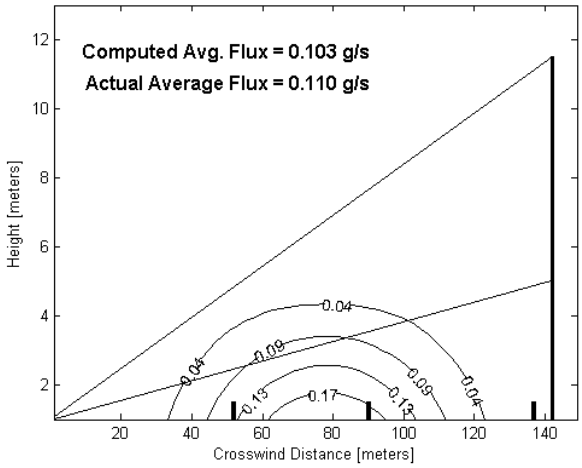

Figure B2. Flux measurement for ethylene.

B2.3.2.2 A moving average is used in the calculation of average values to show temporal variability in the measurements. A moving average involves averaging values from several different consecutive cycles. For example, a data set may be reported using a moving average with a group size of 4, where values from cycles 1 to 4, and 2 to 5 are averaged together to show any variability in the values.

The example in this appendix explores the dependence of the results on the group size of the moving average, and is illustrated in Fig. B3. To assess the accuracy of the reconstruction for each moving average group, the CCF is computed. It is apparent in Fig. B3 that as the group size of the moving averages increase, the standard deviation decreases (smaller error bar). The CCF value increases for larger group sizes of moving averages (indicating a better fit for the measured data), but levels off at a group size of three. A moving average group of three is recommended for the RPM methodology. In some conditions, it may not be advisable to use a larger group size for the moving average.

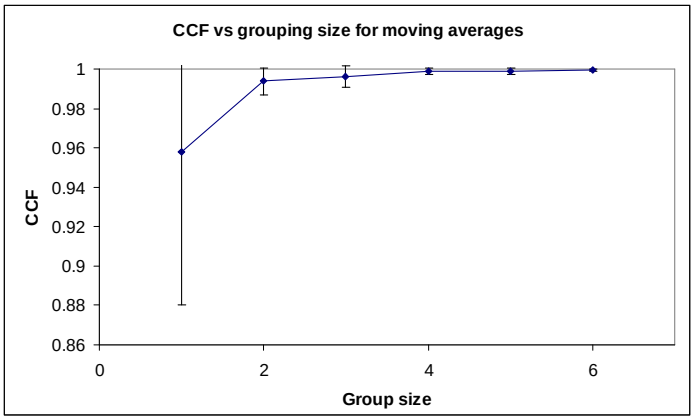

Figure B3. Dependence of CCF on moving average group size.

B2.3.2.3 A time plot of the flux calculation for the ethylene verification release, using a moving average with a group size of three, is shown in Fig. B4. The dashed horizontal line corresponds to the actual mass released; the dashed plot indicates the measured wind direction from perpendicular to the RPM configuration; and the solid plot indicates the calculated emission flux values. The corresponding data are listed in Table B3.

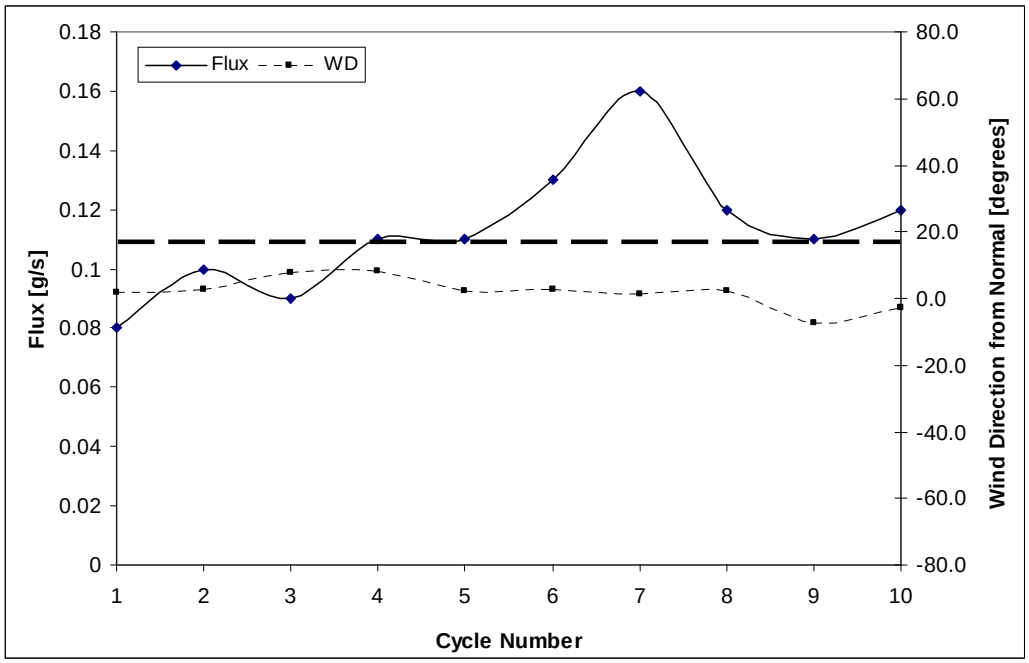

Figure B4. Time series of ethylene emission flux estimation.
(— — — Indicates the actual release rate)

Table B3. Moving average of three ethylene emission data points for Figure B4.

Group	CCF	Flux(g/s)	WS(m/s)	WD(deg.)
1	0.95	0.08	2.2	2
2	0.96	0.1	2.1	3
3	0.96	0.09	2.2	8
4	0.96	0.11	2.4	8
5	0.96	0.11	2.7	2
6	0.97	0.13	2.5	3
7	0.98	0.16	2.2	2
8	0.96	0.12	1.8	2
9	0.98	0.11	1.7	-7
10	0.94	0.12	1.8	-3
Average	0.96	0.11		
Std. Dev.	0.012	0.022		

B2.3.2.4 The example below of flux data from the Duke Forest study provides guidance for determining the range of wind directions that will ensure complete capture of the plume (in the horizontal direction) by the RPM configuration. The RPM flux results are representative of the source emission rate only during periods that the prevailing wind directions meet the established criterion.

The determination of the acceptable wind criterion is done by analyzing a data set of calculated flux values, with the corresponding wind direction, at the time of the flux calculation. The data set should consist of data collected over a wide range of wind directions on both sides of the perpendicular direction to the RPM configuration. A plot is create of the calculated flux values as a function of the angle of the prevailing wind direction (from perpendicular to the RPM configuration) of all runs made when the wind direction angles were close to the perpendicular direction of the RPM configuration. Because these runs were collected over a period of six months, the flux values were normalized to the maximum flux value in each run.

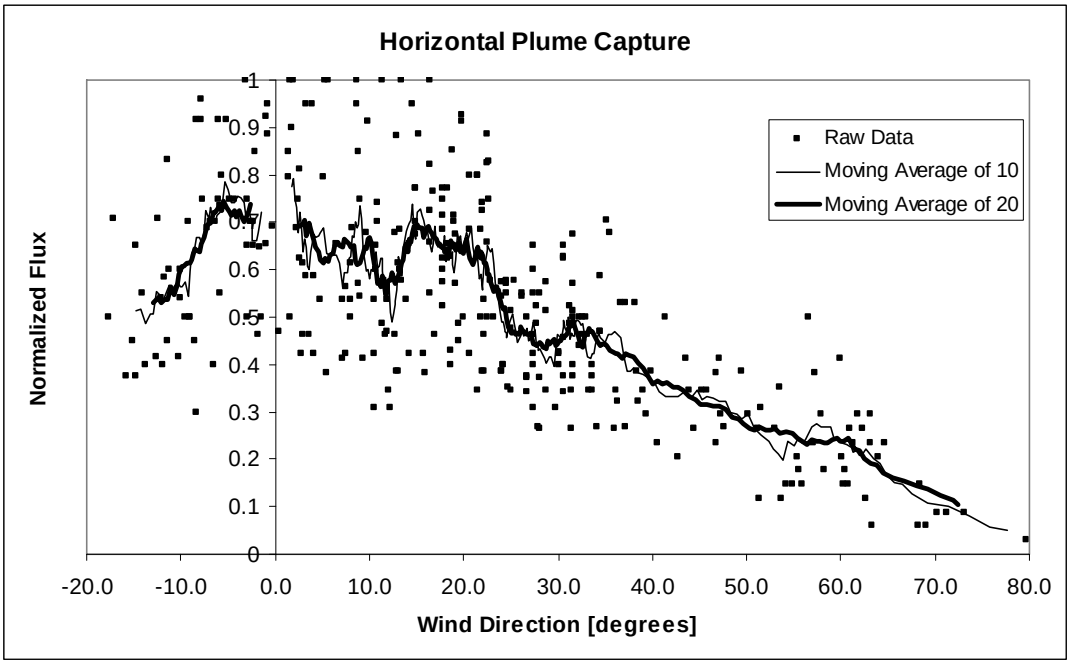

Figure B5. Plot of calculated flux values and corresponding wind direction during the time of measurements.

Fig. B5 presents a plot of this data set. The figure shows the calculated normalized flux values and the corresponding wind direction (from the normal to the RPM configuration during the time of the measurements). The figure shows that the raw flux values steadily increase, up to a certain point, as the prevailing wind direction becomes closer to

perpendicular to the configuration. However, over a certain range of wind directions, there appears to be no relationship between calculated flux values and prevailing wind direction. This range is approximately between -10° and +25° for the Duke Forest validation study. This is the approximate range of acceptable wind directions, as the variations in flux values in this range are due to variations in the source strength, and not due to changes in wind direction. It is recommended that these flux plots be smoothed out with a moving average approach to retrieve a more definite and accurate cutoff of the wind criterion. The lined curves in the figure show examples of such moving averages, one with a grouping of 10 data values (thin line) and the other with a grouping of 20 data values (thicker line). These examples of moving averages clearly define the range of wind directions where flux values are independent from the wind direction values.

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USE OF CONTROL CHARTS FOR PERFORMANCE MONITORING OF GAS ANALYZERS AND ANALYTICAL INSTRUMENTS

Standard Operating Procedure (SOP) Q1

USE OF CONTROL CHARTS FOR PERFORMANCE MONITORING OF GAS ANALYZERS AND ANALYTICAL INSTRUMENTS

Standard Operating Procedure (SOP) Q1

Prepared by

Bill W. Bogan and Claude A. Diehl

Reviewed by

Albert J. Heber

Effective Date: November 6, 2006

PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Control charts provide a real-time graphical representation of the performance of a gas analyzer or other analytical instrument, which can be used to assess data quality and to spot long-term trends in the instrument's performance. The purposes of control charts are as follows:
  1.1.1. Visual presentation of the quality control of the analyzers and other instruments
  1.1.2. Real-time assessment of the data quality of the analyzers or measurement devices
  1.1.3. To monitor the long-term performance of the instrument
  1.1.4. To determine when a corrective action must be done

1.2. The control charts described in this SOP can be applied to gas analyzers, and to any other type of measurement device (e.g. temperature, relative humidity, and pressure sensors).

1.3. A control chart plotting the standard deviation is beyond the scope of this SOP.

2. Summary of Method

Control Charts are generated by plotting data from the zero-precision checks (SOP G9) with known reference standards (control sample). After the zero-precision check is conducted, the control chart must immediately update to give real-time assessment of the instrument's performance. A control sample is used to check the instrument's performance. The instrument's response to a control sample is an indication of the instrument's deviation from the true value that is a result of intrinsic instrumental measurement error. Control limits are established to maintain statistical control of the data quality. If the reference standard results in a measurement outside the control limits, the control chart is a tool used to alert the analyst / researcher to increased uncertainty in the instrument's measurements. Other Control Chart parameters include the mean and standard deviation of the last *n* samples, where *n* may be from 5 to 20.

3. Definitions

AirDAC	Air data acquisition and control program
Control Limits	The bounds of the range (above and below the true value) that denote acceptable performance of the analyzer or sensor.
Control Sample	A known reference standard
PAAQL	Purdue Agricultural Air Quality Laboratory
QAPP	Quality Assurance Project Plan

4. Cautions

4.1. Use the correct range for the analyzer or sensor, and for AirDAC. A range that is too small will cause the analyzer or sensor's analog output to be pegged in response to the reference standard.

4.2. The control sample applied to check the analyzer or sensor must be consistent over time. In the case of gas analyzers, for example, use the same concentration for the reference gas for the zero-precision check (SOP G9).

4.3. The control sample should be representative of the range of measurements which the analyzer or sensor is expected to measure. In the case of gas analyzers, verify that the concentration of the reference gas is similar to that in the gas samples being analyzed.

5. Personnel Qualifications

5.1. Personnel must be trained in the use of control charts before working with any analyzer or sensor for which a control chart is used.
5.2. Each analyst must also read and understand this SOP before conducting a multipoint calibration (SOP G8) and zero-precision check (SOP G9).

6. Equipment and Supplies

6.1. Computer and AirDAC software program (SOP B2)
6.2. Microsoft Excel software

7. Procedures

7.1. Setup of the Control Chart
7.1.1. A template of the Control Chart will be supplied by PAAQL to each site, and will be located in the Instrument Performance Record spreadsheet of each individual instrument. Each instrument (analyzer or sensor) will have its own Control Chart.
7.1.2. General formatting and style (Fig. 1)
7.1.2.1. Use Microsoft Excel's x-y plot function for all Control Charts.
7.1.2.2. Use SI units.
7.1.2.3. The ratio of the width to height of the chart should be 1.62. This ratio is known as the Golden Ratio, and is related to the Golden Rectangle. A template is in the Instrument Performance Record File.
7.1.2.4. Use Arial font in graphs and do not bold.
7.1.2.5. Use 14-point font for the title.
7.1.2.6. Use 12-point font for all other notations (axes, labels, comments, and numbering).
7.1.2.7. Place the tic marks on the outside of the graph.
7.1.2.8. Format each tic label with fixed decimal places.
7.1.2.9. The x-axis is time (Date). Include one tic mark per week (every 7 d), and label every so many weeks with mm/dd such that the labels fit on the axis.
7.1.2.10. Don't use vertical labeling on the x-axis.
7.1.2.11. Put the legend of the graph on the inside of the chart box, not outside.
7.1.2.12. Place captions outside the chart.
7.1.2.13. Avoid redundancies in graph labeling. For example, there is no need for a title, since a caption covers it.
7.1.2.14. Label the control limits.
7.1.2.15. Multiple baselines can be used for one instrument.
7.1.2.15.1. Simultaneous baselines for the precision check gas standard and the zero reference gas can be plotted on the same chart.

7.1.2.16. Ancillary data can be plotted on the control chart (e.g. reaction chamber pressure for a chemiluminescence ammonia analyzer).

7.1.2.17. Include the serial number of the instrument in the control chart.

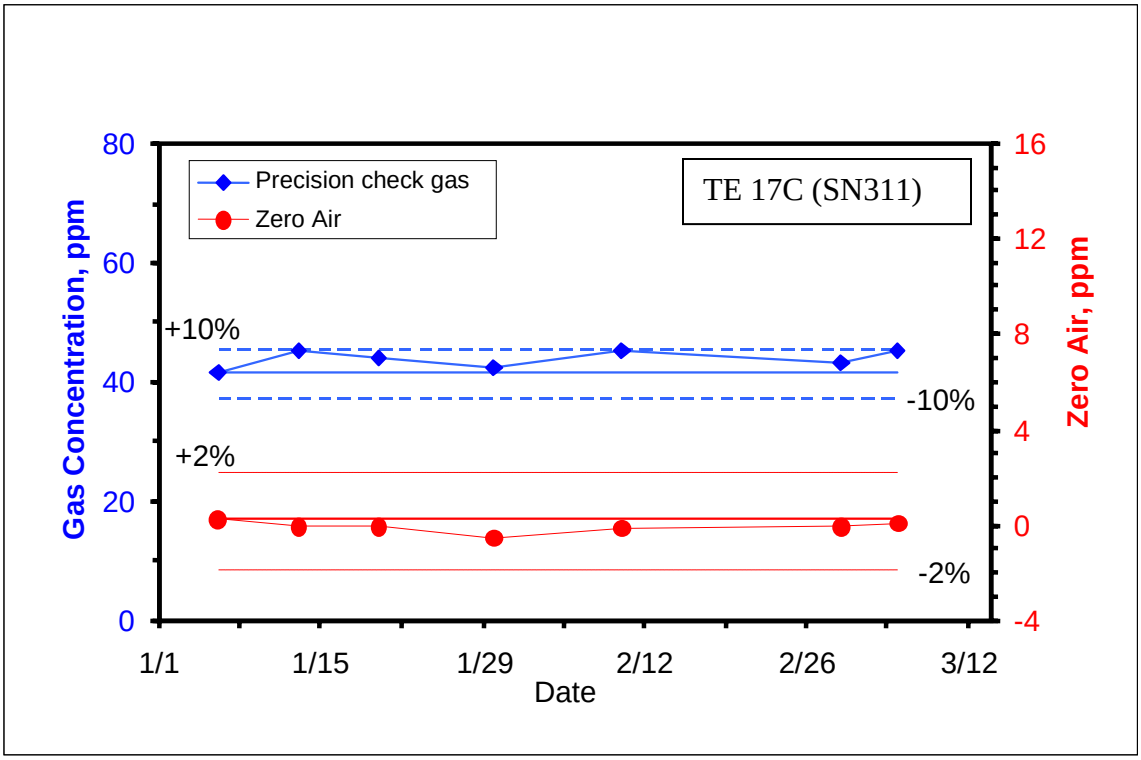

Figure 1. An example of a Control Chart, in this case for a TE 17C Ammonia Analyzer. Two baselines (both components of the zero/precision check) are included, along with their control limits (± 2% for the zero gas and ± 10% for the precision check gas).

7.2. Updating the control chart

7.2.1. Before updating, save the current control chart in the Instrument Performance Record File's "Zero – Precision Record" worksheet to keep a record of past control charts.

7.2.2. The control chart is updated from the zero-precision check data that is tabulated in the Instrument Performance Record File's "Zero – Precision Check" worksheet. This data is entered as described in SOP G9.

7.2.3. The baseline measurement is the first zero-precision check after a multipoint calibration (SOP G8) that is the target value.

7.2.3.1. The baseline measurement is established using a standard reference, the value of which is chosen to be consistent with values that are expected to be measured.

7.2.4. Save the updated control chart in the Instrument Performance Record File's "Zero – Precision Check" worksheet, as described in SOP G9.

7.2.5. Control limits

7.2.5.1. Control limits are used to determine whether the analyzer or sensor has drifted out of calibration.

7.2.5.1.1. Do the following when data points fall outside the control limits:

7.2.5.1.1.1. Access the analyzer's or sensor's operation to determine if the equipment is operating properly or is in need of repair.

7.2.5.1.1.2. Recalibrate the analyzer or sensor, and establish a calibration curve and new control chart

7.2.5.2. The controls limits are set to a ± percentage of the baseline measurement. This percentage is dependent upon the Data Quality Objectives (DQO's) in the QAPP for the gas analyzer or sensor that the Control Chart is monitoring.

7.2.5.3. The control limits can be set in the Instrument Performance Record File's "Zero – Precision Check" worksheet. The percentage is entered into the boxes labeled "Control Limit %" for both the precision control limit and the zero control limit.

8. Data and Records Management

8.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method. Supplement this electronic record by a bound record book designated for the method, which should contain copies of the electronic record.

8.2. Manage all data according to SOP B5.

8.3. Document all data and information on field data sheets, and within site logbooks with permanent ink, or in electronic field notes. Overstrike all errors in writing with a single line. Initial and date all corrections.

9. Quality Control and Quality Assurance

9.1. Maintain a control chart for all gas analyzers or sensors specified in the QAPP for the project in question.

9.2. Update the Control Chart immediately after performing a zero/precision check of a gas analyzer (SOP G9) or other sensor.

9.3. Review the Control Chart to assess data quality and instrument performance every time it is updated.

9.4. E-mail the Control Charts to the research leaders (PI, QC Manager, Gas Analyzer Manager, etc.) in a timely manner. The exact list of persons who should receive Control Charts, and the frequency, will be specified in the QAPP for the particular project.

9.5. Keep a printout of the most recent Control Chart for each analyzer or sensor in the on-farm instrument shelter (OFIS). Keep these copies available for site audits, either by PAAQL personnel or outside QA auditors.

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PRODUCER COLLABORATIONS AT OPEN-SOURCE MONITORING SITES

Standard Operating Procedure (SOP) S7

PRODUCER COLLABORATIONS AT OPEN-SOURCE MONITORING SITES

Standard Operating Procedure (SOP) S7

Prepared by:

Richard H. Grant

Reviewed by:

Bill W. Bogan and Albert J. Heber

Effective Date: November 6, 2006

PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The collection of high-quality air emissions data from a livestock facility requires communication and collaboration between the field operations staff (FOS) and the livestock producer and his/her staff.

1.1.1. The livestock producer's staff may or may not have a specific interest in the data collected at the open-source site.

1.2. This SOP describes the following:

1.2.1. Procedures for collaboration between the FOS and livestock producer and his/her staff responsible for open-source sites (lagoons and corrals)

1.2.2. Information related to the open-source sites that must be collected from livestock producers or his/her staff

1.2.3. Expectations placed upon collaborating livestock producers or his/her staff, and on the FOS

1.2.4. Possible modifications to farm operations that may be needed to accommodate the study.

1.3. This SOP applies specifically to the National Air Emissions Monitoring Study.

2. Summary of Method

The research staff must establish and maintain effective communication with any livestock-production that is participating in a research study. The facility design and operational information of the farm must be provided by the producer or his/her staff to the FOS. In addition, the FOS must communicate to the livestock producer and his/her staff those requirements that he/she must meet in order to conduct a successful study. The collaboration and communication will include email messages, phone calls, face-to-face meetings, reports, data forms, presentations, data monitoring, and project documentation such as the Quality Assurance Project Plan (QAPP).

3. Definitions

3.1.	Biosecurity	Measures that are taken to prevent spread of disease to or from livestock or poultry.
3.2.	DM	Data Manager
3.3.	FOS	Field operations staff
3.4.	PM/PI	Project Manager or Pincipal Investigator
3.5.	PPR	Pull plug with recharge
3.6.	QAPP	Quality Assurance Project Plan
3.7.	SOP	Standard Operating Procedure

4. Health and Safety

4.1. Beware of, and do not interrupt, worker traffic. FOS may request a slight delay or interruption in normal farm activities during set up and disassembly of instrumentation, but must always defer to the decisions and activities of the producer and his/her staff.

4.2. Watch out for vehicular traffic such as litter, feed, animal, milk, and egg trucks, loaders, cars, and other vehicles.
4.3. The farm's licensed electrician should conduct or approve all electrical work associated with the study. An example is connecting power to the instrument shelter.
4.4. Be careful around animals and birds to prevent personal injury.
4.5. Post the phone number for medical emergency personnel and directions (map) to the nearest hospital in the instrument trailer close to the entrance.
4.6. Emergency evacuation procedures at each measurement location will be those established by the livestock producer.
4.7. Maintain a first aid kit in the instrument trailer.

5. Cautions

5.1. Take steps to overcome language barriers (e.g. Spanish vs. English). For example, if any worker has Spanish as his/her primary language, distribute a pamphlet in Spanish indicating the objectives of the study and the importance of taking care of the instrumentation. The pamphlet can be complemented with a video and/or PowerPoint presentation in Spanish that can be distributed to all research sites, and can be included in a periodic (quarterly) refresher session (as rotation of workers in the farms can be high).
5.2. Post signs or labels by sensitive test equipment and in measurement paths, indicating that they should not be touched or worked around unless authorized by study personnel. These should also be written in the primary language(s) of the farm workers.
5.3. Fence the region around any light emitters that may cause eye damage.
5.4. FOS must follow all biosecurity protocols and guidelines requested by individual livestock producer or his/her staff. At minimum, these can be expected to include:
  5.4.1. Cleaning research vehicles and equipment entering the farm according to the producer's specific protocol
  5.4.2. Accessing only areas that are directly involved in the study
  5.4.3. Ensuring that FOS have not exceeded producer-specified limits on foreign travel and/or visits to other poultry or livestock farms.
  5.4.4. Notifying the livestock producer prior to visiting the site
5.5. The FOS should, to the greatest extent possible, solicit input and suggestions from the livestock producer and his/her staff as to safe locations for equipment, possible hazards that might occur, and appropriate precautions that might best protect equipment and staff.
5.6. Remember that the producer's involvement and time commitment to the project is less than that of the FOS. The amount of time required for the livestock producer or his/her staff to execute their commitments to the study is a major factor influencing current and future involvement. Take care not to use more of the producer's and/or staff's time than is absolutely required for the study.

6. Interferences

6.1. The participating farms should operate with typical management practices, particularly during active monitoring periods, to minimize the potential for bias in the emission data. If changes to the farm operations occur, they must be documented, and these records retained according to SOP D1.
  6.1.1. Livestock producer or his/her staff should notify FOS if research equipment is

interfering with farm operations and needs to be moved or modified.

6.1.2. Livestock producer and his/her staff must agree not to move or modify study equipment themselves.

6.2. FOS must not give tours of the study site without livestock producer's permission. Establish a policy about tours prior to setting up instrumentation on the farm.

6.3. Any add-on research projects at the farm must be approved by the livestock producer.

7. Personnel Qualifications and Training

7.1. All livestock producer and research staff involved in the study should read this SOP.

7.2. A pre-study training and orientation session for the livestock producer and his/her staff will be conducted by the FOS or Project manager, and will include time for the livestock producer or his/her staff to explain the farm operation. The training session will also be conducted in the primary language of the farm workers, with the help of translated video and/or a PowerPoint presentation.

8. Utilities, Equipment and Supplies Provided by Farm Staff

8.1. Personal protection equipment

8.1.1. Levels of protective equipment will likely vary at a given facility, depending upon the season, activity, and other factors.

8.1.2. Protective clothing may be provided by the FOS, or by the livestock producer or his/her staff, depending, for example, on the preferences of the livestock producer. Reach an agreement on this point with each producer at the beginning of the study.

8.1.2.1. For example, if livestock producer wishes to supply their own boots as part of their biosecurity program, FOS will abide by this preference.

8.2. A suitable area for placement of the open-source instrument trailer, including all-weather (e.g. gravel) access as necessary

8.3. Electric power hookup post (SOPs U4 and U5)

8.4. Utility located to ensure the FOS does not accidentally damage underground cables, gas lines, tiles, drains, or other underground hazards while sinking anchors.

8.5. Phone line (required) and internet service (preferred) (SOP U4)

8.6. A garden hose with a nozzle near the site of the open-source instrument trailer

8.7. Restroom and shower facilities, if available

9. Procedures

9.1. Livestock producer and his/her staff will allow free access to farm by project staff.

9.2. Livestock producer or his/her staff will be apprised of all necessary structural modifications (SOPs U4 and U5).

9.2.1. Provide a project schedule and QAPP to the livestock producer at least 90 days prior to initiation of setup.

9.2.2. Set up a monthly phone call with farm management to solve problems, provide updates and facilitate collaboration.

9.2.3. Detailed information about the farm will be collected for each participating site as part of the site-selection process. Site-selection criteria and parameters that should be collected before initiating a study are included as appendices.

9.2.3.1. Lagoon and basin site forms are included in Appendix A.

9.2.3.2. Corral site forms are included in Appendix B.

9.2.4. At the end of each measurement period, each collaborating livestock producer at a lagoon or basin site is requested to provide the following information (Appendix A: Table A2) for all barn(s) whose waste goes to the lagoon or basin:

9.2.4.1. Animal inventory, average weight and average age

9.2.4.2. Record of animal movements in and out of the barn

9.2.4.3. Animal diet (feed composition, including N and S levels, and feed consumption rates).

9.2.4.4. Production (quantity and weight of marketed animals, eggs, milk, etc.)

9.2.4.5. Record of sludge removals

9.2.4.6. Record of pump outs (contractor or livestock producer)

9.2.4.7. Record of water consumption

9.2.4.8. Advance notice of any change in production schedules and methods

9.2.5. At the end of each measurement period, each collaborating livestock producer at a corral site is requested to provide the following information (Appendix B: Table B2):

9.2.5.1. Animal inventory, average weight and average age

9.2.5.2. Animal diet (feed composition, including N and S levels, and feed consumption rates)

9.2.5.3. Production (quantity and weight of marketed animals, milk, etc)

9.2.5.4. Record of cleaning operations

9.2.5.5. Record of animal movements in and out of the corral

9.2.5.6. Record of water consumption

9.2.5.7. Advance notice of any change in production schedules and methods

9.3. Livestock producer and his/her staff should be made aware that placement of equipment or sensors may in some cases require some site modification. FOS and livestock producer staff should work together to ensure that both the equipment and animals are well-protected.

9.3.1. Trailers placed in lots accessible to animals will likely need to be enclosed with protective fencing.

9.3.2. Equipment placed in areas that may occasionally have vehicular traffic may need additional flagging or warning bumpers.

9.4. Livestock producer or his/her representative should contact the PM/PI whenever there are any questions or concerns relating to measurement operations, or if there is catastrophic damage to farm operations.

10. Data and Records Management

10.1. Site Identification. Each site will be labeled in a standard format to denote site type (in this case, area component), location and number. For example, the finisher swine basin in Iowa is “IA3A”. This format is described in more detail in SOP B5. Producers shall not be identified in each site plan.

10.2. The FOS will maintain a log of farm visits in the lab notebook.

10.3. The livestock producer will maintain a log sheet of non-monitored farm activities that affect emissions (See Appendix C).
10.4. Data collected using Producer Event Forms (Appendix C) will be entered into an Excel spreadsheet and included in the site field notes, as described in SOP D1. Management of this data is also described in SOP D1.
10.4.1. Scan all producer event forms, and keep them in electronic form and in paper form at the site. Electronic copies will then be ftp transferred to the PM and DM, as described in SOP D1.
10.5. Initial and date any corrections made on hard copies of forms. Use only indelible ink.

11. Quality Control and Quality Assurance

11.1. Each FOS member must maintain a log of animal exposures at other farms.
11.2. Monthly conference calls ensure communication between FOS and livestock producer.
11.3. Livestock producer must check daily to make sure his/her staff are filling out the Producer Event Form, because they do not normally record such data during daily or weekly activities.
11.4. Document all decisions and action items on paper in ink during all planning and status meetings so that it can be confirmed that all parties are in agreement.
11.5. Be sure livestock producer has a copy of the rationale for the study (found in the QAPP) and a copy of the schedule.
11.5.1. If the livestock producer wishes, provide a copy of any relevant SOPs.
11.6. Training/ information session will include a verification of understanding of the basic aspects of the project, importance of the instrumentation and effects of farm operation on the study. Verification of understanding will be through the use of a question and answer session.
11.7. Livestock producer should designate a responsible staff member (liaison between the farm and the research team) for collecting and transmitting operational information, and also provide the name of his or her substitute when he or she is not available. This person should attend all informational meetings.

12. References

12.1. SOP D1. 2006. Management of Open-source, Weather, and Lagoon-characterization Data. Standard Operating Procedure D1. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.
12.2. SOP U4. 2006. Open-source Instrument Trailer. Standard Operating Procedure U4. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.
12.3. SOP U5. 2006. The Installation of Open-source Measurement Equipment. Standard Operating Procedure U5. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

Appendix A Site Information Form for Lagoons and Basins (SOP S7)
Table A1. Lagoon and basin site-selection criteria

Category	Information
Farm name	
Address, phone	Contact Person:
Livestock Producer	Biosecurity: time since farm visit, days:
	Willing to provide production information?
	Cooperative and enthusiastic participant?
	How long has the farm been in operation under current owner?
	Able to provide feed and water consumption data? Sample analysis records?
	Willing to possibly test abatement technologies after the NAEMS?
	Describe management style (tools used, etc.):
Convenience	Distance from university, miles:
	Phone, internet, and electric power available? 240 VAC?
	Lodging nearby for research team?
Facilities	Generally describe rations:
	Animal breed:
	Describe feed delivery system
	Describe waste collection, handling, treatment and storage systems
	Rate lagoon maintenance from 1 to 5 (1 is cleanest):
	Any emission control measures at facility?
Surroundings	Describe surrounding landscape and topography (hills, flat, etc.)
	Describe other pollution sources within one mile:
	Distance to nearest land application sites
	Distance from public road. Type of road (gravel or paved).

Table A2. Characteristics of test site lagoons or basins.

Descriptive parameters	Unit 1	Unit 2	Unit 3
Livestock type			
Year of facility construction			
Separation distance from barn fans, ft			
Type of storage (basin, lagoon or tank)			
Stage of lagoon (1st, 2nd, 3rd)			
Manure contributors to unit			
Animal 1 type (sows, cows, etc.)			
Animal 1 average weight (lb)			
Animal 1 inventory (# head)			
Animal 2 type (sows, cows, etc.)			
Animal 2 average weight (lb)			
Animal 2 inventory (# head)			
Animal 3 type (sows, cows, etc.)			
Animal 3 average weight (lb)			
Animal 3 inventory (# head)			
Manure collection (flush, scrape, PPR)			
Source flush or recharge water (if any)			
Lagoon loading frequency, hours			
Minimum space surrounding unit, ft.			
Volumetric loading rate, lb/d-ft^3			
Surface loading rate, lb/d-ft^2			
Obstructions within 3X height of unit?			
If yes, what kind? (e.g. trees, barns)			
Height of highest obstruction, ft			
Distance from worst obstruction, ft			
Type of cover (crust, straw, none, etc.)			
Are solids separated from influent?			
Odor control: (digester, additives)			
Sludge removal cycle, years			
Last time sludge removed (e.g., 1999)			
Agitation prior to pumpout?			
Manure removal frequency, days			
Pump out (contractor or producer)			
Type of liner (clay, plastic, etc.)			
Volume, cubic ft			
Surface area, square feet			
Berm slope (e.g. 3:1, 3.5:1, 4 :1, etc.)			
Maximum side length, ft			
Minimum side length, ft.			
Actual freeboard, ft.			
Inner berm height, ft.			
Outer berm height, ft.			
Liquid depth, ft.			
Sludge depth, ft.			
Number of inlets (show on drawings)			
Shape (rectangular, oval, etc.)			

Appendix B Dairy Corral Site Information Form (SOP S7)
(Email to Al Heber, Purdue University: heber@purdue.edu)

Table B1. Dairy Corral Site Selection Criteria, SOP S7.

Category	Information
Farm name	
Address, phone	
Livestock Producer	Provide production and herd management information (DC305)?
	Cooperative and enthusiastic about study?
	Willing to make some nonconsequential changes for the test?
	Willing to train herdspersons about importance of test?
	Able to provide feed and water consumption data per cow group?
	Willing to possibly test abatement technologies after the NAEMS?
	Describe management style (tools used, etc.):
Convenience	Distance to site from university, miles:
	Cell phone signal?
	Phone, internet, electric power available?
	Lodging nearby for research team?
Corrals	Generally describe rations (including forages and purchased feeds)
	Describe feed delivery system.
	Describe waste collection, handling, treatment and storage systems
	Rate corral hygiene from 1 to 5 (1 is cleanest).
Surroundings	Describe surrounding landscape and topography.
	Describe other pollution sources within one mile of site;
Farm	Describe all facilities on the site (# hd, size, age);
	Distance to nearest land application sites.
	On-site heifer growing program?

Table B2. Characteristics of test site: corrals, SOP S7.

Descriptive parameters.	Type 1	Type 2	Type 3
Breed			
Inventory (cow capacity)			
Average mass, lb			
Year(s) of construction			
Overall site width (E-W dist), ft			
Overall site length (N-S dist), ft			
Heifer growing program?			
Corrals			
Type (yearlings, lactation, hosp, etc.)			
Number			
Corral orientation			
Corral width, ft			
Corral length, ft			
Corral area, ft^2			
Apron width, ft.			
Apron length, ft.			
Apron cleaning (flush, scrape, vac)			
Maintenance technique (scr, harrow)			
Maintenance frequency (days)			
Shade height, ft.			
Shade length, ft.			
Shade width, deg.			
Side slope, %			
Cross slope, %			
Cow lane width, ft			
Cow lane length, ft			
Windbreak			
Height, ft			
Length, ft			
Lagoon			
Length, ft			
Width, ft			
Depth, ft			
Berm height, ft			
Number of stockpiles			
Weeping pad area, ft^2			
Number of separators			
Number of silage bunkers			
Number of hay barns			
Parlor			
Width, ft			
Length, ft			
Sidewall height, ft			
Roof ridge height, ft.			
Type of ventilation			
Number of air outlets in ridge			
Type of sidewall inlets			
Air circulation fans in ceiling			
Misting?			

Exit lane drenching?			
Holding time, min			
Wash cows?			
Milking frequency, times daily			
Parlor occupancy, # cows			
Holding pen			
Manure removal (flush, hand wash)			
Manure removal frequency			
Width, ft			
Length, ft			
Sidewall height, ft			
Roof ridge height, ft.			
Type of ventilation (NV, MV)			
Number of air outlets in ridge			
Type of sidewall inlets			
How is feed weighed?			
How is manure loads weighed?			
How are animals weighed?			
Number of pumps to monitor			
Access around property for sensors?			

Appendix C Producer Event/Change Form (SOP S7)

In order for the Purdue Air Quality group to do its job, they need to know about events/changes around the lagoon, basin, or corral that affect airflow or air emissions. A few jotted notes here will help them not make mistakes when analyzing the data. Thank you for your cooperation! [Examples of changes include (but are not limited to): major water leaks, power interruptions, sludge removal, pump outs, and diet changes.]

Description of event/change	Start time/date	End time/date	Contact person

Project contact information:
Name(s):_____
Office phone: _____
Cell phone: _____

THE OPEN-SOURCE INSTRUMENT TRAILER

Standard Operating Procedure (SOP) U4

THE OPEN-SOURCE INSTRUMENT TRAILER

Standard Operating Procedure (SOP) U4

Prepared by

Chris D. Fullerton and Richard H. Grant

Reviewed by

Bill W. Bogan and Albert J. Heber

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. This standard operating procedure defines the characteristics of the instrument trailer to be used by each mobile measurement team in the measurement of gaseous emissions from open area sources using open-path and synthetic open path techniques.
1.2. An instrumentation trailer provides weather protection and a central communication point for all measurements made at the source as well as a means to transport the equipment from location to location.
1.3. The trailer is also used to provide a stable platform for the cellular communications antennas and all instrument communications antennas.

2. Definitions

2.1.	Al	Aluminum
2.2.	bLS	Backward Lagrangian Stochastic model
2.3.	CD	Compact disk
2.4.	cfm	Cubic feet per minute
2.5.	COM	Serial communications port
2.6.	DVD	Digital video disk
2.7.	GFCI	Ground fault circuit interrupter
2.8.	GSS	Gas sampling system
2.9.	HVAC	Heating, ventilation, and air conditioning
2.10.	kW	Kilowatt
2.11.	LAN	Local area network
2.12.	PAML	Purdue Applied Meteorology Lab
2.13.	PC	Personal computer
2.14.	PIC	Path-integrated concentration
2.15.	PM	Project manager
2.16.	RF	Radio frequency
2.17.	RPM	Radial Plume model
2.18.	SMP	Site Monitoring Plan
2.19.	S-OPS	Synthetic Open Path Sampling System
2.20.	TDLAS	Tunable Diode Laser Absorption Spectrometer
2.21.	UPS	Un-interruptible power supply
2.22.	USB	Universal serial bus
2.23.	VAC	Volts alternating current
2.24.	VDC	Volts direct current
2.25.		

3. Health and Safety

3.1. Power connections
3.1.1. Exercise care when working with the electrical system of the trailer. Wear proper personal protective equipment, such as leather gloves and safety glasses, when working around electrical circuits.

3.2. There is danger of falling with significant injury or death when working on the roof of the trailer, or on a ladder leading to the roof.
  3.2.1. Roof work safety:
    3.2.1.1. Do not attempt to climb onto slippery roofs. Inspect for and remove ice and snow before getting onto roof surfaces. If the roof surface is wet, wait until the surface is dry.
    3.2.1.2. Do not access the roof during storms, high winds or other adverse weather conditions.
    3.2.1.3. Remove or properly guard any impalement hazards.
    3.2.1.4. Wear shoes with slip-resistant soles.
    3.2.1.5. If you drop something while working on a roof, never try to catch or stop it. Let it fall and keep your own balance secure.
  3.2.2. Ladder safety:
    3.2.2.1. Keep manufactured and job-made ladders in good condition and free of defects.
    3.2.2.2. Inspect ladders before use for broken rungs or other defects so falls don't happen.
    3.2.2.3. Secure ladders near the top or at the bottom to prevent them from slipping.
    3.2.2.4. When you can't tie the ladder off, be sure the ladder is on a stable and level surface so it cannot be knocked over or have its bottom kicked out.
    3.2.2.5. Place ladders at the proper angle (4:1 slope = rise:run).
    3.2.2.6. Extend ladders at least 3 ft above the eave of the roof to provide a handhold, or for balance when getting on and off the ladder from the roof.
    3.2.2.7. Always face the ladder and maintain 3 points of contact when climbing it.
3.3. Be careful climbing the outside steps to and from the exterior door, particularly in inclement weather. Be mindful of wet or iced steps.
3.4. During lightning storms, avoid contact with electrical instruments, or with the exterior shell of the trailer.
3.5. Make yourself aware of the layout of the area upon arrival at a new location, and ask the property owner about where to find shelter in the event of a severe storm or tornado.
3.6. All field personnel must know the physical address of the current field location, so that this may be communicated in an emergency; if you’re not sure ask the property owner or the PM.
3.7. Do not operate the trailer tongue lift jack or attempt to hitch trailer without wearing suitable personnel protection equipment.
3.8. Trailer towing connections
  3.8.1. Be careful not to pinch hands when inserting the trailer socket onto the truck ball. Wear leather gloves.
  3.8.2. The ball and socket hitch connection must be firm.
  3.8.3. Chain the trailer to the truck at the trailer hitch, and be sure the chains do not drag on the ground.
    3.8.3.1. Chain lengths can be shortened to keep them from dragging on the road by twisting the chain prior to hooking it up to the truck.
3.9. Exercise proper care when setting up the trailer, including when setting up the blocks on which the trailer rests. Be mindful of crushing hazards.

3.10. Trailer tires
  3.10.1. Periodically inspect and maintain tow vehicle and trailer tires (including spare tires) and wheels.
  3.10.2. Keep appropriate pressure in the tires at all times. Proper tire pressure affects vehicle handling and the safety of tires. Find the correct tire pressure for a tow vehicle in the owner's manual, or on the tire information placard.
    3.10.2.1. Under inflation reduces the load-carrying capacity of a tow vehicle or trailer, may cause sway and control problems, and may result in overheating, causing blowouts or other tire failure.
    3.10.2.2. Over-inflation causes premature tire wear and affects the handling characteristics of the tow vehicle or trailer.
3.11. Improper loading/weight distribution in the trailer causes towing instability and may cause sudden and unexpected loss of control.
3.12. On a regular basis, have the brakes on both vehicles inspected. Be sure that necessary adjustments are made and any damaged or worn parts are replaced.
3.13. When transporting the trailer to and from the site, make sure that proper spare tires are available, and securely lock all exterior doors. Tow only with vehicles and hitches that are rated for the trailer weight. Follow any applicable state codes, and make sure that the trailer is properly licensed for the state.
3.14. Secure equipment prior to moving: Equipment may shift in transit when the equipment is not securely held to the trailer walls or floor.
  3.14.1. Load and secure instruments and equipment according to Appendix B.
3.15. Make sure gas cylinders are secured as described in SOP G2. Use a strap, chain or other fastener near the bottom of each cylinder, in addition to the top restraint, to prevent the cylinder from moving during transport. As per SOP G2, never transport cylinders with regulators attached.
  3.15.1. Pressurized gases can explode if cylinders are allowed to fall over.
  3.15.2. Leaking calibration gases can cause suffocation. Close cylinders tightly.
3.16. Be aware of traffic patterns on the farm. If possible, do not position the trailer in an area which is frequented by trucks or other vehicles.
3.17. Ensure that ventilation systems work properly, taking into account the following:
  3.17.1. If possible, do not position the trailer in a location where it will be directly in the exhaust stream of barn fans. Locate the trailer air inlet away from the barn fan exhausts.
  3.17.2. Ensure that the filters on the air inlet are changed often enough to mitigate the odors and exhausts which may be encountered on the site.

4. **Cautions**

4.1. Always check to see that trailer marker lights and both brake lights are functioning before towing trailer on any public roadway.
4.2. Power connections in the trailer
  4.2.1. Line voltage surges may damage computers and communications equipment.
  4.2.2. Improper connection of the trailer supply wiring may cause damage to computers and communications equipment, as well as personal injury.

4.3. Take care when installing, maintaining, or securing the communications antennas, and towers. The antenna and associated cables are delicate and must not be bent or broken. Do not drop.
4.4. Improper maintenance of the HVAC system can impair performance, leading to uncomfortable conditions.
4.4.1. High levels of dust, feathers, and other airborne debris can readily clog the air inlets for the HVAC systems. This can impair performance, and may result in damage to the motor, compressor, and/or heating element.
4.4.2. Clean or replace filters on the HVAC unit once a month (at minimum).
4.4.3. Check the outdoor coils once a month (at minimum), and clean as necessary.
4.4.4. Do not stack or prop anything against the outside portion of the HVAC unit, or block the outdoor coils in any way.
4.4.5. Do not allow snow to pile up or drift around the outdoor HVAC unit.
4.4.6. Periodically check the permanent drain connection near the inside coil (indoor HVAC unit) to make sure it is unobstructed, and that water is draining properly.
4.5. Calibration gases can become depleted if cylinders are not closed tightly.
4.5.1. Replace cylinder when pressure drops below 200 psi.

5. Interferences

5.1. The trailer communications systems may not function properly if the trailer is located in the vicinity of a television station or radio station transmitting tower.
5.2. Power failures will adversely affect all communications and computational equipment.
5.3. Heating and cooling failures may result in environmental conditions which are outside the specifications of the equipment.

6. Personnel Qualifications

6.1. All field personnel must wear proper protective equipment while working in the field. This includes, but is not limited to, steel-toed shoes, leather gloves, and safety glasses.
6.2. All field personnel must have practiced driving and maneuvering with the trailer before leaving for a site. In addition to the cautions listed in Section 4, and the procedures listed in Section 8.3, guidelines for driving with a trailer are found in Appendix A.
6.3. All field personnel must read and understand this SOP prior to using the trailer.
6.4. All field personnel must be able to use the severe weather alert radio.
6.5. All personnel must be familiar with the general survival skills for severe storms and tornados in the field.
6.6. All personnel must be familiar with the dangers of lightning while working in open fields and on electrical/electronic equipment in general (see SOP U5 Appendix C).
6.7. All field personnel should know how to administer first aid in the event of an accident or emergency, and know the basics of CPR.
6.8. All field personnel should be aware of the location of your field partner(s) at all times. (Field units consist of a scientist and technician that function as a team).
6.9. All personnel should tell their team partner and the PM of any special needs or health concerns they might have in the event of an emergency.

6.10. All field personnel should know how to use the provided handheld two-way radios and cell phone to contact their team partner or emergency services personnel in the event of an accident/emergency.
6.11. Personnel must be able to use a multimeter and other necessary diagnostic tools required by the job.

7. Equipment and Supplies

7.1. Tools
  7.1.1. Tire iron
  7.1.2. Multimeter
  7.1.3. Chemical protective gloves
  7.1.4. Wrenches
    7.1.4.1. To fit gas regulators
    7.1.4.2. To fit tower bolts
  7.1.5. Screwdrivers
7.2. Spare bolts and nuts
7.3. 5 ft. ladder
7.4. Work light
7.5. Clock
7.6. Compressed air can for cleaning parts
7.7. 0.5 m TDLAS calibration cell
7.8. 1.0-ft^3 240-V 800-W electric convection oven
7.9. 1.5 cu ft. refrigerator
7.10. Hitch lock to prevent unauthorized towing.
7.11. (5) Lightweight wooden landing blocks for the purpose of leveling trailer, and landing hitch jack.
7.12. Data vault
7.13. Batteries for UPS unit installed inside
7.14. Activated charcoal (if charcoal filters are used)
7.15. Cleaning supplies: hand soap, paper towels, cloths, bucket, broom, trash bags and trash can
7.16. Fly traps or strips, mouse/rat poison
7.17. Trailer: Order or obtain a trailer that meets or exceeds the following minimum specifications, or their equivalents:
  7.17.1. Spare tires (minimum of two, stored in bed of tow vehicle)
  7.17.2. Frame & structural support
    7.17.2.1. 7′ wide x 14′ long
    7.17.2.2. Tandem 3500-lb (2 brake) axles
    7.17.2.3. Standard towing hitch
  7.17.3. Floor
    7.17.3.1. 3/4″ plywood deck
    7.17.3.2. R-11 insulation
    7.17.3.3. Tile floor covering
    7.17.3.4. Recessed D-ring tie downs every 2′ on centerline (starting 1′ from end)

7.17.4. Roof
- 7.17.4.1. Minimum 8′ height inside
- 7.17.4.2. R-10 insulation w/vapor barrier
- 7.17.4.3. 3/8″ plywood sheathing inside
- 7.17.4.4. 30-gage galvanized steel

7.17.5. Walls
- 7.17.5.1. Heavy duty studs w/top and bottom plates
- 7.17.5.2. R-10 insulation
- 7.17.5.3. 3/8″ plywood interior walls
- 7.17.5.4. D-ring tie downs every 2′ at 2′ and 4′ height (starting 1′ from end)

7.17.6. Exterior doors
- 7.17.6.1. (1) Steel/wood door in side of trailer with bar lock
- 7.17.6.2. (1) Large single hinge down steel/wood solid door at trailer back for loading/unloading with cam locks and lift assist system

7.17.7. Electrical system
- 7.17.7.1. 100-Amp 240 VAC load center
  - 7.17.7.1.1. Two 50-A circuit branches (Phases) at 120 VAC (this is considered a standard 240VAC single-phase service)
  - 7.17.7.1.2. Standard 3-wire single phase (includes neutral).
- 7.17.7.2. 100-Amp circuit breaker panel
- 7.17.7.3. Receptacles
  - 7.17.7.3.1. (1) 240 VAC 15-Amp interior
  - 7.17.7.3.2. (2) 110-V 20-A Interior (for master UPS connection)
  - 7.17.7.3.3. (8) 110 VAC duplex 15-Amp interior
  - 7.17.7.3.4. (1) 110 VAC 15-Amp exterior with water seal protection
- 7.17.7.4. Interior Lighting
  - 7.17.7.4.1. (3) 48″ 120VAC standard dual tube fluorescent lights with diffusers (installed lengthwise one in front, one in middle, one in rear).
  - 7.17.7.4.2. (2) 12 VDC “dome lights”.
- 7.17.7.5. Lightning arrestor (built into UPS unit)
  - 7.17.7.5.1. Surge suppressor with minimum of 120,000 Amp/phase capacity (built into UPS unit)

7.17.8. HVAC system
- 7.17.8.1. Sidewall closeable pass-through tube (for signal cable pass-through)
- 7.17.8.2. 24,000 BTU/hr cooling or that adequate to cool to 70°F if outside is 120°F
- 7.17.8.3. 5 kW heater or that adequate to heat to 70°F if outside is -30°F
- 7.17.8.4. Return air at unit with remotely located thermostatic control.

7.17.9. General exterior
- 7.17.9.1. 24″ Stoneguard on front
- 7.17.9.2. Siding: 0.024 Al
- 7.17.9.3. (4) Tie down points
- 7.17.9.4. 4 Stabilizer jacks
- 7.17.9.5. Running lights and tail lights

7.17.10. Furniture
- 7.17.10.1. (1) 8′x2′ counter top permanently affixed to the front of the trailer walls

7.17.10.2. (1) stool/chair
7.17.11. Storage
7.17.11.1. (1) wall-mounted file holder
7.17.11.2. (2) 18″ deep lockable cabinets on sidewall
7.17.11.3. (1) Portable file cabinet
7.17.11.4. (1) Three-drawer cabinet affixed to the sidewall
7.18. Cable pass-through should accommodate the following
7.18.1. Coaxial cables for RF modems:
7.18.1.1. (4) for communications with TDLAS/scanner system
7.18.1.2. (1) for communications with data logger
7.18.1.3. (1) for communications with sonic anemometers
7.18.1.4. (1) for cellular internet
7.19. Tubing pass-through should accommodate the following
7.19.1. (4) 3/8″ OD Teflon tubing:
7.19.2. (1) 1/4″ OD Teflon tubing:
7.19.3. (2) 5/8″ ID PVC tubing
7.19.4. (1) 3/16″ ID PVC tubing:
7.20. Install the following in the trailer:
7.20.1. Instrument rack: Constructed of steel and able to accept sliding trays or rails. Open racks help to maintain low instrument temperature and good air circulation firmly secured to the sidewall.
7.20.1.1. (1) INNOVA 1412 multi-gas analyzer (SOP G7)
7.20.1.2. (1) Thermo Fisher Scientific 450i Pulsed Florescence H2S Analyzer (SOP G5)
7.20.1.3. (1) Thermo Fisher Scientific 146i Diluter (SOP C3)
7.20.1.4. (1) LAN server computer (SOP D1), which includes the following:
7.20.1.4.1. Serial port expansion bus
7.20.1.4.2. UPS web adapter card and Network Protection Module
7.20.1.5. (1) Web power switch for internet access of power in trailer
7.20.1.6. (1) LAN server external storage drive
7.20.1.7. (1) Power distribution and surge protection device
7.20.1.8. (1) 120-VAC In/Out double conversion Uninterruptible Power Supply.
7.20.1.9. (1) Read//write CD/DVD drive
7.20.1.10. (1) Flash memory drive reader
7.20.2. Install on wall near instrument rack
7.20.2.1. (1) Cellular RF internet modem for communication with PAML and internet
7.20.2.2. (1) 24VDC power supply for GSS solenoid power
7.20.2.3. Multiple Ethernet ports using an Ethernet switch and router
7.20.2.4. (6) RF modem transceivers (in trailer)
7.20.2.4.1. (1) for meteorological data logger
7.20.2.4.2. (1) for sonic anemometers
7.20.2.4.3. (4) for TDLAS
7.20.2.5. (8) RF modem transceivers (at instruments)
7.20.2.5.1. (1) for meteorological data logger
7.20.2.5.2. (3) Built into power unit of sonic anemometers
7.20.2.5.3. (4) Built into power unit of TDLAS

7.20.2.6. (1) Scanner (for copying paper documents)
7.20.2.7. USB, RF modems
7.20.2.8. Gas sampling system: attached with shelf brackets near or mounted on top of instrumentation rack..
7.20.2.9. CR800 Data logger and A21 REL-12 relay controller.
7.20.3. Compressed gases
7.20.3.1. Total non-flammable gases and total flammable gases must weigh less than 220 lbs each. If not, Department of Transportation placarding and special inspections and approvals are required.
7.20.3.2. One four-cylinder rack on the wheel well and two auxiliary positions in front of wheel well to hold calibration gas cylinders. See SOP G2 for the proper means of securing cylinders to the rack(s), and for the proper regulators to use with each gas. Cylinders should be A3 size or equivalent, except for CEM zero air (size AQ).
7.20.3.2.1. NH_3
7.20.3.2.2. H_2S
7.20.3.2.3. Methane/propane
7.20.3.2.4. Methanol/ethanol
7.20.3.2.5. CEM zero air
7.20.3.2.6. SO_2 calibration
7.20.3.3. One cylinder rack on cabinet to hold zero (N_2) gas cylinders.
7.20.4. Miscellaneous radio equipment
7.20.4.1. NOAA severe weather alert receiver with internal battery backup
7.20.4.2. Two way radios for communications between FOS.
7.20.5. Appliances under counter
7.20.5.1. Small refrigerator to store chemicals only
7.20.5.2. Convection oven to dry chemicals and desiccants.
7.20.6. Internal configuration of storage areas (Fig. 1)
7.20.6.1. Store the following in place on meteorological mast secured using straps attached to D-rings:
7.20.6.1.1. (1) NEMA box with data logger, barometer, and RF modem, and antenna for modem
7.20.6.1.2. (1) Solar radiation sensor and mounting fixture and bracket
7.20.6.1.3. (1) RH/T sensor in passive radiation shield
7.20.6.1.4. (3) Sonic anemometers and their modems
7.20.6.1.5. (2) TDLAS/scanner systems
7.20.6.1.6. (20) Retro-reflectors with mounting brackets (10″ x 9″ x 7″ boxes)
7.20.6.1.6.1. (8) Mounting on tripods
7.20.6.1.6.2. (12) Mounting on fixed towers
7.20.6.2. Store the following in the rear of tow vehicle inside plastic pail
7.20.6.2.1. (1-2) 107-L thermistor
7.20.6.2.2. (1-2) ORP redox state sensor
7.20.6.2.3. (1-2) pH sensor
7.20.6.2.4. Lagoon probe float(s) and associated tie down ropes
7.20.6.3. Tripods (stored in plastic bin)

7.20.6.3.1. (8) Tripods for retro-reflectors
7.20.6.3.2. (2) Tripods for TDLAS/scanner systems
7.20.6.3.3. (1) Tripod for calibration cells
7.20.6.4. (1) Fold-down 3-m mast
7.20.6.5. Ground rods (SOP U5)
7.20.6.6. 3/8″ ID Teflon tubing for SOPS sampling
7.20.6.6.1. (1) 500′ section of tubing for S-OPS extension
7.20.6.6.2. (1) 1000′ section of tubing for S-OPS extension
7.20.6.6.3. (2) 50′ S-OPS sampling manifold with filtered inlets
7.20.6.7. 1/4″ ID tubing for connections between cylinders, analyzers, rotameters, diluter, and calibration chamber.
7.20.6.8. Cables
7.20.6.8.1. (2) Power cables for TDLAS/scanner systems
7.20.6.8.2. (2) Power/Signal cables for TDLAS to scanner and scanner to power supply hookup
7.20.6.8.3. (4) Serial communications cables for TDLAS/scanner
7.20.6.8.4. Coaxial cables for RF modems:
7.20.6.8.5. (4) for trailer for communications with TDLAS/scanner system
7.20.6.8.6. (1) for trailer for communications with CR1000 data logger
7.20.6.8.7. (1) for trailer for communications with CR800 data logger
7.20.6.8.8. (1) for trailer for communications with sonic anemometers
7.20.6.8.9. (1) for trailer for communications with Cellular Modem
7.20.6.8.10. (1) spare cable
7.20.6.9. Additional computers (stored in protective cases under front counter)
7.20.6.9.1. (2) TDLAS/ laptop computers (SOP C2, SOP O2).
7.20.6.10. Communications equipment
7.20.6.10.1. Antenna for RF communications (stored in cabinet drawer):
7.20.6.10.1.1. (4) for trailer for TDLAS/scanner systems
7.20.6.10.1.2. (1) for trailer for communications with data logger
7.20.6.10.1.3. (1) for trailer for communications with sonic anemometers
7.20.6.10.1.4. (1) for trailer for communications with Cellular Modem
7.20.6.10.2. RF modems (internal means in trailer mounted on wall):
7.20.6.10.2.1. (4) internal for TDLAS/scanner systems
7.20.6.10.2.2. (1) internal for data logger communications
7.20.6.10.2.3. (1) internal for polled anemometer communications
7.20.6.10.2.4. (1) Airlink “Raven X” Cellular Internet Modem
7.20.6.10.2.5. (4) external for TDLAS/scanner systems (built into TDLAS power supply boxes)
7.20.6.10.2.6. (1) external secured inside NEMA box for data logger
7.20.6.10.2.7. (3) external built into anemometer power boxes
7.20.6.11. Miscellaneous hardware supplies (to be stored in cardboard or plastic boxes):
7.20.6.11.1. Stakes
7.20.6.11.2. Clamps
7.20.6.11.3. Tie-down straps
7.20.6.11.4. Spare bolts for towers and sensor mounting brackets

7.20.6.12. Eye wash station (attached to wall)
7.20.6.13. Two-gallon container for hand/emergency wash water
7.20.6.14. First Aid kit (attached to wall)
7.20.6.15. Fire extinguisher (stored in truck during transit)
7.20.6.16. (2) 1400VA APC brand UPS units for TDLAS system field backups (stored on floor under front counter during transport)
7.20.6.17. TDLAS back-up battery protection box stored on floor during transport (used for containing straps/cords during transport).

8. Procedures

8.1. Acceptance
8.1.1. Conduct a thorough check of the wiring system before turning power on to the trailer. Make sure that all instruments are disconnected before supplying power to the trailer for the first time.
8.1.2. Environment monitoring
8.1.2.1. Heating and cooling
8.1.2.1.1. .Set thermostat to ambient temperature + 20°F to test heating, or ambient temperature - 20°F to test cooling.
8.1.2.1.2. If air temperature in trailer stabilizes at set temperature ± 3°F, system passes.
8.1.2.1.3. If air temperature in trailer does not stabilize at set temperature ± 3°F, system fails; contact manufacturer for repair.
8.1.3. Power distribution
8.1.3.1. Test each outlet for line voltage.
8.1.3.1.1. Identify which outlets go with each circuit breaker and mark in breaker box and in trailer log.
8.1.3.1.1.1. If an outlet does not have appropriate voltage, check circuit breaker or upper GFCI receptacle (if one is above it).
8.1.3.1.1.2. Reset if needed and retest.
8.1.3.1.1.3. If there is still no power, contact manufacturer for rectification.
8.1.3.2. Test each outlet for correct polarity.
8.1.3.2.1. If polarity is incorrect, notify manufacturer for resolution.
8.1.4. Lighting
8.1.4.1. Turn lights on and check for all lamps to light.
8.1.4.1.1. If lamp does not light, replace lamp and retry. If problems continue, contact manufacturer for rectification.
8.1.5. Storage (according to Fig. 1)
8.1.5.1. Fire-proof data vault for storage of data backups between measurement periods
8.1.5.2. Drawers in plastic file cabinet
8.1.5.2.1. Logbooks, calibration tables, and checklists
8.1.5.2.1.1. For individual sensors
8.1.5.2.1.2. Data logger installation
8.1.5.2.2. Site installation forms
8.1.5.2.2.1. Towers
8.1.5.2.2.2. Open source gas measurement systems

8.1.5.2.3. Material Safety Data sheets for calibration gases, pH calibration solutions, redox calibration solutions and other chemicals
8.1.5.2.4. All relevant SOPs
8.1.5.2.5. Copy of QAPP
8.1.5.2.6. Copy of SMPs
8.1.5.2.7. Manuals for all instruments
8.1.5.3. Cabinets according to Fig. 1
8.1.5.3.1. Electronic storage media: Writeable DVDs and CDs
8.1.5.3.2. pH calibration solutions
8.1.5.3.3. Redox calibration solutions
8.1.5.3.4. Relative humidity salts
8.1.5.3.4.1. Individual sensors attached to each SOP
8.1.5.3.5. Trailer walls
8.1.5.3.5.1. HVAC unit
8.1.5.3.5.2. RF modems
8.1.5.4. Cable storage tie downs according to Fig. 1
8.1.5.5. Tubing storage on walls and on reels as needed.
8.1.5.5.1. 1/4″ ID tubing for connections between cylinders, analyzers, rotameters, diluter, and calibration chamber.
8.1.5.5.2. 3/8″ ID tubing for S-OPS and connection of S-OPS with GSS
8.1.5.5.2.1. (1) 500′ section of tubing for S-OPS extension
8.1.5.5.2.2. (1) 1000′ section of tubing for S-OPS extension
8.1.5.5.2.3. (2) 50′ S-OPS sampling manifold with filtered inlets
8.1.5.6. Rack mount according to Fig. 1 (SOP D1)
8.1.5.6.1. Network LAN server computer
8.1.5.6.2. Thermo Fisher Scientific 146i diluter
8.1.5.6.3. Thermo Fisher Scientific Pulsed Florescence H_2S analyzer
8.1.5.6.4. UPS
8.1.5.6.5. Power distribution center for computers
8.1.5.6.6. External storage drives
8.1.5.6.7. Ethernet communications switch
8.1.5.7. Gas cylinders affixed to wall storage unit/tie downs (SOP G2)
8.1.5.7.1. Seven cylinder mounting brackets for compressed gases
8.1.5.7.2. NH_3 calibration gas cylinder and appropriate regulator (CGA 705)
8.1.5.7.3. H_2S calibration gas cylinder and appropriate regulator (CGA 330)
8.1.5.7.4. CEM Zero air (N_2) gas cylinder and appropriate regulator (CGA 580)
8.1.5.7.5. CEM Zero air gas cylinder and appropriate regulator (CGA 580)
8.1.5.7.6. SO_2 calibration gas cylinder and appropriate regulator (CGA 660)
8.1.5.7.7. Methane/propane calibration gas cylinder and appropriate regulator (CGA 350)
8.1.5.7.8. Methanol/ethanol calibration gas cylinder and appropriate regulator (CGA 350)
8.1.5.8. First aid kit (attached to wall near side entrance door)
8.1.5.8.1. A first aid kit is located in the field trailer. It can be used for minor injuries, including abrasions, contusions, punctures, and burns

8.1.5.9. Eye Wash Stations

8.1.5.9.1. An eye wash station is located in the field trailer. It is to be used when chemicals spill on skin, or to flush a foreign object from the eye. Do not use if the tamper seal is broken, or if the solution is cloudy. Do not drink the solution.

8.1.5.10. A two-gallon water container is located in the trailer for the purpose of washing hands, or for quick access to water in the event of a small emergency (stored on floor).

8.1.5.11. Fire extinguisher

8.1.5.11.1. A dry chemical (ABC) type fire extinguisher is located in the field trailer. ABC-type fire extinguishers can be used for most types of fires, including the following:

Class A - Ordinary Combustibles; examples: trash, wood, and paper.
Class B - Flammable & Combustible Liquids: e.g. gasoline, diesel, grease.
Class C - Electrical Equipment; examples: computers, outlets and cords.

8.1.5.11.2. Fire extinguisher to be carried in truck during transport of trailer

8.2. Troubleshooting

8.2.1. Heating/cooling

8.2.1.1. Check thermostat settings.

8.2.1.2. Check for the presence of 240 VAC at supply.

8.2.1.3. Check breakers in circuit breaker box and GFCI outlet on circuit, and reset as needed.

8.2.2. If power fails for an instrument in field:

8.2.2.1. Check connection to power outlet on post.

8.2.2.2. Check breakers in circuit breaker box, and reset as needed.

8.2.3. If signal fails for an instrument:

8.2.3.1. Follow procedures indicated in the SOP for the instrument.

8.2.4. If RF Communications fails for an instrument:

8.2.4.1. Follow procedures in appropriate instrument SOP (SOPs W6, W2, C1, C2).

8.2.5. If Cellular Communications fails:

8.2.5.1. Check operational lights on RF modem.

8.2.5.1.1. If proper lights are lit, reset router and wait three minutes for it to reboot

8.2.5.1.2. If still not working, turn modem off then back on (reset).

8.2.5.1.3. Wait four minutes then reset router again.

8.2.5.1.4. If problems continue, contact PM at PAML for remediation.

8.3. Transportation

8.3.1. Ensure that all exterior doors are securely locked, all instruments and all gas cylinders are securely fastened.

8.3.2. Ensure vehicle and trailer maintenance is current. This is very important because towing puts additional stress on the tow vehicle.

8.3.3. Check and correct tire pressure on the tow vehicle and trailer.

8.3.4. Check for proper trailer loading to ensure balance is correct. Use common sense when determining trailer balance.

8.3.4.1. The trailer should be weighted so that the tongue drops the rear of the tow vehicle somewhat when dropping onto the hitch ball.

8.3.4.2. If the weight is excessive (tow vehicle squats significantly), check trailer loading and re-orient the contents slightly to provide less tongue weight.

8.3.4.3. Conversely, if the tongue is very light (tow vehicle doesn't respond to dropping ball onto hitch) check trailer loading and re-orient the contents slightly to provide more tongue weight.

8.3.4.3.1. Use caution when entering the trailer after the stabilizers have been raised, as the trailer might suddenly tip back if not securely hitched to tow vehicle, causing damage to trailer, contents, and the possibility of severe personal injury!

8.3.5. Be sure the hitch, coupler, and other equipment that connect the trailer and the tow vehicle are properly secured and adjusted.

8.3.6. Check that the wiring is properly connected—not touching the road, but loose enough to make turns without disconnecting or damaging the wires.

8.3.7. Make sure all running lights, brake lights, turn signals, and hazard lights work.

8.3.8. Verify that the brakes on the tow vehicle and trailer are operating correctly.

8.3.9. Check that all items are securely fastened on and in the trailer.

8.3.10. Be sure the trailer jack, tongue support, and any attached stabilizers are raised and locked in place.

8.3.11. Check to see that the wooden landing blocks have been picked up and loaded into trailer or tow vehicle.

8.3.12. Fully extend side mirrors and check all mirrors to make sure they are properly adjusted and you have good visibility.

8.3.13. Check routes and restrictions on bridges and tunnels.

8.4. Site establishment and trailer unloading

8.4.1. Position trailer to match correct location for ground driven anchors .

8.4.2. Prop the hitch and disconnect it from the truck.

8.4.3. Disconnect trailer wiring cable from the tow vehicle.

8.4.4. Level trailer according to Appendix C.

8.4.5. Anchor trailer between ground-driven anchors and trailer anchor points with new strap set and special purpose bolts.

8.4.6. Attach hitch lock on the hitch for security purposes.

8.4.7. Connect trailer power:

8.4.7.1. Attach the bare #6 Grounding wire from the trailer supply box to the ground rod.

8.4.7.2. Using a multimeter set to measure AC voltage, test the provided power access point for the correct supply voltage. Acceptable limits are 210-240 volts phase to phase, and 105-120 volts phase to neutral. Be absolutely certain to turn off the supply source (where possible) before connecting the power cable.

8.4.7.3. Use a long 80-A power cord to connect to an appropriate circuit breaker or switch box at the farm-provided power access point and to the internal electrical panel

8.4.7.3.1. Be sure to hook the correct wire to neutral and each of the of the phases to the respective 120 volt phase lugs of the circuit breaker or fuse block to achieve 240 volts phase to phase and 120 volts phase to neutral.

8.4.7.3.2. Test the neutral to earth ground voltage with a multimeter to determine whether it meets the requirements of the electric code.

8.4.7.3.2.1. Use extreme caution when making this measurement, as potentially hazardous voltages could be present between the earth ground point and the neutral connection to the trailer.

8.4.7.3.3. If the voltage exceeds 2 volts, or the specified value in the local electric code (whichever is lower), take corrective action.

8.4.7.3.3.1. Check the condition of the supply cable and connectors at both ends, paying particular attention to the neutral conductor.

8.4.7.3.3.2. Check the neutral to earth ground voltage at the supply from the farm-provided power access point, to determine if the problem is coming from there. If so, turn off the source and contact the electrician contracted with the respective farm for remediation (SOP S7).

8.4.7.3.3.2.1. Use caution near the suspected faulty power access point.

8.4.7.4. Ensure that the shelter is sufficiently grounded for proper operation of all equipment

8.4.7.5. Check polarity of all wiring before connecting instruments.

8.4.7.6. Check for power in trailer.

8.4.7.6.1. Check to see that the voltage is within acceptable limits (210-240 volts phase to phase and 105-120 volts phase to neutral). If not, check voltages at the farm-provided power access point.

8.4.7.6.1.1. If the voltage is not acceptable at the provided access point, turn off the source and contact the electrician contracted with the respective farm for remediation (SOP S7).

8.4.7.6.1.2. If the voltage is acceptable at the provided access point, but is not correct at the trailer, check the power cable and connections at each end.

8.4.8. Turn on the rack-mounted UPS in accordance with manufacturer's instructions, wait two minutes for the unit to self test and power up.

8.4.8.1. Verify that the UPS is operating properly.

8.4.9. Unpack radio antenna from trailer.

8.4.10. Mount all communications antennas to the roof mount points on the trailer.

8.4.11. Connect the modem receiver cables to the antennas.

8.4.12. Route the RF modem receiver cables from the outside antennas into the trailer through the antenna cable pass-through, and connect to the modem receivers. Attach the 2.4-GHz antennas to the proper radios and the 900-MHz antenna cable to the 900-MHz modem.

8.4.13. Follow SOP U5 and SOP U7 to connect and set up the modems.

8.4.14. Unpack sensors and conduct installation procedures for each.

8.4.14.1. Return packing boxes to trailer.

8.4.15. Set up synthetic open paths according to SOP C4, U5 or U7, and the respective site monitoring plan (SMP).

8.4.15.1. (1) S-OPS extension is 500′ long and belongs at the path location nearest the trailer.

8.4.15.1.1. Connect section of extension with stainless steel connectors.

8.4.15.2. (1) S-OPS extension is 1000′ long and belongs at the path location furthest from the trailer.

8.4.15.2.1. Connect section of extension with stainless steel connectors.

8.4.15.3. Pass S-OPS extension tube through trailer tubing pass-through and connect to GSS.
8.4.15.4. Return tubing reels to trailer.
8.4.15.5. Attach S-OPS extensions to S-OPS sampling manifolds
8.4.15.6. Follow procedures in SOP C4 to prepare for S-OPS operation.
8.4.16. Check communications between appropriate computer and sensor(s) (SOP W6).
8.4.16.1. TDLAS (SOP C2)
8.4.16.2. 3 sonic anemometers (SOP W2)
8.4.16.3. CR1000 data logger (SOP W6)
8.4.16.4. CR800 data logger (SOP C4)
8.4.16.5. Cellular internet modem
8.4.17. Verify all critical internal equipment is functioning normally through the UPS.
8.5. Site disassembly and trailer loading
8.5.1. Remove Retro-reflectors and anemometers from towers (SOP U5).
8.5.1.1. Perform anemometer intercomparison check using meteorological mast and special mount (stored in rear of tow vehicle).
8.5.2. Remove S-OPS from posts, roll up tubing and disconnect tubing from 47-mm filter in trailer on intake line.
8.5.3. Disconnect RF modem cables and pass back outside.
8.5.3.1. Remove cables from RF modem antennas and store in trailer.
8.5.3.2. Remove radio antennas from roof mount points on the trailer and store in cabinet drawer,
8.5.4. Load trailer with equipment according to plan in Appendix B so that weight distribution is optimized.
8.5.4.1. Store TDLAS/scanners, retro-reflectors, tripods, etc, in appropriate shipping boxes.
8.5.4.2. Remove gas regulators from all cylinders and store regulators in appropriate shipping boxes.
8.5.4.3. Install cylinder caps to protect cylinder valves during transport.
8.5.4.4. Install safety frame over A3 gas cylinders and secure with wing nuts.
8.5.5. Switch power feed off at trailer.
8.5.5.1. Switch power feed off at source.
8.5.6. Disconnect trailer power cable from post power socket.
8.5.7. Disconnect #6 ground wire and store in trailer.
8.5.8. Remove anchor strap from trailer to ground-driven anchors.
8.5.8.1. Store anchor strap bolts in trailer.
8.5.9. Raise all corner jacks and lock into upper (travel) position
8.5.10. Hitch trailer to tow vehicle.
8.5.10.1. Visually inspect the nuts, bolts, and other fasteners to ensure that the hitch remains secured to the tow vehicle and the coupler remains secured to the trailer. The connection point may require periodic lubrication to permit free movement of the coupler to the hitch ball.
8.5.11. Secure trailer to tow vehicle with chain and check slack.
8.5.11.1. Correct problems if chain is loose.
8.5.12. Load towers and mast onto trailer according to SOP U5.

8.5.13. Connect backup and brake lights cables.
8.5.13.1. Test lights.
8.5.13.2. If a problem exists, make sure connector-plug prongs and receptacles, light sockets, wire splices, and ground connections are clean and shielded from moisture. Lightly coat all electrical terminal connections with non-conducting (dielectric), light waterproof grease.
8.5.13.2.1. Clean the prongs with very fine sandpaper, being careful not to damage the contact area.
8.5.13.2.2. Clean the surface deposits in the connector holes (while lights are off to prevent blowing a fuse). Try to clean off only the deposits and lubricate lightly with dielectric, light waterproof grease.
8.5.13.2.3. If problems continue, correct wiring problems before leaving nearest repair facility.

8.6. Operations
8.6.1. Communications (Fig. 2)
8.6.1.1. Between trailer laptop PCs and TDLAS is via RF modems
8.6.1.2. Between trailer PC and weather CR1000 data logger is via RF modems
8.6.1.3. Between trailer PC and PAML is via a Cellular RF modem
8.6.1.4. Between trailer PC and GSS CR800 data logger is via hard-wired RS-232
8.6.1.5. The outside weather conditions will be monitored.

8.7. Computer Hardware & Software
8.7.1. PCs for collecting data and quality control of measurements (SOP D1) (Fig. 2)
8.7.2. Computers will be on a local-area network.
8.7.2.1. Each computer will have surge protection via the UPS.
8.7.2.2. Each computer will have a 20-min capacity backup power supply.
8.7.3. (1) Rack-mounted network LAN server computer
8.7.3.1. The computer will run the LoggerNet software for the control of the GSS and meteorological/ lagoon measurement data loggers and the storage of measurements from the dataloggers.
8.7.3.1.1. All weather conditions (temperature, barometric pressure, solar radiation, relative humidity, surface wetness), and lagoon conditions (pH, temperature, and redox state) will be recorded by the CR1000 data logger and periodically transferred to the LAN server via RF modem link (SOP W6)
8.7.3.1.2. GSS conditions (sample manifold pressure, flow direction, and mass flow) will be recorded by the CR800 Data logger and continuously transferred to the LAN server (SOP C4).
8.7.3.1.3. GSS solenoid control for sampling synthetic open paths will be through a relay controller and the CR800 Data logger (SOP C4).
8.7.3.2. The computer will run “Visual Basic” software to collect and record wind component, turbulence (SOP W2), and NH_3 and VOC measurements (SOP G7).
8.7.3.3. The computer will run “iPort” software to collect and record H_2S measurements (SOP G5).

9. Data and Records Management

9.1. Document all data and information from the field on field data sheets and in site logbooks with permanent ink, or in electronic notes.
9.2. Overstrike all errors in writing with a single line. Initial and date all such corrections.

10. Quality Control and Quality Assurance

10.1. At the beginning and end of each measurement period on site
  10.1.1. Follow and document a checklist of setup procedures.
  10.1.2. Follow and document a checklist of disassembly procedures.
10.2. Document all problems encountered during setup, and their resolutions, on the checklists.
10.3. If environmental conditions in the trailer exceed equipment specifications, log the event in the daily log and take remedial action. Document the action taken, and the resolution.
10.4. Lock trailer when unoccupied.

11. References

11.1. iPort Instruction Manual. 2007. *i*Port Instruction Manual. Communications software for iSeries and C Series Instruments. Part#102606-00. Thermo Fisher Scientific, Franklin, MA.
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Figure 1. Trailer storage configuration (14’ x 7’).

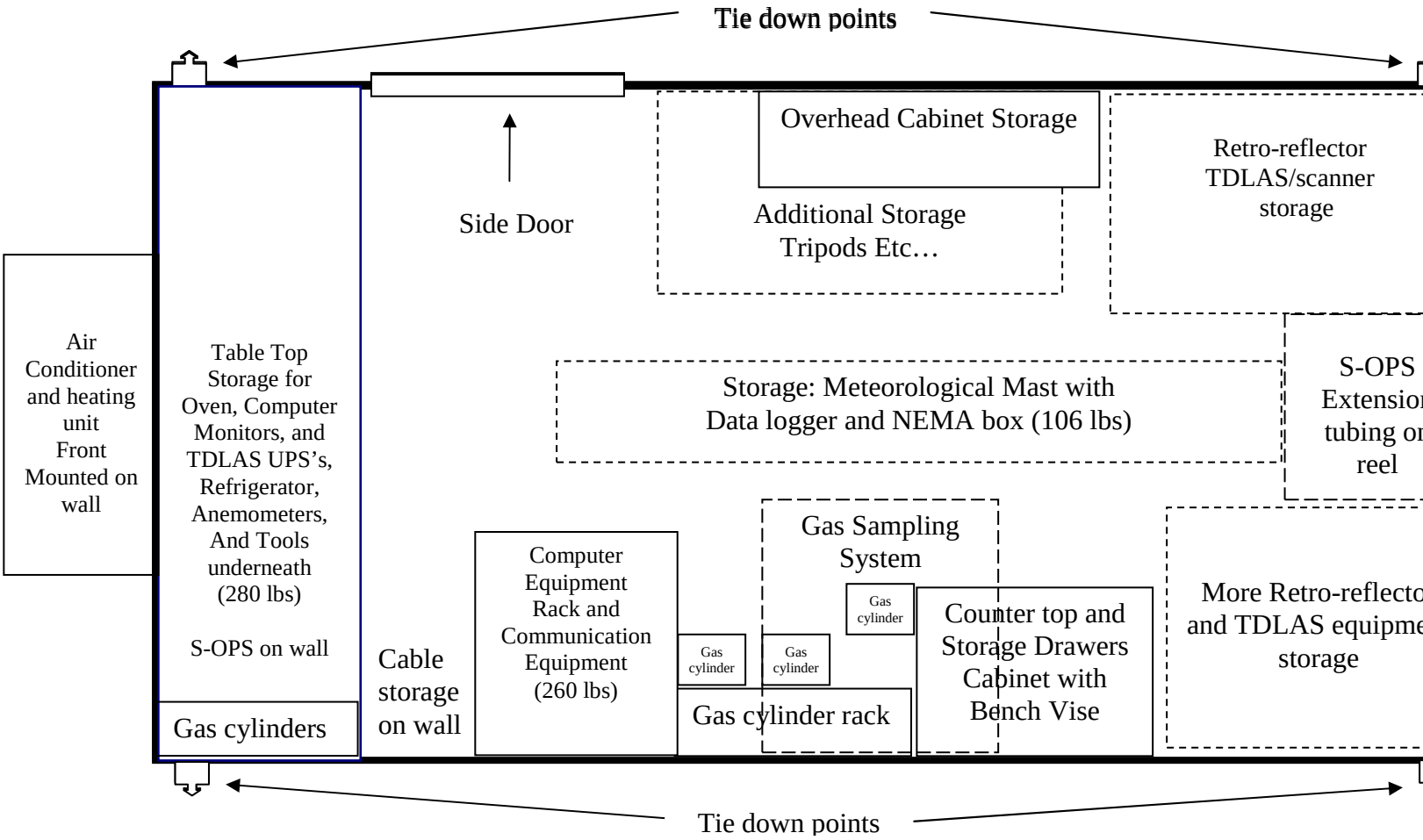
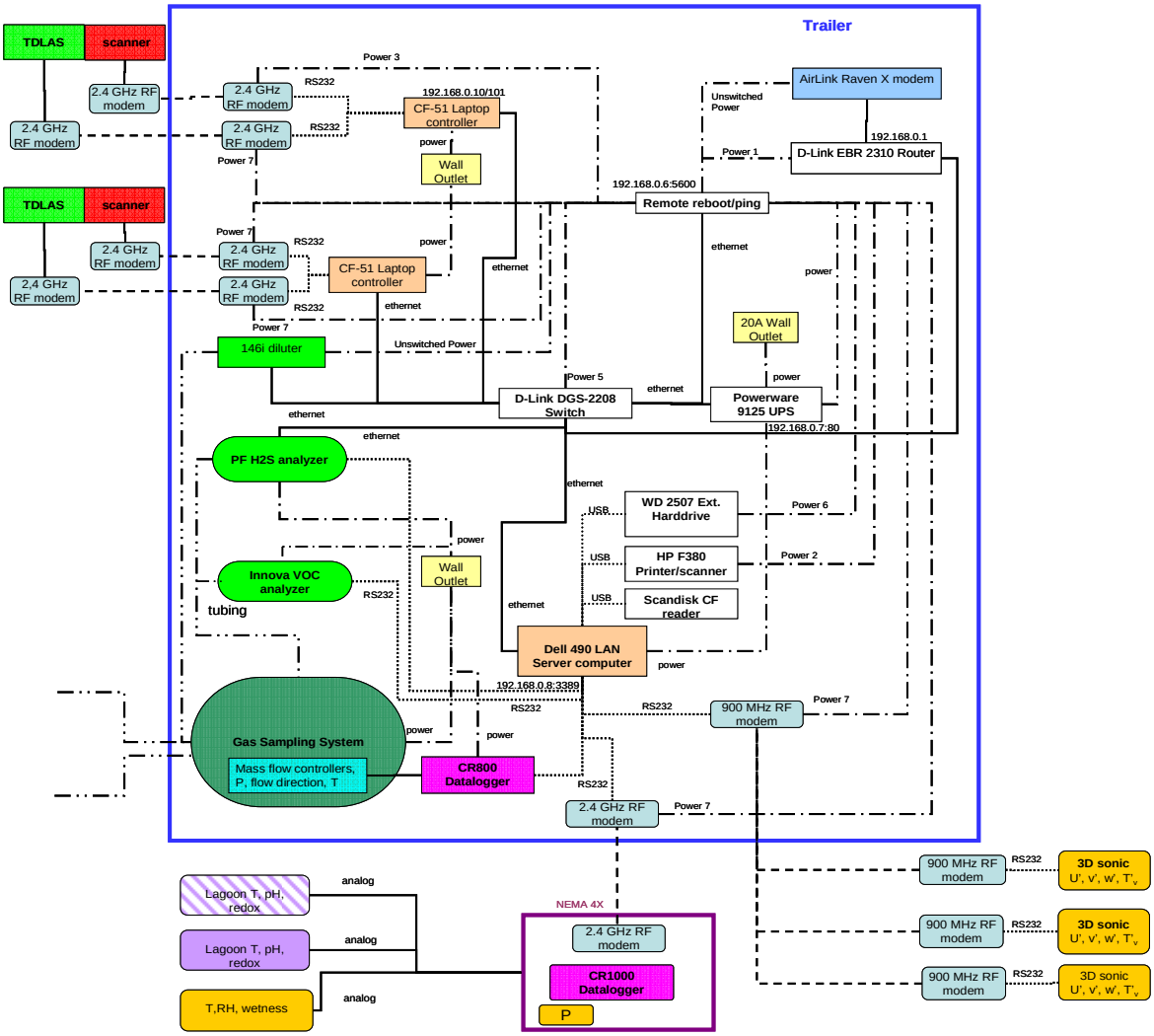


Figure 2. Communications schematic.



Appendix A. Safety Tips for Driving with a Trailer

Take time to practice before driving on main roads and never allow anyone to ride in or on the trailer. Before you leave, remember to check routes and restrictions on bridges and tunnels. Consider the following safety tips each time you drive with a trailer.

General Handling

- Use the driving gear that the manufacturer recommends for towing.
- Drive at moderate speeds. This will place less strain on your tow vehicle and trailer. Trailer instability (sway) is more likely to occur as speed increases.
- Avoid sudden stops and starts that can cause skidding, sliding, or jackknifing.
- Avoid sudden steering maneuvers that might create sway or undue side force on the trailer.
- Slow down when traveling over bumpy roads, railroad crossings, and ditches.
- Make wider turns at curves and corners. Because your trailer's wheels are closer to the inside of a turn than the wheels of your tow vehicle, they are more likely to hit or ride up over curbs.
- To control swaying caused by air pressure changes and wind buffeting when larger vehicles pass from either direction, release the accelerator pedal to slow down and keep a firm grip on the steering wheel.

Braking

- Allow considerably more distance for stopping.
- If you have an electric trailer brake controller and excessive sway occurs, activate the trailer brake controller by hand. Do not attempt to control trailer sway by applying the tow vehicle brakes; this will generally make the sway worse.
- Always anticipate the need to slow down. To reduce speed, shift to a lower gear and press the brakes lightly.

Acceleration and Passing

- When passing a slower vehicle or changing lanes, signal well in advance and make sure you allow extra distance to clear the vehicle before you pull back into the lane.
- Pass on level terrain with plenty of clearance. Avoid passing on steep slopes.
- If necessary, downshift for improved acceleration or speed maintenance.
- When passing on narrow roads, be careful not to go onto a soft shoulder. This could cause your trailer to jackknife or go out of control.

Downgrades and Upgrades

- Downshift to assist with braking on downgrades and to add power for climbing hills.
- On long downgrades, apply brakes at intervals to keep speed in check. Never leave brakes on for extended periods of time or they may overheat.
- Some tow vehicles have specifically calibrated transmission tow-modes. Be sure to use the tow-mode recommended by the manufacturer.

Backing Up

- Put your hand at the bottom of the steering wheel. To turn left, move your hand left. To turn right, move your hand right. Back up slowly. Because mirrors cannot provide all of the visibility you may need when backing up, have someone outside at the rear of the trailer to guide you, whenever possible.
- Use slight movements of the steering wheel to adjust direction. Exaggerated movements will cause greater movement of the trailer. If you have difficulty, pull forward and realign the tow vehicle and trailer and start again.

Parking

- Try to avoid parking on grades. If possible, have someone outside to guide you as you park. Once stopped, but before shifting into Park, have someone place blocks on the downhill side of the trailer wheels. Apply the parking brake, shift into Park, and then remove your foot from the brake pedal. Following this parking sequence is important to make sure your vehicle does not become locked in Park because of extra load on the transmission. For manual transmissions, apply the parking brake and then turn the vehicle off in either first or reverse gear.
- When uncoupling a trailer, place blocks at the front and rear of the trailer tires to ensure that the trailer does not roll away when the coupling is released.
- An unbalanced load may cause the tongue to suddenly rotate upward; therefore, before un-coupling, place jack stands under the rear of the trailer to prevent injury.

Appendix B. Trailer Weight Distribution

The ability to handle and control the tow vehicle and trailer is greatly improved when the cargo is properly loaded and distributed. Refer to your tow vehicle and trailer owner's manual to find out how to

- Balance weight from side to side
- Distribute cargo weight evenly along the length of the trailer
- Secure and brace all items to prevent them from moving during travel
- Adjust the height of the tow vehicle/trailer interface
- Use common sense when balancing trailer, if the tongue appears to weight the rear of the tow vehicle excessively, check trailer loading and rebalance. Conversely if the tongue appears very light and doesn't lower the rear of the tow vehicle much, check load and rebalance trailer for more weight in the front.
- Use caution when entering the trailer after the stabilizers have been removed as the trailer might suddenly tip back if not securely hitched to tow vehicle causing damage to trailer, contents, and the possibility of severe personal injury!

Fig. 1 shows the storage locations of major equipment and supplies.

Appendix C. Trailer Leveling Procedure

1. Before Beginning;
    a. Carefully center the trailer into position among the anchor points as the trailer cannot be moved laterally with the available tools once the leveling procedure has begun. And then remove the trailer from the truck hitch. (Use extreme caution to avoid striking the tie downs with the tires of the truck or trailer or the tire may be instantly & irreparably damaged!)
    b. *Be sure everyone stays out of the trailer and out from under the trailer during the leveling procedure.*
2. Begin by lowering the nose of the trailer all the way by cranking the hitch jack down until one corner of the trailer touches the ground.
3. Level the ground under the rear jack stand points and place a couple of the wood blocks under each of the rear corners of the trailer.
4. Lower the jack stand of the LOWEST rear corner all the way to the blocks.
    a. Don't extend the rear jacks more then 12-14" from the holder inside the trailer as they become inadequate to sustain the lateral forces the trailer may impart upon them if they are extended too far.
    b. Instead add more blocks to bring the ground up to meet them. As a rule the shorter the jack stands are extended the more stable the trailer will be. (6-8" inches is ideal)
5. If the trailer almost level;
    a. Lower the other jack stand (higher side) by only the amount needed to level the trailer if the jacks were both sitting on the blocks. *For example, if the trailer sits 2" higher on the left you would lower the right side all the way to the blocks (As instructed in step #4) and lower the left side until it is two inches from the blocks.*
    b. If the trailer is significantly out of level proceed to step #10.
6. Now all that is needed is to carefully raise the hitch jack until the trailer is level front to back and left to right. (The trailer is now supported on three points, front, right rear, and left rear) *The hitch jack will be difficult to crank as it is supporting half the weight of the entire trailer.*
7. Now level the ground under the two front scissors jacks and place two more wood blocks on the ground under each front jack position and lower the scissor jack for each side onto the blocks and crank in enough pressure to slightly lift that side a bit.
8. Now proceed to securing the trailer with the tie downs.
9. To reverse the procedure start by cranking up on the tongue jack enough to relieve stress on the scissors jacks, crank them up and lower the tongue to relieve the forces on the rear jack stands, remove the pins and push them up into the support and pin them at the highest (traveling) position.
10. If the trailer is significantly out of level (left to right) then place enough boards under the side that is HIGHEST so that the jack stand can be extended only about 6-8" to meet the board surface and pin it into place.

11. Now repeat the step above on the other leg (lowest side) and raise the nose of the trailer (with the hitch jack) enough to place the nose a bit higher then the rear of the trailer.
12. Using the hydraulic jack, place the jack under the frame rail on the side that is lowest at rear edge. (The frame rails are two long steel beams that run the length of the trailer front to back) *Don't use the jack on any point other then the frame rail.*
13. Place enough boards under the hydraulic jack to bring it up to meet the frame rail without pumping it up much.
14. Now slowly close the relief valve on the bottom of the hydraulic jack and begin pumping the hydraulic jack to raise the low side of the trailer just enough to place another board under the foot of the rear jack stand.
15. Gently open the relief valve on the bottom of the hydraulic jack to lower the corner of the trailer onto the new board.
16. Repeat steps 13-15 until the trailer is level left to right.
17. Raise or lower the hitch jack until the front of the trailer is level with the rear.
18. Now level the ground under the two front scissors jacks and place two more wood blocks on the ground under each front jack position and lower the scissor jack for each side onto the blocks and crank in enough pressure to slightly lift that side a bit.
19. Now proceed to securing the trailer with the tie downs.
20. To reverse the procedure start by cranking up on the tongue jack enough to relieve stress on the scissors jacks, crank them up and lower the tongue to relieve the forces on the rear jack stands, use the hydraulic jack to relieve the side still supporting the trailer, then remove the pins and push the jack stands up into the support and pin them at the highest (traveling) position.

THE INSTALLATION OF OPEN-SOURCE MEASUREMENT EQUIPMENT

Standard Operating Procedure (SOP) U5

THE INSTALLATION OF OPEN-SOURCE MEASUREMENT EQUIPMENT

Standard Operating Procedure (SOP) U5

Prepared by

Chris D. Fullerton and Richard H. Grant

Reviewed by

Albert J. Heber and Bill W. Bogan

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Micrometeorological techniques are useful for measuring emissions from area sources like anaerobic treatment lagoons at livestock facilities, and include open-path concentration measurements and weather measurements.
1.2. The measurement sites are typically at locations remote from headquarters.
1.3. All equipment needed to measure lagoon emissions must be transported to the site.
1.4. The method requires careful positioning of many optical and physical components of the equipment.
1.5. A generalized representation of a typical open-source area is assumed.

2. Summary of Method

2.1. The objective of this SOP is to specify the procedures associated with the installation and tear-down of equipment and sensors associated with the open-path measurement of gas concentrations. Equipment and sensors include:
  2.1.1. Two fixed corner towers
  2.1.2. Meteorology tower/mast
  2.1.3. Standard fence posts for supporting SOPS inlets
  2.1.4. Synthetic Open Path equipment (SOP C4)
  2.1.5. TDLAS equipment (SOP C2)
  2.1.6. Pulsed fluorescence H_2S analyzer SOP G5)
  2.1.7. Photo-acoustic multi-gas analyzer (SOP G7)
  2.1.8. Instrument trailer (SOP U4)
  2.1.9. Meteorological data logger (SOP W6)
  2.1.10. Weather characterization sensors (SOP W1-W5)
  2.1.11. Lagoon characterization sensors (SOP L1-3)

3. Definitions

3.1.	FOS	Field Operations Staff
3.2.	GFCI	Ground fault circuit interrupter
3.3.	GSS	Gas sampling system
3.4.	LCD	Liquid Crystal Display
3.5.	OSHA	Occupational Safety and Health Administration
3.6.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.7.	PAML	Purdue Applied Meteorology Laboratory
3.8.	PDC	Pathlength-defining component. PDC is used to denote the component on the other end of the optical path from the PI-ORS instrument. Depending on the instrument selected, this could be a source, detector, mirror, or other reflecting object.
3.9.	PI	Principal Investigator
3.10.	PIC	Path Integrated Concentration. Given in units of parts per million-meter (ppm-m), PIC is the integrated concentration of a gaseous pollutant measured along the beam pathlength.

3.11.	PI-ORS	Path-Integrated Optical Remote Sensing. An instrument system used to acquire gaseous PIC data along an open optical beam path.
3.12.	PM	Project Manager
3.13.	PPE	Personal protection equipment
3.14.	QAM	Quality Assurance Manager
3.15.	QAPP	Quality Assurance Project Plan
3.16.	Retro-reflector	A PDC in which the reflected radiation is always back to the direction from which it came
3.17.	SMP	Site Monitoring Plan
3.18.	S-OPS	Synthetic Open Path Sampling System
3.19.	TDLAS	Tunable Diode Laser Absorption Spectroscopy
3.20.	USDOT	US Department of Transportation

4. Health and Safety

4.1. 120 VAC line current is distributed around the lagoon area. Take care to prevent shock, injury and possible loss of life. Always de-energize equipment before performing installation, maintenance, and removal. Hot work is not allowed; if an instrument has capacitors, they must be bled off before work is performed.

4.2. All outdoor receptacles, receptacles 6 ft from exterior doors, outlets around the lagoon, and all extensions cords must be protected by GFCIs.

4.3. Never substitute any of the manufacturer-supplied hardware when constructing or servicing the sheet metal towers. Doing so could cause the tower to collapse, resulting in serious personal injury or death.

4.4. Equipment weighs up to 150 lb. Use proper lifting techniques and personal protection.

4.5. Wear a suitable life jacket if working near the lagoon. One researcher nearly drowned.

4.6. On-site spiders, snakes, insects, and scorpions can be dangerous (Appendix A).

4.7. Wild animals may be in the vicinity of the site (Appendix B).

4.8. Weather (lightning, high winds, hail) can be hazardous (Appendix C).

4.9. Significant injury or death can result from falling off roof or ladder up to the roof.

4.10. Be careful climbing outside steps of trailer, particularly if wet or iced.

4.11. Avoid contact with tower, mast, or with the exterior trailer shell during thunderstorms.

4.12. Beware of traffic patterns on the farm and location of the lagoon and lagoon berm. If possible, do not drive over the lagoon berm.

4.13. The weight of the mast must be considered before lifting.

4.13.1. Mast weighs 30 lb.

5. Cautions

5.1. Take care when working on the tower, as tools and equipment will likely be bent or damaged if dropped.

5.1.1. Carefully inspect all rivets and bolt joints to look for cracks or loose bolts. If loose bolts or rivets are found, retighten bolts immediately, replace broken or missing rivets with a screw and nut combination and document their location.

5.1.2. Carefully inspect the tower to verify it is true and structurally sound.

5.2. Be sure to observe correct polarity/voltage or the instruments may be irreparably damaged!
5.3. The instruments and retro-reflectors are delicate and will be damaged if dropped.
5.3.1. If an instrument is dropped, record the event in the instrument logbook and carefully evaluate the instrument for possible damage prior to installation.
5.4. Proper connection of line power is necessary. Proper care from crimping cables and connectors should be used.
5.5. Take care when climbing on roof in vicinity of antennae, and towers. Antennae, mounts, and cables are delicate and must not be bent or broken. Do not drop.
5.6. Tighten all bolts/wire ties on retro-reflectors. Loose bolts or wire ties may result in a retro-reflector coming loose and falling, resulting in significant damage to the retro-reflector and heater.
5.7. Tighten all bolts on NEMA box. Loose bolts will result in NEMA box slipping down or turning on mast and possibly colliding with and misaligning the other instruments.
5.8. Be sure producer has provided information locating all underground utilities and pipes before driving any stake, ground rod, or other piece of equipment into the ground.
5.9. Lightning damage to sensors is less likely if instruments and towers are properly grounded.

6. Interferences

6.1. The trailer communications systems may not function properly if the trailer is located in the vicinity of a television or radio station transmitting tower.
6.2. Power failures may adversely affect all communications and computers.
6.3. Heating or cooling failures may result in environmental conditions that are outside the specifications of the equipment.

7. Personnel Qualifications

7.1. Personnel must be trained in the use of the handheld multimeter before initiating the procedure. Training requires 10 min.
7.2. All personnel must read and understand this SOP and all cited SOPs (See References).
7.3. Field personnel must be able to lift 40 lb.

8. Equipment and Supplies

8.1. Safety Equipment and PPE
8.1.1. Climbing belt and lanyard (when more than 6 ft off the ground)
8.1.2. Hard hats (where required, or for anyone while work is being done overhead)
8.1.3. Leather gloves
8.1.4. Safety goggles
8.1.5. Ear plugs
8.1.6. Flashlight/trouble light
8.1.7. 100-ft 5/8″ Work rope – for sheet metal tower work

8.2. Hand tools (kept in trailer tool box)
- 8.2.1. Shovel (square mouth)
- 8.2.2. Cement trowel (for concrete work on tower installation)
- 8.2.3. Hammer
- 8.2.4. Small sledge hammer – to drive stakes or grounding rod
- 8.2.5. Open end wrenches (7/16″, 1/2″, 9/16″ 3/4″, 15/16″)
- 8.2.6. Socket wrench and 3/4″ and 9/16″ deep well sockets
- 8.2.7. Allen wrench set (0.05″) for LI2003S – one is supplied with LI2003S
- 8.2.8. Straight-bit screwdrivers (small, medium, and large)
- 8.2.9. Phillips screwdrivers (small and medium)
- 8.2.10. Pliers
- 8.2.11. Needle-nose pliers
- 8.2.12. Channel locks
- 8.2.13. (2) Small diagonal side-cutters
- 8.2.14. Wire strippers
- 8.2.15. (2) Adjustable (crescent) wrenches
- 8.2.16. Cable cutters
- 8.2.17. (2) Files – one flat and one rat tail
- 8.2.18. Hacksaw
- 8.2.19. Pocket knife
- 8.2.20. Sheet metal cutters (tin snips)
- 8.2.21. Tool aprons
- 8.2.22. Nylon cable ties
- 8.2.23. Enclosure supply kits (CSI P/N 7363)
- 8.2.24. Electrician’s putty
- 8.2.25. Bailing wire
- 8.2.26. Common screws to mount enclosure
- 8.2.27. Wire multi-color
- 8.2.28. Caulking gun and caulk
- 8.2.29. Long bolts, washers, and nuts
- 8.2.30. Self tapping sheet metal screws
- 8.2.31. Grabber screws

8.3. Hardware
- 8.3.1. Spare nuts, washers, U-bolts, etc.
- 8.3.2. Spare cable clamps
- 8.3.3. Ground wire
- 8.3.4. (4) Ground rods

8.4. Soldering tools (kept in trailer tool box)
- 8.4.1. Soldering iron
- 8.4.2. Cigarette lighter
- 8.4.3. Solder
- 8.4.4. Heat shrink assortment
- 8.4.5. Electrical tape

8.5. Power tools (kept in trailer tool box)
- 8.5.1. Cordless variable speed drill with spare battery and charger

8.5.2. Drill bits
8.5.3. Screw/nut driver bits
8.6. Electrical equipment
8.6.1. Calculator (kept in trailer)
8.6.2. (2) 1400VA UPS units for TDLAS in-field backups
8.6.3. Portable computer (kept with FOS)
8.6.4. Handheld multi-meter (current, resistance, and voltage testing instrument)
8.6.5. Spare cables (kept in trailer)
8.6.6. 100-ft extension cord
8.7. Calibration equipment (kept in trailer drawer)
8.7.1. Brunton 8099 compass or equivalent (for radiation and anemometer sensor alignment)
8.7.2. Torpedo level (12” to 24”)
8.7.3. Tape measures, 10-ft and 100-ft
8.7.4. Handheld Garmin 76 GPS unit or equivalent (kept with FOS)
8.7.5. Nikon 8358 Laser rangefinder (1200m) or equivalent (kept with FOS)
8.8. Miscellaneous
8.8.1. 5-ft step ladder
8.8.2. Locks and keys
8.8.3. Batteries and battery cables
8.8.4. RF Antennas
8.8.4.1. (1) for meteorological data logger
8.8.4.2. (1) for sonic anemometers
8.8.4.3. (4) for TDLAS/scanners
8.8.5. (3) Stakes for mast
8.8.6. Digital camera with wide angle capability (kept with FOS)
8.9. Original equipment set for each sheet metal tower installation (Appendix D) for initial installation
8.9.1. Delhi DMX60 or optional DMX68 stub kit (shown installed in Fig. 1A)
8.9.2. Delhi DMX60 or optional DMX68 tower (6 sections - Fig. 1B)
8.9.3. Delhi DMX60 or optional DMX68 bolt kit
8.9.4. Custom-made 4-m anemometer mount (built by PAML)
8.9.5. (3) Ground point lugs (for attaching ground wire to tower legs)
8.9.6. (3) Ground rods with clamp
8.9.7. Lightning rod with mounting bracket
8.9.8. (2) 10′ 2x4 boards (for concrete form Fig. 1C)
8.9.9. (1/2) lb 2 1/2″ framing nails (build forms with)
8.9.10. (3) Bricks common size, any color or style (to set base stubs on)
8.10. Documentation
8.10.1. Sensor manuals
8.10.2. Site monitoring plan
8.10.3. Mounting angle for solar panel
8.10.4. Station log and pen
8.10.5. Felt-tipped marking pen

8.11. Communication equipment
8.11.1. Head-held radios
8.11.2. Cellular phone
8.11.3. Appropriate phone numbers
8.12. Equipment and materials to be stored in the bed of the tow vehicle
8.12.1. Two man heavy duty Composite Plastic Dingy (SOP L5).
8.12.2. Roll of plastic sheeting (SOP L5).
8.12.3. (3) 2-m holding stakes (corkscrew anchors may be substituted).
8.12.4. 100′ Nylon rope (for tri-sensor float).
8.13. Equipment and sensors to be installed (stored in trailer according to SOP U4)
8.13.1. (1) Campbell Scientific CM110 tripod tower
8.13.2. (1) NEMA box with CR1000 datalogger, CS100 Barometer, and XStream® RS-232/485 RF Modem
8.13.2.1. (1) Antenna for modem
8.13.3. (1) LiCOR 200 solar radiation sensor and mounting fixture and bracket
8.13.4. (1) Vaisala HMP45C RH/T sensor in passive radiation shield
8.13.5. (1) Surface wetness grid and mounting bracket
8.13.6. (3) RMYoung 81000 sonic anemometers, each with XStream® RS-232/485 RF Modem
8.13.7. (1 or 2) 107-L Thermistor
8.13.8. (1 or 2) Innovative sensors CSIM11 ORP redox state sensor
8.13.9. (1 or 2) Innovative sensors CSIM11 pH sensor
8.13.10. (2) TDLAS/scanners on tripod
8.13.11. (2) TDLAS/scanner power supply/ communications boxes (with 2 antennas).
8.13.12. (2) TDLAS/scanner UPS systems.
8.13.13. (20) Retro-reflectors

9. Procedures

9.1. Acceptance
9.1.1. Criteria for acceptance of all meteorological and lagoon sensors are described in the SOP covering each instrument.
9.1.2. Data logger acceptance criteria are described in SOP W6.
9.1.3. Expected windload
9.1.3.1. Retro-reflectors consist of at least four retro-reflector cubes mounted in a 10″ x 9″ x 7″ box.
9.1.3.1.1. Three reflectors on each of two sides
9.1.3.1.2. Windload on tower: 2.4 ft^2
9.1.3.2. Sonic anemometer cross-sectional area is approx 18″ x 1″.
9.1.3.2.1. Two anemometers
9.1.3.2.2. Windload: 0.2 ft^2
9.1.4. Allowable wind displacement of the retro-reflectors
9.1.4.1. The diameter of the laser beam when it exits the TDLAS is about 2.5 mm, and the divergence is approximately 1.5 mrad (milliradians). This means that at a

distance of 150 m, the beam diameter is 1.5 x 150 = 225 mm (9″). Similarly, for a path of 300 m, the beam diameter would be 450 mm (18″).

9.1.4.2. Retro-reflector area is 6″ x 8″

9.1.4.3. Allowable movement of tower at top is approximately 18″ at 150 m and 36″ at 300 m (assuming reflection of 3″ width beam needed).

9.2. Acceptance of sheet metal tower and components (Appendix D)

9.2.1. 56’ Sheet metal towers (DMX60) consist of (6) 8-ft tower sections, one 6′ 1 ¼″ mast pipe with mounting clamps, one stub kit, and one manufacturer-supplied bolt kit. The 64’ model (DMX68) is identical except it has one additional bottom section.

9.2.1.1. Lay the tower on its side if not already lying down.

9.2.1.2. Cut the steel banding (Fig. 1B) holding the sections together using sheet metal cutters.

9.2.1.3. Separate all sheet metal tower sections by pulling the smallest section out of the tower bundle from the bottom (largest end).

9.2.1.4. Visually inspect all sides and both ends of each section for damage (deformed or damaged end pieces or broken/missing rivets).

9.2.1.4.1. If damage is found, contact the manufacturer or shipper for remediation.

9.2.1.4.2. Each sheet metal tower must have a hardware kit containing at least thirty-six (36) hardened steel specialty bolt sets of varying sizes (each bolt set contains one bolt, one nut, and one washer).

9.2.1.4.2.1. These are specially-manufactured bolts with a built-in centering taper. Standard hardware parts must never be substituted for any of the hardware supplied with the tower. If any of the bolt set pieces are missing contact the PM and have replacements brought to the site before continuing to construct the tower.

9.2.1.4.3. Each section of the tower gets six bolts of the same size to fasten it to the next section. All the intended bolt holes are predrilled for the tower. The largest bolts go in the bottom section and smaller bolts are used on each consecutive section. The bolts will exactly fit the holes in the tower for the section of which they are intended. Never use a small size bolt in a large predrilled hole and never ream any hole to fit a larger bolt. Three large standard hardware bolt sets will be placed in the bottom of the base stub for each tower leg to be cemented into the concrete and prevent slippage (Fig. 1A). **This is the only place where standard (non-manufacturer-supplied) hardware components are to be used except when replacing missing or damaged rivets.**

9.2.1.4.4. If any parts are missing or damaged, contact the PM to locate or replace the missing component. Again, never substitute any standard hardware for the manufacturer-supplied tower components.

9.3. 3-m meteorology tower/mast (Campbell Scientific CM110)

9.3.1. Characteristics

9.3.1.1. Aluminum construction

9.3.1.2. 10-ft (3-m) height

9.3.1.3. Storage in trailer (SOP U4)

9.3.1.4. Withstands sustained winds of 75 mph

9.3.1.5. Withstands wind gusts to 95 mph
9.3.1.6. Vertical load limit is 100 lb
9.3.1.7. Weighs 30 lb
9.3.2. Assembly test (see Manual)
9.3.2.1. Stand tripod up on end and rotate feet to be perpendicular to the legs.
9.3.2.2. Each leg has a slide collar with black plastic T-bolt and a spring-loaded pin that locks in holes located on the underside of the leg.
9.3.2.2.1. Loosen T-bolts and extend each leg until pin engages in the center hole.
9.3.2.3. With legs extended, orient tripod so that the open channel of the tripod faces parallel to the lagoon edge.
9.3.2.4. Attach lower mast section by aligning holes at the bottom of the mast section with the upper set of slanted holes at the tripod base. Insert pin through holes and rotate the wire retainer over the end of the pin. (The pin should be at the bottom of the slanted hole when the mast is upright.)
9.3.2.5. Lift the mast up so that the pin is in the upper end of the slotted hole to allow the mast to be tilted down to a horizontal position.
9.3.2.5.1. Verify functionality.
9.3.2.6. Lift up the mast so that the pin in is the lower end of the slotted hole to align the mast to the vertical.
9.3.2.6.1. Verify functionality.
9.3.2.7. Secure the mast in the vertical position by installing the locking bracket.
9.3.2.7.1. Insert the top of the bracket into the notches in the mast tripod base. Using both thumbs, press the bracket into the body of the base until the lower tabs lock into position.
9.3.2.7.2. Install the locking pin.
9.3.2.8. Evaluate rigidity.
9.4. Retro-reflectors
9.4.1. Reflectors consist of at least five retro-reflector cubes mounted in a 10″ x 9″ x 7″ box. They are heated by a Thermon DSE-70 Heater (Fig. 2) or other equivalent device.
9.4.2. The heater is supplied by 110VAC.
9.4.3. When powered, the 40-W heater is capable of heating base of reflector cubes 50°C above ambient temperature.
9.4.3.1. If the heater does not heat the reflector cubes adequately, inspect wiring and contact Boreal Laser for replacement or repair.
9.5. Document overall layout
9.5.1. Photograph site from the following orientations:
9.5.1.1. Cardinal directions (N, S, E, W) from location of each wind sensor
9.5.1.2. Views perpendicular to each beamline, using lens with wide angle view
9.6. Installation
9.6.1. Always refer to the individual Site Monitoring Plan for each site when determining exact placement of **all** sensors, tripods, masts, towers, etc.
9.6.1.1. Correct locations of all instruments and devices will have been pre-located during initial site setup and will already have anchors driven at the correct location.

9.6.2. At each power access location, check GFCI for ability to trip.

9.6.3. Due to terrain and clearance limitations, it is necessary to use a self-supporting 15-m tower capable of supporting retro-reflectors and anemometers.

9.6.3.1. The Delhi QDMX52 is a 48-ft, self-supporting sheet metal tower model with a 4-ft mast mounted to the top, and is capable of a 3-ft^2 wind load at the top.

9.6.3.2. The Delhi DMX68 is a 64-ft self-supporting sheet metal tower similar to the DMX60 with the same wind load specifications) used to overcome height and position limitations at the lagoon corners

9.6.3.3. The sheet metal tower will have its base (bottom) section bolted to stubs, and the stubs will be cemented into concrete and allowed to cure. The tower will then be erected by bolting on additional sections hauled upward by hand using a rope to bring up each additional section (this is a common practice for this type of tower).

9.6.3.4. The towers are outfitted during initial installation with standard 110V exterior in-use covered outlets for each instrument, UV-resistant outdoor wiring and a drop cord near the bottom to plug into a nearby power outlet to provide power for all necessary instruments during measurement periods.

9.6.3.5. The towers are fitted with grounding hardware during initial construction consisting of a single 8′ ground rod and a short section of #6 bare copper wire.

9.6.3.6. The entire tower will stand for the duration of all the measurement periods at the site where it is installed and only the instruments and retro-reflectors will be removed in between measurement periods.

9.6.3.7. The tower will be disassembled and removed using the same method used to install the tower but in reverse only when all measurements for the project are complete at the site.

9.6.3.8. The sheet metal tower will have the retro-reflector mounting points pre-located and marked with red paint during initial setup of the site.

9.6.3.9. The 16-m anemometer will attach directly to the top of the short mast pipe on the top of one of the towers at each site, and a special Galvanized pipe mount will be constructed at PAML for each site to mount the 4-m anemometer at the correct distance as specified in SOP W2 and bolted to the tower at the required location on the proper tower for each site (4-m above berm height) using common hardware. This mount will remain on the tower at the site for the project duration.

9.6.3.10. Free-standing sheet metal towers will be used at all sites requiring retro-reflectors and anemometers to be mounted above 3 m.

9.6.3.11. Follow the installation procedure in Appendix D (Sheet metal tower installation) in such locations.

9.6.4. 3-m meteorology tower/mast (Fig. 4)

9.6.4.1. Install at location indicated by SMP (anchor and locating stake should already be present at the proper location).

9.6.4.2. Normally data logger, NEMA box, and meteorological characterization sensors, as specified in SOP W6, remain attached to the mast after initial installation for the duration of the project (except for service).

9.6.4.2.1. If unable to find locating stake, determine location with GPS unit.

9.6.4.2.2. Record any deviations in notes on open path sensor installation report (Appendix E).
9.6.4.2.3. Stand tripod up on end and rotate feet to be perpendicular to the legs.
9.6.4.2.4. Each leg has a slide collar with black plastic T-bolt and a spring-loaded pin that locks in holes located on the underside of the leg.
9.6.4.2.4.1. Loosen T-bolts and extend each leg until pin engages in center hole.
9.6.4.2.5. With legs extended, orient tripod so that the open channel of the tripod faces parallel to the lagoon edge.
9.6.4.2.6. Lift the mast up so that the pin is in the upper end of the slotted hole.
9.6.4.2.7. Tilt mast to the horizontal such that the mast rests on the ladder.
9.6.4.3. Initial installation requires the insertion of the anemometer mount for three sonic anemometers for intercomparison
9.6.4.4. Unpack and install (3) sonic anemometers.
9.6.4.4.1. Storage location indicated in SOP U4
9.6.4.4.2. Install anemometers at the top of the mast for intercomparisons (SOP W2).
9.6.4.4.3. Unpack and inspect instrument Power/Radio Units, check cable and repair or replace as needed. Log inspection results on checklist (Appendix F) with comments and remediation.
9.6.4.4.4. Connect instrument cables from power units to anemometers.
9.6.4.5. Lift up the mast so that the pin in is the lower end of the slotted hole to align the mast to the vertical position. Secure with locking bracket.
9.6.4.5.1. Insert the top of the bracket into the notches in the mast tripod base and using both thumbs press the bracket into the body of the base until the lower tabs lock into position.
9.6.4.5.2. Install the locking pin
9.6.4.6. Verify that the mast is vertical using a torpedo level.
9.6.4.6.1. If not, adjust the length of the mast legs until the mast is vertical.
9.6.4.6.2. Stake all legs of mast using medium hammer.
9.6.4.7. Unpack and drive ground rod in ground near base of mast using large hammer. (Storage location shown in Fig. 1 of SOP U4)
9.6.4.7.1. Attach ground wire from mast to ground rod and secure with wire ties or tape.
9.6.4.8. Inspect power cable and repair or replace as needed. Log inspection results on checklist (Appendix F) with comments and remediation.
9.6.4.9. Conduct sonic anemometer intercomparison (SOP W2)
9.6.4.10. Remove sonic anemometers from intercomparison mount and place in shipping containers.
9.6.4.11. Using shipping containers as ancheotic chambers, check anemometer zero values according to SOP W2.
9.6.4.12. Remove intercomparison sonic sensor mount and install single sensor mount on mast top
9.6.4.13. Remount one sonic anemometer on the top of the mast
9.6.4.14. Return shipping container to trailer
9.6.4.15. Disconnect sonic Power/Radio Units from other two sonic anemometers and power.

9.6.5. Fixed tower instrument installation (Fig 3).

9.6.5.1. Locate correct locations of retro-reflectors and anemometers on tower by using pre-painted cross sections (Red colors represent a retro-reflector location and yellow colors represent the 4-m Anemometer location). Log any deviations of open path sensor installation report (Appendix E).

9.6.5.1.1. Sonic anemometers

9.6.5.1.1.1. Install the 16-m sonic anemometer at top of the mast on the correct tower for the site (location shown in the SMP). Orient the instrument to true N.

9.6.5.1.1.2. Return storage container to trailer.

9.6.5.1.1.3. Install sonic anemometer on the 4-m high mount arm (already mounted to tower and marked with yellow paint) and check level of instrument to ensure it is vertical and orient instrument to true north.

9.6.5.1.1.4. Return shipping container to trailer(storage location shown in SOP U4).

9.6.5.1.1.4.1. Inspect cables and repair or replace as needed. Log inspection results on checklist (Appendix F) with comments and remediation.

9.6.5.1.2. Connect instrument cables to anemometers (SOP W2) and secure down the tower at three-foot intervals using electrical tape.

9.6.5.1.3. Connect to power source and verify sensor operation by viewing data in instrument trailer.

9.6.5.1.4. If anemometer data is not present, troubleshoot system using the following method.

9.6.5.1.4.1. Open anemometer power boxes and check for power at RF modem.

9.6.5.1.4.2. Check anemometer for power by listening for “buzz” from sensor.

9.6.5.1.4.3. Check antenna connection at base radio and data connection into LAN server.

9.6.5.1.4.4. If still not functioning, contact PAML for further help or remediation.

9.6.5.2. Retro-reflectors

9.6.5.2.1. Unpack 6 retro-reflectors (storage location shown in SOP U4) and attach the custom made mounting backboards of tower mounting from trailer.

9.6.5.2.2. Mount 3 reflectors on the red paint marked sections of the fixed tower at the 1, 7, and 15 m heights so that the open sides of the retro-reflector enclosure are facing an adjacent corner of the lagoon; secure with wire ties.

9.6.5.2.3. Mount 3 reflectors on the red paint marked sections of the fixed tower at the 1, 7, and 15 m heights so that the open sides of the retro-reflector enclosure are facing the other adjacent corner of the lagoon; secure with wire ties.

9.6.5.2.4. Inspect cables and repair as needed. Log inspection results with comments and remediation

9.6.5.2.5. Connect retro-reflector power cables to power boxes on tower and secure with tape.

9.6.5.2.6. Repeat procedure for mounting retro-reflectors on tower at opposite side of lagoon.

9.6.6. Calibration verification of pH and redox probe must be done prior to installation of probes on tri-sensor float.

9.6.6.1. Unpack and remove lagoon sensors and cables from storage area in trailer (SOP U4) and uncoil cables only enough to conduct calibration verification.

9.6.6.2. Conduct calibration verifications of redox and pH probes according to SOP L1 and L3..

9.6.7. Installation of tri-sensor float and lagoon characterization sensors

9.6.7.1. Life jacket needs to be worn when working on the inside of the berm top.

9.6.7.2. Float, rope, and 2-m holding stakes are located in bed of tow vehicle. Lagoon sensors are located in trailer (SOP U4).

9.6.7.3. Refer to Fig. 5 for installation of tri-sensor float. Float will be secured using a rope stretched across a corner of the lagoon and secured by two 2-m stakes placed so as to hold the float a minimum of three meters from the waterline of each edge in the corner of the lagoon.

9.6.7.4. Locate the position (at least 100-m from the lagoon inflow pipe) on the lagoon corner where the tri-sensor float should be placed based on appropriate SMP.

9.6.7.5. Take the 100-ft nylon rope from the bed of tow vehicle and stretch it out lengthwise in a dry location, grab one end and walk towards the other in a straight line, lay your end next to the other and walk back to the center. The location where the rope bends 180° will be the center and mounting location for the tri-sensor float. Mark the center with a simple single knot. Now measure 4 m from that knot and tie another knot. Now going the other direction from the first (center) knot, again measure 4 m and tie another knot. These knots will help ensure the float is placed 3 meters from the waterline of each edge in the corner.

9.6.7.5.1. To space the float 3 m from each edge, the distance the rope must cross the water's edge from each corner at is 6 m given the corner is 90°. Using the formula $A^2+B^2=C^2$, the length of the rope diagonally from waterline to waterline must be 8.5 m. The distance to the water's edge from the center each way is 4.25 m. The outside knots will cross each edge at the waterline 6 m from the corner on each side, ensuring the float is approximately 3 m from each bank.

9.6.7.6. Using the rope you just marked, a stake for each of you to mark the desired location, and your partner, stretch the rope diagonally across the corner from just outside the berm to find the location outside the berm to drive the holding stake. Use the marker knots you made in the rope to ensure the correct positioning of the stakes by aligning the two outside knots are at the water's edge so the middle knot is in the center of the water at the corner.

9.6.7.7. Drop your stake at the location you wish to drive it, Have your partner do the same things at his location. Walk the rope back to dry land and lay it down.

9.6.7.8. Now go back and drive the stakes just outside lagoon berm at each previously marked location. (Be sure the producer has provided locates and the area is free of underground wires pipes etc… before driving stakes!).

9.6.7.9. Secure guide rope to tri-sensor float assembly using the center knot in the rope as the center marker for the float.

9.6.7.10. Set the tri-sensor float on a suitable work surface to mount the probes.

9.6.7.10.1. Remove lagoon sensors and cables from trailer and uncoil cables.

9.6.7.10.2. Inspect cable and repair or replace as needed. Log inspection results on checklist (Appendix F) with comments and remediation

9.6.7.10.3. Position and secure all probes in the tri-sensor float so that the respective

sensor will be at the correct distance below the waterline of the float (See SOP L1 (PH sensor), SOP L2 (Temperature sensor), and SOP L3 (Redox sensor) for correct positioning information of the probes).

9.6.7.10.4. Connect the probe cable to the rope closest to the meteorological mast and using wire ties attach the cables to the section of rope that will contact the water.

9.6.7.11. Using the rope to lift the tri-sensor float assembly, have your partner take one end and you take the other end and the probe cable, and carefully suspend the probe and carry over the location in the lagoon where the float will rest by pulling each end of the rope against the center. Gently lower the float into the water being careful not to tip it or set it in any debris in the lagoon (Be sure to wear your life jacket while working near the lagoon edge).

9.6.7.12. Secure the ends of the rope to each of the holding stakes to ensure proper location of the tri-sensor float.

9.6.7.13. Visually verify the waterline of the float matches to the 0.3 m mark on the tri-sensor float and the that the rope has enough slack to allow for proper floatation while still maintaining the float's proper location.

9.6.7.14. Run cable into the NEMA box through the proper knockout and secure. Be sure to coil any extra cable at the foot of the mast and secure with nylon wire ties (Do not cut the cable to length).

9.6.7.15. Attach wires to data logger in NEMA box using the ⅛″ slotted screwdriver. Connect black wire to the switched excitation channel, purple to ground, clear to ground, and red to the single-ended analog channel.

9.6.7.16. Connect data logger to RF modem.

9.6.7.17. Verify the instrument cable is floating as expected and ensure that it is secured at the mast base and the NEMA box.

9.6.8. Connect meteorological (NEMA box) power cable and verify that all sensors, data logger, and RF modem have power and are operating as expected.

9.6.8.1. Note any deviations from normal parameters, repair or replace the troubled component if any, and document the repair in field notes.

9.6.8.2. Check sonic anemometer (SOP W2).

9.6.8.3. Check humidity and temperature sensor (SOP W1).

9.6.8.4. Check wetness grid sensor (SOP W3).

9.6.8.5. Check solar radiation sensor (SOP E3)

9.6.8.6. Check barometric pressure sensor (SOP W5).

9.6.8.7. Check lagoon temperature sensor (SOP L1).

9.6.8.8. Check lagoon pH sensor (SOP L2).

9.6.8.9. Check lagoon redox sensor (SOP L3).

9.6.8.10. Check communications (SOP W6).

9.6.8.11. Verify that the solar radiation sensor mount is off the south side of the mast.

9.6.8.11.1. If not, correct position.

9.6.8.12. Check again that the mast is vertical using a torpedo level.

9.6.8.12.1. If not, re-adjust the length of the mast legs until the mast is vertical.

9.6.9. Install S-OPS path
- 9.6.9.1. Locate S-OPS paths according to appropriate SMP.
- 9.6.9.2. If not in place already, locate and install fence posts with 5-m spacing along path of S-OPS.
- 9.6.9.3. Be sure that all inlets of S-OPS have rubber stoppers installed and taped and tubing end is taped.
- 9.6.9.4. Roll out S-OPS tubing and attach to fence posts according to SOP C4.
- 9.6.9.5. Roll out S-OPS extension tubing and connect to S-OPS according to SOP C4 and Figure 7.
- 9.6.9.6. Connect S-OPS extension tubing to GSS in trailer through trailer tubing pass-through.
- 9.6.9.7. Check connections of CR800 data logger, AS21-12V relay controller, GSS, and LAN computer, and verify that GSS, data logger, and relay controller have power and are operating as expected using LoggerNet software.
- 9.6.9.8. Start GSS and check relay/solenoid, flow direction, mass flow, and pressure sensor operation (SOP C4).
- 9.6.9.9. Verify sampling and bypass airflow in GSS (SOP C4).
- 9.6.9.10. Check GSS and sampling system for leaks (SOP C4).
- 9.6.9.11. Remove rubber stoppers from inlets and store in trailer.
- 9.6.9.12. Note any deviations from normal parameters, repair or replace the troubled component if any, and document the repair in field notes.
- 9.6.9.13. Conduct sampling system flow balance (SOP C4).

9.6.10. Innova VOC multi-analyzer (SOP G7)
- 9.6.10.1. Check connections of Innova and LAN computer and verify that Innova has power and is operating as expected.
- 9.6.10.2. Verify calibration of Innova (SOP G7).

9.6.11. Thermo Fisher Corp 450I Pulsed Fluorescence H_2S Analyzer (SOP G5).
- 9.6.11.1. Check connections of 450I and LAN computer and verify that 450I has power and is operating as expected.
- 9.6.11.2. Start iPort software for control of 450I
- 9.6.11.3. Verify calibration of 450I (SOP G5).

9.6.12. TDLAS and scanner
- 9.6.12.1. Locate stake and anchor for TDLAS (SOP C2) and scanner tripod at the corner of the lagoon (Fig. 6) as defined in the individual SMP (use GPS if necessary to find anchor location).
  - 9.6.12.1.1. Platform specifications related to beam alignment are found in Appendix G.
    - 9.6.12.1.1.1. Specified platform is an original equipment manufacturer selected tripod and meets all platform specifications.
  - 9.6.12.1.2. Setup and level tripod platform for TDLAS/scanner at 1 m above berm height and secure to anchor with Nylon ratchet strap (if necessary use GPS unit to help locate the anchor).
  - 9.6.12.1.3. Record deviations (if any) in locations of any TDLAS/scanner components on the site open path sensor installation report (Appendix E).
- 9.6.12.2. Remove TDLAS/scanner UPS from storage area in trailer and install next to tripod.

9.6.12.3. Remove TDLAS/scanner power/radio unit and associated cables from storage area in trailer (SOP U4) and uncoil.
9.6.12.3.1. Inspect cable and repair or replace as needed. Log inspection results on checklist (Appendix F) with comments and remediation.
9.6.12.4. Connect power/signal cables at TDLAS/scanner (SOP C2)
9.6.12.5. Connect power cable UPS at power access point.
9.6.12.5.1. Verify power at UPS.
9.6.12.6. Connect power cable from TDLAS/scanner power supply to UPS
9.6.12.6.1. Verify power at TDLAS and scanner with LCD display on TDLAS unit (SOP C2).
9.6.12.7. Unpack and remove all remaining retro-reflectors and tripods from trailer storage location (SOP U4).
9.6.12.8. Position tripods with 'surface' reflectors at the staked locations 1-m height above lagoon berm at 1/3 and 2/3 of the distance between corner towers and TDLAS and scanner, according to Fig. 6 (Retro-reflectors D, E, F, G, N, O, P, Q).
9.6.12.8.1. Visually align reflectors so that the retro-reflector box opens towards TDLAS/scanner system.
9.6.12.8.2. Determine position of retro-reflectors by locating marker stake and anchor, if necessary use GPS unit.
9.6.12.8.3. Secure tripod to anchor using tie down strap.
9.6.12.8.4. Record position deviations (if any) on site open-path sensor installation report (Appendix E).
9.6.12.8.5. Inspect power cable and repair or replace as needed. Inspection results logged on checklist (Appendix F) with comments and remediation.
9.6.12.8.6. Connect power cables from each retro-reflector enclosure to nearest power access point.
9.6.12.8.6.1. Verify power at retro-reflector with visible red light on heater unit

9.7. Lagoon sludge depth measurements
9.7.1. Measurements may be done either at time of site installation or disassembly.
9.7.2. Wear protective clothing when working in lagoon.
9.7.3. Wear life jacket when working inside of the berm top.
9.7.4. Use the boat,(stored in truck bed) to move around lagoon to position for measurements of lagoon depth and sludge depth.
9.7.5. Number and location of measurements are indicated by the SMP for the site.
9.7.6. Procedure for measurements is described in SOP M5.

9.8. Disassembly
9.8.1. Fixed towers
9.8.1.1. Disconnect power cables to retro-reflectors and remove from towers, Remove and store mounting boards, store retro-reflectors in protective boxes and secure in trailer (SOP U4).
9.8.1.2. Disconnect cables from sonic anemometers and remove from tower.
9.8.1.3. Dismount anemometers and perform intercomparison and stationarity checks. Pack anemometers in shipping container and store in trailer in designated storage area (SOP U4).
9.8.1.4. Unplug power cable feeding tower, roll up and secure to tower.

9.8.2. 3-m meteorology tower/mast.
- 9.8.2.1. Perform intercomparison tests on anemometers (Sections 9.6.4.4 through 9.6.4.11) before disassembly and storage of meteorological mast.
- 9.8.2.2. Disconnect power to system at power access point.
- 9.8.2.3. Disconnect all lagoon sensor cables from data logger and pass back outside NEMA box
- 9.8.2.4. Remove all sonic anemometers, pack in designated container and store in trailer (SOP U4).
- 9.8.2.5. Remove ground rod, ground wire, and pack in designated area in trailer (SOP U4).
- 9.8.2.6. Remove stakes at each foot, pack in designated containers and store in trailer (SOP U4).
- 9.8.2.7. Loosen clamps and fold mast legs, store in trailer complete with remaining instruments and NEMA box still attached (SOP U4) and secure to center of floor using D-rings and ratchet straps.

9.8.3. S-OPS disassembly
- 9.8.3.1. Document sample flows according to SOP C4.
- 9.8.3.2. Plug inlets with rubber stoppers and tape stopper to filter holder.
- 9.8.3.3. Conduct system leak test according to SOP C4.
- 9.8.3.4. Disconnect inlets from fence posts.
- 9.8.3.5. Tape any open tubing ends, and roll up S-OPS tubing according to SOP C4.
- 9.8.3.6. Disconnect S-OPS extension tubing from GSS and tape ends.
- 9.8.3.7. Remove S-OPS extension tubing from trailer tubing pass-through.
- 9.8.3.8. Roll up S-OPS extension tubing, taping open ends as necessary according to Figure 7.

9.8.4. Innova 1412 VOC multi-analyzer (SOP G7)
- 9.8.4.1. Verify calibration of Innova according to SOP G7.

9.8.5. Thermo Fisher 450I Pulsed Fluorescence H2S Analyzer (SOP G5).
- 9.8.5.1. Verify calibration of 450I according to SOP G5.

9.8.6. TDLAS and scanner
- 9.8.6.1. Disconnect power to UPS system at power access point.
- 9.8.6.2. Disconnect power/signal cables at TDLAS/ Scanner unit and UPS system.
- 9.8.6.3. Store UPS with plastic box in trailer.
- 9.8.6.4. Coil cable and fasten into storage area in trailer at location (SOP U4).
- 9.8.6.5. Dismount TDLAS/Scanner unit from tripod, perform and log calibration check and then pack in shipping container, store TDLAS, Scanner unit, and tripod in trailer in designated protective boxes in storage area (SOP U4).

9.8.7. Retro-reflectors
- 9.8.7.1. Disconnect power for all retro-reflector enclosures at power access points.
- 9.8.7.2. Dismount retro-reflectors from tripods and store retro-reflector enclosures and tripods in trailer in designated storage area (SOP U4).

9.8.8. Lagoon sensors and tri-sensor float
- 9.8.8.1. Disconnect signal cables at NEMA box.
- 9.8.8.2. Extract tri-sensor float and sensor package from lagoon using rope attached to tri-sensor float, with two persons and pulling each end against the center to lift

the float from the water and walk the assembly to a dry area for cleaning and removing the sensors.

9.8.8.2.1. Rinse the float assembly, instrument cable, and rope with clean water and remove sensors.

9.8.8.2.2. Store float and rope in bed of tow vehicle.

9.8.8.3. Perform calibration check on redox and pH sensor and log results according to SOP L1 and SOP L3.

9.8.8.4. Store sensors with cable attached in trailer in designated storage area (SOP U4).

9.8.8.5. Remove 2-m holding stakes and store in bed of tow vehicle.

9.9. Look over the entire measurement area for any tools, sensors, or parts that may have been left out, if found, store them in the proper location.

10. Data and Records Management

10.1. Fill out an inspection checklist (Appendix F) at the beginning of each measurement period.

11. Quality Control and Quality Assurance

11.1. Maintain locations of sensors and retro-reflectors within 1 m of those specified in the SMP.

11.2. Perform the following QC and QA measures once at each location each time the location is set up to be measured and again if there are any data failures at the site due to human error, vandalism, theft, lightning/surge, storm, or other damage to the instruments during the measurement period.

11.3. At each power access location, check GFCI for ability to trip.

11.4. Verify that 120VAC supply power is available at each power access point.

11.5. Inspect the grounding rod for firmness in ground. Log inspection results on checklist (Appendix F) with remediation indicated.

11.6. Stability of instrument platforms:

11.6.1. Verify that the mast is staked tightly. Log inspection results on checklist (Appendix F) with remediation indicated.

11.7. Check that all masts, towers, and tripods are vertical.

11.8. Check for any indications of broken, bent or cracked mast or tower structural components. Log inspection results on checklist (Appendix F) with comments and remediation.

11.9. Orientation of sensors: Verify that the sonic anemometers are seated in their positions (SOP W2).

11.10. Verify that the lagoon probe cables have wire ties every 1 m along the rope all the way to the edge of the waterline. Log inspection results on checklist (Appendix F) with comments and remediation.

11.11. Check all retro-reflector heater power cables for damage. Log inspection results on checklist (Appendix F) with comments and remediation.

11.12. Check all sensor wires and cable at transmitter, receivers, scanner, and meteorological data logger NEMA box for tightness and damage. Check all enclosures for water

intrusion. Log inspection results on checklist (Appendix F) with comments and remediation.

11.13. Additional QA procedures for sensors are indicated in each respective SOP.

12. References

12.1. LoggerNet Instruction Manual. 2005. LoggerNet Instruction Manual. Campbell Scientific Inc, Logan, UT.

12.2. iPort Instruction Manual. 2007. *i*Port Instruction Manual. Communications software for iSeries and C Series Instruments. Part#102606-00. Thermo Fisher Scientific, Franklin, MA.

12.3. CM110 Tripod Mast Manual. 2005. Tripod installation manual, Models CM110, CM115, CM120, Campbell Scientific Inc., Logan, UT.

12.4. SOP C2. 2006. Open Path Tunable Diode Laser Acoustic Spectroscopy (TDLAS). Standard Operating Procedure C2. Purdue Applied Meteorology Lab.

12.5. SOP C4. 2006. Synthetic Open Path Sampling System. Standard Operating Procedure C4. Purdue Applied Meteorology Lab.

12.6. SOP E3. 2006. The Measurement of Solar Radiation with the Licor Model 200SL or 200SZ Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab.

12.7. SOP G5. 2007. Measurement of Hydrogen Sulfide (H_2S) with the Thermo Fisher Scientific Model 450I Pulsed-Fluorescence Analyzer. Standard Operating Procedure G5. Purdue Ag Air Quality Lab

12.8. SOP G7. 2007. Standard Operating Procedure for the Operation of the INNOVA 1412 Photoacoustic multi-gas analyzer. Purdue Ag Air Quality Lab.

12.9. SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Applied Meteorology Lab.

12.10. SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.

12.11. SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Applied Meteorology Lab.

12.12. SOP L5. 2006. Markland Sludge Gun. Standard Operating Procedure L5. Purdue Ag Air Quality Lab/ Purdue Applied Meteorology Lab.

12.13. SOP U4. 2006. Open-source Instrument Trailer. Standard Operating Procedure U4. Purdue Applied Meteorology Lab.

12.14. SOP W1. 2006. Humidity and Temperature Probe. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.

12.15. SOP W2. 2006. Ultrasonic Anemometer for Wind Velocity. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.

12.16. SOP W3. 2006. Wetness Grid for Measuring Precipitation. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.

12.17. SOP W5. 2006. The Measurement of Barometric Pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.

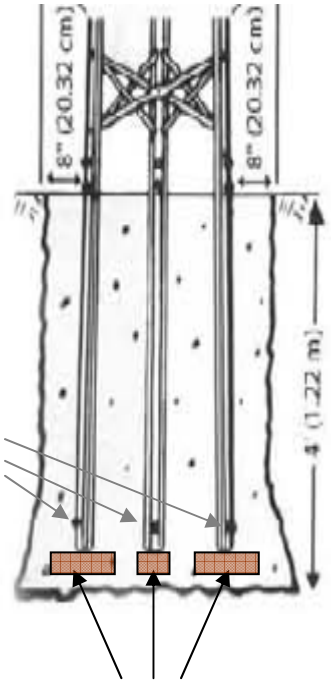
12.18. SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.

13. Contacts

13.1. Source for Delhi Sheet metal towers:
Lafayette Electronics Supply
405B North Earl Avenue
Lafayette, Indiana 47904 (Shipping)
P.O. Box 4549 Lafayette, Indiana 47903 (Mailing) or near site distributor (if available locally).
Tel: 800-842-1527

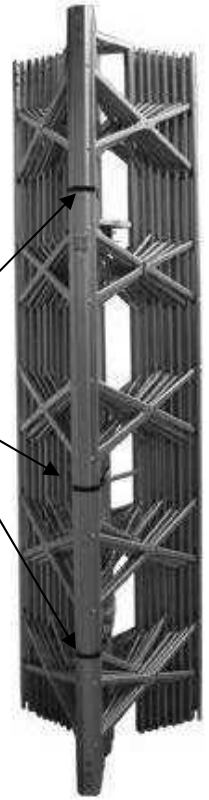
13.2. Source for CM 110 Masts:
Campbell Scientific, Inc.
815 West 1800 North,
Logan, UT 84321
Technical support: 435-753-2342

Figure 1A
Sheet metal tower stub kit
(Shown installed in concrete)



Standard bolt set in solitary stub holes

Bricks for landing stub ends in bottom of base form hole



Steel Shipping Bands

Figure 1B Sheet metal tower
48' tower has six sections
(Not eight as shown here but is otherwise identical to the tower shown)

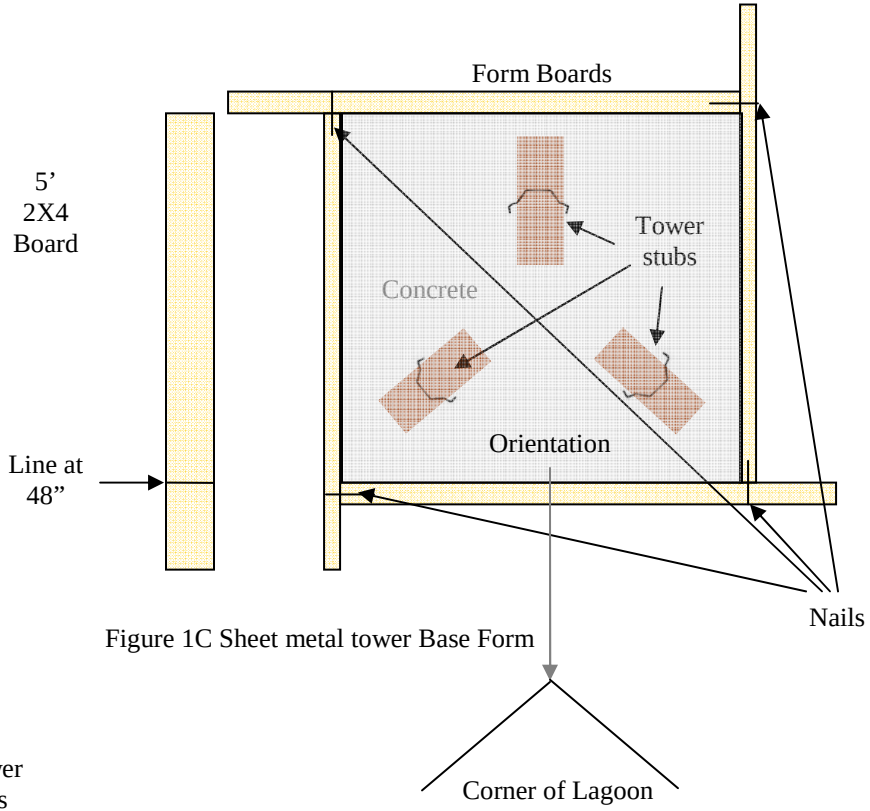


Figure 1C Sheet metal tower Base Form

Note: These figures are not shown to scale

Figure 1. Schematic diagrams for optional sheet metal tower components and the form for pouring the tower base.

Figure 2. Retro-reflector housing configuration.

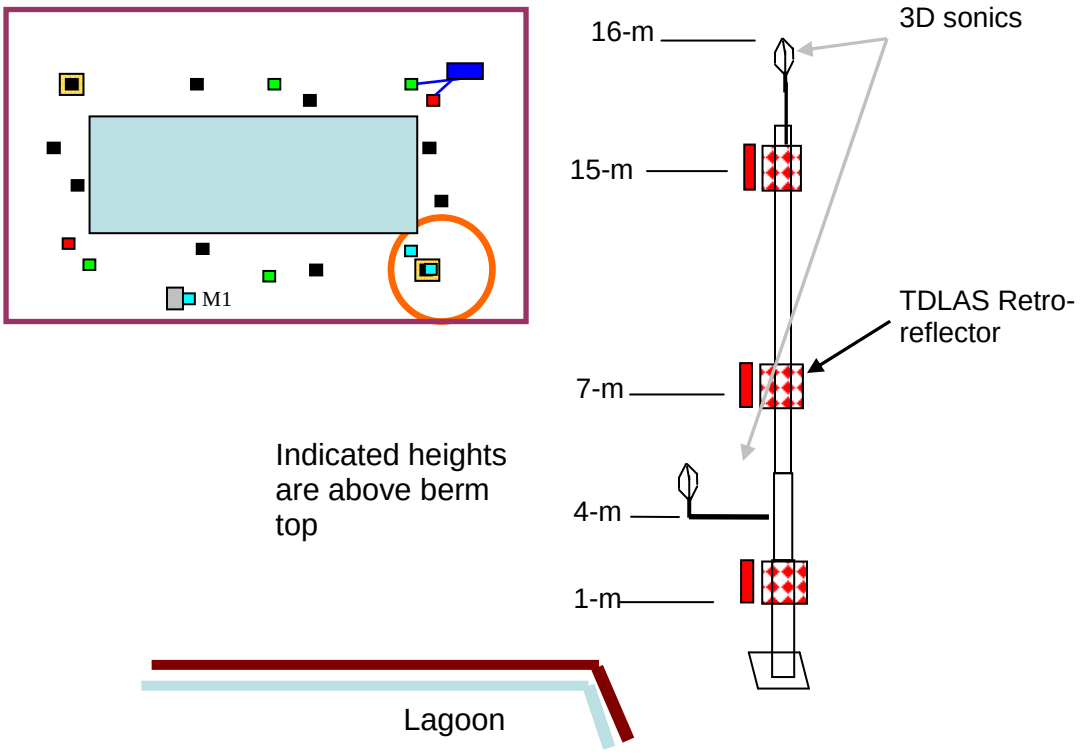


Figure 3. Ideal fixed tower configuration.

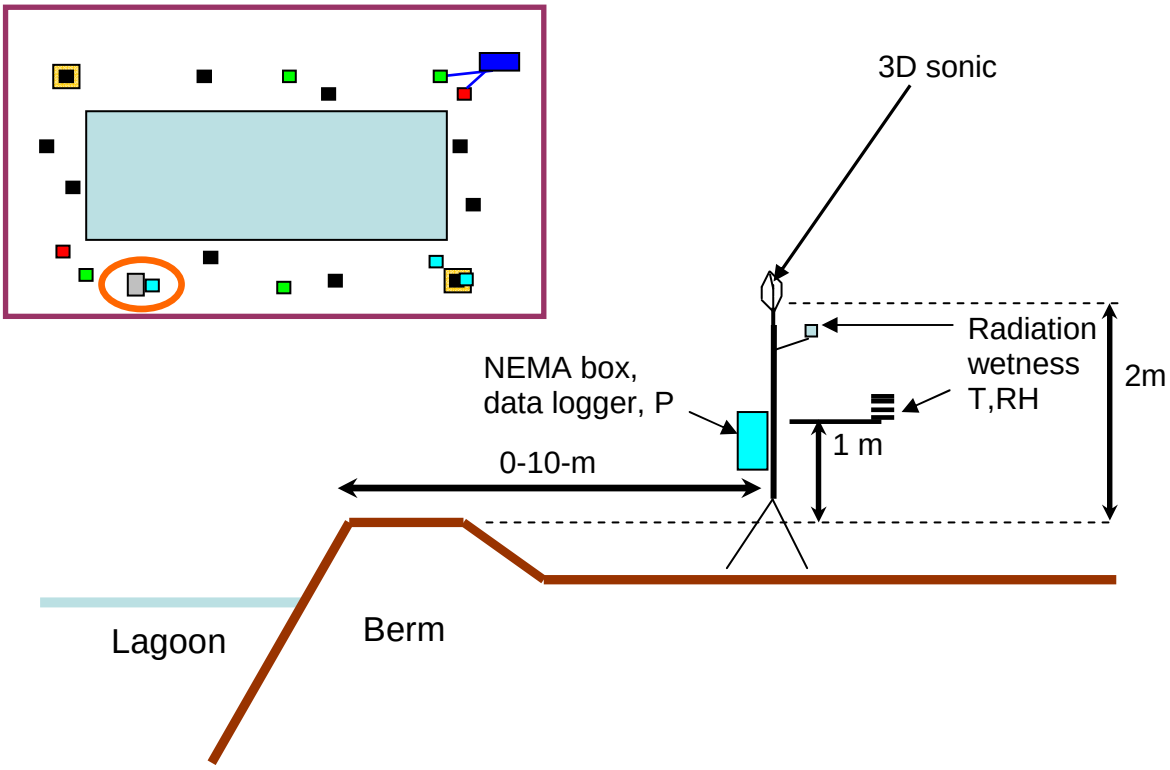


Figure 4. Ideal configuration for the meterological mast.

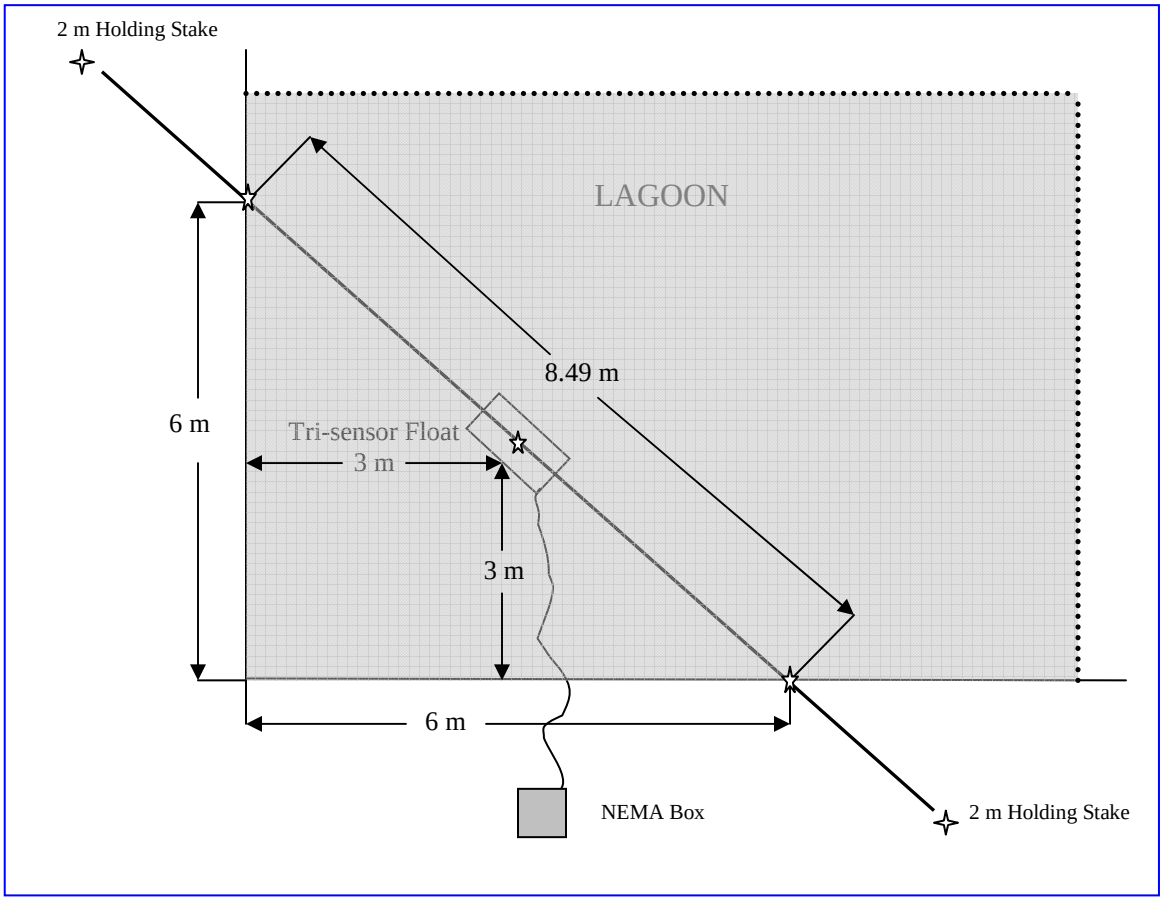


Figure 5. Proper deployment and orientation of the tri-sensor float.

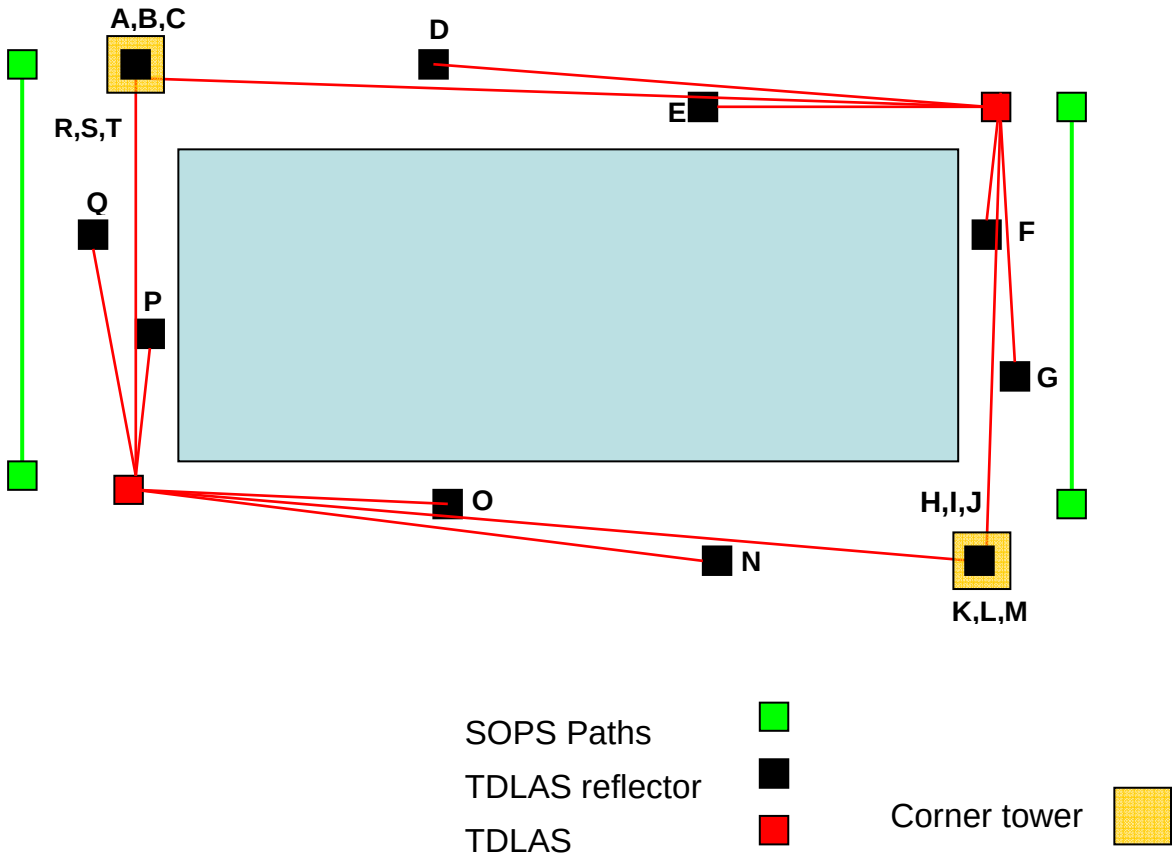


Figure 6. Ideal open-source gas measurement configuration for a lagoon source.

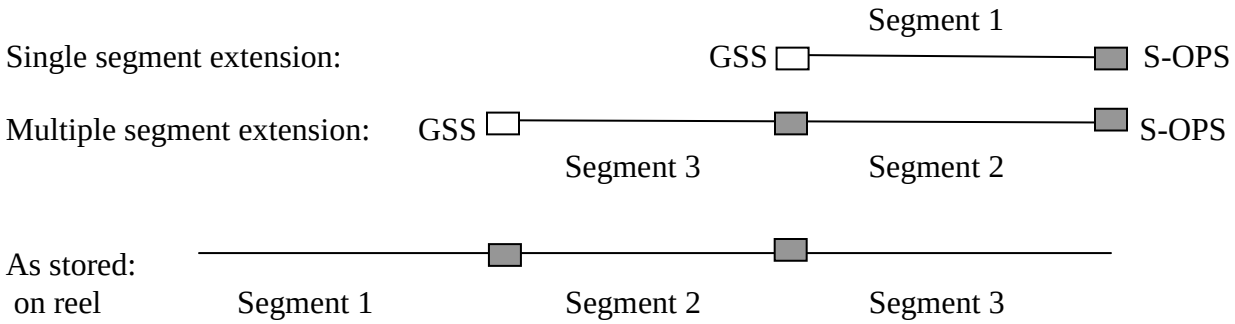


Figure 7 – Extension tubing configuration.
Connector material: Stainless steel (▬) and Teflon (▭). Extension tubing is stored on the reel with Stainless Steel unions connecting segments together. An additional union is needed to attach both the single and multiple segment extension lines to the two S-OPS.

APPENDIX A
RESPONSE FOR BITES AND STINGS

- Spiders: Some spiders can cause great pain, and injury.
  - The Black Widow is a small, shiny spider, less than half an inch long but with a leg span of up to two inches. It has a red hourglass shape on its underside. A bite from a Black Widow spider can cause severe pain and muscle spasms, heavy sweating, stomach cramps, nausea, vomiting, tightness in the chest, breathing difficulty and a sharp rise in blood pressure.
  - The Brown Recluse spider is brown or brown-yellow in color and has a dark violin-shaped area on the back. The brown recluse is found under rocks and woodpiles as well as closets and attics. A bite from the brown recluse can cause severe pain, reddening, blistering, and death of the tissue followed by deep ulceration at the site of the wound. The bite may not be noticed at first. Pain at the bite site begins one to four hours later.
  - If you should get bitten by a spider, try to identify the type of spider. If possible, kill the spider without smashing it beyond recognition. Inform the site scientist and seek medical attention for your bite.

- Snakes: Most snakes are nonpoisonous. The bite of a nonpoisonous snake can cause pain and infection, but is rarely serious. There are three types of poisonous snakes in the study area, and their bites can cause serious illness and even death. They are:
  a. Eastern/Western/Pygmy Diamondback Rattlesnakes
  b. Water Moccasin
  c. Copperhead
  - First aid steps to remember if bitten
    a. Stay calm
    b. Look at snake for identification (shape of head, color and markings)
    c. Seek help
    d. Keep the bite at the level of the heart
    e. **Do not incise the bite**
- Insects and other invertebrates:
  - Ticks: The Lone Star Tick, the American Dog Tick, the Brown Dog Tick, and the Black Legged Tick or Deer Tick are some common ticks. Most ticks are capable of transmitting a variety of diseases, including Rocky Mountain Spotted Fever, Colorado Tick Fever, Lyme Disease and even Tularemia (a disease that causes toxins in the blood; high fever is a symptom).
    a. First aid -- remove ticks with tweezers. Gently grasp the tick behind the head and remove with a slow, steady pull. Wash the area thoroughly with soap and water.

RESPONSE FOR BITES AND STINGS
(Continued)

b. Mark the date of the bite on the calendar and also report it to the program manager. If any flu-like symptoms, such as fever, muscle pain, extreme fatigue, headache, chills, joint pain, swollen glands or a rash appear, see your doctor. Lyme disease symptoms may not develop for up to two months.
c. To avoid ticks, tuck pant legs into socks and spray an insect repellent on pants.
d. Perform a self check for ticks at the end of the work day or at the completion of work in areas that contain ticks.

- Fleas/Chiggers: To avoid exposure to chiggers and fleas, do not walk in uncultivated areas and heavy vegetation. Spray an insect repellent on pants. High boots and socks mitigate chigger bites.
- Gnats/Mosquitoes: Although most gnats are not bothersome, Kansas has a gnat (Buffalo Gnat) that bites much like a mosquito. To repel these gnats it is recommended to use Avon *Skin So Soft* or vanilla extract. To avoid contact with mosquitoes, spray an insect repellent on the outside of clothing and on bare skin if repellent is designated for it.
- Blister Beetles: Blister Beetles are small insects that have yellow and black stripes running the entire length of the body. The bite produces immediate pain, redness, itching and swelling that can persist for hours.
- Hornets/Wasps/Bees:
  a. Bees have a stinger attached to a poison sac that is left in the wound when a sting occurs. Wasps and hornets may sting repeatedly.
  b. First aid -- remove the stinger from the wound by scraping a blunt object, such as a dull blade, across the wound. Symptoms usually result within a few hours. If symptoms such as difficulty breathing or rapid, severe swelling occur, seek medical attention immediately.
- Scorpions: All scorpions can produce a painful sting, but serious life threatening symptoms are rare. First aid is similar to that given for a wasp sting.

APPENDIX B.
RESPONSE TO WILD ANMIALS

- The badger is a small (average 20 lb) mammal that feeds on small rodents, fruits and roots. They have very sharp teeth and long, sharp claws and can be quite aggressive. They are a defensive animal and will usually only attack if provoked. The badger, in cooler weather, will make a burrow and remain there for several months. The opening to the burrow is six to eight inches in diameter. Should you spot a badger hole, **keep your distance and do not put your feet or hands in the hole**.

- The skunk is a small mammal that produces a very unpleasant odor when excited or threatened. Please keep your distance from these small mammals. If bitten by a skunk (many carry rabies), you should seek medical attention immediately.

- Coyotes are a small dog-like mammal. They attack small animals and livestock. For the most part they are very shy and afraid of humans. They do carry rabies; so, if bitten, you should seek immediate medical attention.

APPENDIX C
WEATHER RISKS

Severe Weather. Be aware of weather conditions at all times while on site. Do not work outside during lightning storms. In case of severe thunder storm and/or a tornado warnings, cease work and seek shelter. It is your responsibility to locate the nearest available tornado shelter. In case an unexpected tornado occurs, lay flat in the nearest depression until the tornado has passed. The site PI or scientist has the authority to stop work, at his discretion, during severe weather activity.

Cold Weather exposure. There are two main personnel effects cold weather can produce.

a. Hypothermia : Hypothermia results when the body loses heat faster than it can produce it. When this situation first starts to occur the blood vessels start to constrict, and hands and feet are first affected. Next, involuntary shivers begin to occur. The shivering is your body's first warning sign. Further heat loss produces speech difficulty, forgetfulness, loss of manual dexterity, collapse, and finally death.
b. Frost bite: As your blood vessels constrict to keep vital organs warm, hands and feet can experience frost bite. Hands and feet are the first body parts affected. Frost bite begins with a burning sensation in your hands and feet and then enters a numbing phase. The numbing phase is very dangerous and actual frost bite may occur.

Cold Weather Exposure Prevention: Dress warmly, wear layered clothing. Cover all exposed flesh. If clothes become wet, change as soon as possible and take frequent breaks in a heated area. Do not drink alcoholic beverages.

Hot weather exposure. There are three heat-related illnesses that hot weather exposure can produce. They are:

a. Heat stroke is life threatening. The victim's temperature control mechanisms stop working. The body temperature can rise so high that brain damage and death may occur if the body is not cooled quickly.
   (1) Symptoms include dry, red skin, hot, and very high body temperature.
   (2) First aid is to cool the person down as quickly as possible and call for medical help.
b. Heat exhaustion is less dangerous than heat stroke. It typically occurs when people work in a warm, humid place where body fluids are lost through heavy sweating.
   (1) Symptoms include cool, moist, pale, or red skin or heavy sweating, dilated pupils, headache, nausea, and dizziness.
   (2) First aid is to get the person in a cooler place, place him or her on their back with feet elevated. Cool by fanning or using cold packs and give 1/2 cup water every 15 minutes.
c. Heat Cramps are muscular pains and spasms due to heavy exertion. Heat cramps usually involve the abdominal muscles or the legs. It is generally thought that the loss of water and salt from heavy sweating causes cramps..

Hot-weather illness prevention: Drink plenty of liquids such as water, fruit and vegetable juices, and electrolyte solutions (avoid soda pop, alcohol, and coffee). In addition limit strenuous activity during hot periods, wear loose fitting, light colored clothing, preferably made of natural fibers such as cotton (man-made fibers do not absorb water well). Wear a hat.

APPENDIX D.

Sheet Metal Tower Installation and Removal

Sheet metal tower installation (Base form)

1. Use proper protective equipment when working with sheet metal tower.
    a. Wear a pair of boots with heavy soles for climbing the tower during installation.
    b. Use a pair of leather gloves for handling the rope and tower sections.
    c. When climbing, wear the safety climbing harness and lanyard.
    d. Have your partner wear a helmet and leather gloves when working under the tower and assisting you.
    e. Uncured concrete is acetic in nature and can cause mild burns and irritation to unprotected skin, wash concrete from skin as soon as possible if you get uncured concrete on your skin.
    f. When working on the tower, be sure to securely fasten one of the two way radios on your person for communication with your partner and remove any item from your person that might fall and cause injury or be damaged (pocket or belt worn knives, cell phones etc.).
2. Do not start this procedure if below-freezing temperatures, high winds (gusts in excess of 15 mph), storms, or heavy precipitation are expected in less than 24 h, as the tower base may not set correctly in those conditions.
3. Contact the local cement provider and ask them if they can supply you with concrete this day at the time you think you may need it. You will need approximately 1.8 yd^3 for each sheet metal tower base.
    a. Each sheet metal tower base takes approximately 1-4 h to prepare, depending on the difficulty of the excavation of the base.
    b. The base generally must be excavated by hand or done very carefully with a small excavator, as the walls of the excavation need to be relatively vertical on all sides.
    c. Contact the producer or his/her staff before beginning concrete work to determine where you can dispose of any excess concrete, and where the concrete provider can clean out the truck chute.
    d. Inform the producer or his/her staff there will be about 2 yd^3 of dirt excavated from each tower base. Ask if they can dispose of or move the dirt, and ensure that the farm staff does not disturb the tower base during the installation process.
    e. Obtain clearance from the producer and a suggested route to allow the heavy concrete truck to drive over the area to deliver concrete. These trucks are very heavy and can damage some underground pipes and landscaping.
4. Assemble one of the stubs (Fig. 1A) from the stub kit to the outside of the leg on the largest end of the biggest tower section at the two predrilled holes in each base stub and tower section, using two bolt sets from the largest bolt set in the tower bolt kit. Securely tighten the stub mounting bolts using a box end wrench and the ½″drive socket and ratchet. The head of

the bolt should be on the outside of the stub on all sections (use the box end wrench here) and the nut and washer should go on the inside of the tower leg (use the socket and ratchet there).

a. Install a large standard hardware bolt set (one bolt, one nut, and a washer) in the solitary pre-drilled hole at the bottom of the base stub you just bolted to the tower base. This will be immersed in concrete to prevent the tower stub from pulling out of the concrete after it hardens.
b. Turn the tower over one step to the right and repeat step #4 until all the base stubs (3) have been installed onto bottom of the base section (largest end of the largest section) and then lay the assembly aside.

5. Using a shovel, dig a square hole 44″x44″x4′ deep at each sheet metal tower location to fill with concrete and form the base for each tower. **The tower location cannot easily be moved more then a few inches once the excavation of the base form has begun!**
    a. Dig only as many holes as you have time to finish this day. Start this in the morning, so that there is time to finish all the tower bases in one day. Sheet metal tower base installation (assembling base section, digging bases, building and filling concrete forms) takes between two to more than five hours depending on the difficulty of the soil excavation of the base form for each tower. Tubular tower base assembly, digging bases, and building and filling concrete forms takes approximately an hour for each tower.
6. Once the excavation of the base form is complete, place the three bricks in the bottom of the form hole at the approximate location where the ends of the base stubs will sit to land the stubs and help keep the tower at the proper level during curing of the concrete (Figs. 1A and 1C show the position of the bricks in the hole).
    a. The tower should be oriented so that one side of the tower is facing the corner of the lagoon (Fig. 1C) and a leg faces each adjacent corner for proper mounting of the retro-reflectors later.
7. Level the bricks at the bottom of the form hole using the carpenters level so that the tower will sit perfectly vertical once the stubs are placed on the landing bricks.
8. Have your partner hand you the tower base assembly (stubs first) and place it on the bricks. Adjust the bricks so that the stubs sit squarely in the center of them (Fig. 1C).
9. Have your partner check each tower leg above the hole with the level in the vertical position and adjust the bricks so that the bubble in the level has exactly the same slight offset for each leg. Note that the bubble in the level should be in the center (indicating the leg is nearly perfectly vertical), but the bubble will rest on one line slightly more then the other on each leg. When the offset is exactly the same for each leg, the tower section is vertically true.
10. Call the local cement provider; tell them you are now ready for concrete delivery.
11. Construct the concrete form for the tower base as follows (Fig. 1C):
    a. Using the tape measure, a pencil, and a “T” square draw a line straight across one 10′ 2x4 in the center.
    b. Using the circular saw cut the board at the line to form two 5′ sections.
    c. Repeat to cut two more 5′ sections from the other 10′ 2x4 (four 5′ sections are required for each tower base).
    d. Using the tape measure, a pencil, and a “T” square draw a line straight across all of the 5′ sections, at 48″ from one end of each board.

    e. Using the 2.5″ framing nails, make a square form for each of the tubular towers by nailing the boards at the lines to form a 48″ square (Fig. 1C).
12. Place the form on the tower base hole by lifting the form over the tower base assembly.
    a. If you disturb the tower, you must recheck the tower (Step 8) to ensure it is still vertical.
13. Have the concrete truck back up to the hole and deliver the concrete into the formed hole while holding the tower base assembly with both hands and a foot to ensure the tower doesn't move while pouring the concrete.
14. After filling the base form use a level to ensure the tower is still vertically true.
15. Smooth the concrete of each base using a trowel so that it is even with the form.
16. You must re check the tower once again to ensure it is still vertical using the method described in Step #9 now and again before you leave the site in the evening for each sheet metal tower base you construct.
17. Allow the bases to sit for at least 72 h before constructing the towers or climbing on the bases.
    a. The base forms can easily be removed the following day by tapping the extended sections of form boards with a hammer.

Sheet metal tower installation (Tower installation)

18. Separate all the tower sections and locate all necessary bolts for the tower, if any bolts are missing, locate or replace them before proceeding.
19. Lay the tower sections near the base in the order in which they will go up (largest first, smallest last).
20. Place the bolts for the first section in your pocket, tie the work rope onto the climbing belt loop and proceed to the top of the base section. Secure yourself to the top of the section so that the top of the tower is at your waist using the lanyard.
    a. Wrap the lanyard from the loop where it is hooked to the left side of your climbing belt, around the legs of the base section near the top and hook to the loop on the right side of your climbing belt.
    b. Wrap the lanyard around the tower legs to eliminate slack so that you are closely secured to the face of the top section at your waist.
    c. Avoid wrapping the rope **over** the ends of the section you are standing on as it will obstruct your ability to assemble the section, and might slip back over the leg while you are lifting the next section, causing you to lose your balance or fall.
21. Have your partner tie the free end of your work rope to the top of the next section to be installed (this will be the smallest end of the largest uninstalled section).
    a. Tie the rope firmly so it doesn't become loosened as the section is hoisted up but loosely enough that it can easily be untied once it reaches the top.
22. Have your partner move back out of the way in case you drop the section. Now, hoist the section using the rope. Hook one rung of the section of tower you just lifted over one of the ends of the section you are standing on when it reaches you.
23. Untie the rope from the section and let the free end of the rope fall back to the ground.

24. Standing firm on the tower, grasp the section with both hands and lift it about half way up to where it will sit and again hook it over the end of the section you are standing on so that you can re-orient your hands.
25. Now, grasp the section again and lift the bottom of it the rest of the way above the section you are standing on and lower the bottom of it (largest end) into the top ends of the section you are standing on.
    a. Each section slips into the top of the previous section where it sits on a set of riveted stops designed to allow the parts to rest at the correct position while the sections are bolted together.
26. Insert each of the six bolt sets into the pre-drilled bolt holes to fasten the two sections together and tighten.
    a. Be sure to use the largest bolt set that will fit in the hole from the bolt kit. Each section has the holes drilled to exactly fit the correct bolts.
    b. Place the bolt into the hole from the outside of the tower so that the head of the bolt is on the outside and the nut and washer are on the inside.
    c. Tighten the bolts firmly, but do not over-tighten the bolts and cause them to break, as they are specially-made bolts. Standard hardware must not be substituted for them.
27. Climb the section you just installed and repeat the procedure from Step #21 to install the remaining sections of tower.
    a. Fatigue, height, and other conditions such as light winds do make the task a bit more difficult with each section you install but the sections get smaller and lighter as you go up, and this tends to offset the difficulty level.
28. Proceed to “Optional sheet metal tower installation (Equipment installation)”.

Sheet metal tower installation (Initial Equipment installation)

29. Have your partner unpack and assemble the following:
    a. Lightning rod and mounting bracket (storage location shown in SOP U4)
    b. Connect one end of the green #6 ground cable to the lighting rod mounting bracket
    c. Mount the assembly near the top of the mast pipe.
    d. Unpack and install sonic anemometer at top of the mast pipe (This will become the 16-m location) storage location shown in Fig. 1 of SOP U4.
    e. Unpack the sonic long anemometer power cable from storage area in trailer (Storage location shown in Fig. 1 of SOP U4) and uncoil it.
    f. Inspect cable and repair or replace as needed. Log inspection results on checklist (Appendix F) with comments and remediation.
    g. Connect power cable to anemometer (SOP W2).
    h. Secure the ground and anemometer cables to the mast pipe using electrical tape.
    i. Leave two feet un-taped at the bottom of the mast pipe to slip into the tower mounting location at the top section.
    j. Securely tie the assembly to the work rope with the top facing upward.
30. Carefully hoist the mast assembly to the top of the tower using the work rope, have your partner help control the assembly using the ground cable and the remaining free end of the rope.

31. Slip the bottom of the assembly into the tower and secure using the manufacturer-supplied mounting hardware kit for the mast pipe.
32. Tape the cable at the top of the tower and every two feet along the way as you work your way down (these cables will remain on the tower for the remainder of the measurement period, so leave a small loop of anemometer power cable at top for later repairs if necessary).
33. Have your partner unpack 6 retro-reflectors (storage location shown in SOP U4) and attach mounting board using wire ties.
    a. Inspect cables and repair or replace as needed. Log inspection results with comments and remediation.
    b. Have your partner tie a retro-reflector and mounting board, one at a time, to the work rope.
34. Hoist the parts up to the 15-m retro-reflector mounting location and have your partner help control the ascent with the dangling section of rope.
35. Tie the rope off so it is within reach near the top and attach the retro-reflector, then repeat the procedure for the second retro-reflector.
36. Mount two (2) retro-reflectors on the tower at the 15-m above berm height, one on each leg facing adjacent corners of the lagoon. Align the units so that the open sides of each retro-reflector enclosure are facing the area where the TDLAS spectrometers are to be located.
37. Connect the power cables from the retro-reflectors to the power boxes on the tower and secure them with tape.
38. Proceed to the 7-m mounting location on the tower. Have your partner tie another retro-reflector to the work rope and repeat the procedure used for the 15-m retro-reflector mounting to install the retro-reflectors at the 7-m location.
39. As before, mount two (2) retro-reflectors on the tower at the 7-m above berm height, one on each leg facing adjacent corners of the lagoon. Align the units so that the open sides of each retro-reflector enclosure are facing the area where the TDLAS spectrometers are to be located.
40. Connect the power cables from the retro-reflectors to the power boxes on the towers, and secure them with tape.
41. Proceed to the 4-m anemometer mounting location.
42. Have your partner do the following:
    a. Locate the 4-m custom-made anemometer mount (may have been shipped to the site or transported in the bed of tow vehicle).
    b. Securely tie the assembly to the work rope with the top facing upward.
    c. Carefully hoist the assembly to the 4-m level of the tower using the work rope, have your partner help control the assembly using the free portion of remaining rope.
    d. Attach the custom mount to the tower using the hardware supplied with the custom made mount.
    e. Unpack and install sonic anemometer (storage location shown in Fig. 1 of SOP U4) at the short mounting stub on custom mount.
    f. Unpack sonic anemometer power cable from storage area in trailer (Storage location shown in Fig. 1 of SOP U4) and uncoil. Inspect cable and repair or replace as needed. Log inspection results on checklist (Appendix F) with comments and remediation.
    g. Connect power cable to anemometer (SOP W2).
    h. Secure the anemometer power cable to the 4-m custom mount using electrical tape.

   i. Tape the cable here and every two feet along the way as you work your way down (this cable will also remain on the tower for the remainder of the measurement period) be sure to leave a small loop of wire for later repairs if necessary.
43. Proceed down to the base of the tower.
44. Mount two (2) retro-reflectors on the tower at 1 m above berm height, one on each leg facing adjacent corners of the lagoon. Align the units so that the open sides of each retro-reflector enclosure are facing the area where the TDLAS spectrometers are to be located.
45. Connect the power cables from the retro-reflectors to the power boxes on the tower, and secure them with tape here and at every two feet down to the tower base.
46. Unpack and drive an 8′ ground rod in the ground near the base using large hammer (Storage location shown in Fig. 1 of SOP U4).
    a. Drive the ground rod near the tower base.
    b. Connect to a tower leg using a piece of the bare #6 grounding wire using the provided hardware.
47. Connect the drop cord feeding the tower to the power access point and check for normal operation.

Sheet metal tower installation (Equipment removal)

48. Remove all instrumentation and equipment from the tower and pack into the respective storage boxes and locations in the instrument trailer.
49. If this is not the last measurement period at the site:
    a. Leave the grounding cable on the tower.
    b. Disconnect the drop cord feeding the tower from the power source, coil up and tape it to side of tower.
50. If this is the last measurement period, remove all cables and equipment from tower and proceed to “Optional sheet metal tower installation (Tower removal)” below.

Sheet metal tower installation (Tower removal)

51. Discuss the tower base removal with the producer. He/she may want to leave the base in the ground and cut off the base stubs, or remove the base and fill the hole him/her self. If not, the bases weighs nearly 9,000 lb, and can be removed with the aid of a large backhoe or excavator. Disposal of the concrete will require a tri-axle or other heavy truck to haul the cube to a landfill location. Fill the hole immediately to prevent injury to humans or animals that might fall into the holes. Contact an excavating company to remove the base and take care of those details. Note the following:
    a. If the base is left in the ground the stubs MUST be cut off flush with the concrete to prevent impalement or serious injury from falling over or onto them.
    b. If a torch is used to cut the stubs off flush with the concrete, be careful, as sections of the concrete can fracture under high heat stress with sometimes near-explosive force.
52. Climb tower and firmly secure yourself waist high at the top of the second section down from the top with the lanyard.

a. Wrap the lanyard from the loop where it is hooked to the left side of your climbing belt, around the legs of the base section near the top and hook to the loop on the right side of your climbing belt.
b. Wrap the lanyard around tower legs to eliminate slack so that you are closely secured to the top of the section at your waist.
c. Avoid wrapping the rope **over** the top end of the section you are standing on (the area where the bolts are), as it will obstruct your ability to disassemble the section above and might slip back over the leg while you are lifting off the section above, causing you to lose your balance or fall.

53. Remove tower section above:
    a. Remove the bolt sets attaching the section above you to the tower and secure them in your pocket or a satchel.
    b. Use both hands and wiggle the section out of the section you are standing on and let it down as far as is comfortable then hook it over the exposed leg of the section you are standing on.
    c. Now, re-adjust your hands and lower the section down further to hook the top of it over the section you are standing on and tie the work rope to the section to be lowered.
    d. Lower the section to your partner and have them untie the rope and lay the section aside.
54. Move down to the next lowest section, and repeat Step #58 until all sections of the tower have been removed.
55. Load the largest section into the bed of the tow vehicle (smallest end forward).
56. Load each progressively smaller section into the center of the previous section in the tow vehicle (smallest ends first) until the entire tower is loaded inside itself in the rear of the tow vehicle for transport to PAML.
57. Store the tower bolt sets in a bag or bucket in the rear of tow vehicle.
58. Remove ground rods and store in trailer.
59. Remove tower base or cut off the base stubs as discussed in Step #56.

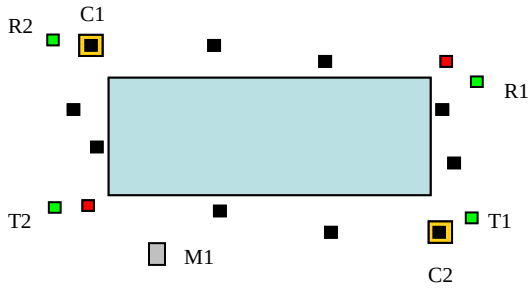
If the base and stubs are not to be removed immediately cover the stubs with a pile of wood, bucket, or some other item to prevent risk of serious injury to humans or animals.

14. APPENDIX E
Site Open-path Sensor Installation Report

Location: _____

Date: _____/_____/_____

FOS: _____



Mast location deviation? (M1) _____Deg (N) _____Min_____Sec

SOPS Path #1 start location (T1) _____Deg (N) _____Min_____Sec

SOPS Path #1 end location (R1) _____Deg (N) _____Min_____Sec

Distance between Path #1 outlet tube and GSS manifold: _____ m

Deviation of path#1 height above lagoon berm : _____ m

SOPS Path #2 start location (T2) _____Deg (N) _____Min_____Sec

SOPS Path #2 end location (R2) _____Deg (N) _____Min_____Sec

Distance between Path #2 outlet tube and GSS manifold: _____ m

Deviation of path #2 height above lagoon berm : _____ m

Notes:

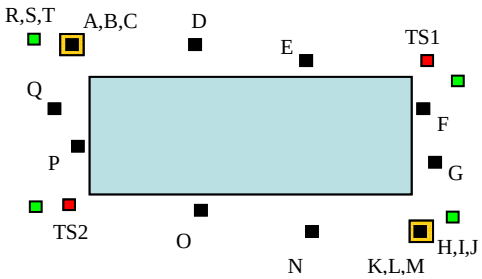
Site Open path sensor Installation Report

(Continued)

Location: _____

Date: _____/_____/_____

FOS: _____



TDLAS/scanner 1 location deviation (TS1) _____Deg (N) _____Min_____Sec

---------- Location ----------

Retro-reflector	Deg (N)	Min	Sec	Distance from TDLAS (m)	Actual height above berm (m)
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					

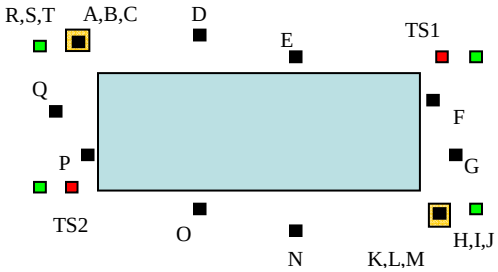
Site Open path sensor Installation Report

(Continued)

Location: _____

Date: _____/_____/_____

FOS: _____



TDLAS/scanner 2 location deviation (TS2) _____Deg (N) _____Min_____Sec

---------- Location ----------

Retro-reflector	Deg (N)	Min	Sec	Distance from TDLAS (m)	Actual height above berm (m)
K					
L					
M					
N					
O					
P					
Q					
R					
S					
T					

Notes: (continue on separate page if necessary)

APPENDIX F
Inspection Checklist Form

(Cables)

Date: _____

Item	All OK	One Bad	Repaired or Replaced Unit # or Description	Note #
Retro-reflector Cables (15-m/Tower)				
Retro-reflector Cables (7-m/Tower)				
Retro-reflector Cables (1- m/Tower)				
Retro-reflector Cables (1-m 2/3)				
Retro-reflector Cables (1-m 1/3)				
SOPS Tubing Path #1				
SOPS Tubing Path #2				
TD-LAS Power/Signal Cables				
Meteorological Unit Power Cable				
Lagoon Sensor Data Cables				
Sonic Anemometer Cables (16-m)				
Sonic Anemometer Cables (4-m)				
Sonic Anemometer Cables (1-m)				

All notes to be documented on back of form and note # referenced to the appropriate entry!

Name: _____

Inspection Checklist Form SOP U5

(Continued)

(Hardware)

Date: _____

Item	**OK**	**Problem**	Note #
GFCI Trip and Power OK?			
Lightning Rod OK?			
Ground Wire OK?			
Mast Stakes			
SOPS paths operating at normal flow rates?			
Indication of flow at all SOPS orifices?			
All Towers, Tripods, & Mast Look Vertical?			
All Towers, Tripods, & Mast Intact?			
Sonic Anemometers Mounted & Oriented Correctly?			
Lagoon Cable Floats Intact And Spaced Correctly?			
All Heater Cables Look OK, Mounted Securely?			
All Other Sensor Cables Look Intact			
Meteorological Boxes Weather Tight?			
Desiccant Fresh In Meteorological Boxes?			

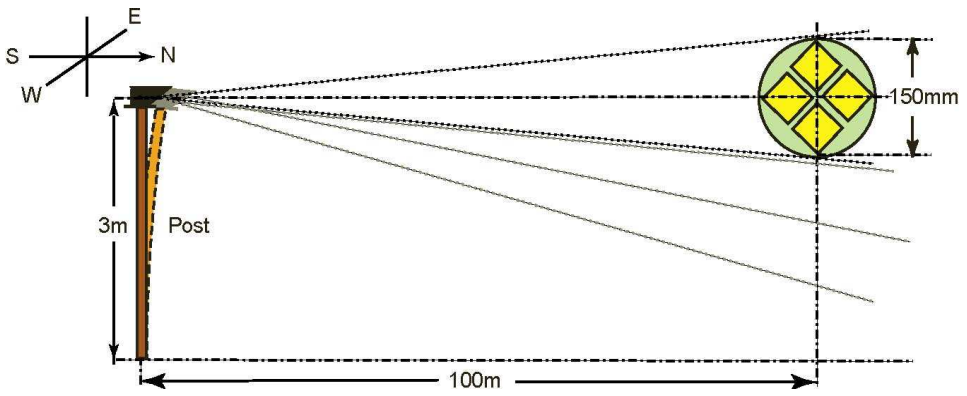
All notes to be documented on back of form and note # referenced to the appropriate entry!

Name: _____

APPENDIX G

Calculating the Effects of Movement

Consider the example of a 150 mm-diameter retro-reflector array located 100 m due N of the remote head:



The TDLAS/scanner can move vertically or horizontally 150 mm (6″) to either side of the centreline before the beam will move completely off the retro array. This ***translational*** movement is not common. However, because the TDLAS/scanner system is fixed at the bottom, ***torsional*** or bending movement of the TDLAS/scanner is much more likely, due to wind loading or thermal distortion. Any bending perpendicular to the centreline is manifested as a lateral motion, and will have a minimal effect. Conversely, any bending along the centerline will have a serious negative effect: The top of a 3-m tall post can only move 4.5 mm (0.18″) before the beam will have moved all the way off the retro. For a 500-m path length, with the retro-reflector array doubled in diameter to 300 mm (12″), the top of 3-m post can only move 1.8 mm (0.07″) before beam will completely miss the retro-reflector.

The diameter of the laser beam when it exits the TDLAS is about 2.5 mm, and the divergence is approximately 1.5 mrad (milliradians). This means that at a distance of 100 m the beam diameter is 1.5 x 100 = 150 mm (6″). Similarly, for a 1,000-m path, the beam diameter would be 1,500 mm (59″).

The remote head can be mounted on a tripod, post, or platform, and directs the laser beam to a reflector, which can be from a few meters to several hundred meters distant.

THE POWERWARE 9125 UNINTERRUPTIBLE POWER SUPPLY

Standard Operating Procedure (SOP) U6

THE POWERWARE 9125 UNINTERRUPTIBLE POWER SUPPLY

Standard Operating Procedure (SOP) U6

Prepared by

Bill W. Bogan and Sam M. Hanni

Reviewed by

Albert J. Heber

Effective Date: November 6, 2006

PURDUE AGRICULTURAL AIR QUALITY LABORATORY (PAAQL)

Agricultural and Biological Engineering, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. A means is needed to prevent power outages or disruptions to the equipment in the on-farm instrument shelter (OFIS) in order to ensure that data collection is not interrupted.
1.2. A means is also needed to protect the equipment from possible poor power quality. Power surges or spikes, for example, could be damaging to some of the gas analyzers, or to the DAC system.
1.3. This SOP details the use of the Powerware Model 9125 uninterruptible power system (UPS), which provides both of these functions.
1.4. SOP U1 provides a list of which equipment should be connected to the UPS. Sampling pumps and converter ovens are not connected to the UPS.

2. Summary of Method

The Powerware 9125 (Powerware Corporation, Espoo, Finland) UPS filters incoming AC power, and provides consistent, spike-free power with a pure sine wave output. The unit's double-conversion online design constantly conditions and controls AC output, assuring zero delay when transferring to backup power in the event of a power failure. The unit incorporates proprietary "Advanced Battery Management" technology, which allows the unit to operate without draining the battery, extends battery life, reduces battery recharge time, and provides a warning when the batteries are nearing the end of their useful life. The Model 9125 can accept up to four Extended Battery Modules (EBMs), further extending the length of time that the UPS can support equipment in the event of a power disruption or outage. Batteries are hot-swappable, so that power to the equipment does not need to be interrupted.

3. Definitions

3.1.	EBM	Extended battery module
3.2.	OFIS	On-Farm Instrument Shelter
3.3.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.4.	QAPP	Quality Assurance Project Plan
3.5.	UPS	Uninterruptible power system

4. Health and Safety

4.1. The Powerware 9125 contains potentially lethal voltages. There are no user-serviceable parts in the unit. Do not attempt any service to the UPS other than changing of batteries. Under no circumstances should repairs to the UPS or its batteries be attempted by anyone other than authorized service personnel.
4.2. Because the Model 9125 contains batteries as a backup power supply, these voltages may be present even when the unit is not plugged in.
4.3. The batteries themselves can cause electrical shocks if they are handled improperly. Do not contact both poles of the battery simultaneously, and do not attempt to service the batteries. Damaged batteries can cause acid burns.
4.4. Remove watches, rings, or any other metal objects when handling the batteries.

4.5. Use only tools with insulated handles around the batteries.
4.6. Do not lay tools or any other metal parts or equipment on top of the batteries, or allow them to contact the battery poles.
4.7. When connecting the UPS and EBM, some arcing may occur. This is normal, and will not harm personnel. Minimize arcing by quickly inserting the EBM cable into the UPS battery connector, and establishing a firm connection.
4.8. Batteries are lead-acid, and must be properly disposed of or recycled. Do not discard in the trash.
4.9. Never unplug the unit while it is turned on, as this will remove the safety ground from the unit, and therefore from all equipment which is connected to the unit.
4.10. The UPS and EBM weigh approximately 100 lb combined. Do not attempt to lift the UPS and EBM without assistance.
4.11. Operate this UPS only in temperature- and humidity-controlled environments (i.e. inside the OFIS). Do not operate if the temperature exceeds 40ºC (104ºF), or if the humidity exceeds 95%. Operation under these conditions can present a fire or shock hazard.
4.12. Total earth leakage current from all equipment plugged into this UPS must be <1.5 mA.

5. Cautions

5.1. If the UPS is positioned vertically, the air vents must be at the top of the unit.
5.2. Although EBM batteries will have charged to 80% of their capacity after approximately 2 h in a plugged-in unit, it is recommended that batteries be allowed to charge for 24 h after they are initially installed, or after long-term storage. Batteries may not perform optimally if the power is interrupted to the UPS during this period.
5.3. Do not turn the UPS off while it is in Configuration mode (Section 9.2), as this will immediately shut off all power to the equipment as the UPS goes into Standby mode.
5.4. Do not plug laser printers into the UPS, as their power requirements are too high.
5.5. Make sure the receptacle into which the UPS is connected has the correct polarity. Setup of the OFIS will include a polarity check (with a GFCI receptacle tester) of all outlets.
5.6. Disconnect power to the UPS when initially connecting power to the OFIS.

6. Interferences

6.1. Batteries in the EBM can wear out. The indicator and alarm signal that batteries may need to be replaced. If this indicator is lit, press and hold the Test/Alarm Reset button (Section 9.2) for 3 s. If the indicator remains lit, check the battery connections and, if necessary, replace the batteries.
6.2. For full battery life, operate the UPS at ambient temperatures as close to 25°C (77°F) as possible. Battery life can be reduced if the unit is operated outside this range.
6.3. Dust entering the unit can affect its performance. Keep the surrounding area as dust-free as possible, and vacuum the exterior of the unit periodically if it becomes dusty.

7. Personnel Qualifications

7.1. Personnel should be trained in the use of the UPS before installing or operating it.
7.2. Each individual must read and understand the Model 9125 manual and this SOP.

8. Equipment and Supplies

8.1. Uninterruptible power system (Model, 9125 700-3000 VA, Powerware Corporation, Espoo, Finland)
8.2. EBM: (Powerware Corporation, Espoo, Finland)
8.3. GFCI receptacle tester (to verify outlet polarity)

9. Procedures

9.1. Initial acceptance and installation
9.1.1. Inspect the unit and its box to ensure that no damage has occurred during shipping. Chapter 3 of the UPS Manual describes procedures to file a claim for receipt of a damaged unit.
9.1.2. Check the required battery recharge date on the label of the shipping carton. If the date has passed without the batteries being recharged, do not use the UPS until new batteries are obtained. Contact the distributor (Section 13.2).
9.1.3. Install the Model 9125, and any EBMs, in an instrument rack, following the "Rack-Mount Setup" procedure in the UPS Manual (Pg. 18).
9.1.4. If installing an EBM, plug the EBM cable into the UPS battery connector (Fig. 1). If installing more than one EBM, plug the EBM cable of the second (and subsequent) module into the EBM Battery Connector of the previous module (Fig. 1). See the note in Section 4.1.6 concerning arcing which may occur at this point.

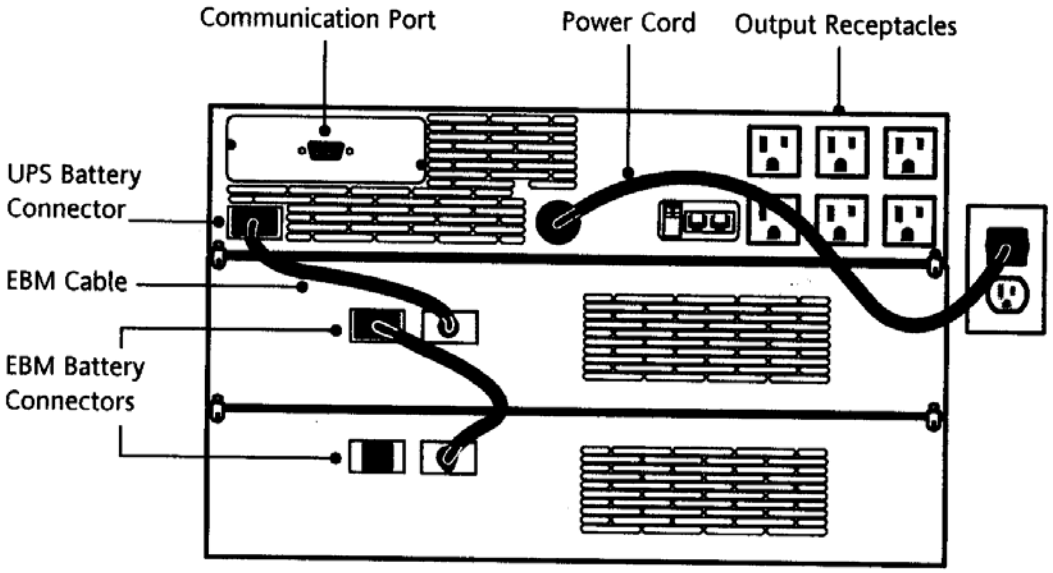

Figure 1. Rear Panel of the Model 9125 and two EBMs, showing connections.

9.2. Operation

9.2.1. Connect UPS to power source. It will conduct a 5-s self-test, and enter Standby mode.

9.2.2. Turn UPS on. The Normal Mode indicator on the front panel (Fig. 2) will come on, and a bar graph indicator will display the connected load (as percentage of capacity).

9.2.3. When the unit is plugged into a working power source (i.e. conditioning power only, not supplying it), it will run in Normal Mode.

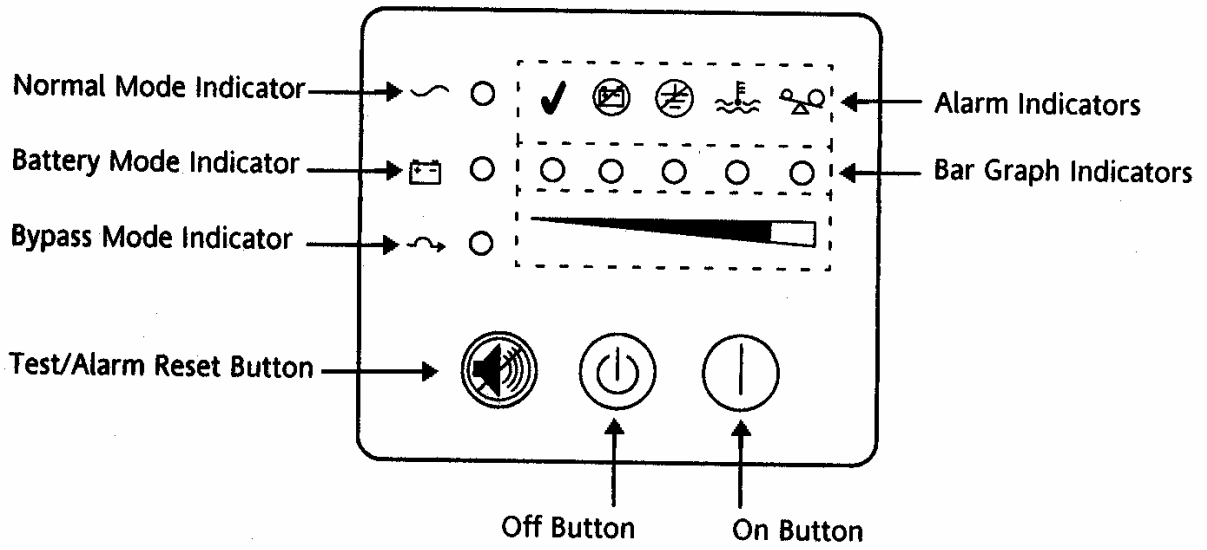

Figure 2. Front panel of the Model 9125, including power buttons and indicator lights.

9.2.4. If power to the Model 9125 is disrupted, it will go into Battery Mode. The Battery Mode indicator will be lit, and an alarm will beep.

9.2.4.1. If power is restored before the batteries become drained, the unit will automatically return to Normal Mode, and begin recharging the batteries.

9.2.4.2. If power is not restored quickly enough, the unit will use up its battery power. The indicator will flash, and a continuous alarm will sound, when there is approximately 3 min of battery power remaining. When the check-mark indicator to the left of the low battery indicator begins to flash, a shutdown is imminent. See Section 11.1.1.

9.2.5. The unit will go into Bypass Mode if its temperature is too high, if it detects a fault in its batteries or internal electronics, or if it is overloaded. While in Bypass Mode, the unit continues to condition the utility power source, but the option to switch to Battery Mode in the event of a disruption is not available.

9.3. Configuration

9.3.1. 120 VAC input power is the default setting for the low-voltage version of the Model 9125 (the 700-3000 VA), and should not be changed. If it is changed, reconfigure the unit as follows:

9.3.1.1. Press the On and Test/Alarm Reset buttons simultaneously for one beep. The five Bar Graph indicators will either illuminate (option enabled) or not (option disabled). The proper configuration is as follows:

9.3.1.1.1. First indicator (AC Input Failure Alarm): Illuminated/enabled
9.3.1.1.2. Second indicator (Site Wiring Fault Alarm): Illuminated/enabled
9.3.1.1.3. Third indicator (127 VAC Input): Not illuminated/disabled
9.3.1.1.4. Fourth indicator (110 VAC Input): Not illuminated/disabled
9.3.1.1.5. Fifth indicator (120 VAC Input): Illuminated/enabled

9.3.1.2. If any of these are set incorrectly, use the On button to scroll to the correct indicator. The LEDs immediately above the indicators will light individually to denote which indicator is selected. Once an indicator is selected, if that option is disabled, the indicator will switch from not illuminated to flashing.

9.3.1.2.1. Once the desired indicator is selected, change its status by pressing the Test/Alarm Reset button once.

9.3.2. The unit will automatically exit Configuration Mode if no changes are made for 2 min.

10. Data and Records Management

10.1.1. Record the following in the electronic field notes:
10.1.2. Data pertaining to initial setup (receptacle polarity check, earth leakage current)
10.1.3. Dates and results of all UPS self-tests
10.1.4. Dates and specifics of any changes in configuration
10.1.5. Manage the field notes according to SOP B5.

11. Quality Control and Quality Assurance

11.1. The Model 9125 provides audible alarms for a number of conditions that might affect the unit's performance. A full list of these alarms is provided in Table 10 (Pgs. 56-57) of the UPS Manual. Included among these are the following:

11.1.1. Warnings indicate when the unit switches to battery power, when the unit has only 3 min of battery power remaining, or when a shutdown is imminent due to low battery power. Under all of these circumstances, switch off all the equipment using the power supplied by UPS. Write down the time and cause of this action in the field notebook, and transfer to the electronic fieldnotes when power is restored.

11.1.1.1. If the total load of all equipment is very close to the maximum of the power circuit, turn off power to most of the equipment, so that there will not be a sudden significant draw when power is restored.

11.1.2. Warnings indicate when the batteries in a plugged-in unit are not charging properly. The last of these can mean that the batteries are not connected properly, or that they need to be replaced. Follow Section 6.1 to run a self-test and address this warning.

11.1.3. Warnings indicate when the unit is overtemperature. Turn off and unplug the unit for at least 5 min to cool, check the airflow around the unit, and verify that there is no dust buildup on the vents. If the alarm persists when the unit is turned back on, contact the distributor.

11.1.4. Warnings indicate when the unit is overloaded. Turn off and unplug the unit for at least 5 min, unplug some of the equipment from the UPS and restart. Determine if a higher-capacity UPS is required. Fig. 3 shows the pattern in which indicator lights will be lit to display the load level of the UPS.

11.2. Even in the absence of alarm messages, perform a self-test (Section 6.1) of the unit on a weekly basis. Record self-tests in the electronic field notes.

11.3. The hot-swapping feature of the batteries allows battery replacement without interrupting power to the equipment that is connected to the UPS, thus preserving the continuity of data.

12. References

12.1. UPS Manual. 2003. Powerware 9125 Two-in-One User's Guide. Powerware Corporation, Espoo, Finland.

12.2. SOP U1. 2006. On-farm Instrument Shelters for Barn Sources. Standard Operating Procedure U1. Purdue Ag Air Quality Lab.

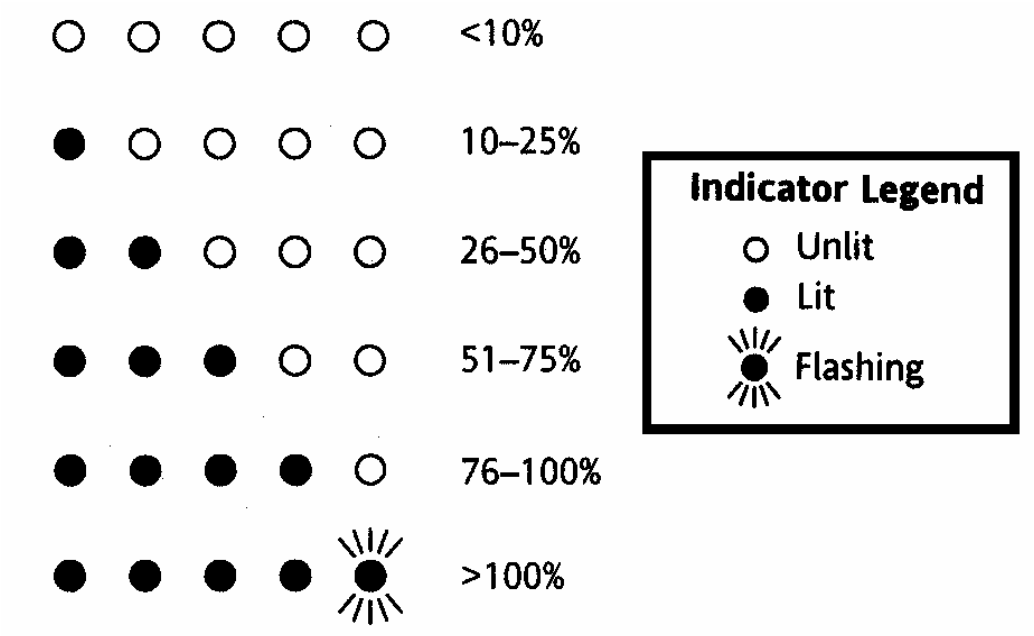

Figure 3. Status of Model 9125 indicator lights in Normal Mode at various loads (% capacity).

13. Contact Information

13.1. Manufacturer:

Powerware Corporation
Koskelontie 13, FIN-02920 Espoo, FINLAND
Phone: +358-9-452 661
Fax: +358-9-452 665 68

13.2. Distributor:

Perfect Power
3405 W. 96th St., Indianapolis, IN 46268
Phone: 317-874-4260
Fax: 219-462-2227

MEASUREMENT OF ATMOSPHERIC TEMPERATURE AND HUMIDITY WITH THE VAISALA MODEL HMP45C SENSOR AND SOLAR SHIELD

Standard Operating Procedure (SOP) W1

MEASUREMENT OF ATMOSPHERIC TEMPERATURE AND HUMIDITY WITH THE VAISALA MODEL HMP45C SENSOR AND SOLAR SHIELD

Standard Operating Procedure (SOP) W1

Prepared by

Richard H. Grant and Jenafer M. Wolf

Reviewed by

Congna Li, Albert J. Heber, and Bill W. Bogan

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The range of the HMP45C Temperature and Humidity Sensor, in normal atmospheric conditions, is 10 to 100% RH, and -40°C to 60°C temperature.
1.2. The accuracy of the sensor's relative humidity (RH) readings is ±3% RH (for RH from 90% - 100%) or ±2% (for RH from 0% - 90%).
1.3. The accuracy of the sensor's temperature readings is ±0.4°C for temperatures between -20°C and +60°C.
1.4. This procedure applies only to the Vasiala HMP45C temperature and RH probe when it is used, together with a solar radiation shield, to monitor temperature at an outdoor location.
1.4.1. This SOP is not intended to cover use of the Vaisala Model HMP45C to monitor temperature and RH inside a barn or other building. This is covered in SOP E2.

2. Summary of Method

The HMP45C Temperature and Humidity Sensor contains a platinum resistance temperature detector and a Vasiala HUMICAP® 180 capacitive RH sensor. Capacitance of the HUMICAP® semiconductor increases with increasing humidity. A solar shield is used in conjunction with the sensor to eliminate direct heating of the sensor by sunlight, which could otherwise lead to inaccurately high temperature readings.

3. Definitions

ARM	Atmospheric Radiation Monitoring Network
h_r	Relative humidity ratio
QAPP	Quality Assurance Project Plan
PAAQL	Purdue Agricultural Air Quality Laboratory
PAML	Purdue Applied Meteorology Laboratory
RH	Relative humidity
CS	Campbell Scientific, Inc
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service

4. Cautions

4.1. Do not touch the HUMICAP® RH sensor chip (located within condensate screen) with ungloved fingers.
4.2. The black outer jacket of the cable is Santoprene® rubber that will support combustion in air.
4.3. Be careful when connecting the sensor cable to the datalogger, being sure the connections are tight and made according to the SOP W6.
4.4. The sensors are electrical. Avoid crimping cables and connectors.

5. Interferences

5.1. Hydrogen sulfide levels above 10 ppm interfere with the sensor; however, ambient (outdoor) levels of hydrogen sulfide are not expected to be this high.
5.2. Ammonia concentrations above 100,000 ppm interefere with the sensor; however, ambient (outdoor) concentrations of ammonia are not expected to be this high.
5.3. Buildup of salt on condensate filter or HUMICAP chip
5.4. The sensor must be maintained in the passive radiation shield, as solar radiation will otherwise interfere with the measurement by heating the sensor.

6. Personnel Qualifications

6.1. Each member of the field staff must read and understand the sensor instruction manual and this SOP before operating this equipment.

7. Equipment and Supplies

7.1. #2 common head screwdriver
7.2. 1/8″slotted screwdriver
7.3. Heat shrink tubing
7.4. Heat blower
7.5. Distilled water bottle
7.6. Vacuum glass jar with silica gel dessicant
7.7. Soft toothbrush
7.8. Dish soap (without hand lotion)
7.9. Sling psychrometer
7.10. Data logger for acceptance and calibration
7.11. Still-air temperature calibration chamber
7.12. NIST-traceable certified immersion calibration thermometer
7.13. Ultrasonic cleaner
7.14. Plastic bottle
7.15. Vaisala HMK15 humidity calibrator
7.15.1. Calibrated Lithium chloride salt packet (traceable to Standards Laboratory of the Centre for Metrology and Accreditation, Finland)
7.15.2. Calibrated Potassium Sulfate salt packet (traceable to Standards Laboratory of the Centre for Metrology and Accreditation, Finland)
7.15.3. Calibration thermometer (traceable to Standards Laboratory of the Centre for Metrology and Accreditation, Finland)
7.16. HMP45C probe
7.17. Solar shield
7.18. LI-610 portable dew point generator
7.19. Dew point generator/HMP45C calibration chamber

8. Procedures

8.1. Acceptance

8.1.1. Attach sensor wires to data logger using the 1/8″slotted screwdriver according to wiring scheme in SOP W6.

8.1.1.1. Clear wire to ground, Black wire to ground, White wire to signal ground, Yellow wire to single-ended analog input, Blue wire to single-ended analog input, Red wire to switched 12V on data logger.

8.1.2. Program data logger to read sensor according to program provided in SOP W6, setting sampling time to 5 s and changing averaging time to one minute (from 5 min during normal operation as indicated in SOP W6).

8.1.2.1. Compile program

8.1.3. Measure RH and temperature using a sling psychrometer.

8.1.3.1. The thermometers on the sling psychrometer are NIST-traceable, with an accuracy of ±0.5^{o}C

8.1.3.2. The sling psychrometer must have a clean wick to achieve an accuracy of ±0.5^{o}C, according to NOAA-NWS specifications. The accuracy of the thermometers in the psychrometer is verified by a single point comparison to an immersion thermometer calibrated to a NIST standard.

8.1.3.3. Shield the psychrometer from direct solar radiation.

8.1.3.4. Wet the (clean) wick of the sling psychrometer with distilled water and whirl the psychrometer at a rate of about four revolutions per second. Stand clear of obstructions while whirling. Whirl for about one minute, then read the thermometers immediately, the wet bulb first, and record values on acceptance sheet (example attached). Whirl again for another 10 s, read the thermometers again, and record on acceptance sheet. If the readings are unchanged from the first time, this is the measured value. If the readings are different at the second reading, repeat until two successive sets of readings are the same.

8.1.3.5. Calculate the RH from the dry and wet bulb temperatures according to the chart in Appendix A.

8.1.3.6. Read average value from data logger and record on acceptance worksheet (Appendix B).

8.1.3.6.1. If measured RH is greater than 20% different from that derived from standard sling psychrometer measurement, then the sensor is faulty and must be returned to manufacturer.

8.1.3.6.2. If the measured air temperature differs by more than 1°C from that of the dry bulb temperature of the sling psychrometer, then the sensor is faulty, and must be returned to manufacturer.

8.2. Installation

8.2.1. The HM45C probe is housed in a radiation shield mounted on the 10 ft. mast according to SOP U5.

8.2.2. Securely mount sensor into the radiation shield using common head screwdriver.

8.2.3. Pass cable down tower and through specified weatherproofed NEMA 4X datalogger knockout.

8.2.4. Attach wires to datalogger using the1/8″ slotted screwdriver.
8.2.4.1. Clear wire to ground, Black wire to ground, White wire to signal ground, Yellow wire to single-ended analog input, Blue wire to single-ended analog input, Red wire to switched 12V on datalogger, according to SOP W6.

8.3. Preventive maintenance
8.3.1. Clean filter yearly.
8.3.1.1. Unscrew the filter cap from the HMP45C. Remove it and place it in a soap solution consisting of dish detergent.
8.3.1.1.1. Put in a plastic bottle. Shake the container gently.
8.3.1.1.2. Once the heavy concentration of dirt has been removed, use a small-diameter blunt punch to press out the inner filter frame from the cap. There is a small hole on top of the filter cap where a punch can be inserted to remove the insert.
8.3.1.1.3. Remove dirt from the outside of the paper filter with a soft toothbrush.
8.3.1.1.4. Remove filter paper from frame and complete cleaning cycle by putting it in ultrasonic cleaner, again using dish soap as the cleaner.
8.3.1.1.5. Rinse thoroughly in clean water.
8.3.1.1.6. Put filter in vacuum glass jar containing silica gel to remove moisture.
8.3.1.1.7. After 1 day, reinstall filter into filter cap and reinstall filter cap on HMP45C.

8.4. Temperature calibration
8.4.1. Sensor is single-point calibrated in a temperature-controlled environment.
8.4.1.1. Insert HMP45C and calibration thermometer into a still-air chamber that is in equilibrium with its surroundings.
8.4.1.2. Allow 10 min for equilibration after inserting sensors into still-air chamber
8.4.1.3. Record the mean temperature over the next 5 min from the data logger output of the HMP45C measurement, and the reading from the calibration thermometer on the calibration data sheet (example attached).
8.4.1.4. Calculate difference in temperature reported by calibration thermometer and sensor.
8.4.1.4.1. If the temperature error is >0.5 °C, return sensor to factory for repair.
8.4.2. If difference in temperature reported by calibration thermometer (expected) and sensor (measured) is within 2°C, adjust temperature measurements taken since the last calibration to account for the drift, according to Equation 1.

$$T_{corr}(t) = T(t)\left[1 - \frac{\overline{T_{measured} - T_{expected}}}{\overline{T_{expected}}}\right]\left(\frac{t}{p}\right) \qquad \text{(Equation 1)}$$

Where:

T_{corr} = Back-corrected value at time *t* into the last measurement period
$T(t)$ = Original measured value at time *t*,
$T_{measured}$ = Measured temperature during calibration comparison
$T_{expected}$ = Temperature indicated by the calibration thermometer during calibration comparison
p = Length of time between calibrations.

8.5. RH calibration. Standardized humidities for calibration can be established using either a dew point generator or saturated salt solutions.

8.6. Calibration using LI-610 portable dew point generator:

8.6.1. Construct dew point generator/HMP45C calibration chamber.

8.6.1.1. Cut a piece of 2-inch PVC pipe to a length of 17 cm.

8.6.1.2. Cut a 2-inch diameter disc from a piece of 3/8-inch-thick plastic.

8.6.1.3. Cut a 3/4-inch diameter hole in center of plastic disc to fit sensor probe diameter.

8.6.1.4. Using PVC cement, glue disc onto one end of the 17-cm long PVC pipe and let cement set for at least 15 min.

8.6.1.5. Drill a #27 hole into 2-inch PVC pipe cap and tap hole using a 1/8-27 tapping bit.

8.6.1.6. Using PVC cement, glue and screw cap onto other end of 17-cm long PVC pipe and let cement set for at least 15 min. This hole will be used as an inlet of airflow during calibration.

8.6.1.7. Create air exhaust vents in chamber to be used during calibration. Drill four evenly-spaced holes around PVC piping approximately 1 inch from the end of pipe containing the plastic disc. Be sure holes are smaller than inlet hole.

8.6.1.8. Screw 1/8-27 tubing nipple into tapped hole in PVC piping and connect tubing from the nipple to OUTPUT 1 on LI-610 portable dew point generator.

8.6.2. Calibrate relative humidity probe using LI-610 (Fig. 1).

8.6.2.1. Insert HMP45C probe into the end of the PVC pipe containing the disc.

8.6.2.2. Be sure the distilled water in the LI-610 dew point generator is filled to the proper level (Reference 11.4).

8.6.2.3. Turn the POWER switch ON

8.6.2.4. Attach HMP45C wires to datalogger using 1/8″ slotted screwdriver.

8.6.2.5. Determine the ambient temperature from the datalogger.

8.6.2.6. Set the function switch on the LI-610 to the TEMP SET position.

8.6.2.6.1. Calculate the saturation vapor pressure based on the ambient temperature (T) in degrees Celsius, according to Eq. 2:

$$e_s = 0.61365e^{\frac{17.502T}{240.97+T}} \qquad \text{(Equation 2)}$$

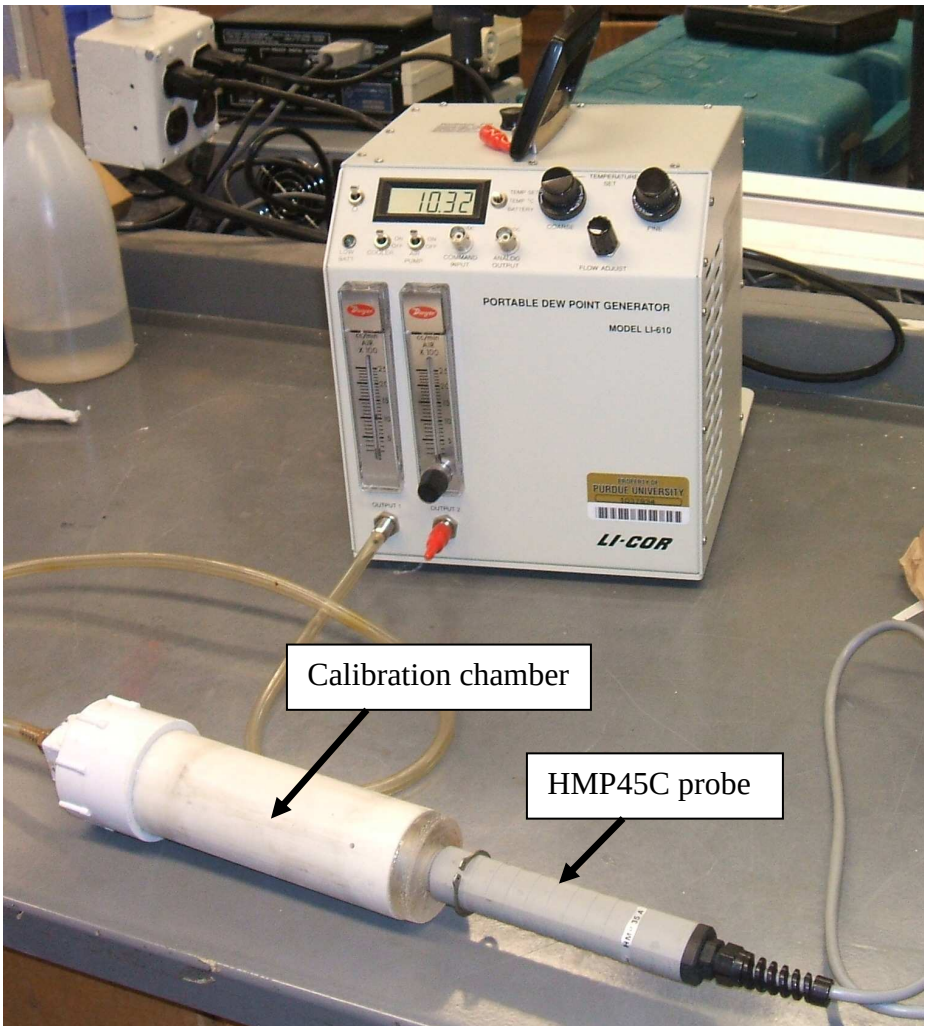

Figure 1. HMP45C Relative Humidity Calibration using LI-610 Dew Point Generator.

8.6.2.6.2. Calculate the set point (dew point) temperature (T_d) using Eq. 3:

$$T_d = h_r \frac{240.97 \ln(e_s / 0.61365)}{17.502 - \ln(e_s / 0.61365)} \qquad \text{(Equation 3)}$$

for humidity h_r of 0.11

8.6.2.6.3. Use the COARSE and FINE TEMP SET knobs to set a desired dew point temperature.

8.6.2.7. Set the function switch to the TEMP ºC position, and turn the COOLER switch ON.
8.6.2.8. Turn the AIR PUMP switch ON
8.6.2.8.1. Turn the knob on the rotameter above OUTPUT 2 clockwise until the flow is shut off and the rotameter shows zero flow.
8.6.2.8.2. Use the FLOW ADJUST knob to control the rate of air flow through the LI-610.
8.6.2.8.2.1. Set flow to 500 cm^3/min. This allows for 5 exchanges through the chamber in 3 min.
8.6.2.8.2.2. Watch for the display to show the desired dew point temperature.
8.6.2.8.2.3. Wait approximately 1 hour for HMP45C to stabilize in the calibration chamber.
8.6.2.8.3. Record temperature, measured humidity and applicable calibration table RH on the calibration data sheet (Appendix C).
8.6.2.9. Repeat sections 8.6.2.6- 8.6.2.7 for h_r= 0.50 and 0.98.

8.7. Saturated salt solution calibration
8.7.1. Conduct calibration in a temperature-controlled environment.
8.7.2. Calibration conducted in HMK 15 calibrator chambers.
8.7.3. Prepare solutions of lithium chloride (LiCl), sodium chloride (NaCl), and potassium sulfate (K_2SO_4) in three chambers of the HMK15 calibrator according to HMK15 manual.
8.7.4. Leave the HMK15 calibrator and the probe at the calibration site for at least 30 min before starting the calibration in order to let the probe temperature stabilize to the room temperature.
8.7.5. Take off the filter protecting the HMP45C sensor. Take care not to damage the sensor.
8.7.6. Low humidity calibration
8.7.6.1. Insert the HMK15 calibration thermometer into the 13.5-mm hole of the LiCl salt chamber (low RH reference). Press it downwards until it passes the O-rings.
8.7.6.2. Insert probe into the 13.5-mm hole of the LiCl salt chamber. Press it downwards until it passes the O-rings. The shorter the time the hole stays open before inserting the probe, the shorter the stabilization time required.
8.7.6.3. Wait 10-30 min for RH stabilization.
8.7.6.4. Read the closest humidity value from the calibration Table 1, given the temperature of the thermometer.
8.7.6.4.1. Record temperature, measured humidity and applicable calibration table RH on the calibration data sheet (example in Appendix C).
8.7.6.4.2. Compare measured RH with Greenspan's value in Table 1.
8.7.6.4.2.1. If measured RH is within expected annual drift (+/-3% RH), sensor is good. Adjust the DRY potentiometer (Fig. 2) to correspond to value given in the calibration table.
8.7.6.4.2.2. If measured RH is outside expected annual drift (+/-3% RH), sensor is defective and must be sent to factory for repair or replacement.

8.7.7. High humidity calibration

8.7.7.1. Insert the HMK15 calibration thermometer into the 13.5-mm hole of the K_2SO_4 salt chamber (high RH reference). Press it downwards until it passes the O-rings.

8.7.7.2. Insert the probe into a suitable hole of the K_2SO_4 salt chamber. Press it downwards until it passes the O-rings. The shorter the time the hole stays open before inserting the probe, the shorter the stabilization time required.

8.7.7.3. Wait 20-40 min for RH stabilization.

8.7.7.4. Read the closest humidity value from the calibration table for the chamber temperature (Table 1).

8.7.7.4.1. Record temperature, measured RH and applicable calibration table RH on the calibration data sheet (Appendix C).

8.7.7.4.2. Compare measured RH with Greenspan's value in Table 1.

8.7.7.4.2.1. If measured RH is within expected annual drift (+/-10% RH), sensor is good. Adjust the WET potentiometer (Fig. 2) to correspond to the value given in the calibration table.

8.7.7.4.2.2. If measured RH is outside expected annual drift (+/-10% RH), sensor is defective and must be sent to factory for repair or replacement.

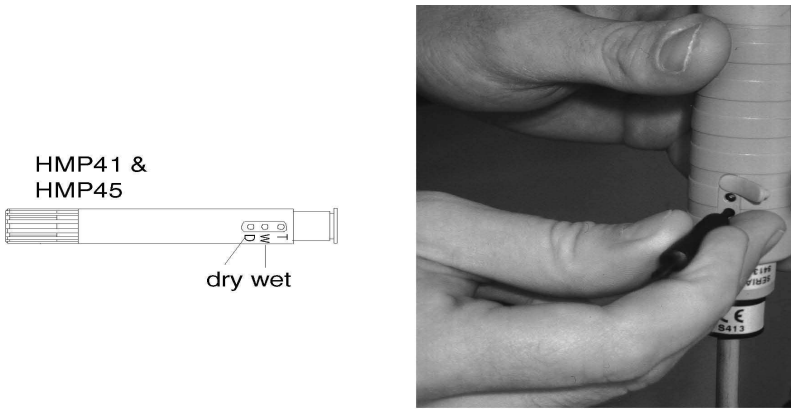

Figure 2. Potentiometer adjustment location on the HMP45C.

8.8. Troubleshooting

8.8.1. Lack of response of either temperature of RH to variation in ambient conditions can be due to the following:

8.8.1.1. Poor connections of the sensor at the datalogger: Check electrical connections (especially excitation voltage wire) according to SOP W6.

8.8.1.2. Damage to plastic casing of the signal cable: If damaged slightly, repair with heat-shrink tubing. If damaged significantly, replace sensor and return sensor to manufacturer for repair.

8.8.2. Lack of at least 95% RH at saturation conditions (fog and light rain) is possibly due to contamination of the condensation filter or HUMICAP. Check filter and HUMICAP and clean or replace as needed.

8.9. Data acquisition, calculations & data reduction.
8.9.1. RH output (Voltages 0.008 to 1 VDC) is monitored by the datalogger.
8.9.2. Temperature output (Voltages 0.008 to 1 VDC) is monitored by the datalogger.
8.9.3. Data are reported to three significant digits.
8.10. Computer hardware & software
8.10.1. The sensors will be attached through electrical wires to the datalogger that will extract data from the instrument (Section 9.1.4).
8.10.2. The datalogger will record the data and store it.
8.10.3. Datalogger operates using on-board BASIC-like programming.
8.10.3.1. General program for measurements stated in Model HMP45C Temperature and Humidity Probe Instruction Manual.

9. Data and Records Management

9.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method, as well as in a bound record book designated for meteorological sensors.
9.2. Manage all data according to SOP D1.
9.3. At the end of this SOP is a form to record the calibration information.
9.4. Document all data and information on field data sheets and in site logbooks with permanent ink, or in electronic notes.
9.5. Date, initial, and overstrike errors in writing with a single line.

10. Quality Control and Quality Assurance

10.1. Annual drift of RH measurement increases with increased temperature and RH.
10.1.1. Annual drift of RH measurement of 6% to 10% for 100% humidity and 35 to 45 °C and up to 4% for 100% humidity and 10 to 25 °C, as reported in personal communication from the NOAA High Plains Climate Center.
10.1.2. Annual drift of RH measurement of less than 3% at 10% humidity for temperatures from 10 to 45 °C as reported in personal communication from the NOAA High Plains Climate Center.
10.2. Calibration
10.2.1. RH sensor is calibrated annually using either a Vaisala HMK15 Humidity calibrator with salt solutions of lithium chloride (LiCl) and potassium sulfate (K_2SO_4) or a LiCOR portable dew point generator.
10.2.2. Temperature sensor is calibrated annually
10.3. Reasonableness of data values (daily check)
10.3.1. Relative humidity
10.3.1.1. If a data value is missing, flag.it as invalid.
10.3.1.2. If a data value is less than -2% or greater than 104% (range of the sensor calibration and uncertainty), flag it as invalid.
10.3.1.3. If the standard deviation of the data over one hour is greater than 20%, flag the data as invalid.

10.3.1.4. If a data value differs by more than 10% from the temperature-corrected RH from the nearest National Weather Service (NWS) weather station, flag it as invalid.

10.3.1.4.1. Calculate humidity mixing ratio at NWS weather station (W) using station barometric pressure and RH according to Appendix D.

10.3.1.4.2. Calculate saturation humidity mixing ratio (Ws) for measurement location using location barometric pressure and air temperature setting RH at 100% (1.0) according to Appendix D.

10.3.1.4.3. Calculate the RH at measurement location as W/Ws*100.

10.3.1.5. If data is flagged for any of the above reasons, troubleshoot sensor according to Section 8.6.

10.3.2. Temperature

10.3.2.1. If a data value is missing, flag.it as invalid..

10.3.2.2. If a data value is less than -40 °C or greater than +50 °C (bounds of sensor calibration), flag it as invalid.

10.3.2.3. If the standard deviation of the data over an hour is <2 °C, flag the data as invalid.

10.3.2.4. If data values change more than 5 °C (9 °F) from the previous hour, flag as invalid.

10.3.2.5. If data values vary by less than 0.5 °C (0.9 °F) for 12 consecutive hours, flag as invalid.

10.3.2.6. If data value is greater than the local record high or is less than the local record low on a monthly average, flag as invalid.

10.3.2.7. If data value differs by more than 3 °C from the altitude-corrected air temperature from the nearest National Weather Service (NWS) weather station, flag as invalid.

10.3.2.7.1. Calculate altitude-adjusted air temperature at NWS weather station (Tadj) based on the station air temperature according to:

$$T_{adj}=T_{NWS}+(Z_{NWS}-Z_{site})*0.0098$$

Where:
T_{adj} and T_{NWS} are in units of ^{o}C
Z_{NWS} and Z_{site} are the altitudes of the NWS station and site (in m)

10.3.2.8. If data is flagged for any of the above reasons, troubleshoot sensor according to Section 8.6

10.4. Physical inspection

10.4.1. Integrity of the plastic casing of the signal cable will be checked.

10.4.1.1. If damaged slightly, repair with heat-shrink tubing.

10.4.1.2. If damaged significantly, replace sensor and return sensor to manufacturer for repair.

10.4.2. Check for debris in solar radiation shield. Remove if present.

10.4.3. Check screen at sensor end for dirt. If dirty, clean screen according to Section 9.2.

10.4.4. Check HUMICAP® sensor chip for contaminants.

10.4.4.1. If dirt or crystals are present, remove chip with latex-gloved fingers and rinse with distilled water. Do not scratch while cleaning. Let air dry before re-assembling.

10.5. Calibrate sensor in laboratory according to procedures outlined in Sections 8.6 - 8.7.

11. References

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11.4. LI-COR Inc. 1991. LI-610 Portable Dew Point Generator Instruction Manual, 3-3.
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11.11. SOP U5. 2006. The Installation of Open-source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.
11.12. SOP W6. 2006. Establishment, Data Acquisition and Control of Weather and Lagoon Characterization Hardware. Standard Operating Procedure W6. Purdue Applied Meteorology Lab.
11.13. SOP D1. 2006. Management of Open Source, Weather and Lagoon-Characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.

12. Contact Information

12.1. HMP45C Distributor: Campbell Scientific, Inc., 815 West 1800 North, Logan, Utah, 84321
12.1.1. Technical support: 435-753-2342.
12.2. HMK15 Distributor: Vaisala Sales: 888-824-7252 x1053, email: Barry Eisen, b.eisan@vaisala.com
12.2.1. Technical support: North American Service Center, Boston, MA, USA
Phone: 888 VAISALA or 781 933 4500, Fax: 781 933 8029

Table 1. Calibration table[1]

°C	LiCl	MgCl2	NaCl	K_2SO_4
0	11.3 ±0.5	33.7 ±0.3	75 ±0.3	98.8 ±1.1
5	11.3 ±0.5	33.6 ±0.3	75 ±0.3	98.5 ±0.9
10	11.3 ±0.4	33.5 ±0.2	75 ±0.2	98.2 ±0.8
15	11.3 ±0.4	33.3 ±0.2	75 ±0.2	97.9 ±0.6
20	11.3 ±0.3	33.1 ±0.2	75 ±0.1	97.6 ±0.5
25	11.3 ±0.3	32.8 ±0.2	75 ±0.1	97.3 ±0.5
30	11.3 ±0.2	32.4 ±0.1	75 ±0.1	97.0 ±0.4
35	11.3 ±0.2	32.1 ±0.1	74 ±0.1	96.7 ±0.4
40	11.2 ±0.2	31.6 ±0.1	74 ±0.1	96.4 ±0.4
45	11.2 ±0.2	31.1 ±0.1	74 ±0.2	96.1 ±0.4
50	11.1 ±0.2	30.5 ±0.1	74 ±0.2	95.8 ±0.5

[1] Greenspan, L.: Journal of Research of the National Bureau of Standards -A Physics and Chemistry Vol. 81A, No. 1 January-February 1977, pp. 89-95

Appendix A - Dry Bulb/Wet Bulb - Relative Humidity Conversion Chart

This table gives the approximate relative humidity in percent directly from the reading of the air temperature (dry bulb) (t °C) and the wet bulb (T °C). **Condensed from Bulletin of the U.S. Weather Bureau No. 1071**

Dry bulb Temp.- Wet Bulb Temp.

Dry Bulb	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0
5	72	69	67	64	61	58	56	53	51	48	45	39	33	26	20	13	7	..	..	..	..	..	..	..	..
6	73	70	68	65	63	60	58	55	53	50	48	41	35	29	24	17	11	5	..	..	..	..	..	..	..
7	74	72	69	67	64	62	59	57	54	52	50	44	38	32	26	21	15	10	..	..	..	..	..	..	..
8	75	73	70	68	65	63	61	58	56	54	51	46	40	35	29	24	19	14	8	..	..	..	..	..	..
9	76	74	71	69	67	64	62	60	58	55	53	48	42	37	32	27	22	17	12	7	..	..	..	..	..
10	77	74	72	70	68	66	63	61	59	57	55	50	44	39	34	29	24	20	15	10	6	..	..	..	..
11	78	75	73	71	69	67	65	62	60	58	56	51	46	41	36	32	27	22	18	13	9	5	..	..	..
12	78	76	74	72	70	68	66	64	62	60	58	53	48	43	39	34	29	25	21	16	12	8	..	..	..
13	79	77	75	73	71	69	67	65	63	61	59	54	50	45	41	36	32	28	23	19	15	11	7	..	..
14	79	78	76	74	72	70	68	66	64	62	60	56	51	47	42	38	34	30	26	22	18	14	10	6	..
15	80	78	76	74	73	71	69	67	65	63	61	57	53	48	44	40	36	32	27	24	20	16	13	9	6

Dry bulb Temp.- Wet Bulb Temp.

Dry Bulb	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	16.0	17.0	18.0
16	81	76	71	67	63	58	54	50	46	42	38	34	30	26	23	19	15	12	8	5	..	..	..	..	..	..	..	..	..	
17	81	76	72	68	64	60	55	51	47	43	40	36	32	28	25	21	18	14	11	8	..	..	..	..	..	..	..	..	..	
18	82	77	73	69	65	61	57	53	49	45	41	38	34	30	27	23	20	17	14	10	7	..	..	..	..	..	..	..	..	
19	82	78	74	70	65	62	58	54	50	46	43	39	36	32	29	26	22	19	16	13	10	7	..	..	..	..	..	..	..	..
20	83	78	74	70	66	63	59	55	51	48	44	41	37	34	31	28	24	21	18	15	12	9	6	..	..	..	..	..	..	..
21	83	79	75	71	67	64	60	56	53	49	46	42	39	36	32	29	26	23	20	17	14	12	9	6	..	..	..	..	..	..
22	83	80	76	72	68	64	61	57	54	50	47	44	40	37	34	31	28	25	22	19	17	14	11	8	6	..	..	..	..	..
23	84	80	76	72	69	65	62	58	55	52	48	45	42	39	36	33	30	27	24	21	19	16	13	11	8	6	.	..	..	..
24	84	80	77	73	69	66	62	59	56	53	49	46	43	40	37	34	31	29	26	23	20	18	15	13	10	8	5	..	..	..
25	84	81	77	74	70	67	63	60	57	54	50	47	44	41	39	36	33	30	28	25	22	20	17	15	12	10	8	..	..	..
26	85	81	78	74	71	67	64	61	58	54	51	49	46	43	40	37	34	32	29	26	24	21	19	17	14	12	10	5	..	..
27	85	82	78	75	71	68	65	62	58	56	52	50	47	44	41	38	36	33	31	28	26	23	21	18	16	14	12	7	..	..
28	85	82	78	75	72	69	65	62	59	56	53	51	48	45	42	40	37	34	32	29	27	25	22	20	18	16	13	9	5	..
29	86	82	79	76	72	69	66	63	60	57	54	52	49	46	43	41	38	36	33	31	28	26	24	22	19	17	15	11	7	..
30	86	83	79	76	73	70	67	64	61	58	55	52	50	47	44	42	39	37	35	32	30	28	25	23	21	19	17	13	9	5

Appendix B
HMP45C Acceptance Worksheet

Serial Number _____

Evaluator : _____

Date (DD/MM/YYYY):_____

	Psychrometer					HMP35C		Action
Time (HH:MM:SS)	Temp. (^{o}C)				Calculated RH (%)	Measured RH (%)	RH difference (%)	
	Dry Bulb	Wet bulb #1	Wet bulb #2	Wet bulb Final				

Appendix C : Calibration Record (RH): Vaisala HMP45C Sensor

Instrument Serial Number:_____ Location:_____

Date (D-M-Y) Time: Begin/End	Temperature (^{o}C)	% RH		Action Taken (Adjust, Replace)	Analyst
		Expected (Table)	Measured		

Calibration Record (Temperature): Vaisala HMP45C Sensor

Instrument Serial Number:_____ Location:_____

Date (D-M-Y) Time: Begin-End	Temperature (^{o}C)			Action Taken (Adjust, Replace)	Analyst
	Calibration	Measured	Difference		

Appendix D
Conversion between relative humidity and humidity mixing ratio

Conversion of relative humidity (φ) to humidity mixing ratio (W) is calculated as:

$$W = 0.62198\frac{e^{f(T)}\varphi}{P_a - e^{f(T)}\varphi} \qquad \text{(Equation A.4)}$$

Where:

W Humidity mixing ratio, kg/kg

P_a Pressure at the sampling location

φ Relative humidity, decimal

$$f(T) = \frac{C_1}{T} + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln T \qquad \text{for } T < 273.15 \text{ K}$$

$$f(T) = \frac{C_8}{T} + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln T \qquad \text{for } T > 273.16 \text{ K}$$

Where

T= Air temperature (K)

$C_1 = -5.675 \times 10^{3}$

$C_2 = 6.392$

$C_3 = -9.678 \times 10^{-3}$

$C_4 = 6.222 \times 10^{-7}$

$C_5 = 2.075 \times 10^{-9}$

$C_6 = -9.484 \times 10^{-13}$

$C_7 = 4.163$

$C_8 = -5.800 \times 10^{3}$

$C_9 = 1.391$

$C_{10} = -4.864 \times 10^{-2}$

$C_{11} = 4.176 \times 10^{-5}$

$C_{12} = -1.445 \times 10^{-8}$

$C_{13} = 6.545.$

MEASUREMENT OF WIND WITH THE RM YOUNG MODEL 81000 3-DIMENSIONAL SONIC ANEMOMETER

Standard Operating Procedure (SOP) W2

MEASUREMENT OF WIND WITH THE RM YOUNG MODEL 81000 3-DIMENSIONAL SONIC ANEMOMETER

Standard Operating Procedure (SOP) W2

Prepared by

Richard H. Grant

Reviewed by

Albert J. Heber and Bill W. Bogan

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. The measurement of the directional components of wind is used in the gaseous emissions measurement methodologies.
  1.1.1. Statistical values of instantaneous wind components and the virtual temperature are used in the backward Lagrangian Stochastic method of emission measurement (SOP O1).
  1.1.2. Statistical values of instantaneous horizontal wind components are used in the radial plume method of emission measurement (SOP O2).
1.2. The difference in time required for sound to travel through the moving air is a fast response method of measuring each directional component of the wind.
1.3. The detection limit of the method described in this SOP is 0.05 m/s.
1.4. The range of wind speeds which can be measured under this SOP is 0.05 to 40 m/s.
1.5. For wind speed, the manufacturer-reported sensor accuracy is 0.02 m/s, while the manufacturer-reported sensor precision (rms) is 0.05 m/s for speeds of 0 to 5 m/s, 1% of reading for speeds from 5 to 30 m/s and 3% of reading for speeds from 30 to 40 m/s.
1.6. This procedure applies only to the RM Young Model 81000 Ultrasonic Anemometer.

2. Summary of Method

The RM Young Model 81000 measures three-dimensional wind velocity and speed of sound based on the transit time of ultrasonic acoustic signals at 4Hz to 32 Hz. Sonic temperature is derived from speed of sound which is corrected for crosswind effects. Measurement data are available as serial output using RS-232 or RS-485 connections. Operating parameters may be edited via simplified menus using an ordinary serial communication program like HyperTerminal ®. All parameters are stored in non-volatile memory. Superior environmental resistance is achieved by using UV stabilized thermoplastic, stainless steel, and anodized aluminum components.

3. Definitions

COM port	A serial communications port of a computer
HyperTerminal®	A Windows® program that provides communication through a serial communications port of a computer
PAAQL	Purdue Agricultural Air Quality Laboratory
PAML	Purdue Applied Meteorology Laboratory
QAPP	Quality Assurance Project Plan
RS-232	A serial communications protocol
RS-485	A serial communications protocol

4. Health and Safety

4.1. The sensor has electrical components, and proper care should be used as with all electrical equipment.

5. Cautions

5.1. The sensor is acoustical and therefore cannot be dropped without damage.
5.2. Be sure that the sensor is properly grounded.
5.3. Tilt of sensor induces an error in the measurement of approximately 6% in the correlations of wind deviations and 3% in the derived friction velocity with 1° tilt.

6. Interferences

6.1. Wakes from obstructions such as buildings, storage piles, trees and other vegetation which are closer than ten times the sensor height.
6.1.1. Incorrect siting of the anemometer will cause greater uncertainties in the data due to failure of assumptions of homogeneity and stationarity.
6.2. Sensor response under high winds can result in extreme values.
6.3. The sensor does not respond under conditions of accumulated freezing rain, heavy frost and snow on the transducers.
6.4. Wake flow around support struts reduces sensor performance.

7. Personnel Qualifications

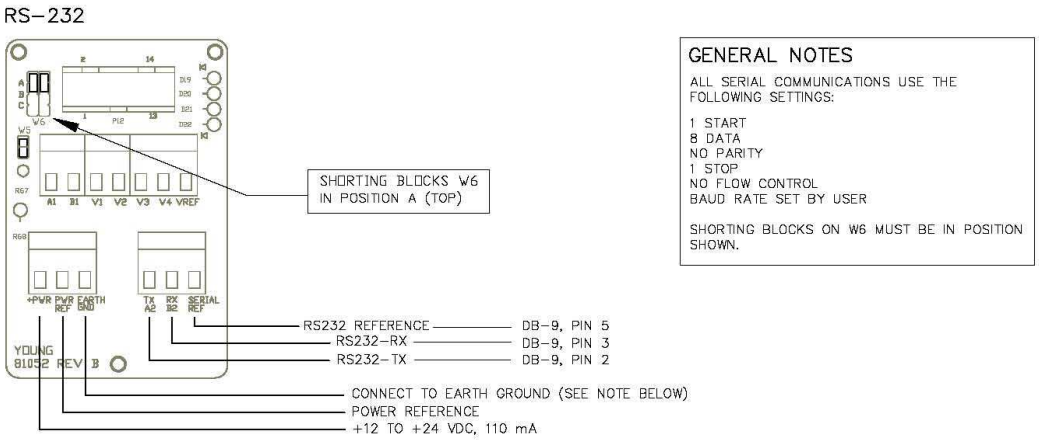
7.1. Read and understand the sensor instruction manual and this SOP before operating this sensor.

8. Equipment and Supplies

8.1. 3-D sonic anemometer
8.2. #2 common head screwdriver
8.3. 1/8″ slotted screwdriver
8.4. Anechoic box
8.5. Laptop computer
8.6. DB9 modem cable
8.7. Labview software
8.8. XStream® RS-232/485 RF Modem
8.9. Sonic anemometer intercomparison stand

9. Procedures

9.1. Instrument acceptance
9.1.1. Carefully unpack the unit and inspect for physical damage. Report any damage to the shipper. The sensor arrives fully calibrated and ready to use.
9.1.2. Remove junction box cover. Connect power and signal wires to terminals as in the wiring diagram below. Connect serial cable to computer COM port.
9.1.2.1. Supply power must be in the range of 12 to 24 VDC **at the sensor junction box terminals** in order for the sensor to operate properly.



9.1.3. Start HyperTerminal® on the computer with baud rate at 38400 and flow control set to NONE.

9.1.4. Apply power to the 81000 sensor. There will be a 4-s delay for initialization; then, the unit will begin to output data at 4 Hz using the following format: speed (m/s), azimuth (deg), elevation (deg), speed-of-sound (m/s), and sonic-temperature (°C). Verify that all values are present on the display. Typical output is:

0.00	0.0	0.0	346.70	25.14
0.00	0.0	0.0	346.68	25.11
0.00	0.0	0.0	346.76	25.25
0.00	0.0	0.0	346.80	25.30
0.00	0.0	0.0	346.82	25.35

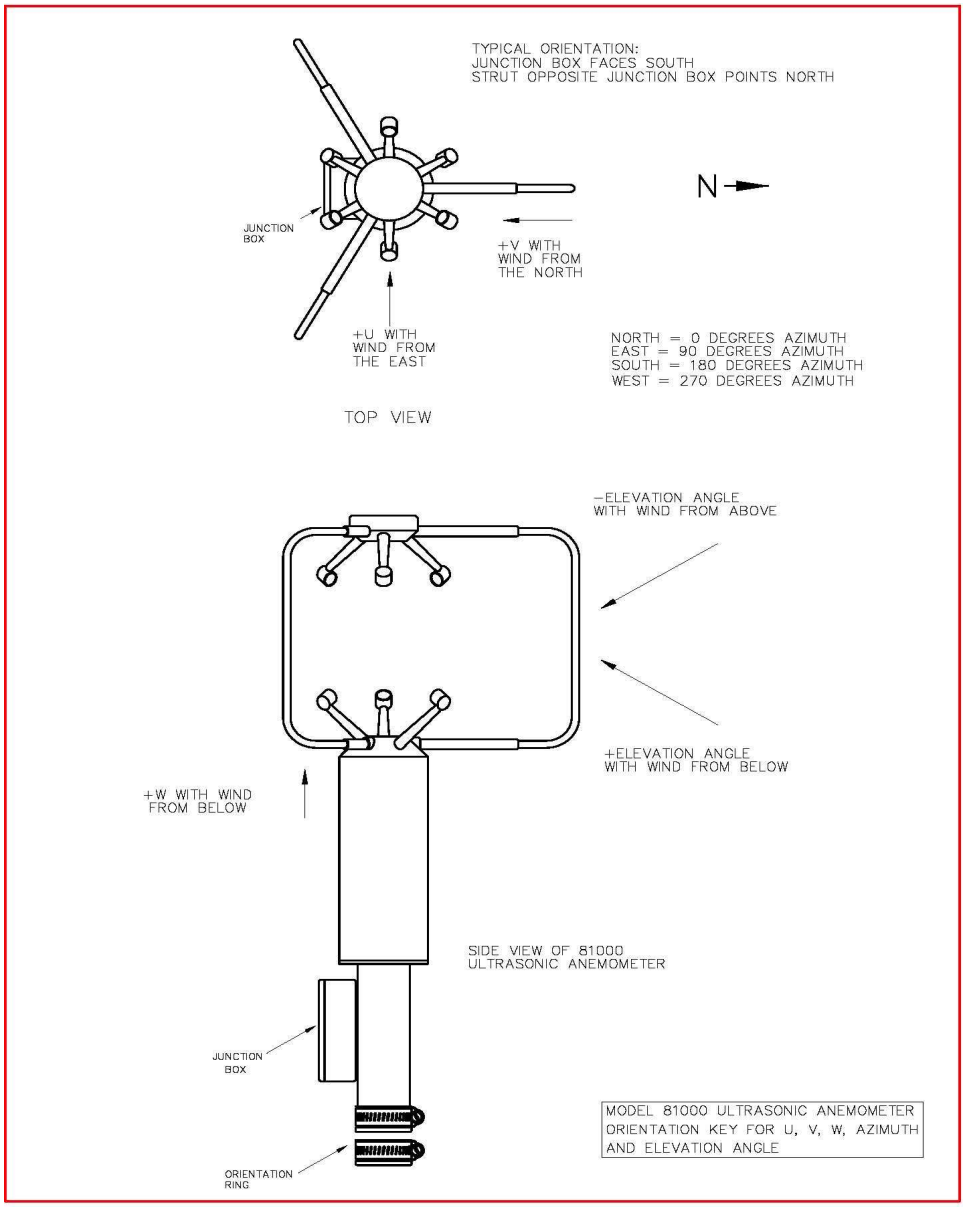
Wind below the 0.05 m/s detection limit is output as 0.00 m/s. Azimuth may be any value from 0.0 to 359.9 degrees. When wind speed is below threshold, azimuth output is maintained at the last value read before wind speed went below threshold. Elevation remains zero until threshold is exceeded. Speed of sound ranges from 300 m/s to 360 m/s, depending on temperature. At 20°C, the value is ~ 344 m/s. Sonic temperature may be compared to a standard Celsius thermometer and should agree within ±2°C. If values appear questionable or any value is not displayed, remove power and check all wiring connections. If the problem cannot be corrected, contact service support (Section 13.1).

9.1.5. Verify sensor response by gently blowing through the measuring section. Wind from the north side (marked “N”), should produce a positive SPEED response and an AZIMUTH display corresponding to North (i.e.: values around 359.9 or 0.0). Wind from the opposite direction should produce AZIMUTH values indicating south, (around 180) and so forth. Downward wind produces negative ELEVATION values, upward wind produces positive values.

9.2. Instrument installation

9.2.1. Mount the sensor securely on top of a mast or tower such that it will not twist, rotate, or sway, according to SOP U5.

9.2.2. Mount the sensor with the following orientation:



9.2.3. Attach earth ground for proper operation.

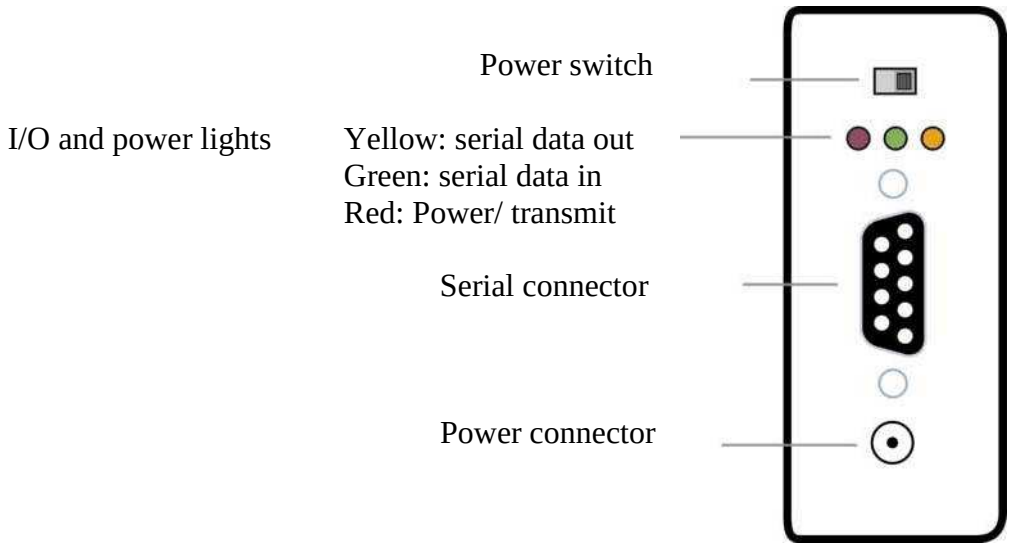
9.3. Instrument operation

9.3.1. Connect a serial cable from the XStream RS-232/485 RF Modem to the COM port of a laptop computer.

9.3.2. Connect antenna to RF Modem.

9.3.3. Provide power to radio modem by connecting power cable to power connector and switching on power switch (See figure below)

9.3.4. Verify power to radio modem by checking red light on modem indicated below:



9.3.4.1. Using X-CTU® program on the laptop computer, verify configuration of Modem (8 data bits, 1 stop bit, no parity, 19200 baud), in accordance with SOP U5.

9.3.5. Connect the serial cable from XStream RS-232/485 RF Modem serial output connector (See figure in Section 9.3.5) to the anemometer, according to figure in Section 9.1.2.

9.3.5.1. Test communication link to the computer in the trailer.

9.3.6. Establish communications with the sensor, according to Sections 9.1.3 and 9.1.4.

9.3.7. Provide power to sensor, and wait 4-s for initialization.

9.3.8. Using the HyperTerminal® window, send the ESC character (ASCII 27) three times in quick succession. This takes the unit out of OPERATE mode and causes the COMMAND MENU to appear:

```
COMMANDS (VERSION 6.6.07)
 -------------------------
R) REPORT
S) SETUP
X) EXIT TO OPERATE MODE
```

9.3.9. Go to SETUP. The SETUP menu appears as follows:

```
SET PARAMETERS
 -------------------------
 A) AVERAGING
 B) BAUD
 E) ERROR HANDLING
 N) SCALING MULT
 O) OUTPUT RATE
 P) POLL CHARACTER (ADDR)
 S) SER OUT FORMAT
 T) THRESHOLD
 U) UNITS
 V) V OUT FORMAT
W) WAKE CORRECTION
 X) EXIT TO MAIN MENU
```

9.3.9.1. Set AVERAGING at 0.
9.3.9.2. Set ERROR HANDLING to "INCLUDE INVALID DATA".
9.3.9.3. Set OUTPUT RATE at 16-Hz
9.3.9.4. Set SER OUT FORMAT as "CUSTOM". The following appears:

```
CURRENT SERIAL OUTPUT FORMAT:
[      ]
CONSTRUCT AN OUTPUT FORMAT BY SELECTING FROM THE LIST BELOW.
ELEMENTS MAY BE IN ANY ORDER. REFER TO MANUAL FOR DETAILS.
5) UVW
6) 2D SPEED
7) 3D SPEED
8) AZIMUTH
9) ELEVATION
A) SOS
B) Ts
E) ERR CODE
V) INTERNAL VOLTAGE

ENTER CUSTOM STRING (12 CHARACTERS MAX):
```

9.3.9.4.1. Enter Custom string as "5BE".
9.3.9.5. Set WAKE CORRECTION to "YES".
9.3.9.6. Exit to main menu and return to OPERATE mode.
9.3.9.7. Locate the appropriate input serial channel on the computer in trailer (SOP U4) and evaluate output for reasonable values.
9.3.9.8. Check output of sensors on the instrument trailer computer.
9.3.9.8.1. If output is not providing three wind vectors, a temperature and an error code, in accordance with the manual, re-enter setup menu and correct problem, starting anew at Section 9.3.5.

9.4. Instrument calibration

9.4.1. The sensor response under constant wind is calibrated at the factory.

9.4.2. The sensor cannot be calibrated for turbulence components.

9.4.3. Standard intercomparison: Compare the output of all three in-use sensors with that of three unused sensors (Standard Triad). This is done after every 6 mos.

9.4.3.1. Locate the sensors to minimize wind interference given prevailing winds.

9.4.3.2. Conduct measurements with the sensors for a period of 24-48 h, so that a variety of atmospheric conditions are included. Then, reverse the locations of the sensors and sample for another 24-48 h.

9.4.3.3. Compare the measurements obtained from the three sensors of the Standard Triad to ensure that the mean wind speed agrees to within 0.2 m/s. If the sensors agree within this amount, then use the average of all 3 sensors of the Triad as the standard. If one of the sensors lies outside this range, then use the average of the two remaining sensors as the standard.

9.4.3.3.1. Troubleshoot any Standard sensor that is out of agreement with other sensors, and resolve problem (Section 9.5).

9.4.3.4. Compare the mean wind speed from each used sensor with the standard set obtained above. If the mean difference is less than 0.2 m/s, then the used sensor being compared is in good working order. If the mean difference is greater than 0.2 m/s, then the used sensor being compared is defective

9.4.3.4.1. Troubleshoot defective sensor and resolve problem (Section 9.5).

9.4.4. In-field intercomparison: Compare the sensor with two identical units which are in routine use.

9.4.4.1. Locate all sensors next to each other on the sonic anemometer intercomparison stand. Orient the stand so that it is perpendicular to the wind, to minimize interference among the instruments.

9.4.4.2. Conduct measurements with all sensors for a one-hour period. Record the mean wind speeds for the three sensors over this period on the Field Intercomparison Form (Appendix B).

9.4.4.3. Determine the three paired differences between the sensors' measurements.

9.4.4.3.1. If all paired differences are less than 0.2 m/s, then the sensors are in good working order.

9.4.4.3.2. If one of the sensor's measurement differs by more than 0.2 m/s from the other sensors' measurements, then conduct tests for another one-hour period. If the difference remains greater than 0.2 m/s, then the sensor is defective, and must be returned to the factory for repair or replacement. Otherwise, if the difference in the second hour is less than 0.2 m/s, then the differences in the first hour were likely due to unsteady wind conditions.

9.4.4.3.2.1. If a sensor fails this test, inspect all measurements made since the sensor last passed to determine the time of failure. Invalidate measurements made after that time.

9.4.4.3.2.2. Contact PM for sensor replacement.

9.5. Troubleshooting
9.5.1. If no measurements are reported at computer:
9.5.1.1. Check for obstructions in the acoustic path. Invalid measurements occur when the acoustic path of the sonic signal is blocked or internal circuits fail.
9.5.1.1.1. Acoustic blockage may be caused by rain drops, ice, snow, or other debris, and is indicated by the output error code (see Section 11).
9.5.1.2. Check communications.
9.5.1.2.1. Verify communications link between radio modems (Yellow and Green lights intermittently lit during communications) on modems; (See figure in Section 9.3.3).
9.5.1.2.2. Verify firm connections for power, signal, and antenna for serial communications.
9.5.1.2.2.1. Correct as needed.
9.5.1.2.3. Verify power at modems in trailer and at anemometer, as indicated by a lit red light on the modems (See figure in Section 9.3.3).
9.5.1.2.3.1. If not within acceptable range, check continuity of wires and tightness of cable connections and correct as needed.
9.5.1.2.3.1.1. If all connections are tight and of good continuity, send sensor to manufacturer for repair and/or replacement of the appropriate modem.
9.5.1.2.4. Verify Destination Address of radio modems (SOP W6), and correct as needed.
9.5.1.2.5. Check that the correct baud rate is selected (See Section 9.1.3) and correct as needed.
9.5.1.3. Sensor troubleshooting
9.5.1.3.1. Verify power at anemometer by voltage measurement with multimeter: Voltage should be 12 to 24 VDC **at the sensor junction box terminals** (See figure in Section 9.1.2).
9.5.1.3.1.1. If voltage is not within acceptable range, check continuity of wires and tightness of cable connections.
9.5.1.3.1.1.1. Correct as needed.
9.5.1.3.1.1.2. If all connections are tight and of good continuity, send sensor to manufacturer for repair or replacement.
9.6. Data acquisition, calculations & data reduction requirements
9.6.1. Data are collected on the LAN server (SOP D1).
9.6.2. Corrections for wake effects are internally conducted.
9.6.3. Identify spikes in 16-Hz values of *U*, *V*, *W*, *T* using 100-s mean filter and dynamically calculated standard deviation.
9.6.3.1. Calculations are made by a computer program on the LAN server (SOP D1).
9.6.3.2. Spikes are defined as data points with values more than 3 standard deviations away from running mean.
9.6.3.2.1. Spike data are omitted.
9.6.3.3. Count spikes and calculate their mean value.
9.6.3.4. Inspect and flag data falling outside of acceptable limits based on spike counts.
9.6.3.4.1. Write to a data file the spike count, as well as the mean value of spikes, over a 5-min interval.

9.6.3.4.2. If spike count is greater than 160 for any variable, then the 5-min measurement period for that variable is flagged and investigated.

9.6.3.4.2.1. Do not calculate the derived variables in Sections 9.6.4 and 9.6.5 using any invalidated variables as dependencies.

9.6.3.4.3. If spikes count is less than 160 for a variable, then that variable passes the spike test.

9.6.3.4.3.1. Store instantaneous *U, V, W, T* and corresponding qc flags (See table in Section 11.4.1) in temporary data file.

9.6.3.4.3.2. Store 16-Hz sampling of instantaneous values of wind components *u'* and *w'* from 2 m and 16 m anemometers over the period from 12:00 PM to 12:30 PM in a data file (for spectral analysis on LAN server).

[NOTE: There is no correction for tilt of the sensor since inhomogeneities of the surface type (lagoon vs. land surrounding lagoon) and terrain elevation (lagoon berm) create streamlines assumed to be variable with wind direction].

9.6.4. Mean horizontal winds derived from 2-s periods of 16-Hz sampling of instantaneous wind components *u'* and *v'*.

9.6.4.1. Computations are made by computer program on the LAN server (SOP D1).

9.6.4.2. Compute the means of U, V ($\overline{U},\overline{V}$). Computed values are used in the radial plume method of emission measurement (SOP O2).

9.6.5. Turbulence statistics derived from 5-min periods of 16-Hz sampling of instantaneous wind components *u', v', w'* and *T'*.

9.6.5.1. Computations are made by computer program on the LAN server (SOP D1).

9.6.5.2. Compute the means of U, V, W, and T ($\overline{U},\overline{V},\overline{W},\overline{T}$). Computed values are used in the quality assurance routines and the backward Lagrangian Stochastic emissions measurement (SOP O1).

9.6.5.3. Compute the variance of the three orthogonal wind components σ_u^2, σ_v^2, σ_w^2 and σ_T^2 ($\overline{u'u'},\overline{v'v'},\overline{w'w'},\overline{T'T'}$). Computed values are used in the Quality Control and Assurance checks (Section 11) and the backward Lagrangian Stochastic emissions measurement (SOP O1).

9.6.5.4. Compute averaged correlations of instantaneous deviations in wind components *u', v', w'* and the temperature *T'* derived from the speed of sound: $\overline{u'w'},\overline{u'v'},\overline{v'w'},\overline{u'T'},\overline{w'T'},\overline{v'T'}$. Computed values are used in the Quality Control and Assurance checks (Section 11) and the backward Lagrangian Stochastic emissions measurement (SOP O1).

9.6.6. Mean horizontal winds derived from 5 and 30-min periods of 16-Hz sampling of instantaneous wind components *u'* and *v'*.

9.6.6.1. Computations are made by computer program at PAML.

9.6.6.2. Computed values are used to characterize wind conditions.

9.6.6.3. Compute mean vector wind speed ($\overline{S}$) according to the following:

$$\overline{S} = \sqrt{\overline{U}^2 + \overline{V}^2}$$

9.6.6.4. Compute mean wind direction ($\overline{\Theta}$) according to:

$$\overline{\Theta} = \begin{cases} 0^\circ & \text{if } \overline{U} = 0 \text{ and } \overline{V} > 0 \\ 180^\circ & \text{if } \overline{U} = 0 \text{ and } \overline{V} < 0 \\ -\tan^{-1}\left(\overline{V}/\overline{U}\right) + 90^\circ & \text{if } \overline{U} > 0 \\ -\tan^{-1}\left(\overline{V}/\overline{U}\right) + 270^\circ & \text{if } \overline{U} < 0 \end{cases}$$

The convention for the sonic anemometer output is that U is positive for wind from the east, and V is positive for wind from the north. The directions obtained from the above formula are 0° for wind from the north, 90° for wind from the east, and so on.

9.6.7. Turbulence statistics derived from 5 and 30-min periods of 16-Hz sampling of instantaneous wind components *u'*, *v'*, *w'* and virtual temperature *T'*.

9.6.7.1. Computations are made by computer program at PAML.

9.6.7.2. Re-compute LAN-computed variances σ_u^2, σ_v^2, and σ_w^2 and correlations $\overline{u'w'}, \overline{u'v'}, \overline{v'w'}, \overline{u'T'}, \overline{w'T'}, \overline{v'T'}$ with rotated coordinates so that mean wind is in the u direction.

9.6.7.2.1. Rotated values are used in the stationarity and homogeneity quality assurance tests (Sections 11.3.2, 11.3.3)

9.6.7.3. Compute the friction velocity (u_*):

$$u_* = \sqrt[4]{\overline{u'w'}^2 + \overline{v'w'}^2} \qquad \text{(Flesch et al. 2005)}$$

9.6.7.3.1. Computed values are used to characterize wind conditions, and to qualify backward Lagrangian Stochastic emission measurements (SOP O1).

9.6.7.4. Compute the characteristic temperature:

$$T_* = \overline{w'T'} / u_* \qquad \text{(Kaimal and Finnigan 1994)}$$

9.6.7.4.1. Computed values are used to characterize wind conditions.

9.6.7.5. Compute the Obukov length (*L*):

$$z / L = \frac{-kzg\overline{w'T'}}{\overline{T}u_*^3} \qquad \text{(Flesch et al. 2005)}$$

Where:

z	=	Sensor height (m)
k	=	von Karman's constant (0.4)
g	=	Acceleration due to gravity (9.8 m/s)

9.6.7.5.1. Computed values are used to characterize wind conditions and qualify backward Lagrangian Stochastic emission measurements (SOP O1).

9.6.7.6. The program estimates the roughness length (z_o) as the average value of the three heights of wind measurement, each calculated as:

$$z_o = \frac{(z-d)}{e^{kU/u_* - \psi_m}} \quad \text{(Flesch et al. 2005)}$$

Where (Flesch et al. 2004, Businger et al. 1971, Paulson 1970):

ψ_M = 4.7 (z-d)/L for $z/L > 0.0001$

ψ_M = 0 for $0.0001 > z/L > 0.0001$

ψ_M = $-2\ ln[(1+x)/2] - ln\ (1+x^2)/2\ ] + 2\tan^{-1} x - \pi/2$ and

X = $(1-15(z\text{-d})/L\ )^{1/4}$ for $z/L>0.0001$

9.6.7.6.1. Computed values are used to characterize wind conditions.

9.6.7.7. Estimate dissipation rate ε:

$$\varepsilon = \frac{u_*^3}{kz}\varphi_\varepsilon \qquad \text{(Flesch et al. 2004)}$$

Where:

$\varphi_\varepsilon = 1 + 5z/L$ for $L>0$

$$\varphi_\varepsilon = \frac{b_w^4(1-3z/L)^{1.33}+1}{(b_w^4+1)(1-3z/L)^{0.33}(1-6z/L)^{0.25}} \quad \text{for } L<0$$

9.6.7.7.1. Computed values are used to characterize wind conditions.

9.6.8. Write values of $\overline{U}, \overline{V}, \overline{W}, \overline{T}, \overline{S}, \overline{\Theta}$, σ_u^2($\overline{u'u'}$), σ_v^2($\overline{v'v'}$), σ_w^2 ($\overline{w'w'}$) u_*, T_*, z/L, z_o, ε and corresponding qc flags (Table 1) to data file

9.7. Computer hardware & software

9.7.1. Using electrical wires, attach sensor serial port to an XStream® RS-232/485 RF Modem.

9.7.2. A computer in the instrumentation trailer will receive the data using an identically addressed XStream® RS-232/485 RF Modem on a COM port.

9.7.3. Computer will record and process the data, and store it using LABView software.

10. Data and Records Management

10.1. Manage data according to SOP D1.

10.2. Document all data and information checked in the field on field data sheets and in site logbooks with permanent ink, or in electronic notes.

10.3. Overstrike errors in writing with a single line; date and initial all such corrections.

11. Quality Control and Quality Assurance

11.1. Physical inspection

11.1.1. Inspect sensor support arms for dents or deep scratches in the metal.

11.1.1.1. If present, conduct an in-field intercomparison (Section 9.4.3).

11.2. Zero check

11.2.1. Enclose sensor within an anechoic box and check for non-zero values on all wind components (similar to ASTM 2001).

11.2.1.1. Record sensor biases in the *U*, *V*, and *W* components on an audit form similar to the one in Appendix A of this SOP.

11.2.1.2. If sensor does not indicate values of less than 0.2 m/s in all three components, then send it back to the factory for repair or replacement.

11.3. Path obstruction check

11.3.1. The instrument's internal processing determines individual invalid measurements due to a path obstruction (e.g. debris, dew, mist, ice, or snow) preventing or radically altering acoustic transit time measurement. Instrument output includes invalid data and an error code, the sum of values for the following conditions:

```
2   Zero samples on at least one acoustic path
4   Path A speed < -50 m/s
8   Path A speed > +50 m/s
16  Path B speed < -50 m/s
32  Path B speed > +50 m/s
64  Path C speed < -50 m/s
128 Path C speed > +50 m/s
```

11.3.1.1. If less than 10% of the sampling interval has non-zero error codes, the measurement period is considered valid and computation on the valid data beginning at section 9.6 will be conducted.

11.3.1.2. If greater than 10% of the sampling interval has a non-zero error code, the measurement period is given an error code (Table 1).

11.3.2. Stationarity check Determine stationarity in the time series by comparing 5-min covariances of u' and w' and w' and T_v' (Section 9.6.6.2) with the 30-min covariance (Section 9.6.5) where *i* and *j* are different variables:

$$\sum \left| \left(\overline{u'_i\, u'_j}\right)_{5\,\mathrm{min}} - \left(\overline{u'_i\, u'_j}\right)_{30\,\mathrm{min}} \right| \Big/ \left(\overline{u'_i\, u'_j}\right)_{30\,\mathrm{min}}$$ (Foken and Wichura 1996)

where the 5-min periods included in the sum are sequential within the 30-min interval. Computations are done by computers at PAML.

11.3.2.1. If greater than 0.30 with the inclusion of any 5-min period to the sum, the 5-min period of data is given a QA/QC error code (Table 1).

11.3.3. Homogeneity check: Given values computed according to Section 9.6.6.2, check for homogeneity of turbulence during 30-min sample periods (six sequential 5-min periods) by comparing the theoretically derived and measured integral turbulence

scales of w', u' and T' (u_* and T_*) to the standard deviation of w' and T'. Computations are done by computers at PAML.

11.3.3.1. The theoretically-derived values are computed according to (Foken and Wichura 1996):

z/L	<-1	-1...-0.0625	-0.0625...<0	>=0
$\frac{\sigma_w}{u_*}$	$2.00(-z/L)^{1/6}$	$2.00(-z/L)^{1/8}$	1.41	1.25
$\frac{\sigma_u}{u_*}$	$2.83(-z/L)^{1/6}$	$2.83(-z/L)^{1/8}$	1.99	2.4
$\frac{\sigma_T}{T_*}$	$1.00(-z/L)^{1/3}$	$1.00(-z/L)^{1/4}$	$0.50(-z/L)^{1/2}$	

11.3.3.2. Compute the differences between theoretical and measured values as:

$$\sum\left[\frac{\sigma_w}{u_*}-\left(\frac{\sigma_w}{u_*}\right)_{theory}\right]\Bigg/\left(\frac{\sigma_w}{u_*}\right)_{theory}$$

$$\sum\left[\frac{\sigma_u}{u_*}-\left(\frac{\sigma_u}{u_*}\right)_{theory}\right]\Bigg/\left(\frac{\sigma_u}{u_*}\right)_{theory}$$

$$\sum\left[\frac{\sigma_T}{T_*}-\left(\frac{\sigma_T}{T_*}\right)_{theory}\right]\Bigg/\left(\frac{\sigma_T}{T_*}\right)_{theory}$$

11.3.3.2.1. If the value of any of these is greater than 0.30, the 30-min period is given a QA/QC error code (Table1).

11.4. Turbulence structure check: Conduct spectral turbulence checks of the 16-Hz sampling of instantaneous wind components *u'*and *w'* collected over an approximately 30-min period between 12:00 AM and 12:30 PM. Computations are done by computers at PAML.

11.4.1. Store instantaneous values of wind components *u'*, *v'* and *w'* from all anemometers in a data file for processing at PAML.

11.4.2. Calculate spectral statistics of *u'*and *w'*:

11.4.3. Calculate the spectral density function of the first 32,384 values at the all heights by fast Fourier transform.

11.4.4. Using u_* calculated for the 30-min period, calculate the spectral density function normalized to u_*^2 and plot as

$fS(f)/u_*^2$ by f for both measurement heights.

11.4.5. Compare shape of spectra and evaluate similarity.

11.4.5.1. If more than one peak in the spectra for either height, flag period values as suspect (Table 1).

11.4.5.2. If the peak spectral density in the 16-m height spectra is at a higher frequency than that for the 2-m height, flag period values as suspect (Table 1).

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13. Contact Information

13.1. Anemometer manufacturer:

R. M. Young Company, 2801 Aero Park Drive, Traverse City, MI, 49686, USA,
email: met.sales@youngusa.com
Customer support and repair: 231-946-3980, Fax 231-946-4772

13.2. Modem manufacturer:

Maxstream, Inc., 355 South 520 West, Suite 180, Lindon, UT 84042
Phone: (801) 765-9885
Fax: (801) 765-9895
email: rf-xperts@maxstream.net

Table 1. Data QA/QC conditions.

Individual measurements

Condition
Value not suspect
Value missing (>10% of records in 5 min period)
Value below minimum or above maximum or value is +/- infinity
Spike count >160
Value has variance >10 m^2/s^2 (u, v, w) or 10 C^2 (T)
> 10% of sampling interval has path obstruction

Combinational measurements

$u'w'$ not stationary (30-min period)
$w'T'$ not stationary (30-min period)
σ_u inhomogeneous turbulence in 5-min period
σ_w inhomogeneous turbulence in 5-min period
σ_T inhomogeneous turbulence in 5-min period

APPENDIX A
AUDIT FORM

SOP W2 RM YOUNG MODEL 81000 3-DIMENSIONAL SONIC ANEMOMETER

Date/time Yymm/dd hhmm-hhmm	Bias in U (m/s)	Bias in V (m/s)	Bias in W (m/s)	Auditor

APPENDIX B
FIELD INTERCOMPARISON FORM

SOP W2 RM YOUNG MODEL 81000 3-DIMENSIONAL SONIC ANEMOMETER

Date/time Yymm/dd hhmm-hhmm	Mean Speed (m/s)			Auditor
	Sensor 1	Sensor 2	Sensor 3	

MEASUREMENT OF WETNESS WITH THE CAMPBELL SCIENTIFIC MODEL RESISTANCE GRID

Standard Operating Procedure (SOP) W3

MEASUREMENT OF WETNESS WITH THE CAMPBELL SCIENTIFIC MODEL RESISTANCE GRID

Standard Operating Procedure (SOP) W3

Prepared by

Juan Carlos Ramirez and Richard H. Grant

Reviewed by

Bill W. Bogan and Albert J. Heber

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PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Electrical resistance grids are useful for the determination of surface wetness.
1.2. Surface wetness measurements indicate precipitation, an important weather variable.
1.3. This procedure applies only to the Campbell Scientific Model 237 Leaf Wetness Sensor Resistance Grid, to be used coated with white latex ceiling house paint.
1.4. This device is used as a wet/dry sensor in this application. Sensor readings in between wet and dry are simply interpreted as "Conditions other than wet or dry".
1.4.1. If measuring resistance with a multimeter, connect the leads to the red and black sensor leads. The sensor lead has a built-in 100,000–Ω, resistor in series with the sensor that must be included in any resistance calculations. See R1 in Fig. 1 of the Model 237 manual. The resistance (including the 100,000-Ω resistor) will be approximately 120,000 Ω – 500,000 Ω when wet, and above 3,100,000 Ω when dry.

2. Summary of Method

2.1. The 237 Leaf Wetness Sensor design emulates the surface area of a leaf. The dimensions of the sensor are 2.75″ W x 3″ L x 0.25″ D, and its weight is 0.5 lb. Surface wetness is detected using a resistance grid (see Fig. 1 at right) of interlaced gold-plated copper etched 'fingers' on an electronic circuit board. Condensation connects the etched 'fingers' of the board, resulting in a resistance change. The change in resistance is detected by change in voltage of a half bridge of fixed resisters (built into sensor cable) excited by AC current.

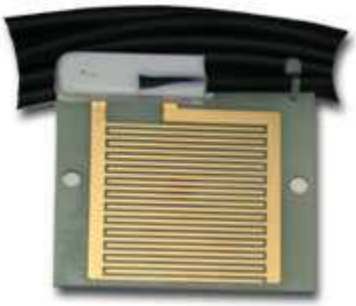

Figure 1.
Leaf Wetness Sensor

3. Definitions

3.1.	CS	Campbell Scientific, Inc
3.2.	NEMA	National Electrical Manufacturers Association
3.3.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.4.	PAML	Purdue Applied Meteorology Laboratory
3.5.	QAPP	Quality Assurance Project Plan
3.6.	SOP	Standard operating procedure

4. Cautions

4.1. Be careful when connecting the sensor cable to the data logger, being sure the connections are tight and made according to SOP W6.
4.2. Replace the sensor if the cable should become detached from the sensor (do not attempt to resolder it to the sensor), as the cable contains built-in components (a half bridge of fixed resistors) specifically designed to make the sensor operate correctly.
4.3. As with any electrical device, use proper care when crimping cables and connectors.

5. Interferences

5.1. Dust will reduce the sensitivity of the sensor to drying conditions.
5.2. Fingerprints and grease will reduce the sensitivity of the sensor to wetting conditions.

6. Personnel Qualifications

6.1. Each member of the field staff must read the sensor instruction manual and this SOP before operating this equipment.
6.2. Personnel must be trained in the use of the handheld multimeter before initiating the procedure. Training requires 10 min.

7. Equipment and Supplies

7.1. Leaf Wetness Sensor (Campbell Scientific, Model 237, Logan, Utah)
7.2. #2 common head screwdriver
7.3. 1/8″ slotted screwdriver
7.4. Bottle of distilled water for cleaning and testing sensor
7.5. Multimeter

8. Procedures

8.1. Preparation for use
  8.1.1. Clean the Model 237 Leaf wetness sensor thoroughly using acetone; allow to dry.
  8.1.2. Coat the sensor with a single coat of standard Latex exterior house paint; allow to thoroughly dry.
8.2. Acceptance
  8.2.1. Attach multimeter probes to red and black wires of sensor cable.
  8.2.2. Set multimeter to measure resistance.
    8.2.2.1. Read sensor response on multimeter when sensor is dry.
      8.2.2.1.1. Value should be greater than 3,100,000 Ω.
      8.2.2.1.2. If less than 3,100,000 Ω, allow sensor to dry in a warm environment for a minimum of 24 h. If the sensor still reads less then 3,100,000 Ω, return sensor to manufacturer.
    8.2.2.2. Wet sensor with tap water and read sensor response on multimeter.
      8.2.2.2.1. Value should be in the range of 120,000 – 500,000 Ω (±40,000 Ω).
      8.2.2.2.2. If wet resistance is <80,000 Ω or >540,000 Ω, return sensor to manufacturer.
8.3. Calibration check
  8.3.1. Note that this device is not a precision instrument, and exact resistance readings may vary considerably, depending on a wide variety of conditions including the mineral content of the distilled test or rain water.
  8.3.2. Attach red and black sensor wires to probe wires of multimeter.
  8.3.3. Set multimeter to measure resistance.
    8.3.3.1. Read sensor response on multimeter when sensor is dry.

8.3.3.1.1. Record value on calibration check sheet (Appendix A). If resistance is over-range on the multimeter's highest resistance scale, record resistance as infinite.
8.3.3.1.2. Value should be greater than 3,100,000 Ω.
8.3.3.1.3. If not, return sensor to manufacturer.
8.3.3.2. Wet sensor with distilled water and read sensor response on multimeter.
8.3.3.2.1. Record value on calibration check sheet (Appendix A)
8.3.3.2.2. Value should be within 120,000 Ω – 500,000 Ω (wet resistance tolerance is not critical).
8.3.3.2.3. If after one minute, resistance value is less than 80,000 Ω, or over 1,000,000 Ω, return sensor to manufacturer.

8.4. Installation
8.4.1. Mount sensor on the 3-m (10-ft) meteorological mast (SOP U5) at 2-m (6.6-ft) height, according to SOP W6.
8.4.2. Pass cable along ground to weatherproofed NEMA 4X box (SOP W6) and through specified knockout.
8.4.3. Attach sensor wires to data logger according to SOP W6 using the 1/8″ slotted screwdriver.
8.4.3.1. Connect black wire to 5 VAC excitation, purple wire to ground, clear wire to ground, and red wire to analog single ended measurement channel.
8.4.3.2. Data logger will log voltage returned from the wetness sensor's output wire (red wire) as a ratio of the measured voltage divided by the excitation voltage (Vs/Vx). The datalogger applies 5 VAC to the sensor's exciter (black) wire.
8.4.3.2.1. Sensor resistance (Rs) is recorded as a voltage ratio using the following calculation: Vs/Vx=R2/(R2+R1+Rs).
8.4.3.2.2. R1 and R2 are fixed values; R1=100,000 Ω and R2=1,000 Ω (Fig. 1 of Model 237 manual).
8.4.3.2.3. For example, if the sensor resistance is 101,200 Ω, the voltage ratio recorded would be 0.0049455 (1000(R2)/(102,200(R2+R1+Rs)).
8.4.3.3. This logged voltage will indicate the condition the sensor is currently detecting.
8.4.3.4. Values from 4.524 mV to 1.663 mV (120,000 Ω < Rs < 500,000 Ω will indicate "Wet" conditions.
8.4.3.5. Values less than 0.3124 mV (Rs >3,100,000 Ω) will indicate "Dry" conditions.
8.4.3.6. Values between 1.663 mV and 0.3124 mV 500,000 Ω < Rs < 3,099,999 Ω) will indicate transition "Conditions other then wet or dry".
8.4.4. While sensor is dry, check to see that data logger is indicating "Dry" conditions. Check wiring connections for error if response is incorrect.
8.4.5. Rinse the wetness grid with tap water and verify data logger's proper "Wet" response. Check wiring connections for error if response is incorrect.

8.5. Troubleshooting
8.5.1. If readings are noisy or erratic, check for poor connections.
8.5.2. If sensor does not respond to wetness, check for broken wires or connections.

8.6. Data acquisition, calculations & data reduction requirements
8.6.1. Analog input is monitored by the datalogger.

8.6.1.1. Ratio of excitation to sensor resistance is recorded and then calculated at PAML to be “Wet”, “Dry” or “Conditions other then wet or dry”, based on sensor resistance calculated from recorded voltage ratio.

8.6.2. Datalogger will record measurements every 5 minutes.

8.7. Computer hardware & software.

8.7.1. Attach the sensor to a Campbell Scientific datalogger through electrical wires that will extract data from the instruments.

8.7.2. The Campbell Scientific data logger will record the data and store it.

8.7.3. Datalogger operates using on-board BASIC-like programming.

8.7.3.1. The general program for measurements is stated in the Model 237 Manual.

9. Data and Records Management

9.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method, and in a record book designated for meteorological sensors.

9.2. Manage all data according to SOP D1.

9.3. Document all data and information on field notes with permanent ink, or in electronic notes. Overstrike errors in ink with a single line, then initial and date the overstrike.

10. Quality Control and Quality Assurance

10.1. Daily check from PAML

10.1.1. If value is -6999, flag with “1”.

10.1.1.1. Voltages over the maximum measurable input are indicated by data logger as -6999, and indicate sensor failure (short circuit). Dispatch personnel to check sensor and sensor wiring on site.

10.1.2. Check weather data from an outside source for the area such as http://www.crh.noaa.gov/iwx/index.php?mystation=KLAF (Lafayette, IN). If indicated data does not match conditions shown by outside weather sources on two or more days:

10.1.2.1. Flag recorded value with a “2” as invalid.

10.1.2.2. Dispatch personnel to check sensor and sensor wiring on site.

10.1.2.2.1. If damage is indicated, repair or replace as indicated in Section 8.4.

10.2. Perform the following checks at the beginning and end of each measurement period.

10.2.1. Check to be sure probe surface is clean.

10.2.1.1. If dirty, clean with distilled water and cloth.

10.2.2. Check integrity of the plastic casing of the signal cable.

10.2.2.1. If damaged slightly, repair with heat-shrink tubing.

10.2.2.2. If damaged significantly, replace sensor and return sensor to manufacturer for repair.

10.2.3. Wet sensor with tap water.

10.2.3.1. Check datalogger for value corresponding to a wet sensor

10.2.3.2. If data logger does not indicate wet conditions, check wiring (Section 8.2).

10.2.4. Dry sensor.

10.2.4.1. Check datalogger for value corresponding to a dry sensor.

10.2.4.2. If data logger does not indicate dry conditions, check wiring (Section 8.2).
10.2.5. Record results of checks on the site logbook and electronic spreadsheet.

11. References

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12. Contact Information

12.1. Distributor: Campbell Scientific, Inc., 815 West 1800 North, Logan, Utah, 84321
12.1.1. Technical support: 435-753-2342

Appendix A

Calibration Check Form: Campbell Scientific Resistance Grid Wetness Sensor

Instrument Serial Number:_____ Location:_____

Date (D-M-Y)	Time		Resistance (Ω)		Action Taken (Adjust, Replace)	Analyst
	Begin	End	Dry	Wet		

THE MEASUREMENT OF BAROMETRIC PRESSURE WITH THE SETRA MODEL 278 (CAMPBELL SCIENTIFIC CS100) BAROMETER

Standard Operating Procedure (SOP) W5

THE MEASUREMENT OF BAROMETRIC PRESSURE WITH THE SETRA MODEL 278 (CAMPBELL SCIENTIFIC CS100) BAROMETER

Standard Operating Procedure (SOP) W5

Prepared by

Richard H. Grant

Reviewed by

Albert. J. Heber and Bill W. Bogan

Effective Date: November 6, 2006

PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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Appendix B. Calibration Record: Setra 278 Barometric Pressure Sensor....12

1. Scope and Applicability

1.1. Barometric pressure measurements are needed to determine the mass concentration of gases from volume concentration measurements.
1.2. The resonant frequency of silicon is a useful means of measuring pressure.
1.3. The lower detection limit for the instrumentation described in this SOP is 600 hPa.
1.4. The range of the instrument, under normal atmospheric conditions, is from 600 to 1100 hPa.
1.5. Sensor response is 5mV / hPa.
1.6. Sensor accuracy is ±3 hPa
1.7. This procedure applies only to the Setra model 278 barometric pressure sensor, purchased as CS100 Barometric Pressure Sensor
1.8. This procedure applies to the open source portion of the National Air Emissions Study.

2. Summary of Method

Barometric pressure is measured using two closely-spaced, parallel, electrically-isolated metallic surfaces, one of which is essentially a diaphragm capable of slight flexing under applied pressure. The surfaces are mounted to allow slight mechanical flexing by small changes in pressure. Changes in the gap between the surfaces change the electrical capacitance of the gap, which is detected and converted to a proportional high level analog signal. The Setra model 278 sensor is used under this SOP because it is well-suited to long-term environmental applications, as its housing and all of its wettable parts are constructed of stainless steel or polyester. The sensor itself is enclosed in a thermally stable, low-hysteresis glass fused ceramic capsule which minimizes temperature effects on pressure readings.

3. Definitions

ARM	Atmospheric Radiation Monitoring Network
CS	Campbell Scientific, Inc
hPa	The S.I. unit of pressure is Pascal. The worldwide meteorological community uses the hectopascal(hPa) i.e. a hundred Pascals, which is the metric equivalent of a millibar. “Standard atmospheric pressure=1013 hPa = 101,325 Pa= 101.3 kPa=760 mm Hg=14.696 psi.”
NEMA	National Electrical Manufacturers Association
PAAQL	Purdue Agricultural Air Quality Laboratory
PAML	Purdue Applied Meteorology Laboratory
QAPP	Quality Assurance Project Plan
VDC	Direct Current voltage

4. Cautions

4.1. Static charge damages the sensor. To avoid damage, take adequate anti-static measures when handling.
  4.1.1. Wear an antistatic wrist strap that is properly connected to earth ground when in contact with the sensor.
  4.1.2. If an antistatic wrist strap is not available, discharge static electricity by touching a grounded metal object before touching the sensor itself.

5. Interferences

5.1. Failure to provide an open vent at the bottom of the NEMA 4X box will interfere with barometric measurements by blocking the sensor's ability to sense atmospheric pressure changes.
5.2. Failure to protect sensor from condensation or liquid water may cause permanent damage. See Section 8.2.2 for proper installation to avoid condensation. Place desiccant inside the NEMA box to absorb any moisture which does occur.

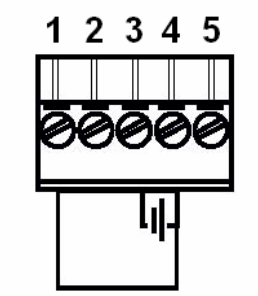
6. Personnel Qualifications

6.1. Personnel must be trained in the use of the handheld frequency multimeter before initiating the procedure. Training requires 10 min.
6.2. Personnel must be trained in the use of the power supply before initiating the procedure. Training requires 10 min.
6.3. Each staff member must read and understand the sensor instruction manual and this SOP before operating this sensor.

7. Equipment and Supplies

7.1. Multimeter
7.2. #2 Phillips head screwdriver
7.3. 1/8" slotted screwdriver
7.4. 2-inch length of jumper wire
7.5. 12 VDC power supply
7.6. 2-in. section of plastic tubing
7.7. Toothbrush
7.8. Electrical cleaner
7.9. Fortin Barometer (kept at PAML)
7.10. CS100 Barometric Pressure Sensor
7.11. NEMA 4X Box
7.12. Campbell Scientific Data Logger

8. Procedures



8.1. Acceptance

8.1.1. Connect terminal 4 to positive terminal of 12 VDC supply and terminal 3 to power supply ground (See diagram at right).

8.1.2. Connect a jumper across terminals 1 and 4.

8.1.3. With multimeter off, connect terminal 2 to negative terminal of multimeter and terminal 5 to positive terminal of multimeter.

8.1.4. Turn multimeter on and set to mV DC.

8.1.5. After 2 s, read measured voltage on multimeter.

8.1.6. Voltage should be approximately 1-2.25 VDC (800-1050 hPa).

8.1.6.1. If values are less than 1V or greater than 2.25 VDC, the sensor is defective, and should be returned to the manufacturer for replacement or repair.

8.2. Setup

8.2.1. Mount the instrument on the inside of the NEMA 4X box on the 10-foot mast according to SOP U5.

8.2.2. Mount the sensor with the pneumatic connector pointing vertically downwards to prevent condensation collecting on the pressure cavity and ensure that water cannot enter the sensor. Place fork lug under the mounting screw for grounding.

8.2.3. Using the 1/8”slotted screwdriver, connect the red wire to 12 VDC supply, black to power ground, yellow to signal ground, clear to shield, green to the external trigger (control terminal), and blue to a single-ended analog terminal of the data logger, according to SOP W6.

8.2.4. On power-up, the sensor requires less than 1 second of warm-up time.

8.2.5. The voltage across the blue and yellow wires (when terminals 1 and 4 are jumper wired as in Step 8.1.2) should be approximately 1-2.25 VDC (800-1050 hPa).

8.2.5.1. If values are less than 1 VDC, the sensor is defective, and should be returned to the manufacturer for replacement or repair.

8.3. Calibration

8.3.1. Calibrate the sensor every 6 mos., or at a different frequency if specified by the QAPP for a particular project.

8.3.2. Calibrate the sensor system (sensor and data logger) against a Fortin Barometer at PAML.

8.3.2.1. Follow the procedures for reading and adjusting the Fortin barometer documented in Appendix A of this SOP.

8.3.2.2. Read instantaneous measurements from datalogger/ sensor system at the time of each Fortin Barometer reading.

8.3.3. Conduct six paired measurements over a two–day period, average mean of their respective readings are taken out and if this matches then it is calibrated.

8.3.4. Record the results of the calibration on the sensor lab notebook form (Appendix B).

8.3.4.1. If the mean difference between Fortin barometer and senor/datalogger measurement is less than or equal to 2 hPa, then the sensor passes calibration and the drift is back-corrected according to Equation 1.

$$P_{corr}(t) = P(t)\left[1 - \frac{\overline{P_{measured}(i) - P_{expected}(i)}}{\overline{P_{expectd}}}\right]\left(\frac{t}{p}\right) \qquad \text{(Equation 1)}$$

Where:

P_{corr} = Back-corrected value at time *t* into the last measurement period

$P(t)$ = Original measured value at time *t*

$P_{measured}$ = Measured barometric pressure during calibration comparison

$P_{expected}$ = Barometric pressure indicated by the Fortin barometer during calibration comparison

p = Length of time between calibrations

8.3.4.2. If the mean difference between Fortin barometer and senor/datalogger measurement is >2 hPa, return sensor to manufacturer for repair or replacement.

8.3.4.2.1. If the mean difference is <6 hPa, adjust measurements since the last passed calibration linearly over time to the current calibration to account for the drift according to Equation 1. Correction coefficients determined at this point can be entered into the PAML computers to correct data collected during the next measurement period; the QAPP for a particular project will specify whether or not this is to be done.

8.3.4.2.2. If the mean difference is >6 hPa, invalidate barometric pressure measurements over the preceeding measurement period.

8.4. Troubleshooting

8.4.1. If pressure measurements vary widely over 24 h, check that the NEMA box is not 'hermetically sealed'. A hermetic seal is evident when air is distinctly forced out at the sides of the opening when the box is closed.

8.4.2. Be sure there is no condensate in the NEMA box.

8.4.3. Visually inspect the casing for damage.

8.4.4. Ensure there is a secure, clean ground connection.

8.4.5. Ensure that the pneumatic connection and tubing are secure and undamaged.

8.4.6. Replace desiccant in the NEMA box as needed.

8.5. Data acquisition, calculations & data reduction requirements

8.5.1. Monitor the analog voltage output with a Campbell Scientific datalogger or equivalent data acquisition system (See SOP W6).

8.5.2. Take measurements every 5 min

8.5.3. Report voltage data to five significant digits.

8.6. Computer hardware & software

8.6.1. Attach the sensors through electrical wires to a Campbell Scientific datalogger (or equivalent data acquisition system) that will extract data from the instruments.

8.6.2. The logger program for reading the sensor is written in a version of BASIC language.

8.6.2.1. The program converts the sensor voltage to hPa using the following formula:

$$\text{hPa} = 600 + 0.2\ \text{mVDC} \qquad \text{(Equation 2)}$$

8.6.2.2. The sensor units are logged as hPa.
8.6.3. Record and store the data with the datalogger.

9. Data and Records Management

9.1. Maintain all laboratory records in a worksheet of the electronic field notes spreadsheet designated for this method, as well as in a bound record book designated for meteorological sensors.
9.2. Manage data according to SOP D1.
9.3. Record the calibration information on the form provided in Appendix B.
9.3.1. Maintain a separate record sheet for each individual sensor.
9.4. Document all data and information on field data sheets and in site logbooks with permanent ink, or in electronic notes.
9.5. Overstrike errors in writing with a single line. Initial and date all corrections.

10. Quality Control and Quality Assurance

10.1. Daily
10.1.1. If value is missing, flag with "1".
10.1.2. If value is less than 600 hPa or greater than 1100 hPa (i.e. outside the range of the sensor), then flag value with "2".
10.1.3. Calculate the altitude-adjusted barometric pressure from the nearest National Weather Service Weather Station.
10.1.3.1. Correct NWS measured pressure to height of measurement location according to Equation 2 (Holton, 1979):

$$P_{site} = P_{NWS} e^{-(Z_{site} - Z_{NWS})/H} \quad \text{(Equation 3)}$$

Where:
P_{site} = Height-adjusted NWS pressure for site
P_{NWS} = Pressure at NWS station
Z_{site} = Site elevation
Z_{NWS} = NWS station elevation
H = $287(T_{NWS})/9.80665$
T_{NWS} = Absolute temperature (ºK) at NWS station.

10.1.4. If the altitude-adjusted difference between the barometric pressure at the sampling site and the nearest local weather station is > 4 hPa , then flag the day's data with "3".
10.1.4.1. Further investigation of the cause for the difference (such as synoptic weather front over the area) will be conducted.
10.2. Repeat the Acceptance Check (Section 8.1) before beginning a measurement period (i.e. during the setup of equipment at a site).
10.3. Do the following at the beginning and end of each measurement period:
10.3.1. Visually inspect the casing for damage.
10.3.1.1. Replace sensor if damaged.

10.3.2. Ensure there is a good secure and clean ground connection.
10.3.2.1.Secure ground if needed.
10.3.3. Ensure that the pneumatic connection and tubing is secure and undamaged.
10.3.3.1.Replace tubing if needed.
10.3.4. Check dessicant in the NEMA box.
10.3.4.1. Replace as needed.
10.3.5. Check cleanliness of connectors.
10.3.5.1.If corroded, clean with toothbrush and electrical cleaner.

11. References

11.1. ARM. 2005.: Temperature, Humidity, Wind, and Pressure System Handbook. Atmospheric Radiation Measurement Climate Research Facility, ARM TR-030, 13p.
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11.10. USEPA. 1989. Quality Assurance Handbook For Air Pollution Measurement Systems, Volume IV- Meteorological Measurements.
11.11. USEPA. 2000. Meteorological Monitoring Guidance for Regulatory Modeling Applications, EPA-454/R-99-005.

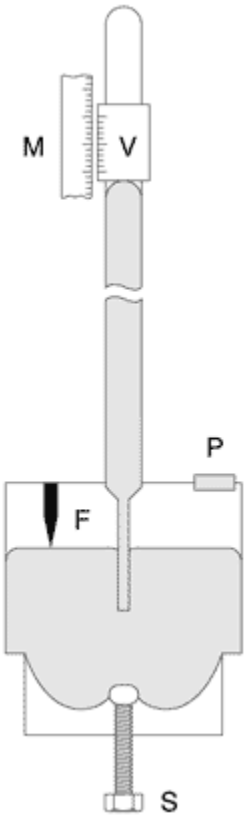
12. Contact Information

12.1. Distributor: Campbell Scientific, Inc., 815 West 1800 North, Logan, UT, 84321
12.1.1. Technical support: 435-753-2342
12.2. Manufacturer: Setra Systems, Inc., 159 Swanson Road, Boxborough, MA 01719
12.2.1. Repair Dept. Fax: 978-266-2158/Phone: 978-266-2194

Appendix A. Fortin Barometer Operation

The correct procedure for measuring pressure with a Fortin Barometer is:

- Adjust the cistern mercury surface to within a small distance of the fiducial point.
- Tap the barometer (to achieve a stable meniscus).
- Set the fiducial point.
- Set the vernier.
- Measure the barometer's temperature (and add calibration correction).
- Read the vernier.
- Apply the calibration correction for the barometer.
- Apply the temperature and gravity corrections (from tables or formula).



Fortin barometers should be used with their axis of rotation vertical - such that a setting of the mercury surface to the fiducial point remains correct after axial rotation through any angle.

Setting the Fiducial Point (F in diagram at right)

The lower mercury surface in a Fortin barometer has to be set to a datum level before adjusting its vernier (see schematic diagram) and the accuracy of pressure measurement depends crucially upon proper setting.

To achieve this, the mercury surface should first be lowered until it is clearly *below* the fiducial point (F in diagram at right). After tapping the barometer, the level-adjusting screw (S in diagram at right) should be turned slowly until the thin background of light between the mercury surface and the point just disappears, while viewed along a horizontal line of sight. To confirm proper setting, observe the point of contact at an angle of elevation of about 30° and determine whether or not the fiducial point is making an indentation in the mercury.

When the setting is correct there should be no more than the slightest dimple where the fiducial point makes contact with the mercury surface. If the surface is bright and the setting correct, the tip of the point will appear to coincide with its reflected image in the mercury surface. Correct setting is achieved when the mercury surface is *raised* to the fiducial point but not lowered - if the mercury surface overshoots the point it should be lowered and then raised again.

Setting the vernier: With suitably bright background illumination (using flashlight aimed at the white plastic background for the vernier), and taking care to correctly align the front and back setting edges, the vernier cursor (V in diagram at right) should be lowered until it appears on the

summit of the mercury meniscus. Proper setting can be aided by making small 'pecking' head movements to ensure that both cursor edges just meet the meniscus. Read the vernier.

Measuring temperature: Mercury barometers have a temperature coefficient of nearly 0.2 hPa per °C so it is important to ensure that their thermometers respond to ambient temperature changes in the same fashion as the barometer. Read the temperature off the thermometer attached to the barometer case.

Calculation of pressure from barometer readings: Three corrections to the measured barometric pressure must be made:

- Temperature correction
- Calibration correction
- Gravity correction

Theoretically, the corrections are made according to the following equations:

$t = (t` - 32) * 5/9$

$$\text{Pressure} = \frac{g}{9.806\,65}\left\{R + c - R\frac{(b-a)t}{(1+bt)}\right\}$$

where R is the barometer reading (in inches Hg)

c is its calibration correction (+.003 in Hg for barometer at PAML)

g is the acceleration due to gravity at the level of the barometer in m/s^2 (see below)

b is the coefficient of expansion of mercury (taken to be 0.000 181 8 $°C^{-1}$ for meteorological purposes)

a is the coefficient of linear expansion of the scale (taken to be 0.000 018 4 $°C^{-1}$ for brass)

t is the temperature of the barometer in °C

$t`$ is the temperature of the barometer in °F

and $g = 9.780\,318\,4\,(1 + A\sin^2 L - B\sin^2 2L) - 3.086\times10^{-6} H$

where A = 0.005 302 4

B = 0.000 005 9

L = Latitude (40.5)

H = height of barometer meters above sea level (197 m)

At West Lafayette, g = 9.80153, so the gravity correction is 9.80153 / 9.80665 = 0.999.

The correction terms involving a, b, and c were combined in the following table. To correct for the barometer local gravity and temperature, multiply the measured value by the value from the following tables and subtract from the measured value, then multiply by 0.999.

deg. F	correction	deg. F	correction	deg. F	correction
50	0.001631	70	0.003436	90	0.005234
50.5	0.001676	70.5	0.003481	90.5	0.005279
51	0.001721	71	0.003526	91	0.005324
51.5	0.001767	71.5	0.003571	91.5	0.005369
52	0.001812	72	0.003617	92	0.005414
52.5	0.001857	72.5	0.003662	92.5	0.005459
53	0.001902	73	0.003707	93	0.005504
53.5	0.001947	73.5	0.003752	93.5	0.005548
54	0.001993	74	0.003797	94	0.005593
54.5	0.002038	74.5	0.003842	94.5	0.005638
55	0.002083	75	0.003887	95	0.005683
55.5	0.002128	75.5	0.003932	95.5	0.005728
56	0.002173	76	0.003977	96	0.005772
56.5	0.002219	76.5	0.004022	96.5	0.005817
57	0.002264	77	0.004067	97	0.005862
57.5	0.002309	77.5	0.004111	97.5	0.005907
58	0.002354	78	0.004156	98	0.005952
58.5	0.002399	78.5	0.004201		
59	0.002444	79	0.004246		
59.5	0.002489	79.5	0.004291		
60	0.002535	80	0.004336		
60.5	0.00258	80.5	0.004381		
61	0.002625	81	0.004426		
61.5	0.00267	81.5	0.004471		
62	0.002715	82	0.004516		
62.5	0.00276	82.5	0.004561		
63	0.002805	83	0.004606		
63.5	0.00285	83.5	0.004651		
64	0.002896	84	0.004696		
64.5	0.002941	84.5	0.004741		
65	0.002986	85	0.004786		
65.5	0.003031	85.5	0.004831		
66	0.003076	86	0.004875		
66.5	0.003121	86.5	0.00492		
67	0.003166	87	0.004965		
67.5	0.003211	87.5	0.00501		
68	0.003256	88	0.005055		
68.5	0.003301	88.5	0.0051		
69	0.003346	89	0.005145		
69.5	0.003391	89.5	0.00519		

Appendix B.

Calibration Record: Setra 278 Barometric Pressure Sensor

Instrument Serial Number:_____ Location:_____

Date (D-M-Y) Time: Begin-End (HHMM-HHMM)	Temp. (^{o}C)	Manometer pressure (in. Hg)	Hg Temp. correction (in. Hg)	Pressure			Difference hPa	Action*	Analyst
				Corrected		Measured			
				in. Hg	hPa**	hPa			

* Sensor adjustment or replacement made after the measurement, if necessary. If action is taken, next entry should show result of re-calibration following that action.
**1hPa = 0.02953 in Hg

ESTABLISHMENT, DATA ACQUISITION AND CONTROL OF WEATHER AND LAGOON CHARACTERIZATION HARDWARE

Standard Operating Procedure (SOP) W6

ESTABLISHMENT, DATA ACQUISITION AND CONTROL OF WEATHER AND LAGOON CHARACTERIZATION HARDWARE

Standard Operating Procedure (SOP) W6

Prepared by

Richard H. Grant

Reviewed by

Bill W. Bogan and Albert J. Heber

Effective Date: November 6, 2006

PURDUE APPLIED METEOROLOGY LABORATORY (PAML)

Agronomy, Purdue University

West Lafayette, IN 47907

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1. Scope and Applicability

1.1. Weather and lagoon characteristics data are needed when measuring lagoon emissions at livestock facilities.
1.2. The measurement sites are typically at locations remote from headquarters.
1.3. The instrumentation on the tower must be in proper communication with the datalogger, which, in turn, must communicate properly with the PC in the trailer.
1.4. All equipment needed for these measurements must be transported to the site.

2. Summary of Method

2.1. Set up meteorological towers in an unobstructed, level area at the corner of the lagoon, referring to SOP U5, and to the site-specific site monitoring plan. Mount weather related sensors on the towers, as per instructions in their individual SOPs; these include barometric pressure (SOP W5), surface wetness (SOP W3), solar radiation (SOP W4), T/RH (SOP W1), and sonic anemometers (SOP W2). Another group of sensors, including T (SOP L1), pH (SOP L2), and redox state (SOP L3), is deployed, via the use of a float, into the lagoon. All these sensors are connected to a datalogger, which communicates with a 'LAN server' at the site.

3. Definitions

3.1.	DM	Data Manager
3.2.	FIFO	First in first out
3.3.	FOS	Field operations staff
3.4.	LAN server	Local Area Network server
3.5.	OSHA	Occupational Safety and Health Administration
3.6.	PC	Personal computer (laptop)
3.7.	PDC	Pathlength-defining components. PDC is used to denote the component on the other end of the optical path from the PI-ORS instrument. Depending on the instrument selected, this could be a source, detector, mirror, or other reflecting object.
3.8.	PAAQL	Purdue Agricultural Air Quality Laboratory
3.9.	PAML	Purdue Applied Meteorology Laboratory
3.10.	PI-ORS	Path-Integrated Optical Remote Sensing
3.11.	PM	Project Manager
3.12.	PPE	Personal protection equipment
3.13.	QAPP	Quality Assurance Project Plan
3.14.	QAM	Quality Assurance Manager
3.15.	RF	Radio frequency
3.16.	RH	Relative humidity
3.17.	SE	Single-ended
3.18.	Site PI	Site Principal Investigator
3.19.	T	Temperature
3.20.	T/RH	Temperature/Relative humidity

3.21. TDLAS Tunable Diode Laser Absorption Spectroscopy
3.22. USDOT US Department of Transportation
3.23. UV-DOAS Ultraviolet Differential Optical Absorption Spectrometer

4. Health and Safety

4.1. Be sure to use proper protective equipment (Section 8.1) while working at the field site.
4.2. Be careful when using the hinge pivot of the crank-up tower, in order to avoid pinching or other injury during setup and takedown.
4.3. Misuse or mishandling of electrical equipment may cause electrocution, severe burns, injury, or death.

5. Cautions

5.1. The sensors have electrical components, and proper care should be used as with all electrical equipment.
5.2. Firmly stake down the mast to prevent collapse under high winds or heavy ice
5.3. Proper connection of line power is necessary. Carefully crimp cables and connectors.
5.4. Lightning damage is more likely if the datalogger is not properly grounded.
5.5. Tighten all bolts on NEMA box to prevent the box from slipping down or turning on mast.

6. Interferences

6.1. Incorrect sighting of meteorological towers and masts cause measurement inaccuracies.
6.2. Field radio frequency (RF) noise can cause inaccuracies in the measurements if signals are not appropriately filtered and datalogger is not appropriately grounded.

7. Personnel Qualifications

7.1. Personnel must be capable of lifting at least 50 lbs.
7.2. Personnel must be trained in the use of the handheld multi-meter and voltage calibrator.
7.3. Personnel must be trained in the programming and operation of the datalogger and must have read the associated manual
7.4. Personnel must be trained in the programming and operation of the RF modem and must have read the associated manual.
7.5. Personnel must read and understand this SOP and all cited SOPs.

8. Equipment and Supplies

8.1. Safety equipment
  8.1.1. Leather gloves
  8.1.2. Safety goggles
  8.1.3. Ear plugs
  8.1.4. Flashlight/trouble light

8.1.5. 8-ft step ladder

8.2. Hand tools

8.2.1. Shovel (square mouth)
8.2.2. Level (12″ to 24″)
8.2.3. Tape measures (10 ft and 100 ft)
8.2.4. Conduit and associated tools (as required)
8.2.5. Hammer
8.2.6. Small sledge hammer – to drive stakes or grounding rod
8.2.7. Open-end wrenches (7/16″, 1/2″, 9/16″)
8.2.8. Socket wrench and 7/16″ deep well socket for radiation shields
8.2.9. Allen wrench set (0.05″) for LI2003S – one is supplied with LI2003S
8.2.10. Straight-bit screwdrivers (small, medium, and large)
8.2.11. Phillips screwdrivers (small and medium)
8.2.12. Pliers and needle-nose pliers
8.2.13. Channel locks
8.2.14. (2) Small diagonal side-cutters
8.2.15. Wire strippers
8.2.16. (2) Adjustable (crescent) wrenches
8.2.17. (2) Files – flat rat tail
8.2.18. Hacksaw
8.2.19. Pocket knife
8.2.20. Sheet metal cutters (tin snips)
8.2.21. Nylon cable ties
8.2.22. Enclosure supply kit (CSI P/N 7363)
8.2.23. Electrician's putty
8.2.24. Bailing wire
8.2.25. Lag screws to mount enclosure
8.2.26. Wire (multi-color)
8.2.27. Caulking gun and caulk
8.2.28. Long bolts, washers, nuts
8.2.29. Self tapping sheet metal screws
8.2.30. Grabber screws
8.2.31. Spare nuts, washers, U-bolts, etc.

8.3. Soldering tools

8.3.1. Soldering iron
8.3.2. Cigarette lighter
8.3.3. Solder
8.3.4. Distilled water
8.3.5. Heat shrink assortment
8.3.6. Electrical tape

8.4. Power tools

8.4.1. Variable speed drill
8.4.2. Drill bits and screw/nut driver bits
8.4.3. Hammer drill

8.5. Electrical equipment

8.5.1. Multi-meter
8.5.2. Calculator
8.5.3. Portable scope
8.5.4. Earth resistance checker
8.5.5. Break-out box
8.5.6. PC with LoggerNet® and DevConfig programs
8.5.7. Spare cables
8.6. Calibration equipment
8.6.1. Brunton compass or solar sighter (for wind direction alignment)
8.6.2. Handheld GPS unit
8.6.3. Voltage calibrator
8.7. Miscellaneous
8.7.1. Locks and keys
8.7.2. Back-up battery and battery cables
8.7.3. 2 RF antennas
8.7.4. Dessicant packages
8.8. Documentation
8.8.1. Data logger program listing, manual and prompt sheet
8.8.2. Sensor manuals
8.8.3. Site monitoring plan
8.8.4. Mounting angle for solar panel
8.8.5. Station log and pen
8.8.6. Felt-tipped marking pen
8.8.7. Declination angle for the site
8.9. Communication equipment
8.9.1. Two head-held radios
8.9.2. Cellular phone
8.9.3. Hand set (for site with phone line)
8.9.4. Appropriate phone numbers
8.10. Equipment and sensors to be installed
8.10.1. NEMA box with CR1000 data logger, CS100 Barometer, XStream® RS-232/485 RF Modem, and CompactFlash memory card
8.10.1.1. Antenna for modem
8.10.2. LiCOR 200 solar radiation sensor and mounting fixture and bracket (SOP E3)
8.10.3. Vaisala HMP45C RH/T sensor in passive radiation shield (SOP W1)
8.10.4. Surface wetness grid and mounting bracket (SOP W3)
8.10.5. (3) RMYoung 81000 sonic anemometers, each with XStream® RS-232/485 RF Modem and antenna (SOP W2)
8.10.6. CSI 107-L Thermistor (SOP L2)
8.10.7. Innovative Sensors CSIM11 ORP redox state sensor (SOP L3)
8.10.8. Innovative Sensors CSIM11 pH sensor (SOP L1)

9. Procedures

9.1. Acceptance
9.1.1. Criteria for the following sensors are specified in their respective SOP.
9.1.1.1. Barometric pressure (SOP W5)
9.1.1.2. Surface wetness (SOP W3)
9.1.1.3. Solar radiation (SOP W4)
9.1.1.4. Air T/RH (SOP W1)
9.1.1.5. Lagoon T (SOP L1)
9.1.1.6. Lagoon pH (SOP L2)
9.1.1.7. Lagoon redox state (SOP L3)
9.1.1.8. Sonic anemometer (SOP W2)
9.1.2. Criteria for data logger (Fig. 1)
9.1.2.1. Startup self-test of data logger indicates satisfactory operation (See manual).
9.1.2.2. Use voltage calibrator.
9.1.2.3. Check data logger output for an 5 VDC input on each SE analog channel. Most measurements are single-ended voltage measurements.
9.1.2.3.1. Manufacturer's accuracy specifications
9.1.2.3.1.1. At 5V, accuracy is ±0.1% of reading +1.332 mV (offset for single-ended measurement) across -25° to +50°C. For 5VDC input, factory accuracy is +/- 6.3 mV
9.1.2.3.2. Set data logger to read single-ended voltages at 5-s intervals for ≥5 min and report mean of measurements.
9.1.2.3.3. Attach high and low end of voltage calibrator to each a ground terminal and a single-ended input terminal
9.1.2.3.3.1. Record mean value on Calibration form (Appendix A).
9.1.2.3.3.2. Calculate error as (5 V - mean output voltage), and record on form.
9.1.2.3.4. Repeat 9.1.2.3.2 until all single-ended measurement channels are evaluated.
9.1.2.3.5. If output on all channels is within specifications, the data logger is acceptable.
9.1.2.3.6. If output on any channel is outside specifications, contact the manufacturer for resolution of problem.
9.2. Installation
9.2.1. Configure data logger:
9.2.1.1. Uses LoggerNet® software
9.2.1.2. Connect data logger RS232 and PC COM port with modem cable.
9.2.1.3. Set team 'East' or 'West' as "Station Name".
9.2.1.4. Set and record passwords for three levels of security, and send to PM, DM and QAM.
9.2.1.5. Conduct configuration procedures according to data logger manual.
9.2.2. Configure RF Modems
9.2.2.1. Connect a serial cable from XStream Modem to COM port of a laptop PC.
9.2.2.2. Provide power to radio modem by connecting power cable to power connector and switching on power switch (Fig. 2).

9.2.2.3. Verify power to modem by checking red light on modem (Fig. 2):
9.2.2.4. Using Windows HyperTerminal® program on the PC, verify Modem configuration: 8 data bits, 1 stop bit, no parity, 19,200 baud.
9.2.2.5. Press program button on modem for one second, and set modem channel to address "0" (Table 1) under selection #1 "Standard settings" See RF400 Radio modem instruction manual (Pg. 21, Section 5.3.1).
9.2.2.6. Press "5" to save parameters and exit.
9.2.2.7. Disconnect modem cable from PC and modem.
9.2.2.8. Remove power from modem.
9.2.3. Install 3-m meteorological mast (SOP U5)
9.2.3.1. In horizontal position install sensors on mast as follows:
9.2.3.1.1. Solar radiation sensor and mounting arm (SOP W4) at 3-m height.
9.2.3.1.2. RM Young sonic anemometer (SOP W2) at the top of mast (SOP U5). It communicates directly with the 'LAN server' PC in the instrumentation trailer (SOP U4) according to SOP W2.
9.2.3.1.3. Lightning rod and ground wire.
9.2.3.1.4. RF antenna and RF signal wire to antenna.
9.2.3.2. With mast in vertical position, install NEMA box at 1.5-m height.
9.2.3.2.1. Install data logger and CompactFlash card in NEMA box.
9.2.3.2.2. Install barometric pressure sensor in NEMA box (SOP W5).
9.2.3.2.3. Install RF modem into NEMA box.
9.2.3.2.4. Connect data logger to RF Modem.
9.2.3.2.5. Install radiation shielded RH/T probe (SOP W1), at 2-m height (1 m above berm).
9.2.3.2.6. Install wetness grid (SOP W3) facing north at 2-m height.
9.2.3.2.7. Connect all cables for the following sensors to the data logger in accordance with their SOPs (Section 9.1.1, Table 2): barometric pressure, surface wetness, solar radiation, air RH/T, lagoon T, lagoon pH, and lagoon redox state.
9.2.3.2.8. Connect RF cable to RF modem.
9.2.3.2.9. Install ground rod with sledge hammer, connect ground wire from ground rod (using football clamp) to data logger, and test quality of earth ground with earth resistance tester.
9.2.3.2.9.1. If resistance exceeds 2 ohms, check wire connections and firmness of ground rod in ground. Tighten or replace as indicated.
9.2.3.2.10. Attach 120VAC to data logger according to data logger manual. Establish communications.
9.2.4. Verify communications between data logger and LAN server computer (SOP D1).
9.2.4.1. Using LoggerNet® software, establish communications with data logger.
9.2.4.1.1. Link COM port, modem, and data logger.
9.2.4.1.2. Set data logger clock and automatic clock update schedule.
9.2.4.1.2.1. Clock will be automatically updated to LAN server computer time each night.
9.2.4.1.3. Set automatic 1-h download cycle from data logger to LAN server computer.
9.2.4.1.4. Set filename for data downloads.

9.2.4.1.5. Load data logger program (Appendix B) into data logger.
9.2.5. Verify communications between anemometer and LAN server computer (SOP D1), following the procedure in SOP W2.
9.3. Operation
9.3.1. Data logger measurements of most parameters are made at 5-s intervals.
9.3.1.1. The following measurements are sampled every 5 s, and averaged every 5 min: barometric pressure, surface wetness, solar radiation, air T, lagoon T, lagoon pH and lagoon redox state.
9.3.1.2. The following measurements are sampled every 5 min: air RH/T.
9.3.1.3. Measurements are stored on data logger CompactFlash memory (SOP D1).
9.3.1.3.1. CompactFlash memory mounted in Compact Flash Module (Fig. 3).
9.3.1.3.2. There is one LED that indicates module status (Fig. 3).
9.3.1.3.3. LED flashes red when card is being accessed.
9.3.1.3.4. LED is solid green when it is OK to remove compact card.
9.3.1.3.5. LED is solid orange if there is an error in operation.
9.3.1.4. Averaged and sampled measurements transmitted to 'LAN server' (SOP D1).
9.3.1.5. Values are visualized on LoggerNet® software on 'LAN server' PC
9.3.2. Wind component measurements are made at 16 Hz.
9.3.2.1. Measurements of the x (U), y (V), and z (W) wind direction components
9.3.2.2. Measurements are conducted as described in SOP W2.
9.3.2.3. Data are transmitted to 'LAN server' using XStream Modems (SOP D1).
9.3.2.3.1. Measurements are stored on 'LAN server' PC (SOP D1).
9.3.2.4. Values can be visualized on LabView® software on 'LAN server' PC
9.4. Downloading data from data logger
9.4.1. LoggerNet® software will automatically download data every hour into LAN server computer (SOP D1).
9.4.1.1. Software controls data download
9.5. Exchanging compact flash cards.
9.5.1. Removing compact flash card.
9.5.1.1. Press CONTROL button on Compact Flash Module (Fig. 3).
9.5.1.2. Status LED will turn green when ready.
9.5.1.3. Unscrew Compact Flash Module lid with screwdriver or hand.
9.5.1.4. Remove card.
9.5.1.5. If card is not removed within 20 s, it will be reactivated, and data on card will be written over. Remove card before this occurs.
9.5.2. Loading compact flash card.
9.5.2.1. Open Compact Flash Module lid with screwdriver or hand (Fig. 3).
9.5.2.2. Insert Compact Flash Card into Compact Flash Module.
9.5.2.3. Close Compact Flash Module and tighten screw by hand.
9.6. Troubleshooting
9.6.1. If communications between data logger and trailer PC has failed:
9.6.1.1. Check power to modems, PC, and data logger. If no power, check circuit breakers in trailer; reset breaker if off.

9.6.1.2. Check connections between RF modems and antennae for firm connection. Correct as needed.
9.6.1.2.1. Check communications.
9.6.1.2.2. Verify communications link between radio modems (Yellow and Green lights intermittently lit during communications) on modems (Fig. 2).
9.6.1.2.3. Verify firm connections for power, signal, and antenna for serial communications. Correct as needed.
9.6.1.2.4. Verify power at modems in trailer and at anemometer, as indicated by a lit red light on the modems (Fig. 2).
9.6.1.2.4.1. If not within acceptable range, check continuity of wires and tightness of cable connections. Correct as needed.
9.6.1.2.4.2. If all connections are tight and of good continuity, send sensor to manufacturer for repair and/or replacement of the modem.
9.6.1.2.5. Verify destination address of radio modems (Table 1). Correct as needed.
9.6.1.2.6. Check that the correct baud rate is selected (Section 9.2.2). Correct as needed.
9.6.2. If communications between data logger and PC is working, but data logger is not indicating data being logged:
9.6.2.1. Check program (See Appendix B) for accuracy. If necessary, reload program according to data logger manual
9.6.2.2. Check battery voltage of data logger.
9.6.2.2.1. If necessary, replace battery and check for problem with sensor wiring.
9.6.2.2.2. If problems persist, contact manufacturer for repair or replacement.
9.6.2.3. If input table of data logger indicates invalid measurements, Check appropriate sensor SOP for possible corrective measures.
9.6.3. If communications between sonic anemometer and trailer PC is not working, follow procedures in SOP W2.
9.6.4. If communications between sonic anemometer and trailer PC is working, but no data is being collected at the PC, follow procedures in SOP W2.
9.7. Data acquisition, calculations & data reduction requirements
9.7.1. Data from RH, air T, lagoon T, barometric pressure, surface wetness, solar radiation, lagoon pH and lagoon redox state will be logged on the CR1000 data logger.
9.7.1.1. Calculations and data reduction for each sensor are indicated in SOPs W1, W3, W4, W5, L1, L2, and L3.
9.7.1.2. Data logger is programmed using a BASIC-like language specifically designed by the manufacturer.
9.7.1.3. Communications between data logger and trailer PC (radio telemetry, SOP D1).
9.7.2. Data from sonic anemometers is stored on ‘LAN server’ PC.
9.7.2.1. Calculations and data reductions for each sensor are in SOP W2.
9.7.2.2. Communications between sensors and trailer PC uses radio telemetry (SOP D1).
9.8. Computer hardware & software
9.8.1. Data processing is conducted by the network LAN server (SOP D1).
9.8.1.1. Processing of measurements reported by data logger uses LoggerNet® program.
9.8.1.2. Processing of measurements reported by the sonic anemometers uses Labview® program.

10. Data and Records Management

10.1. Data logger
- 10.1.1. Measurements of RH, air T, lagoon T, barometric pressure, surface wetness, solar radiation, lagoon pH and lagoon redox state
- 10.1.2. Data is stored in a FIFO memory and on a 64Mb CompactFlash® memory card, which is typically filled in about 20 d.
- 10.1.3. Three 5-digit security passwords are needed to change the data acquisition program, download data, or change the clock.
- 10.1.4. The NEMA box is locked to limit unauthorized entry.

10.2. Network LAN server-data acquisition task
- 10.2.1. Measurements from sonic anemometers (SOP W2) are stored in on-site network server PC.
- 10.2.2. Data is stored in the LAN server, and transferred to PAML (SOP D1).

11. Quality Control and Quality Assurance

11.1. Perform the following QC actions after the initial setup of the site, before departing grounds for an extended period, and in the event of a failure of any piece of equipment that requires technical personnel to be dispatched to the site or results in a critical loss of data (including failures caused by severe weather, vandalism, lightning/power surges, or negligence):
- 11.1.1. Inspection of site grounds near instrument
  - 11.1.1.1. Visually check the site grounds around the tower for hazards such as rodent burrows, buried conduit trench settling, and insect nests.
  - 11.1.1.2. Log inspection results by checklist with comments and remediation.
- 11.1.2. Tower structures
  - 11.1.2.1. Check that all masts and towers are vertical and all guy wires, turnbuckle and tower base bolts are tight.
  - 11.1.2.2. Check for broken or cracked tower structure components. Inspect lightning rod ground wire for tightness and damage.
  - 11.1.2.3. Log inspection results by checklist with comments and remediation.
- 11.1.3. Sensors
  - 11.1.3.1. Check that all sensors are tightly attached to towers at appropriate heights.
  - 11.1.3.2. Check broken, pinched, or cracked cables between sensors and NEMA box.
  - 11.1.3.3. Log inspection results by checklist with comments and remediation.
- 11.1.4. NEMA box
  - 11.1.4.1. Check that the box is locked
  - 11.1.4.2. Check that the box is secured tightly to the meteorological tower.
  - 11.1.4.3. Check for wet dessicant in box and replace if indicator is pink.
  - 11.1.4.4. Check for any indications of broken or cracked NEMA box.
  - 11.1.4.5. Inspect grounding wire and lightning rod ground wire for tightness and damage.
  - 11.1.4.6. Log inspection results by checklist with comments and remediation.

11.1.5. Data logger
11.1.5.1. Check that all wires are correctly and firmly connected to the correct terminals of the data logger (Table 2).
11.1.5.2. Check that correct destination address (Table 1) is in RF Modem.
11.2. Perform the following QC actions every six months, and in the event of a failure of the data logger that requires technical personnel to be dispatched to the site or results in a critical loss of data from severe weather, lightning or power surges:
11.2.1. Evaluate accuracy of all single-ended voltage measurement channels according to Section 9.1.2.3..Record results on Calibration Form (Appendix A).
11.2.1.1. If problem cannot be resolved in field, then return datalogger to manufacturer for repair and recalibration.

12. References

12.1. ARM, Atmospheric Radiation Monitoring Network: Standard Operating Procedures
12.2. Campbell Scientific Inc. 2004. CR1000 Measurement and Control System Operators Manual, preliminary, Logan, UT.
12.3. Campbell Scientific Inc. 2005. LoggerNet Instruction Manual. Logan, UT.
12.4. Tripod Manual. 2005. Tripod installation manual, Models CM110, CM115, CM120, Campbell Scientific Inc., Logan, UT.
12.5. Crank-Up Tower Manual. Model LPT Towers Manual. FORCE12, Inc., Pas Robles, CA.
12.6. Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV-Meteorological Measurements, U.S. EPA, August 1989.
12.7. IMPROVE, Particulate Monitoring Network: Standard Operating Procedures, University of California, Davis.
12.8. Xstream Model Manual. 2005. XStream-PKG-R RS-232/485 RF Modem. Product Manual v4.2B, Maxstream, Lindon, UT.
12.9. SOP D1. 2006. Management of Open Source, Weather and Lagoon-Characterization Data. Standard Operating Procedure D1. Purdue Applied Meteorology Lab.
12.10. SOP E3. 2006. The Measurement of Solar Radiation with the Licor Model 200SL Silicon Pyranometer. Standard Operating Procedure E3. Purdue Ag Air Quality Lab.
12.11. SOP L1. 2006. Measurement of Lagoon pH with Innovative Sensors Model CSIM11 Sensor. Standard Operating Procedure L1. Purdue Applied Meteorology Lab.
12.12. SOP L2. 2006. Measurement of Lagoon Temperature with Campbell Scientific Model 107-L Thermistor. Standard Operating Procedure L2. Purdue Applied Meteorology Lab.
12.13. SOP L3. 2006. Measurement of Lagoon Redox State with Campbell Scientific CSIM11_ORP Sensor. Standard Operating Procedure L3. Purdue Applied Meteorology Lab
12.14. SOP U4. 2006. Open-source Instrument Trailer. Standard Operating Procedure U4. Purdue Applied Meteorology Lab.
12.15. SOP U5. 2006. The Installation of Open-source Measurement Equipment. Standard Operating Procedure U5. Purdue Applied Meteorology Lab.

12.16. SOP W1. 2006. Measurement of Atmospheric Temperature and Humidity with the Vaisala Model HMP45C Sensor and Solar Shield. Standard Operating Procedure W1. Purdue Applied Meteorology Lab.
12.17. SOP W2. 2006. Measurement of Wind with the RM Young Model 81000 3-Dimensional Sonic Anemometer. Standard Operating Procedure W2. Purdue Applied Meteorology Lab.
12.18. SOP W3. 2006. Measurement of Wetness with the Campbell Scientific Model Resistance Grid. Standard Operating Procedure W3. Purdue Applied Meteorology Lab.
12.19. SOP W5. 2006. The Measurement of Barometric Pressure with the Setra Model 278 (Campbell Scientific CS100) Barometer. Standard Operating Procedure W5. Purdue Applied Meteorology Lab.

13. Contacts

13.1. Data logger manufacturer: Campbell Scientific, Inc.
Address: 815 W 1800 N, Logan, UT 84321
Technical support: 435-753-2342

13.2. Modem manufacturer: Maxstream, Inc.
Address: 355 S 520 W, Suite 180, Lindon, UT 84042
Phone: (801) 765-9885
Fax: (801) 765-9895
E-mail: rf-xperts@maxstream.net

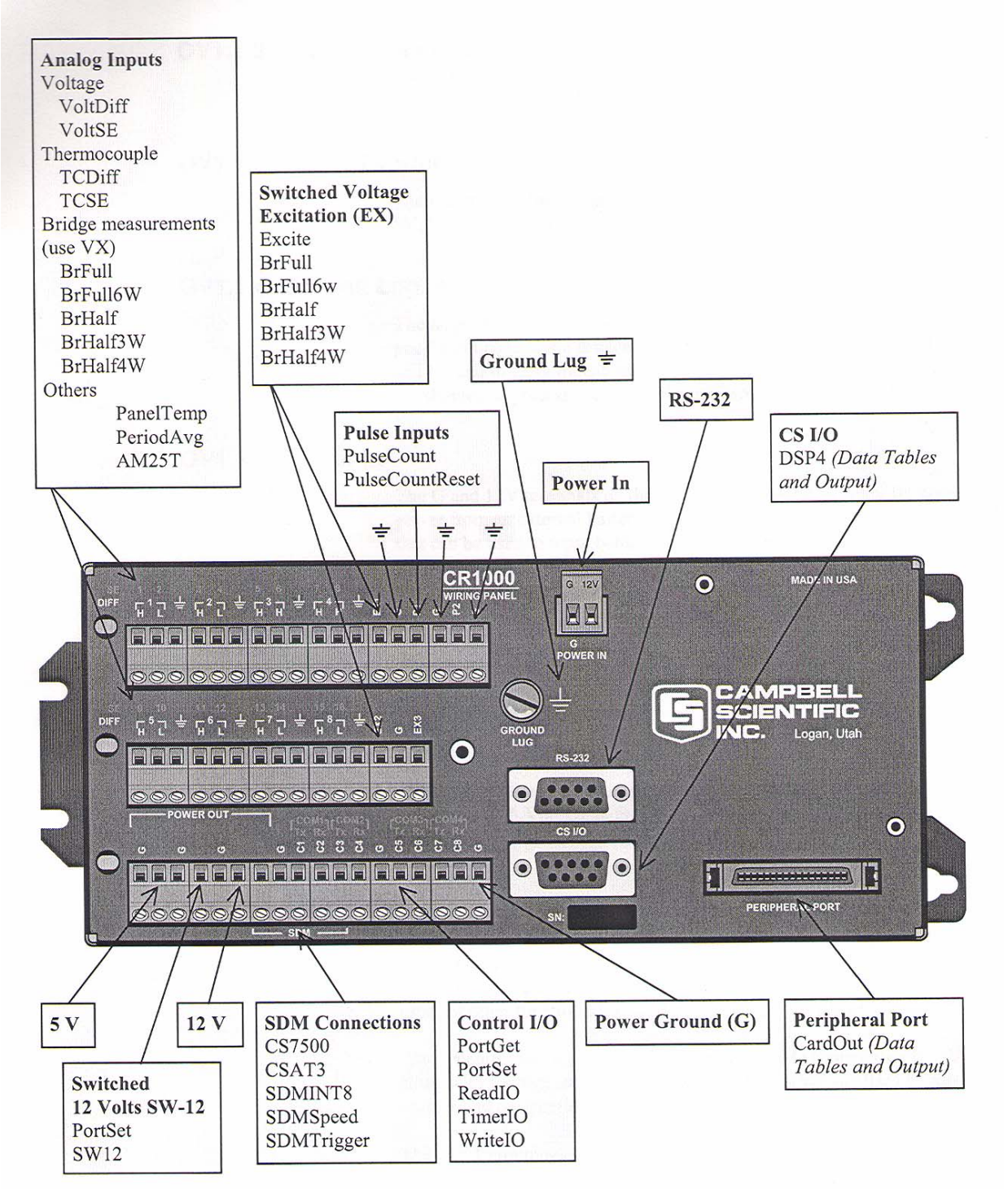

Figure 1. CR1000 Data Logger layout.

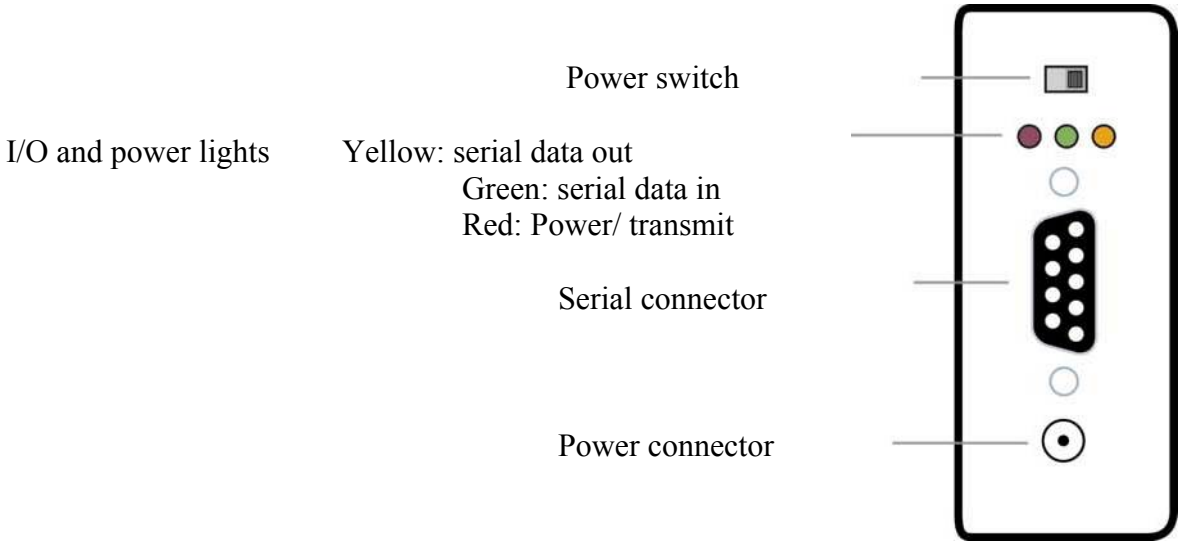

_Figure 2. Radio modem connectors and indicators.

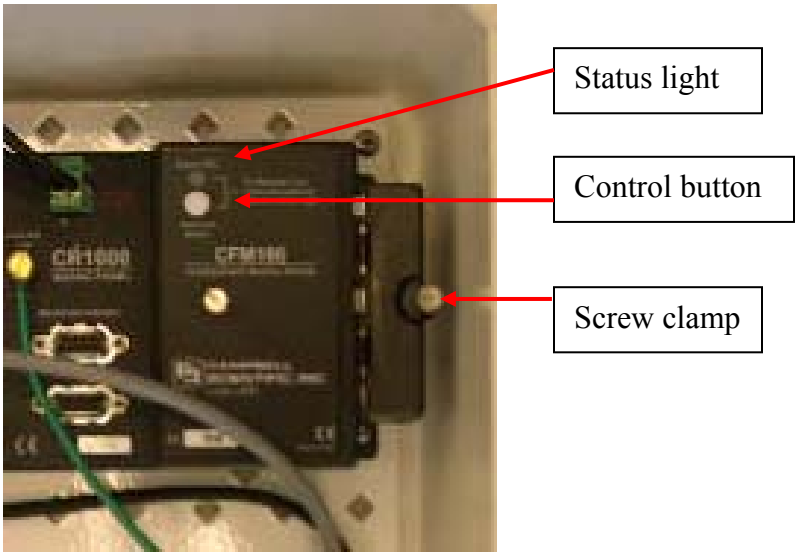

Figure 3. Compact Flash module, as mounted on CR1000 datalogger peripheral port (Fig. 1). Locations of the Status light, control button, and screw clamp are indicated.

Table 1. Radio modem communications channels.

Device Radio Is Connected to	Radio address *
CR1000 data logger	0
2m sonic anemometer	1
8m sonic anemometer	2
16m sonic anemometer	3
UV-DOAS -1	4
UV-DOAS -2	5
TDLAS – 1	6
TDLAS Scanner-1	7
TDLAS – 2	8
TDLAS Scanner-2	9

* Note: leave network address at "0"

Table 2. Wiring diagram for meteorological and lagoon characterization sensors.

Sensor	Wire color	Connection needed	Terminal on Data logger
Barometric pressure sensor	Red	+12VDC	
	Clear	Analog ground	
	Green	Ext control	C1
	Blue	SE	SE 1 (DE 1 H)
Wetness grid	Black	5VDC excitation	EX1
	Purple	Ground	
	Red	SE	SE 2 (DE 1 L)
LiCOR 200 solar radiation sensor	Red/Center	SE	SE 3 (DE 2 H)
	Black/Shield	Analog ground	
HMP 45C RH and air temperature sensor	Clear	Ground	
	Red	Switched 12VDC	SW12
	Black	Ground	
	Blue	SE	SE 4 (DE 2 H)
	Yellow	SE	SE 5 (DE 3 H)
	White	Analog ground	
Lagoon water temperature	Black	Switched EX	EX2
	Purple	Ground	
	Clear	Ground	
	Red	SE	SE 6 (DE 3 L)
Lagoon Ph sensor CSIM11	Brown	Analog ground	
	Red	+ DE	DE 4 H
	Green	- DE	DE 4 L
Lagoon redox sensor CSIM11-ORP	Brown	Analog ground	
	Red	+ DE	DE 5 H
	Green	- DE	DE 5 L

APPENDIX A

CR1000 Data logger Quality Assurance Form

Instrument Serial Number:_____

Date (MM/DD/YYYY): ____/_____/_____ Calibrator: _____

Begin time (HrHr:MinMin) _____ End time (HrHr:MinMin) _____

For 5VDC input, factory accuracy: +/- 6.3 mV

SE Channel	Recorded voltage Mean value	Error (5-mean)	Within factory accuracy (+/- 6.3 mV)? (Y/N)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
12			
13			
14			
15			
16			

APPENDIX B
CR1000 Data logger Program

```
'CR1000
'Created by RHGrant

'Declare Variables and Units
Dim pHMult_10
Public Batt_Volt
Public BP_kPa
Public LW_kOhm
Public SlrW
Public SlrMJ
Public AirTC
Public RH
Public T107_C
Public pH
Public ORP

Units Batt_Volt=Volts
Units BP_kPa=kPa
Units LW_kOhm=kOhms
Units SlrW=W/m²
Units SlrMJ=MJ/m²
Units AirTC=Deg C
Units RH=%
Units T107_C=Deg C
Units pH=pH
Units ORP=mV

'Define Data Tables
DataTable(Table1,True,-1)
Cardout(0,-1)
      DataInterval(0,15,Min,10)
      Average(1,BP_kPa,FP2,False)
      Average(1,LW_kOhm,FP2,False)
      Average(1,SlrW,FP2,False)
      Average(1,AirTC,FP2,False)
      Sample(1,AirTC,FP2)
      Sample(1,RH,FP2)
      Sample(1,T107_C,FP2,False)
      Sample(1,pH,FP2,False)
      Sample(1,ORP,FP2,False)
      sample(1,Batt_Volt,FP2,False)
EndTable

'Main Program
BeginProg
      Scan(5,Sec,1,0)
            'Default Datalogger Battery Voltage measurement Batt_Volt:
            Battery(Batt_Volt)
            'CS100 Barometric Pressure Sensor measurement BP_kPa:
```

```
            PortSet(1,1)
            VoltSE(BP_kPa,1,mV2500,1,1,0,_60Hz,0.2,600.0)
            BP_kPa=BP_kPa*0.1
            '237 Leaf Wetness Sensor measurement LW_kOhm:
            BrHalf(LW_kOhm,1,mV250,2,Vx1,1,250,True,0,250,1,0)
            LW_kOhm=1/LW_kOhm-101
            'LI200S Pyranometer measurements SlrMJ and SlrW:
            VoltDiff(SlrW,1,mV7_5,2,True,0,_60Hz,1,0)
            If SlrW<0 Then SlrW=0
            SlrMJ=SlrW*0.001
            SlrW=SlrW*200.0
            'HMP45C (7-wire) Temperature & Relative Humidity Sensor
measurements AirTC and RH:
            PortSet(2,1)
            Delay(0,150,mSec)
            VoltSE(AirTC,1,mV2500,5,0,0,_60Hz,0.1,-40.0)
            VoltSE(RH,1,mV2500,6,0,0,_60Hz,0.1,0)
            PortSet(2,0)
            If RH>100 And RH<108 Then RH=100
            '107 Temperature Probe measurement T107_C:
            Therm107(T107_C,1,7,1,0,_60Hz,1.0,0.0)
            'CSIM11 pH Probe (ISI M11-pH) measurement pH:
            'Calculate temperature correction multiplier
            pHMult_10=1/(((T107_C+273)/298)*59)
            'Make pH measurement
            VoltDiff(pH,1,mV2500,5,True,0,_60Hz,pHMult_10,7.0)
            'CSIM11 ORP Probe (ISI M11-ORP) measurement ORP:
            VoltDiff(ORP,1,mV2500,6,True,0,_60Hz,1,0.0)
            'Call Data Tables and Store Data
            CallTable(Table1)
      NextScan
EndProg
```

Appendix D

FINAL REPORTS

Final Report
Site IA3A
Pork Production Facility
for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
Site IA3A
Pork Production Facility

for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

July 2, 2010

Citation

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on the location (relative to climate and typical practice), method of manure collection, manure storage and physical configuration of the buildings and lagoons/basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3), hydrogen sulfide (H_2S) emissions from wastewater basin open source at the Midwestern hog finisher facility. Within that objective, this report will:

- Describe the farm and the basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the basin were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Basin emissions were measured up to 21 d each season over two years. The duration of measurement periods designated ‘up to 21 d’ depended on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the basin were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50-m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc,

Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*WindTrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model, which uses the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding RPM NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the basin rim (Table 1-2).

Table 1-1: Critical measurements

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder 2.0™	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind speed	3D Sonic anemometer/ RM Young 81000	0-60 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
Wind direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
3D Turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min
Temperature variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01°C	160 Hz sampling/ 16 Hz averaging	30 min
GSS sample flow rate	GSS/SOP-S	10 L min^{-1}	0.1 L min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/SOP-S	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to RPM Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the basin (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation, and wind) were telemetered to an instrumentation

trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure, flow, temperature and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer that was downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Additional information concerning farm operations was routinely collected from the producers. In addition, samples of the basin manure were collected during approximately each measurement period at the basin and analyzed for pH, total and ammoniacal nitrogen, sulfur and total solids by a commercial laboratory (Table 1-2).

Table 1-2: Non-critical measurements.

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
Ambient temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50 ^{o} C	0.1 ^{o} C	5 min	30 min, 24 h
Relative humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min & 24 h
Solar radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 Wm^{-2}	10 Wm^{-2}	5 min	30 min & 24 h
Manure NH_4	Micro Kjeldahl+ titrometric	0.5-10 mg L^{-1} (diluted)	0.05 mg L^{-1}	1/ meas. period	1/ meas. period
Manure total Kjeldahl nitrogen	Micro Kjeldahl+ titrometric	0.5-10 mg L^{-1} (diluted)	0.05 mg L^{-1}	1/ meas. period	1/ meas. period
Manure pH	KCl pH electrode	0-14 units	0.02	1/ meas. period	1/ meas. period
Manure total solids content	Dry at 103-105 ^{o}C	0-50 g sample	3 mg L^{-1}	1/ meas. period	1/ meas. period

1.3 Farm description and operation

The Midwestern finisher basin facility was located in Iowa. The elevation at the farm was 351 m (1151 ft). The farm consisted of four barns and a manure basin (Figure 1-1). The facility had a capacity of 3840 finishers in the four units. The construction of the facility was completed in 1998.

Manure from the 2-ft deep pits in each of the four barns was transferred to the basin, which was W of the barns (Figure 1-1), approximately once every ten weeks through two inlets (Figure 1-1). The concrete, circular basin had a diameter of 55-m (180-ft) with its sides approximately 1.5 ft above (agl) and 6.5 ft below ground level. While the basin was circular, the measurements are described below in terms of the north, east, south and west “sides” and “corners” of the basin,

which refers to measurements made to the north, east, south and west. Manure was surface-applied yearly, alternating between the adjacent fields and the remote fields (those located up to 2 mi from the basin).

Figure 1-1: Configuration of the IA3A farm.

1.4 Measurement layout

The NH_3 emissions from the basin were monitored for 8 to 20 d each quarter of the year for two years using scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements, the radial plume mapping (*RPM*), and backward Lagrangian Stochastic (bLS) emissions models. The H_2S emissions from the basin were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments

(TDLAS/scanner) were mounted at 1-m height above the basin rim (abl) at the northeast and southwest 'corners' (Figure 1-2). The northeast TDLAS/scanner was located 12 m northwest of northwest corner of northernmost barn. Towers for mounting retro-reflectors were located off the northwest and southeast 'corners' of the basin (Figure 1-2). The southeast tower was located 12 m west of the barns. A description of the position and path length of the optical paths along each side of the basin follows:

- North side of basin: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 25 m and 45.5 m from the northeast TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 75 m from the TDLAS/scanner at heights of 1.5 m, 8 m, and 13.6 m abl. The optical paths were approximately 3 m from the basin at their closest point.
- East side of basin: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 27 and 48 m from the northeast TDLAS/ scanner. Retro-reflectors were located halfway between barns 2 and 3, and 3 and 4. Three retro-reflectors were mounted on the southeast tower 80.5 m from the TDLAS/scanner at heights of 1.2 m, 8.2 m, and 14.3 m abl. The optical paths were approximately 1 m from the basin at their closest point.
- South side of basin: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 22 m and 44 m from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the southeast tower 71 m from the TDLAS/scanner at heights of 1.2 m, 8.2 m, and 14.3 m. The optical paths were approximately 9 m from the basin at their closest point.
- West side of basin: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 18 m and 36 m from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 60.5 m from the southwest TDLAS/scanner at heights of 1.5 m, 8 m, and 13.6 m abl. The optical paths were approximately 12 m west of the basin rim at their closest point.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1 m abl. A 50-m length S-OPS path began at the northeast TDLAS/scanner and ended 19 m south of the fence and 59 m west of the northernmost barn (Figure 1-2). The nearest point from S-OPS path to basin was 3 m. The second 50-m S-OPS path ran east-west along the TDLAS path lines with closest point at 9 m south of the basin. S-OPS path began 11 m west of barns, 1 m above basin rim height, and ended along the TDLAS path lines, 62 m west of the barns (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Meteorological measurement sensors, including barometric pressure, air temperature, relative humidity, solar radiation, and surface wetness, were located 10 m to the southwest of the basin and 66 m west of the barns (Figure 1-2). The meteorological measurement data were collected on the data logger. The 3D sonic anemometers were located on the meteorological tower at 2.3-m heights, and on the northwest corner tower (Figure 1-2) at 4-m and 15.4-m heights agl (Figure 1-2).

Figure 1-2: Locations of instrumentation around the basin under measurement.

Retro-reflectors are indicated according to side (north-N, south-S, east-E, west-W) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The locations of the two S-OPS are indicated by the solid yellow lines. The instrumentation trailer was located between the middle barns.

The farm was located in rolling terrain. The barns, 12 m to the east of the basin, had an approximate ridge height of 5 m agl, which resulted in a fetch ratio (rise: run) of 1:3 or better for the nearest TDLAS beam line. Crops were grown to the north, south and west of the basin. The area to the north alternated between corn and soybeans, while the west and south varied between wheat, soybean, and corn. Crops approximately 10 m to the north, south, and west of the basin had a height ranging from 1 m (soybeans, wheat) to 3 m (corn). Since measurements were at 1.5 m agl or higher, the soybean and wheat crops did not affect the air flow at beam line or anemometer measurement heights. The fetch for the TDLAS and S-OPS paths to the south of the basin was 1:17 or better when cropped with corn. The fetch for TDLAS paths to the west of the basin was 1:6 or better when cropped with corn. The fetch for the S-OPS and TDLAS to the north of the basin was 1:3 or better when cropped with corn. The 2-m anemometer had a prevailing wind upwind fetch of 1:36 for the northwest, 1:33 for south winds, and 1:22 for the east winds coming from the barns. The 4-m anemometer fetch in all directions except east winds was greater than 1:100; for the east wind, fetch was 1:78. All wind measurements were relatively

unaffected by upwind conditions, however the concentration measurements and wind profile along the east side of the basin was affected by the barn exhausts. Consequently, emissions calculated when the winds were from between 10° and 170° were excluded from analysis.

Three samples of the basin liquid/ manure were collected during most measurement periods at random locations around the basin edge and analyzed for pH, total and ammoniacal nitrogen, sulfur and total solids. No samples were collected during the winter when the basin was frozen.

2 Monitoring activities

2.1 Measurement periods

This location was measured as part of an approximate 20-d rotation between three other farms. The equipment was on site a total of 164 d over eight measurement periods (Table 2.1-1). Setup calibrations and site takedowns reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 153 d and H_2S emissions were measured 96 d.

Table 2.1-1: Days on site

Measurement Period	Start date	End date	# days
2	8/30/2007	9/26/2007	27
3	12/19/2007	1/15/2008	27
4	5/14/2008	6/4/2008	21
5	6/4/2008	6/25/2008	21
6	11/13/2008	11/25/2008	12
7	11/25/2008	12/16/2008	21
8	4/8/2009	4/23/2009	15
9	7/28/2009	8/17/2009	20

2.2 Site visits

The Field operation team visited this farm 31 d (Table 2.2-1). Visits to set up the site instrumentation and conduct calibration verification checks of instruments typically lasted 3 d while visits for calibration verifications and take-down of the equipment on site typically needed 2 d.

Table 2.2-1: Dates of site visits

Year	Spring	Summer	Fall	Winter
2007			Aug 30,31 Sep 17,18,26	Dec,19,20 Jan 14,15
2008	May 14,15	Jun 4,5,12,23,24	Nov 12,13,14,25	Dec 15,16
2009	Apr 8,9,22,23	Jul 27,28,29 Aug 17,18		

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements (most susceptible to deterioration) were generally conducted within 21 d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder 2.0™ NH_3 TDLAS serial number (s/n) 1026, 1027, 1028, 1030, and 1031 (Section 6.1)

- TEC 450i H_2S Analyzer s/n 0733825129 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1920, 1926, 1928, 1932, 1933 and 1945 (Section 6.3)
- GSS/ S-OPS s/n 4-0018 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multipoint calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers (Section 6.3) with three unused 'standard' anemometers. The TDLAS units on location (s/n 1031 and 1028) were inter-compared on 6/5/2008.

2.4 Audits

Two internal audits were conducted at this location: 1) on 6/5/2008 with particular attention to the H_2S Analyzer and TDLAS calibration verification, and 2) on 7/28/2009 with particular attention to the sonic anemometer inter-comparison and H_2S Analyzer and TDLAS calibration verification.

2.5 Repair trips

Two repair trips were made to this location: 7/18/2007 and 6/12/2008.

2.6 Remote site checks

Over the course of measurements, there were 63 remote checks made through the computer for instruments operating at this location.

2.7 Measurement data acquisition

Data from the TDLAS units (Model GasFinder 2.0™ NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *Loggernet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *Loggernet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA)were downloaded in real-time through a serial cable to the trailer computer using the *iPort* (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built *Visual Basic* software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory “FTP” and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory “Data”. The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the “FTP” directory.

3 Data processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDLAS. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes need to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site, data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer causing the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period, unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one minute off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the basin and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream may depend on one or more of the preceding streams, but not on following data streams. For each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data

exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment failures, calibration failures, and calibration checks were in progress. Periods of invalidated measurements associated with the calibration check failures is documented in the calibration reports in Section 6. Significant data exclusions of greater than 1-d duration are indicated below by instrument. All time references are in Coordinated Universal Time (UTC):

TDLAS measurement exclusions: Excluded measurements are summarized in Table 3.2-1.

Table 3.2-1: TDLAS measurement exclusions

Begin		End		Reason
9/1/2007	00:30	9/18/2007	16:35	TDLAS 1 could not maintain communication with laptop
6/8/2008	09:45	6/9/2008	18:41	TDLAS 1 unknown failure
6/5/2008	22:33	6/11/2008	23:20	TDLAS 2 scanner / power supply issue

Wetness measurement exclusions: Excluded measurements are summarized in Table 3.2-2.

Table 3.2-2: Wetness measurement exclusions

Begin		End		Reason
8/30/2007	22:15	9/26/2007	19:10	Sensor not functioning; reads continuously wet
12/19/2007	21:40	1/15/2008	15:10	Sensor not functioning; reads continuously wet

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-3.

Table 3.2-3: Sonic anemometer measurement exclusions

Begin		End		Reason
6/8/2008	09:45	6/9/2008	12:15	Sonic program failure
11/29/2008	23:30	11/30/2008	19:45	All 3 sonic anemometers inoperable due to icing
12/9/2008	02:15	12/10/2008	01:30	All 3 sonic anemometers inoperable due to icing

GSS/S-OPS measurement exclusions: Excluded measurements are summarized in Table 3.2-4.

Table 3.2-4: GSS/S-OPS measurement exclusions

Begin		End		Reason
8/7/2009	22:45	8/8/2009	09:45	Condensation inside GSS

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20^oC (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in supersaturated "holes" in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a supersaturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maxed-out light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably supersaturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-s value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be supersaturated were flagged as supersaturated. However, it was found that simply using the light

levels as the super-saturation criteria resulted in the removal of much data that was clearly not supersaturated. To determine which points truly were supersaturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest path integrated concentrations corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be supersaturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as supersaturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the S-OPS changed from one line to the other line. This array was later used when separating the H_2S data according to which S-OPS line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points

recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic temperature variance of greater than 2.5 $m^2 s^{-2}$, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic temperature variance had to be less than 2.5 $m^2 s^{-2}$ To be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most, of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH_3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be *RPM* processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH_3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the basin or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *WindTrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant.. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3}\frac{34.0818\left(\left[H_2S\right]_{downwind} - \left[H_2S\right]_{upwind}\right)}{17030.4\left[NH_3\right]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H_2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and

wind statistics required by the model and tells the model to run depending on whether or not the u_* and L values are acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the basin or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the basin include transfer of waste from barns into the basin (Table 4.1-1) and basin pump-outs for irrigation. Animal inventories for the calculation of basin loading rates are indicated in Table 4.1-1.

Table 4.1-1: Producer activities

Period	Activity	Animal inventory
2: 8/30/2007 - 9/26/2007	Pit agitation and pump out 9/21/07	3592
3: 12/19/2007 -1/15/2008	No events	3564
4: 5/14/2008 - 6/4/2008	No events	3547
5: 6/4/2008-6/25/2008	Pulled plugs in building to drain manure into pits 6/18/08 and 6/25/08	3111
6: 11/13/2008-11/25/2008	No events	3873
7: 11/25/2008 - 12/16/2008	Drained manure from 2 north barns 12/6/08 and the 2 south barns 12/8/08	3800
8: 4/8/2009-4/23/2009	No events	3201
9: 7/28/2009 - 8/17/2009	Pit agitation and pump out. 8/12/09 12pm-6pm 8/13 - 8/14/09 8am-6pm 8/17/09 8am-12pm	3374

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for midlatitude climates (Table 4.2-1). Twenty-five percent of the days had extra-tropical frontal systems overhead while 75% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Measurement period	# days	# Warm front passages	# Cold front passages	# days stationary front	# days tropical storms
2	27	0	7	0	0
3	27	0	4	2	0
4	21	1	5	1	0
5	21	0	3	1	0
6	12	0	2	0	0
7	21	2	4	0	0
8	15	1	1	0	0
9	20	1	6	0	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from -19.1 ^{o}C to 28 ^{o}C while the barometric pressure varied from 95.85 kPa to 99.88 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ hr solar irradiance of 1194 Wm^{-2} to overcast conditions with maximum ½ hr solar irradiance of 92 Wm^{-2} (Section 6.10). The wetness sensor failed frequently due to corrosion issues.

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared to the monthly climatology is indicated in Figure 4-1. Temperatures were generally within the climatological normal conditions throughout the study measurement periods at this location.

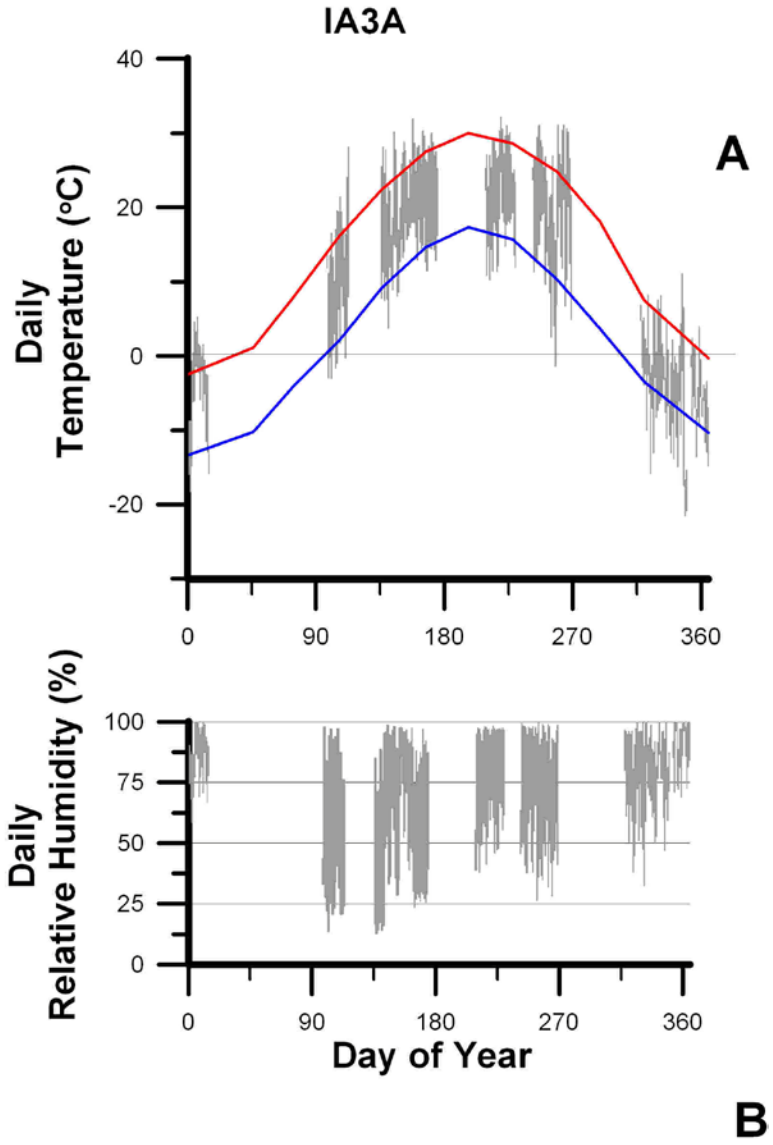

Figure 4-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line)

temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidity for measurement days is indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figure 4.2-1 through 4.2-4. Emission calculation exclusion regions due to surrounding sources (wind directions of 10° through 170°) are indicated as a grayed region in the figures.

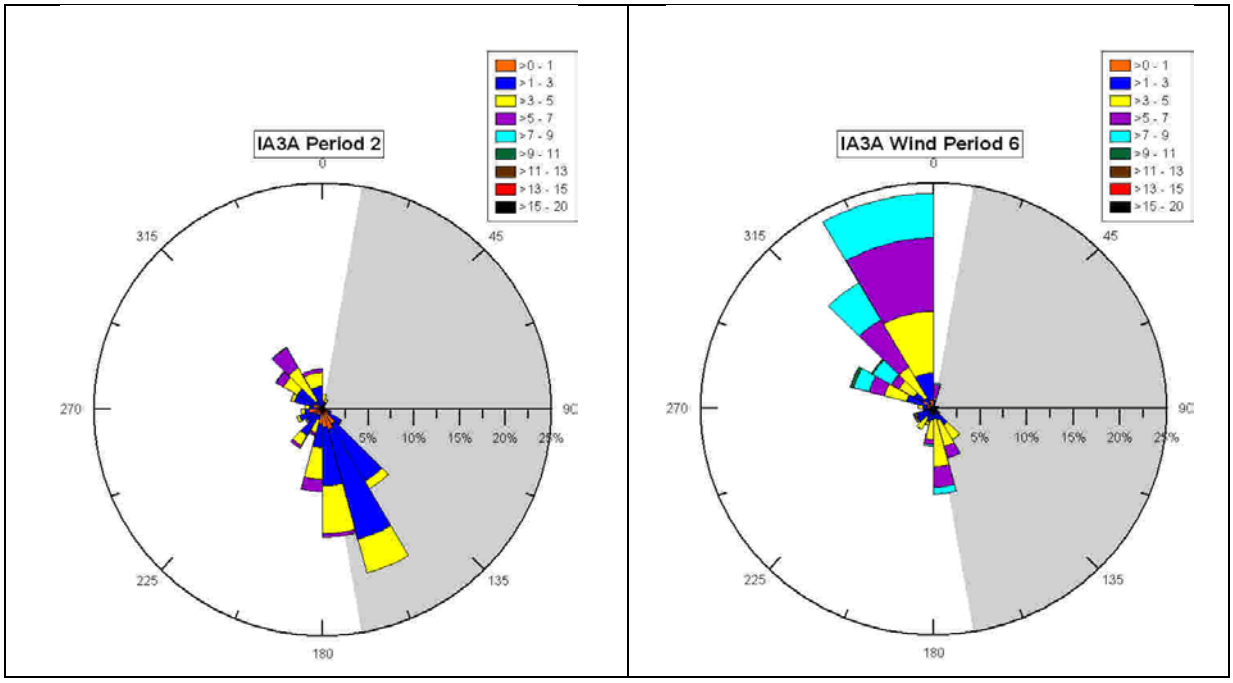

Figure 4.2-1: Wind roses for ½ hourly wind measurements during the Fall Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

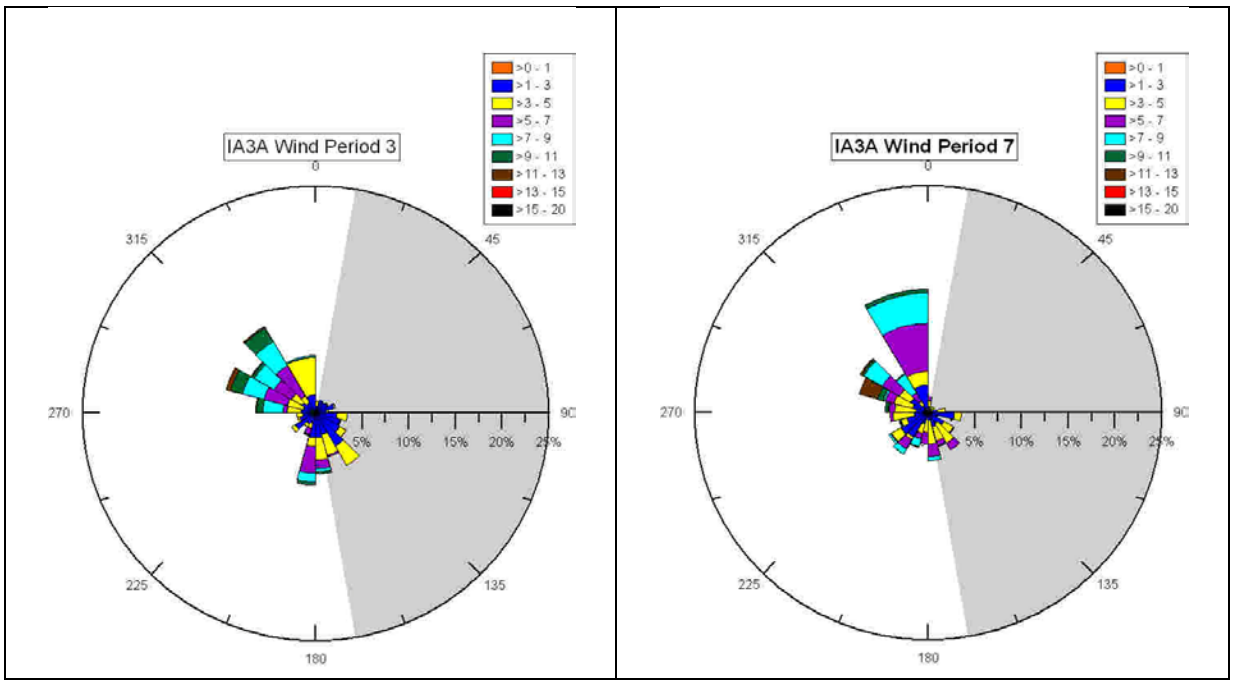

Figure 4.2-2: Wind roses for ½ hourly wind measurements during the Winter Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

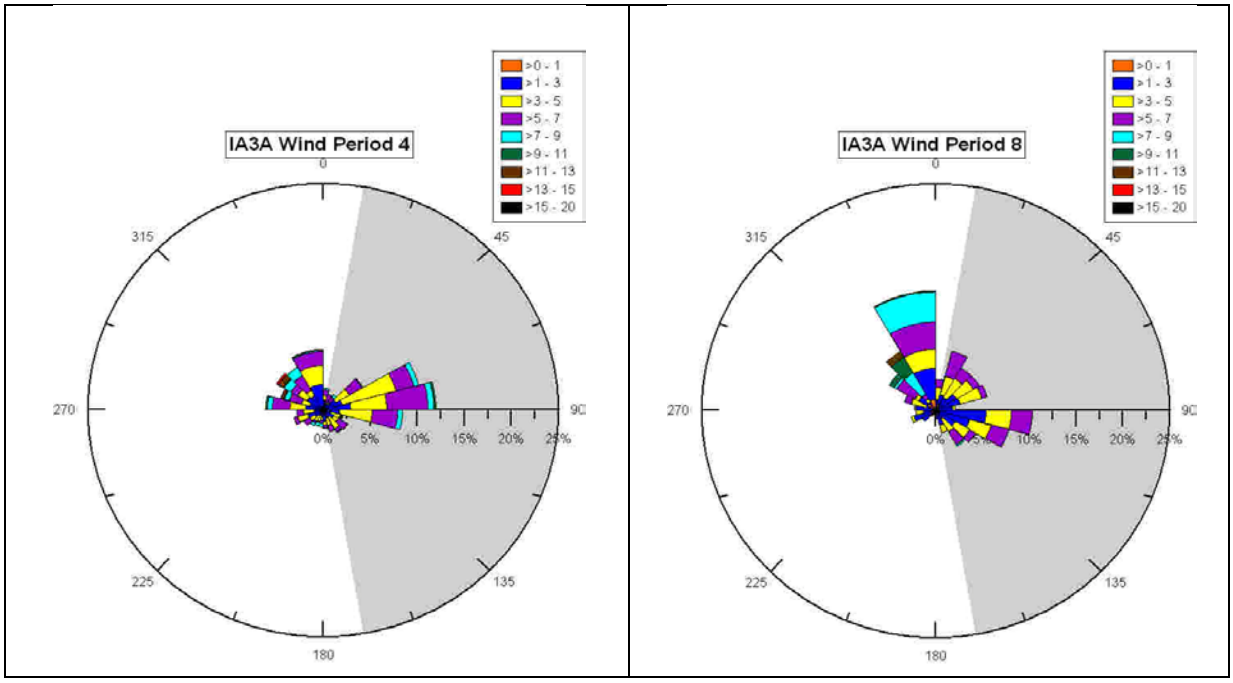

Figure 4.2-3: Wind roses for ½ hourly wind measurements during the Spring Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

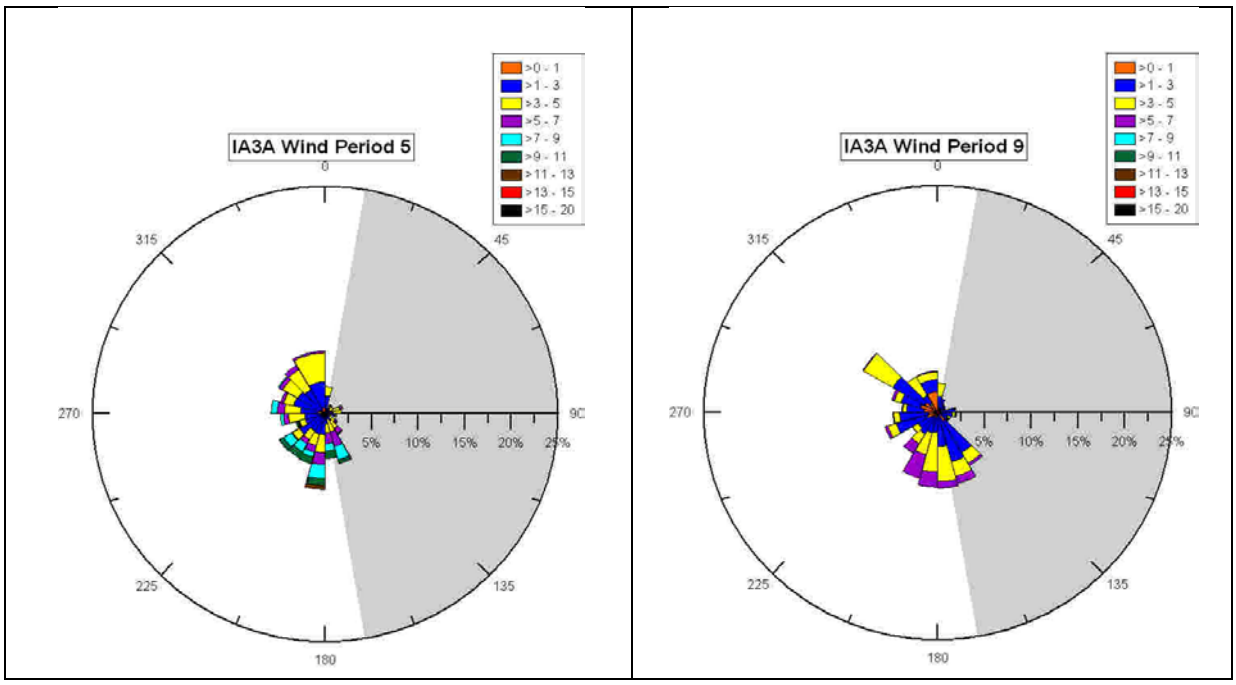

Figure 4.2-4: Wind roses for ½ hourly wind measurements during the spring measurement periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

4.3 Basin conditions

4.3.1 Basin appearance

The appearance of the basin was recorded on almost every site visit (Table 4.3-1). The basin generally appeared brown or black with surface characteristics ranging from frozen during the winter to free of crust during the remainder of the year. Crusting was evident in many of the measurement periods.

Table 4.3-1: Basin description

Period	Date, appearance (color/crust)
2: 8/30/2007 - 9/26/2007	8/30/2007 - 100% crusted 8/31/2007 - 100% crusted 9/17/2007 - brown/100% crust 9/18/2007 - brown 9/26/2007 - black/ 40% crust

Period	Date, appearance (color/crust)
3: 12/19/2007 - 1/15/2008	12/19/2007 - black/90% crust 12/20/2007 - black/90% crust 1/14/2008 - brown/100% crust 1/15/2008 - brown/100% crust
4: 5/14/2008 - 6/4/2008	5/14/2008 - black/no crust 5/15/2008 - black/no crust 6/4/2008 - black/no crust
5: 6/4-25/2008	6/4/2008 - black/no crust 6/5/2008 - black/no crust 6/12/2008 - black/no crust 6/23/2008 - black/no crust 6/24/2008 - black/no crust
6: 11/13-25/2008	11/12/2008 - black/no crust 11/13/2008 - dark/no rust 11/14/2008 - black/no crust 11/25/2008 - dark/100% frozen
7: 11/25/2008 - 12/16/2008	11/25/2008 - dark/100% frozen 12/15/2008 - white - 100% frozen 12/16/2008 - white - 100% frozen
8: 4/8-23/2009	4/8/2009 - black/no crust 4/9/2009 - black/no crust 4/22/2009 - brown/light scum 4/23/2009 - brown/light scum
9: 7/28/2009 - 8/17/2009	7/27/2009 - brown/100% crust 7/28/2009 - brown/100% crust 7/29/2009 - brown/100% crust 8/18/2009 - brown/100% crust

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4.3.2 Basin Chemistry

The composition of waste in the basin is documented in Table 4.3-2.

Table 4.3-2: Characteristics of liquid manure samples from the basin

			Percent (wet weight basis)			
Date	**n**	**pH (SU)** (Mean ± standard deviation)	**Nitrogen** (Mean ± standard deviation)	**Solids** (Mean ± standard deviation)	**Ammonia** (Mean ± standard deviation)	**Sulfur** (Mean ± standard deviation)
6/4/2008	3	7.54 ± 0.02	N/A	1.33 ± 0.05	0.24 ± 0.01	N/A
4/9/2009	3	7.62 ± 0.03	0.37 ± 0.02	1.81 ± 0.04	0.30 ± 0.01	N/A
(est 4/15/2009)	3	7.44 ± 0.08	0.40 ± 0.02	1.82 ± 0.12	0.30 ± 0.03	N/A
7/29/2009	3	6.91 ± 0.02	0.47 ± 0.02	4.20 ± 0.13	0.36 ± 0.02	0.03 ± 0.00
8/18/2009	3	7.11 ± 0.10	0.48 ± 0.02	4.37 ± 0.07	0.33 ± 0.00	0.03 ± 0.00

4.4 Emissions measurements

Emissions data were calculated on a ½ h basis since this was the interval over which the S-OPS system sampled both sides of the basin and since this interval is in the range over which turbulence statistics are often calculated. Emissions reported on a head basis were scaled by the design animal population and not the animal population at the time of measurements to account for the longer term manure storage of the basin or basin. Emissions reported on an animal unit (AU) basis assumed an animal weight of 500 kg equals 1 AU and the typical animal weight values reported by the producer. Emissions reported on an area basis are based on the surface area of the basin.

Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison was based on 624 ½ h half-hour measurement periods over the entire measurement time at this location. Results show that the bLS emissions did not have a significantly difference precision (F=0.70, critical F 1.0) but had a significant bias over the *RPM* emissions (t=-20.5, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 0.63 (Table 4.4.1-1). Consequently the ½ hour bLS emissions measurements are biased low by 36% compared to the *RPM* measurements.

Table 4.4.1-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	bLS	bLS-RPM
Mean emission (gs^{-1})	0.662	0.432	-0.240
Standard deviation (gs^{-1})	0.458	0.384	
Variance of the mean (gs^{-1})	0.210	0.148	

4.4.1 NH_3 Emissions

4.4.1.1 Mean daily NH_3 emissions

An annual trend in the daily NH_3 emissions based on the *RPM* model was indicated (Figure 4.4.1-1) with a summer maximum emission of approximately 30 g $NH_3d^{-1}hd^{-1}$. The daily emissions during the winter decreased to approximately 5 g $NH_3d^{-1}hd^{-1}$. The measurements with potential for atmospheric moisture interference could be low by 40% (Figure 4.4.1-1: green circles). There were only a small number of measurements with more than 75% of the day's emissions measured. The wide variability during the summer in combination with the few 'complete' days of measurements limits confidence in the magnitude of the emissions. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

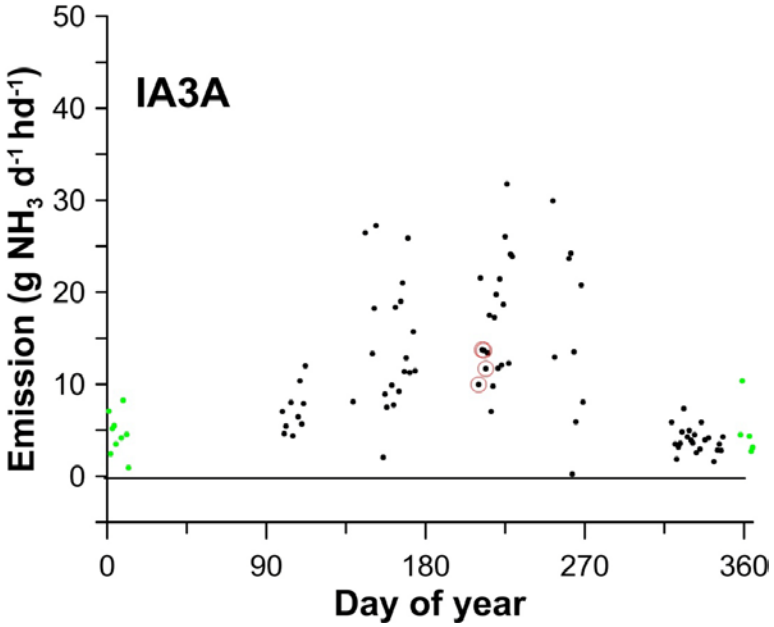

Figure 4.4.1-1: Annual variation in daily RPM-computed NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

An annual trend in the daily NH_3 emissions based on the bls model was indicated (Figure 4.4.1-2) with a fall maximum emission of approximately 30 g $NH_3 d^{-1} hd^{-1}$. The daily emissions during the winter decreased to negligible levels. The measurements with potential for atmospheric moisture interference could be low by 40% (Figure 4.4.1-2: green circles). The number of daily emissions measurements based on more than 75% of the day's emissions measured during the summer suggest a summer emissions of 5 g $NH_3 d^{-1} hd^{-1}$ and a fall emissions of approximately 20 g $NH_3 d^{-1} hd^{-1}$. The wide variability during the summer in combination with the few 'complete' days of measurements limits confidence in the magnitude of the emissions. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

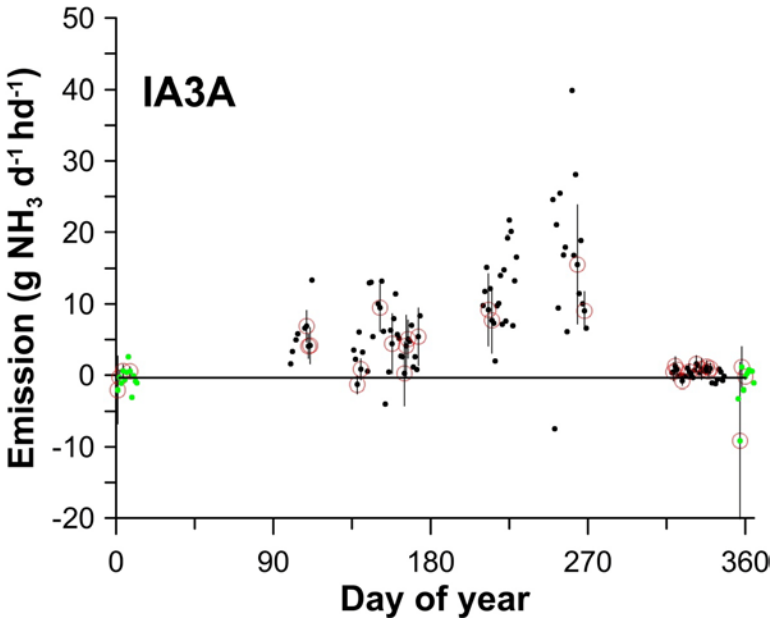

Figure 4.4.1-2: Annual variation in daily bLS-computed NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH_3 concentration measurement. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS model is influenced by the calculated background concentrations. Results indicate that the background concentration of NH_3 was generally less than 0.3 ppm (Figure 4.4.1-3). Given that the typical path length around the basin was 50 m and the typical background concentration is less than 0.3 ppm, this corresponds to a background concentration for a given PIC of aproximately 15 ppm-m. This is approximately seven times the MDL for the TDLAS instruments of 2 ppm-m (Section 8.1) and therefore represents a real background for this location. This may be expected given the close proximity of the barns on this farm.

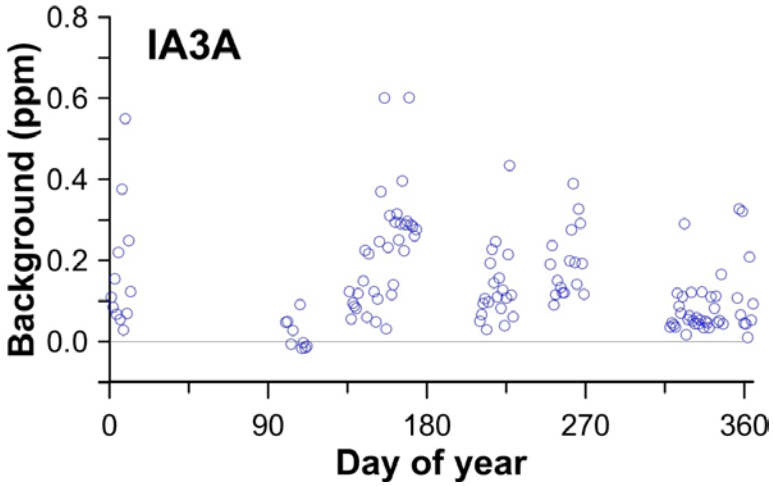

Figure 4.4.1-3: Annual variation in mean daily bLS-computed background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

There was a distinct diurnal pattern in the daily NH_3 emissions during most of the measurement periods except during the winter with emissions higher during the daytime (Figure 4.4.1-4).

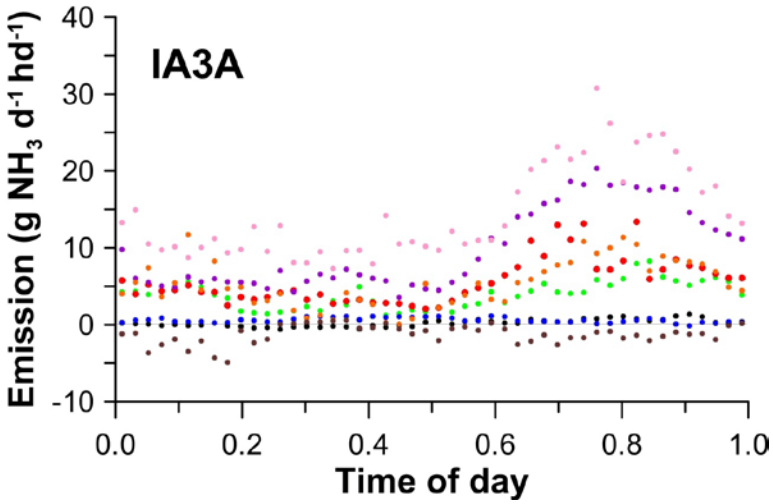

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 2-Fall (pink), Period3-Winter (brown), Period 4-Spring (orange), Period 5 (green), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ h periods (corresponding to 75% completeness on a daily basis) is given. Because of the requirement of 5 to 10 valid TDLAS measurements before an *RPM* emission measurement is possible, the number of valid ½ h periods with *RPM* emissions was greatly limited. The wind conditions and wind direction exclusion region did not greatly reduce the yield of valid bLS emission measurements. The completeness statistics are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

	Measurement periods								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
NH_3 RPM model									
Valid 1/2 h measurements (d)	1.8	1.5	1.1	2.9	0.9	1.9	2.6	9.5	**22.1**
Measurements excluded due to wind direction (d)	0.5	0.1	0.1	0.9	0.0	1.0	5.3	1.5	**9.3**
Measurements excluded because at least one downwind path is missing or invalid (d)	22.6	17.5	18.1	12.4	5.6	4.2	2.0	5.9	**88.3**
Number of days with ≥ 36 valid 1/2 h periods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	**4.0**
NH_3 bLS model									
Valid 1/2 h measurements (d)	6.0	11.4	6.7	10.1	7.0	10.2	3.9	8.9	**64.1**
Measurements excluded due to wind direction (d)	3.9	5.7	9.8	3.3	1.5	3.8	7.0	3.6	**38.5**
Measurements excluded because touchdown fraction < 0.1 (d)	3.6	0.4	0.0	0.1	0.0	0.2	0.0	0.0	**4.3**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| <$ 2 m (d)	6.1	5.2	2.8	3.4	1.8	3.2	2.6	6.6	**31.6**
Number of days with ≥ 36 valid 1/2 h periods	2.0	7.0	3.0	5.0	5.0	5.0	3.0	2.0	**32.0**

In total, 22 d of valid NH_3 emissions were determined from the 153 measurement days using the *RPM* model, with only 4 d having at least 36 valid ½ hour NH_3 emissions. The absence or invalidation of at least one downwind path led to 88 d for which emissions could not be calculated.

Sixty four days of valid NH_3 emissions were determined from the 153 measurement days using the bLS model, with 32 d having at least 36 valid ½ hour NH_3 emissions. The exclusion wind directions due to the location of the barns relative to the basin resulted in the loss of 39 d of measurements. Invalid turbulence statistics ($u_* < 0.15$ m/s or $|L| < 2$ m) led to 23 d for which emissions could not be calculated. A touchdown fraction of less than 0.1 led to the exclusion of

4 d of data. Low touchdown fractions indicated that little, if any, downwind data was available. This corresponded to either when the downwind TDLAS was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ hour interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ hour mean wind speed and direction, in contrast to the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times that the *RPM* model produces a valid emission that the bLS model does not. However, these times are overwhelmed by the times that the *RPM* model is missing concentration data for one or more paths, while the bLS model is able to run.

4.4.2 H_2S emissions

4.4.2.1 Mean daily H_2S emissions

Emissions of H_2S calculated using the Ratiometric model were highest in the late summer (Figure 4.4.2-1). Peak emissions were approximately 6 g H_2S d^{-1} hd^{-1}. There was however wide variability in H_2S emissions from day to day (Figure 4.4.2-1). Since only one day had more the 75% of the ½ periods with valid emissions measurements, there is no confidence that the emissions pattern illustrated is representative of conditions on the farm. One value (45.4 g H_2S d^{-1} hd^{-1}) is not plotted. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

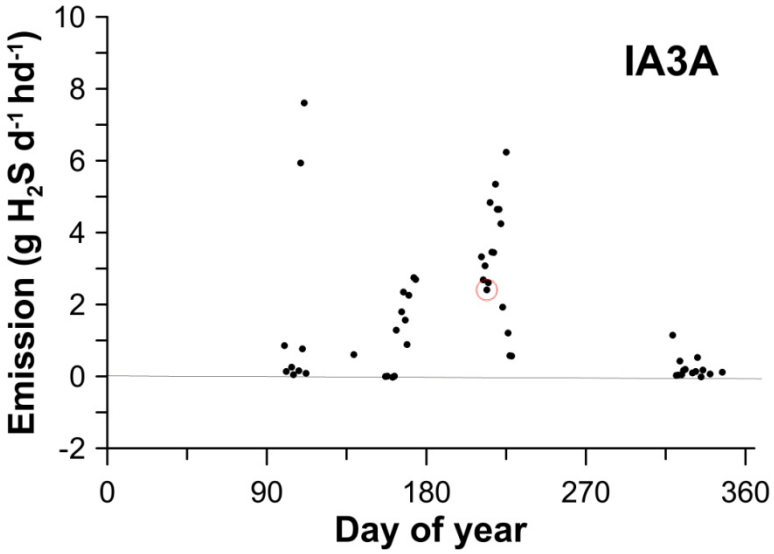

Figure 4.4.2-1: Annual variation in daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

Emissions of H_2S calculated using the bLS model were highest in the summer (Figure 4.4.2-1). Peak emissions were approximately 20 g H_2S d^{-1} hd^{-1}. There was however wide variability in

H_2S emissions from day to day (Figure 4.4.2-2). Since only a few days had more the 75% of the ½ periods with valid emissions measurements, there is no confidence that the emissions pattern illustrated is representative of conditions on the farm. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4

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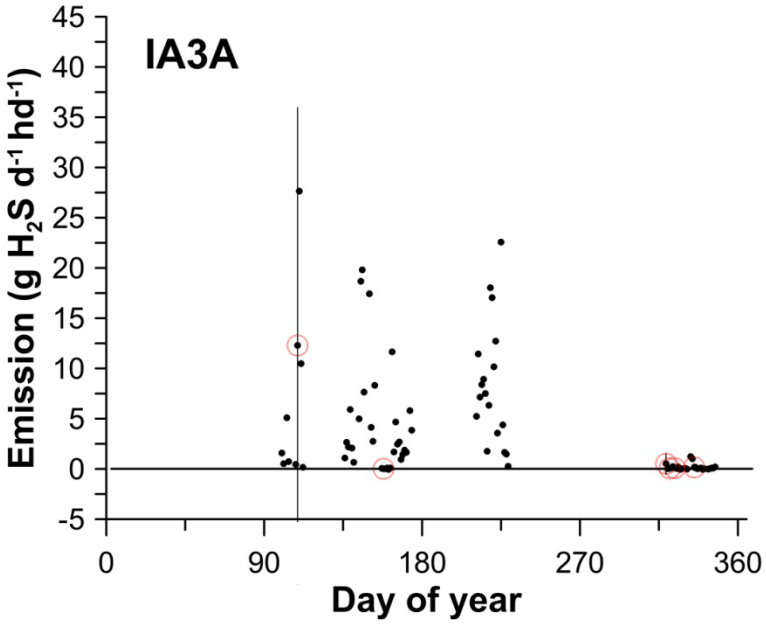

Figure 4.4.2-2: Annual variation in daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements. The bar reaching the x-axis falls below the axis.

The bLS model is influenced by the calculated background concentrations. Results indicate that the background concentration of H_2S was generally less than 5 ppb (Figure 4.4.3-3). This is approximately two times the MDL for the instrument (Section 6.2) and therefore may represent a real background for this location. This may be expected given the close proximity of the barns on this farm.

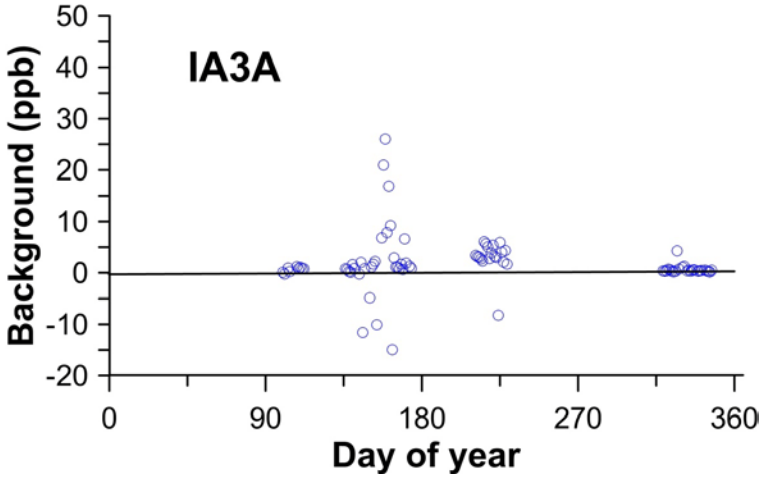

Figure 4.4.3-3: Annual variation in mean daily background concentration of H_2S.

4.4.2.2 Diurnal variation in H_2S emissions

No distinct diurnal pattern was evident in the measurements although higher emissions didi occur during the daytime (Figure 4.4.2-4).

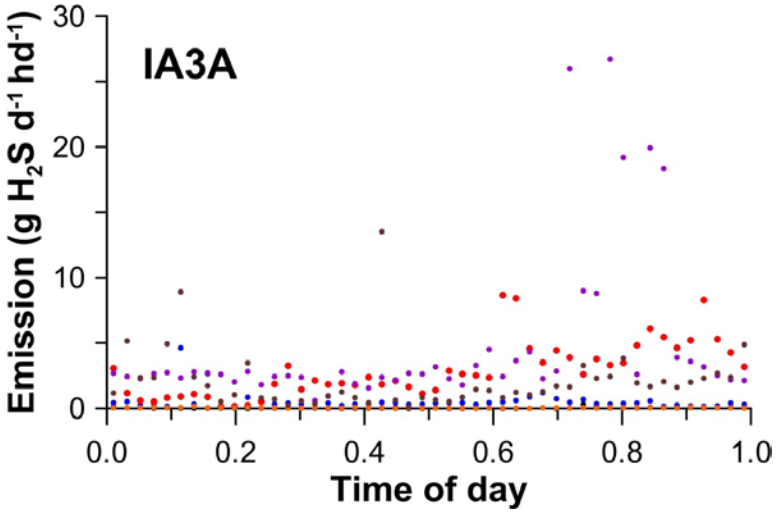

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 4-Spring (brown)), Period 5-Summer (blue), Period 6-Fall (orange), Period 7-Winter (black), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.2.3 H_2S emissions data completeness

H_2S Measurements were begun in Period 3. Consequently there were no measurements possible for Fall 2007. As described for the NH_3 emissions, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the

indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics are summarized in Table 4.4.2-1.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

	Measurement periods								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
H_2S Ratiometric model									
Valid 1/2 h measurements (d)	0.0	0.0	0.0	1.7	0.4	0.4	1.3	4.7	8.5
Number of days with ≥ 36 valid 1/2 h periods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
H_2S bLS model									
Valid 1/2 h measurements (d)	0.0	0.0	3.1	6.3	5.0	5.8	2.1	5.6	**28.0**
Measurements excluded due to wind direction (d)	0.0	0.0	9.6	2.3	1.5	3.8	6.4	3.4	**26.9**
Measurements excluded because angle of attack > 60 degrees (d)	0.0	0.0	2.8	3.4	1.1	3.3	1.1	2.6	**14.4**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| <$ 2 m (d)	0.0	0.0	2.9	3.7	1.6	2.9	2.5	6.2	**19.8**
Number of days with ≥ 36 valid 1/2 h periods	0.0	0.0	0.0	1.0	3.0	1.0	1.0	0.0	**6.0**

Because there were few valid ½ measurements of the NH_3 emissions based on the *RPM* model (Table 4.4.1-2), the number of valid ½ periods of valid Ratiometric emissions measurements of H_2S is small. The majority of bLS emissions measurements were invalidated due to wind conditions. In total, 8 d of valid H_2S emissions were determined using the Ratiometric emission method, with only one day having at least 36 valid ½ hour H_2S emissions. Twenty eight days of valid H_2S emissions were determined using the bLS model, with 6 d having at least 36 valid ½ hour H_2S emissions. Measurements excluded due to wind direction was the dominant source of invalidate measurements. Invalidation of measurements due to turbulence statistics ($u_* < 0.15$ m/s or $|L| < 2$ m) was also a significantly factor in the number of days with valid measurements.

4.4.3 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of the TDLAS serial numbers 1026, 1027, and 1028 prior to July 21, 2008. TDLAS 1026 was used at IA3A from 8/30/2007 to 9/26/2007 (Measurement period 2) and 12/19/2007 to 1/15/2008 (Measurement period 3). TDLAS 1027 was used at IA3A from 5/14/2008 to 6/4/2008 (Measurement period 4). TDLAS 1028 was used at IA3A from 8/30/2007 to 9/26/2007 (Measurement period 2), 12/19/2007 to 1/15/2008 (Measurement period 3) and 5/14/2008 to 6/4/2008 (Measurement period 4), and 6/4/2008 to 6/25/2008 (Measurement period 5). Under the calibration verification checks, the TDLAS error of all units was 10% accuracy. However due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and

units without apparent interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from dewpoint temperatures of -2°C to 20°C. A conservative estimate of the accuracy of all of the above TDLAS units with evident moisture interference was estimated at 40%.

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions, underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%. Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was -36% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -76% for TDLAS NH_3 measurements made by units with moisture interference and a bias of -36% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the Ratiometric measurement of H_2S emissions was ± 18%.

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6 Appendices

6.1 TDLAS NH_3 calibrations

Five TDLAS units (Model GasFinder 2.0^{TM} NH3OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used at this location: TDLAS 1026, TDALS 1027, TDLAS 1028, TDLAS 1030, and TDLAS 1031.

TDLAS 1026 was multipoint calibrated seven times during the study (Figure 6.1-1). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 1/17/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ± 10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and

11/10/2009 bias exceedances were followed the same or next day with a passing verification and was deemed to be a result of operator error. The negative bias over the period 4/2/2008 through 7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used). During operations the bias was only intermittently evident because to different multipoint calibration was applied to the calibration verification measurements during the progress of the study than finally applied during the analysis. Repeated calibrations within 24 h often showed biases differing by more than 10 ppm-m suggesting operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period are considered valid and the error assumed to be due to the calibration verification operator.

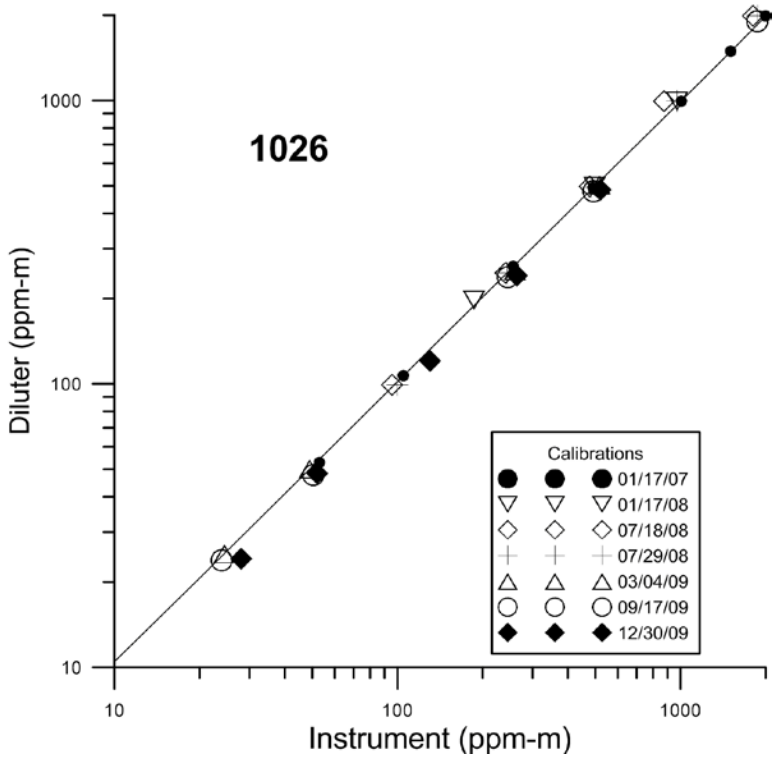


Figure 6.1-1: Multipoint calibrations of the GasFinder 2.0 ™ s/n NH3OP-1026. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

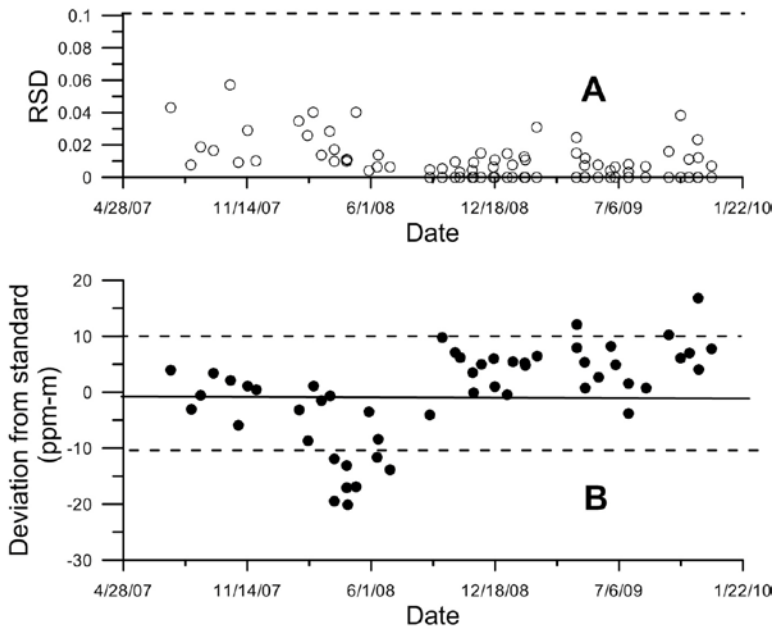


Figure 6.1-2: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1026

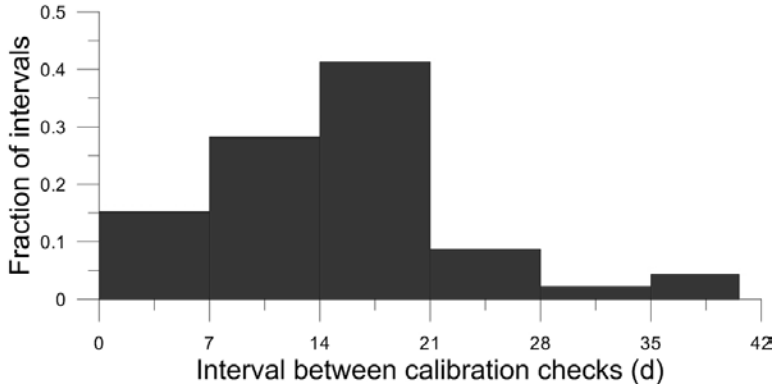


Figure 6.1-3: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1026

TDLAS 1027 was multipoint calibrated eight times during the study (Figure 6.1-4). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 6/18/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 2.24 + 0.9936 * X - 3.59E\text{-}5 * X^2 + 6.230E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference

cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.13 ppm-m prior to the July 2008 modification and 1.83 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 5.36 ppm-m. The precision DQI was ± 10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 9/26/2008 and 9/24/2009 (Figure 6.1-4). No negative biases exceeding the DQI occurred. Since both positive bias exceedances were followed by a DQI compliant verification on the subsequent calibration verification without intervention, it is assumed that operator error was the cause for the non-compliance.

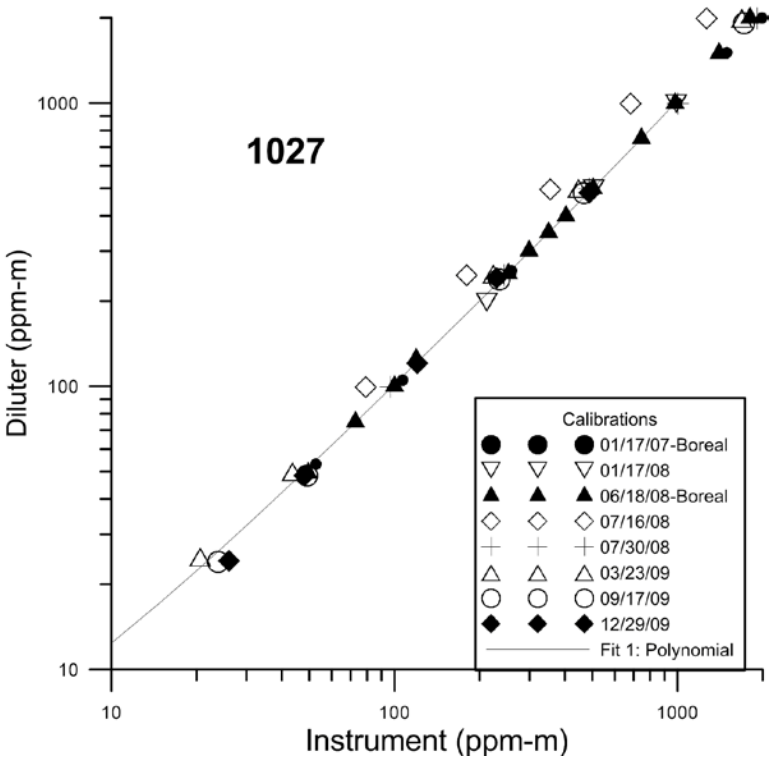


Figure 6.1-4: Multipoint calibrations of the GasFinder 2.0 ™ s/n NH3OP-1027. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

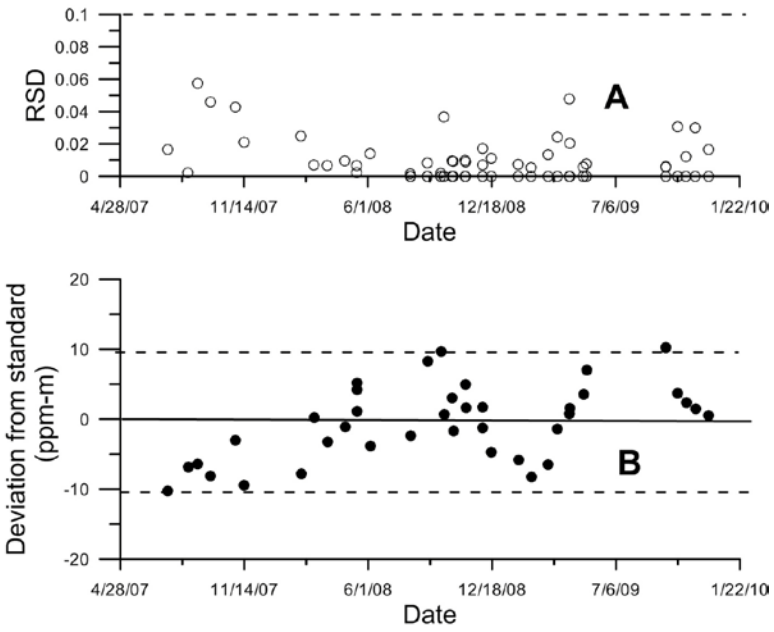


Figure 6.1-5: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1027

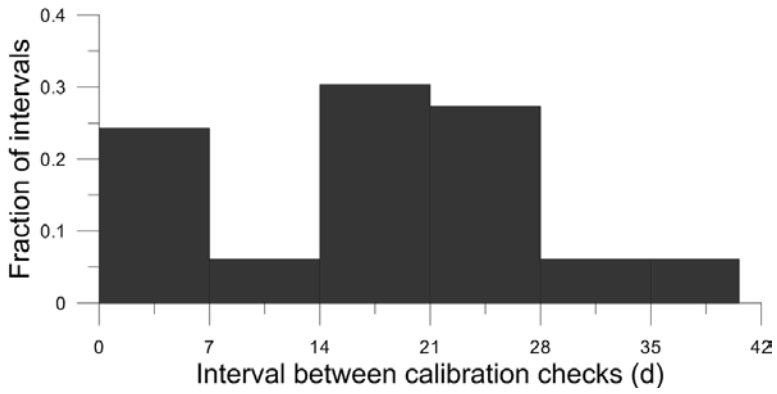


Figure 6.1-6: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1027

TDLAS 1028 was multipoint calibrated six times during the study (Figure 6.1-7). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/23/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 1.46 + 0.985 * X + 8.465E\text{-}6 * X^2 + 3.879E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision

DQI was ± 10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-8) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 6.1-8). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

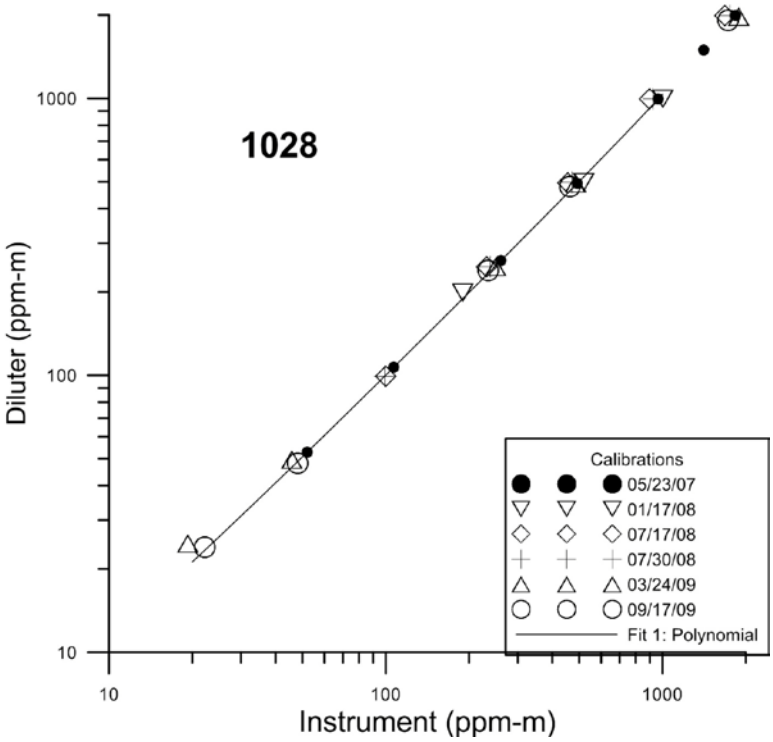


Figure 6.1-7: Multipoint calibrations of the GasFinder 2.0 ^{TM} s/n NH3OP-1028. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

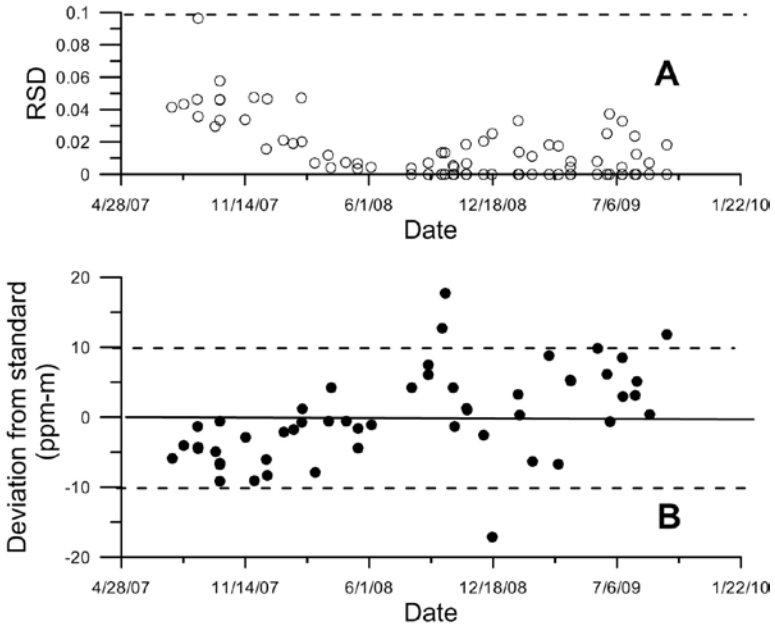


Figure 6.1-8: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1028

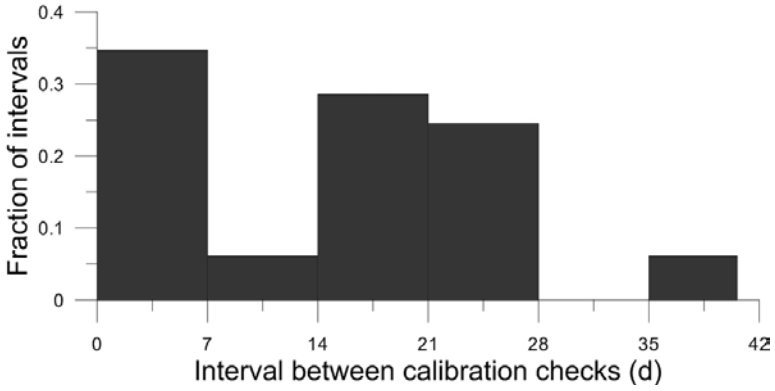


Figure 6.1-9: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1028

TDLAS 1030 was multipoint calibrated eight times (Figure 6.1-10). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 3/26/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 0.13 + 0.9974 * X - 2.1056E\text{-}005 * X^2 + 3.050E\text{-}008 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference

cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. The adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 3.05 ppm-m prior to the July 2008 modification and 0.685 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-12). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 7.27 ppm-m. The precision DQI was ± 10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m except on 8/30/2007 (Figure 6.1-11) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 8/14/2008 and 9/23/2008 while negative biases exceeding the DQI occurred on 10/4/2007, 9/23/2008, and 4/28/2009 (Figure 6.1-11). In all cases, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

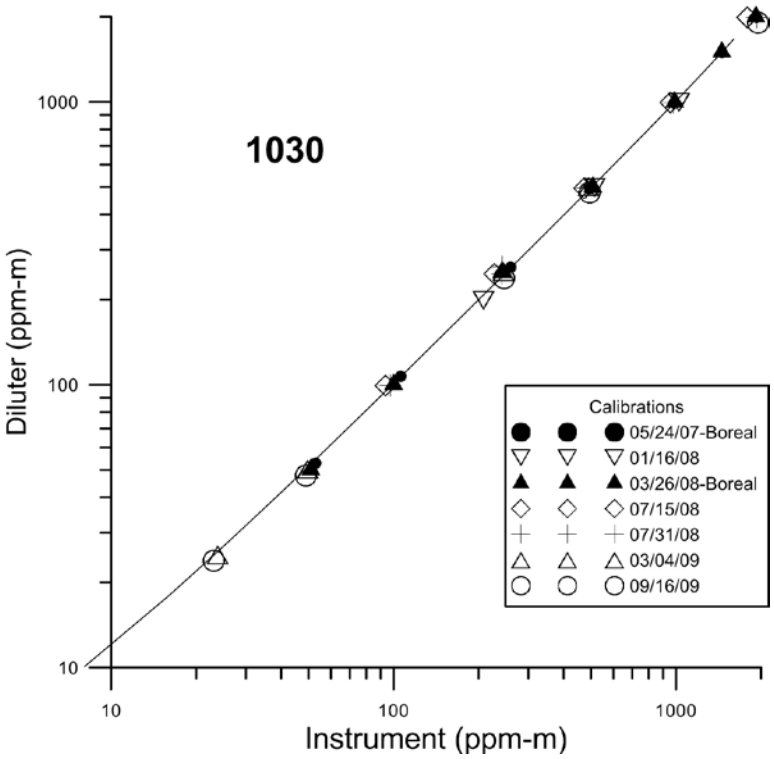


Figure 6.1-10: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1030. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

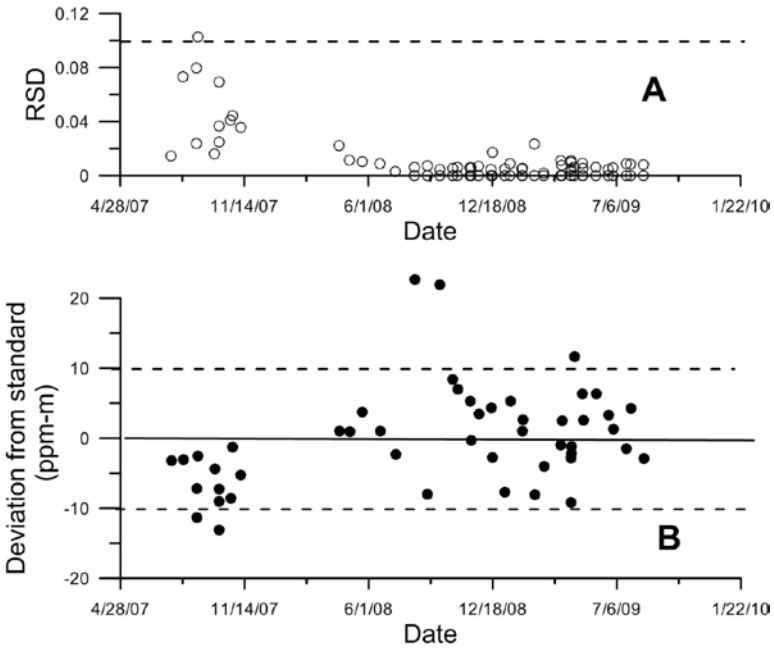


Figure 6.1-11: Control charts of the GasFinder 2.0 [TM] s/n NH3OP-1030

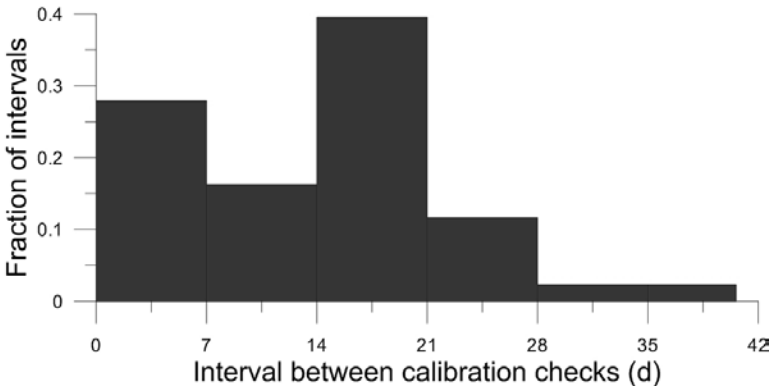


Figure 6.1-13: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1030

TDLAS 1031 was multipoint calibrated six times during the study (Figure 6.1-13). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/30/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -4.43 + 1.0120 * X - 5.7496E\text{-}005 * X^2 + 6.0196E\text{-}008 * X^3$$

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 5.70 ppm-m prior to the July 2008 modification and 1.92 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The average MDL was approximately equal to the offset indicated in the calibration regression. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-14) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-15). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 15.60 ppm-m. The precision DQI was ± 10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-14) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI occurred in the calibration verifications between 8/2/2007 and 9/18/2007 (Figure 6.1-14). Positive DQI bias

exceedances occurred on 6/28/2007, 9/11/2008, 4/8/2009 and 8/12/2009. Verification failures in the 6/28/2007 to 9/18/2007 interval were a result of un-anticipated optical noise in the calibration procedure which was later corrected. The 4/8/2009 exceedance was preceded and followed by DQI-compliant verifications and the 8/12/2009 verification was preceded by a compliant verification and followed by a multipoint indicating no problem with instrument performance. The instrument was taken out of service between 9/11/2008 and 12/31/2008.

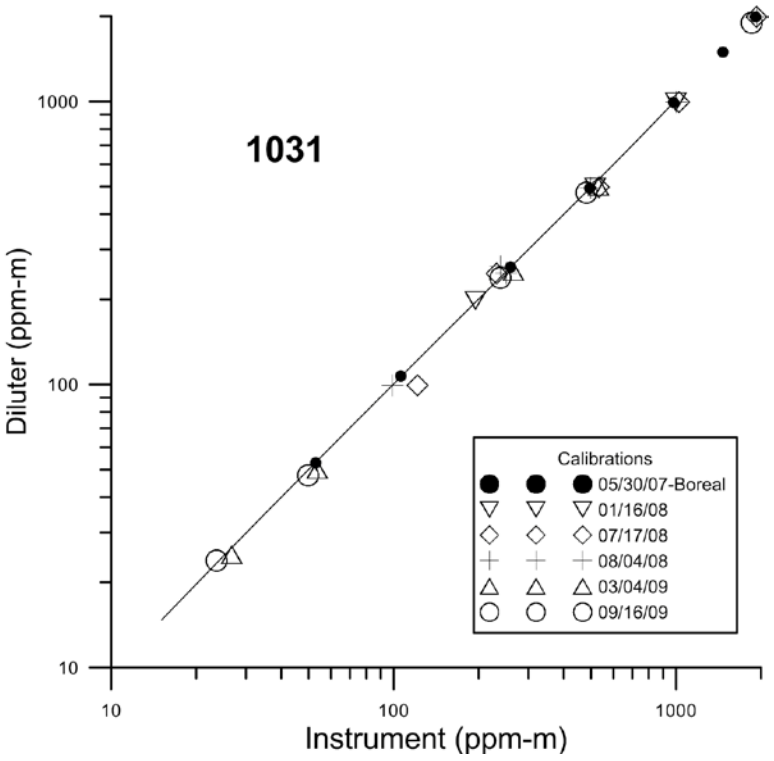


Figure 6.1-13: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1031. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

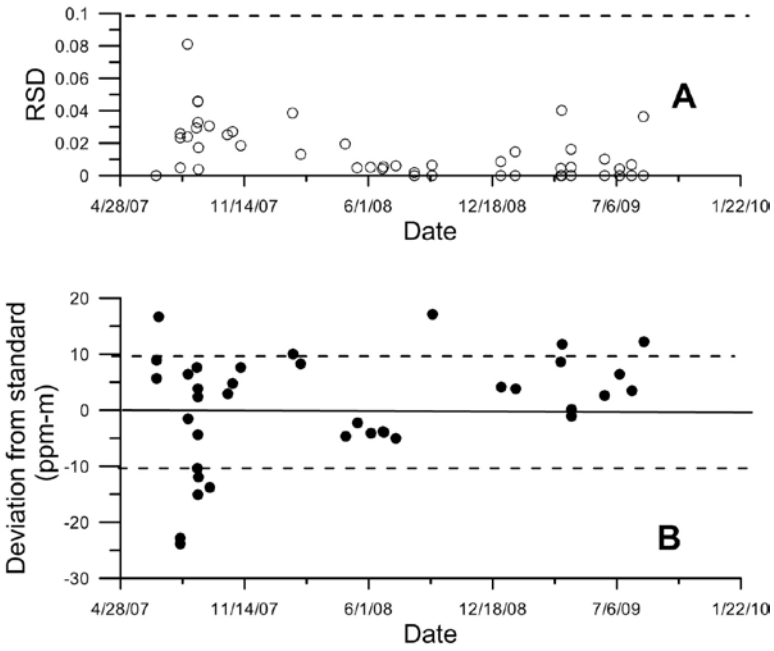


Figure 6.1-14: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1031

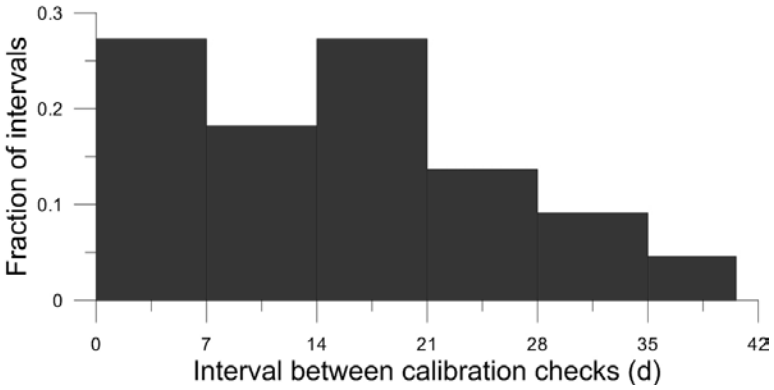


Figure 6.1-15: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1031

6.2 TEC 450i analyzer H_2S calibrations

The H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA) with serial number 0733825129 was multipoint calibrated seven times during the study (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.67 to 0.94 (Table 6.2-1). The initial 12/30/07 multipoint calibration records were lost.

Table 6.2-1: Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
7/21/2008	0.67	0.0100	0.999
11/25/2008	0.81	0.0070	0.999
3/5/2009	0.94	0.0165	0.999
4/23/2009	0.73	0.0263	0.999
4/29/2009	0.78	0.0206	0.999
9/1/2009	0.75	0.0054	0.999
12/29/2009	0.81	0.0083	0.999

The standard deviation of instrument response with CEM zero air measured over a one h period was 0.81 ppb (12/29/2009). The instrument MDL, defined as 3σ was 2.4 ppb and is indicated in Figure 6.1-2A with dashed lines. This is much less than the mean absolute value of the multipoint calibration intercept of 13.4 ppb.

Instrument performance calibration checks (Figure 6.1-2, 6.1-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 25 d (Figure 6.1-4). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.800. The mean zero concentration was +0.3 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). The initial calibration check (1/15/2008) was conducted prior to the complete burn-in of the converter and consequently differs from the other calibrations and indicated a failed check in the post-study response check (Figure 6.1-2B). Post-study response checks in August and September 2008 also indicated check failures (Figure 6.1-2B), although all of these failures are associated with a non-diluted calibration cylinder where the balance gas was N_2 and consequently the 450i converter was unable to function properly.

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedances (Figure 6.1-3) occurred on 2/12/2008 and 3/5/2009. The 2/2/2008 failure was likely due to the burn-in of the converter and signals changes in the instrument response as the instrument is conditioned. The failure on 3/5/2009 was likely a result of the use of an out-of-certification range calibration cylinder (although within certification period; FF44447). This cylinder was 38% below the mean concentration of nine cylinder inter-compared on 8/28, 31/2009. Calibration certification before and after this date were valid.

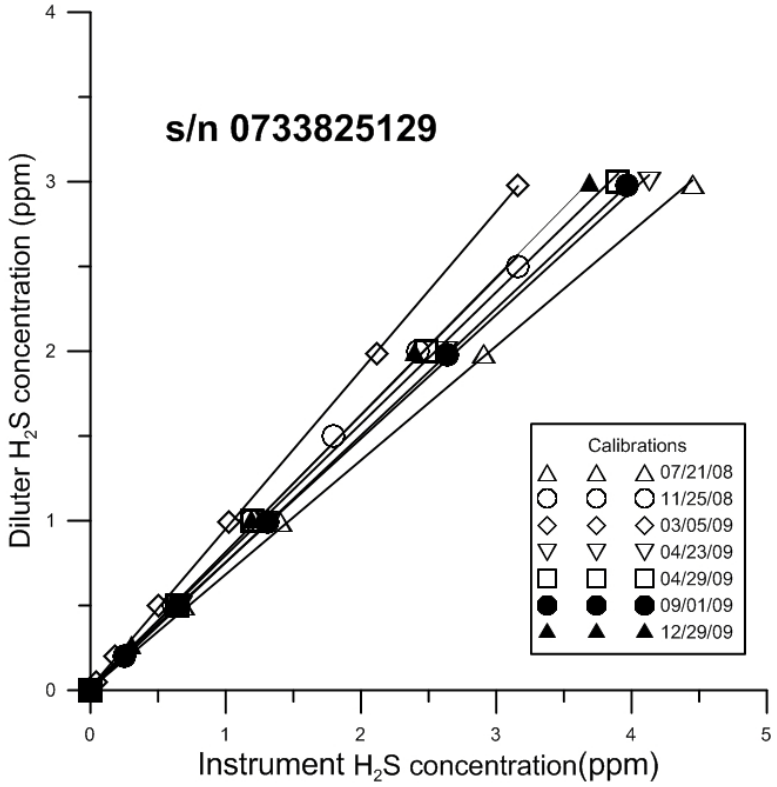


Figure 6.2-1: Multipoint calibrations of the 450i SO_2/H_2S Analyzer

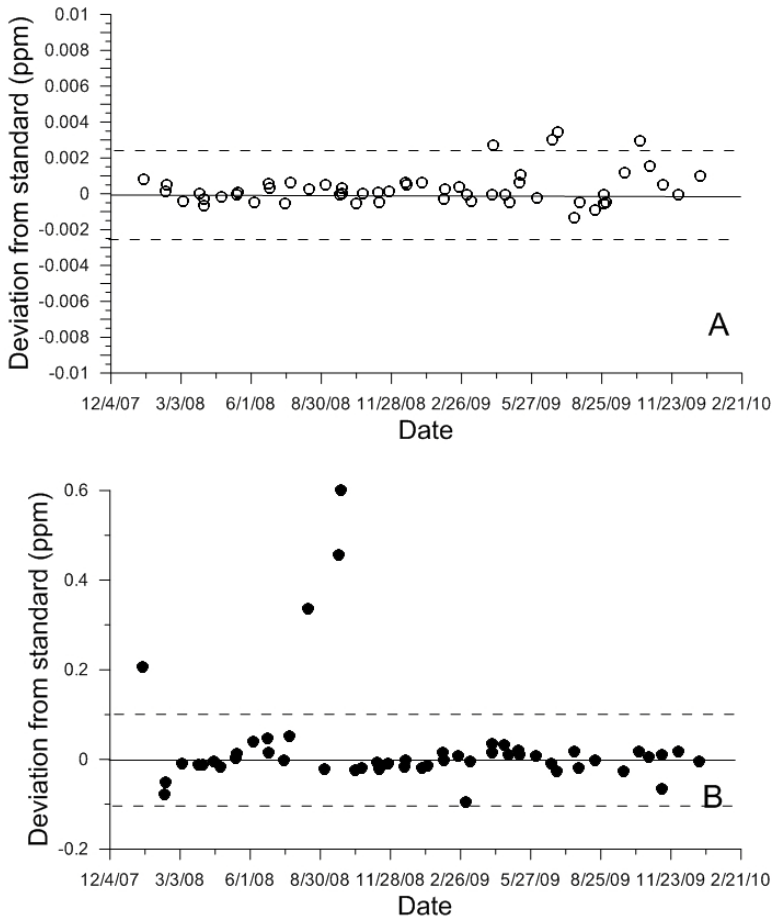


Figure 6.1-2: Instrument Control Charts

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

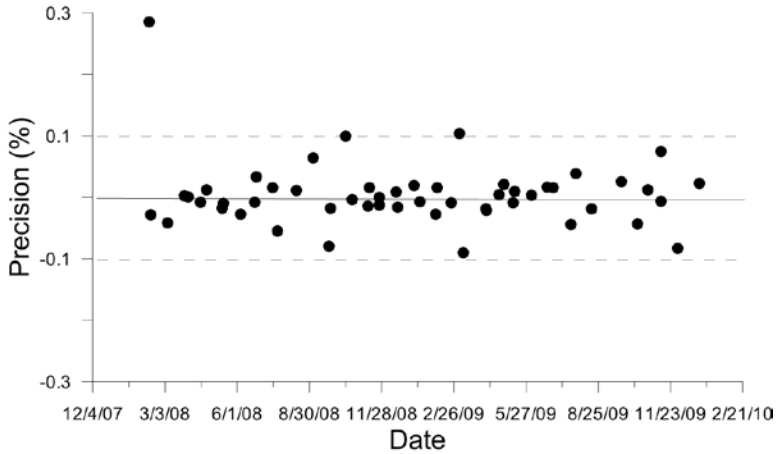


Figure 6.1-3: Instrument Precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

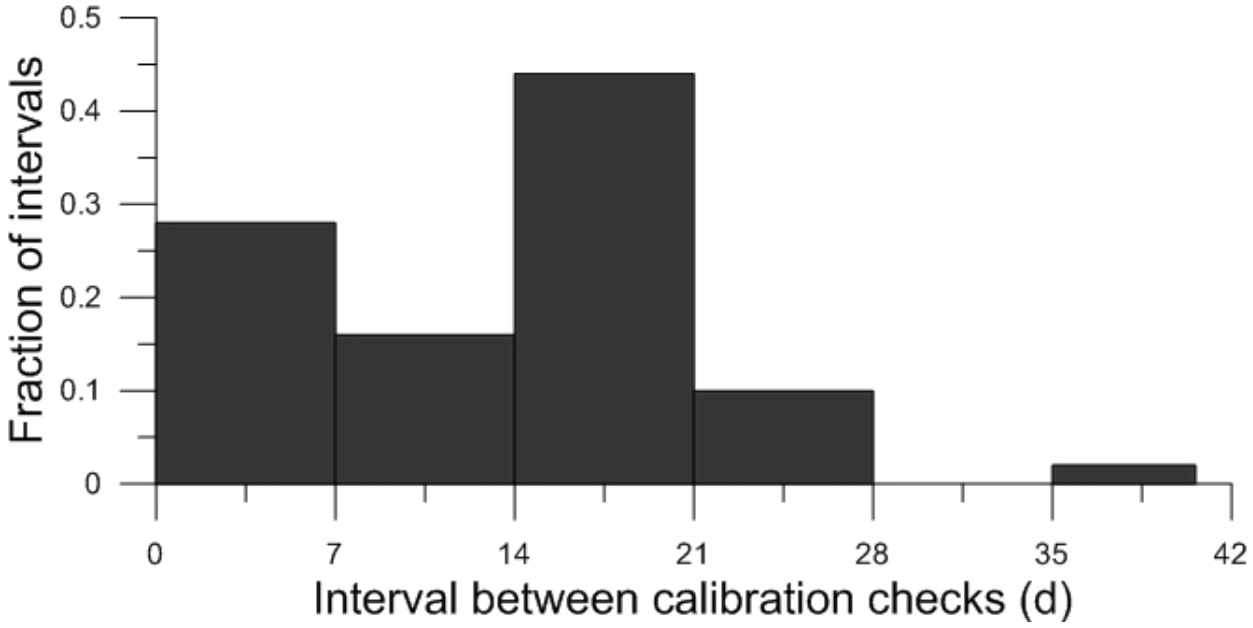


Figure 6.1-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Six sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were used at this location: serial numbers 1926, 1933, 1920, 1928, 1945, and 1932.

Sonic anemometer 1926 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-1). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail such the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-1: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29 - 7/2/2007	-0.005	-0.033
1/17-18/2008	1/20-21/2008	-0.013	-0.032
7/16-17/2008	7/17-18/2008	+0.037	+0.059
3/6-7/2009	3/7-9/2009	+0.004	+0.048
9/16-17/2009	9/17-18/2009	+0.059	+0.001

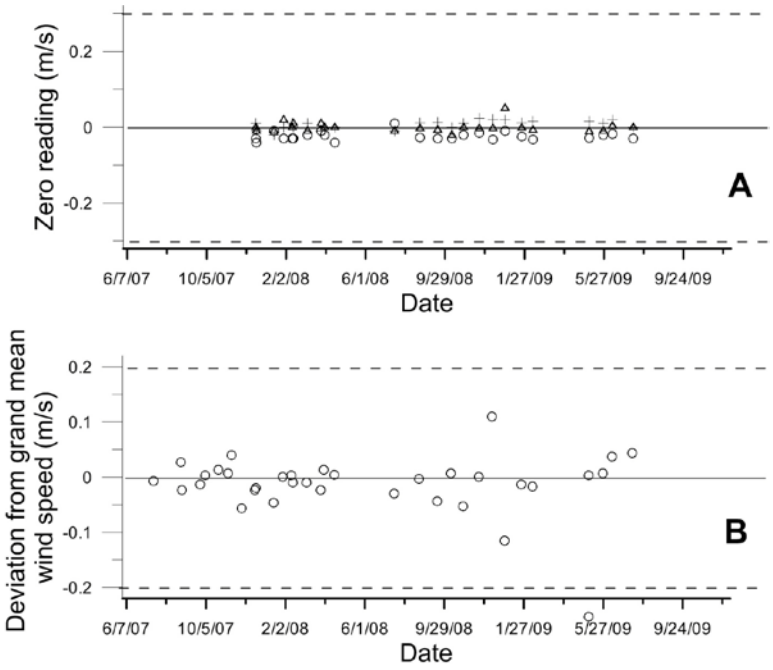


Figure 6.3-1: On-site quality assurance of s/n 1926. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

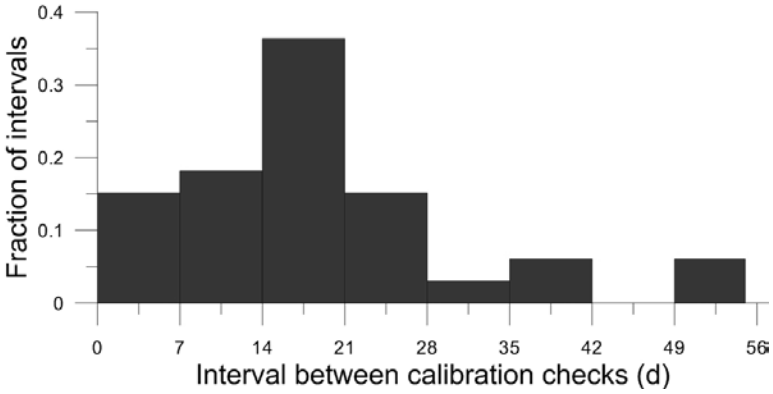


Figure 6.3-2: Inter-comparison check intervals for s/n 1926

Sonic anemometer 1933 was inter-compared with three standard anemometers of identical design three times during the study (Table 6.3-2). This instrument was used as a standard prior to use in the on-site measurements beginning 4/23/2008. No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 23 times (Figure 6.3-3). The

majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-3B). This instrument passed this check on all checks except 7/21/2009 and was taken out of service. The last standard inter-comparison (1/2010) failed due to loss of communications.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-3A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-2: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
7/18-19/2008	7/21-22/2008	+0.012	+0.014
3/3-5/2009	3/5-6/2009	-0.016	-0.004
1/7-9/2010	1/23-25/2010	-3.733	-3.930

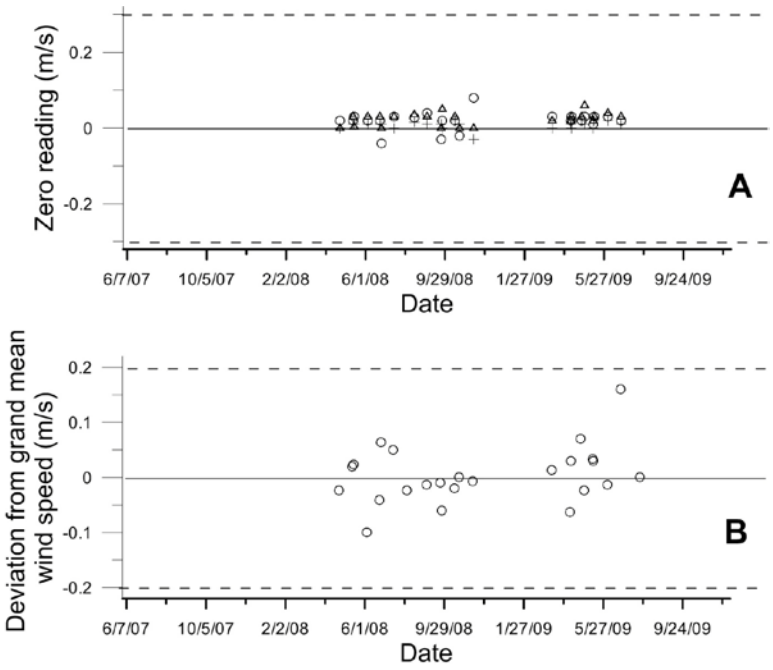


Figure 6.3-3: On-site quality assurance of s/n 1933. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

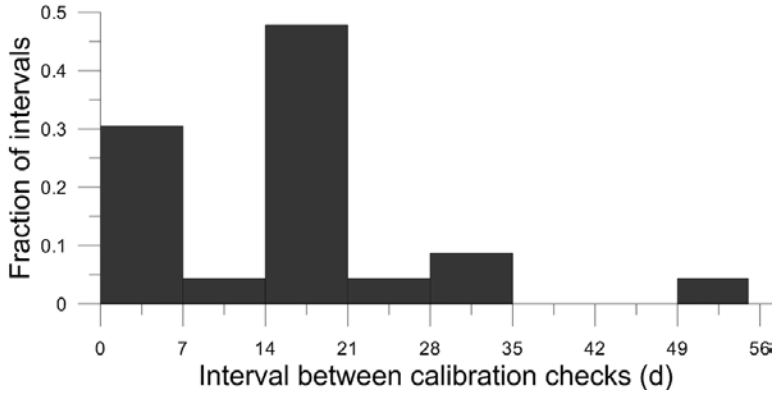


Figure 6.3-4: Inter-comparison check intervals for s/n 1933.

Sonic anemometer 1920 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-3). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 51 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-5B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 10/10/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-3: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29 - 7/2/2007	+0.001	+0.002
1/17-19/2008	1/20-21/2008	+0.045	+0.003
7/18-21/2008	7/21-22/2008	+0.017	-0.006
3/23-25/2009	3/25-27/2009	-0.036	-0.033
9/1-2/2009	9/2-3/2009	-0.046	-0.025

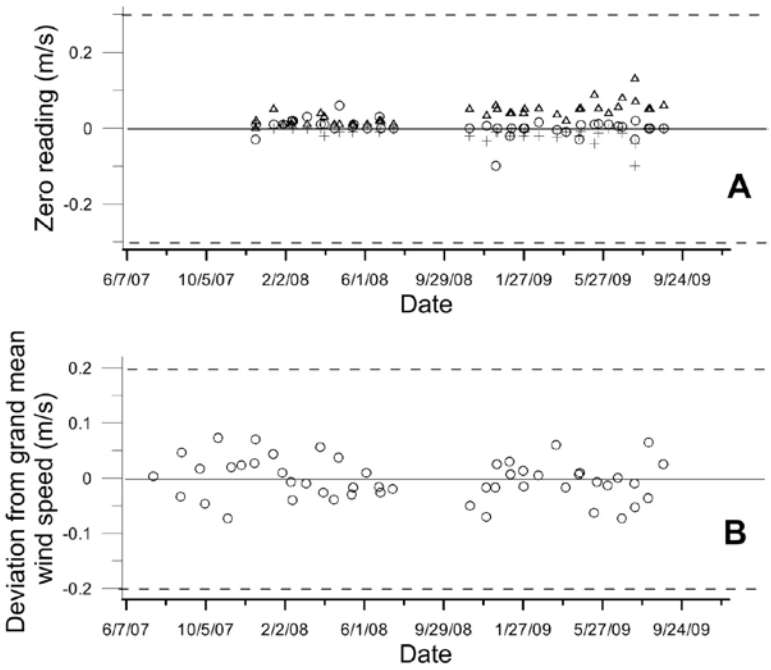


Figure 6.3-5: On-site quality assurance of s/n 1920. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

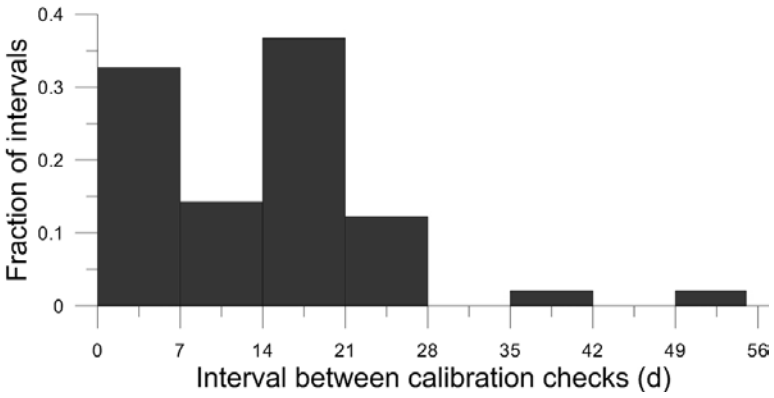


Figure 6.3-6: Inter-comparison check intervals for s/n 1920

Sonic anemometer 1928 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-4). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 48 times (Figure 6.3-7). The majority of calibration checks were made within 21 d (Figure 6.3-8). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments(Figure 6.3-7B). This instrument passed this check all but one time. On this one date, the inter-comparison was rerun and the instrument passed the check.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-7A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-4: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.004	+0.019
12/27-28/2007	12/29-31/2007	+0.003	-0.005
7/10-11/2008	7/11-14/2008	+0.022	+0.007
3/3-4/2009	3/5-6/2009	+0.070	-0.027
9/16-17/2009	9/17-18/2009	+0.056	+0.022
12/18-19/2009	12/21-23/2009	+0.094	-0.077

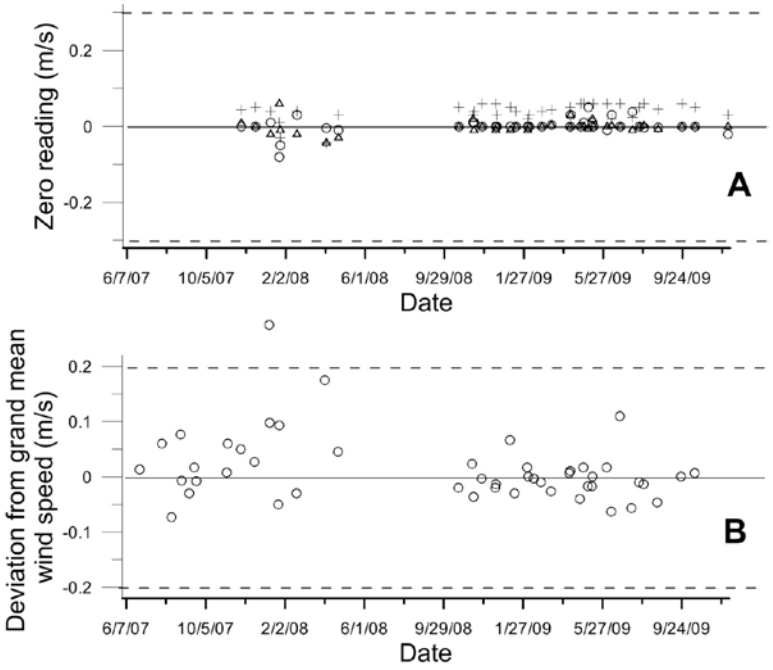


Figure 6.3-7: On-site quality assurance of s/n 1928. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

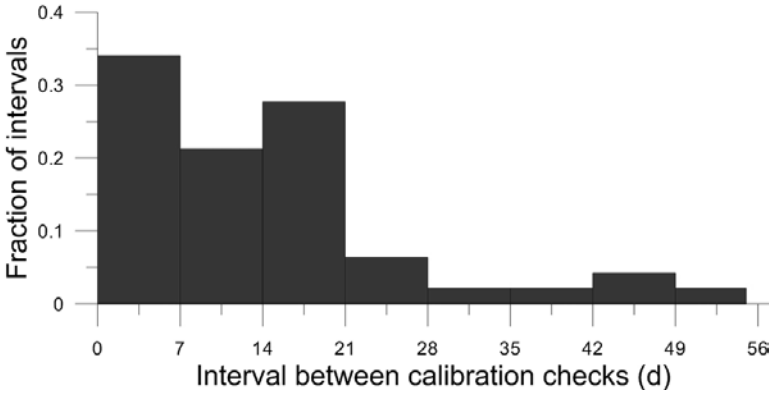


Figure 6.3-8: Inter-comparison check intervals for s/n 1928

Sonic anemometer 1945 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-5). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period

at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 45 times (Figure 6.3-9). The majority of calibration checks were made within 21 d (Figure 6.3-10). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-9B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-9A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-5: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/27 - 7/2/2007	+0.001	-0.051
1/17-19/2008	1/20-21/2008	-0.023	-0.037
7/18-21/2008	7/21-22/2008	+0.023	+0.026
3/3-4/2009	3/5-6/2009	+0.014	+0.171
9/16-17/2009	9/17-18/2009	+0.028	-0.012

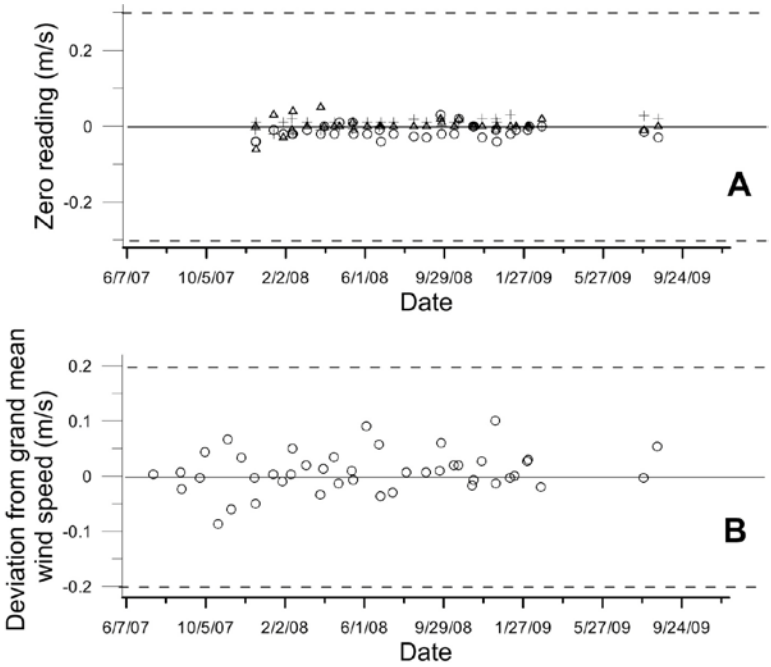


Figure 6.3-9: On-site quality assurance of s/n 1945. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

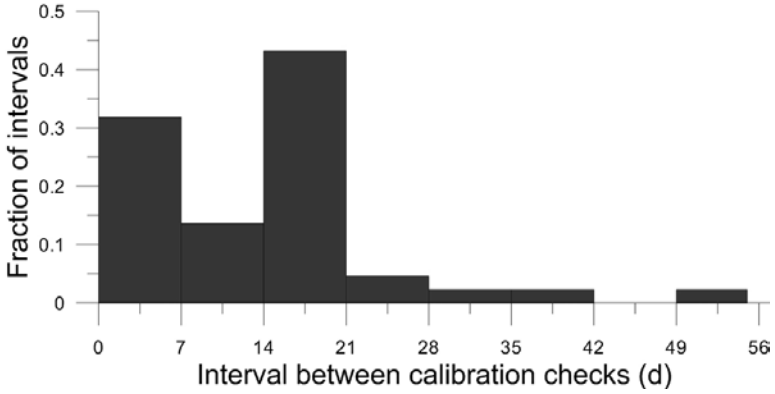


Figure 6.3-10: Inter-comparison check intervals for s/n 1945.

Sonic anemometer 1932 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-6). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 55 times (Figure 6.3-11). The majority of calibration checks were made within 21 d (Figure 6.3-12). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-11B). This instrument passed this check on all checks except 10/15-16/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back in use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-11B). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-6: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**

Calibration date		Mean difference from reference anemometers (ms^{-1})	
6/15-17/2007	6/18-19/2007	+0.004	+0.160
12/27-28/2007	12/29-31/2007	+0.014	-0.009
7/10-11/2008	7/11-14/2008	+0.008	+0.031
3/3-5/2009	3/5-6/2009	-0.024	-0.005
9/8-14/2009	9/15-16/2009	-0.025	-0.044
1/7-9/2010	1/23-24/2010	+0.020	-0.016

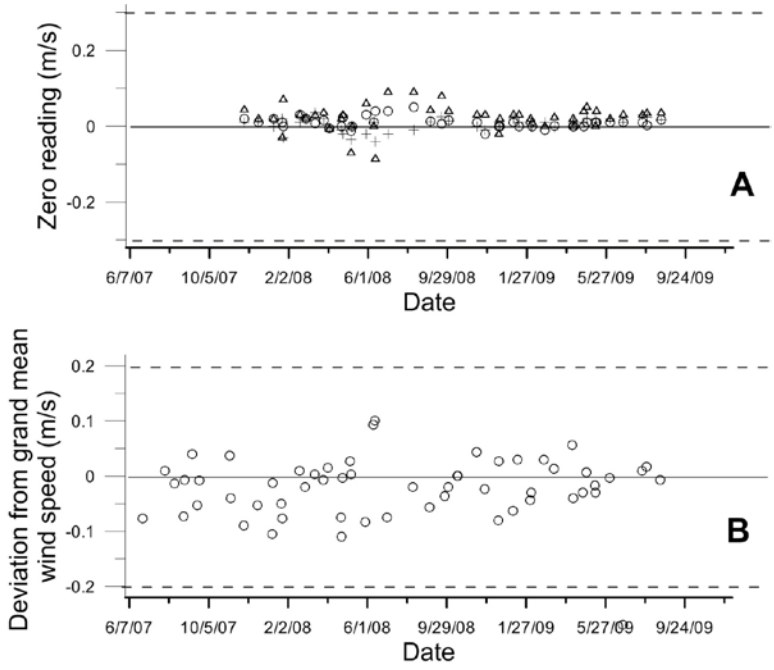


Figure 6.3-11: On-site quality assurance of s/n 1932. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

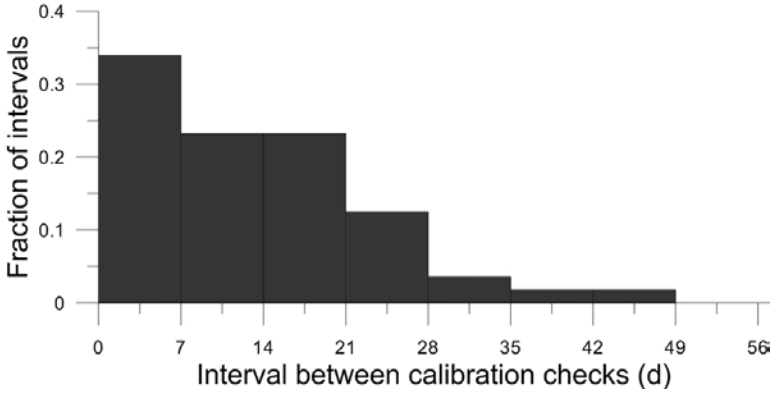


Figure 6.3-12: Inter-comparison check intervals for s/n 1932.

6.4 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n D and F) and the Gas Sampling System (GSS s/n 4-0018) were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results for the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 6.6-1. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Often GSS leak check failures corresponded to successful S-OPS leak checks that included the GSS within the system check (Table 6.6-1). Leaks in the GSS generally were a result of pump problems or incorrect zero offset determinations. Leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 6/26/2008, 7/15/2008, 12/17/2008, 1/15/2009, 2/3/2009, 2/6/2009, and both lines on 10/22/2008 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on subsequent visits.
- GSS leak check failures that paired with S-OPS leak check passes indicated that the GSS leak check test may have been in error.
- GSS leak check failure on 10/14/2008 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 6.6-1).

Table 6.6-1: Record of leak checks for GSS and GSS/S-OPS

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
4/1/2008	NC4A	2	0.04	-38.42	Pass	9.7	0.49	-35.63	Pass
		3	0.07	-38.12	Pass	9.8	0.62	-37.59	Pass
4/15/2008	NC4A	2	0.04	-36.59	Pass	6.5	0.54	-38.45	Pass
		3	0.04	-36.36	Pass	9.6	0.68	-36.38	Pass
4/24/08	WI5A	2	0.07	-35.13	Pass	8.3	0.62	-35.39	Pass
		3	0.09	-37.54	Pass	8	0.61	-35.54	Pass
5/13/08	WI5A	2	0.08	-34.5	Pass	7.7	0.69	-36.06	Pass
		3	0.07	-37.35	Pass	10	0.65	-37	Pass
5/15/08	IA3A	2	0.01	-37.16	Pass	8.2	0.51	-36.29	Pass
		3	0.04	-36.72	Pass	10	0.65	-35.9	Pass
6/4/2008	IA3A	2	0.08	-38.67	Pass	9.9	0.32	-37.49	Pass
		3	0.07	-23.71	Pass	10	0.47	-20.66	Pass
6/23/2008	IA3A	2	0.01	-35.74	Pass	10	0.38	-36.45	Pass
		3	0.05	-34.5	Pass	10	1.00	-37.66	Pass
6/25/2008	WI5A	2	0.05	-35.75	Pass	10	0.31	-34.95	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
		3	-0.01	-35.63	Pass	10	1.07	-36.71	Fail
7/15/2008	WI5A	2	0.05	-37.52	Pass	10	0.39	-36.92	Pass
		3	0.08	-34.45	Pass	8	0.90	-34.97	Fail
8/13/2008	NC4A	2	0.11	-36.28	Pass	10.1	0.38	-36.27	Pass
		3	0.08	-35.29	Pass	10	1.03	-36.16	Fail
9/3/2008	NC4A	2	-0.01	-35.49	Pass	9.8	0.46	-35.83	Pass
		3	-0.01	-37.07	Pass	9.5	0.62	-35.51	Pass
9/22/2008	NC4A	2	0.07	-37.58	Pass	10	0.61	-35.03	Pass
		3	0.04	-36.9	Pass	9.8	0.89	-35.95	Pass
9/25/2008	NC3A	2	0.08	-38.32	Pass	10	0.59	-35.9	Pass
		3	0.12	-37.84	Pass	10	0.96	-35.15	Pass
10/14/2008	NC3A	2	0.23	2.01	Fail	9.9	0.85	2.24	Pass
		3	0.24	2.76	Fail	9.8	0.82	3.74	Pass
10/22/2008	WI5A	2	0.03	-37.7	Pass	9.1	1.01	-37.55	Fail
		3	0.05	-36.53	Pass	8.3	0.93	-35.01	Fail
11/11/2008	WI5A	2	0.23	-38.84	Fail	9	0.32	-36.7	Pass
		3	0.09	-40.18	Pass	10	0.18	-39.43	Pass
11/13/2008	IA3A	2	0.14	-35.89	Pass	10	0.31	-33.84	Pass
		3	0.15	-36	Fail	10	0.32	-37.98	Pass
11/25/2008	IA3A	2	0.09	-32.04	Pass	9.9	0.63	-32.86	Pass
		3	0.09	-32.17	Pass	9.8	0.81	-32.56	Pass
12/16/2008	IA3A	2	0.18	-34.49	Fail	10	0.84	-35.46	Pass
		3	0.16	-32.41	Fail	10	0.51	-31.94	Pass
12/17/2009	WI5A	2	0.15	-36.18	Fail	8	0.82	-35.46	Fail
		3	0.18	-37.68	Fail	9.2	0.69	-35.44	Pass
1/6/2009	WI5A	2	0.20	-35.97	Fail	7	0.65	-35.46	Pass
		3	0.24	-23.82	Fail	9.1	0.68	-36.42	Pass
1/15/2009	NC4A	2	-0.05	-44.56	Pass	9.2	0.63	-43.36	Pass
		3	0.12	-43.57	Pass	8.5	1.03	-42.33	Fail
2/3/2009	NC4A	2	-0.03	-32.52	Pass	9	0.66	-31.73	Pass
		3	0.16	-32.07	Fail	8.5	1.07	-30.71	Fail
2/6/2009	NC3A	2	-0.28	-46.68	Pass	9.9	1.43	-33.54	Fail
		3	-0.01	-34.92	Pass	9.7	0.78	-33.01	Pass
2/23/2009	NC3A	2	0.05	-35.36	Pass	9.9	0.85	-35.24	Pass
		3	0.05	-35.51	Pass	9.7	0.43	-36.15	Pass
3/10/2009	WI5A	2	0.00	-36.55	Pass	8.2	0.39	-36.06	Pass
		3	0.03	-34.443	Pass	9.2	0.34	-36.32	Pass
4/7/2009	WI5A	2	0.12	-34.35	Pass	8.3	0.20	-32.15	Pass
		3	0.12	-32.31	Pass	9.4	0.24	-32.25	Pass
4/9/2009	IA3A	2	0.03	-33.32	Pass	10	0.23	-34.89	Pass
		3	0.11	-34.66	Pass	10	0.22	-36.33	Pass
4/23/2009	IA3A	2	0.01	-34.49	Pass	10.1	0.16	-34.9	Pass
		3	0.03	-36.36	Pass	10.1	0.15	-36.06	Pass
4/29/2009	NC4A	2	0.04	-33.83	Pass	9.8	0.14	-33.81	Pass
		3	0.00	-34.77	Pass	9.7	0.15	-34.79	Pass
5/11/2009	NC4A	2	0.03	-34.5	Pass	9.7	0.20	-34.34	Pass
		3	0.04	-32.88	Pass	9.7	0.20	-35.06	Pass
5/13/2009	NC3A	2	0.04	-34.4	Pass	9.3	0.30	-34.94	Pass
		3	0.03	-35.18	Pass	9.7	0.23	-34.04	Pass
6/2/2009	NC3A	2	0.04	-37.94	Pass	9.6	0.14	-37.45	Pass
		3	0.04	-35.54	Pass	9.5	0.22	-35.11	Pass
6/22/2009	NC3A	2	0.01	-35.46	Pass	9.8	0.20	-37.18	Pass
		3	0.03	-35.24	Pass	9.7	0.22	-37.89	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
7/1/2009	NC4A	2	0.03	-35.48	Pass	9.7	0.14	-36.58	Pass
		3	0.01	-34.46	Pass	9.5	0.14	-34.58	Pass
7/21/2009	NC4A	2	0.01	-35.69	Pass	9.8	0.11	-36.99	Pass
		3	0.03	-35.72	Pass	9.6	0.15	-35.37	Pass
7/28/2009	IA3A	2	0.01	-34.9	Pass	10	0.20	-33.94	Pass
		3	0.04	-34.55	Pass	10	0.31	-34.19	Pass
8/17/2009	IA3A	2	0.07	-42.67	Pass	10.05	0.14	-42.19	Pass
		3	0.07	-42.05	Pass	10.05	0.18	-41.85	Pass

The inlet flow balance checks are summarized in sequence in Tables 6.6-2A and 6.6-2B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A - Record of flow balancing- Side 1 (s/n D)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check result**
3/26/08	4/1/2008	NC3A	0.00	0.02	0.00	-0.01	0.19	-0.03	-0.01	-0.03	-0.07	-0.09	**Fail**
4/1/2008	4/15/2008	NC4A	0.03	0.01	0.02	0.09	0.03	0.04	-0.07	0.20	0.28	-0.06	**Fail**
4/15/2008	4/24/2008	NC4A	-0.13	-0.14	-0.15	-0.12	-0.21	-0.26	-0.32	-0.31	-0.33	-0.36	**Fail**
4/24/2008	5/13/2008	WI5A	-0.04	-0.03	-0.03	-0.06	-0.03	-0.02	-0.02	-0.02	-0.03	-0.03	**Pass**
5/15/2008	6/4/2008	IA3A	0.00	-0.05	-0.02	-0.03	-0.01	-0.07	-0.02	-0.03	0.01	0.02	**Pass**
6/4/2008	6/23/2008	IA3A	0.05	0.02	0.00	0.05	0.00	0.08	0.01	0.01	-0.01	-0.03	**Pass**
6/25/2008	7/15/2008	WI5A	0.05	0.02	0.07	-0.03	-0.01	-0.05	0.02	-0.03	-0.02	-0.01	**Pass**
7/15/2008	8/13/2008	WI5A	-0.05	0.10	-0.02	0.03	0.08	-0.09	0.00	0.06	-0.01	0.04	**Pass**
8/13/2008	9/3/2008	NC4A	-0.27	-0.12	-0.17	-0.13	-0.14	-0.29	-0.20	-0.21	-0.25	-0.22	**Pass**
9/3/2008	9/22/2008	NC4A	-0.12	-0.13	-0.11	-0.10	-0.15	-0.09	-0.10	-0.06	-0.10	-0.11	**Pass**
9/25/2008	10/14/2008	NC3A	-0.12	-0.09	-0.11	-0.12	-0.17	-0.16	-0.17	-0.22	-0.17	-0.23	**Pass**
10/14/2008	10/22/2008	NC3A	-0.32	-0.18	-0.23	-0.31	-0.19	-0.31	-0.29	-0.24	-0.22	-0.13	**Pass**
10/22/2008	11/11/2008	WI5A	-0.07	-0.10	-0.10	-0.13	-0.10	-0.10	-0.09	-0.13	-0.12	-0.15	**Pass**
11/13/2008	11/25/2008	IA3A	-0.10	-0.17	-0.18	-0.17	-0.13	-0.06	-0.15	-0.13	-0.15	-0.17	**Pass**
11/25/2008	12/16/2008	IA3A	-0.22	-0.18	-0.17	-0.18	-0.17	-0.20	-0.20	-0.16	-0.19	-0.16	**Pass**
12/17/2008	1/6/2009	WI5A	-0.30	-0.41	-0.27	-0.62	-0.15	-0.22	-0.29	-0.15	-0.23	-0.05	**Fail**
1/6/2009	1/15/2009	WI5A	-0.10	0.17	-0.17	0.34	-0.20	-0.12	-0.02	-0.18	-0.11	-0.17	**Fail**
1/15/2009	2/3/2009	NC4A	-0.27	-0.32	0.14	-0.07	-0.25	-0.32	-0.13	0.04	-0.40	-0.29	**Fail**
2/5/2009	2/23/2009	NC3A	-0.11	-0.13	-0.12	-0.12	-0.13	-0.11	-0.13	-0.16	-0.16	-0.09	**Pass**
2/23/2009	3/10/2009	NC3A	-0.11	-0.07	-0.12	-0.17	-0.15	-0.18	-0.19	-0.03	-0.19	-0.21	**Pass**
3/10/2009	4/7/2009	WI5A	-0.17	-0.17	-0.16	-0.19	-0.11	-0.08	-0.06	-0.22	-0.07	-0.11	**Pass**
4/9/2009	4/23/2009	IA3A	-0.15	-0.13	-0.11	-0.14	-0.15	-0.13	-0.13	-0.09	-0.11	-0.10	**Pass**
4/23/2009	4/29/2009	IA3A	-0.13	-0.11	-0.14	-0.14	-0.14	-0.16	-0.15	-0.20	-0.22	-0.20	**Pass**
4/29/2009	5/11/2009	NC4A	-0.26	-0.19	-0.16	-0.14	-0.15	-0.13	-0.14	-0.14	-0.11	-0.10	**Fail**
5/13/2009	6/2/2009	NC3A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.14	-0.14	-0.15	-0.15	-0.14	**Pass**
6/2/2009	6/22/2009	NC3A	-0.12	-0.10	-0.11	-0.11	-0.11	-0.13	-0.09	-0.14	-0.13	-0.14	**Pass**
6/22/2009	6/30/2009	NC3A	-0.15	-0.13	-0.13	-0.13	-0.13	-0.11	-0.13	-0.13	-0.12	-0.12	**Pass**
6/30/2009	7/21/2009	NC4A	-0.09	-0.13	-0.10	-0.11	-0.09	-0.11	-0.11	-0.08	-0.10	-0.10	**Pass**
7/21/2009	7/28/2009	NC4A	-0.08	-0.06	-0.08	-0.07	-0.06	-0.06	-0.05	-0.06	-0.06	-0.02	**Pass**
7/28/2009	8/17/2009	IA3A	-0.14	-0.14	-0.15	-0.13	-0.14	-0.15	-0.13	-0.12	-0.11	-0.15	**Pass**

Table 6.6-2B - Record of flow balancing- Side 2 (s/n F)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check result**
3/26/08	4/1/2008	NC3A	0.09	0.03	0.02	0.04	0.00	0.06	0.06	0.05	0.04	0.02	**Pass**
4/1/2008	4/15/2008	NC4A	0.05	0.21	0.05	0.04	0.10	0.03	0.27	0.00	0.08	0.13	**Fail**
4/15/2008	4/24/2008	NC4A	0.09	0.24	0.26	0.26	0.21	0.29	0.22	0.25	0.30	0.22	**Fail**
4/24/2008	5/13/2008	WI5A	-0.04	-0.03	-0.02	-0.02	0.12	-0.02	-0.04	-0.04	-0.07	0.03	**Fail**
5/15/2008	6/4/2008	IA3A	-0.09	-0.12	-0.08	-0.10	0.34	-0.02	-0.05	0.88	-0.06	-0.08	**Fail**
6/4/2008	6/23/2008	IA3A	0.05	0.06	0.04	0.02	0.03	-0.01	0.00	-0.01	0.07	-0.01	**Pass**
6/26/2008	7/15/2008	WI5A	0.03	0.03	0.02	0.02	-0.02	0.05	0.06	-0.01	0.00	0.01	**Pass**
7/15/2008	8/13/2008	WI5A	-0.27	-0.25	-0.30	-0.29	-0.23	-0.34	-0.36	-0.17	-0.27	-0.26	**Pass**
8/13/2008	9/3/2008	NC4A	0.02	0.02	0.06	0.05	0.00	0.09	0.06	-0.07	0.03	0.08	**Pass**
9/3/2008	9/22/2008	NC4A	0.00	0.02	0.00	-0.01	-0.02	-0.06	-0.02	-0.01	-0.06	-0.03	**Pass**
9/25/2008	10/14/2008	NC3A	0.00	0.02	0.02	0.00	0.02	-0.01	-0.06	0.03	0.04	0.08	**Fail**
10/14/2008	10/22/2008	NC3A	0.22	0.16	0.17	0.20	0.23	0.24	0.20	0.19	0.23	0.14	**Fail**
10/22/2008	11/11/2008	WI5A	-0.02	0.03	0.02	-0.01	0.00	-0.07	-0.09	-0.01	-0.02	0.00	**Fail**
11/13/2008	11/25/2008	IA3A	-0.23	-0.06	-0.11	-0.09	-0.06	-0.17	-0.16	-0.21	-0.12	-0.10	**Pass**
11/25/2008	12/16/2008	IA3A	-0.14	-0.23	-0.19	-0.18	-0.21	-0.17	-0.10	-0.07	-0.11	-0.13	**Fail**
12/17/2008	1/6/2009	WI5A	-0.26	-0.36	-0.28	-0.31	-0.31	-0.33	-0.35	-0.11	-0.26	-0.36	**Fail**
1/6/2009	1/15/2009	WI5A	0.02	-0.28	0.09	0.12	0.08	0.21	0.24	-0.97	0.20	0.20	**Fail**
1/16/2009	2/3/2009	NC4A	-0.29	-0.32	-0.20	0.34	-0.42	0.63	0.50	-0.51	0.23	0.23	**Fail**
2/5/2009	2/23/2009	NC3A	-0.11	-0.11	-0.13	-0.13	-0.15	-0.14	-0.17	-0.16	-0.16	-0.11	**Pass**
2/23/2009	3/10/2009	NC3A	-0.16	-0.16	-0.18	-0.19	-0.15	-0.19	-0.22	-0.15	-0.17	-0.12	**Pass**
3/10/2009	4/7/2009	WI5A	-0.21	-0.24	-0.21	-0.21	-0.24	-0.22	-0.23	-0.23	-0.20	-0.32	**Pass**
4/9/2009	4/23/2009	IA3A	0.00	0.00	0.00	-0.01	-0.03	-0.02	0.00	-0.04	-0.03	-0.05	**Pass**
4/23/2009	4/29/2009	IA3A	-0.15	-0.16	-0.15	-0.16	-0.16	-0.17	-0.18	-0.18	-0.20	-0.17	**Pass**
4/29/2009	5/11/2009	NC4A	-0.14	-0.10	-0.14	-0.13	-0.16	-0.11	-0.14	-0.11	-0.09	-0.11	**Pass**
5/13/2009	6/2/2009	NC3A	-0.12	-0.14	-0.14	-0.14	-0.19	-0.14	-0.22	-0.11	-0.15	-0.21	**Pass**
6/2/2009	6/22/2009	NC3A	-0.10	-0.77	-0.09	-0.10	-0.04	-0.05	-0.03	-0.04	-0.05	-0.03	**Fail**
6/22/2009	6/30/2009	NC3A	-0.14	0.53	-0.16	-0.15	-0.22	-0.18	-0.25	-0.20	-0.19	-0.22	**Fail**
6/30/2009	7/21/2009	NC4A	-0.14	-0.12	-0.11	-0.12	-0.14	-0.10	-0.06	-0.09	-0.10	-0.09	**Pass**
7/21/2009	7/28/2009	NC4A	-0.08	-0.08	-0.08	-0.10	-0.03	-0.06	-0.06	-0.05	-0.03	-0.03	**Fail**
7/28/2009	8/17/2009	IA3A	-0.04	-1.01	-0.07	-0.05	-0.04	-0.07	0.01	-0.09	-0.06	-0.05	**Fail**

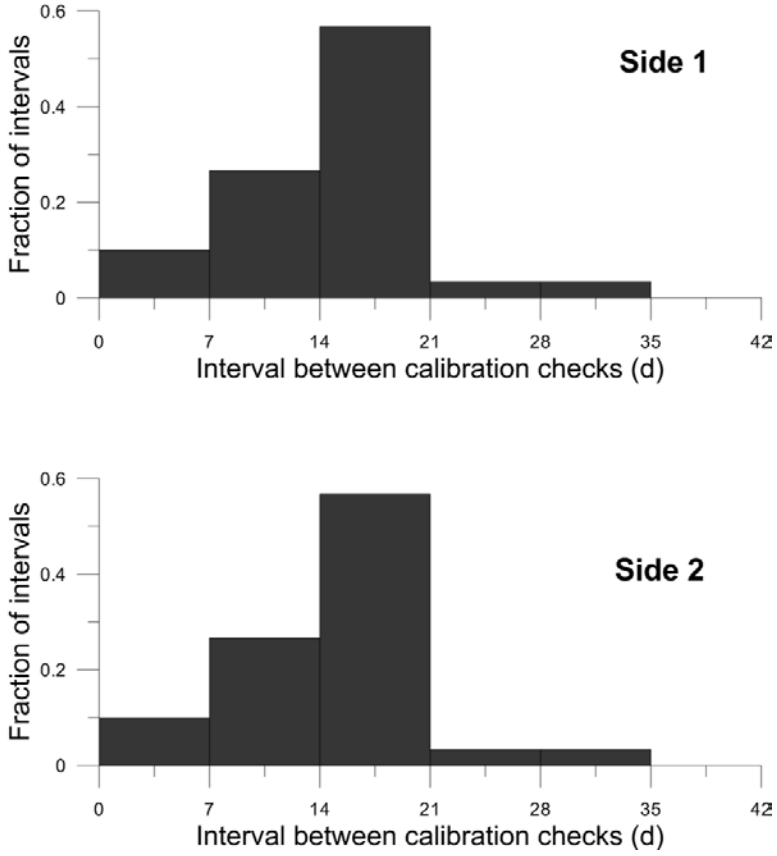


Figure 6.6-1 – Intervals between checks

6.5 Miscellaneous meteorological calibrations

6.5.1 Air temperature/humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n 4410027

Relative humidity (RH)					
Calibration date	**Temperature (°C)**	**Expected RH (%)**	**Difference from expected RH (%)**	**Mean difference RH (%)**	**Action**
3/8/2010	24.7	25.0	1.86		Accept
	24.7	50.0	1.41		Accept
	24.7	95.0	2.28		Accept
				1.85	Accept
3/6/2010	N/A	39.6	1.19	1.19	Accept
8/1/2008	27.8	10.9	-0.72		Accept
	27.5	50.8	2.48		Accept
	27.8	96.4	7.63		Accept
				3.13	Accept
Temperature (T)					
Calibration date	**Expected T (°C)**	**Measured T (°C)**	**Difference from expected T (°C)**		**Action**
3/8/2010	25.6	24.7	0.9		Pass
3/6/2009	25.3	25.2	0.2		Pass
8/1/2008	27.5	27.3	0.2		Accept

6.5.2 Barometric pressure

An aneroid barometer (Model 278, Setra Inc., Boxborough, MA) was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278 s/n 30351828

Calibration date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
3/4-8/2010	997-1004	4	0.1	Pass
2/27 - 3/2/2009	990.9-1007.1	6	1.6	Pass
7/23-27/2008	995.3-996.5	6	0.9	Pass
1/17-18/2008	984.9-996.9	6	0.8	Pass

6.5.3 Solar radiation

The LiCOR was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-3.

Table 6.7-3: Calibration record of LiCOR 200SB Pyranometer, s/n PY554448

Calibration date	Mean difference from reference (Wm^{-2})	Mean deviation from standard (%)	Action
3/5-3/8/2010	-3.81	0.71	Pass
8/30/2006			Pass, Factory Calibration

6.5.4 CR1000 data logger

The CR1000 data logger (Campbell Scientific Inc., Lagan, UT) was used to log air temperature, relative humidity, barometric pressure, and wetness. Calibration checks of this unit were conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. Two different loggers were used. The record of calibration checks are documented in Table 6.7-4 and Table 6.7-5.

Table 6.7-4: Calibration record of Campbell Scientific CR1000 data logger, s/n 7886 (7675)

Factory calibration						
Calibration date: 1/18/2007			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance (mV)**	**Measured mV**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
11	5000	± 3	5001.25	-1.25	5001.35000	-1.35000
11	-5000	± 3	-5001.48	-1.48	-5001.69000	-1.69000
11	2500	± 1.5	—	—	2500.30000	-0.30000
11	250	± 0.15	—	—	249.99900	0.00100
11	25	± 0.015	—	—	25.00320	-0.00320
11	7.5	± 0.0045	—	—	7.49571	0.00429
11	2.5	± 0.0015	—	—	2.50062	-0.00062
11	-2.5	± 0.0015	—	—	-2.49924	0.00024
11	5000	± 6	4999.45	0.45	4999.32000	0.32000
11	5000	± 6	5001.96	-1.96	5001.69000	-1.69000
11	5000	± 6	—	—	—	—
11	5000	± 6	—	—	—	—

PAML calibration						
SE channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured mV (mean value)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
1	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
2	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
3	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
4	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
5	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
6	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
7	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
8	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
9	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
10	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
12	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
13	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
14	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
15	4950	± 6.96 | 4.97	4950.5	-0.5	—	—

PAML calibration						
SE channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured mV (mean value)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
16	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
Calibration date: 5/28/2010			**Single-ended**		**Differential**	
1	100	± 2.06 | 1.06	99.49	0.51	—	
2	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
3	100	± 2.06 | 1.06	99.49	0.51	—	—
4	100	± 2.06 | 1.06	99.49	0.51	—	—
5	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
6	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
7	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
8	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
9	100	± 2.06 | 1.06	99.49	0.51	—	—
10	100	± 2.06 | 1.06	99.49	0.51	—	—
11	100	± 2.06 | 1.06	99.49	0.51	—	—
12	100	± 2.06 | 1.06	99.49	0.51	—	—
13	100	± 2.06 | 1.06	99.49	0.51	—	—
14	100	± 2.06 | 1.06	99.49	0.51	—	—
15	100	± 2.06 | 1.06	99.49	0.51	—	—
16	100	± 2.06 | 1.06	99.49	0.51	—	—
Calibration date: 5/28/2010			**Single-ended**		**Differential**	
1	0	± 2.06 | 1.06	0	0	—	
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0	—	—
4	0	± 2.06 | 1.06	0	0	—	—
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0	—	—
10	0	± 2.06 | 1.06	0	0	—	—
11	0	± 2.06 | 1.06	0	0	—	—
12	0	± 2.06 | 1.06	0	0	—	—
13	0	± 2.06 | 1.06	0	0	—	—
14	0	± 2.06 | 1.06	0	0	—	—
15	0	± 2.06 | 1.06	0	0	—	—
16	0	± 2.06 | 1.06	0	0	—	—

Table 6.7-5: Calibration record of Campbell Scientific CR1000 data logger, s/n 7752

PAML calibration						
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
Calibration date: 3/1/2010			**Single-ended**		**Differential**	
1	100	± 2.06 | 1.06	99.23	0.77	—	—
2	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
3	100	± 2.06 | 1.06	99.23	0.77	—	—
4	100	± 2.06 | 1.06	99.23	0.77	—	—
5	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
6	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
7	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
8	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
9	100	± 2.06 | 1.06	99.23	0.77	—	—
10	100	± 2.06 | 1.06	99.23	0.77	—	—
11	100	± 2.06 | 1.06	99.23	0.77	—	—
12	100	± 2.06 | 1.06	99.23	0.77	—	—
13	100	± 2.06 | 1.06	99.23	0.77	—	—
14	100	± 2.06 | 1.06	99.23	0.77	—	—
15	100	± 2.06 | 1.06	99.23	0.77	—	—
16	100	± 2.06 | 1.06	99.23	0.77	—	—
Calibration date: 3/1/2010			**Single-ended**		**Differential**	
1	0	± 2.06 | 1.06	0	0	—	—
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0	—	—
4	0	± 2.06 | 1.06	0	0	—	—
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0	—	—
10	0	± 2.06 | 1.06	0	0	—	—
11	0	± 2.06 | 1.06	0	0	—	—
12	0	± 2.06 | 1.06	0	0	—	—
13	0	± 2.06 | 1.06	0	0	—	—
14	0	± 2.06 | 1.06	0	0	—	—
15	0	± 2.06 | 1.06	0	0	—	—
16	0	± 2.06 | 1.06	0	0	—	—

6.5.5 CR800 data logger

The CR800 data logger (Campbell Scientific Inc., Logan, UT) was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration check was conducted only at end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-6.

Table 6.7-6: Calibration record of Campbell Scientific CR800 data logger, s/n 3697

Channel	Input (mV)	Tolerance SE (mV)	Measured (mV)	Error (mV)
Calibration date: 3/8/2010			**Single-ended**	
1	100	± 2.061	99.29	0.71
2	100	± 2.061	99.29	0.71
3	100	± 2.061	99.29	0.71
4	100	± 2.061	99.29	0.71
5	100	± 2.061	99.29	0.71
6	100	± 2.061	99.29	0.71
Calibration date: 3/8/2010			**Single-ended**	
1	0	± 2.061	0	0
2	0	± 2.061	0	0
3	0	± 2.061	0	0
4	0	± 2.061	0	0
5	0	± 2.061	0	0
6	0	± 2.061	0	0

6.6 Site activity

Time (UTC)	Date (mm/dd/yyyy)	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	8/30/2007	Setup	Anemometer heights taken.
21:35-22:35	8/30/2007	Setup	Sonic inter-comparison: Sonic 1: 0.85 Sonic 2: 0.78 Sonic 3: 0.85
22:55	8/30/2007	Setup	Zero calibration performed on sonic anemometers; all pass.
23:31-23:36	8/30/2007	Setup	Calibrated TDLAS 1030: Mean:49.95 SD: 5.71
00:54-00:59	8/30/2007	Setup	Calibrated TDLAS 1028: Mean 50.17 SD: 3.49 Note: two calibrations done but no explanation given.
	8/31/2007	Setup	Retro-reflectors are on both towers and on the ground. Retro reflector heights are recorded. Sensors are calibrated and installed.
	8/31/2007	Setup	Wetness sensor doesn't seem to be working.
	8/31/2007	Setup	TDLAS system on NE corner NOT operating. Part of system taken back to Purdue for repair. No communication from GasFinder 2.0™ to trailer.
	8/31/2007	Setup	Barometer audit: accepted
	9/17/2007	Repair	TDLAS 1 loses comm. Thru *GasView MP* v17, v19 when signal strength goes to zero (cable could be problem).
	9/17/2007	Repair	No internet connection.
	9/17/2007	Repair	Optimization problems with TDLAS 1028. See notes for detailed explanation.
16:00	9/17/2007	Repair	Changed observation to zero, still have problem. Swapped info 1030 on TDLAS 2 paths with 1028-problem occurred on TDLAS 2 paths with 1028.
	9/17/2007	Repair	Still no internet connection.
	9/17/2007	Repair	Reestablished TDLAS 1 laptop in trailer. Communications ok except when signal separation and pumping hamper connectivity.
	9/18/2007	Repair	Reset clock on TDLAS 1/1028 from 00:54 1/15/2006 to 16:15 9/18/2007. Synched with TDLAS 2.
	9/19/2007	Remote	Purpose was to realign TDLAS systems.
	9/24/2007	Remote	Checking instruments from Purdue. Sonic program error: "Subscript out of range." Occurred near top of Initial Summing subroutine in line son_1005_time=timeGetTime. Program restarted at 1815 UTC. It had stopped at 1733 UTC. Program still crashes.
	9/26/2007	Takedown	In this period, for 3 d trucks were put in way near the barns, emptied the basin.
	9/26/2007	Takedown	Barometer audit: accepted
15:15-16:15	9/26/2007	Takedown	Sonic inter-comparison: Sonic 1: 2.17 Sonic 2: 2.14 Sonic 3: 2.16
18:47	9/26/2007	Takedown	Zero calibration performed on sonic anemometers; all pass.
20:17-20:22	9/26/2007	Takedown	Calibrated TDLAs 1028− Mean: 50.06 SD: 3.17
20:48-20:53	9/26/2007	Takedown	Calibrated TDLAS 1030− Mean: 51.64 SD: 1.17
	9/26/2007	Remote	Check times on computers.
	12/19/2007	Setup	During transportation of trailer, trailer breaks were not working smoothly. Cover of one light fell down and got broken.

Time (UTC)	Date (mm/dd/yyyy)	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	12/19/2007	Setup	While starting TDLAS scanner, initially there was no power in both scanners. For TDLAS 1026, hooked and unhooked power cables, and after that it started functioning. For TDLAS 1028, tried hooking and unhooking power cables and warming and drying the power cables with heat gun. Helped it working.
	12/19/2007	Setup	Wetness sensor calibration: accepted
19:30-20:30	12/19/2007	Setup	Sonic inter-comparison: Sonic 1: 1.84 - Sonic 2: 1.75 - Sonic 3: 1.87 -Action: pass
20:13-20:18	12/19/2007	Setup	Calibrated TDLAS 1026 − Mean: 24.73 - SD: 0.52 - RSD: 2.1% - Bias: -1.1%
20:42	12/19/2007	Setup	Calibrated TDLAS 1028− Mean: 26.67 - SD: 1.24 - RSD: 4.7% - Bias: 6.7%
21:08	12/19/2007	Setup	Zero calibration performed on sonic anemometers
21:40	12/19/2007	Setup	Barometer audit: accepted
	12/20/2007	Setup	Checked CR1000 and collected data.
	12/20/2007	Setup	Taped all power supply boxes.
	12/20/2007	Setup	Orange light on CR1000 card reader; blinking, red light when card first put in.
	1/14/2008	Remote	Realign path on TDLAS 1 (1026)/
	1/14/2008	Takedown	Upon arrival found TDLAS laptops malfunctioning. Unable to log in to check out. Turned off and on again and went through hard disk check.
	1/14/2008	Takedown	Found that TDLAS data collection stopped on 1/12/2008 at 1800 UTC (scanner 1) and on 1/13/2008 at 0 UTC (scanner 2). It looks like it simply stopped creating log files. When checked at Purdue this morning, the screens looked fine.
	1/14/2008	Takedown	Sonic collection error at 1310 UTC. Had restarted program at 12:53Z.
	1/14/2008	Takedown	Evidence of power failures on 12/3/2007 at 1018 UTC, on 1/7/2008 at 2053 UTC, and on 1/10/2008 at 2002 UTC.
	1/15/2008	Takedown	Wetness sensor dirty/gritty.
	1/15/2008	Takedown	Rubber feet on tripods buried/frozen in ground. Some difficulty removing due to thawing/freezing since last setup. Some feet sunk 6-10 inches into frozen mud.
	1/15/2008	Takedown	Several tripods on W and N sides were loose.
15:20	1/15/2008	Takedown	Barometer audit: accepted
15:20	1/15/2008	Takedown	Wetness sensor calibration: returned to Purdue for cleaning.
15:30-16:30	1/15/2008	Takedown	Sonic inter-comparison: Sonic 1: 4.88 - Sonic 2 :4.79 - Sonic 3: 4.83 - Action: pass
16:46	1/15/2008	Takedown	Zero calibration performed on sonic anemometers
01:35-01:40	1/16/2008	Takedown	Calibrated TDLAS 1026 − Mean: 23.56 - SD: 0.61 - RSD: 2.6% - Bias: -6.2%
02:19-02:24	1/16/2008	Takedown	Calibrated TDLAS 1028 − Mean: 23.98 - SD: 0.51 - RSD: 2.1% - Bias: -4.6%
	5/14/2008	Setup	While doing TDLAS calibration, 1028 passed, but 1027 failed, giving concentration of 87.56 ppm, so it passed 200 ppm, giving 182.94. After waiting five min, 1027 passed calibration, giving 90.30 (it just passed).

Time (UTC)	**Date** (mm/dd/yyyy)	**Activity** (Setup, Takedown, Calibration, Repair, Remote)	**Event**
22:23	5/14/2008	Setup	Calibrated TDLAS 1028 − Mean: 48.97 - SD:0.20 - RSD: 0.4% - Bias: -2.7%
23:47	5/14/2008	Setup	Calibrated TDLAS 1027− Mean: 45.15 - SD: 0.29 - RSD: 0.7% - Bias: -9.8% Note: Passed on third attempt
	5/15/2008	Setup	TDLAS 1027 (power box 3) at SW. TDLAS 1028 (power box 4) at NE.
	5/15/2008	Setup	GSS no flow test
	5/15/2008	Setup	S-OPS/GSS leak test: Pass
	5/15/2008	Setup	GSS leak test: Pass
	5/15/2008	Setup	S-OPS inlet flow verification: Pass
	5/15/2008	Setup	S-OPS max flow test: Pass
19:05	5/15/2008	Setup	Wetness sensor calibration.
19:05	5/15/2008	Setup	Barometer audit: accepted
23:32	5/15/2008	Setup	TFC 450i calibration.
15:15	5/19/2008	Remote	Daily Status Check from PAML Notes: *iPort* fill data from 5/17/2008 1800 UTC. While downloading Fill data, received error message: "error: Bad command: "iscreen."' Reconnected and resumed fill from 5/18/2008 0021 UTC. Communication error required another restart from 5/19/2008 521 UTC. Got connection error multiple times; finally worked when starting load from 5/19/2008 0 UTC. Unable to get fill data after 5/19/2008 1220 UTC. Successfully filled gap by "loading last xx records."
12:15	5/20/2008	Remote	Daily Status Check from PAML
12:30	5/21/2008	Remote	Daily Status Check from PAML
12:10	5/22/2008	Remote	Daily Status Check from PAML − Notes: Graph for w graph looks different. r^2 on TDLAS 2 is between 0.96 and 0.99.
12:20	5/27/2008	Remote	Daily Status Check from PAML Notes: All 3 sonic anemometers had sonic anemometer flags over the extended weekend. Finding strong "spikes" in the wind data. Maybe due to strong thunderstorms? Stopped and restarted sonic anemometer program. *iPort* data collection ended on day 511. *iPort* locked up; last date collected 5/25/2008 at 0357 UTC. Collected H_2S data through *iPort* (required multiple tries). Restarted real-time data download. Unable to realign retro-reflectors 1 and 2 on TDLAS 1. Likely caused by thunderstorms in the area (winds >20 ms^{-1}) at time paths lost on 5/24/2008 around 12 UTC.
14:30	5/28/2008	Remote	Daily Status Check from PAML − Notes: About half day flagged yesterday on sonic anemometer 1. Back giving good values now. Unusual values showing up during this time. Retros 1 and 2 were knocked down by high winds on 5/24/2008and straightened yesterday.
12:15	5/29/2008	Remote	Daily Status Check from PAML − Notes: TDLAS reference r^2 values fluctuating from 0.96 to 0.99. Error messages related to sonic/*iPort*/Innova programs: Connect screen "communication with the station failed."
13:54	6/3/2008	Remote	Daily Status Check from PAML − Notes: Supply voltage has dropped from 1345 on day 515 to 1320 on day 520.

Time (UTC)	Date (mm/dd/yyyy)	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	6/4/2008	Calibration	TDLAS 1031 replaces TDLAS 1027. Changed filter papers (nos. 2, 3, 4, 5, 6 and 9) for north side of S-OPS. Added plastic on all ground retro-reflectors; cleaned all ground retro-reflectors and took pictures of the cubes. UPS switched to battery power on 5/30/2008 at 02:39:49--02:39:54 and 6/3/2008 at 10:13:34.
	6/4/2008	Calibration	Basin site layout recorded. See open site notes for details.
	6/4/2008	Calibration	S-OPS inlet flow verification: Pass
	6/4/2008	Calibration	S-OPS max flow test: Pass
	6/4/2008	Calibration	GSS leak test: Pass
	6/4/2008	Calibration	GSS no flow test
	6/4/2008	Calibration	S-OPS/GSS leak test: Pass
	6/4/2008	Calibration	Barometer audit: accepted
	6/4/2008	Calibration	Wetness sensor calibration: accepted
14:00-15:00	6/4/2008	Calibration	Sonic inter-comparison: Pass
14:55	6/4/2008	Calibration	TFC 450i calibration.
15:12	6/4/2008	Calibration	TFC 450i reference precision check
15:28	6/4/2008	Calibration	Sonic zero calibration: Pass
18:15	6/4/2008	Calibration	Calibrated TDLAS 1028− Mean: 47.01 - SD: 0.2 - RSD: 0.4% - Bias: -6.4%
18:56	6/4/2008	Calibration	Calibrated TDLAS 1027 − Mean: 95.21 - SD: 1.33 - RSD: 1.4% - Bias: -5.3% - Notes: Pass 100 ppm of NH_3. Got max conc of 43.10 ppm and max r^2 of 0.91; therefore, passed 200 ppm.
19:29	6/4/2008	Calibration	Calibrated TDLAS 1031 − Mean: 53.35 - SD: 0.27 - RSD: 0.5% - Bias: 6.4%
	6/5/2008	Calibration	Prof. Grant did QA and inter-comparison of TDLAS (1031 and 1028). Yesterday, water was seen (half-filled) inside UPS box (SW). Drained water and dried UPS with heat gun. Saw much water inside retro-reflector boxes. Flagged all the extension tubing; used duct tape to seal retro-reflector box (#6 SW). Power box of retro-reflector #2 (NE) was sealed with plastic bag, for it was missing its lid. Capped both UPS boxes and kept wood and a small rock.
	6/9/2008	Remote	Daily Status Check from PAML − Notes: Sonic, GSS, H_2S QC files stopped updating on 6/8/2008 13:45 UTC. TDLAS QC files stopped updating at 13:07 UTC on 6/8/2008. Only one TDLAS is working as the power supply to the other TDLAS got corroded. CR1000 data stopped updating on 6/8/2008. Cannot remotely connect to TDLAS laptops.
12:15	6/10/2008	Remote	Daily Status Check from PAML − Notes: Sonic 1 graph looks different slightly. TDLAS QC data was incrementing and was up to date. However, scanner 1 data had only incremented to 6/8/2008. Started transferring .bat file, and it started working; data is up to date. No pH probe need for a basin. Scanner for TDLAS 2 has corroded power supply; therefore, there is only one TDLAS working.
12:55	6/11/2008	Remote	Daily Status Check from PAML − Notes: TDLAS 2 scanner is broken. No pH probe needed for this site.
	6/12/2008	Repair	Changed scanner and reaimed all the paths for SW TDLAS (1031). Changed #6 retro-reflector plastic from dense to light plastic.

Time (UTC)	Date (mm/dd/yyyy)	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	6/12/2008	Repair	Checked all the power supply outlets and tapped them properly. Checked antennas. Checked to make sure all data was incrementing.
12:10	6/13/2008	Remote	Daily Status Check from PAML − Notes: Re-aimed paths 2, 3, and 7 on TDLAS 2. Will check again because path 2 is not behaving well (low light values). Spent at least one hour working to align path 2 but could not. At 20:50 UTC, called farm owner (Scott) and asked him to remove plastics from retro-reflectors 2 and 7. All the paths are giving valid light values now.
12:00	6/16/2008	Remote	Daily Status Check from PAML − Notes: Graph w for sonic anemometer 1 looks slightly different (as compared to sonic anemometers 2 and 3). Higher concentrations of H_2S are seen after 6/12/2008. Cannot explain. No pH probe necessary at this site.
12:10	6/17/2008	Remote	Daily Status Check from PAML − Notes: 2-3 values for sonic anemometer 1 are more than 160 in spike count.
12:10	6/18/2008	Remote	Daily Status Check from PAML − Notes: Graph for sonic anemometer 1 for average w values looks slightly different from sonic anemometers 2 and 3. On TDLAS 2, fraction will all 10 paths aligned is only 0.04, and values for reference cell quality are more than 12800.
17:00	6/18/2008	Remote	Remote login to change power settings on IA3A scanners. Changed power settings on both scanners to "PMR TMR PHL THL"
12:10	6/19/2008	Remote	Daily Status Check from PAML
12:40	6/20/2008	Remote	Daily Status Check from PAML
	6/23/2008	Takedown	Found water in retro-reflector 6 on TDLAS 1031 (SW corner). Tape around retro-reflector box appears to be worn off, allowing water inside.
	6/23/2008	Takedown	Barometer audit: accepted
	6/23/2008	Takedown	S-OPS max flow test conducted
	6/23/2008	Takedown	S-OPS/GSS leak test: Pass
	6/23/2008	Takedown	GSS no flow test
	6/23/2008	Takedown	GSS leak test: Pass
13:00	6/23/2008	Remote	Daily Status Check from PAML Notes: TDLAS 1 is finding all paths but optimizing frequently. Sonic 3 had flagging briefly at one time but is currently not flagging.
14:11	6/23/2008	Takedown	TEC 450i calibration verification check
14:34	6/23/2008	Takedown	TEC 450i reference precision check
20:55	6/23/2008	Takedown	Wetness sensor calibration: accepted
21:45	6/23/2008	Takedown	Calibrated TDLAS 1028 − Mean: 46.71 - SD: 0.31 - RSD: 0.7% - Bias: -6.7%
22:27	6/23/2008	Takedown	Calibrated TDLAS 1031 − Mean: 54.54 - SD: 0.21 - RSD: 0.4% - Bias: 8.3%
0:05-0:59	6/24/2008	Takedown	Sonic inter-comparison: Pass
01:20	6/24/2008	Takedown	Sonic zero calibration: Pass
00:00	6/24/2008	Takedown	Front left jack of the trailer is not working well.
	6/24/2008	Takedown	TEC 450i instrument operating parameters calculated

Time (UTC)	**Date** (mm/dd/yyyy)	**Activity** (Setup, Takedown, Calibration, Repair, Remote)	**Event**
12:30	6/24/2008	Remote	Daily Status Check from PAML Notes: Sonic 1 w values are slightly above zero. Flag "64" in H_2S analyzer data--could be caused by FOS on site yesterday. GSS pressure drops off dramatically in late afternoon; FOS arrived on site yesterday. Not a full day of data yesterday for TDLAS QC; FOS on site.
	11/12/2008	Setup	Reached site at 3:00 P.M. local time. Ground is muddy.
	11/12/2008	Setup	Saw three fenceposts missing from S-OPS (south side).
	11/12/2008	Setup	Two power poles (with sockets) were missing upon arrival, so there was no electricity around the basin; only electric power was around the towers.
	11/12/2008	Setup	While setting up tralier, the trailer slipped resulting in breaking of one scissor jack (which has been temporarily repaired).
00:02	11/13/2008	Setup	TEC 450i instrument operating parameters calculated
00:02	11/13/2008	Setup	TEC 450i calibration verification check
00:24	11/13/2008	Setup	TEC 450i reference precision check
00:35	11/13/2008	Setup	SO_2 calibration
	11/13/2008	Setup	Checked leak test for TEC 450i (H_2S analyzer). Flow showing is 0.00 but pressure showing 547.8 mmHg (i.e., pump needs to be replaced).
	11/13/2008	Setup	Changed filters for nozzles #1, 2, 3, and 8 of "F" S-OPS. Changed filters for nozzle #4 for "D" S-OPS.
	11/13/2008	Setup	Fixed electric wires at retro-reflector #1 of SW TDLAS and retro-reflector #6 of NE TDLAX
	11/13/2008	Setup	Basin site layout recorded. See open site notes for details.
	11/13/2008	Setup	GSS no flow test
	11/13/2008	Setup	GSS leak test: Pass
	11/13/2008	Setup	GSS max flow test
	11/13/2008	Setup	S-OPS max flow test conducted
	11/13/2008	Setup	S-OPS/GSS leak test: Pass
	11/13/2008	Setup	S-OPS balance: F
	11/13/2008	Setup	S-OPS balance: D
12:35	11/13/2008	Setup	Wetness sensor calibration: pass.
16:55	11/13/2008	Setup	Calibrated TDLAS 1030
17:00-17:54	11/13/2008	Setup	Sonic inter-comparison; all pass.
17:34	11/13/2008	Setup	Calibrated TDLAS 1026
18:10	11/13/2008	Setup	Zero sonic anemometer calibration; all pass.
	11/14/2008	Setup	Set up all ground retros. Set up TDLAS, aimed both; rain made obtaining good light values difficult. Initially found little problem with scanner at SW (s/n: 1122), but after a while it worked well.
	11/14/2008	Setup	Barometer audit: accepted
	11/14/2008	Setup	Maintenance list completed.
17:50	11/17/2008	Remote	Daily Status Check from PAML Notes: On TDLAS 1, found 5 paths had dwell times set to zero s. Changed to 15 s. Paths 2, 4, 6, 7, and 10 are now good. Sonic 3 w goes up to 1 ms^{-1}. Sonic 1 w goes to up to 0.5 ms^{-1}. No communication with CR 1000.
13:35	11/18/2008	Remote	Daily Status Check from PAML Notes: Graphs for u, v, and w look different for sonic anemometers 1 and 3. No communication with CR 1000.

Time (UTC)	**Date** (mm/dd/yyyy)	**Activity** (Setup, Takedown, Calibration, Repair, Remote)	**Event**
14:42	11/19/2008	Remote	Daily Status Check from PAML Notes: No QC file for 11/19/2008. No communication with CR 1000.
14:15	11/20/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 has quite a few periods with 10-50 sonic anemometer flagged points and less than 4000 data points. No communication with CR 1000.
13:36	11/21/2008	Remote	Daily Status Check from PAML Notes: Path 7 on TDLAS 1 and path 8 on TDLAS 2 did not have good light levels; re-aimed them, and they are now working well. Graphs for u, v, and w look different for sonic anemometers 1 and 2. No communication with CR 1000.
13:00	11/24/2008	Remote	Daily Status Check from PAML Notes: All 3 sonic anemometers had major flagging from 693.2-693.8 (dense freezing fog). No communication with CR 1000.
	11/25/2008	Calibration	Scott fixed the missing power outlets.
	11/25/2008	Calibration	Could not do manure sampling as it was frozen.
	11/25/2008	Calibration	Changed (fixed) diaphragm of TEC 450i pump; now it is working well, giving 1.08 LPM. Last time 450i failed, we have done multipoint calibration.
	11/25/2008	Calibration	Maintenance list completed.
	11/25/2008	Calibration	GSS no flow test
	11/25/2008	Calibration	GSS max flow test
	11/25/2008	Calibration	S-OPS max flow test conducted
	11/25/2008	Calibration	S-OPS/GSS leak test: Pass
	11/25/2008	Calibration	GSS leak test: Pass
	11/25/2008	Calibration	S-OPS balance: D
	11/25/2008	Calibration	S-OPS balance: F
16:25	11/25/2008	Calibration	Calibrated TDLAS 1026
16:58	11/25/2008	Calibration	Calibrated TDLAS 1030
17:10	11/25/2008	Calibration	Barometer audit: accepted
17:13	11/25/2008	Calibration	Wetness sensor calibration: pass.
17:10-18:05	11/25/2008	Calibration	Sonic inter-comparison; all pass.
20:05	11/25/2008	Calibration	Zero sonic anemometer calibration; all pass.
20:48	11/25/2008	Calibration	TEC 450i calibration verification check
20:48	11/25/2008	Calibration	TEC 450i instrument operating parameters calculated
21:01	11/25/2008	Calibration	TEC 450i reference precision check
22:54	11/25/2008	Calibration	SO_2 calibration
14:15	11/26/2008	Calibration	Daily Status Check from PAML
13:10	12/1/2008	Calibration	Daily Status Check from PAML Notes: Sonic measurement stopped on 11/29/2008 from 23:00 to 11/30/2008 at 20:14:57.
13:05	12/2/2008	Calibration	Daily Status Check from PAML
14:00	12/3/2008	Calibration	Daily Status Check from PAML
12:50	12/4/2008	Calibration	Daily Status Check from PAML Notes: Sonic 1 w may be slightly different than other graphs.
13:10	12/5/2008	Calibration	Daily Status Check from PAML Notes: On TDLAS 1, found paths 1 and 4 with low light levels. Re-aimed the paths, and they are now working well.
13:40	12/11/2008	Remote	Daily Status Check from PAML
14:15	12/12/2008	Remote	Daily Status Check from PAML – Notes: GSS/H_2S data stops at about 712.239

Time (UTC)	Date (mm/dd/yyyy)	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	12/15/2008	Takedown	Arrived on site at 5:00 pm CST.
	12/15/2008	Takedown	TDLAS PC error message upon arrival. TDLAS 2: "Valve creation failed at line 599." (parser message) (locked up). TDLAS 1: Error connecting to existing session for registration. A device attached to the system is not functioning. A new session were created. (unable to log in).
00:52	12/15/2008	Takedown	Calibrated TDLAS 1026
01:13	12/15/2008	Takedown	Calibrated TDLAS 1030
	12/16/2008	Takedown	Temp -17C. Basin frozen.
	12/16/2008	Takedown	Maintenance list completed.
16:50-17:50	12/16/2008	Takedown	Sonic inter-comparison; all pass.
18:30	12/16/2008	Takedown	Barometer audit: accepted
18:30	12/16/2008	Takedown	Sonic zero calibration: Pass
18:31	12/16/2008	Takedown	Wetness sensor calibration: pass.
	4/8/2009	Setup	Reached site at 9:30 A.M. local time. Saw many dead animals near the basin towards the basin.
	4/8/2009	Setup	Maintenance list completed.
17:49-18:54	4/8/2009	Setup	Sonic inter-comparison; all pass.
19:18	4/8/2009	Setup	Zero sonic calibration; all pass.
20:00	4/8/2009	Setup	Calibrated TDLAS 1030
20:42	4/8/2009	Setup	Calibrated TDLAS 1031
21:27-21:55	4/8/2009	Setup	TEC 450i Single Point calibration
	4/9/2009	Setup	Did manure sampling today.
	4/9/2009	Setup	Basin site layout recorded.
12:15-13:50	4/9/2009	Setup	S-OPS/GSS calibrations
13:00	4/9/2009	Setup	Barometer audit: accepted
13:01	4/9/2009	Setup	Wetness sensor calibration: accepted
14:00	4/9/2009	Setup	Started sonic anemometer 1
14:55	4/9/2009	Setup	Started TEC 450i sampling
15:50	4/10/2009	Remote	Daily Status Check from PAML − Notes: Check out paths that QC indicates might be in a "hole." TDLAS 2 R1 current position of 12724, -246 is surrounded by 16368 in optimization plots. However this location is not in a hole now as indicated by manual searching to left and right of this position. Believe that the indicated holes are base on the data collected before additional plastics were added around 8:00 P.M. CDT on 4/8/2009. Sonic 1 w reaches 1 ms^{-1}; direction is across the basin at that time (excluded due to barns).

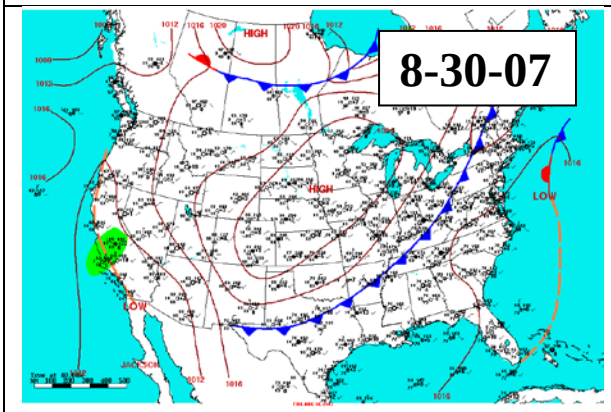
Time (UTC)	**Date** (mm/dd/yyyy)	**Activity** (Setup, Takedown, Calibration, Repair, Remote)	**Event**
13:30	4/13/2009	Remote	Daily Status Check from PAML − Notes: *iPort* encountered an error and had to be restarted. Stopped sonic anemometers at 15:50, filled missing data, restarted data collection, and restarted sonic anemometers s. Sonics showing wind from the east most of the time. H_2S chamber pressure dropped by 20 (643 to 623) at NAEMS day 832.65 and has steadily dropped to about 600 since. TDLAS 2 reference cell quality fluctuates between ~1000 and ~6000. When it is ~6000, the reference r^2 is about 50%. Also, at these times, the measured r^2 at about 50.
12:10	4/14/2009	Remote	Daily Status Check from PAML Notes: Sonic 3 has no data on 4/13/2009 between about 15:30 and 16:30. H_2S chamber pressure has stabilized around 600.
12:00	4/15/2009	Remote	Daily Status Check from PAML Notes: *iPort* encountered an error and had to be restarted. Stopped sonic anemometers, filled missing data, restarted data collection, and restarted sonic anemometers. According to Scott Shriver the dead animals (where were lying beside the barns towards the basin) were removed on Sunday (4/12/2009). TDLAS 2 reference cell quality and reference r^2 both alternating.
12:00	4/16/2009	Remote	Daily Status Check from PAML − Notes: Max r^2 on TDLAS 2 around 0.6.
12:10	4/20/2009	Remote	Daily Status Check from PAML
13:15	4/21/2009	Remote	Daily Status Check from PAML − Notes: Average w for sonic anemometer 1 is 0.4 ms^{-1}; for sonic anemometer 3 the average is 0.4 ms^{-1}.
	4/22/2009	Takedown	Stopped TDLAS's, sonic anemometer anemometers, H_2S, and GSS log files at around 4:00 CDT.
	4/22/2009	Takedown	Took down all tower equipment and ground equipment except the met tower station.
	4/22/2009	Takedown	Started sonic anemometer calibration at 22:46 UTC; will let the sonic anemometers run overnight.
	4/23/2009	Takedown	TDLAS calibration took about 3 h. Did tie-tin of old NH_3 cylinder with new using TDLAS 1030. Conducted two trials of each calibration because of large difference between tanks on trial 1. Got good agreement on trial 2. Calibration cell was bumped while changing cylinders during trial 1. TDLAS 1030 failed trial 1, but passed trial 2. TDLAS 1031 was very erratic in oscilloscope; failed trial 1 and barely passed trial 2.
	4/23/2009	Takedown	Conducted multipoint calibration of 450i. Read about 30% higher than the last multipoint. Value at 0.5 ppm consistent with last several calibration checks.
	4/23/2009	Takedown	Took manure sample at end of day while packing trailer. Will ship tomorrow morning.
	4/23/2009	Takedown	Maintenance list completed.
	4/23/2009	Takedown	Basin site layout made.
12:04-15:00	4/23/2009	Takedown	Sonic inter-comparison; all pass.
15:10	4/23/2009	Takedown	Wetness sensor calibration: pass.
15:10	4/23/2009	Takedown	Barometer audit: accepted
15:28	4/23/2009	Takedown	Zero sonic anemometer calibration; all pass.

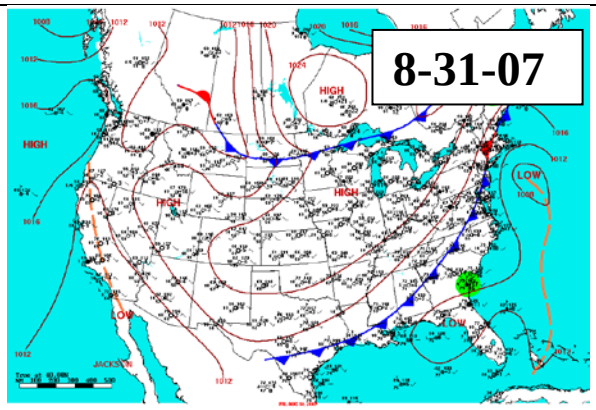
Time (UTC)	Date (mm/dd/yyyy)	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
15:45	4/23/2009	Takedown	S-OPS/GSS calibrations
17:10-19:31	4/23/2009	Takedown	Calibrated TDLAS 1030 (see open site notes for details)
17:32-19:01	4/23/2009	Takedown	Calibrated TDLAS 1030 (see open site notes for details)
17:57-19:54	4/23/2009	Takedown	Calibrated TDLAS 1031 (see open site notes for details)
20:29-21:17	4/23/2009	Takedown	TEC 450i multipoint calibration.
	7/27/2009	Setup	Connected trailer
	7/27/2009	Setup	Distributed retros and scanners
	7/27/2009	Setup	Mounted S-OPS
	7/28/2009	Setup	Open site notes completed
15:45-16:45	7/28/2009	Setup	Sonic inter-comparison; all pass.
17:51	7/28/2009	Setup	Zero sonic anemometer calibration; all pass.
18:00	7/28/2009	Setup	S-OPS/GSS calibrations Notes: S-OPS F line failed inlet flow on the first try. Changed filters 3 and 4.
18:15-19:00	7/28/2009	Setup	Calibrated TDLAS 1030 Notes: A second background test was needed because tripod was bumped during testing.
18:48	7/28/2009	Setup	Barometer audit: accepted
18:50	7/28/2009	Setup	Wetness sensor calibration: accepted
19:44-20:01	7/28/2009	Setup	Calibrated TDLAS 1026
23:47-00:29	7/28/2009	Setup	TEC 450i Single Point calibration
	7/29/2009	Setup	H_2S analyzer hooked up to sample line at about 13:30 UTC on 7/29/2009.
	7/29/2009	Setup	Maintenance list completed.
15:30	7/30/2009	Remote	Daily Status Check from PAML Notes: No communication with CR 1000. Reaimed TDLAS 1 path 8.
12:20	7/31/2009	Remote	Daily Status Check from PAML Notes: Reaimed TDLAS 1 path 8 (xxxx appeared briefly while aiming). Having a difficult time keeping path 8 with good light levels. It get great light levels when aiming, but then has low light levels of the same pan/tilt on the next path. Changed obstruction level from 200 to 2 to try to correct TDLAS 1. No communication with CR 1000.
12:40	8/3/2009	Remote	Daily Status Check from PAML Notes: CDC brief fell to 133 on both TDLAS's. No communication with CR 1000.
12:20	8/4/2009	Remote	Daily Status Check from PAML Notes: Small amount of sonic anemometer flagging sonic anemometer anemometers 2 and 3. No communication with CR 1000. TDLAS paths have low light levels, probably due to fog/mist in area.
12:10	8/5/2009	Remote	Daily Status Check from PAML Notes: No communication with CR 1000. Low light levels on TDLAS's (alarm 50 on TDLAS 1), probably caused by fog/moisture.
12:10	8/6/2009	Remote	Daily Status Check from PAML Notes: Re-aimed TDLAS 1 path 1 and TDLAS 2 path 7; having trouble with TDLAS 2 path 7. Will see if they recover by themselves.

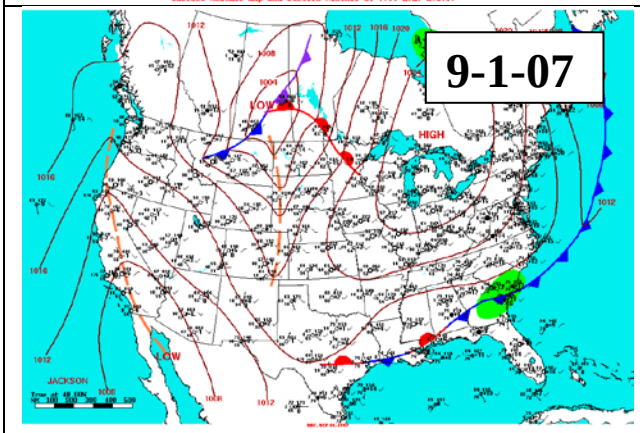
Time (UTC)	Date (mm/dd/yyyy)	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
12:15	8/7/2009	Remote	Daily Status Check from PAML Notes: Many TDLAS paths have low light levels, probably caused by rain at the site. No communication with CR 1000.
12:45	8/10/2009	Remote	Daily Status Check from PAML Notes: Nearly all TDLAS paths have low light levels, caused by dew/fog. MFC dropped to less than zero for about 12 h (950.9-951.4). RH jumped over 100% for some periods of time. H_2S data was not updated. Filled missing data. Period of flag 64 in H_2S data. No communication with CR 1000.
12:15	8/11/2009	Remote	Daily Status Check from PAML Notes: TDLAS paths recovering from dew. No communication with CR 1000.
13:15	8/12/2009	Remote	Daily Status Check from PAML Notes: No communication with CR 1000. TDLAS 2 paths are likely recovering from dew. T/RH sensor in GSS appears to have failed due to high humidity/condensation. H_2S concentration spiked to >20000 ppb.
12:45	8/13/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 is optimizing a lot. Will check later.
12:20	8/14/2009	Remote	Daily Status Check from PAML Notes: No communication with CR 1000. T/RH sensor in GSS appears to have failed due to high humidity/condensation. H_2S concentration spiked to >20000 ppb.
	8/17/2009	Takedown	Relabeled S-OPS D line.
	8/17/2009	Takedown	Maintenance list completed.
	8/17/2009	Takedown	Basin site layout completed.
12:16	8/17/2009	Remote	Daily Status Check from PAML Notes: Paths are off on both TDLAS units, probably caused by fog/moisture. Humidity is 100% currently.
22:00-22:37	8/17/2009	Takedown	S-OPS/GSS calibrations performed
22:45-23:12	8/17/2009	Takedown	TEC 450i Single Point calibration
	8/18/2009	Takedown	NAEMS Open site notes completed.
13:25-14:25	8/18/2009	Takedown	Sonic inter-comparison; all pass.
15:00	8/18/2009	Takedown	Wetness sensor calibration: pass.
15:03	8/18/2009	Takedown	Barometer audit: accepted
15:08	8/18/2009	Takedown	Zero/Bias sonic anemometer check: pass
15:10-15:33	8/18/2009	Takedown	Calibrated TDLAS 1026 Notes: Having the air conditioner results in significant background values; turned air conditioner off.
16:04-16:25	8/18/2009	Takedown	Calibrated TDLAS 1030 Notes: Cleaned TDLAS window. TDLAS would go into Menu mode. ESC and ENT keys are not functioning.

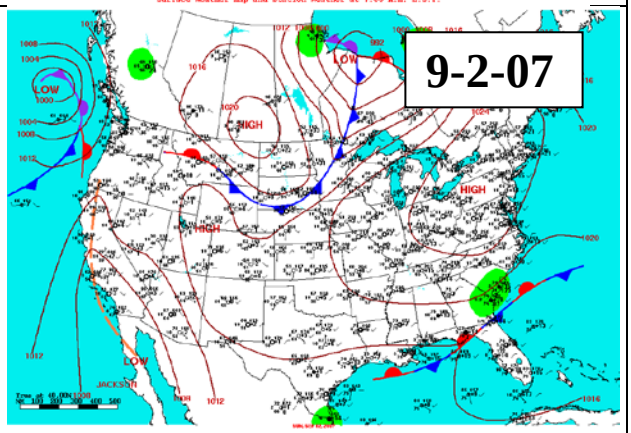
6.7 Site Weather

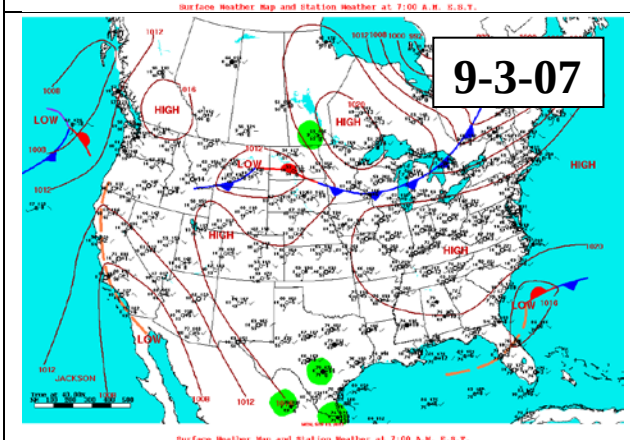
Period 2

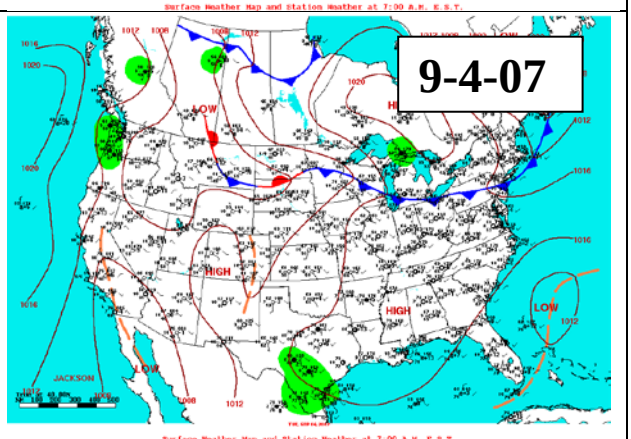


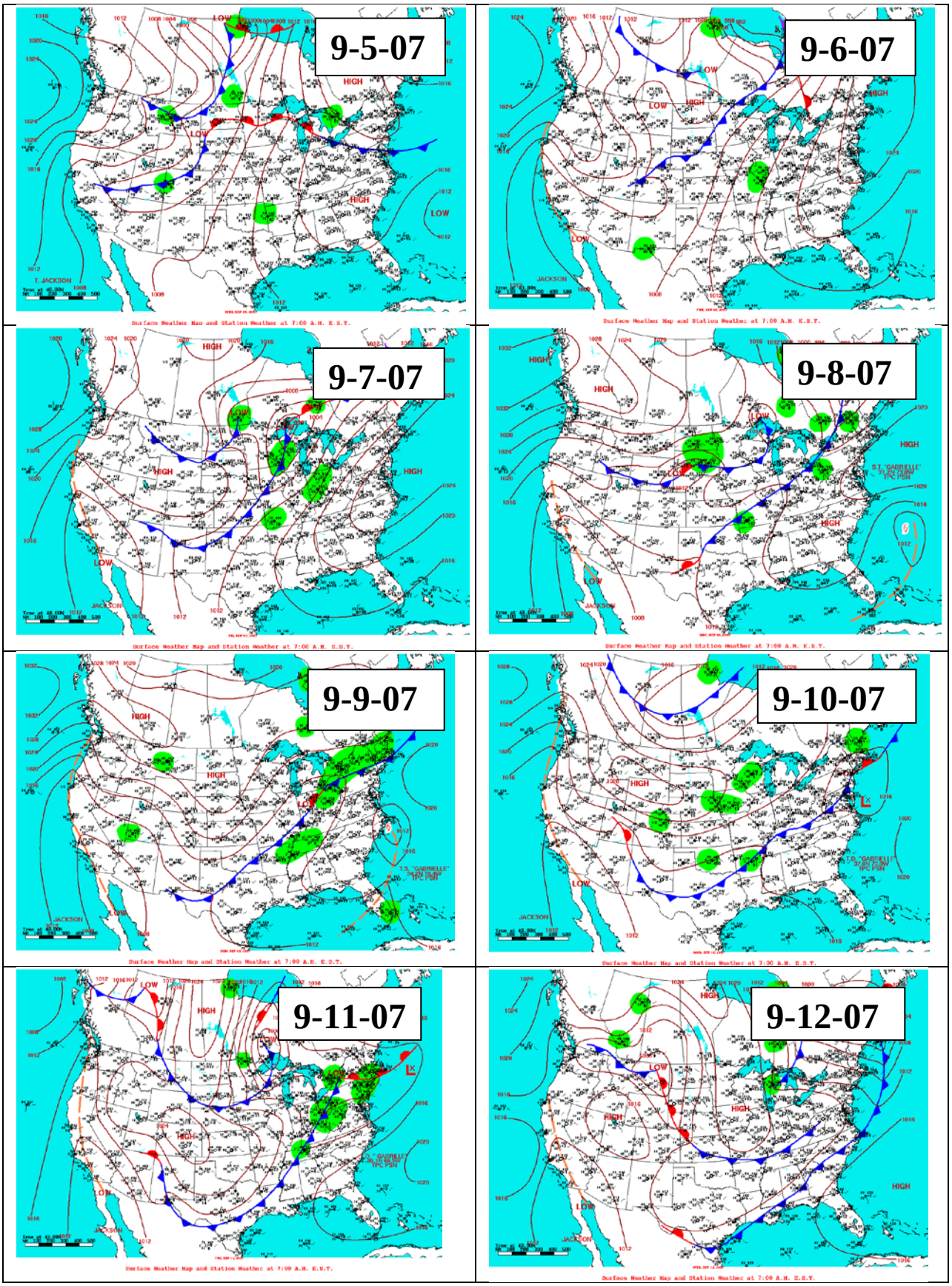








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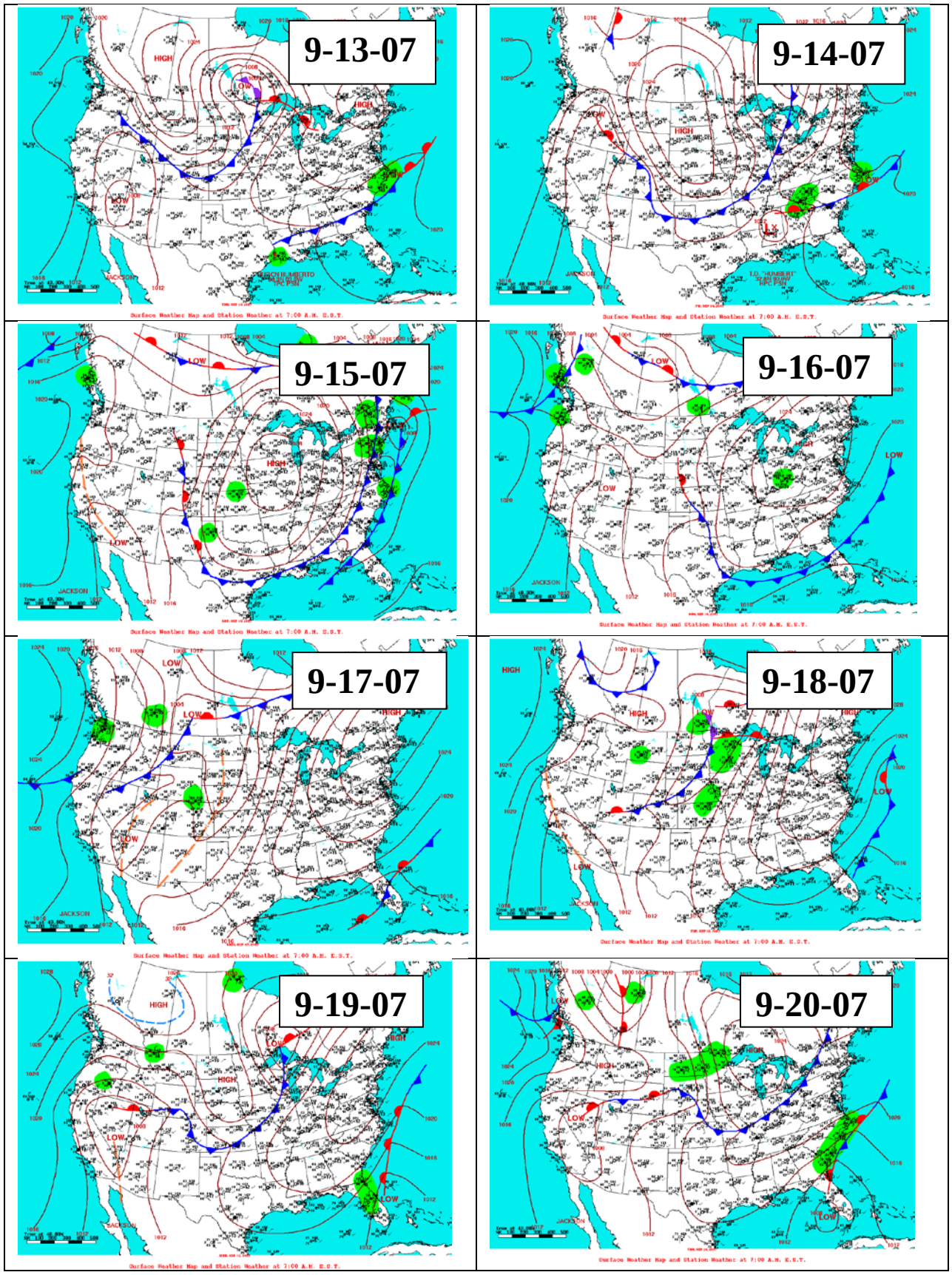
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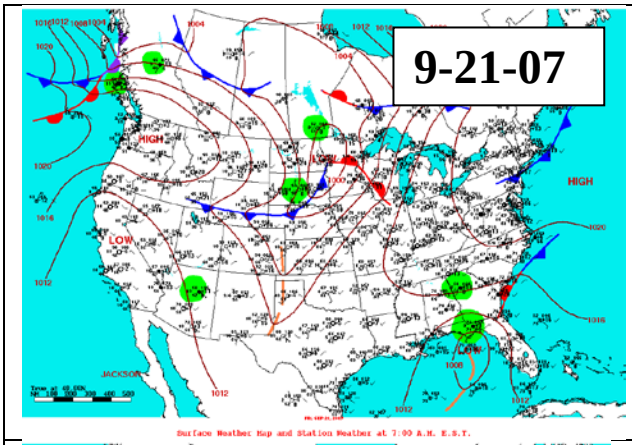
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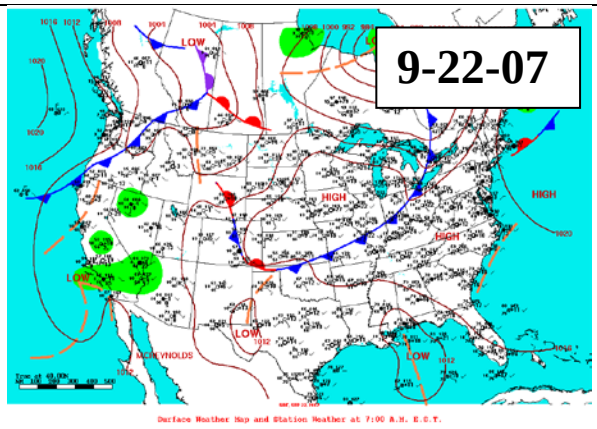
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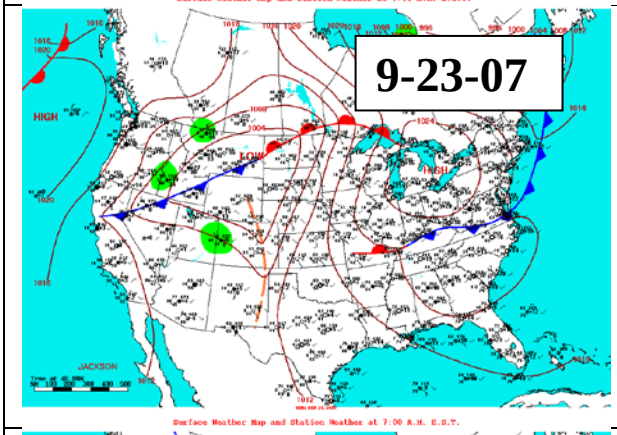
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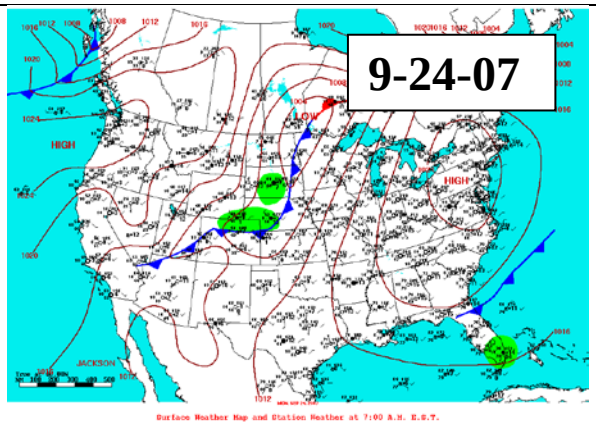
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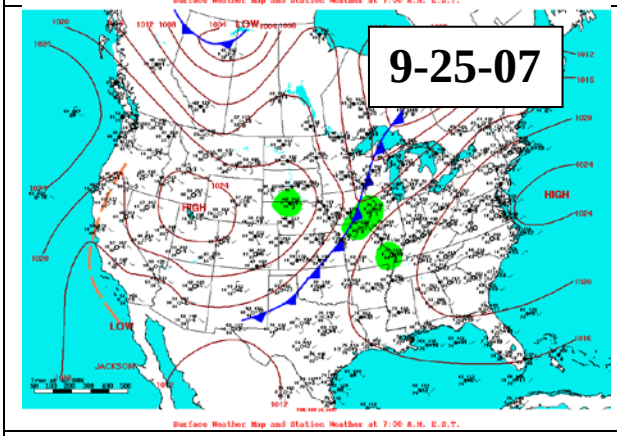
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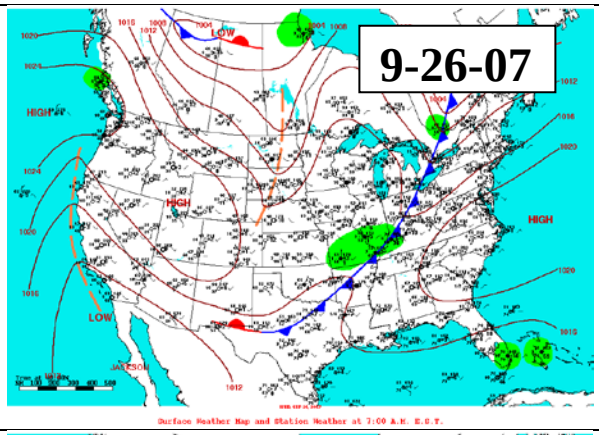
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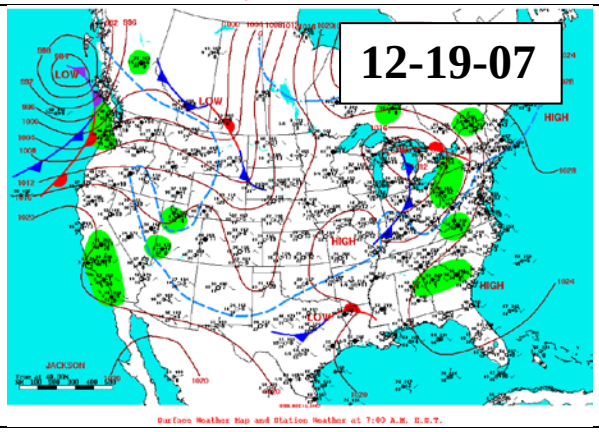
Period 3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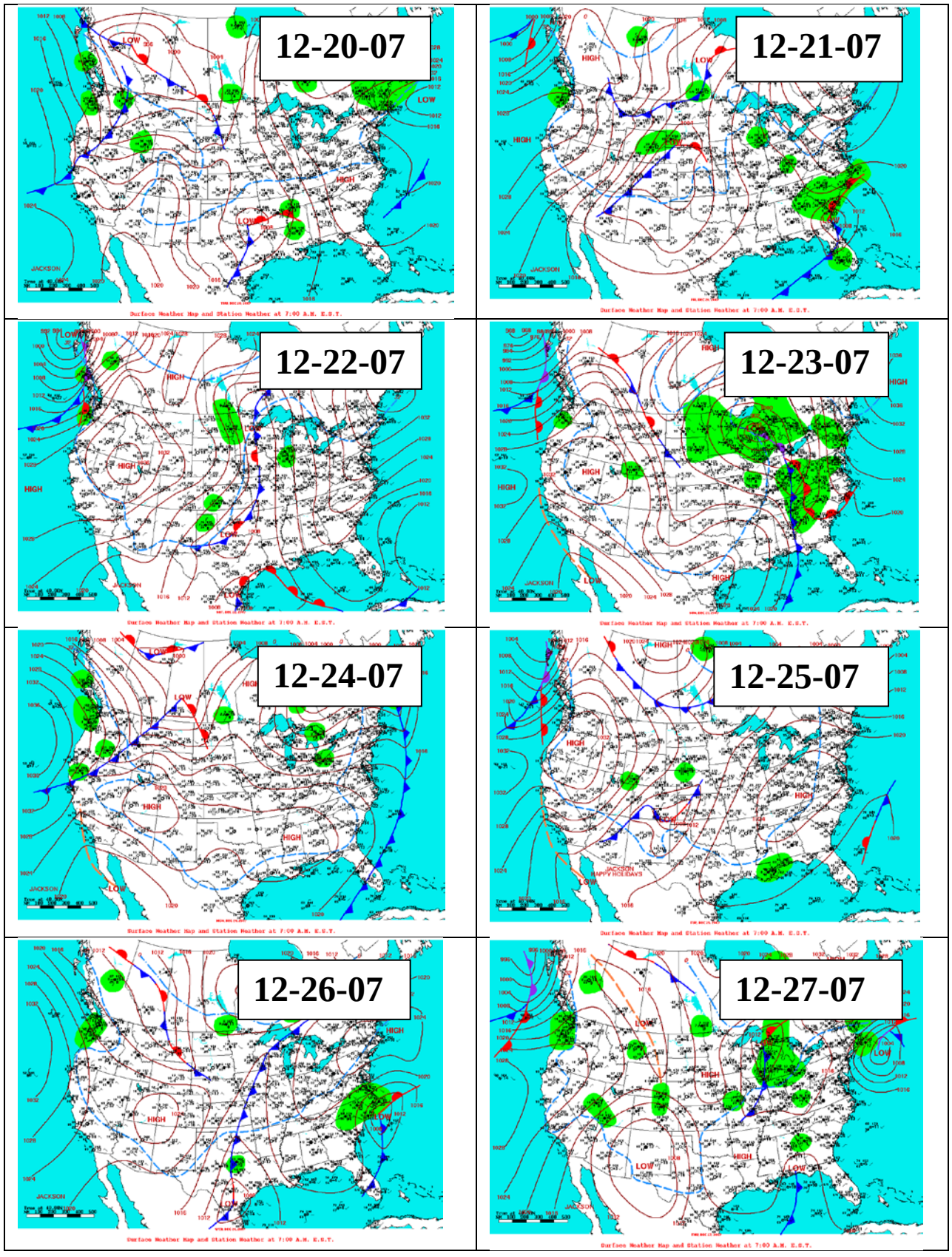
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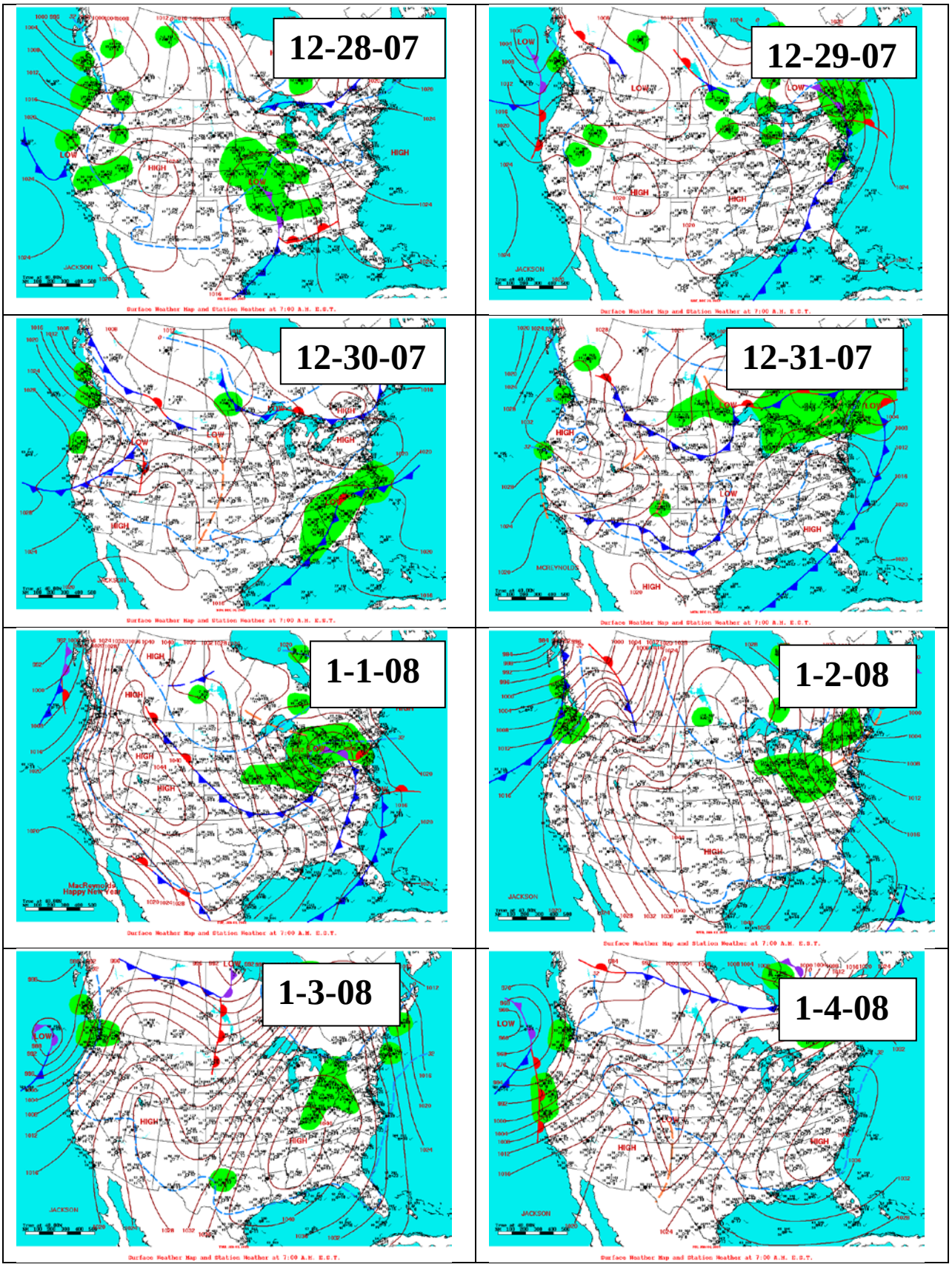
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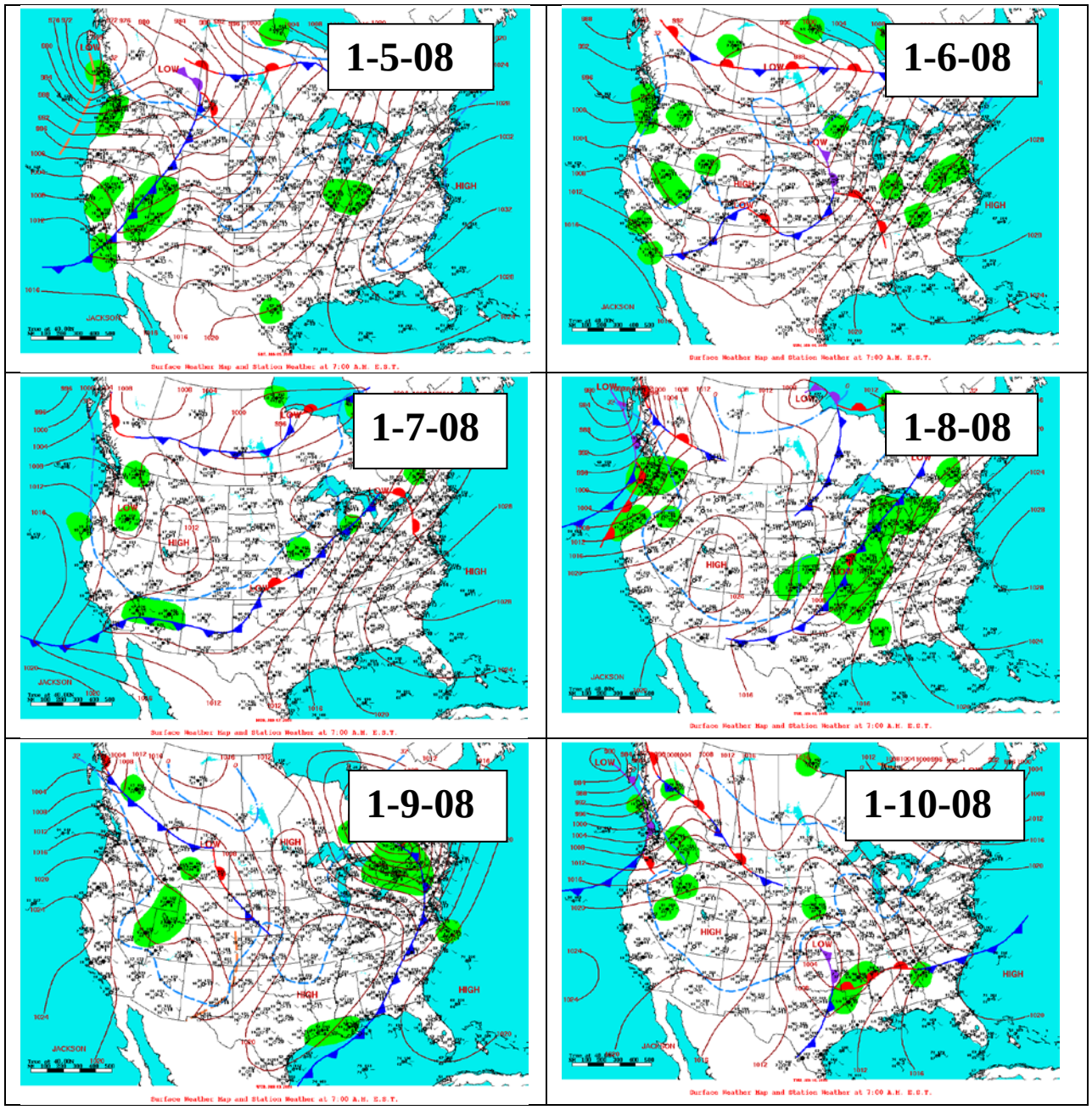
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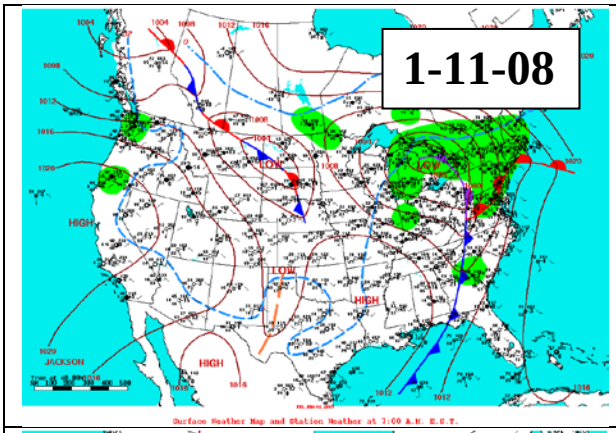

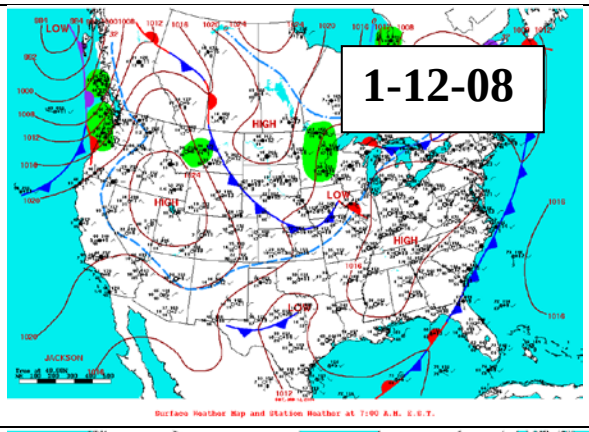

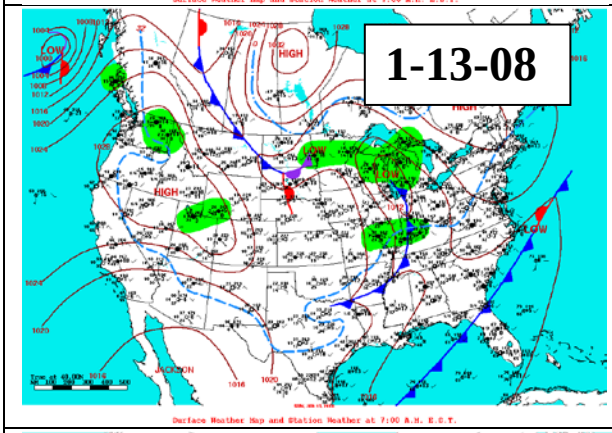

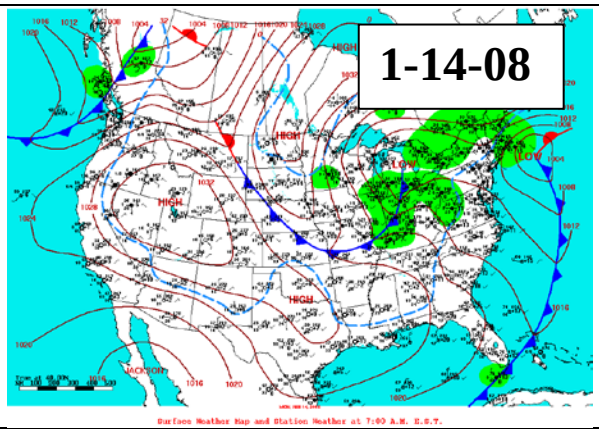

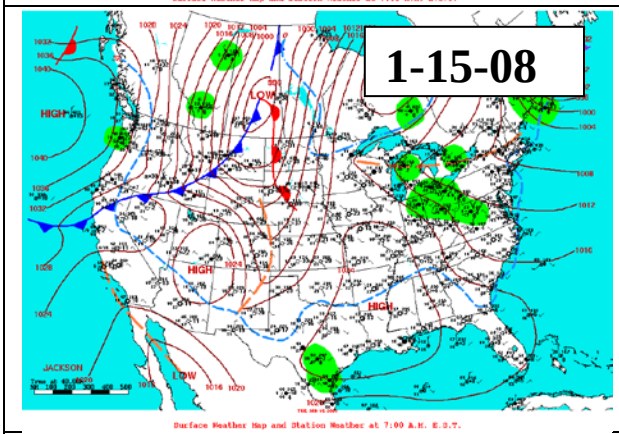

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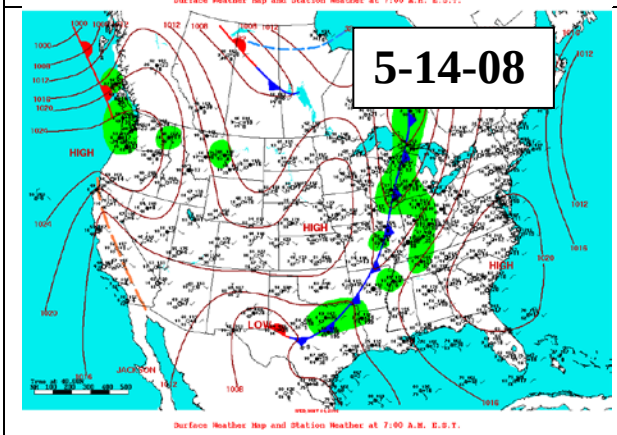

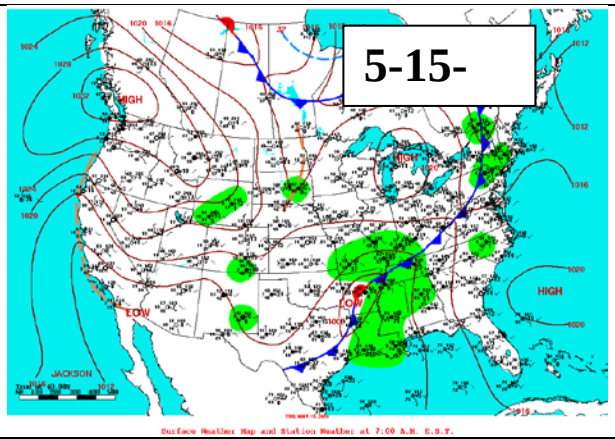

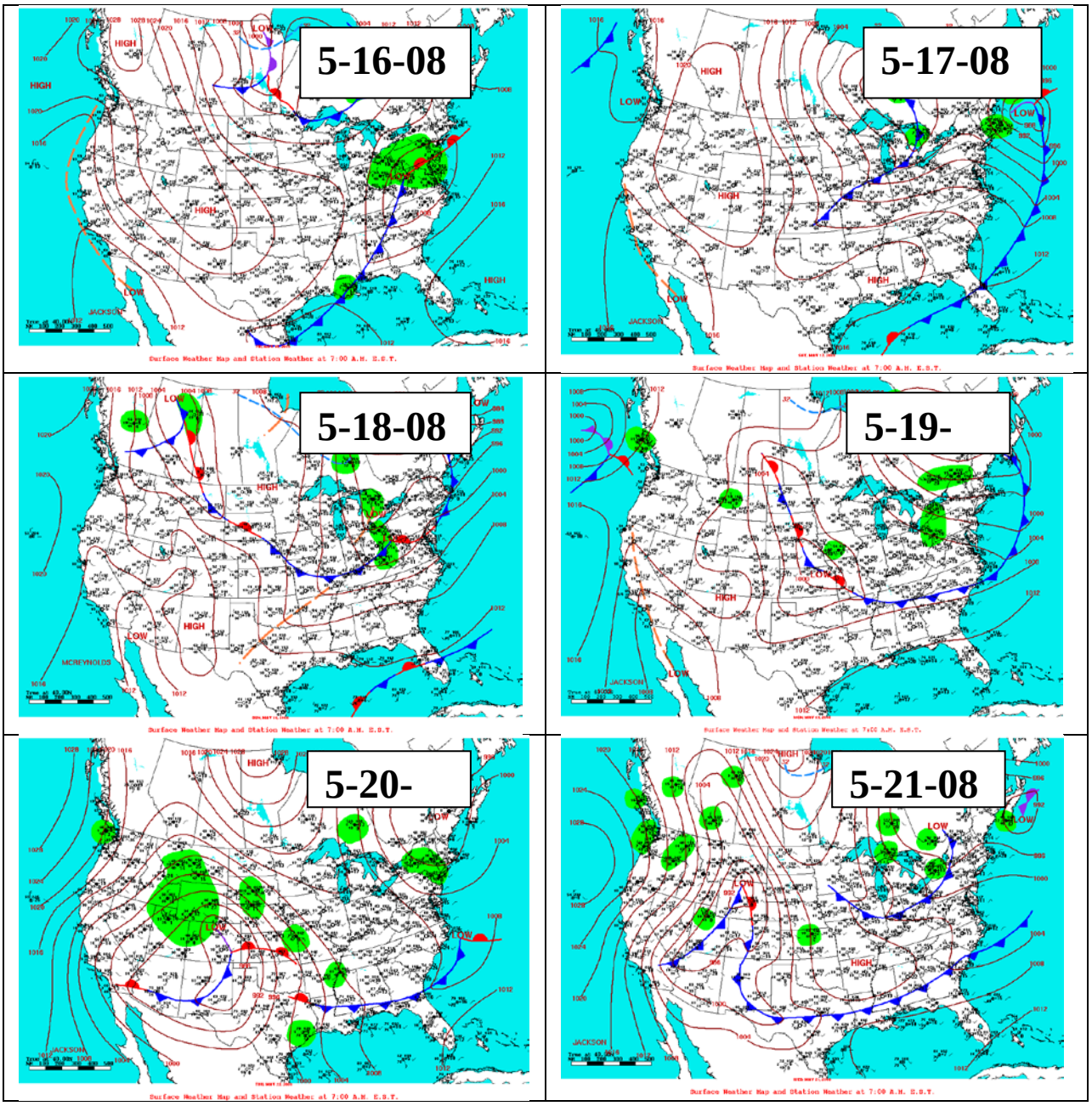
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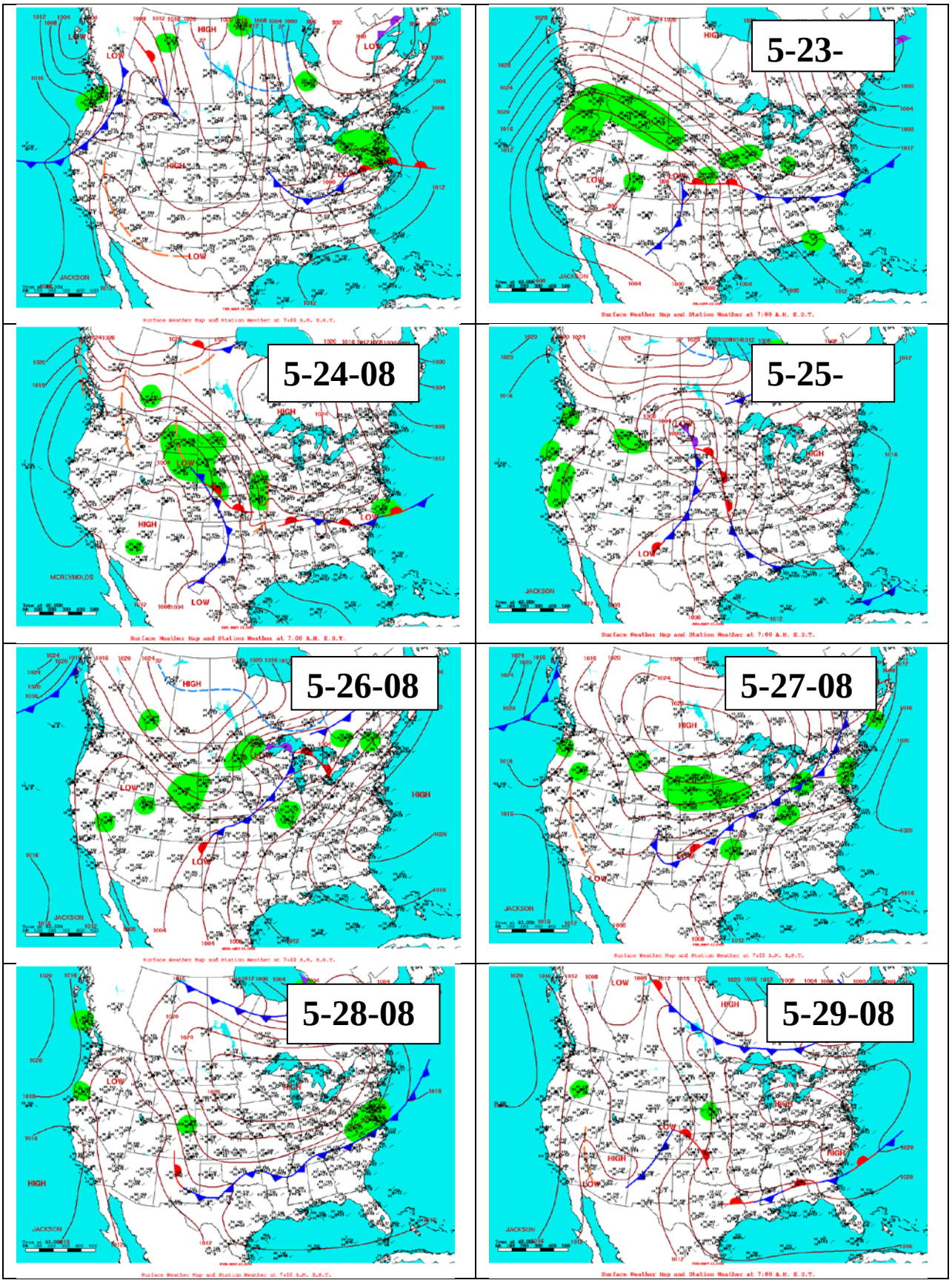
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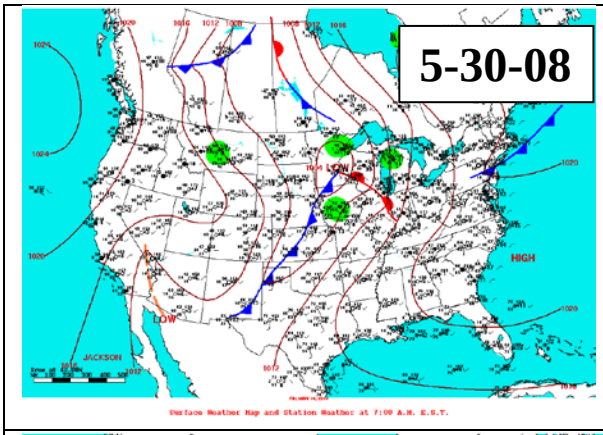

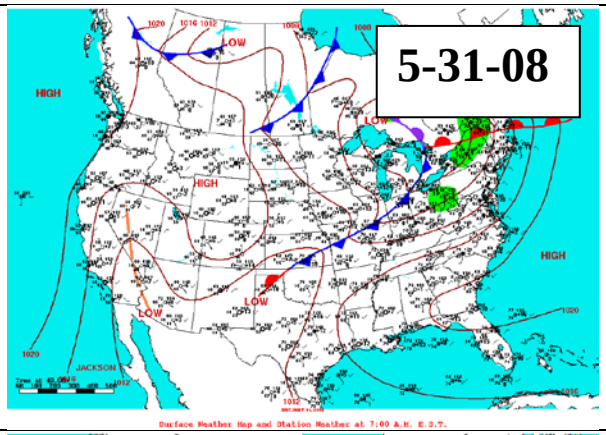

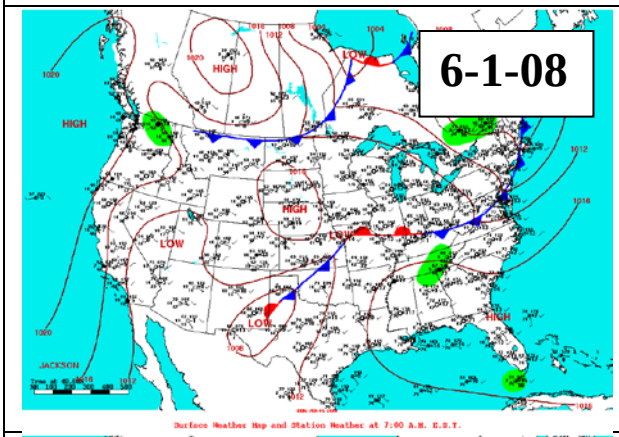

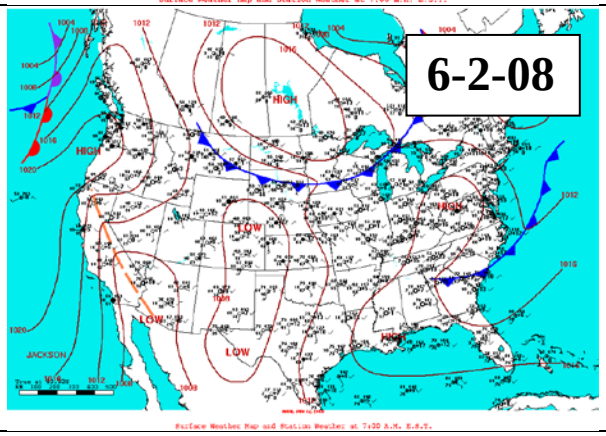

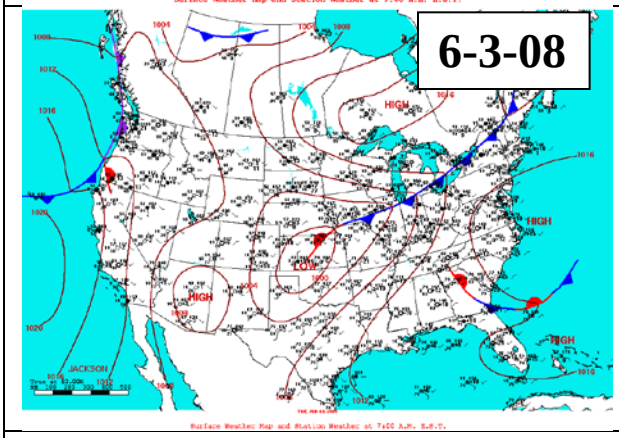

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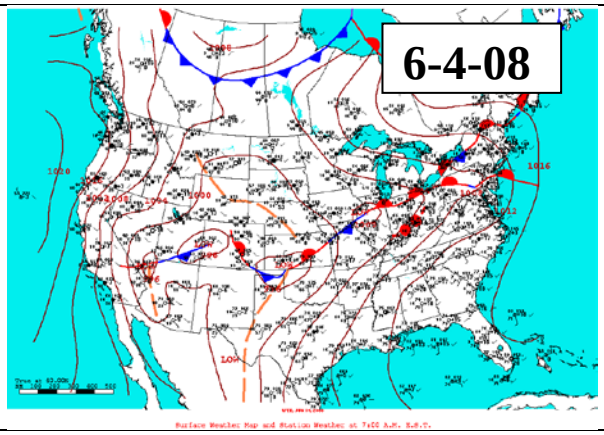

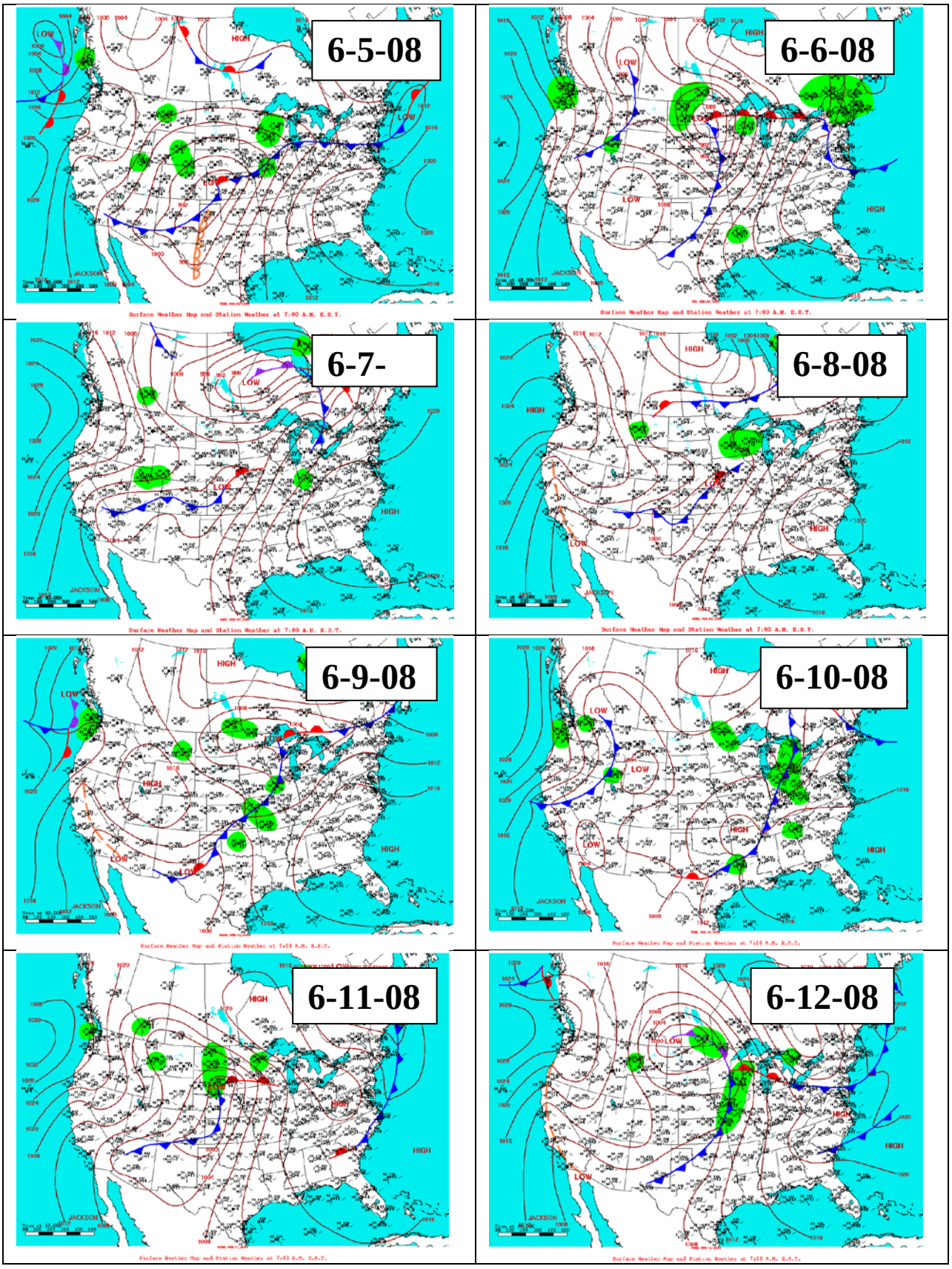
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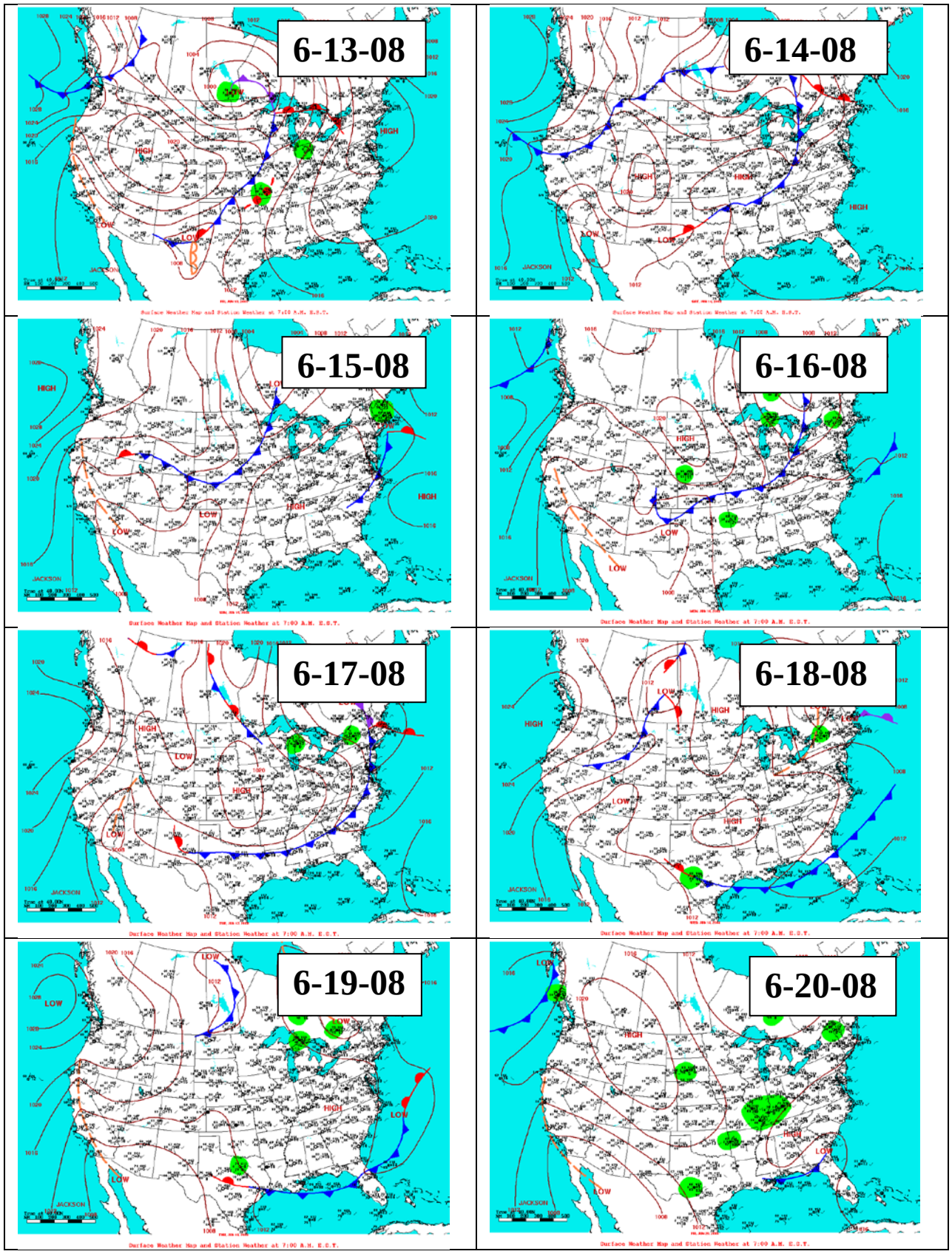
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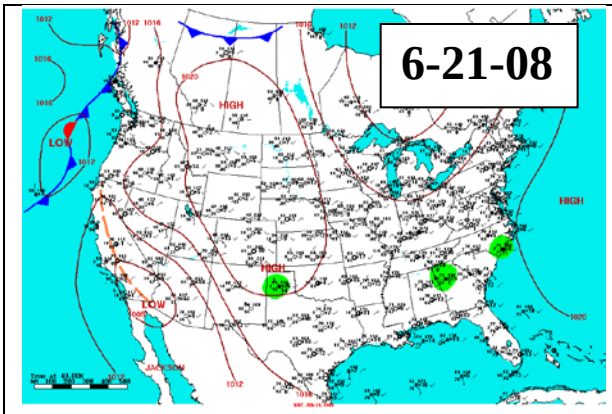
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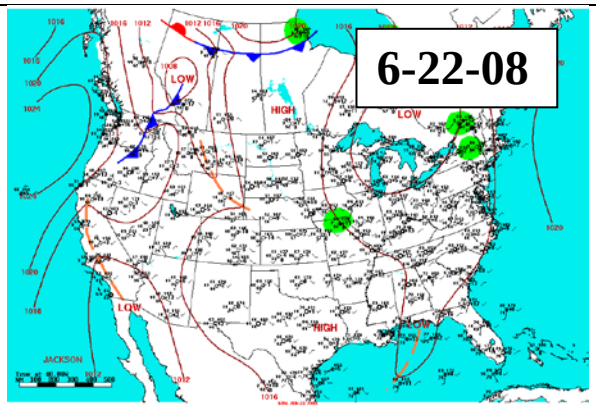
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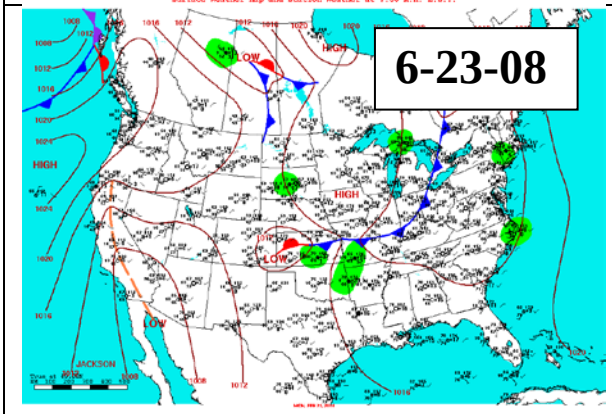
JACKSON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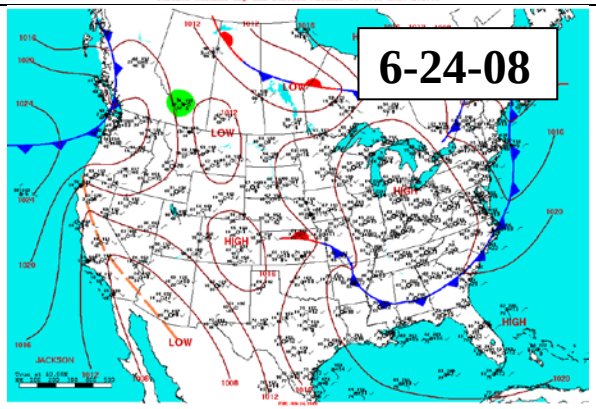
JACKSON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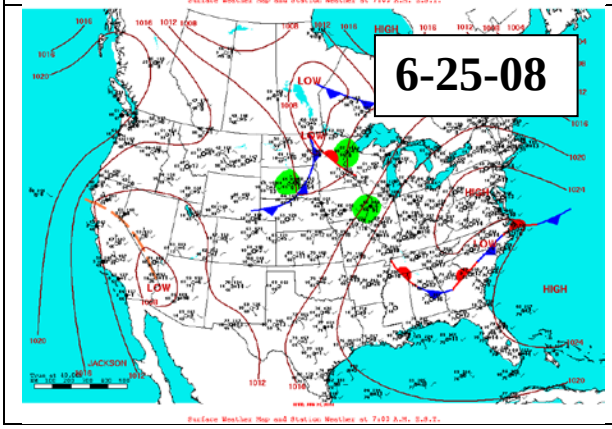
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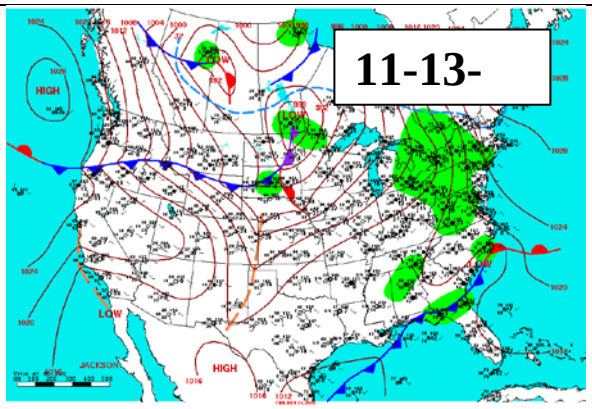
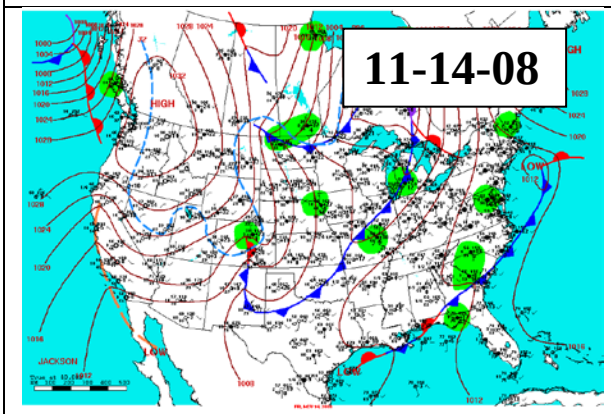
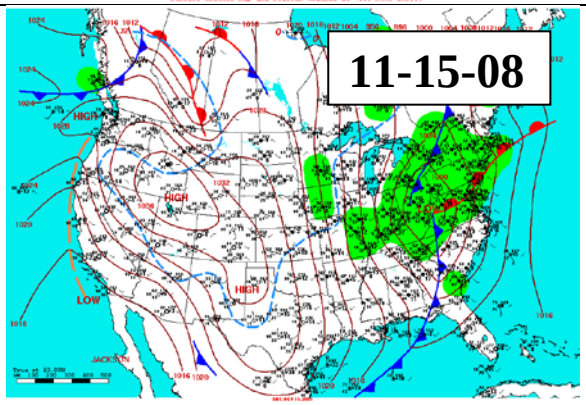
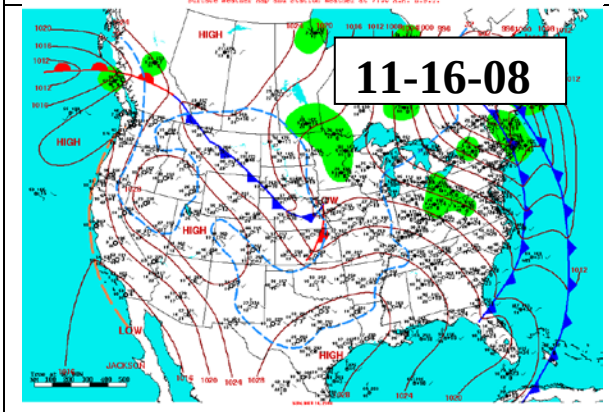
JACKSON

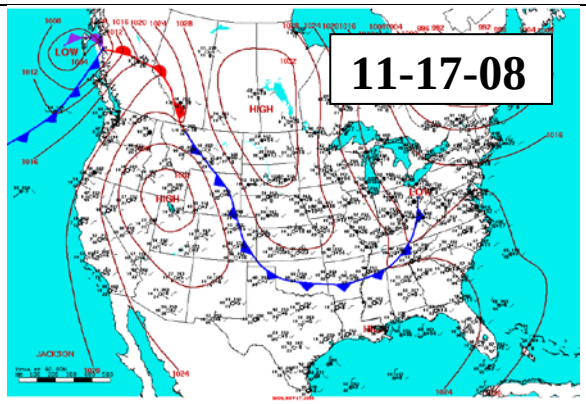
Period 6

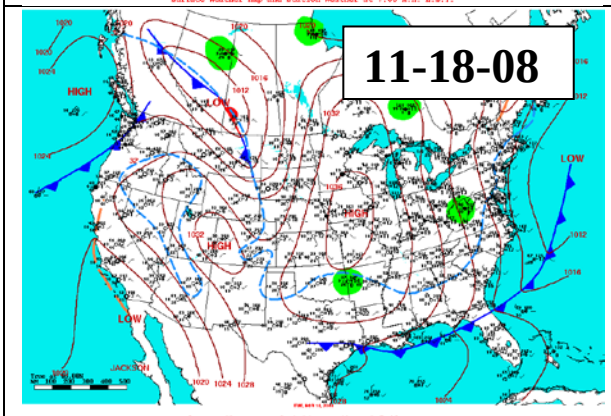


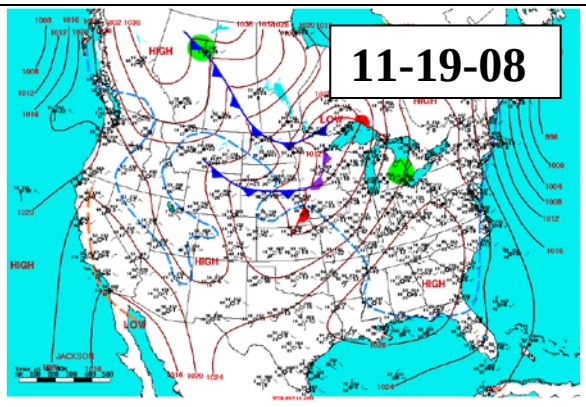


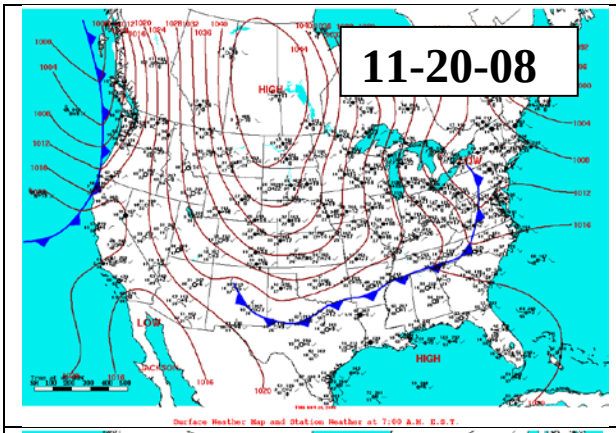


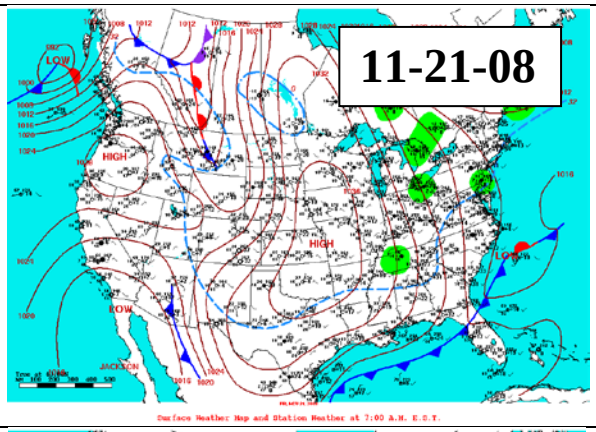


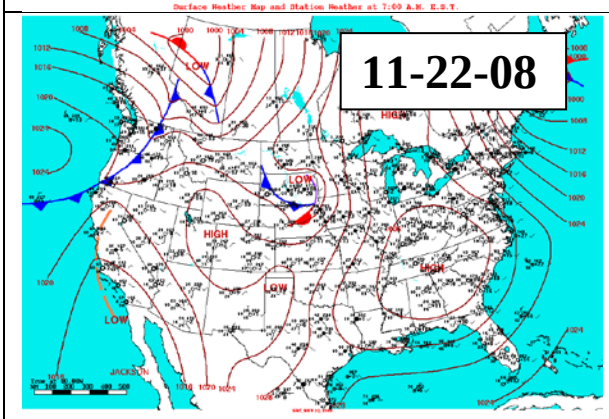


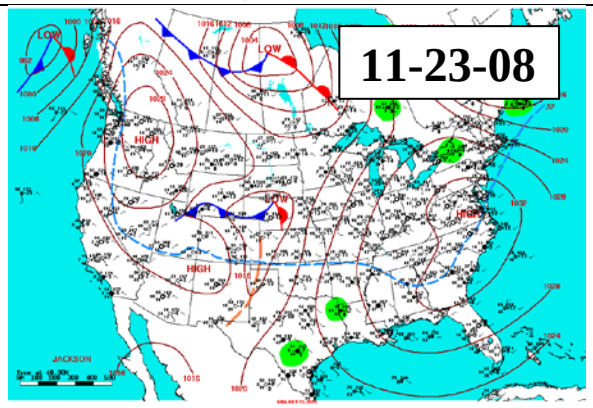


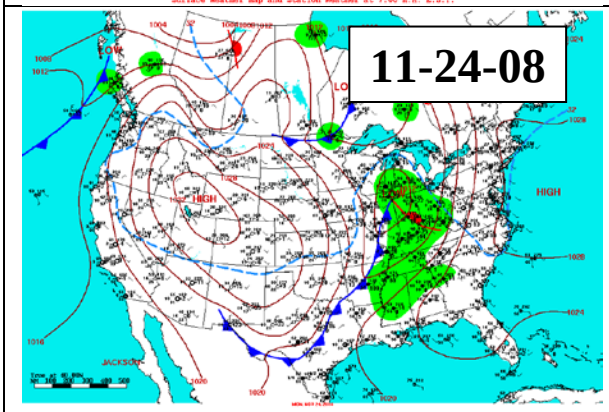




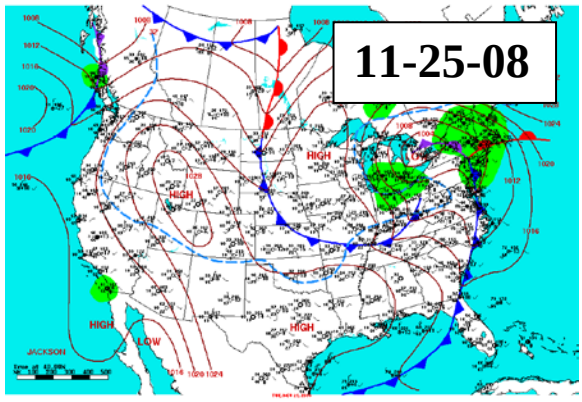


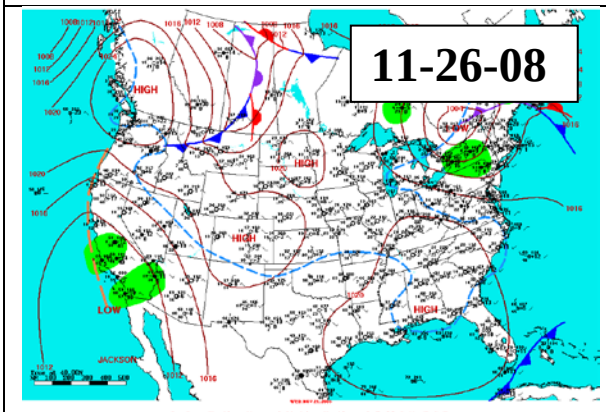


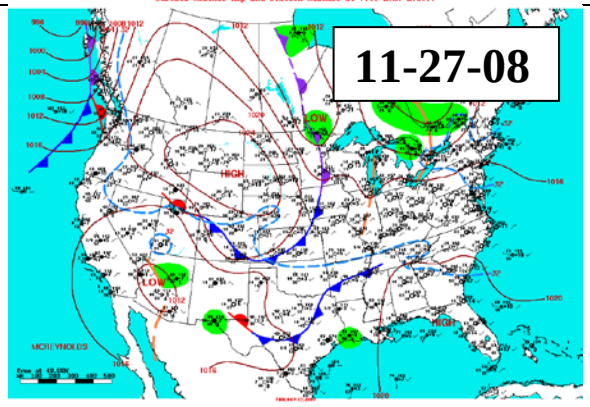


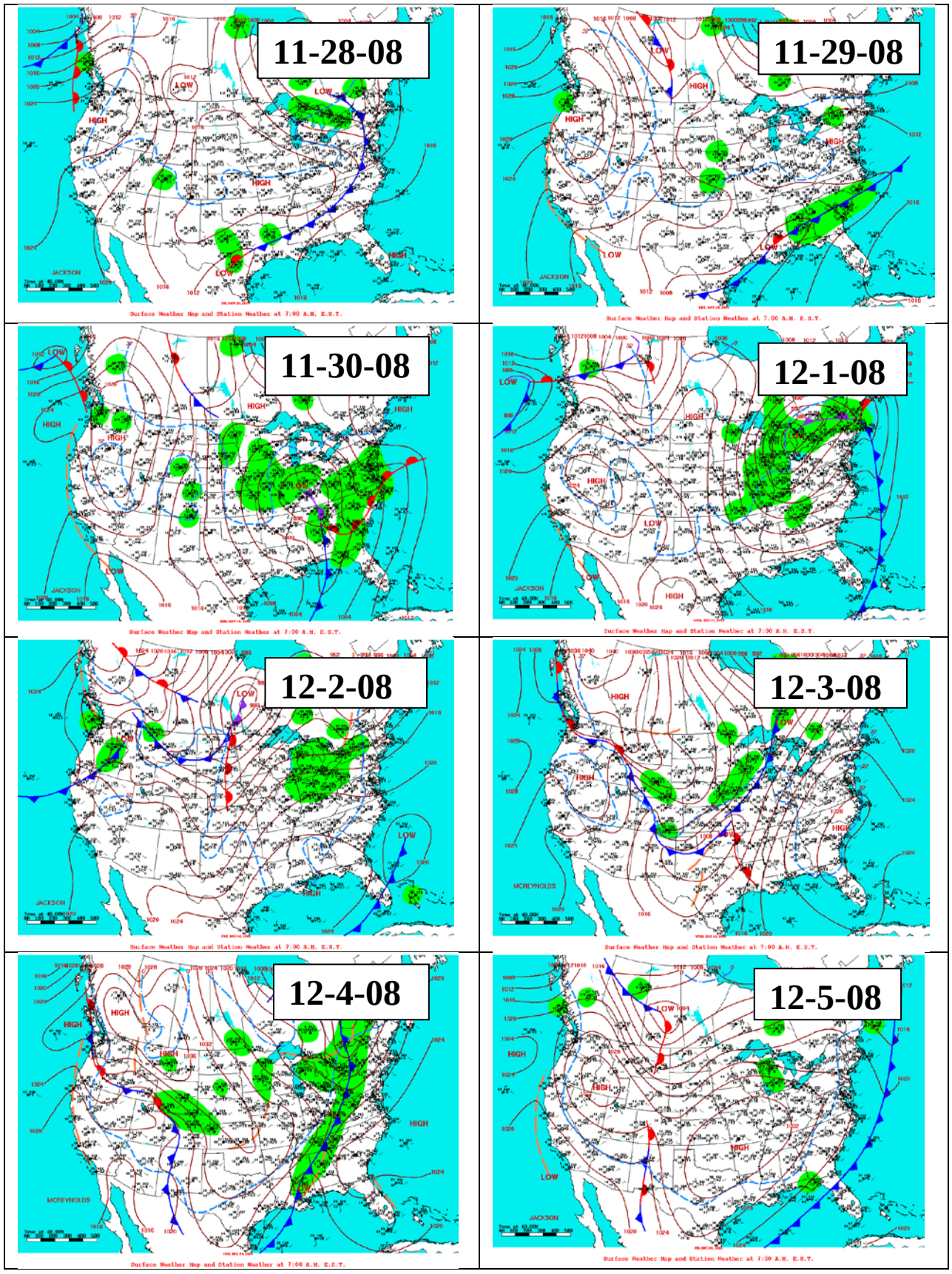


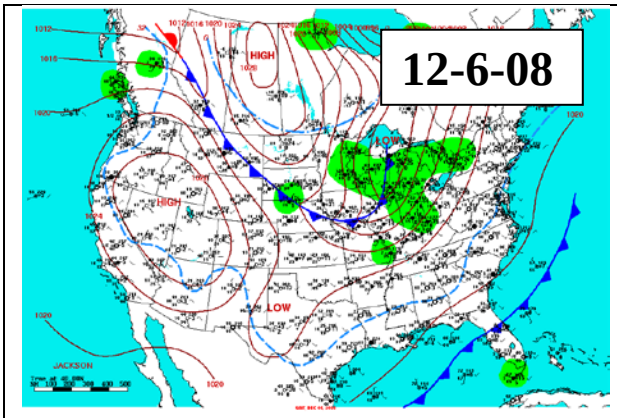
Period 7








11-28-08
11-29-08
11-30-08
12-1-08
12-2-08
12-3-08
12-4-08
12-5-08


12-6-08
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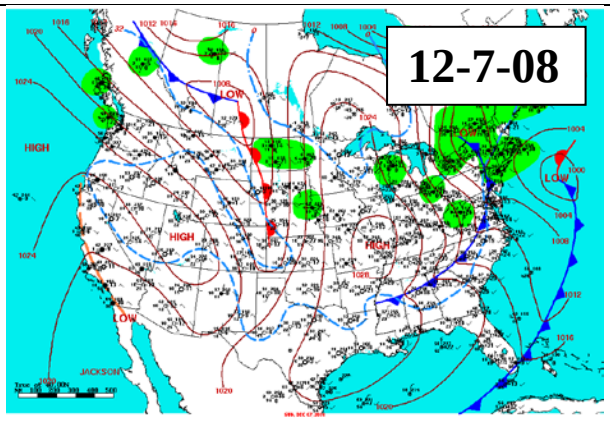
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


12-7-08
LOW
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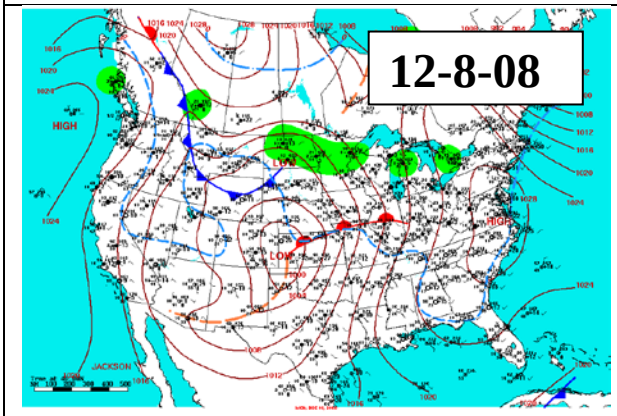
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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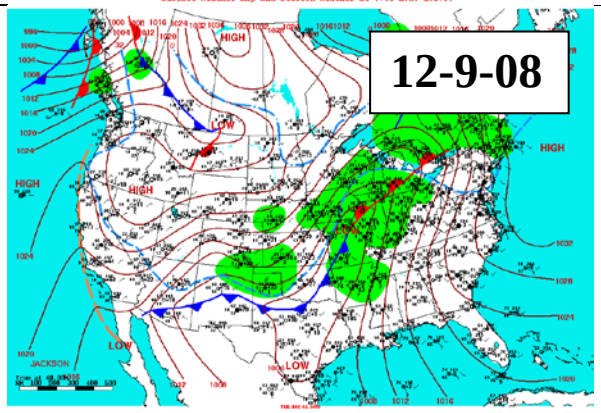
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


12-9-08
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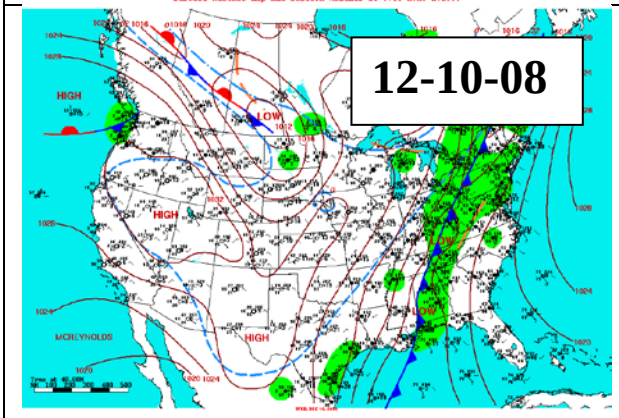
LOW
HIGH
HIGH
HIGH
LOW
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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HIGH
HIGH
LOW
MCREYNOLDS
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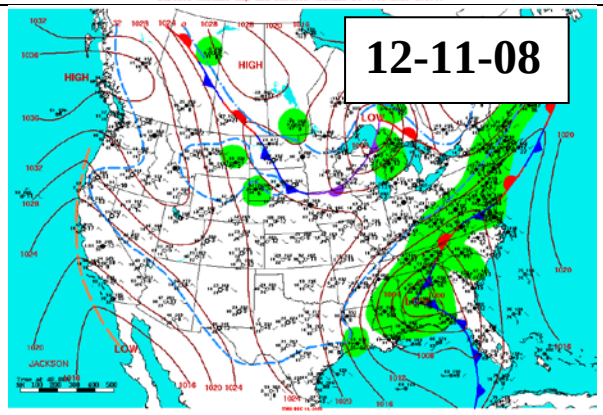
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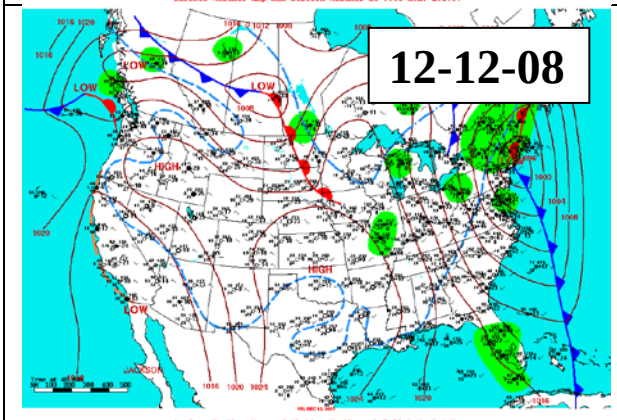
HIGH
LOW
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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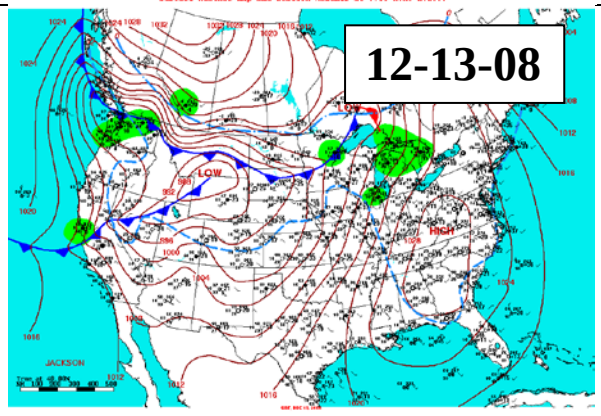
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


12-13-08
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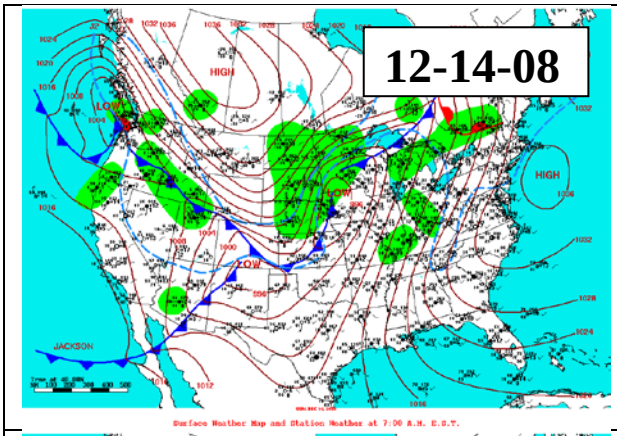
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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HIGH
LOW
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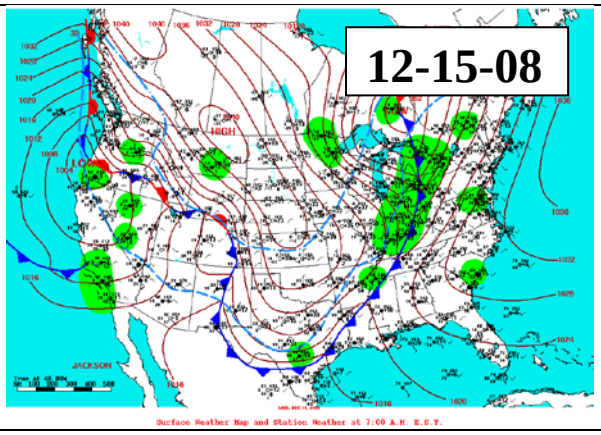
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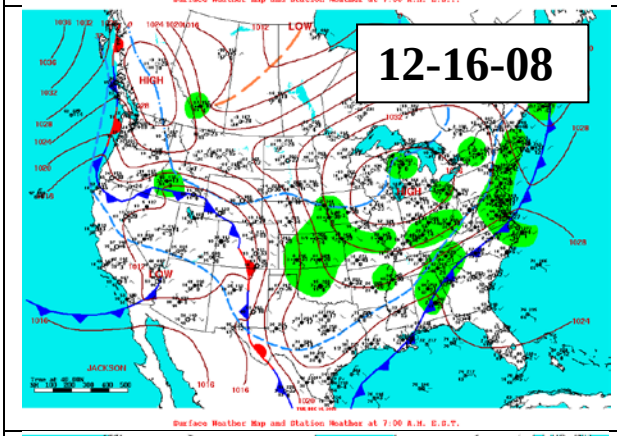
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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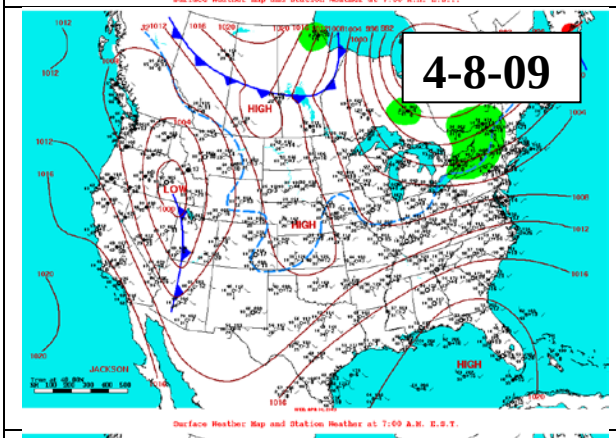
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

Period 8


4-8-09
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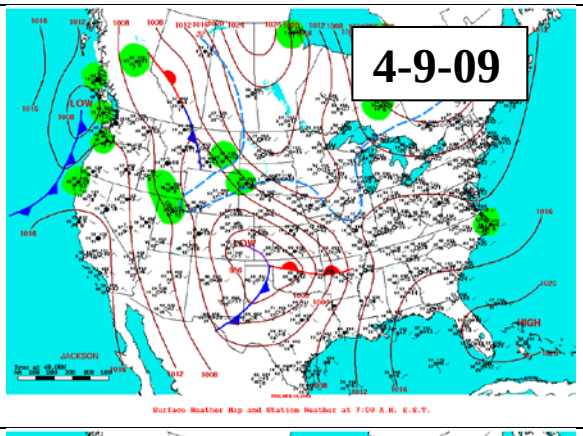
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


4-9-09
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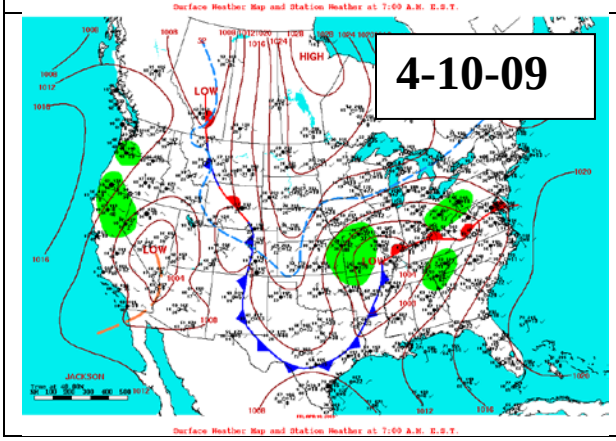
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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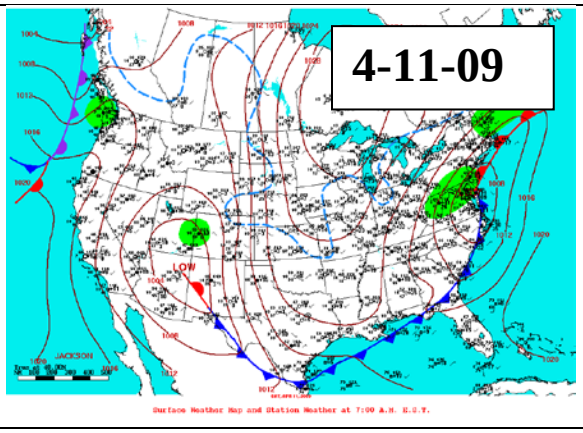
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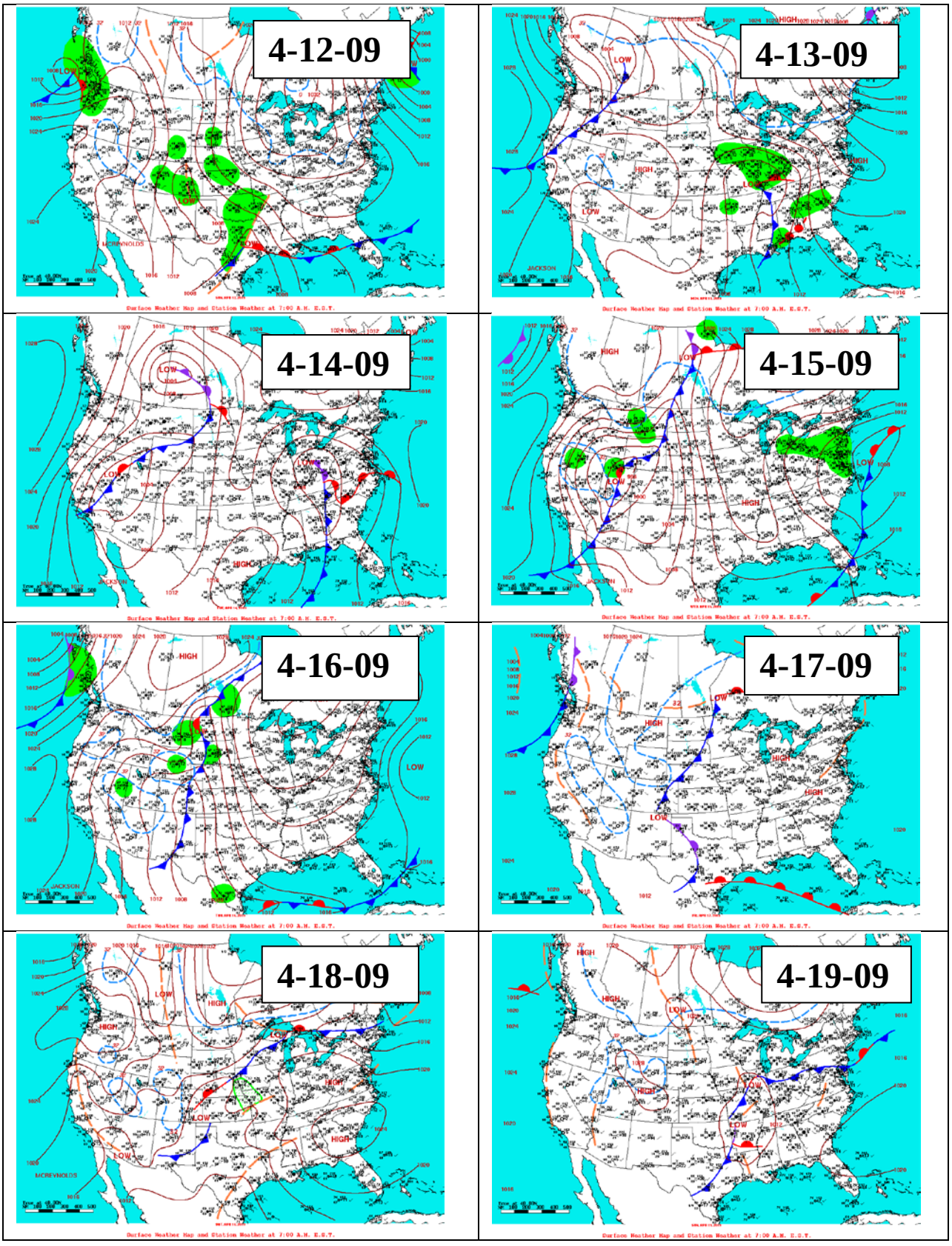
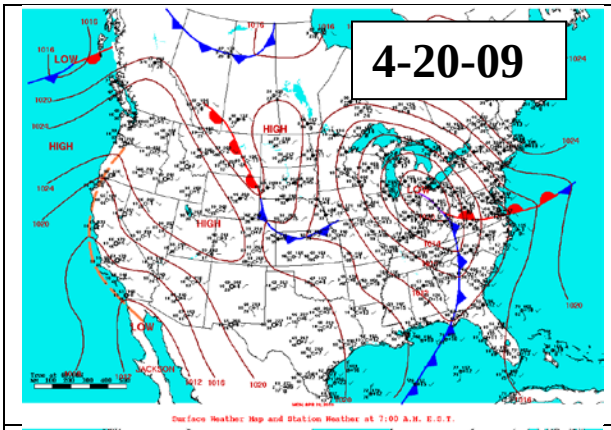
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


4-12-09
4-13-09
4-14-09
4-15-09
4-16-09
4-17-09
4-18-09
4-19-09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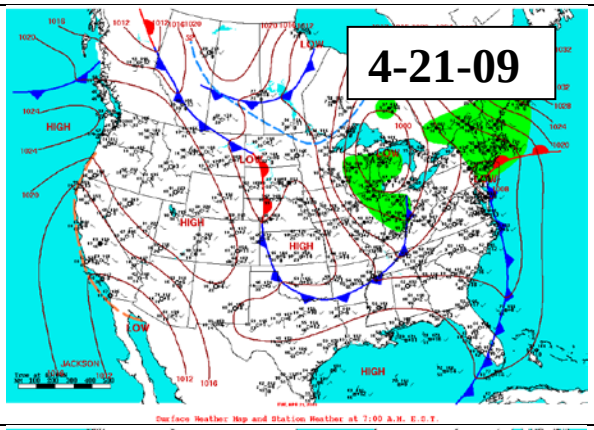
JACKSON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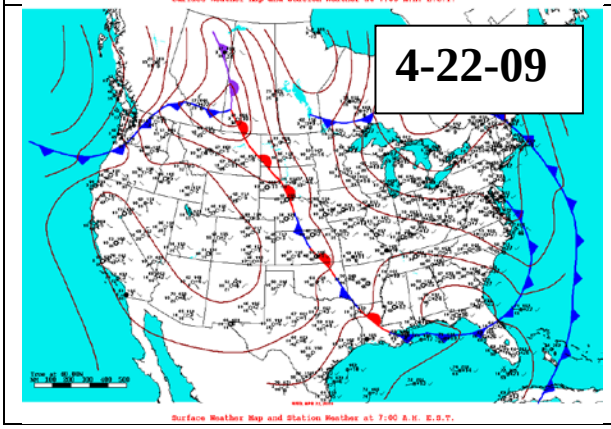
LOW
HIGH
JACKSON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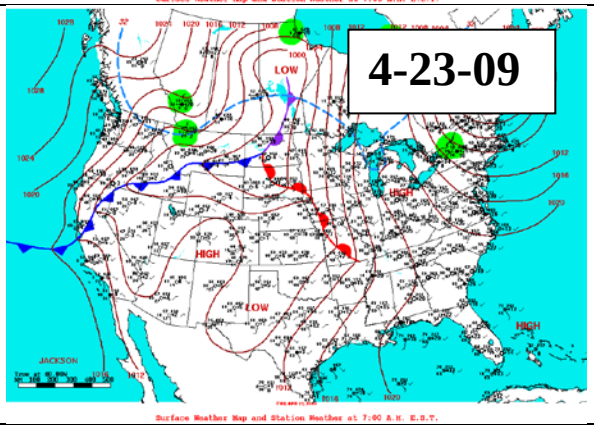
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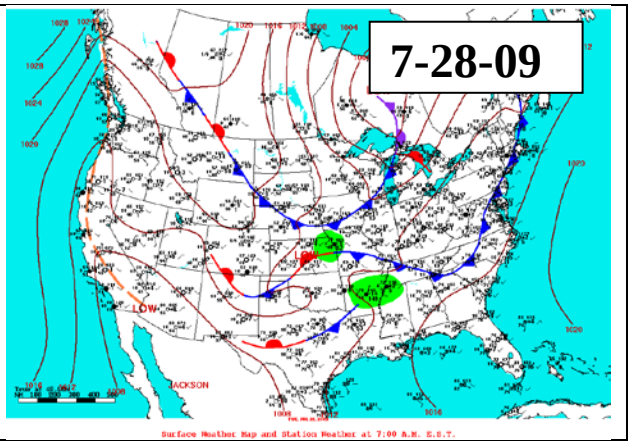
JACKSON

Period 9


7-28-09
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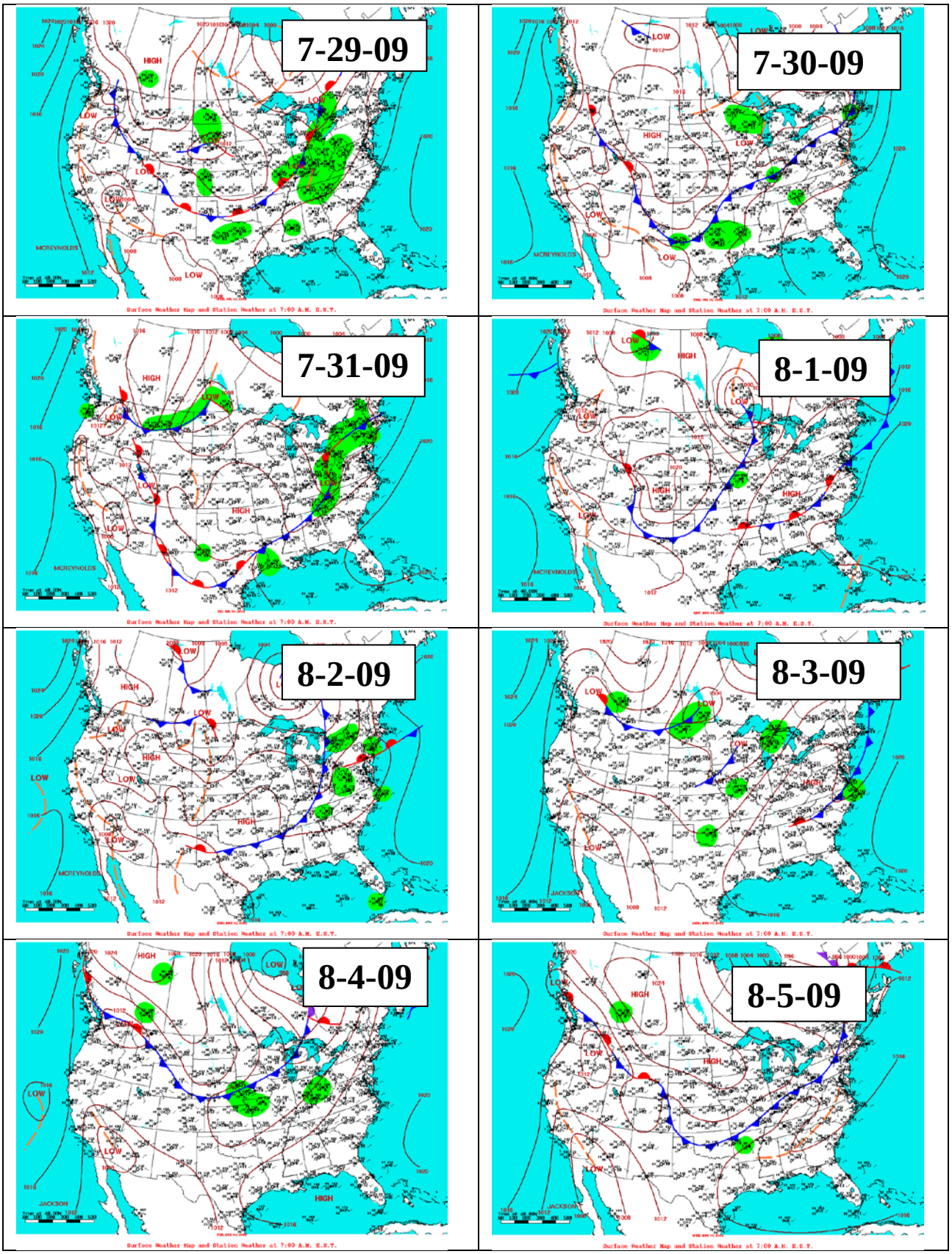
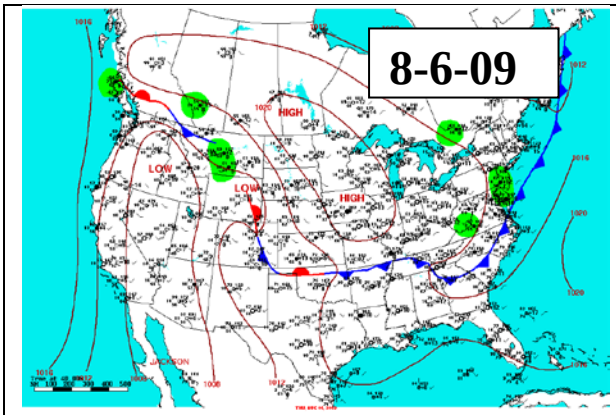
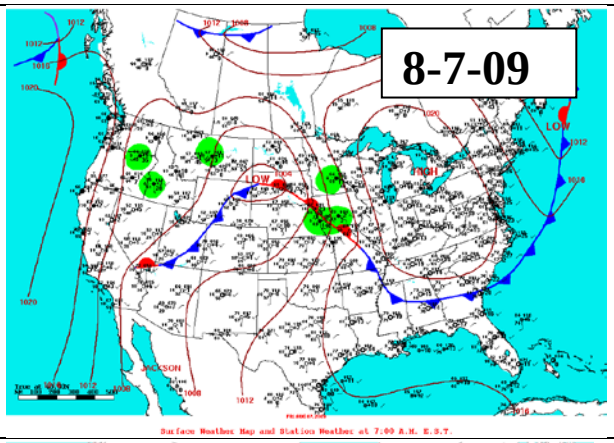
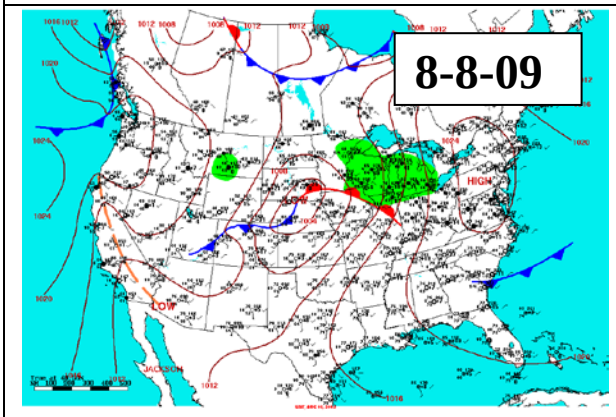
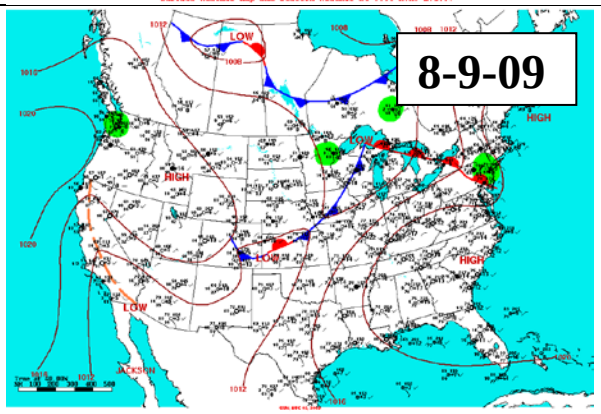
JACKSON

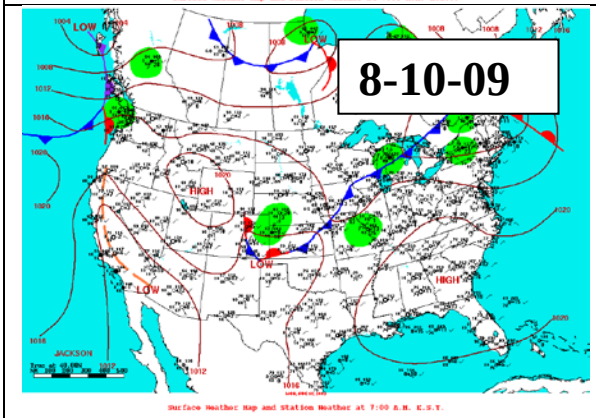

7-29-09
7-30-09
7-31-09
8-1-09
8-2-09
8-3-09
8-4-09
8-5-09


8-6-09
HIGH
LOW
LOW
HIGH
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-7-09
LOW
LOW
HIGH
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-8-09
HIGH
LOW
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-9-09
LOW
HIGH
LOW
HIGH
LOW
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-10-09
LOW
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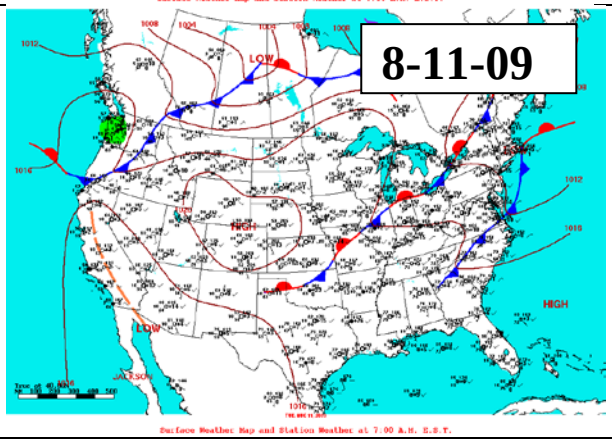
LOW
LOW
HIGH
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-11-09
LOW
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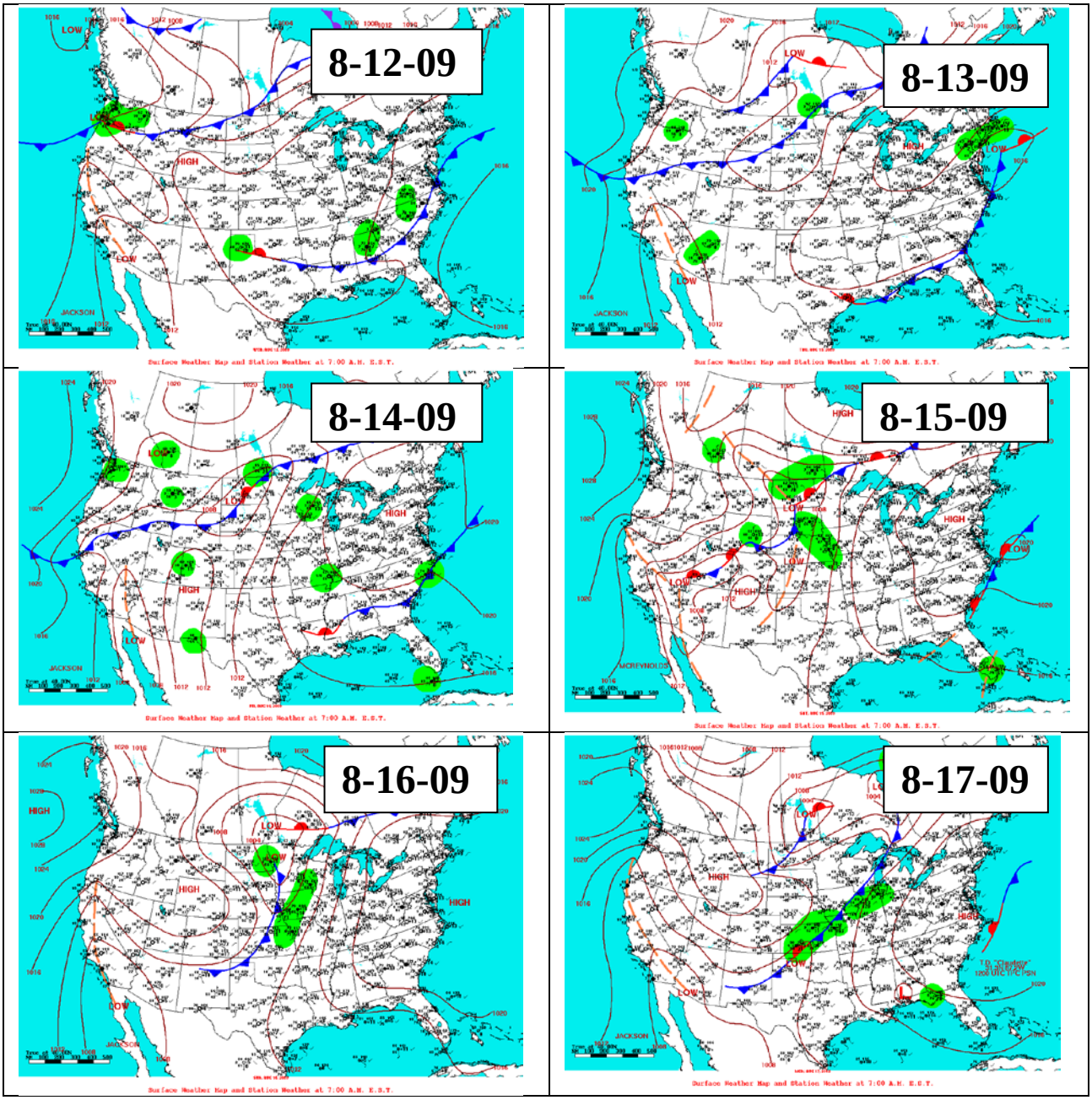
LOW
HIGH
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-12-09
8-13-09
8-14-09
8-15-09
8-16-09
8-17-09

6.8 Daily weather conditions

Date	Barometric pressure (kPa)	Max solar radiation (Wm^{-2})	Wetness (%)	Avg. air temperature (°C)
Period 2				
8/30/2007	98.25	437	N/A	24.6
8/31/2007	98.27	809	N/A	18.9
9/1/2007	98.20	817	N/A	19.5
9/2/2007	97.99	798	N/A	20.3
9/3/2007	97.95	799	N/A	22.9
9/4/2007	97.57	789	N/A	22.8
9/5/2007	97.23	808	N/A	23.4
9/6/2007	97.03	796	N/A	22.9
9/7/2007	97.02	869	N/A	22.3
9/8/2007	97.73	764	N/A	18.4
9/9/2007	97.99	725	N/A	17.8
9/10/2007	98.23	565	N/A	13.5
9/11/2007	97.83	797	N/A	13.8
9/12/2007	98.00	755	N/A	11.2
9/13/2007	97.40	794	N/A	17.2
9/14/2007	98.10	892	N/A	10.7
9/15/2007	98.62	692	N/A	7.0
9/16/2007	97.88	797	N/A	14.0
9/17/2007	97.22	743	N/A	22.5
9/18/2007	97.20	351	N/A	22.6
9/19/2007	97.94	739	N/A	18.2
9/20/2007	97.90	712	N/A	19.3
9/21/2007	97.03	752	N/A	24.3
9/22/2007	97.89	770	N/A	16.0
9/23/2007	97.75	741	N/A	18.5
9/24/2007	97.21	817	N/A	23.8
9/25/2007	97.56	707	N/A	16.9
9/26/2007	97.94	733	N/A	10.9
Period 3				
12/19/2007	97.44	92	N/A	-0.7
12/20/2007	97.04	417	N/A	-3.3
12/21/2007	96.89	219	N/A	-2.3
12/22/2007	97.01	152	N/A	-2.1
12/23/2007	97.03	440	N/A	-10.6
12/24/2007	97.61	226	N/A	-5.7
12/25/2007	97.41	463	N/A	-2.3

Date	Barometric pressure (kPa)	Max solar radiation (Wm^{-2})	Wetness (%)	Avg. air temperature (°C)
12/26/2007	97.48	412	N/A	-3.5
12/27/2007	97.79	175	N/A	-6.9
12/28/2007	97.58	368	N/A	-4.8
12/29/2007	97.47	439	N/A	-6.6
12/30/2007	97.05	523	N/A	-9.1
12/31/2007	97.06	452	N/A	-11.3
1/1/2008	98.71	450	N/A	-12.9
1/2/2008	99.88	446	N/A	-14.8
1/3/2008	98.96	454	N/A	-9.1
1/4/2008	97.52	650	N/A	-2.7
1/5/2008	96.61	439	N/A	-0.7
1/6/2008	96.25	338	N/A	1.2
1/7/2008	96.63	479	N/A	0.4
1/8/2008	96.93	314	N/A	-0.1
1/9/2008	97.57	273	N/A	-2.4
1/10/2008	96.76	174	N/A	-1.1
1/11/2008	96.73	456	N/A	-3.5
1/12/2008	97.23	169	N/A	-3.5
1/13/2008	97.88	588	N/A	-7.2
1/14/2008	98.32	476	N/A	-8.7
1/15/2008	98.24	198	N/A	-14.6
Period 4				
5/16/2008	97.43	1124	0	17.1
5/17/2008	96.73	1088	0	20.7
5/18/2008	96.74	1029	0	16.1
5/19/2008	96.35	1014	0	17.6
5/20/2008	96.81	1157	0	14.3
5/21/2008	96.87	1025	0	13.7
5/22/2008	96.88	525	0	14.6
5/23/2008	97.35	396	0	13.2
5/24/2008	97.59	772	1	12.0
5/25/2008	97.02	1000	1	19.9
5/26/2008	96.93	1079	0	19.9
5/27/2008	97.77	488	1	12.9
5/28/2008	98.57	885	0	11.4
5/29/2008	97.82	694	0	14.5
5/30/2008	96.83	1104	1	19.8
5/31/2008	97.20	1017	0	20.5

Date	Barometric pressure (kPa)	Max solar radiation (Wm^{-2})	Wetness (%)	Avg. air temperature (°C)
Period 5				
6/1/2008	97.45	1055	0	21.6
6/2/2008	97.27	1167	0	21.8
6/3/2008	96.40	723	1	19.6
6/4/2008	96.20	460	1	17.7
6/5/2008	95.98	787	1	21.5
6/6/2008	95.96	1085	0	20.3
6/7/2008	96.63	1008	0	24.3
6/8/2008	96.46	777	1	22.2
6/9/2008	96.94	1029	0	20.0
6/10/2008	97.11	981	0	20.5
6/11/2008	96.75	908	0	21.9
6/12/2008	96.63	1121	0	20.4
6/13/2008	97.30	1086	0	20.2
6/14/2008	97.37	1150	0	22.0
6/15/2008	97.18	1089	0	23.4
6/16/2008	97.69	1015	0	19.1
6/17/2008	97.97	1017	0	19.0
6/18/2008	97.58	1173	0	22.3
6/19/2008	97.37	1083	1	21.8
6/20/2008	97.53	1095	1	21.6
6/21/2008	97.85	1111	0	22.8
6/22/2008	97.69	1017	0	21.0
6/23/2008	97.75	1194	0	20.8
6/24/2008	N/A	273	N/A	19.3
Period 6				
11/14/2008	97.15	158	0	5.6
11/15/2008	97.90	577	0	0.2
11/16/2008	97.67	419	0	0.4
11/17/2008	98.72	573	0	-0.5
11/18/2008	99.14	429	0	-4.7
11/19/2008	97.65	482	0	1.1
11/20/2008	99.02	459	0	-2.0
11/21/2008	99.40	420	0	-9.5
11/22/2008	98.41	206	0	-3.3
11/23/2008	97.85	640	1	-5.2
11/24/2008	97.77	441	1	0.9

Date	Barometric pressure (kPa)	Max solar radiation (Wm^{-2})	Wetness (%)	Avg. air temperature (°C)
11/25/2008	98.12	428	1	-4.5
11/26/2008	97.65	427	1	-1.4
11/27/2008	97.73	455	1	-0.9
11/28/2008	97.71	437	0	0.1
11/29/2008	97.02	124	0	-1.4
11/30/2008	96.24	294	1	-1.7
Period 7				
12/1/2008	96.92	482	1	-5.1
12/2/2008	96.92	417	0	-4.8
12/3/2008	97.35	421	0	-3.0
12/4/2008	98.72	548	0	-8.3
12/5/2008	98.52	461	0	-8.1
12/6/2008	97.28	443	0	-2.5
12/7/2008	98.03	447	0	-9.2
12/8/2008	96.82	140	0	-4.2
12/9/2008	97.18	177	1	-5.3
12/10/2008	98.38	307	1	-10.6
12/11/2008	97.82	502	1	-2.9
12/12/2008	97.98	392	1	-3.4
12/13/2008	96.40	381	0	2.3
12/14/2008	95.85	163	1	-2.8
12/15/2008	98.68	382	0	-19.1
12/16/2008	99.21	158	0	-18.8
Period 8				
4/8/2009	96.92	833	0	13.2
4/9/2009	97.07	624	1	3.9
4/10/2009	97.45	887	0	6.9
4/11/2009	98.31	883	0	6.3
4/12/2009	98.15	874	0	7.1
4/13/2009	97.31	432	0	6.6
4/14/2009	97.43	887	0	6.9
4/15/2009	97.97	944	0	9.9
4/16/2009	98.41	900	0	12.3
4/17/2009	98.46	881	0	12.4
4/18/2009	97.77	549	0	13.2
4/19/2009	97.54	851	1	10.7
4/20/2009	97.34	685	0	7.0
4/21/2009	97.28	1073	0	7.6

Date	Barometric pressure (kPa)	Max solar radiation (Wm^{-2})	Wetness (%)	Avg. air temperature (°C)
4/22/2009	97.19	894	0	12.9
4/23/2009	96.88	955	0	16.1
Period 9				
7/28/2009	97.28	935	0	23.7
7/29/2009	97.30	886	0	18.0
7/30/2009	97.29	1062	1	18.0
7/31/2009	97.53	982	0	18.2
8/1/2009	97.38	1049	0	19.2
8/2/2009	97.33	891	0	19.2
8/3/2009	96.93	882	1	23.6
8/4/2009	97.29	928	1	22.1
8/5/2009	97.96	996	1	17.8
8/6/2009	98.02	907	1	19.2
8/7/2009	97.36	892	1	22.6
8/8/2009	96.86	854	0	27.8
8/9/2009	97.23	949	1	24.1
8/10/2009	97.59	875	1	22.1
8/11/2009	97.89	862	1	21.6
8/12/2009	97.83	850	1	23.5
8/13/2009	97.63	810	1	24.2
8/14/2009	97.66	702	1	23.7
8/15/2009	97.35	820	1	21.7
8/16/2009	97.14	857	1	22.1
8/17/2009	97.63	835	1	19.1
8/18/2009	97.80	548	1	15.7

6.9 Daily Site emissions and data completeness

6.9.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year

Valid values: Number of ½ h periods with valid emissions data

Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction

Missing downwind NH_3: Number of ½ h periods invalidated because at least 1 TDL path was either missing or else had invalid concentration values

Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods

Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods

Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods

Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area

Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis

Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 2										
8/31/2007	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/2/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/3/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/4/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/6/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/7/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/8/2007	0	6	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/9/2007	20	4	24	605.0	183.6	309.1	872.7	115.0	29.9	221.8
9/10/2007	25	8	14	260.9	53.7	181.8	363.6	49.6	12.9	95.7
9/11/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/12/2007	0	2	39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/13/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/14/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/15/2007	0	1	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/16/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/18/2007	10	1	37	477.7	93.0	359.1	704.5	90.8	23.6	175.2
9/19/2007	3	2	39	489.4	41.2	445.5	527.3	93.0	24.2	179.4
9/20/2007	1	0	46	4.5	N/A	4.5	4.5	0.9	0.2	1.7
9/21/2007	1	0	47	272.7	N/A	272.7	272.7	51.8	13.5	100.0
9/22/2007	10	0	36	119.5	62.4	45.5	254.5	22.7	5.9	43.8
9/23/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/24/2007	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2007	3	0	42	419.7	97.2	359.1	531.8	79.8	20.8	153.9
9/26/2007	12	0	13	162.5	52.9	77.3	250.0	30.9	8.0	59.6
Period 3										
12/20/2007	0	0	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/21/2007	0	0	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/22/2007	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/23/2007	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/24/2007	1	0	30	90.9	N/A	90.9	90.9	17.3	4.5	33.3
12/25/2007	1	0	36	209.1	N/A	209.1	209.1	39.7	10.4	76.7
12/26/2007	0	1	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/27/2007	0	2	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/28/2007	0	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/29/2007	17	0	16	87.7	27.1	36.4	140.9	16.7	4.3	32.2
12/30/2007	1	0	34	54.5	N/A	54.5	54.5	10.4	2.7	20.0
12/31/2007	3	0	27	63.6	34.3	27.3	95.5	12.1	3.2	23.3
1/1/2008	2	0	32	143.2	80.4	86.4	200.0	27.2	7.1	52.5
1/2/2008	6	0	26	49.2	12.0	36.4	63.6	9.4	2.4	18.1
1/3/2008	19	0	18	104.1	51.5	27.3	200.0	19.8	5.2	38.2
1/4/2008	3	0	33	110.6	37.8	68.2	140.9	21.0	5.5	40.6
1/5/2008	2	0	32	70.5	16.1	59.1	81.8	13.4	3.5	25.8
1/6/2008	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/7/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/8/2008	2	0	41	84.1	3.2	81.8	86.4	16.0	4.2	30.8
1/9/2008	7	0	34	166.2	52.7	81.8	227.3	31.6	8.2	61.0
1/10/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/11/2008	5	0	31	91.8	67.2	18.2	186.4	17.5	4.5	33.7
1/12/2008	2	0	33	18.2	0.0	18.2	18.2	3.5	0.9	6.7
Period 4										

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/15/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/17/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/19/2008	2	0	45	163.6	38.6	136.4	190.9	31.1	8.1	60.0
5/20/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/21/2008	0	3	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2008	10	0	37	534.5	174.3	372.7	927.3	101.6	26.5	196.0
5/27/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2008	5	0	41	269.1	123.5	90.9	390.9	51.1	13.3	98.7
5/31/2008	17	0	27	368.2	161.9	181.8	650.0	70.0	18.2	135.0
6/1/2008	18	0	28	550.0	223.7	268.2	1150.0	104.5	27.2	201.7
6/2/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/3/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/4/2008	0	0	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5										
6/5/2008	1	2	42	40.9	N/A	40.9	40.9	7.8	2.0	15.0
6/6/2008	2	0	40	179.5	54.6	140.9	218.2	34.1	8.9	65.8
6/7/2008	6	0	37	151.5	26.0	127.3	190.9	28.8	7.5	55.6
6/8/2008	0	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2008	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/10/2008	9	0	37	199.5	55.1	109.1	272.7	37.9	9.9	73.1
6/11/2008	3	0	45	156.1	41.2	109.1	186.4	29.7	7.7	57.2
6/12/2008	4	6	36	370.5	352.0	22.7	704.5	70.4	18.3	135.8
6/13/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/14/2008	5	0	40	186.4	30.2	163.6	236.4	35.4	9.2	68.3
6/15/2008	17	0	27	383.7	221.9	127.3	800.0	72.9	19.0	140.7
6/16/2008	26	0	13	424.1	191.7	140.9	859.1	80.6	21.0	155.5
6/17/2008	26	4	15	229.4	111.2	95.5	513.6	43.6	11.4	84.1
6/18/2008	18	1	25	259.6	124.5	90.9	540.9	49.3	12.9	95.2
6/19/2008	2	21	18	522.7	70.7	472.7	572.7	99.4	25.9	191.7
6/20/2008	2	0	42	227.3	90.0	163.6	290.9	43.2	11.3	83.3
6/21/2008	0	2	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/22/2008	10	0	27	316.8	193.8	100.0	622.7	60.2	15.7	116.2
6/23/2008	10	7	16	231.4	100.4	77.3	427.3	44.0	11.5	84.8
Period 6										
11/14/2008	0	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/15/2008	3	0	44	118.2	13.6	104.5	131.8	22.5	5.9	43.3
11/16/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/17/2008	2	0	42	70.5	3.2	68.2	72.7	13.4	3.5	25.8
11/18/2008	7	0	11	37.0	8.1	22.7	45.5	7.0	1.8	13.6
11/19/2008	6	0	10	64.4	33.3	36.4	127.3	12.2	3.2	23.6
11/20/2008	4	0	14	71.6	63.8	9.1	150.0	13.6	3.5	26.3
11/21/2008	3	0	15	97.0	101.7	27.3	213.6	18.4	4.8	35.6
11/22/2008	3	0	27	148.5	29.6	118.2	177.3	28.2	7.4	54.4
11/23/2008	0	0	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/24/2008	12	0	8	86.4	46.4	31.8	181.8	16.4	4.3	31.7
11/25/2008	1	1	2	100.0	N/A	100.0	100.0	19.0	5.0	36.7
Period 7										
11/26/2008	3	1	8	78.8	60.5	9.1	118.2	15.0	3.9	28.9
11/27/2008	4	0	6	72.7	9.8	63.6	86.4	13.8	3.6	26.7
11/28/2008	14	0	1	90.6	36.3	36.4	168.2	17.2	4.5	33.2
11/29/2008	5	4	4	51.8	23.7	31.8	81.8	9.8	2.6	19.0
11/30/2008	0	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2008	12	0	7	59.1	31.1	27.3	109.1	11.2	2.9	21.7
12/2/2008	2	0	9	118.2	45.0	86.4	150.0	22.5	5.9	43.3
12/3/2008	0	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/4/2008	29	0	1	80.1	32.5	40.9	190.9	15.2	4.0	29.4
12/5/2008	0	0	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/6/2008	7	0	17	83.8	26.7	54.5	131.8	15.9	4.1	30.7
12/7/2008	0	6	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/8/2008	0	27	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/9/2008	2	2	6	31.8	0.0	31.8	31.8	6.0	1.6	11.7
12/10/2008	0	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/11/2008	6	0	15	56.8	30.5	18.2	86.4	10.8	2.8	20.8
12/12/2008	4	0	15	70.5	19.1	50.0	90.9	13.4	3.5	25.8
12/13/2008	3	0	15	56.1	2.6	54.5	59.1	10.7	2.8	20.6
12/14/2008	1	6	2	86.4	N/A	86.4	86.4	16.4	4.3	31.7
12/15/2008	0	0	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8										
4/8/2009	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/9/2009	9	14	13	141.9	59.1	86.4	245.5	27.0	7.0	52.0

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
4/10/2009	2	38	4	93.2	16.1	81.8	104.5	17.7	4.6	34.2
4/11/2009	22	17	1	109.7	33.8	36.4	172.7	20.9	5.4	40.2
4/12/2009	0	33	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2009	0	28	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2009	11	21	2	161.6	96.7	81.8	331.8	30.7	8.0	59.2
4/15/2009	8	20	1	88.6	54.9	36.4	195.5	16.8	4.4	32.5
4/16/2009	0	39	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/17/2009	0	20	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/18/2009	7	25	1	130.5	44.2	63.6	177.3	24.8	6.5	47.9
4/19/2009	19	0	6	209.1	47.5	127.3	290.9	39.7	10.4	76.7
4/20/2009	9	0	17	114.6	29.4	81.8	168.2	21.8	5.7	42.0
4/21/2009	2	0	29	159.1	38.6	131.8	186.4	30.2	7.9	58.3
4/22/2009	34	0	4	242.0	164.7	77.3	700.0	46.0	12.0	88.7
Period 9										
7/28/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/29/2009	41	1	2	201.6	57.1	95.5	345.5	38.3	10.0	73.9
7/30/2009	17	2	18	435.6	225.1	54.5	686.4	82.8	21.6	159.7
7/31/2009	37	0	10	277.9	121.8	100.0	550.0	52.8	13.8	101.9
8/1/2009	41	0	1	275.8	148.4	54.5	609.1	52.4	13.7	101.1
8/2/2009	47	0	1	235.9	134.1	59.1	472.7	44.8	11.7	86.5
8/3/2009	35	1	2	270.4	163.0	50.0	604.5	51.4	13.4	99.1
8/4/2009	15	9	22	353.0	106.9	140.9	563.6	67.1	17.5	129.4
8/5/2009	3	10	19	142.4	21.5	118.2	159.1	27.1	7.1	52.2
8/6/2009	11	14	10	197.5	100.9	68.2	413.6	37.5	9.8	72.4
8/7/2009	8	10	6	348.9	126.5	159.1	495.5	66.3	17.3	127.9
8/8/2009	21	8	0	398.9	138.5	204.5	622.7	75.8	19.7	146.3
8/9/2009	22	9	6	236.8	71.3	77.3	345.5	45.0	11.7	86.8
8/10/2009	23	1	24	433.2	147.8	122.7	704.5	82.3	21.4	158.8
8/11/2009	29	1	11	243.9	93.6	100.0	418.2	46.4	12.1	89.4
8/12/2009	14	4	26	377.3	107.1	209.1	536.4	71.7	18.7	138.3
8/13/2009	23	0	24	525.9	165.0	181.8	831.8	100.0	26.0	192.8
8/14/2009	23	0	25	641.9	216.7	245.5	986.4	122.0	31.8	235.4
8/15/2009	4	1	35	247.7	98.1	145.5	368.2	47.1	12.3	90.8
8/16/2009	27	0	16	487.2	225.7	181.8	972.7	92.6	24.1	178.6
8/17/2009	13	1	26	482.5	133.6	272.7	704.5	91.7	23.9	176.9

6.9.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year

Valid: Number of ½ h periods with valid emissions data

Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction

Touchdown limited: Number of ½ h periods invalidated because fraction of source area surface covered by particle touchdowns was less than 0.1

Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m

Background (ppm): bLS model calculated daily average background concentration (ppm); average is over the ½ h periods included in the valid column

Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods

Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods

Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods

Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area

Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis

Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 2												
8/31/2007	0	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2007	0	1	15	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/2/2007	0	0	1	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/3/2007	0	0	2	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/4/2007	0	0	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2007	0	2	14	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/6/2007	0	0	19	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/7/2007	18	3	10	0	0.19	515.9	172.0	241.7	822.7	94.3	24.6	181.9
9/8/2007	1	16	3	24	0.24	-157.2	N/A	-157.2	-157.2	-28.7	-7.5	-55.4
9/9/2007	23	4	3	15	0.09	441.3	167.2	216.4	780.5	80.7	21.0	155.6
9/10/2007	35	9	0	4	0.12	198.2	60.4	108.5	322.5	36.2	9.4	69.9

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/11/2007	19	0	2	3	0.15	534.3	150.4	268.3	830.4	97.7	25.4	188.4
9/12/2007	0	3	18	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/13/2007	5	1	13	4	0.13	354.5	55.7	287.1	414.7	64.8	16.9	125.0
9/14/2007	32	0	10	2	0.12	377.3	187.7	117.8	795.2	69.0	18.0	133.1
9/15/2007	1	2	10	13	0.12	128.3	N/A	128.3	128.3	23.5	6.1	45.2
9/16/2007	0	11	30	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2007	0	13	13	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/18/2007	11	4	6	0	0.20	837.9	170.4	555.3	1148.9	153.2	39.9	295.5
9/19/2007	22	15	1	5	0.28	352.8	127.4	201.3	681.3	64.5	16.8	124.4
9/20/2007	6	20	1	15	0.39	590.0	154.5	443.0	872.4	107.9	28.1	208.1
9/21/2007	39	9	0	0	0.19	325.8	175.1	165.1	797.8	59.6	15.5	114.9
9/22/2007	13	18	0	16	0.14	240.3	166.9	96.9	623.3	43.9	11.4	84.8
9/23/2007	6	27	0	14	0.33	396.4	90.8	311.9	553.5	72.5	18.9	139.8
9/24/2007	9	26	0	2	0.29	209.8	54.0	105.4	294.5	38.4	10.0	74.0
9/25/2007	46	1	0	0	0.19	189.7	57.0	74.5	343.5	34.7	9.0	66.9
9/26/2007	3	0	0	20	0.12	138.4	48.6	90.2	187.4	25.3	6.6	48.8
Period 3												
12/20/2007	0	20	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/21/2007	0	16	5	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/22/2007	23	16	4	2	0.11	-68.2	119.1	-459.2	-11.4	-12.5	-3.2	-24.1
12/23/2007	47	0	0	0	0.33	-192.1	230.7	-815.8	43.6	-35.1	-9.1	-67.8
12/24/2007	43	0	0	5	0.07	23.5	60.7	-342.3	90.2	4.3	1.1	8.3
12/25/2007	23	12	0	13	0.32	-43.5	72.4	-194.5	19.6	-7.9	-2.1	-15.3
12/26/2007	36	5	1	5	0.04	-4.8	8.4	-35.8	10.1	-0.9	-0.2	-1.7
12/27/2007	27	16	0	5	0.04	4.8	17.7	-17.6	54.4	0.9	0.2	1.7
12/28/2007	10	28	5	5	0.01	15.7	10.2	0.9	32.6	2.9	0.7	5.5
12/29/2007	15	9	1	22	0.21	11.9	46.8	-112.1	44.0	2.2	0.6	4.2
12/30/2007	4	23	0	20	0.05	10.9	6.8	4.1	19.9	2.0	0.5	3.8
12/31/2007	20	1	0	21	0.09	-23.3	44.9	-174.2	15.5	-4.3	-1.1	-8.2
1/1/2008	48	0	0	0	0.11	-42.8	99.5	-417.1	49.2	-7.8	-2.0	-15.1
1/2/2008	39	0	0	9	0.08	-6.2	19.9	-72.4	12.4	-1.1	-0.3	-2.2
1/3/2008	31	7	0	10	0.15	-24.1	50.7	-217.8	17.1	-4.4	-1.1	-8.5
1/4/2008	37	10	0	0	0.07	12.4	18.0	-32.9	46.5	2.3	0.6	4.4
1/5/2008	16	22	0	10	0.22	-13.5	30.9	-74.2	20.1	-2.5	-0.6	-4.8
1/6/2008	4	15	4	24	0.05	7.4	7.8	1.2	18.8	1.4	0.4	2.6
1/7/2008	4	7	1	31	0.38	53.3	261.2	-133.4	433.8	9.8	2.5	18.8
1/8/2008	37	1	0	10	0.03	10.6	13.9	-7.1	56.2	1.9	0.5	3.7
1/9/2008	13	24	0	11	0.55	-64.3	59.9	-136.3	18.2	-11.8	-3.1	-22.7
1/10/2008	16	28	0	4	0.07	-2.7	11.7	-37.6	8.3	-0.5	-0.1	-0.9
1/11/2008	34	10	0	4	0.25	-18.3	67.0	-210.6	120.4	-3.3	-0.9	-6.4
1/12/2008	20	2	0	14	0.12	-23.1	31.1	-104.9	35.2	-4.2	-1.1	-8.2
Period 4												
5/15/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2008	33	5	0	9	0.12	73.2	64.6	-29.4	214.4	13.4	3.5	25.8
5/17/2008	35	0	0	11	0.06	46.5	62.9	-33.7	225.7	8.5	2.2	16.4
5/18/2008	38	0	0	10	0.09	-28.0	25.8	-89.2	33.3	-5.1	-1.3	-9.9

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/19/2008	10	31	0	5	0.09	127.1	149.5	-64.0	414.5	23.2	6.1	44.8
5/20/2008	39	3	0	6	0.08	17.2	31.4	-26.8	124.8	3.1	0.8	6.1
5/21/2008	12	15	0	16	0.12	67.8	102.3	-30.9	348.7	12.4	3.2	23.9
5/22/2008	0	39	0	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	44	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	1	47	0	0	0.15	10.9	N/A	10.9	10.9	2.0	0.5	3.9
5/25/2008	18	30	0	0	0.23	271.6	99.1	94.0	411.4	49.7	12.9	95.8
5/26/2008	33	3	0	11	0.06	274.3	149.5	-82.4	578.0	50.1	13.1	96.7
5/27/2008	3	43	0	1	0.22	113.7	32.7	77.1	139.8	20.8	5.4	40.1
5/28/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2008	0	46	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2008	31	15	0	0	0.12	210.7	127.0	-18.9	551.1	38.5	10.0	74.3
5/31/2008	43	0	0	5	0.05	198.6	70.2	104.3	338.4	36.3	9.5	70.0
6/1/2008	18	1	0	29	0.10	277.5	240.6	-14.3	665.7	50.7	13.2	97.9
6/2/2008	5	22	0	19	0.25	128.7	120.3	-17.5	292.3	23.5	6.1	45.4
6/3/2008	1	47	0	0	0.37	-83.6	N/A	-83.6	-83.6	-15.3	-4.0	-29.5
6/4/2008	0	32	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5												
6/5/2008	4	37	0	0	0.60	8.5	71.4	-45.6	113.5	1.6	0.4	3.0
6/6/2008	35	13	0	0	0.03	132.4	51.2	9.0	318.6	24.2	6.3	46.7
6/7/2008	46	2	0	0	0.23	92.9	88.6	-0.9	272.4	17.0	4.4	32.8
6/8/2008	19	0	1	0	0.31	166.7	100.4	55.8	457.6	30.5	7.9	58.8
6/9/2008	9	0	2	0	0.12	239.6	98.0	90.5	393.8	43.8	11.4	84.5
6/10/2008	34	0	1	10	0.14	119.3	63.8	20.4	262.7	21.8	5.7	42.1
6/11/2008	7	41	0	0	0.29	108.4	148.9	32.4	444.0	19.8	5.2	38.2
6/12/2008	27	15	0	6	0.32	55.7	74.7	-30.6	304.4	10.2	2.7	19.7
6/13/2008	32	1	0	15	0.25	54.4	40.3	-11.8	154.4	9.9	2.6	19.2
6/14/2008	41	0	0	7	0.29	5.2	94.4	-165.5	160.4	1.0	0.2	1.8
6/15/2008	37	0	0	10	0.40	86.3	90.6	-39.5	242.1	15.8	4.1	30.4
6/16/2008	42	0	0	6	0.22	106.2	56.5	13.2	248.6	19.4	5.1	37.4
6/17/2008	21	6	0	17	0.29	99.6	68.1	11.3	250.0	18.2	4.7	35.1
6/18/2008	22	5	0	18	0.30	147.0	111.5	17.9	532.5	26.9	7.0	51.9
6/19/2008	8	17	0	20	0.60	24.1	53.9	-70.5	86.2	4.4	1.1	8.5
6/20/2008	26	2	0	19	0.29	54.1	86.3	-24.9	428.3	9.9	2.6	19.1
6/21/2008	32	4	0	12	0.28	15.9	40.8	-105.5	86.5	2.9	0.8	5.6
6/22/2008	38	2	0	8	0.26	113.1	85.2	-17.3	342.2	20.7	5.4	39.9
6/23/2008	3	12	0	17	0.28	174.4	47.9	137.3	228.5	31.9	8.3	61.5
Period 6												
11/14/2008	10	0	0	0	0.04	6.6	15.0	-24.5	31.8	1.2	0.3	2.3
11/15/2008	47	0	0	1	0.05	9.3	27.0	-28.8	69.8	1.7	0.4	3.3
11/16/2008	40	0	0	8	0.04	26.5	28.0	-9.9	112.9	4.8	1.3	9.4
11/17/2008	43	0	0	5	0.04	15.8	14.0	-15.9	58.8	2.9	0.8	5.6
11/18/2008	22	8	0	16	0.12	-3.9	15.0	-30.6	24.9	-0.7	-0.2	-1.4
11/19/2008	34	7	0	6	0.09	-0.3	22.1	-47.9	48.0	-0.1	0.0	-0.1
11/20/2008	48	0	0	0	0.07	-16.5	13.9	-46.9	20.2	-3.0	-0.8	-5.8
11/21/2008	26	8	0	14	0.11	-2.1	13.9	-25.9	32.7	-0.4	-0.1	-0.8

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
11/22/2008	6	31	0	4	0.29	-3.9	30.7	-37.9	46.9	-0.7	-0.2	-1.4
11/23/2008	2	17	0	15	0.02	20.4	20.3	6.0	34.7	3.7	1.0	7.2
11/24/2008	46	0	0	1	0.06	10.3	23.0	-33.3	43.3	1.9	0.5	3.6
11/25/2008	12	1	0	17	0.06	1.2	12.3	-12.6	31.9	0.2	0.1	0.4
Period 7												
11/26/2008	15	2	0	30	0.12	-8.0	15.8	-31.1	20.5	-1.5	-0.4	-2.8
11/27/2008	24	0	0	23	0.05	14.1	14.3	-24.8	41.4	2.6	0.7	5.0
11/28/2008	40	0	0	7	0.04	33.0	24.7	-4.8	141.9	6.0	1.6	11.6
11/29/2008	12	7	0	25	0.06	27.9	16.8	1.1	50.5	5.1	1.3	9.9
11/30/2008	14	0	0	0	0.04	6.7	23.1	-45.1	31.8	1.2	0.3	2.4
12/1/2008	48	0	0	0	0.05	17.8	31.3	-34.6	91.9	3.3	0.8	6.3
12/2/2008	25	11	0	12	0.12	14.9	36.6	-36.1	89.6	2.7	0.7	5.3
12/3/2008	33	7	0	6	0.03	9.8	22.2	-46.6	51.9	1.8	0.5	3.5
12/4/2008	48	0	0	0	0.05	24.5	18.2	-4.0	66.3	4.5	1.2	8.6
12/5/2008	40	0	0	8	0.05	11.3	14.0	-18.7	57.8	2.1	0.5	4.0
12/6/2008	48	0	0	0	0.03	19.4	16.4	-27.7	52.1	3.5	0.9	6.8
12/7/2008	16	30	0	2	0.11	-23.5	14.2	-59.0	-0.9	-4.3	-1.1	-8.3
12/8/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/9/2008	5	4	0	0	0.08	-25.7	7.0	-34.4	-19.0	-4.7	-1.2	-9.1
12/10/2008	27	4	0	17	0.11	-12.5	14.0	-57.5	24.1	-2.3	-0.6	-4.4
12/11/2008	30	0	0	17	0.05	17.1	17.2	-28.7	47.8	3.1	0.8	6.0
12/12/2008	24	17	0	6	0.05	9.2	25.0	-19.1	66.6	1.7	0.4	3.2
12/13/2008	21	27	0	0	0.17	-15.9	24.2	-64.5	9.0	-2.9	-0.8	-5.6
12/14/2008	20	27	0	1	0.04	-3.5	29.8	-43.8	83.7	-0.6	-0.2	-1.2
12/15/2008	0	0	9	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8												
4/8/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/9/2009	0	26	0	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/10/2009	2	46	0	0	0.05	32.9	1.3	31.9	33.8	6.0	1.6	11.6
4/11/2009	7	22	0	15	0.05	69.9	25.4	39.1	108.4	12.8	3.3	24.7
4/12/2009	0	43	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2009	2	46	0	0	-0.01	103.6	4.3	100.6	106.7	18.9	4.9	36.5
4/14/2009	13	21	0	12	0.03	121.4	95.6	10.2	290.6	22.2	5.8	42.8
4/15/2009	0	23	0	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/16/2009	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/17/2009	0	40	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/18/2009	4	18	0	25	0.09	138.7	56.4	72.2	201.7	25.4	6.6	48.9
4/19/2009	47	0	0	1	-0.02	144.4	46.6	57.4	265.3	26.4	6.9	50.9
4/20/2009	43	0	0	4	0.00	85.2	36.0	25.5	169.6	15.6	4.1	30.0
4/21/2009	48	0	0	0	-0.02	86.8	53.7	11.7	200.3	15.9	4.1	30.6
4/22/2009	20	1	1	19	-0.01	280.0	249.6	-72.0	759.9	51.2	13.3	98.7
Period 9												
7/28/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/29/2009	16	1	0	21	0.05	204.6	78.9	95.2	374.9	37.4	9.7	72.2
7/30/2009	30	7	0	10	0.07	246.4	139.8	17.1	496.7	45.1	11.7	86.9
7/31/2009	23	0	0	25	0.09	317.5	106.1	107.4	544.7	58.0	15.1	112.0

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
8/1/2009	44	0	0	4	0.11	192.5	106.9	58.3	431.5	35.2	9.2	67.9
8/2/2009	32	0	0	16	0.03	255.5	149.1	50.1	551.4	46.7	12.2	90.1
8/3/2009	40	5	0	3	0.10	161.4	96.9	19.1	350.2	29.5	7.7	56.9
8/4/2009	20	9	0	17	0.19	152.4	68.7	8.2	266.3	27.9	7.3	53.8
8/5/2009	1	14	0	30	0.23	41.0	N/A	41.0	41.0	7.5	2.0	14.5
8/6/2009	4	17	0	25	0.14	204.5	135.5	41.2	358.8	37.4	9.7	72.1
8/7/2009	12	33	0	3	0.25	211.1	130.9	7.8	438.8	38.6	10.0	74.4
8/8/2009	33	15	0	0	0.11	293.3	124.5	149.9	492.0	53.6	14.0	103.4
8/9/2009	30	12	0	4	0.16	149.7	62.9	6.8	313.5	27.4	7.1	52.8
8/10/2009	23	5	0	14	0.08	310.2	111.3	31.0	445.8	56.7	14.8	109.4
8/11/2009	10	3	0	35	0.13	159.0	72.4	59.2	260.8	29.1	7.6	56.1
8/12/2009	18	7	0	23	0.04	404.7	84.3	272.3	596.9	74.0	19.3	142.7
8/13/2009	20	0	0	28	0.11	455.5	120.9	185.4	717.5	83.3	21.7	160.6
8/14/2009	24	4	0	19	0.21	422.2	185.2	121.9	701.7	77.2	20.1	148.9
8/15/2009	3	24	1	12	0.43	145.4	59.0	79.6	193.8	26.6	6.9	51.3
8/16/2009	31	16	0	1	0.11	277.6	139.3	75.9	558.7	50.8	13.2	97.9
8/17/2009	11	3	1	26	0.06	347.4	54.2	283.2	455.2	63.5	16.5	122.5

6.9.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year

Valid: Number of ½ h periods with valid emissions data

Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods

Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods

Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods

Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area

Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis

Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 4								
5/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/19/2008	2	12.2	105.1	8.6	15.8	2.3	0.6	4.5
5/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5								
6/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/6/2008	2	-0.1	0.0	-0.4	0.2	0.0	0.0	0.0
6/7/2008	6	0.1	5.6	-1.3	2.1	0.0	0.0	0.0
6/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/10/2008	9	-0.5	0.0	-5.0	2.5	-0.1	0.0	-0.2
6/11/2008	3	0.1	9.6	-1.2	1.9	0.0	0.0	0.0
6/12/2008	3	25.9	129.0	1.0	41.3	4.9	1.3	9.5
6/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/15/2008	7	36.4	134.0	17.3	49.9	6.9	1.8	13.3
6/16/2008	19	47.4	142.8	17.9	122.8	9.0	2.3	17.4
6/17/2008	11	31.7	121.4	1.2	78.5	6.0	1.6	11.6
6/18/2008	7	17.9	95.8	7.1	31.7	3.4	0.9	6.6
6/19/2008	2	45.5	198.8	43.4	47.6	8.7	2.3	16.7
6/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/22/2008	6	55.5	164.6	38.0	77.3	10.6	2.7	20.4
6/23/2008	6	54.4	162.5	12.7	95.9	10.3	2.7	20.0
Period 6								
11/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/15/2008	3	23.1	122.5	8.9	31.1	4.4	1.1	8.5
11/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/17/2008	2	0.5	21.7	-0.2	1.2	0.1	0.0	0.2
11/18/2008	4	0.6	19.8	-0.4	2.3	0.1	0.0	0.2
11/19/2008	3	8.7	76.2	3.5	17.0	1.6	0.4	3.2
11/20/2008	4	0.9	22.9	-4.0	8.1	0.2	0.0	0.3
11/21/2008	1	3.4	0.0	3.4	3.4	0.6	0.2	1.2
11/22/2008	3	3.9	51.9	1.0	7.4	0.8	0.2	1.4
11/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7								
11/26/2008	1	2.0	0.0	2.0	2.0	0.4	0.1	0.7
11/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/28/2008	3	2.7	42.8	2.3	3.4	0.5	0.1	1.0
11/29/2008	5	10.5	76.4	-0.5	46.6	2.0	0.5	3.9
11/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2008	5	-0.3	0.0	-2.4	0.8	-0.1	0.0	-0.1
12/2/2008	2	3.5	56.8	0.6	6.4	0.7	0.2	1.3
12/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/6/2008	1	1.3	0.0	1.3	1.3	0.2	0.1	0.5
12/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
12/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/13/2008	3	2.4	40.2	1.8	3.1	0.5	0.1	0.9
12/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8								
4/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/10/2009	2	17.3	123.3	10.1	24.5	3.3	0.9	6.3
4/11/2009	10	2.7	36.9	0.3	7.3	0.5	0.1	1.0
4/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2009	5	5.1	53.4	2.1	6.9	1.0	0.3	1.9
4/15/2009	5	1.0	23.8	-0.7	2.3	0.2	0.0	0.4
4/16/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/18/2009	6	3.1	40.8	2.1	4.7	0.6	0.2	1.1
4/19/2009	19	119.9	207.0	3.9	294.4	22.8	5.9	44.0
4/20/2009	2	15.5	116.8	8.3	22.6	2.9	0.8	5.7
4/21/2009	2	153.7	314.5	80.3	227.1	29.2	7.6	56.4
4/22/2009	9	1.7	29.9	0.9	2.7	0.3	0.1	0.6
Period 9								
7/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/30/2009	5	67.2	190.8	27.2	124.7	12.8	3.3	24.6
7/31/2009	12	54.3	155.1	29.0	75.7	10.3	2.7	19.9
8/1/2009	16	62.1	161.8	33.9	116.1	11.8	3.1	22.8
8/2/2009	38	48.5	142.5	31.0	105.0	9.2	2.4	17.8
8/3/2009	19	52.6	149.8	39.3	63.2	10.0	2.6	19.3
8/4/2009	14	97.6	195.5	77.7	174.0	18.6	4.8	35.8
8/5/2009	2	69.7	233.9	32.4	107.0	13.3	3.5	25.6
8/6/2009	1	69.6	0.0	69.6	69.6	13.2	3.4	25.5
8/7/2009	8	107.9	212.0	86.1	148.6	20.5	5.3	39.6
8/8/2009	17	93.8	190.8	48.7	138.4	17.8	4.6	34.4
8/9/2009	13	93.8	195.1	56.0	131.0	17.8	4.6	34.4
8/10/2009	2	85.9	265.2	83.9	87.8	16.3	4.2	31.5
8/11/2009	7	38.8	137.5	8.0	99.0	7.4	1.9	14.2
8/12/2009	14	916.9	0.0	3.8	3469.8	174.3	45.4	336.2
8/13/2009	23	125.9	208.0	1.9	579.9	23.9	6.2	46.2
8/14/2009	23	24.4	104.7	0.8	158.0	4.6	1.2	8.9
8/15/2009	4	11.6	83.1	7.7	14.9	2.2	0.6	4.3
8/16/2009	7	11.5	77.1	2.5	25.5	2.2	0.6	4.2
8/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.9.4 Daily H_2S emission using bLs emissions model

Column headings for the following table are:

Date: Month/Day/Year

Valid: Number of ½ h periods with valid emissions data

Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction

Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees

Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m

Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column

Emission average (μgm^{-2}s^{-1}): Daily average emission calculated from the valid ½ h periods

Emissions SD (μgm^{-2}s^{-1}): Daily emission standard deviation of the valid ½ h periods

Emission minimum (μgm^{-2}s^{-1}): Daily minimum emission of the valid ½ h periods

Emission maximum (μgm^{-2}s^{-1}): Daily maximum emission of the valid ½ h periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area

Emission average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis

Emission average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average (μgm^{-2}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd^{-1}AU^{-1})
Period 4												
5/16/2008	4	0	21	8	0.8	5.7	0.7	5.1	6.7	1.1	0.3	2.1
5/17/2008	9	0	22	13	0.6	13.6	5.9	5.9	24.7	2.6	0.7	5.1
5/18/2008	30	0	8	10	0.2	11.2	6.4	1.5	26.4	2.2	0.6	4.2
5/19/2008	7	31	3	5	0.1	30.5	58.1	1.5	161.5	5.9	1.5	11.4
5/20/2008	28	3	11	6	1.6	10.6	5.1	-0.4	20.1	2.1	0.5	4.0
5/21/2008	9	15	3	21	0.9	3.4	2.5	-0.4	8.2	0.7	0.2	1.3
5/22/2008	0	39	0	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	46	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	1	47	0	0	-0.2	25.8	N/A	25.8	25.8	5.0	1.3	9.6
5/25/2008	18	30	0	0	2.0	96.4	28.2	37.0	146.4	18.7	4.9	36.0
5/26/2008	15	3	17	11	-11.6	102.3	127.0	14.9	509.1	19.8	5.2	38.2
5/27/2008	3	43	0	1	0.8	39.4	8.2	31.0	47.4	7.6	2.0	14.7

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/28/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2008	0	46	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2008	10	15	16	0	-4.9	89.9	137.9	8.2	441.2	17.4	4.5	33.6
5/31/2008	3	0	21	5	1.1	21.4	5.9	17.6	28.1	4.1	1.1	8.0
6/1/2008	9	1	9	29	1.7	14.2	7.8	1.9	24.8	2.8	0.7	5.3
6/2/2008	4	22	1	20	2.2	43.0	30.9	22.7	88.0	8.3	2.2	16.1
6/3/2008	1	47	0	0	-10.1	529.2	N/A	529.2	529.2	102.5	26.7	197.8
6/4/2008	0	23	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5												
6/6/2008	33	13	2	0	6.8	0.3	1.5	-2.6	5.0	0.1	0.0	0.1
6/7/2008	46	2	0	0	21.0	0.2	1.5	-3.0	4.3	0.0	0.0	0.1
6/8/2008	18	0	1	0	26.0	0.2	1.4	-2.0	3.2	0.0	0.0	0.1
6/9/2008	3	0	17	0	7.8	0.5	0.4	0.1	0.9	0.1	0.0	0.2
6/10/2008	30	3	4	10	16.9	-0.2	1.4	-3.9	2.8	0.0	0.0	-0.1
6/11/2008	7	41	0	0	9.2	0.5	1.1	-1.3	1.7	0.1	0.0	0.2
6/12/2008	10	15	12	6	-14.9	60.1	139.6	1.3	452.3	11.6	3.0	22.5
6/13/2008	3	1	19	15	2.9	8.7	1.2	7.7	10.0	1.7	0.4	3.2
6/14/2008	26	0	13	7	1.1	24.0	17.4	9.4	73.1	4.7	1.2	9.0
6/15/2008	25	0	12	10	1.1	12.7	4.8	2.2	21.7	2.5	0.6	4.7
6/16/2008	28	0	13	6	0.8	13.8	4.3	5.3	22.0	2.7	0.7	5.2
6/17/2008	13	6	8	21	1.6	4.8	3.7	0.1	11.4	0.9	0.2	1.8
6/18/2008	12	5	10	19	0.6	7.4	4.5	1.3	16.1	1.4	0.4	2.8
6/19/2008	8	17	0	21	6.6	9.6	6.0	2.0	21.2	1.9	0.5	3.6
6/20/2008	17	2	9	19	1.9	8.5	4.0	1.2	15.3	1.7	0.4	3.2
6/21/2008	0	4	26	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/22/2008	19	2	17	8	1.2	29.9	32.1	1.9	155.5	5.8	1.5	11.2
6/23/2008	2	0	0	22	0.8	19.9	0.7	19.4	20.4	3.9	1.0	7.4
Period 6												
11/15/2008	36	0	11	1	0.4	2.7	2.0	0.0	9.2	0.5	0.1	1.0
11/16/2008	17	0	18	8	0.3	0.1	0.4	-0.5	1.0	0.0	0.0	0.0
11/17/2008	37	0	6	5	0.3	0.3	0.6	-1.2	2.8	0.1	0.0	0.1
11/18/2008	21	8	1	17	0.7	0.4	0.7	-0.3	2.5	0.1	0.0	0.2
11/19/2008	28	7	5	7	0.6	1.2	1.2	-0.6	3.4	0.2	0.1	0.4
11/20/2008	48	0	0	0	0.3	0.4	0.8	-1.9	2.0	0.1	0.0	0.1
11/21/2008	25	8	0	14	0.1	0.3	0.5	-0.8	1.0	0.1	0.0	0.1
11/22/2008	13	31	0	4	0.3	1.0	1.1	-0.4	2.8	0.2	0.0	0.4
11/23/2008	2	17	0	18	4.3	-0.2	0.3	-0.4	0.0	0.0	0.0	-0.1
11/24/2008	14	0	13	2	0.7	0.1	0.5	-0.8	1.0	0.0	0.0	0.0
Period 7												
11/26/2008	12	0	2	10	1.0	0.2	0.4	-0.2	1.2	0.0	0.0	0.1
11/27/2008	4	0	16	24	1.3	-0.1	0.5	-0.9	0.3	0.0	0.0	0.0
11/28/2008	0	0	15	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/29/2008	11	7	2	27	0.3	6.4	15.9	-0.3	51.4	1.2	0.3	2.4
11/30/2008	14	0	0	0	0.5	5.2	3.1	0.7	9.9	1.0	0.3	1.9
12/1/2008	37	0	7	0	0.3	0.9	2.5	-1.5	13.0	0.2	0.0	0.3
12/2/2008	21	11	3	12	0.5	0.8	0.7	-0.1	3.2	0.2	0.0	0.3

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}1hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
12/3/2008	25	7	8	8	0.5	0.1	0.8	-1.3	2.2	0.0	0.0	0.0
12/4/2008	0	0	36	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/5/2008	29	0	10	8	0.3	0.4	0.6	-0.7	2.2	0.1	0.0	0.2
12/6/2008	28	0	15	0	0.4	-0.2	0.8	-2.0	1.2	0.0	0.0	-0.1
12/7/2008	16	30	0	2	0.4	0.2	0.5	-0.5	1.4	0.0	0.0	0.1
12/8/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/9/2008	5	4	0	0	0.5	0.0	0.4	-0.5	0.5	0.0	0.0	0.0
12/10/2008	24	4	3	17	0.4	0.1	0.5	-1.1	1.0	0.0	0.0	0.1
12/11/2008	16	0	13	18	0.2	0.4	0.5	-0.8	1.4	0.1	0.0	0.1
12/12/2008	17	17	6	6	0.1	0.4	0.4	-0.4	1.3	0.1	0.0	0.1
12/13/2008	21	27	0	0	0.5	0.9	1.0	-0.6	3.3	0.2	0.0	0.3
12/14/2008	0	27	5	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2008	0	0	19	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8												
4/10/2009	2	46	0	0	0.0	8.2	5.3	4.4	12.0	1.6	0.4	3.1
4/11/2009	4	22	3	19	-0.2	2.6	0.4	2.4	3.2	0.5	0.1	1.0
4/12/2009	0	43	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2009	2	46	0	0	0.9	26.3	5.6	22.4	30.3	5.1	1.3	9.8
4/14/2009	5	21	5	14	0.2	3.8	1.7	0.9	5.2	0.7	0.2	1.4
4/15/2009	0	23	0	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/16/2009	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/17/2009	0	40	0	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/18/2009	4	18	0	25	1.2	2.2	0.5	1.6	2.6	0.4	0.1	0.8
4/19/2009	46	0	1	1	0.8	63.4	49.4	1.6	172.7	12.3	3.2	23.7
4/20/2009	17	0	18	5	1.0	142.6	93.4	2.9	331.8	27.6	7.2	53.3
4/21/2009	22	0	23	0	0.7	54.0	34.7	17.2	139.8	10.5	2.7	20.2
4/22/2009	1	0	5	18	0.8	0.9	N/A	0.9	0.9	0.2	0.0	0.3
Period 9												
7/30/2009	11	7	19	10	3.4	26.9	11.4	14.1	52.9	5.2	1.4	10.1
7/31/2009	11	0	12	25	3.1	59.0	12.2	46.4	87.5	11.4	3.0	22.1
8/1/2009	18	0	24	4	3.0	36.9	17.7	10.7	62.6	7.1	1.9	13.8
8/2/2009	31	0	1	16	2.7	43.2	9.4	27.3	75.1	8.4	2.2	16.2
8/3/2009	26	5	14	3	2.3	46.0	9.8	23.1	71.8	8.9	2.3	17.2
8/4/2009	19	9	1	18	6.0	38.8	15.3	0.1	62.1	7.5	2.0	14.5
8/5/2009	1	14	0	33	5.6	9.1	N/A	9.1	9.1	1.8	0.5	3.4
8/6/2009	2	17	2	27	5.0	32.6	18.3	19.7	45.6	6.3	1.6	12.2
8/7/2009	12	30	0	3	2.8	93.0	17.9	62.9	127.5	18.0	4.7	34.8
8/8/2009	28	0	0	0	3.9	88.0	17.4	47.7	116.5	17.0	4.4	32.9
8/9/2009	24	12	6	4	5.3	52.5	26.3	1.9	107.7	10.2	2.6	19.6
8/10/2009	4	5	20	14	3.2	65.6	34.3	23.4	107.2	12.7	3.3	24.5
8/11/2009	5	3	5	35	3.0	18.4	15.4	2.9	38.3	3.6	0.9	6.9
8/12/2009	18	7	0	23	-8.2	993.1	1296.6	3.6	3846.5	192.4	50.1	371.1
8/13/2009	20	0	0	28	5.9	116.4	156.7	1.7	539.3	22.6	5.9	43.5
8/14/2009	25	4	0	19	4.0	22.6	36.8	0.6	124.2	4.4	1.1	8.5
8/15/2009	3	33	0	12	2.1	8.4	1.4	7.1	9.8	1.6	0.4	3.2
8/16/2009	10	16	21	1	4.3	7.5	3.7	2.0	14.0	1.5	0.4	2.8

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
8/17/2009	1	1	0	22	1.6	1.3	N/A	1.3	1.3	0.3	0.1	0.5

Final Report
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Pork Production Facility
for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
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for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on the location (relative to climate and typical practice), method of manure collection, manure storage and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3) and hydrogen sulfide (H_2S) emissions from the wastewater lagoon open source at the Midwestern sow facility. Within that objective, this report will:

- Describe the farm and the lagoon/basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the lagoon were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Lagoon emissions were measured continuously for about one year. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the area sources were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc, Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*WindTrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were

determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the lagoon pH, oxidation-reduction potential, and temperature at 0.3 m depth were also measured from a float located at least 30 m from the lagoon inlet (Table 1-2). Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the lagoon berm.

Table 1-1: Critical measurements

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder2™	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind Speed	3D Sonic anemometer/ RM Young 81000	0-60 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
Wind Direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
3D Turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min
Temperature Variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01°C	160 Hz sampling/ 16 Hz averaging	30 min
GSS sample flow rate	GSS/S-OPS	10 L min^{-1}	0.1 L min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/S-OPS	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to *RPM* Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the lagoon (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation, lagoon pH, lagoon oxidation-reduction potential, lagoon temperature, and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure, flow, temperature and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a

computer in the trailer that was downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Table 1-2: Non-critical measurements.

Measurement	Method/ Instrument	Required Operating range	MDL	Minimum sample frequency	Final Data-Aggregation
Ambient Temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50 ° C	0.1 ° C	5 min	30 min, 24 h
Relative Humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric Pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min & 24 h
Solar Radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 Wm^{-2}	10 Wm^{-2}	5 min	30 min & 24 h
Lagoon solids depth	Sludge level detector/ Sludge Gun 10HD, Markland Specialty Eng.	0-10 m	0.05 m	1/ measurement period	1 time
Lagoon/ basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	0-14 units	0.2 unit	5 min	30 min & 24 h
Lagoon/ basin Oxidation-reduction potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	-800 - +1100 mV	20 mV	5 min	30 min & 24 h
Lagoon/ basin Temperature	Thermistor/ Campbell Scientific Inc 107-L	-35 - +50 ºC	0.5 ºC	5 min	30 min & 24 h

1.3 Farm description and operation

The Midwestern sow lagoon facility was located in Indiana. The elevation at the farm was 264 m. The farm consisted of nine barns and a lagoon (Fig. 1-1), and had a capacity of 1400 sows. The facility had been added to for many years, starting operations in 1968, while the last building addition was completed in 1992. Eight years ago (1998), the facility was changed from a finisher operation to a farrow-to-wean operation.

Liquid waste from the deep pits of the barns was transferred once every two weeks to the lagoon by a single inlet on the east side of the lagoon (Fig. 1-1). The lagoon was south from the barns. The clay-lined waste lagoon was 112 m by 115 m. The lagoon berm was 2-3 m high and had a slope of 3:1. At maximum capacity, the liquid depth was 4 m with a volume of 34,000 m^3 and surface area of 13,580 m^2. Sludge had never been removed from the lagoon. Since the lagoon was inherently a source of gases emanating from manure and effluent residing in the lagoon for multiple months, it was assumed that the number of animals contributing to the lagoon was the maximum capacity of the farm. During the growing season, corn completely surrounded the lagoon.

Figure 1-1: Configuration of the IN4A farm.

1.4 Measurement layout

The NH_3 emissions from the lagoon were monitored continuously for one year using scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*) and backward Lagrangian Stochastic (bLS) emissions models. The H_2S emissions from the lagoon were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments (TDLAS/scanner) were mounted at 1-m height above the lagoon berm (abl) at the northwest and southeast corners (Figure 1-2). Towers for mounting retro-reflectors were located off the northeast and southwest corners of the lagoon (Figure 1-2). A description of the position and path length of the optical paths along each side of the lagoon follows:

- North side: Retro-reflectors were located on anchored tripods at 1 abl at distances of 39 m and 79.5 m from the northwest TDLAS/scanner. Three TDLAS retro-reflectors were mounted on the northeast tower 132 m from the northwest TDLAS/scanner at heights of 1.3 m, 6.4 m, and 14.3 m abl.

- East side: Retro-reflectors were located on anchored tripods at 1 abl at distances of 38 m and 76 m north of the southeast TDLAS/scanner. Three TDLAS retro-reflectors were mounted on the northeast tower 134 m from the southeast TDLAS/scanner at heights of 1.3 m, 6.4 m, and 14.3 m abl.
- South side: Retro-reflectors were located on anchored tripods at 1 abl at distances of 38.5 m and 74.5 m from the southeast TDLAS/scanner. Three TDLAS retro-reflectors are mounted on the southwest tower 129 m from the southeast TDLAS/scanner at heights of 1.4 m, 6.6 m, and 14.5 m abl.
- West side: Retro-reflectors were located on anchored tripods at 1 abl at distances of 38 m and 76.5 m from the northwest TDLAS/scanner. Three retro-reflectors were mounted on the southwest corner tower 129.5-m from the northwest TDLAS/scanner at heights of 1.4 m, 6.6 m, and 14.5 m abl.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1-m abl. A 50-m long S-OPS path was parallel to and 2 m north of the north berm and began 12 m east of northwest berm corner and extended east (Figure 1-2). The second 50-m long S-OPS was parallel to and 2 m south of the south lagoon berm and began 12 m east of southeast corner of berm (in the drainage swale) and extended west (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Meteorological measurements, including barometric pressure, air temperature, relative humidity, solar radiation, and surface wetness were made on the berm 15 m to the east of the lagoon's southwest berm corner. The data from these meteorological measurements were collected by a data logger (Model CR1000, Campbell Scientific, Logan UT) and telemetered to the on-site instrumentation trailer. The 3D sonic anemometers were located on the meteorological tower at 2.5 m height, and on the southwest corner tower (Fig. 1-2) at 4.2 m and 16.3 m heights above berm level and also telemetered to the on-site instrumentation trailer.

Lagoon measurements (pH, oxidation-reduction potential, and temperature) were made from a float located in the southwest corner of the lagoon.

Figure 1-2: Locations of instrumentation around the lagoon under measurement.

Retro-reflectors are indicated according to side (north, south, east, and west) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The locations of the two S-OPS lines are indicated by the solid yellow lines. The instrumentation trailer was located on the east side of the lagoon.

2 Monitoring activities

2.1 Measurement periods

Measurements were made continuously between 7/1/2007 and 7/14/2008 at this location (Table 2.1-1). The equipment was on site a total of 374 d over five measurement periods. Calibrations reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 303 d and H_2S emissions were measured 71 d.

Table 2.1-1: Days on site

Period	Start date	End date	# days
1	7/1/2007	8/31/2007	61
2	9/1/2007	11/30/2007	90
3	12/1/2007	2/28/2008	89
4	3/1/2008	5/31/2008	91
5	6/1/2008	7/14/2008	43

2.2 Site visits

The Field operation team visited this farm 55 d (Table 2.2). Since this site was the first-year long-term fixed location site, the site set-up and take-down occurred only once each. Most site visits were either for calibration verifications or equipment replacement.

Table 2.2: Dates of site visits

Year	Spring	Summer	Fall	Winter
2007		Jul 24 Aug 8,10,15,16,17,20,22,23,30	Sep 4,5,12,19,20 Oct 4,17,18,23 Nov 1,13,15	Jan 29,30,31 Feb 12,
2008	Mar 5,12,17,20,21 Apr 7,8,14,15,30 May 1,7,12,20,21,27,28	Jun 5,11,19,20,24 Jul 1,2,3,8,14,15,16		

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21 d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder2™ NH3-OP TDLAS serial number (s/n) 1026, 1027, 1028, 1029 and 1030 (Section 6.1)
- TEC 450i H_2S Analyzer s/n 0733825130 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1925, 1926, 1927 and 1938 (Section 6.3)
- lagoon pH probes s/n 001 and 003 (Section 6.4)
- lagoon ORP probe s/n 010 and 40 (Section 6.5)

- GSS/ S-OPS s/n 4-0019 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multipoint calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers (Section 6.3) with three unused 'standard' anemometers.

2.4 Audits

No internal audits were conducted at this location due to the location's close proximity to Purdue University and the diverse individuals maintaining the equipment on the location. There was a Technical Systems Audit conducted by USEPA at this location on 24 September, 2007.

2.5 Repair trips

Numerous repair trips were made to this location: 7/20/2007, 8/16/2007, 8/17/2007, 8/20/2007, 8/22/2007, 8/23/2007, 10/4/2007, 10/17/2007, 10/18/2007, 10/23/2007, 11/1/2007, 11/13/2007, 2/12/2008, 4/15/2008, 5/1/2008, 5/7/2008, 5/12/2008, 6/5/2008, 6/11/2008, 6/24/2008, 7/1/2008, 7/3/2008, and 7/8/2008. In addition many trips were made to this location to swap out equipment needed for the continued operation of the many outlying NAEMS measurement locations.

2.6 Remote site checks

Over the course of measurements, there were 77 remote checks made from PAML through the computer for instruments operating at this location. The limited number of remote site checks is due to the close proximity of the site and the early establishment of the site relative to the establishment of the remote-site check routines

2.7 Measurement data acquisition

Data from the TDLAS units (Model GasFinder2™ NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather and lagoon data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *Loggernet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *Loggernet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA) were downloaded in real-time through a serial cable to the trailer computer using the iPort (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built *Visual Basic* software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic anemometer temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory “FTP” and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory “Data”. The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the “FTP” directory.

3 Data processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometer anemometers were not yet in place. If the location and/or period were not adjusted in the sonic anemometer parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDLAS. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes need to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site, data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software that was used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer causing the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period,

unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one minute off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the lagoon and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream

may depend on one or more of the preceding streams, but not on following data streams. For each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment failures, calibration failures, and calibration checks in progress. Periods of invalidated measurements associated with the calibration check failures is documented in the calibration reports in Section 6. Significant data exclusions of greater than one-day duration are indicated below by instrument with all time in Coordinated Universal Time (UTC):

TDLAS measurement exclusions: Excluded measurements are summarized in Table 3.2-1.

Table 3.2-1: TDLAS measurement exclusions

Begin		End		Reason
8/21/2007	11:16	8/22/2007	14:16	Program stopped
9/11/2007	17:59	9/12/2007	13:38	TDLAS 1 (SE Scanner; 1026) Power disconnected
10/18/2007	0:51	1/30/2008	20:01	Removed TDLAS 1 (SE Scanner; 1026) to replace East Trailer TDLAS
10/19/2007	2:19	10/23/2007	14:58	TDLAS laptops shut down by power failure caused by strong storms
12/1/2008	0:00	2/12/2008	23:59	TDLAS 2 (NW Scanner) Scanner Failure
2/6/2008	3:54	2/12/2008	19:33	TDLAS 1 (NW Scanner; 1030) covered in ice
3/5/2008	21:41	4/15/2008	14:50	TDLAS 2 (SE Scanner; 1030) out for repair
5/20/2008	15:19	5/27/2008	15:44	TDLAS 1 (NW Scanner; 1030) scanner failure
6/9/2008	5:55	6/11/2008	15:45	TDLAS 1 (NW Scanner; 1029) laptop locked up
6/21/2008	17:55	6/23/2008	13:03	TDLAS 1 (NW Scanner(1029) driving program locked up

TEC 450i measurement exclusions: The 450i was returned to the factory for repair resulting in a loss of measurements between 3/21/2008 and 5/28/2008. Exclusions associated with calibrations are summarized in Table 3.2-2.

Table 3.2-2: TEC 450i measurement exclusions

Begin		End		Reason
2/28/2008	17:00	2/28/2008	19:00	Calibration Check
6/19/2008	15:00	6/21/2008	0:00	Calibration Check

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-3.

Table 3.2-3: Sonic anemometer measurement exclusions

Begin		End		Reason
6/19/2007	20:50	6/20/2007	1:15	Beginning Calibration Check
7/14/2007	4:49	7/14/2007	16:14	Calibration Check
8/8/2007	15:30	8/15/2007	16:00	Removed from tower for calibration check, but program wouldn't run. Calibration check finished week later
9/2/2007	9:38	9/5/2007	14:10	Sonic anemometers not working and taken down for calibration check.
9/19/2007	17:05	9/20/2007	19:20	Calibration Check
10/12/2007	22:00	10/19/2007	12:25	New sonic anemometer program installed. Calibration check.
10/17/2007	16:05	10/19/2007	12:20	Calibration Check
11/13/2007	14:39	11/13/2007	20:10	Calibration Check
12/9/2007	12:05	12/10/2007	19:00	Ice blocking transducers
12/15/2007	23:10	12/18/2007	14:30	Ice blocking transducers
1/5/2008	4:23	1/9/2008	14:35	Sonic anemometer program failure
1/18/2008	17:29	1/30/2008	18:40	6 month calibration check
3/8/2008	13:28	3/10/2008	12:30	Sonic anemometer program failure
3/10/2008	21:35	3/12/2008	21:30	Sonic anemometer program failure
3/21/2008	13:55	3/21/2008	17:05	Calibration Check
4/7/2008	16:15	4/7/2008	19:30	Calibration Check
5/1/2008	13:42	5/1/2008	20:25	Calibration Check
5/27/2008	17:04	5/28/2008	16:00	Calibration Check
6/7/2008	10:50	6/9/2008	12:55	Sonic anemometer program failure
6/19/2008	13:49	6/20/2008	14:40	Calibration Check

Lagoon temperature, pH, and ORP measurement exclusions: Excluded measurements are summarized in Table 3.2-4.

Table 3.2-4: Lagoon temperature, pH, and ORP measurement exclusions

Begin		End		Reason
Lagoon temperature exclusion times				
6/19/2007	20:50	6/21/2007	20:55	Probe not yet installed
6/28/2007	16:55	6/28/2007	17:50	Calibration Check
7/24/2007	17:00	7/24/2007	17:20	Calibration Check
8/8/2007	15:30	8/8/2007	16:25	Calibration Check
8/17/2007	15:00	8/17/2007	15:55	Probe wire was cut by mower. Temporary fix was made
8/22/2007	14:35	8/22/2007	15:00	Installing new probe wire.
9/4/2007	16:05	9/4/2007	17:25	Calibration Check
9/19/2007	13:55	9/19/2007	16:40	Calibration Check
10/18/2007	14:40	10/18/2007	15:45	Calibration Check
11/1/2007	16:20	11/1/2007	16:50	Calibration Check
11/15/2007	15:35	11/15/2007	17:50	Calibration Check
1/26/2008	9:25	5/6/2008	14:55	Wires cut during winter due to freezing/thawing of lagoon. Fixed and reinstalled 4/30/2008. Took several days to come back online to good readings
5/12/2008	16:40	5/14/2008	19:05	Numbers spiked unreasonably, then went back to normal readings
6/20/2008	16:55	6/20/2008	18:10	Calibration Check
7/4/2008	14:55	7/6/2008	11:35	Calibration Check

Begin		End		Reason
pH exclusion times				
6/19/2007	20:50	6/21/2007	20:55	Probe not yet installed
6/28/2007	16:55	6/28/2007	17:50	Calibration Check
7/24/2007	17:00	7/24/2007	17:20	Calibration Check
8/8/2007	15:30	8/8/2007	16:25	Calibration Check
8/17/2007	15:00	8/17/2007	15:55	Probe wire was cut by mower. Temporary fix was made
8/22/2007	14:35	8/22/2007	15:00	Installing new probe wire.
9/4/2007	16:05	9/4/2007	17:25	Calibration Check
9/19/2007	13:55	9/19/2007	16:40	Calibration Check
10/18/2007	14:40	10/18/2007	15:45	Calibration Check
11/1/2007	16:20	11/1/2007	16:50	Calibration Check
11/15/2007	15:35	11/15/2007	17:50	Calibration Check
1/26/2008	9:25	7/14/2008	13:50	Wires cut during winter due to freezing/thawing of lagoon. Discovered on 3/17/2008. Passed calibration on 4/8/2008. Failed calibration on 4/15/2008; wires may be bad. Failed calibration 4/30/2008. Probe not replaced during remainder of IN4A.
ORP exclusion times				
Begin		**End**		**Reason**
6/19/2007	20:50	6/21/2007	20:55	Probe not yet installed
6/28/2007	16:55	6/28/2007	17:50	Calibration Check
7/24/2007	17:00	7/24/2007	17:20	Calibration Check
8/8/2007	15:30	8/8/2007	16:25	Calibration Check
8/17/2007	15:00	8/17/2007	15:55	Probe wire was cut by mower. Temporary fix was made
8/22/2007	14:35	8/22/2007	15:00	Installing new probe wire
9/4/2007	16:05	9/4/2007	17:25	Calibration Check
9/19/2007	13:55	9/19/2007	16:40	Calibration Check
10/18/2007	14:40	10/18/2007	15:45	Calibration Check
11/1/2007	16:20	11/1/2007	16:50	Calibration Check
11/15/2007	15:35	11/15/2007	17:50	Calibration Check
1/26/2008	9:25	5/14/2008	19:05	Wires cut during winter due to freezing/thawing of lagoon. Fixed and reinstalled 4/30/2008. Took several days to come back online to good readings
6/20/2008	16:55	6/20/2008	18:10	Calibration Check
7/4/2008	14:55	7/6/2008	11:35	Calibration Check

GSS/S-OPS measurement exclusions: Excluded measurements are summarized in Table 3.2-5.

Table 3.2-5: GSS/S-OPS measurement exclusions

Begin		End		Reason
3/17/2008	15:15	3/17/2008	17:45	Calibration Check
4/7/2008	16:45	4/7/2008	19:15	Calibration Check
5/1/2008	13:45	5/1/2008	15:15	Calibration Check
5/20/2008	15:45	5/20/2008	19:45	Calibration Check
6/19/2008	14:30	6/19/2008	15:30	Calibration Check

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20°C (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in super-saturated "holes" in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a super-saturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maximized light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably super-saturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-s value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be super-saturated were flagged as super-saturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not super-saturated. To determine which points truly were super-saturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest paths integrated concentrations corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to

be super-saturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as super-saturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the S-OPSs changed from one line to the other line. This array was later used when separating the H_2S data according to which S-OPSs line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic anemometer temperature variance of greater than 2.5 K^2, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic

anemometer temperature variance had to be less than 2.5 K^2 To be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH_3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be *RPM* processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH_3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigned values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro-reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *WindTrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3} \frac{34.0818\left([H_2S]_{downwind} - [H_2S]_{upwind}\right)}{17030.4[NH_3]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigned values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was

generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths. All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the lagoon include transfer of waste from barns into the lagoon (Table 4.1-1) and lagoon pump-outs for irrigation. Date of lagoon pump-out activity was not recorded by the producer and consequently not listed.

Table 4.1-1: Producer activities

Period	Activity
1: 7/1 - 8/31/2007	N/A
2: 9/1 - 11/30/2007	10/11/2007 Farrowing Building 92,100 gal pumped to lagoon. 10/17/2007 Gestation Building 72,500 gal pumped to lagoon. 10/22/2007 Gestation Building 102,000 gal pumped to lagoon. 11/14/2007 Farrowing Building 82,800 gal pumped to lagoon. 11/23/2007 Gestation Building 172,800 gal pumped to lagoon
3: 12/1/2007 - 3/5/2008	12/10/2007 Farrowing Building 103,000 gal pumped to lagoon. 1/11/2008 Breeding and Gestation Buildings 200,880 gal pumped to lagoon. 1/18/2008 Farrowing Building 44,000 gal pumped to lagoon. 1/28/2008 Breeding and Gestation Buildings 118,000 gal pumped to lagoon. 2/29/2008 Unknown Buildings 158,000 gal pumped to lagoon
4: 3/6 - 6/6/2008	4/15/2008 Breeding and Gestation Buildings 152,000 gal pumped to lagoon. 5/1/2008 Farrowing Building 41,000 gal pumped to lagoon. 5/7/2008 Farrowing Building 93,100 gal pumped to lagoon. 5/14/2008 Farrowing and Gestation Buildings 190,000 gal pumped to lagoon.
5: 6/7 - 7/14/2008	6/9/2008 Gestation Buildings 57,280 gal pumped to lagoon. 6/18/2008 Farrowing Building 98,000 gal pumped to lagoon.

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for midlatitude climates (Table 4.2-1). Approximately 22% of the days had extra-tropical frontal systems overhead while 78% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Measurement Period	# days	# Warm front passages	# Cold front passages	# days stationary front	# days tropical storms
1	61	3	12	2	0
2	90	3	17	3	0
3	89	7	18	1	0
4	91	4	19	3	0
5	43	1	8	0	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from -15.2 ^{o}C to 27.9 ^{o}C while the barometric pressure varied from 96.4 kPa to 100.7 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ h solar irradiance of 1140 Wm^{-2} to overcast conditions with maximum ½ hr solar irradiance of 83 Wm^{-2} (Section 6.10). The wetness sensor failed frequently due to corrosion issues.

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared to the monthly climatology is indicated in Figure 4-1. Temperatures during the spring and summer measurements were near normal, those during the fall were above normal, while those during the winter ranged from below to above normal. Daily mean relative humidity was greater during the winter than spring, summer and fall.

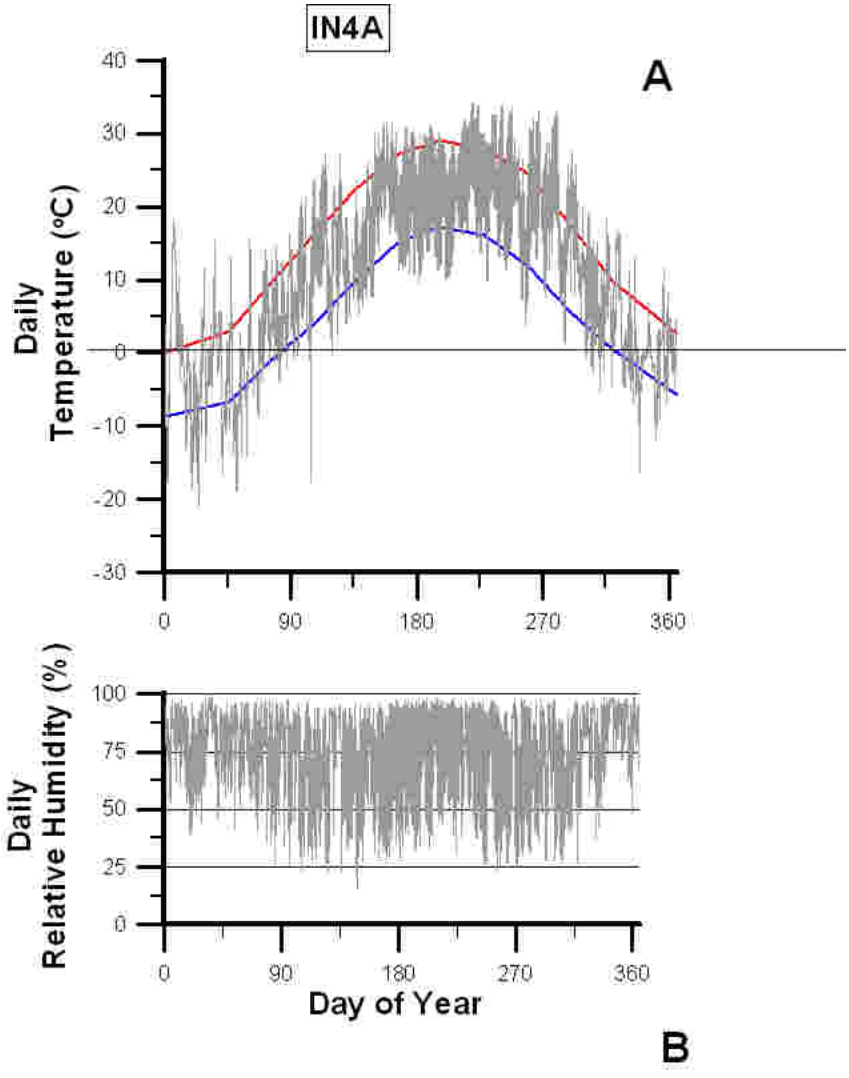
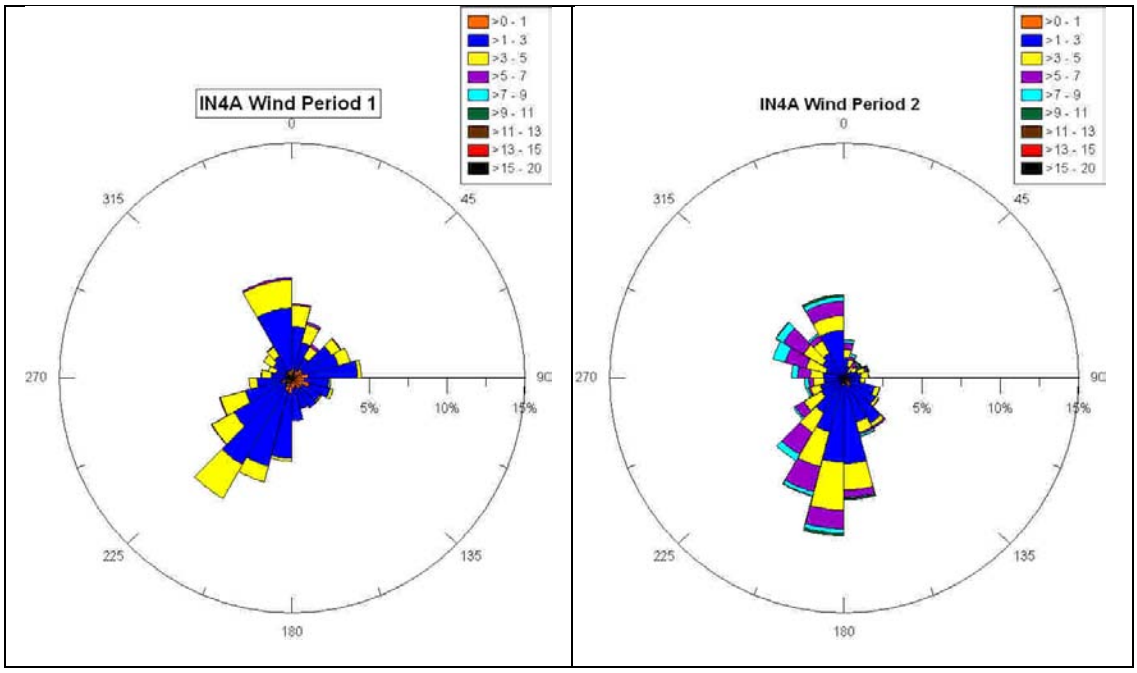


Figure 4-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line)

temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidity for measurement days is indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figure 4-2. Winds were largely from the southwest and north-northwest during Period 1, from the south to southwest and northwest during Period 2, from the west during Period 3, from the south or north-northwest during Period 4, and from the south to southwest during Period 5. The frequency of light winds (≤ 1 ms^{-1}) was greatest during the summer (Period 1), with light winds rarely measured during other periods.



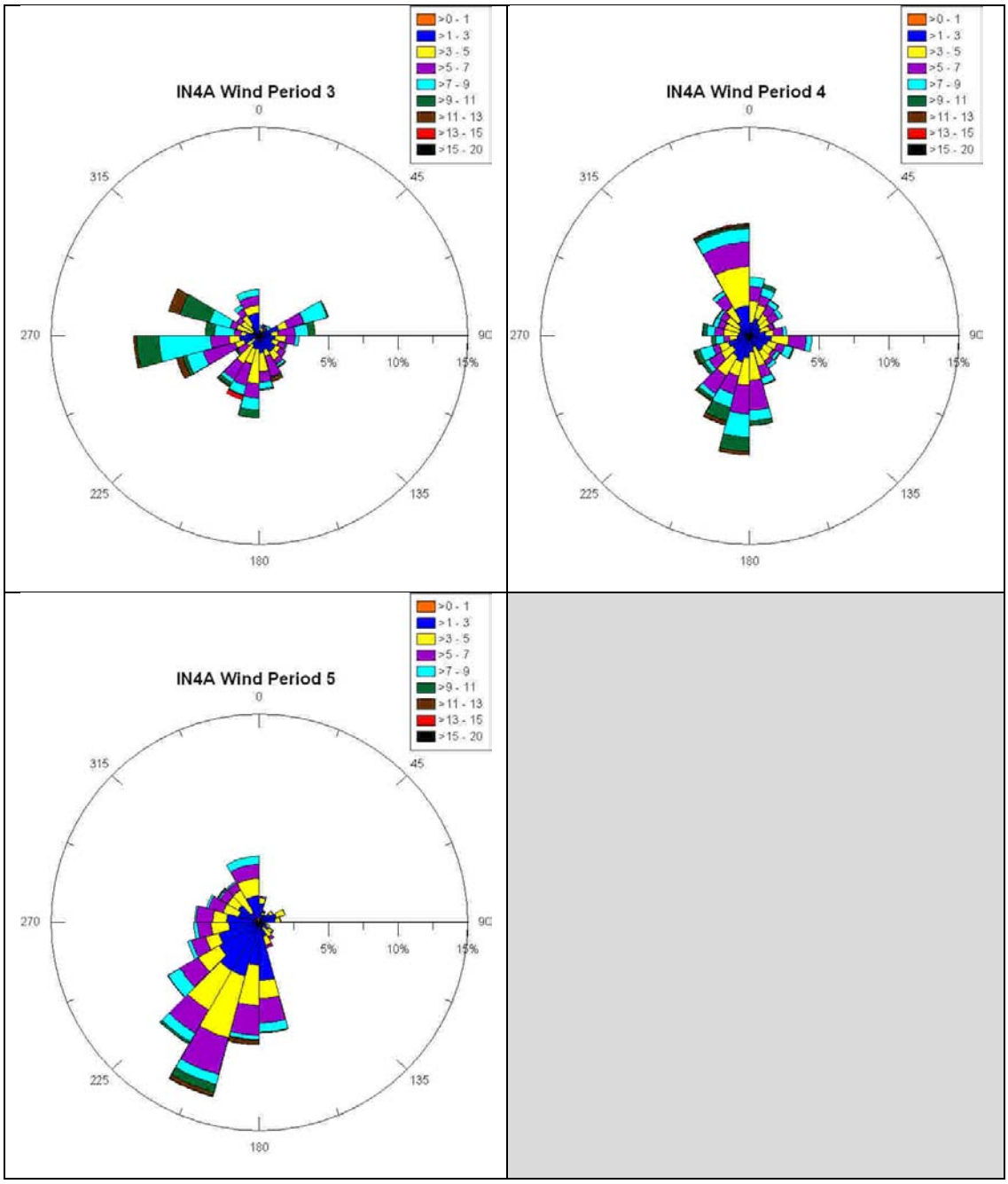


Figure 4-2: Wind roses for ½ hourly wind measurements during the measurement periods. The five periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle.

4.3 Lagoon conditions

4.3.1 Lagoon appearance, liquid depth and sludge depth

The appearance of the lagoon was recorded on almost every site visit (Table 4.3-1). The lagoon generally appeared brown with surface characteristics ranging from frozen during the winter to free of crust during the remainder of the year.

Table 4.3-1: Lagoon physical characteristics

Period	Appearance	Liquid depth	Sludge depth	Source of measure-ment
	Color/Crust	(m)	(m)	
1: 7/1 - 8/31/2007	7/20/2007 - brown/no crust 7/24/2007 - brown/no crust 8/8/2007 - brown/no crust 8/10/2007 - brown/no crust 8/15/2007 - brown/no crust 8/16/2007 - brown/no crust 8/17/2007 - brown/no crust 8/20/2007 - brown/no crust 8/22/2007 - brown/no crust 8/23/2007 - brown/no crust 8/30/2007 - brown/no crust	1.79	0.25	Sludge Gun
2: 9/1 - 11/30/2007	9/4/2007 - brown/no crust 9/5/2007 - brown/no crust 9/12/2007 - brown w/ pink crust/3% crust 9/19/2007 - brown/no crust 9/20/2007 - brown/no crust 10/4/2007 - brown/no crust 10/18/2007 - brown/no crust 10/23/2007 - brown/no crust 11/1/2007 - brown/no crust 11/13/2007 - brown/no crust 11/15/2007 - brown/no crust	1.7	0.3	Sludge Gun
3: 12/1/2007-3/5/2008	1/29/2008 - brown/ 30% frozen 1/30/2008 - brown/100% frozen 1/31/2008 - brown/100% frozen 2/12/2008 - 100% frozen 3/5/2008 - brown/100% frozen	N/A	N/A	N/A

Period	Appearance	Liquid depth	Sludge depth	Source of measure-ment
	Color/Crust	(m)	(m)	
4: 3/6 - 6/6/2008	3/12/2008 - blackish/no crust 3/17/2008 - brown/no crust 3/20/2008 - brown/no crust 3/21/2008 - brown/no crust 4/7/2008 - brown/no crust 4/8/2008 - brown/no crust 4/14/2008 - brown/no crust 4/15/2008 - brown/no crust 4/30/2008 - brown/no crust 5/1/2008 - brown/no crust 5/12/2008 - brown/no crust 5/20/2008 - blackish/no crust 5/21/2008 - blackish/no crust 5/27/2008 - blackish/no crust 5/28/2008 - dark blue/no crust 6/5/2008 - dark brown/no crust	2.25	0.29	Sludge Gun
5: 6/7 - 7/14/2008	6/19/2008 - brown/no crust 6/20/2008 - brown/no crust 6/24/2008 - brown/no crust 7/1/2008 - brown/no crust 7/2/2008 - clear/no crust 7/3/2008 - brown/black/no crust 7/8/2008 - brown/no crust 7/14/2008 - brown/no crust 7/15/2008 - brown/no crust 7/16/2008 - brown/no crust	N/A	N/A	N/A

4.3.2 Temperature, pH and oxidation-reduction potential

The measured daily average lagoon liquid temperature varied from 0 °C to 31 °C. The probe float was not removed during the winter so temperatures of 0 °C were measured for extended periods (Section 6.11). The measured lagoon pH varied from 7.6 during the fall to 8.2 during the winter (Section 6.11). The corresponding oxidation-reduction potentials varied from -483 mV to -248 mV during the summer to -147 mV during the winter (Section 6.11). Significant losses to the record limit the utility of these measurements in relating conditions in the lagoon to the emissions of the lagoon.

4.4 Emissions measurements

Emissions data were calculated on a ½ hour basis since this was the interval over which the S-OPS system sampled both sides of the lagoon and since this interval is in the range over which turbulence statistics are often calculated. To account for the longer term manure storage of the lagoon or basin, emissions reported on a head basis were scaled by the animal population for which the facility was designed and not the animal population at the time of measurements. Emissions reported on an animal unit (AU) basis (1 AU = 500 kg) assumed the typical animal weight values reported by the producer. Piglets were not included in the populations or AU determinations. Emissions reported on an area basis are based on the surface area of the lagoon.

4.4.1.1 Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison was based on 530 half- hour measurement periods over the entire measurement time at this location. Results show that the bLS emissions had a significantly difference precision (F=1.16, critical F 1.0) and a significant bias over the *RPM* emissions (t=3.80, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 1.08 (Table 4.4.1-1). Consequently the ½ hour bLS emissions measurements are biased high by 8% compared to the *RPM* measurements.

Table 4.4.1-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	bLS	bLS-RPM
Mean emission (gs^{-1})	0.515	0.557	0.042
Standard deviation (gs^{-1})	0.323	0.348	
Variance of the mean (g^2s^{-2})	0.105	0.121	

4.4.2 NH_3 emissions

4.4.2.1 Mean daily NH3 emissions

An annual trend in the daily NH_3 emissions based on the *RPM* model was indicated (Figure 4.4.1-1) with a summer emission of approximately 60 g NH_3 $d^{-1}hd^{-1}$. There was, however, only one day in which 75% of the ½ hour periods within the day had measurable emissions using the *RPM* model. Consequently the high emissions values indicated may be either over or under-representing the mean daily emission depending on the time of day in which the measurable emission occurred. The daily emission during the winter was not measurable using the *RPM* model due to equipment problems. There was a wide variability in emissions from day to day. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

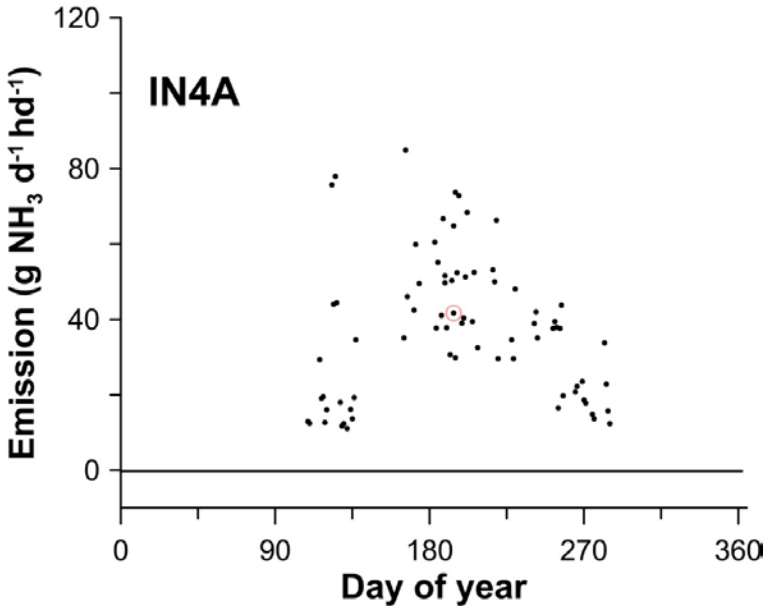


Figure 4.4.1-1: Annual variation in RPM-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

A distinct annual trend in NH_3 emissions based on the bLS model was evident (Figure 4.4.1-2). The bLS emissions model provided not only more daily estimates of the NH_3 emissions, but also more days in which more than 75% of the day had valid NH_3 measurements (Table 4.4.1-2). Comparing the standard deviation of the ½ hr emissions estimates of the daily emission rate to the range of partial-day estimates of the daily emission rate shows that the wide range of emission measurements during the summer are due to both day-to-day variability and estimates made on incomplete measurement days (having less than 75% of the possible ½ hrs with valid measurements). There was more variability day to day in the bLS-modeled NH_3 emissions values (Figure 4.4.1-2) than the *RPM*-modeled NH_3 emissions values (Figure 4.4.1-1). This is largely because there were many more partial days of valid emissions measurements. Negative emissions during the fall and winter were likely a result of near MDL concentrations around the lagoon in combination with NH_3 transported to the lagoon from the barns to the North. Emissions during the winter when the lagoon was frozen were not, however, always zero. Maximum NH_3 emissions during the summer are between 40 and 80 g NH_3 $d^{-1}hd^{-1}$. There was wide variability in NH_3 emissions from day to day during the entire year (Figure 4.4.1-2). The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

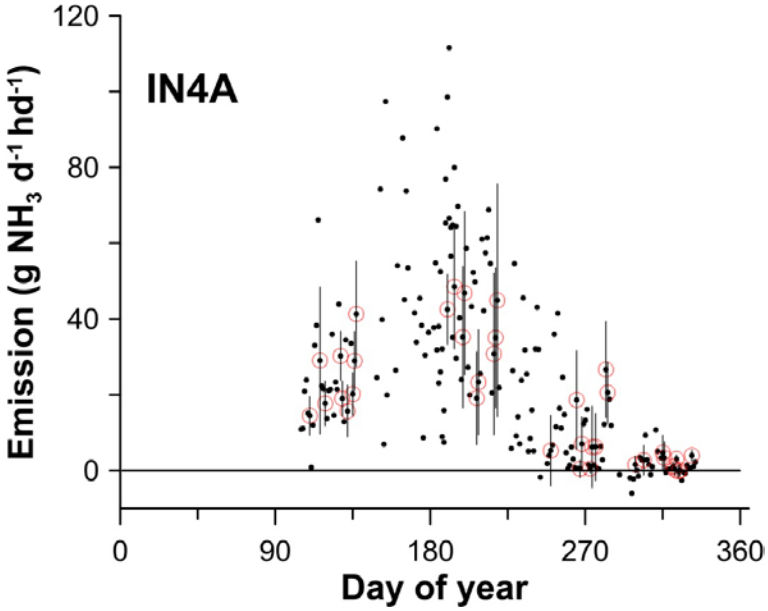


Figure 4.4.1-2: Annual variation in bLS-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

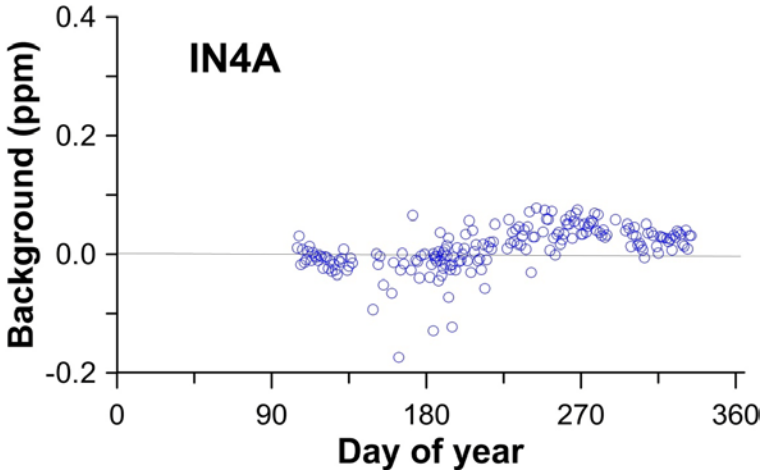


Figure 4.4.1-3: Annual variation in bLS-computed mean daily background concentration of NH_3.

The bLS model was influenced by the calculated background concentrations. Results indicate that the background concentration of NH_3 was generally less than 0.1 ppm (Figure 4.4.1-3). The greatest background concentrations occurred around day of year 270. Given that the typical path length around the lagoon was 50 m to 100 m, this translates to a background concentration for a given PIC of 5 to10 ppm-m. This is above the MDL for the TDLAS instruments (2 ppm-m: Section 6.1) and therefore represents a real background concentration. The negative background

concentrations < -0.05 ppm during the summer contributed to some of the very high emissions calculated by the bLS model (Figure 4.4.1-2). These negative values were largely a result of winds shifting within the 5-min time interval for NH_3 measurements.

4.4.2.2 Diurnal variation in NH_3 emissions

The NH_3 emissions were generally higher during the day time than during the night time (Figure 4.4.1-4). During the winter when no significant emissions of NH_3 occurred there was no diurnal variation evident. The greatest diurnal variation occurred during the summer. The wide range of ½ h measurements of the daily emission rate during the summer supports the wide standard deviations of ½ h emission measurements within a single day emission estimate illustrated in Figure 4.4.1-2.

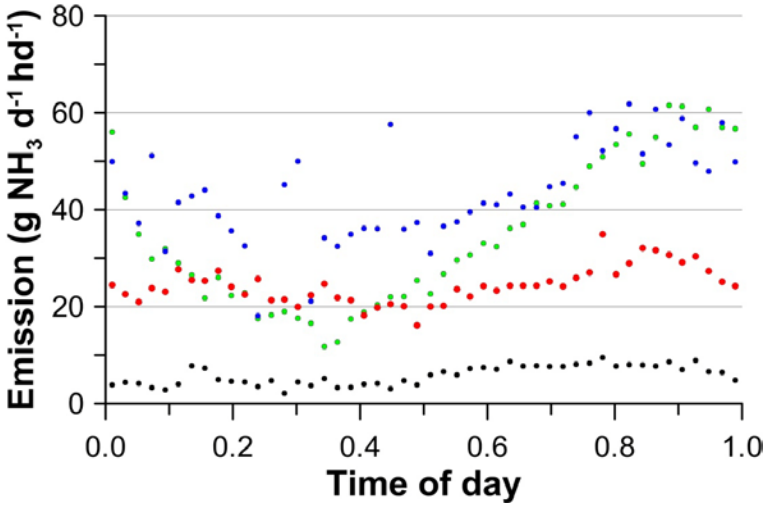


Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 1-Summer (greed), Period 2-Winter (black), Period 4-Summer (red), and Period 5-Spring (blue)) are indicated.

4.4.2.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ hour intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ hour periods (corresponding to 75% completeness on a daily basis) is given. There was no wind direction exclusion region at IN4A, so no data were excluded solely based on wind direction. The completeness statistics are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

Parameter	RPM model	bLS model
Valid ½ h measurements (d)	14.8	89.8
Measurements excluded due to wind direction (d)	0 .0	0.0
Measurements excluded because touchdown fraction < 0.1	—	30.8
Measurements excluded because at least one downwind path is missing or invalid (d)	249.1	—
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\|<2$ m (d):	—	71.8
Number of days with ≥ 36 valid ½ hour periods (d):	1.0	37.0

In total, approximately 15 d of valid NH_3 emissions were determined from the 264 measurement days using the *RPM* model, with only 1 day having at least 36 valid ½ hour NH_3 emissions. The absence or invalidation of at least one downwind path led to 249.1 d for which emissions could not be calculated.

Approximately 90 d of valid NH_3 emissions were determined from the 264 measurement days using the bLS model, with 37 d having at least 36 valid ½ hour NH_3 emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) led to approximately 72 d in which emissions could not be calculated. These invalid turbulence statistics were most prevalent during the night when light winds were more predominant. A touchdown fraction of less than 0.1 led to the exclusion of 31 d of data. Low touchdown fractions indicated that little, if any, downwind data was available. This corresponded to either when the downwind TDLAS was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ hour interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ hour mean wind speed and direction, in contrast to the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times that the *RPM* model produces valid emissions that the bLS model does not. However, these times are overwhelmed by the times that the *RPM* model is missing concentration data for one or more paths, while the bLS model is able to run.

4.4.3 H_2S Emissions

4.4.3.1 Mean daily H2S emissions

There were too few daily H_2S emissions based on the Ratiometric emissions model to detect any annual emissions pattern (Figure 4.4.2-1). There were no days at this location that had valid measurements during at least 75% of the day using this calculation method. Consequently, no interpretation of the variability in H_2S emissions is possible. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

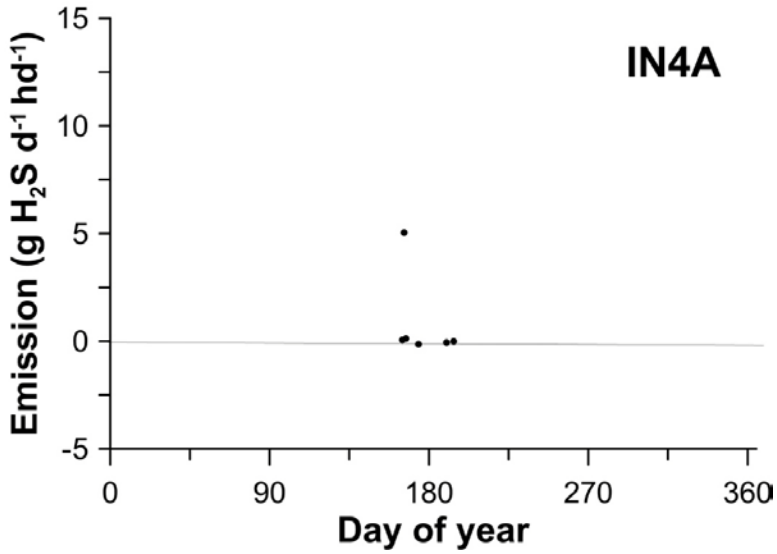


Figure 4.4.2-1: **Annual variation in radiometric-computed daily H_2S emissions.** Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

A peak in H_2S emissions during the spring was suggested based on the bLS emissions model (Figure 4.4.2-2). Although the number of days with H_2S emissions measurements is limited, the bLS emissions model provided not only more daily estimates of the H_2S emissions, but also more days in which more than 75% of the day had valid H_2S measurements (Table 4.4.2-1). There were no H_2S emissions during the winter when the lagoon was frozen or during the summer. A maximum H_2S emission suggested by measurements during the spring could not be determined with any confidence. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

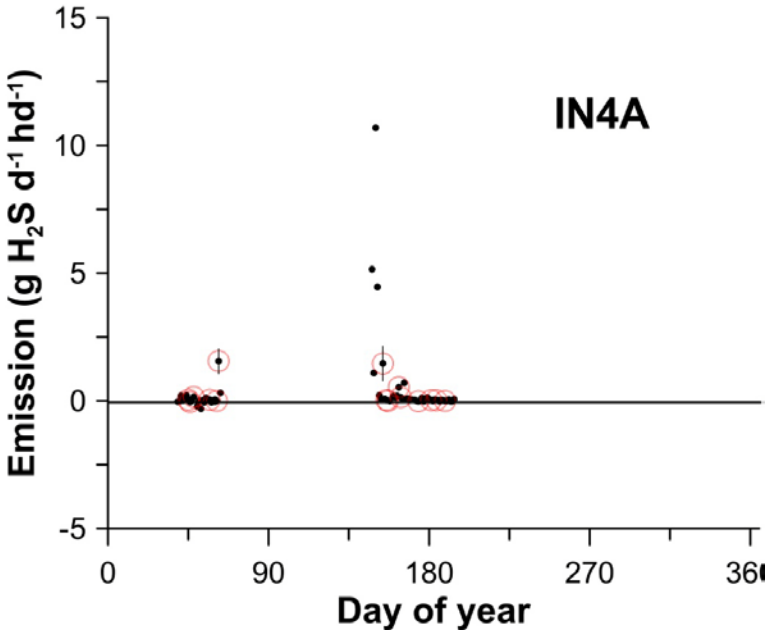


Figure 4.4.2-2: Annual variation in bLS-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS emission model depends on a good estimate of the background H_2S concentration. Results indicate that the background concentration was generally less than ±2.5 ppb (Figure 4.4.2-3). This background is consistent with an equivalent zero value where the instrument MDL was 3.4 ppb (Section 6.2).

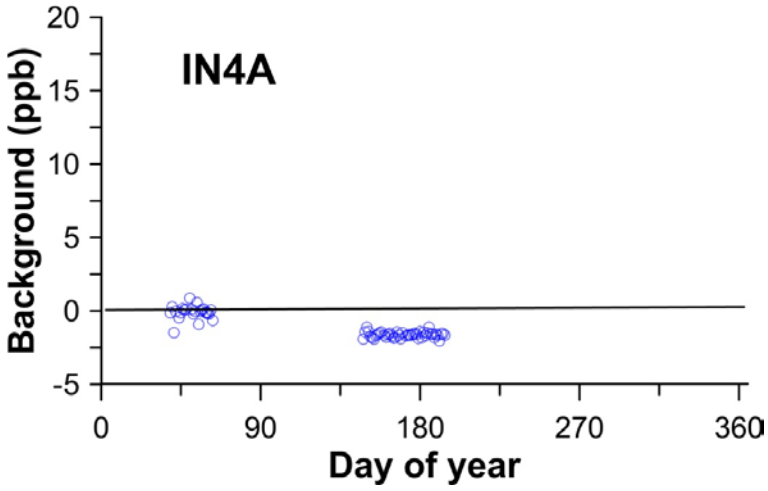


Figure 4.4.2-3: Annual variation in bLS-computed mean daily background concentration of H_2S.

4.4.3.2 Diurnal variation in H_2S emissions

There was no evident diurnal variation in H_2S emissions regardless of season (Figure 4.4.2-4).

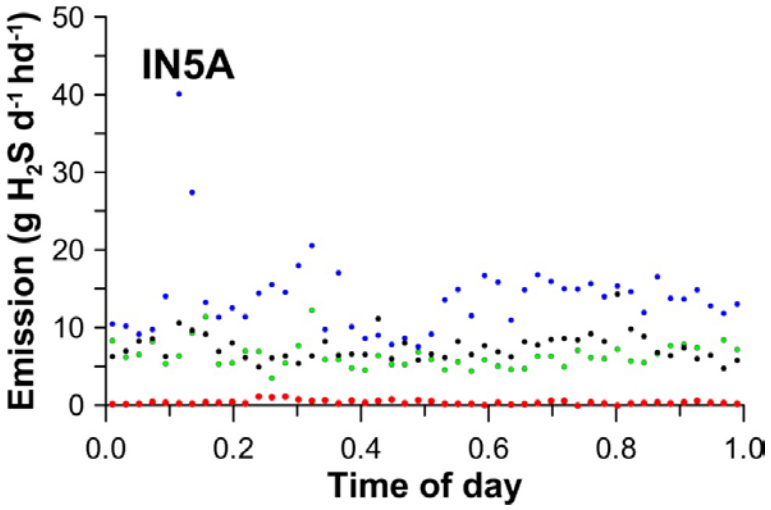


Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 3-Winter (black), Period 4-Summer (red), Period 5-Fall (blue)) are indicated.

4.4.3.3 H_2S emissions data completeness

H_2S Measurements were begun in Period 3. Consequently there were no measurements possible for Fall or Winter. As described for the NH_3 emissions, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ hour intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics are summarized in Table 4.4.2-1. The completeness statistics are summarized in Table 4.4.2-1.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

Parameter	Ratiometric model	bLS model
Valid ½ h measurements (d)	0.4	32.8
Measurements excluded due to wind direction (d)	0.0	0.0
Measurements excluded because angle of attack > 60° (d)	—	14.8
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| < 2$ m (d)	—	16.2
Number of days (d) with ≥ 36 valid ½ hour periods:	0.0	15 .0

There was less than one day of valid H_2S emissions that were determined using the Ratiometric emission method, with no days having at least 36 valid ½ hour H_2S emissions. Given the limited period of measurements, there was still a poor yield of valid measurements during the Spring and Summer as a result of three factors. The primary cause for poor yield was the return of the instrument to the manufacturer for repair: no measurements were made between 3/21/2008 and 5/28/2008. Another factor was that this method requires a valid NH_3 emission calculation by the *RPM* model. As indicated, the *RPM* model itself has relatively low completeness as a result of

the loss of at least one of the ten needed measurement paths. In addition, that the lack of S-OPS lines on the north and south sides of the lagoon limits the range of wind directions for which the Ratiometric method can be used due to the requirement of a valid downwind H_2S concentration reading.

Approximately 33 d of valid H_2S emissions were determined using the bLS model, with 15 d having at least 36 valid ½ hour H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) led to 16 d for which emissions could not be calculated. These invalid turbulence statistics were most prevalent during the night when light winds were more predominant. An angle of attack greater than 60 degrees led to the exclusion of 15 d of data. The absence of S-OPS lines on the east and west sides of the lagoon is largely responsible for these large angles of attack, as winds from the east or west were more or less parallel to the S-OPS lines on the north and south sides, leading to poorly defined inputs to the bLS models and invalid results.

4.4.4 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of the TDLAS serial numbers 1026, 1027, and 1028 prior to July 21, 2008. TDLAS 1026 and 1027 were used at IN4A from 7/1/2007 to 2/28/2008 (Measurement periods 1 through 3). Under the calibration verification checks, the TDLAS error of all units was within a10% accuracy. However due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and units without apparent interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from dew point temperatures of -2^oC to 20^oC. A conservative estimate of the bias of all of the above TDLAS units with evident moisture interference was estimated at -40%.

4.4.4.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.4.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions, underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%. Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This

was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was +8% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -32% for TDLAS NH_3 measurements made by units with moisture interference and a bias of +8% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.4.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the Ratiometric measurement of H_2S emissions was ± 18%.

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6 Appendices

6.1 TDLAS NH_3 calibrations

Five TDLAS units (Model GasFinder2^{TM} NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used for measurements at this location: TDLAS 1026, TDLAS 1027, TDLAS 1028, TDLAS 1029, and TDLAS 1030.

TDLAS 1026 was multipoint calibrated seven times during the study (Figure 6.1-1). The response is non-linear and consequently a third-order polynomial was used to correct the raw data for the instrument response. The multipoint calibration on 1/17/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3$$

where X is the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and 11/10/2009 bias exceedences were followed the same or next day with a passing verification and

were deemed to be a result of operator error. The negative bias over the period 4/2/2008 through 7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used). During operations the bias was only intermittently evident because to different multipoint calibration was applied to the calibration verification measurements during the progress of the study than finally applied during the analysis. Repeated calibrations within 24 hours often showed biases differing by more than 10 ppm-m suggesting operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period are considered valid and the error assumed to be due to the calibration verification operator.

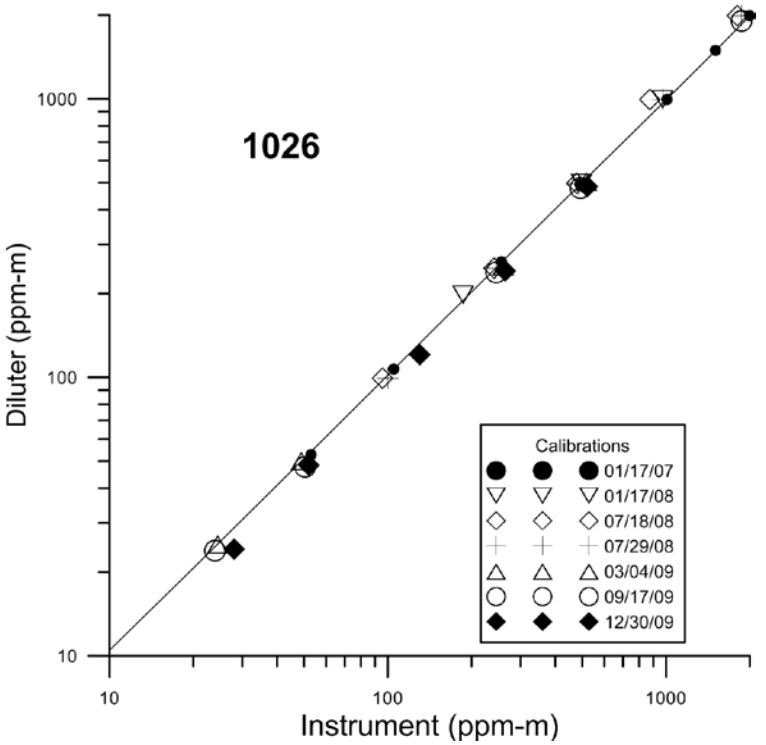


Figure 6.1-1: Multipoint calibrations of the GasFinder2 [TM] s/n NH3-OP-1026. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

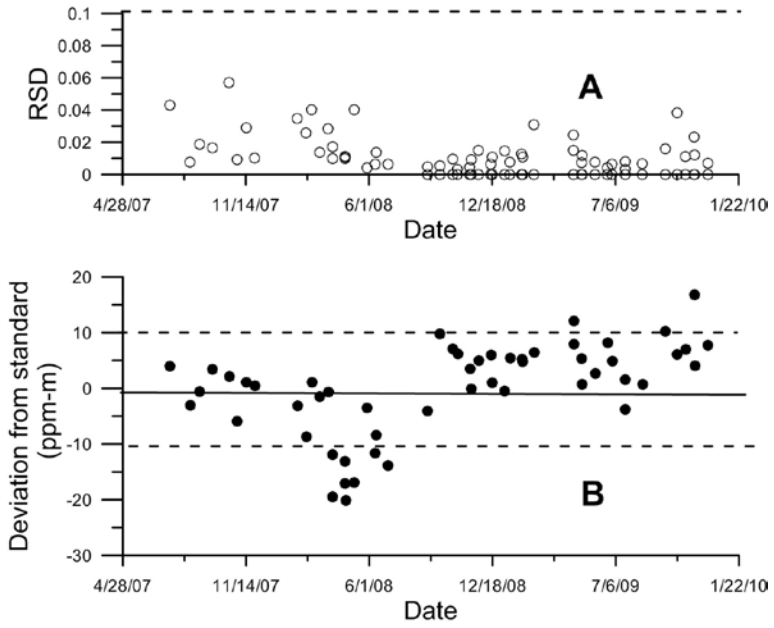


Figure 6.1-2: Control charts of the GasFinder2 ™ s/n NH3-OP-1026

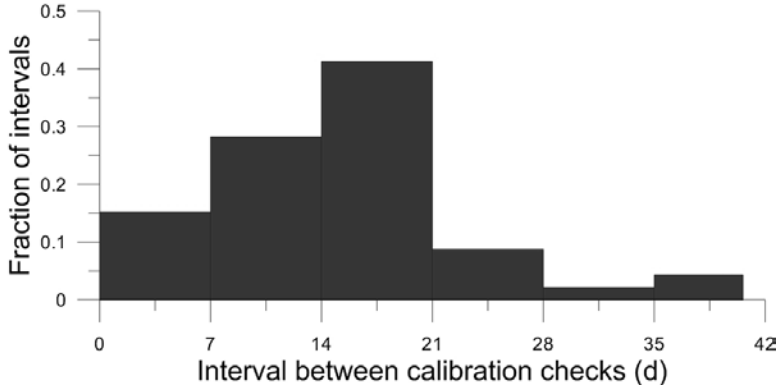


Figure 6.1-3: Calibration check intervals of the GasFinder2 ™ s/n NH3-OP-1026

TDLAS 1027 was multipoint calibrated eight times during the study (Figure 6.1-4). The response is non-linear and consequently a third-order polynomial was used to correct the raw data for the instrument response. The multipoint calibration on 6/18/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 2.24 + 0.9936 * X - 3.59E\text{-}5 * X^2 + 6.230E\text{-}8 * X^3$$

where X is the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.13 ppm-m prior to the July 2008 modification and 1.83 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 5.36 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 2) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 9/26/2008 and 9/24/2009 (Figure 6.1-4). No negative biases exceeding the DQI occurred during the study. Since both positive bias exceedences were followed by a DQI compliant verification on the subsequent calibration verification without intervention, it is assumed that operator error was the cause for the non-compliance.

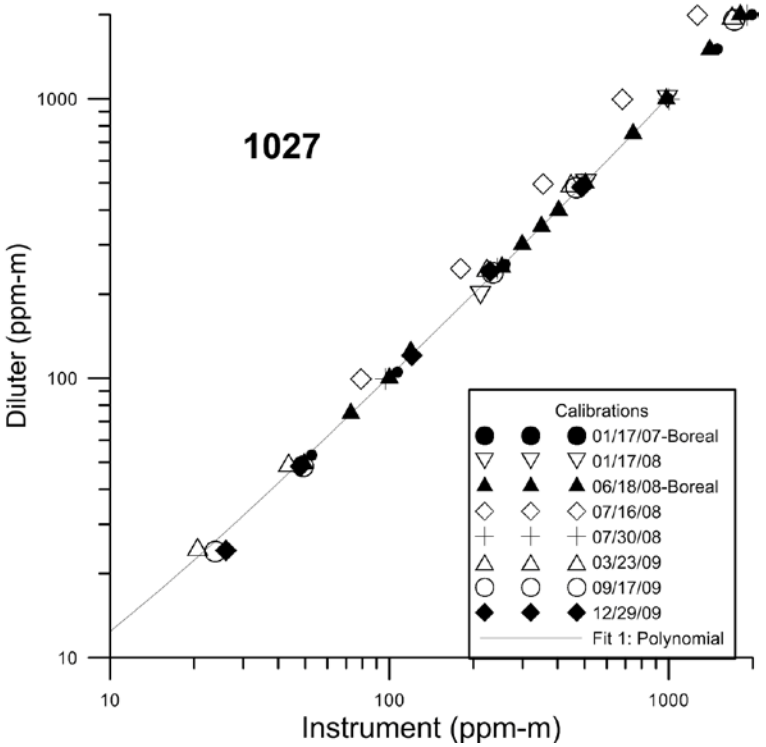


Figure 6.1-4: Multipoint calibrations of the GasFinder2 [TM] s/n NH3-OP-1027. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

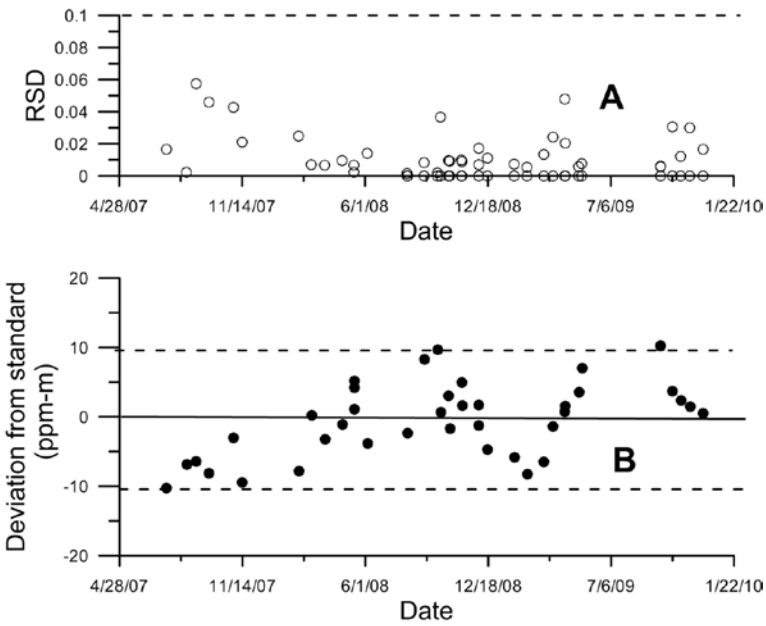


Figure 6.1-5: Control charts of the GasFinder2 [TM] s/n NH3-OP-1027

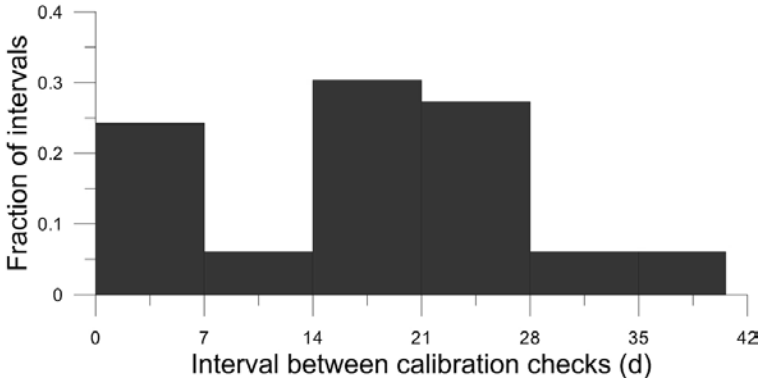


Figure 6.1-6: Calibration check intervals of the GasFinder2 ™ s/n NH3-OP-1027

TDLAS 1029 was multipoint calibrated seven times during the study (Figure 6.1-7). The response is non-linear and consequently a third-order polynomial was used to correct the raw data for the instrument response. Table 6.1-1 indicates the multipoint calibrations used during different periods in the study.

Table 6.1-1: Multipoint calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
6/24/2007	03/01/2008	05/24/2007
3/24/2008	07/15/2008	03/24/2008
7/31/2008	08/03/2009	03/04/2009
8/4/2009	12/2/2009	12/29/2009

The offsets of the calibration equations were determined from a least squares fit of the appropriate period (Table 6.1-1) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

05/24/2007: ppm-m = -1.48 + 0.967 * X + 4.842E-005 * X^2 - 7.312-009 * X^3

03/24/2008: ppm-m = -2.58 + 0.998 * X - 1.611E-004 * X^2 + 7.449E-008 * X^3

03/04/2009: ppm-m = 4.36 + 1.069 * X + 1.128-004 * X^2 - 1.206E-007 * X^3

12/29/2009: ppm-m = 5.48+ 1.268 * X - 6.072E-005 * X^2

where X is the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.74 ppm-m prior to the July 2008 modification and 1.66 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL prior to the July 2008 modification was greater than the offset in the calibration regression equations but less than the offset in the calibration equations after the modification. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equations were 4.65, 4.15, 5.23, and 4.27 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-8) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI threshold occurred on two dates (Figure 6.1-8). No positive bias exceeding the DQI threshold occurred. In all cases subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedences rather than instrument failure.

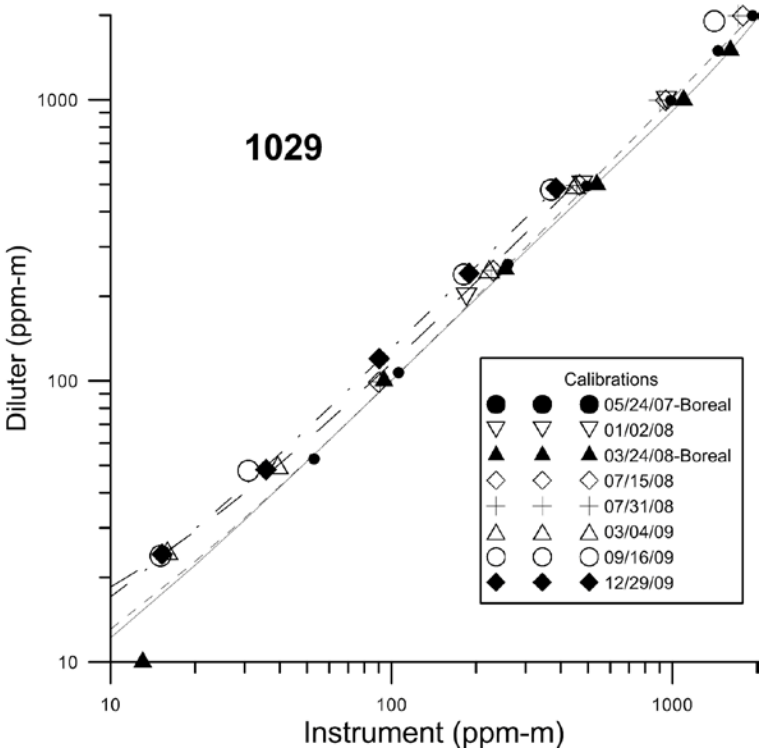


Figure 6.1-7: Multipoint calibrations of the GasFinder2 [TM] s/n NH3-OP-1029. The solid (5/24/2007), dotted (3/24/2008), dashed (3/4/2009) and dash-dot (12/29/2009) lines are the 3rd order polynomial regression for the chosen multipoint calibration.

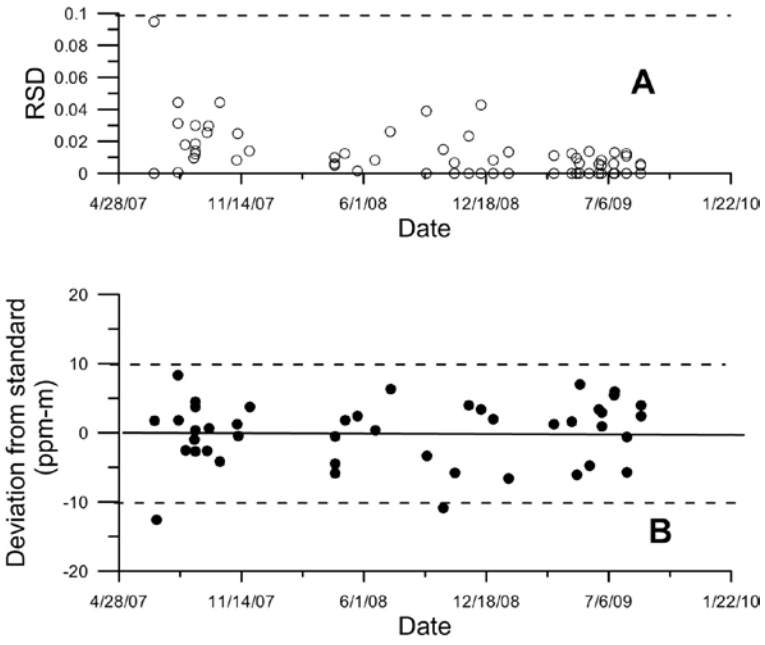


Figure 6.1-8: Control charts of the GasFinder2 [TM] s/n NH3-OP-1029

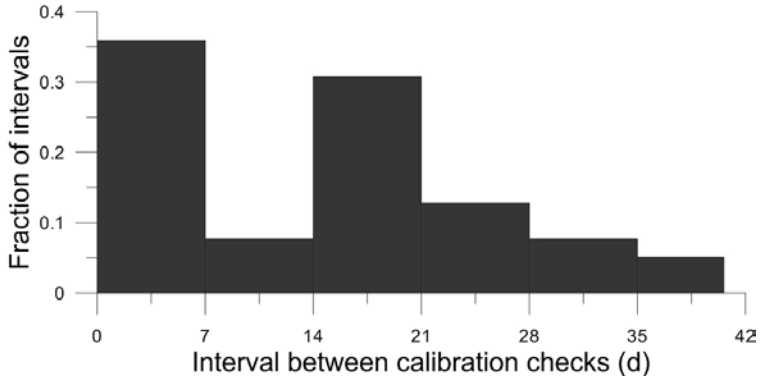


Figure 6.1-9: Calibration check intervals of the GasFinder2 ™ s/n NH3-OP-1029

TDLAS 1030 was multipoint calibrated eight times during the study (Figure 6.1-10). The response is non-linear and consequently a third-order polynomial was used to correct the raw data for the instrument response. The multipoint calibration on 3/26/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 0.13 + 0.9974 * X - 2.1056E\text{-}005 * X^2 + 3.050E\text{-}008 * X^3$$

where X is the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 3.05 ppm-m prior to the July 2008 modification and 0.685 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-12). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 7.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m except on 8/30/2007 (Figure 6.1-11) and well within the precision DQI. The accuracy

DQI was ±10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 8/14/2008 and 9/23/2008 while negative biases exceeding the DQI occurred on 10/4/2007, 9/23/2008, and 4/28/2009 (Figure 6.1-11). In all cases, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedences rather than instrument failure.

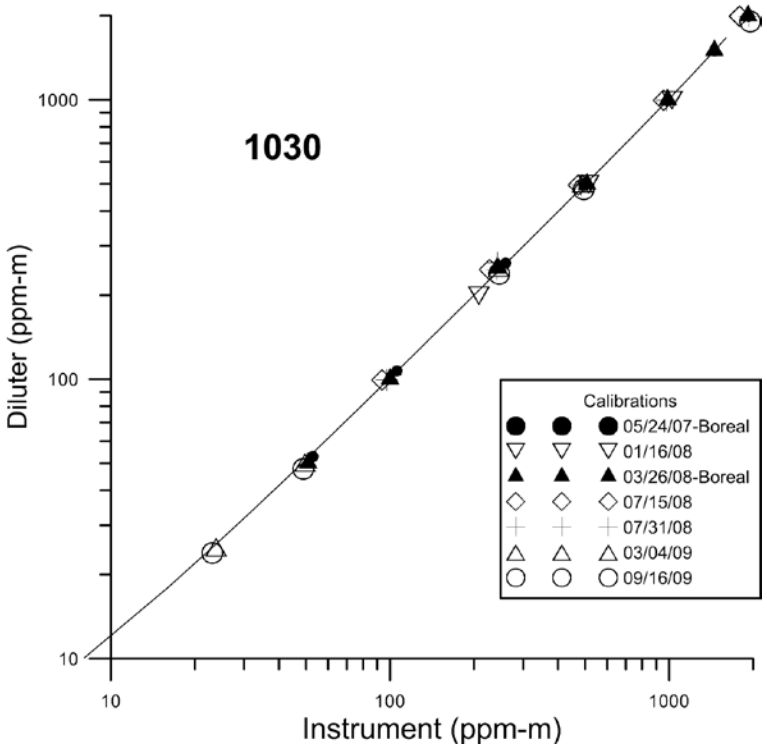


Figure 6.1-10: Multipoint calibrations of the GasFinder2 [TM] s/n NH3-OP-1030. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

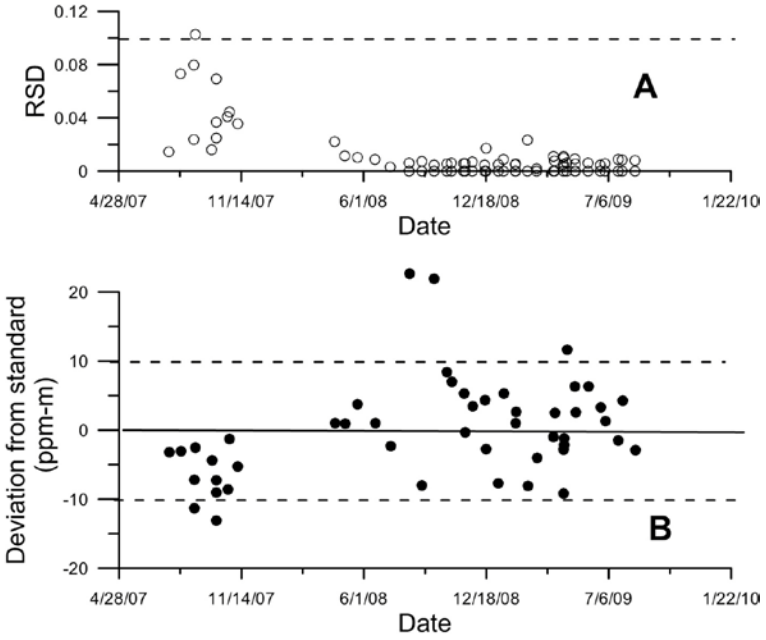


Figure 6.1-11: Control charts of the GasFinder2 ™ s/n NH3-OP-1030

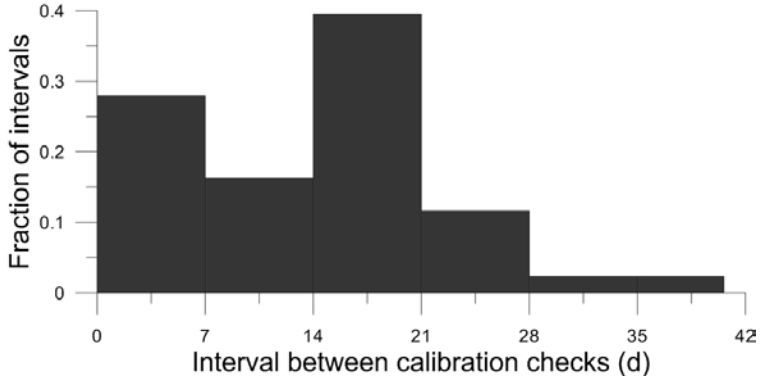


Figure 6.1-12: Calibration check intervals of the GasFinder2 ™ s/n NH3-OP-1030

TDLAS 1028 was multipoint calibrated six times during the study (Figure 6.1-13). The response is non-linear and consequently a third-order polynomial was used to correct the raw data for the instrument response. The multipoint calibration on 5/23/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 1.46 + 0.985 * X + 8.465E\text{-}6 * X^2 + 3.879E\text{-}8 * X^3$$

where X is the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At

that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL was greater than the offset indicated in the calibration regression. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-14) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-15). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-14) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 6.1-14). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedences rather than instrument failure.

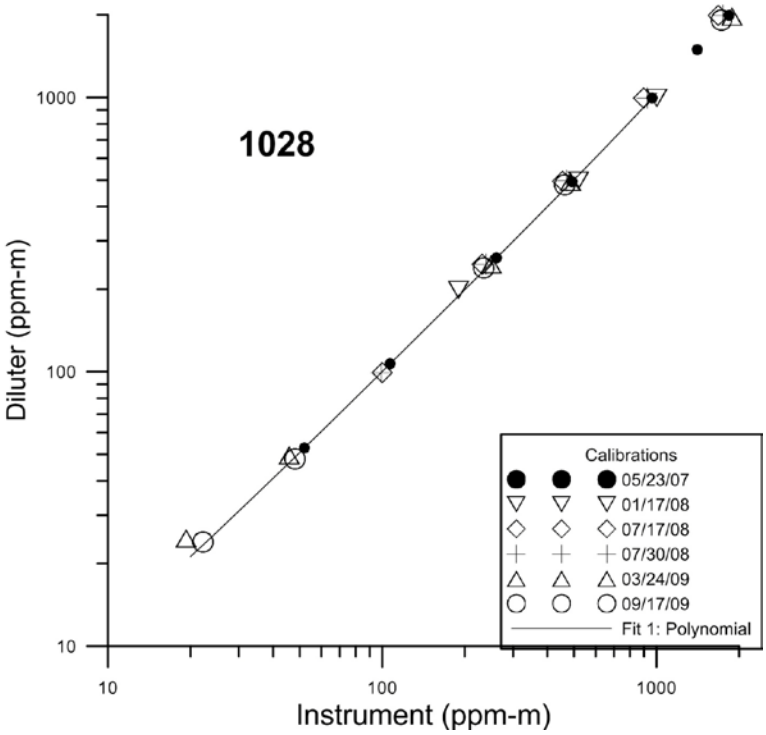


Figure 6.1-13: Multipoint calibrations of the GasFinder2 [TM] s/n NH3-OP-1028. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

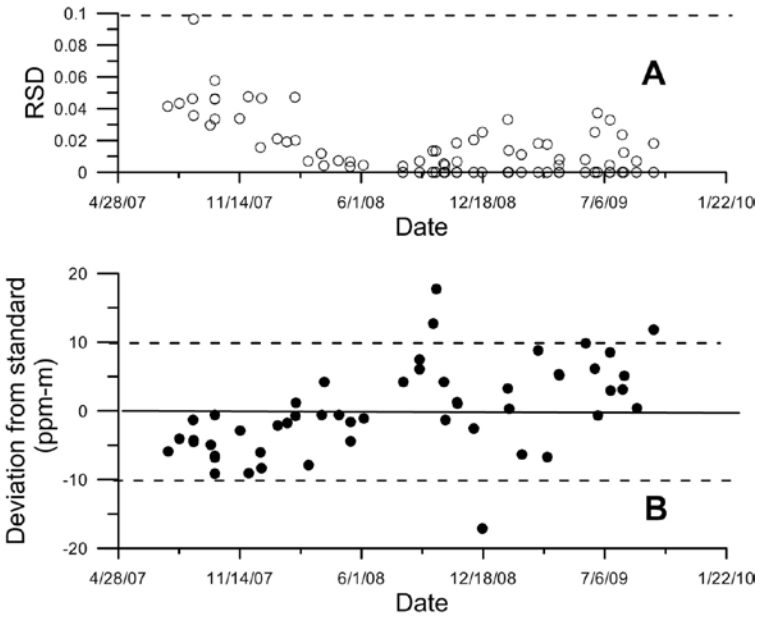


Figure 6.1-14: Control charts of the GasFinder2 [TM] s/n NH3-OP-1028

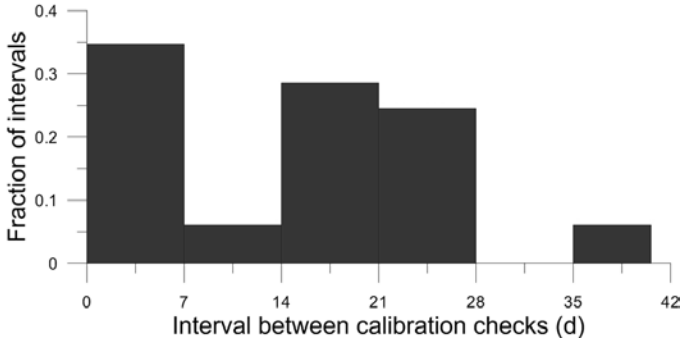


Figure 6.1-15: Calibration check intervals of the GasFinder2 ™ s/n NH3-OP-1028

6.2 TEC 450i analyzer H_2S calibrations

The H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA) with serial number 0733825130 was multipoint calibrated twelve times during the study (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values was never less than 0.990 although the slope of the linear regression equation varied from 0.73 to 1.20 (Table 6.2-1). The initial multipoint calibration was conducted prior to the complete burn-in of the converter and consequently differs greatly from the other calibrations. Part of the variation in slope was a result of the H_2S calibration cylinders used.

Table 6.2-1- Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
12/12/2007	1.20	0.0018	0.999
5/21/2008	0.95	-0.0031	0.999
7/28/2008	0.74	0.0051	0.999
9/24/2008	1.08	-0.0643	0.991
10/28/2008	0.98	0.0049	0.999
10/30/2008	0.98	0.0019	0.999
11/19/2008	0.80	-0.0077	0.999
12/09/2008	0.87	-0.0008	0.999
12/10/2008	0.83	0.0026	0.999
3/11/2009	0.92	0.0112	0.999
4/30/2009	0.80	0.0124	0.999
9/9/2009	0.73	0.0014	0.999

The instrument was returned to the manufacturer for repair on 3/21/2008 and put back into service after a multipoint calibration (Table 6.2-1) on 5/28/2008.

The standard deviation of instrument response with CEM zero air measured over a 1-h period was 1.13 ppb (10/19/2009). The instrument MDL, defined as 3σ was 3.4 ppb and is indicated in Figure 2A with dashed lines. This is much less than the mean absolute value of the multipoint calibration intercept of 10.5 ppb.

Instrument performance calibration checks (Figure 6.2-2, 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 28 d (Figure 6.2-4). Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.819. The mean zero concentration was -1.3 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). Based on the correlation of instrument performance and the calibration cylinder used, it was determined that the concentration of H_2S in the FF44447 cylinder (expiration date 5/13/2009), which was inter-compared with other H_2S calibration cylinders on 8/28/2009 and found to have been much below

the indicated specification. This resulted in unusually high ratios of diluter concentration versus instrument response on 3/11/2009 and a post-study calibration failure.

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedences (Figure 6.2-3) occurred on 1/31/2008 and 10/28/2008. The 1/31/2008 failure is due to the burn-in of the converter and signals changes in the instrument response as the instrument is conditioned. The 10/28/2008 DQI failure was likely due to the use of a different calibration tank for one check. Although it cannot be confirmed, the cylinder (SA15346) was likely either not within certification specifications or at the opposite end of the valid certification bound as the cylinder used before (FF20675) and after (LL34303) the date the cylinder is used resulted in valid calibration verifications.

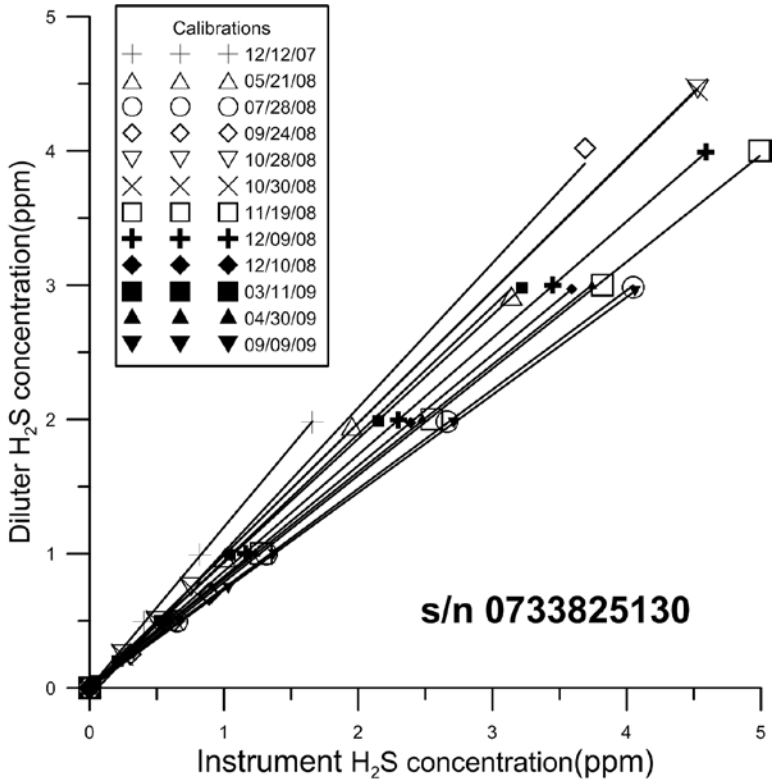


Figure 6.2-1: Multipoint calibrations of the 450i SO_2/ H_2S Analyzer

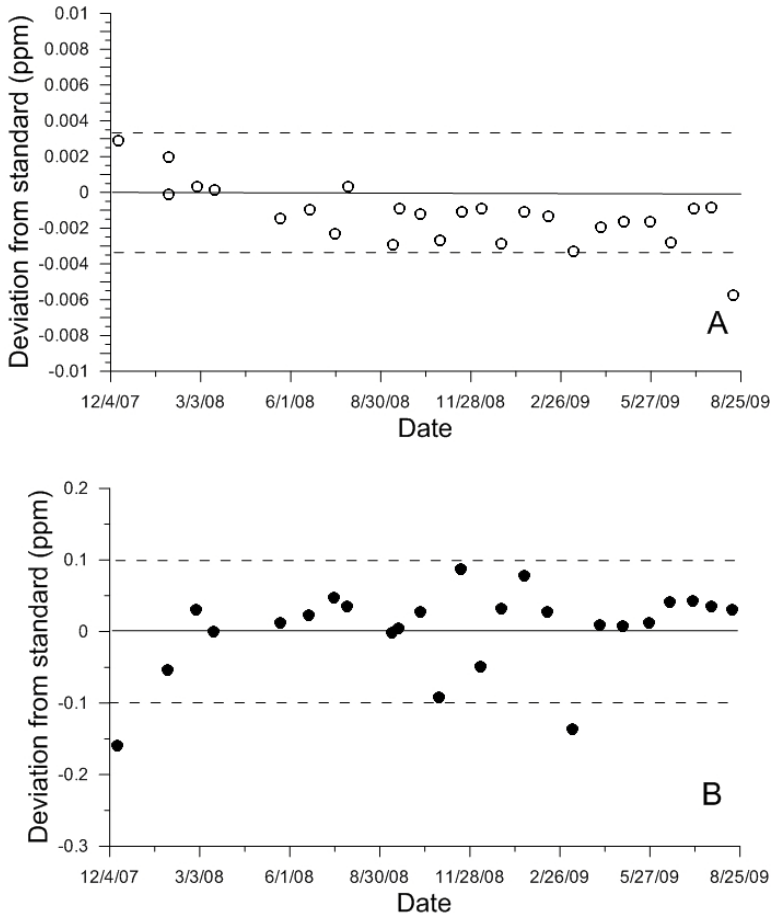


Figure 6.2-2: Instrument control charts

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1ppm).

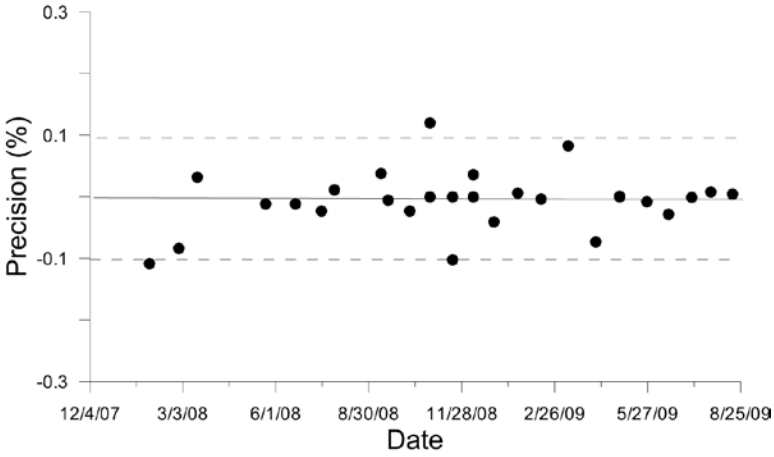


Figure 6.2-3: Instrument precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1ppm).

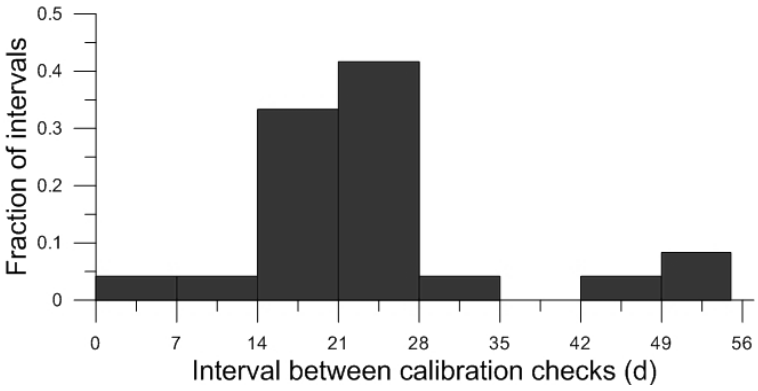


Figure 6.2-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Three sonic anemometers (Model 81000, RM Young Inc, Traverse City, MI) were used at this location: serial numbers 1938, 1927, 1925, and 1926.

Sonic anemometer 1938 was inter-compared with three standard anemometers of identical design eight times during the study (Table 6.3-1). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site26 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check at all times. The last standard inter-comparison (1/2010) failed due to loss of communications.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-1: Standards inter-comparisons, s/n 1938

Calibration periods		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.013	+0.011
1/21/2008	1/23/2008	+0.002	-0.036
7/16-17/2008	7/17-18/2008	-0.005	+0.010
3/6-7/2009	3/8-9/2009	-0.007	+0.002
1/7-9/2010	1/21-25/2010	-3.73	-3.94

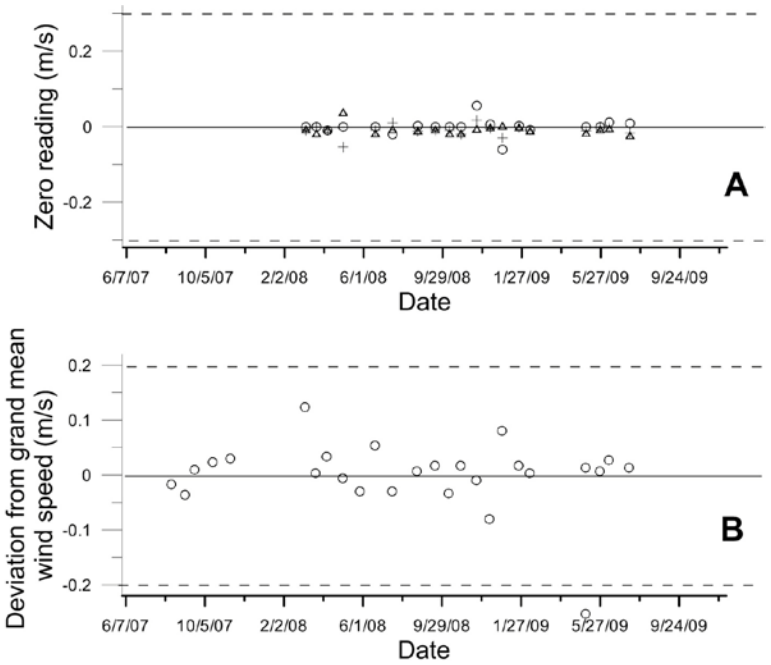


Figure 6.3-1: On-site quality assurance, s/n 1938. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

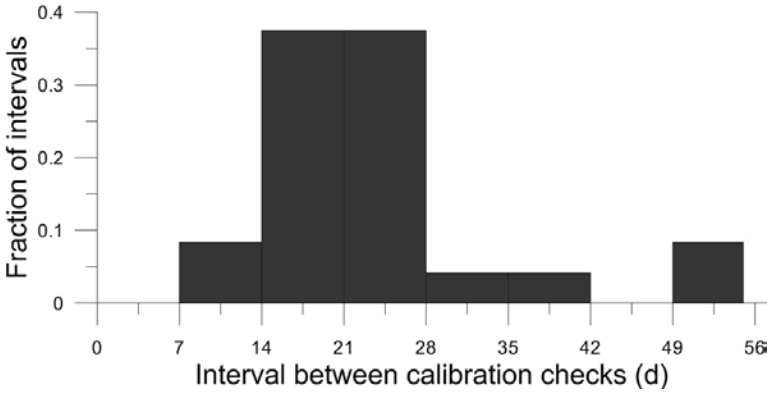


Figure 6.3-2: Inter-comparison check intervals, s/n 1938

Sonic anemometer 1927 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-2). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-3). The majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of

checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-3B). This instrument passed this check on all checks except 9/23-25/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back in use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-3A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-2: Standards inter-comparisons, s/n 1927

Calibration periods		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.025	-0.043
1/21/2008	1/23/2008	-0.051	-0.033
7/16-17/2008	7/17-18/2008	+0.042	+0.029
3/23-25/2009	3/25-27/2009	-0.050	-0.028
9/1-2/2009	9/2-3/2009	-0.035	-0.023

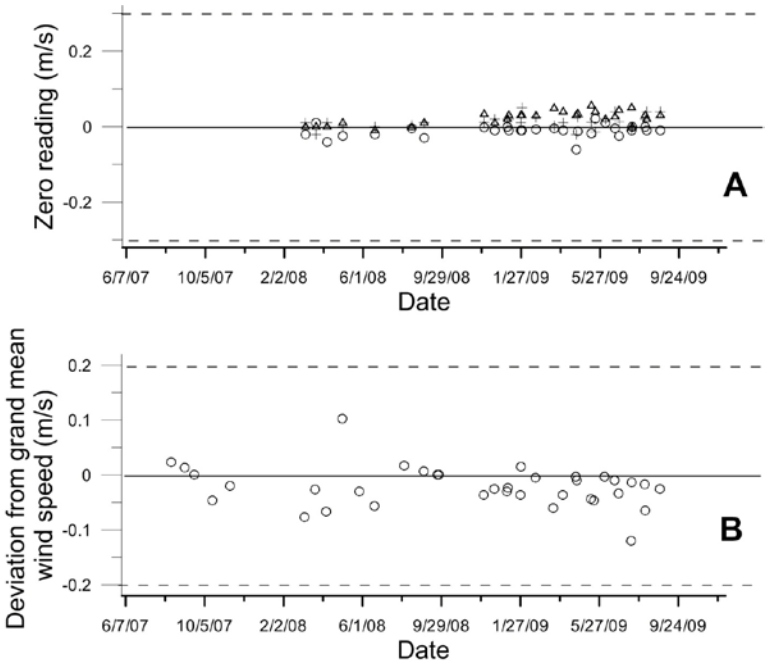


Figure 6.3-3: On-site quality assurance, s/n 1927. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

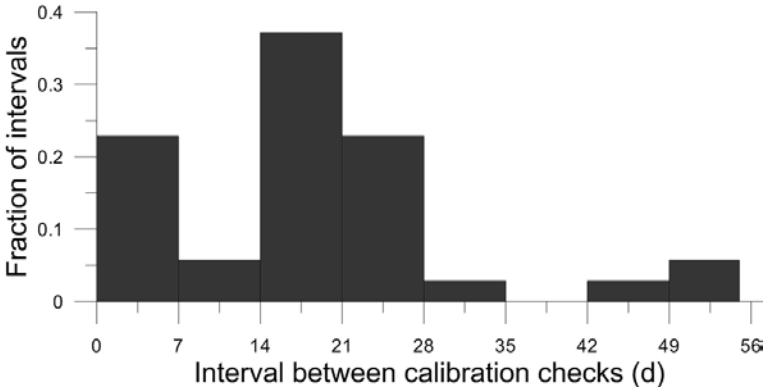


Figure 6.3-4: Inter-comparison check intervals, s/n 1927

Sonic anemometer 1925 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-3). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 26 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 1B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-3: Standards inter-comparisons, s/n 1925

Calibration periods		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.013	-0.022
1/21-22/2008	1/23/2008	-0.053	-0.075
7/16-17/2008	7/17-18/2008	+0.023	+0.004
3/6-7/2009	3/7-9/2009	-0.018	-0.058
9/8-14/2009	9/15-16/2009	-0.013	-0.022
12/18-19/2009	12/21-23/2009	+0.095	-0.084

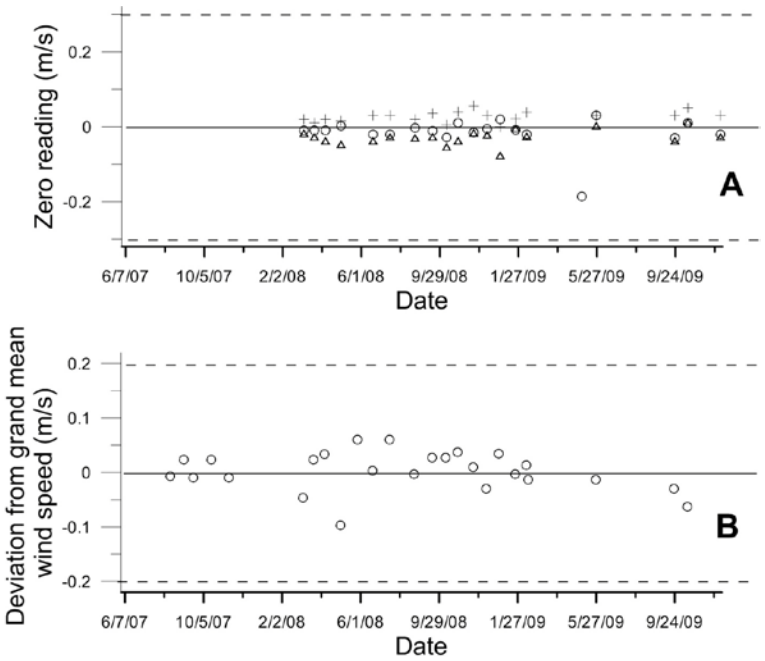


Figure 6.3-5: On-site quality assurance, s/n 1925. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

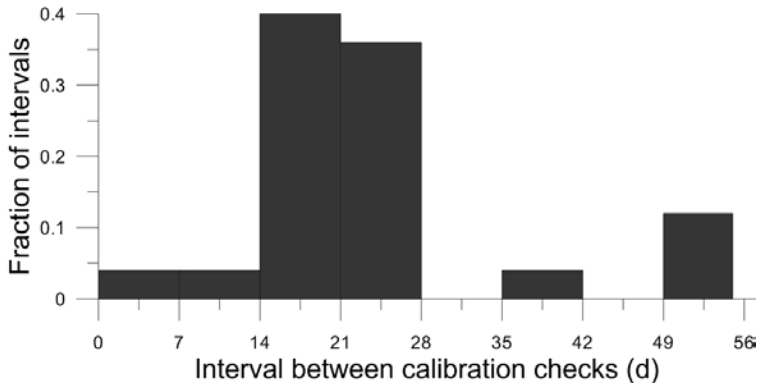


Figure 6.3-6: Inter-comparison check intervals, s/n 1925

Sonic anemometer 1926 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-4). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-7). The majority of calibration checks were made within 21 d (Figure 6.3-8). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-7B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 1A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-4: Standards inter-comparisons, s/n 1926

Calibration periods		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29-7/2/2007	-0.005	-0.033
1/17-18/2008	1/20-21/2008	-0.013	-0.032
7/16-17/2008	7/17-18/2008	+0.037	+0.059
3/6-7/2009	3/7-9/2009	+0.004	+0.048
9/16-17/2009	9/17-18/2009	+0.059	+0.001

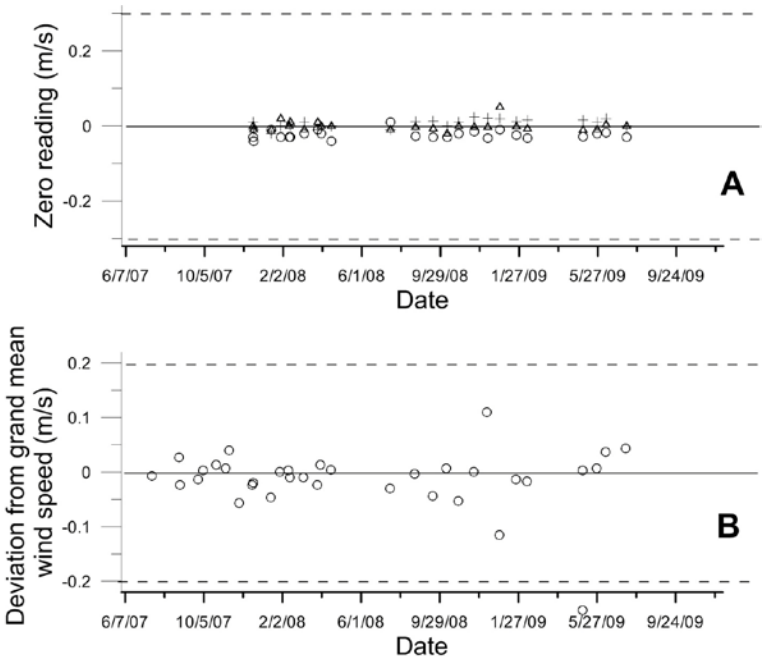


Figure 6.3-7: On-site quality assurance, s/n 1926. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

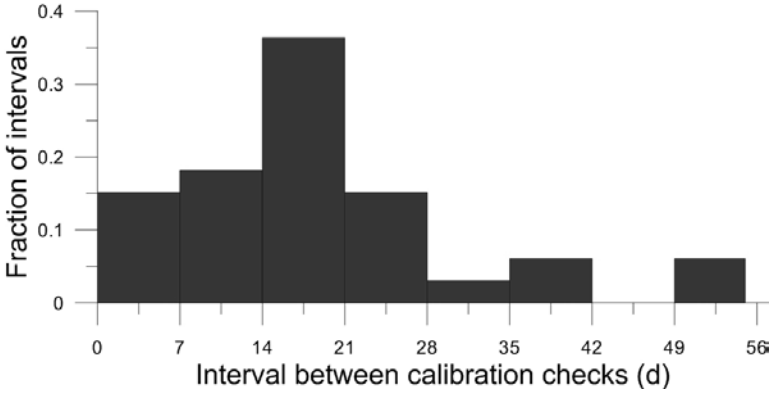


Figure 6.3-8: Inter-comparison check intervals, s/n 1926

6.4 pH probe calibrations

Two pH probes (Model CSIMM-ph, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 001 and 003.

Probe 001 was used between 7/18/2007 and 4/30/2008. The probe was calibrated 17 times. The pH probe DQI specified an accuracy of ±0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-1A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed both the accuracy DQI and the stability checks.

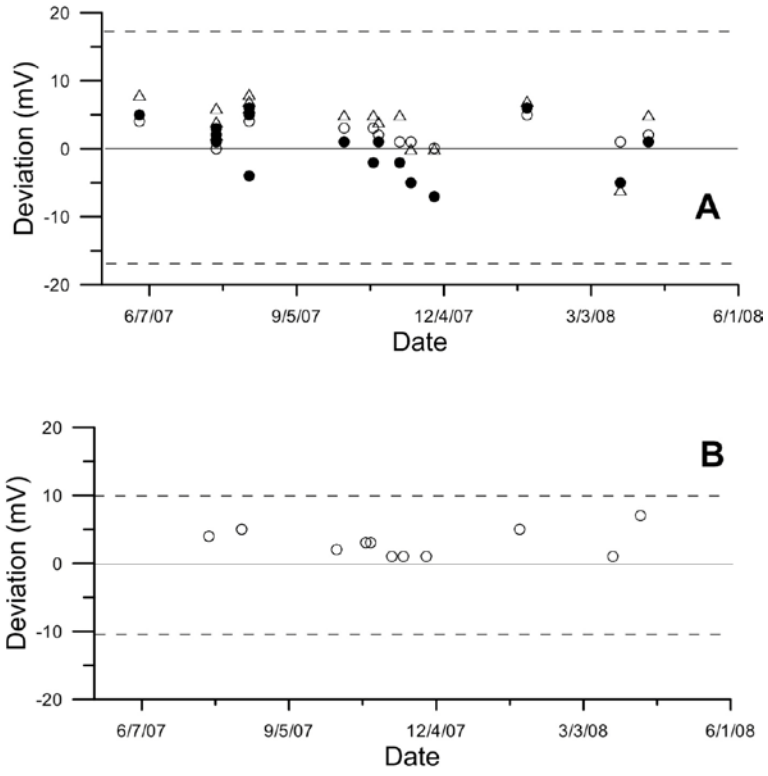


Figure 6.4-1: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 001. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

Probe 003 was used between 7/24/2007 and 11/15/2007. The probe was calibrated seven times. The pH probe DQI specified an accuracy of ±0.3 pH units, corresponding to a difference

between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-2A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed both the accuracy DQI and the stability checks.

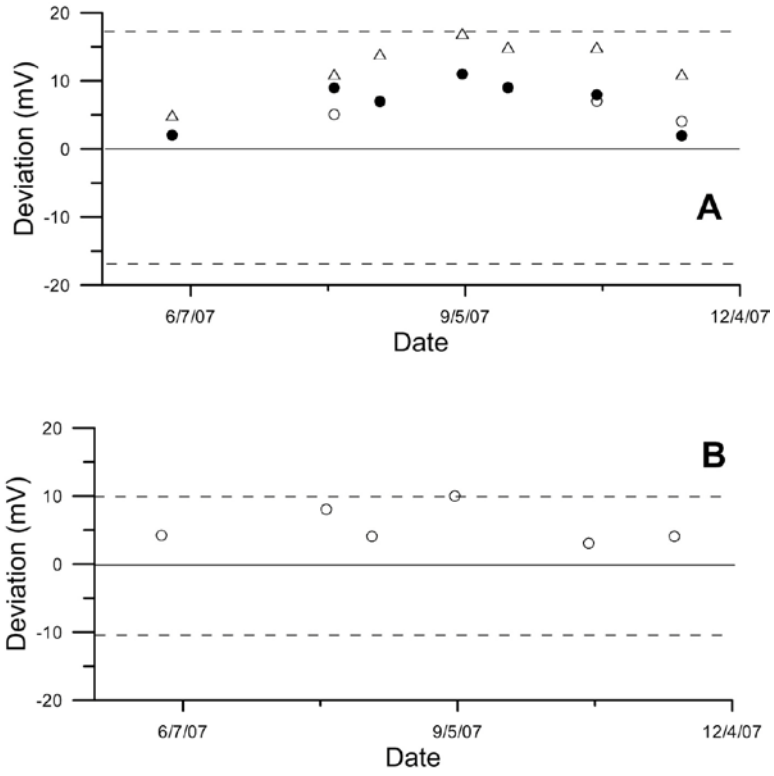


Figure 6.4-2: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 003. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

In general, the probe calibrations were conducted about every 20 d. Since freezing conditions damage the probe, the probes were not used during the winter.

6.5 ORP probe calibrations

Two oxidation-reduction potential (ORP) probes (Model CSIM11-ORP, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 010 and 040.

Probe 010 was used between 5/31/2007 and 10/15/2007. The probe was calibrated three times. The probe was first checked and the failure to meet the DQI resulted in the probe's return to the manufacturer. On return, the probe was calibrated and installed. This probe was then destroyed during the winter in the frozen lagoon and could not be checked at the end of the winter due to its destruction by the ice. The ORP probe DQI specified an accuracy of ±20 mV (Figure 6.5-1A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-1B.

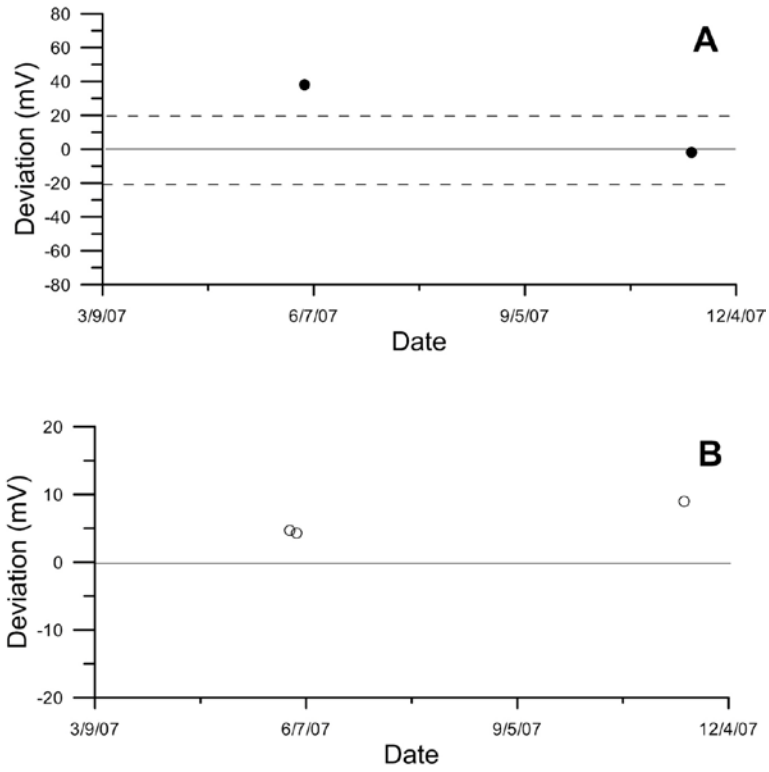


Figure 6.5-1: Accuracy and stability calibration checks of CSIM11 ORP probe, s/n 010. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

Probe 040 was used between 7/18/2007 and 4/7/2008. The probe was calibrated six times. The ORP probe DQI specified an accuracy of ±20 mV (Figure 6.5-2A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the

frequency of these checks. The probe always passed the accuracy check DQI and the stability check indicated excellent probe stability.

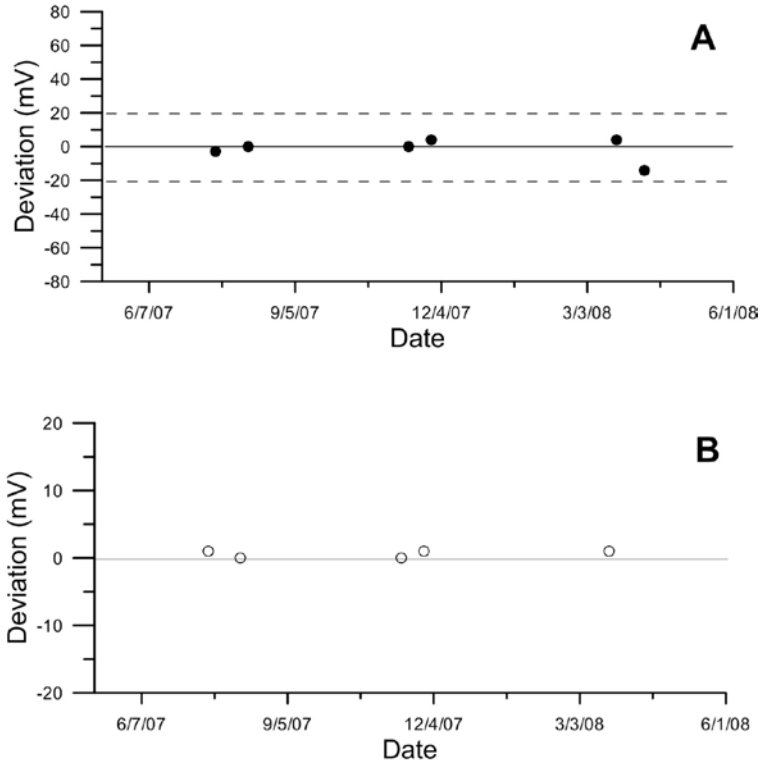


Figure 6.5-2: Accuracy and stability calibration checks of CSIM11 ORP probe, s/n 040. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

In general, the probe calibrations were conducted about every 20 d. Since freezing conditions damage the probe, the probes were not used during the winter.

6.6 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n A and C) and the Gas Sampling System (GSS s/n 4-0019) used at this location were checked about every 20 d. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results of the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in Table 6.6-1.

Table 6.6-1: Record of leak check for GSS and GSS/S-OPS

Date	Site	GSS solenoid/ S-OPS	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
04/07/2008	IN4A	2	0.12	-36.70	Pass	7.6	0.54	-36.46	Pass
		3	0.12	-34.97	Pass	7.6	0.62	-36.34	Pass
05/01/2008	IN4A	2	0.13	-33.98	Pass	9.6	0.52	-35.70	Pass
		3	0.07	-33.68	Pass	9.8	0.64	-37.50	Pass
05/20/2008	IN4A	2	0.05	-34.84	Pass	9.1	0.49	-35.67	Pass
		3	0.03	-34.89	Pass	9.8	0.59	-35.86	Pass
06/19/2008	IN4A	2	0.00	-2.17	Pass	9.6	0.52	-1.09	Pass
		3	0.05	-37.25	Pass	9.8	0.70	-38.28	Pass
07/14/2008	IN4A	2	0.15	2.20	Pass	9.4	0.71	2.20	Pass
		3	0.22	-11.72	Fail	9.6	0.92	-12.11	Pass

The inlet flow balance checks are summarized in Tables 6.6-2A and 6.6-2B. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet. Inlet flow balance checks were not conducted on 6/19/2008 and 7/14/2008 due to wet conditions.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A: Change in flow over period, Area source Side 1 (s/n A)

		Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
4/7/2008	5/1/2008	0.03	0.00	0.03	0.02	0.03	0.00	-0.01	-0.05	-0.02	-0.03	Fail
5/1/2008	5/20/2008	0.08	0.03	0.08	0.09	-0.07	-0.21	0.13	0.05	-0.88	0.05	Fail
5/20/2008	6/19/2008	-0.01	-0.01	-0.07	-0.02	0.00	-0.03	-0.05	-0.02	-0.06	-0.09	Pass

Table 6.6-2B: Change in flow over period, Area source Side 2 (s/n C)

		Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
4/7/2008	5/1/2008	-0.04	0.05	-0.04	0.05	0.00	-0.02	0.04	0.05	0.00	0.02	Pass
5/1/2008	5/20/2008	0.02	-0.04	0.05	0.00	0.01	0.07	0.08	-0.19	0.06	-0.01	Fail
5/20/2008	6/19/2008	-0.20	-0.11	-0.13	-0.12	-0.13	-0.10	-0.05	-0.11	-0.04	-0.16	Pass

The nominal planned interval between S-OPS checks was 20 d (three weeks). S-OPS checks were conducted at this long-term measurement location a relatively few times with the period of time between checks varying from one to three weeks (Figure 6.6-1). Shorter intervals between checks occurred due to work on the systems.

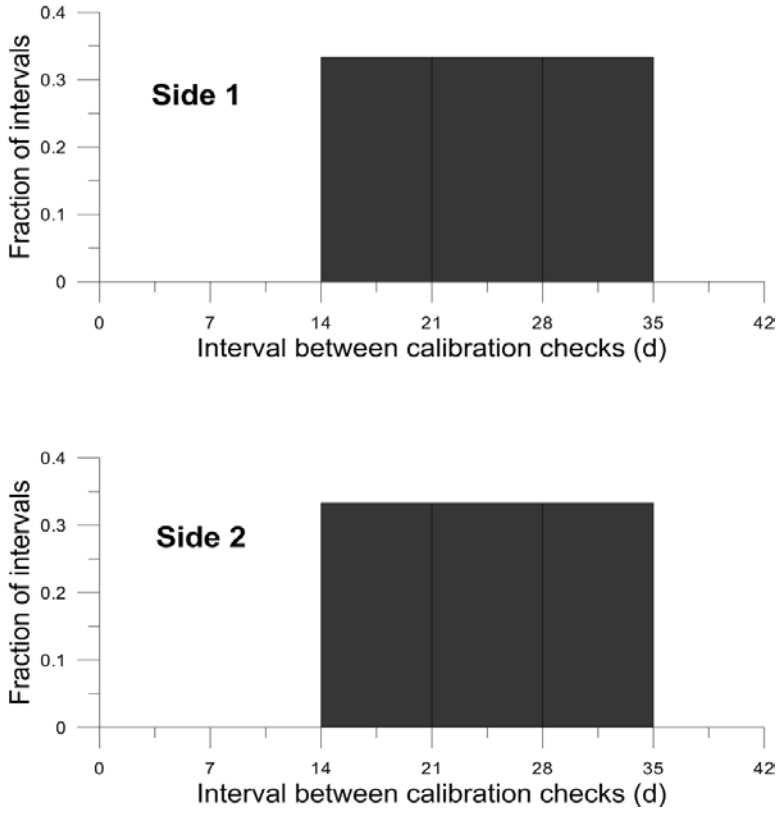


Figure 6.6-1: Intervals between checks

6.7 Miscellaneous meteorological and lagoon calibrations

6.7.1 Air temperature/ humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n: 4410007

Relative humidity (RH)					
Calibration date	**Expected RH (%)**	**Measured RH (%)**	**Deviation from expected RH (%)**	**Average deviation RH (%)**	**Action**
2/17/2010	21	102	-81		Replace/repair
	50	132	-82		Replace/repair
	95	184	-89		Replace/repair
				-84.0	Replace/repair
7/10/2008	11	11	0		Accept
	50	48	2		Accept
	84	78	6		Accept
				2.5	Accept
Temperature (T)					
Calibration date	**Expected T (°C)**	**Measured T (°C)**	**Deviation from expected T (°C)**		**Action**
2/17/2010	24.3	-81.7	106.0		Replace
7/10/2008	27.1	26.8	0.2		Pass

6.7.2 Barometric pressure

An aneroid barometer (Model 278, Setra Inc, Boxborough, MA.) with serial number 3033745 was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278 s/n 3033745

Calibration date	Expected value range (hPa)	Number of comparisons (n)	Mean difference from reference (hPa)	Action
2/11-12/2010	998.4-992.5	6	1.6	Pass
9/16-17/2009	997.4-1000.1	6	0.8	Pass
2/27-3/2/2009	992.3-1010.0	6	2.0	Pass
7/23-27/2008	995.6-996.8	6	1.1	Pass
1/22-23/2008	995.6-998.2	6	1.5	Pass

6.7.3 Solar radiation

A pyranometer (Model 200SB, LiCOR Inc., Lincoln, NE) was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-3.

Table 6.7-3: Calibration record of LiCOR 200SB pyranometer, s/n PY554447

Calibration date	Mean difference from reference (Wm^{-2})	Mean difference from reference (%)	Action
3/5-3/8 2010	4.84	0.91	Pass
8/30/2006			Factory calibration

6.7.4 Lagoon water temperature

A thermistor (Model 107-L, Campbell Scientific Inc, Logan, Utah) was used to measure lagoon temperature. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. Three thermistor probes were used at this location: serial numbers 0030, 005, and 006. The calibration checks are documented in Table 6.7-4.

Table 6.7-4: Calibration record of thermistor CSI 107-L

Calibration date	Expected value (°C)	Difference from expected (°C)	Action
Thermistor CSI 107-L, s/n 0030 (7777)			
6/18/2007	25.0	-0.0	Accept
	24.5	0.0	Accept
	24.0	0.3	Accept
Thermistor CSI 107-L, s/n 005			
2/1/2008	0.0	0.4	Accept
4/30/2008	20.0	3.3	Replaced
Thermistor CSI 107-L, s/n 006			
4/30/2008	19.5	0.3	New unit

6.7.5 Sludge gun

A sludge gun (Model 10, Marklin Specialty Engineering, Toronto, Ontario, Canada) with serial number 20176A was used to measure sludge depth in the lagoon. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-5.

Table 6.7-4: Calibration record of Marklin sludge gun s/n 20176A

Calibration date	Mean (mm)	Standard deviation (mm)	Accuracy (mm)	Action
2/23/2010	73.88	0.78	1.88	Accept
7/23/2008	72.06	0.58	1.17	Accept
7/24/2008	77.56	0.72	1.56	Accept
3/23/2007	81.78	0.83	1.78	Accept

6.7.6 CR1000 data logger

The CR1000 data logger (Campbell Scientific Inc., Logan, Utah) was used to log all lagoon measurements (pH, oxidation-reduction potential, and temperature) and air temperature, relative humidity, barometric pressure, and wetness. Calibration check of this unit was conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. The calibration checks are documented in Tables 6.7-6.

Table 6.7-6: Calibration record of Campbell Scientific CR1000 data logger, s/n 7676

Channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV mean value	Error (mV)	Measured (mV)	Error (mV)
Factory Calibration						
Calibration date: 1/18/2007			**Single-ended**		**Differential**	
12	5000	± 3	5000.19	-0.19	5001.01	-1.01
12	-5000	± 3	-5002.51	-2.51	-5001.35	-1.35
12	2500	± 1.5	—	—	2500.42	-0.42
12	250	± 0.15	—	—	250.042	-0.042
12	25	± 0.015	—	—	25.005	-0.005
12	7.5	± 0.0045	—	—	7.50015	-0.0015
12	2.5	± 0.0015	—	—	2.49929	0.00071
12	-2.5	± 0.0015	—	—	-2.49967	0.00067
12	5000	± 6	4997.99	2.99	4999.32	0.32
12	5000	± 6	5001.97	-1.97	5003.03	-3.03
12	5000	± 6	—	—	—	—
12	5000	± 6	—	—	—	—
PAML Calibrations						
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
1	4950	± 6.96| 4.97	4951.7	-1.7	—	—
2	4950	± 6.96| 4.97	4951.7	-1.7	—	—
3	4950	± 6.96| 4.97	4951.7	-1.7	—	—
4	4950	± 6.96| 4.97	4951.7	-1.7	—	—
5	4950	± 6.96| 4.97	4951.7	-1.7	—	—
6	4950	± 6.96| 4.97	4951.7	-1.7	—	—
7	4950	± 6.96| 4.97	4951.7	-1.7	—	—
8	4950	± 6.96| 4.97	4951.7	-1.7	—	—
9	4950	± 6.96| 4.97	4951.7	-1.7	—	—
10	4950	± 6.96| 4.97	4951.7	-1.7	—	—
12	4950	± 6.96| 4.97	4951.7	-1.7	—	—
13	4950	± 6.96| 4.97	4951.7	-1.7	—	—
14	4950	± 6.96| 4.97	4951.7	-1.7	—	—
15	4950	± 6.96| 4.97	4951.7	-1.7	—	—
16	4950	± 6.96| 4.97	4951.7	-1.7	—	—
Calibration date: 2/24/2010			**Single-ended**		**Differential**	
1	100	± 2.06 | 1.06	99.13	0.87	—	—

Channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV mean value	Error (mV)	Measured (mV)	Error (mV)
2	100	± 2.06 | 1.06	99.13	0.87	99.53	0.47
3	100	± 2.06 | 1.06	99.13	0.87	—	—
4	100	± 2.06 | 1.06	99.13	0.87	—	—
5	100	± 2.06 | 1.06	99.13	0.87	99.53	0.47
6	100	± 2.06 | 1.06	99.13	0.87	99.53	0.47
7	100	± 2.06 | 1.06	99.45	0.87	99.53	0.47
8	100	± 2.06 | 1.06	99.13	0.87	99.53	0.47
9	100	± 2.06 | 1.06	99.43	0.87	—	—
10	100	± 2.06 | 1.06	99.13	0.87	—	—
11	100	± 2.06 | 1.06	99.13	0.87	—	—
12	100	± 2.06 | 1.06	99.13	0.87	—	—
13	100	± 2.06 | 1.06	99.13	0.87	—	—
14	100	± 2.06 | 1.06	99.13	0.87	—	—
15	100	± 2.06 | 1.06	99.13	0.87	—	—
16	100	± 2.06 | 1.06	99.13	0.87	—	—
Calibration date: 2/24/2010			**Single-ended**		**Differential**	
1	0	± 2.06 | 1.06	0	0	—	
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0	—	—
4	0	± 2.06 | 1.06	0	0	—	—
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0	—	—
10	0	± 2.06 | 1.06	0	0	—	—
11	0	± 2.06 | 1.06	0	0	—	—
12	0	± 2.06 | 1.06	0	0	—	—
13	0	± 2.06 | 1.06	0	0	—	—
14	0	± 2.06 | 1.06	0	0	—	—
15	0	± 2.06 | 1.06	0	0	—	—
16	0	± 2.06 | 1.06	0	0	—	—

6.7.7 CR800 data logger

The CR800 data logger (Campbell Scientific Inc., Logan, Utah) was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration check of this unit was conducted only at end of the study. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-7.

Table 6.7-7: Calibration record of Campbell Scientific CR800 data logger s/n 3699

Calibration date: 3/22/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.061	99.40	0.6
2	100	± 2.061	99.40	0.6
3	100	± 2.061	99.41	0.6
4	100	± 2.061	99.41	0.6
5	100	± 2.061	99.41	0.6
6	100	± 2.061	99.41	0.6
Calibration date: 3/22/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.061	0	0
2	0	± 2.061	0	0
3	0	± 2.061	0	0
4	0	± 2.061	0	0
5	0	± 2.061	0	0
6	0	± 2.061	0	0

6.8 Site Activity

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	7/13/2007	Setup	Retro-reflectors and anemometers mounted
16:29-16:42	7/13/2007	Setup	Calibrated TDLAS 1026 - Mean: 45.91 - SD: 2.52
17:55-18:00	7/13/2007	Setup	Calibrated TDLAS 1027 - Mean: 53.55 - SD: 1.75
	7/20/2007	Repair	Purpose of visit was to change plastics on retro-reflectors
	7/24/2007	Calibration	Sludge depth measurements taken. No calculations made.
	7/24/2007	Calibration	pH sensor: calibration done, acceptance done, and QA accepted.
	8/8/2007	Calibration	Took down sonic anemometers for preparation of anemometer inter-comparison on 8/10/2007.
	8/8/2007	Calibration	pH sensor: calibration done, acceptance done, and QA accepted.
14:30	8/8/2007	Calibration	Sludge depth measurements taken. Avg. depth to sludge layer: 1.54m
	8/10/2007	Calibration	Tried to perform sonic anemometer inter-comparison but could not get program to run.
	8/10/2007	Calibration	Tried to re-aim TDLAS 1026 but got a pan-tilt error. Did not have time to re-aim all paths; therefore, TDLAS 1026 was not running upon departure.
	8/15/2007	Calibration	Calibrated TDLAS and sonic anemometers. Re-aimed TDLAS paths that were not aligned.
13:30-14:25	8/15/2007	Calibration	Sonic anemometer inter-comparison performed. Sonic anemometer 1: 1.36 Sonic anemometer 2: 1.33 Sonic anemometer 3: 1.37
15:00-15:05	8/15/2007	Calibration	Calibrated TDLAS 1026: Mean: 51.73 SD: 1.38
15:45-15:50	8/15/2007	Calibration	Calibrated TDLAS 1027: Mean: 50.41 SD: 0.74
16:39	8/15/2007	Calibration	Zero calibration performed on sonic anemometers; all pass.
	8/16/2007	Repair	Tried new polyethylene plastic sheeting in short path ground retro-reflectors to try to diffuse beam. New sheets worked well but may be too thick. Will try thinner plastic sheeting tomorrow.
	8/17/2007	Repair	Changed polyethylene sheeting in ground retro-reflectors to thinner plastic. Also re-aimed some TDLAS paths. TDLAS paths were working well upon departure.
	8/17/2007	Repair	Noticed producer cut wire for pH probe when mowing. Performed temporary repair; will fix properly on Monday.
	8/20/2007	Repair	Cleaned up trailer, organized cables, mounted modems to walls, and copied period 1 data to CD's, DVD's, and memory stick.
	8/22/2007	Repair	Repaired pH probe wire; checked data and works well. Organized trailer. Sealed NE tower retro-reflectors with silicone.
	8/23/2007	Repair	Sealed retro-reflector windows. Re-aimed TDLAS 1 and 2.
	8/30/2007	Calibration	Calibrated TDLAS. Re-aimed TDLAS paths that were not aligned.
18:09-18:14	8/30/2007	Calibration	Calibrated TDLAS 1026: Mean: 49.38 SD: 1.62
19:13-19:18	8/30/2007	Calibration	Calibrated TDLAS 1027: Mean: 50.57 SD: 3.21
	9/4/2007	Calibration	Performed sludge depth measurements. Avg. depth to sludge layer: 1.40m.
	9/4/2007	Calibration	pH sensor: calibration done, acceptance done, and QA accepted.

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	9/4/2007	Repair	Sonic anemometer program was not running upon arrival. Bird droppings found on sonic anemometer sensor 3.
	9/5/2007	Repair	Cleaned bird droppings off of sonic anemometer sensor 3. Downloaded sonic anemometer data for period 2 onto disk.
14:10-15:10	9/5/2007	Calibration	Inter-comparison on sonic anemometers: Sonic anemometer 1: 2.02 Sonic anemometer 2: 2.03 Sonic anemometer 3: 2.08
15:35	9/5/2007	Calibration	Zero calibration performed on sonic anemometers; all pass.
	9/12/2007	Repair	Realigned TDLAS. Checked all instruments to see if they are working properly.
	9/19/2007	Repair	Maintenance and Inspection checklist completed.
	9/19/2007	Repair	Switched CR1000 memory card from F2 to F1. Put weatherproof tape over junctions on both TDLAS cables.
	9/19/2007	Calibration	pH sensor: calibration done, acceptance done, and QA accepted.
	9/19/2007	Calibration	Barometer audit: accepted.
	9/19/2007	Calibration	Inter-comparison on sonic anemometers: Sonic anemometer 1: 2.33 Sonic anemometer 2: 2.32 Sonic anemometer 3: 2.31
	9/20/2007	Repair	Re-aimed TDLAS paths.
	9/20/2007	Calibration	Sludge depth measurements taken. Avg. depth to sludge layer: 1.44 m.
	9/20/2007	Calibration	Zero calibration performed on sonic anemometers; all pass.
16:53-16:59	9/20/2007	Calibration	Calibrated TDLAS 1027: Mean: 52.06 SD: 2.30 Note: Attempted to adjust calibration tube position to obtain r^2 in upper 0.90's, but highest I could get was 0.93 or 0.94.
17:22-17:27	9/20/2007	Calibration	Calibrated TDLAS 1026: Mean: 45.71 SD: 1.28
	10/4/2007	Repair	Cleaned and painted wetness sensor with latex paint.
	10/4/2007	Repair	Put power strip at met tower into kitty litter box for water protection.
	10/4/2007	Repair	Noticed that retro-reflectors were not plugged in completely and had dew on outer plastic causing light values to be too low.
	10/4/2007	Repair	External hard drive was not backing up data. It was turned off. Turned it back on and backed up existing data.
	10/4/2007	Repair	Scanner/laptop froze up and restarted automatically after login,
	10/4/2007	Repair	Realigned TDLAS.
	10/17/2007	Repair	Not able to remotely connect in office before arriving. LAN computer looked to be in safe mode. Restarted computer and now can remotely connect.
	10/17/2007	Repair	NH_3 tank expired (10/13/2007), so calibration could not be finished.
	10/17/2007	Repair	Noticed connection problem ("GFOP-xxxx") with TDLAS 1026. It would be in and out of connection. Looked at back of TDLAS when connection was out and the screen said "unlocked." No reading.
	10/17/2007	Repair	Painting wetness sensor may have affected sensor values (got value of 60 instead of expected 100). Noticed during wetness sensor acceptance,
14:10	10/17/2007	Calibration	Wetness sensor calibration: accepted
15:43-15:44	10/17/2007	Calibration	Unable to calibrate either TDLAS because of expired NH_3 gas tank. Also connection was lost with TDLAS 1026 despite

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			being in direct connection with laptop
17:35	10/17/2007	Calibration	Sonic anemometer inter-comparison performed: Sonic anemometer 1: 3.64 Sonic anemometer 2: 3.71 Sonic anemometer 3: 3.64
18:20	10/17/2007	Calibration	Barometer audit: accepted.
19:00	10/17/2007	Calibration	Zero calibration performed on sonic anemometers; all pass.
	10/17/2007	Calibration	Maintenance and Inspection checklist completed.
	10/18/2007	Repair	pH cord was damaged in same spot as before. Put new tape (electrical and rubber) around damaged area. Still recording valid data.
	10/18/2007	Repair	Mounted sonic anemometers on tower and met tower.
	10/18/2007	Repair	Removed plastics from NE tower and from S1R7, S2R6/7
	10/18/2007	Repair	Removed TDLAS 1026 and scanner 1 for repair/East team.
	10/18/2007	Repair	Put extension cord on SW tower so we could plug in bottom tower retro-reflector heaters.
	10/18/2007	Repair	Switched out data card in CR1000 and copied period 2 data.
	10/23/2007	Repair	Could not remotely connect from office to check TDLAS 1027. Both Panasonics were turned off upon arrival. Turned on Panasonic for scanner 2. Loaded setup from 10/5/2007 and had to realign most of the paths (moved ~5 steps to the right).
	10/23/2007	Repair	There were storms last Thursday, so it may have lost power during the storms which shut off the computers.
	10/30/2007	Calibration	Calibrated TDLAS 1026 and 1026 with NH_3 (1000 ppm). Forgot to change cylinder tank concentrations from 500 ppm to 1000 ppm. Diluter concentrations 10:1—wanted to dilute tank so concentration was 100 ppm, but forgot to change cylinder concentration; diluter concentration to 200 ppm at 1 meter. TDLAS read 100 ppm instead of expected 50 ppm at 0.5 meter.
17:27-17:32	10/30/2007	Calibration	Calibrated TDLAS 1026: Mean: 101.6 SD: 0.5. Note: Background 1 could not be used because we accidently forgot to change the distance in *GasView MP* to 1.0. Did not change tank concentration on diluter from 500ppm to 1000ppm, so *GasView MP* program/TDLAS will still read ~100ppm at 0.5m. Bumped calibration chamber on "trial 2" calibration gas.
17:58-18:03	10/30/2007	Calibration	Calibrated TDLAS 1027; no measurements recorded. Note: Did not change tank concentration on diluter from 500 ppm to 1000ppm, so *GasView MP* program/TDLAS will still read ~100 ppm at 0.5 m.
	11/1/2007	Calibration	Installed ORP probe onto probe float (checked results of new probe: ~70mV)
	11/1/2007	Calibration	Producer pumping out lagoon and spreading onto nearby fields.
	11/1/2007	Calibration	Installed fence posts every 5 m for GSS.
	11/3/2007	Repair	Tried calibrating TDLAS 1031 but noticed shutter was not clicking like normal. Took TDLAS apart but shutter was not functions properly. Will send back to manufacturer. Could not put instrument into concentration mode because it was stuck "calibrating."
	11/13/2007	Repair	When calibration TDLAS 1027, it took longer than 2 hours to

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			calibrate and get valid r^2 and concentrations. Had to excessively bump, wiggle, etc. to get desirable measurements.
15:36	11/13/2007	Calibration	Zero calibration performed on sonic anemometers; all pass.
15:50-16:50	11/13/2007	Calibration	Sonic anemometer inter-comparison performed. Sonic anemometer 1: 2.91 Sonic anemometer 2: 2.98 Sonic anemometer 3: 2.93
16:20	11/15/2007	Calibration	ORP sensor: calibration and acceptance done.
18:29-18:34	11/15/2007	Calibration	Calibrated TDLAS 1027: Mean: 52.8 SD: 2.11% Accuracy: 6.27% - Note: Took longer than 2 hours to calibrate and get valid r^2 and concentrations. Had to bump, wiggle, etc. excessively to get numbers that were desirable.
	11/15/2007	Calibration	Windy conditions both today and Thursday, so no sludge depth measurements taken.
	11/15/2007	Calibration	Switched out scanner/TDLAS connecting cable on scanner 2.
	11/15/2007	Calibration	pH sensor: calibration done, acceptance done, and QA accepted. Notes: Noticed that when calibrating ORP, red and brown wires seemed to be switched. Wired differently when placing probes into lagoon.
18:30	11/15/2007	Calibration	Wetness sensor calibration: accepted
18:40	11/15/2007	Calibration	Barometer audit: accepted.
14:02	1/15/2008	Calibration	TEC 450i reference precision check (done at PAML)
	1/29/2008	Calibration	S-OPS acceptance: Pass
	1/31/2008	Calibration	S-OPS inlet flow verification
	2/12/2008	Repair	TDLAS 1030 (NW corner) was covered in ice; plastic window covered in ice.
	2/12/2008	Repair	Restarted LAN-H_2S analyzer after changing baud rate—found connection.
	2/12/2008	Repair	Installed SO_2 cylinder mount.
	2/12/2008	Repair	Tried using TDLAS 1030 in SE corner on scanner unit 1. Sent "high power" command through *GasView MP* software in Pan/Tilt Options: No response. No response using Hyperterminal. Tried switching COM ports, but still no communication. Power-cycled computer and modems.
	2/28/2008	Calibration	Innova single point calibration
17:20	2/28/2008	Calibration	TEC 450i calibration verification check
	2/29/2008	Calibration	Producer Event/Change Form completed.
	3/5/2008	Calibration	No DVD's in trailer. Could not burn 16 hertz data.
	3/5/2008	Calibration	Barometer audit: accepted.
17:25-18:25	3/5/2008	Calibration	Sonic anemometer inter-comparison performed; all pass. Sonic anemometer 1: 3.89 Sonic anemometer 2: 3.92 Sonic anemometer 3: 3.72
19:21-19:30	3/5/2008	Calibration	Zero calibration performed on sonic anemometers.
19:29-19:34	3/5/2008	Calibration	Calibrated TDLAS 1030: Mean: 72.364 SD: 1.31 RSD: 1.8% Bias: 44.9% - Note: Tried calibrating TDLAS 1030 at 50 ppm; got values ~30-35ppm (expecting ~25). Used new chamber. Moved to field without chamber; with ambient air. New chamber concentrations stable with high r^2 value. Old chamber still acting unstable
20:45	3/5/2008	Calibration	Wetness sensor calibration: accepted
	3/5/2008	Remote	Daily site check from PAML
	3/12/2008	Calibration	Tried to calibrate TDLAS 1030 by using 100 ppm of NH_3.

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			However the TDLAS failed during calibration, so it was taken back to Purdue. TDLAS power supply was also found missing. Scott said it was back at Purdue.
19:50	3/12/2008	Calibration	Calibrated TDLAS 1030 — Mean: 61.09 SD: 1.709 - RSD: 2.8% - Bias: 21.8% — Notes: TDLAS power supply (inside trailer) was not there. Unhooked scanner and used it for calibration. Used 100 pmm instead of 50 ppm.
	3/17/2008	Calibration	S-OPS inlet flow verification
	3/17/2008	Calibration	S-OPS acceptance: Pass
	3/17/2008	Calibration	GSS acceptance: Pass
	3/17/2008	Calibration	Innova single point calibration
17:07	3/17/2008	Calibration	Barometer audit: accepted.
	3/17/2008	Check	Lagoon probes (pH, ORP, temperature) all with broken cables. Presumably due to winter ice locking cables then having lagoon height changes stressing the cables.
	3/20/2008	Calibration	TEC 450i multipoint calibration, calibration problems. Discussed problem and troubleshoot with Thermo technician. Problem not resolved.
	3/20/2008	Calibration	Sonic anemometer inter-comparison showed failure of sonic anemometer 1. Will try again tomorrow.
	3/21/2008	Calibration	Sonic anemometer inter-comparison performed.
	3/21/2008	Calibration	Calibrated pH, ORP probes and reinstalled in lagoon with temperature probe.
	3/21/2008	Check	Lagoon temperature probe not working properly.
	3/27/2008	Remote	Daily site check from PAML
	3/28/2008	Remote	Daily site check from PAML
	3/31/2008	Remote	Daily site check from PAML
	4/1/2008	Remote	Daily site check from PAML
	4/7/2008	Calibration	Slurry being pumped into lagoon this morning.
	4/7/2008	Calibration	Need to make new 1M KCl solution.
	4/7/2008	Calibration	Need new temperature probe.
	4/7/2008	Calibration	Added 24 volt power source to relay because there is no H_2S analyzer to power relay.
	4/7/2008	Calibration	Trained Bill Randolph in pH, ORP calibration, wetness, pressure, GSS, S-OPS, sonic anemometers, and TEC 146i.
	4/1/2008	Calibration	Maintenance and inspection checklist completed.
	4/7/2008	Calibration	Did not perform sludge depth measurements because it was too windy.
	4/7/2008	Calibration	GSS was stationary on south side.
	4/7/2008	Calibration	Barometer audit: accepted.
	4/7/2008	Calibration	pH sensor: calibration done, acceptance done, and QA accepted.
	4/7/2008	Calibration	ORP sensor: calibration and acceptance done.
	4/7/2008	Calibration	GSS leak test: Pass
	4/7/2008	Calibration	GSS max flow test: Fail
	4/7/2008	Calibration	S-OPS verification: Pass
14:05	4/7/2008	Calibration	Wetness sensor calibration: accepted
15:10-16:10	4/7/2008	Calibration	Sonic anemometer inter-comparison: all pass.
16:40	4/7/2008	Calibration	Zero sonic anemometer calibration: all pass.
	4/8/2008	Calibration	Performed Innova calibration. Difference in the values between the Innova screen and the program: For NH_3:

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			instrument read 34; program read 48. For methane: instrument read 1.3; program read 1.03. For propane: instrument read 5.22; program read 9.31. For water vapor: instrument read 7.3; program read 8.13.
	4/9/2008	Remote	Daily site check from PAML
	4/10/2008	Remote	Daily site check from PAML
	4/11/2008	Remote	Daily site check from PAML
	4/14/2008	Calibration	TDLAS 1031 would not zero; will bring back to PAML to test.
	4/14/2008	Calibration	Calibrated TDLAS 1029 with old gas cylinder first. On second calibration trial, used new cylinder. TDLAS was bumped during calibration; still passed. On third calibration trial, used old cylinder, same position as trial two.
	4/14/2008	Calibration	Calibrated TDLAS 1030 with old gas cylinder first. Performed second calibration with new cylinder. Aligned scanner 1/TDLAS 1030 (NW). Could not align SE scanner/TDLAS because required cords were not in box, scanner case, van, or trailer.
	4/14/2008	Calibration	Lagoon site layout made
15:04-17:48	4/14/2008	Calibration	Calibrated TDLAS 1030 — See site notes for details.
16:03-17:19	4/14/2008	Calibration	Calibrated TDLAS 1029 — See site notes for details.
	4/15/2008	Repair	Producer pumping into lagoon today.
	4/15/2008	Repair	Set up and aimed TDLAS 1 (1029) in SE corner of lagoon.
	4/15/2008	Repair	Copied missing data from periods 1, 2, 3, and 4 to CD's and DVD's.
	4/15/2008	Repair	Checked readings of pH/ORP probes both before and after unhooking RH/temp probe to see if they affect the readings. See site notes for details.
	4/15/2008	Repair	Results confirm problem of pH probe (pH reading is 33.5). Found bad pH started occurring at 21:00 UTC on 4/12/2008. Checked voltage across red and green wires on pH probe and got about 1600 mV, which is the reason for the incorrect pH reading. Checked pH probe connections to CR 1000, and everything looked fine. Unable to pull pH probe from lagoon today, so it will need to be checked another day.
	4/16/2008	Remote	Daily site check from PAML
	4/17/2008	Remote	Daily site check from PAML
	4/18/2008	Remote	Daily site check from PAML
12:00	4/24/2008	Remote	Daily status check from PAML — Note: Very limited data with sonic anemometer flagging. There appears to be communication problems since beginning of period (all 3 sonic anemometers). Total number of data points frequently reduced below normal. Lots of "large variance" flags.
14:20	4/25/2008	Remote	Some sonic anemometer flagged points in all sensors. More spikes in all 3 sonic anemometers than normal.
14:16	4/29/2008	Remote	Sonic anemometer 2 w different from 0 briefly on 482. Sonic anemometer 3 different from 0 at last data points. TDLAS 2 was aligned for almost entire day on 8 paths. TDLAS 1 was not aligned for paths 3 and 5. Loaded previous setup and re-aimed paths—successful. Saved new setup with new pan-tilt values—logged on Daily TDLAS/sonic anemometer log.

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	4/30/2008	Calibration	pH sensor: calibration done, acceptance done, and QA accepted.
	4/30/2008	Calibration	Evidence of power failure for 5 s on 2008-4-1. The pH probe not working properly. It always reads ~1700mV, and does not respond to any calibration solutions. Tried changed internal solution of pH probe to 1M KCl, but that did not remedy the problem. Installed and calibrated new temp probe because old one was not working. S/N: 006. Also calibrated ORP.
	4/30/2008	Calibration	ORP sensor: calibration and acceptance done.
	5/1/2008	Calibration	Had to drive back to PAML from IN4A after FTIR. Cylinder #FF44397 was empty when hooked up to diluter—was old East team cylinder. Sonic anemometer inter-comparisons did not pass during first trial. May be caused by high winds. Farm manager attempting to pump into lagoon. Too windy to perform sludge depth measurements.
	5/1/2008	Calibration	No DVD's in trailer. Could not burn 16 hz data.
	5/1/2008	Calibration	Maintenance and Inspection checklist completed.
	5/1/2008	Calibration	Innova single point calibration
	5/1/2008	Calibration	S-OPS/GSS test: Pass
	5/1/2008	Calibration	S-OPS max flow test
	5/1/2008	Calibration	S-OPS inlet flow verification: Pass (North C and South A)
	5/1/2008	Calibration	GSS leak test: Pass
	5/1/2008	Calibration	GSS no flow test
	5/1/2008	Calibration	GSS max flow test: Fail
13:44	5/1/2008	Calibration	Wetness sensor calibration: accepted
15:15-16:15	5/1/2008	Calibration	Sonic anemometer inter-comparison: all pass.
17:16	5/1/2008	Calibration	Sonic anemometer zero calibration: all pass.
17:24-17:39	5/1/2008	Calibration	Calibrated TDLAS 1029: Mean 49.6 SD 0.62 RSD 1.2% Bias -0.7%
18:01-18:06	5/1/2008	Calibration	Calibrated TDLAS 1030: Mean 46.96 SD 0.54 RSD 1.1% Bias -5.8%
12:44	5/2/2008	Remote	Daily Site Check from PAML — Notes: Had to restart sonic anemometer program. Had to re-aim path 2 on TDLAS 1. No pH probe present.
13:50	5/5/2008	Remote	Daily Status Check from PAML — Notes: Sonic anemometer 2 gradually dropped out on day 489 (lost communication?). Restarted sonic anemometer program. Sonic anemometer 2 still missing. H_2S analyzer not present. pH probe not present. ORP giving values of ~+50.
13:15	5/6/2008	Remote	Daily Status Check from PAML — Notes: Sonic anemometer 2 no data. H_2S analyzer not present. pH probe not present
	5/7/2008	Repair	Sonic anemometer 2 was not sending data. Found antenna lying on ground near tower. Placed back in box, and it started sending data.
	5/7/2008	Repair	TDLAS laptops not responding. Unable to connect remotely either. Screens are black except for white mouse cursor. Power-cycled and restored.
	5/7/2008	Repair	TDLAS's were not recording new data. Connected to FTP server at PAML and retrieved most recent good GMP files. Replaced bad pan/tilt values in one of the files. TDLAS systems are now running.

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	5/7/2008	Repair	Discovered paths 1 and 2 on TDLAS 1 (1029) were both pointing at retro-reflector 1. Fixed.
14:10	5/7/2008	Remote	Daily Status Check from PAML - Notes: H_2S analyzer not present. Data not transferred last night. TDLAS laptops froze up. pH probe not present. Unable to remotely connect to TDLAS laptops. Last TDLAS2 data on 5-6 at 0615 UTC. Last TDLAS1 data 5-6 at 0620 UTC. TDLAS laptops last checked on 5-6 (yesterday) at 1300 UTC.
12:30	5/8/2008	Remote	Daily status check from PAML - Notes: No pH probe. No H_2S analyzer. TDLAS1 current day scans are less as yesterday it was under repair process.
18:31	5/8/2008	Remote	Checked time issues on LAN and TDLAS PC's. Added timesync batch file to LAN, TDLAS1, and TDLAS2. LAN was about 2 min ahead of TDLAS PC's at check this morning. Generally, the agreement had been much better. The "internet time" tab under "date and time properties" has generally been working.
16:30	5/9/2008	Remote	Daily status check from PAML. Notes: H_2S analyzer not present. pH probe not present. Red checkmark error on DynDNS updater. "Update result: Error with update." Red boxes on TDLAS 1 (1029). Path 2: Replaced corrupt values with 18279, 179. Re-aimed to 18284, 196. Path 5: Replaced corrupt values with 18513, -745. Loaded setup at 1712 UTC.
	5/12/2008	Repair	Tested TDLAS/scanner power/moden box #5 (from west team) to see if it would work. We tested it on TDLAS 1029 (SW corner), and it would not work properly. It was showing the same symptoms as it did at OK3A.
	5/12/2008	Repair	We also took some retro-reflector cubes out of the ground retro-reflectors. Took four cubes out of the 1/3 distance retro-reflectors (leaving one), and took two cubes out of the 2/3 distance retro-reflectors (leaving 3). Started the scanner program up, and it worked very well.
13:38	5/12/2008	Remote	Daily status check from PAML. Notes: Scott and Derrick visited site; could not align paths with low light level. Will visit remotely again in the afternoon.
13:46	5/13/2008	Remote	Daily status check from PAML. Notes: Sonic anemometer 2 "w" values different from 0; back to normal. All sonic anemometer 2 data looked odd during this period; back to normal. No 450i present at site. GSS values are within range but displaying irregular patterns. TDLAS2: centerline duty cycle dropping off; currently normal. Referenced r^2 not at 99; normal now but dropped to 0-20 temporarily. Scott and Derrick were testing new power supply yesterday; could be what affected values temporarily. No working pH probe present at site. Could not see anything but a black screen when logged onto LAN remotely. Restarted computer using task manager—worked successfully. Cannot connect to CR1000; stopped updating files at 2008-5-12 at 1640 UTC. TDLAS 1: Retro-reflectors 9 and 10 were out of range. Loaded previous setup and maximized light values.
13:00	5/13/2008	Remote	Daily status check from PAML - Notes: There is no H_2S analyzer at IN4A. Had to re-aim path 7 on TDLAS 1 because

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			the scanner was getting an error with the red boxes on path 7.
16:08	5/15/2008	Remote	Daily status check from PAML — Notes: Last QC data from GSS/ H_2S /Innova was from 2008-5-13. Last QC data from CR1000 was from 2008-5-12.
13:29	5/16/2008	Remote	Daily status check from PAML — Notes: Last QC data from GSS/ H_2S /Innova was from 2008-5-13. Last QC data from CR1000 was from 2008-5-12.
14:31	5/19/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 1 flagged data and graph of sonic anemometer 1 looks different. Since 2008-5-14 there was a gradual fall in series 2 of the GSS pressure and then increased shortly on 2008-5-16. There is no pH probe. TDLAS 1 showing alarm 10 and pan/tilt error. Solved pan/tilt error, but still not working properly. No light values for all the paths.
	5/20/2008	Calibration	Southeast scanner for TDLAS 1 was not working. It will be returned to Purdue.
	5/20/2008	Calibration	S-OPS south side: orifice #9 had no flow. Changed filter paper, and it's working well.
	5/20/2008	Calibration	S-OPS north side: orifice #8 had water droplets which lowered flow rate. Changed filter paper, and it's now working well.
	5/20/2008	Calibration	S-OPS/GSS test: Pass
	5/20/2008	Calibration	S-OPS max flow test
	5/20/2008	Calibration	S-OPS inlet flow verification: Pass (North C and South A)
	5/20/2008	Calibration	GSS leak test: Pass
	5/20/2008	Calibration	GSS no flow test
	5/20/2008	Calibration	GSS max flow test: Fail
16:05-17:38	5/20/2008	Calibration	Innova single point calibration
	5/21/2008	Calibration	Taking H_2S cylinder, NH_3 cylinders, and TDLAS power supply back to PAML.
21:00	5/21/2008	Calibration	Calibrated TDLAS 1030 — Mean: 46.77 - SD:0.48 - RSD: 1.0% - Bias: -6.5%
21:36	5/21/2008	Calibration	Calibrated TDLAS 1029 — Mean: 50.99 - SD: 0.08 - RSD: 0.2% -Bias: 1.7%
12:45	5/22/2008	Remote	Daily status check from PAML — Notes: H_2S analyzer not present. TDLAS 1 has a broken scanner. TDLAS 2 is in fixed trailer for calibration check. pH probe not present. Back-up error related to sonic anemometer/*iPort*/Innova programs.
	5/27/2008	Calibration	Saw water droplets in the sample inflow tubes for Innova and TEC 450i. There was less water in the Innova tube, but there was much more in the 450i tube. Water droplets were also seen in the exhaust tube for the GSS. After 2 hours the water droplets had disappeared. Reinstalled 450i.
	5/27/2008	Calibration	Did sonic anemometer inter-comparison, but it started to rain before zero/bias test could be done.
18:00-19:00	5/27/2008	Calibration	Sonic anemometer inter-comparison: all pass.
	5/28/2008	Calibration	Too windy to perform sludge depth measurements.
	5/28/2008	Calibration	Finished sonic anemometer calibration by performing zero calibrations.
	5/28/2008	Calibration	Tried to reinstall TDLAS 1029 (without scanner), but could

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			not directly communicate with TDLAS laptop.
	5/28/2008	Calibration	Barometer audit: accepted.
	5/28/2008	Calibration	ORP sensor: calibration and acceptance done.
14:15	5/27/2008	Calibration	Sonic anemometer zero calibration: all pass.
15:25	5/28/2008	Calibration	Wetness sensor calibration: accepted
13:30-14:25	5/29/2008	Remote	Daily status check from PAML — Notes: Graph for sonic anemometer 2 looks different. Graph of Innova data points is dropped on current date. TDLAS 1029 has just been aligned for single path (#8) (scanner is not working). No pH probe.
13:15	5/30/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 graph looks different. TDLAS 1 (1029) is only aimed at one path (path 8). No pH probe. Backup error: not enough space to perform backup.
13:14	6/2/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 has not been working since 19:50 UTC on 2005-5-31. Tried restarting sonic anemometer program, but it did not work. TDLAS 1 is aimed at path 8 only. No pH probe present. TDLAS 2 (1030) had no connection ("xxxx") initially when logging in. A few minutes later it reconnected.
12:20	6/3/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 has not been communicating since 0:00 UTC Friday. TDLAS 1029 is currently aimed at path 8 only due to broken scanner. It is still giving vaild light values, but they have dropped from 10000 on Thursday to about 2000 today. pH probe not present in lagoon.
12:18	6/4/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 is still not communicating. There is a noticeable increase in the amount of flagged data in sonic anemometer 3 after day 515. TDLAS 1 (1029) is aimed only at path 8 due to a broken scanner. Light levels have dropped to about 1500 from 2000 yesterday. No pH probe at site.
	6/5/2008	Repair	Found sonic anemometer modems were mounted too low (below berm level) for communication with trailer. Moved modems up to berm level, and now they are working properly.
	6/5/2008	Repair	Installed barometer tube in NEMA box.
	6/5/2008	Repair	Put desiccants and a humidity test strip into NEMA box and the sonic anemometer modem boxes.
	6/5/2008	Repair	Scanner for TDLAS 1029 failed about an hour after installation. Tested power supply, and it was found to be working. Switched with power supply for TDLAS 1030, but it would still not work. Scanners were returned to PAML.
	6/5/2008	Repair	Put 0.25-inch plastics into each retro-reflector on paths 1 and 2 for TDLAS 2 (1030).
	6/5/2008	Repair	Found a very large amount of water in the GSS exhaust tube (~100 mL). The water could not move because of the dips in the tube. Moved exhaust tube back inside of the trailer.
12:20	6/6/2008	Remote	Daily status check from PAML Notes: Sonic anemometer 2 is now working after moving modems higher on tower. Sonic anemometer 1 w graph was showing readings of 0.5 to 1.0 ms^{-1} during yesterday (day 522). No pH probe at site. Replacement scanner for TDLAS 1 (1029) failed after

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			installation, so the TDLAS is again aimed at path 8 only. Changed distance on TDLAS from 1 m to 136 m.
12:10	6/9/2008	Remote	Daily status check from PAML — Notes: Overflow error caused sonic anemometer program to stop on day 524.452. Program was restarted on 2008-6-9 at 13:00 UTC. TDLAS QC files are formatted incorrectly and cannot be checked. Air temperature flags have increased to 60 since 06:10 on 2008-6-9 (day 526). Air temperature graph looks normal. No pH probe present. Unable to remotely connect to TDLAS 2 (1030) laptop. TDLAS 1 (1029) is aimed only at path 8 due to broken scanner. Light values are holding around 2500.
12:40	6/10/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 has shown high amounts of flagged data over the last few hours. Sonic anemometer 2 u, v, and T graphs are have changed significantly over the last few hours. Will monitor closely. File name error in TDLAS QC files; cannot access data. No pH probe present. TDLAS 1 is aimed at path 8 only due to a scanner malfunction. TDLAS 1 light values have dropped to around 600. Unable to remotely connect to TDLAS 2 laptop to check TDLAS status.
	6/11/2008	Repair	Found a lot of liquid water in the GSS exhaust tube. Dip in tubing was acting like a trap. Drained about 70 mL from this line. Condensation was also present in input lines for Innova and 450i, but it was a very small amount. Turned up temperature in trailer to prevent further condensation.
	6/11/2008	Repair	TDLAS 2 laptop (192.160.0.10) locked up on arrival. Power-cycled but locked up during startup. Restarted again, and it worked properly. Installed updated on TDLAS laptops (12 on .11 and 10 on.10). Installed update on LAN (1).
	6/11/2008	Repair	TDLAS 2 last stored data on 6/9/2008 at 5:56 UTC.
	6/11/2008	Repair	Stopped TDLAS 1 (1029 on single path) at 15:12 UTC. Replaced scanner bypass with repaired scanner.
	6/11/2008	Repair	On TDLAS 2, the most recent GMP file was in period 4 and was blank. It was last modified (TDL2_NW_IN4A_06052008_running.gmp) on 6/11/2008 at 14:46 UTC. Loaded TDL_NW_IN4A_06052008_bkp.gmp.
	6/11/2008	Repair	New scanner/TDLAS layout in site notes.
12:38	6/11/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 data have improved from yesterday's status check. File name error in TDLAS_QC files. Cannot access data. TDLAS 1 (1029) is aimed only at path 8 due to broken scanner. Light values have risen from 600 yesterday to about 1350 today. TDLAS 2 (1030) laptop is frozen and cannot be accessed remotely. No pH probe present.
13:30	6/12/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 3 w values slightly, but not uncomfortably, less than zero. No remedial action necessary. Sonic anemometer 1 w values about 0.4 ms^{-1}. Again, no remedial action necessary. TDLAS_QC file name error. Cannot access files. Pan/tilt errors on paths 3 and 4 on TDLAS 1029. Saved new setup with old values for paths 3 and 4. Seems to work. No pH probe present.

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
12:52	6/13/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 1 w graph has shown 1.0 ms^{-1} readings for the last day. TDLAS 1030 laptop locked up, causing data to be lost. Red box errors on TDLAS 1029, paths 1, 4, and 8. Loaded previous pan/tilt values for paths 1, 4, and 8. All paths look nice now. Air temperature, relative humidity, and barometric pressure flags have risen 07:00 UTC on day 528. No pH probe present.
12:07	6/16/2008	Remote	Daily status check from PAML — Notes: H_2S analyzer stopped incrementing at 2:19 UTC on day 531. Cannot get program to restart. TDLAS 1029 has a red box error for path 9. Loaded previous setup for path 9. All paths seem to be giving valid data now. No pH probe present.
13:30	6/17/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 has more flagging than sonic anemometers 1 or 3. Sonic anemometer 2 temperature value jumps around more than the other sonic anemometer's temperature graphs. Sonic anemometer 1 has some, but not excessive, spiking above 160. Innova flags 16 and 20. TDLAS 1029 path 4 out of range. All paths for TDLAS 1029 are unaligned and tried for over an hour to aim unsuccessfully using previous setup. Saved pan/tilt values from QC optimize chart. FOS were on site Thursday (day after tomorrow) and will align paths then. No pH probe present.
13:00	6/18/2008	Remote	Daily status check from PAML — Notes: Since yesterday sonic anemometer 1 has excessive sonic anemometer flagging causing data to be lost. Sonic anemometer 1 spike count has increased to over 250 since yesterday. Innova flags 16 and 20. All paths on TDLAS 1029 are not aligned. TDLAS 1029 path 9 has a pan-tilt error. Loaded previous setup but could not align paths. FOS will fix tomorrow during trip to Frankfort. H_2S analyzer is woefully behind LAN (6 min). No pH probe present at site.
16:50	6/18/2008	Remote	Remote login to change power settings on both IN4A scanners. Changed power settings on scanners to "PMR TMR PHL THL"
	6/19/2008	Calibration	Found scanner in SE corner (TDLAS 1029) stuck in one spot. Power-cycled the scanner and it began to work. However, TDLAS 1029 has no power, and scanner seems not to be able to send power to the TDLAS. Will return malfunctioning scanner to PAML, and we will replace scanner. New scanner seems to be working.
	6/19/2008	Calibration	New scanner does not power TDLAS 1029, so a separate power supply for the TDLAS was installed and placed with UPS.
	6/19/2008	Calibration	TEC 450i IP address was incorrect, causing clock to fall over 6 min behind LAN. Entered default IP address, and 450i is now synchronized with LAN.
	6/19/2008	Calibration	Looked for missing temperature probes but was unable to find them.
	6/19/2008	Calibration	S-OPS/GSS test: Pass
	6/19/2008	Calibration	S-OPS max flow test

Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	6/19/2008	Calibration	S-OPS inlet flow verification: Pass (North C and South A)
	6/19/2008	Calibration	GSS leak test: Pass
	6/19/2008	Calibration	GSS no flow test
	6/19/2008	Calibration	GSS max flow test: Fail
14:55	6/19/2008	Calibration	Sonic anemometer inter-comparison: all pass.
16:09	6/19/2008	Calibration	Calibrated TDLAS 1029 — Mean: 51.35 - SD: 0.43 - RSD: 0.8% - Bias: 2.6%
16:48	6/19/2008	Calibration	Calibrated TDLAS 1030 — Mean: 47.92 - SD: 0.42 - RSD: 0.9% - Bias: -4.2%
17:46	6/19/2008	Calibration	Zero sonic anemometer calibration: all pass.
	6/20/2008	Calibration	Installed new 24 V supply to relay. Copied data and switched CR1000 flash drive.
	6/20/2008	Calibration	Barometer audit: accepted.
	6/20/2008	Calibration	Maintenance and inspection checklist completed.
	6/20/2008	Calibration	Innova single point calibration
12:30	6/20/2008	Remote	Daily status check from PAML — Notes: Sonic anemometers are currently disconnected for calibration. Before calibration, sonic anemometer 1 showed excessive flagging and spike counts; will monitor data after calibration. H_2S analyzer is currently disconnected, due to power cycling and calibration. H_2S PMT voltage dropped to -630 at day 533.615. Innova flags 2, 16, and 18. Supply voltage on TDLAS 1029 dropped from 1340 to 1240 at the start of day 536, probably due to change of power supply.
15:15	6/20/2008	Calibration	TEC 450i instrument operation parameters
15:15	6/20/2008	Calibration	TEC 450i calibration verification check
15:27	6/20/2008	Calibration	TEC 450i reference precision check
17:02	6/20/2008	Calibration	Wetness sensor calibration: accepted
	6/23/2008	Remote	On 2008-5-28 Innova settings were changed accidentally to pre-set monitoring period="yes" and monitoring period="001:00." Added line to InnovaInterface.vbp to set to "No" the option to use a preset monitoring period. "SE M_M1N" & Chr(10)—Checked "backup" file, and preset monitoring period is now "No.)
13:27	6/23/2008	Remote	Daily status check from PAML — Notes: *GasView MP* program on TDLAS 1 laptop had frozen up upon login and had the error: "Boreal Laser has encountered an error and needs to close…." Restarted program and loaded previous setup but had red boxes around pan/tilt values of 21474 and 21474. Also, clicking "stop" button on program did not stop the scanner from moving and getting pan/tilt errors. Loaded backup file of previous setup, and the scanner was aimed correctly at all paths. Sonic anemometer 1 has a day or two with high spike counts. Flags 16 and 18 on Innova data. No pH probe present.
	6/24/2008	Repair	Came out to look at TDLAS 1 (1029) because it would not connect to the *GasView MP* program. By taking the laptop out and directly connecting directly to the scanner with the laptop, no connection with TDLAS could still be established. Tried connecting to TDLAS (by bypassing scanner) and was able to connect to the TDLAS. Therefore, the TDLAS signal

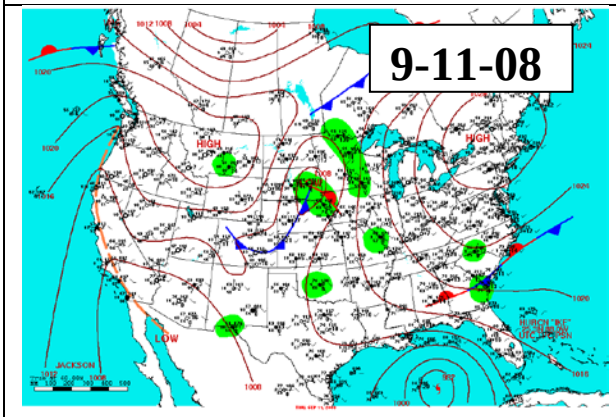
Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			would not pass through the scanner. Mounted TDLAS 1029 on stationary mount and aimed it at path 8 on the south side of lagoon.
	6/24/2008	Repair	Started to perform 450i multipoint calibration, but later realized that H_2S tank did not have the correct concentration to perform calibration.
12:45	6/24/2008	Remote	Daily status check from PAML — Notes: Innova flags 2, 16, and 18. No pH probe present. FOS on site.
12:13	6/25/2008	Remote	Daily status check from PAML — Notes: Only one path for TDLAS 1 (1029). Flags 16 and 18 in Innova data. No pH probe present.
13:39	6/26/2008	Remote	Daily status check from PAML — Notes: Only one path for TDLAS 1 (1029). Flag 16 in Innova data. No pH probe present.
16:20	6/27/2008	Remote	Daily status check from PAML — Notes: TDLAS 1 (1029) is aimed only at one path. No pH probe.
13:00	6/30/2008	Remote	Daily status check — Notes: Sonic anemometer 2 stopped working at 20:00 UTC on 6/27/2008. TDLAS 1 (1029) is aimed only at one path due to broken scanner. Light values have dropped below valid levels. Innova flag 16. Lagoon pH probe not present.
	7/1/2008	Repair	Tried to repair sonic anemometer 2, which was not communicating. Could not find climbing belt, so we will return tomorrow. Saw no evidence of damage in modem box, or on sonic anemometer itself.
	7/1/2008	Repair	Realigned TDLAS 1 (1029) at path 8. Light levels are now valid (~6000). r^2 values are good (~0.98-0.99)
12:07	7/1/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 is still not communicating. See yesterday's QC for details. FOS were on site today. Sonic anemometer 1 had a few spike counts over 160 yesterday. Innova flag 16. TDLAS 1 (1029) is aimed only at one path due to broken scanner. Light values have dropped below valid limits. FOS were on site today to address problem. TDLAS 2 (1030) is optimizing a lot but is aimed at all 10 paths. No pH probe.
	7/2/2008	Repair	Took sonic anemometer 2 down and checked the modem box; desiccant pouch was stuck between the plug wires. Tightened up the plugs and put the desiccant into the lower part of the modem box. Sonic anemometer 2 is now working.
	7/2/2008	Repair	Readjusted TDLAS 1029; light levels are now around 12,000.
12:17	7/2/2008	Remote	Daily status check from PAML — Notes: TDLAS 1 (1029) is aimed at path 8 only due to broken scanner. FOS adjusted TDLAS yesterday, but light values have already dropped below valid levels. FOS were on site again today. H_2S analyzer lost connection with LAN at 7:18 UTC on 7/2/2008. Reconnected to the program and created fill file to add missing data. Data now incrementing normally. Sonic anemometer 2 still not communicating. FOS will address issue today.
	7/3/2008	Repair	Sonic anemometer 2 failed again this morning at 7:49 UTC. Found modem for sonic anemometer 2 to be working. Took down sonic anemometer 2 and hooked it up to sonic

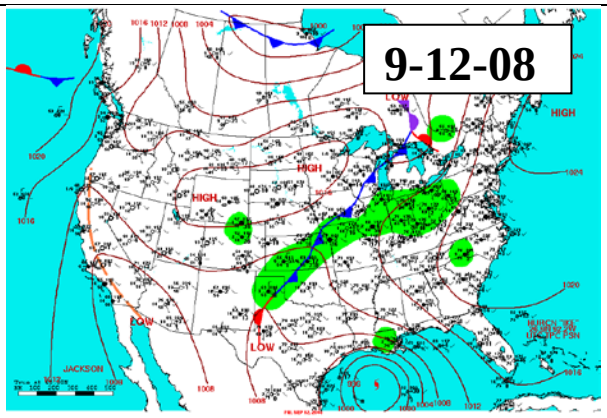
Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			anemometer 1's modem; sonic anemometer 2 would still not work. Taking sonic anemometer 2 back to PAML for repair. Also, put a thick plastic in retro-reflector 8 for TDLAS 1029. Plastic can only get light values around 3500. The r^2 values are very good (0.97-0.99).
12:07	7/3/2008	Remote	Daily status check from PAML — Notes: Sonic anemometer 2 was repaired yesterday, but stopped communicating this morning at 7:49:59 UTC, after QC data had been loaded. Tomorrow's QC files should show sonic anemometer 2 not working, at least for several hours. Strong winds may have been a factor. TDLAS 1 (1029) is aimed at only one path (path 8) due to a broken scanner. Light values have dropped from 12000 yesterday to below valid levels today. Strong winds may have knocked the TDLAS out of alignment, because light values dropped from about 2000 to 30 at 7:49 UTC, which is the same time sonic anemometer 2 recorded 14 ms^{-1} winds before losing communication. H_2S analyzer flag 1 appeared yesterday, but for a very short period. No pH probe.
12:07	7/7/2008	Remote	Daily status check from PAML — Notes: TDLAS 1 (1029) is aimed only at path 8 because of a broken scanner. TDLAS was re-aimed around 15:00 UTC on 7/4/2008. Light values were valid until 10:00 UTC on 7/7/2008 (caused by heavy rain). Sonic anemometer 3 has a few spike counts over 200 for day 533. Innova flag 16. CR1000 stopped incrementing data around 15:00 UTC on 7/4/2008. Data incrementing restarted around 17:30 UTC on 7/6/2008. Cause of lost power is unknown. Sonic anemometer 1 (plugged into same outlet as CR 1000) did not have any lost data. No pH probe.
	7/8/2008	Repair	Installed PTU #6 in SW corner. Aimed scanner. First file is TDL1_IN4A_2008_07_08_1405.gvl. PTU #6 still has grinding sound but still works ok.
	7/8/2008	Repair	Tested TDLAS 1027 for 5 min on path 3 (east side). The r^2 concentration values much better.
12:08	7/8/2008	Remote	Daily status check from PAML Notes: TDLAS 1 (1029) was aimed only at path 8 due to a broken scanner, but FOS installed new scanner this morning. All paths are aligned as of 16:31 UTC, and the status code is 1. Sonic anemometers 2 and 3 had missing data (about 500 data points) from sonic anemometer flagging. No pH probe.
12:10	7/9/2008	Remote	Daily status check from PAML — Notes: Upon login found TDLAS 1 (1029) to be giving pan/tilt errors for several paths. Stopped program and checked each path in the "aim" program. Light levels were unique for each path, meaning the scanner was moving. Restarted program and scanner seems to be working well. Will monitor closely. Sonic anemometer 2 had a brief period of 1000+ flagged points; occurred yesterday. No pH probe.
12:40	7/10/2008	Remote	Daily status check from PAML — Notes: Unable to connect to TDLAS laptop. No TDLAS data was sent back after 12:45 UTC yesterday. FOS will check problem today. Innova flag 16. No pH probe.
17:27	7/11/2008	Remote	Daily status check from PAML — Notes: "Red Box" error on

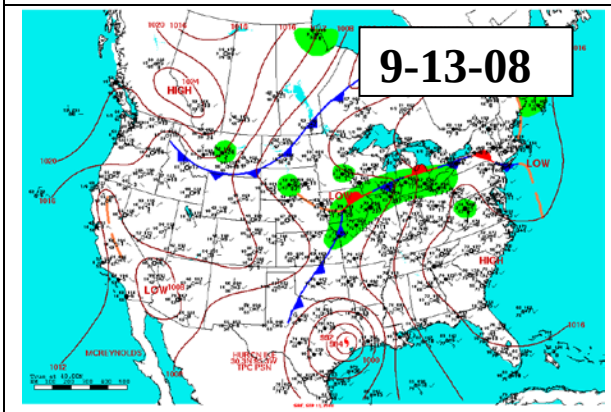
Time HH:MM UTC	Date (dd/mm/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			TDLAS 1 (1029) path 6. Loaded previous setup and all paths are now aligned. Sonic anemometer 3 v had 15 ms^{-1} spikes yesterday. Sonic anemometer 2 had over 3000 flags yesterday. Sonic anemometer 1 had 10 ms^{-1} spikes yesterday. High wind spikes may have been caused by storms overnight. Innova flag 16. Innova data seems to be incrementing but is not showing up on V: drive. No pH probe.
	7/14/2008	Takedown	NH_3 tank #FF44436 had a different concentration reading on the tank (516 ppm) than the certification record (504 ppm).
	7/14/2008	Takedown	Took sludge depth measurements.
	7/14/2008	Takedown	Took down TDLAS's 1029 and 1030 with scanners to be sent back to Purdue. Scanners were sent to DP for maintenance.
	7/14/2008	Takedown	Found mold in S-OPS south inlet #1. Will clean when S-OPS/GSS is returned to Purdue.
	7/14/2008	Takedown	ORP sensor: calibration and acceptance done.
	7/14/2008	Takedown	Innova single point calibration
	7/14/2008	Takedown	S-OPS/GSS test: Pass
	7/14/2008	Takedown	S-OPS max flow test
	7/14/2008	Takedown	S-OPS inlet flow verification: Pass (North C and South A)
	7/14/2008	Takedown	GSS leak test: Pass
	7/14/2008	Takedown	GSS no flow test
	7/14/2008	Takedown	GSS max flow test: Fail
15:27	7/14/2008	Takedown	Calibrated TDLAS 1030 — Mean: 49.40 - SD: 0.15 - RSD: 0.3% - Bias: -1.1%
16:08	7/14/2008	Takedown	Calibrated TDLAS 1029 — Mean: 48.0 - SD: 1.27 - RSD: 2.6% - Bias: -3.8%
	7/15/2008	Takedown	Forgot keys; Scott stayed to take down retro-reflectors and sonic anemometers while Derrick went back to PAML. Took down sonic anemometers and retro-reflectors on SW corner.
	7/15/2008	Takedown	Barometer audit: accepted.
16:05	7/15/2008	Takedown	Wetness sensor calibration: accepted
16:20-17:20	7/15/2008	Takedown	Sonic anemometer inter-comparison: all pass.
16:42	7/15/2008	Takedown	TEC 450i instrument operation parameters
16:42	7/15/2008	Takedown	TEC 450i calibration verification check
16:53	7/15/2008	Takedown	TEC 450i reference precision check
17:10	7/15/2008	Takedown	Sonic anemometer zero calibration: all pass.
	7/16/2008	Takedown	Finished taking down site. Took trailer back to PAML.
	7/16/2008	Takedown	S-OPS installation report made.
	7/16/2008	Takedown	Maintenance and Inspection checklist completed.
	9/2/2008	Takedown	Electronic Data Chain of Custody form completed.

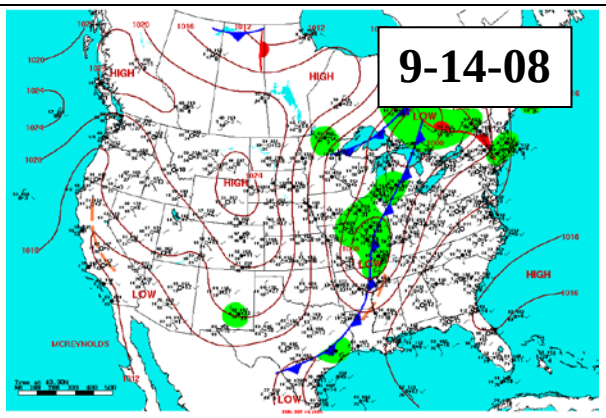
6.9 Site Weather

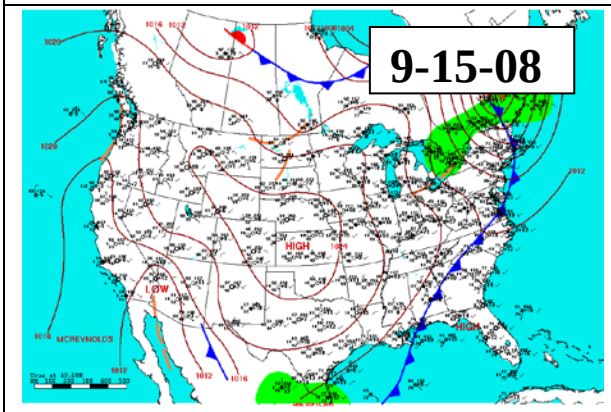
Period 6

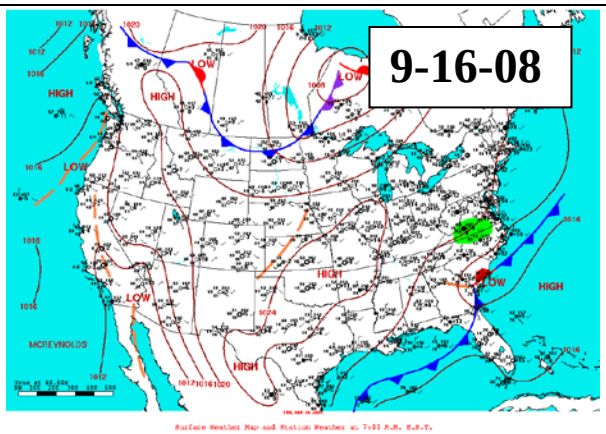


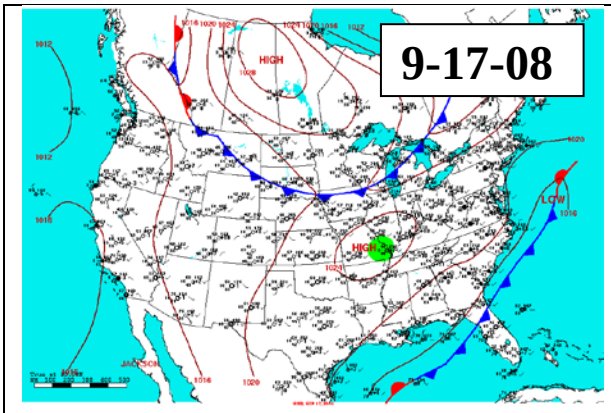








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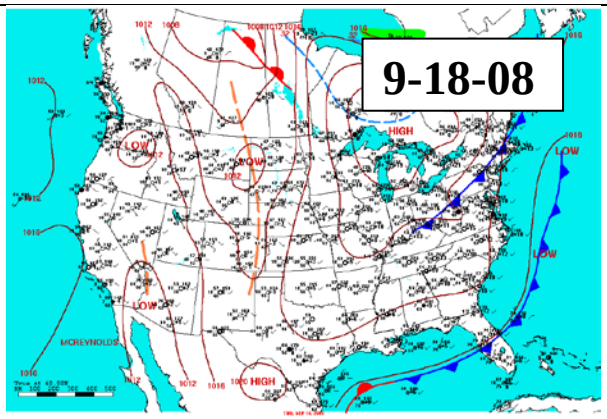
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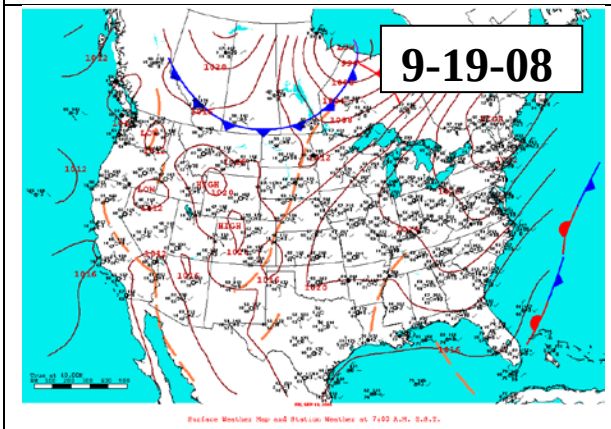
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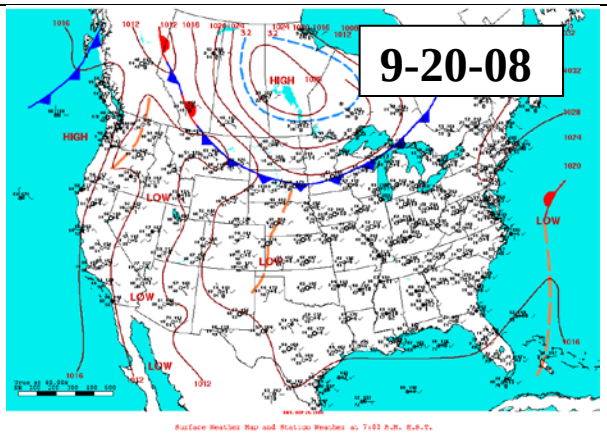
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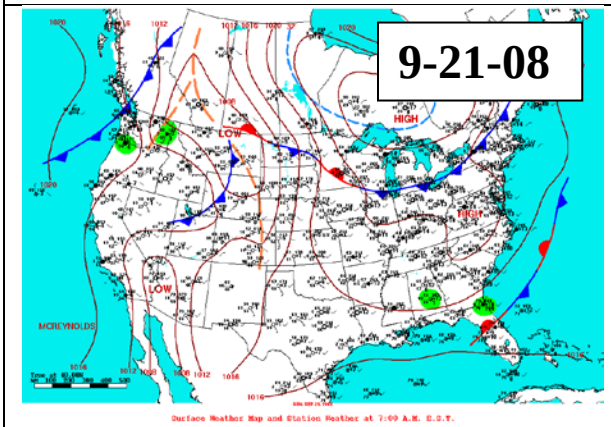
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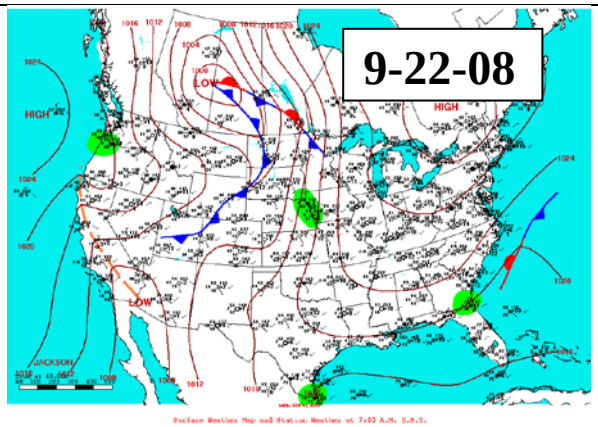
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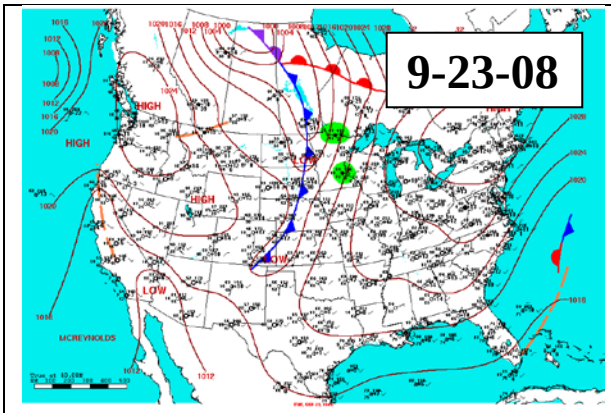
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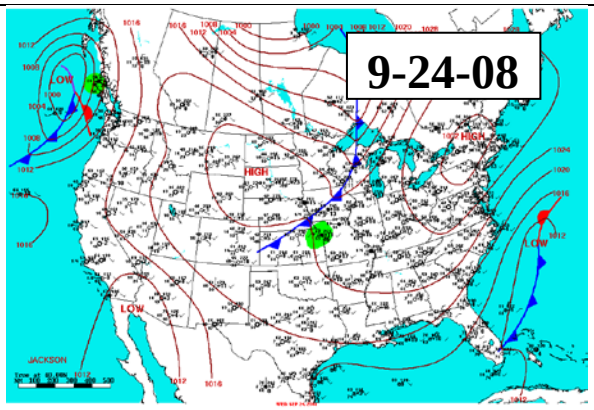
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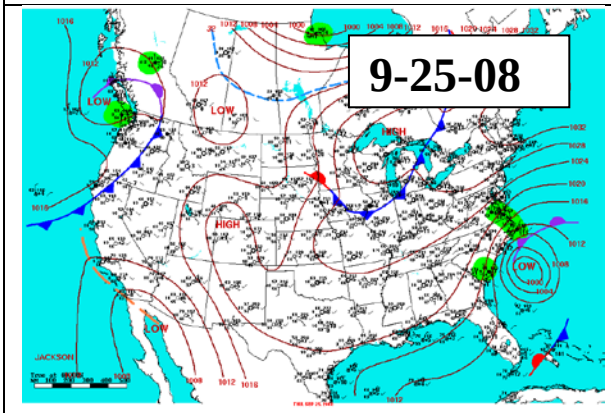
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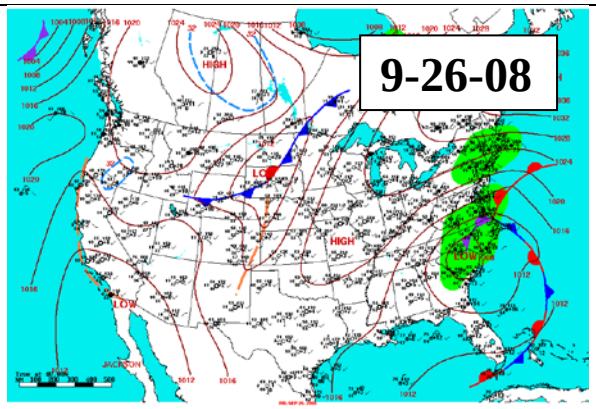
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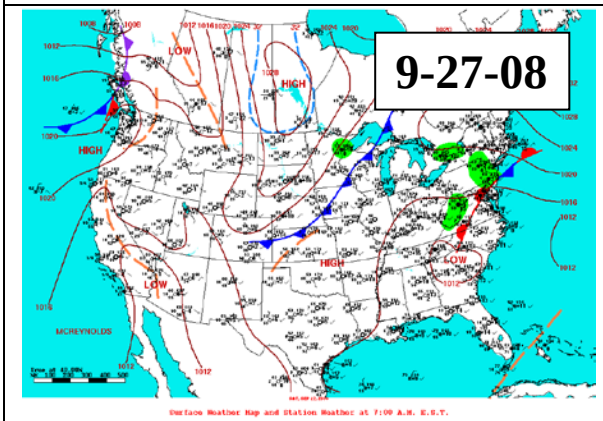
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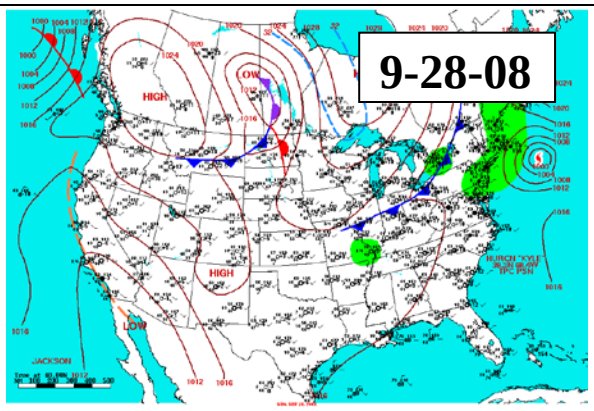
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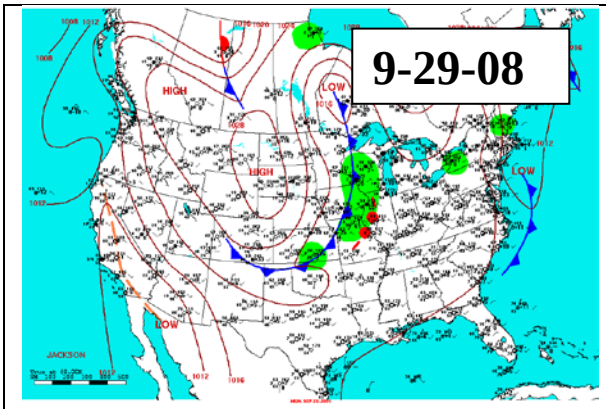
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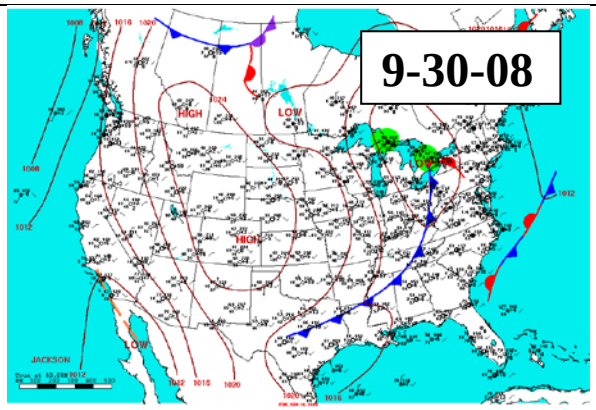
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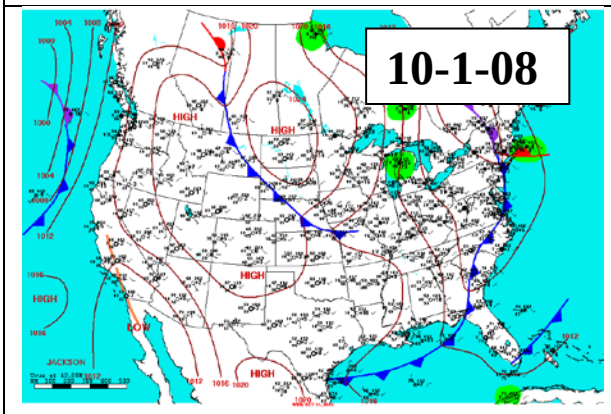
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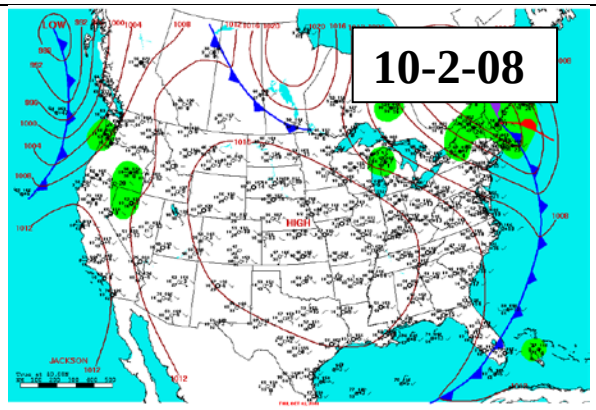
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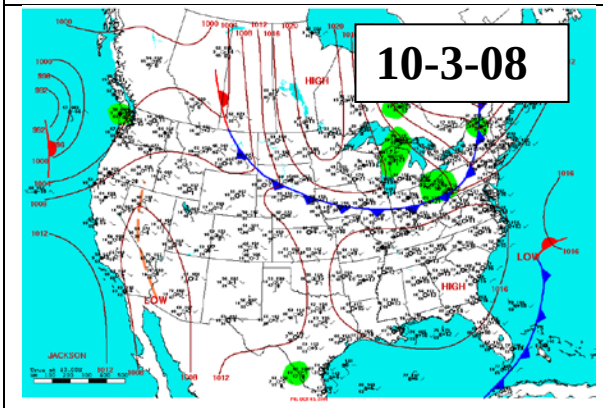
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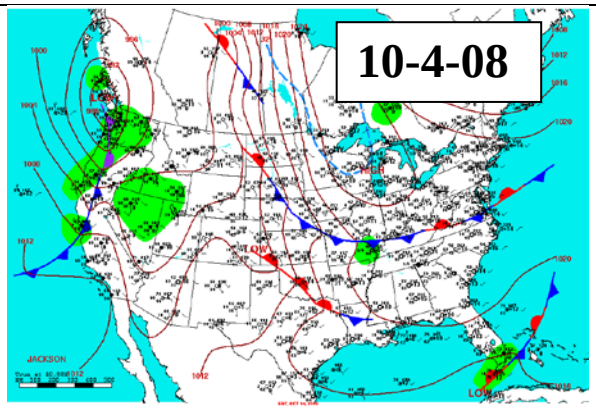
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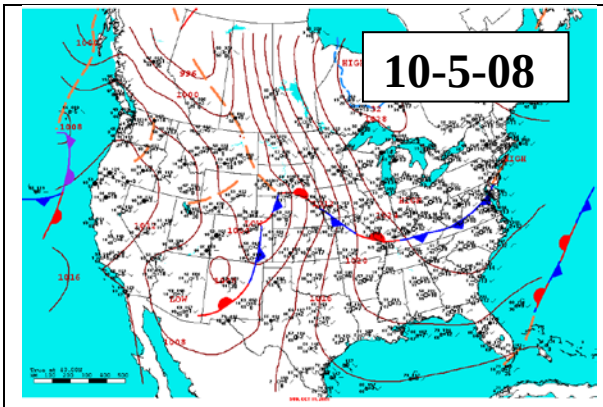
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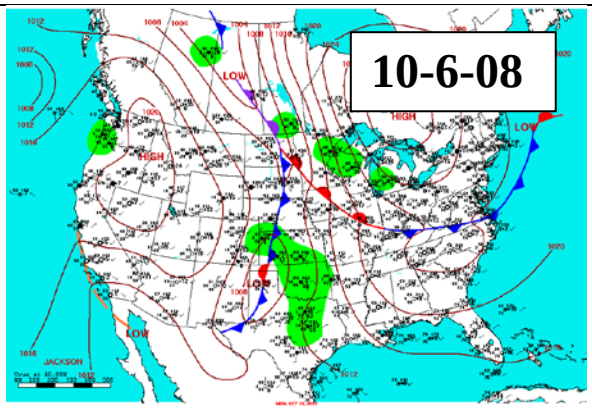
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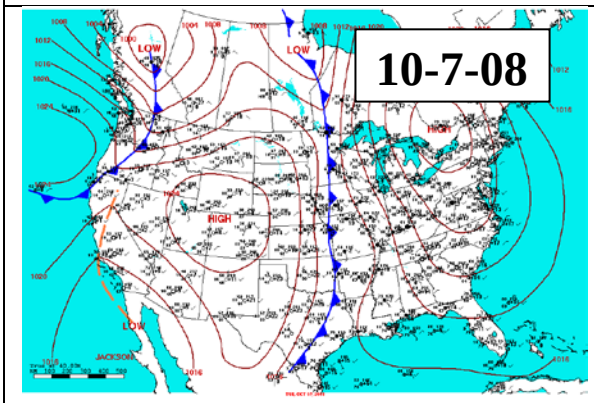
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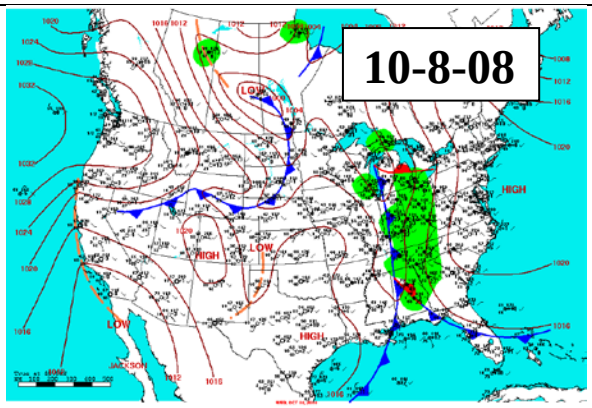
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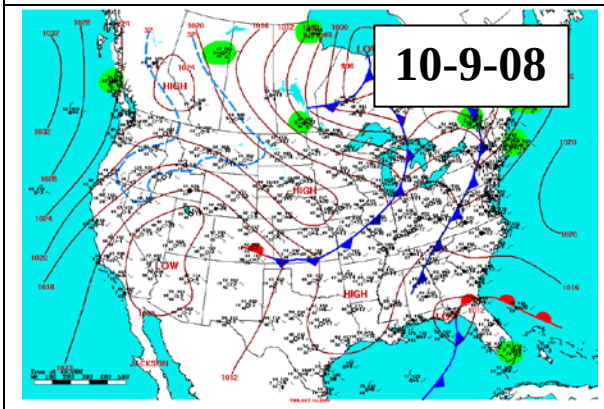
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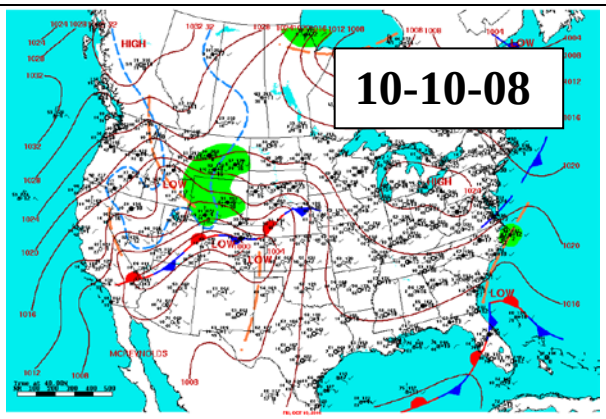
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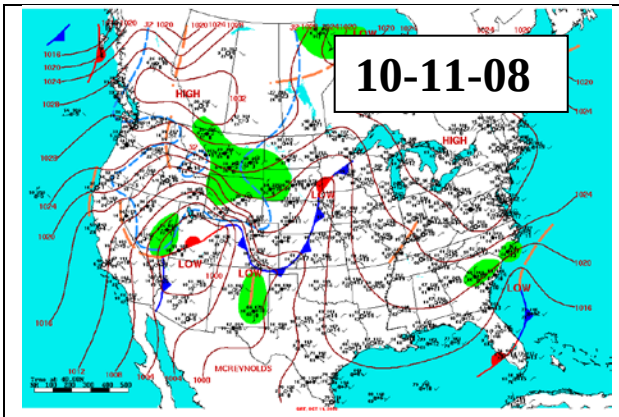
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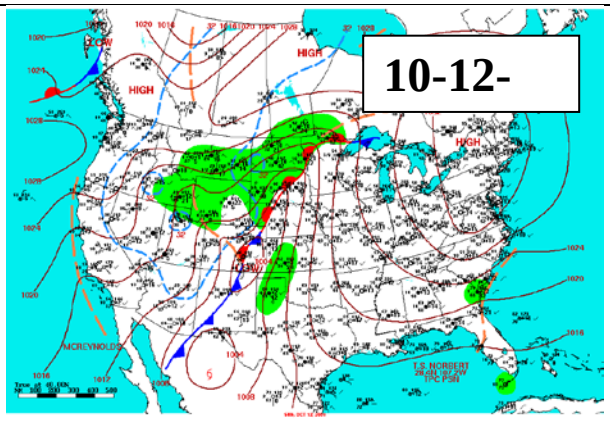
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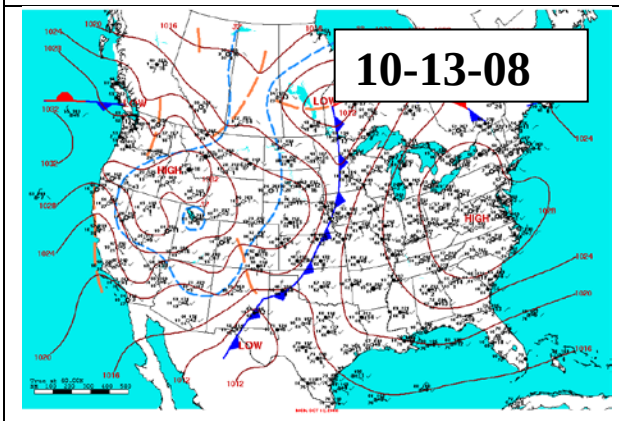
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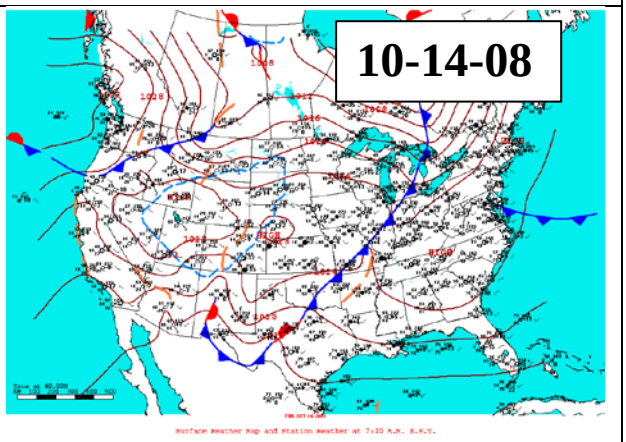
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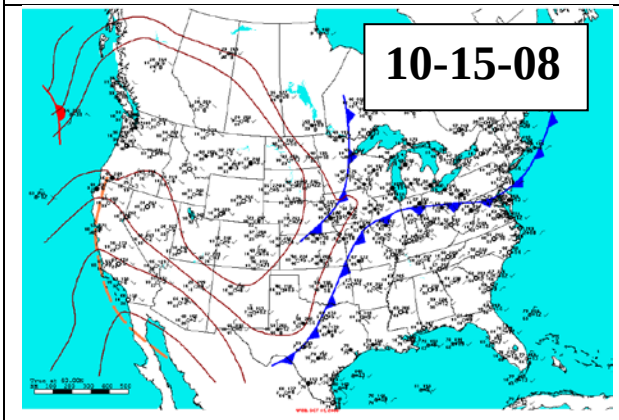
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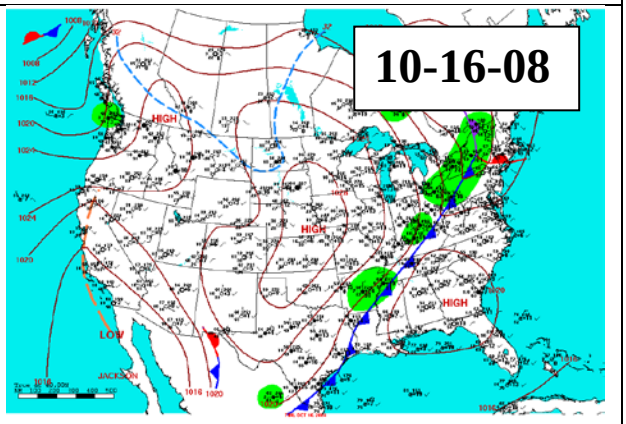
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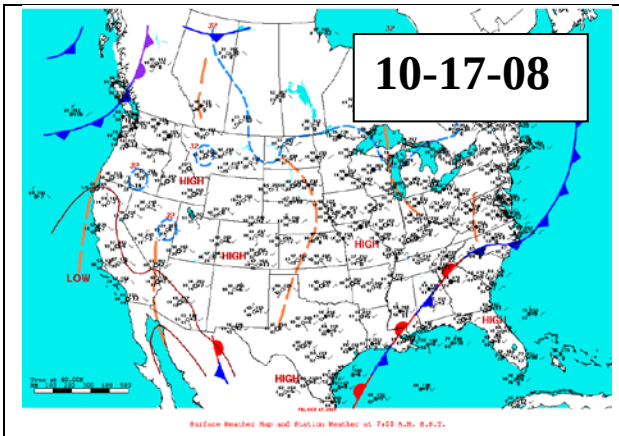
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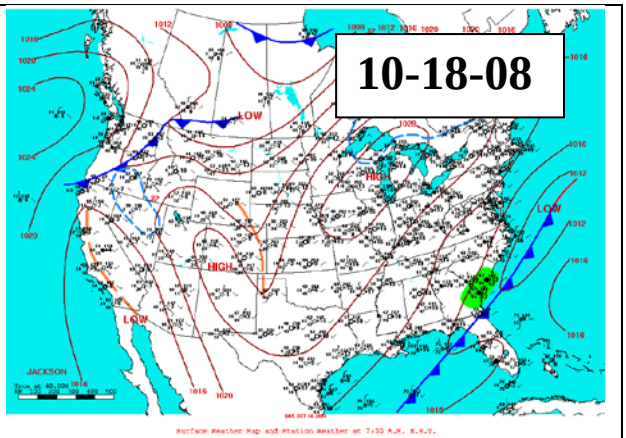
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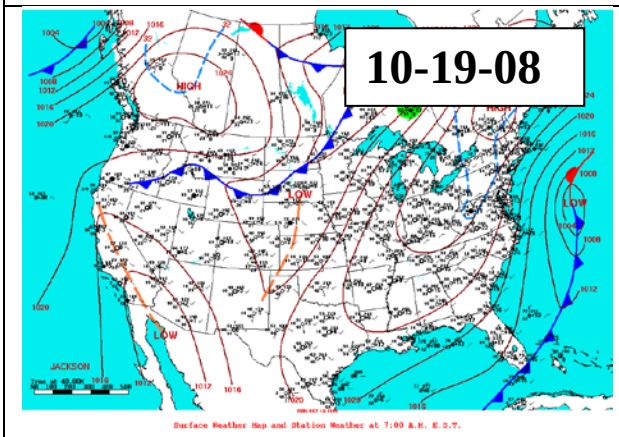
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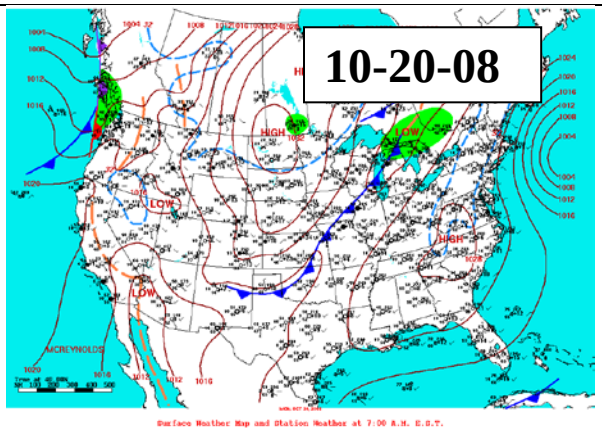
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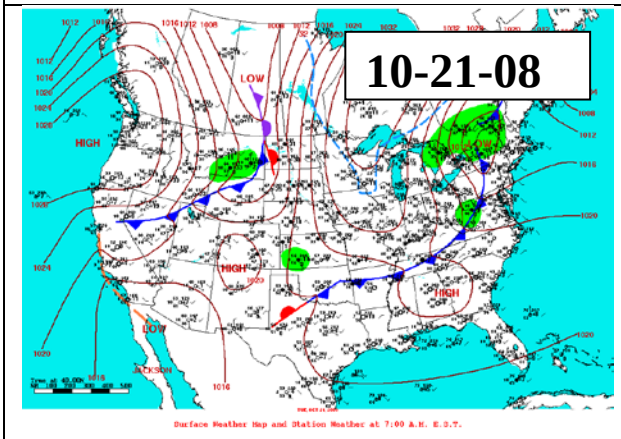
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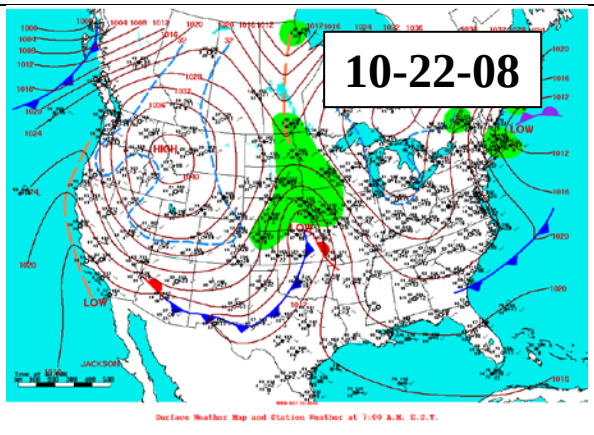
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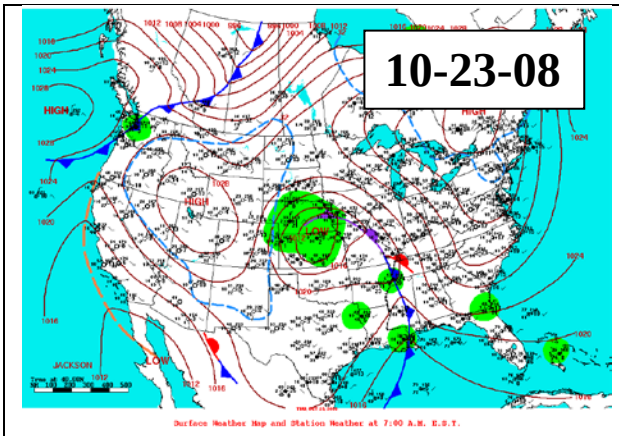
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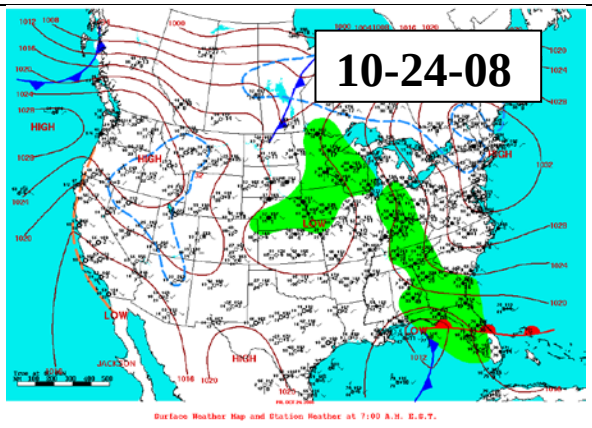
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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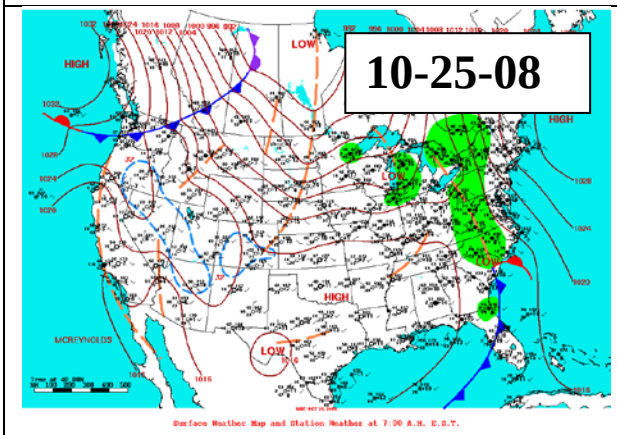
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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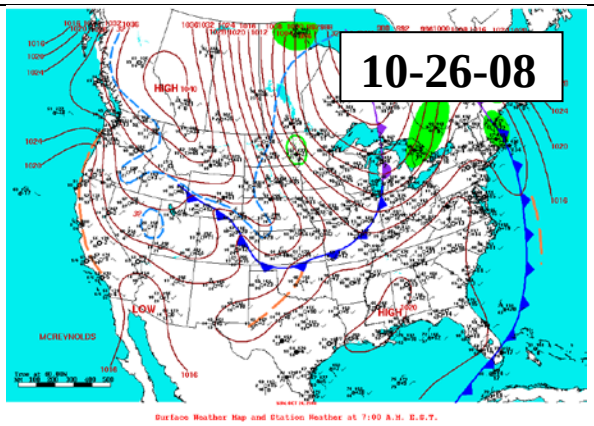
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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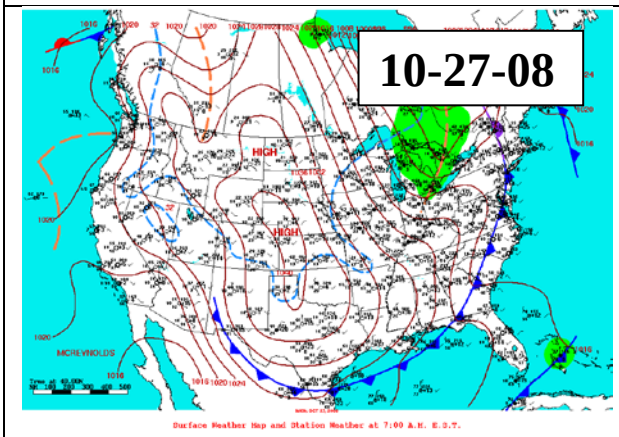
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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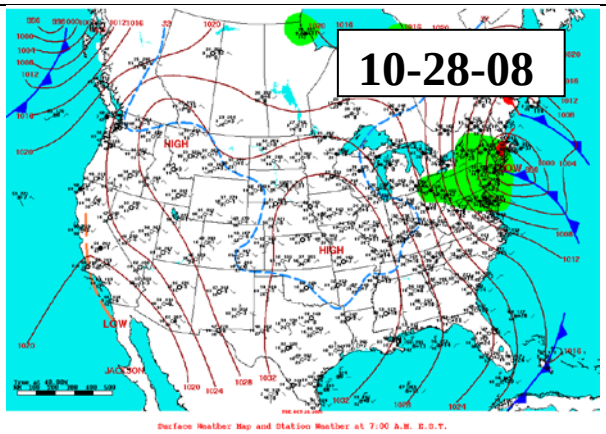
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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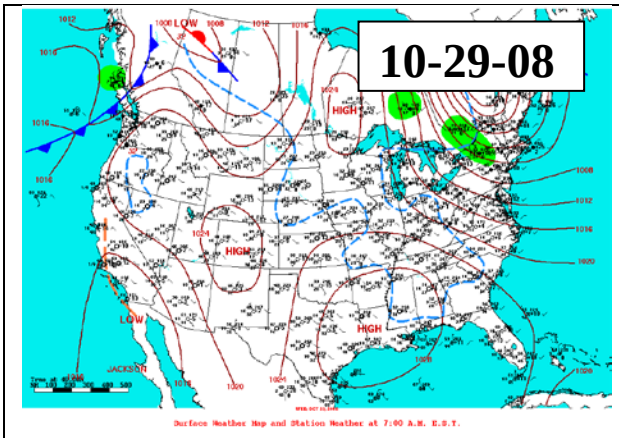
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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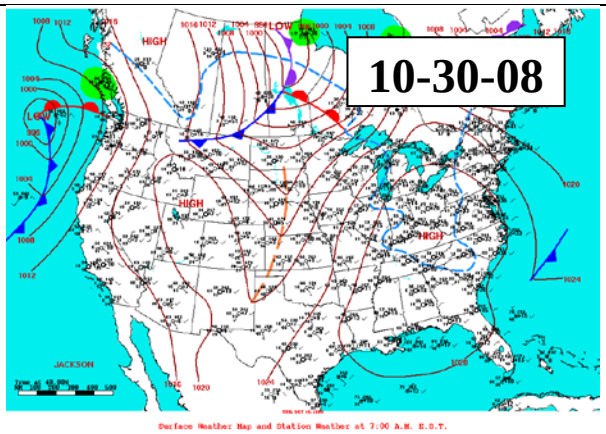
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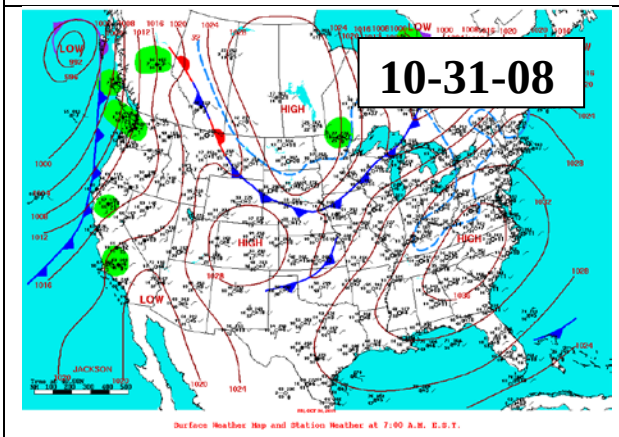
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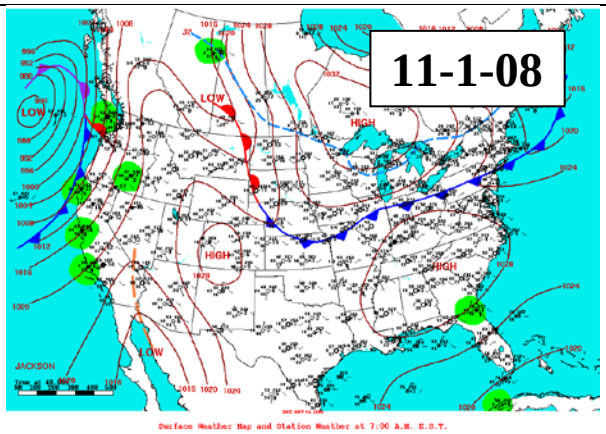
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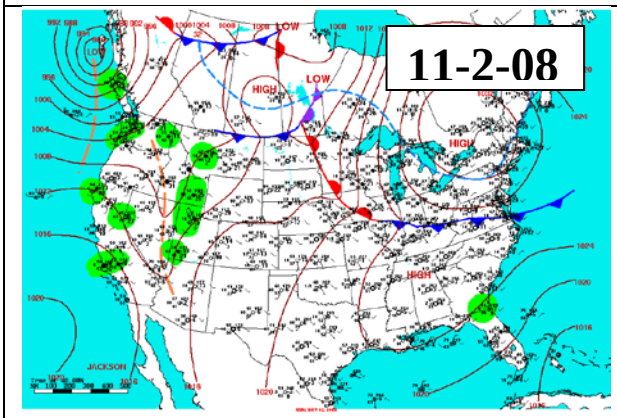
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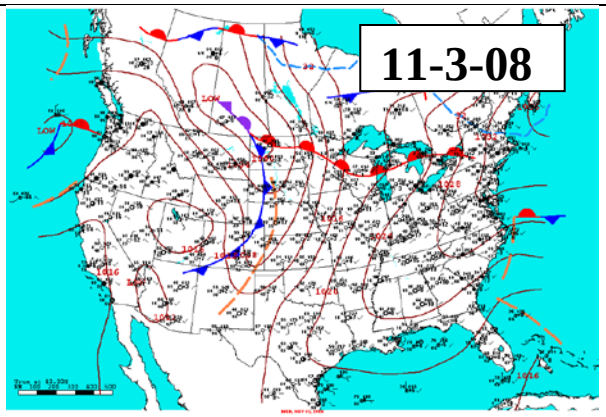
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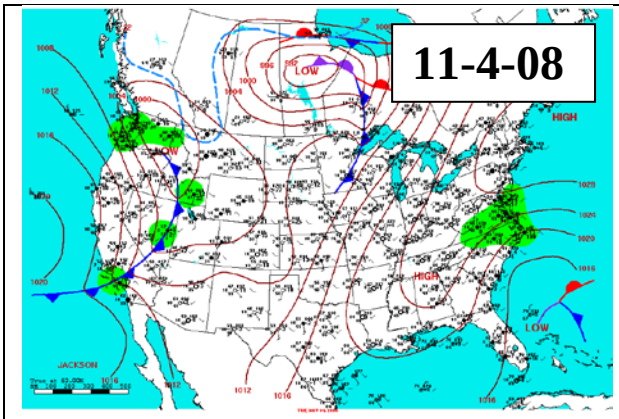
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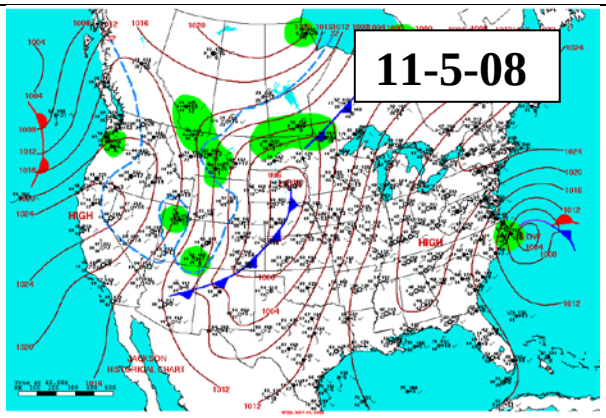
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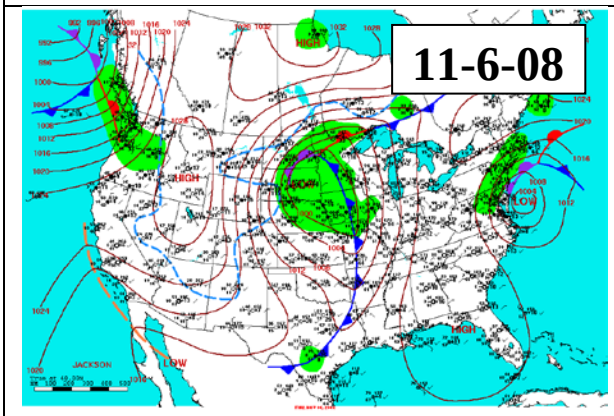
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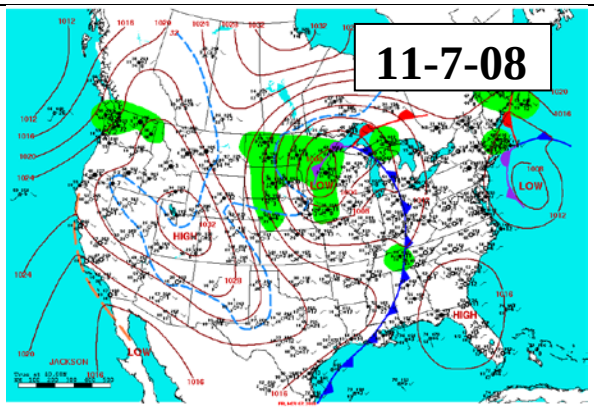
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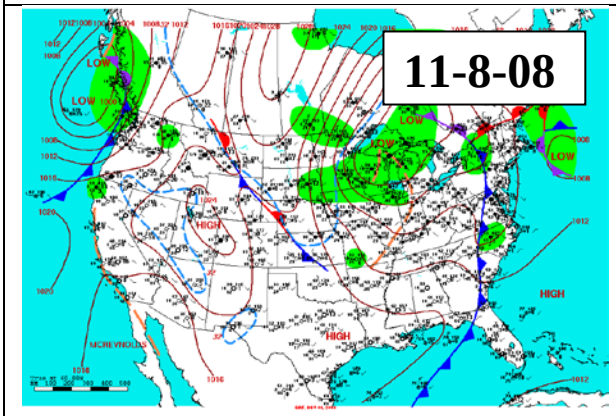
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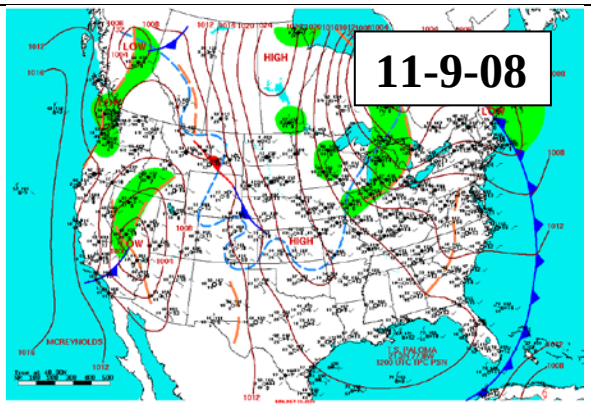
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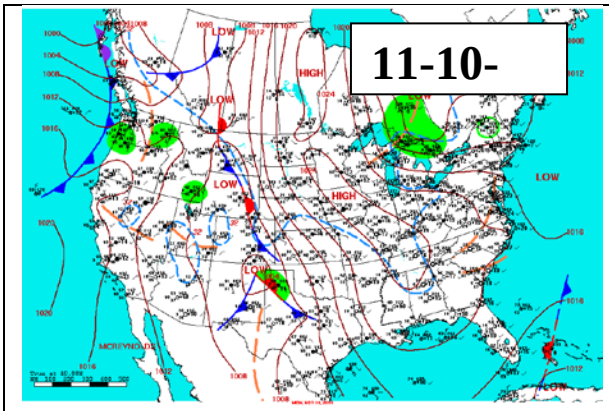
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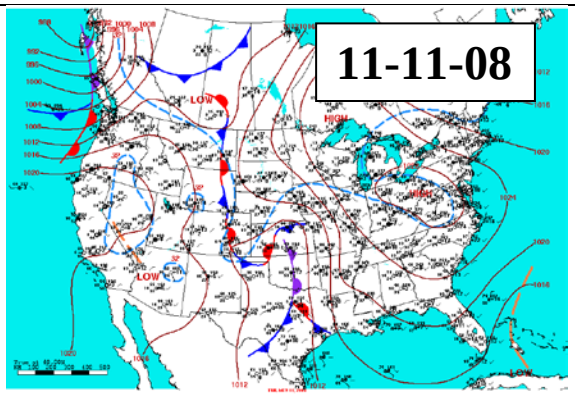
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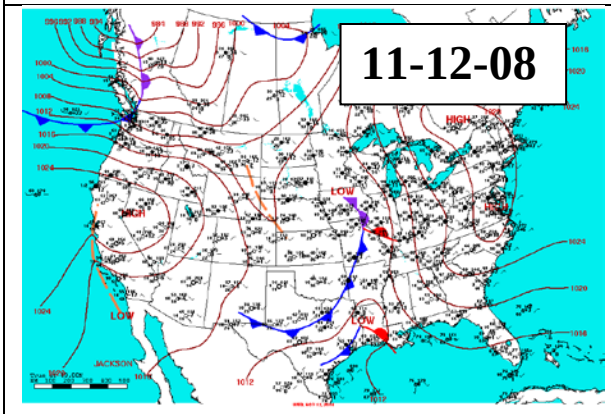
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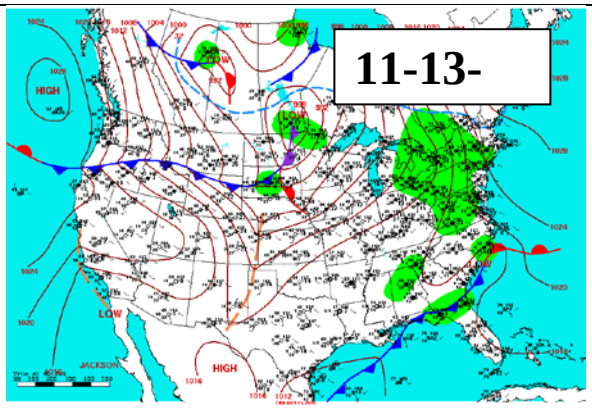
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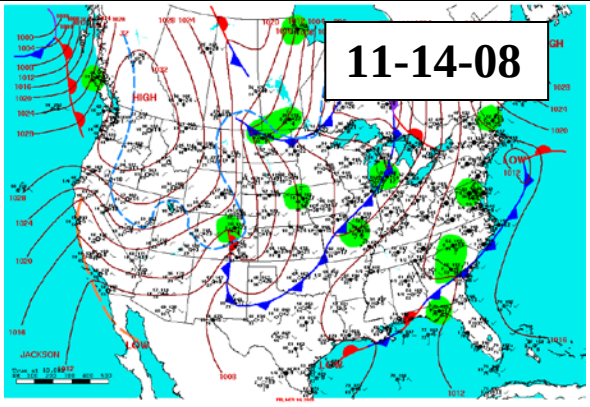
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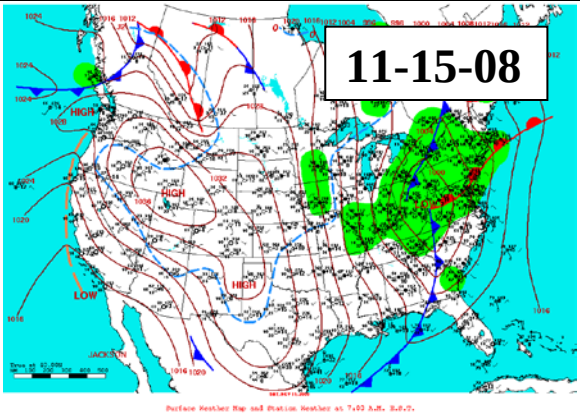
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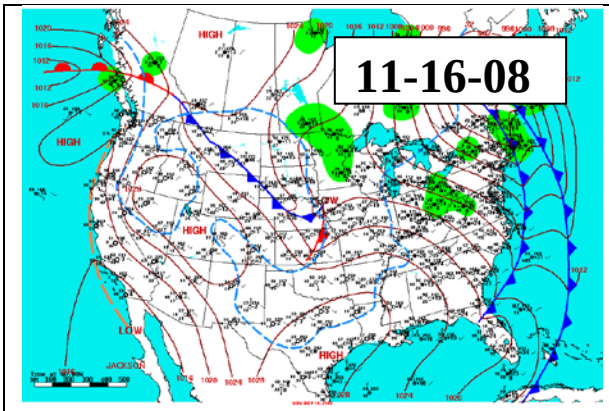
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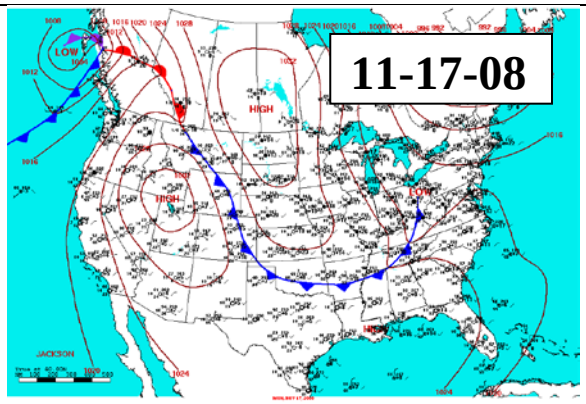
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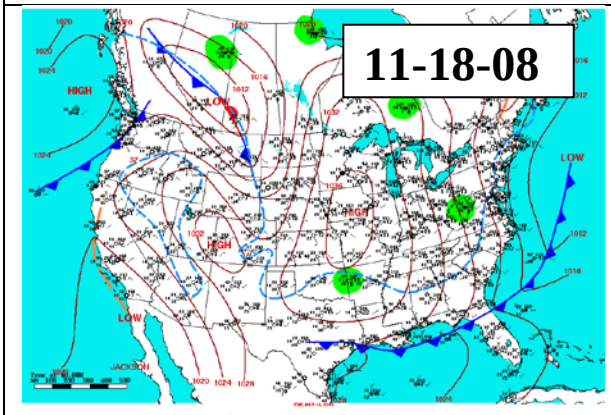
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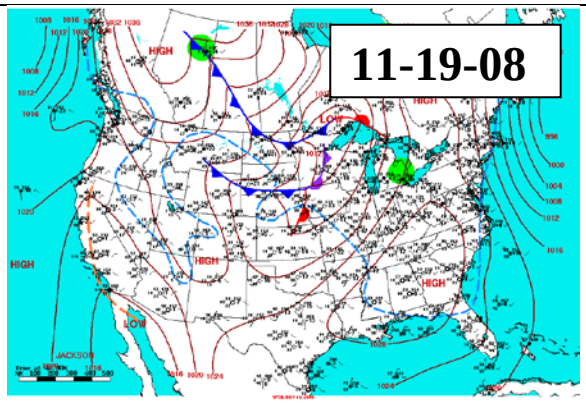
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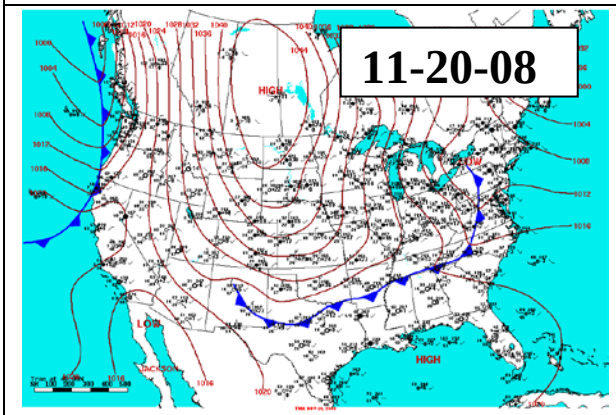
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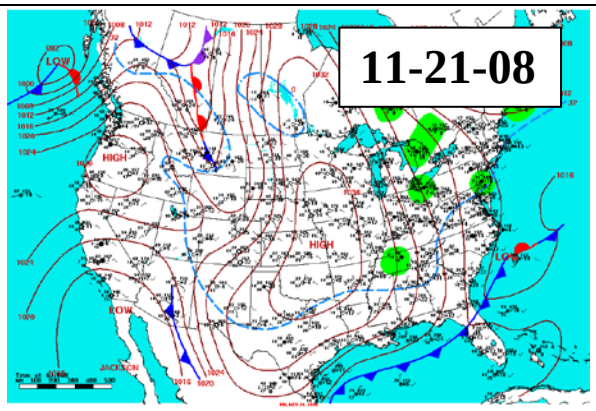
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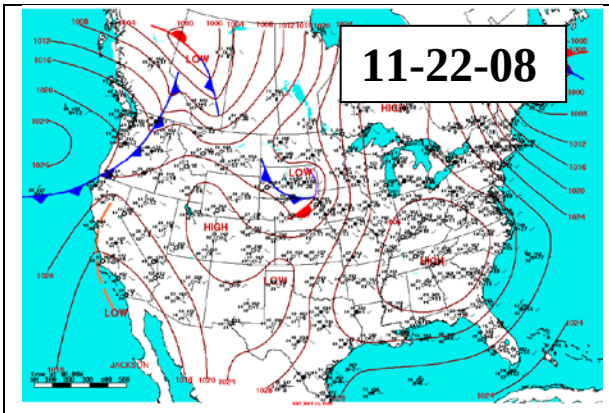
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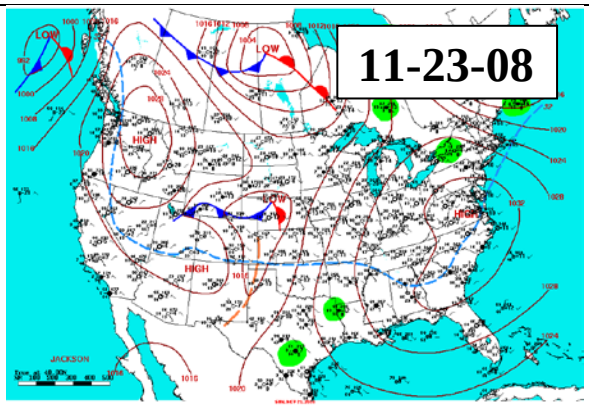
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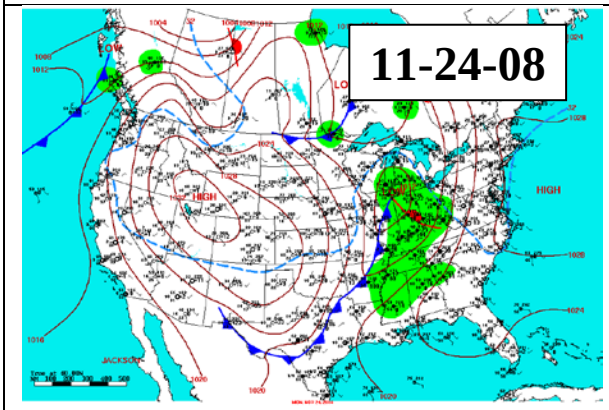
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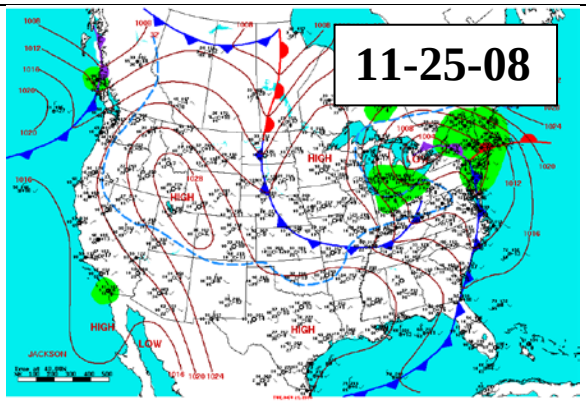
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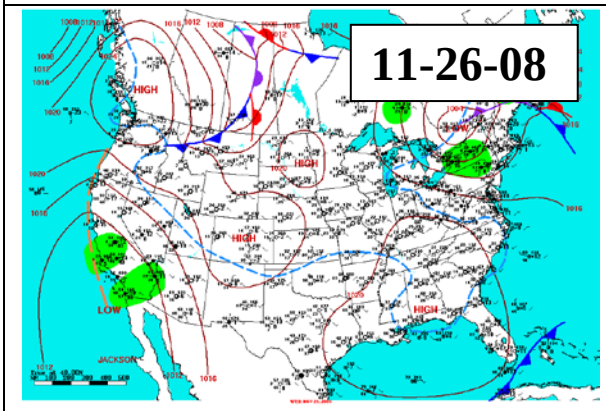
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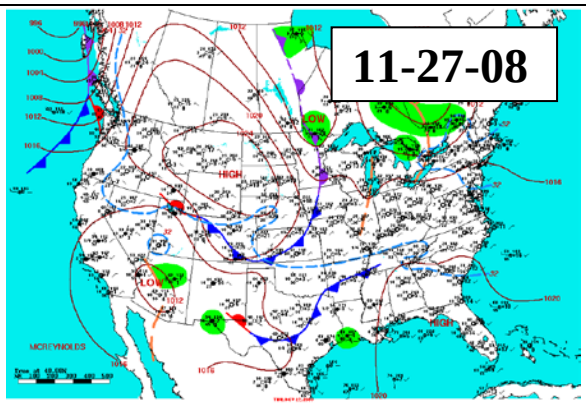
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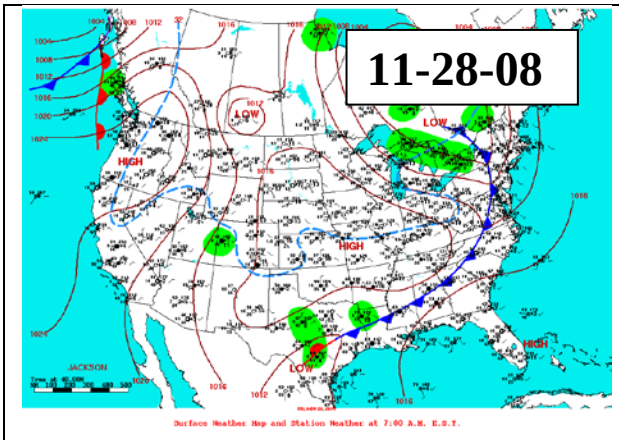
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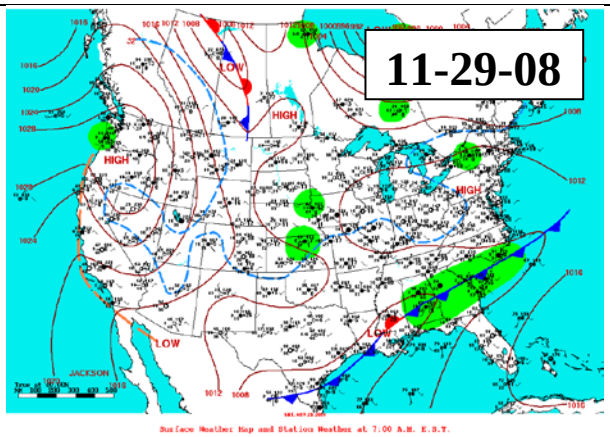
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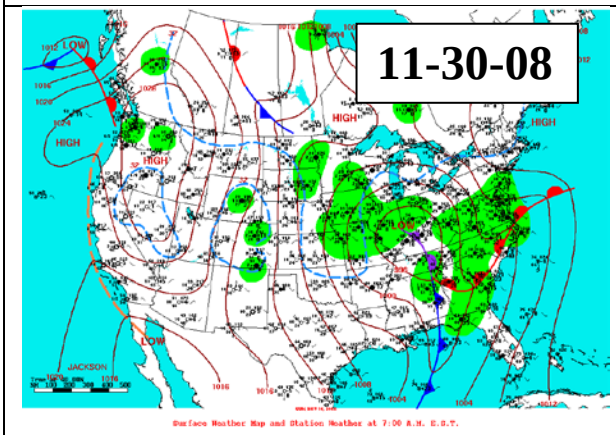
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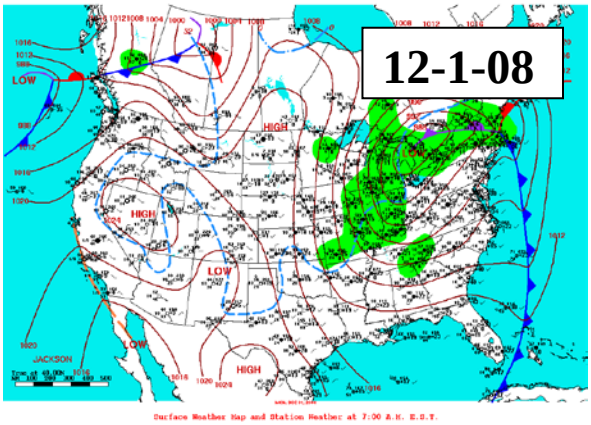
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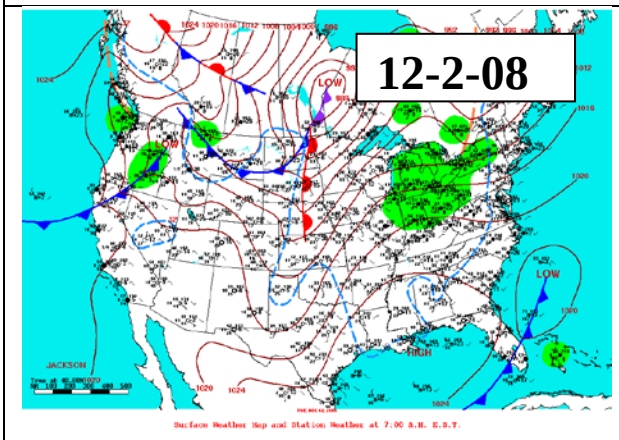
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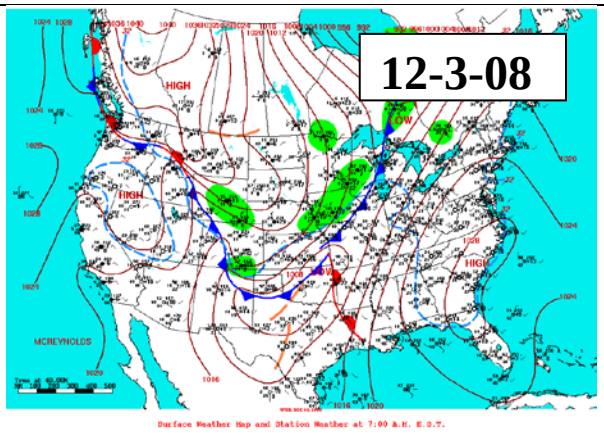
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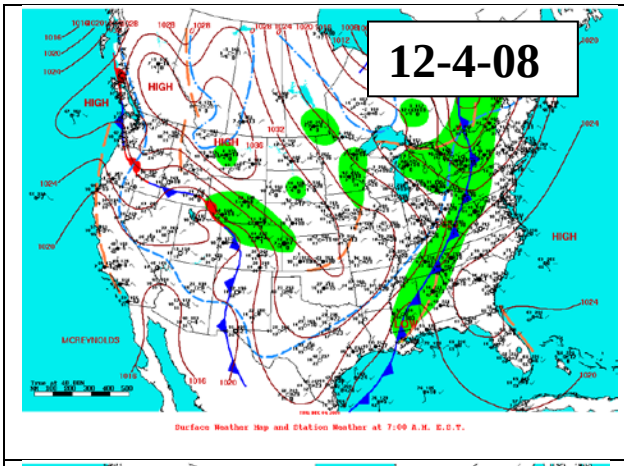
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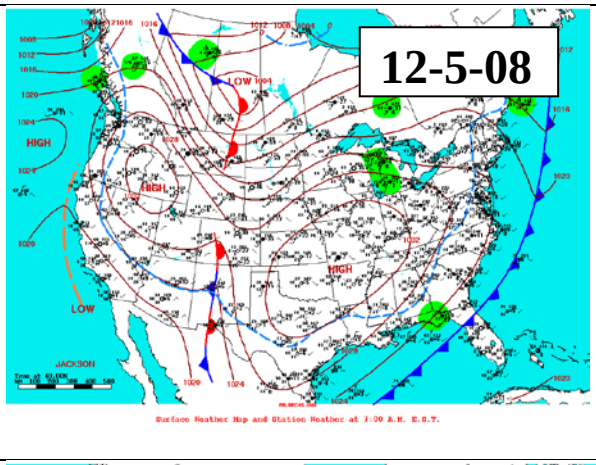
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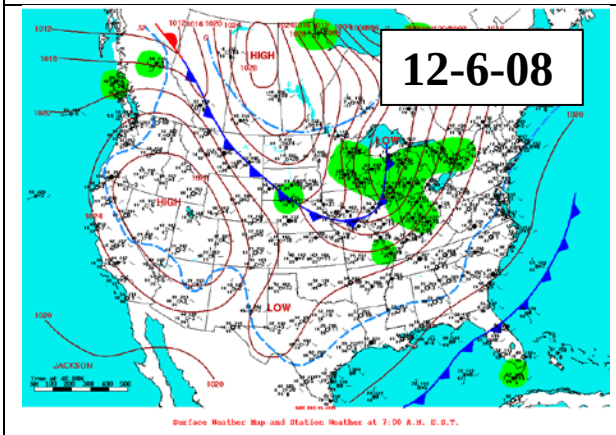
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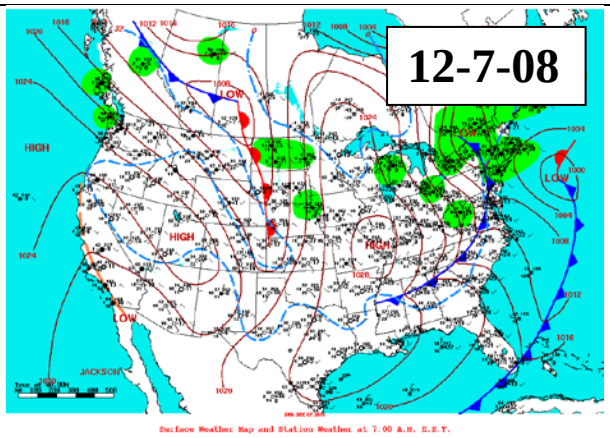
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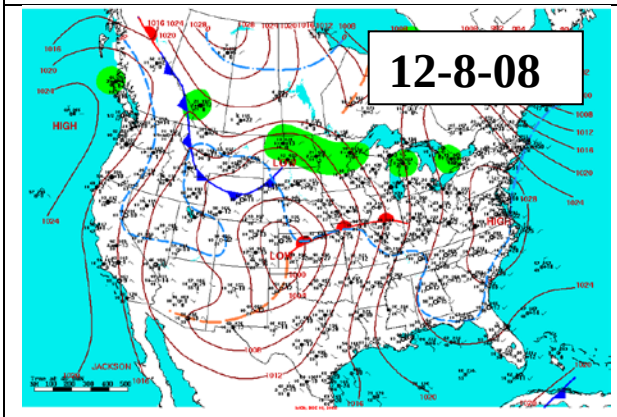
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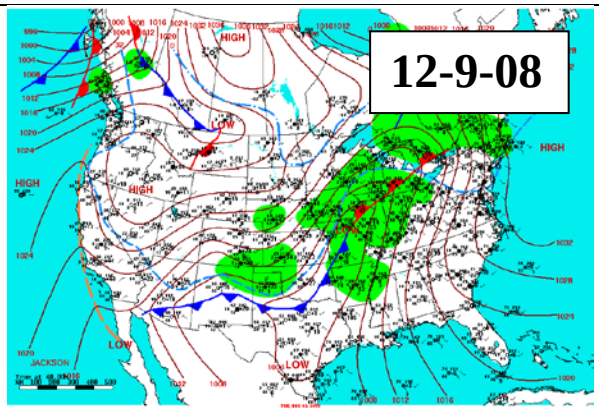
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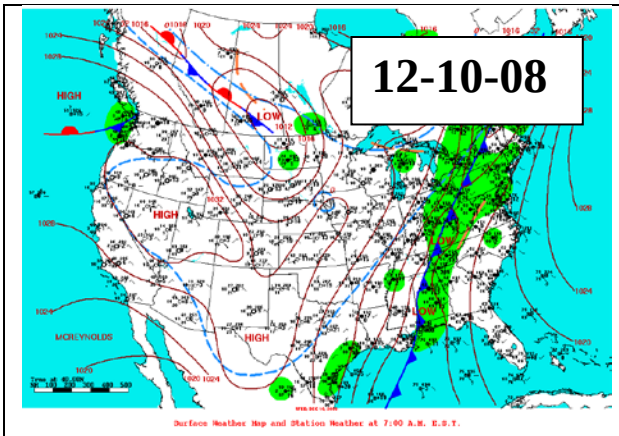
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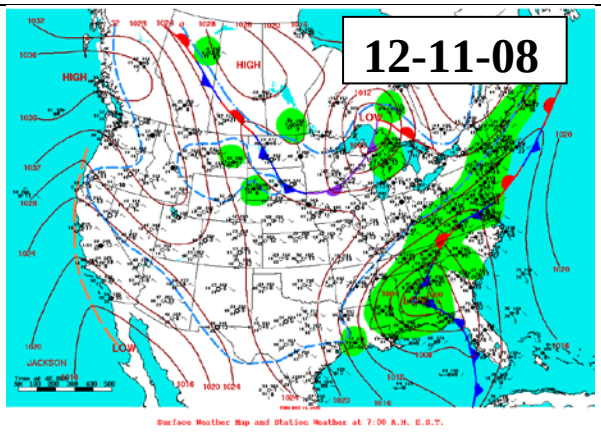
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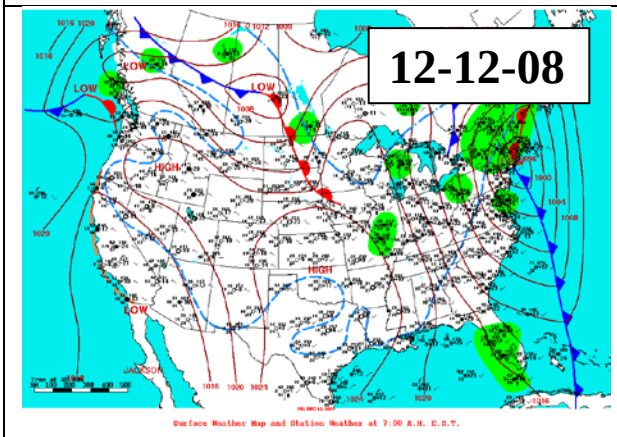
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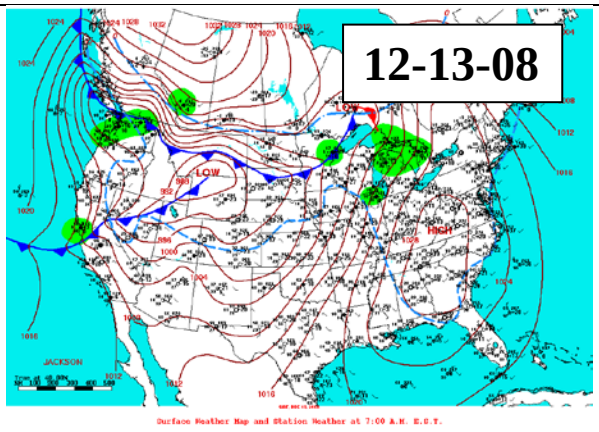
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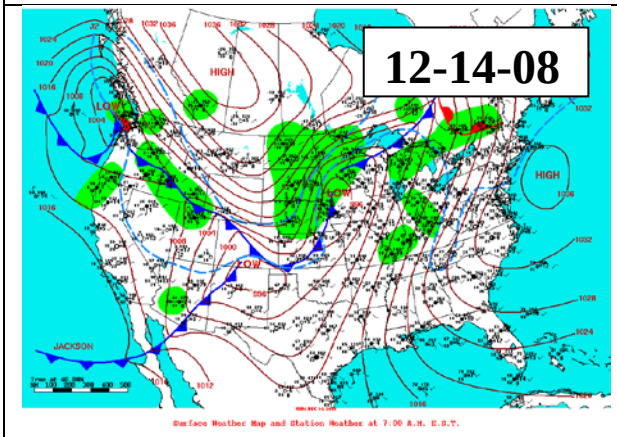
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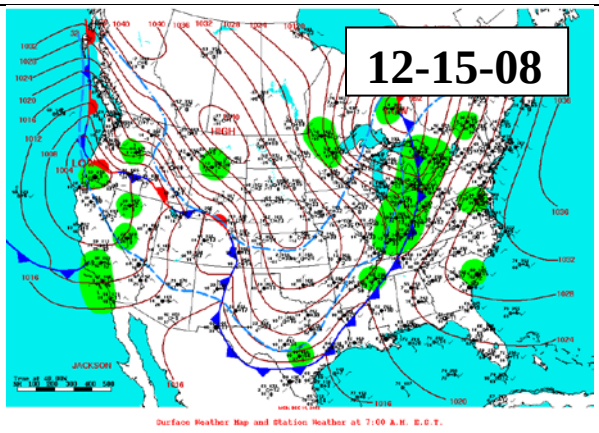
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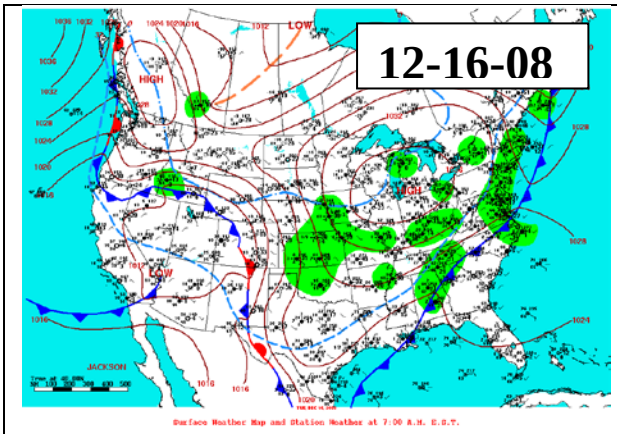
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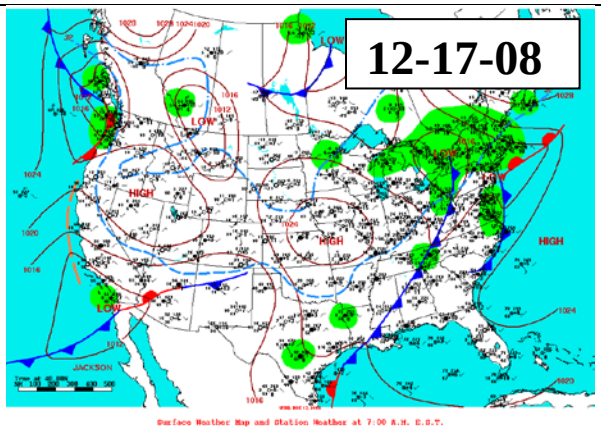
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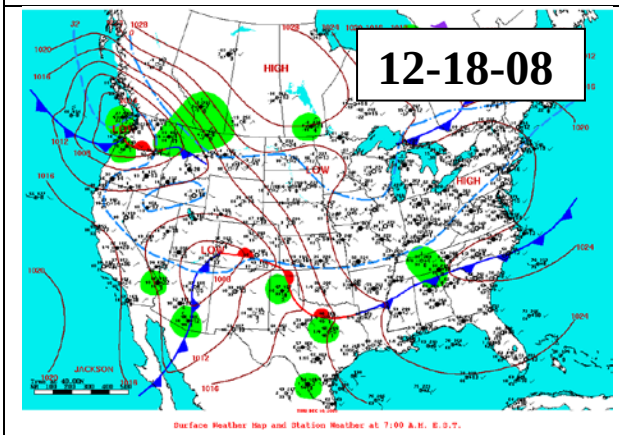
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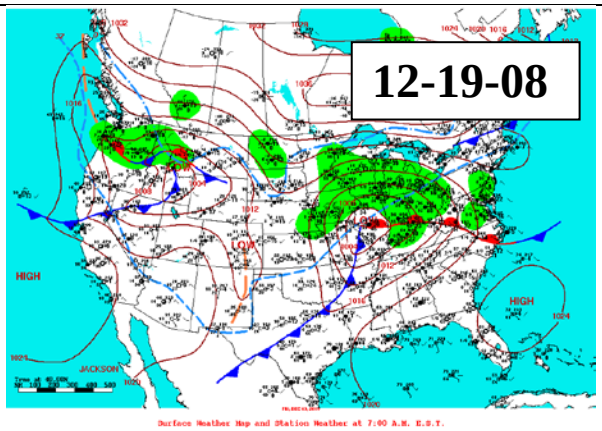
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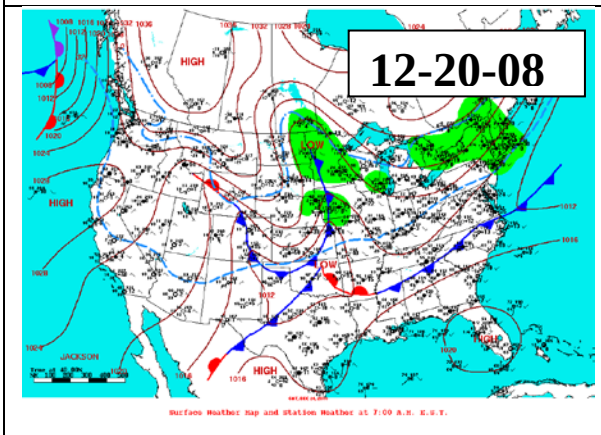
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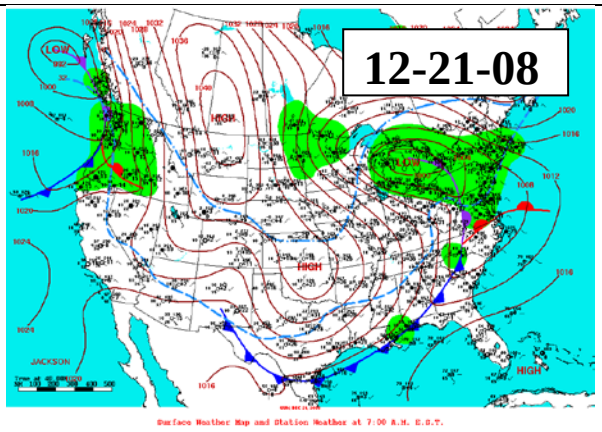
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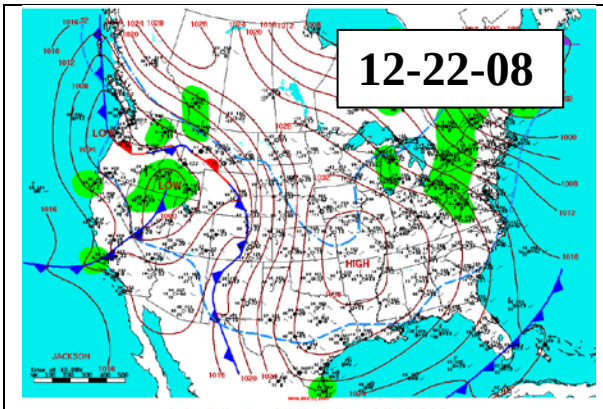
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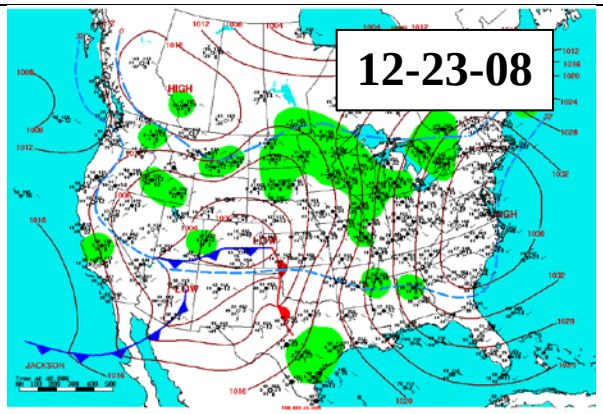
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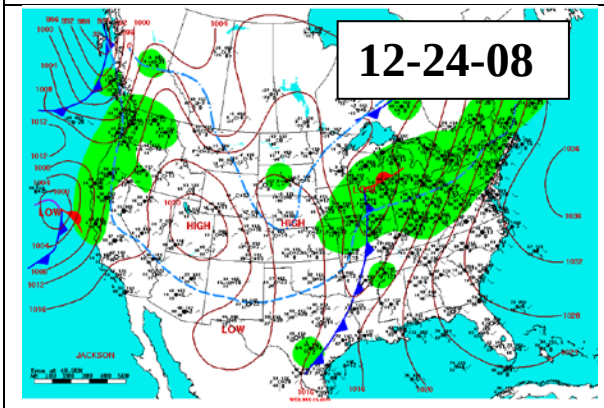
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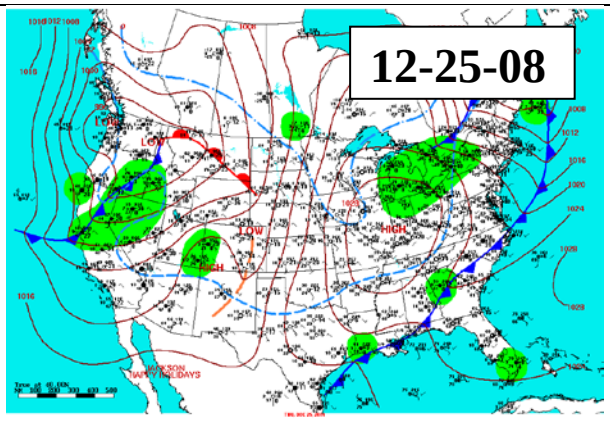
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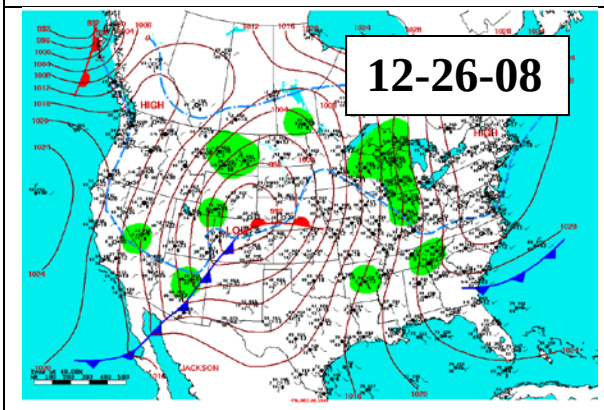
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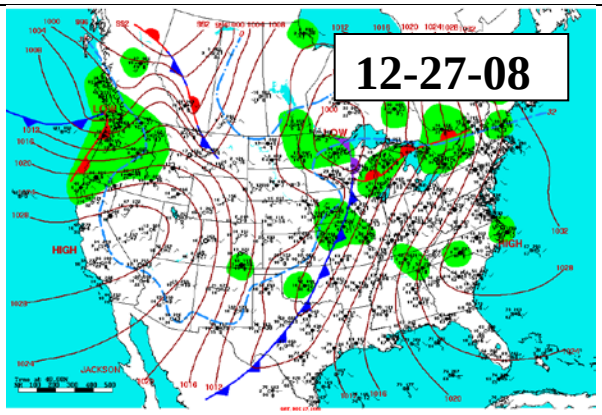
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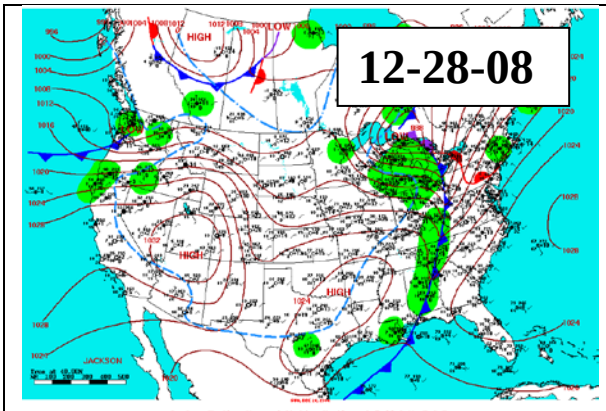
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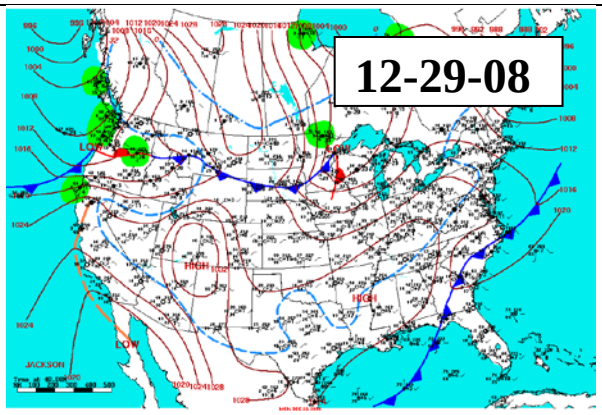
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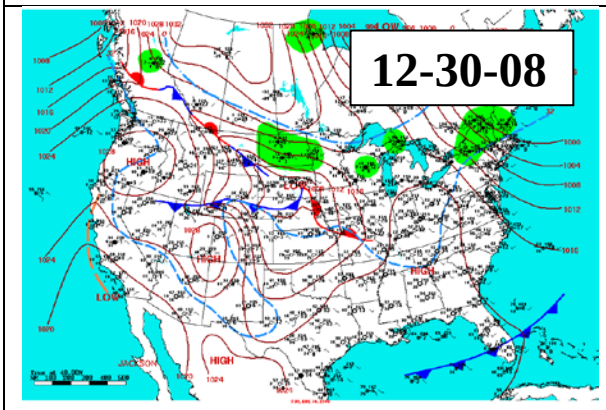
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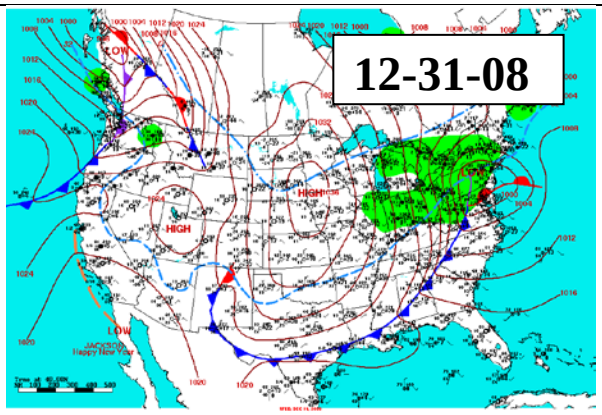
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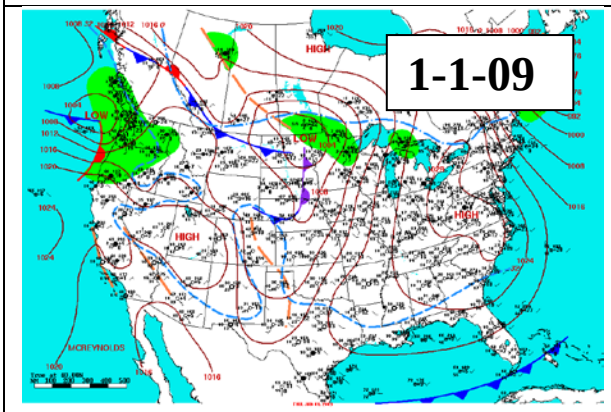
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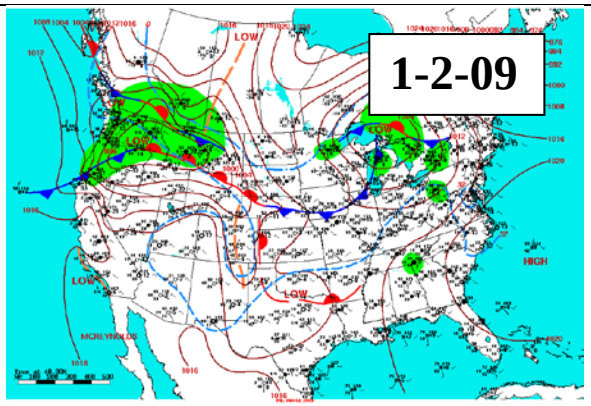
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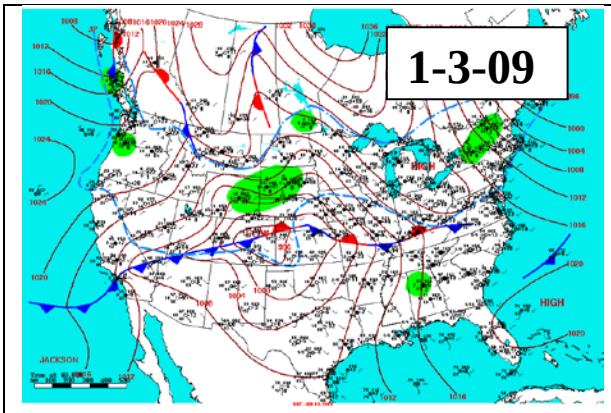
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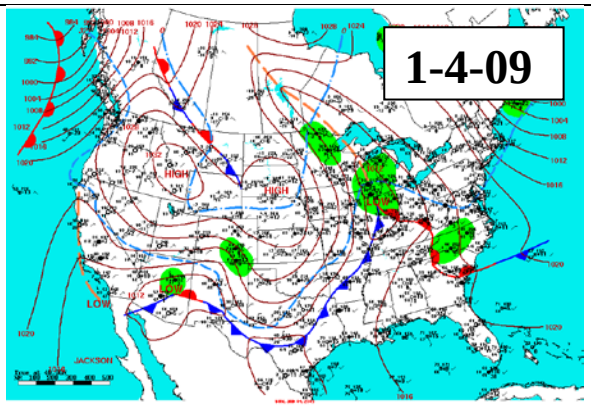
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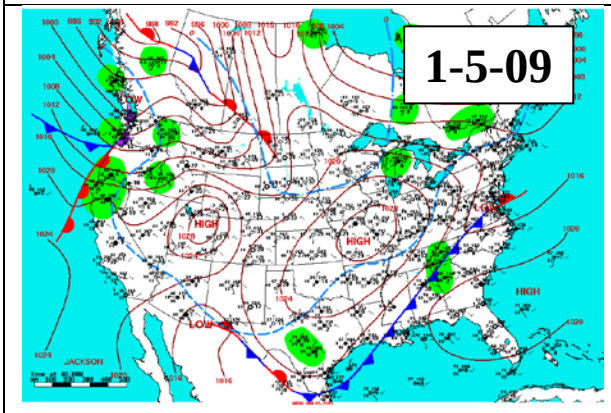
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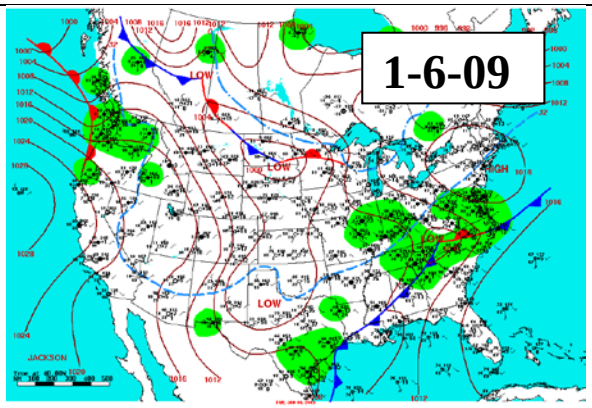
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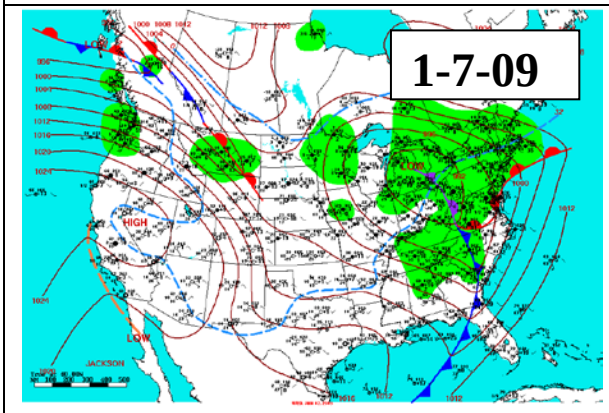
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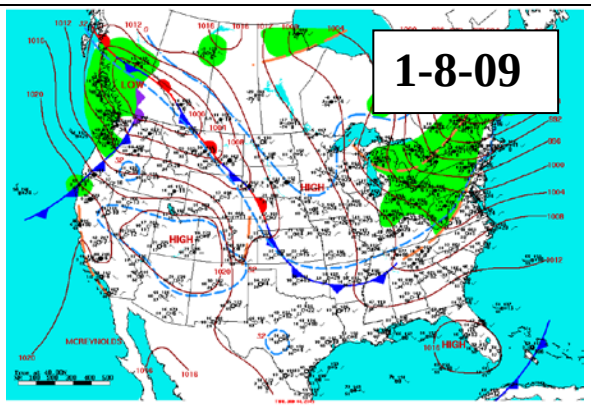
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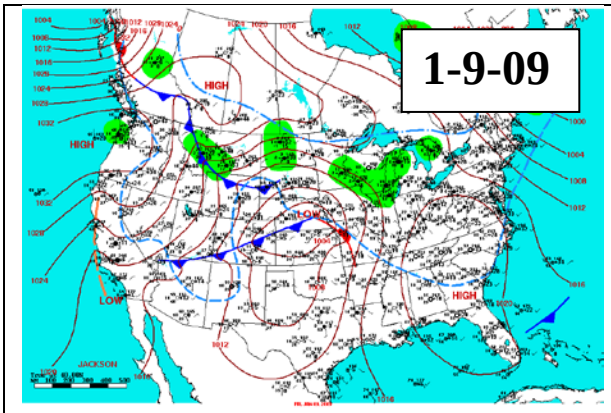
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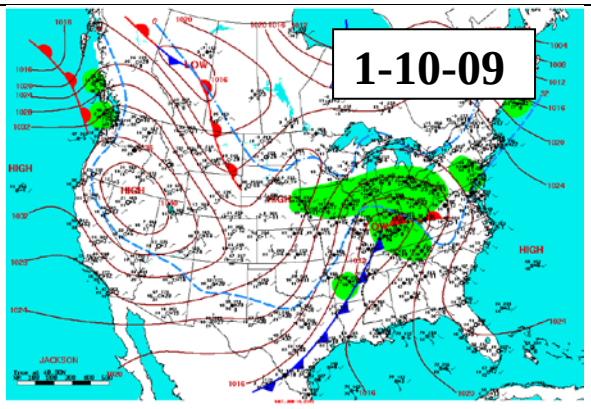
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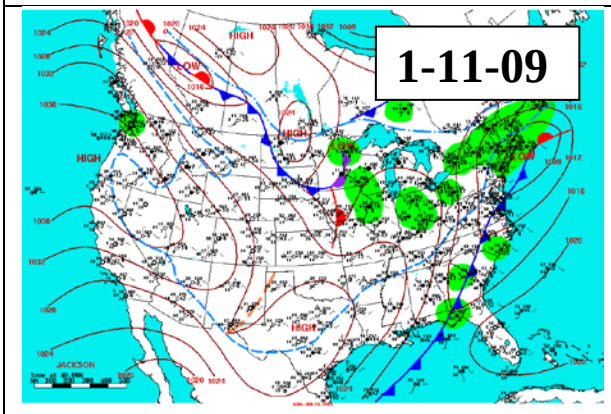
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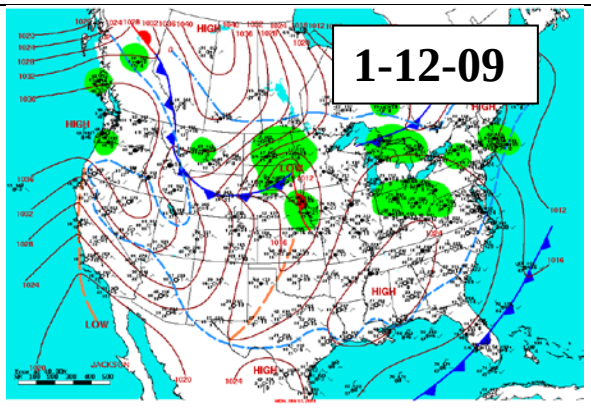
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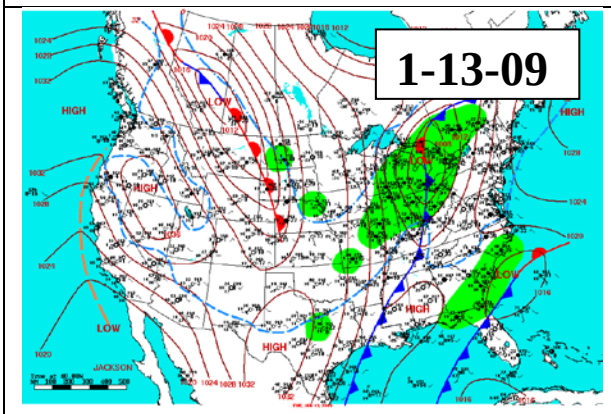
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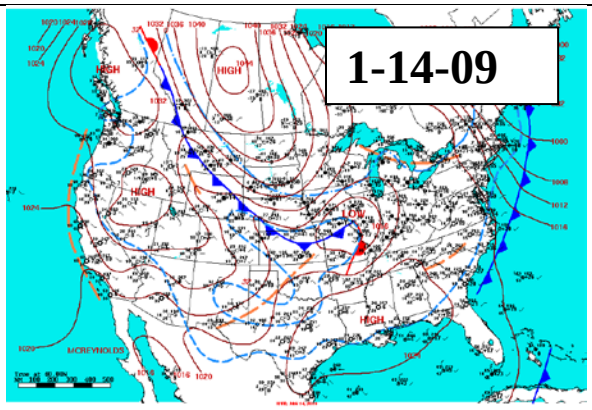
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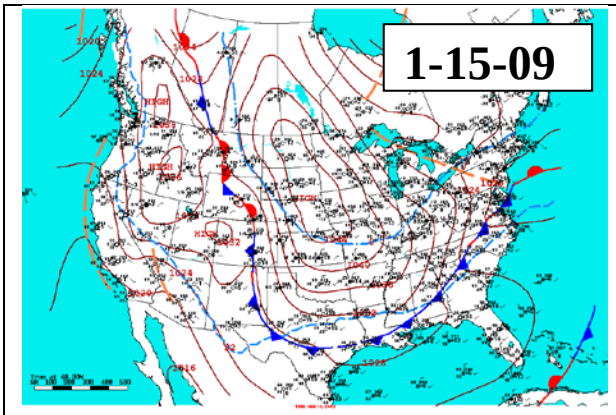
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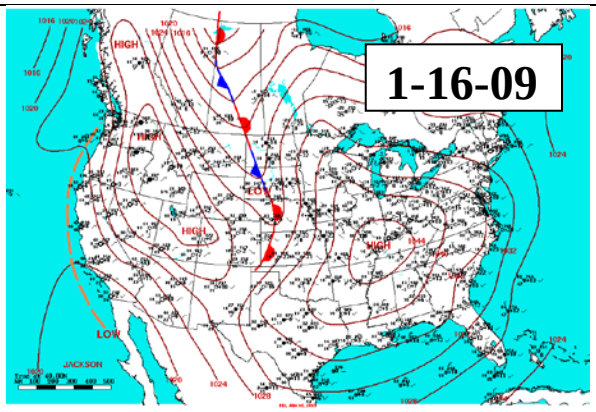
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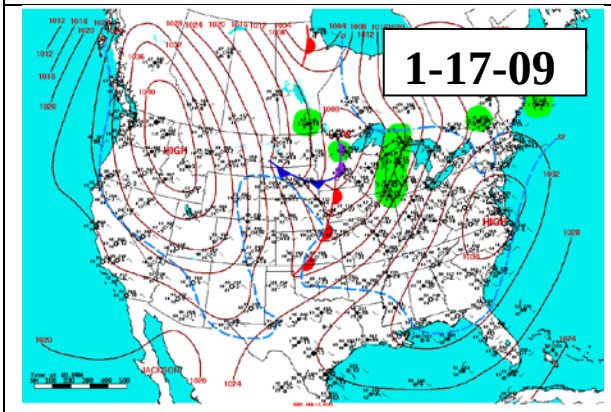
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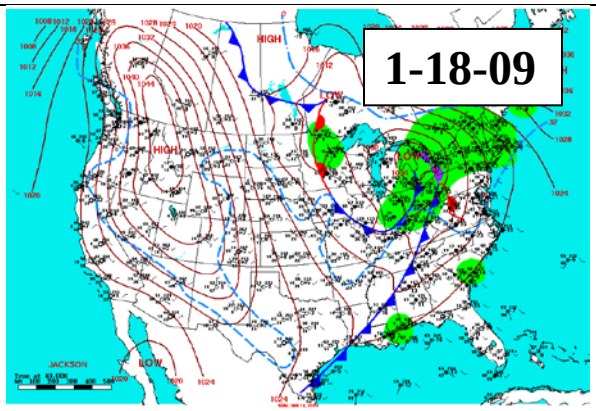
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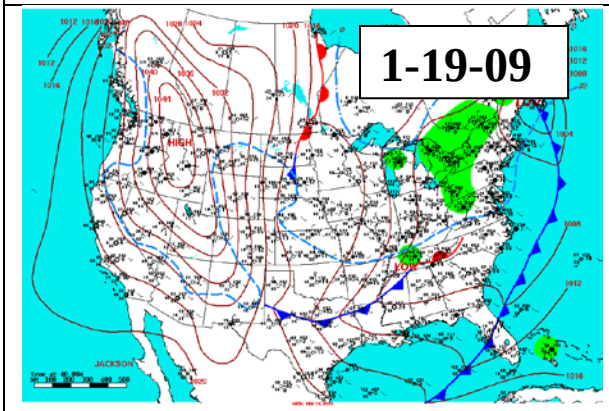
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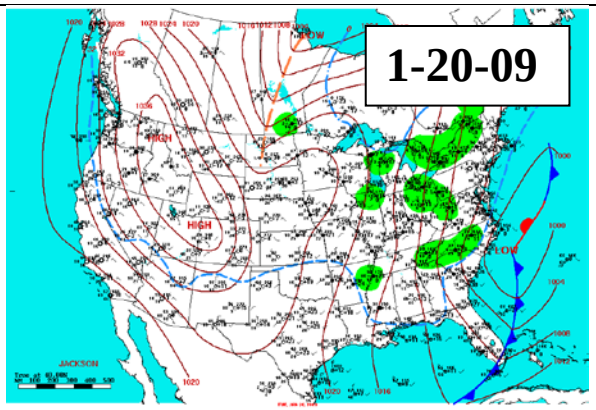
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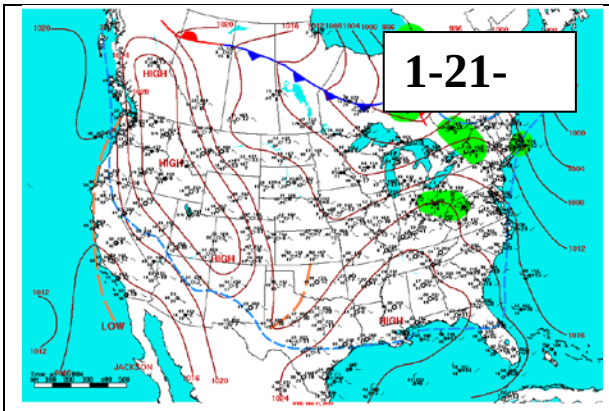
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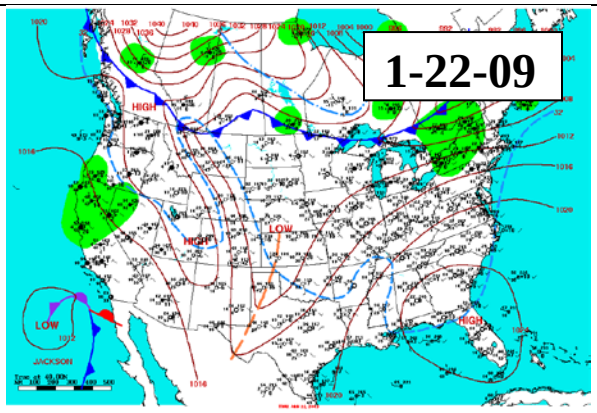
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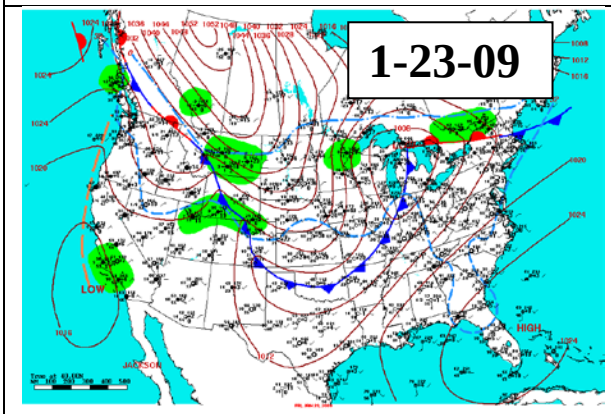
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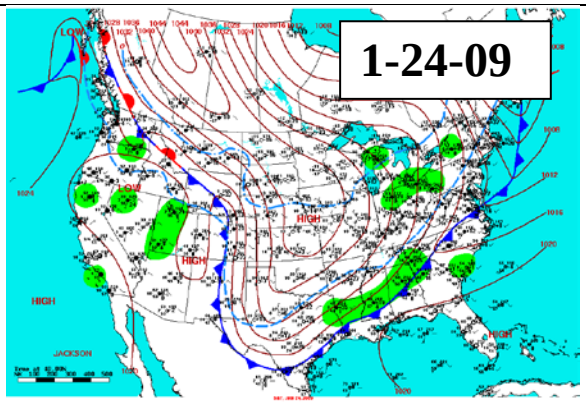
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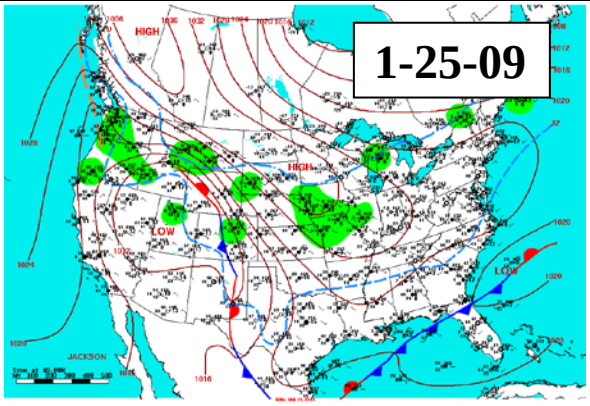
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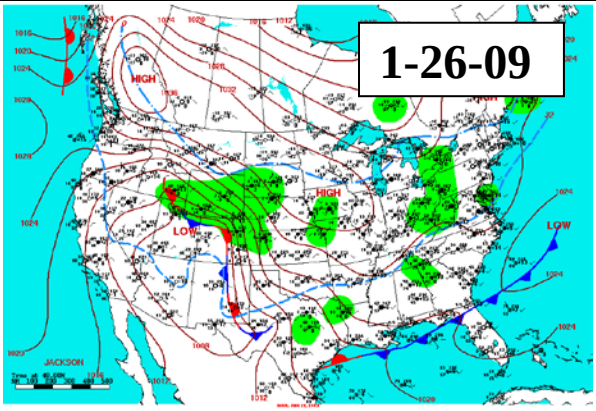
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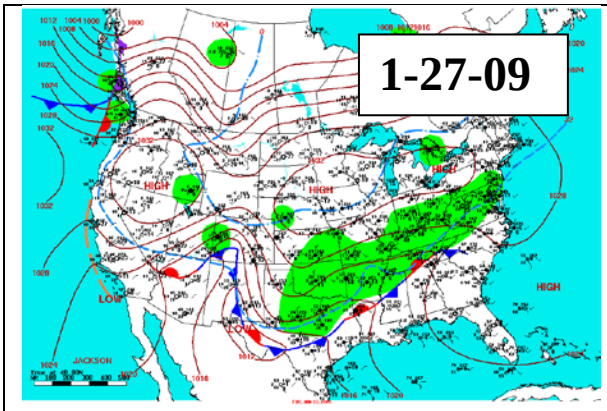
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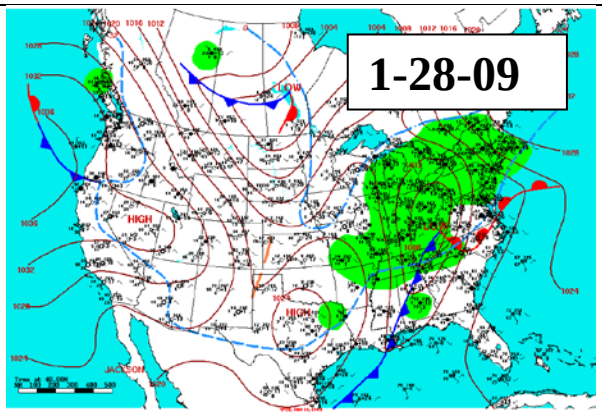
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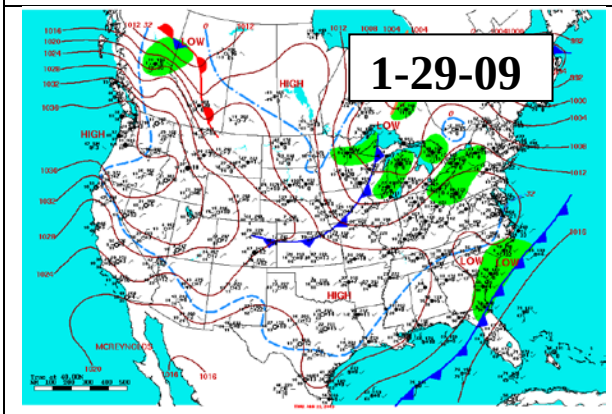
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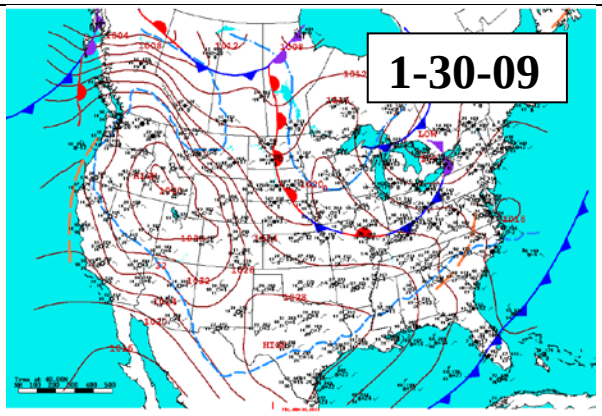
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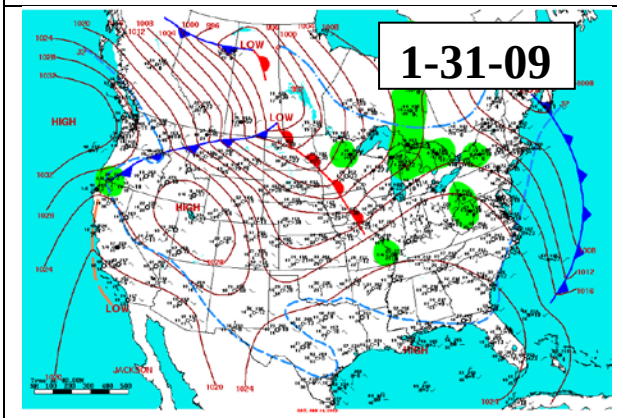
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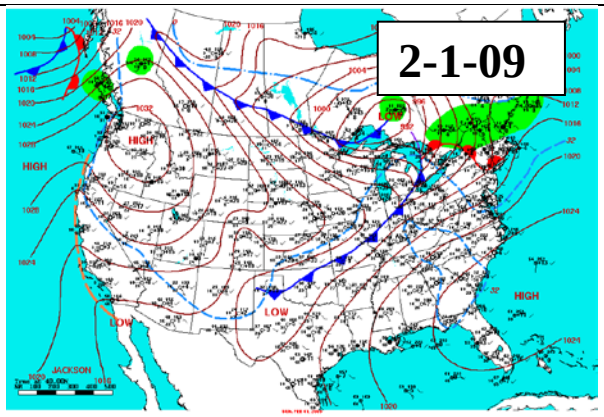
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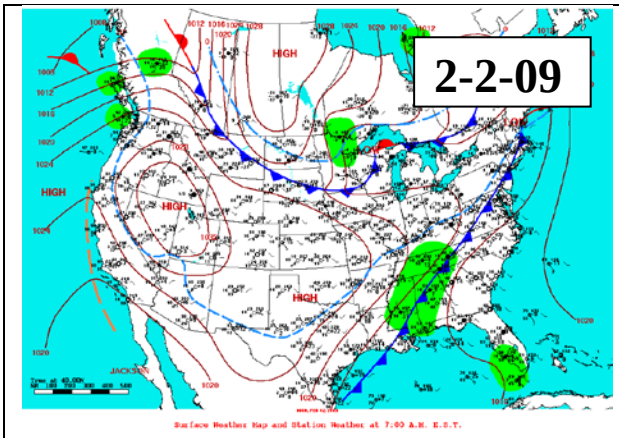
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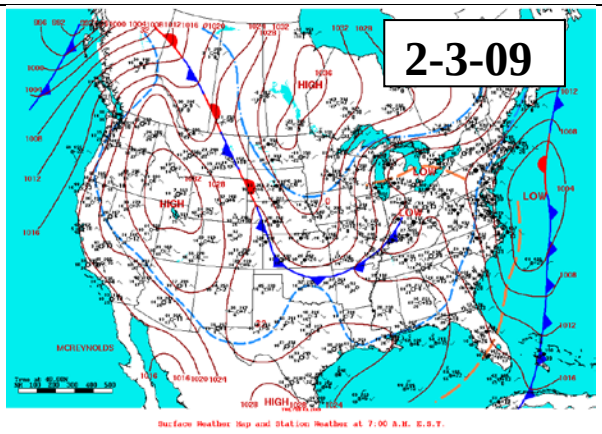
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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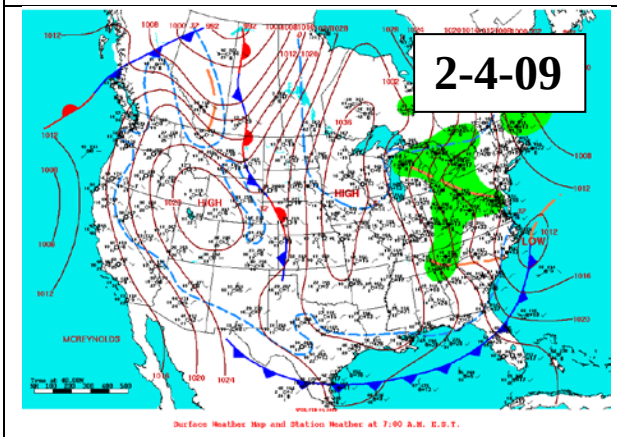
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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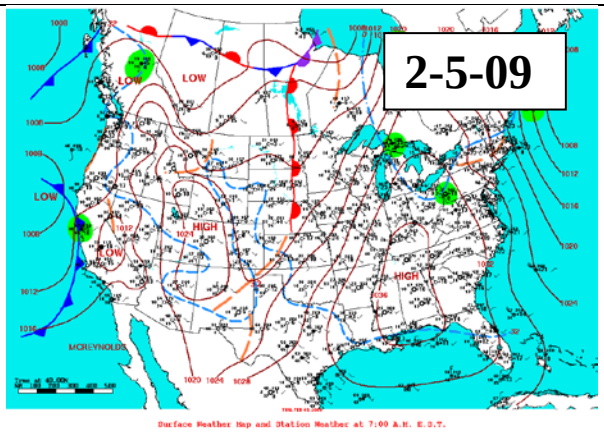
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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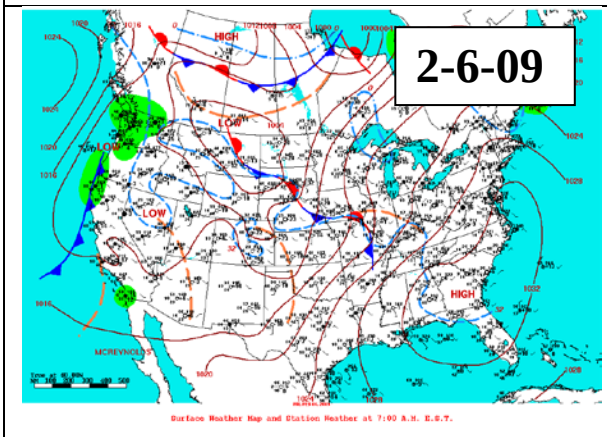
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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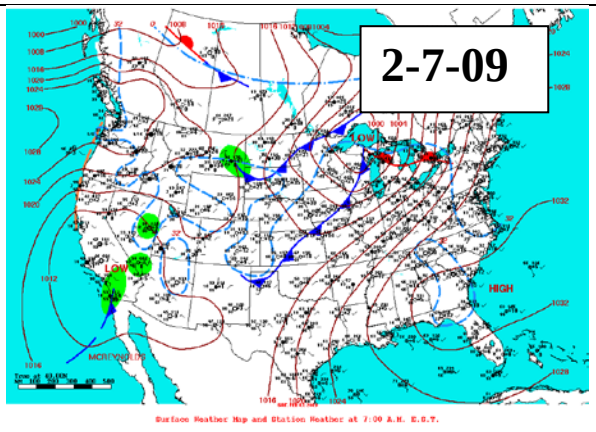
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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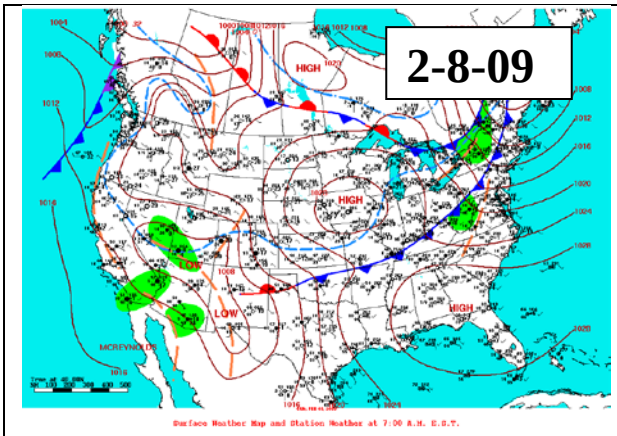
HIGH
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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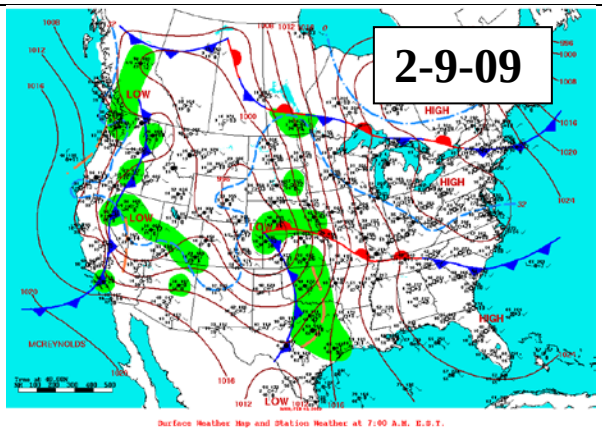
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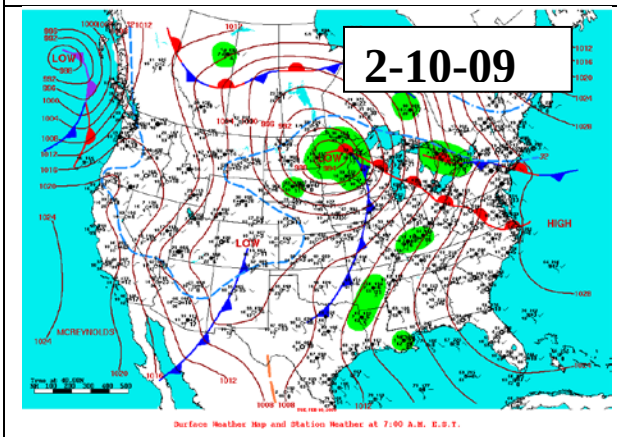
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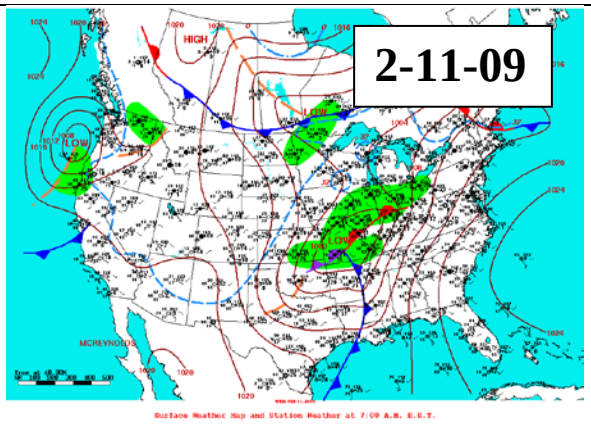
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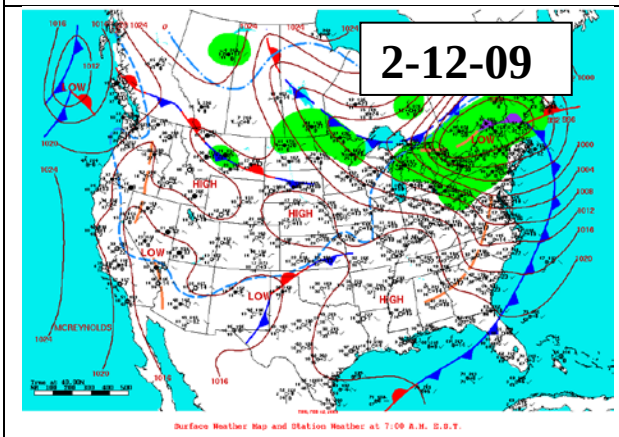
2-12-09
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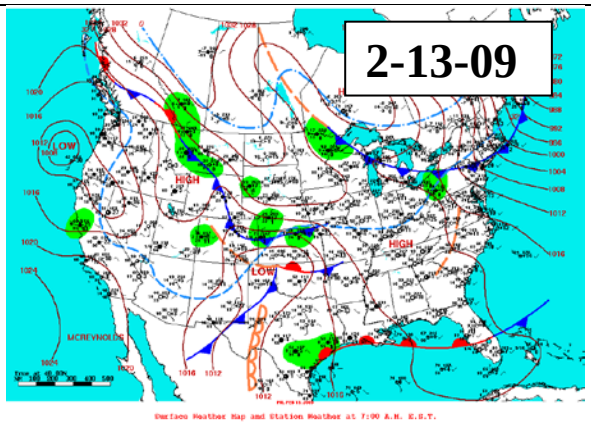
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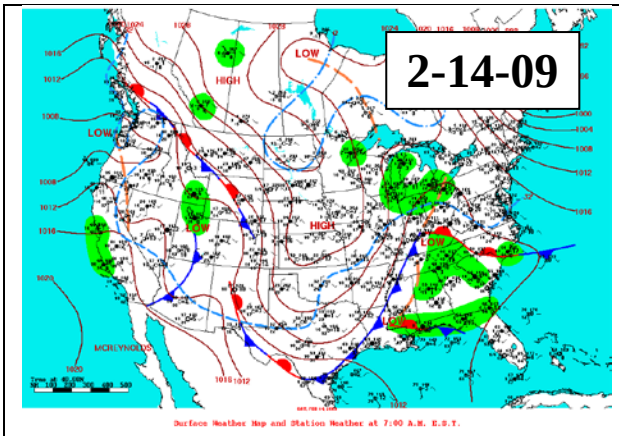
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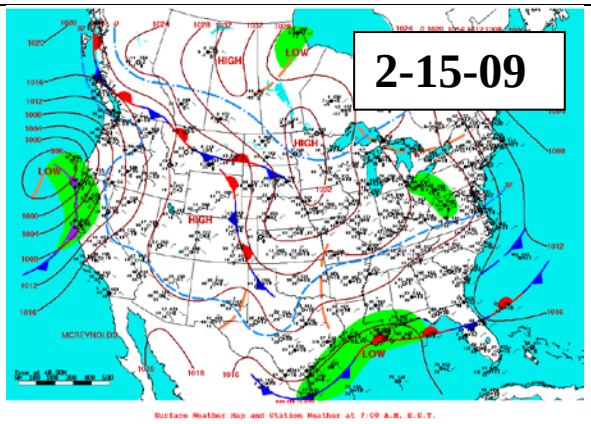
LOW
MORLYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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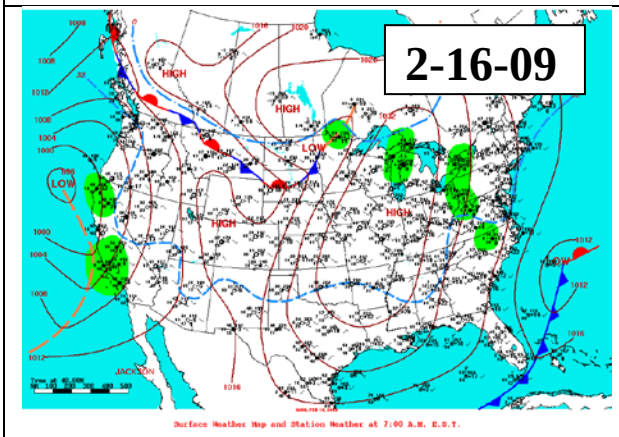
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


2-16-09
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HIGH
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HIGH
HIGH
LOW
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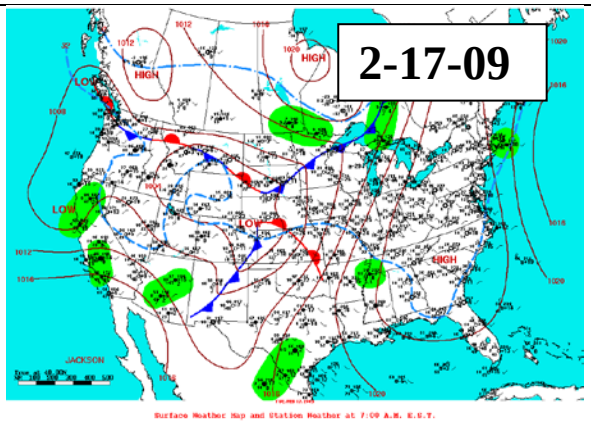
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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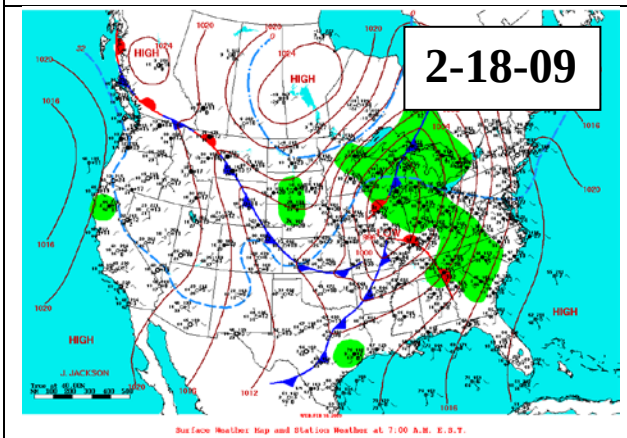
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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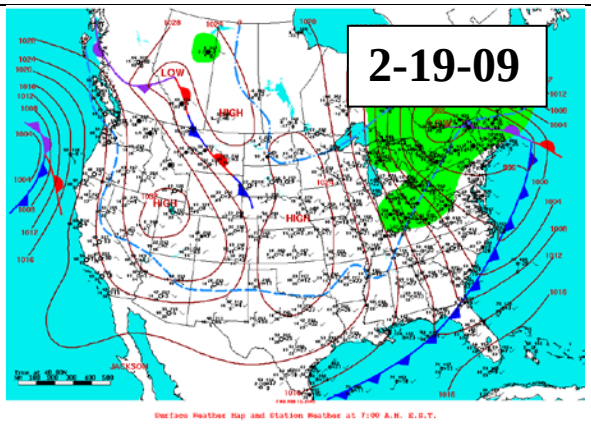
J JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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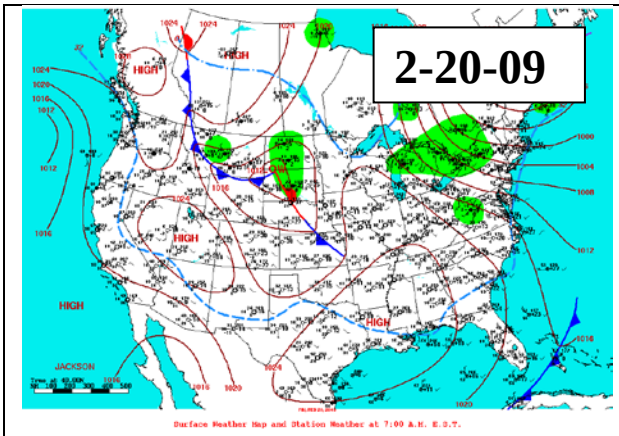
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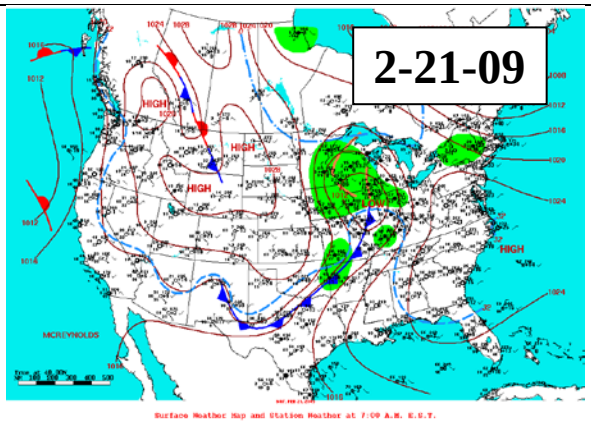
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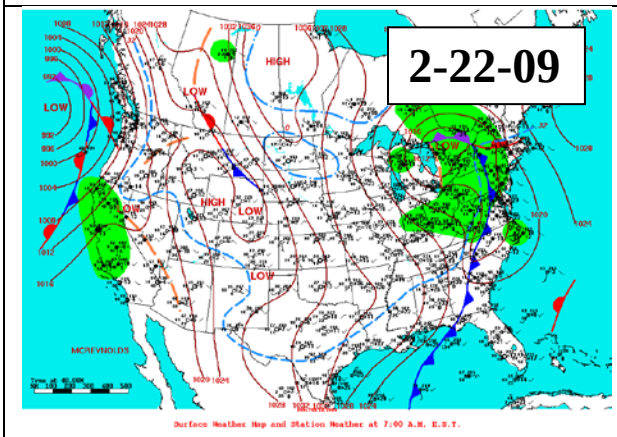
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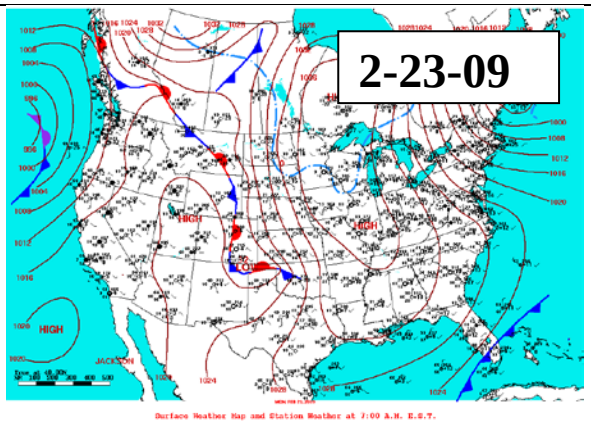
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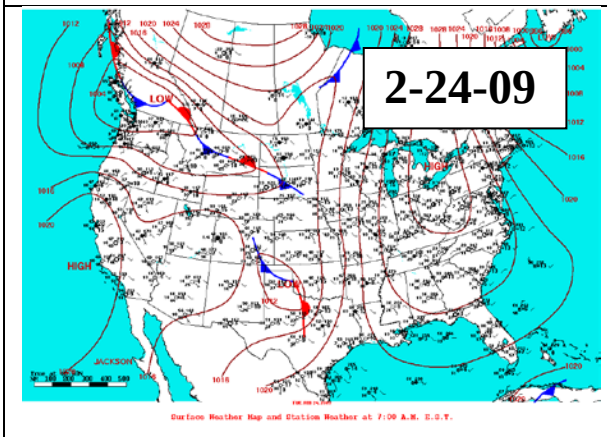
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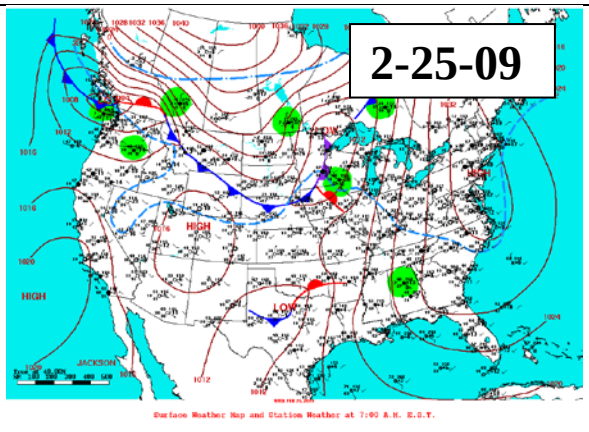
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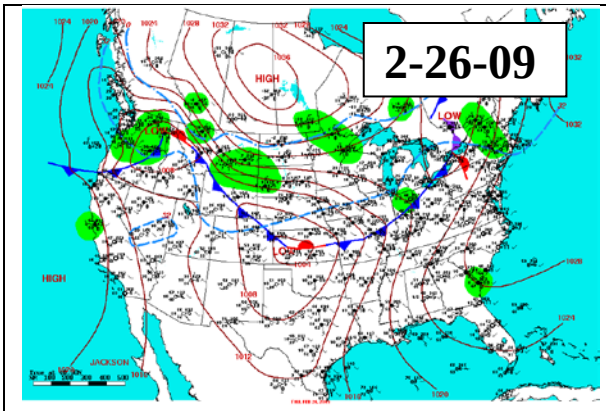

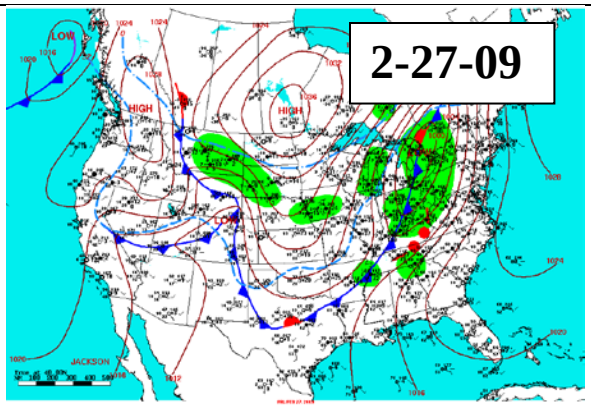

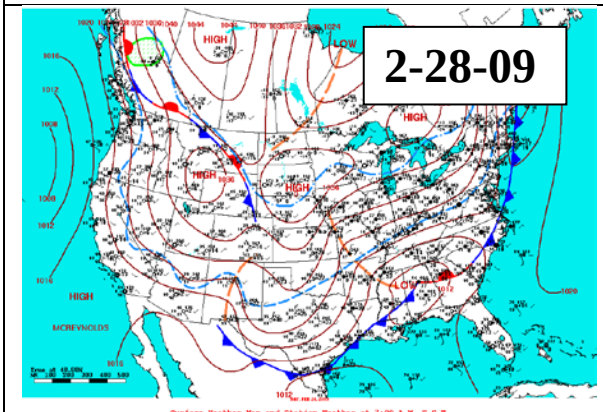

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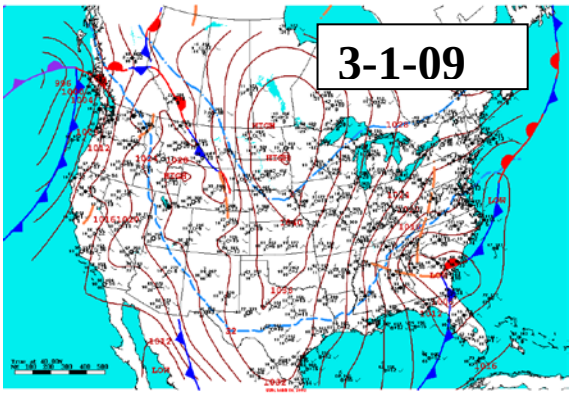

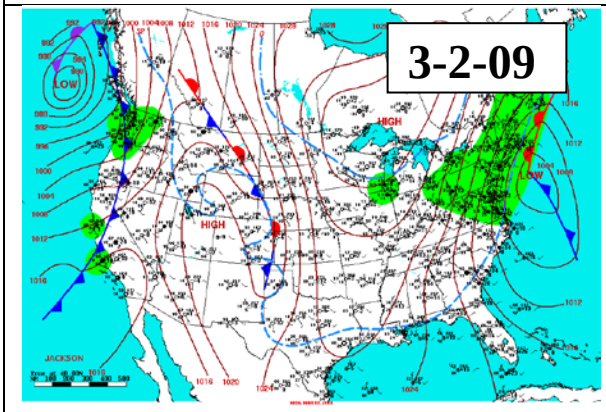

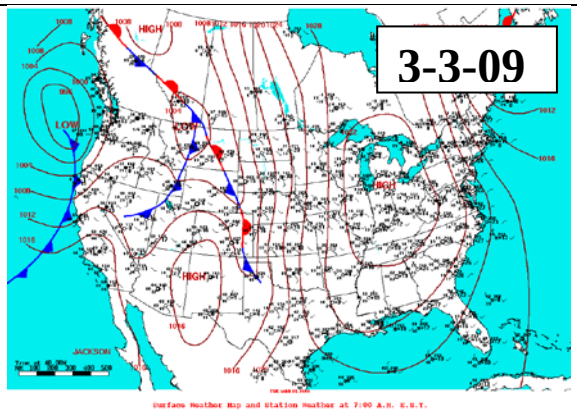

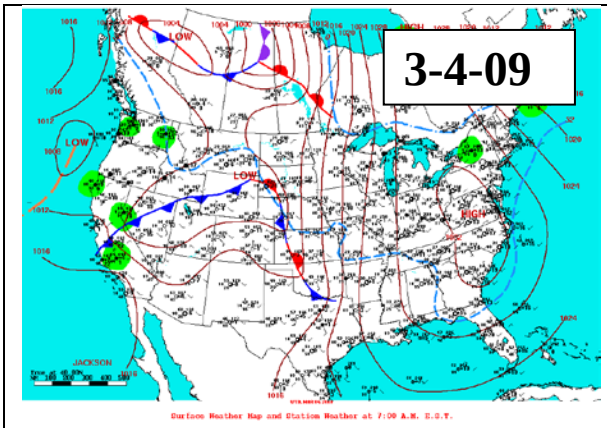
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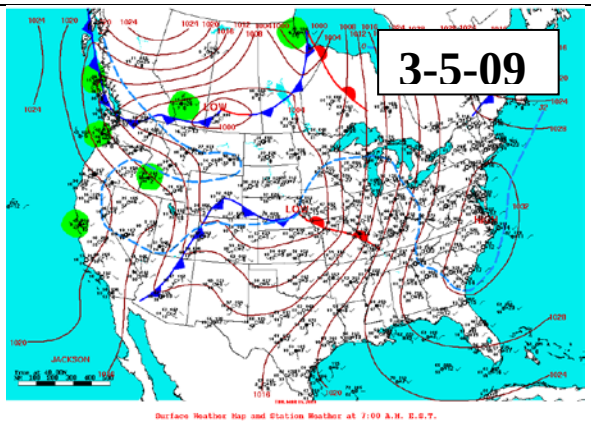
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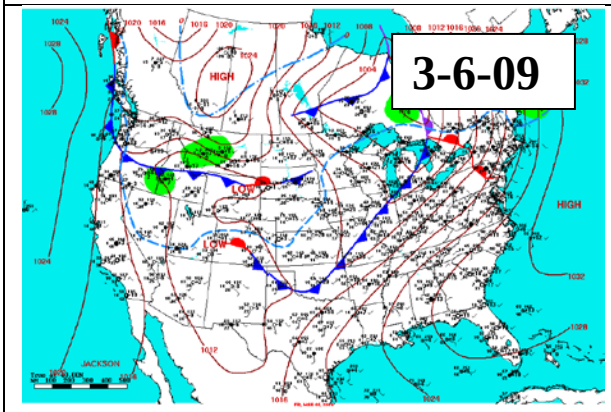
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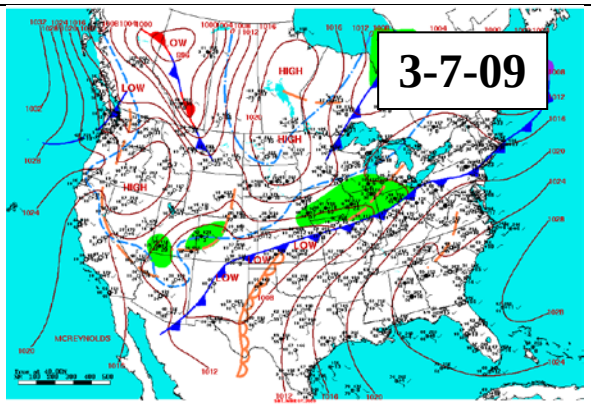
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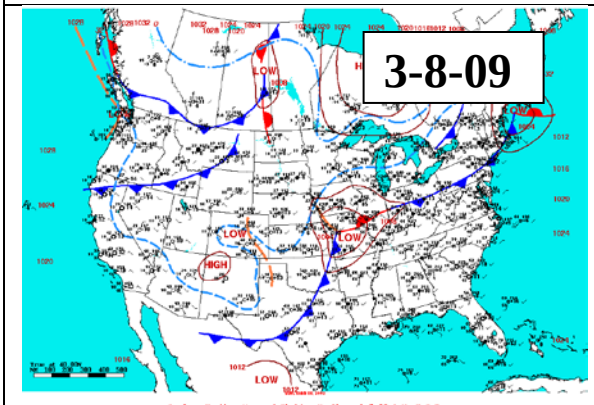
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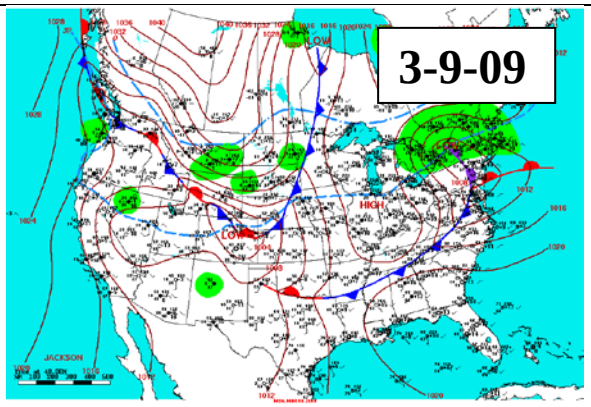
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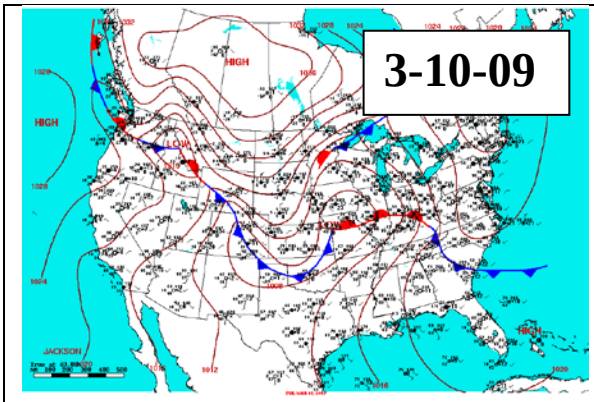
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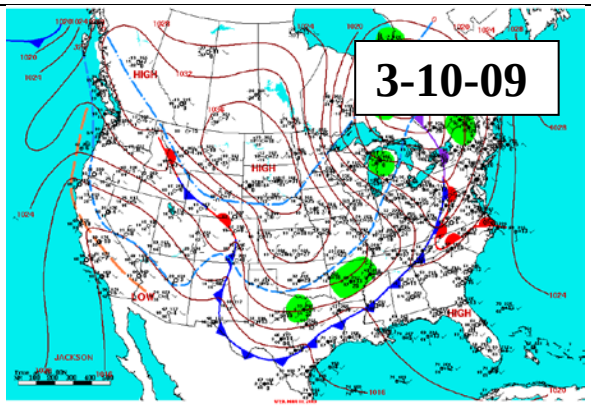
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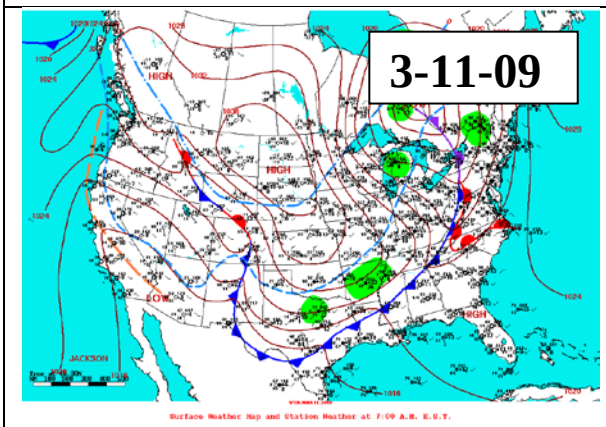
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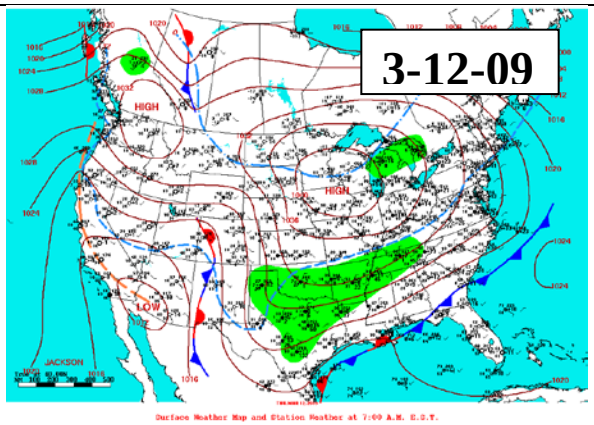
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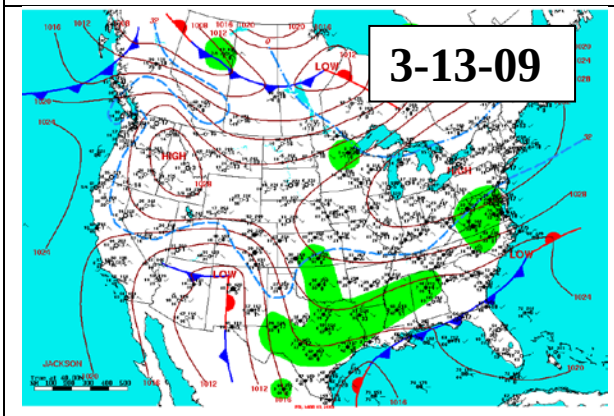
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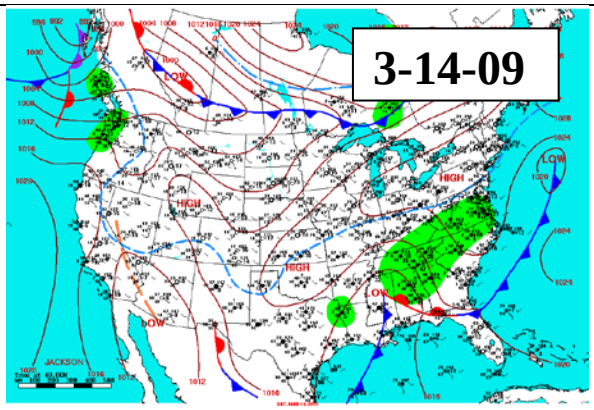
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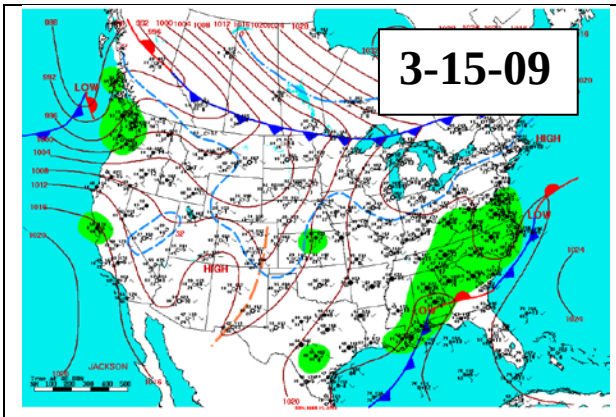
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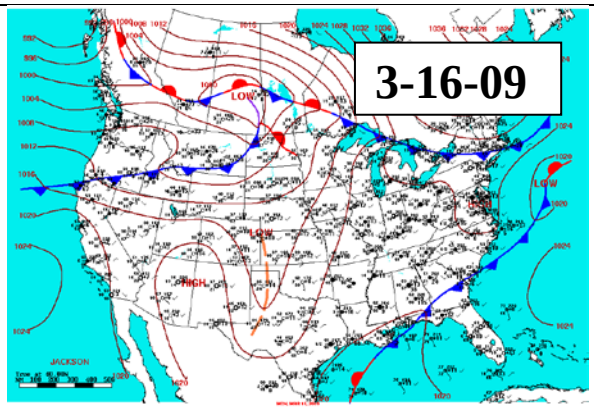
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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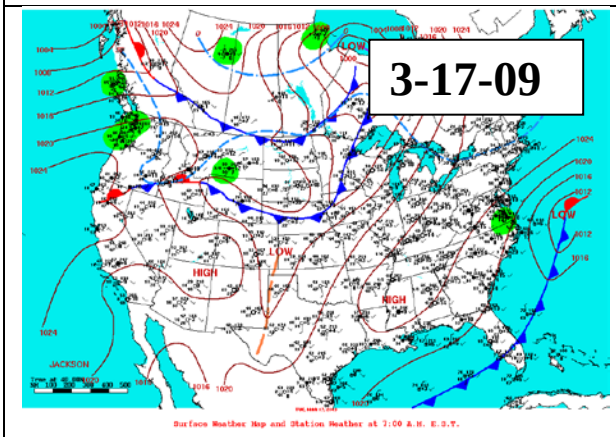
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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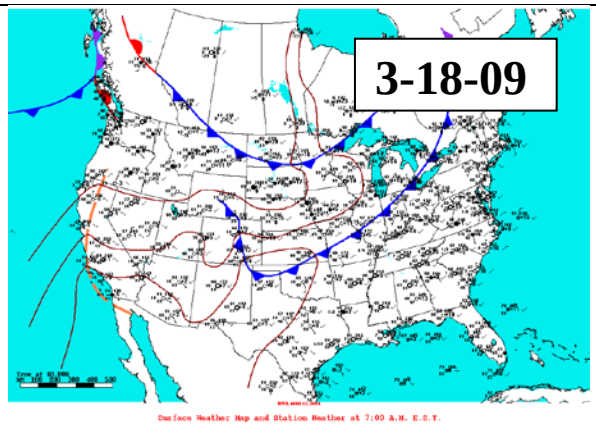
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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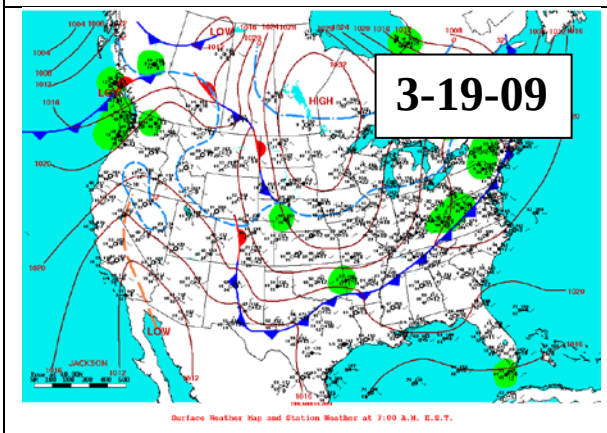
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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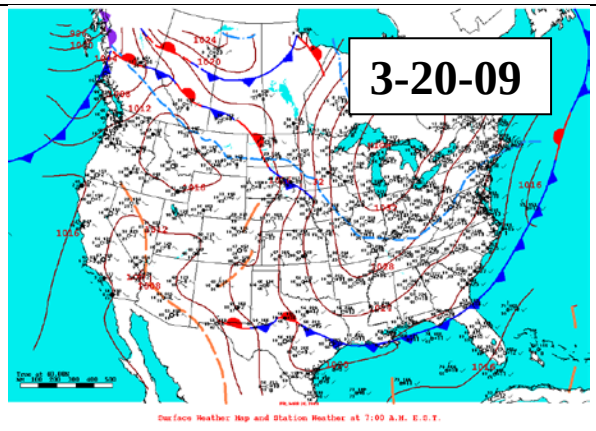
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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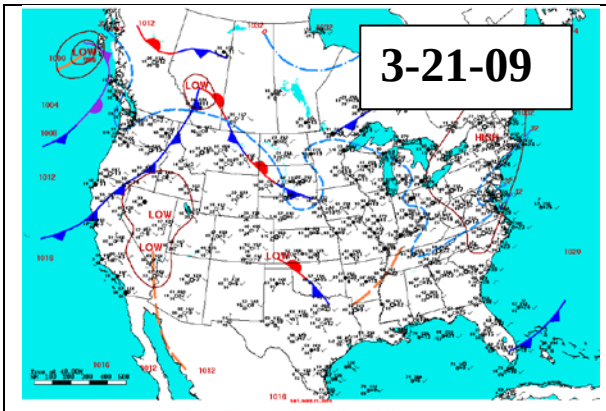
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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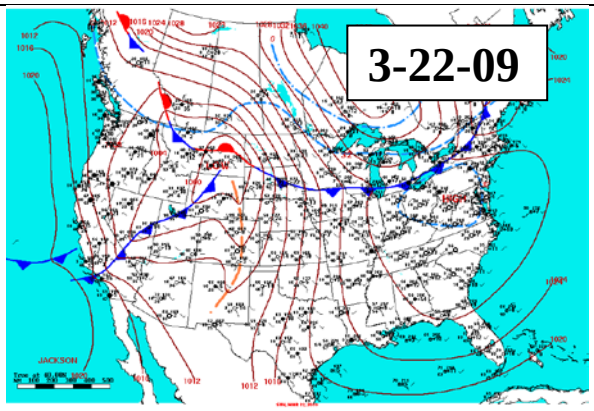
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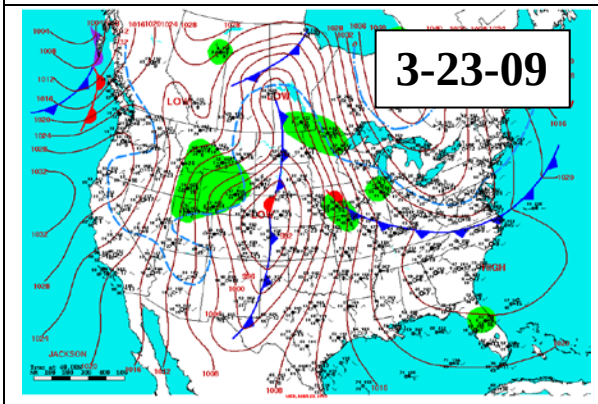
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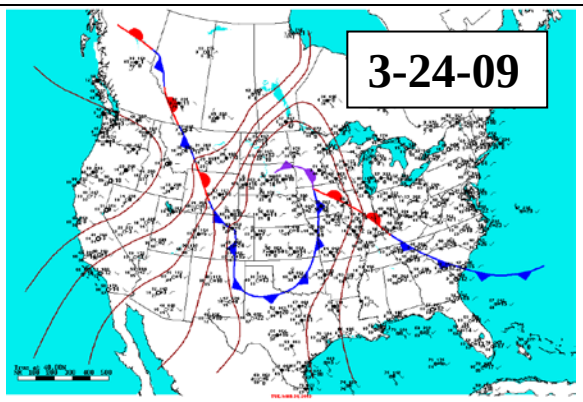
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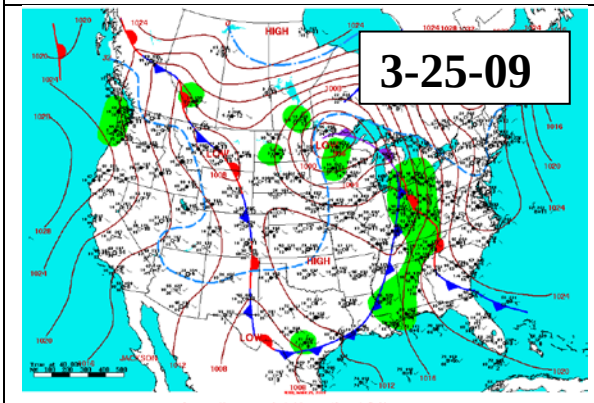
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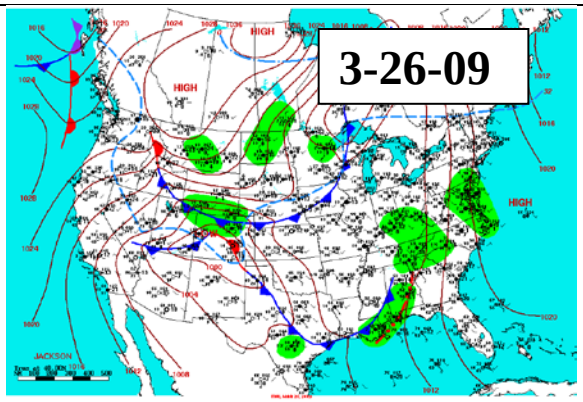
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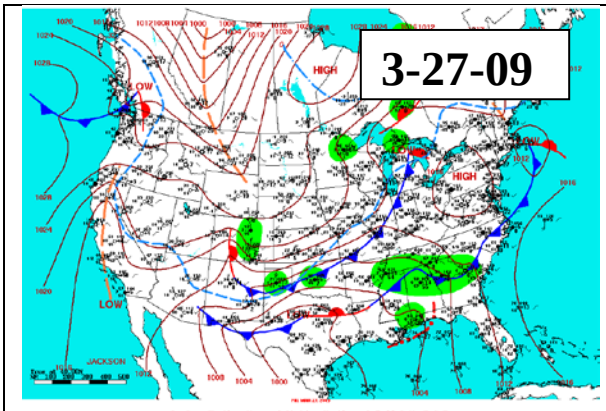
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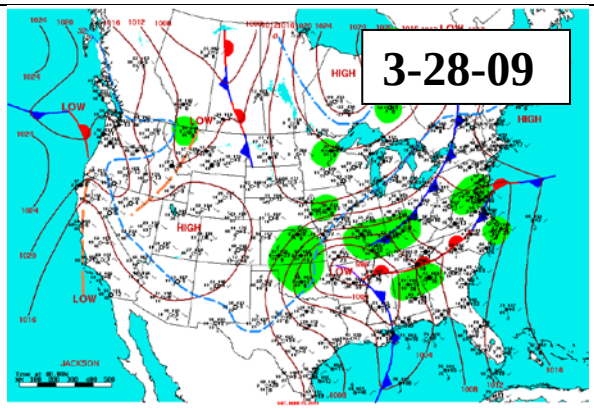
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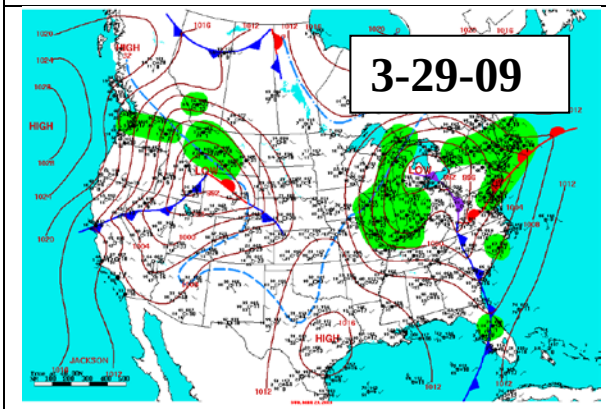
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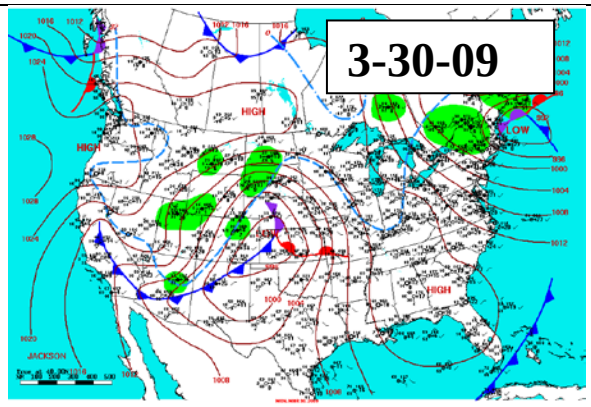
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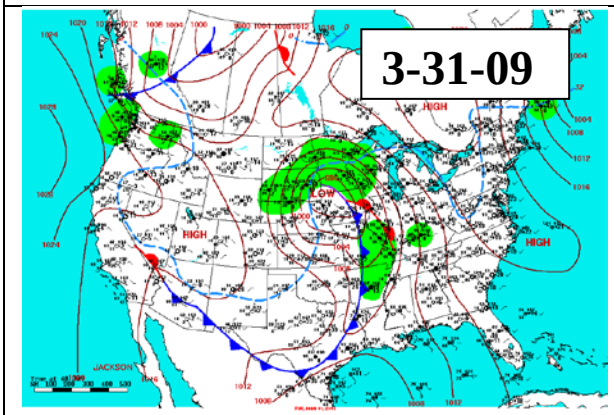
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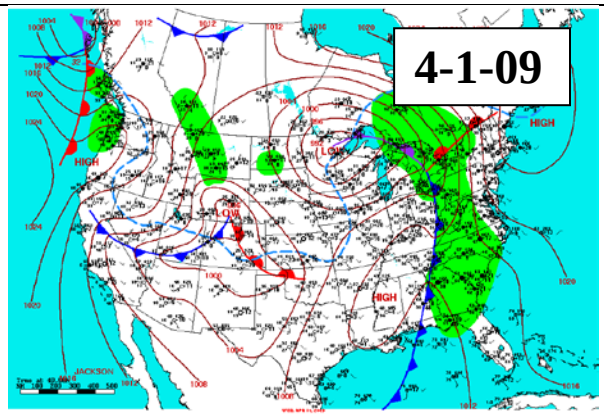
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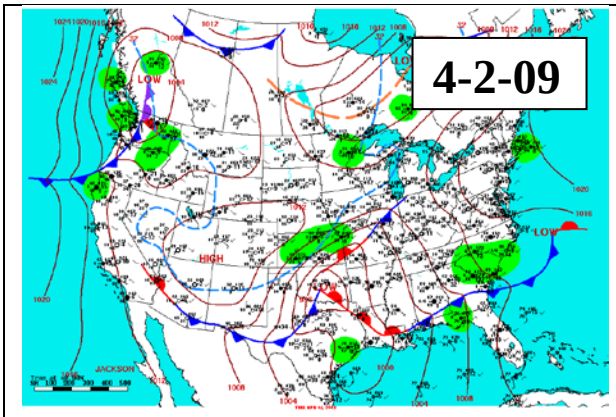
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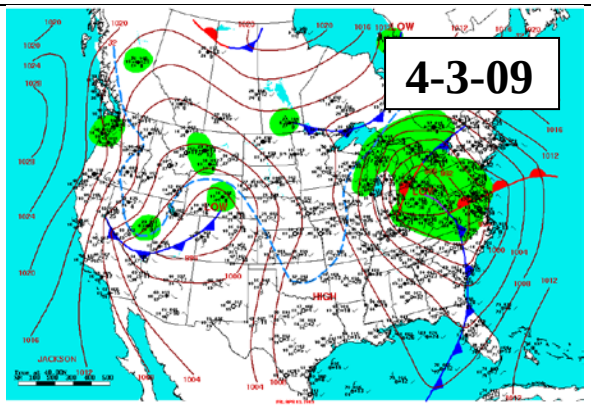
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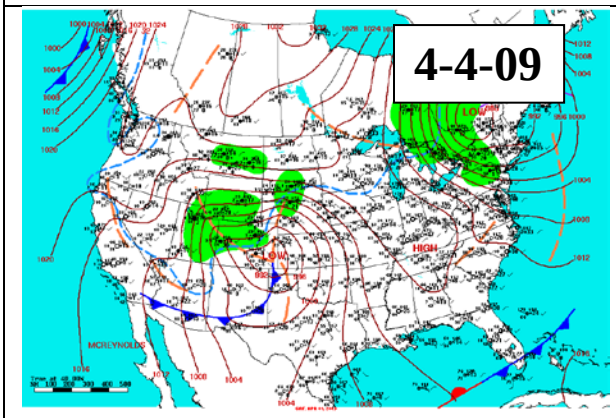
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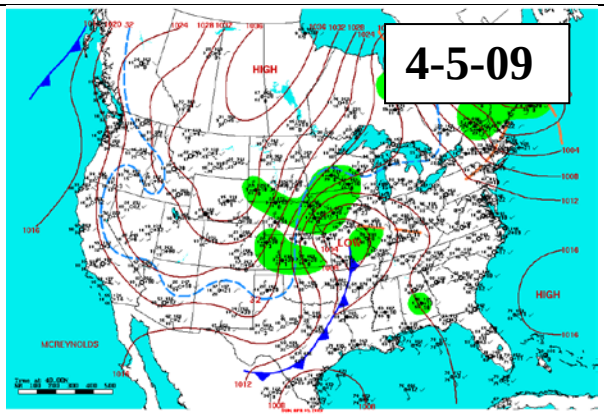
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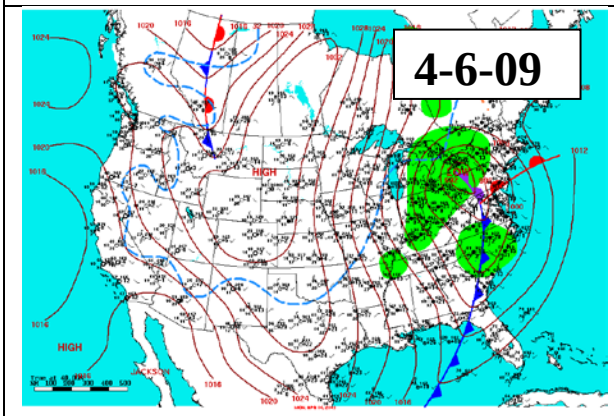
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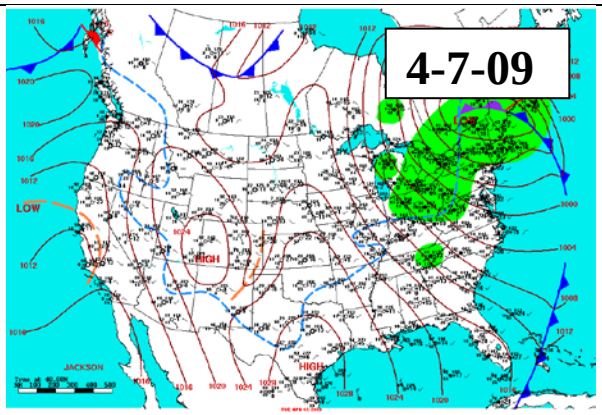
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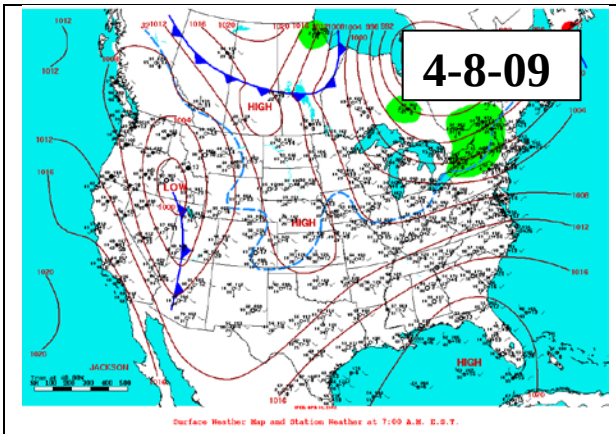
JACKSON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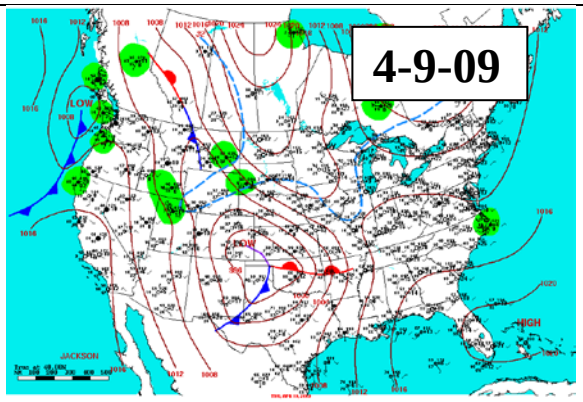
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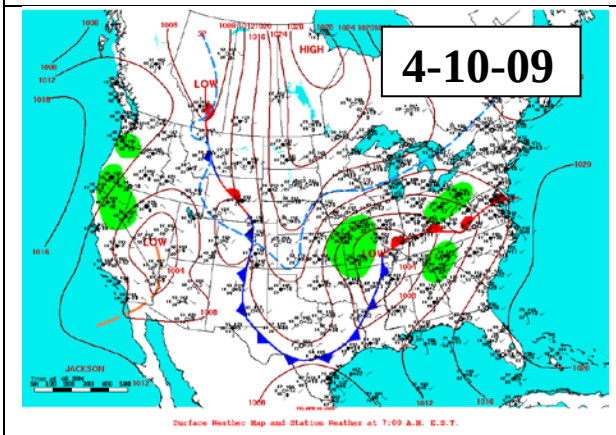
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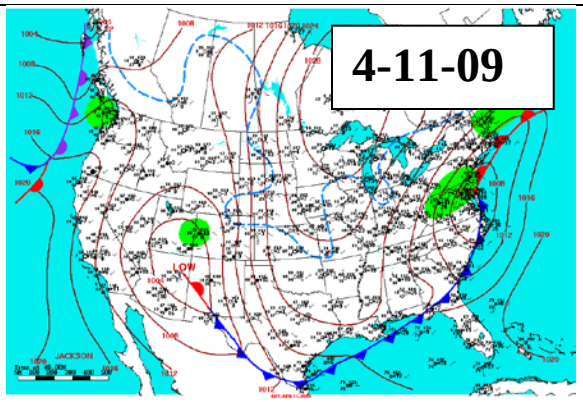
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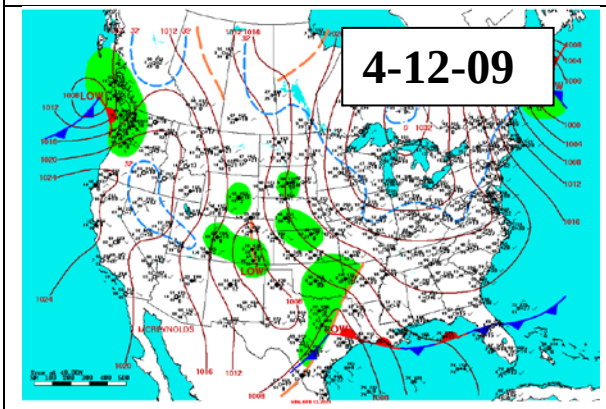
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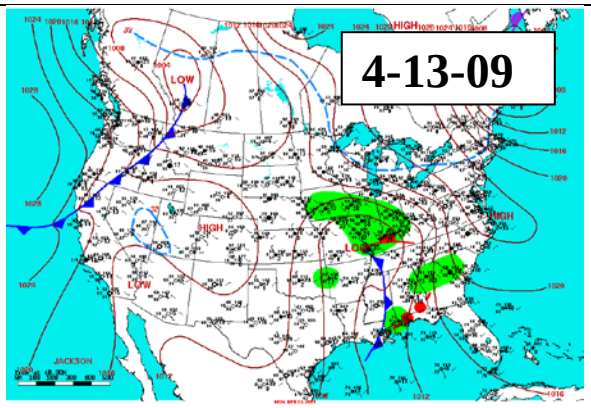
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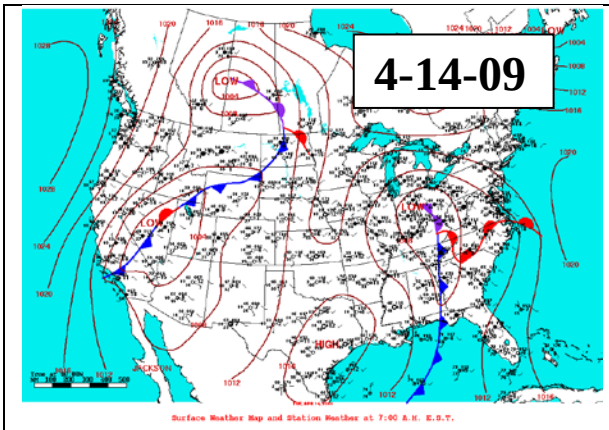
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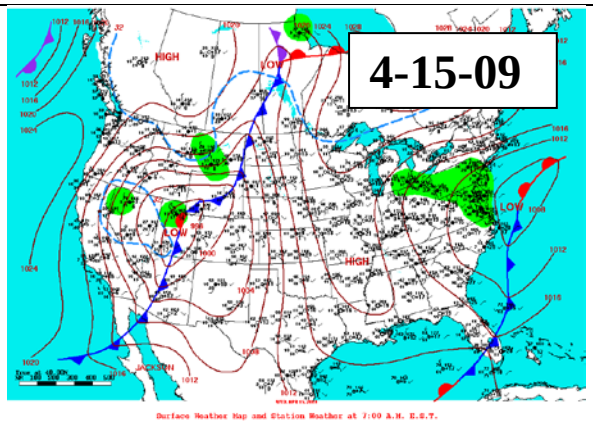
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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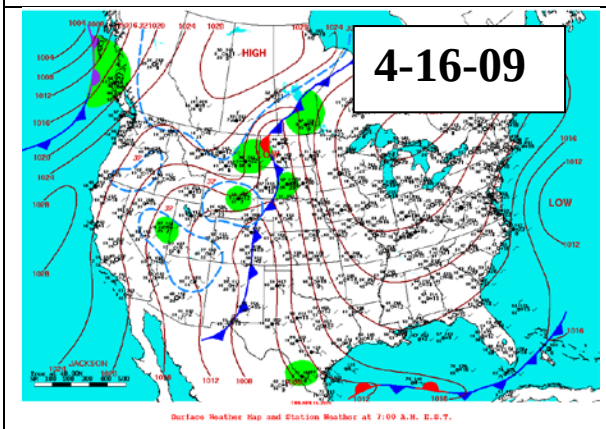
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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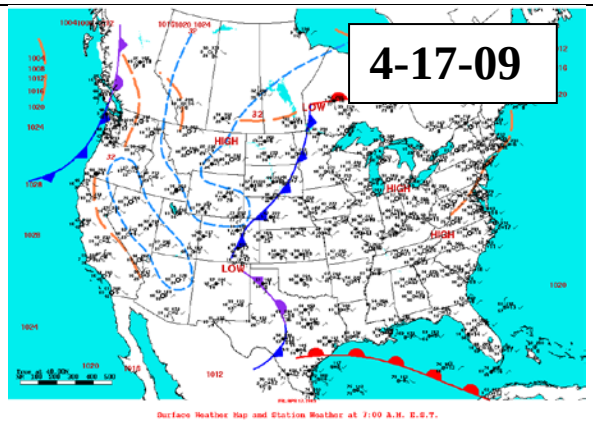
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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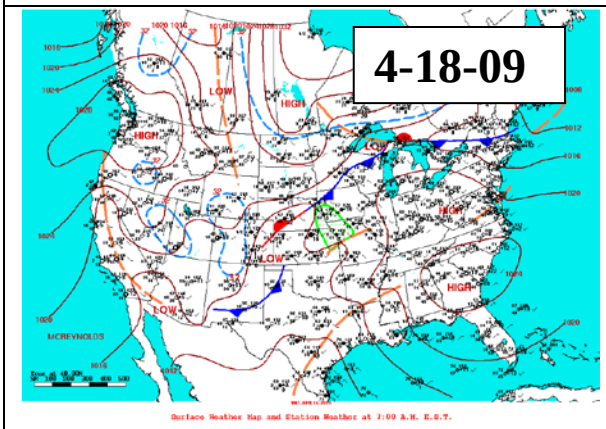
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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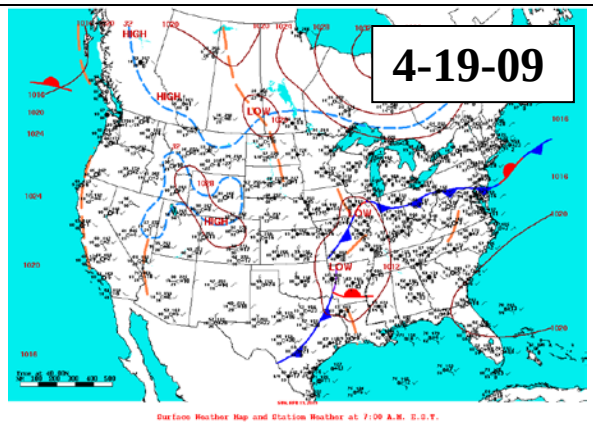
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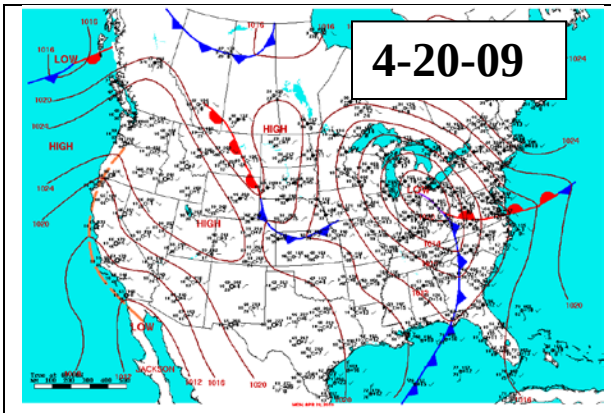
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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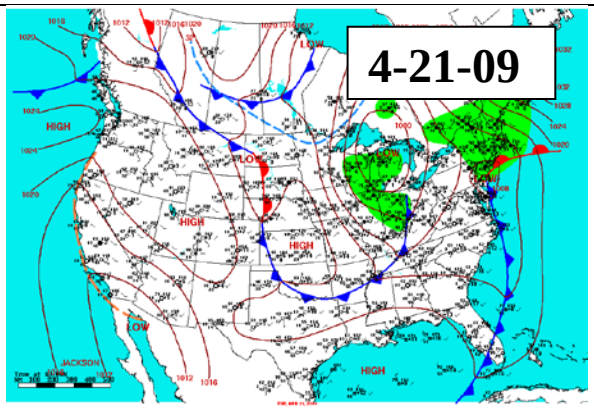
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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JACKSON
HIGH
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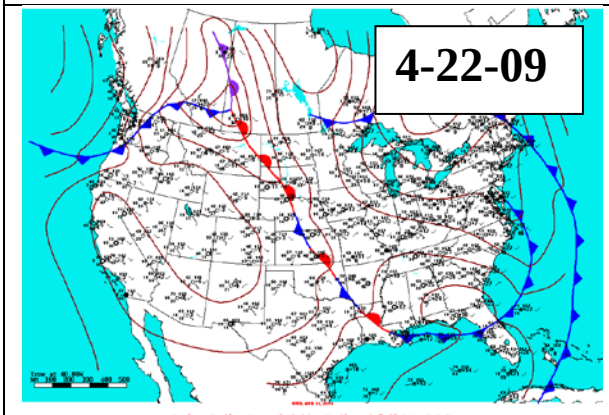
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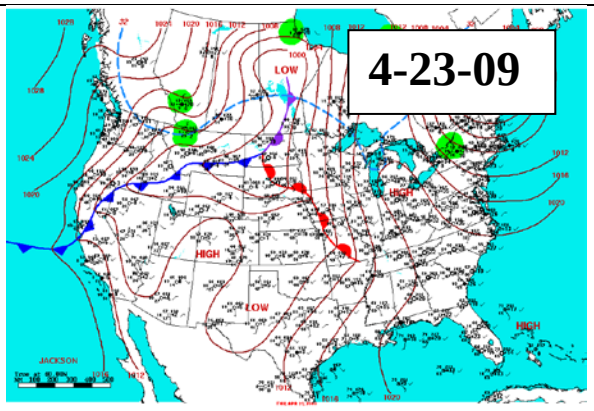
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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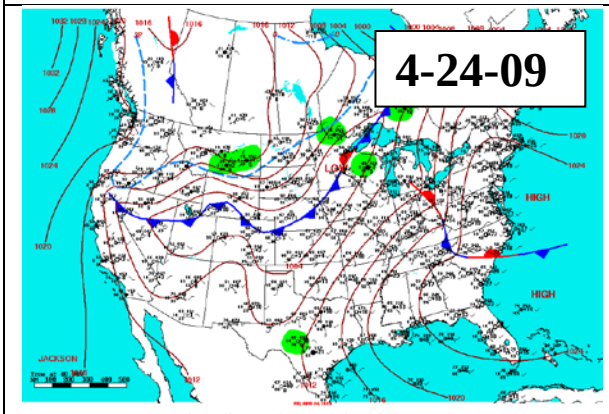
HIGH
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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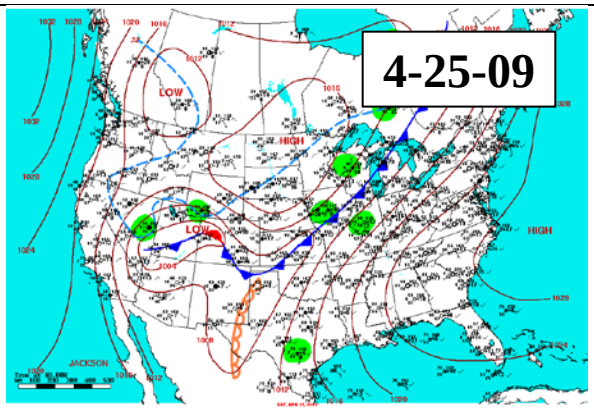
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


4-25-09
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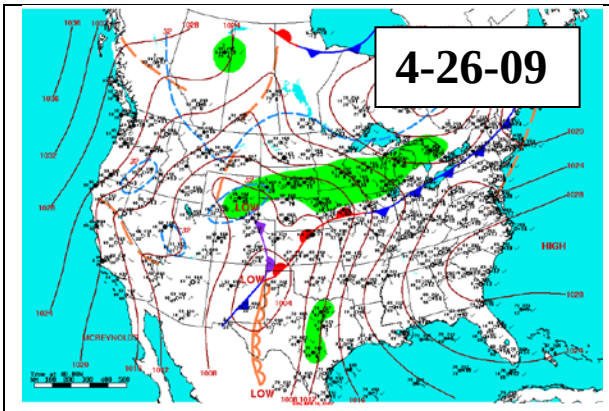
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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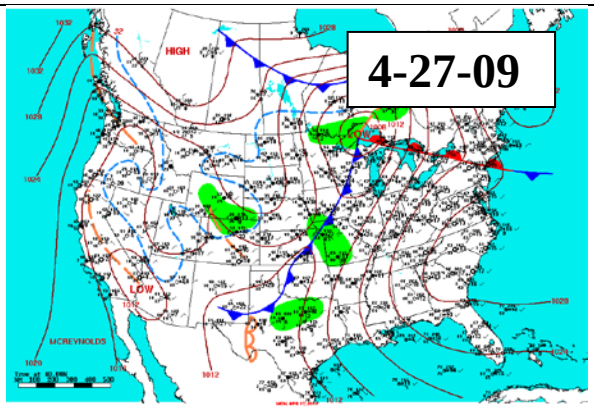
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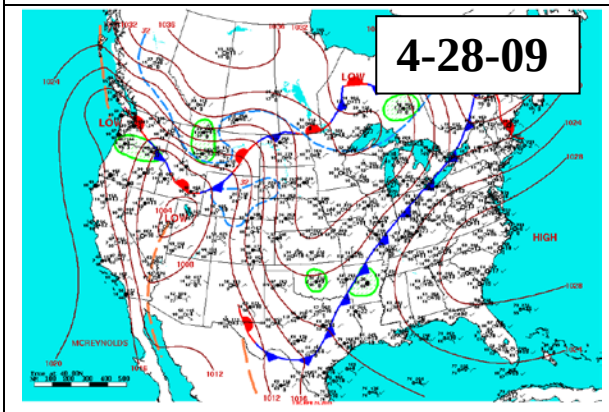
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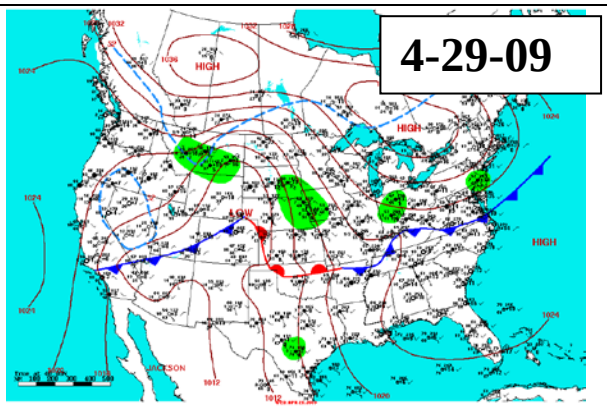
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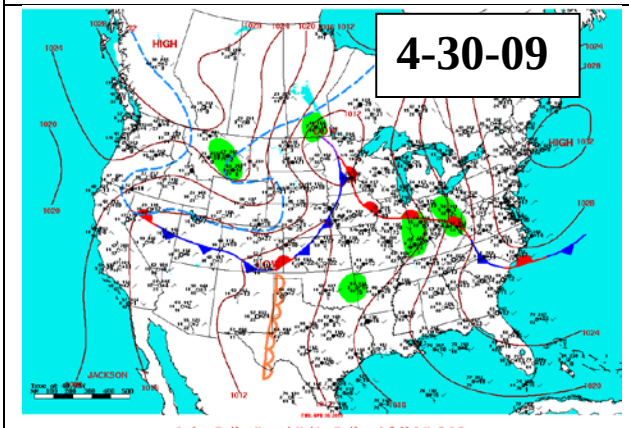
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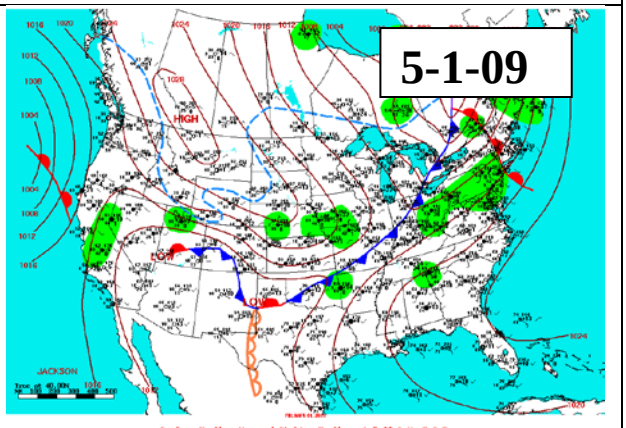
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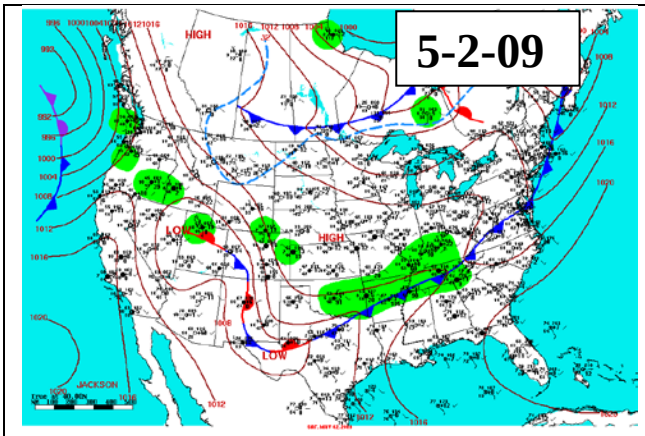
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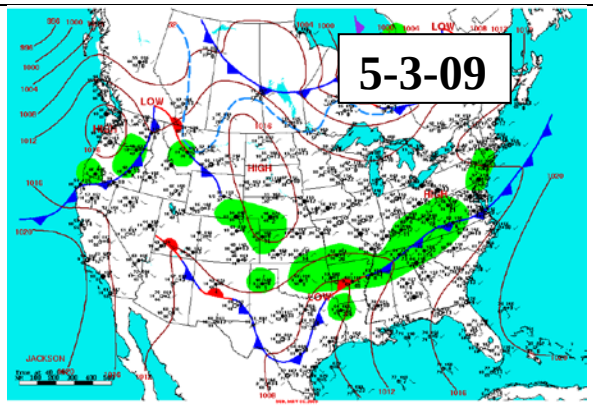
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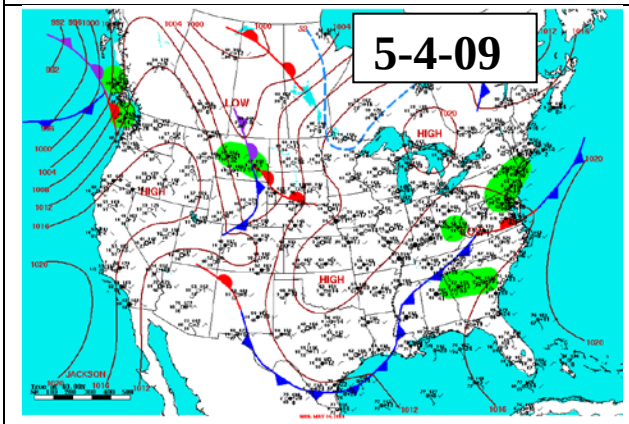
JACKSON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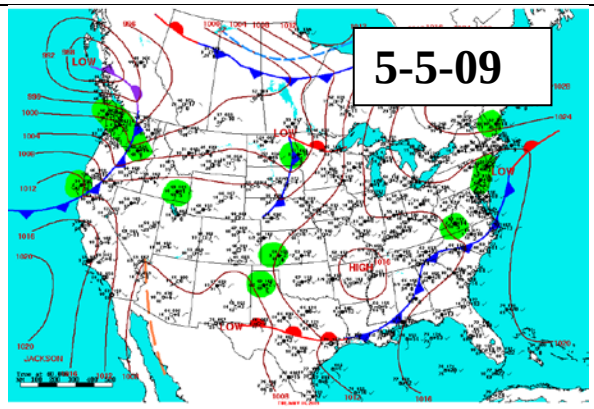
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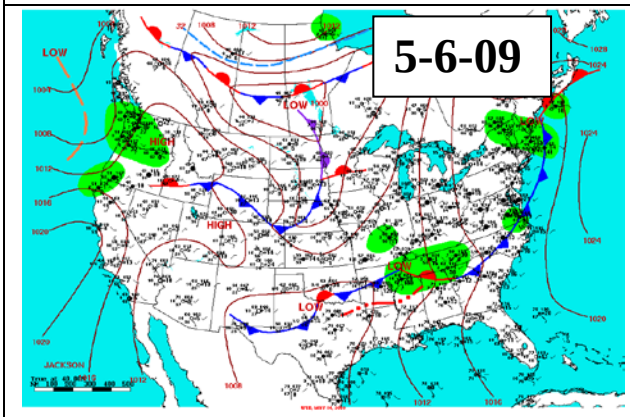
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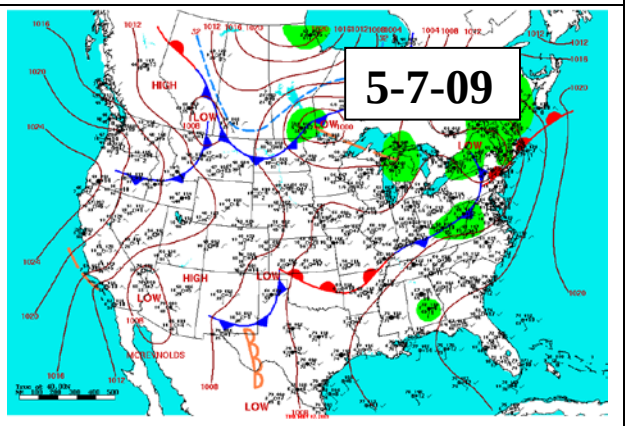
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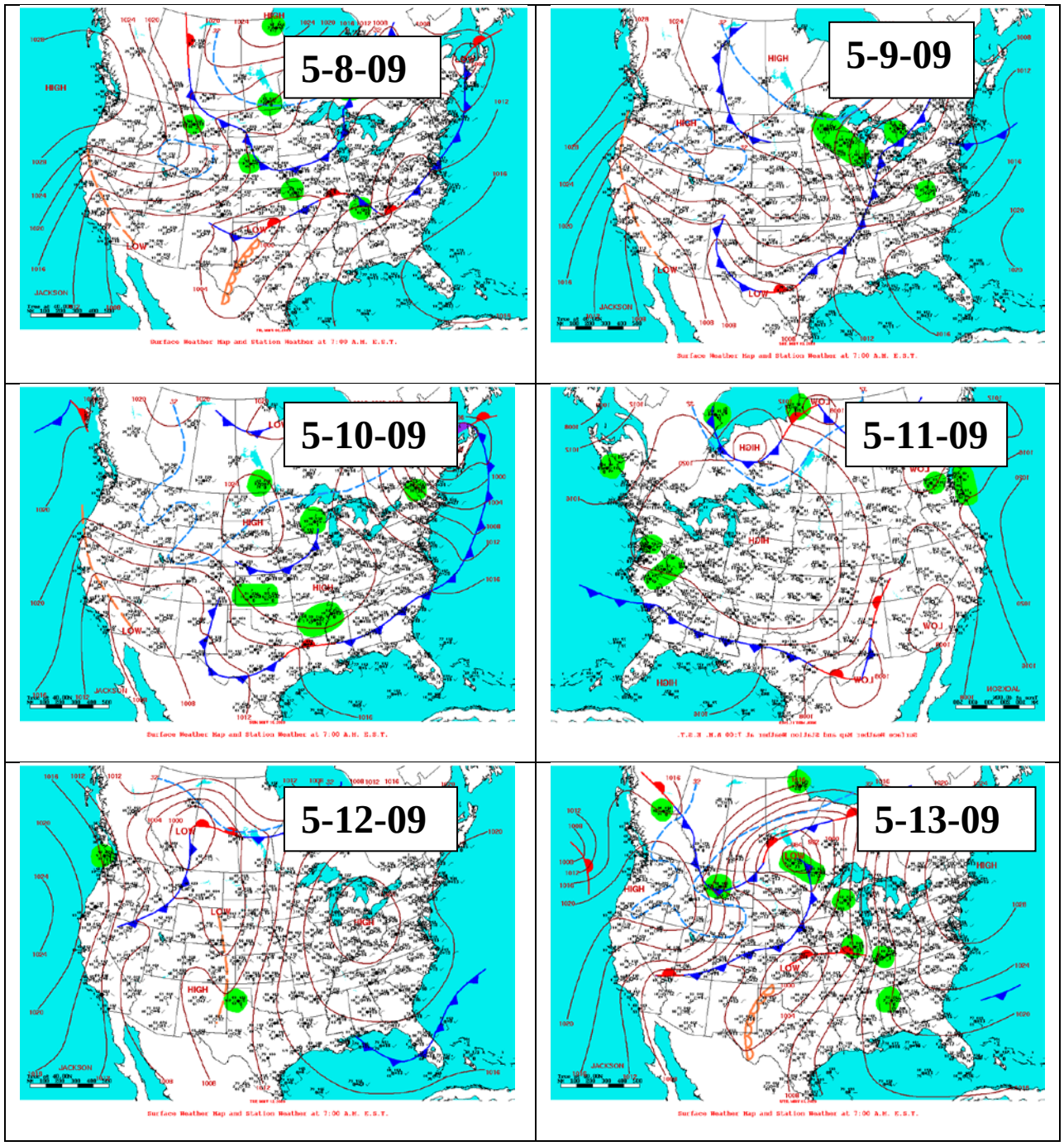
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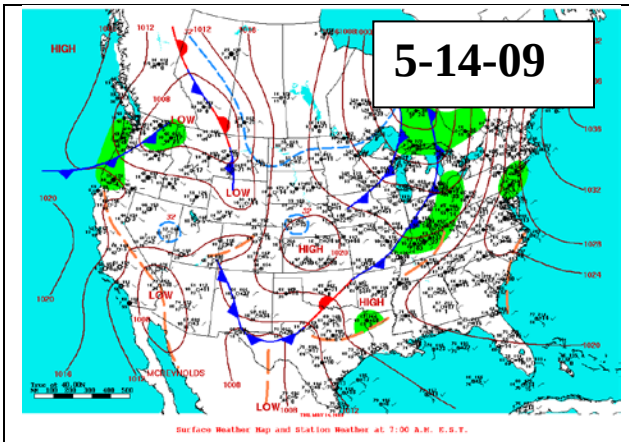
5-12-09
5-13-09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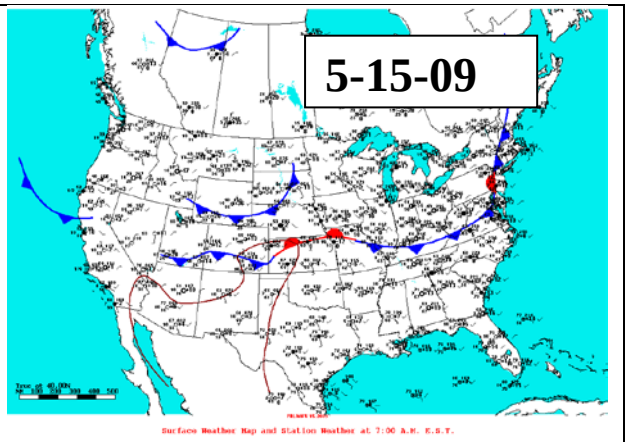
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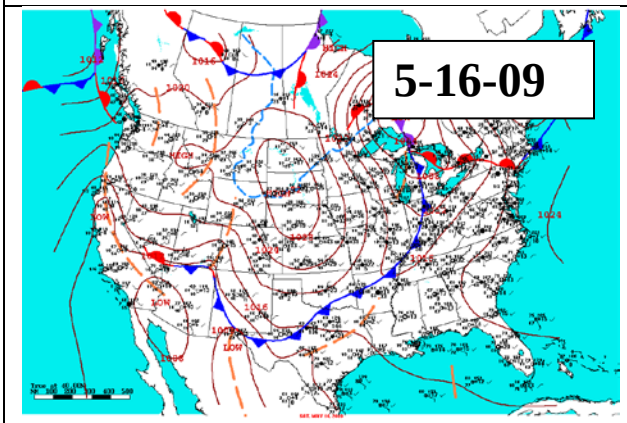
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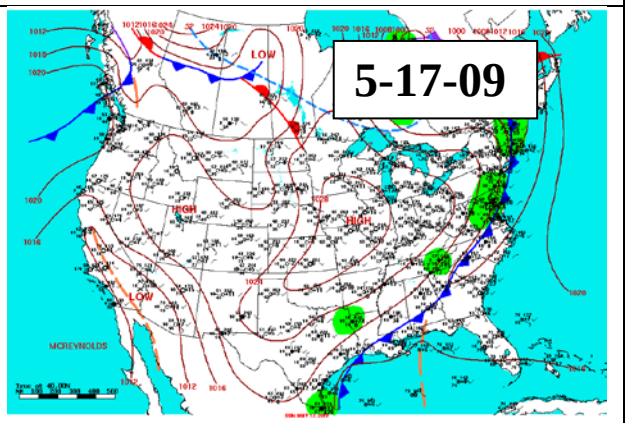
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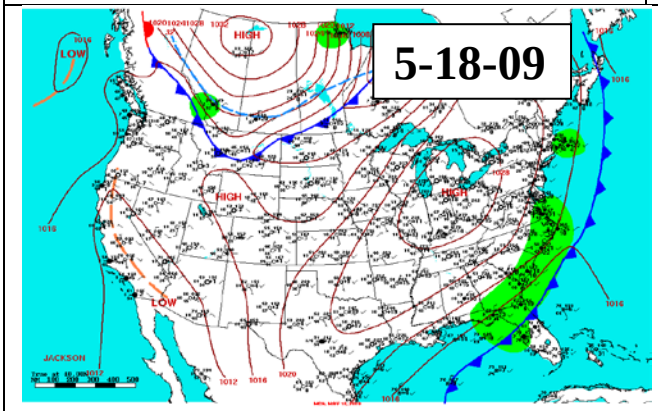
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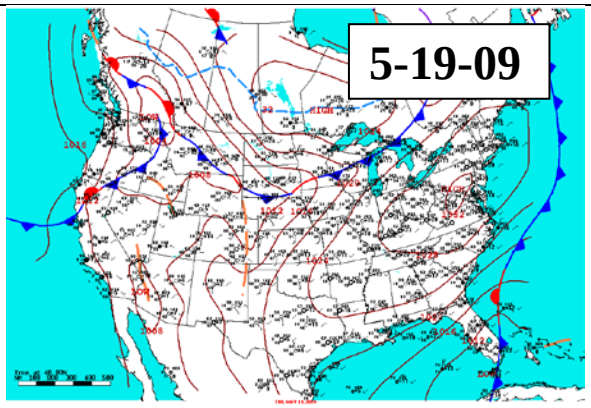
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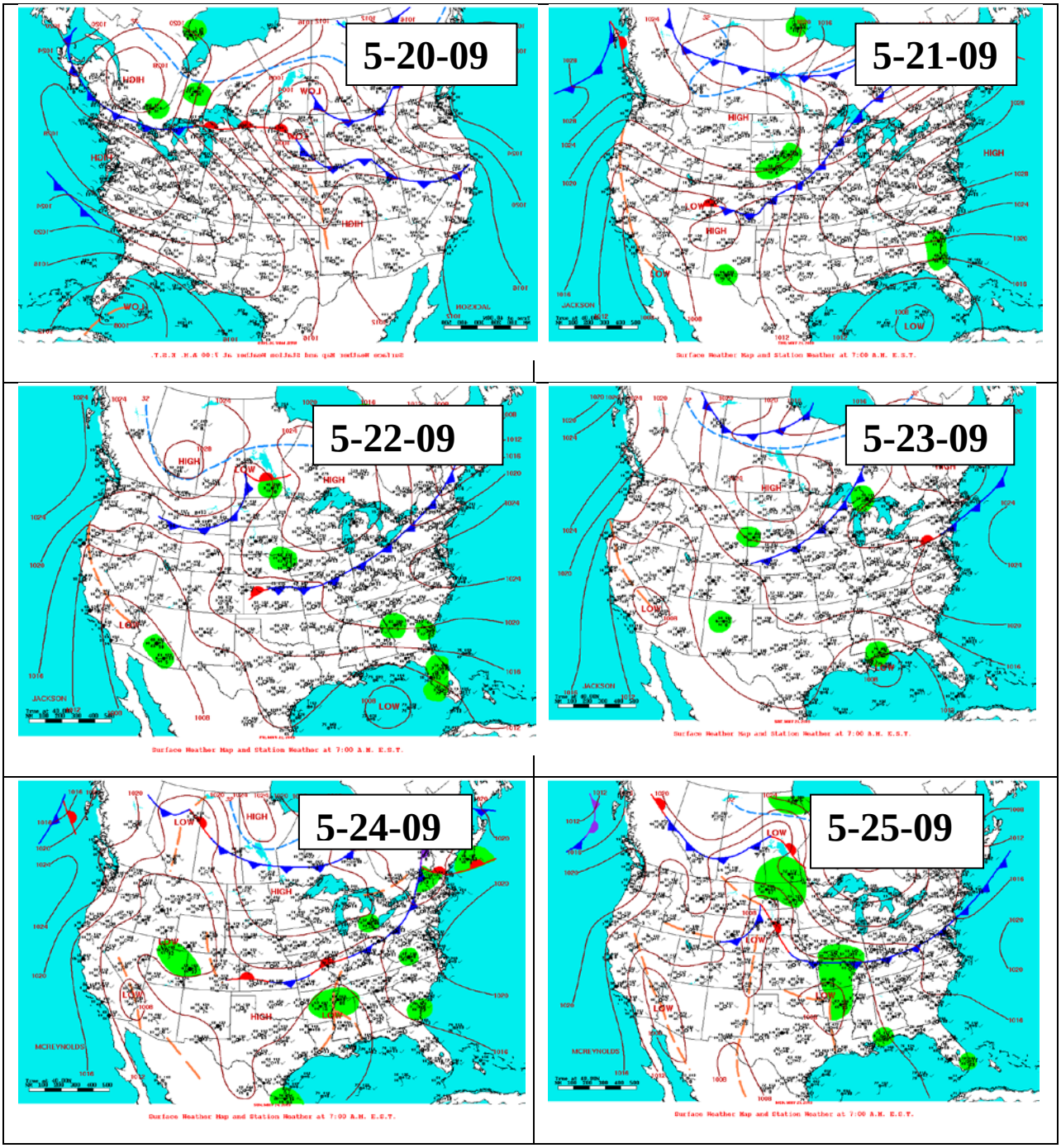
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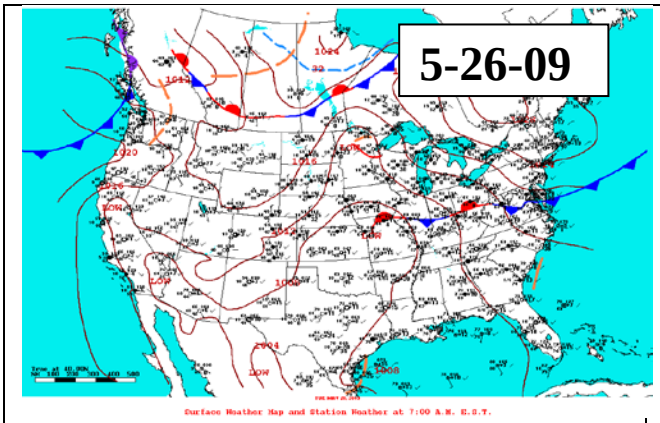
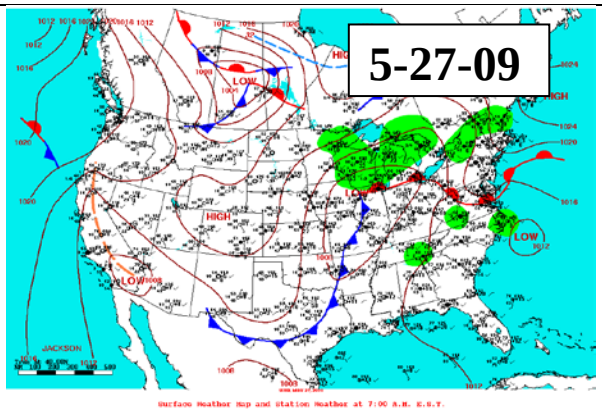
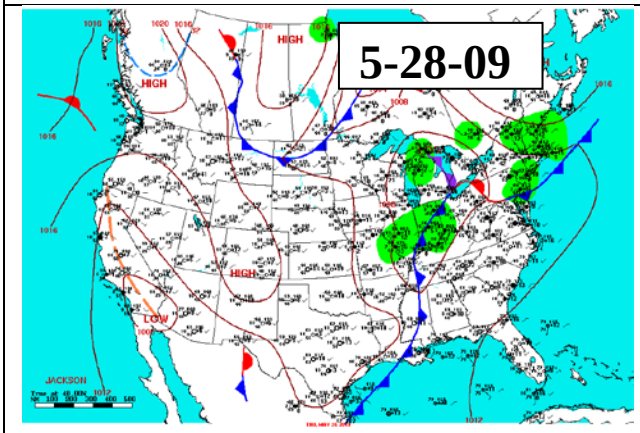
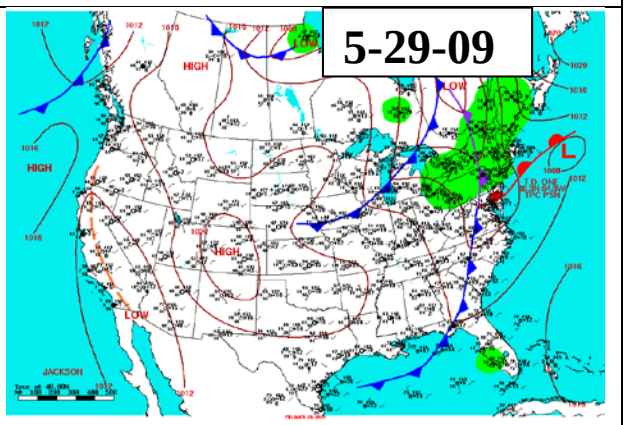
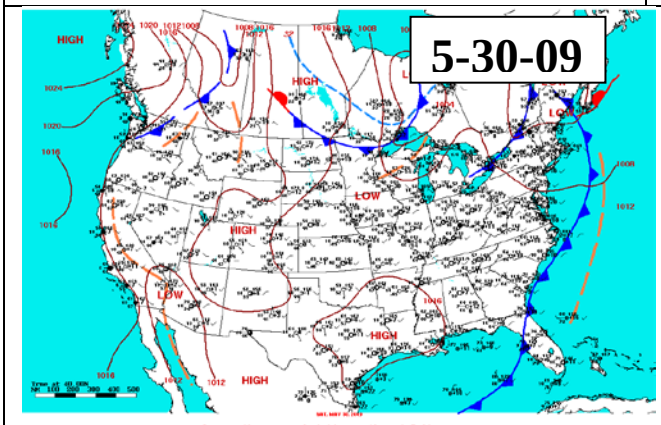
5-25-09

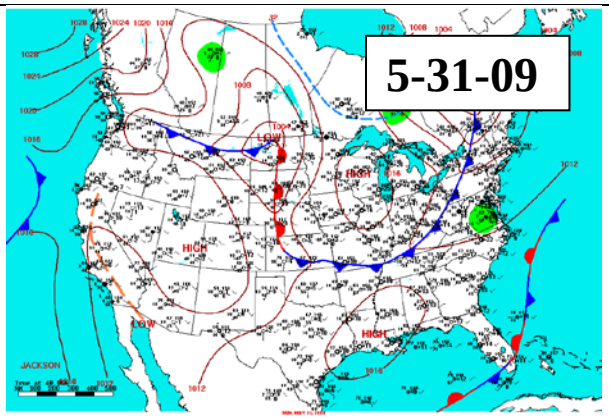




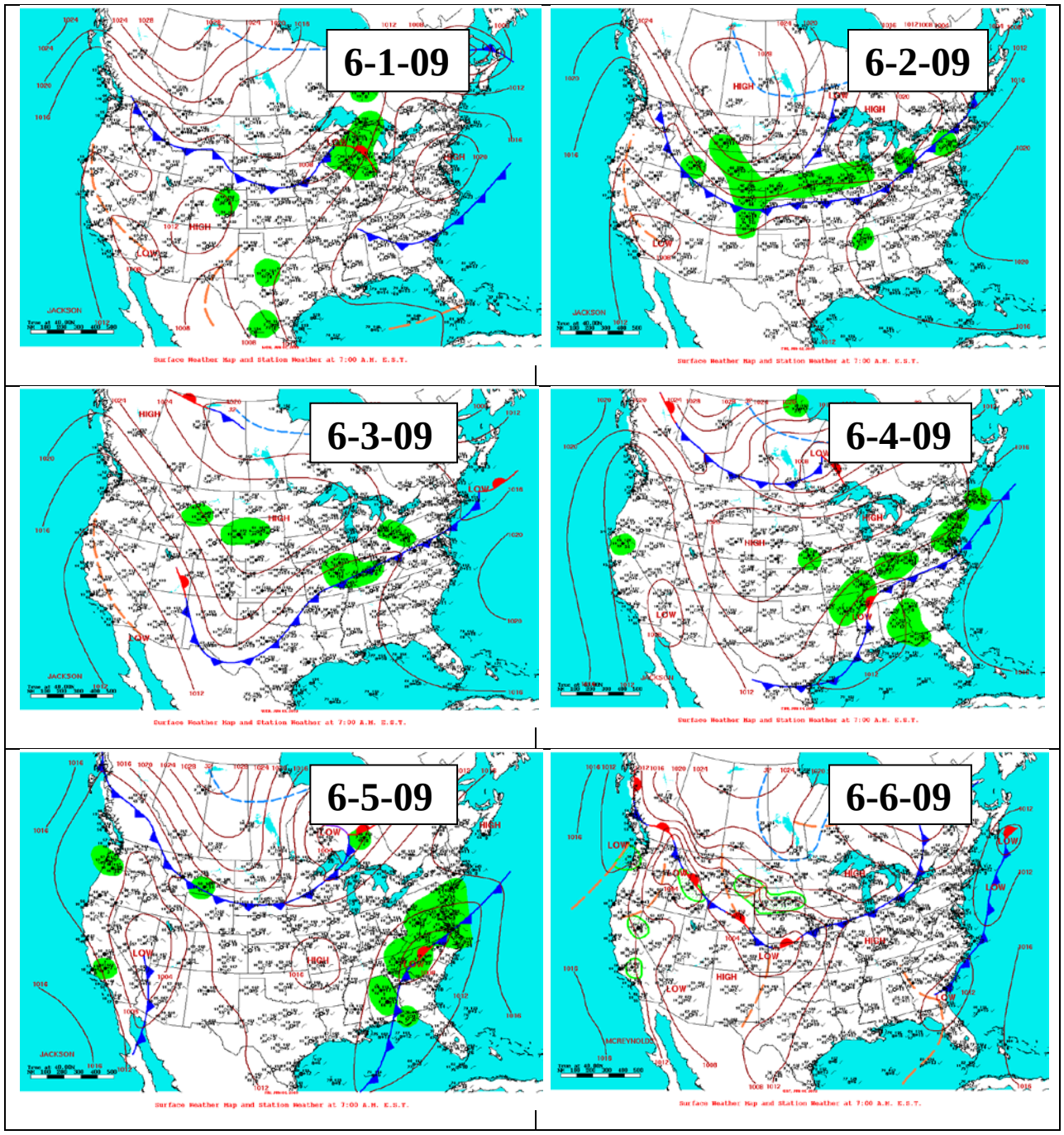








Period 9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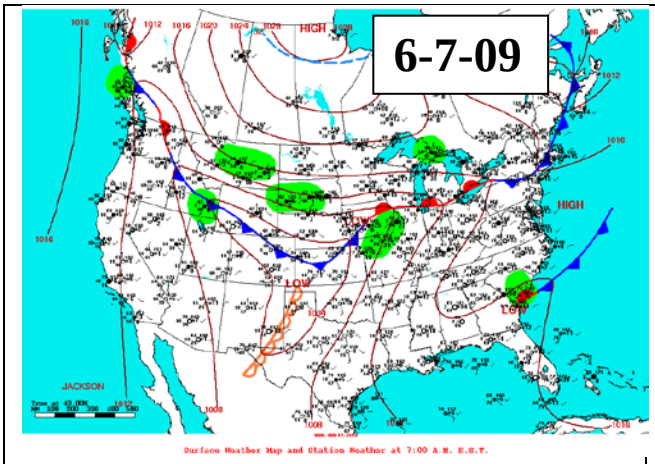
6-3-09
6-4-09
6-5-09
6-6-09


6-7-09
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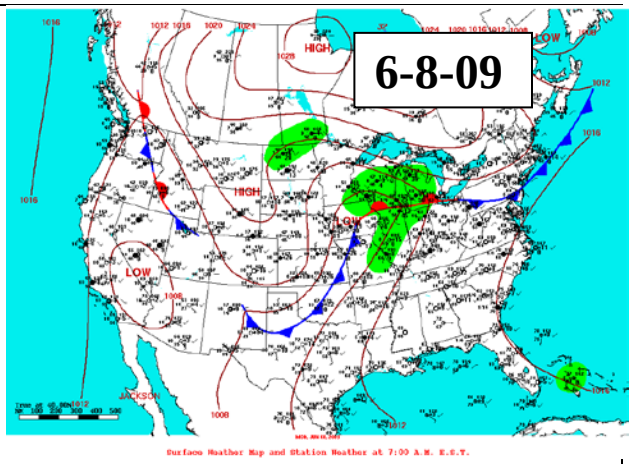
LOW
JACKSON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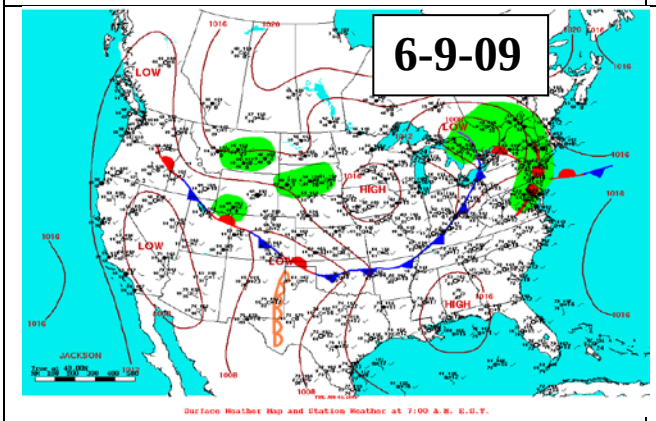
6-9-09
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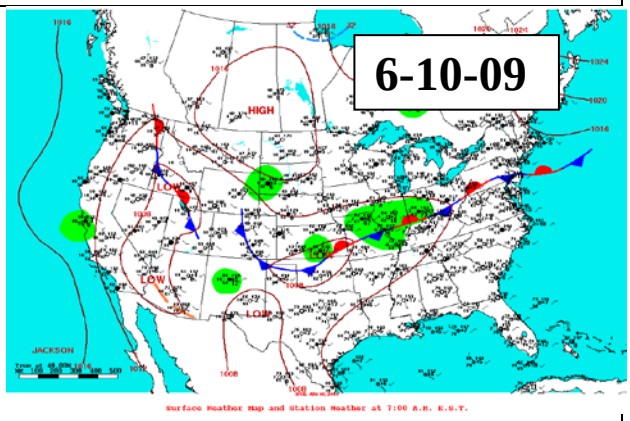
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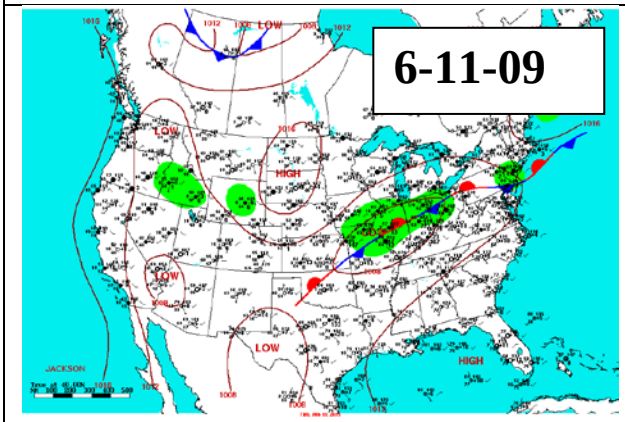
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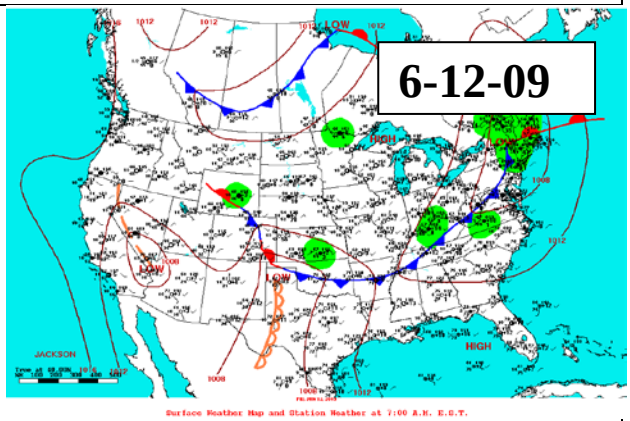
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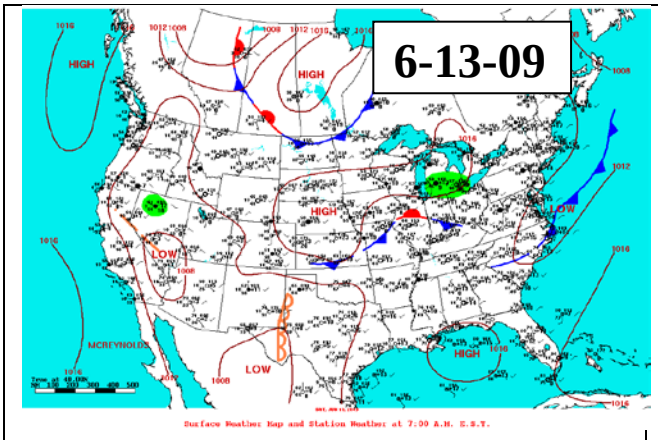
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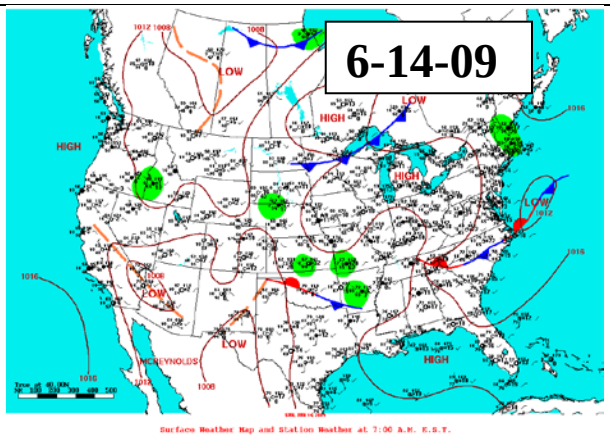
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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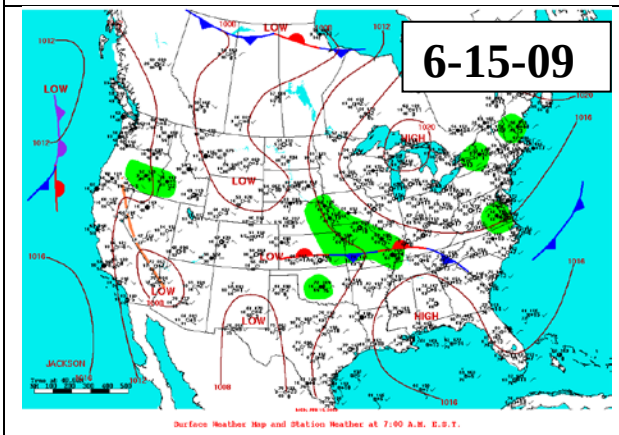
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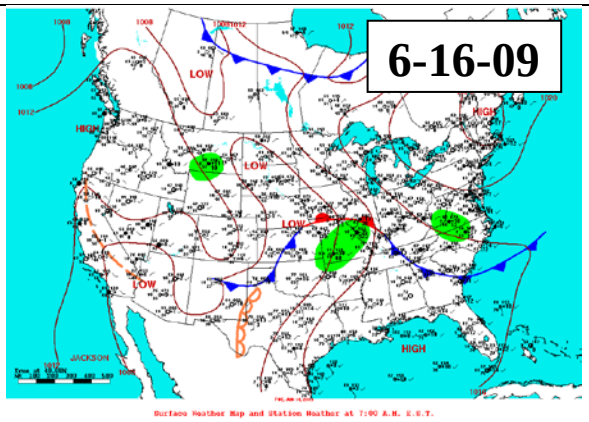
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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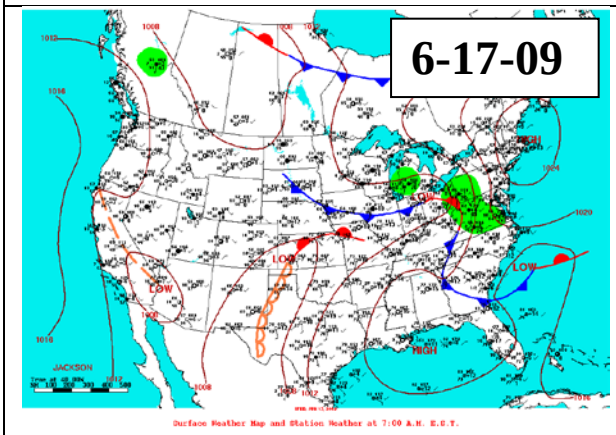
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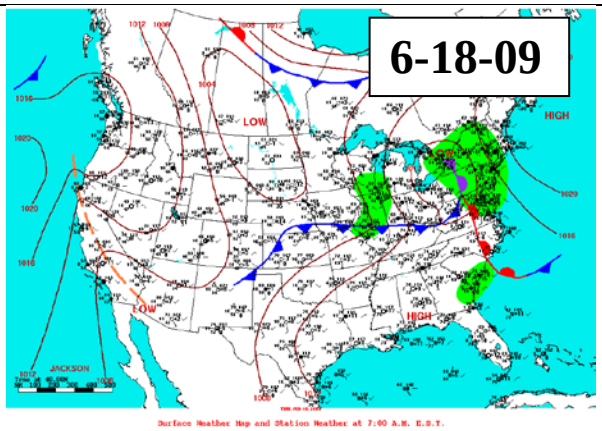
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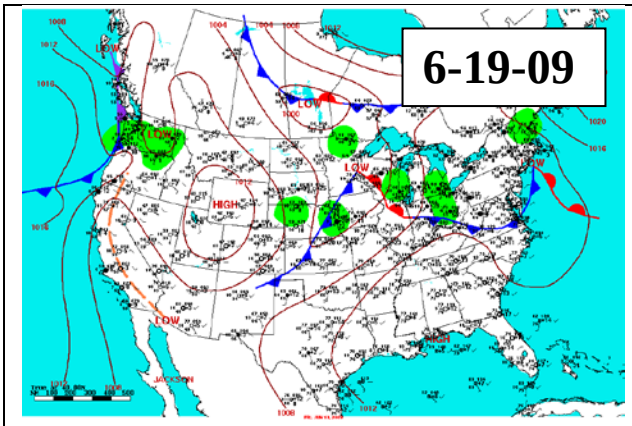
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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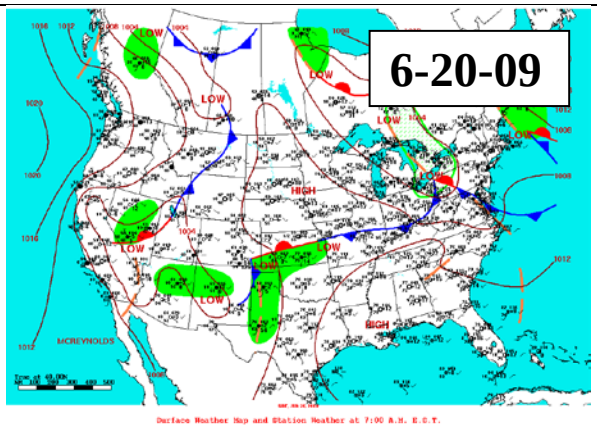
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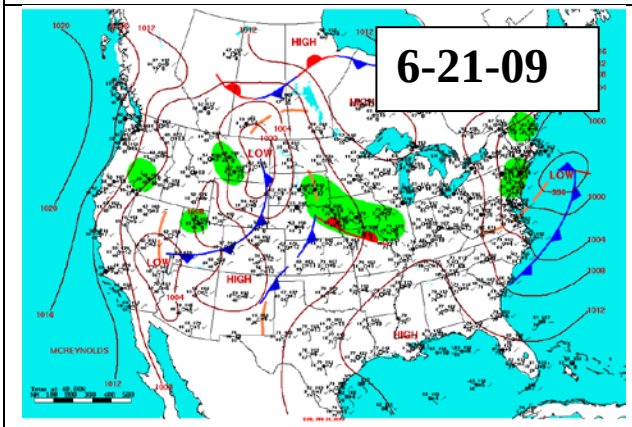
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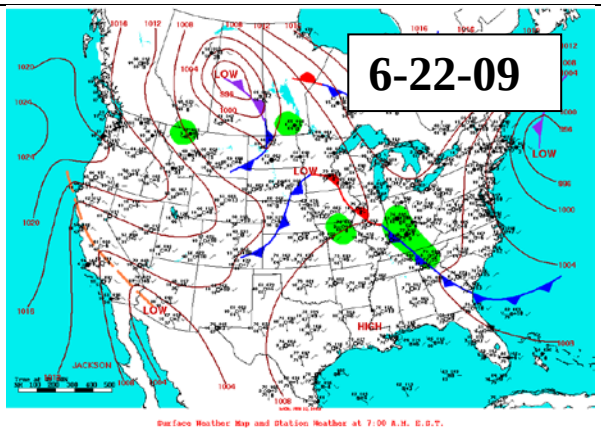
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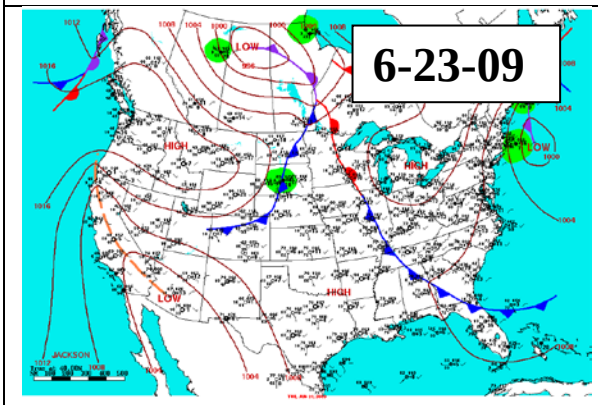
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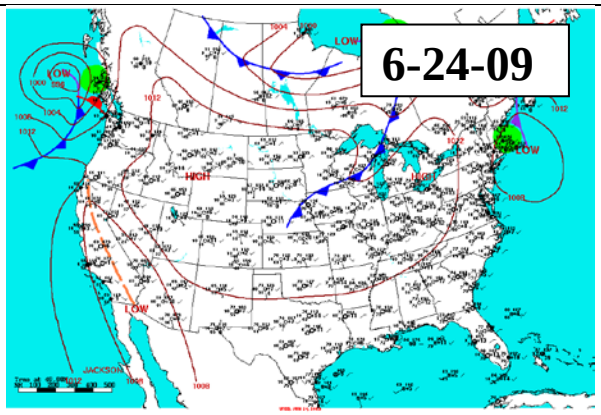
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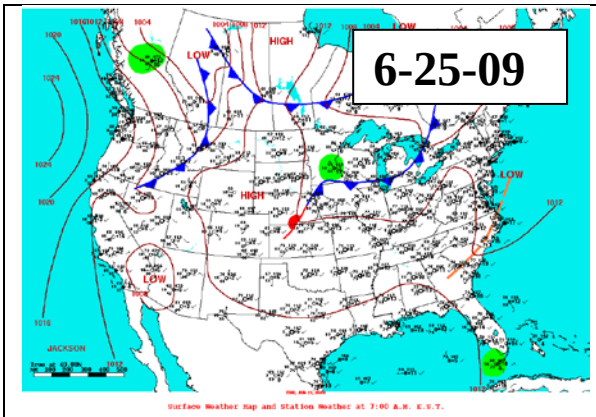
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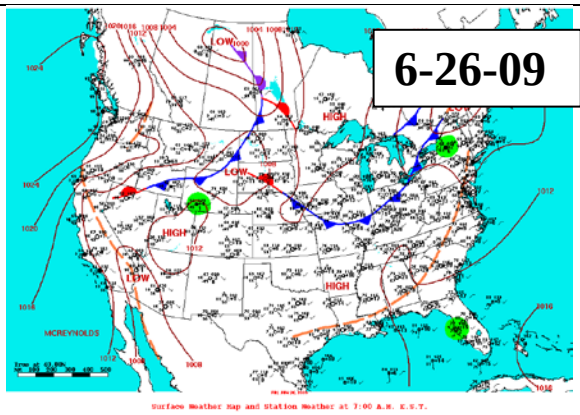
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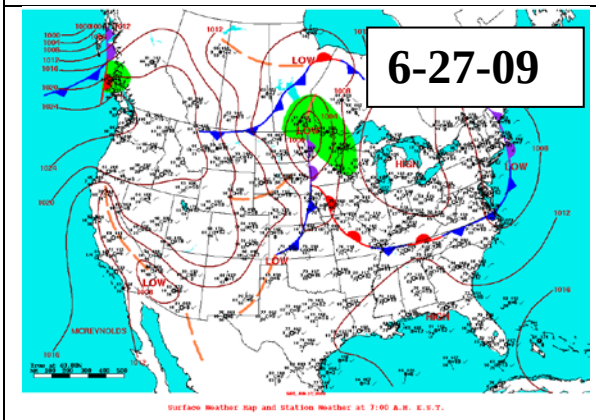
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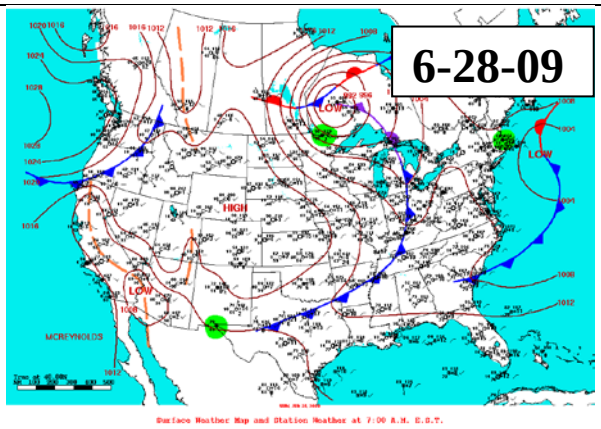
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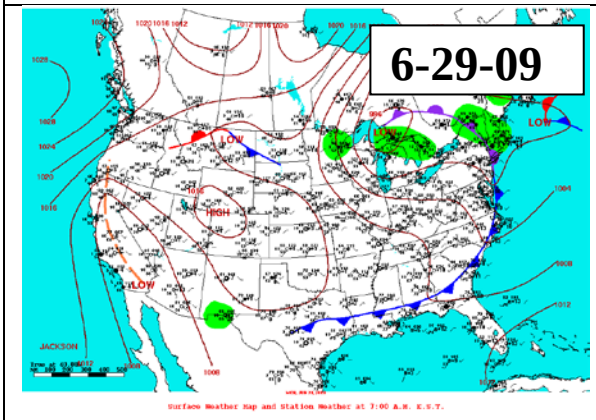
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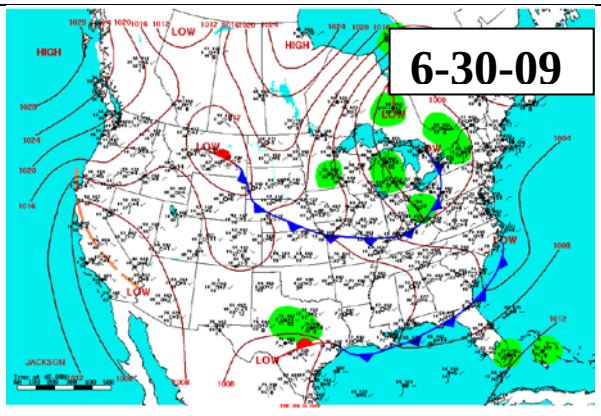
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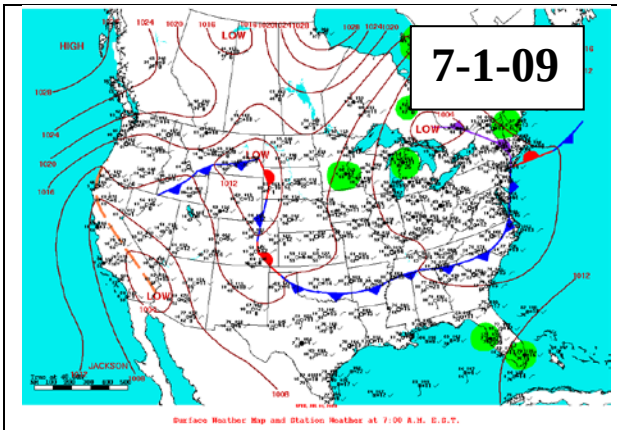
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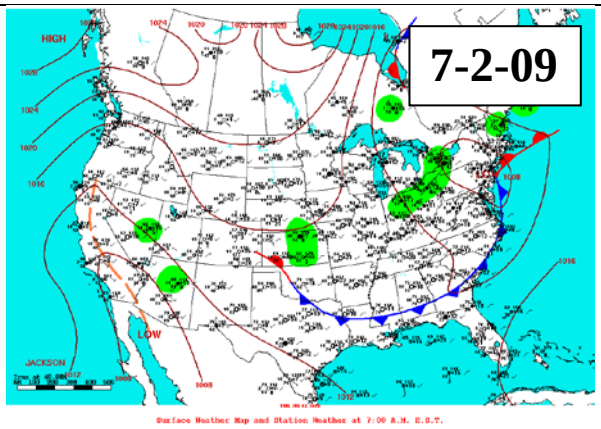
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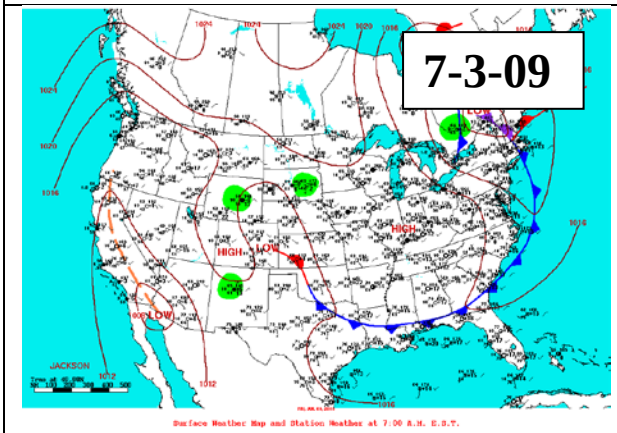
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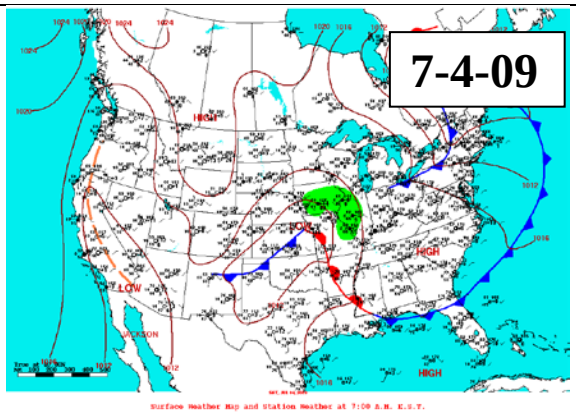
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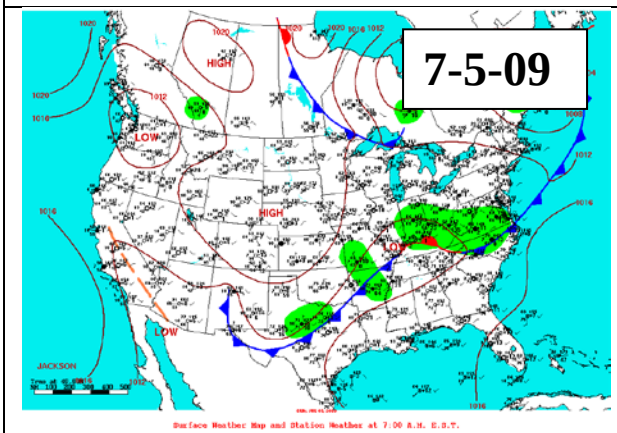
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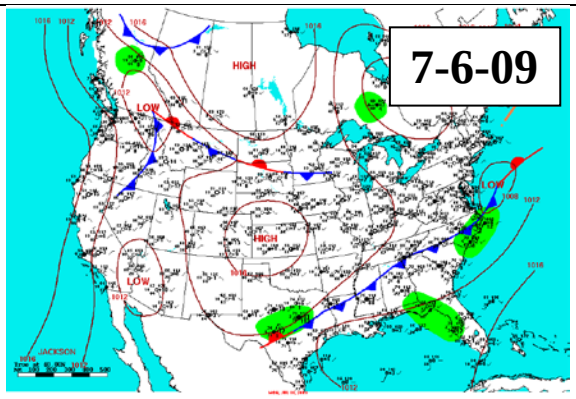
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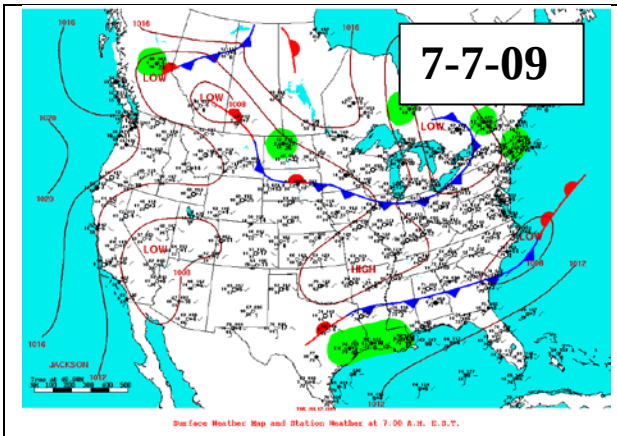
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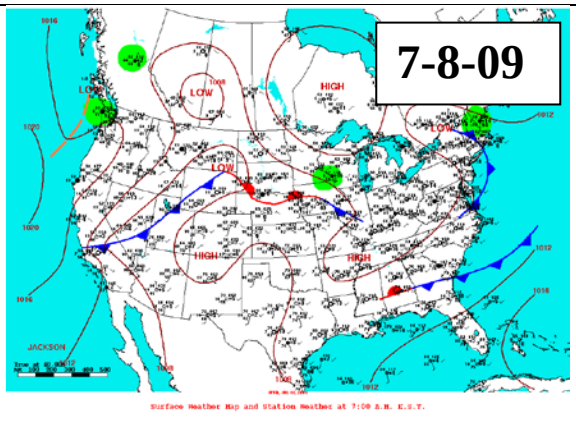
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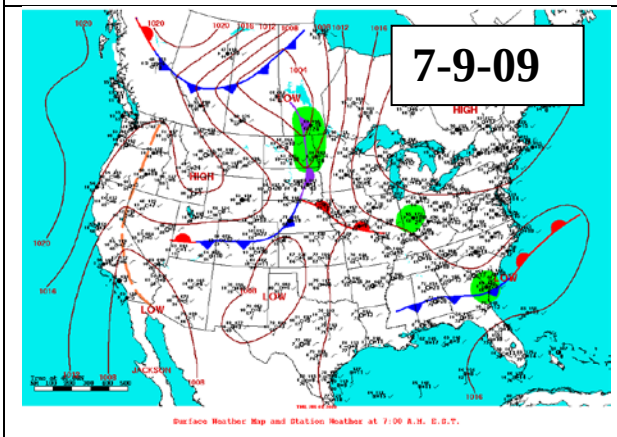
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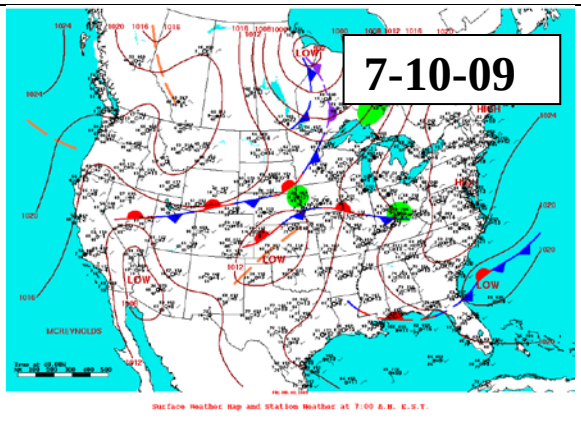
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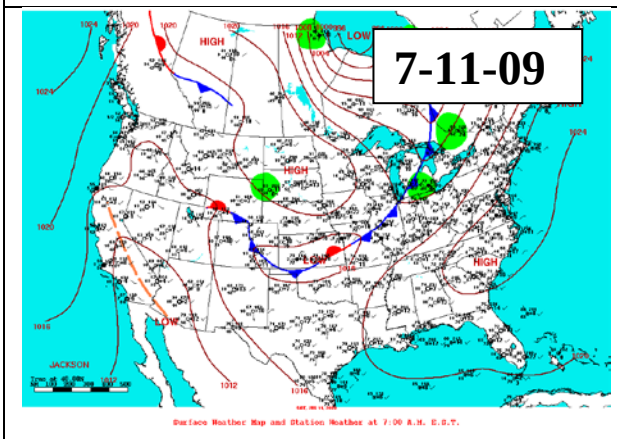
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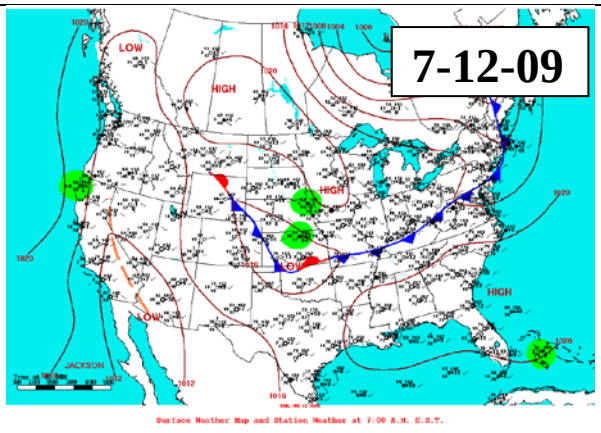
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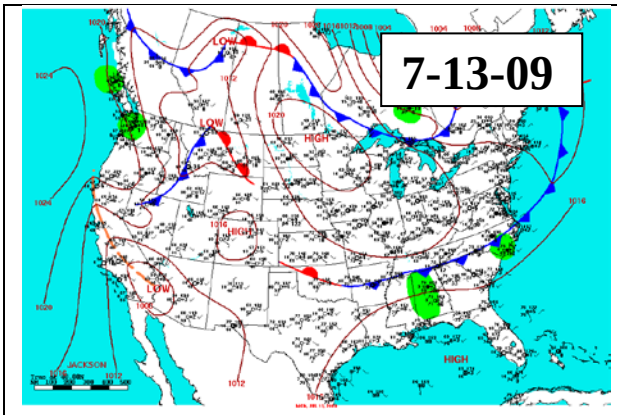
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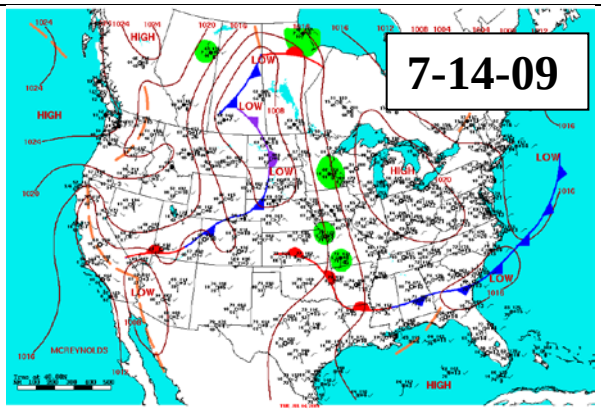
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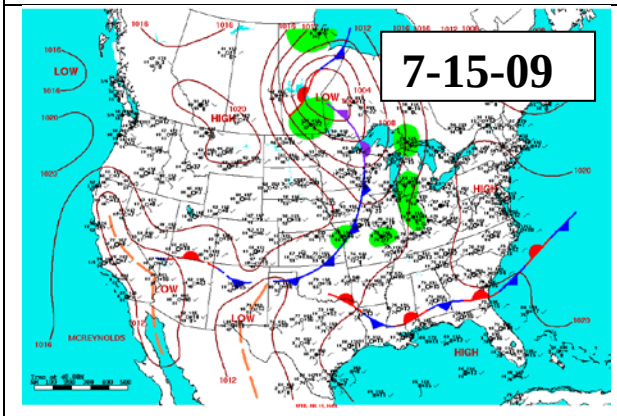
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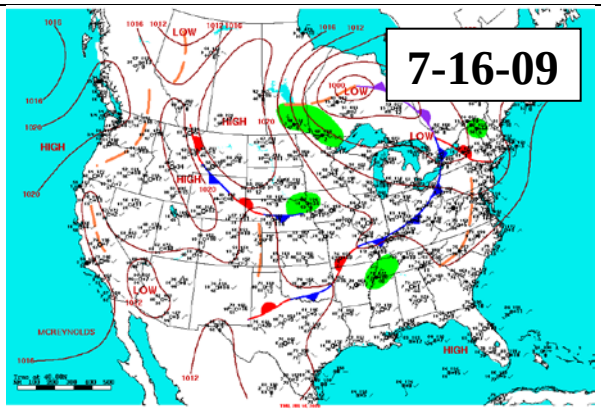
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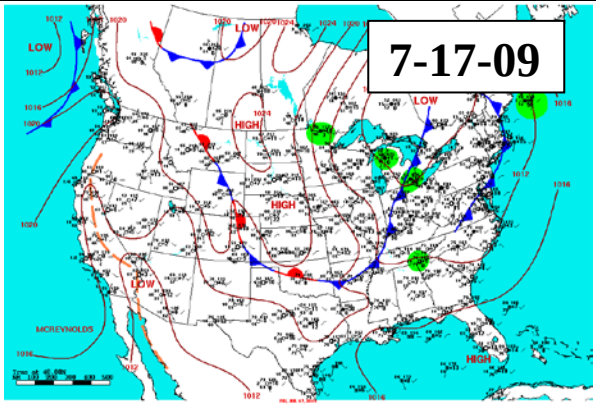
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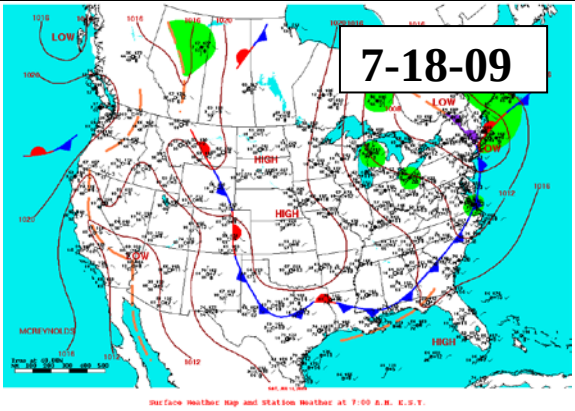
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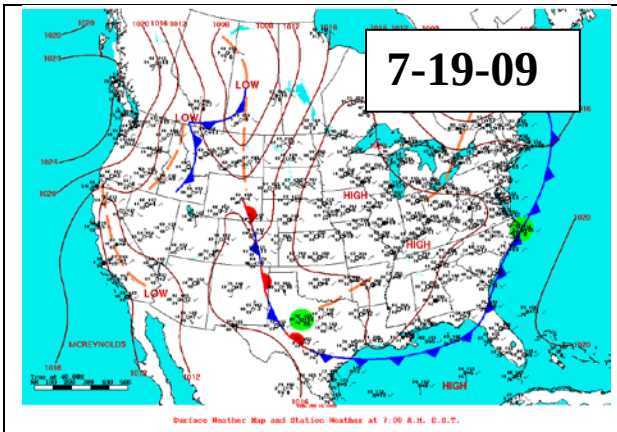
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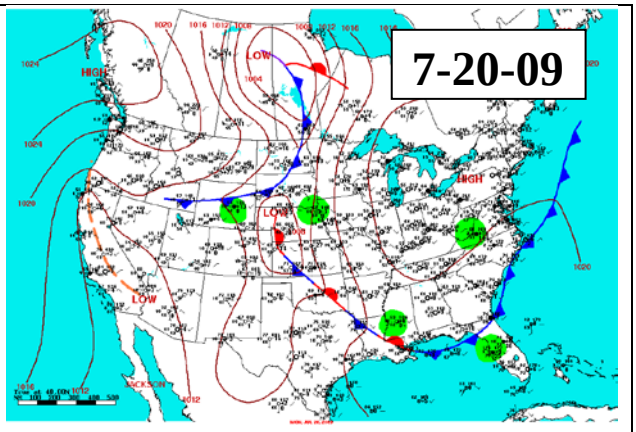
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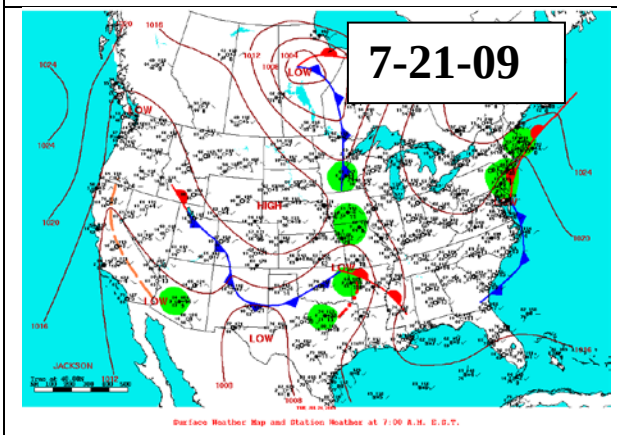
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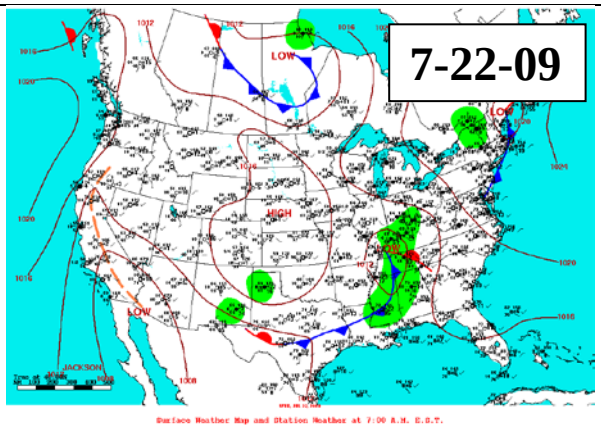
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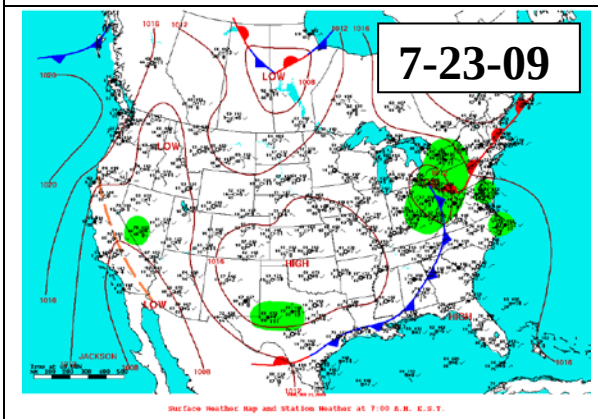
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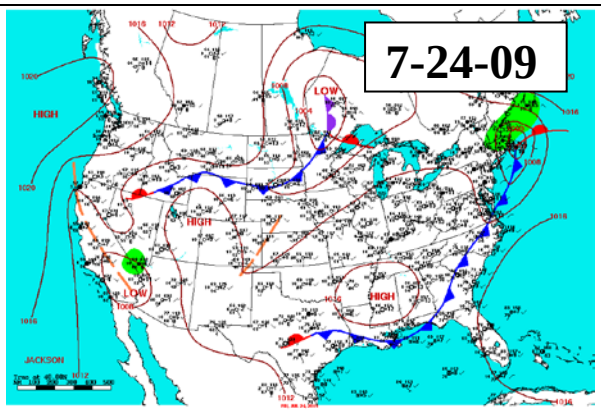
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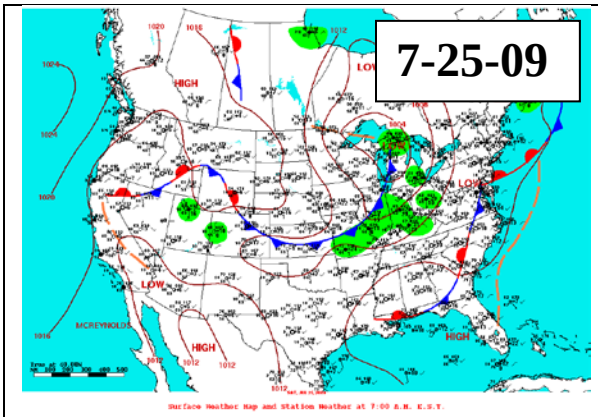
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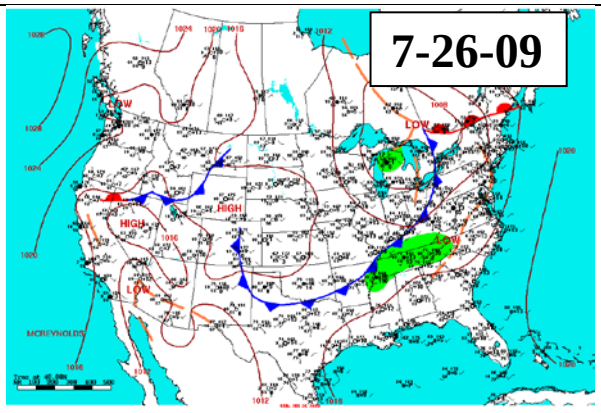
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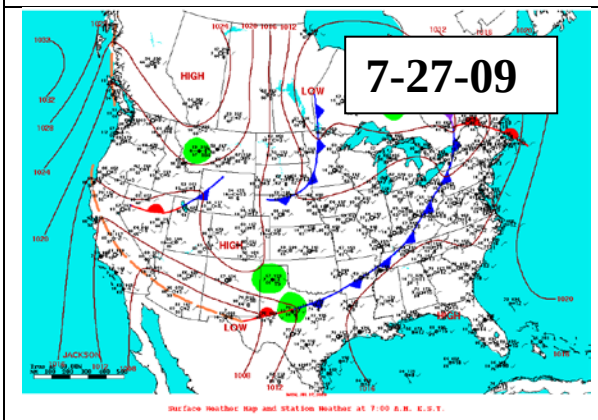
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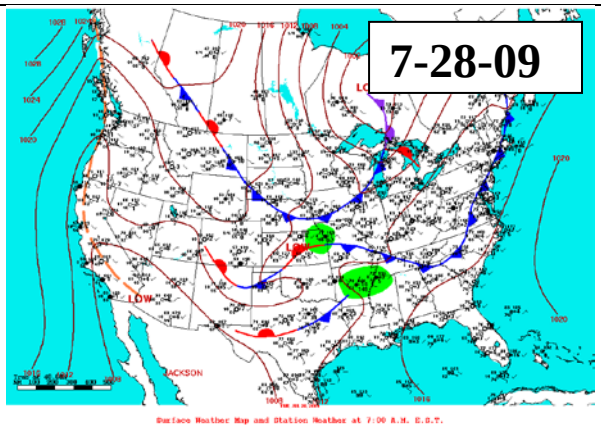
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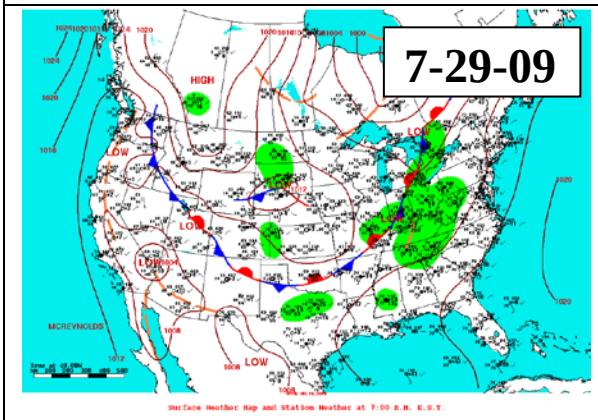
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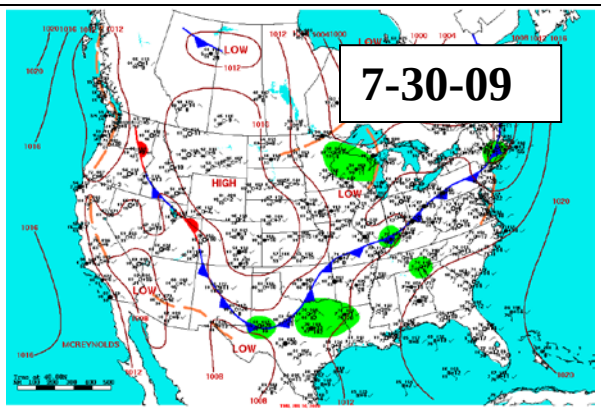
MCREYNOLDS


7-30-09
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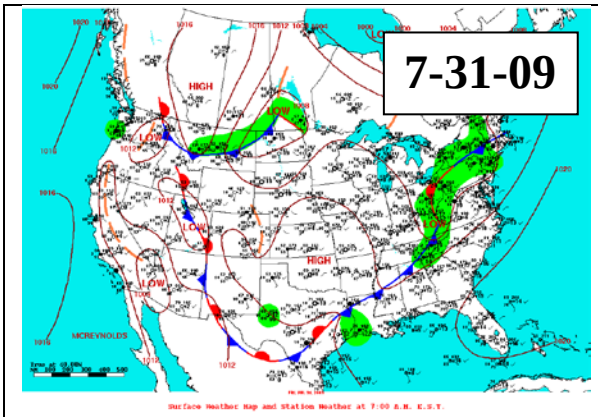
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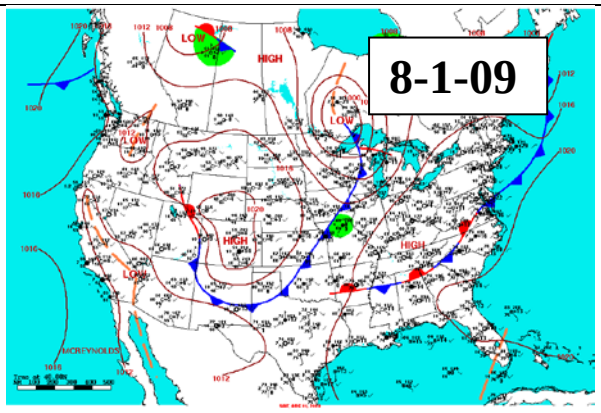
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-1-09
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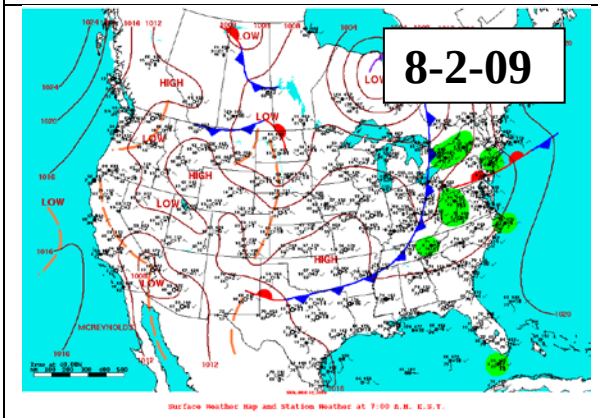
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-2-09
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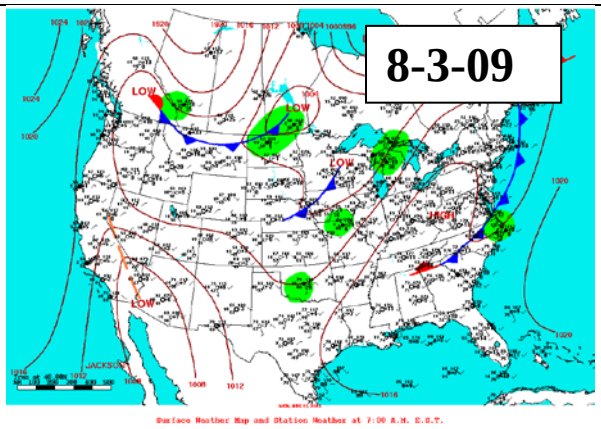
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-3-09
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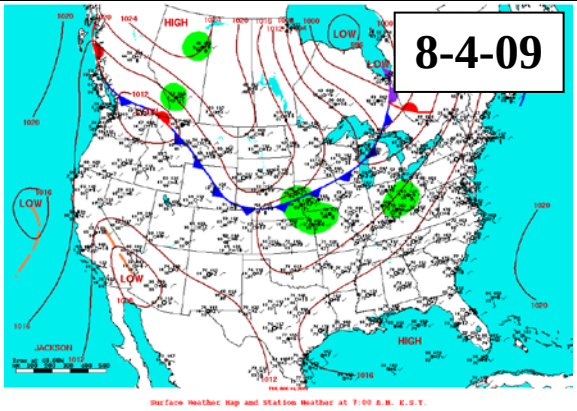
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-4-09
HIGH
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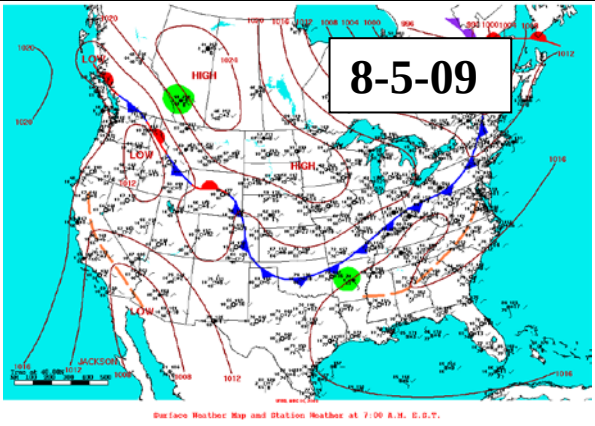
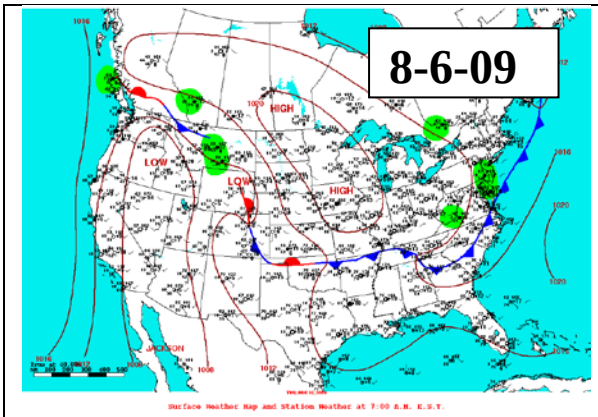
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-5-09
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-6-09
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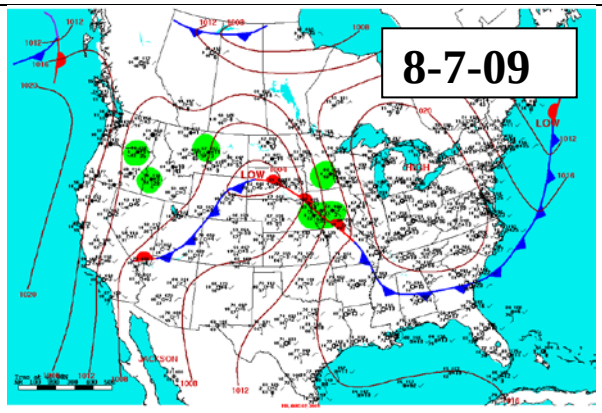
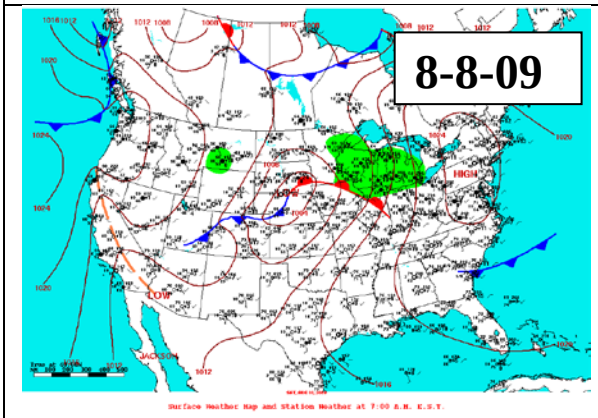
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-7-09
LOW
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-8-09
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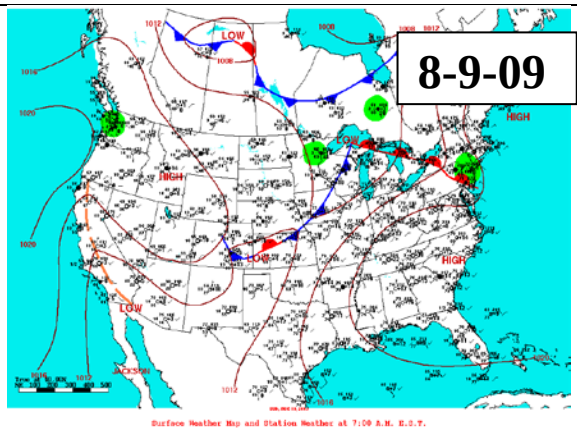
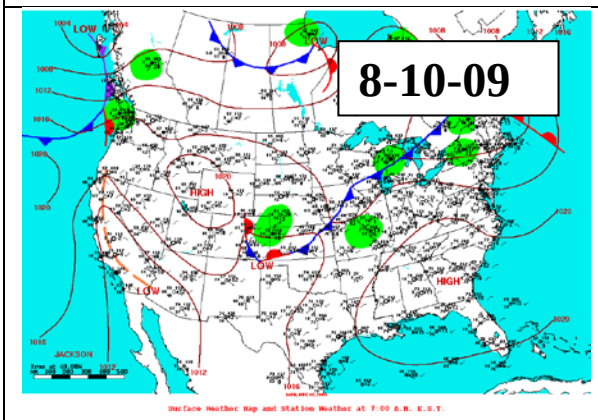
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-9-09
LOW
HIGH
LOW
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-10-09
LOW
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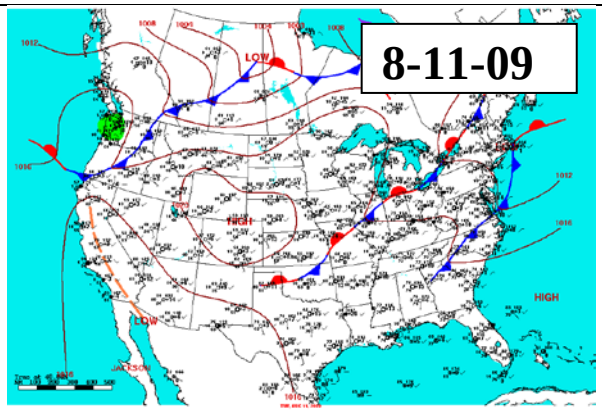
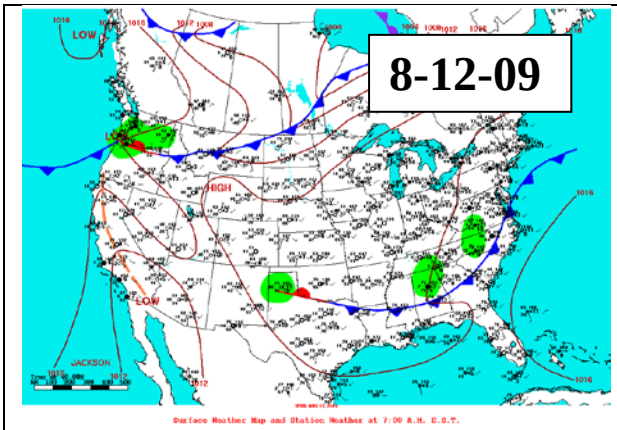
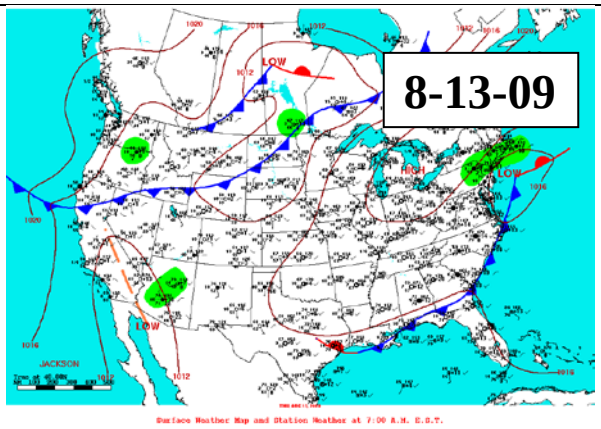
LOW
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-11-09
LOW
HIGH
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-12-09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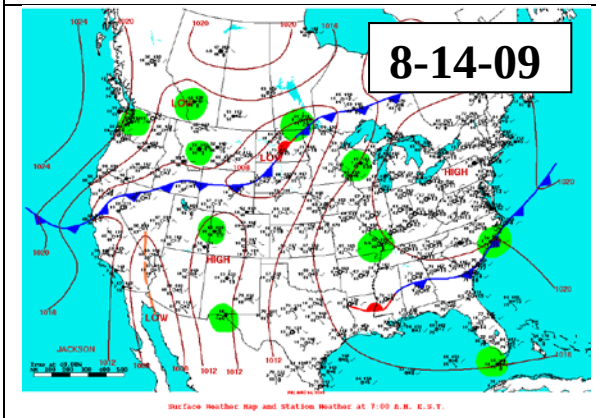
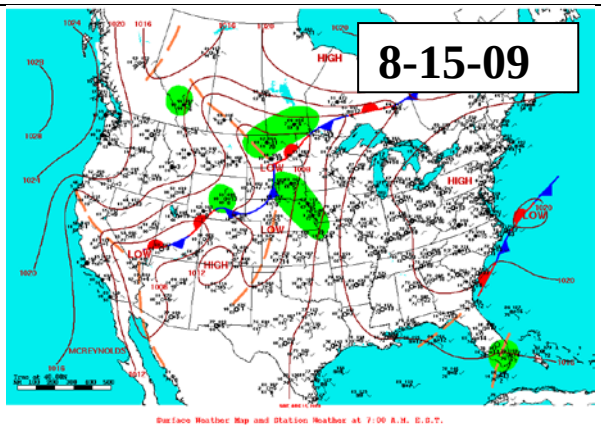
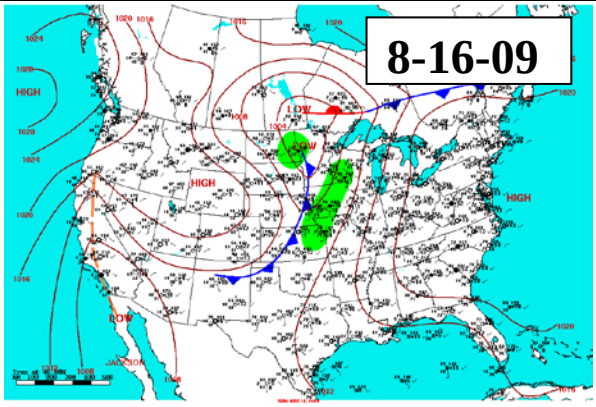
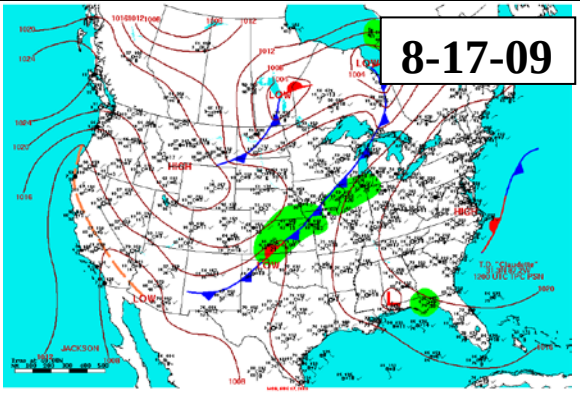

8-14-09


8-15-09


8-16-09


8-17-09

6.10 Daily weather conditions

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 1				
6/19/2007	98.45	757	0%	26.5
6/20/2007	98.92	985	26%	20.2
6/21/2007	98.83	1043	29%	22.2
6/22/2007	98.69	885	58%	19.7
6/23/2007	98.41	377	47%	17.9
6/24/2007	98.32	686	87%	19.1
6/25/2007	98.75	879	53%	23.2
6/26/2007	99.09	958	66%	24.2
6/27/2007	98.87	846	56%	23.3
6/28/2007	98.66	514	67%	22.2
6/29/2007	98.75	1031	10%	19.7
6/30/2007	98.78	951	33%	20.4
7/1/2007	98.97	1013	39%	20.1
7/2/2007	99.25	977	30%	17.9
7/3/2007	98.97	1056	43%	19.8
7/4/2007	98.38	920	36%	21.6
7/5/2007	98.32	1031	85%	24.1
7/6/2007	98.58	1007	88%	22.3
7/7/2007	98.50	941	61%	22.8
7/8/2007	98.12	920	99%	23.7
7/9/2007	98.08	1001	99%	24.8
7/10/2007	98.07	967	99%	24.4
7/11/2007	98.12	967	63%	22.2
7/12/2007	98.46	1076	56%	19.4
7/13/2007	98.46	1093	58%	20.8
7/14/2007	98.17	994	54%	20.1
7/15/2007	98.02	1054	51%	21.4
7/16/2007	98.45	950	38%	20.8
7/17/2007	98.39	822	31%	21.1
7/18/2007	98.31	982	56%	22.2
7/19/2007	98.02	903	44%	23.2
7/20/2007	98.69	953	14%	17.2
7/21/2007	99.06	1130	30%	18.2
7/22/2007	99.22	945	19%	18.4
7/23/2007	98.92	968	39%	19.7
7/24/2007	98.68	1098	38%	20.2
7/25/2007	98.67	1078	41%	21.7
7/26/2007	98.53	961	54%	21.3
7/27/2007	98.09	485	35%	21.9
7/28/2007	98.06	905	79%	21.8

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
7/29/2007	98.32	960	47%	22.5
7/30/2007	98.48	974	43%	22.9
7/31/2007	98.64	896	46%	23.5
8/1/2007	98.58	894	44%	25.3
8/2/2007	98.51	912	47%	25.0
8/3/2007	98.55	943	56%	24.1
8/4/2007	98.63	834	1%	22.4
8/5/2007	98.20	1013	51%	24.6
8/6/2007	98.02	877	10%	27.2
8/7/2007	97.99	939	54%	27.9
8/8/2007	97.98	881	46%	27.9
8/9/2007	97.97	967	50%	27.4
8/10/2007	98.27	981	52%	25.2
8/11/2007	98.61	981	49%	24.8
8/12/2007	98.72	906	46%	25.4
8/13/2007	98.79	878	44%	25.1
8/14/2007	98.55	936	67%	19.6
8/15/2007	98.20	837	33%	23.2
8/16/2007	98.21	679	24%	24.3
8/17/2007	98.70	845	55%	23.1
8/18/2007	99.12	904	55%	17.6
8/19/2007	98.55	927	16%	22.1
8/20/2007	98.25	420	91%	22.5
8/21/2007	98.28	804	59%	24.6
8/22/2007	98.52	881	0%	26.5
8/23/2007	98.37	893	8%	26.8
8/24/2007	98.12	999	6%	25.3
8/25/2007	98.17	883	66%	22.6
8/26/2007	98.70	931	38%	20.2
8/27/2007	98.81	895	31%	20.5
8/28/2007	98.72	833	18%	23.8
8/29/2007	98.60	872	28%	25.3
8/30/2007	98.83	881	70%	22.0
8/31/2007	98.95	857	52%	18.7
Period 2				
9/1/2007	99.12	843	54%	18.5
9/2/2007	99.07	845	52%	20.0
9/3/2007	98.91	840	47%	21.8
9/4/2007	98.68	826	43%	23.4
9/5/2007	98.51	840	44%	24.2
9/6/2007	98.61	641	56%	23.2
9/7/2007	98.37	758	10%	23.9

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
9/8/2007	98.47	335	80%	23.0
9/9/2007	98.44	931	58%	22.5
9/10/2007	98.61	911	29%	20.8
9/11/2007	98.17	821	21%	18.4
9/12/2007	98.68	822	10%	14.5
9/13/2007	98.75	817	25%	16.2
9/14/2007	98.35	801	0%	16.7
9/15/2007	99.28	973	13%	10.7
9/16/2007	99.28	791	14%	12.8
9/17/2007	99.15	790	0%	15.2
9/18/2007	99.03	765	0%	20.5
9/19/2007	98.95	804	4%	22.4
9/20/2007	98.94	777	39%	23.0
9/21/2007	98.51	728	27%	23.4
9/22/2007	98.59	769	0%	21.7
9/23/2007	99.07	733	0%	20.8
9/24/2007	98.83	819	0%	24.5
9/25/2007	98.61	956	11%	25.1
9/26/2007	98.51	244	99%	18.9
9/27/2007	98.45	868	66%	17.8
9/28/2007	98.82	748	24%	16.7
9/29/2007	99.41	789	12%	16.7
9/30/2007	99.28	741	0%	19.1
10/1/2007	98.76	769	4%	20.5
10/2/2007	98.72	790	42%	18.9
10/3/2007	98.36	814	28%	20.6
10/4/2007	98.70	690	31%	20.9
10/5/2007	98.89	886	62%	23.3
10/6/2007	98.87	866	63%	24.6
10/7/2007	98.78	801	58%	24.6
10/8/2007	98.52	740	55%	24.3
10/9/2007	98.43	696	53%	19.5
10/10/2007	98.17	700	0%	11.2
10/11/2007	98.19	679	32%	10.6
10/12/2007	98.43	799	36%	10.5
10/13/2007	98.56	729	56%	8.5
10/14/2007	98.75	497	0%	15.1
10/15/2007	98.53	720	0%	18.1
10/16/2007	98.22	624	47%	18.1
10/17/2007	98.31	760	88%	15.6
10/18/2007	96.98	672	53%	21.6
10/19/2007	96.81	185	38%	15.1

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
10/20/2007	97.76	645	9%	15.0
10/21/2007	98.17	665	0%	18.2
10/22/2007	98.41	497	21%	15.6
10/23/2007	98.03	327	65%	10.7
10/24/2007	98.44	700	54%	9.4
10/25/2007	98.85	622	48%	8.5
10/26/2007	98.66	486	45%	13.5
10/27/2007	98.89	403	76%	10.8
10/28/2007	100.18	620	57%	6.9
10/29/2007	100.09	606	31%	6.1
10/30/2007	99.56	601	3%	8.7
10/31/2007	98.80	699	32%	11.4
11/1/2007	99.15	602	10%	6.8
11/2/2007	99.28	586	11%	5.6
11/3/2007	98.99	589	9%	6.5
11/4/2007	98.38	572	0%	6.4
11/5/2007	97.89	420	0%	9.1
11/6/2007	98.63	541	0%	3.2
11/7/2007	99.35	565	22%	1.8
11/8/2007	98.56	525	0%	4.5
11/9/2007	98.30	529	26%	5.3
11/10/2007	99.00	550	50%	2.8
11/11/2007	98.66	153	51%	5.9
11/12/2007	98.59	524	69%	12.7
11/13/2007	98.52	547	50%	11.6
11/14/2007	97.71	577	58%	13.1
11/15/2007	98.30	253	2%	3.8
11/16/2007	98.74	557	25%	-0.2
11/17/2007	98.02	534	0%	3.9
11/18/2007	98.98	197	66%	3.3
11/19/2007	98.86	320	80%	7.2
11/20/2007	98.33	244	40%	15.1
11/21/2007	97.90	135	76%	12.9
11/22/2007	98.48	130	84%	2.7
11/23/2007	99.64	522	19%	-2.0
11/24/2007	99.57	638	64%	-1.8
11/25/2007	99.15	417	78%	-1.3
11/26/2007	98.27	184	100%	1.7
11/27/2007	99.13	485	63%	1.1
11/28/2007	99.19	738	25%	2.0
11/29/2007	98.98	494	9%	0.5
11/30/2007	99.45	504	1%	-0.7

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 3				
12/1/2007	99.74	185	11%	-3.7
12/2/2007	97.94	219	75%	8.1
12/3/2007	98.98	601	13%	-2.7
12/4/2007	98.58	431	59%	-2.2
12/5/2007	97.64	527	69%	-3.2
12/6/2007	99.11	493	80%	-9.4
12/7/2007	98.78	332	96%	-2.1
12/8/2007	99.35	591	100%	-1.2
12/9/2007	99.32	153	100%	-0.8
12/10/2007	99.30	307	100%	-0.4
12/11/2007	98.94	151	100%	1.5
12/12/2007	99.00	485	74%	2.0
12/13/2007	98.64	110	99%	1.3
12/14/2007	99.29	481	72%	-1.3
12/15/2007	98.86	143	98%	-1.7
12/16/2007	97.47	535	100%	-4.3
12/17/2007	99.07	358	100%	-7.6
12/18/2007	98.90	476	83%	-4.0
12/19/2007	98.61	457	60%	-1.5
12/20/2007	98.68	420	87%	-2.8
12/21/2007	98.30	133	92%	1.4
12/22/2007	98.35	175	100%	5.7
12/23/2007	97.48	517	63%	1.8
12/24/2007	98.47	242	7%	-3.5
12/25/2007	99.08	454	74%	-2.1
12/26/2007	98.67	461	63%	0.5
12/27/2007	98.37	126	99%	0.7
12/28/2007	98.44	103	99%	1.5
12/29/2007	98.59	168	39%	-1.0
12/30/2007	98.51	364	81%	-1.8
12/31/2007	97.94	522	77%	0.5
1/1/2008	98.43	326	71%	-4.7
1/2/2008	100.01	364	96%	-14.4
1/3/2008	100.72	476	78%	-12.9
1/4/2008	99.69	472	27%	-3.8
1/5/2008	98.63	86	63%	3.0
1/6/2008	98.15	134	100%	10.0
1/7/2008	98.23	331	86%	15.9
1/8/2008	97.74	125	85%	14.3
1/9/2008	98.35	494	40%	4.0
1/10/2008	98.02	216	77%	2.4

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
1/11/2008	97.22	212	94%	3.1
1/12/2008	98.39	430	60%	0.2
1/13/2008	98.27	92	69%	0.8
1/14/2008	98.51	234	89%	-3.7
1/15/2008	98.81	508	74%	-8.7
1/16/2008	99.02	529	66%	-6.4
1/17/2008	98.27	203	79%	-0.4
1/18/2008	98.49	512	57%	-5.4
1/19/2008	N/A	555	55%	-11.2
1/20/2008	N/A	522	46%	-15.2
1/21/2008	N/A	515	55%	-9.4
1/22/2008	N/A	722	70%	-3.3
1/23/2008	N/A	533	77%	-10.3
1/24/2008	N/A	546	84%	-11.8
1/25/2008	N/A	592	65%	-14.6
1/26/2008	N/A	184	96%	-4.1
1/27/2008	N/A	532	85%	-3.2
1/28/2008	N/A	313	87%	1.1
1/29/2008	N/A	83	67%	7.9
1/30/2008	N/A	570	15%	-11.1
1/31/2008	N/A	179	10%	-8.2
2/1/2008	N/A	530	68%	-2.8
2/2/2008	N/A	573	70%	-2.0
2/3/2008	N/A	330	99%	-2.1
2/4/2008	N/A	250	100%	3.9
2/5/2008	N/A	142	100%	8.2
2/6/2008	N/A	247	79%	2.1
2/7/2008	N/A	193	30%	-2.0
2/8/2008	N/A	637	59%	0.4
2/9/2008	N/A	669	65%	2.5
2/10/2008	N/A	708	7%	-8.4
2/11/2008	N/A	479	1%	-14.1
2/12/2008	N/A	240	99%	-8.5
2/13/2008	N/A	637	99%	-7.8
2/14/2008	N/A	638	99%	-5.9
2/15/2008	N/A	638	99%	-1.2
2/16/2008	N/A	635	99%	-4.4
2/17/2008	N/A	662	82%	6.6
2/18/2008	N/A	617	36%	-1.2
2/19/2008	N/A	623	0%	-10.4
2/20/2008	N/A	696	66%	-7.7
2/21/2008	N/A	376	90%	-12.2

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
2/22/2008	N/A	315	100%	-6.1
2/23/2008	N/A	707	69%	-3.9
2/24/2008	N/A	665	99%	-7.0
2/25/2008	N/A	319	100%	-0.6
2/26/2008	N/A	590	97%	-0.7
2/27/2008	N/A	876	37%	-6.4
2/28/2008	N/A	764	66%	-9.2
2/29/2008	N/A	774	98%	-0.3
3/1/2008	N/A	636	70%	-0.3
3/2/2008	N/A	873	98%	5.0
3/3/2008	N/A	113	90%	8.7
3/4/2008	N/A	217	100%	-1.2
3/5/2008	N/A	771	96%	-3.6
Period 4				
3/6/2008	N/A	678	67%	-1.4
3/7/2008	N/A	547	49%	-3.3
3/8/2008	N/A	861	20%	-5.6
3/9/2008	N/A	792	74%	-2.9
3/10/2008	N/A	936	99%	1.3
3/11/2008	N/A	827	98%	-0.1
3/12/2008	N/A	825	83%	3.5
3/13/2008	N/A	794	85%	7.8
3/14/2008	N/A	812	61%	8.1
3/15/2008	N/A	516	93%	4.1
3/16/2008	N/A	657	87%	1.4
3/17/2008	N/A	560	83%	2.0
3/18/2008	N/A	160	93%	7.6
3/19/2008	N/A	233	89%	4.3
3/20/2008	N/A	814	51%	3.9
3/21/2008	97.70	883	62%	4.6
3/22/2008	98.53	792	85%	2.3
3/23/2008	99.26	978	65%	-0.3
3/24/2008	99.45	1065	68%	0.1
3/25/2008	98.60	520	66%	3.5
3/26/2008	98.71	873	73%	6.7
3/27/2008	98.15	194	96%	5.8
3/28/2008	98.49	950	61%	2.7
3/29/2008	99.59	950	66%	1.8
3/30/2008	99.05	618	85%	5.4
3/31/2008	98.42	674	88%	12.9
4/1/2008	98.17	398	79%	8.2
4/2/2008	99.79	897	56%	3.7

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
4/3/2008	98.93	507	77%	3.9
4/4/2008	97.76	117	100%	5.7
4/5/2008	98.48	878	58%	5.7
4/6/2008	98.41	887	52%	9.2
4/7/2008	98.21	847	54%	12.7
4/8/2008	98.53	544	64%	11.7
4/9/2008	98.54	1005	77%	10.0
4/10/2008	98.45	126	98%	8.6
4/11/2008	96.95	936	54%	16.1
4/12/2008	97.32	271	44%	5.1
4/13/2008	98.13	376	100%	2.7
4/14/2008	99.00	869	62%	3.6
4/15/2008	99.29	715	54%	6.2
4/16/2008	98.70	727	38%	11.0
4/17/2008	98.48	745	30%	15.2
4/18/2008	98.23	821	88%	16.8
4/19/2008	97.83	882	77%	12.9
4/20/2008	98.15	766	64%	12.2
4/21/2008	98.55	949	54%	15.0
4/22/2008	98.56	1055	35%	16.8
4/23/2008	98.80	958	73%	19.4
4/24/2008	98.83	862	63%	19.1
4/25/2008	98.08	910	99%	21.4
4/26/2008	98.30	885	57%	13.3
4/27/2008	98.93	743	23%	9.6
4/28/2008	98.24	793	87%	7.6
4/29/2008	98.60	1001	65%	5.2
4/30/2008	98.59	910	49%	7.7
5/1/2008	97.78	895	26%	15.9
5/2/2008	97.37	696	19%	19.5
5/3/2008	97.40	1016	48%	13.6
5/4/2008	98.60	913	40%	10.4
5/5/2008	98.68	908	6%	14.6
5/6/2008	98.45	996	46%	18.8
5/7/2008	97.73	601	100%	17.9
5/8/2008	97.54	315	100%	13.0
5/9/2008	97.63	566	99%	10.8
5/10/2008	98.07	884	58%	11.7
5/11/2008	96.44	186	98%	11.8
5/12/2008	97.85	925	98%	8.2
5/13/2008	N/A	N/A	N/A	N/A
5/14/2008	98.13	184	100%	14.6

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
5/15/2008	98.46	461	100%	10.6
5/16/2008	98.23	958	98%	12.0
5/17/2008	97.51	944	79%	16.2
5/18/2008	97.08	1088	99%	13.0
5/19/2008	97.47	756	99%	9.9
5/20/2008	97.30	795	93%	11.0
5/21/2008	97.38	1021	83%	11.9
5/22/2008	97.87	975	85%	13.2
5/23/2008	98.54	493	100%	11.7
5/24/2008	98.95	944	61%	13.9
5/25/2008	98.69	849	79%	16.5
5/26/2008	98.02	1060	100%	21.2
5/27/2008	98.41	1066	100%	16.3
5/28/2008	99.35	962	54%	12.9
5/29/2008	99.17	1041	53%	16.3
5/30/2008	98.32	1002	99%	20.9
5/31/2008	97.86	1001	61%	22.2
6/1/2008	98.20	936	75%	21.0
6/2/2008	98.34	1100	93%	21.9
6/3/2008	97.65	820	95%	21.7
6/4/2008	97.27	1099	83%	22.0
6/5/2008	97.77	994	100%	25.6
6/6/2008	98.18	794	100%	25.2
Period 5				
6/7/2008	98.24	731	87%	21.5
6/8/2008	98.29	932	47%	26.7
6/9/2008	97.98	1021	38%	25.9
6/10/2008	98.19	1020	61%	21.3
6/11/2008	98.64	974	94%	23.2
6/12/2008	98.57	852	100%	24.4
6/13/2008	98.46	494	100%	23.1
6/14/2008	98.46	960	54%	22.2
6/15/2008	98.26	977	49%	22.6
6/16/2008	97.88	1057	62%	20.3
6/17/2008	98.46	1031	61%	17.4
6/18/2008	98.20	998	91%	18.4
6/19/2008	98.25	1048	59%	19.1
6/20/2008	98.36	993	61%	22.0
6/21/2008	98.49	1120	87%	21.2
6/22/2008	98.22	1080	60%	19.9
6/23/2008	98.37	1040	90%	18.8
6/24/2008	99.06	966	70%	19.2

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
6/25/2008	98.81	971	98%	23.1
6/26/2008	98.26	1005	99%	24.4
6/27/2008	98.02	961	63%	22.9
6/28/2008	97.75	1010	76%	22.7
6/29/2008	97.74	1061	94%	20.2
6/30/2008	98.24	1140	98%	18.7
7/1/2008	98.60	963	56%	19.2
7/2/2008	98.23	981	97%	22.9
7/3/2008	98.23	918	99%	21.7
7/4/2008	98.62	431	100%	18.1
7/5/2008	N/A	N/A	N/A	N/A
7/6/2008	98.44	1042	67%	25.3
7/7/2008	98.42	956	99%	21.7
7/8/2008	98.13	1039	85%	24.5
7/9/2008	98.26	937	90%	22.9
7/10/2008	98.68	936	57%	22.1
7/11/2008	98.60	967	91%	23.4
7/12/2008	98.35	948	89%	24.4
7/13/2008	98.14	936	99%	21.6
7/14/2008	98.27	982	57%	20.4
7/15/2008	98.63	998	6%	23.0
7/16/2008	98.85	152	100%	22.7

6.11 Daily lagoon conditions

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
Period 1				
6/19/2007	26.5	N/A	N/A	N/A
6/20/2007	20.2	N/A	N/A	N/A
6/21/2007	22.2	N/A	N/A	N/A
6/22/2007	19.7	25.6	7.86	N/A
6/23/2007	17.9	23.8	7.91	N/A
6/24/2007	19.1	21.9	7.96	N/A
6/25/2007	23.2	23.4	7.94	N/A
6/26/2007	24.2	25.3	7.90	N/A
6/27/2007	23.3	26.2	7.91	N/A
6/28/2007	22.2	25.8	7.90	-156
6/29/2007	19.7	25.3	7.92	-84
6/30/2007	20.4	25.8	7.94	-62
7/1/2007	20.1	25.7	7.95	-56
7/2/2007	17.9	25.4	7.94	-58
7/3/2007	19.8	24.5	7.95	-53
7/4/2007	21.6	23.9	7.94	-52
7/5/2007	24.1	25.8	7.91	-47
7/6/2007	22.3	26.4	7.90	-50
7/7/2007	22.8	25.6	7.95	-51
7/8/2007	23.7	26.0	7.95	-50
7/9/2007	24.8	27.8	7.92	-50
7/10/2007	24.4	27.8	7.90	-49
7/11/2007	22.2	27.6	7.88	-53
7/12/2007	19.4	25.9	7.88	-52
7/13/2007	20.8	25.4	7.87	-54
7/14/2007	20.1	25.0	7.88	-52
7/15/2007	21.4	26.1	7.85	-54
7/16/2007	20.8	25.2	7.88	-51
7/17/2007	21.1	24.5	7.88	-53
7/18/2007	22.2	24.2	7.85	-54
7/19/2007	23.2	25.0	7.82	-52
7/20/2007	17.2	24.8	7.84	-54
7/21/2007	18.2	25.6	7.86	-54
7/22/2007	18.4	25.3	7.88	-57
7/23/2007	19.7	25.5	7.87	-57
7/24/2007	20.2	25.2	7.82	-55
7/25/2007	21.7	24.3	7.86	-53
7/26/2007	21.3	24.2	7.88	-59
7/27/2007	21.9	24.4	7.86	-61
7/28/2007	21.8	24.4	7.90	-51

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
7/29/2007	22.5	26.4	7.91	-46
7/30/2007	22.9	27.5	7.90	-49
7/31/2007	23.5	26.6	7.91	-49
8/1/2007	25.3	26.5	7.92	-47
8/2/2007	25.0	26.3	7.96	-47
8/3/2007	24.1	26.8	7.98	-51
8/4/2007	22.4	27.6	7.95	-53
8/5/2007	24.6	26.0	7.92	-48
8/6/2007	27.2	26.5	7.88	-39
8/7/2007	27.9	27.6	7.83	-37
8/8/2007	27.9	29.2	7.79	-37
8/9/2007	27.4	29.3	7.81	-27
8/10/2007	25.2	30.5	7.77	-17
8/11/2007	24.8	28.6	7.82	-34
8/12/2007	25.4	28.0	7.87	-38
8/13/2007	25.1	29.6	7.82	-43
8/14/2007	19.6	26.6	7.86	-47
8/15/2007	23.2	25.7	7.90	-43
8/16/2007	24.3	26.2	7.89	-42
8/17/2007	23.1	26.3	7.86	-41
8/18/2007	17.6	24.8	7.82	-46
8/19/2007	22.1	23.6	7.83	-43
8/20/2007	22.5	23.9	7.79	-47
8/21/2007	24.6	23.7	7.76	-36
8/22/2007	26.5	25.5	7.75	-32
8/23/2007	26.8	27.9	7.74	-31
8/24/2007	25.3	27.8	7.76	-37
8/25/2007	22.6	27.0	7.73	-41
8/26/2007	20.2	26.5	7.74	-41
8/27/2007	20.5	25.4	7.76	-39
8/28/2007	23.8	25.1	7.79	-38
8/29/2007	25.3	26.1	7.80	-39
8/30/2007	22.0	26.1	7.78	-52
8/31/2007	18.7	24.4	7.80	-50
Period 2				
9/1/2007	18.5	24.0	7.76	-46
9/2/2007	20.0	23.4	7.78	-42
9/3/2007	21.8	23.5	7.80	-45
9/4/2007	23.4	24.8	7.79	-49
9/5/2007	24.2	25.4	7.81	-52
9/6/2007	23.2	25.1	7.81	-50
9/7/2007	23.9	23.5	7.75	-50

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
9/8/2007	23.0	23.8	7.77	-52
9/9/2007	22.5	24.6	7.75	-53
9/10/2007	20.8	24.3	7.80	-49
9/11/2007	18.4	23.3	7.77	-55
9/12/2007	14.5	22.0	7.76	-46
9/13/2007	16.2	21.3	7.83	-46
9/14/2007	16.7	21.0	7.83	-49
9/15/2007	10.7	19.9	7.85	-48
9/16/2007	12.8	19.3	7.87	-49
9/17/2007	15.2	18.6	7.89	-48
9/18/2007	20.5	19.0	7.89	-48
9/19/2007	22.4	19.1	7.84	-46
9/20/2007	23.0	23.1	7.80	-48
9/21/2007	23.4	22.9	7.82	-46
9/22/2007	21.7	23.2	7.79	-48
9/23/2007	20.8	22.3	7.80	-46
9/24/2007	24.5	22.5	7.83	-46
9/25/2007	25.1	23.4	7.81	-47
9/26/2007	18.9	22.6	7.69	-51
9/27/2007	17.8	21.5	7.70	-54
9/28/2007	16.7	21.3	7.73	-45
9/29/2007	16.7	20.4	7.77	-42
9/30/2007	19.1	19.6	7.76	-42
10/1/2007	20.5	19.4	7.75	-42
10/2/2007	18.9	19.2	7.69	-40
10/3/2007	20.6	20.0	7.67	-43
10/4/2007	20.9	20.4	7.68	-40
10/5/2007	23.3	22.3	7.65	-39
10/6/2007	24.6	23.4	7.65	-40
10/7/2007	24.6	24.1	7.63	-39
10/8/2007	24.3	23.8	7.67	-39
10/9/2007	19.5	22.6	7.67	-41
10/10/2007	11.2	19.1	7.72	-39
10/11/2007	10.6	15.5	7.73	-41
10/12/2007	10.5	14.6	7.77	-44
10/13/2007	8.5	13.8	7.76	-42
10/14/2007	15.1	14.1	7.79	-43
10/15/2007	18.1	14.5	7.79	-44
10/16/2007	18.1	15.6	7.73	-43
10/17/2007	15.6	16.1	7.72	-42
10/18/2007	21.6	17.8	7.70	-44
10/19/2007	15.1	18.0	7.68	-39

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
10/20/2007	15.0	15.9	7.71	-39
10/21/2007	18.2	15.5	7.74	-40
10/22/2007	15.6	15.3	7.71	-38
10/23/2007	10.7	14.4	7.83	-43
10/24/2007	9.4	13.3	7.78	-41
10/25/2007	8.5	11.6	7.84	-45
10/26/2007	13.5	11.5	7.83	-45
10/27/2007	10.8	11.8	7.83	-44
10/28/2007	6.9	11.6	7.81	-43
10/29/2007	6.1	10.9	7.79	-42
10/30/2007	8.7	10.7	7.80	-42
10/31/2007	11.4	11.0	7.82	-43
11/1/2007	6.8	11.1	7.83	-52
11/2/2007	5.6	10.0	7.81	-72
11/3/2007	6.5	10.1	7.85	-66
11/4/2007	6.4	9.6	7.87	-64
11/5/2007	9.1	8.9	7.94	-64
11/6/2007	3.2	6.8	8.04	-65
11/7/2007	1.8	5.5	8.03	-65
11/8/2007	4.5	5.5	8.03	-64
11/9/2007	5.3	6.0	8.03	-64
11/10/2007	2.8	5.9	8.02	-64
11/11/2007	5.9	6.0	8.08	-66
11/12/2007	12.7	6.9	8.06	-66
11/13/2007	11.6	9.5	8.00	-67
11/14/2007	13.1	10.7	7.98	-67
11/15/2007	3.8	8.4	8.00	-66
11/16/2007	-0.2	6.1	8.04	-54
11/17/2007	3.9	5.4	8.10	-50
11/18/2007	3.3	5.2	8.11	-55
11/19/2007	7.2	5.2	8.09	-66
11/20/2007	15.1	8.3	8.07	-97
11/21/2007	12.9	10.5	8.05	-105
11/22/2007	2.7	8.8	8.10	-94
11/23/2007	-2.0	5.9	8.16	-106
11/24/2007	-1.8	4.8	8.20	-107
11/25/2007	-1.3	3.8	8.22	-113
11/26/2007	1.7	3.6	8.23	-106
11/27/2007	1.1	3.3	8.20	-112
11/28/2007	2.0	2.9	8.19	-109
11/29/2007	0.5	3.0	8.20	-76
11/30/2007	-0.7	1.9	8.17	-70

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
Period 3				
12/1/2007	-3.7	1.2	8.10	-71
12/2/2007	8.1	1.8	8.10	-73
12/3/2007	-2.7	2.2	8.12	-56
12/4/2007	-2.2	1.0	8.13	-54
12/5/2007	-3.2	0.6	8.14	-52
12/6/2007	-9.4	0.1	8.11	-55
12/7/2007	-2.1	0.2	8.08	-60
12/8/2007	-1.2	0.2	8.07	-68
12/9/2007	-0.8	0.4	8.05	-75
12/10/2007	-0.4	0.8	8.03	-78
12/11/2007	1.5	1.3	8.03	-84
12/12/2007	2.0	2.2	8.05	-60
12/13/2007	1.3	2.5	8.00	-68
12/14/2007	-1.3	1.7	8.03	-63
12/15/2007	-1.7	1.0	8.04	-58
12/16/2007	-4.3	-0.2	8.09	-54
12/17/2007	-7.6	-0.4	8.07	-56
12/18/2007	-4.0	-0.3	8.04	-59
12/19/2007	-1.5	-0.2	8.02	-60
12/20/2007	-2.8	-0.2	8.02	-66
12/21/2007	1.4	-0.1	8.02	-71
12/22/2007	5.7	0.1	8.02	-81
12/23/2007	1.8	1.4	8.07	-56
12/24/2007	-3.5	-0.4	8.13	-42
12/25/2007	-2.1	-0.4	8.11	-43
12/26/2007	0.5	-0.1	8.15	-43
12/27/2007	0.7	0.1	8.14	-53
12/28/2007	1.5	0.2	8.14	-56
12/29/2007	-1.0	0.2	8.16	-41
12/30/2007	-1.8	-0.1	8.15	-39
12/31/2007	0.5	0.2	8.13	-41
1/1/2008	-4.7	-0.1	8.18	-33
1/2/2008	-14.4	-0.4	8.15	-31
1/3/2008	-12.9	-0.4	8.16	-29
1/4/2008	-3.8	-0.4	8.15	-28
1/5/2008	3.0	-0.4	8.14	-29
1/6/2008	10.0	-0.1	8.14	-45
1/7/2008	15.9	3.5	8.11	-16
1/8/2008	14.3	8.4	8.07	-8
1/9/2008	4.0	8.6	8.10	-5
1/10/2008	2.4	7.0	8.12	-5

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
1/11/2008	3.1	6.1	8.15	-1
1/12/2008	0.2	4.6	8.17	-4
1/13/2008	0.8	4.1	8.17	-6
1/14/2008	-3.7	2.2	8.20	0
1/15/2008	-8.7	0.4	8.21	-3
1/16/2008	-6.4	0.3	8.18	-12
1/17/2008	-0.4	0.6	8.16	-27
1/18/2008	-5.4	0.4	8.15	-24
1/19/2008	-11.2	0.4	8.14	-32
1/20/2008	-15.2	-0.2	8.10	-82
1/21/2008	-9.4	-0.2	8.07	-139
1/22/2008	-3.3	-0.2	8.06	-147
1/23/2008	-10.3	-0.3	8.05	-140
1/24/2008	-11.8	-0.3	8.04	-139
1/25/2008	-14.6	-0.4	8.04	-129
1/26/2008	-4.1	-0.4	8.03	-126
1/27/2008	-3.2	N/A	N/A	N/A
1/28/2008	1.1	N/A	N/A	N/A
1/29/2008	7.9	N/A	N/A	N/A
1/30/2008	-11.1	N/A	N/A	N/A
1/31/2008	-8.2	N/A	N/A	N/A
2/1/2008	-2.8	N/A	N/A	N/A
2/2/2008	-2.0	N/A	N/A	N/A
2/3/2008	-2.1	N/A	N/A	N/A
2/4/2008	3.9	N/A	N/A	N/A
2/5/2008	8.2	N/A	N/A	N/A
2/6/2008	2.1	N/A	N/A	N/A
2/7/2008	-2.0	N/A	N/A	N/A
2/8/2008	0.4	N/A	N/A	N/A
2/9/2008	2.5	N/A	N/A	N/A
2/10/2008	-8.4	N/A	N/A	N/A
2/11/2008	-14.1	N/A	N/A	N/A
2/12/2008	-8.5	N/A	N/A	N/A
2/13/2008	-7.8	N/A	N/A	N/A
2/14/2008	-5.9	N/A	N/A	N/A
2/15/2008	-1.2	N/A	N/A	N/A
2/16/2008	-4.4	N/A	N/A	N/A
2/17/2008	6.6	N/A	N/A	N/A
2/18/2008	-1.2	N/A	N/A	N/A
2/19/2008	-10.4	N/A	N/A	N/A
2/20/2008	-7.7	N/A	N/A	N/A
2/21/2008	-12.2	N/A	N/A	N/A

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
2/22/2008	-6.1	N/A	N/A	N/A
2/23/2008	-3.9	N/A	N/A	N/A
2/24/2008	-7.0	N/A	N/A	N/A
2/25/2008	-0.6	N/A	N/A	N/A
2/26/2008	-0.7	N/A	N/A	N/A
2/27/2008	-6.4	N/A	N/A	N/A
2/28/2008	-9.2	N/A	N/A	N/A
2/29/2008	-0.3	N/A	N/A	N/A
3/1/2008	-0.3	N/A	N/A	N/A
3/2/2008	5.0	N/A	N/A	N/A
3/3/2008	8.7	N/A	N/A	N/A
3/4/2008	-1.2	N/A	N/A	N/A
3/5/2008	-3.6	N/A	N/A	N/A
Period 4				
3/6/2008	-1.4	N/A	N/A	N/A
3/7/2008	-3.3	N/A	N/A	N/A
3/8/2008	-5.6	N/A	N/A	N/A
3/9/2008	-2.9	N/A	N/A	N/A
3/10/2008	1.3	N/A	N/A	N/A
3/11/2008	-0.1	N/A	N/A	N/A
3/12/2008	3.5	N/A	N/A	N/A
3/13/2008	7.8	N/A	N/A	N/A
3/14/2008	8.1	N/A	N/A	N/A
3/15/2008	4.1	N/A	N/A	N/A
3/16/2008	1.4	N/A	N/A	N/A
3/17/2008	2.0	N/A	N/A	N/A
3/18/2008	7.6	N/A	N/A	N/A
3/19/2008	4.3	N/A	N/A	N/A
3/20/2008	3.9	N/A	N/A	N/A
3/21/2008	4.6	N/A	N/A	N/A
3/22/2008	2.3	N/A	N/A	N/A
3/23/2008	-0.3	N/A	N/A	N/A
3/24/2008	0.1	N/A	N/A	N/A
3/25/2008	3.5	N/A	N/A	N/A
3/26/2008	6.7	N/A	N/A	N/A
3/27/2008	5.8	N/A	N/A	N/A
3/28/2008	2.7	N/A	N/A	N/A
3/29/2008	1.8	N/A	N/A	N/A
3/30/2008	5.4	N/A	N/A	N/A
3/31/2008	12.9	N/A	N/A	N/A
4/1/2008	8.2	N/A	N/A	N/A
4/2/2008	3.7	N/A	N/A	N/A

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
4/3/2008	3.9	N/A	N/A	N/A
4/4/2008	5.7	N/A	N/A	N/A
4/5/2008	5.7	N/A	N/A	N/A
4/6/2008	9.2	N/A	N/A	N/A
4/7/2008	12.7	N/A	N/A	N/A
4/8/2008	11.7	N/A	N/A	N/A
4/9/2008	10.0	N/A	N/A	N/A
4/10/2008	8.6	N/A	N/A	N/A
4/11/2008	16.1	N/A	N/A	N/A
4/12/2008	5.1	N/A	N/A	N/A
4/13/2008	2.7	N/A	N/A	N/A
4/14/2008	3.6	N/A	N/A	N/A
4/15/2008	6.2	N/A	N/A	N/A
4/16/2008	11.0	N/A	N/A	N/A
4/17/2008	15.2	N/A	N/A	N/A
4/18/2008	16.8	N/A	N/A	N/A
4/19/2008	12.9	N/A	N/A	N/A
4/20/2008	12.2	N/A	N/A	N/A
4/21/2008	15.0	N/A	N/A	N/A
4/22/2008	16.8	N/A	N/A	N/A
4/23/2008	19.4	N/A	N/A	N/A
4/24/2008	19.1	N/A	N/A	N/A
4/25/2008	21.4	N/A	N/A	N/A
4/26/2008	13.3	N/A	N/A	N/A
4/27/2008	9.6	N/A	N/A	N/A
4/28/2008	7.6	N/A	N/A	N/A
4/29/2008	5.2	N/A	N/A	N/A
4/30/2008	7.7	N/A	N/A	N/A
5/1/2008	15.9	N/A	N/A	N/A
5/2/2008	19.5	N/A	N/A	N/A
5/3/2008	13.6	N/A	N/A	N/A
5/4/2008	10.4	N/A	N/A	N/A
5/5/2008	14.6	N/A	N/A	N/A
5/6/2008	18.8	16.7	N/A	N/A
5/7/2008	17.9	16.9	N/A	N/A
5/8/2008	13.0	16.3	N/A	N/A
5/9/2008	10.8	15.0	N/A	N/A
5/10/2008	11.7	15.4	N/A	N/A
5/11/2008	11.8	15.1	N/A	N/A
5/12/2008	8.2	12.8	N/A	N/A
5/13/2008	N/A	N/A	N/A	N/A
5/14/2008	14.6	15.3	N/A	-368

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
5/15/2008	10.6	14.6	N/A	-353
5/16/2008	12.0	14.2	N/A	-350
5/17/2008	16.2	15.4	N/A	-390
5/18/2008	13.0	16.3	N/A	-390
5/19/2008	9.9	16.1	N/A	-459
5/20/2008	11.0	15.5	N/A	-424
5/21/2008	11.9	15.7	N/A	-376
5/22/2008	13.2	17.9	N/A	-456
5/23/2008	11.7	17.3	N/A	-466
5/24/2008	13.9	16.9	N/A	-450
5/25/2008	16.5	17.5	N/A	-483
5/26/2008	21.2	18.3	N/A	-486
5/27/2008	16.3	19.3	N/A	-434
5/28/2008	12.9	18.2	N/A	-366
5/29/2008	16.3	19.1	N/A	-449
5/30/2008	20.9	19.3	N/A	-470
5/31/2008	22.2	20.8	N/A	-412
6/1/2008	21.0	22.9	N/A	-356
6/2/2008	21.9	23.6	N/A	-440
6/3/2008	21.7	22.9	N/A	-429
6/4/2008	22.0	22.6	N/A	-427
6/5/2008	25.6	23.7	N/A	-407
6/6/2008	25.2	24.6	N/A	-430
Period 5				
6/7/2008	21.5	24.0	N/A	-359
6/8/2008	26.7	24.1	N/A	-401
6/9/2008	25.9	25.7	N/A	-439
6/10/2008	21.3	26.1	N/A	-470
6/11/2008	23.2	26.0	N/A	-480
6/12/2008	24.4	25.7	N/A	-483
6/13/2008	23.1	25.4	N/A	-479
6/14/2008	22.2	24.8	N/A	-470
6/15/2008	22.6	24.9	N/A	-462
6/16/2008	20.3	24.7	N/A	-399
6/17/2008	17.4	24.2	N/A	-357
6/18/2008	18.4	24.0	N/A	-354
6/19/2008	19.1	24.0	N/A	-374
6/20/2008	22.0	25.3	N/A	-349
6/21/2008	21.2	23.6	N/A	-435
6/22/2008	19.9	23.0	N/A	-473
6/23/2008	18.8	23.1	N/A	-318
6/24/2008	19.2	23.4	N/A	-360

Date	Air temperature (°C)	Lagoon temperature (°C)	pH	ORP (mV)
6/25/2008	23.1	23.4	N/A	-426
6/26/2008	24.4	23.8	N/A	-449
6/27/2008	22.9	24.2	N/A	-474
6/28/2008	22.7	24.0	N/A	-469
6/29/2008	20.2	23.9	N/A	-398
6/30/2008	18.7	23.2	N/A	-285
7/1/2008	19.2	23.0	N/A	-383
7/2/2008	22.9	23.4	N/A	-399
7/3/2008	21.7	23.7	N/A	-364
7/4/2008	18.1	23.3	N/A	-351
7/5/2008	N/A	N/A	N/A	N/A
7/6/2008	25.3	24.4	N/A	-389
7/7/2008	21.7	24.7	N/A	-386
7/8/2008	24.5	24.3	N/A	-443
7/9/2008	22.9	26.3	N/A	-299
7/10/2008	22.1	26.6	N/A	-281
7/11/2008	23.4	26.7	N/A	-269
7/12/2008	24.4	27.0	N/A	-248
7/13/2008	21.6	26.5	N/A	-283
7/14/2008	20.4	25.7	N/A	-465
7/15/2008	23.0	N/A	N/A	-465
7/16/2008	22.7	N/A	N/A	N/A

6.12 Daily site emissions and data completeness

6.12.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year

Valid values: Number of ½ hour periods with valid emissions data

Direction limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction

Missing downwind NH_3: Number of ½ hour periods invalidated because at least 1 TDLAS path was either missing or else had invalid concentration values

Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ hour periods

Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ hour periods

Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ hour periods

Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ hour periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area

Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis

Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/2/2007	1	0	8	72.6	N/A	72.6	72.6	84.7	60.5	111.2
7/3/2007	11	0	37	45.3	29.7	-5.2	86.7	52.8	37.7	69.3
7/4/2007	10	0	37	66.2	26.1	37.0	125.9	77.2	55.2	101.4
7/5/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/6/2007	2	0	46	49.3	2.6	47.4	51.1	57.5	41.0	75.4
7/7/2007	1	0	46	80.0	N/A	80.0	80.0	93.3	66.7	122.5
7/8/2007	6	0	42	59.6	9.1	46.7	69.6	69.6	49.7	91.3
7/9/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/10/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/11/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/12/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2007	5	0	43	77.8	15.3	53.3	95.6	90.7	64.8	119.1
7/14/2007	3	0	8	88.4	14.2	75.6	103.7	103.1	73.6	135.4
7/15/2007	9	0	27	62.9	19.0	29.6	88.1	73.3	52.4	96.3
7/16/2007	5	0	34	87.4	34.0	34.8	117.0	102.0	72.8	133.9
7/17/2007	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/18/2007	6	0	35	46.8	10.7	30.4	60.7	54.6	39.0	71.7
7/19/2007	15	0	29	48.4	12.6	26.7	71.9	56.5	40.4	74.2
7/20/2007	18	0	27	61.6	11.0	43.0	80.7	71.8	51.3	94.3
7/21/2007	3	0	45	82.0	11.6	69.6	92.6	95.6	68.3	125.5
7/22/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/23/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/24/2007	1	0	39	47.4	N/A	47.4	47.4	55.3	39.5	72.6
7/25/2007	4	0	43	63.0	16.4	42.2	81.5	73.4	52.5	96.4

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/26/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/27/2007	4	0	39	39.1	10.0	26.7	51.1	45.6	32.6	59.8
7/28/2007	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/29/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/30/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/31/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/1/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/2/2007	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/3/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/4/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/5/2007	1	0	47	63.7	N/A	63.7	63.7	74.3	53.1	97.6
8/6/2007	2	0	42	60.0	19.9	45.9	74.1	70.0	50.0	91.9
8/7/2007	5	0	38	79.6	31.8	34.1	118.5	92.8	66.3	121.8
8/8/2007	3	0	31	35.6	8.7	28.1	45.2	41.5	29.6	54.4
8/9/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/10/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/14/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/15/2007	0	0	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/16/2007	1	0	41	41.5	N/A	41.5	41.5	48.4	34.6	63.5
8/17/2007	6	0	39	35.6	8.5	27.4	49.6	41.5	29.6	54.4
8/18/2007	5	0	43	57.6	6.9	48.1	67.4	67.2	48.0	88.3
8/19/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/20/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/21/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/23/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/24/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/25/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/26/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/27/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/28/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/29/2007	4	0	38	46.7	14.3	32.6	63.0	54.4	38.9	71.5
8/30/2007	1	0	47	50.4	N/A	50.4	50.4	58.8	42.0	77.1
8/31/2007	7	0	39	42.1	7.3	32.6	52.6	49.1	35.1	64.5
9/1/2007	0	0	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/2/2007	0	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/3/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/4/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2007	0	0	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/6/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/7/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/8/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/9/2007	4	0	32	45.2	5.6	39.3	51.9	52.7	37.6	69.2
9/10/2007	12	0	36	47.4	3.3	43.0	53.3	55.3	39.5	72.6
9/11/2007	28	0	17	45.5	11.4	27.4	70.4	53.1	37.9	69.7
9/12/2007	11	0	32	19.9	9.1	8.1	38.5	23.2	16.6	30.4
9/13/2007	2	0	46	45.2	4.2	42.2	48.1	52.7	37.6	69.2
9/14/2007	11	0	26	52.5	10.7	31.9	68.9	61.2	43.7	80.3
9/15/2007	24	0	22	23.7	9.2	12.6	43.7	27.6	19.7	36.3
9/16/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/18/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/19/2007	0	0	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/20/2007	0	0	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/21/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/22/2007	15	0	22	24.9	6.7	17.0	40.0	29.0	20.7	38.1
9/23/2007	1	0	47	26.7	N/A	26.7	26.7	31.1	22.2	40.8
9/24/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2007	20	0	19	28.3	4.7	18.5	37.8	33.0	23.5	43.3
9/27/2007	7	0	29	22.3	7.0	13.3	32.6	26.0	18.6	34.2
9/28/2007	18	0	17	21.4	5.1	14.8	31.9	24.9	17.8	32.7
9/29/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/30/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/1/2007	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/2/2007	1	0	46	17.8	N/A	17.8	17.8	20.7	14.8	27.2
10/3/2007	7	0	29	16.4	11.1	6.7	39.3	19.1	13.7	25.1
10/4/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/5/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/6/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/8/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/9/2007	22	0	15	40.6	17.5	14.8	78.5	47.3	33.8	62.1
10/10/2007	21	0	14	27.5	5.4	13.3	34.8	32.1	22.9	42.1
10/11/2007	7	0	11	18.8	5.8	13.3	30.4	22.0	15.7	28.8
10/12/2007	9	0	22	14.8	2.8	11.1	18.5	17.3	12.3	22.7
10/13/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/14/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/15/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/16/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/17/2007	0	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/18/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/19/2007	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/20/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/21/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/22/2007	0	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/23/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/24/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/25/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/26/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/27/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/28/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/29/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/30/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/31/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/1/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/2/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/3/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/4/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/5/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/6/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/7/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/8/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/9/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/10/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/11/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/12/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/13/2007	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/14/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/15/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/16/2007	0	0	39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/17/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/18/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/19/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/20/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/21/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/22/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/23/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/24/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/25/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/26/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/27/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/28/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/29/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/30/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/30/2008	0	0	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2008	0	0	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/2/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
2/3/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/4/2008	0	0	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2008	0	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2008	0	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2008	0	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/8/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/9/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/12/2008	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/13/2008	0	0	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/14/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/15/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/16/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/17/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/19/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/20/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/21/2008	0	0	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/7/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/8/2008	0	0	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/9/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2008	0	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/13/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/26/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/27/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/28/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/29/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
3/30/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/31/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/1/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/4/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/5/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/7/2008	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/8/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/9/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/10/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/12/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/15/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/16/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/17/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/19/2008	9	0	35	15.5	3.5	10.4	22.2	18.0	12.9	23.7
4/20/2008	20	0	19	15.0	6.9	4.4	31.1	17.5	12.5	22.9
4/21/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/22/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/23/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/24/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/26/2008	14	0	30	35.2	6.0	23.7	45.2	41.0	29.3	53.9
4/27/2008	18	0	30	22.9	7.5	11.1	40.0	26.7	19.1	35.1
4/28/2008	16	0	22	23.4	9.8	7.4	40.0	27.3	19.5	35.8
4/29/2008	12	0	24	15.1	6.0	5.2	24.4	17.6	12.6	23.2
4/30/2008	1	0	47	19.3	N/A	19.3	19.3	22.5	16.0	29.5
5/1/2008	0	0	36	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2008	16	0	28	90.8	18.8	63.7	132.6	105.9	75.7	139.1
5/4/2008	5	0	32	52.7	21.7	24.4	77.8	61.5	43.9	80.8
5/5/2008	4	0	42	93.5	21.0	72.6	122.2	109.1	77.9	143.2
5/6/2008	1	0	46	53.3	N/A	53.3	53.3	62.2	44.4	81.7
5/7/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/8/2008	7	0	40	21.6	4.0	17.0	28.9	25.2	18.0	33.1
5/9/2008	16	0	28	14.1	3.7	7.4	20.7	16.4	11.7	21.6
5/10/2008	15	0	33	14.9	3.6	8.9	20.7	17.3	12.4	22.8
5/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/12/2008	13	0	32	13.3	4.0	8.1	20.0	15.5	11.1	20.3

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5/13/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/14/2008	8	0	39	19.4	3.2	14.1	23.7	22.6	16.1	29.6
5/15/2008	11	0	33	16.4	2.4	12.6	20.0	19.2	13.7	25.2
5/16/2008	34	0	12	23.2	7.8	14.8	46.7	27.0	19.3	35.5
5/17/2008	1	0	47	41.5	N/A	41.5	41.5	48.4	34.6	63.5
5/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/19/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/20/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/21/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2008	0	0	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2008	0	0	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/1/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/2/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/3/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/4/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/5/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/6/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2008	0	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2008	0	0	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/10/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/12/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/13/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/14/2008	18	0	26	42.1	17.4	13.3	80.7	49.2	35.1	64.5
6/15/2008	3	0	44	102.0	57.0	63.0	167.4	118.9	85.0	156.2
6/16/2008	15	0	28	55.3	33.0	26.7	151.1	64.5	46.0	84.6
6/17/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/19/2008	0	0	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/20/2008	8	0	10	50.9	28.9	17.0	97.8	59.4	42.4	78.0
6/21/2008	1	0	47	71.9	N/A	71.9	71.9	83.8	59.9	110.0
6/22/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/23/2008	4	0	44	59.4	12.6	49.6	77.0	69.3	49.5	91.0
6/24/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/25/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/26/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/27/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/28/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/29/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/30/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/1/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/2/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/3/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/4/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/5/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/6/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/7/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/8/2008	7	0	40	61.9	14.4	48.1	87.4	72.2	51.6	94.8
7/9/2008	13	0	33	45.4	15.0	23.0	77.8	53.0	37.8	69.5
7/10/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/11/2008	5	0	43	36.7	4.8	28.9	40.7	42.9	30.6	56.3
7/12/2008	8	0	40	60.4	18.2	28.1	77.8	70.4	50.3	92.4
7/13/2008	37	0	11	50.0	10.6	31.1	68.9	58.4	41.7	76.6
7/14/2008	13	0	16	35.8	9.1	23.7	50.4	41.8	29.9	54.9

6.12.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year

Valid: Number of ½ hour periods with valid emissions data

Direction limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction

Touchdown limited: Number of ½ hour periods invalidated because fraction of source area surface covered by particle touchdowns was less than 0.1

Turbulence limited: Number of ½ hour periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m

Background (ppm): bLS model calculated daily average background concentration (ppm); average is over the ½ hour periods included in the valid column

Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ hour periods

Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ hour periods

Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ hour periods

Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ hour periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area

Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis

Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/2/2007	5	0	1	1	-0.02	65.4	9.4	54.4	75.8	76.7	54.8	100.7
7/3/2007	21	0	0	25	-0.13	107.5	62.5	0.3	268.7	126.2	90.1	165.7
7/4/2007	28	0	5	14	-0.01	45.4	27.9	6.0	96.6	53.2	38.0	69.9
7/5/2007	17	0	20	2	-0.01	62.5	28.9	7.6	113.2	73.4	52.4	96.4
7/6/2007	5	0	12	30	0.00	38.3	24.0	13.4	67.7	45.0	32.1	59.0
7/7/2007	2	0	5	27	0.04	8.9	15.1	-1.8	19.6	10.4	7.4	13.7
7/8/2007	25	0	0	20	0.00	91.8	25.1	43.3	148.8	107.7	76.9	141.4
7/9/2007	29	0	0	19	0.00	117.6	37.3	41.4	191.0	138.0	98.6	181.2
7/10/2007	32	0	0	16	0.01	133.1	40.5	50.5	202.1	156.2	111.6	205.0
7/11/2007	12	0	19	1	0.01	76.6	25.1	41.8	123.1	89.8	64.2	117.9
7/12/2007	10	0	19	11	0.03	41.9	19.4	6.7	75.8	49.1	35.1	64.5
7/13/2007	5	0	33	8	-0.02	95.4	11.5	79.4	110.4	112.0	80.0	147.0
7/14/2007	2	0	0	7	-0.12	76.9	54.2	38.6	115.2	90.3	64.5	118.5
7/15/2007	20	0	0	17	-0.01	83.2	49.0	2.7	193.2	97.6	69.7	128.1
7/16/2007	12	0	3	29	-0.03	48.0	39.9	10.0	136.9	56.4	40.3	74.0
7/17/2007	29	0	2	16	0.01	28.6	23.6	-2.2	73.1	33.5	23.9	44.0
7/18/2007	36	0	1	11	-0.01	42.0	22.3	5.4	88.4	49.3	35.2	64.7
7/19/2007	44	0	2	2	-0.01	55.9	25.7	-0.3	123.8	65.6	46.8	86.1
7/20/2007	28	0	0	20	0.00	70.0	18.6	34.7	121.4	82.1	58.7	107.8
7/21/2007	22	0	0	26	0.01	32.5	22.3	-1.5	93.7	38.1	27.2	50.0
7/22/2007	23	0	0	25	0.03	23.8	13.0	6.1	43.1	27.9	19.9	36.6
7/23/2007	25	0	0	23	-0.01	51.6	31.7	10.9	105.6	60.5	43.2	79.5

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/24/2007	8	0	0	27	0.06	62.4	25.6	11.9	85.2	73.2	52.3	96.2
7/25/2007	10	0	0	34	-0.03	59.4	29.1	4.5	89.7	69.7	49.8	91.5
7/26/2007	42	0	2	2	0.04	22.8	14.7	-1.5	53.6	26.8	19.1	35.2
7/27/2007	44	0	1	3	0.00	27.8	16.5	-7.8	57.8	32.6	23.3	42.8
7/28/2007	13	0	1	32	0.02	30.5	14.7	-5.8	55.5	35.7	25.5	46.9
7/29/2007	20	0	0	28	-0.01	72.8	16.3	36.8	101.3	85.5	61.0	112.2
7/30/2007	20	0	0	28	-0.01	50.2	24.9	22.2	90.9	58.9	42.1	77.4
7/31/2007	11	0	0	34	-0.03	68.6	39.3	28.2	154.7	80.4	57.5	105.6
8/1/2007	12	0	0	36	0.02	73.3	36.7	10.2	147.9	86.0	61.4	112.9
8/2/2007	20	0	0	27	-0.06	82.0	52.3	19.1	186.8	96.3	68.8	126.4
8/3/2007	22	0	0	20	-0.01	65.2	41.4	-3.3	153.5	76.5	54.6	100.4
8/4/2007	16	0	0	32	0.01	24.4	10.4	12.2	49.4	28.6	20.4	37.6
8/5/2007	41	0	0	7	0.02	36.7	25.4	2.5	82.0	43.1	30.8	56.6
8/6/2007	47	0	0	1	0.01	41.8	22.0	-3.8	90.7	49.0	35.0	64.3
8/7/2007	38	0	0	8	0.02	53.6	36.7	-2.9	130.2	62.9	44.9	82.6
8/8/2007	15	0	0	18	0.05	26.1	13.4	5.1	56.8	30.7	21.9	40.2
8/9/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/10/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/14/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/15/2007	9	0	2	3	0.01	7.0	5.7	0.9	16.1	8.2	5.8	10.7
8/16/2007	30	0	1	14	0.06	31.5	31.5	-9.0	76.3	36.9	26.4	48.5
8/17/2007	23	0	0	25	0.02	65.1	21.6	31.9	103.3	76.4	54.5	100.3
8/18/2007	21	0	6	20	0.04	10.9	27.4	-8.5	72.5	12.8	9.2	16.9
8/19/2007	33	0	9	6	0.02	17.0	22.4	-8.9	60.2	19.9	14.2	26.1
8/20/2007	34	0	11	2	0.04	8.4	22.7	-65.1	48.2	9.8	7.0	12.9
8/21/2007	18	0	24	5	0.02	28.3	27.4	0.4	85.6	33.2	23.7	43.6
8/22/2007	32	0	10	5	0.05	54.3	22.5	27.6	104.0	63.8	45.6	83.7
8/23/2007	26	0	6	15	0.01	37.9	32.1	-10.5	95.7	44.5	31.8	58.4
8/24/2007	35	0	0	8	0.03	30.4	36.5	0.3	138.8	35.7	25.5	46.9
8/25/2007	30	0	2	8	0.04	6.1	15.6	-3.6	64.4	7.2	5.1	9.4
8/26/2007	7	0	10	28	0.01	10.1	5.4	1.5	16.4	11.9	8.5	15.6
8/27/2007	20	0	0	26	0.05	19.0	25.1	-9.9	100.3	22.3	15.9	29.3
8/28/2007	30	0	0	18	0.07	6.2	8.0	-0.6	33.4	7.3	5.2	9.5
8/29/2007	24	0	0	22	-0.03	38.3	24.8	-9.9	75.0	44.9	32.1	59.0
8/30/2007	19	0	6	15	0.03	51.3	26.1	-3.7	76.6	60.2	43.0	79.1
8/31/2007	22	0	0	26	0.03	38.2	11.2	19.1	59.8	44.8	32.0	58.9
9/1/2007	22	0	0	19	0.08	-2.0	4.5	-9.8	5.4	-2.4	-1.7	-3.1
9/2/2007	0	0	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/3/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/4/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2007	9	0	0	4	0.04	2.2	2.8	-0.2	6.9	2.6	1.9	3.4
9/6/2007	29	0	0	19	0.07	4.8	9.1	-2.7	36.8	5.6	4.0	7.3
9/7/2007	48	0	0	0	0.06	6.3	11.1	-6.9	31.4	7.3	5.2	9.6

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/8/2007	33	0	1	14	0.06	8.0	9.8	-1.9	31.2	9.4	6.7	12.3
9/9/2007	24	0	0	20	0.01	42.9	21.5	1.5	70.6	50.3	36.0	66.1
9/10/2007	19	0	0	29	0.07	13.7	12.0	0.9	45.9	16.1	11.5	21.1
9/11/2007	24	0	12	10	0.03	49.5	16.4	28.4	113.1	58.1	41.5	76.3
9/12/2007	15	0	6	24	0.00	19.6	13.2	-0.9	45.1	23.0	16.4	30.2
9/13/2007	21	0	0	25	0.03	13.3	9.4	-1.2	26.1	15.7	11.2	20.6
9/14/2007	34	0	0	14	0.04	29.3	19.5	0.1	55.3	34.4	24.6	45.2
9/15/2007	23	0	0	25	0.02	17.6	8.1	5.6	35.8	20.6	14.7	27.1
9/16/2007	34	0	0	13	0.02	5.6	6.9	-0.7	20.7	6.6	4.7	8.7
9/17/2007	33	0	0	15	0.03	0.5	1.2	-1.8	3.3	0.6	0.4	0.8
9/18/2007	32	0	0	16	0.06	1.7	5.6	-6.8	15.7	2.0	1.4	2.6
9/19/2007	20	0	0	14	0.05	7.3	8.7	-1.2	23.1	8.6	6.2	11.3
9/20/2007	5	0	0	3	0.05	3.6	5.1	-1.5	12.1	4.2	3.0	5.5
9/21/2007	27	0	0	21	0.06	0.9	4.4	-8.5	10.7	1.1	0.8	1.4
9/22/2007	38	0	0	10	0.03	22.2	15.5	2.7	50.6	26.0	18.6	34.2
9/23/2007	23	0	0	25	0.05	0.7	3.0	-3.7	6.7	0.8	0.6	1.0
9/24/2007	39	0	0	9	0.07	0.6	2.7	-2.7	8.1	0.7	0.5	0.9
9/25/2007	48	0	0	0	0.07	8.4	8.5	-3.9	28.3	9.9	7.0	12.9
9/26/2007	32	0	0	15	0.05	14.6	10.7	-4.1	33.3	17.2	12.3	22.5
9/27/2007	25	0	2	17	0.03	15.9	11.7	-2.4	38.1	18.6	13.3	24.4
9/28/2007	20	0	0	24	0.03	19.2	6.4	10.3	33.7	22.6	16.1	29.6
9/29/2007	24	0	0	24	0.05	1.7	4.2	-4.0	13.4	2.0	1.4	2.7
9/30/2007	42	0	0	6	0.04	0.7	1.5	-0.9	7.2	0.8	0.6	1.1
10/1/2007	48	0	0	0	0.05	7.4	12.8	-6.1	36.7	8.7	6.2	11.4
10/2/2007	29	0	0	19	0.05	1.6	4.2	-6.4	10.1	1.9	1.4	2.5
10/3/2007	44	0	1	3	0.06	7.4	10.6	-7.3	27.1	8.7	6.2	11.5
10/4/2007	17	0	6	22	0.05	0.7	2.9	-4.8	7.0	0.8	0.6	1.1
10/5/2007	22	0	0	25	0.07	0.4	4.8	-6.2	14.5	0.5	0.3	0.6
10/6/2007	34	0	0	14	0.04	7.6	9.0	-1.9	26.7	8.9	6.4	11.7
10/7/2007	18	0	0	26	0.07	3.4	4.9	-3.1	15.2	3.9	2.8	5.2
10/8/2007	22	0	0	24	0.04	14.5	13.0	-3.0	41.6	17.1	12.2	22.4
10/9/2007	37	0	1	10	0.03	31.8	15.1	-2.1	62.9	37.3	26.6	49.0
10/10/2007	47	0	0	1	0.04	24.5	9.6	4.1	43.0	28.8	20.6	37.8
10/11/2007	26	0	0	1	0.03	22.4	9.1	7.1	34.8	26.3	18.8	34.5
10/12/2007	30	0	0	14	0.03	14.1	7.1	1.9	37.7	16.6	11.9	21.8
10/13/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/14/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/15/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/16/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/17/2007	1	0	3	0	0.06	-1.4	N/A	-1.4	-1.4	-1.6	-1.1	-2.1
10/18/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/19/2007	0	0	22	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/20/2007	0	0	45	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/21/2007	0	0	46	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/22/2007	0	0	14	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/23/2007	7	0	4	7	0.04	-2.3	1.1	-3.8	-0.9	-2.7	-1.9	-3.6

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/24/2007	19	0	14	10	0.05	-7.2	19.8	-88.5	1.6	-8.4	-6.0	-11.1
10/25/2007	34	0	13	1	0.04	-2.7	7.0	-20.5	9.2	-3.2	-2.3	-4.1
10/26/2007	46	0	0	2	0.01	1.9	2.7	-8.7	4.7	2.3	1.6	3.0
10/27/2007	23	0	9	5	0.03	0.1	1.7	-1.3	4.3	0.1	0.1	0.1
10/28/2007	6	0	9	30	0.05	-1.8	15.0	-19.5	19.9	-2.1	-1.5	-2.7
10/29/2007	20	0	0	22	0.03	4.1	5.0	-0.9	13.1	4.8	3.4	6.2
10/30/2007	16	0	4	24	0.01	3.3	1.4	1.6	6.8	3.9	2.8	5.1
10/31/2007	41	0	4	2	0.02	3.3	4.7	-3.1	16.4	3.8	2.7	5.0
11/1/2007	1	0	16	11	0.01	11.1	N/A	11.1	11.1	13.0	9.3	17.1
11/2/2007	16	0	0	27	0.01	3.4	3.0	0.3	12.6	4.0	2.8	5.2
11/3/2007	1	0	9	24	-0.01	1.8	N/A	1.8	1.8	2.2	1.5	2.8
11/4/2007	10	0	17	19	0.05	-1.4	11.3	-26.2	14.2	-1.6	-1.1	-2.1
11/5/2007	19	0	8	14	0.04	1.2	3.4	-6.5	8.3	1.4	1.0	1.8
11/6/2007	0	0	23	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/7/2007	9	0	8	27	0.04	12.8	18.3	-2.3	57.8	15.0	10.7	19.7
11/8/2007	31	0	0	15	0.03	6.1	8.4	-10.8	24.3	7.1	5.1	9.4
11/9/2007	0	0	16	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/10/2007	8	0	1	34	0.01	4.0	8.8	-1.0	25.5	4.7	3.3	6.1
11/11/2007	42	0	0	4	0.00	5.6	5.6	1.8	27.9	6.5	4.7	8.6
11/12/2007	42	0	1	3	0.03	3.9	5.2	-2.9	15.4	4.6	3.3	6.0
11/13/2007	11	0	3	18	0.03	-0.5	1.9	-2.4	2.7	-0.6	-0.4	-0.8
11/14/2007	22	0	7	0	0.03	0.3	2.9	-3.0	6.2	0.4	0.3	0.5
11/15/2007	0	0	4	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/16/2007	15	0	2	18	0.03	0.6	1.9	-2.7	3.9	0.7	0.5	0.9
11/17/2007	41	0	4	3	0.02	1.2	1.4	-1.7	4.3	1.4	1.0	1.9
11/18/2007	36	0	4	8	0.02	0.5	1.8	-2.6	3.9	0.6	0.4	0.8
11/19/2007	47	0	0	1	0.01	3.7	1.4	1.8	8.0	4.3	3.1	5.6
11/20/2007	48	0	0	0	0.03	-0.3	2.1	-3.1	3.7	-0.4	-0.3	-0.5
11/21/2007	36	0	8	0	0.03	0.1	1.8	-3.3	2.2	0.1	0.1	0.1
11/22/2007	3	0	5	0	0.04	-3.0	0.9	-3.7	-2.0	-3.6	-2.6	-4.7
11/23/2007	3	0	6	3	0.04	-0.4	0.6	-1.1	0.1	-0.5	-0.4	-0.7
11/24/2007	17	0	0	30	0.03	-0.8	1.8	-4.2	1.4	-1.0	-0.7	-1.3
11/25/2007	9	0	0	36	0.02	1.6	1.3	-0.5	2.9	1.9	1.4	2.5
11/26/2007	11	0	16	11	0.01	1.0	1.9	-1.7	2.9	1.2	0.9	1.6
11/27/2007	11	0	19	2	0.04	0.7	3.5	-2.5	7.6	0.8	0.6	1.1
11/28/2007	37	0	0	11	0.01	4.7	1.7	1.9	9.5	5.5	3.9	7.2
11/29/2007	10	0	23	0	0.03	1.3	2.8	-2.1	4.7	1.6	1.1	2.1
11/30/2007	19	0	5	11	0.03	2.6	7.6	-2.3	24.4	3.1	2.2	4.0
1/30/2008	0	0	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2008	0	0	0	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/2/2008	0	0	1	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/3/2008	0	0	3	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/4/2008	0	0	3	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2008	0	0	1	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2008	0	0	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
2/7/2008	0	0	1	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/8/2008	0	0	2	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/9/2008	0	0	5	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/11/2008	0	0	12	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/12/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/13/2008	0	0	0	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/14/2008	0	0	0	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/15/2008	0	0	3	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/16/2008	0	0	4	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/17/2008	0	0	4	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/18/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/19/2008	0	0	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/20/2008	0	0	4	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/21/2008	0	0	0	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	0	0	2	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/7/2008	0	0	0	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/8/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/9/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	0	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2008	0	0	2	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/13/2008	0	0	1	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	0	10	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	0	0	1	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2008	0	0	9	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	0	0	6	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/18/2008	0	0	4	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2008	0	0	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	0	4	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	0	3	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	0	0	5	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2008	0	0	13	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2008	0	0	9	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2008	0	0	2	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/26/2008	0	0	6	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/27/2008	0	0	5	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/28/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/29/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/30/2008	0	0	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/31/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/1/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2008	0	0	1	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2008	0	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/4/2008	0	0	0	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
4/5/2008	0	0	12	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2008	0	0	16	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/7/2008	0	0	4	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/8/2008	0	0	2	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/9/2008	0	0	11	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/10/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/11/2008	0	0	2	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/12/2008	0	0	11	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2008	0	0	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2008	0	0	4	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/15/2008	16	0	2	22	0.01	13.0	10.1	-6.2	27.6	15.3	10.9	20.0
4/16/2008	10	0	28	9	0.03	13.2	13.0	-13.2	31.9	15.5	11.1	20.3
4/17/2008	23	0	18	6	-0.02	25.0	9.7	6.1	39.3	29.3	20.9	38.4
4/18/2008	7	0	21	10	0.01	28.5	11.8	13.5	43.4	33.4	23.9	43.9
4/19/2008	26	0	7	7	-0.01	18.0	4.7	6.5	27.8	21.1	15.1	27.8
4/20/2008	39	0	0	9	-0.01	17.2	6.1	5.6	35.0	20.2	14.4	26.5
4/21/2008	3	0	17	23	0.00	1.0	27.1	-29.9	21.1	1.1	0.8	1.5
4/22/2008	12	0	10	17	0.01	14.3	9.7	-3.3	30.9	16.7	12.0	22.0
4/23/2008	18	0	5	22	-0.01	39.4	9.8	20.6	58.0	46.2	33.0	60.7
4/24/2008	1	0	19	3	0.00	45.7	N/A	45.7	45.7	53.6	38.3	70.3
4/25/2008	9	0	38	0	0.00	78.9	22.8	34.1	115.3	92.5	66.1	121.5
4/26/2008	40	0	5	0	-0.01	34.6	23.1	-0.2	77.2	40.7	29.0	53.4
4/27/2008	28	0	0	19	-0.01	26.7	10.5	4.7	43.8	31.3	22.3	41.1
4/28/2008	29	0	2	11	0.00	25.7	12.6	5.3	48.5	30.1	21.5	39.6
4/29/2008	48	0	0	0	0.00	21.1	7.1	9.6	38.4	24.8	17.7	32.5
4/30/2008	4	0	13	22	-0.02	16.4	2.6	13.7	20.0	19.3	13.8	25.3
5/1/2008	2	0	12	3	0.00	25.2	0.5	24.8	25.5	29.5	21.1	38.8
5/2/2008	6	0	39	0	-0.01	25.5	4.0	22.0	31.8	29.9	21.4	39.3
5/3/2008	27	0	17	4	-0.02	42.9	11.8	14.9	63.8	50.3	36.0	66.1
5/4/2008	32	0	1	15	-0.01	17.4	9.5	3.1	43.0	20.4	14.5	26.7
5/5/2008	24	0	0	17	-0.03	27.9	5.3	18.6	36.8	32.7	23.3	42.9
5/6/2008	31	0	4	13	-0.02	25.5	13.0	3.2	55.0	30.0	21.4	39.3
5/7/2008	18	0	1	6	-0.03	52.4	10.7	32.6	66.1	61.5	43.9	80.7
5/8/2008	44	0	0	1	-0.04	36.1	7.8	22.0	54.5	42.4	30.3	55.6
5/9/2008	37	0	0	6	-0.01	22.7	5.5	9.8	30.6	26.6	19.0	34.9
5/10/2008	11	0	16	18	-0.01	15.4	7.4	2.3	24.2	18.1	12.9	23.8
5/11/2008	12	0	9	3	-0.01	41.1	15.5	23.3	81.5	48.3	34.5	63.4
5/12/2008	43	0	0	1	0.01	18.7	8.1	5.2	35.8	22.0	15.7	28.9
5/13/2008	0	0	23	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/14/2008	24	0	14	2	-0.03	40.1	9.8	25.5	57.8	47.0	33.6	61.7
5/15/2008	36	0	2	10	-0.02	24.1	6.7	4.3	32.7	28.3	20.2	37.1
5/16/2008	47	0	0	0	-0.01	34.5	9.3	13.7	54.6	40.5	28.9	53.2
5/17/2008	45	0	0	2	-0.02	49.3	16.6	18.6	87.9	57.8	41.3	75.9
5/18/2008	0	0	8	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/19/2008	0	0	9	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/20/2008	0	0	5	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/21/2008	0	0	12	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2008	0	0	14	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	0	14	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	0	0	11	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2008	0	0	2	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2008	0	0	9	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2008	0	0	1	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2008	0	0	10	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2008	7	0	3	27	-0.09	29.3	21.8	15.7	76.1	34.4	24.6	45.2
5/30/2008	0	0	0	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2008	9	0	14	0	0.00	88.6	12.1	58.8	97.0	103.9	74.2	136.4
6/1/2008	20	0	4	19	-0.02	47.5	15.1	12.8	77.7	55.8	39.9	73.3
6/2/2008	1	0	0	20	0.00	8.2	N/A	8.2	8.2	9.6	6.9	12.6
6/3/2008	1	0	1	8	-0.98	116.1	N/A	116.1	116.1	136.3	97.3	178.9
6/4/2008	6	0	0	6	-0.05	23.7	12.5	7.4	43.1	27.9	19.9	36.6
6/5/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/6/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2008	1	0	1	0	-0.07	31.5	N/A	31.5	31.5	37.0	26.4	48.6
6/10/2008	14	0	14	10	-0.01	64.5	37.8	16.4	140.5	75.6	54.0	99.3
6/11/2008	0	0	11	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/12/2008	0	0	19	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/13/2008	3	0	26	2	-0.17	104.7	42.8	55.7	134.8	122.9	87.8	161.3
6/14/2008	26	0	5	17	-0.03	53.8	28.0	7.7	109.6	63.1	45.1	82.8
6/15/2008	19	0	3	22	0.00	88.0	30.9	32.5	146.5	103.3	73.8	135.6
6/16/2008	22	0	6	8	-0.02	63.8	37.1	0.7	159.1	74.9	53.5	98.3
6/17/2008	0	0	11	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2008	0	0	8	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/19/2008	0	0	2	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/20/2008	19	0	0	0	-0.03	49.6	36.8	5.9	153.8	58.2	41.6	76.4
6/21/2008	23	0	4	11	0.07	40.4	30.8	-54.4	76.6	47.4	33.9	62.3
6/22/2008	0	0	14	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/23/2008	10	0	9	6	-0.01	54.2	15.9	36.5	75.7	63.6	45.5	83.5
6/24/2008	13	0	2	25	-0.01	45.7	17.2	20.2	74.4	53.6	38.3	70.4
6/25/2008	3	0	0	18	-0.04	10.3	6.0	5.2	16.9	12.1	8.6	15.9
6/26/2008	8	0	6	9	0.00	36.3	8.1	24.6	48.7	42.6	30.4	55.9
6/27/2008	0	0	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/28/2008	1	0	3	0	0.00	43.4	N/A	43.4	43.4	50.9	36.4	66.9
6/29/2008	0	0	5	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/30/2008	0	0	3	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/1/2008	5	0	8	22	-0.04	45.0	24.6	21.6	75.0	52.8	37.7	69.3
7/2/2008	0	0	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/3/2008	10	0	4	6	0.00	38.0	3.8	32.5	43.3	44.6	31.9	58.5
7/4/2008	25	0	10	10	0.00	27.5	5.2	15.6	36.6	32.3	23.1	42.4
7/5/2008	23	0	1	23	0.00	31.1	7.1	20.7	45.9	36.5	26.0	47.9

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/6/2008	1	0	2	25	-0.04	10.7	N/A	10.7	10.7	12.6	9.0	16.5
7/7/2008	2	0	5	19	-0.01	18.9	25.0	1.2	36.6	22.2	15.8	29.1
7/8/2008	19	0	0	4	-0.04	77.8	13.6	40.4	97.0	91.3	65.2	119.9
7/9/2008	43	0	3	1	-0.02	50.8	11.0	26.7	80.2	59.6	42.5	78.2
7/10/2008	11	0	8	25	-0.02	79.4	19.3	38.6	100.4	93.2	66.6	122.4
7/11/2008	31	0	3	10	0.00	67.4	26.7	21.1	115.2	79.1	56.5	103.8
7/12/2008	21	0	14	3	-0.07	77.4	28.8	13.0	144.6	90.8	64.9	119.2
7/13/2008	46	0	1	1	-0.03	57.8	19.5	23.0	97.8	67.9	48.5	89.1
7/14/2008	8	0	0	20	-0.02	35.3	3.4	30.0	40.2	41.4	29.6	54.4

6.12.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year

Valid: Number of ½ hour periods with valid emissions data

Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ hour periods

Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ hour periods

Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ hour periods

Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ hour periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area

Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis

Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Count	Average ratioH_2S ($\mu gm^{-2}s^{-1}$)	SD ratioH_2S ($\mu gm^{-2}s^{-1}$)	Min ratioH_2S ($\mu gm^{-2}s^{-1}$)	Max ratioH_2S ($gm^{-2}s^{-1}$)	Area emissions average (kgd^{-1})	Area emissions average ($gd^{-1}hd^{-1}$)	Area emissions average ($gd^{-1}AU^{-1}$)
1/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Count	Average ratioH_2S ($\mu gm^{-2}s^{-1}$)	SD ratioH_2S ($\mu gm^{-2}s^{-1}$)	Min ratioH_2S ($\mu gm^{-2}s^{-1}$)	Max ratioH_2S ($gm^{-2}s^{-1}$)	Area emissions average (kgd^{-1})	Area emissions average ($gd^{-1}hd^{-1}$)	Area emissions average ($gd^{-1}AU^{-1}$)
2/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Count	Average ratioH_2S ($\mu gm^{-2}s^{-1}$)	SD ratioH_2S ($\mu gm^{-2}s^{-1}$)	Min ratioH_2S ($\mu gm^{-2}s^{-1}$)	Max ratioH_2S ($gm^{-2}s^{-1}$)	Area emissions average (kgd^{-1})	Area emissions average ($gd^{-1}hd^{-1}$)	Area emissions average ($gd^{-1}AU^{-1}$)
4/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Count	Average ratioH_2S ($\mu gm^{-2}s^{-1}$)	SD ratioH_2S ($\mu gm^{-2}s^{-1}$)	Min ratioH_2S ($\mu gm^{-2}s^{-1}$)	Max ratioH_2S ($gm^{-2}s^{-1}$)	Area emissions average (kgd^{-1})	Area emissions average ($gd^{-1}hd^{-1}$)	Area emissions average ($gd^{-1}AU^{-1}$)
5/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/14/2008	4	0.1	2.6	0.0	0.1	0.1	0.1	0.1
6/15/2008	1	6.0	0.0	6.0	6.0	7.1	5.0	9.3
6/16/2008	6	0.1	3.5	-0.1	0.3	0.2	0.1	0.2
6/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/23/2008	4	-0.2	0.0	-0.3	0.0	-0.2	-0.1	-0.3
6/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/9/2008	1	-0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1
7/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Count	Average ratioH_2S ($\mu gm^{-2}s^{-1}$)	SD ratioH_2S ($\mu gm^{-2}s^{-1}$)	Min ratioH_2S ($\mu gm^{-2}s^{-1}$)	Max ratioH_2S ($gm^{-2}s^{-1}$)	Area emissions average (kgd^{-1})	Area emissions average ($gd^{-1}hd^{-1}$)	Area emissions average ($gd^{-1}AU^{-1}$)
7/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2008	2	0.0	0.0	-0.2	0.1	0.0	0.0	0.0
7/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year

Valid: Number of ½ hour periods with valid emissions data

Direction Limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction

Angle limited: Number of ½ hour periods invalidated because angle of attack to the downwind side was greater than 60 degrees

Turbulence limited: Number of ½ hour periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m

Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ hour periods included in the valid column

Emission average (μgm^{-2}s^{-1}): Daily average emission calculated from the valid ½ hour periods

Emissions SD (μgm^{-2}s^{-1}): Daily emission standard deviation of the valid ½ hour periods

Emission minimum (μgm^{-2}s^{-1}): Daily minimum emission of the valid ½ hour periods

Emission maximum (μgm^{-2}s^{-1}): Daily maximum emission of the valid ½ hour periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area

Emission average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis

Emission average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average (μgm^{-2}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd^{-1}AU^{-1})
2/8/2008	26	0	0	3	-0.1	0.0	0.2	-0.4	0.2	0.0	0.0	-0.1
2/9/2008	23	0	21	4	0.3	0.0	0.2	-0.6	0.5	0.0	0.0	0.0
2/10/2008	2	0	46	0	-1.5	0.2	0.0	0.2	0.3	0.3	0.2	0.4
2/11/2008	13	0	31	4	0.0	0.0	0.1	-0.3	0.2	0.0	0.0	0.0
2/12/2008	0	0	23	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/13/2008	3	0	9	3	-0.5	0.2	0.3	-0.1	0.4	0.3	0.2	0.4
2/14/2008	36	0	0	12	-0.1	0.1	0.3	-1.3	0.8	0.1	0.0	0.1
2/15/2008	41	0	6	1	0.2	-0.1	0.2	-0.4	0.6	-0.1	0.0	-0.1
2/16/2008	16	0	1	30	0.1	0.0	0.2	-0.5	0.4	0.0	0.0	0.0
2/17/2008	43	0	2	3	0.1	0.2	0.6	-0.8	3.1	0.2	0.1	0.3
2/18/2008	0	0	48	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/19/2008	1	0	47	0	0.9	-0.3	N/A	-0.3	-0.3	-0.3	-0.2	-0.4
2/20/2008	22	0	12	14	0.1	0.0	0.2	-0.3	0.3	0.0	0.0	0.0
2/21/2008	1	0	16	25	-0.2	-0.4	N/A	-0.4	-0.4	-0.4	-0.3	-0.6
2/22/2008	34	0	14	0	0.0	0.0	0.2	-0.3	0.5	0.0	0.0	0.0
2/23/2008	3	0	0	45	0.6	-0.1	0.1	-0.1	0.0	-0.1	-0.1	-0.1
2/24/2008	2	0	1	43	-0.9	0.1	0.2	0.0	0.3	0.2	0.1	0.2
2/25/2008	27	0	0	8	0.0	0.0	0.2	-0.4	0.6	0.0	0.0	0.1
2/26/2008	42	0	2	4	0.1	0.0	0.2	-0.5	0.5	0.0	0.0	0.1
2/27/2008	28	0	0	0	0.1	-0.1	0.3	-0.5	0.4	-0.1	-0.1	-0.1
2/28/2008	2	0	0	9	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2/29/2008	26	0	20	2	-0.1	0.0	0.3	-0.3	0.7	0.0	0.0	0.1

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
3/1/2008	4	0	34	10	-0.2	0.0	0.2	-0.2	0.1	0.0	0.0	-0.1
3/2/2008	42	0	4	2	-0.2	0.0	0.2	-0.5	0.4	0.0	0.0	0.0
3/3/2008	42	0	5	1	0.1	1.9	3.7	-0.3	14.4	2.2	1.6	2.9
3/4/2008	1	0	0	0	-0.6	0.4	N/A	0.4	0.4	0.4	0.3	0.6
5/28/2008	14	0	0	0	-1.9	6.2	2.8	1.0	11.1	7.2	5.1	9.5
5/29/2008	12	0	6	29	-1.4	1.3	1.5	-0.2	4.0	1.5	1.1	2.0
5/30/2008	31	0	0	17	-1.1	12.8	6.5	0.4	23.2	15.0	10.7	19.6
5/31/2008	20	0	26	0	-1.4	5.3	4.6	0.0	23.6	6.2	4.4	8.2
6/1/2008	19	0	8	19	-1.7	0.2	0.5	-0.1	1.7	0.3	0.2	0.4
6/2/2008	23	0	1	22	-1.8	0.0	0.2	-0.4	0.5	0.1	0.0	0.1
6/3/2008	36	0	2	8	-1.9	1.7	3.5	-0.4	17.4	2.0	1.5	2.7
6/4/2008	34	0	5	6	-1.7	0.1	0.3	-0.4	1.0	0.1	0.1	0.1
6/5/2008	47	0	0	0	-1.6	0.0	0.3	-0.6	0.6	0.0	0.0	0.1
6/6/2008	44	0	0	0	-1.5	0.2	0.3	-0.5	1.0	0.0	0.0	0.0
6/7/2008	21	0	0	0	-1.4	0.0	0.2	-0.2	0.3	0.0	0.0	0.0
6/8/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2008	20	0	1	0	-1.7	0.2	0.9	-0.7	3.7	0.3	0.2	0.3
6/10/2008	11	0	24	10	-1.8	0.2	0.2	0.0	0.6	0.2	0.1	0.2
6/11/2008	25	0	1	22	-1.6	0.2	0.3	-0.4	0.8	0.3	0.2	0.4
6/12/2008	36	0	0	12	-1.5	0.6	1.0	-0.4	3.1	0.7	0.5	1.0
6/13/2008	45	0	0	2	-1.7	0.2	0.3	-0.4	1.1	0.2	0.1	0.3
6/14/2008	16	0	14	17	-1.9	0.1	0.1	-0.1	0.3	0.1	0.1	0.1
6/15/2008	22	0	2	23	-1.8	0.8	1.6	-0.3	6.3	1.0	0.7	1.3
6/16/2008	20	0	13	8	-1.4	0.1	0.2	-0.3	0.4	0.1	0.1	0.1
6/17/2008	19	0	13	16	-1.6	0.1	0.3	-0.4	0.5	0.1	0.1	0.2
6/18/2008	16	0	14	18	-1.9	0.0	0.2	-0.3	0.5	0.0	0.0	0.0
6/19/2008	4	0	1	22	-1.5	0.0	0.2	-0.1	0.3	0.1	0.0	0.1
6/20/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/21/2008	21	0	15	11	-1.7	0.0	0.2	-0.5	0.4	0.0	0.0	0.1
6/22/2008	16	0	11	19	-1.7	0.0	0.2	-0.4	0.4	0.0	0.0	0.0
6/23/2008	40	0	2	6	-1.6	0.0	0.2	-0.5	0.3	0.0	0.0	0.0
6/24/2008	11	0	9	26	-1.6	0.0	0.1	-0.2	0.2	0.0	0.0	0.0
6/25/2008	24	0	2	18	-1.6	0.1	0.3	-0.4	0.7	0.2	0.1	0.2
6/26/2008	28	0	9	10	-1.5	0.0	0.1	-0.3	0.3	0.0	0.0	0.0
6/27/2008	29	0	0	19	-1.6	0.0	0.2	-0.2	0.4	0.0	0.0	0.1
6/28/2008	28	0	20	0	-1.9	0.2	0.2	-0.2	0.6	0.2	0.1	0.2
6/29/2008	17	0	20	9	-1.4	0.0	0.4	-0.7	0.8	0.0	0.0	0.0
6/30/2008	36	0	12	0	-1.8	0.0	0.2	-0.6	0.7	0.0	0.0	0.0
7/1/2008	16	0	8	24	-1.5	0.0	0.2	-0.3	0.5	0.0	0.0	0.0
7/2/2008	33	0	0	14	-1.7	0.0	0.3	-0.5	1.3	0.0	0.0	0.1
7/3/2008	37	0	3	6	-1.5	0.0	0.2	-0.2	0.5	0.0	0.0	0.1
7/4/2008	6	0	32	10	-1.1	0.0	0.1	-0.1	0.3	0.0	0.0	0.0
7/5/2008	16	0	9	23	-1.6	0.0	0.1	-0.2	0.2	0.0	0.0	0.0
7/6/2008	17	0	3	26	-1.6	0.0	0.2	-0.2	0.5	0.0	0.0	0.0
7/7/2008	22	0	3	19	-1.8	0.0	0.2	-0.3	0.4	0.0	0.0	0.0
7/8/2008	36	0	8	4	-1.6	0.0	0.2	-0.4	0.5	0.0	0.0	0.0

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/9/2008	34	0	13	1	-1.6	0.0	0.2	-0.4	0.4	0.0	0.0	0.0
7/10/2008	23	0	0	25	-2.0	0.0	0.2	-0.4	0.4	0.0	0.0	0.1
7/11/2008	30	0	5	10	-1.5	0.0	0.2	-0.5	0.3	0.0	0.0	0.0
7/12/2008	33	0	9	3	-1.6	0.0	0.2	-0.3	0.3	0.0	0.0	0.0
7/13/2008	8	0	39	1	-1.7	0.1	0.1	-0.2	0.2	0.1	0.0	0.1

Final Report
Site IN5A
Milk Production Facility
for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
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Milk Production Facility

for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on the location (relative to climate and typical practice), method of manure collection, manure storage and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3) and hydrogen sulfide (H_2S) emissions from the wastewater lagoon open source at the Midwestern dairy facility. Within that objective, this report will:

- Describe the farm and the lagoon/basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the lagoon were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Lagoon emissions were measured continuously for about one year. The DQO for completeness stipulates 75% completeness of 10 d per quarter.

Atmospheric concentrations of NH_3 around the area sources were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc,, Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*WindTrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the

air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the lagoon pH, oxidation-reduction potential (ORP), and temperature at 0.3 m depth were also measured from a float located at least 30 m from the lagoon inlet (Table 1-2). Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the lagoon berm.

Table 1-1: Critical measurements

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder2™	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind speed	3D Sonic anemometer/ RM Young 81000	0-60 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
Wind direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
3D Turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min
Temperature variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01^{o}C	160 Hz sampling/ 16 Hz averaging	30 min
GSS sample flow rate	GSS/S-OPS	10 L min^{-1}	0.1 L min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/S-OPS	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to *RPM* Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the lagoon (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation, lagoon pH, lagoon oxidation-reduction potential, lagoon temperature, and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure, flow, temperature and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer that was downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Table 1-2: Non-critical measurements.

Measurement	Method/ Instrument	Required Operating range	MDL	Minimum sample frequency	Final data-aggregation
Ambient temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50 ^{o} C	0.1 ^{o} C	5 min	30 min, 24 h
Relative humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min & 24 h
Solar radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 W/m^2	10 Wm^{-2}	5 min	30 min & 24 h
Lagoon solids depth	Sludge level detector/ Sludge Gun 10HD, Markland Specialty Eng.	0-10 m	0.05 m	1/ measurement period	1 time
Lagoon/basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	0-14 units	0.2 unit	5 min	30 min & 24 h
Lagoon/ basin oxidation-reduction potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	-800 - +1100 mV	20 mV	5 min	30 min & 24 h
Lagoon/ basin temperature	Thermistor/ Campbell Scientific Inc 107-L	-35 - +50 ^{o}C	0.5 ^{o}C	5 min	30 min & 24 h

1.3 Farm description and operation

The Midwestern dairy lagoon facility was located in Indiana. The elevation at the farm was 238 m. The dairy consisted of three barns, a feed storage area, special needs barn, milking parlor, an office, and tool and repair shops (Fig. 1-1). The facility had a capacity of 2600 cows. Construction of the dairy was completed in 2002.

Manure was vacuumed from the lactating cow barns and special needs barn every 12 hrs and placed in basins near the barns. Manure was flushed from the holding area and milking parlor every ½ hr. Manure from the barns was scraped into pits that are located at the end of each barn (Fig. 1-1). A small fraction of scraped waste was held in a slurry tank. The wastewater (flush) from the holding area and milking parlor was transferred into a rectangular settling basin south of the road then into the waste lagoon south of the road. The inlet to the lagoon was located at its north end. The clay-lined waste lagoon was 85 m wide and 116 m long, and is oriented north-south. The lagoon bank has a berm slope of 2.5:1. At maximum capacity, the liquid depth was 5 m with a volume of 48,212 m^3 and surface area of 9884 m^2. Sludge had never been removed from the lagoon. Since the lagoon was inherently a source of gases emanating from manure and effluent residing in the lagoon for multiple months, and the lagoon being monitored at this farm received effluent from the parlor and holding area, it was assumed that the number of animals contributing to the lagoon was the maximum capacity of the farm.

Figure 1-1: Configuration of the IN5A farm.

1.4 Measurement layout

The NH_3 emissions from the lagoon were monitored continuously for one year using scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*) and backward Lagrangian Stochastic (bLS) emissions models. The H_2S emissions from the lagoon were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments (TDLAS/scanner) were mounted at 1-m height above the lagoon berm (abl) at the northwest and southeast corners (Figure 1-2). Towers for mounting retro-reflectors were located off the northeast and southwest corners of the lagoon (Figure 1-2). A description of the position and path length of the optical paths along each side of the lagoon follows:

- North side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 41.5 m and 67 m from the northwest TDLAS/scanner. Three retro-reflectors were mounted on the northeast tower 106 m from the TDLAS/scanner at heights of 0.9 m, 7.9 m, and 15.4 m abl.

- East side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 53.5 m and 96.5 m from the southeast TDLAS/scanner. Three retro-reflectors were mounted on the northeast tower 139 m from the TDLAS/scanner at heights of 0.9 m, 7.9 m, and 15.4 m abl.
- South side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 36.5 m and 74.5 m from the southeast TDLAS/scanner. Three retro-reflectors were mounted on the southwest tower 109 m from the TDLAS/scanner at heights of 0.9 m, 7.4 m, and 14.9 m abl.
- West side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 49 m and 90 m from the northwest TDLAS/scanner. Three retro-reflectors were mounted on the southwest tower 138 m from the TDLAS/scanner at heights of 0.9 m, 7.4 m, and 14.9 m abl.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1-m abl. A 50-m long S-OPS path was parallel to and 5 m north of the north berm and began 5 m east of northwest berm corner and extended east (Figure 1-2). The second 50-m long S-OPS was parallel to and 5 m south of the south lagoon berm and began 5 m west of southwest corner of berm (in the drainage swale) and extended west (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Meteorological measurements, including barometric pressure, air temperature, relative humidity, solar radiation, and surface wetness were made 5 m west and 30 m north from the southwest berm corner. The data from these meteorological measurements were collected by a data logger (Model CR1000, Campbell Scientific, Logan, Utah) and telemetered to the on-site instrumentation trailer. The 3D sonic anemometers were located on the meteorological tower at 2.5 m height, and on the southwest corner tower (Fig. 1-2) at 4.4 m and 16.2 m heights above ground level and also telemetered to the on-site instrumentation trailer.

Lagoon measurements (pH, oxidation-reduction potential, and temperature) were made from a float located in the southwest corner of the lagoon.

Figure 1-2: Locations of instrumentation around the lagoon under measurement. Retro-reflectors are indicated according to side (north, south, east, and west) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The locations of the two S-OPS lines are indicated by the solid yellow lines. The instrumentation trailer was located in the northeast corner of the lagoon.

2 Monitoring activities

2.1 Measurement periods

Measurements were made continuously between 9/11/2008 and 8/17/2009 at this location (Table 2.1-1). The equipment was on site a total of 337 d over four measurement periods. Calibrations reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 321 d and H_2S emissions were measured 322 d.

Table 2.1-1: Days on site

Period	Start date	End date	# days
6- Fall	9/11/2008	11/30/2008	80
7- Winter	12/1/2008	2/28/2009	89
8- Spring	3/1/2009	5/31/2009	91
9- Summer	6/1/2009	8/17/2009	77

Measurements of H_2S commenced on 9/11/2008 with the TDLAS established around 9/16/2008. The later TDLAS establishment was due to the scanner problems that resulted in the brass to steel scanner upgrade for the entire network. Internet (DSL) communication was established on 9/11/2008. The proximity of this site to PAML resulted in substitution of equipment from this site to maintain operational capabilities for the two roving teams. As a result many equipment repair and/or replacement trips were made to solve problems.

2.2 Site visits

The field operation team visited this farm 53 d during the study (Table 2.2-1). Since this site was the second-year long-term fixed location site, the set-up and take-down occurred only once. Most site visits were either for calibration verifications or equipment replacement.

Table 2.2-1: Dates of site visits

Year	Spring	Summer	Fall	Winter
2008		Aug 21,22	Sep 10,11,16,18,24 Oct 8,9,10,22,27,28 Nov 19,20	Dec 9,10,11,29,30,31 Jan 12,21,23,29 Feb 9,13,25
2009	Mar 11 Apr 7,8,16,30 May 5,20,22,26,28	Jun 9,15,16,23 Jul 2,8,9,10,15,16,20,22,23 Aug 12,18		

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21 d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder2™ NH_3 TDLAS serial number (s/n) 1029, 1031 and 1032 (Section 6.1)
- TEC 450i H_2S Analyzer s/n 0733825130 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1925, 1926, 1928 and 1938 (Section 6.3)
- lagoon pH probes s/n 005 and 006 (Section 6.4)
- lagoon ORP probe s/n 080 (Section 6.5)
- GSS/ S-OPS s/n 4-0019 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multipoint calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers (Section 6.3) with three unused 'standard' anemometers. A further QA check was made by inter-comparing TDLAS units: on July 10, 2009 three TDLAS units were inter-compared on site (s/n 1027, 1031, and 1032).

2.4 Audits

An internal audit was conducted on July 8, 2008, with particular attention to the S-OPS operation verification and the calibration checks made of the meteorological sensors.

2.5 Repair trips

Four major repair trips were made to this location: September 24, 2008, October 22, 2008, December 31, 2008, and June 16, 2009. In addition, many trips were made to this location to swap out equipment needed for the continued operation of the many outlying NAEMS measurement locations.

2.6 Remote site checks

Over the course of measurements there were 151 remote checks made from PAML through the computer for instruments operating at this location.

2.7 Measurement data acquisition

Data from the TDLAS units (Model GasFinder2™ NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather and lagoon data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *Loggernet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line

currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *Loggernet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA) were downloaded in real-time through a serial cable to the trailer computer using the *iPort* (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built *Visual Basic* software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic anemometer temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory “FTP” and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory “Data”. The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the “FTP” directory.

3 Data Processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic anemometer parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDL. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes needed to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site , data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software that was used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer and caused the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period, unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one minute off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the lagoon and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream may depend on one or more of the preceding streams, but not on following data streams. For

each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment and calibration failures, and because calibration checks were in progress. Periods of invalidated measurements associated with the calibration check failures are documented in the calibration reports in Section 6. Significant data exclusions of greater than one-day duration are indicated below by instrument with all time references in Coordinated Universal Time (UTC):

TDLAS measurement exclusions: Excluded measurements are summarized in Table 3.2-1.

Table 3.2-1: TDLAS measurement exclusions

Begin		End		Reason
9/16/2008	18:58	10/8/2008	15:08	TDLAS 2 reading very low; had been wet at a previous location
10/14/2008	23:40	10/22/2008	16:24	TDLAS 1 laptop locked up
10/14/2008	05:54	10/22/2008	16:25	TDLAS 2 laptop locked up
11/17/2008	11:39	11/19/2008	19:57	TDLAS 1 laptop locked up
11/17/2008	11:06	11/19/2008	19:53	TDLAS 2 laptop locked up
12/28/2008	06:20	12/31/2008	17:17	TDLAS 1 condensation inside unit
1/19/2009	23:47	1/23/2009	19:02	TDLAS 1 power failure
1/19/2009	23:57	1/23/2009	19:03	TDLAS 2 power failure
1/29/2009	21:00	2/9/2009	15:25	TDLAS 2 scanner failure; placed on single path
2/5/2009	14:22	2/9/2009	15:47	TDLAS 1 shutter failure
4/4/2009	05:58	4/6/2009	12:10	TDLAS 1 laptop locked up
4/4/2009	05:56	4/6/2009	12:10	TDLAS 2 laptop locked up
4/27/2009	17:53	4/30/2009	18:31	TDLAS 1 laptop locked up
4/27/2009	17:54	4/30/2009	18:37	TDLAS 2 laptop locked up
5/5/2009	17:22	6/17/2009	15:12	TDLAS 1 removed to replace unit in west trailer
5/20/2009	23:24	5/22/2009	15:03	TDLAS 2 laptop locked up
6/18/2009	11:32	6/23/2009	16:26	TDLAS 2 laptop locked up
7/11/2009	07:45	7/13/2009	17:33	TDLAS 1 laptop locked up
7/14/2009	23:57	7/15/2009	14:30	TDLAS 1 laptop locked up
7/22/2009	16:19	8/11/2009	15:14	TDLAS 1 removed to replace unit in east trailer

TEC 450i measurement exclusions: None.

Air temperature and relative humidity measurement exclusions: Excluded measurements are summarized in Tables 3.2-2 and 3.2-3

Table 3.2-2: Air temperature measurement exclusions

Begin		End		Reason
2/25/2009	14:30	3/11/2009	17:00	6-month Calibration Check
5/16/2009	02:25	5/28/2009	17:50	Instrument malfunction

Table 3.2-3: Relative humidity measurement exclusions

Begin		End		Reason
2/25/2009	14:30	3/11/2009	17:00	6-month Calibration Check

Solar radiation measurement exclusions: Excluded measurements are summarized in Table 3.2-4.

Table 3.2-4: Solar radiation measurement exclusions

Begin		End		Reason
2/25/2009	14:30	3/11/2009	17:00	6-month Calibration Check

Wetness measurement exclusions: Excluded measurements are summarized in Table 3.2-5.

Table 3.2-5: Wetness measurement exclusions

Begin		End		Reason
9/10/2008	19:30	12-10/2008	16:20	Instrument failure
2/25/2009	14:30	3/11/2009	17:00	6-month Calibration Check

Barometric Pressure measurement exclusions: Excluded measurements are summarized in Table 3.2-6.

Table 3.2-6: Barometric pressure measurement exclusions

Begin		End		Reason
2/25/2009	14:30	3/11/2009	17:00	6-month Calibration Check

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-7.

Table 3.2-7: Sonic anemometer measurement exclusions

Begin		End		Reason
9/18/2008	14:29	9/18/2008	20:10	Calibration check
10/8/2008	19:50	10/9/2008	18:50	Calibration check
10/27/2008	14:35	10/28/2008	16:20	Calibration check
11/19/2008	15:04	11/20/2008	18:15	Calibration check
12/9/2008	15:24	12/11/2008	16:45	Calibration check
12/17/2008	01:45	12/18/2008	17:45	Communications failure, sonic anemometer 1
12/29/2008	18:50	12/30/2008	21:24	Calibration check
1/6/2009	17:40	1/9/2009	20:10	Communications failure, sonic anemometer 1
1/23/2009	14:20	1/23/2009	17:40	Calibration check
2/9/2009	15:00	2/9/2009	19:05	Calibration check
2/25/2009	14:15	03/11/2009	18:45	6 Month Cal check
5/5/2009	15:20	5/5/2009	19:50	Calibration check
5/25/2009	11:30	5/26/2009	19:35	Calibration check
5/28/2009	15:44	5/28/2009	16:00	Period Break
6/2/2009	14:40	6/3/2009	15:50	Data logging failure
6/2/2009	11:30	6/8/2009	18:45	Inclement weather
6/9/2009	13:54	6/9/2009	18:10	Calibration check
6/16/2009	13:45	6/20/2009	15:50	Inclement weather
6/20/2009	15:55	6/22/2009	12:30	Data logging failure
7/10/2009	14:09	7/10/2009	19:40	Calibration check

Lagoon temperature, pH, and ORP measurement exclusions: Lagoon measurements stopped on 11/20/08 due to expected lagoon freezing before next 20 d visit. No lagoon measurements due to lagoon freezing conditions until 3/2009. Excluded measurements are summarized in Table 3.2-8.

Table 3.2-8: Lagoon temperature, pH, and ORP measurement exclusions

Lagoon Temperature Exclusion Times				
Begin		**End**		**Reason**
10/9/2008	16:30	10/9/2008	18:35	Calibration check
10/27/2008	15:40	5/28/2009	18:05	Probe was not in water
6/16/2009	14:10	6/19/2009	17:50	Calibration check
7/9/2009	16:30	7/9/2009	17:55	Calibration check
7/30/2009	16:55	7/30/2009	17:25	Calibration check
Lagoon pH Exclusion Times				
Begin		**End**		**Reason**
10/9/2008	16:30	10/9/2008	18:35	Calibration check
10/27/2008	15:40	5/28/2009	18:05	Probe was not in water

6/16/2009	14:10	6/17/2009	17:50	Calibration check
7/9/2009	16:30	7/9/2009	17:55	Calibration check
7/30/2009	16:55	7/30/2009	17:25	Calibration check

Lagoon ORP Exclusion Times				
Begin		**End**		**Reason**
10/9/2008	16:30	10/11/2008	17:05	Calibration check
10/27/2008	15:40	5/28/2009	18:05	Probe was not in water
6/16/2009	14:10	6/17/2009	17:50	Calibration check
7/9/2009	16:30	7/9/2009	17:55	Calibration check
7/30/2009	16:55	7/30/2009	17:25	Calibration check

GSS/S-OPS measurement exclusions: Excluded measurements are summarized in Table 3.2-9.

Table 3.2-9: GSS/S-OPS measurement exclusions

Begin		**End**		**Reason**
9/18/2008	16:15	9/18/2008	18:15	Calibration check
10/9/2008	14:45	10/9/2008	16:45	Calibration check
10/28/2008	19:45	10/28/2008	20:45	Calibration check
11/19/2008	19:15	11/19/2008	21:15	Calibration check
12/9/2008	14:45	12/10/2008	18:15	Calibration check
12/30/2008	18:15	12/30/2008	19:45	Calibration check
1/21/2009	16:45	1/21/2009	19:45	Calibration check
2/13/2009	15:45	2/14/2009	00:00	Calibration check
2/25/2009	12:00	2/26/2009	00:00	Calibration check
3/11/2009	18:35	3/12/2009	00:00	Calibration check
4/8/2009	15:00	4/8/2009	19:00	Calibration check
5/5/2009	16:15	5/5/2009	18:45	Calibration check
5/28/2009	14:15	5/28/2009	17:15	Calibration check
6/15/2009	13:45	6/15/2009	18:45	Calibration check
6/23/2009	16:15	6/23/2009	20:45	S-OPS modification
6/24/2009	15:00	6/24/2009	17:00	S-OPS modification
6/30/2009	13:45	6/30/2009	17:45	S-OPS modification
7/2/2009	14:30	7/02/2009	15:00	S-OPS modification
7/8/2009	15:45	7/8/2009	18:15	Calibration check
7/15/2009	14:45	7/15/2009	17:15	S-OPS modification
7/22/2009	14:30	7/22/2009	18:30	S-OPS modification
7/23/2009	15:15	7/23/2009	19:15	Calibration check
7/30/2009	18:00	7/30/2009	19:30	Calibration check
8/5/2009	16:00	8/5/2009	20:30	S-OPS modification
8/6/2009	17:00	8/6/2009	19:30	S-OPS modification
8/11/2009	17:00	8/11/2009	18:30	S-OPS modification

Begin		End		Reason
8/17/2009	15:00	8/17/2009	17:30	Calibration check

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20°C (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in super-saturated "holes" in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a super-saturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maximized light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably super-saturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-s value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be super-saturated were flagged as super-saturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not super-saturated. To determine which points truly were super-saturated and which were not, a

threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest PIC corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be super-saturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as super-saturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the S-OPS changed from one line to the other line. This array was later used when separating the H_2S data according to which S-OPS line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic anemometer software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying,

unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic anemometer temperature variance of greater than 2.5 K^2, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic temperature variance had to be less than 2.5 K^2. To be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH_3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be *RPM* processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH_3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigned values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *WindTrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3}\frac{34.0818\left(\left[H_2S\right]_{downwind} - \left[H_2S\right]_{upwind}\right)}{17030.4\left[NH_3\right]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H_2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigned values to the concentrations

and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths. All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

The only pertinent activity associated with the lagoon was the cleaning of the separator pit located to the north of the lagoon (Table 4.1-1). Animal inventories for the calculation of lagoon loading rates are indicated in Table 4.1-1.

Table 4.1-1: Producer activities

Period	Activity	Animal Inventory
6: 9/11/2008 -11/30/2008	Clean Separator Pit 9/20/2008 9:00am-12:30pm Clean Separator Pit 10/30/2008 10:00am-1:00pm Clean Separator Pit 11/28/2008 9:00am-1:00pm	2971
7: 12/1/2008 - 2/28/2009	Clean Separator Pit 12/20/2008 11:00am-2:30pm Clean Separator Pit 1/30/2009 10:30am-2:00pm	2995
8: 3/1/2009 - 5/31/2009	Clean Separator Pit 3/6/2009 9:30am-12:30pm Clean Separator Pit 4/14/2009 10:00am-1:00pm	3312
9: 6/1/2009 - 8/17/2009	Clean Separator Pit 6/4/2009 9am-12pm Clean Separator Pit 7/16/2009 9am-1pm Clean Separator Pit 8/25/2009 9am-1pm	3298

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for midlatitude climates (Table 4.2-1). Between 20% and 25% of the days had extra-tropical frontal systems overhead while 75% to 80% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Measurement period	# days	# warm front passages	# cold front passages	# days stationary front	# days tropical storms
6- fall	80	1	19	0	0
7- winter	89	5	17	1	0
8- spring	91	8	14	4	0
9- summer	77	2	13	6	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from -24.5 ^{o}C to 27.3^{o}C while the barometric pressure varied from 96.6 kPa to 100.9 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ hr solar irradiance of 1235 W m^{-2} to overcast conditions with maximum ½ hr solar irradiance of 34 W m^{-2} (Section 6.10). The wetness sensor failed frequently due to corrosion issues.

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared with the monthly climatology is indicated in Figure 4-1. Temperatures during the spring, summer and fall measurements were near normal while those during the winter were slightly below normal. Daily mean relative humidity was greater during the winter than spring, summer and fall.

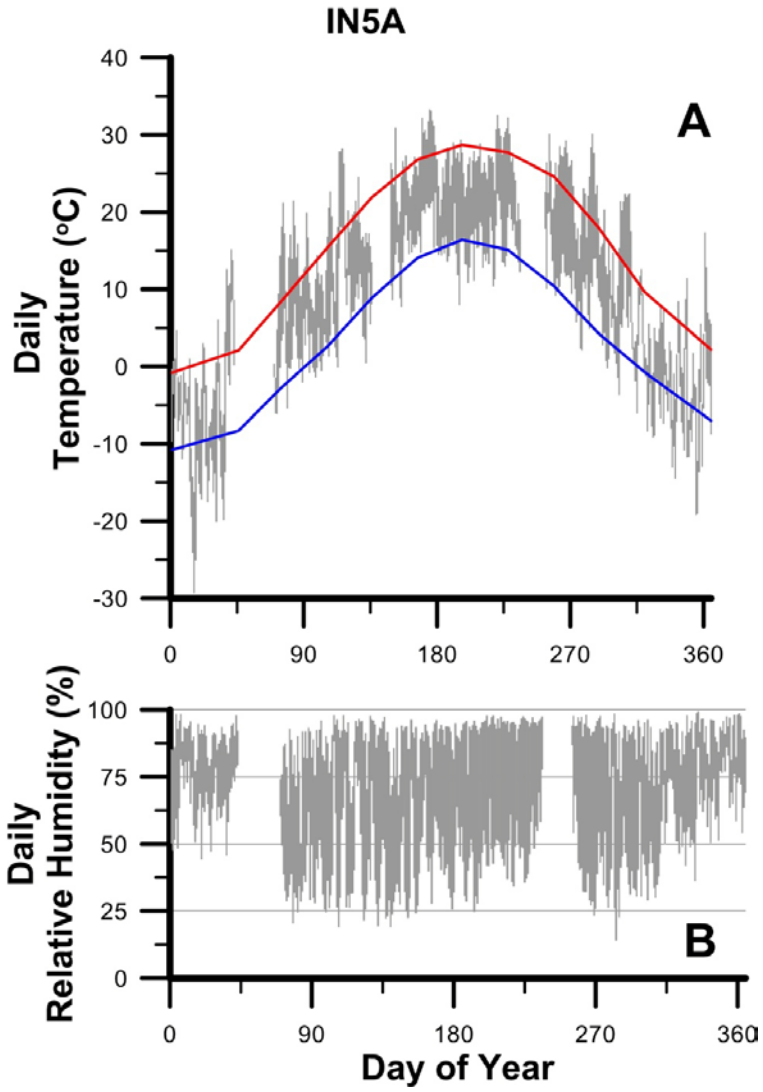

Figure 4-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line) temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidities for measurement days are indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figure 4-2. Winds were mostly from the northeast and east during Period 6, from the west during Period 7, and from the

southwest, east or north in Periods 8 and 9. The frequency of light winds ($\leq$ 1 ms^{-1}) was greatest during the summer and fall (Periods 9 and 6).

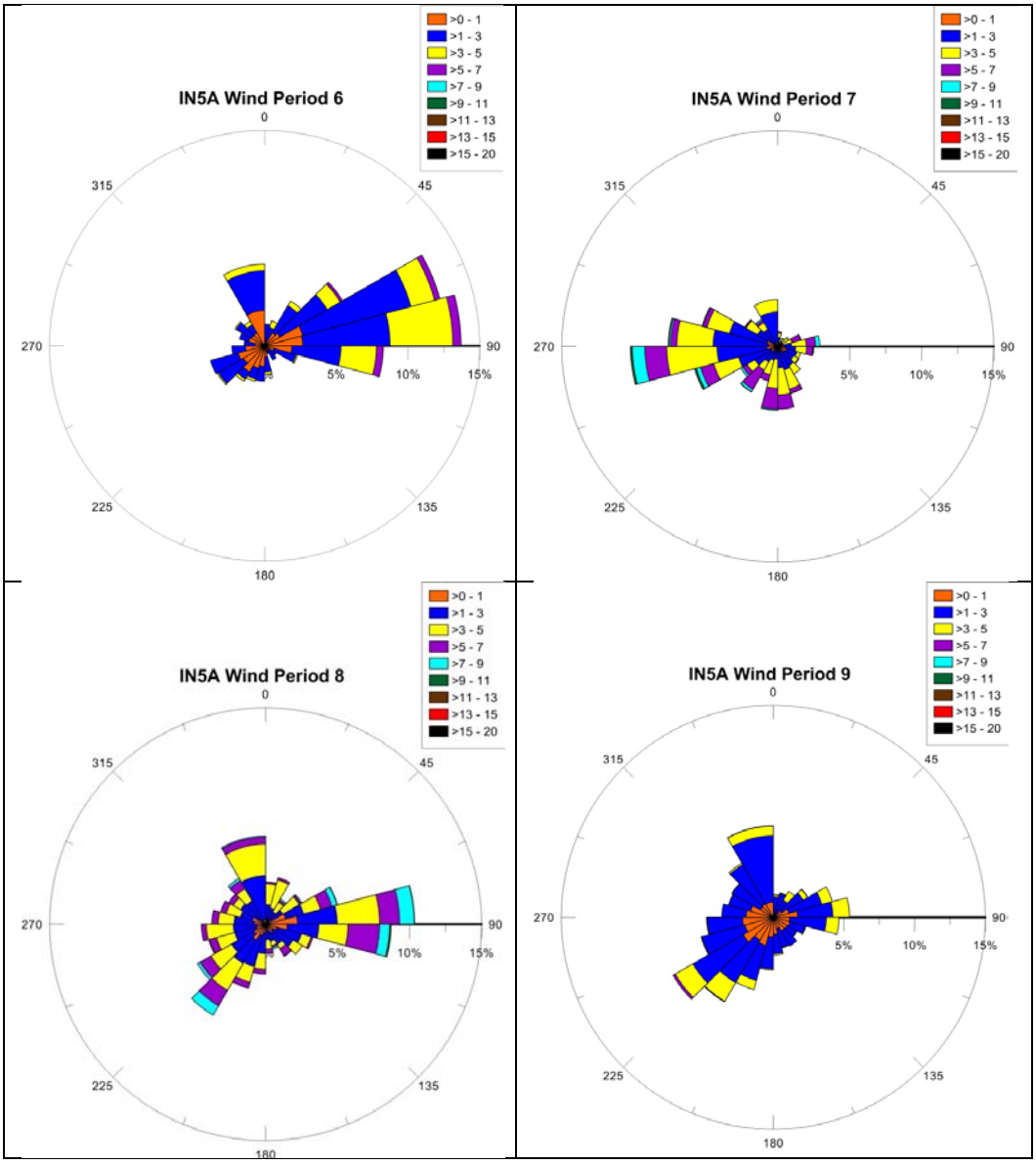

Figure 4-2: Wind roses for ½ hourly wind measurements during the measurement periods. The four periods in which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle.

4.3 Lagoon conditions

4.3.1 Lagoon appearance, liquid depth and sludge depth

The appearance of the lagoon was recorded on almost every site visit (Table 4.3-1). The lagoon generally appeared brown and crust-free.

Table 4.3-1: Lagoon physical characteristics

Period	Date, Appearance (Color/Crust)
6: 09/11/2008 - 11/30/2008	9/11/08 - Brown/No Crust, 9/16/08 - Brown/No Crust, 9/24/08 - Brown/No Crust, 10/8/08 - Brown/No Crust, 10/9/08 - Brown/No Crust, 10/10/08 - Blackish/No Crust 10/22/08 - Brown/No Crust, 10/27/08 - Brown/No Crust, 10/28/08 - Brown/No Crust, 11/19/08 - Brown/No Crust, 11/20/08 - Brown/No Crust
7: 12/1/2008 - 12/28/2009	12/9/08 - Frozen, 12/10/08 - 90% Frozen 12/11/08 - Frozen 12/29/08 - Frozen 12/30/08 - Frozen 1/12/09 - Frozen 1/21/09 - Frozen 1/23/09 - Frozen 1/29/09 - Frozen 2/9/09 - Frozen 2/13/09 - 40% Frozen 2/25/09 – Frozen
8: 03/01/2009 - 05/31/2009	3/11/09 - Brown/Black 4/7/09 - Brown 4/8/09 - Brown 4/16/09 - Brown 4/30/09 - Brown 5/5/09 - Brown 5/22/09 - Blackish 5/26/09 - Blackish/60% Scum 5/28/09 - Brown/40% Scum and foam

Period	Date, Appearance (Color/Crust)
9: 06/01/2009 - 08/17/2009	6/9/09 - Brown/20% Crust 6/15/09 - Brown/15% Crust 6/16/09 - Blackish/20% Crust 6/23/09 - Brown/10% Crust 7/2/09 - Brown/5% Crust 7/8/09 - Brown/25% Scum 7/9/09 - Brown/10% Scum 7/10/09 - Brown/10% Scum 7/15/09 - Brown/5% Crust 7/16/09 - Brown/5% Crust 7/20/09 - Brown/10% Crust 7/22/09 - Blackish/No Crust 7/23/09 - Brown/No Crust 8/12/09 - Brown/2% Crust 8/18/09 - Brown/5% Crust

4.3.2 Temperature, pH and Oxidation-reduction potential

The measured daily average lagoon liquid temperature varied from 11°C to 27°C, with the high temperatures when the lagoon level was very low (Section 6.11). The measured lagoon pH varied from 7.0 during the summer to 8.4 during the previous fall (Section 6.11). The corresponding oxidation-reduction potentials varied from -395 mV to -506 mV during the fall and -301 mV to -509 mV during the summer (Section 6.11). Significant losses to the record limit the utility of these measurements in relating conditions in the lagoon to the emissions from the lagoon.

4.4 Emissions measurements

Emissions data were calculated on a ½ hour basis since this was the interval over which the S-OPS system sampled both sides of the lagoon and since this interval was in the range over which turbulence statistics are often calculated. To account for the longer term manure storage of the lagoon, emissions reported on a head basis were scaled by the animal population for which the facility was designed and not the animal population at the time of measurements. Emission reported on an animal unit (AU) basis (1 AU = 500 kg) assumed the typical animal weight values reported by the producer. Emissions reported on an area basis are based on the surface area of the lagoon.

Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison was based on 2507 half-hour measurement periods over the entire measurement time at this location. Results showed that the bLS emissions had a significantly different precision (F=2.65, critical F=1.0) and a significant bias over the *RPM* emissions (t=4.84, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 1.06 (Table 4.4.1-1). Consequently, the ½ hour bLS emissions measurements were biased high by 6% compared with the *RPM* measurements.

Table 4.4.1-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	bLS	bLS-RPM
Mean emission (gs^{-1})	0.311	0.331	0.020
Standard deviation (gs^{-1})	0.173	0.281	
Variance of the mean (g^{-2} s^{-2})	0.030	0.080	

4.4.1 NH_3 Emissions

4.4.1.1 Mean daily emissions

A distinct annual trend in NH_3 emissions based on the *RPM* model was evident (Figure 4.4.1-1). Negative emissions during the winter were likely a result of near MDL concentrations around the lagoon in combination with NH_3 transported to the lagoon from the barns to the North. Emissions during the winter when the lagoon is frozen averaged approximately 5 g NH_3 $d^{-1}hd^{-1}$. But this may be an artifact of the high threshold in PICs for processing the PIC measurements into *RPM* emissions. There was wide day-to-day variability in NH_3 emissions during the summer (Figure 4.4.1-1). Maximum NH_3 emissions during the summer were approximately 20 g NH_3 $d^{-1}hd^{-1}$ although there were few days during the summer during which there were at least 75% of the measurements valid for a given day. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

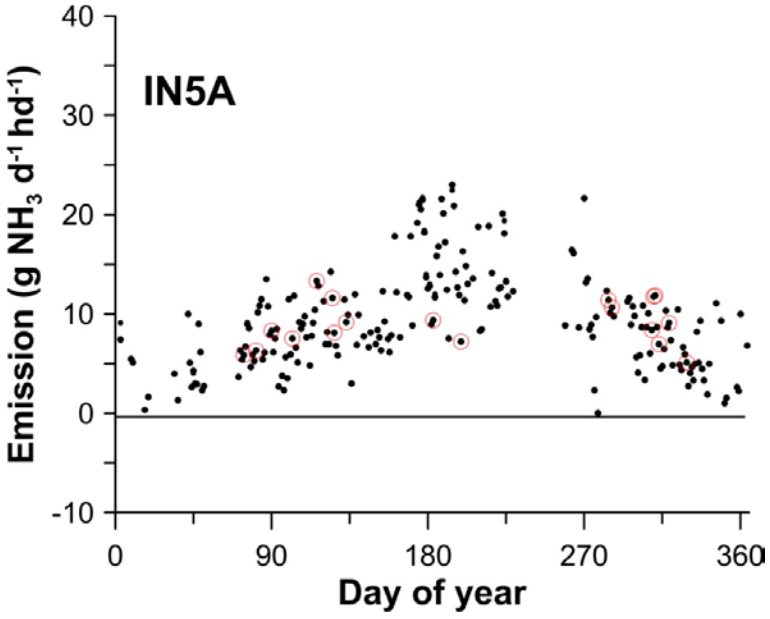

Figure 4.4.1-1: Annual variation in *RPM*-calculated daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

A distinct annual trend in NH_3 emissions based on the bLS model was evident (Figure 4.4.1-2). The bLS emissions model provided not only more daily estimates of the NH_3 emissions, but also more days in which more than 75% of the day had valid NH_3 measurements (Table 4.4.1-2). Comparing the standard deviation of the ½ hr emissions estimates of the daily emission rate with the range of partial-day estimates of the daily emission rate shows that the wide range of emission measurements during the summer are due to both day-to-day variability and estimates made on incomplete measurement days (having less than 75% of the possible ½ hrs with valid measurements). There was less day-to-day variability in the bLS-modeled NH_3 emissions values (Figure 4.4.1-2) than the *RPM*-modeled NH_3 emissions values (Figure 4.4.1-1). Negative emissions during the winter were likely a result of near MDL concentrations around the lagoon in combination with NH_3 transported to the lagoon from the barns to the north. Emissions during the winter when the lagoon is frozen were not however always zero. Maximum NH_3 emissions during the summer were between 20 and 30 g NH_3 $d^{-1}hd^{-1}$. There was however wide variability in NH_3 emissions from day to day during the summer (Figure 4.4.1-2). Both the daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

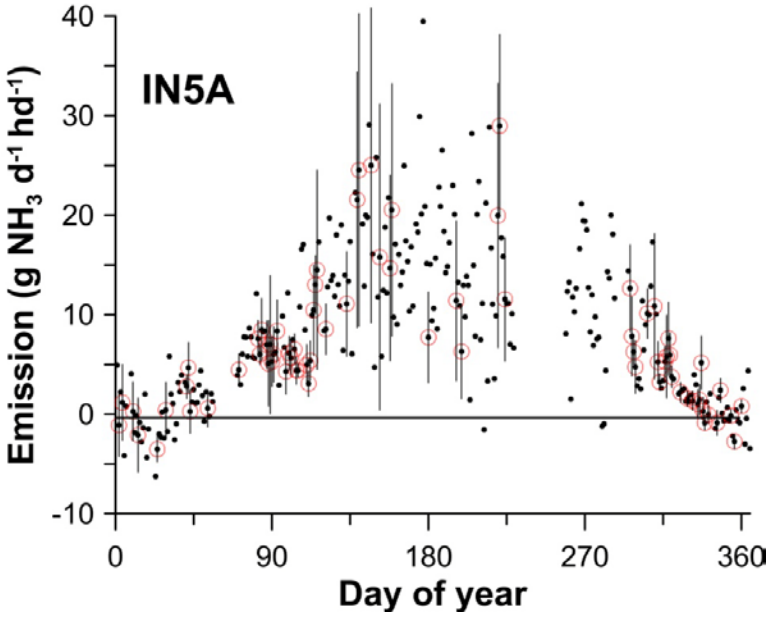

Figure 4.4.1-2: Annual variation in bLS-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS model was influenced by the calculated background concentrations. Results indicate that the background concentration of NH_3 was generally less than 0.05 ppm (Figure 4.4.1-3). The greatest background concentrations occurred around day of year 270. Given that the typical

path length around the lagoon was 50 m to 100 m, this translates to a background concentration for a given PIC of 2.5 to 5 ppm-m. This is approximately the MDL for the TDLAS instruments of 2 ppm-m (Section 6.1) and therefore represents essentially no background concentration. Consequently the relatively large background values around day of year 270 may represent emissions from the settling basin to the north of the lagoon.

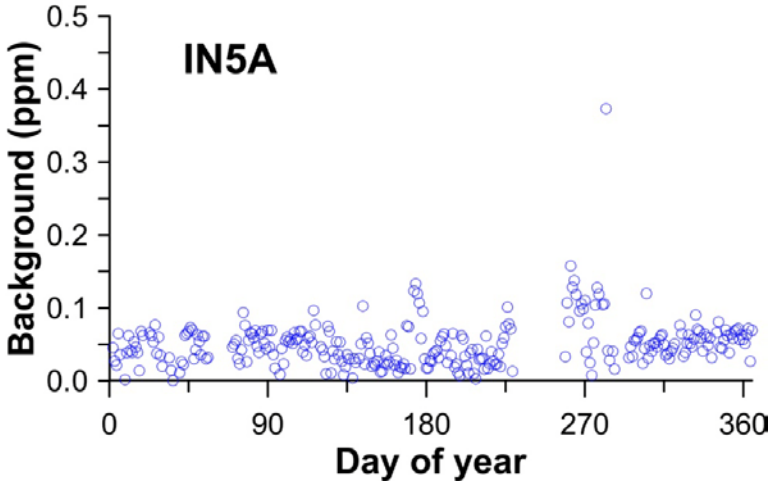

Figure 4.4.1-3: Annual variation in bLS-computed mean daily background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

The NH_3 emissions were generally higher during the day at the night (Figure 4.4.1-4). During the winter when no significant emissions of NH_3 occurred there was no evident diurnal variation. The greatest diurnal variation occurred during the summer. The wide range of ½ hr measurements of the daily emission rate during the summer supports the wide standard deviations of ½ h emission measurements within a single day emission estimate (Figure 4.4.1-2).

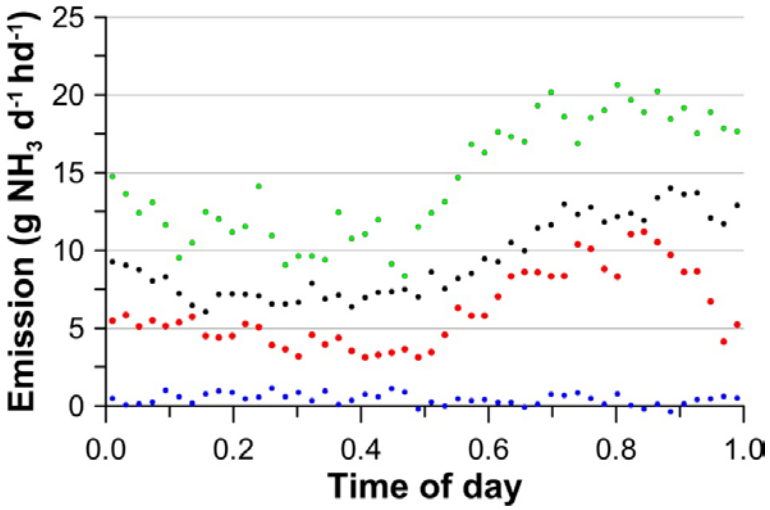

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 6-Fall (red), Period 7-Winter (blue), Period 8-Spring (black), and Period 9-Summer (green)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ hour intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ hour periods (corresponding to 75% completeness on a daily basis) is given. There was no wind direction exclusion region at IN5A, so no data were excluded solely based on wind direction. The completeness statistics are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

Parameter	RPM model	bLS model
Valid ½ hr measurements (d)	77.0	155.5
Measurements excluded due to wind direction (d)	0	0
Measurements excluded because touchdown fraction < 0.1		14.3
Measurements excluded because at least one downwind path is missing or invalid (d)	165.4	
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\|<2$ m: (d)		68.1
Number of days (d) with ≥ 36 valid ½ hour periods:	18	73

In total, 77.0 d of valid NH_3 emissions were determined from the 337 measurement days using the *RPM* model, with 18 d having at least 36 valid ½ hour NH_3 emissions. The absence or invalidation of at least one downwind path led to 165.4 d for which emissions could not be calculated.

Valid NH_3 emissions for 155.5 d were determined from the 337 measurement days using the bLS model, with 73 d having at least 36 valid ½ hour NH_3 emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) led to 68.1 d for which emissions could not be calculated. These invalid turbulence statistics were most prevalent during the night when light winds were more predominant. A touchdown fraction of less than 0.1 led to the exclusion of 14.3 d of data. Low touchdown fractions indicated that little, if any, downwind data was available. This corresponded to either when the downwind TDL was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ hour interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ hour mean wind speed and direction, in contrast with the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times that the *RPM* model produces valid emissions when the bLS model does not. However, these times are overwhelmed by the times that the *RPM* model is missing concentration data for one or more paths, while the bLS model is able to run.

4.4.2 H_2S Emissions

4.4.2.1 Mean daily emissions

An annual pattern in H_2S emissions was suggested from measurements based on the Ratiometric emissions model (Figure 4.4.2-1). Since only one day had valid measurements during at least 75% of the day using this calculation method, the correct interpretation of the annual variability in H_2S emissions is doubtful. In general there were low H_2S emissions during the winter when the lagoon was frozen. Emissions increased during the spring to approximately 5 g H_2S $d^{-1}hd^{-1}$. By day 120, the emissions decreased and remained low throughout the summer at approximately 1 g H_2S $d^{-1}hd^{-1}$. There was however wide variability in H_2S emissions from day to day during the spring (Figure 4.4.2-1). Emissions declined from the spring maximum to a relatively steady 5 g H_2S $d^{-1}hd^{-1}$ until the lagoon froze. A minimum emission during the summer (day of year 180 through approximately 220) was evident in the results. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

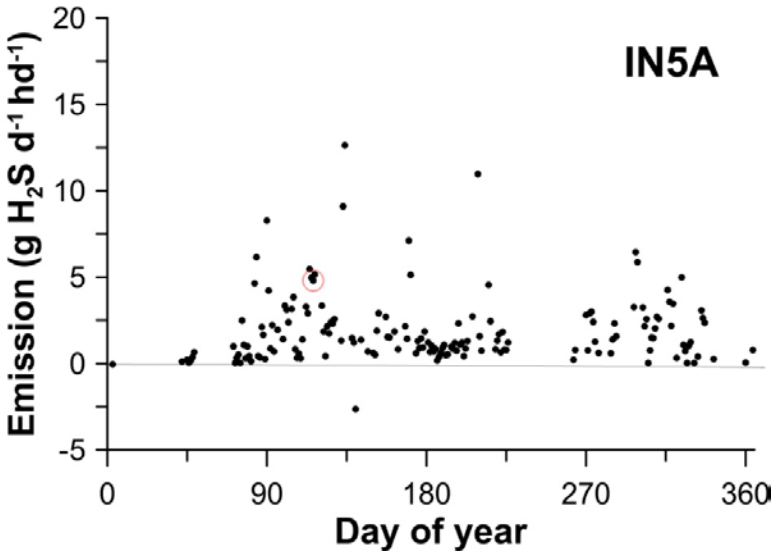

Figure 4.4.2-1: Annual variation in Radiometric-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

A distinct peak in H_2S emissions during the spring was evident in the annual variability derived from measurements based on the bLS emissions model (Figure 4.4.2-2). The bLS emissions model provided not only more daily estimates of the H_2S emissions, but also more days in which more than 75% of the day had valid H_2S measurements (Table 4.4.2-1). Comparing the standard deviation of the ½ hr emissions estimates of the daily emission rate to the range of partial-day estimates of the daily emission rate shows that the wide range of emission measurements during the spring are due to both day-to-day variability and estimates made on incomplete measurement days (having less than 75% of the possible ½ hrs with valid measurements). There was less day to day variability in the bLS-modeled H_2S emissions values (Figure 4.4.2-2) than the Ratiometric-modeled H_2S emissions values (Figure 4.4.2-1). There were no H_2S emissions during the winter when the lagoon was frozen. Maximum H_2S emissions, occurring during the spring, were approximately 20 and 30 g H_2S $d^{-1}hd^{-1}$. There was, however, wide variability in H_2S emissions from day to day during the spring (Figure 4.4.2-2). Emissions declined from the spring maximum to a relatively steady 5 g H_2S $d^{-1}hd^{-1}$ until the lagoon froze. A minimum emission during the summer (day of year 180 through approximately 220) was evident in the results. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

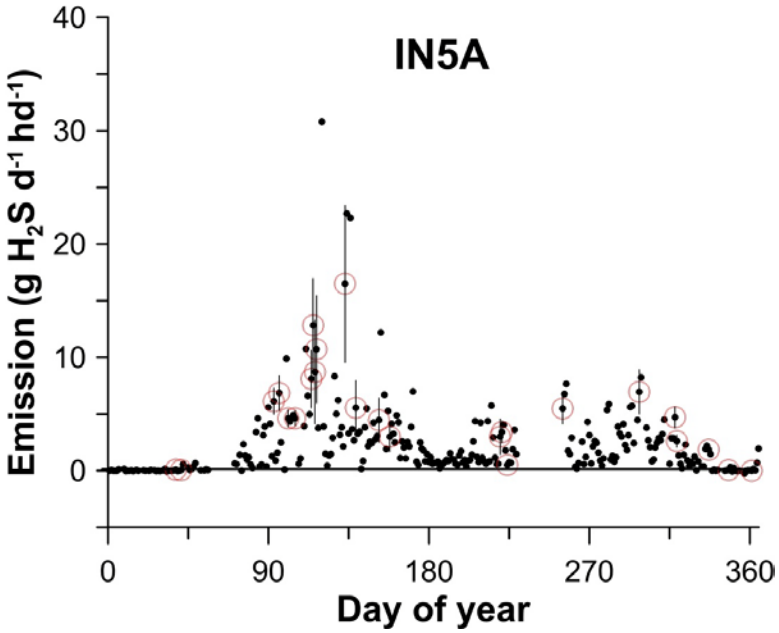

Figure 4.4.2-2: Annual variation in bLS-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS emission model depends on good estimates of the background H_2S concentration. Results indicate that the background concentration was generally less than ± 2.5 ppb (Figure 4.4.2-3). This background is consistent with an equivalent zero value where the instrument MDL was 3.4 ppb (Section 8.2). The largest background concentrations were observed around day of year 270. While it is possible that these values are overestimated by the bLS model, the frequent disturbance of the settling basin may have significantly contributed to higher background levels under northerly winds.

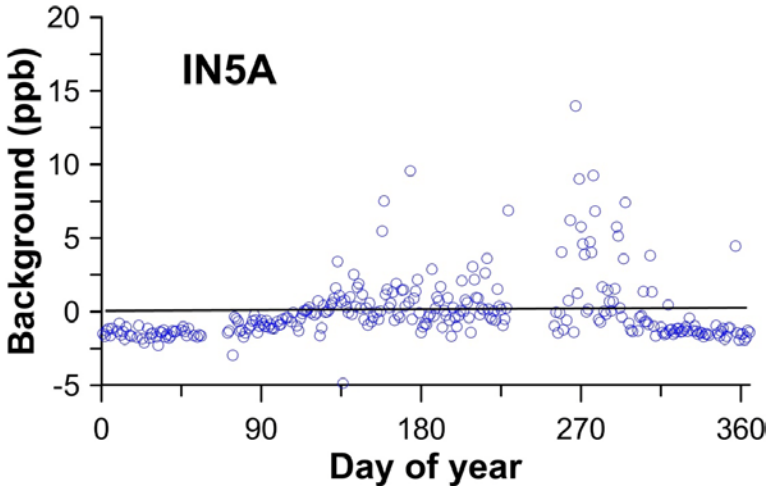

Figure 4.4.2-3: Annual variation in bLS-computed mean daily background concentration of NH_3.

4.4.2.2 Diurnal variation in H_2S emissions

There was no evident diurnal variation in H_2S emissions regardless of season (Figure 4.4.2-4).

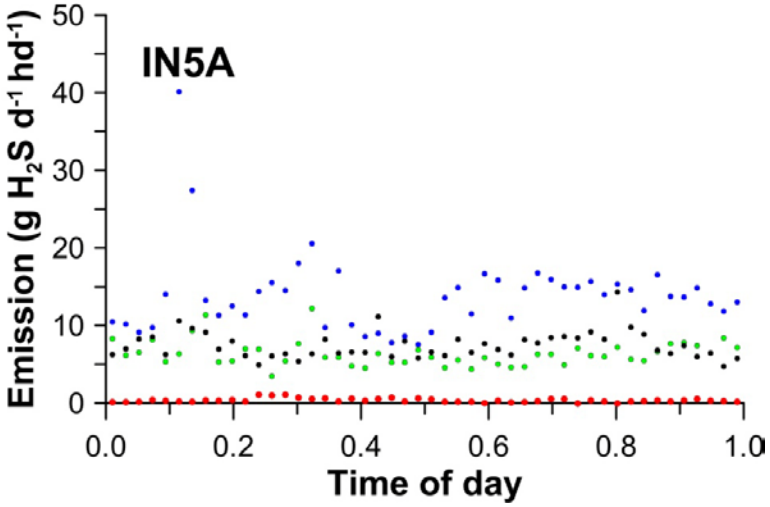

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 6-Fall (black), 7-Winter (red), Period 8-Spring (blue), and Period 9-Summer (green) are indicated.

4.4.2.3 H_2S emissions data completeness

As described for the NH_3 emissions, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ hour intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics are summarized in Table 4.4.2-1.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

Parameter	Ratiometric model	bLS model
Valid ½ hr measurements (d)	36.6	107.3
Measurements excluded due to wind direction (d)	0	
Measurements excluded because angle of attack > 60° (d)		76.0
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| < 2$ m (d)		80.1
Number of days (d) with ≥ 36 valid ½ hour periods (d):	1	24

In total, 36.6 d of valid H_2S emissions were determined using the Ratiometric emission method, with 1 day having at least 36 valid ½ hour H_2S emissions. The poor yield is a result of two factors. One factor is that this method requires a valid NH_3 emission calculation by the *RPM* model. As indicated, the *RPM* model itself has relatively low completeness. The other factor is that the lack of S-OPS lines on the east and west sides of the lagoon limits the range of wind directions for which the Ratiometric method can be used due to the requirement of a valid downwind H_2S concentration reading.

Valid H_2S emissions for 107.3 d were determined using the bLS model, with 24 d having at least 36 valid ½ hour H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) led to 80.1 d for which emissions could not be calculated. These invalid turbulence statistics were most prevalent during the night when light winds were more predominant. An angle of attack greater than 60° led to the exclusion of 76.0 d of data. The absence of S-OPS lines on the east and west sides of the lagoon is largely responsible for these large angles of attack, as winds from the east or west were more or less parallel to the S-OPS lines on the north and south sides, leading to poorly defined inputs to the bLS models and invalid results.

4.4.3 Estimation of emission measurement errors

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions, underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was

valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%. Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was +6% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -34% for TDLAS NH_3 measurements made by units with moisture interference and a bias of +6% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the Ratiometric measurement of H_2S emissions was ± 18%.

5 References

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6 Appendices

6.1 TDLAS NH_3 calibrations

Three TDLAS units (Model GasFinder2^{TM} NH3OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used at this location: TDLAS 1029, TDLAS 1031, and TDLAS 1032.

TDLAS 1029 was multipoint calibrated seven times (Table 6.1-1). The response is non-linear and consequently a third-order polynomial was used to correct the raw data for the instrument response. Table 6.1-1 indicates the multipoint calibrations used during different periods in the study.

Table 6.1-1: Multipoint calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
06/24/2007	03/01/2008	05/24/2007
03/24/2008	07/15/2008	03/24/2008
07/31/2008	08/03/2009	03/04/2009
08/04/2009	12/02/2009	12/29/2009

The offsets of the calibration equations were determined from a least squares fit of the appropriate period (Table 6.1-1) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

05/24/2007: ppm-m = -1.48 + 0.967 * X + 4.842E-005 * X^2 - 7.312-009 * X^3

03/24/2008: ppm-m = -2.58 + 0.998 * X - 1.611E-004 * X^2 + 7.449E-008 * X^3

03/04/2009: ppm-m = 4.36 + 1.069 * X + 1.128-004 * X^2 - 1.206E-007 * X^3

12/29/2009: ppm-m = 5.48+ 1.268 * X - 6.072E-005 * X^2

where X is the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.74 ppm-m prior to the July 2008 modification and 1.66 ppm-m after the modification. The

instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL prior to the July 2008 modification was greater than the offset in the calibration regression equations but less than the offset in the calibration equations after the modification. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviations of the verifications about that predicted by the calibration equations were 4.65, 4.15, 5.23, and 4.27 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI threshold occurred on two dates (Figure 6.1-2). No positive bias exceeding the DQI threshold occurred. In all cases subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

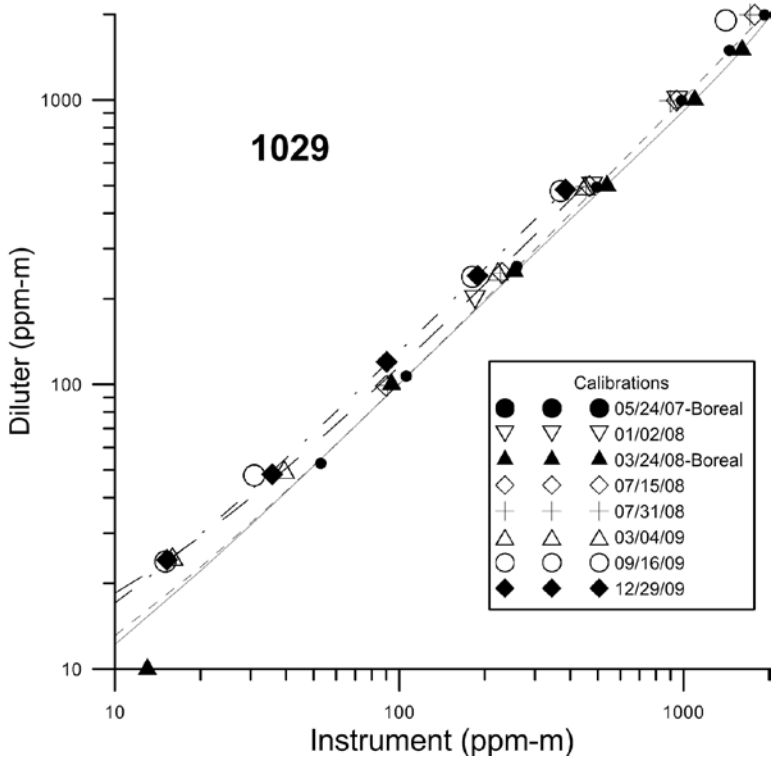


Figure 6.1-1: Multipoint calibrations of the GasFinder2™ s/n NH3OP-1029. The solid (5/24/07), dotted (3/24/08), dashed (3/4/09) and dash-dot (12/29/09) lines are the 3rd order polynomial regressions for the chosen multipoint calibration.

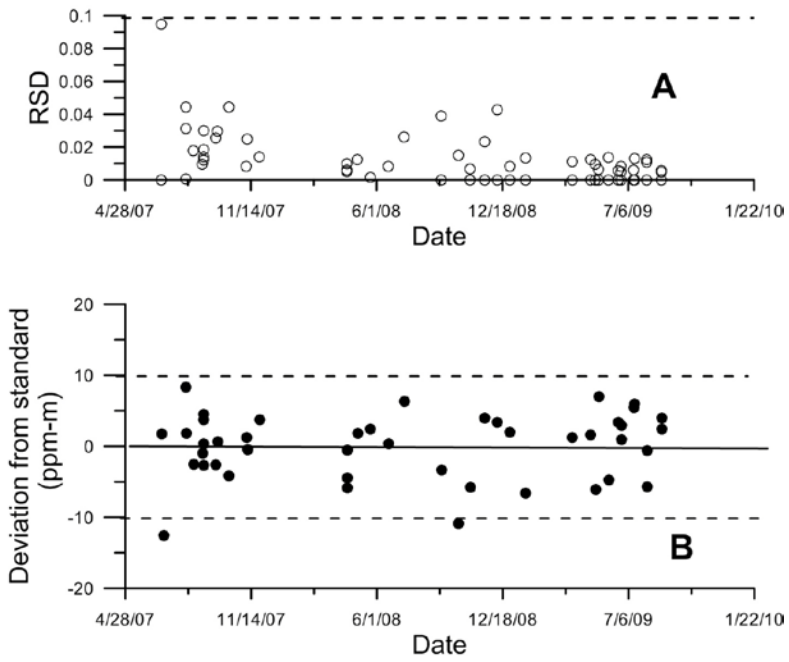


Figure 6.1-2: Control charts of the GasFinder2™ s/n NH3OP-1029

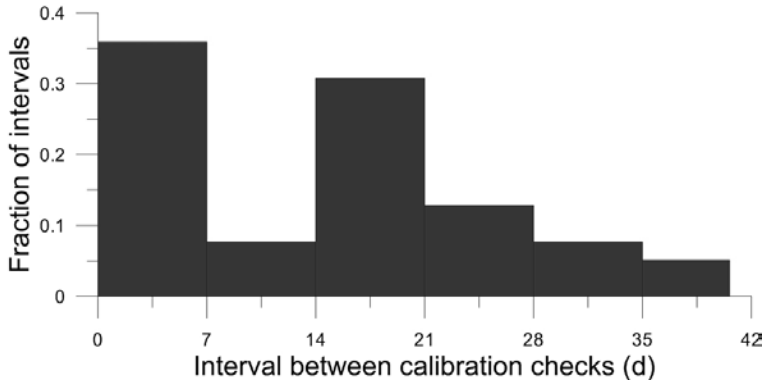


Figure 6.1-3: Calibration check intervals of the GasFinder2™ s/n NH3OP-1029

TDLAS 1031 was multipoint calibrated six times (Figure 6.1-4). The response was non-linear and consequently a third-order polynomial was used to correct the raw data for the instrument response. The multipoint calibration on 5/30/07 was used for the entire study. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -4.43 + 1.0120 * X - 5.7496E\text{-}005 * X^2 + 6.0196E\text{-}008 * X^3$$

where X is the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 5.70 ppm-m prior to the July 2008 modification and 1.92 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The average MDL was approximately equal to the offset indicated in the calibration regression. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 15.60 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI occurred in the calibration verifications between 8/2/07 and 9/18/07 (Figure 6.1-5). Positive DQI bias exceedances occurred on 6/28/2007, 9/11/2008, 4/8/2009 and 8/12/2009. Verification failures in the 6/28/07 to 9/18/07 interval were a result of un-anticipated optical noise in the calibration procedure which was later corrected. The 4/8/2009 exceedance was preceded and followed by DQI-compliant verifications and the 8/12/2009 verification was preceded by a compliant verification and followed by a multipoint indicating no problem with instrument performance. The instrument was taken out of service between 9/11/2008 and 12/31/2008 due to problems associated with moisture in the instrument.

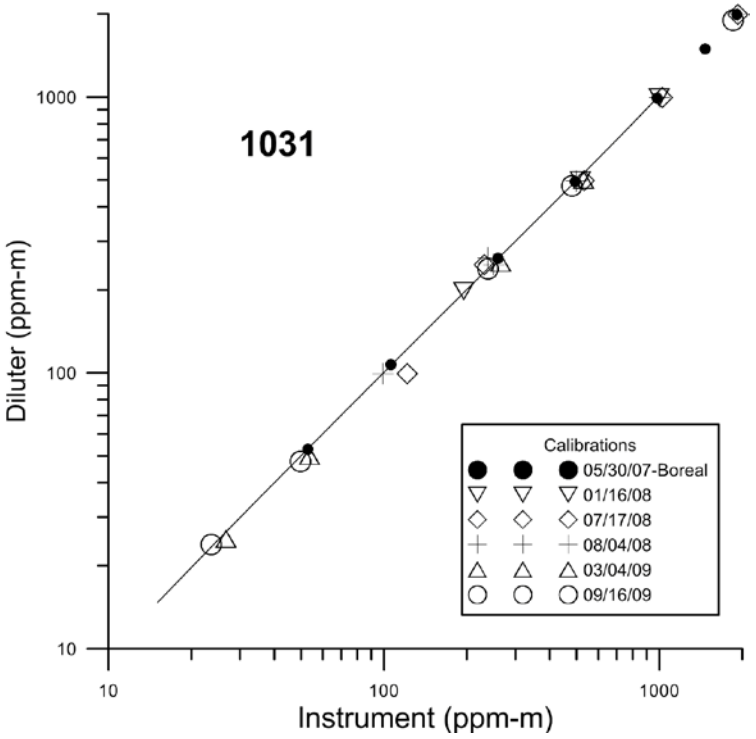


Figure 6.1-4: Multipoint calibrations of the GasFinder2™ s/n NH3OP-1031. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

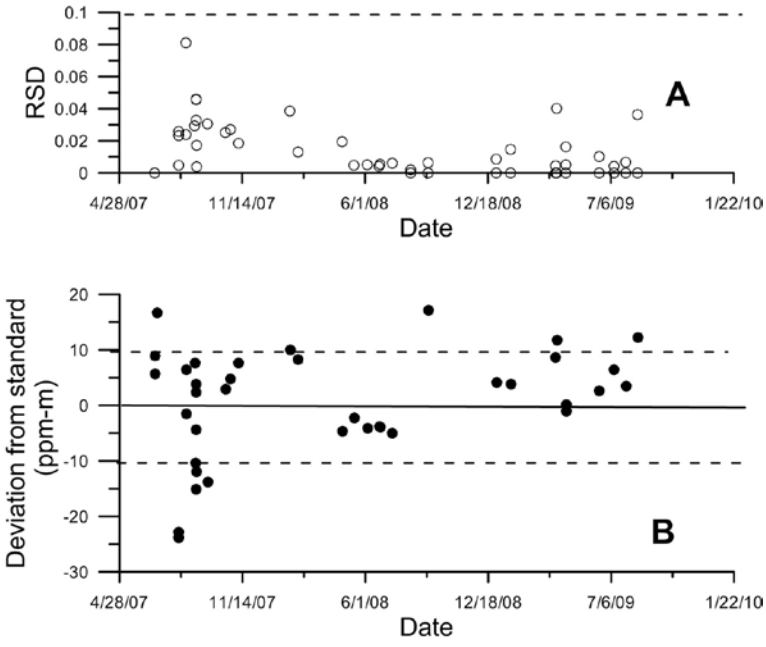


Figure 6.1-5: Control charts of the GasFinder2™ s/n NH3OP-1031

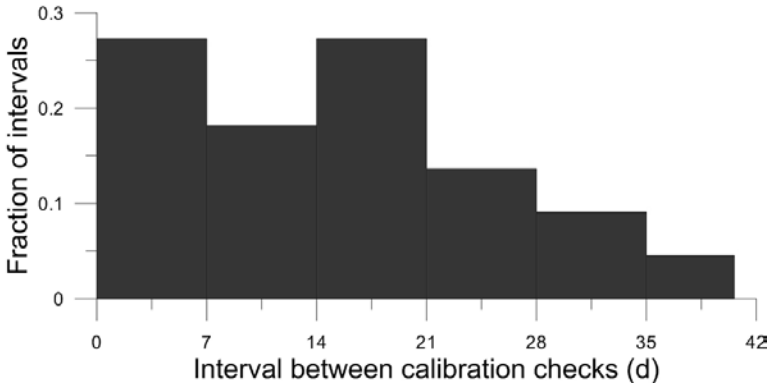


Figure 6.1-6: Calibration check intervals of the GasFinder2™ s/n NH3OP-1031

TDLAS 1032 was multipoint calibrated six times (Figure 6.1-7). The response was non-linear and consequently a third-order polynomial was used to correct the raw data for the instrument response. Table 6.1-2 indicates the multipoint calibrations used during different periods in the study.

Table 6.1-2: Multipoint calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
09/21/2007	08/01/2008	09/12/2007
08/27/2008	08/18/2009	03/04/2009

The offset of the calibration equation was determined from a least squares fit of the appropriate period (Table 6.1-2) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

9/12/07: $ppm\text{-}m = -4.35 + 1.005 * X + 3.563\ E\text{-}005 * X^2 - 2.618\ E\text{-}008 * X^3$

3/4/09: $ppm\text{-}m = -0.69 + 0.995 * X - 2.3298\ E\text{-}004 * X^2 + 2.891\ E\text{-}007 * X^3$

where X is the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments). The laser was found on 7/21/08 to not be internally grounded properly, resulting is the inclusion of responses at very low light levels. The no-measurement light levels were above the minimum light level threshold considered for a valid instrument measurement.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.60 ppm-m prior to the July 2008 modification and 1.36 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL was greater than the offset in the calibration equation for measurements prior to July 2008 and less than that after July 2008. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviations of the verifications about that predicted by the calibration equation were 6.13 and 5.61 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in

less than 10% RSD for 50 ppm-m (Figure 6.1-8) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A positive bias exceeding the DQI occurred on 3/26/2008 and 9/10/2008 (Figure 6.1-8). These exceedances were preceded and followed by valid calibration verifications and it is assumed that since no modifications of the instrument were made that the exceedances are due to operator error. A negative bias exceeding the DQI was indicated in the calibration verifications on 5/6/2008 (Figure 6.1-8). The grounding problem found on 7/21/08 (described above) may have been the cause for the period of consistently negative verifications after 4/21/08 when the background light levels exceeded the minimum acceptable light level. However since the 5/6/2008 exceedance was followed by compliant verifications (although low) without correction of the grounding problem it is assumed that the measurements are valid throughout the period of the grounding problem.

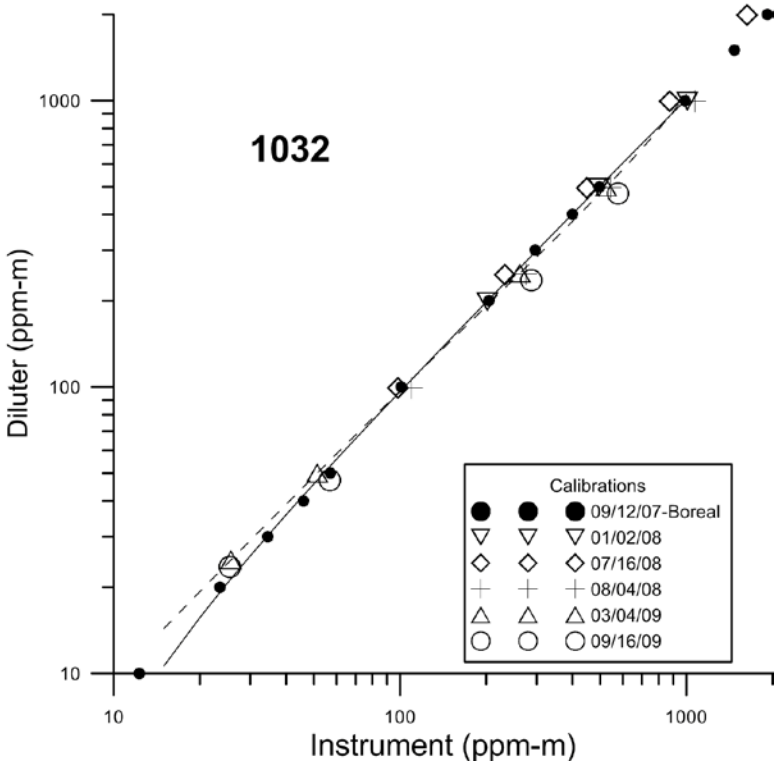


Figure 6.1-7: Multipoint calibrations of the GasFinder2™ s/n NH3OP-1032. The solid (9/12/07) and dashed (3/4/09) lines are the 3rd order polynomial regressions for the chosen multipoint calibration.

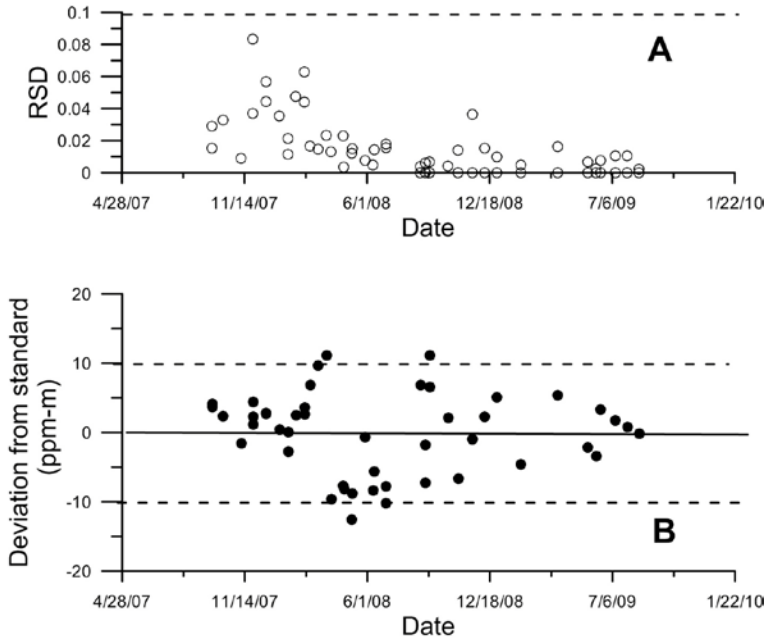


Figure 6.1-8: Control charts of the GasFinder2™ s/n NH3OP-1032

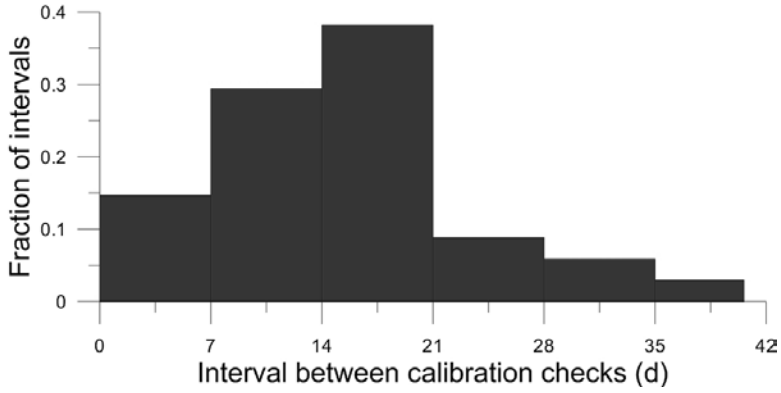


Figure 6.1-9: Calibration check intervals of the GasFinder2™ s/n NH3OP-1032

6.2 TEC 450i analyzer H_2S calibrations

The H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA) with serial number 0733825130 was multipoint calibrated twelve times (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values was never less than 0.990 although the slope of the linear regression equation varied from 0.73 to 1.20 (Table 6.2-1). The initial multipoint calibration was conducted prior to the complete burn-in of the converter and consequently differs greatly from the other calibrations. Part of the variation in slope was a result of the H_2S calibration cylinders used.

Table 6.2-1: Multipoint H_2S calibrations

Date	Slope (ppb response^{-1})	Intercept (ppb)	r^2
12/12/2007	1.20	0.0018	0.999
05/21/2008	0.95	-0.0031	0.999
07/28/2008	0.74	0.0051	0.999
09/24/2008	1.08	-0.0643	0.991
10/28/2008	0.98	0.0049	0.999
10/30/2008	0.98	0.0019	0.999
11/19/2008	0.80	-0.0077	0.999
12/09/2008	0.87	-0.0008	0.999
12/10/2008	0.83	0.0026	0.999
03/11/2009	0.92	0.0112	0.999
04/30/2009	0.80	0.0124	0.999
09/09/2009	0.73	0.0014	0.999

The standard deviation of instrument response with CEM zero air measured over a one hour period was 1.13 ppb (10/19/2009). The instrument MDL, defined as 3σ was 3.4 ppb and is indicated in Figure 6.2-2A with dashed lines. This is much less than the mean absolute value of the multipoint calibration intercept of 10.5 ppb.

Instrument performance calibration checks (Figure 6.2-2, 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 28 d (Figure 6.2-4). Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.819. The mean zero concentration was -1.3 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). Based on the correlation of instrument performance and the calibration cylinder used, it was determined that the concentration of H_2S in the FF44447 cylinder (expiration date 5/13/2009), which was inter-compared with other H_2S calibration cylinders on 8/28/2009 and observed to have been less

significant than the indicated specification. This resulted in unusually high ratios of diluter concentration versus instrument response on 3/11/2009 and a post-study calibration failure.

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedances (Figure 3) occurred on 1/31/2008 and 10/28/2008. The 1/31/2008 failure was due to the burn-in of the converter and signals changes in the instrument response as the instrument was conditioned. The 10/28/2008 DQI failure was likely due to the use of a different calibration tank for one check. Although it cannot be confirmed, the cylinder (SA15346) was likely either not within certification specifications or at the opposite end of the valid certification bound as the cylinder used before (FF20675) and after (LL34303) the date the cylinder was used resulted in valid calibration verifications.

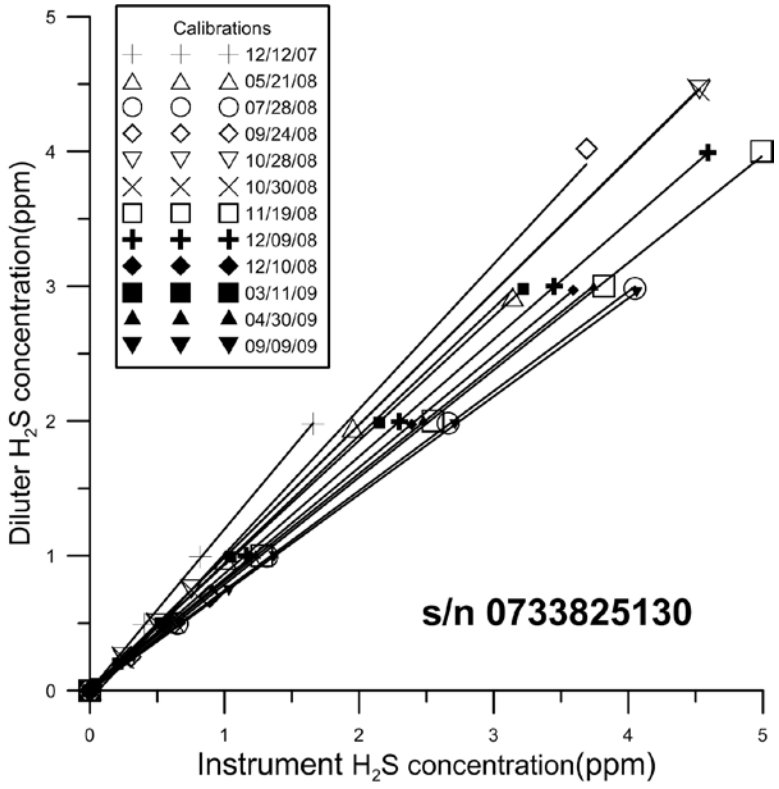


Figure 6.2-1: Multipoint calibrations of the 450i SO_2/H_2S Analyzer

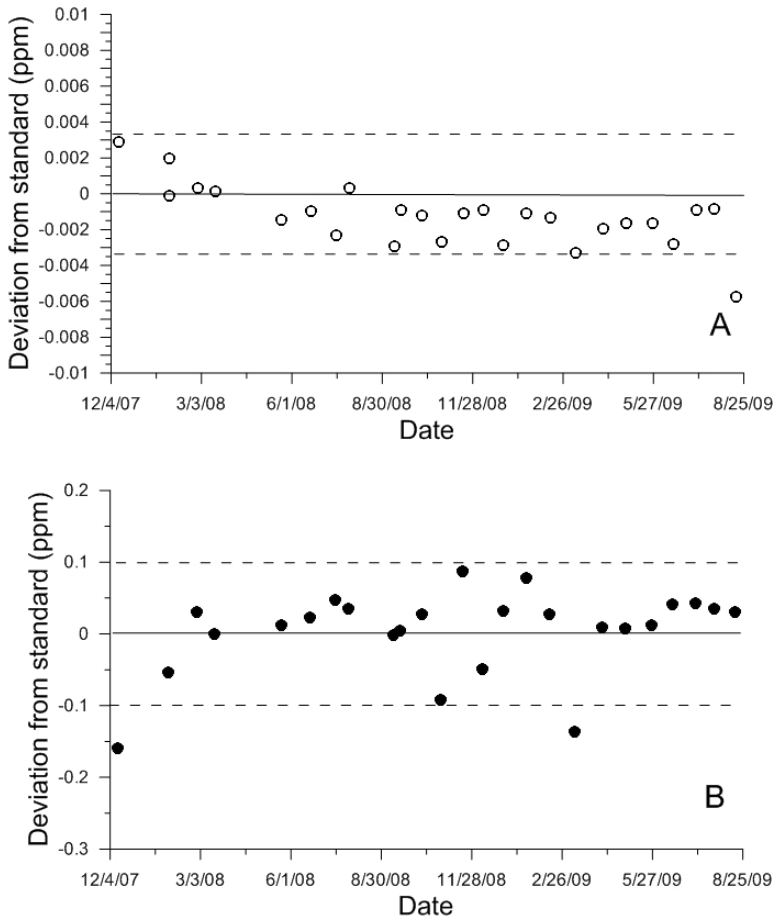


Figure 6.2-2: Instrument Control Charts

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

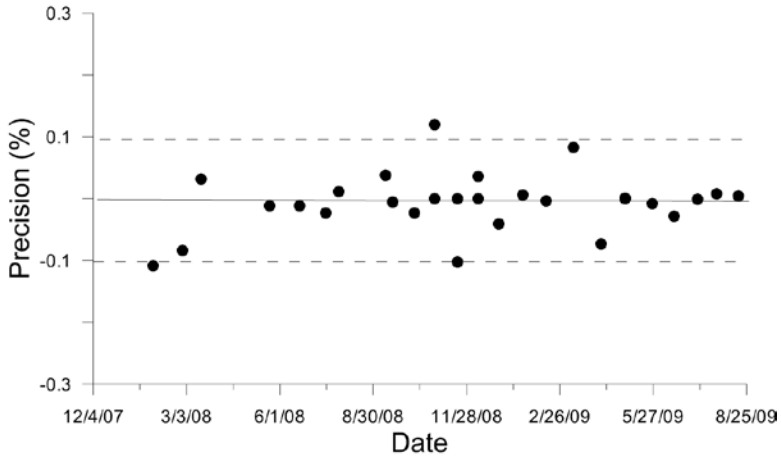


Figure 6.2-3: Instrument Precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

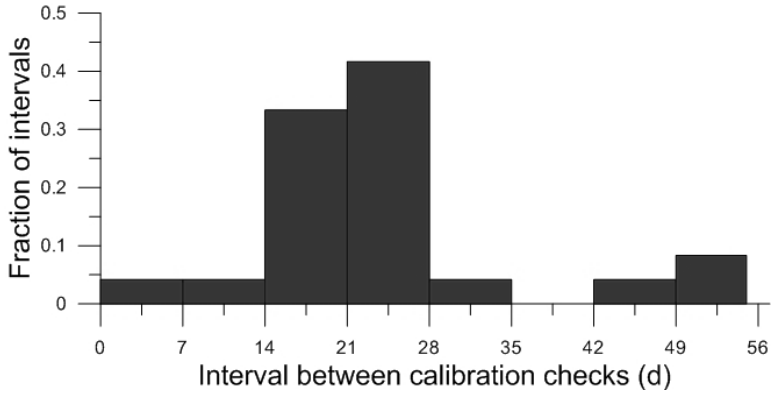


Figure 6.2-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Four sonic anemometers (Model 81000, RM Young Inc, Traverse City, MI) were used at this location: serial numbers 1925, 1926, 1928, and 1938.

Sonic anemometer 1938 was inter-compared with three standard anemometers of identical design five times (Table 6.3-1). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, an anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 26 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check at all times. The last standard inter-comparison (1/2010) failed due to loss of communications.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 8.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-1: Sonic anemometer inter-comparisons (s/n 1938)

Calibration periods		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
06/08-12/2007	06/12-14/2007	-0.013	+0.011
01/21/2008	01/23/2008	+0.002	-0.036
07/16-17/2008	07/17-18/2008	-0.005	+0.010
03/06-07/2009	03/08-09/2009	-0.007	+0.002
01/07-09/2010	01/21-25/2010	-3.730	-3.940

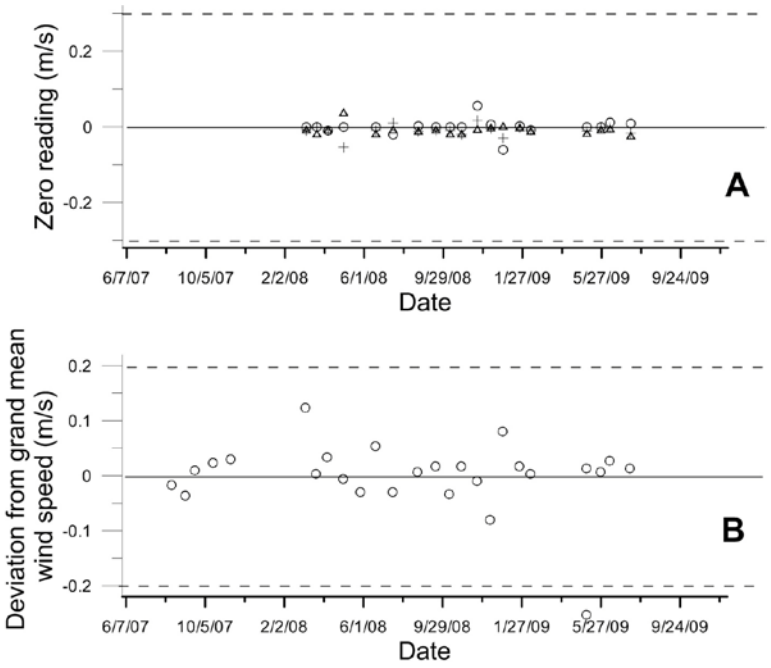


Figure 6.3-1: On-site quality assurance for s/n 1938. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

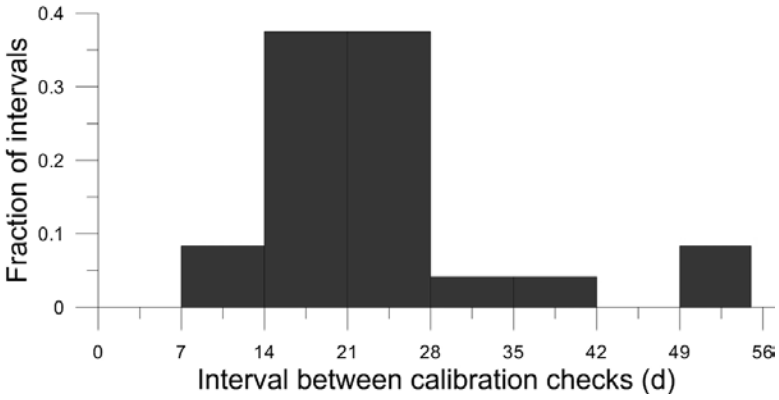


Figure 6.3-2: Inter-comparison check intervals, s/n 1938.

Sonic anemometer 1926 was inter-compared with three standard anemometers of identical design five times (Table 6.3-2). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, and anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of the period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-3). The majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-3B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-3A). Records of the zero checks made before 12/2007 were recorded as pass/fail, and did not include the actual measurements. The instrument always passed this DQI.

Table 6.3-2: Sonic anemometer inter-comparisons, s/n 1926

Calibration periods		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
06/19-22/2007	06/29-07/02/2007	-0.005	-0.033
01/17-18/2008	01/20-21/2008	-0.013	-0.032
07/16-17/2008	07/17-18/2008	+0.037	+0.059
03/06-07/2009	03/07-09/2009	+0.004	+0.048
09/16-17/2009	09/17-18/2009	+0.059	+0.001

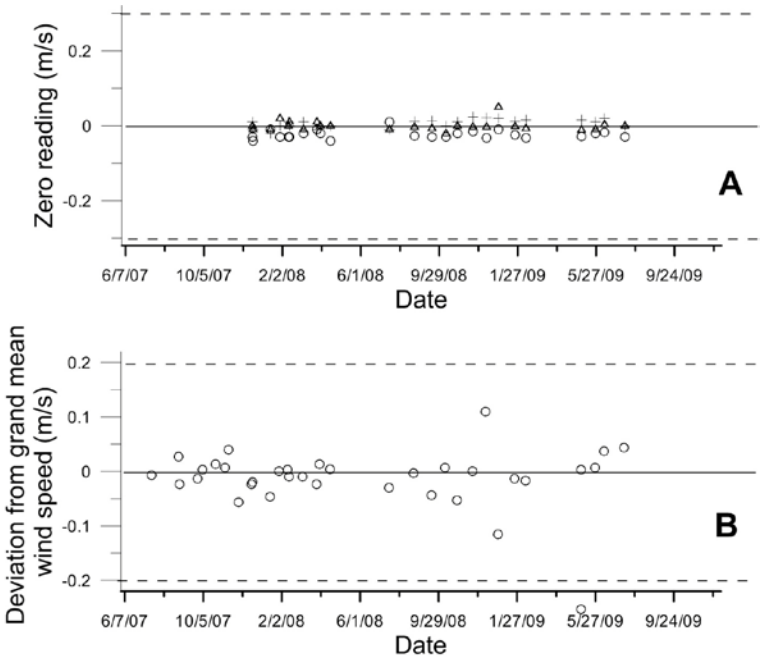


Figure 6.3-3: On-site quality assurance, s/n 1926. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

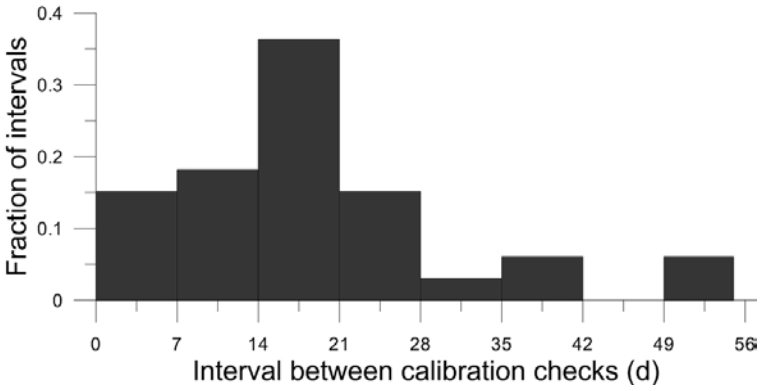


Figure 6.3-4: Inter-comparison check intervals, s/n 1926.

Sonic anemometer 1925 was inter-compared with three standard anemometers of identical design six times (Table 6.3-3). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, and anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 26 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-5B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-3: Sonic anemometer inter-comparisons, s/n 1925

Calibration periods		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
06/08-12/2007	06/12-14/2007	-0.013	-0.022
01/21-22/2008	01/23/2008	-0.053	-0.075
07/16-17/2008	07/17-18/2008	+0.023	+0.004
03/06-07/2009	03/07-09/2009	-0.018	-0.058
09/08-14/2009	09/15-16/2009	-0.013	-0.022
12/18-19/2009	12/21-23/2009	+0.095	-0.084

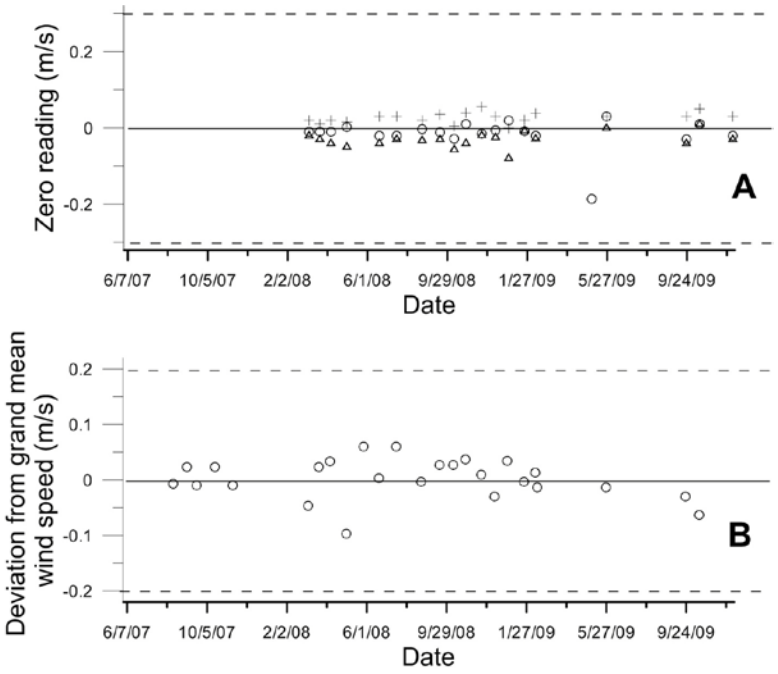


Figure 6.3-5: On-site quality assurance, s/n 1925. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

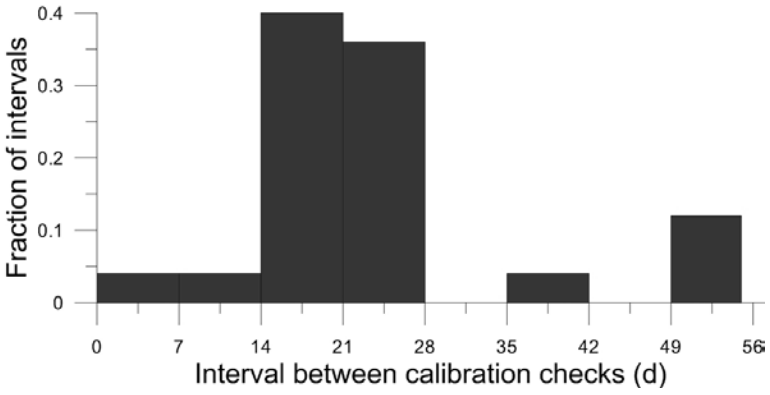


Figure 6.3-6: Inter-comparison check intervals, s/n 1925.

Sonic anemometer 1928 was inter-compared with three standard anemometers of identical design six times (Table 6.3-4). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, an anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 48 times (Figure 6.3-7). The majority of calibration checks were made within 21 d (Figure 6.3-8). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-7B). This instrument passed this check all but one time. On this one date, the inter-comparison was rerun and the instrument passed the check.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-7A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-4: Sonic anemometer inter-comparisons, s/n 1928

Calibration periods		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.004	+0.019
12/27-28/2007	12/29-31/2007	+0.003	-0.005
7/10-11/2008	7/11-14/2008	+0.022	+0.007
3/03-04/2009	3/05-06/2009	+0.070	-0.027
9/16-17/2009	9/17-18/2009	+0.056	+0.022
12/18-19/2009	12/21-23/2009	+0.094	-0.077

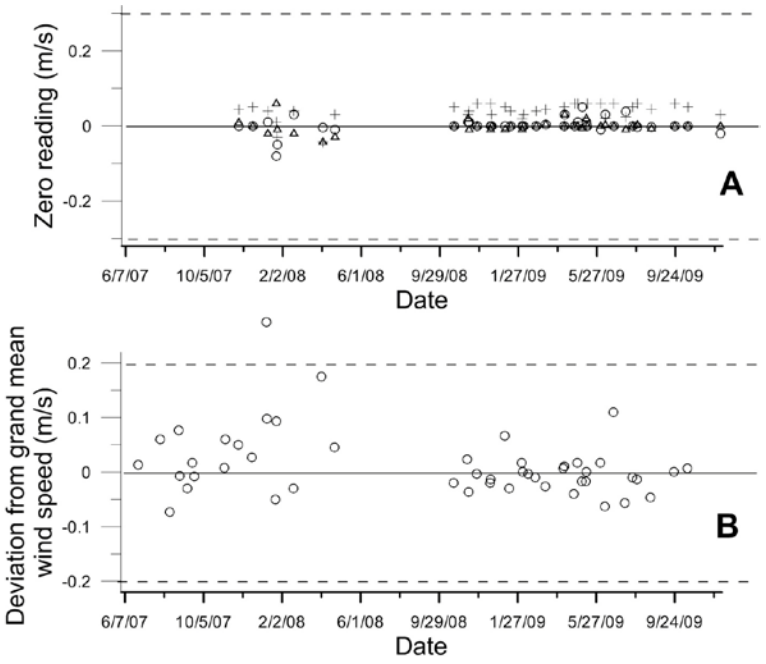


Figure 6.3-7: On-site quality assurance, s/n 1928. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

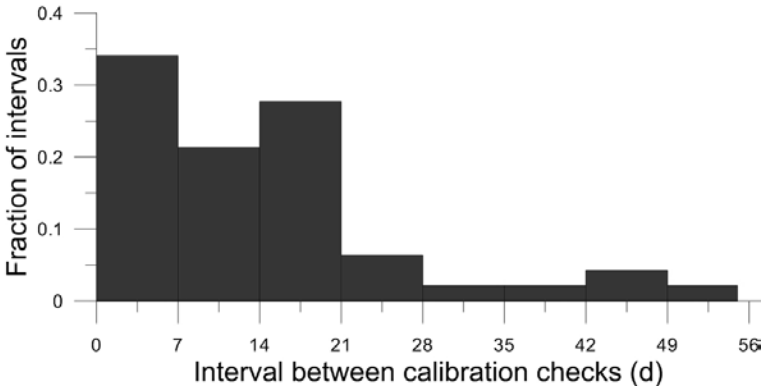


Figure 6.3-8: Inter-comparison check intervals, s/n 1928.

6.4 pH probe calibrations

Two pH probes (Model CSIMM-ph, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 005 and 006.

Probe 005 was used between 7/22/2008 and 11/20/2008. The probe was calibrated five times. The pH probe DQI specified an accuracy of ±0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-1A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the stability check but failed the accuracy DQI for pH 7 on 6/9/2008. Subsequent accuracy checks after 6/9/2008 indicated no problem with the sensor thus operator error was assumed for this check. The probe failed the DQI for all pH solutions on 11/20/08 whereupon it was removed from service.

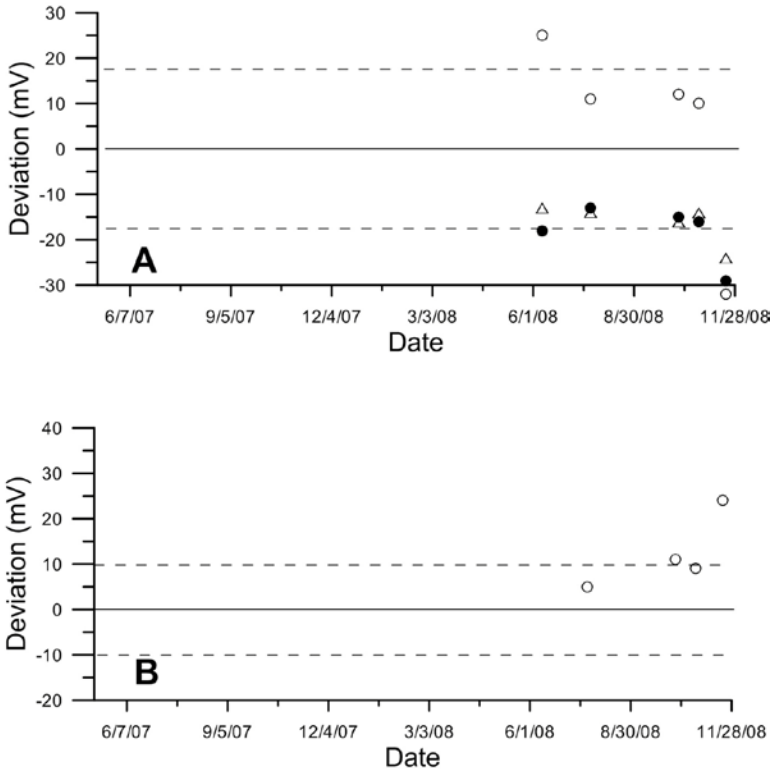


Figure 6.4-1: Accuracy and stability calibration checks of pH probe 005. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

Probe 006 was used between 8/18/2008 and 7/30/2009. The probe was calibrated six times. The pH probe DQI specified an accuracy of ±0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-2A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the stability check and accuracy DQI.

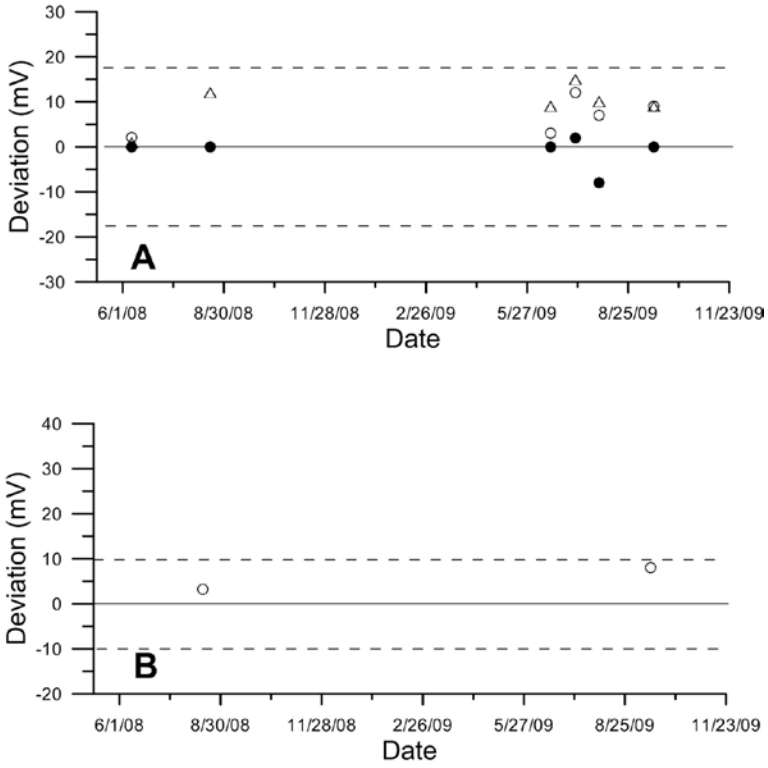


Figure 6.4-2: Accuracy and stability calibration checks of pH probe 006. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

In general, the probe calibrations were conducted about every 20 d. Since freezing conditions damaged the probes, the probes were not used during the winter.

6.5 ORP probe calibrations

Two oxidation-reduction potential (ORP) probes (Model CSIM11-ORP, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 040 and 080.

Probe 080 was first used 5/7/2009 and last used 8/18/2009. The probe was calibrated nine times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-1A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The checks exceeded the DQI on three dates, but the probe accuracy check passed the DQI (although near the upper bound) on dates between the check failures. Therefore it was determined that the DQI failures were a result of operator error and not probe failure.

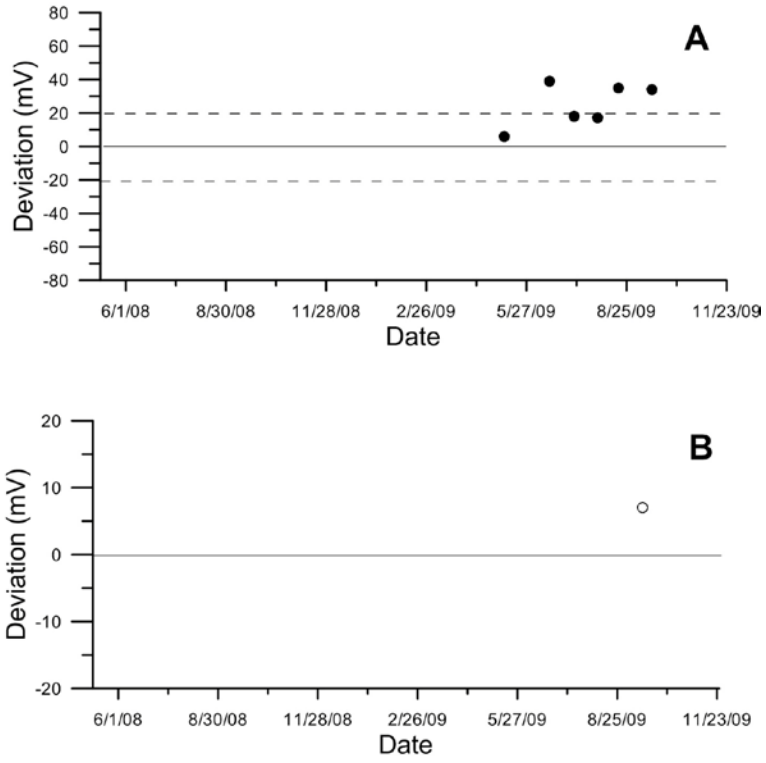


Figure 6.5-1: Accuracy and stability calibration checks of ORP probe 080. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

Probe 040 was used between 7/18/2007 and 4/7/2008. The probe was calibrated six times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-2A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the accuracy check DQI and the stability check indicated excellent probe stability.

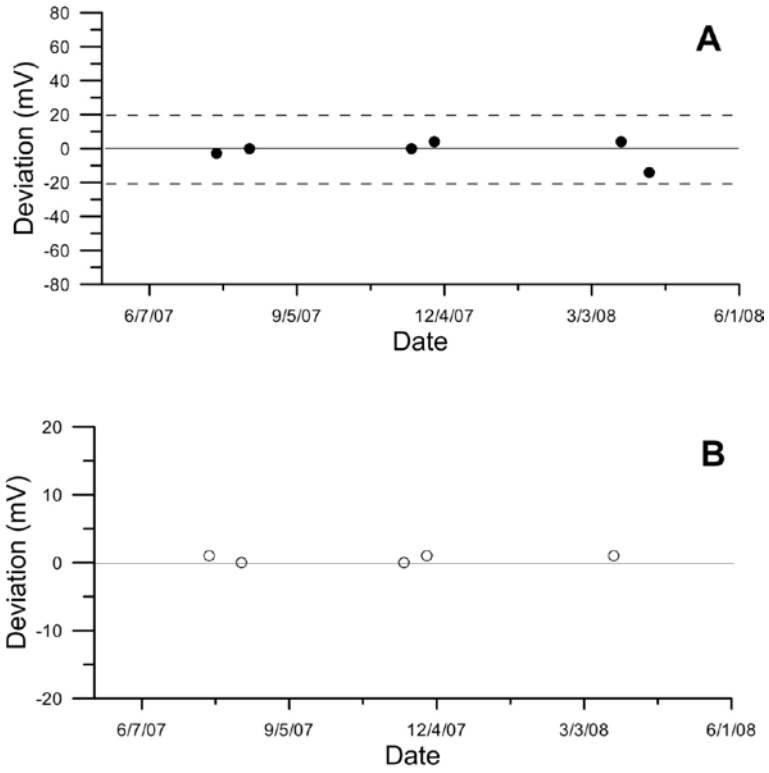


Figure 6.5-2- Accuracy and stability calibration checks of ORP probe 040. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

In general, the probe calibrations were conducted about every 20 d. Since freezing conditions damaged the probes, the probes were not used during the winter.

6.6 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n A and C) and the Gas Sampling System (GSS: s/n 4-0019) used at this location were checked about every 20 d. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results of the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in Table 6.6-1. Leaks in the GSS with check failures commonly corresponded with S-OPS leak check failures. During most of these checks when both GSS and S-OPS failed the check, the difference in flow between the GSS only and S-OPS/GSS check were within specifications (10% of maximum flow). Details of the leak check failures follow:

- S-OPS leak check failure of 8/22/2008 was associated with leaks in the initial setup of the S-OPS.
- GSS leak check failures from 9/11/2008 through 2/13/2009 appeared as a result of post-correction of the mass flow meter and did not appear to be failing during the measurements. No evidence of the failures occurred at the S-OPS leak check. Consequently it is assumed that the failures do not require the invalidation of measurements.
- GSS and S-OPS leak check failures of 2/25/09 through 4/8/2009 were due to a failure of the mass flow meter. The meter was replaced on 4/8/2009.
- GSS leak check failure for solenoid 2 on 6/15/2009 appears to be a result of operator error as no changes were made to the GSS to cause acceptance during the following check.
- GSS and S-OPS leak check failures from 7/23/2009 to 7/30/2009 were a result of a pump diaphragm failure. Consequently the leak check failure of the GSS was the cause of the leak check failure of the S-OPS.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer and the time required to draw air from the S-OPS. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 6.6-1). GSS leaks at a solenoid may reduce the measured concentrations of H_2S by mixing air from the inside of the trailer with the sampled airstream.

Table 6.6-1: Record of Leak checks for GSS s/n 4-0019 and GSS/S-OPS s/n A and C

Date	Site	GSS solenoid/ S-OPS	GSS mass Flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
08/22/2008	IN5A	2	0.07	1.39	Pass	9.9	1.02	-0.86	Fail
		3	0.10	0.36	Pass	10	1.26	0.57	Fail
09/11/2008	IN5A	2	0.22	-37.87	Fail	N/A	N/A	N/A	N/A
		3	0.22	-36.90	Fail	N/A	N/A	N/A	N/A
09/18/2009	IN5A	2	0.18	-35.84	Fail	9.8	0.54	-36.78	Pass
		3	0.17	-37.55	Fail	10	0.61	-36.57	Pass
10/10/2009	IN5A	2	N/A	N/A	N/A	9.8	0.61	-36.7	Pass
		3	N/A	N/A	N/A	10.5	0.69	-36.48	Pass
10/28/2008	IN5A	2	0.22	-38.05	Fail	9.7	0.43	-37.87	Pass
		3	0.22	-38.37	Fail	10	0.49	-38.5	Pass
11/19/2008	IN5A	2	0.12	-37.3	Pass	9.8	0.33	-36.25	Pass
		3	0.07	-37.19	Pass	10.1	0.32	-37.91	Pass
12/10/2008	IN5A	2	0.23	-36.16	Fail	9.9	0.45	-37.58	Pass
		3	0.22	-38.12	Fail	10.3	0.54	-37.47	Pass
12/29/2008	IN5A	2	0.13	-36.19	Pass	9.7	0.46	-35.65	Pass
		3	0.12	-36.87	Pass	10	0.62	-38.03	Pass
01/21/2009	IN5A	2	0.20	-38.98	Fail	9.8	0.34	-37.56	Pass
		3	0.28	-37.2	Fail	10.5	0.38	-38.26	Pass
02/13/2009	IN5A	2	0.26	-37.74	Fail	9.9	0.99	-37.5	Pass
		3	0.20	-37.63	Fail	10.5	0.78	-37.24	Pass
02/25/2009	IN5A	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		3	0.26	-39.04	Fail	11	2.02	-37.06	Fail
03/11/2009	IN5A	2	0.28	-37.9	Fail	9.8	2.49	-39.16	Fail
		3	0.15	-39.28	Pass	11	1.34	-39.97	Fail
04/08/2009	IN5A	2	0.21	-38.05	Fail	6.95	0.83	-37.77	Fail
		3	0.00	-38.94	Pass	7.66	0.65	-38.18	Pass
05/05/2009	IN5A	2	0.21	-38.06	Fail	9.7	1.04	-37.67	Fail
		3	0.01	-36.25	Pass	10.3	0.71	-36.62	Pass
05/28/2009	IN5A	2	0.13	-38.14	Pass	9.9	0.95	-38.93	Pass
		3	0.06	-39.17	Pass	10.5	0.52	-37.71	Pass
06/15/2009	IN5A	2	0.33	-36.81	Fail	10	1.43	-36.24	Fail
		3	0.04	-35.74	Pass	10.5	0.67	-37.66	Pass
07/08/2009	IN5A	2	0.13	-37.4	Pass	9.7	1.28	-35.89	Fail
		3	0.03	-37.84	Pass	10.5	0.83	-37.21	Pass
07/23/2009	IN5A	2	0.31	-37.08	Fail	9.7	1.68	-38.26	Fail
		3	0.19	-36.75	Fail	10.5	1.18	-37.8	Fail
07/30/2009	IN5A	2	0.51	-36.43	Fail	9.5	1.77	-37.17	Fail
		3	0.40	-35.54	Fail	10.5	1.47	-37.8	Fail
08/06/2009	IN5A	2	-0.15	-36.76	Pass	N/A	N/A	N/A	N/A
		3	-0.15	-37.36	Pass	N/A	N/A	N/A	N/A
08/17/2009	IN5A	2	0.06	-37.69	Pass	9.8	1.18	-35.2	Fail
		3	0.04	-35.33	Pass	10.1	1.18	-36.3	Fail

The inlet flow balance checks are summarized in Tables 6.6-2A and 6.6-2B. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation

of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A: Record of flow balancing- Side 1 (s/n A)

		Delta Inlet Flow (Beginning-End) (L min^{-1})										
Start Date	**End Date**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
9/18/2008	10/09/2008	0.01	0.06	0.21	0.07	0.10	0.00	0.07	-0.02	0.03	0.04	Pass
10/09/2008	10/28/2008	-0.02	-0.03	-0.02	0.02	0.03	0.10	-0.02	0.01	0.01	-0.03	Pass
10/28/2008	11/19/2008	0.05	0.03	-0.09	-0.07	-0.04	-0.07	-0.01	0.13	0.01	0.10	Pass
11/19/2008	12/10/2008	-0.06	-0.08	-0.02	-0.04	-0.05	-0.04	-0.06	-0.04	0.05	-0.11	Pass
12/10/2008	12/29/2008	0.03	0.00	-0.01	0.02	-0.01	0.00	0.01	-0.01	-0.01	-0.01	Pass
12/29/2008	01/21/2009	0.02	0.04	-0.02	-0.03	0.08	0.00	0.04	0.02	-0.05	0.03	Pass
01/21/2009	02/13/2009	-0.03	-0.03	-0.03	0.02	-0.11	0.04	-0.01	-0.03	0.05	0.01	Pass
02/13/2009	03/11/2009	0.01	0.06	0.01	0.02	0.05	0.05	0.01	0.06	0.02	0.10	Fail
03/11/2009	04/08/2009	-0.02	-0.02	0.05	-0.01	0.07	0.00	-0.04	-0.02	-0.03	0.00	Pass
04/08/2009	05/05/2009	0.01	-0.03	-0.04	0.00	-0.09	-0.04	-0.02	-0.03	-0.04	-0.04	Pass
05/05/2009	05/28/2009	0.00	0.05	0.01	-0.02	0.06	0.04	-0.04	-0.05	-0.04	0.00	Pass
05/28/2009	06/15/2009	-0.04	-0.03	-0.03	-0.04	-0.05	-0.12	-0.06	0.03	0.01	-0.03	Pass
06/15/2009	07/08/2009	-0.04	-0.01	0.01	0.02	-0.02	0.01	0.01	0.00	-0.02	-0.02	Pass
07/08/2009	07/30/2009	0.16	0.18	0.19	0.02	0.12	0.06	0.10	0.05	0.18	0.17	Pass
07/30/2009	08/17/2009	-0.19	-0.23	-0.21	0.04	-0.16	-0.05	-0.05	-0.10	-0.24	-0.08	Pass

Table 6.6-2B: Record of flow balancing- Side 2 (s/n C)

		Delta Inlet Flow (Beginning-End) (L min^{-1})										
Start Date	**End Date**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
9/18/2008	10/09/2008	-0.01	-0.02	-0.01	-0.07	-0.06	-0.07	-0.11	-0.01	-0.03	-0.01	Pass
10/09/2008	10/28/2008	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.02	-0.02	-0.01	Pass
10/28/2008	11/19/2008	0.10	0.00	0.00	0.07	-0.02	0.16	0.04	0.10	0.15	0.12	Pass
11/19/2008	12/10/2008	-0.13	-0.09	-0.11	-0.07	0.07	-0.10	-0.04	-0.23	-0.20	-0.10	Pass
12/10/2008	12/29/2008	-0.02	-0.01	-0.04	-0.01	0.00	-0.01	-0.03	-0.05	-0.03	0.00	Pass
12/29/2008	01/21/2009	0.05	0.09	0.05	0.05	-0.14	-0.06	0.12	0.14	0.08	-0.16	Pass
01/21/2009	02/13/2009	-0.03	0.00	-0.02	0.01	-0.02	0.03	0.00	-0.03	-0.02	-0.01	Pass
02/13/2009	02/25/2009	0.08	0.06	0.12	-0.08	0.13	0.07	-0.07	0.11	0.09	0.19	Pass
02/25/2009	03/11/2009	0.00	0.00	0.05	0.05	0.08	0.02	0.00	0.00	-0.03	0.04	Pass
03/11/2009	04/08/2009	-0.05	0.00	-0.04	0.03	-0.03	-0.01	0.03	-0.02	0.05	-0.04	Pass
04/08/2009	05/05/2009	0.01	-0.02	0.00	-0.02	-0.11	0.00	-0.06	0.02	-0.01	-0.02	Pass
05/05/2009	05/28/2009	-0.09	0.01	-0.02	0.04	-0.01	0.01	0.06	-0.04	-0.03	0.06	Pass
05/28/2009	06/15/2009	0.04	0.01	-0.02	0.00	-0.05	-0.01	-0.17	-0.01	-0.01	-0.05	Pass
06/15/2009	07/08/2009	-0.02	0.03	0.02	-0.06	0.00	0.03	0.01	0.04	-0.01	0.04	Fail
07/08/2009	07/30/2009	-0.02	-0.03	-0.02	0.09	0.01	-0.01	0.02	-0.04	0.01	-0.08	Pass
07/30/2009	08/17/2009	-0.01	0.01	-0.51	-0.24	-0.36	-0.31	0.10	0.10	-0.73	0.10	Fail

The nominal planned interval between S-OPS checks was 20 d (three weeks). S-OPS checks were conducted at this long term measurement location at one to three week intervals (Figure 6.6-1). The shorter periods between checks were a result of work being done on the site.

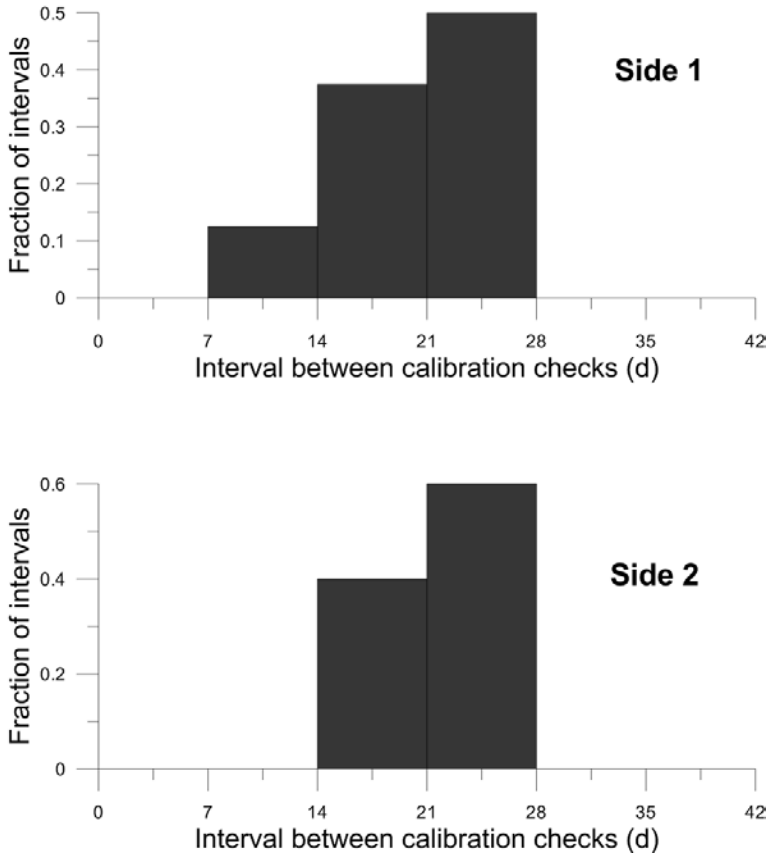


Figure 6.6-1: Intervals between checks

6.7 Miscellaneous meteorological and lagoon calibrations

6.7.1 Air temperature/humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n: 4410007

Relative humidity (RH)					
Calibration Date	**Expected RH (%)**	**Measured RH (%)**	**Difference from expected RH (%)**	**Average difference RH (%)**	**Action**
2/17/2010	21	102	-81		Replace/repair
	50	132	-82		Replace/repair
	95	182	-87		Replace/repair
				-84	Replace/repair
7/10/2008	11	11	0		Accept
	50	48	2		Accept
	84	78	6		Accept
				2	Accept
Temperature (T)					
Calibration Date	**Expected T (°C)**	**Measured T (°C)**	**Difference from expected T (°C)**		**Action**
2/17/2010	24.3	-81.7	106		Replace
7/10/2008	27.1	26.8	0.30		Accept

6.7.2 Barometric Pressure

An aneroid barometer (Model 278, Setra Inc, Boxborough, MA) with serial number 3033745 was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278 s/n 3033745

Calibration Date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
2/11-12/2010	998.4-992.5	6	1.6	Accept
9/16-17/2009	997.4-1000.1	6	0.8	Accept
2/27-3/2/2009	992.3-1010.0	6	2.0	Accept
7/23-27/008	995.6-996.8	6	1.1	Accept
1/22-23/2008	995.6-998.2	6	1.5	Accept

6.7.3 Solar Radiation

A pyranometer (Model 200SB, LiCOR Inc., Lincoln, NE) was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-3.

Table 6.7-3: Calibration record of LiCOR 200SB Pyranometer, s/n PY554447

Calibration Date	Mean difference from reference ($W\ m^{-2}$)	Mean difference from reference (%)	Action
3/5-3/8 2010	4.84	0.91	Accept
8/30/2006			Factory Calibration

6.7.4 Lagoon water temperature

A thermistor (Model 107-L, Campbell Scientific Inc, Logan, Utah) was used to measure lagoon temperature. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-4.

Table 6.7-4: Calibration record of Thermistor CSI 107-L (s/n V)

Calibration date	Expected value (°C)	Deviation from expected (°C)	Action
2/15/2010	1.1	1.2	Accept
2/15/2010	35.7	2.9	Accept
9/14/2009	0.1	-0.1	Accept
3/6/2009	0.0	0.1	Accept

6.7.5 CR1000 Data logger

The CR1000 data logger (Campbell Scientific Inc., Logan, Utah) was used to log all lagoon measurements (pH, oxidation-reduction potential, and temperature) and air temperature, relative humidity, barometric pressure, and wetness. Calibration checks of this unit were conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-6.

Table 6.7-6: Calibration record of Campbell Scientific CR1000 data logger, s/n 7676

Factory Calibration						
Calibration Date: 1/18/2007			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance (mV)**	**Measured mV**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
12	5000	± 3	5000.19	-0.19	5001.01	-1.01
12	-5000	± 3	-5002.51	-2.51	-5001.35	-1.35
12	2500	± 1.5			2500.42	-0.42
12	250	± 0.15			250.042	-0.042
12	25	± 0.015			25.005	-0.005
12	7.5	± 0.0045			7.50015	-0.0015
12	2.5	± 0.0015			2.49929	0.00071
12	-2.5	± 0.0015			-2.49967	0.00067
12	5000	± 6	4997.99	2.99	4999.32	0.32
12	5000	± 6	5001.97	-1.97	5003.03	-3.03
12	5000	± 6	N/A		N/A	
12	5000	± 6	N/A		N/A	

PAML Calibration				
Calibration Date: 2/5/2007	**Single Ended**		**Differential**	

SE Channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV Mean Value	Error (mV)	Measured (mV)	Error (mV)
1	4950	± 6.96| 4.97	4951.7	-1.7		
2	4950	± 6.96| 4.97	4951.7	-1.7		
3	4950	± 6.96| 4.97	4951.7	-1.7		
4	4950	± 6.96| 4.97	4951.7	-1.7		
5	4950	± 6.96| 4.97	4951.7	-1.7		
6	4950	± 6.96| 4.97	4951.7	-1.7		
7	4950	± 6.96| 4.97	4951.7	-1.7		
8	4950	± 6.96| 4.97	4951.7	-1.7		
9	4950	± 6.96| 4.97	4951.7	-1.7		
10	4950	± 6.96| 4.97	4951.7	-1.7		
12	4950	± 6.96| 4.97	4951.7	-1.7		
13	4950	± 6.96| 4.97	4951.7	-1.7		
14	4950	± 6.96| 4.97	4951.7	-1.7		
15	4950	± 6.96| 4.97	4951.7	-1.7		
16	4950	± 6.96| 4.97	4951.7	-1.7		

Calibration Date: 2/24/2010			Single-Ended		Differential	
Channel	Input (mV)	Tolerance SE | DE (mV)	Measured (mV)	Error (mV)	Measured (mV)	Error (mV)
1	100	± 2.06 | 1.06	99.13	0.87		
2	100	± 2.06 | 1.06	99.13	0.87	99.53	0.47
3	100	± 2.06 | 1.06	99.13	0.87		
4	100	± 2.06 | 1.06	99.13	0.87		
5	100	± 2.06 | 1.06	99.13	0.87	99.53	0.47
6	100	± 2.06 | 1.06	99.13	0.87	99.53	0.47
7	100	± 2.06 | 1.06	99.45	0.87	99.53	0.47
8	100	± 2.06 | 1.06	99.13	0.87	99.53	0.47
9	100	± 2.06 | 1.06	99.43	0.87		
10	100	± 2.06 | 1.06	99.13	0.87		
11	100	± 2.06 | 1.06	99.13	0.87		
12	100	± 2.06 | 1.06	99.13	0.87		
13	100	± 2.06 | 1.06	99.13	0.87		
14	100	± 2.06 | 1.06	99.13	0.87		
15	100	± 2.06 | 1.06	99.13	0.87		
16	100	± 2.06 | 1.06	99.13	0.87		
1	0	± 2.06 | 1.06	0	0		
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0		
4	0	± 2.06 | 1.06	0	0		
5	0	± 2.06 | 1.06	0	0	0	0

Calibration Date: 2/24/2010			Single-Ended		Differential	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0		
10	0	± 2.06 | 1.06	0	0		
11	0	± 2.06 | 1.06	0	0		
12	0	± 2.06 | 1.06	0	0		
13	0	± 2.06 | 1.06	0	0		
14	0	± 2.06 | 1.06	0	0		
15	0	± 2.06 | 1.06	0	0		
16	0	± 2.06 | 1.06	0	0		

6.7.6 CR800 Data logger

The CR800 data logger (Campbell Scientific Inc., Logan, Utah) was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration check of this unit was conducted only at end of the study. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-7.

Table 6.7-7: Calibration record of Campbell Scientific CR800 data logger s/n 3699

Calibration date: 3/22/2010			Single-Ended	
SE Channel	**Input(mV)**	**Tolerance (mV)**	**Measured (mV)**	**Error (mV)**
1	100	±2.061	99.40	0.6
2	100	±2.061	99.40	0.6
3	100	±2.061	99.41	0.6
4	100	±2.061	99.41	0.6
5	100	±2.061	99.41	0.6
6	100	±2.061	99.41	0.6

Calibration date: 3/22/2010			Single-Ended	
SE Channel	**Input(mV)**	**Tolerance (mV)**	**Measured (mV)**	**Error (mV)**
1	0	±2.061	0	0
2	0	±2.061	0	0
3	0	±2.061	0	0
4	0	±2.061	0	0
5	0	±2.061	0	0
6	0	±2.061	0	0

6.8 Site Activity

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	8/21/2008		Setup	Set up S-OPS lines and antennas. Used GPS to find locations.
IN5A	8/22/2008		Setup	Too wet to perform wetness sensor calibrations or sludge depth measurement.
IN5A	8/22/2008		Setup	Sonic anemometers heights taken.
IN5A	8/22/2008		Setup	Sonic anemometer 3 pole on tower too big for sonic anemometer. Could not get tower sonic anemometers set up because thunderstorms; sonic anemometer 1 on met station running.
IN5A	8/22/2008		Setup	Could not balance S-OPS on south side. Could not replace the filters because of rain. Rain could be affected balance (H_2S still being measured even though the inlets are not balanced). Could not balance north side S-OPS due to rain (clogging filters). All other tests passed and removed corks for H_2S sampling.
IN5A	8/22/2008		Setup	Strong odor from lagoon on North and East sides due to Southwest winds. Reading H_2S values greater than 300ppb.
IN5A	8/22/2008		Setup	Wetness sensor: Too wet to calibrate
IN5A	8/22/2008		Setup	S-OPS Max Flow Test
IN5A	8/22/2008		Setup	S-OPS/GSS Leak Test: Pass
IN5A	8/22/2008		Setup	GSS No Flow Test
IN5A	8/22/2008		Setup	GSS Max Flow Test
IN5A	8/22/2008		Setup	GSS Leak Test: Pass
IN5A	8/22/2008	15:05-16:05	Setup	sonic anemometer intercomparison: Pass
IN5A	8/22/2008	15:45	Setup	Barometer audit: Accepted
IN5A	8/22/2008	16:20	Setup	sonic anemometer bias/zero check: Pass
IN5A	9/10/2008		Setup	Set up ground and tower retro-reflectors; mounted tower sonic anemometers. All retro-reflectors have 0.25-inch plastics.
IN5A	9/10/2008		Setup	Calibrated TDLAS 1032; ran out of time due to tube-connector leak. Will calibration other TDLAS tomorrow.
IN5A	9/10/2008		Setup	No internet connections to TDLAS laptops.
IN5A	9/10/2008		Setup	Set up CO_2 measuring instrument on North side of lagoon (3 cubes with 0.25-inch plastics).
IN5A	9/11/2008		Setup	Tried to calibrate TDLAS 1031 for 30 minutes, but could not get values within +/-10% bias.
IN5A	9/11/2008		Setup	Changed S-OPS filters and re-taped threads with Teflon tape. GSS leak (0.64 LPM during test); ran out of time and could not perform remaining S-OPS/GSS acceptance.
IN5A	9/11/2008		Setup	Scanner in NW corner grinding even after sending new commands; will bring back to office to troubleshoot.
IN5A	9/11/2008		Setup	GSS Leak Test: Pass
IN5A	9/11/2008		Setup	GSS Max Flow Test
IN5A	9/11/2008	16:34	Setup	Calibrated TDLAS 1029
IN5A	9/16/2008		Setup	Error message on TDLAS 1 laptop - had to power-cycle machine. Lost all paths on TDLAS 1--re-aimed.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	9/16/2008		Setup	Installed TDLAS 2 and scanner. Tried to aim paths. Could not aim paths 5 and 10 on TDLAS 2 because of rain.
IN5A	9/16/2008		Setup	On modem set subact mask=255.255.255.0. Set up single path for bLS/RPM validation study. Path is 102 meters running along the East side of the lagoon.
IN5A	9/17/2008	14:00	Remote	Daily Status Check from PAML Notes: Re-aimed three paths on TDLAS 2. Changed TCP/IP settings on H_2S analyzer because H_2S analyzer was not in time sync with LAN. Found TCP/IP setting had changed to default settings, so they were changed back to proper settings. Set up bLS/RMP validation study yesterday. Path is 102 m long along east side of lagoon. Keep getting red box errors and pan/tilt errors on TDLAS 1. Cannot find path 5 on TDLAS 1. Must be wet. Flagging occurring on all sonic anemometers at regular intervals; must be interference from farm. Centerline Duty Cycle on TDLAS 2 (1031) is around 250. No lagoon probes yet.
IN5A	9/18/2008		Calibration	Wetness Sensor: Calibration accepted
IN5A	9/18/2008		Calibration	GSS Leak Test: Pass
IN5A	9/18/2008		Calibration	GSS Max Flow Test
IN5A	9/18/2008		Calibration	GSS No Flow Test
IN5A	9/18/2008		Calibration	S-OPS/GSS Leak Test: Pass
IN5A	9/18/2008		Calibration	S-OPS Balance: South A
IN5A	9/18/2008		Calibration	S-OPS Balance: North C
IN5A	9/18/2008		Calibration	S-OPS Max Flow Test
IN5A	9/18/2008	14:24	Calibration	TEC 450i Calibration Verification Check
IN5A	9/18/2008	14:50	Calibration	TEC 450i Reference Precision Check
IN5A	9/18/2008	15:25-16:30	Calibration	sonic anemometer intercomparison: Pass
IN5A	9/18/2008	16:38	Calibration	Barometer audit: Accepted
IN5A	9/18/2008	18:00	Calibration	sonic anemometer bias/zero check: Pass
IN5A	9/24/2008		Calibration	Performed H_2S multipoint calibration using diluter (0.5 ppm, 0.7 ppm, 0.25 ppm) and directly from the tank (4.02 ppm--FF20675) to test diluter performance. Could not get enough flow for 1 ppm or 2 ppm.
IN5A	9/24/2008		Calibration	Internet not working; reset router and is now working properly.
IN5A	9/24/2008		Calibration	TDLAS 1 was not aligned upon arrival. The settings were not setup for optimization. It is now enabled and set up for enabling optimization.
IN5A	9/24/2008		Calibration	TDLAS 1031 giving appropriate values for CDC (~148-149); will leave TDLAS on scanner on NW corner and keep single-path with TDLAS 1032.
IN5A	9/24/2008		Calibration	Laptop with single path had error message with *GasView MP* upon arrival; plan to keep instrument running to obtain sufficient data from study assessment (program failure at 9/19/2008 at 11:44:21 GMT).
IN5A	9/24/2008		Calibration	Distances had not yet been entered into *GasView MP* setup files. Distances entered into TDLAS 1 and 2 setup files. Single path distance not entered to maintain consistency with previous data; distance recorded but 1.0 m entered into GasView program (102 m).
IN5A	9/24/2008		Calibration	H_2S concentration continued to decrease on 450i when measuring straight from tank; tank pressure low (~400-500 psi); re-running multipoint to see if trend continues with other concentrations; ran 0.7 ppm for over 20 minutes and received approximately the same value as

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
				with original. Started running low on H_2S gas, so only reran at 0.7 ppm.
IN5A	9/24/2008		Calibration	Restarted single-path laptop computer (*GasView MP* program shut down with error while FOS on site). No CO_2 log file named LI840_IN5A_09242008.txt on desktop. New *GasView MP* log file TDL3_IN5A_bLSRPMstudy_09242008.gvl.
IN5A	9/24/2008		Calibration	Mapped power routing throughout trailer and completed site layout.
IN5A	9/24/2008		Calibration	Wetness sensor reading ~1-2.5 KOhm when dry: starting to corrode and need to repaint during next trip.
IN5A	9/24/2008		Calibration	Need to get new medical information for IN5A.
IN5A	9/29/2008	14:00	Remote	Daily Status Check from PAML Notes: H_2S needs to be power-cycled to enforce the internet connection required for time synchronization. Beginning on day 630, all three sonic anemometers experienced a lot of data loss, likely due to communication interference. Wetness sensor never goes above zero.
IN5A	9/30/2008	16:30	Remote	Daily Status Check from PAML Notes: On extra laptop from bLS validation study, error message from Boreal Laser *GasView MP* program: "Boreal Laser has encountered a problem and needs to close. We are sorry for the inconvenience." Same message also occurred yesterday. Restarted program and problem occurred again. Flag 1 appears a few times in H_2S data. Wetness sensor never reads wet.
IN5A	10/1/2008	12:15	Remote	Daily Status Check from PAML Notes: sonic anemometer 3 frequently has one or so flagged points. Wetness sensor not working properly.
IN5A	10/2/2008	11:50	Remote	Daily Status Check from PAML Notes: GSS/ H_2S /Innova graphs not up to date since month change. Wetness sensor not working properly.
IN5A	10/3/2008	14:05	Remote	Daily Status Check from PAML Notes: On TDLAS 1, only 3 (otherwise all 5) paths are good. After discussing with Matt, it was concluded for the next two paths there were no optimization strings. Wetness sensor not working properly.
IN5A	10/6/2008	12:10	Remote	Daily Status Check from PAML Notes: Overflow error on sonic anemometer program. Restarted program and it is now working. Wetness sensor is not working. FOS will check it during next visit to site.
IN5A	10/7/2008	13:00	Remote	Daily Status Check from PAML Notes: Unable to connect to CR800 at first; power-cycled and it is now working. Data file now up to date.
IN5A	10/8/2008		Calibration	Upon arrival, the laptop for the bLS/RPM study was not working. Power-cycled to make it work again.
IN5A	10/8/2008		Calibration	Both TDLAS's were optimizing a lot and getting poor light values because of rain.
IN5A	10/8/2008		Calibration	TDLAS 1029 and Scanner 6 (s/n: 1202) are now in the NW corner as TDLAS 2. Changed power supplies in both #1 and #2 power supplies to 24 V. Seems to be working well on Scanner 6.
IN5A	10/8/2009	19:42	Calibration	Calibrated TDLAS 1029
IN5A	10/9/2008		Calibration	Spider webs on the inside of inlet filter holders; filters not dirty but cleaned filter holders of webs.
IN5A	10/9/2008		Calibration	Wetness sensor showing wet resistances when dry (~100 KOhm); removed sensor.
IN5A	10/9/2008		Calibration	Removed pH/ORP probes' wires from CR 1000 at 16:38 GMT.
IN5A	10/9/2008	15:15-16:15	Calibration	sonic anemometer intercomparison: Pass
IN5A	10/9/2008	16:32	Calibration	Barometer audit: Accepted
IN5A	10/9/2008	16:33	Calibration	sonic anemometer bias/zero check: Pass

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	10/9/2008	17:50	Calibration	pH sensor: Calibration, Acceptance, and QC check completed
IN5A	10/9/2008	18:01	Calibration	ORP sensor: Acceptance and calibration completed
IN5A	10/10/2008		Calibration	Started doing H_2S 4.02 ppm direct check at 15:20 and ended at 15:32 (data were loading in the running file).
IN5A	10/10/2008		Calibration	Could not calibrate TDLAS 1031. It was not responding well; taking it back to PAML.
IN5A	10/10/2008	17:02	Calibration	Calibrated TDLAS 1032
IN5A	10/20/2008	14:41	Remote	Daily Status Check from PAML Notes: *iPort* program error: "encountered a problem and needed to close." No communication with H_2S analyzer since 8:50 GMT on 10/20/2008. Had to restart sonic anemometer program to get H_2S analyzer to connect; created fill file for missing data. Data are now loading in real-time. Cannot connect to TDLAS laptops. Communication problems causing some flagging in all three sonic anemometers. Wetness sensor not working properly.
IN5A	10/21/2008	16:14	Remote	Daily Status Check from PAML Notes: Some flagging in all sonic anemometers due to communication problems. Flag 1 (missing data) in H_2S data. Cannot connect to either TDLAS laptop. Will look at wetness sensor tomorrow.
IN5A	10/22/2008		Repair	Restarted TDLAS laptops. After restart, could not get *GasView MP* program to load previous setup files; program said files were corrupted. Loaded older setup file for *GasView MP* program and re-aimed paths.
IN5A	10/22/2008		Repair	Checked TCP/IP settings on 450i, and they were correct (time synch was off by over 8 minutes). Power-cycled 450i and time synch is only behind by one minute.
IN5A	10/22/2008		Repair	Tried sanding wetness sensor to get working properly, but it did not help. A new one will be ordered.
IN5A	10/23/2008	12:47	Remote	Daily Status Check from PAML Notes: There is some flagging on all sonic anemometers due to communication issues. H_2S analyzer flag 1 (missing data); connection lost at 15:45 GMT on 10/22/2008. Missing data for TDLAS QC because TDLAS laptops froze up. No wetness sensor.
IN5A	10/24/2008	12:33	Remote	Daily Status Check from PAML Notes: H_2S data since 15:15 GMT 10/22/2008 is missing (flag 1). Filled missing data, and started data loading in real-time. TDLAS 1 is optimizing a lot due to rain. No wetness sensor.
IN5A	10/27/2008		Calibration	Time sync on H_2S analyzer was 2 min 15 sec behind LAN. Checked TCP/IP settings and H_2S, and they were fine. Started both TDLAS computers and LAN, so updates could be installed.
IN5A	10/27/2008		Calibration	pH sensor: Calibration, Acceptance, and QC check completed
IN5A	10/27/2008		Calibration	ORP sensor: Acceptance and calibration completed
IN5A	10/27/2008	14:57	Calibration	Barometer audit: Accepted
IN5A	10/27/2008	15:50-16:40	Calibration	sonic anemometer intercomparison: Pass
IN5A	10/27/2008	16:34	Calibration	Calibrated TDLAS 1029
IN5A	10/27/2008	17:09	Calibration	Calibrated TDLAS 1032
IN5A	10/27/2008	18:10	Calibration	sonic anemometer bias/zero check: Pass
IN5A	10/28/2008		Calibration	Performed multipoint calibration on TEC 450i to check diluter accuracy. Highest concentration is straight from the tank.
IN5A	10/28/2008		Calibration	Measured the retro-reflector heights. See site note for details.
IN5A	10/28/2008		Calibration	Maintenance list completed.
IN5A	10/28/2008	16:15	Calibration	Finished installing lagoon probe float.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	10/29/2008	13:43	Remote	Daily Status Check from PAML Notes: Noticed date on H_2S analyzer is off by several months (May 2009 vs. October 2008). Time is correct, so sync program is working. Found that date changed on 10/22/2008 at 15:51 GMT. Restarted 450i to try to update time sync, but it is still sending the wrong date. Only GSS files up to date because of H_2S date being wrong. No wetness sensor.
IN5A	10/30/2008		Calibration	Restarted 450i to reset the time sync and correct the date. This did not work; date says 5/2/2009
IN5A	10/30/2009		Calibration	Performed a multipoint calibration on the TEC450i with the *Environics* (s/n: 3925) from the office to check the accuracy of the *Environics* diluter.
IN5A	10/30/2010		Calibration	Installed and calibrated a new wetness sensor at the meteorology station.
IN5A	10/31/2008	12:35	Remote	Daily Status Check from PAML Notes: Date on TEC 450i still off. It is reading 5/3/2009. Some flagging on all sonic anemometers due to communication issues. Checked H_2S parameters in real-time because there is on QC data.
IN5A	11/3/2008	12:50	Remote	Daily Status Check from PAML Notes: Date on TEC 450i reading 5/6/2008 instead of current date. Numerous warning with *iPort* screen. See report for details. H_2S parameters look ok during remote login conducted at later time. Communication problems with sonic anemometers.
IN5A	11/4/2008	13:40	Remote	Daily Status Check from PAML Notes: Date on TEC 450i reading 5/7/2009 instead of current date. Parameters still look normal. QC program will be modified to incorporate incorrect date. pH has dropped significantly since yesterday (8.16 to 7.62).
IN5A	11/5/2008	13:20	Remote	Daily Status Check from PAML Notes: TEC 450i date still reading incorrect date (5/8/2009). H_2S QC check incomplete.
IN5A	11/6/2008	12:40	Remote	Daily Status Check from PAML Notes: Wrong date still being shown on LAN. pH decreasing in lagoon.
IN5A	11/7/2008	14:00	Remote	Daily Status Check from PAML Notes: Date on LAN still incorrect. pH in lagoon is gradually decreasing.
IN5A	11/10/2008	16:17	Remote	Daily Status Check from PAML Notes: Path 10 on TDLAS needed to be re-aimed. Lower light levels the past few days due to rain/mist. Paths still aligned. Date on TEC 450i is still incorrect (5/13/2009). Flagging on sonic anemometers due to communication issues. Checked TEC 450i data in real-time, and it appears to be good.
IN5A	11/11/2008	13:40	Remote	Daily Status Check from PAML Notes: Date on TEC 450i is still incorrect (5/14/2009). TEC 450i is also over four minutes behind the LAN. QC graphs are now up to date. Program has been changed.
IN5A	11/12/2008	15:11	Remote	Daily Status Check from PAML Notes: Date on TEC 450i is still incorrect (5/15/2009). Some flagging on all sonic anemometers due to communications issues.
IN5A	11/13/2008	13:41	Remote	Daily Status Check from PAML Notes: Date on TEC 450i is still incorrect (5/16/2009). Some flagging on all sonic anemometers due to communications issues.
IN5A	11/13/2008	13:53	Remote	Daily Status Check from PAML Notes: Date on TEC 450i is still incorrect (5/17/2009). Some flagging on all sonic anemometers due to communications issues. TDLAS's optimizing a lot due to rain at site.
IN5A	11/17/2008	13:45	Remote	Daily Status Check from PAML Notes: TEC 450i date still incorrect. TDLAS 1 laptop has frozen up. Must have happened during site check yesterday because time sync check was fine and scanner was moving originally. FOS will restart computer during site visit for calibrations. GSS pressure and mass flow for both paths are moving closer to each other but not the same (cold weather?) Will monitor in the future. ORP is constant. Will be removing and calibrating probes this week; will check status of probe operation during calibrations.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	11/18/2008	14:00	Remote	Daily Status Check from PAML Notes: Both TDLAS laptops are frozen. See notes for details. FOS will restart all computers tomorrow during site visit. Restarted sonic anemometer programs. TEC 450i still reading wrong date. Flagging on sonic anemometer 1 at 687.2; sonic anemometer 2 at 687.4 (w also spiked to 1.5-2.0 m/s briefly); sonic anemometer 3 at 685.9. ORP sensor is constant. Wetness sensor seems to be wet a lot, but could be due to frost/dew in the morning; will check tomorrow during calibration check.
IN5A	11/19/2008		Calibration	The lagoon level is very low, and the lagoon probe float is not moving at all in the wind, so it appears the lagoon probes are stuck in the mud at the bottom of the lagoon.
IN5A	11/19/2008		Calibration	Restarted TEC 450i at 17:18 GMT/17:25 GMT on LAN. Times and dates are now in sync.
IN5A	11/19/2008		Calibration	Wetness sensor is clean and dry; reading "NAN" on CR 1000. Snow on ground and ice in spot; may have had snow or ice on wetness sensor yielding wet readings.
IN5A	11/19/2008		Calibration	Performed TEC 450i multipoint with new H_2S tank. Single point did not pass. New curve: y=0.795537281-0.007711017; R-squared is 0.999793637.
IN5A	11/19/2008		Calibration	Sonic anemometers will run overnight; higher winds today.
IN5A	11/19/2008		Calibration	Too windy to perform sludge depth measurements.
IN5A	11/20/2008		Calibration	Too windy to perform sludge depth measurements.
IN5A	11/20/2008		Calibration	Sonic anemometers passed overnight in calmer winds.
IN5A	11/20/2008		Calibration	Will remove lagoon probe float for winter. QC program shows lagoon temp has dropped to 2.3 °C in the past four days. Forecast for the next few days is very cold/freezing. Probes may be stuck in the mud, causing higher temperature readings. Puddles are icy; do not want to risk damaging probes during next two week period.
IN5A	11/20/2008		Calibration	Lagoon probes covered in dirt (took pictures). Both were slightly scratched, and pH did not pass. Removing for the winter and bringing back to PAML.
IN5A	11/20/2008		Calibration	Restarted LAN.
IN5A	11/20/2008		Calibration	S-OPS tubing facing downward on most inlets; used heat gun on two inlets on north side and three inlets on south side.
IN5A	11/20/2008		Calibration	Maintenance list completed.
IN5A	11/20/2008		Calibration	ORP sensor: Acceptance and calibration completed
IN5A	11/20/2008		Calibration	pH sensor: Calibration, Acceptance, and QC check completed. Acceptance fails.
IN5A	11/20/2008	10:59-11:59	Calibration	sonic anemometer intercomparison: Pass
IN5A	11/20/2008	15:26	Calibration	sonic anemometer bias/zero check: Pass
IN5A	11/20/2008	16:03	Calibration	Barometer audit: Accepted
IN5A	11/20/2008	16:04	Calibration	Wetness sensor calibration: Accepted.
IN5A	11/20/2008	16:10	Calibration	Unwired lagoon sensors.
IN5A	11/20/2008	17:36	Calibration	Calibrated TDLAS 1029 Notes: light levels approximately 1500 during calibration. Over 12000 without 1/8 plastic; adding plastic brings light levels to about 1500.
IN5A	11/20/2008	18:01	Calibration	Calibrated TDLAS 1032 Notes: accidentally got in beam path; excluded this value during calculations (highlighted in control chart).
IN5A	11/21/2008	13:33	Remote	Daily Status Check from PAML Notes: sonic anemometer QC program not working, but the sonic anemometers are working fine. H_2S data flags (#1) were just due to when LAN was restarted. Lagoon probes

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
				were taken out yesterday.
IN5A	11/24/2008	13:00	Remote	Daily Status Check from PAML Notes: TDLAS light levels were low earlier in the day, but all were back to normal by 14:00 GMT. *iPort* error: see notes for details. Flag 1 in H_2S data; see notes for details. No lagoon probes.
IN5A	11/25/2008	14:00	Remote	Daily Status Check from PAML Notes: sonic anemometer 2 had five periods with flagging around 694.56. Mass flow and pressure dropped significantly around 694.36 (11/24 at 3:30 A.M. EST). This was about the same time it started to rain that night, so perhaps a bunch of filters got wet and may now be frozen.
IN5A	11/26/2008	14:15	Remote	Daily Status Check from PAML Notes: Flagging occurs for all sonic anemometers but not at significant amounts. GSS pressure/mass flow peaked at approx. 23:00 GMT following temp., max and dry wetness sensor. Dropped again to min. at approx. 5:00 GMT following temp., min and wet wetness sensor. Affecting near/short paths much more then far long paths though they both have the same trends.
IN5A	11/27/2008	16:30	Remote	Daily Status Check from PAML Notes: GSS mass flow is dropping.
IN5A	12/2/2008	13:45	Remote	Daily Status Check from PAML Notes: sonic anemometers seem to have stopped incrementing data at 12/2/2008 at 13:29 GMT. Checked a few minutes later, and data were incrementing again. On TDLAS 2, paths 2, 3, and 6 were not aimed. Re-aimed and they seem to be working. Will check later. GSS mass flowing reducing. H_2S internal temperature is rising a little bit.
IN5A	12/3/2008	14:20	Remote	Daily Status Check from PAML Notes: Stopped sonic anemometer program at 14:32 GMT. Restarted *iPort* and filled data since yesterday. Restarted real-time data collection for H_2S. Restarted sonic anemometer program at 14:38 GMT. GSS mass flow and GSS pressure are both still highly variable. No lagoon probes.
IN5A	12/4/2008	13:20	Remote	Daily Status Check from PAML Notes: Low light levels on TDLAS paths, but all paths seem ok. Will check again later. Some sonic anemometer flagging seen with sonic anemometers 2 and 3 (less in sonic anemometer 1).
IN5A	12/9/2008		Calibration	Environics diluter does not seem to be working properly. Had port 1 as air, port 2 as H_2S (30.5 ppm) and port 3 as SO_2 (42.9 ppm). Would only run with port 1; switched SO_2 and air (ports 1 and 3 respectively) and only flowed from SO_2 (port 1); tried with H_2S and air as well (ports 2 and 1 respectively) and only flowed from port 1 (air). Could not perform multipoint with Environics. Used 146i with 30.5 ppm tank (LL34303) to perform multipoint at 1, 2, 3, and 4 ppm. y=0.869024194x-0.000811211. R-squared=0.999994376.
IN5A	12/9/2008		Calibration	TDLAS's not aligned upon arrival; heavy rain most likely causing obstructions.
IN5A	12/9/2008		Calibration	Lagoon is frozen; cannot perform sludge depth measurements.
IN5A	12/9/2008		Calibration	Cannot test wetness sensor because of rain.
IN5A	12/9/2008		Calibration	TDLAS's did not pass calibration although both gave perfect zeros. (1032_-14.25%; 1029_-12.14% bias)
IN5A	12/9/2008		Calibration	12/5/2008 19:15:33: AC restored message sent to registered clients connected to Load Segment 1 12/5/2008 19:15:33: AC restored message sent to registered clients connected to Load Segment 2
IN5A	12/9/2008		Calibration	Lagoon site layout completed
IN5A	12/9/2008	16:57	Calibration	Calibrated TDLAS 1032 Note: Bias -14.25%
IN5A	12/9/2008	17:22	Calibration	Calibrated TDLAS 1029 Note: Bias -12.14%
IN5A	12/10/2008		Calibration	Started GSS calibration at 16:23. Will restart tomorrow.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	12/10/2008		Calibration	12/9/2008 22:05:44: UPS switched to battery power. 12/9/2008 22:05:49: AC restored message sent to registered clients connected to Load Segment 1 12/9/2008 22:05:49: AC restored message sent to registered clients connected to Load Segment 2
IN5A	12/10/2008	16:25-17:25	Calibration	sonic anemometer intercomparison: Pass
IN5A	12/10/2008	17:42	Calibration	Barometer audit: Accepted
IN5A	12/10/2008	17:43	Calibration	sonic anemometer bias/zero check: Pass
IN5A	12/10/2008	17:47	Calibration	Wetness sensor calibration: Accepted.
IN5A	12/11/2008		Calibration	Performed multipoint calibrations on both TDLAS's (1032 and 1029). Performed the multipoint calibrations at a higher flow rate (1500 ccm compared to the normal 500 ccm) because we found the TDLAS's performed at the higher flow rate, especially at the low NH_3 concentrations.
IN5A	12/11/2008		Calibration	Maintenance list completed.
IN5A	12/12/2008	15:30	Remote	Daily Status Check from PAML Notes: QC files not set up yet, remote check only. No Innova.
IN5A	12/22/2008	15:36	Remote	Daily Status Check from PAML Notes: TDLAS 2 has lost paths 7, 8, 9, and 4. TDLAS 1 has lost paths 5, 6, and 7. All H_2S parameters are zero since 12/21/08 at 3:15 GMT (*iPort* was disconnected). Reconnected *iPort* to the 450i; created a fill file for the missing data, then started loading the H_2S data in real time again. Re-aimed all misaligned TDLAS files and saved new setup files. Some missing data in all sonic anemometers due to communication issues and poor weather conditions. No lagoon probes.
IN5A	12/23/2008	18:24	Remote	Daily Status Check from PAML Notes: Some flagging in all sonic anemometer data due to communications issues at site. GSS pressure and flow are still changing a lot. There were some flag #1 for the H_2S analyzer because *iPort* lost connection yesterday. Everything now working.
IN5A	12/24/2008	13:45	Remote	Daily Status Check from PAML Notes: TDLAS paths are off due to freezing rain and fog. Fill H_2S data starting at 12/21/08 at 15:27 through 12/22/208 16:20 (had to revert to filling last 4400 records). All three sonic anemometers have flagged data; likely iced over. Large variability in GSS mass flow.
IN5A	12/29/2008		Calibration	Upon arrival, found TDLAS 1 had lost all paths, and TDLAS 2 had lost two paths. TDLAS 1 (1032) had lost all paths because of condensation on the inside of the TDLAS window. Dried unit inside, but the condensation return when placed outdoors again. Internal temperature of TDLAS is 22.4 °C which should be fine. Will leave it out overnight to see what happens.
IN5A	12/29/2008		Calibration	Installed Innova, but did not perform calibration because a multipoint calibration was performed on the instrument on 12/24/2008 at PAML. Started Innova at 16:35 GMT.
IN5A	12/29/2008		Calibration	After setting up the sonic anemometers for intercomparison, sonic anemometer 1 kept sending back zero values for the first few hours, but eventually it started working properly.
IN5A	12/29/2008	15:35	Calibration	Barometer audit: Accepted
IN5A	12/29/2008	16:08	Calibration	Wetness sensor calibration: Accepted
IN5A	12/29/2008	17:21	Calibration	Calibrated TDLAS 1029 Note: The new cal curves from the last multipoint calibration have not been put in the new control chart yet.
IN5A	12/29/2008	17:45	Calibration	Calibrated TDLAS 1032 Note: The new cal curves from the last multipoint calibration have not been put in the new control chart yet.
IN5A	12/29/2008	18:50-19:50	Calibration	sonic anemometer intercomparison: Pass

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	12/29/2008	20:08	Calibration	Sonic anemometer bias/zero check; all pass. Note: sonic anemometer 2 and 3 bias was done on 12/29/2008. Sonic anemometer 1 bias was done on 12/30/2008 at 14:43:22 GMT.
IN5A	12/30/2008		Calibration	TDLAS 1 (1032) still has condensation inside the window. Will bring back to PAML.
IN5A	12/30/2008		Calibration	Farm workers loading manure out of the pit next to the trailer and spreading it on the field directly to the East of the lagoon. Talked to workers, and they said they would be loading the pit today and tomorrow (because it is forecasted to get warm later today and the field would become too muddy to drive in).
IN5A	12/30/2008		Calibration	Maintenance list completed.
IN5A	12/31/2008		Repair	Installed TDLAS 1031 and aimed all paths.
IN5A	1/5/2009	13:50	Remote	Daily Status Check from PAML Notes: Flagging on all sonic anemometers due to communications issues. GSS pressure and mass flow still quite variable. QC program for Innova not running yet. TDLAS 1 was changed to 1031 on 12/31/2008. Checked with remote login and all paths are aligned.
IN5A	1/9/2009	14:10	Remote	Daily Status Check from PAML Notes: Realigned TDLAS 1 path 10. Path was lost on 1/6 at 16:30, about one hour before sonic anemometers went off line. May be covered in ice. Many other paths were lost around this time, but all others recovered in a day or less.
IN5A	1/12/2009		Calibration	Performed methane calibration on Innova. After calibration, will take Innova back to PAML to be placed in the East trailer. Could not perform NH_3 calibration at site because there is no NH_3 tank. Will calibrate NH_3 at PAML.
IN5A	1/12/2009		Calibration	Lagoon site layout completed
IN5A	1/12/2009	13:50	Remote	Daily Status Check from PAML Notes: All sonic anemometers recovered near beginning of day 741. Innova QC not working. GSS mass flow variable, no lagoon probes.
IN5A	1/13/2009	14:55	Remote	Daily Status Check from PAML Notes: *iPort* program stopped at 12:16 GMT on 1/13/2009. Created fill file for missing data and then started loading data in real time again. Had to stop and restart sonic anemometer program in order to restart *iPort*. Paths 8, 9, and 10 on TDLAS 2 were not aligned. Could not re-aim, probably due to ice or frost.
IN5A	1/14/2009	13:35	Remote	Daily Status Check from PAML Notes: TDLAS paths are covered in ice or frost and are not aligned. Some flagging on all sonic anemometers due to communication issues. GSS pressure and mass flow still very variable. QC graphs are all zero until 15:15 on 1/13/2009, after that the graphs look fine.
IN5A	1/15/2009	13:36	Remote	Daily Status Check from PAML Notes: Some flagging on all sonic anemometers due to communication issues. GSS pressure and flow quite variable.
IN5A	1/16/2009	13:37	Remote	Daily Status Check from PAML Notes: *iPort* program stopped running at 15:15 on 1/15/2009. Created fill file for missing data and then started loading data in real time again. Had to stop and restart sonic anemometer program in order to restart *iPort*. GSS pressure and flow quite variable. Some flagging on all sonic anemometers due to communication issues.
IN5A	1/20/2009	13:50	Remote	Daily Status Check from PAML Notes: GSS pressure and flow quite variable. Some flagging on all sonic anemometers due to communication issues. H_2S flag 1 from day 746.80 to 747.59. TDLAS QC are about one day behind. Both TDLAS laptops have frozen up. We fix during calibration check tomorrow.
IN5A	1/21/2009		Calibration	Replaced ground rod/football clamp on met station.
IN5A	1/21/2009		Calibration	Due to freezing temperatures, will not perform wetness sensor verification. Water could freeze on sensor causing skewed values. Currently reading "NAN" accurately (dry conditions).

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	1/21/2009		Calibration	Snow cover all around lagoon.
IN5A	1/21/2009		Calibration	No error messages on LAN. Panasonic froze up; restarted both Panasonic and LAN.
IN5A	1/21/2009		Calibration	Lagoon probes not installed in lagoon due to freezing temperatures. No lagoon calibrations.
IN5A	1/21/2009		Calibration	Awaiting new NH_3 cylinder; currently no TDLAS calibrations.
IN5A	1/21/2009		Calibration	Sonic anemometer 3 did not pass during intercomparison. Checked placement and alignment with sonic anemometers 1 and 2; could be interfering with wind turbulence from sonic anemometers 1 and 2. Will continue to run through Friday) 1/23/2009) morning to check at different wind conditions.
IN5A	1/21/2009	19:42	Calibration	Barometer audit: Accepted
IN5A	1/23/2009		Calibration	Sonic anemometer data/GSS/ H_2S data not valid until H_2S file created today. Ran sonic anemometers over past few days for intercomparison.
IN5A	1/23/2009		Calibration	Changed memory card in CR 1000. Light was orange upon removal, but was not orange when putting in new card.
IN5A	1/23/2009		Calibration	Maintenance list completed.
IN5A	1/23/2009	14:20-15:20	Calibration	Sonic anemometer intercomparison; all pass.
IN5A	1/23/2009	15:53	Calibration	sonic anemometer bias/zero check: Pass
IN5A	1/23/2009	17:35	Calibration	Calibrated TDLAS 1029
IN5A	1/23/2009	18:20	Calibration	Calibrated TDLAS 1031 Note: Accidentally got in beam's path; will disregard in calculations.
IN5A	1/26/2009	17:30	Remote	Daily Status Check from PAML Notes: GSS/ H_2S /Innova and TDLAS files were not up to date initially. After resending the data and rerunning, files are now up to date. No lagoon probes.
IN5A	1/28/2009	16:15	Remote	Daily Status Check from PAML Notes: Appears like TDLAS 1 is recovering from effects of heavy snow last night. GSS mass flow fluctuating. No lagoon probes.
IN5A	1/29/2009	16:40	Remote	Daily Status Check from PAML Notes: GSS mass flow on both lines has dropped from about 7 to below 5 LPM.
IN5A	1/29/2009		Repair	Changed NW TDLAS to fixed path. Took the scanner to PAML for later use at NC3A.
IN5A	1/30/2009	17:00	Remote	Daily Status Check from PAML Notes: Error message upon login: "The system has recovered from a serious error." Nothing active upon login; system appeared to be rebooting. Message box: "System Configuration Utility. You have used the system configuration utility to make changes to the way Windows starts..." When system configuration utility came up, tried to change to Normal Startup; when clicking "apply" got message "An Access Denied error was returned while attempting to change a service. You may need to log on using an administrator account to make the specified changes." Allowed computer to restart. Last chunk of 300s sonic anemometer data was around 05:00 GMT (created fill file for this time). Last H_2S data on 1/30/09 at 4:56. Single path on north side of lagoon replaced TDLAS 2 yesterday afternoon (needed for NC trip). Until about 18:02 today, this data was spaced across paths 1-10. Starting at 18:10 GMT, changed pan-tilt options to 1 path and created new .GMP file. TDLAS QC too close to start of new segment to tell anything. GSS mass flow still varying quite a bit. No lagoon probes. Some flag 1 in H_2S data. Data has been filled in.
IN5A	2/2/2009	15:40	Remote	Daily Status Check from PAML Notes: TDLAS 2 is on a single path. On TDLAS 1, all ten paths exist and are giving good light values while program is running. Not sure why QC is giving only 9 paths, missing path 2. Checked setup file, and found valid values for all paths. GSS mass flow still dropping overnight but returning to normal during daytime hours. Lagoon probes not present at site due to frozen lagoon.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	2/3/2009	13:45	Remote	Daily Status Check from PAML Notes: QC still missing path 2 in TDLAS 1 but exists in setup file and path is being scanned. Deleted old backup files to make room. GSS mass flow still dropping overnight but recovering during daytime hours. CR 1000 data is updating, but the QC file today is not up to date. No lagoon measurements.
IN5A	2/5/2009	23:00	Remote	Daily Status Check from PAML Notes: TDLAS 2 is on a single path (no scanner). GSS pressure and mass flow are still quite variable.
IN5A	2/6/2009	14:15	Remote	Daily Status Check from PAML Notes: The centerline duty cycle on TDLAS 1031 (TDLAS 1) jumped to 255 on 2/5/2009. Alarm 401 on TDLAS 1. GSS mass flow and pressure quite variable.
PAML	2/6/2009	19:39	Calibration	Calibrated TDLAS 1032. Note: Doing a quick 100 ppm span check at PAML to make sure the TDLAS is working properly. TDLAS had condensation inside it in the past. Taking TDLAS 1032 to IN5A next week to replace TDLAS 1031, which has a high Centerline Duty Cycle.
IN5A	2/9/2009		Calibration	TDLAS 1031 loses communication ("xxxx"); connected at the start up, but disconnected after five minutes. Cal curve looked funny and distorted on oscilloscope. Power cycled; afterwards, would not stop centering. TDLAS was giving "CAL ERR" on screen.
IN5A	2/9/2009		Calibration	Did not calibrate TDLAS 1032 on site because it was already calibrated/passed on 2/6/2009 at PAML.
IN5A	2/9/2009		Calibration	Restarted all computers.
IN5A	2/9/2009		Calibration	UPS History: 1/29/2009: 23:26:18: UPS switched to battery power. 23:26:22: AC Restored Message sent to registered clients connected to Load Segment 1. 23:26:22: AC Restored Message sent to registered clients connected to Load Segment 2. 2/7/2009: 13:01:13: UPS switched to battery power. 13:01:13: Utility power has failed. 13:01:13: UPS bypass unavailable. 13:01:20: AC power has been restored. 13:01:23: AC Fail Message sent to registered clients connected to Load Segment 1. 13:01:23: AC Fail Message sent to registered clients connected to Load Segment 2. 13:01:24: AC Restored Message sent to registered clients connected to Load Segment 1. 13:01:24: AC Restored Message sent to registered clients connected to Load Segment 2.
IN5A	2/9/2009		Calibration	Lagoon site layout completed
IN5A	2/9/2009	15:32	Calibration	Barometer audit: Accepted
IN5A	2/9/2009	15:34	Calibration	Grid wetness sensor calibration: Pass Note: Damp conditions made it hard for dry test to pass.
IN5A	2/9/2009	15:55-16:55	Calibration	Sonic anemometer intercomparison: all pass. Note: At 16:15:09 lost communication so value is zero for all sonic anemometers.
IN5A	2/9/2009	16:32	Calibration	Calibrated TDLAS 1029
IN5A	2/9/2009	17:18	Calibration	sonic anemometer bias/zero check: Pass
IN5A	2/10/2009		Calibration	Performed TDLAS, pH and ORP, and S-OPS/GSS calibrations.
IN5A	2/10/2010		Calibration	Brought sonic anemometer 1938 back to PAML for repairs.
IN5A	2/10/2011		Calibration	Brought back to PAML an empty zero gas cylinder.
IN5A	2/10/2012		Calibration	Printer was not operational.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	2/10/2009	14:30	Remote	Daily Status Check from PAML Notes: Re-aimed path 2 on TDLAS 1. Found it by moving down 35 steps. TDLAS QC files not up to date; everything looked fine in remote check. TDLAS 2 is on a single path. TDLAS 1 has changed from 1031 to 1032. GSS pressure and mass flow still quite variable. Flag 1 in H_2S data; created a fill file for missing data yesterday.
IN5A	2/11/2009	16:00	Remote	Daily Status Check from PAML Notes: Some flagging on sonic anemometers due to communication issues. GSS pressure and mass flow quite variable.
IN5A	2/12/2009	15:10	Remote	Daily Status Check from PAML Notes: Re-aimed paths 2, 6, and 8 on TDLAS 1 and saved the new setup files. Very strong winds and heavy rain caused paths to be lost. Some flagging on sonic anemometers due to communication issues. GSS pressure and mass flow quite variable.
IN5A	2/12/2009	18:30	Remote	Remote login to start a new CR 1000 file since the current one is too long for the CR 1000 QC to handle. New file named CR1000_IN5A_20090212.dat. Overlapped a few hours of data by copying from previous file.
IN5A	2/13/2009		Calibration	Stopped H_2S data collection at 2/13/2009 14:45 GMT. Started H_2S data collection at 2/13/2009 17:13 GMT; beginning of new data file.
IN5A	2/13/2009		Calibration	UPS History: 2/11/2009 16:05:24: UPS switched to battery power. 16:05:24: Utility power has failed. 16:05:24: Utility bypass unavailable. 16:05:34: AC Fail message sent to registered clients connected to Load Segment 1. 16:05:34: AC Fail message sent to registered clients connected to Load Segment 2. 16:05:39: AC power has been restored. 16:05:39: AC Restored message sent to registered clients connected to Load Segment 1. 16:05:39: AC Restored message sent to registered clients connected to Load Segment 2. 17:25:08: UPS switched to battery power. 17:25:08: UPS bypass unavailable. 17:25:15: AC power has been restored. 17:25:18: AC Fail message sent to registered clients connected to Load Segment 1. 17:25:18: AC Fail message sent to registered clients connected to Load Segment 2. 17:25:19: AC Restored message sent to registered clients connected to Load Segment 1. 17:25:19: AC Restored message sent to registered clients connected to Load Segment 2.
IN5A	2/13/2009		Calibration	Changed inlet filters in the south S-OPS line (S-OPS s/n: A). The north S-OPS filters are quite dirty also, but FOS could not change the inlet filters since there were not enough filters. North S-OPS filters (S-OPS s/n: A) will need to be changed at the next calibration check.
IN5A	2/13/2009		Calibration	Maintenance list completed.
IN5A	2/13/2009	15:15-15:48	Calibration	TEC 450i single point calibration.
IN5A	2/13/2009	15:15-17:15	Calibration	S-OPS/GSS calibrations Notes: Changed inlet filters in the south S-OPS line (S-OPS s/n: A). The north S-OPS filters are quite dirty also, but FOS could not change the inlet filters since there were not enough filters. North S-OPS filters (S-OPS s/n: A) will need to be changed at the next calibration check. North S-OPS barely passed inlet balancing.
IN5A	2/16/2009	14:40	Remote	Daily Status Check from PAML Notes: Re-aimed paths 6 and 7 on TDLAS 1. GSS flow was zero from 19:15 on 2/13/2009 to 7:15 on 2/15/2009. GSS battery voltage and panel temperature were zero during this time. Since 7:15 on 2/15/2009, values have returned to normal, but the mass flow is higher than it was in the past. H_2S had flag #192 during time GSS voltage was zero.
IN5A	2/17/2009	14:30	Remote	Daily Status Check from PAML Notes: Unable to connect remotely. GSS mass flow is higher than it has been previously.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	2/18/2009	20:40	Remote	Daily Status Check from PAML Notes: TDLAS 1, path 2 has low light levels; TDLAS 2 paths have low light levels. Probably caused by drizzly, foggy conditions. Will check tomorrow and will re-aim if necessary. No lagoon probes.
IN5A	2/19/2009	14:45	Remote	Daily Status Check from PAML Notes: Almost all paths on TDLs had low light levels. See notes for comments/diagrams. All three sonic anemometers nearly completely flagged starting around 03:00 GMT last night. Snow in area, along with falling temperatures. GSS mass flow has pink line constant but the blue line is highly variable; remains much higher than previously found.
IN5A	2/20/2009	15:30	Remote	Daily Status Check from PAML Notes: All paths on TDLAS 1 have low light levels, and paths 7-10 on TDLAS 2 have low light levels. See notes for new paths alignments. Unable to locate higher light levels; may be blocked due to snow.
IN5A	2/23/2009	15:53	Remote	Daily Status Check from PAML Notes: Tried to re-aim paths 2, 4, 5, and 7 on TDLAS 1. Could not get light values above 200 on path 7; it may be frosted over. Tried to re-aim path 7 again at 18:20 GMT but could not get valid light levels. GSS pressure and mass flow on north side of S-OPS still quite variable.
IN5A	2/24/2009	15:20	Remote	Daily Status Check from PAML Notes: TDLAS 1 paths are aligned, but they are optimizing a lot, probably due to dew or frost on retro-reflectors. GSS pressure and mass flow on north side of S-OPS still quite variable.
IN5A	2/25/2009		Takedown	Removed TDLAS, sonic anemometers, and CR 1000 instruments for 6 month calibrations.
IN5A	2/25/2009		Takedown	Stopped CR 1000 measurements at 14:45 GMT.
IN5A	2/25/2009		Takedown	Did not perform any on-site calibrations because 20 day calibrations were performed less than 20 days ago and six month calibrations are this week and next week.
IN5A	2/25/2009		Takedown	Plan to change inlet filters on north side S-OPS (S-OPS C, 53, false). Performed leak test first (2.90 LPM, -38.50 kPa). GSS leak test indicated bad pump; changed pump diaphragm (2.69 LPM, -39.21 kPa).
IN5A	2/25/2009		Takedown	UPS History: 2/13/2009 18:59:35: AC power has been restored. 18:59:35: AC Restored message sent to registered clients connected to Load Segment 1. 18:59:35: AC Restored message sent to registered clients connected to Load Segment 2.
IN5A	2/25/2009		Takedown	Measured lagoon height using center green pipe on north side and east retro-reflector on north side of lagoon. Eye level does not magnify, so a close measurement spot was necessary (tried measurement spot at north retro-reflector on east side but could not see stadia rod). Measured lagoon height near green pipe from east retro-reflector on north side. Level check form located with Open site notes.
IN5A	3/11/2009		Calibration	Upon arrival, found no power at northwest TDLAS and on the west side of the lagoon. Called Prof. Rich Grant and tried to resolve the problem but was not successful. Called electrician and fixed the problem.
IN5A	3/11/2009		Calibration	Performed multipoint calibration on TEC 450i.
IN5A	3/11/2009		Calibration	Changed filter papers on both S-OPS. South S-OPS could not pass due to wet conditions.
IN5A	3/12/2009	16:48	Remote	Daily Status Check from PAML Notes: Paths 6-10 on TDLAS 1 are not aligned. Could be caused by freezing rain on retro-reflectors.
IN5A	3/13/2009	13:00	Remote	Daily Status Check from PAML Notes: Continuous flag 64 in H_2S data. GSS MFC is not working (large offset causes blue path to be over scale). TDLAS 1 paths 6-10 have low light levels.
IN5A	3/16/2009	12:30	Remote	Daily Status Check from PAML Notes: Re-aimed paths 1 and 4-10 on TDLAS 1. Flag 64 in H_2S data. GSS mass flow reading NAN due to large offset. No lagoon float.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	3/17/2009	14:30	Remote	Daily Status Check from PAML Notes: Flag 64 on blue line in H_2S data (due to MFC offset). Flag 2 was in H_2S data for a time last night (temperature out of range; either internal, chamber or both). Back to normal now. GSS panel temperature reached about 40 °C yesterday; heat is still on in trailer. No lagoon probes.
IN5A	3/18/2009	12:40	Remote	Daily Status Check from PAML Notes: Flag 64 in H_2S data. GSS MFC offset issue. No lagoon float.
IN5A	3/19/2009	12:45	Remote	Daily Status Check from PAML Notes: Flag 64 in H_2S data. GSS MFC offset issue. No lagoon float.
IN5A	3/20/2009	13:00	Remote	Daily Status Check from PAML Notes: TDLAS 1 path 1 has low light levels; re-aimed path. Flag 64 in H_2S data. GSS MFC issue. PS1 (pink) is steady.
IN5A	3/23/2009	12:30	Remote	Daily Status Check from PAML Notes: *Microsoft Visual C++* Runtime Library C:\Program Files\Genie-Soft\CBMPro7.exe - sonic anemometers still running. Deleted previous backups to make room for new backups. Flags in H_2S data: side zero--64/66 flag; side 1--2 flag (high flow?). GSS mass flow says zero, but the flow is high, so the actual reading is NAN).
IN5A	3/24/2009	13:00	Remote	Daily Status Check from PAML Notes: Checked path locations on TDLAS 2, and they are in the correct spots. They were off initially. Will check QC tomorrow to monitor pan/tilt locations. No flags in H_2S data since yesterday's QC check. No lagoon probes.
IN5A	3/25/2009	13:00	Remote	Daily Status Check from PAML Notes: QC program has TDLAS 2 retro-reflector 1 location is different spot than where it actually is. Will save a new setup to try to fix. Sonic anemometer QC files are not up to date. Stopped updating at 814.246583; will check again on remote login. Flags in H_2S data: Side 0 had one flag at 64. No lagoon measurements.
IN5A	3/26/2009	12:45	Remote	Daily Status Check from PAML Notes: *iPort* error; had to stop and restart sonic anemometer program as well. Last H_2S modification was on 3/25/2009 at 15:37 GMT (last data point at 15:36 GMT). Created fill file, FillIN5A450I0326091301.dat, for missing data. Started new real time data file at 13:05 GMT. Restarted sonic anemometers at 13:07 GMT. H_2S side 0 has a few flag 4 points. At approximately 816.656 all the H_2S parameters go to zero; program probably failed and will back up data upon login. Original location of path 1 does not look correct, but current location is where it should be. No lagoon measurements.
IN5A	3/27/2009	12:30	Remote	Daily Status Check from PAML Notes: Flag 64 on path 0 in H_2S data. H_2S file name structure wrong with original H_2S data. Looked okay previously; at the end of the period, will put pieces in one file. No lagoon measurements.
IN5A	4/2/2009	16:15	Remote	Daily Status Check from PAML Notes: Upon remote login, found ten Powerware popup messages with the most recent being on 4/2/2009 around 3:00 AM local time. "Netwatch is experiencing a loss of communication with the shutdown server 192.168.0.7." Remote desktop disconnected as well. There is also a V*isual C++* problem. Re-aimed TDLAS 1 path 1; it has had low light levels since day 820. Sonic anemometer 1 has some flagging on day 819. H_2S graphs went to zero on day 821.489. GSS MFC offset issue. No lagoon probes.
IN5A	4/3/2009	16:15	Remote	Daily Status Check from PAML Notes: Took many attempts throughout day to access site remotely. Error message: "Netwatch is experiencing a loss of communication with the shutdown server 192.168.0.7." Re-aimed TDLAS 1 path 1. Three 5-minute periods for sonic anemometer 3 have greater than 100 flagged points. Paths 1 and 10 on TDLAS 1 have low light levels. No lagoon probes.
IN5A	4/6/2009	15:00	Remote	Daily Status Check from PAML Notes: Cannot connect to TDLAS laptops. Last TDLAS QC data was from 3/31/2009. Sonic anemometer 1 has some flagging on day 827 (probably due to rain/frozen precipitation). Average w on sonic anemometer 1 went up to about 0.4 m/s on day 826 (storm front went through last night). Flow on North S-OPS is too high for sensor to read it, so it reads zero for quite a bit.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	4/7/2009		Calibration	Upon arrival, found both TDLAS laptops had frozen up. Restarted computers and installed updates on both laptops. Additionally, the internet modems and routers were power-cycled. Can now remotely connect to the TDLAS laptops from the LAN computer.
IN5A	4/7/2009		Calibration	Lagoon site layout completed
IN5A	4/7/2009	15:31-15:44	Calibration	Calibrated TDLAS 1032
IN5A	4/7/2009	15:58-16:15	Calibration	Calibrated TDLAS 1029
IN5A	4/8/2009		Calibration	Upon arrival, found there were quite a few Netwatch communication errors, and the LAN lost its connection to both TDLAS laptops again. Found that the cause was a bad cable from the modem to the router.
IN5A	4/8/2009		Calibration	Installed a new flow sensor in the GSS. Performed GSS flow multipoint with the Gilian.
IN5A	4/8/2009	16:25	Calibration	Barometer audit: Accepted
IN5A	4/8/2009	16:27	Calibration	Wetness sensor calibration: Pass.
IN5A	4/9/2009	13:30	Remote	Daily Status Check from PAML Notes: Not enough space to perform backup. Deleted previous backups to make room for new backups. Changed pan/tilt options specs for minimum acceptable light value from 1000 to 2000 to see if it will improve fraction of time with all ten paths aligned; saved new setups (backup and running). No lagoon measurements.
IN5A	4/10/2009	17:40	Remote	Daily Status Check from PAML Notes: Changed acceptable minimum light levels values to 1000. No lagoon measurements.
IN5A	4/13/2009	15:15	Remote	Daily Status Check from PAML Notes: Cannot remotely connect to site. Average w for sonic anemometer 1 was 0.2 m/s and -0.2 m/s for sonic anemometer 3. No lagoon measurements.
IN5A	4/14/2009	12:50	Remote	Daily Status Check from PAML Notes: Rainy/foggy weather at site causing TDLAS 2 to lose paths. No QC updates since 4/13/2009. No lagoon probes.
IN5A	4/16/2009	12:20	Remote	Daily Status Check from PAML Notes: sonic anemometers 1 and 3 had flagging a couple of days ago (rainy). Sonic anemometer 3 u, v, w, and T values very high during that time. No lagoon probes.
IN5A	4/16/2009		Repair	Picked up methane/propane tank to take back to PAML.
IN5A	4/16/2009		Repair	Installed new Firmware on the 146i diluter.
IN5A	4/16/2009		Repair	Changed GSS tubing heater thermostat from 85F to 70F. Changed setting on trailer heater thermostat from "Low Heat" to "Low Cool" because of expected warm temperatures.
IN5A	4/17/2009	12:50	Remote	Daily Status Check from PAML Notes: Some flag 1 in H_2S data yesterday while FOS was on site. GSS mass flow is slow climbing. There was a spike in the GSS/S-OPS RH at NAEMS day 837.677. No lagoon probes.
IN5A	4/20/2009	14:10	Remote	Daily Status Check from PAML Notes: Average w for sonic anemometer 1 is 0.2 m/s. Sonic anemometer 3 has some flagged data on NAEMS day 841. During the flagged period, the u, v, and w values go very high. TDLAS's have been optimizing a lot due to rain at the site. No lagoon probes.
IN5A	4/21/2009	12:30	Remote	Daily Status Check from PAML Notes: TDLAS 1 paths 1 and 10 are off because of rain. TDLAS 2 is optimizing a lot due to rain. Still getting some flagging on sonic anemometer 3; probably due to rain. During flagged times the u, v, and w values spike.
IN5A	4/27/2009	16:50	Remote	Daily Status Check from PAML Notes: Not enough space to perform backup. Deleted previous backups to make room for new backups. No Innova on site. Lagoon probes not present.
IN5A	4/28/2009	12:45	Remote	Daily Status Check from PAML Notes: Cannot connect to TDLAS laptops; they are frozen up. Will be on site tomorrow to perform 20-day calibrations; will restart all computers. TDLAS QC has not updated

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
				since yesterday. GSS mass flow is increasing. No lagoon measurements.
IN5A	4/29/2009	12:20	Remote	Daily Status Check from PAML Notes: Cannot connect to TDLAS laptops; they are frozen. Sonic anemometer 2 shows a lot of flagging. No lagoon probes.
IN5A	4/30/2009		Calibration	Upon arrival, found *iPort* error on LAN. *iPort* had not updated since 4/29/2009 17:12 GMT. Filled data starting at 17:11 GMT on 4/29/2009.
IN5A	4/30/2009		Calibration	Restarted LAN.
IN5A	4/30/2009		Calibration	Strong odor (H_2S) upon arrival.
IN5A	4/30/2009		Calibration	UPS history: 4/9/2009 22:16:48: UPS switched to battery power. 22:16:53: AC Restored message sent to registered clients connected to Load Segment 1. 22:16:53: AC Restored message sent to registered clients connected to Load Segment 2.
IN5A	4/30/2009		Calibration	Set up two Innova Gas View Monitors for intercomparison in the field. Could not sync the two Innova clocks. Open-source Innova (710-216) read 15:47; Barn-source Innova (710-005) read 07:39.
IN5A	4/30/2009		Calibration	Performed multipoint on TEC 450i using H_2S tank #LL34303 (expired tank). Will either perform inter-comparison with new tank or entirely new multipoint with new tank during next visit.
IN5A	4/30/2009	16:02-17:30	Calibration	TEC 450i multipoint calibration Notes: Actual recorded concentration for calibration at 1 ppm (during multipoint) will be used for today's 20-day calibration; see control chart for actual MP values.
IN5A	5/1/2009	14:00	Remote	Daily Status Check from PAML Notes: sonic anemometer 2 is incrementing slowly. Innova data stops incrementing at 4/30 at 23:59. TDLAS data was missing from 4/27 to 4/30, and the last data sent to PAML was on 4/25. Resolved issue; file break error in TDLAS data. Created a new file. No lagoon probes.
IN5A	5/4/2009	13:00	Remote	Daily Status Check from PAML Notes: No lagoon measurements.
IN5A	5/5/2009		Calibration	Removed TDLAS 1029 from SE corner to bring to OK3A.
IN5A	5/5/2009		Calibration	Maintenance list completed.
IN5A	5/5/2009		Calibration	Lagoon site layout completed
IN5A	5/5/2009	15:30-18:30	Calibration	Performed S-OPS/GSS calibrations Note: Inlet balance values are written on separate paper (attached to form).
IN5A	5/5/2009	16:25-17:25	Calibration	Performed sonic anemometer intercomparison; sonic anemometer 2 fails. Notes: sonic anemometer 2 had some zero values that sonic anemometers 1 and 3 did not have. Will replace current sonic anemometer 2 (1925) with sonic anemometer 1928.
IN5A	5/5/2009	17:35-18:35	Calibration	Performed sonic anemometer intercomparison; all pass. Notes: Intercomparison performed with new sonic anemometer 2 (1928).
IN5A	5/5/2009	18:55	Calibration	Sonic anemometer bias/zero calibration; all pass.
IN5A	5/5/2009	12:40	Remote	Daily Status Check from PAML Notes: Starting on day 849, finding significant loss on sonic anemometer 2, most likely caused by communication interference. Ran QC on Innova for the first time for this site/period. GSS mass flow slowly but steadily increasing with time (about 0.5 LPM over the last 22 days). No lagoon probes.
IN5A	5/6/2009	12:25	Remote	Daily Status Check from PAML Notes: TDLAS 1 was removed yesterday to take to OK3A. Sonic anemometer 2 is losing 25%-50% of data because of flagging. Flag 1 in H_2S data during calibration verification yesterday. Brief flag 2 in Innova data. No lagoon probes.
IN5A	5/7/2009	13:20	Remote	Daily Status Checks from PAML Notes: sonic anemometers 1 and 2 have differing u. v. w. and T graphs. TDLAS 1 was relocated to OK3A.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
				No lagoon float.
IN5A	5/8/2009	12:30	Remote	Daily Status Check from PAML Notes: TDLAS 2 has lost paths 3 and 4; checked later and paths recovered. Few excessive spike counts in sonic anemometers 2 and 3.
IN5A	5/18/2009	13:50	Remote	Daily Status Check from PAML Notes: *iPort* error; stopped sonic anemometer and Innova programs. H_2S data missing since 5/10/2009 at 14:01. Filled missing H_2S data files and restarted sonic anemometer and Innova programs. Re-aimed TDLAS 2 paths 2 and 3. TDLAS 1 not present. No lagoon probes. Noticed air temperature malfunction around the start of day 867 (reading between -20 and -40 °C).
IN5A	5/19/2009	15:40	Remote	Daily Status Check from PAML Notes: No lagoon measurements. Temperature sensor reading -40 °C . TDLAS 1 is not present at site. Re-aimed TDLAS 2 path 3 due to low light levels. Reduced minimum acceptable light level to 1000 from 2000.
IN5A	5/20/2009	17:45	Remote	Daily Status Check from PAML Notes: No lagoon measurements. Temperature sensor reading -39 °C . TDLAS 1 is not present at site. Re-aimed TDLAS 2 path 3 due to low light levels.
IN5A	5/21/2009	12:50	Remote	Daily Status Check from PAML Notes: TDLAS laptops are frozen, so there is not connection with TDLAS/scanners. Last data from TDLAS's were sent on 5/20/2009 at 6:15 UTC. Air temperature sensor not working.
IN5A	5/22/2009		Calibration	Upon arrival, found that the TDLAS 1 laptop on arrival. It also had a brief error message that disappeared before it could be written down. Shut down and restarted TDLAS 2 laptop. Installed several updates on both laptops and LAN.
IN5A	5/22/2009		Calibration	Restarted *GasView MP* on TDLAS 2 and tried to download latest setup file, but got error message: " Incompatible or corrupt setup file." Copied correct setup numbers from backup files, and now the program is running ok.
IN5A	5/22/2009		Calibration	Upon arrival, found that the exhaust part on Lumasense Innova was taped over, and no air was exhausting. Also, no tube was available for exhaust of PAML's Innova, so calibration was done using a larger tube taped to the exhaust port. Backup data file: Innova_backupIN5A_20090522_1640.txt
IN5A	5/22/2009		Calibration	Grass is getting very tall around the lagoon. It is currently growing in front of the TDLAS's and completely blocking TDLAS 2 path 3 (NW side). Tried to beat back the grass as much as possible but a mower/weed eater is needed.
IN5A	5/22/2009		Calibration	Found water in the south side retro-reflectors; resealed.
IN5A	5/22/2009		Calibration	Maintenance list completed.
IN5A	5/22/2009	17:20-17:45	Calibration	Innova single point calibration. Notes: Innova started giving Chopper failure error, so the instrument was restarted. Innova time sync: Innova--5/22/2009 8:38; LAN--5/22/2009 16:39.
IN5A	5/26/2009		Calibration	Used string trimmer to trim tall grass weeds from paths 1 and 3 on the west side.
IN5A	5/26/2009		Calibration	Installed updates and restarted computers.
IN5A	5/26/2009		Calibration	NH_3 regulator was loose and was leaking. Checked and saw the junction from the cylinder to gauge (in regulator) was loose. Will take back to PAML to fix.
IN5A	5/26/2009		Calibration	Lumasense Innova hooked up to LAN since last visit on 5/22/2009. Data from PAML Innova collected in the file Innova_backupIN5A_20090526_1506.txt. Lumasense Innova is now running, starting with the file 20090526_1935.txt. Using tape in the inlet of Lumasense as the inlet is not 0.25". Not using any exhaust tubing (missing exhaust tubing for lumasense Innova).
IN5A	5/26/2009	15:55-16:54	Calibration	Sonic anemometer intercomparison; all pass.
IN5A	5/26/2009	16:04-16:36	Calibration	TEC 450i single point calibration.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	5/26/2009	17:18	Calibration	Sonic anemometer bias/zero calibration; all pass.
IN5A	5/26/2009	18:25-18:43	Calibration	Calibrated TDLAS 1032
IN5A	5/26/2009	19:00	Calibration	Wetness sensor calibration: Pass.
IN5A	5/26/2009	19:00	Calibration	Barometer audit: Accepted
IN5A	5/27/2009	18:45	Remote	Daily Status Check from PAML Notes: No lagoon measurements. Flag 1 in H_2S data. FOS will be on site to install new T/RH probe. Temperature sensor reading -39 °C . Wetness probe will be painted tomorrow.
IN5A	5/28/2009		Calibration	UPS History: 5/21/2009 03:41:04: UPS switched to battery power. 03:04:08: AC Restored Message sent to registered clients connected to Load Segment 1. 03:04:08: AC Restored Message sent to registered clients connected to Load Segment 2.
IN5A	5/28/2009		Calibration	Temperature/Thermistor s/n: (5). pH s/n: 006. ORP s/n: 080.
IN5A	5/28/2009		Calibration	Tightened retro-reflectors to ground north and west sides of lagoon. Re-aimed paths 1, 2, 6, and 7.
IN5A	5/28/2009		Calibration	Replaced T/RH sensor in weather station at about 2:00 PM local time. Old s/n: B4340031; new s/n: B4410007.
IN5A	5/28/2009	14:30	Calibration	S-OPS/GSS calibration performed
IN5A	5/28/2009	16:15	Calibration	Lagoon float installed.
IN5A	5/29/2009	13:52	Remote	Daily Status Check from PAML Notes: Not enough space to perform backup. Deleted backups to make space.
IN5A	6/1/2009	12:30	Remote	Daily Status Check from PAML Notes: Re-aimed TDLAS 2 path 3.
IN5A	6/2/2009	13:00	Remote	Daily Status Check from PAML Notes: *IPort* failed; last collected data was at 12:20 GMT on 6/2/2009. Stopped sonic anemometers to restart *iPort* and filled missing data; restarted sonic anemometers. Very dense fog causing paths to be lost.
IN5A	6/3/2009	12:13	Remote	Daily Status Check from PAML Notes: sonic anemometer program stopped at 14:30 GMT 6/2/2009. Tried restarting program, but could not get program running again. Checked again at 19:30 GMT and found that sonic anemometers started incrementing at 14:30 GMT. Fog in area causing low light levels on TDLAS paths. Could not find TDLAS 2 path 3.
IN5A	6/4/2009	12:30	Remote	Daily Status Check from PAML Notes: TDLAS 1 is not present at the site. TDLAS 2 path 3 has low light levels. Sonic anemometer 1 has mean w values above zero.
IN5A	6/5/2009	16:00	Remote	Daily Status Check from PAML Notes: sonic anemometer 1 has mean w values above zero. Sonic anemometer 3 has flagging.
IN5A	6/8/2009	12:30	Remote	Daily Status Check from PAML Notes: sonic anemometer 3 is giving all zeros as data and also has flags 2, 6, and 10 in its data. Runtime error on Genie Soft program. Not enough space to perform backup. Deleted backups to make space.
IN5A	6/9/2009		Calibration	UPS History: 6/3/2009 07:57:42: UPS switched to battery power. 07:57:47: AC Restored message sent to registered clients connected to Load Segment 1. 07:57:47: AC Restored message sent to registered clients connected to Load Segment 2.
IN5A	6/9/2009		Calibration	Grass was not too high for retro-reflectors. Grass and wheat are still pretty low, and the grass around the lagoon has been mowed by the farm.
IN5A	6/9/2009	18:15	Calibration	Stopped recording wetness sensor data. Removed wetness sensor for ice test.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	6/9/2009	14:50-15:50	Calibration	Sonic anemometer intercomparison; all pass.
IN5A	6/9/2009	15:33-15:50	Calibration	Calibrated TDLAS 1032
IN5A	6/9/2009	16:45	Calibration	Sonic anemometer bias/zero calibration; all pass.
IN5A	6/10/2009	18:15	Remote	Daily Status Check from PAML Notes: TDLAS 2 path 3 was not aligned; re-aimed path.
IN5A	6/11/2009	14:15	Remote	Daily Status Check from PAML Notes: TDLAS 2 path 3 was not aligned; re-aimed path. Sonic anemometer 1 u and w graphs look different than the other sonic anemometers.
PAML	6/11/2009	19:25	Calibration	Calibrated wetness sensor: Fail. Note: Calibration was performed before sanding.
PAML	6/11/2009	19:31	Calibration	Calibrated wetness sensor: Pass. Note: Calibration was performed after sanding but before painting.
IN5A	6/12/2009	12:54	Remote	Daily Status Check from PAML Notes: TDLAS 2 path 3 is not aimed correctly. Tried to re-aim path but was not able to obtain a light level reading higher than 700. TDLAS 1 is not present at site. TDLAS 2 has not had all ten paths aligned today; this is probably caused by high moisture levels in the retro-reflector boxes.
PAML	6/12/2009	15:03	Calibration	Calibrated wetness sensor: Pass. Note: Calibration was performed after painting.
IN5A	6/15/2009		Calibration	Measured flow rate of each nozzle on both sides of the S-OPS with Gilibrator flow meter.
IN5A	6/15/2009	18:00	Calibration	S-OPS/GSS calibrations performed Notes: Inlet balance failed initially on the North S-OPS; changed the nozzle on inlet 7, and the system passed. Inlet balance forms are attached to the calibration sheet.
IN5A	6/16/2009		Calibration	Took out the lagoon probes and replaced the wetness sensor.
IN5A	6/16/2009		Calibration	Upon arrival found *iPort* program was frozen. Restarted *iPort* as well as the sonic anemometers. All data were saved.
IN5A	6/16/2009		Calibration	Barometer audit: Accepted
IN5A	6/16/2009	15:48-16:28	Calibration	TEC 450i single point calibration.
IN5A	6/16/2009	16:35	Calibration	Wetness sensor calibration: Pass.
IN5A	6/16/2009	16:57-17:12	Calibration	Calibrated TDLAS 1032
IN5A	6/16/2009	17:25-17:30	Calibration	Calibrated TDLAS 1031
IN5A	6/17/2009		Calibration	Maintenance list completed.
IN5A	6/17/2009	15:45	Calibration	pH sensor: Quality Assurance completed.
IN5A	6/17/2009	15:55	Calibration	Calibrated ORP sensor 080
IN5A	6/18/2009	12:07	Remote	Daily Status Check from PAML Notes: TDLAS 2 stopped running at 17:50 UTC 6/17/2009. Many paths on TDLAS 1 were off, probably caused by heavy rain at site. TDLAS QC program not updating for new TDLAS (TDLAS 1). Upon remote login, found *Microsoft Visual C++* Runtime error. Added "DoEvent" statement to sonic anemometer program. Sonic anemometer 1 w is above zero. Sonic anemometer 3 is not reporting any data currently. When installing lagoon temperature probe, temperature initially read 45 °C , but it has since dropped to normal levels.
IN5A	6/19/2009	12:05	Remote	Daily Status Check from PAML Notes: sonic anemometer 3 does not appear to be reading data correctly. H_2S data stops at 14:45 UTC 6/18/2009. All missing data were filled.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	6/22/2009	12:09	Remote	Daily Status Check from PAML Notes: *Microsoft Visual Basic* run-time error '6' overflow error: "Timeout error while reading response from instrument at address at 173. TDLAS 1 paths are not aligned; probably caused by heavy rainfall in area--will monitor. Sonic anemometer program stopped running and was restarted at 12:30 UTC.
Column1	Column2	Column3	Column4	Column5
IN5A	6/23/2009		Other	Lagoon site layout completed
IN5A	6/23/2009		Other	Restarted TDLAS 2 (1032).
IN5A	6/23/2009	12:44	Remote	Daily Status Check from PAML Notes: TDLAS 2 was turned off at site on 6/18/2009.
IN5A	6/23/2009	16:50-20:22	Other	S-OPS testing done on north S-OPS line. Performed leak test to 1.49 LPM and -37.0 kPa.
IN5A	6/24/2009		Other	Performed T/RH/D S-OPS testing. Weed wacked around N and W ends of lagoon. Cleared around S-OPS on N and cleared TDLAS paths on W. Aimed paths 2 and 3.
IN5A	6/26/2009	12:11	Remote	Daily Status Check from PAML Notes: sonic anemometer 3 u, v, w, and T graphs are still unbalanced. The remote desktop connection keeps getting disconnected. Can only connect to TDLAS 1031 currently.
IN5A	6/29/2009	16:17	Remote	Daily Status Check from PAML Notes: sonic anemometer 3 u, v, w, and T graphs are still unbalanced. Upon remote login, found Runtime error for Genie-soft.
IN5A	7/1/2009	14:36	Other	S-OPS testing done on north S-OPS line. Performed leak test to 1.49 LPM and -37.0 kPa.
IN5A	7/2/2009		Other	Tested all North side inlets for flow rate using Gilibrator. Installed LI-840 CO_2/H_2O analyzer.
IN5A	7/2/2009		Other	Aimed TDLAS path 3. This path has a tendency to drift up and to the right. Set the path at Pan: 15696; Tilt: -245
IN5A	7/2/2009		Other	Shut down H_2S analyzer at 16:18 UTC, restarted at 16:52 UTC.
IN5A	7/2/2009	16:00	Other	Started CO_2 measurements
IN5A	7/7/2009	12:18	Remote	Daily Status Check from PAML Notes: Both TDLAS's (1031 and 1032) cannot be aimed on path 2 with alarm 70. FOS will be on site tomorrow.
IN5A	7/8/2009	16:05	Remote	Daily Status Check from PAML Notes: All TDLs have been fixed and are now working.
IN5A	7/8/2009		Calibration	Wetness and solar radiation sensors need to be cleaned before next calibration check.
IN5A	7/8/2009		Calibration	Prof. Rich Grant performed audit on Ben Evans.
IN5A	7/8/2009		Calibration	UPS history: 6/20/2009 00:53:43: AC Restored Message sent to registered clients connected to Load Segment 2. 7/4/2009 07:12:13: UPS switched to battery power. 07:12:13: Utility power has failed. 07:12:13: UPS bypass unavailable. 07:12:17: AC power has been restored. 07:12:17: AC Restored Message sent to registered clients connected to Load Segment 1. 07:12:17: AC Restored Message sent to registered clients connected to Load Segment 2.
IN5A	7/8/2009	16:00	Calibration	S-OPS/GSS calibrations
IN5A	7/8/2009	17:42	Calibration	Barometer audit: accepted.
IN5A	7/8/2009	17:42	Calibration	Wetness sensor calibration: accepted.
IN5A	7/9/2009		Calibration	Could not perform pH/ORP acceptance/stability because the 5V power supply was not on site.

Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	7/9/2009		Calibration	Will clean wetness sensor and solar radiation sensor tomorrow (7/10/2009).
IN5A	7/9/2009		Calibration	pH sensor: QA and inspection/maintenance performed
IN5A	7/9/2009	16:55	Calibration	ORP sensor: calibration performed
IN5A	7/9/2009	18:06-18:41	Calibration	TEC 450i single point calibration
IN5A	7/10/2009		Calibration	Cannot get AC to work; it's blowing out cool air.
IN5A	7/10/2009		Calibration	Too windy to perform sludge depth measurements.
IN5A	7/10/2009		Calibration	Performed TDLAS inter-comparsion. See open site notes for diagrams.
IN5A	7/10/2009		Calibration	Maintenance and inspection list completed
IN5A	7/10/2009	14:50-15:50	Calibration	Sonic anemometer intercomparison; all pass.
IN5A	7/10/2009	16:28	Calibration	Bias/Zero sonic anemometer calibration; all pass.
IN5A	7/10/2009	18:03-18:19	Calibration	Calibrated TDLAS 1031
IN5A	7/10/2009	18:28-18:44	Calibration	Calibrated TDLAS 1032
IN5A	7/10/2009	19:30-20:00	Calibration	Cleaned wetness sensor and pyranometer.
IN5A	7/13/2009	12:06	Remote	Daily Status Check from PAML Notes: TDLAS 1 (1031) was unresponsive upon login. Last data was recorded on 7/11/2009. Restarted *GasView MP* during later remote login and loaded setup file. TDLAS 2 paths 3 and 4 were off; realigned, and all paths are aligned.
IN5A	7/14/2009	12:11	Remote	Daily Status Check from PAML
IN5A	7/15/2009	11:45	Remote	Daily Status Check from PAML Notes: TDLAS 1 (1031) stopped running at 12:31 UTC 7/14/2009. Update at 18:58: FOS were on site today and restarted both TDLAS laptops, and the TDLAS's are now running fine.
IN5A	7/15/2009		Other	TDLAS 1 laptop was locked up upon arrival. Restarted the computer, and it is now working properly. Currently running GMP file that was empty; used backup file.
IN5A	7/15/2009		Other	TEC 450i has been losing time. Time check showed that the LAN read 15:40:11 while the instrument read 15:37:00 (191 seconds behind). Power-cycled 450i, and it is now synched with the LAN.
IN5A	7/15/2009		Other	Performed CO_2 bag test with GSS/S-OPS. See open site notes for details.
IN5A	7/15/2009		Other	Set up new S-OPS lines for DMI-GHG study.
IN5A	7/16/2009		Setup	Set up new S-OPS lines on east and west side of the lagoon.
IN5A	7/16/2009		Setup	Set up new sonic anemometer on north side of lagoon.
IN5A	7/16/2009		Setup	Installed methane analyzer.
IN5A	7/16/2009		Setup	Worked on plumbing to H_2S analyzer.
IN5A	7/16/2009		Setup	Trimmed grass around retro-reflectors for TDLAS paths.
IN5A	7/16/2009		Setup	Installed hydrogen cylinder.
IN5A	7/16/2009		Setup	While working on all the tubes to the CO_2 analyzer, the tubes were disconnected for about ten minutes.
IN5A	7/16/2009		Setup	S-OPS sensor installation report completed.
IN5A	7/17/2009	12:00	Remote	Daily Status Check from PAML Notes: sonic anemometers were not logging data. Shut down and restarted sonic anemometers at 12:38 GMT. Sonic anemometers are now logging data.

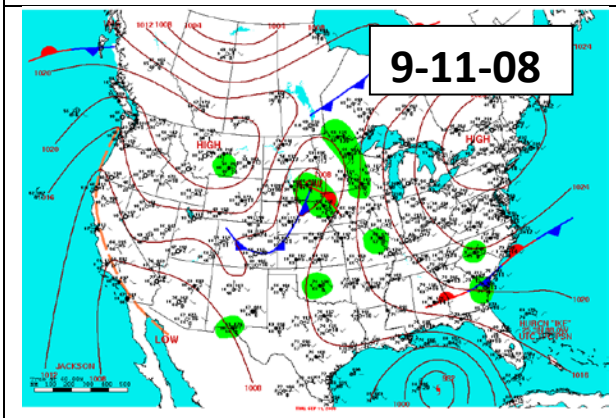
Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	7/20/2009	16:02	Remote	Daily Status Check from PAML Notes: Cannot aim TDLAS 1032 path 3.
IN5A	7/20/2009		Setup	Installed east and west S-OPS lines and extension lines.
IN5A	7/20/2009		Setup	Upon arrival found that the H_2S analyzer was not running.
IN5A	7/20/2009		Setup	Methane analyzer is now running.
IN5A	7/21/2009	13:20	Remote	Daily Status Check from PAML Notes: Re-aimed TDLAS 1 path 7. The H_2S sample flow, voltages, and lamp intensity have all gone to zero.
IN5A	7/22/2009		Other	Performed CH_4 and H_2S bag test.
IN5A	7/22/2009		Other	Took SE scanner back to PAML to replace failed East scanner. Due to a lack of time, could not aim fixed path--will do tomorrow.
IN5A	7/22/2009		Other	Fire burning to the east of the lagoon.
IN5A	7/23/2009	14:25	Remote	Daily Status Check from PAML Notes: Fluctuation in ORP sensor readings.
IN5A	7/23/2009		Calibration	Fire burning to the east of the lagoon.
IN5A	7/23/2009		Calibration	Hooked up S2 and S3 from GSS to east and west paths to perform leak test. Could not get S-OPS leak test flow to pass on west side (~4.2 LPM). Did not have time to deal with east side. Put Teflon tape on inlet tubing (filter holder/tubing "hook" junction) where connections are loose--still leaking however. Tested each filter holder, but could not find leaks. Ran out of time and had to complete leak of the north/south paths for NAEMS project. Did not perform inlet balance on N/S side--will perform at cal check next week.
IN5A	7/23/2009	15:15-16:15	Calibration	S-OPS/GSS calibration (S/N: A, C) Notes: Did not perform inlet balance on N/S side--will perform at cal check next week.
IN5A	7/23/2009	16:15-18:19	Calibration	S-OPS/GSS calibrations (S/N: G, H) Notes: Could not get S-OPS leak test flow to pass on west side (~4.2 LPM). Put Teflon tape on inlet tubing (filter holder/tubing "hook" junction) where connections are loose--still leaking however. Tested each filter holder, but could not find leaks. Ran out of time and had to complete leak of the north/south paths for NAEMS project.
IN5A	7/23/2009	18:16+	Calibration	S-OPS/GSS calibration (S/N: A, C) Notes: Did not perform inlet balance on N/S side--will perform at cal check next week.
IN5A	7/24/2009	12:15	Remote	Daily Status Check from PAML Notes: On remote login screen, "Backup Monitor. Not enough space to perform backup." Clicked OK and backup was aborted. Unable to re-aim TDLAS 2 path 3. Fog/haze in area on 7/24/2009; fire/smoke in area on 7/23/2009. All three H_2S temperature graphs are reading zero for temperature. H_2S chamber pressure and sample flow also all zeros. PMT voltage, lamp voltage, and lamp intensity are all zero as well.
IN5A	7/27/2009		Calibration	Printer not working.
IN5A	7/27/2009		Calibration	Air used for TEC 55C (methane analyzer) dropped a lot.
IN5A	7/27/2009		Calibration	SO_2 gas regulator was found to be open (the cylinder knob is very tight, could not close).
IN5A	7/27/2009		Calibration	After sonic anemometer intercomparison, found sonic anemometer 3 was not collecting data. Wires were loose inside sonic anemometer--fixed. After bias check, found sonic anemometer 2 giving zeros--will check tomorrow.
IN5A	7/27/2009	16:45-17:19	Calibration	H_2S single point calibration
IN5A	7/29/2009	13:30	Remote	Daily Status Check from PAML Notes: Backup error message upon login; clicked ok. Aimed paths 1, 4, 5, 6, 7, 10 on TDLAS 1. Unable to aim path 3, possibly due to moisture. Showers and fog are in the area today.

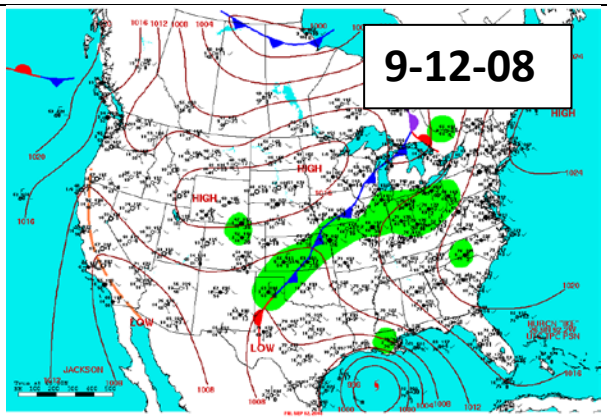
Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	7/30/2009		Calibration	Took sonic anemometer 2 back to PAML for repair.
IN5A	7/30/2009		Calibration	Zero cylinder tank empty, will take back to PAML.
IN5A	7/30/2009		Calibration	Printer not working.
IN5A	7/30/2009	14:52-15:13	Calibration	Calibrated TDLAS 1031
IN5A	7/30/2009	15:34-15:39	Calibration	Calibrated TDLAS 1032
IN5A	7/30/2009	17:00	Calibration	pH sensor: QA and inspection/maintenance performed
IN5A	7/30/2009	17:10	Calibration	Barometer audit: accepted.
IN5A	7/31/2009	13:30	Remote	Daily Status Check from PAML Notes: Re-aimed TDLAS 2 paths 3, 4, 7, and 9. TDLAS 1 is not present.
IN5A	8/3/2009	13:20	Remote	Daily Status Check from PAML Notes: *iPort* stopped at 8/1/2009 18:57 UTC. Filled missing H_2S data. Restarted real-time data collection. Restarted LI 840; it has been down since 7/20. Re-aimed TDLAS 2 paths 1, 3, 4, 7, 8, and 9. TDLAS 1 is not present. No wetness sensor data since day 937. GSS panel temperature out of control. Likely caused by AC problem. Sonic anemometer 2 had up to 300 sonic anemometer flags on day 344.
IN5A	8/6/2009	18:58	Calibration	Calibrated wetness sensor W6 (new)
IN5A	8/6/2009	19:12	Calibration	Calibrated wetness sensor W8
IN5A	8/7/2009	12:35	Remote	Daily Status Check from PAML Notes: TDLAS 1 not present.
IN5A	8/10/2009	13:30	Remote	Daily Status Check from PAML Notes: GSS panel temperature reached 43 °C yesterday. H_2S chamber temperature went from 43 °C to 53 °C .
IN5A	8/11/2009	12:30	Remote	Daily Status Check from PAML Notes: GSS panel temperature reached 43.5 °C yesterday. H_2S chamber temperature spiked to 53 °C . Flag 2 in H_2S data. Sonic anemometer 3 had a handful of five-minute intervals with sonic anemometer flagging. TDLAS 1 not present.
IN5A	8/12/2009	12:06	Remote	Daily Status Check from PAML Notes: Fog in area.
IN5A	8/13/2009	12:09	Remote	Daily Status Check from PAML Notes: Fog in area.
	8/14/2009	12:11	Remote	Daily Status Check from PAML Notes: Fog in area with high dew points, causing low TDLAS light levels. H_2S data were missing; last fill was at 7:07 UTC 8/14/2009. Filled missing data.
IN5A	8/17/2009		Calibration	Forgot to open new file for calibration of H_2S. Used the running file IN5A450I0814091249.dat for calibration. Started at 15:45 UTC and ended at 16:13 UTC.
IN5A	8/17/2009		Calibration	S-OPS North side failed. Changed filter papers on inlets 3 and 9, but the line still failed. Changed all filter papers and the S-OPS passed.
IN5A	8/17/2009		Calibration	Did not take down the sonic anemometers because of rain.
IN5A	8/17/2009		Calibration	Shut down TEC 450i analyzer. Will bring back to PAML.
IN5A	8/17/2009	15:00-17:20	Calibration	S-OPS/GSS calibrations Notes: S-OPS/GSS leak test fails. It has been failing since the last visit. Changed all filter papers for the North S-OPS line.
IN5A	8/17/2009	15:55-16:25	Calibration	TEC 450i single point calibration Notes: Forgot to open a new calibration file, used the running file.
IN5A	8/18/2009		Calibration	Rain/mist all day prevented calibrated of sonic anemometers.
IN5A	8/18/2009		Calibration	Taking back both TDLAS's to PAML.
IN5A	8/18/2009		Calibration	Upon arrival found one TDLAS laptop was frozen.

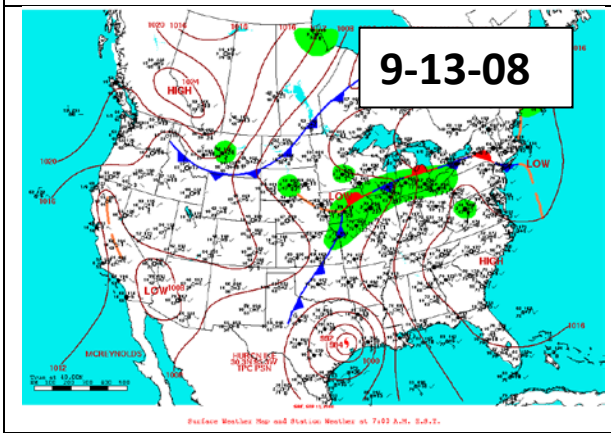
Site	Date (mm/dd/yyyy)	Time (UTC)	Activity (setup, takedown, calibration, repair, or remote)	Event (description, notes, or comments)
IN5A	8/18/2009		Calibration	UPS history: 8/11/2009 2:45-3:45: UPS temperature alarm. 8/17/2009 10:09:15: UPS switched to battery power. 10:09:18: AC Restored Message sent to registered clients connected to Load Segment 1. 10:09:18: AC Restored Message sent to registered clients connected to Load Segment 2.
IN5A	8/18/2009		Calibration	ORP sensor: calibration performed
IN5A	8/18/2009	14:58-15:12	Calibration	Calibrated TDLAS 1032
IN5A	8/18/2009	15:00-17:00	Calibration	S-OPS/GSS calibrations Notes: S-OPS/GSS leak test fails. It has been failing since the last visit. Changed all filter papers for the North S-OPS line.
IN5A	8/18/2009	15:22-15:35	Calibration	Calibrated TDLAS 1031
IN5A	8/18/2009	16:00	Calibration	pH sensor: QA and inspection/maintenance performed
IN5A	8/19/2009	12:20	Remote	Daily Status Check from PAML
IN5A	8/20/2009	12:20	Remote	Daily Status Check from PAML
IN5A	8/21/2009	12:20	Remote	Daily Status Check from PAML

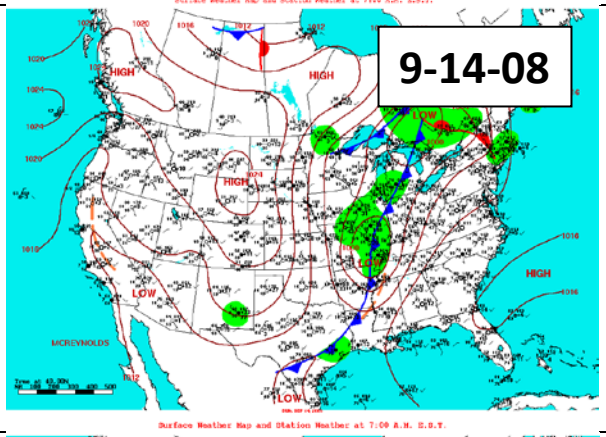
6.9 Site Weather

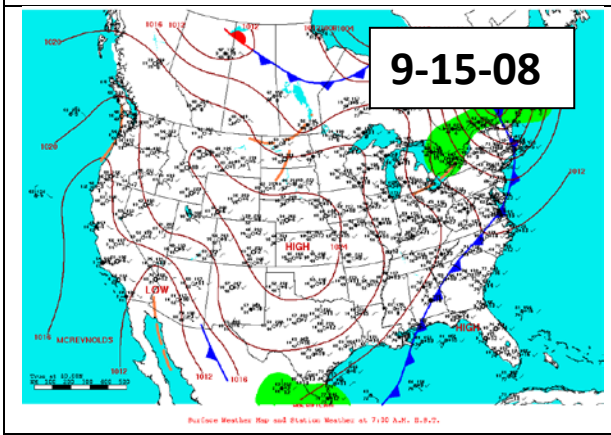
Period 6

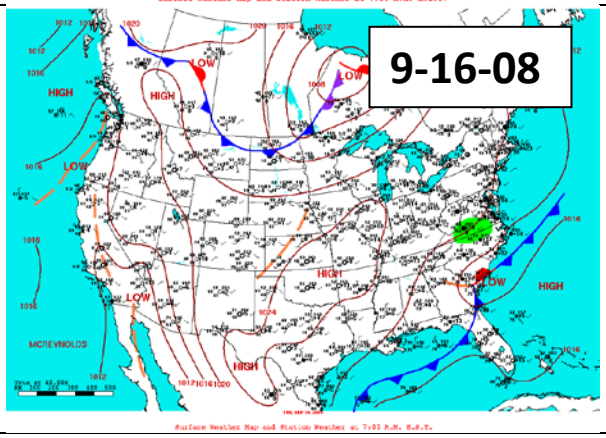


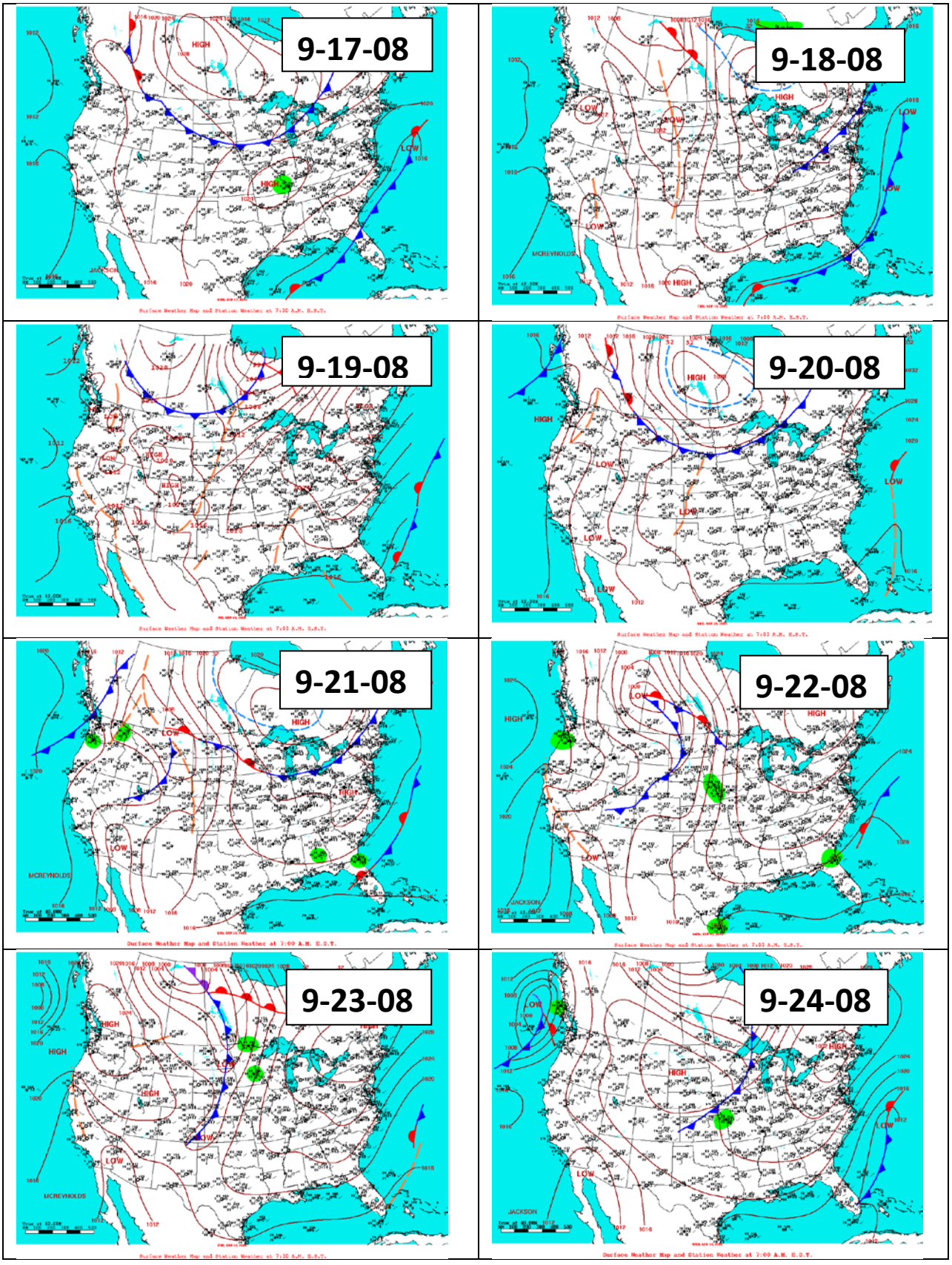








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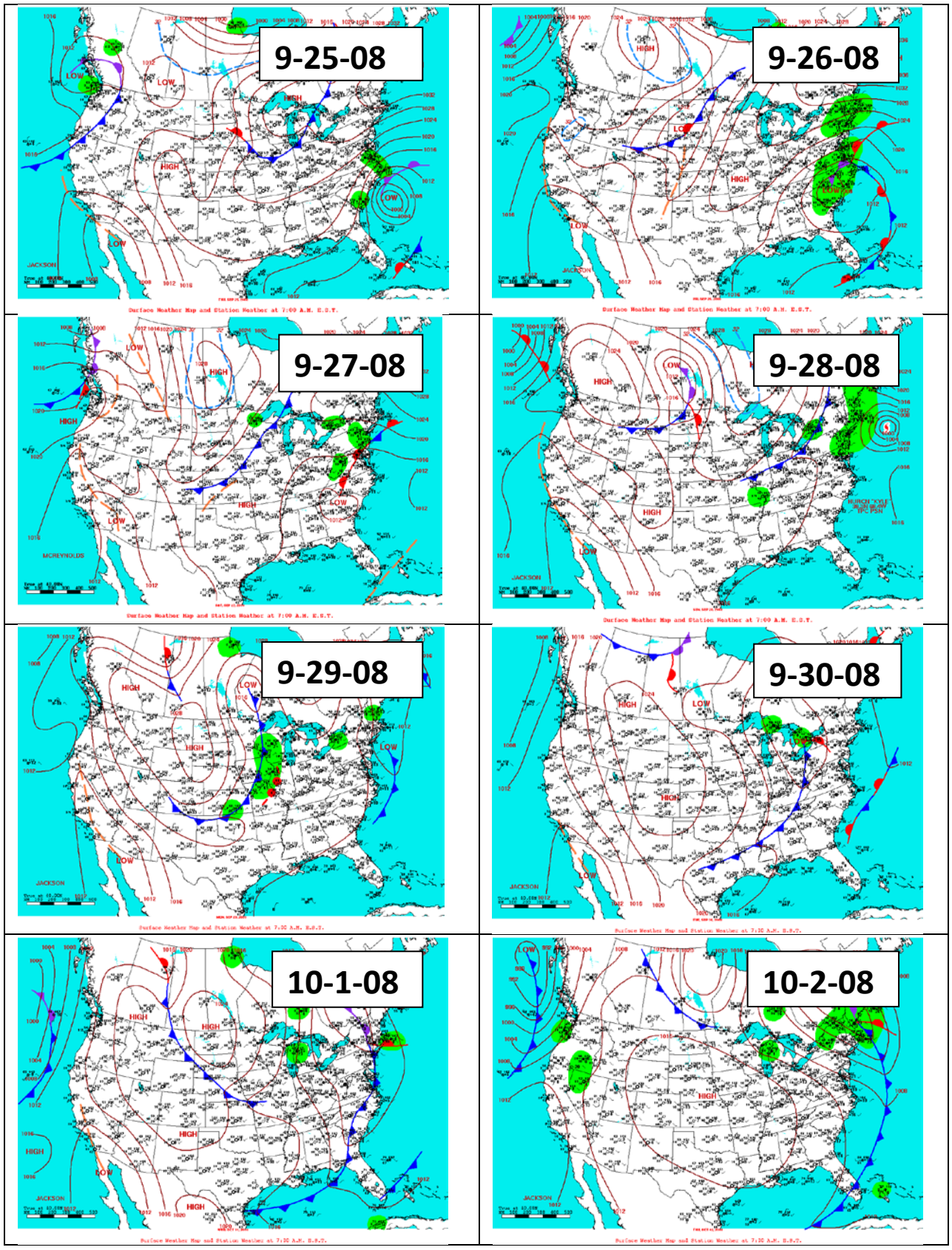
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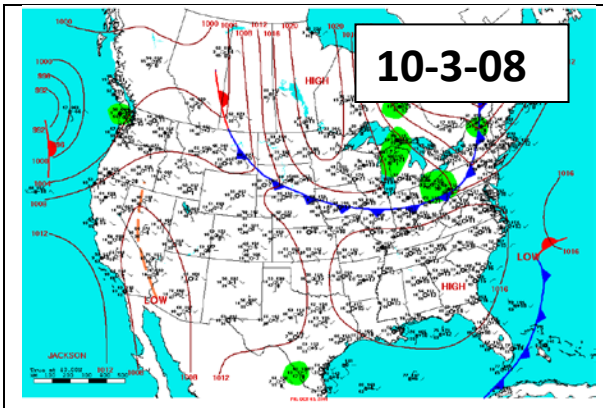
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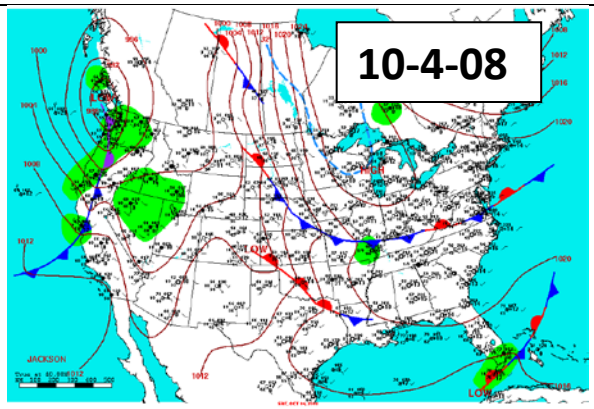
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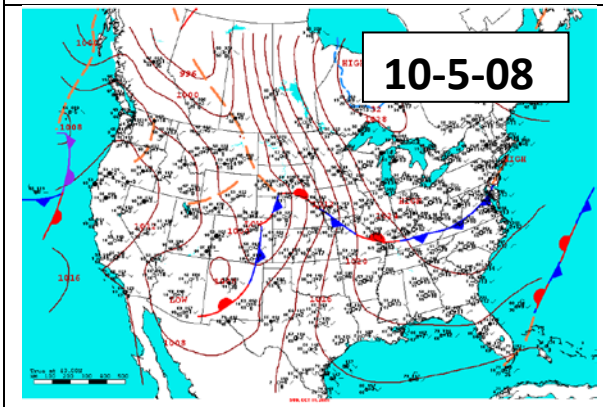
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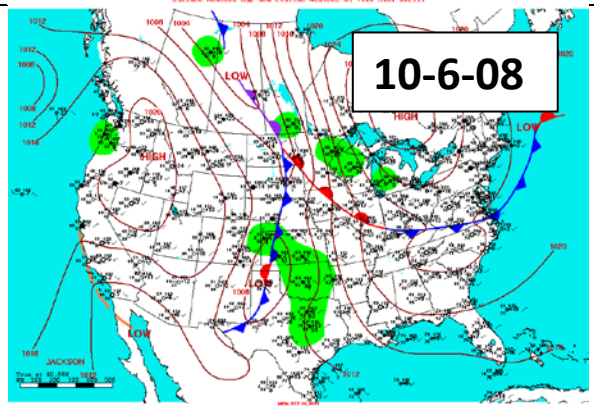
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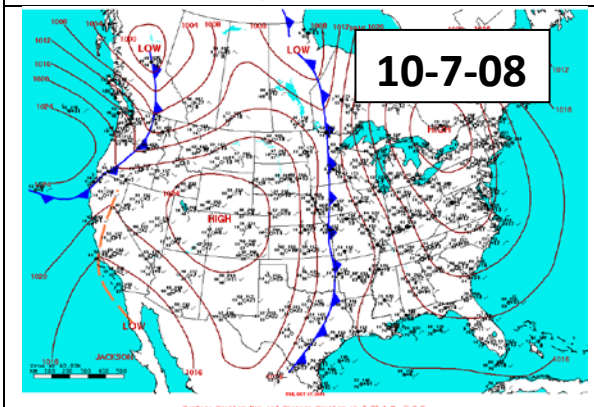
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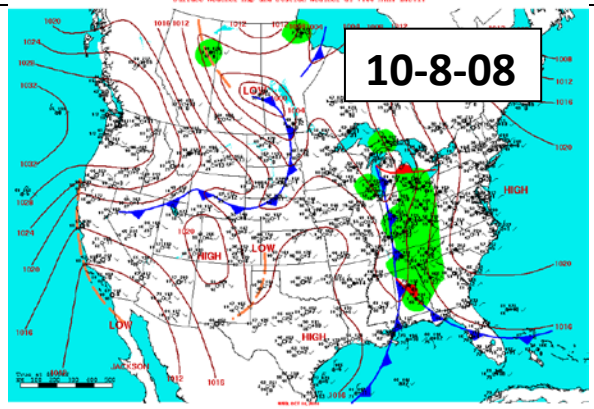
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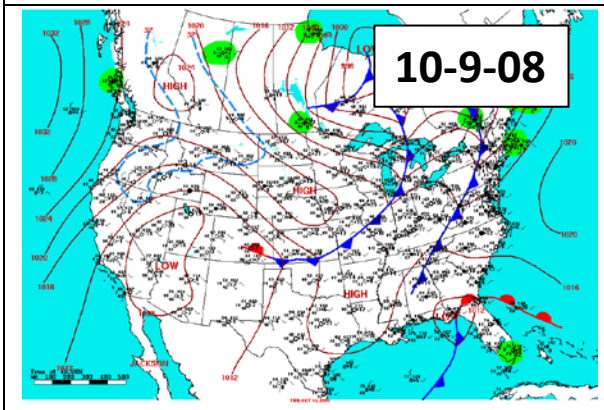
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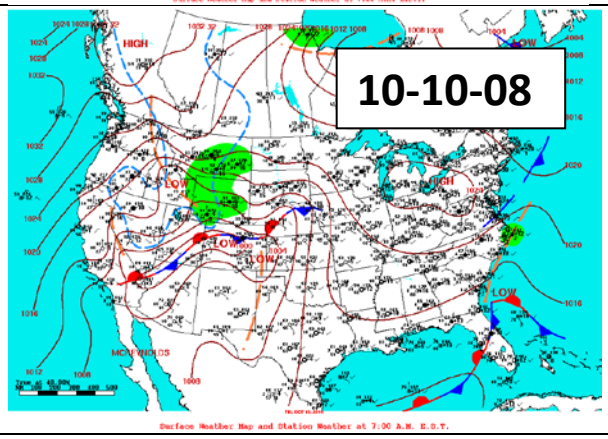
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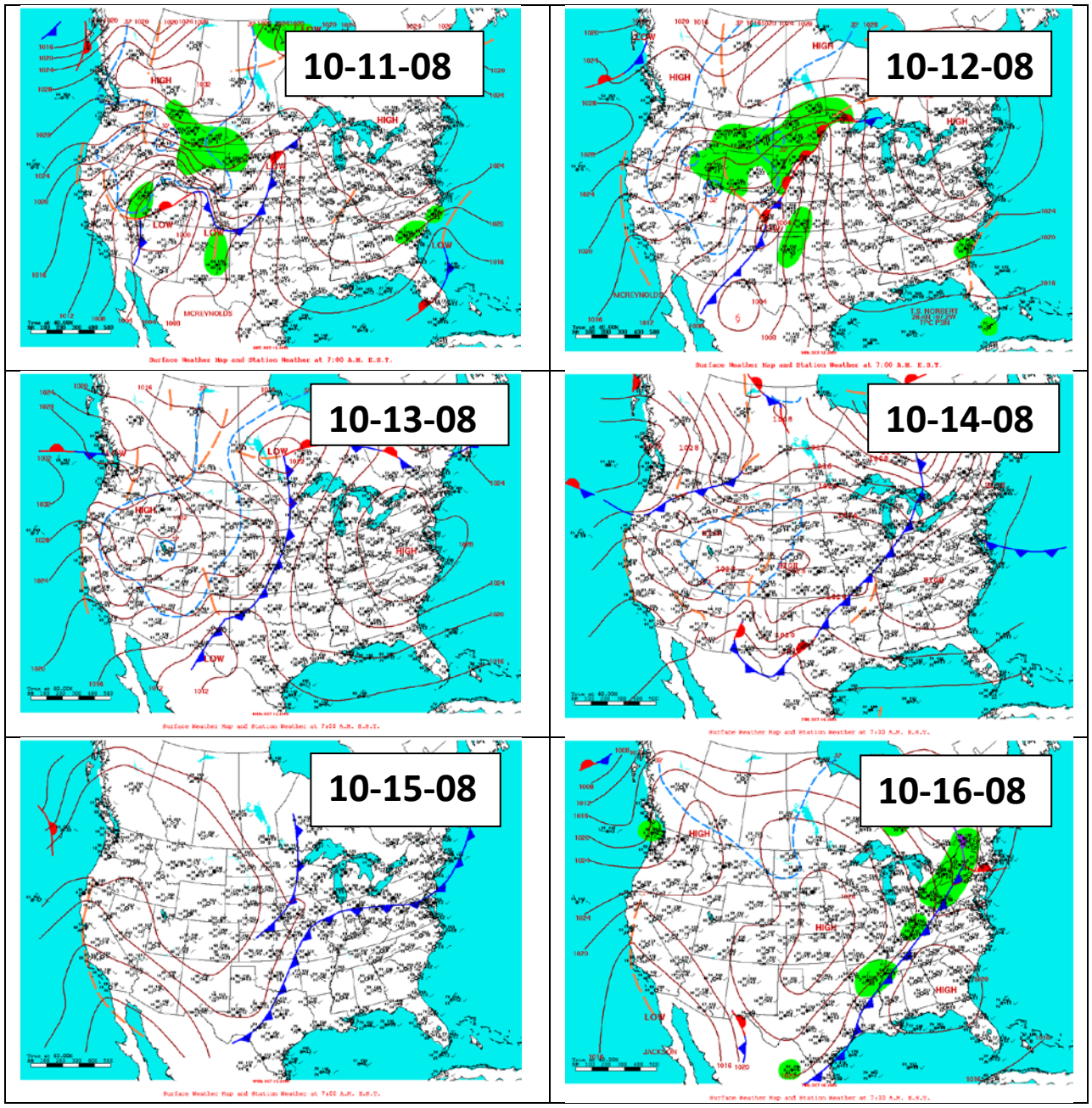
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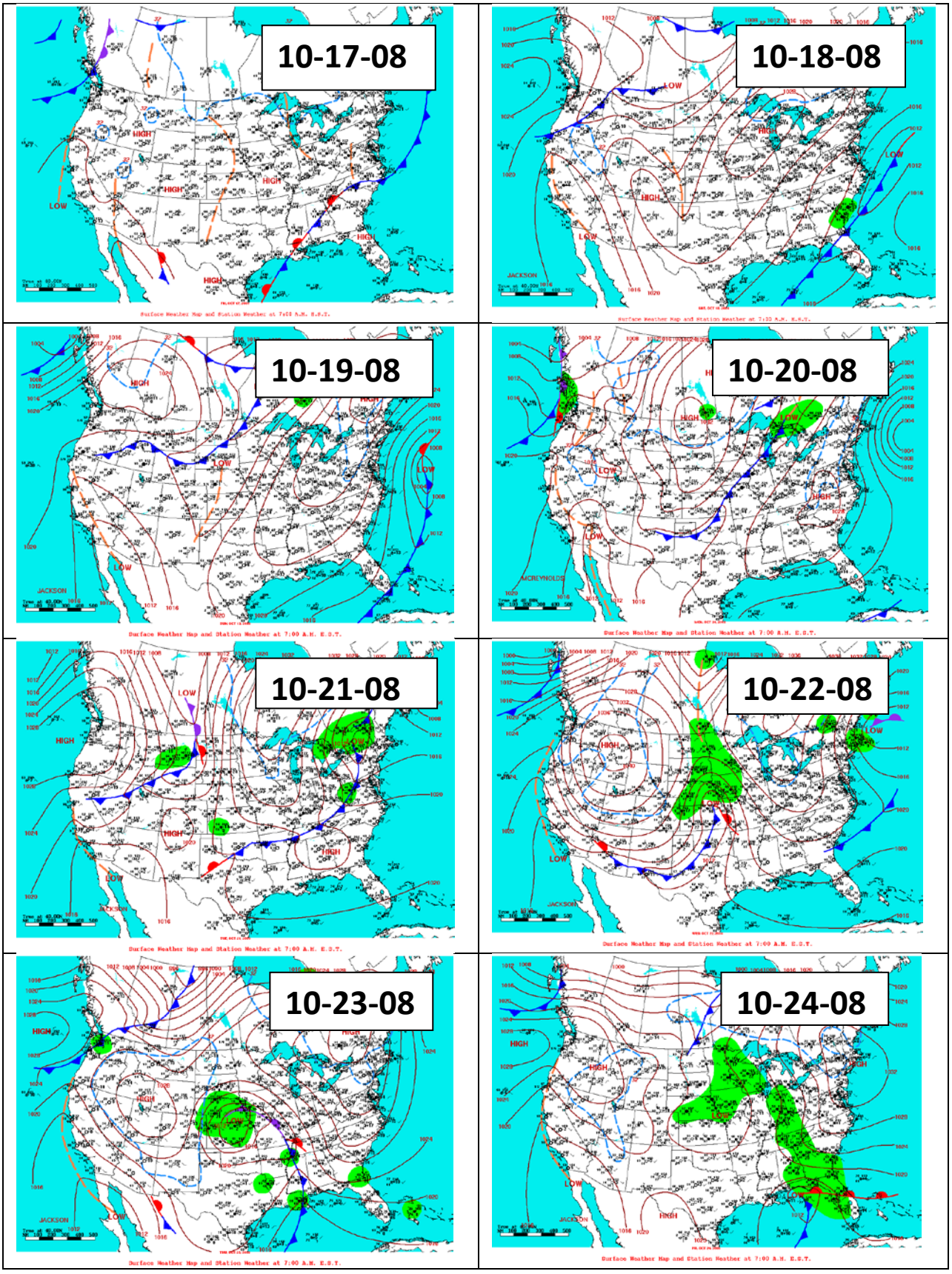
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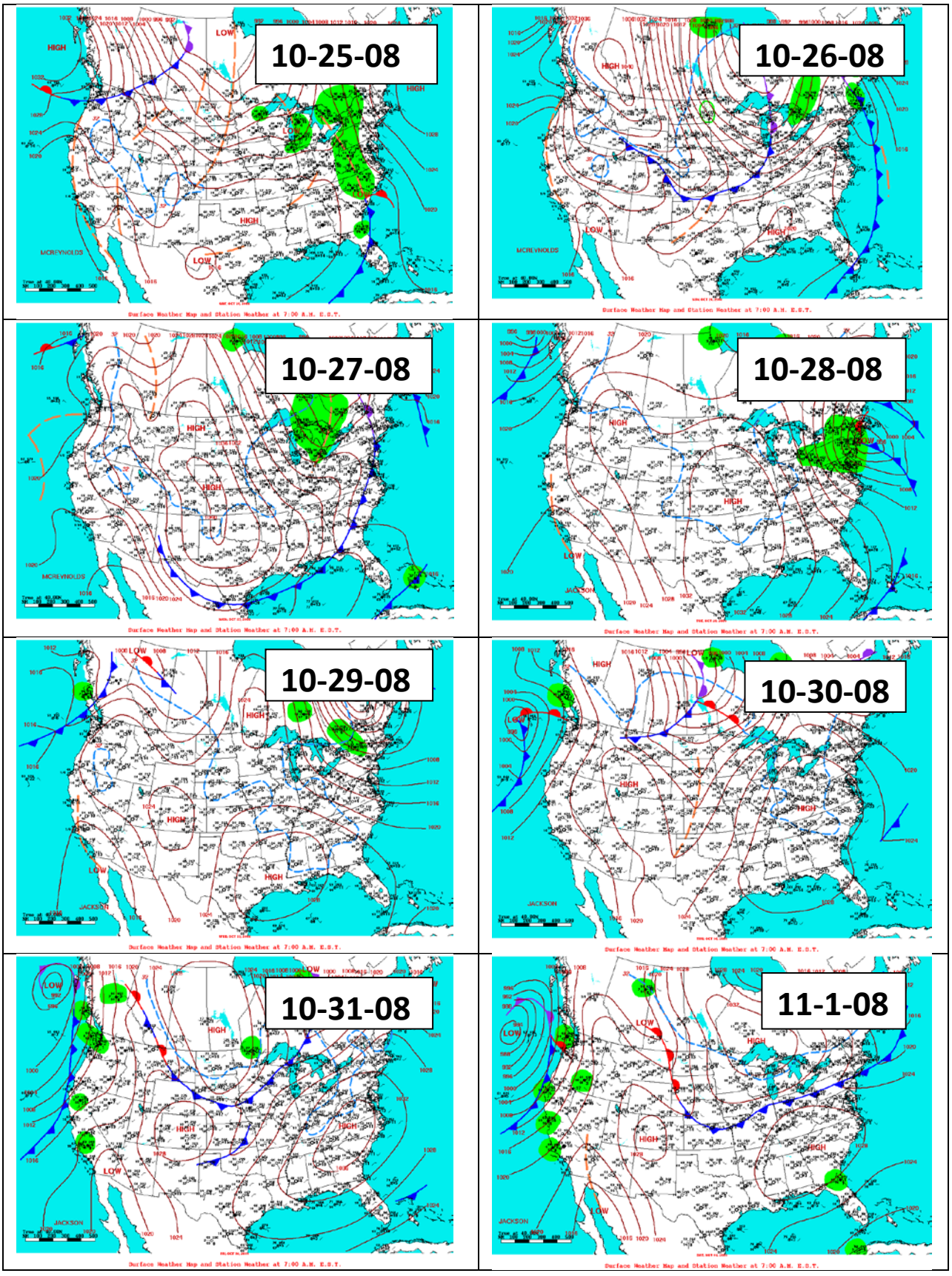
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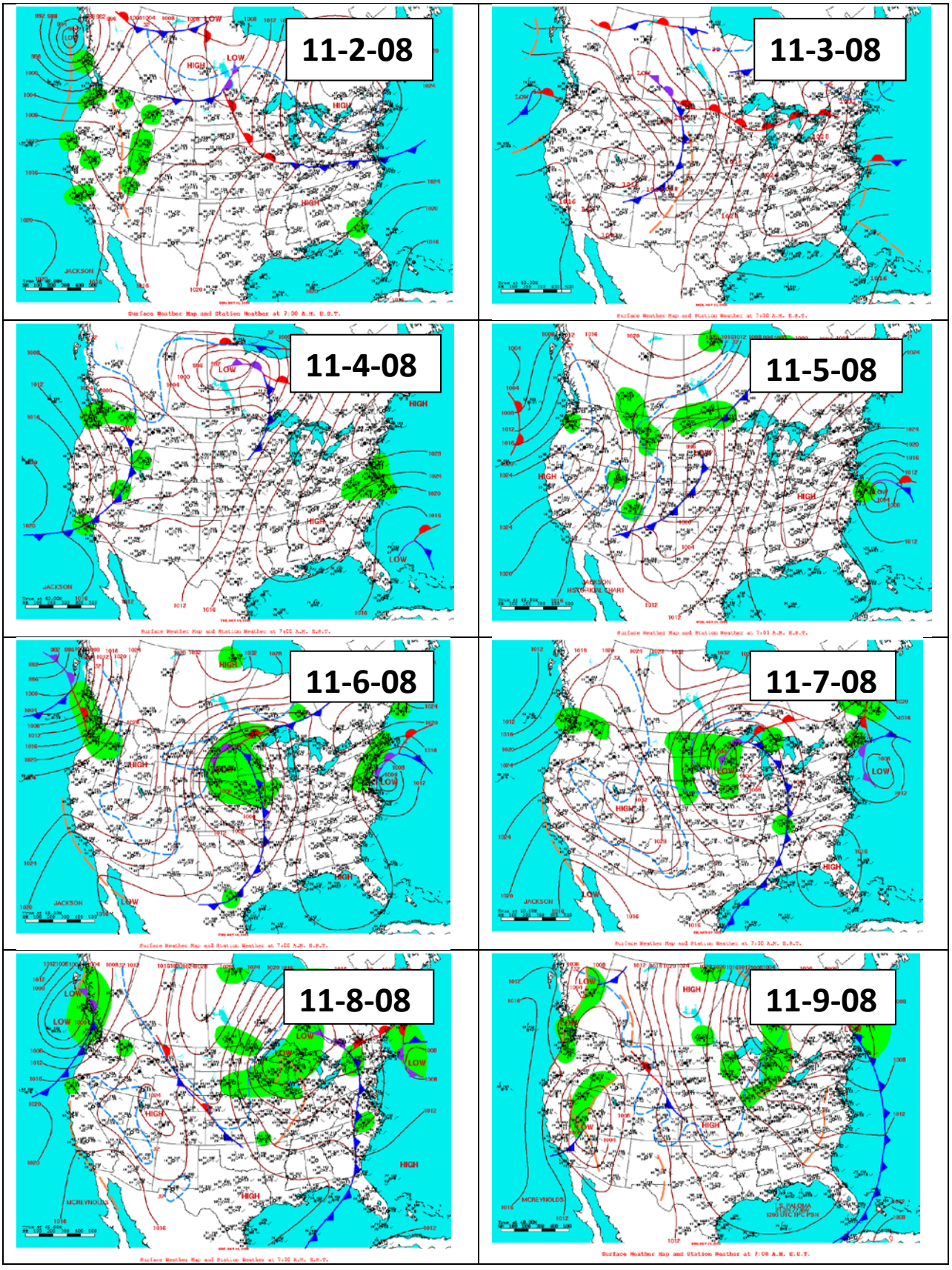
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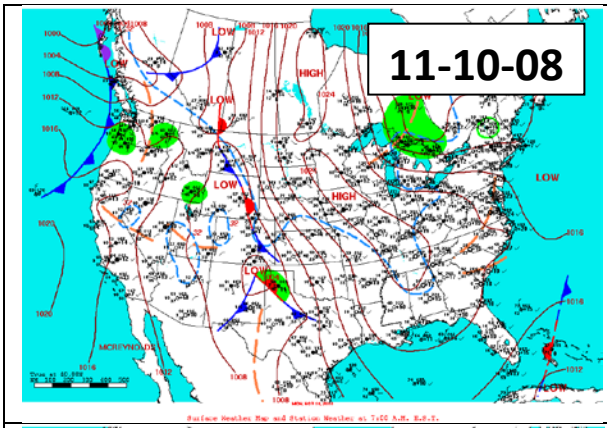
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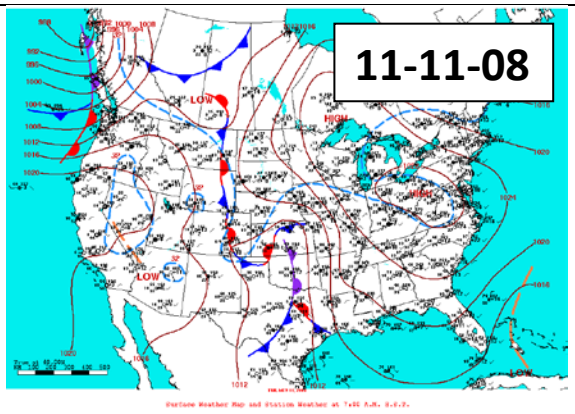
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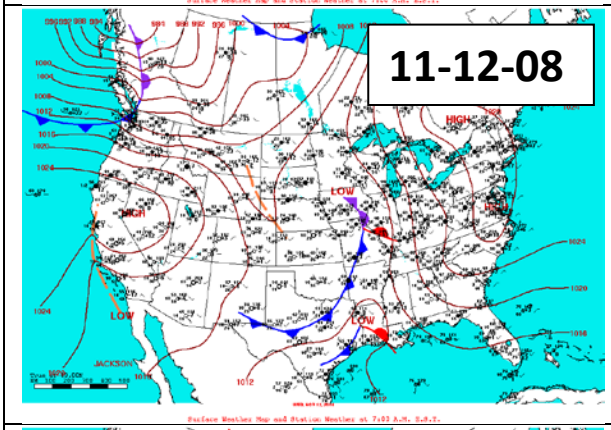
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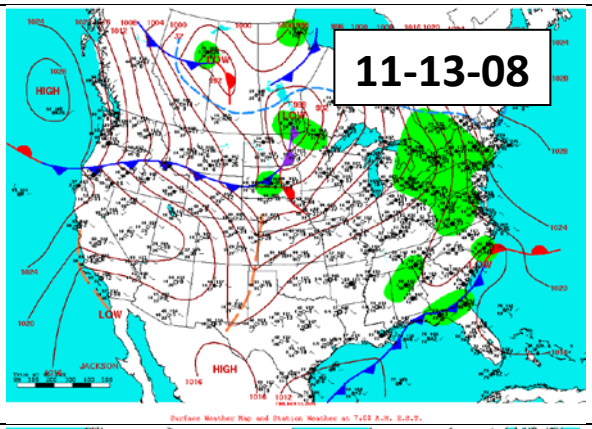
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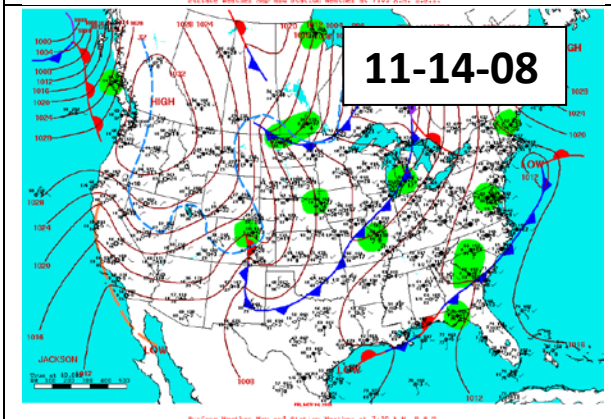
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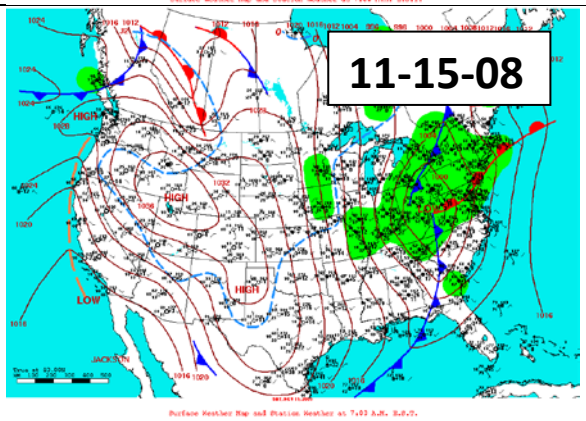
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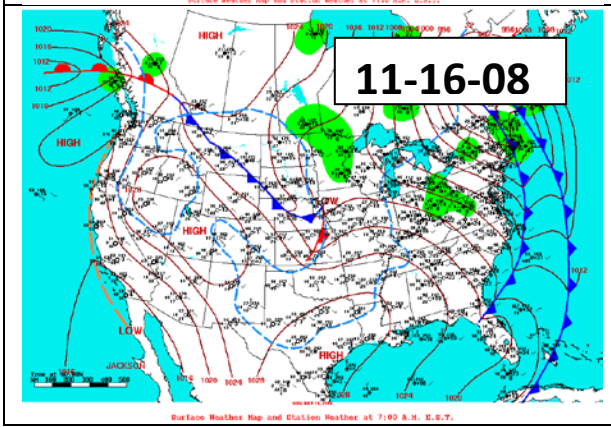
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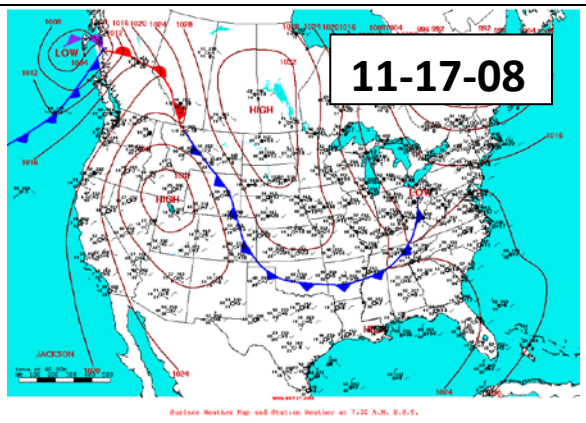
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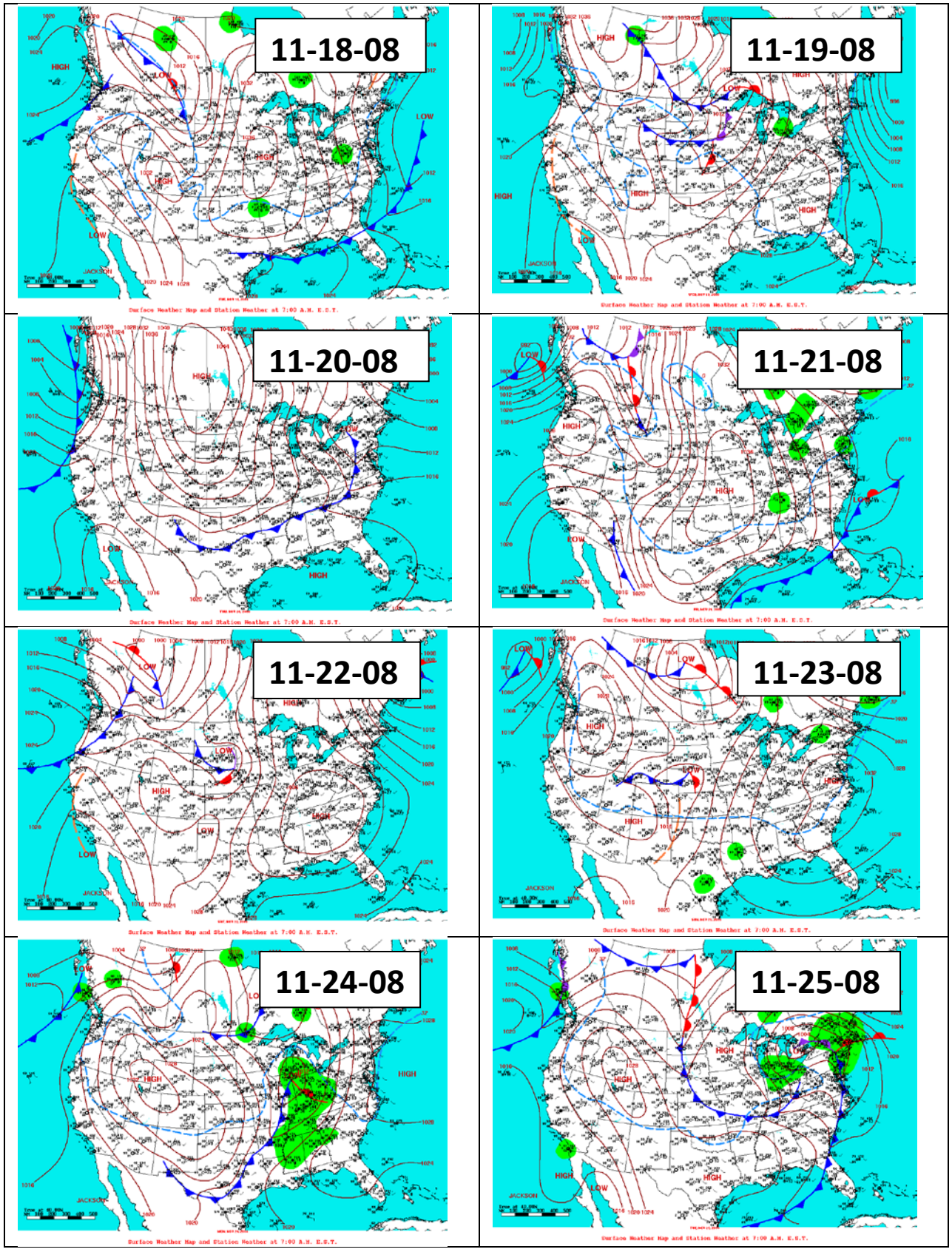
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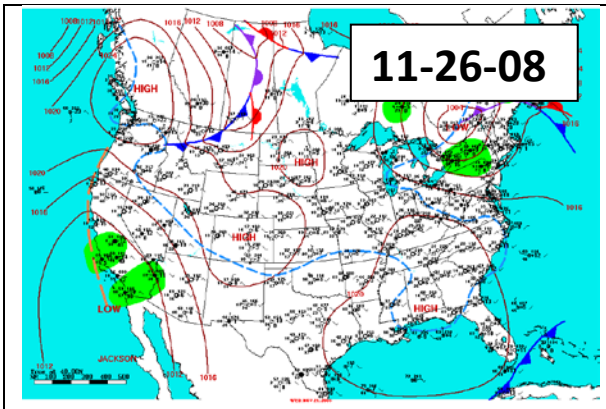

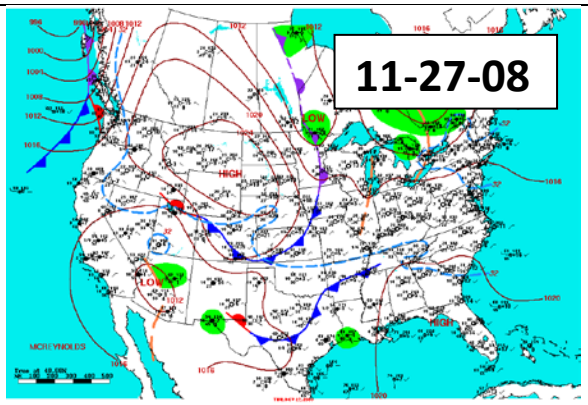

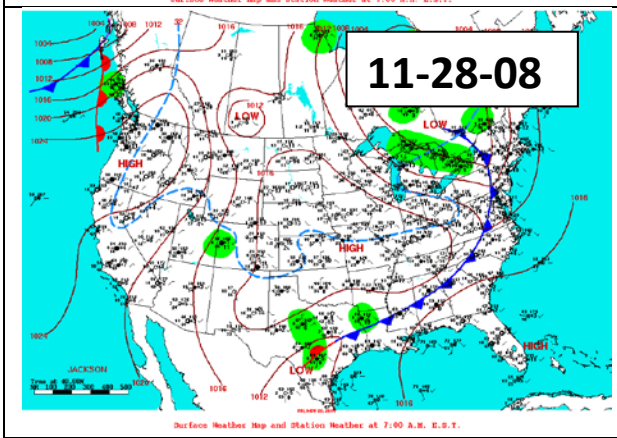

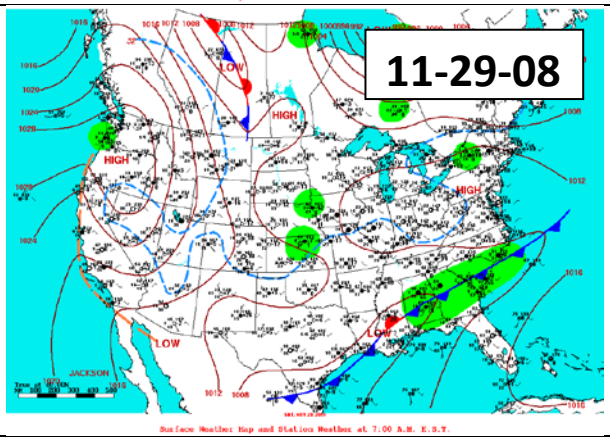

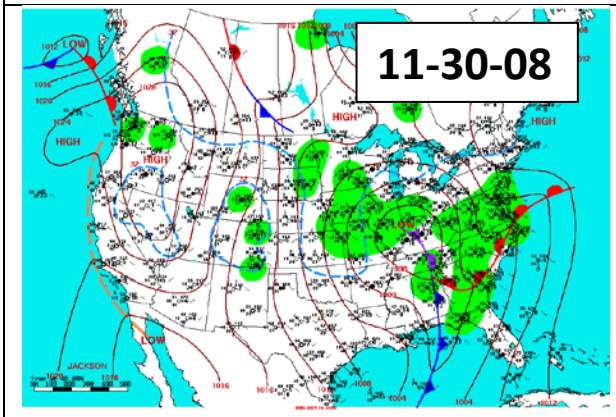

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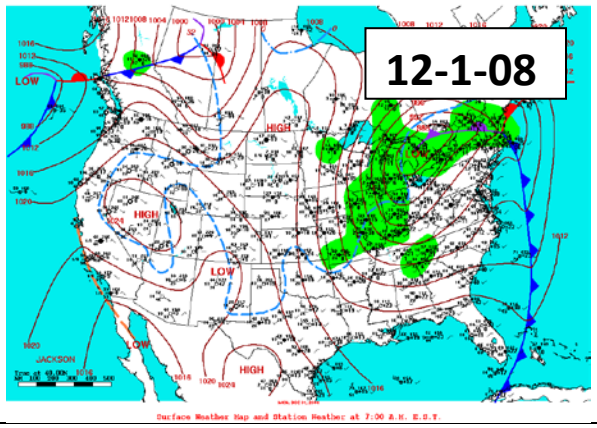

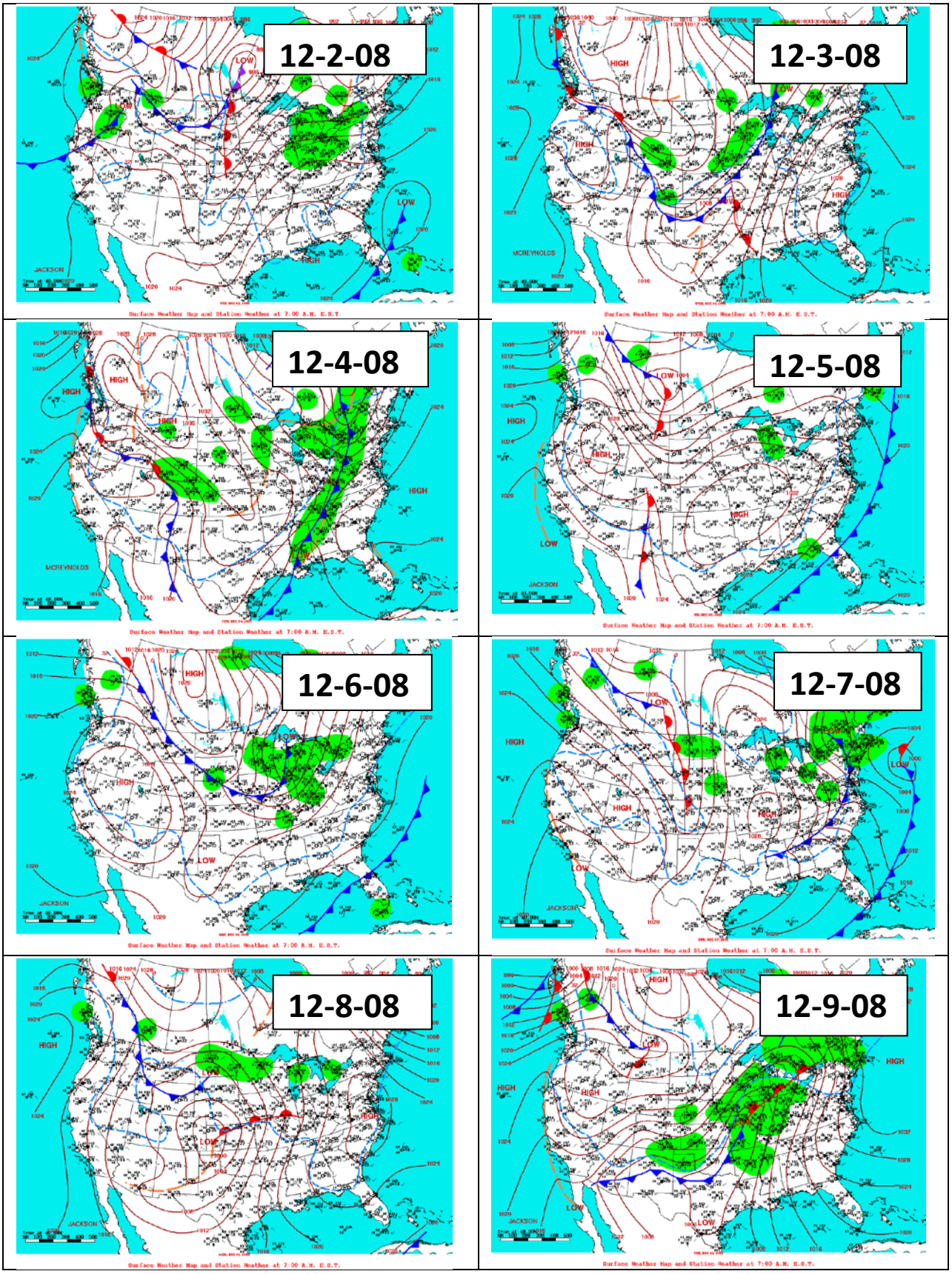
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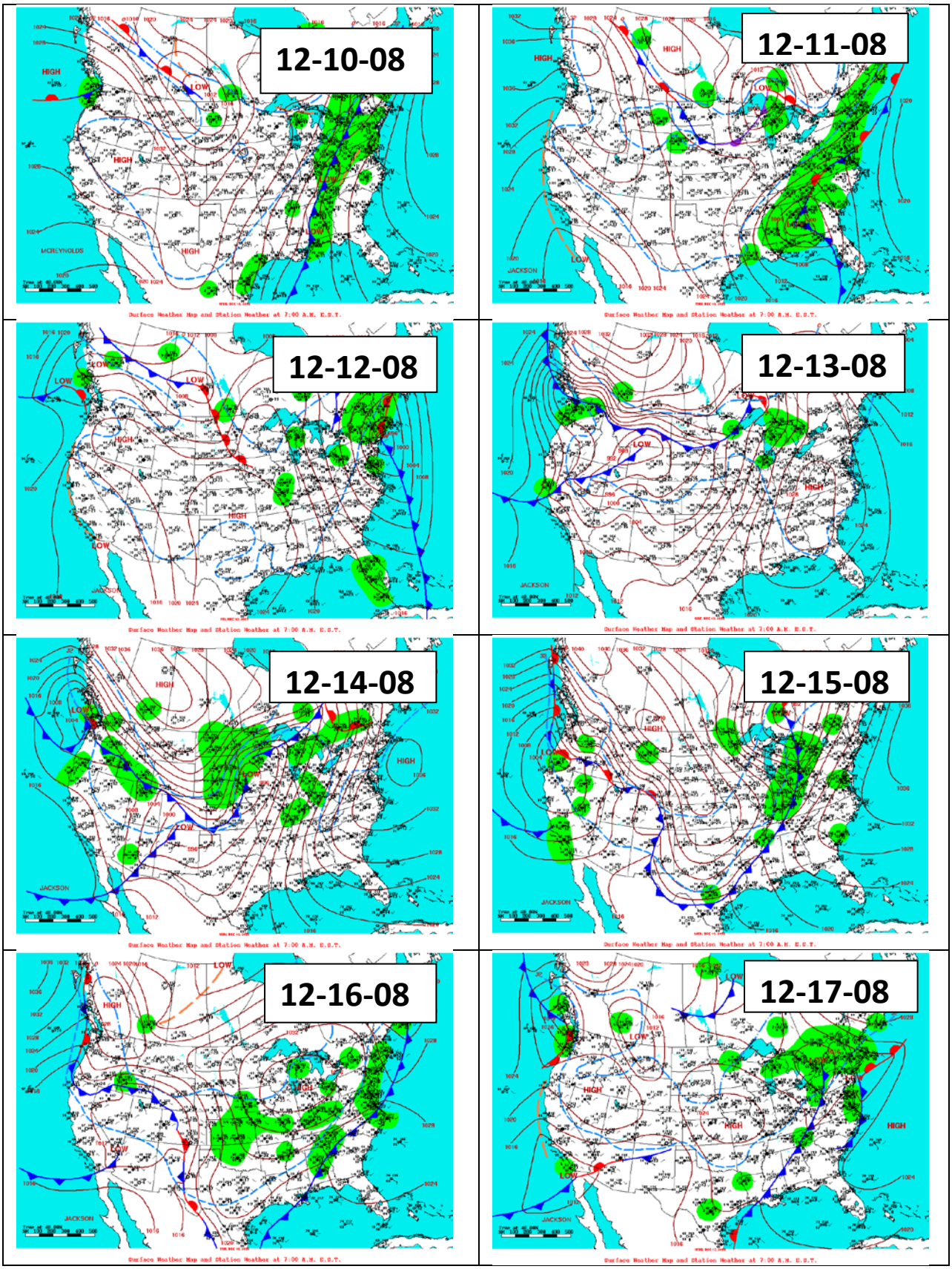
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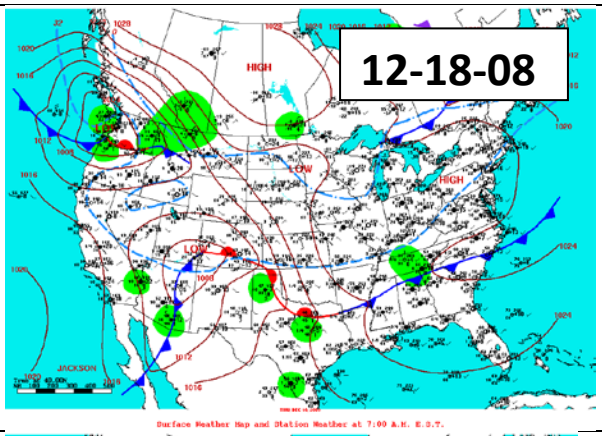
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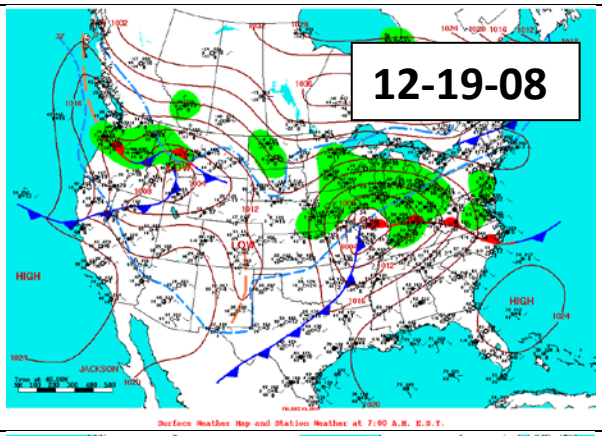
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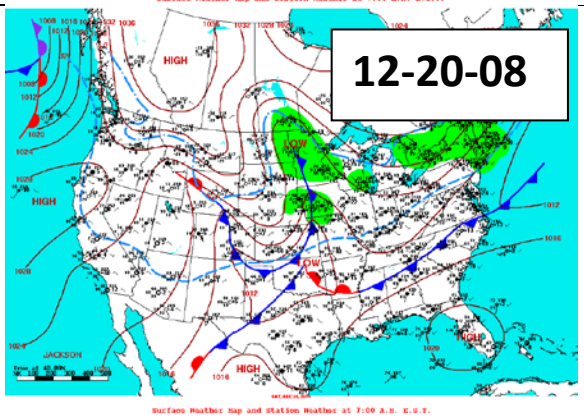
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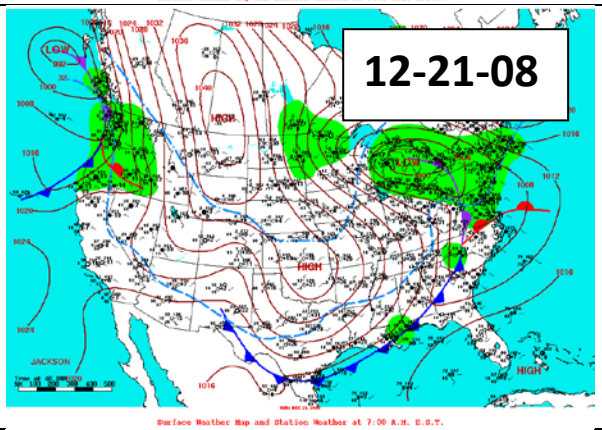
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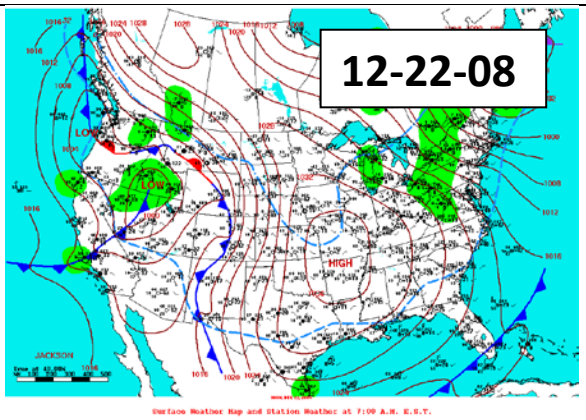
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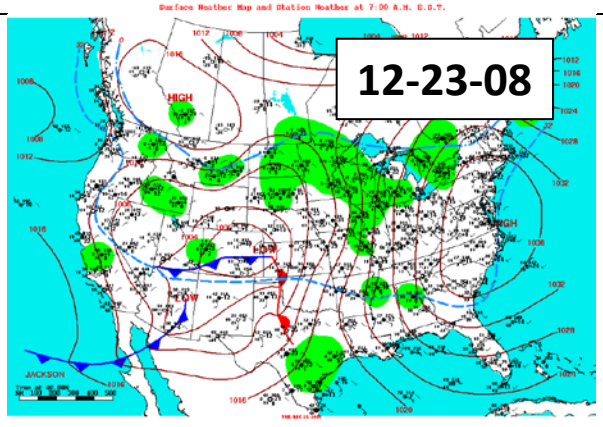
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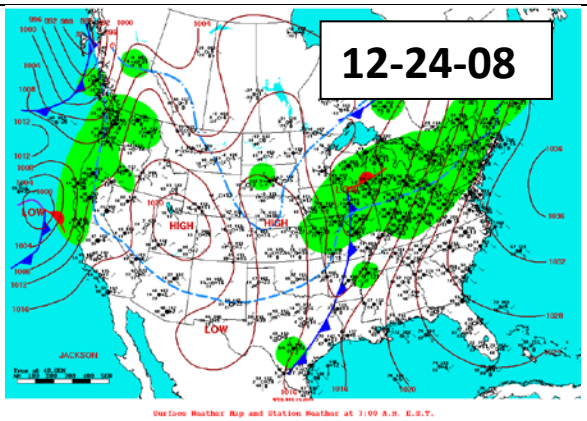
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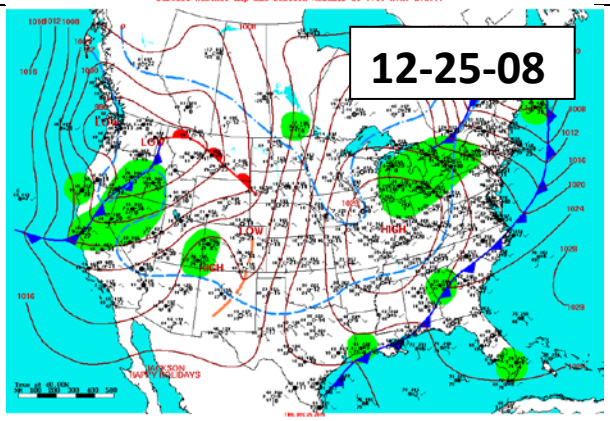
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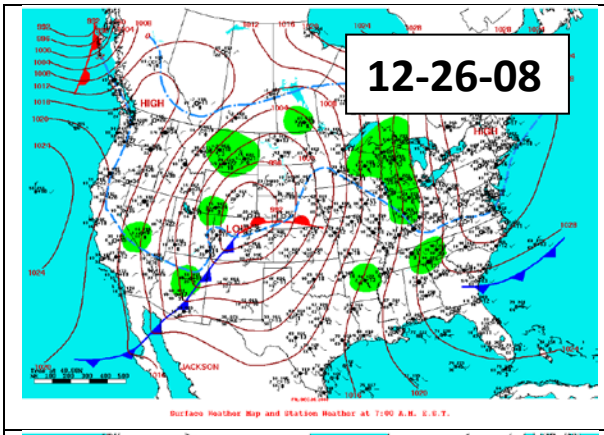
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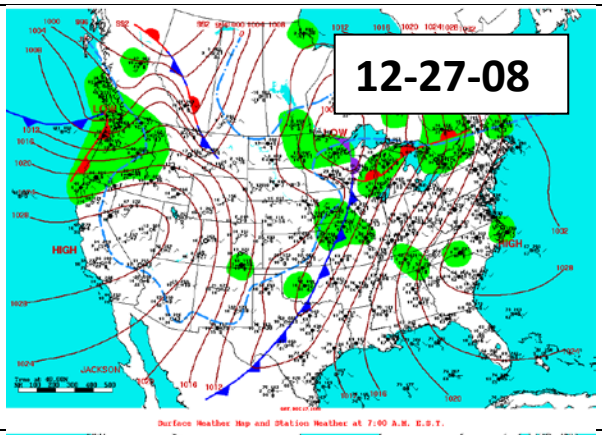
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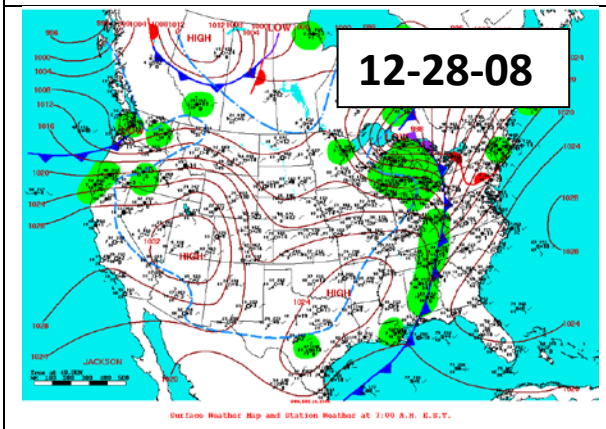
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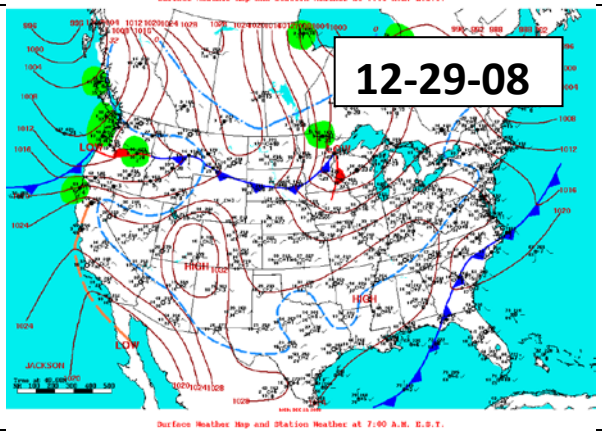
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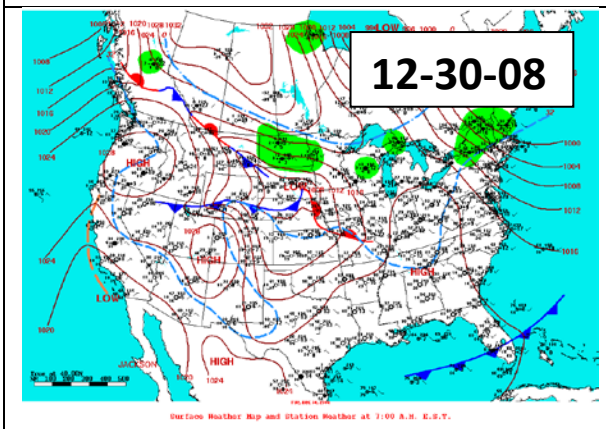
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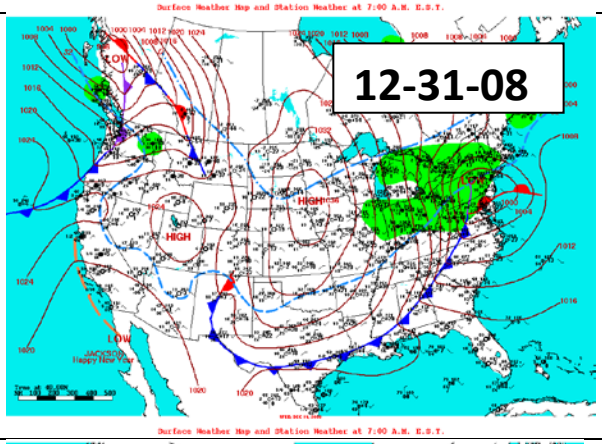
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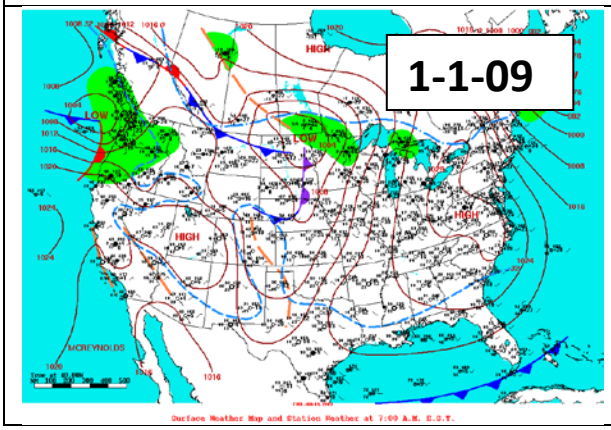
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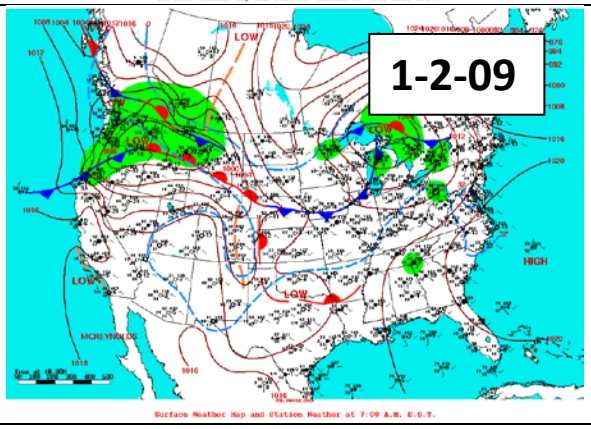
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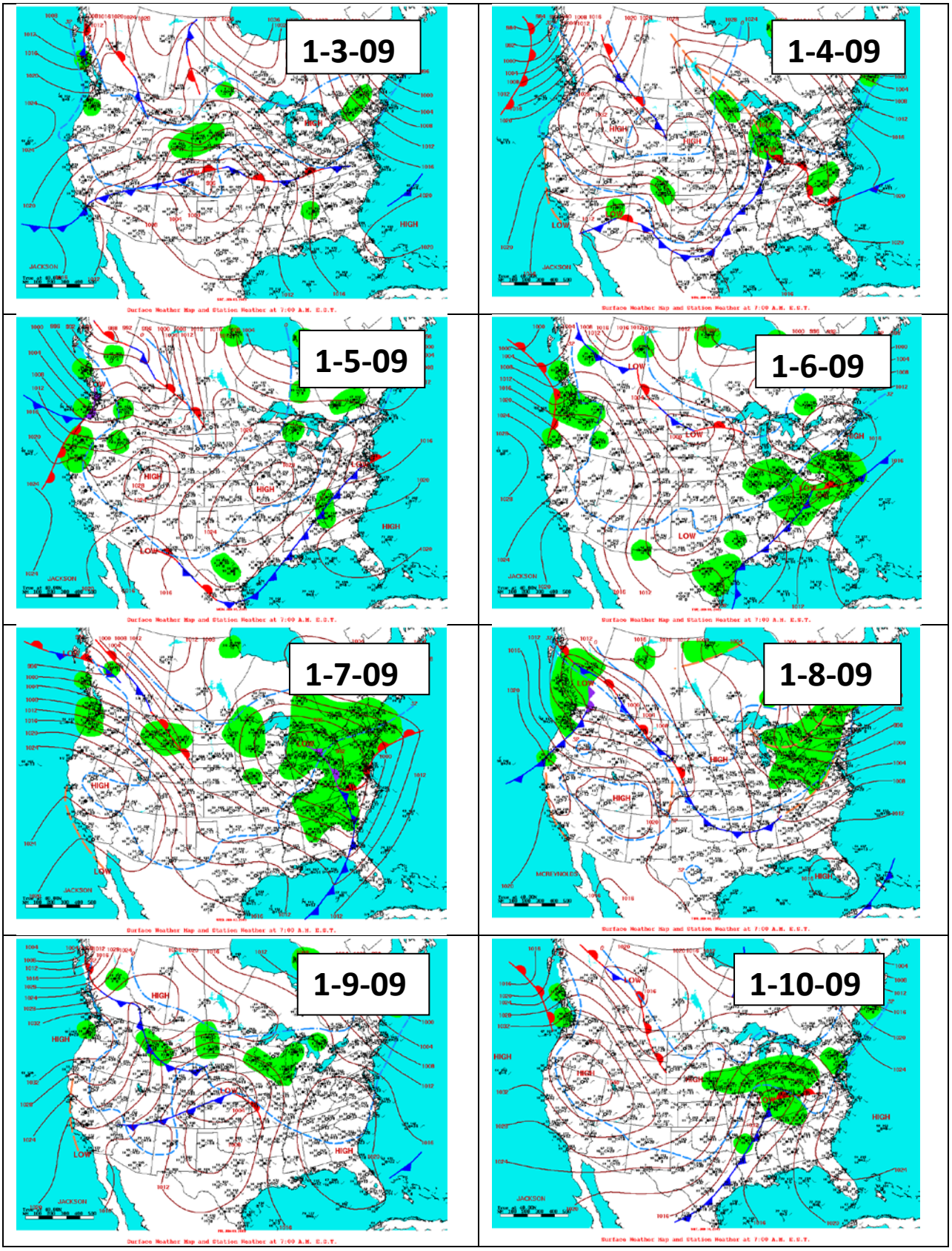
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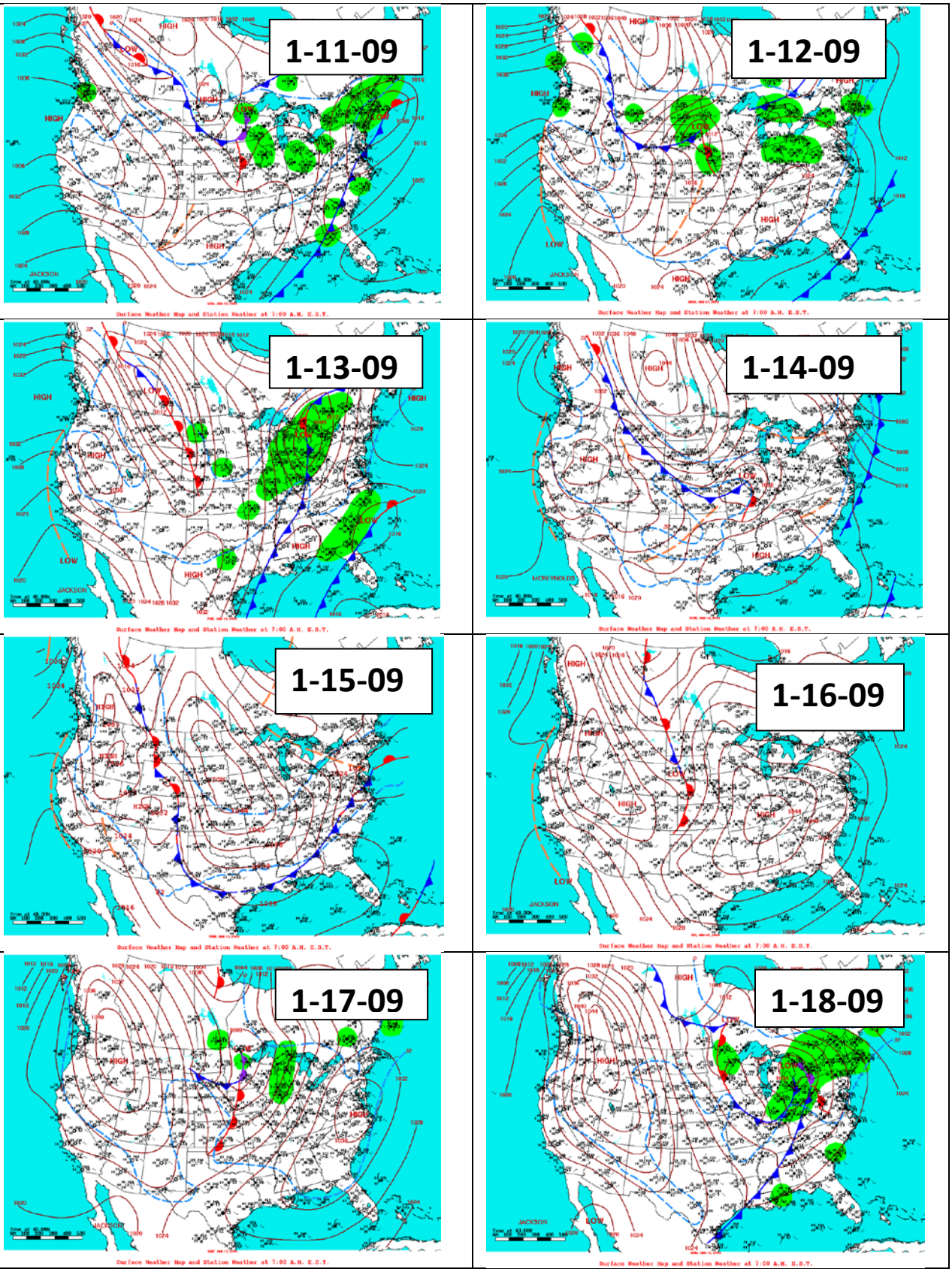
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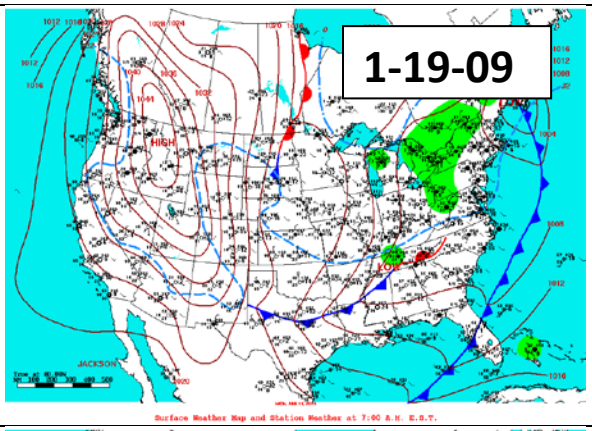
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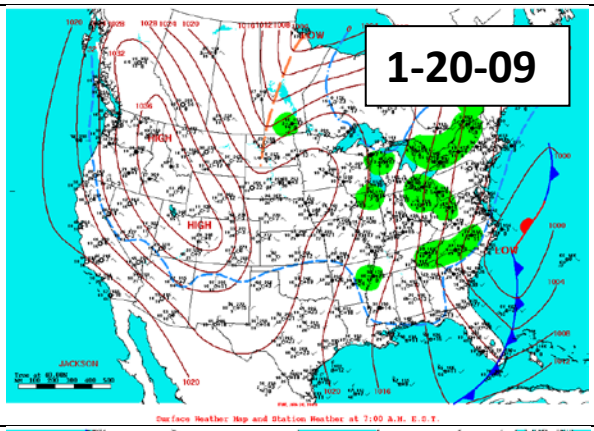
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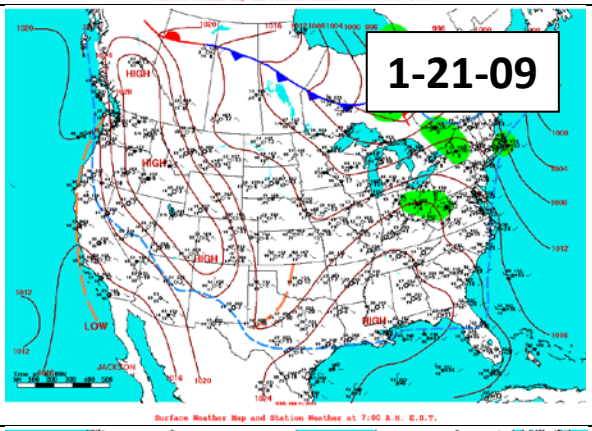
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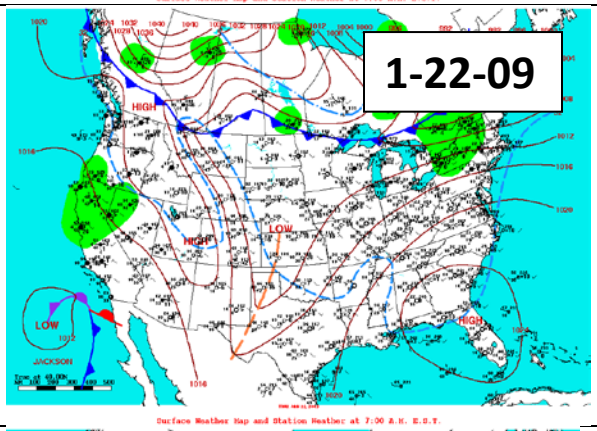
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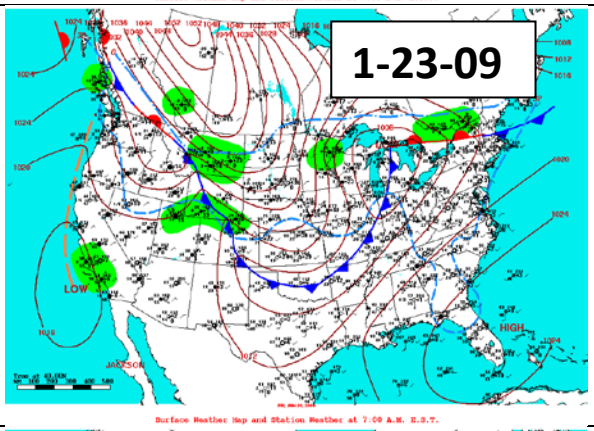
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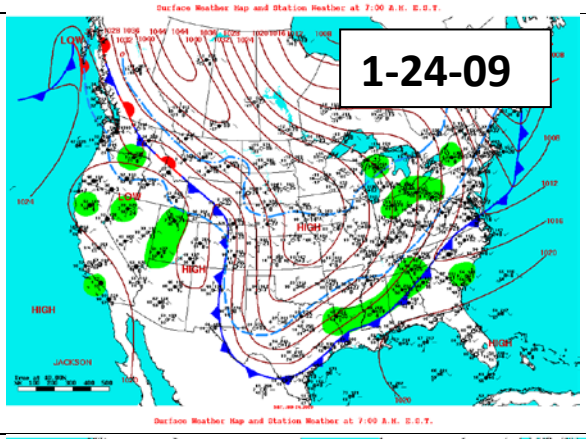
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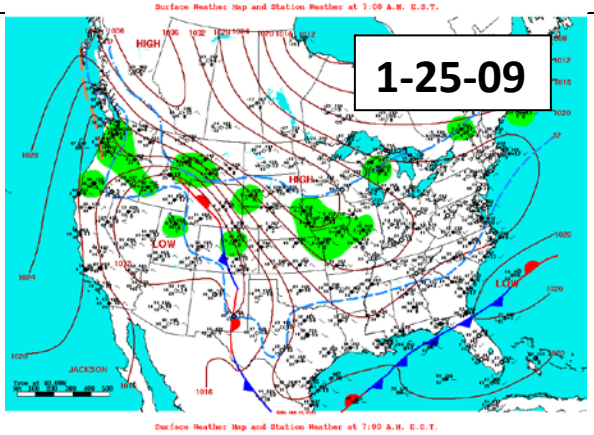
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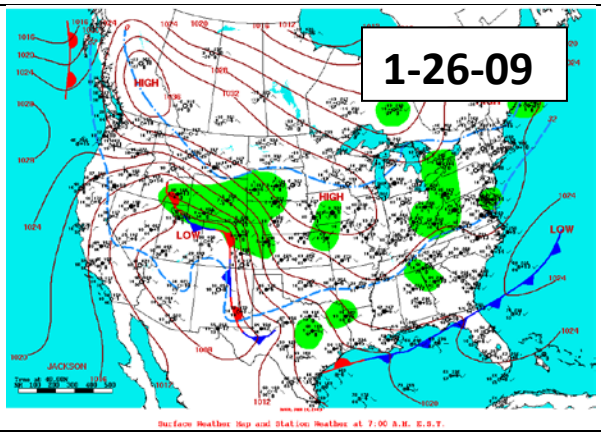
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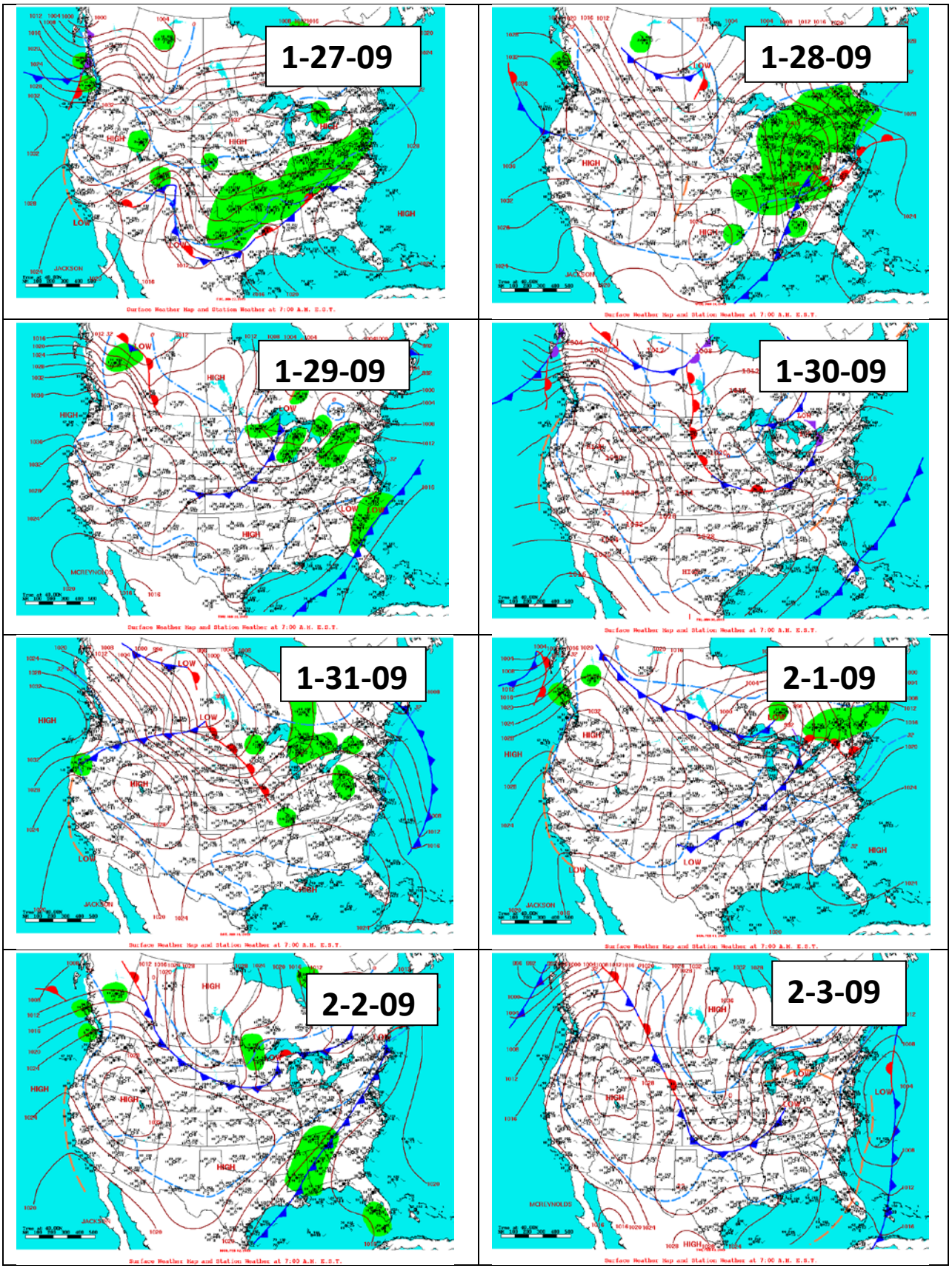
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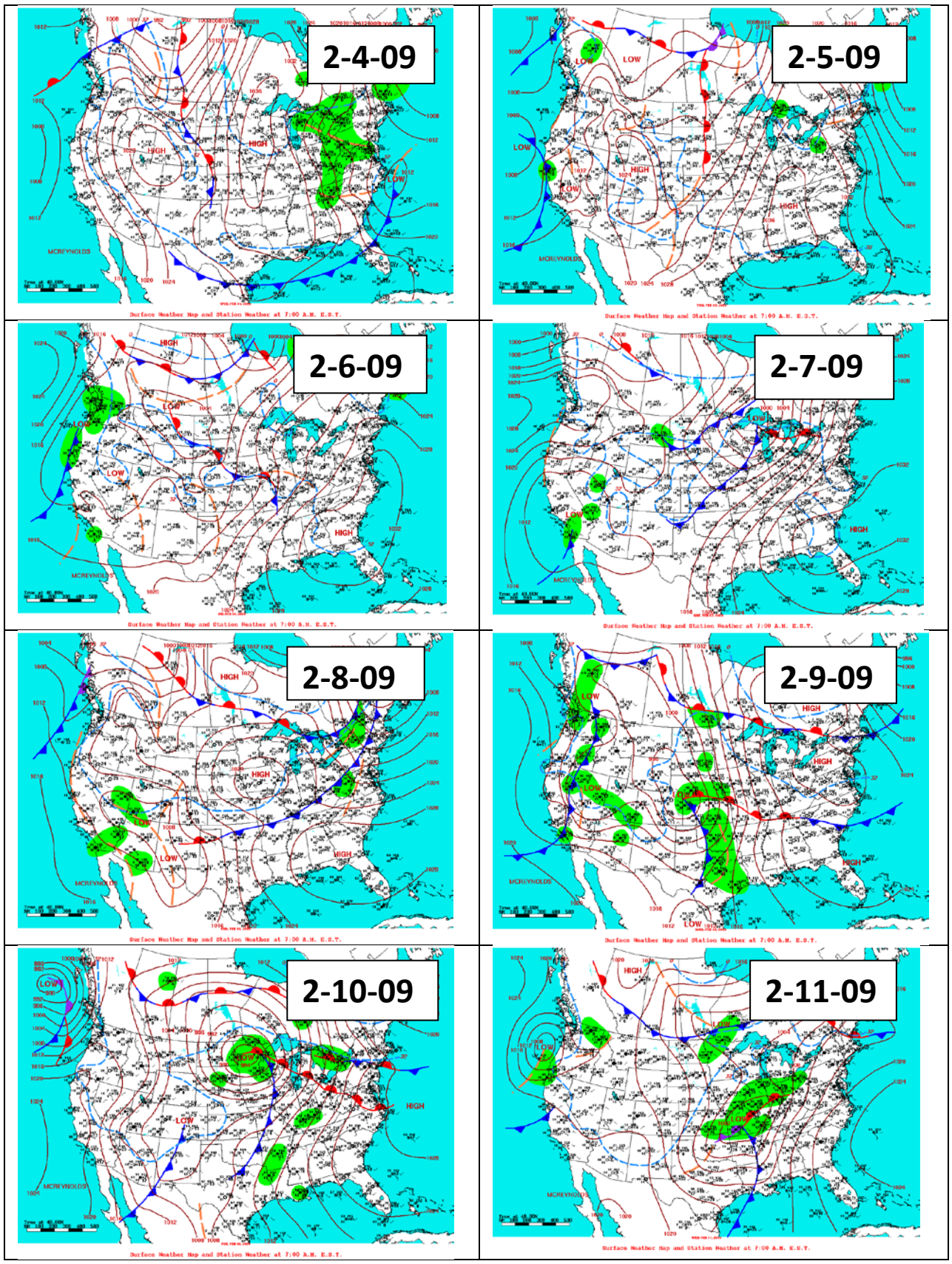
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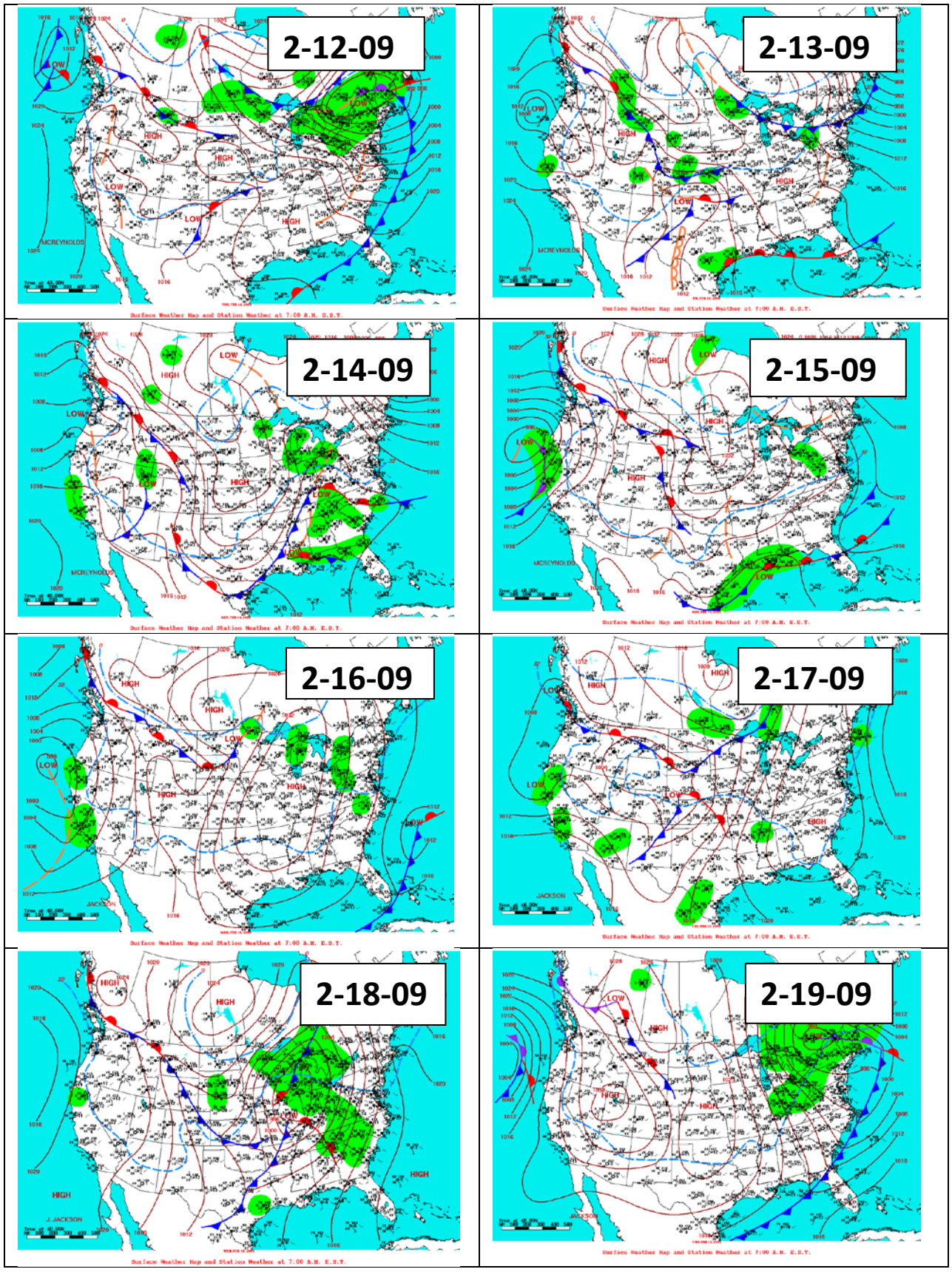
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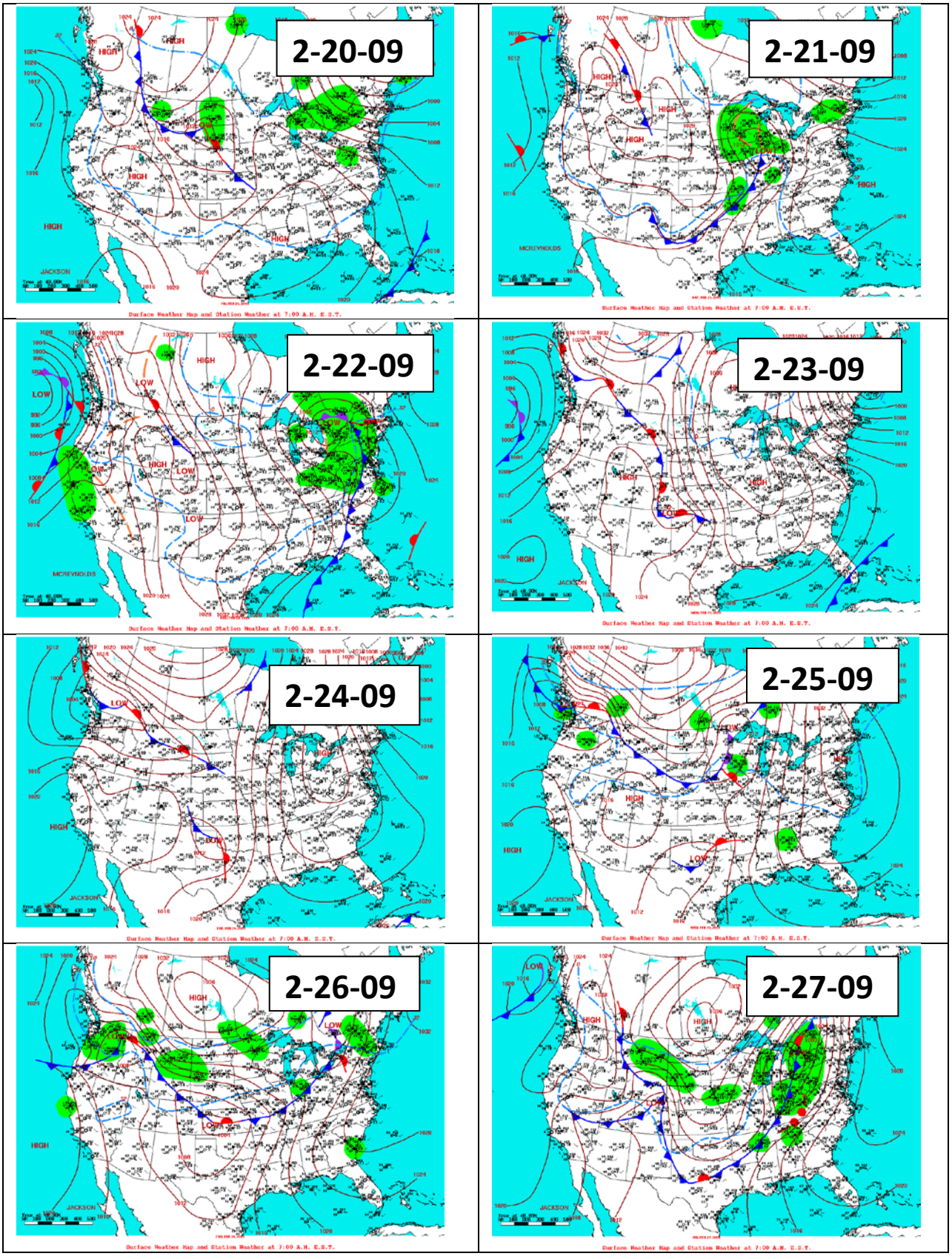
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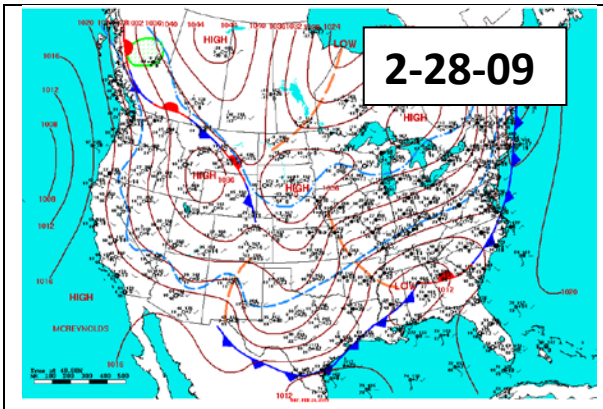
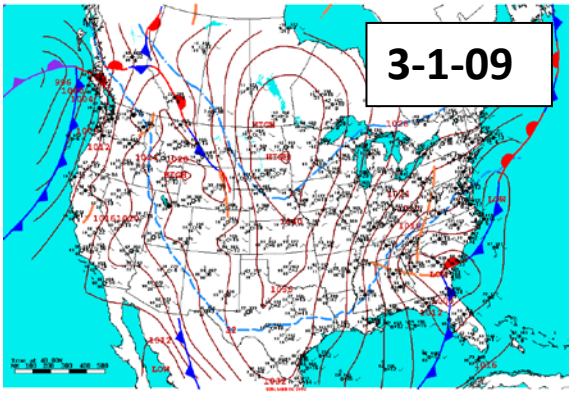
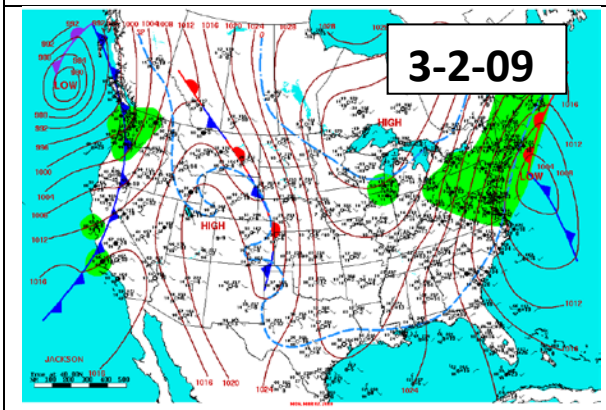
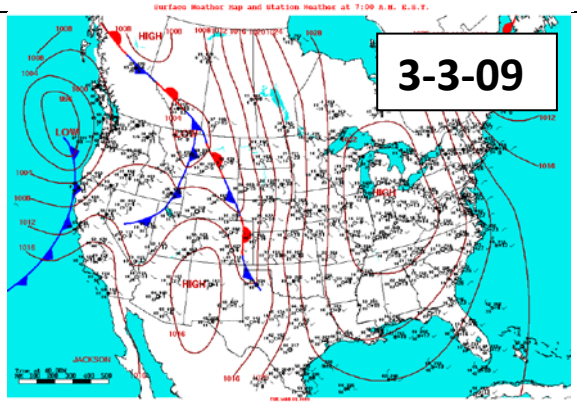
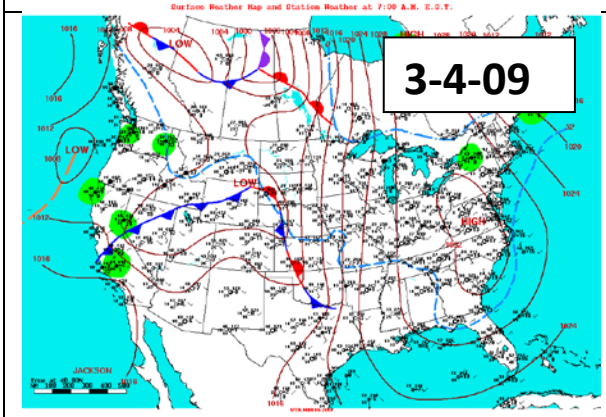
Period 8

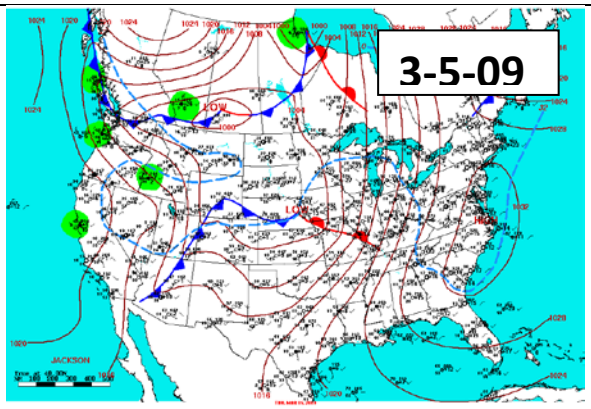


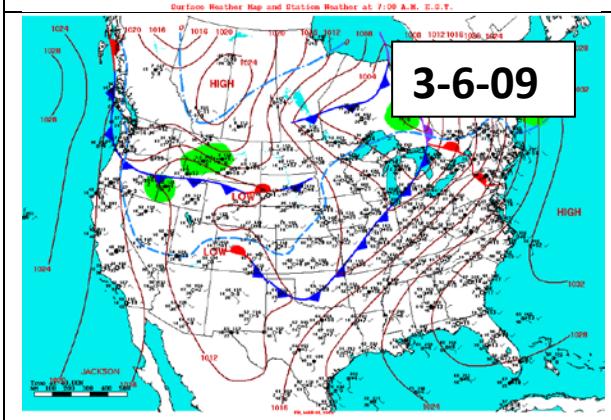


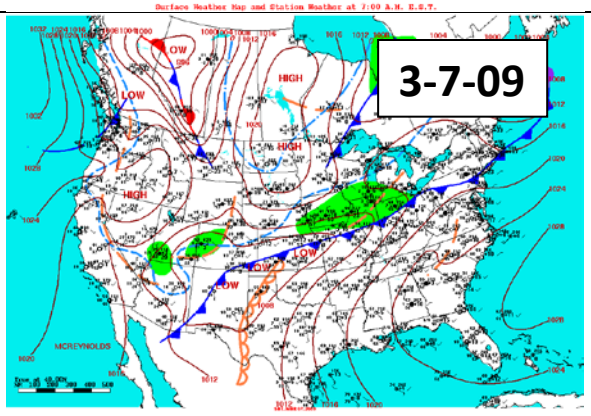


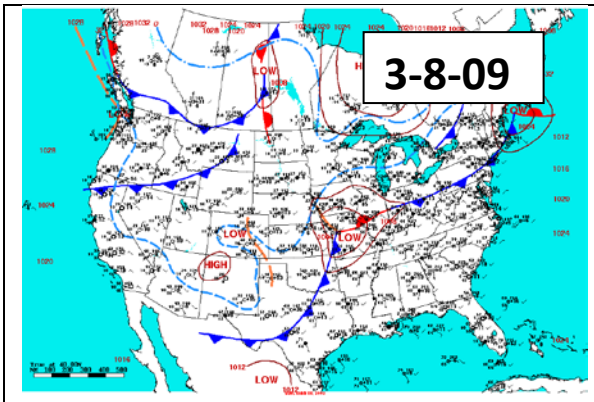








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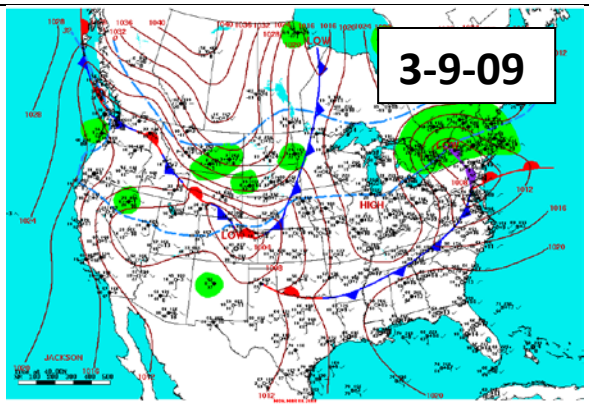
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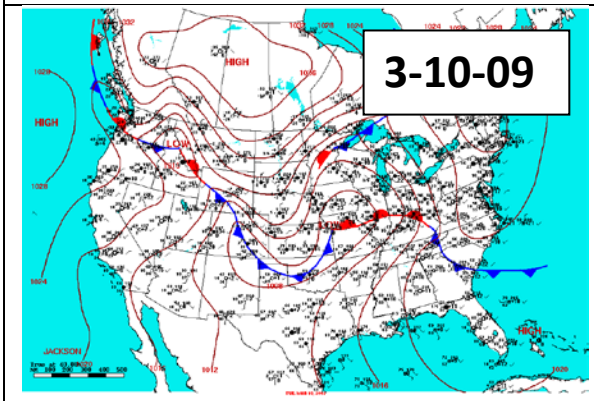
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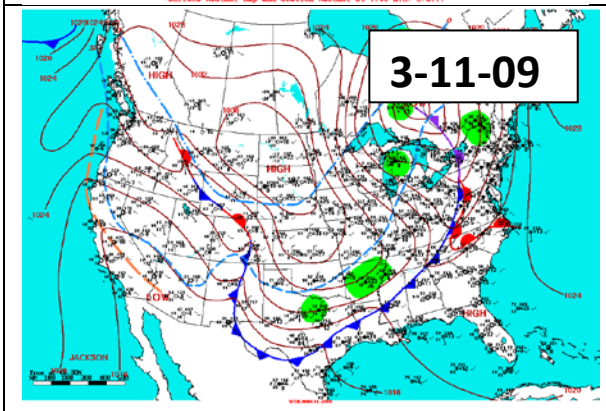
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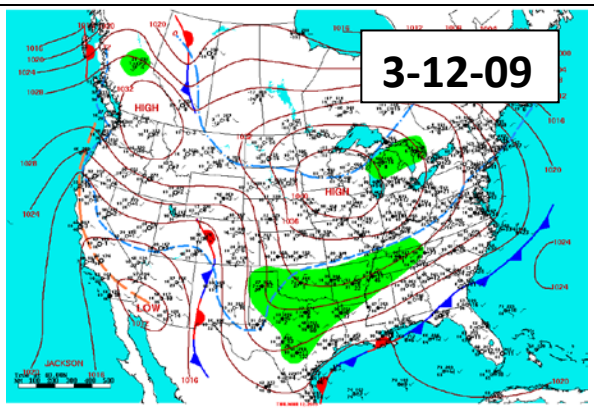
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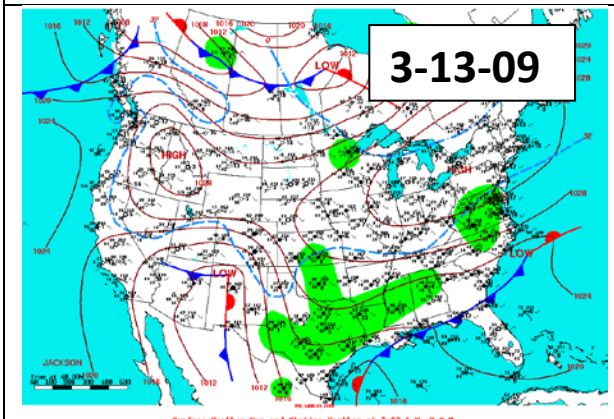
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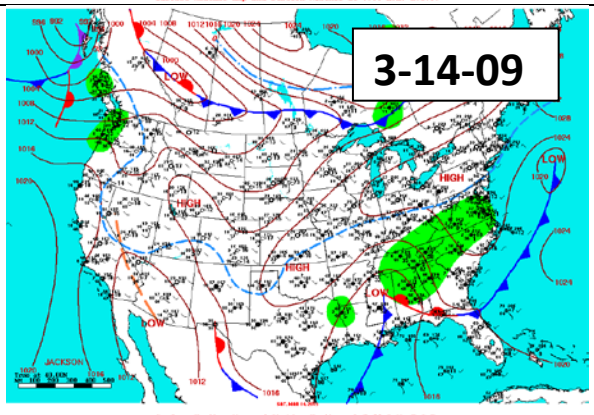
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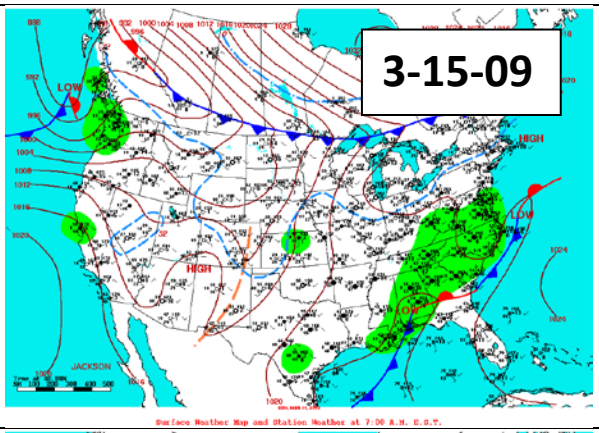
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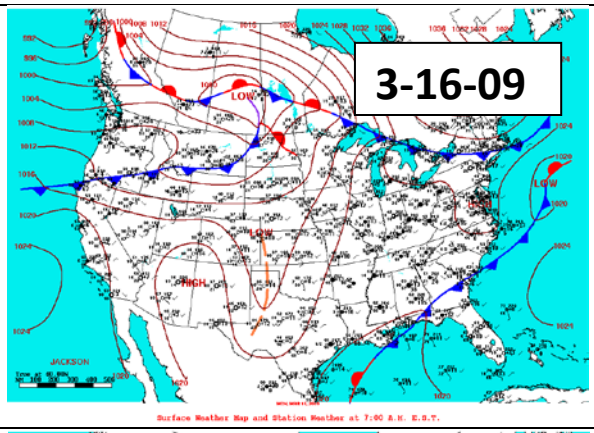
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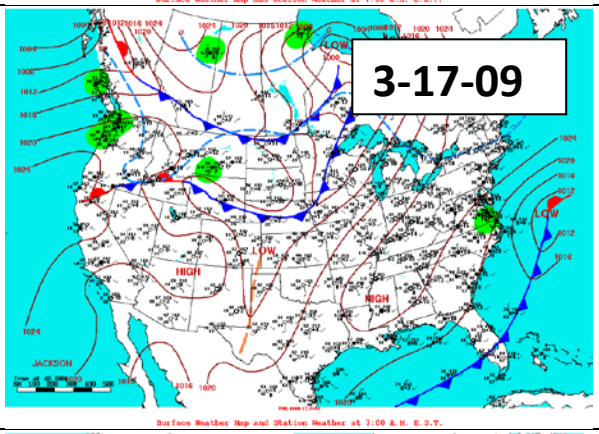
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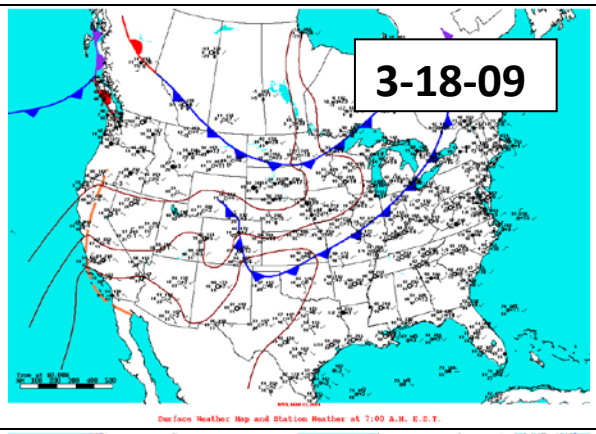
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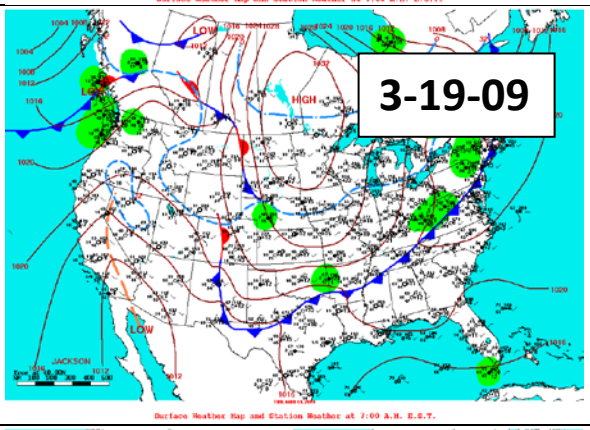
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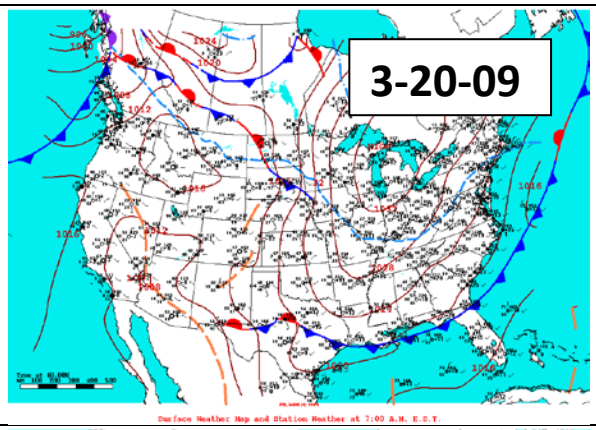
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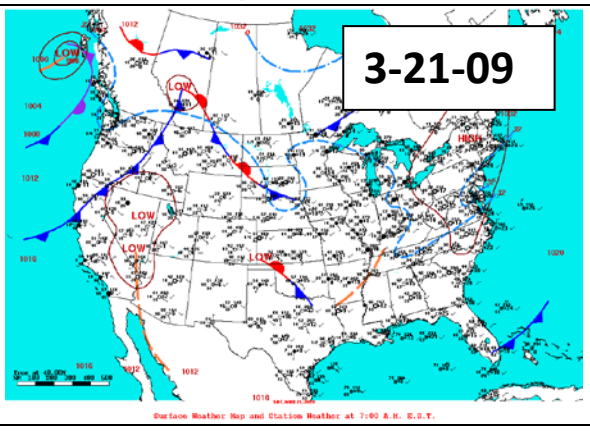
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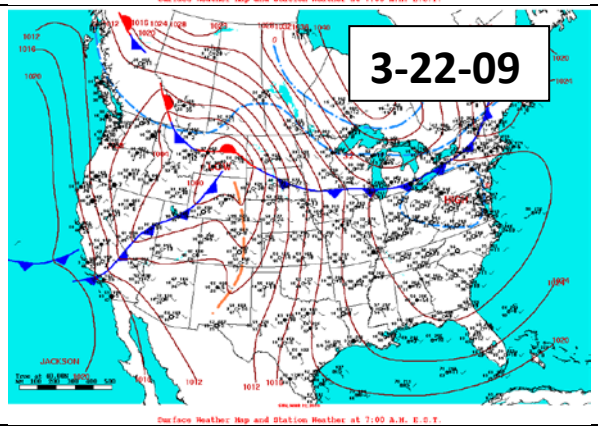
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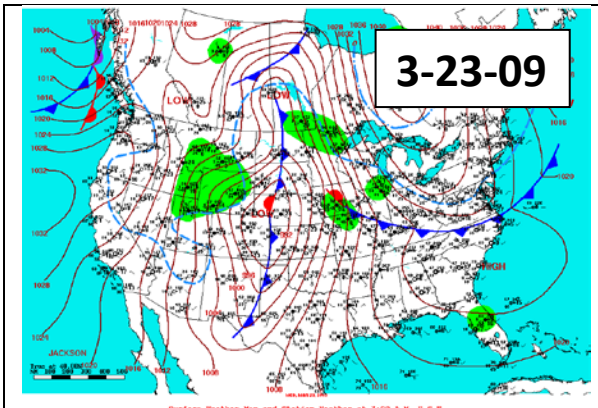
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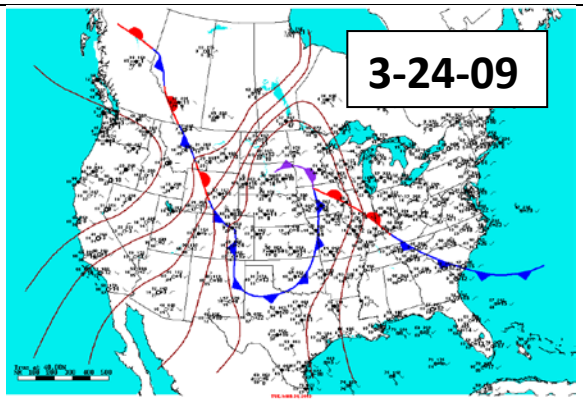
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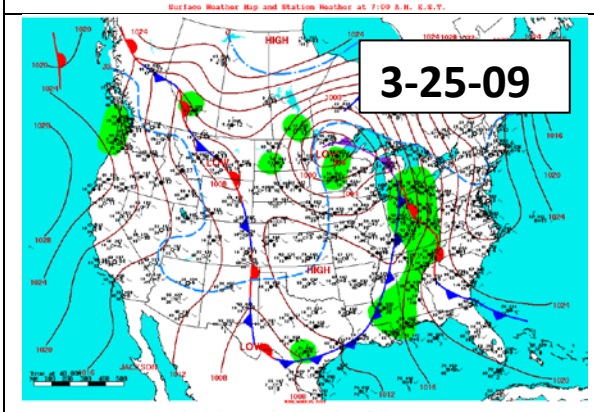
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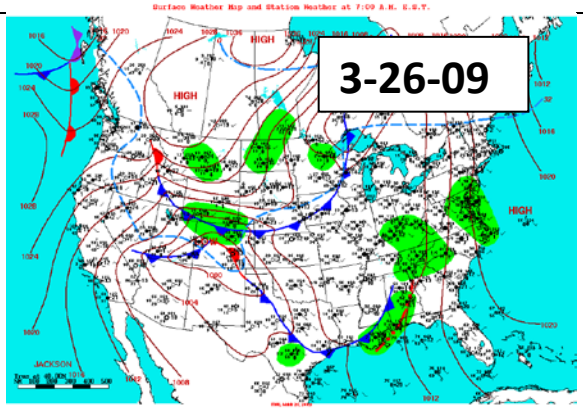
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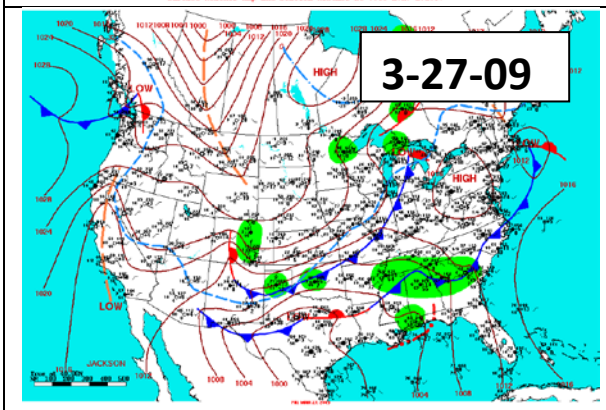
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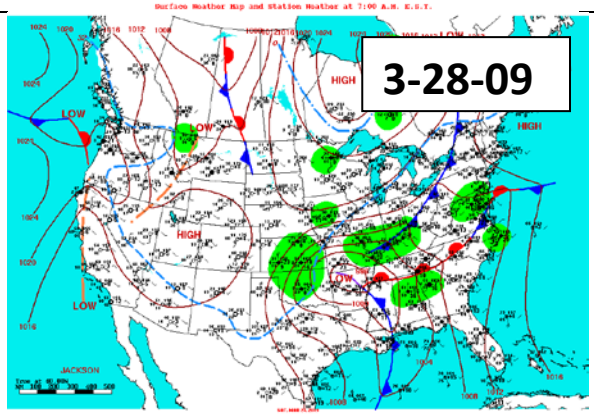
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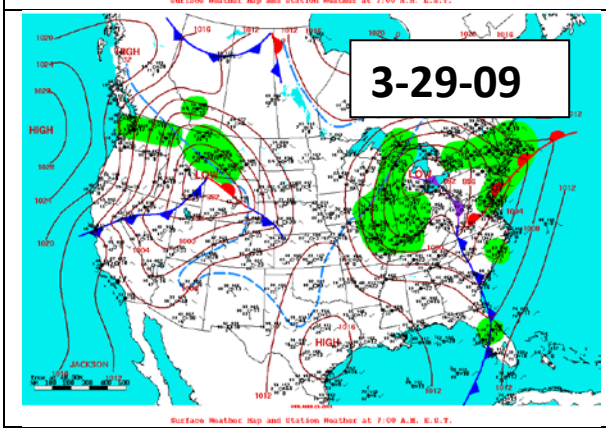
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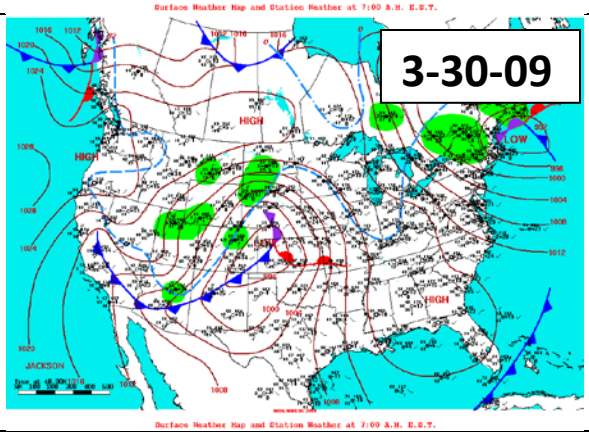
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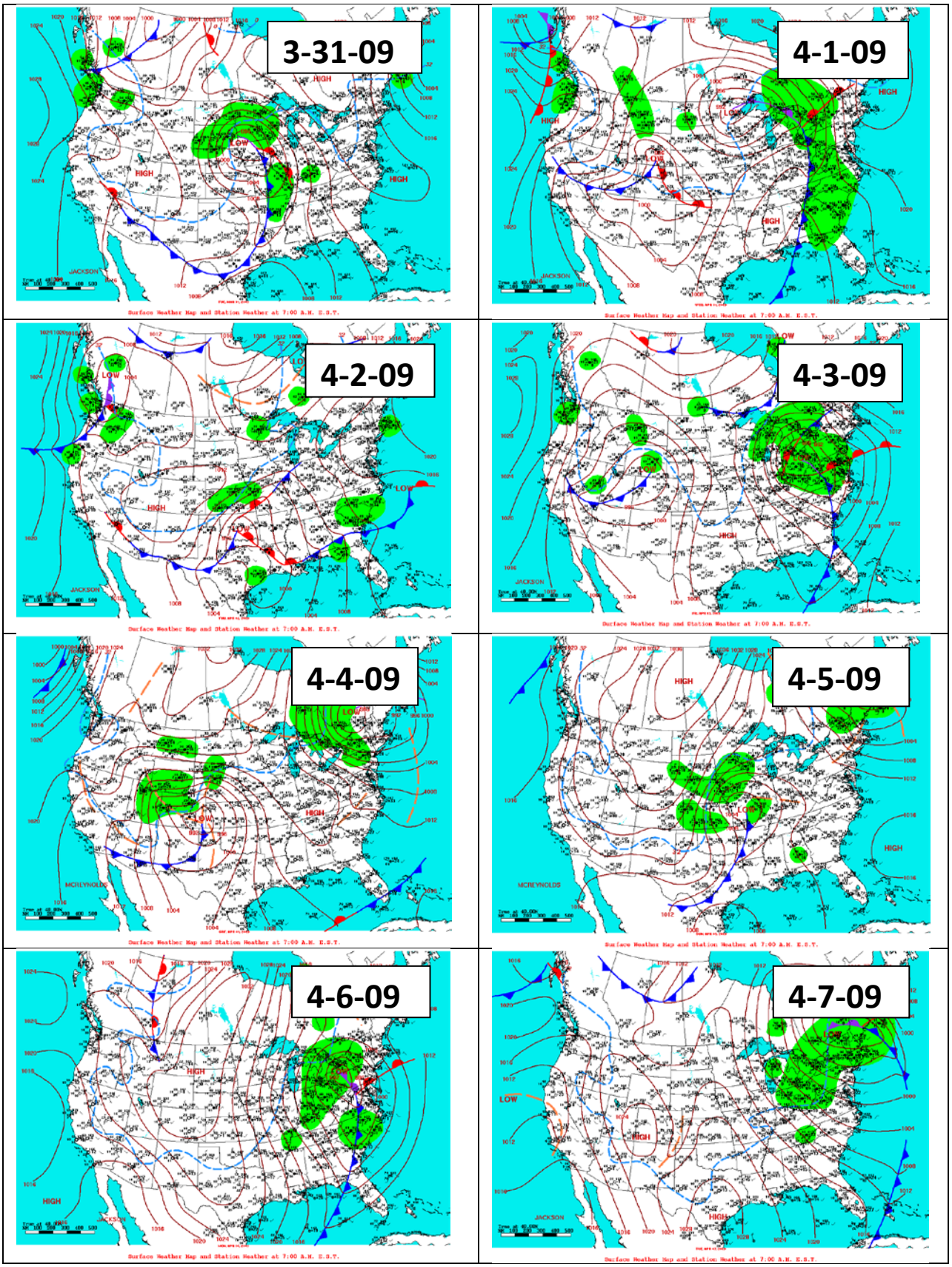
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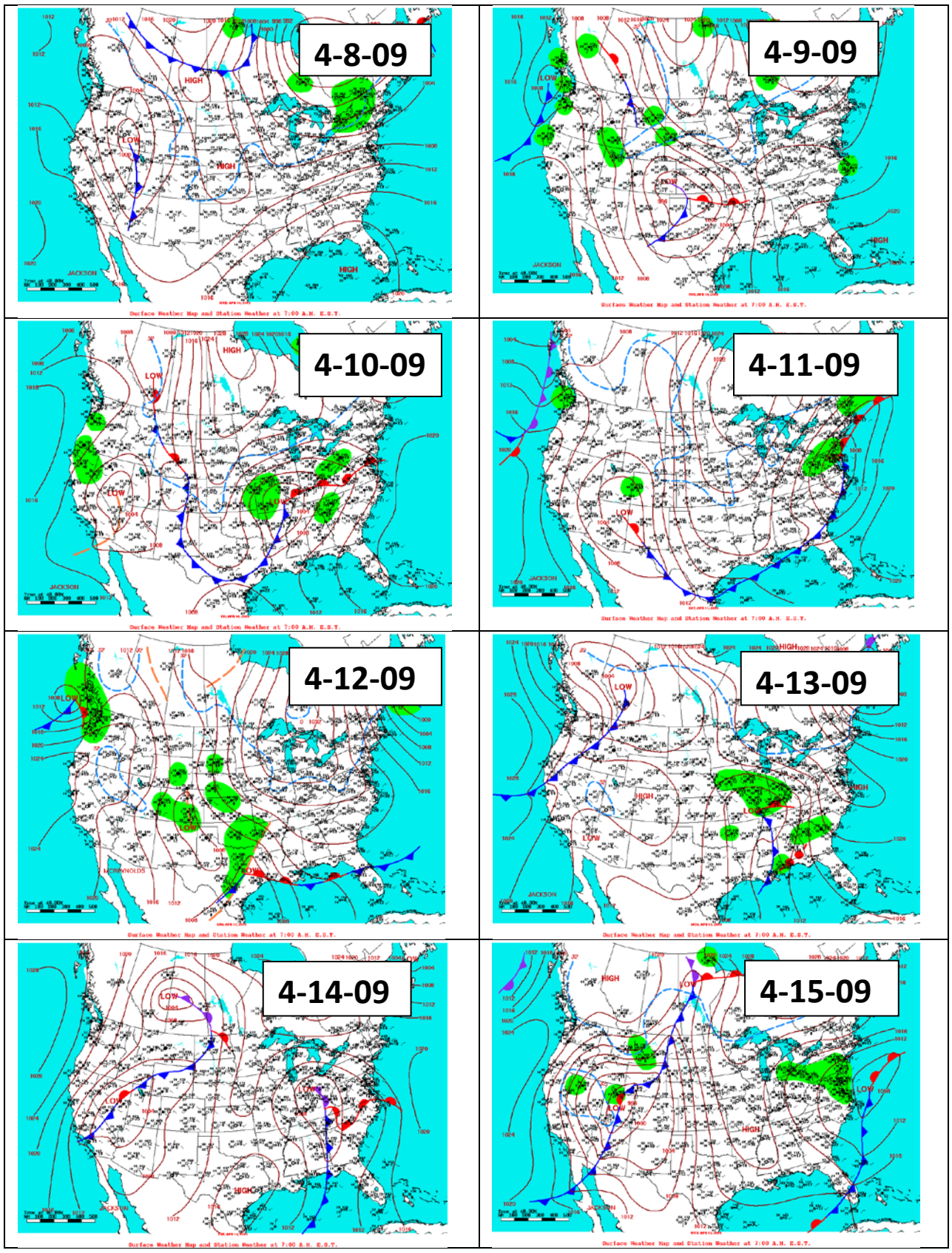
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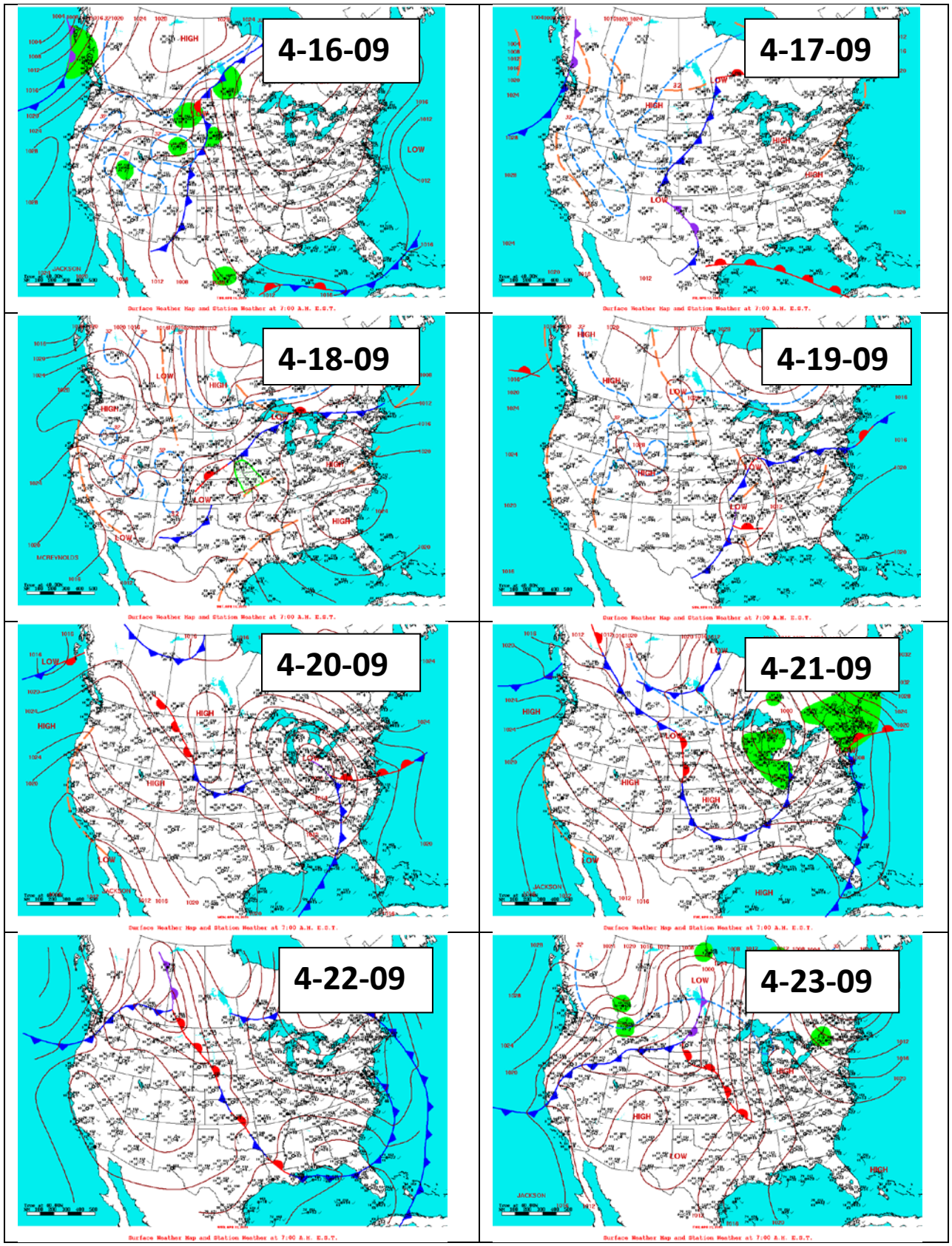
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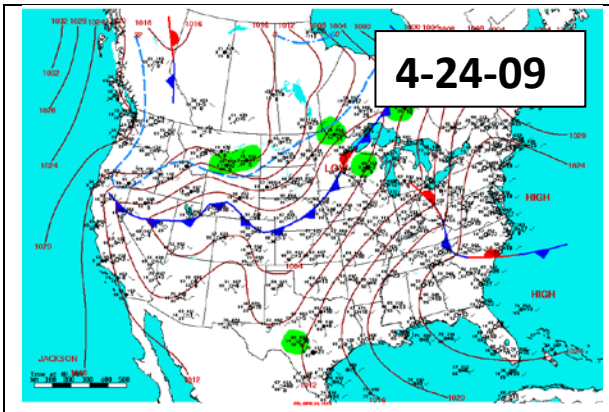
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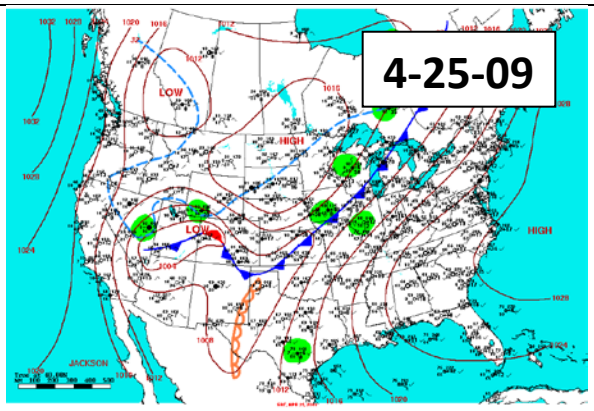
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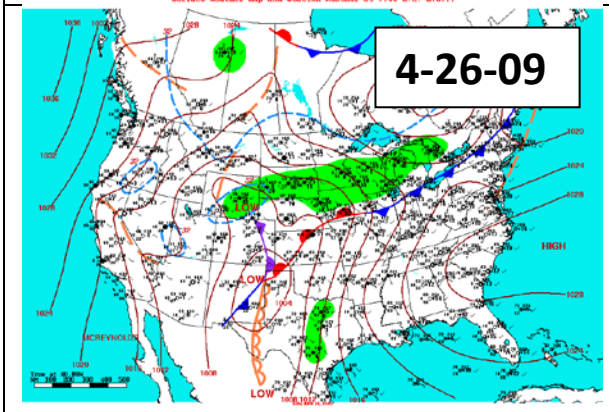
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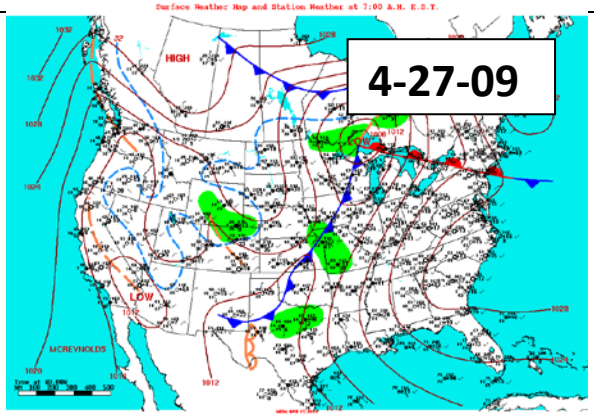
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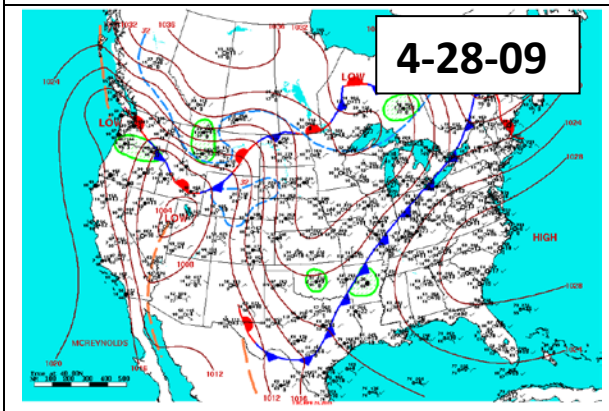
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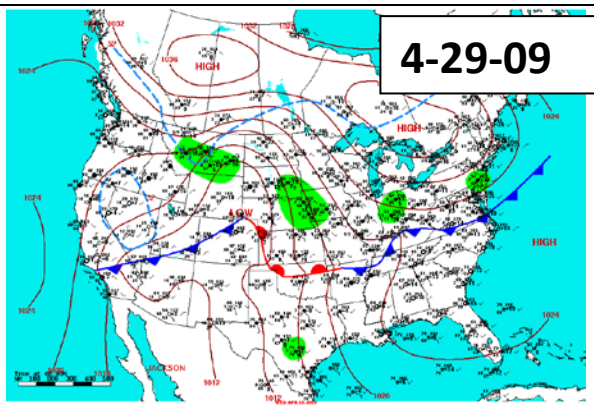
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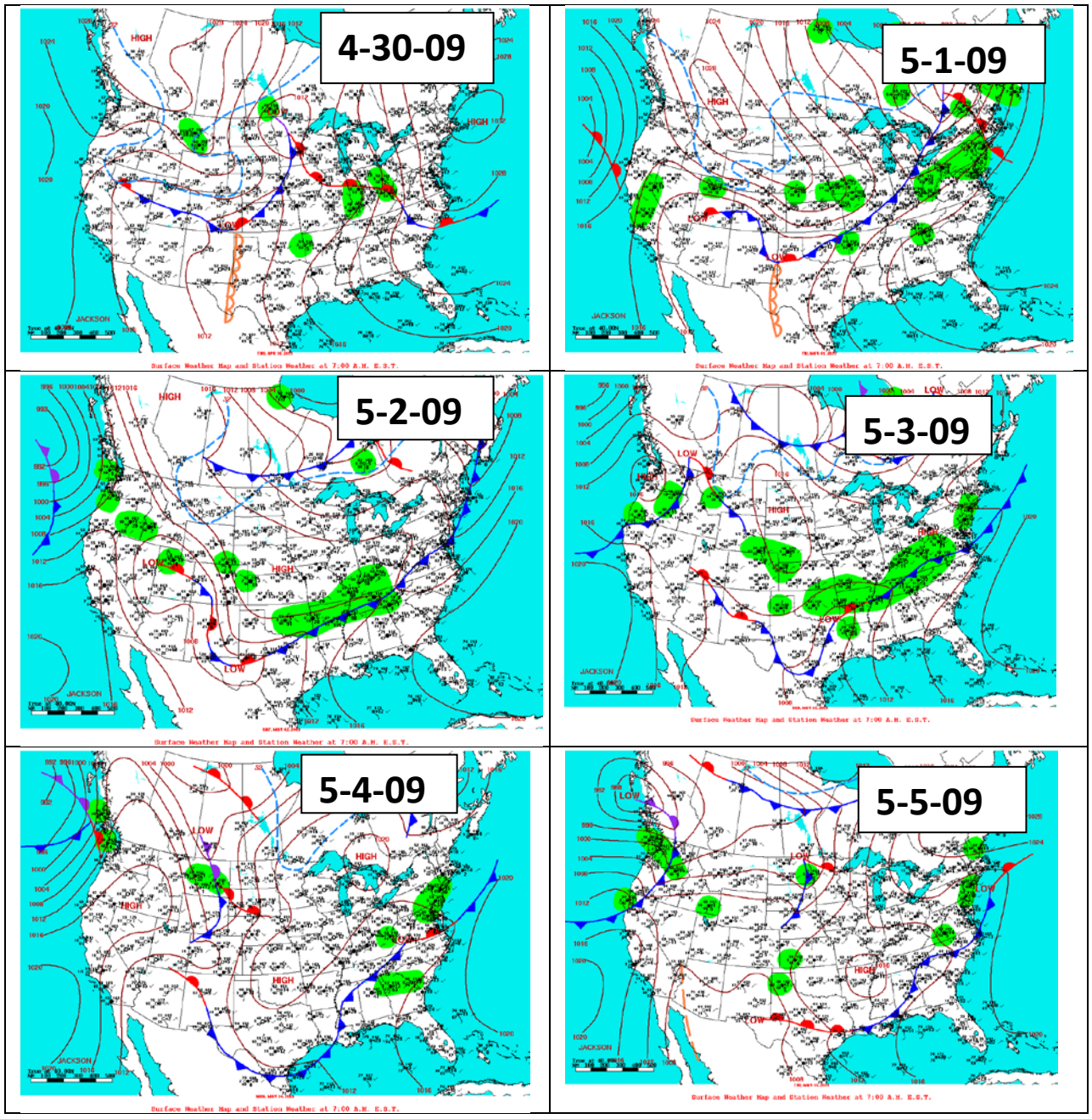
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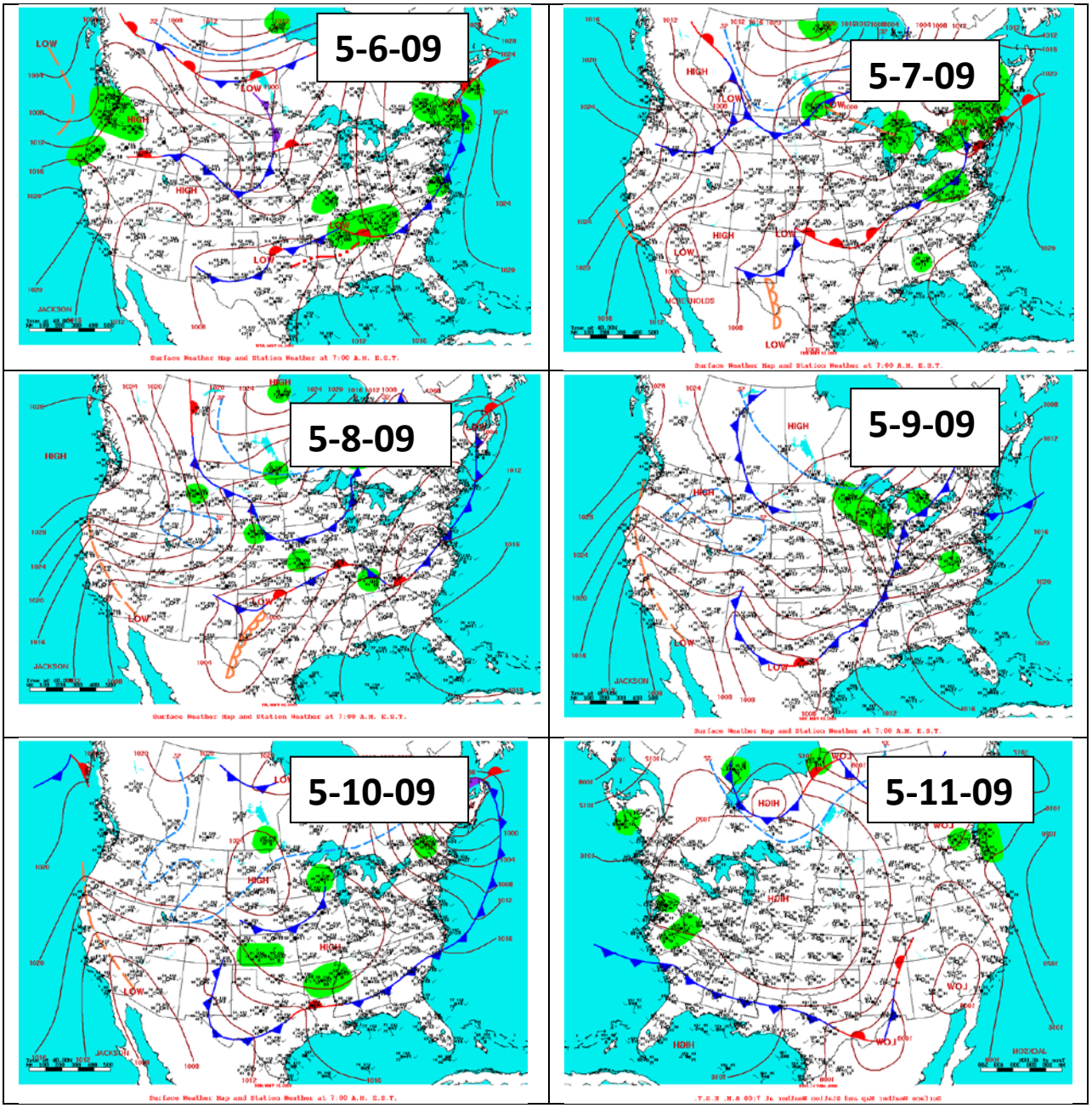
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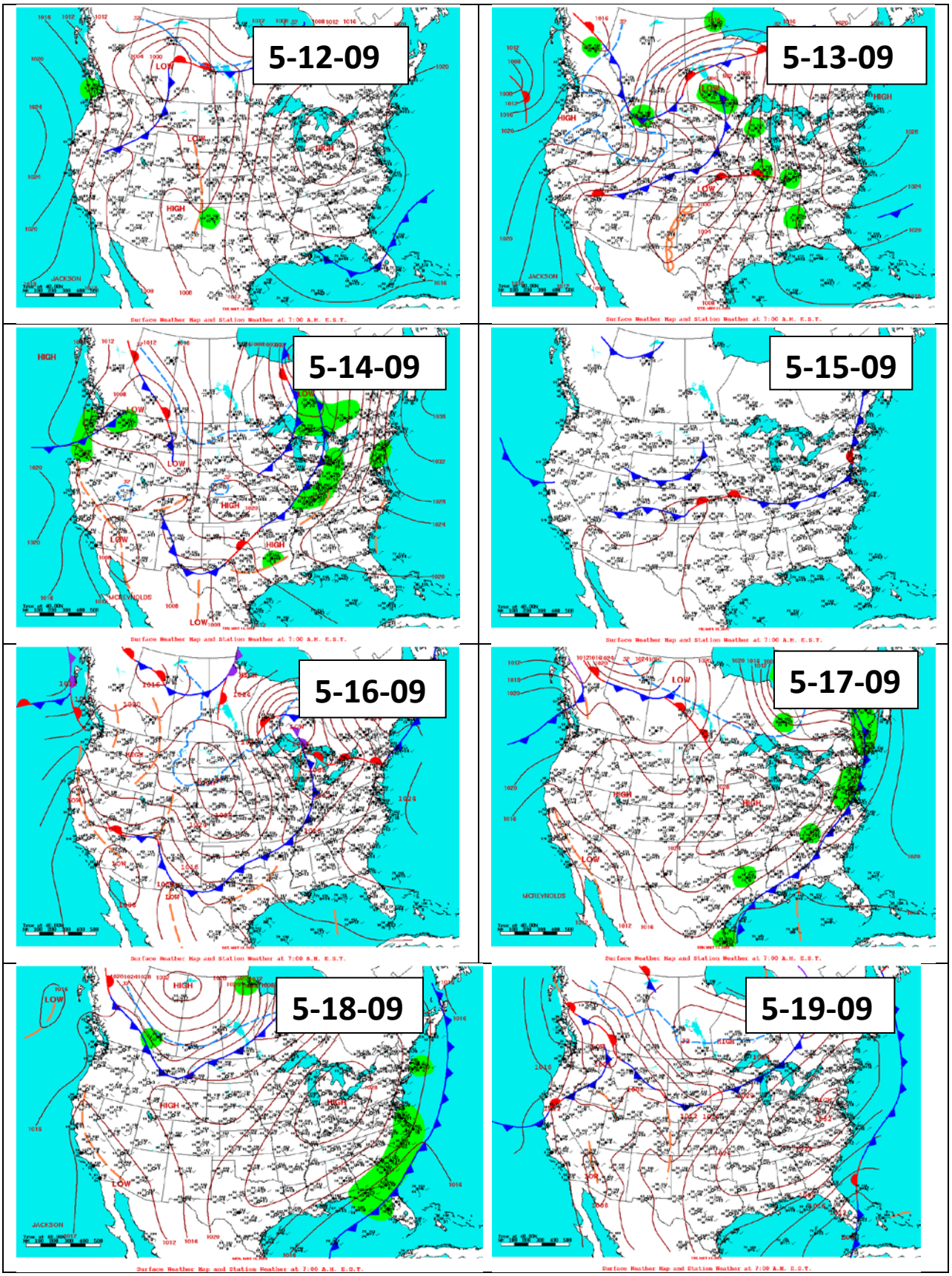
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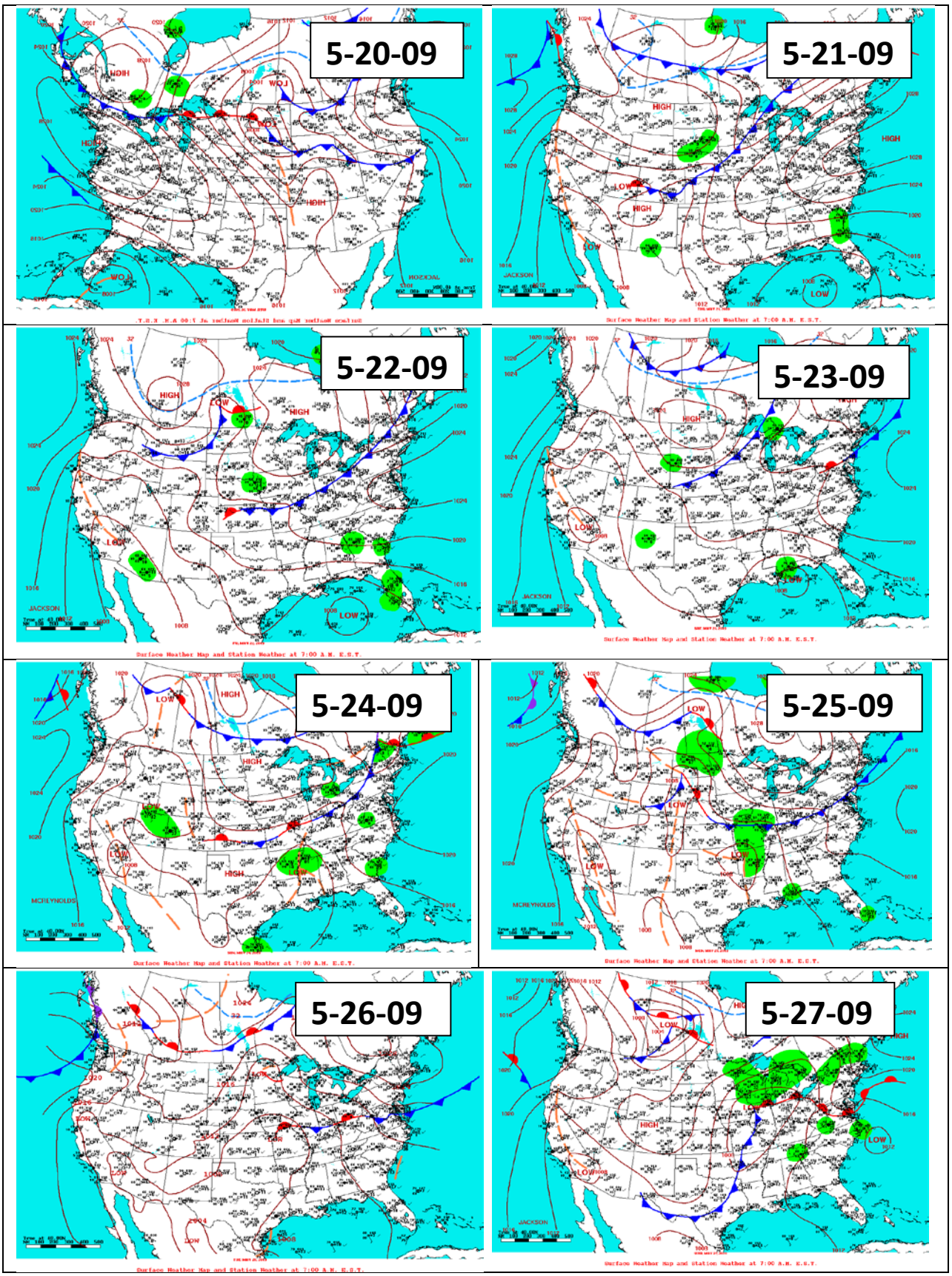
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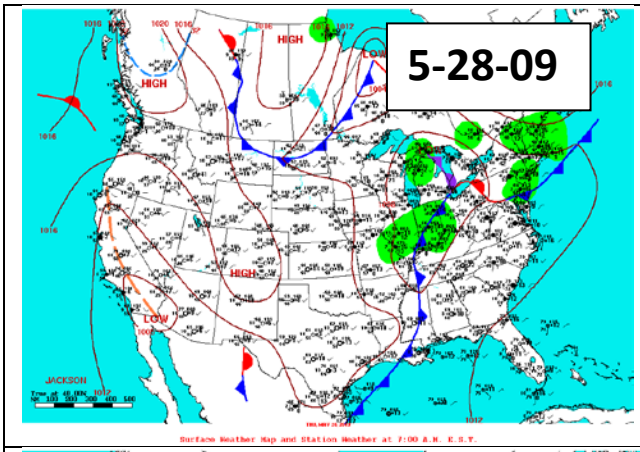
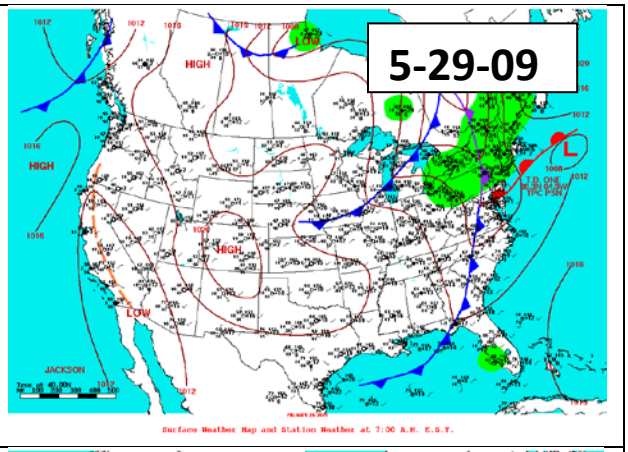
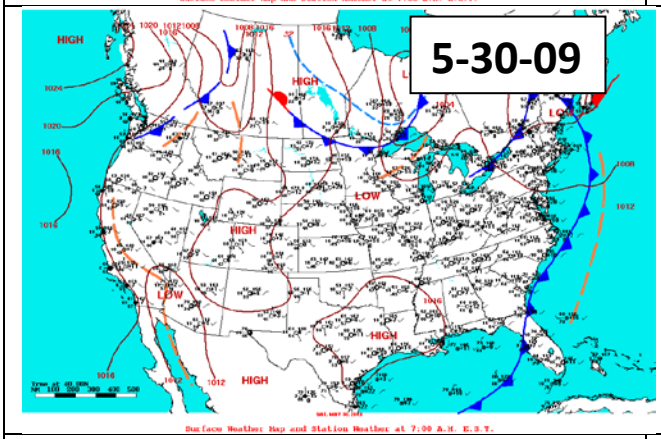
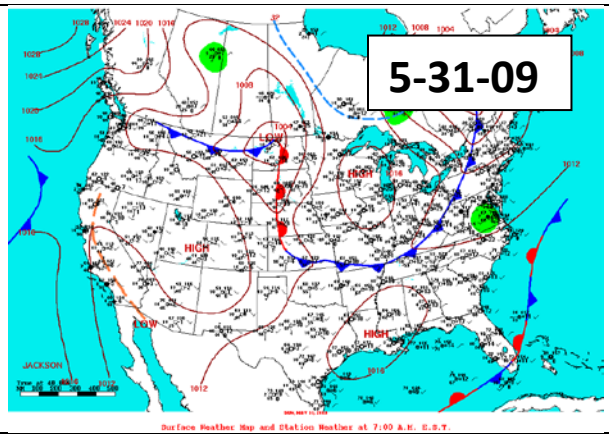
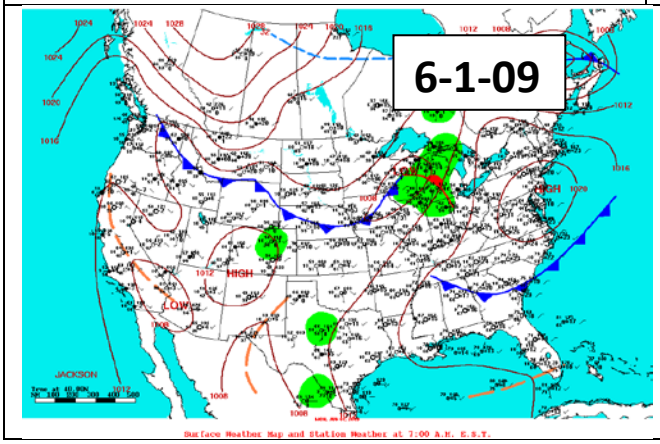


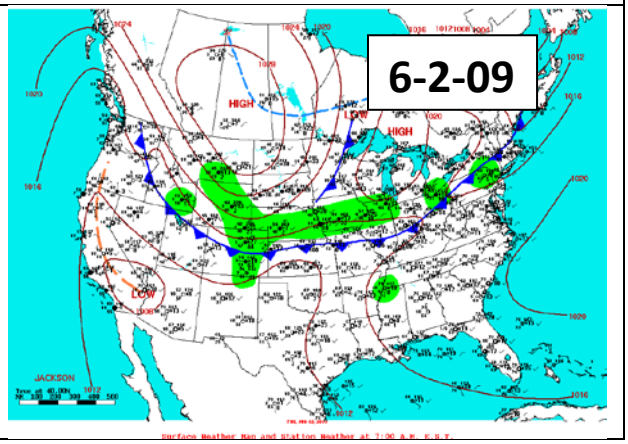


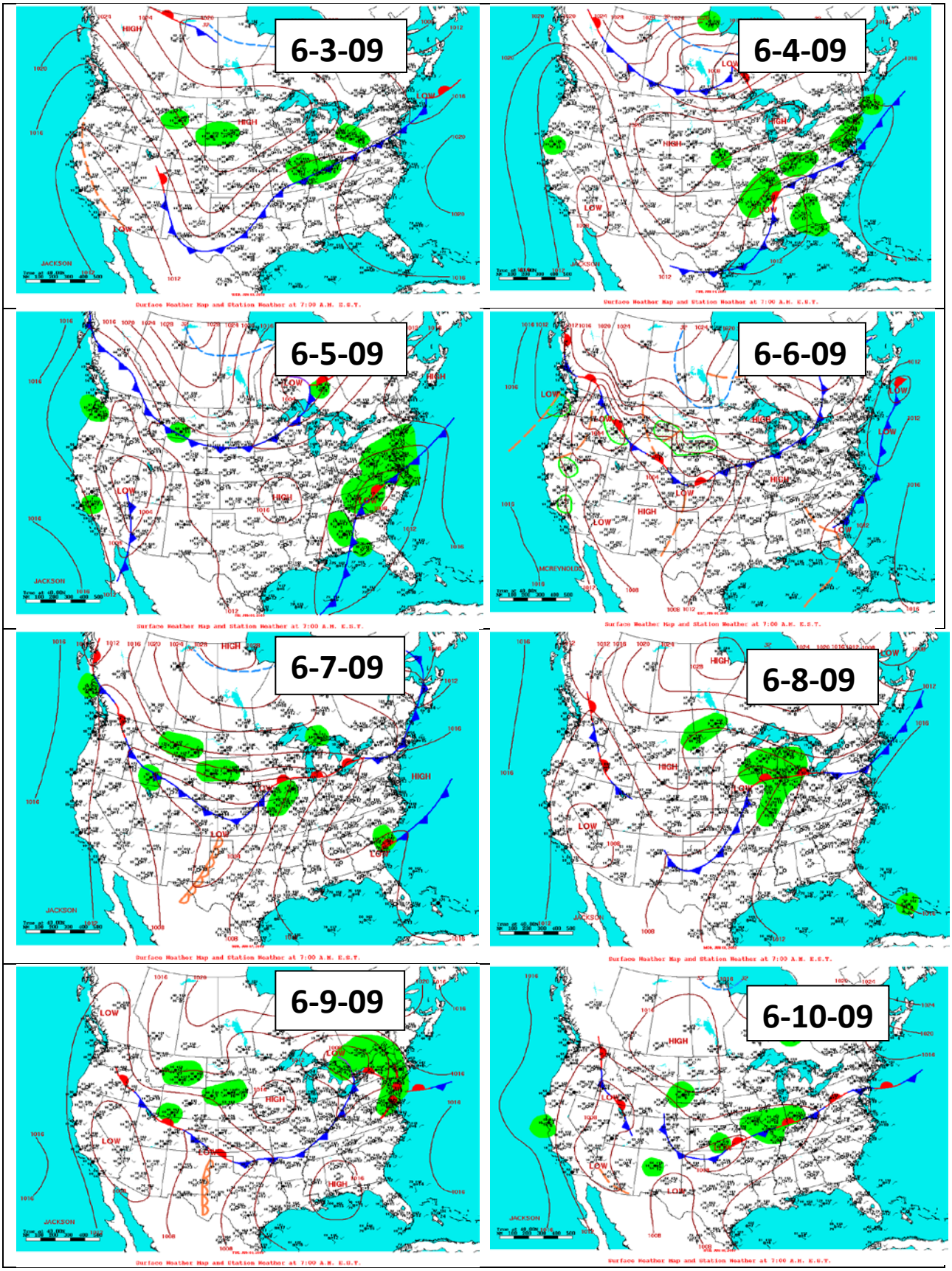




Period 9



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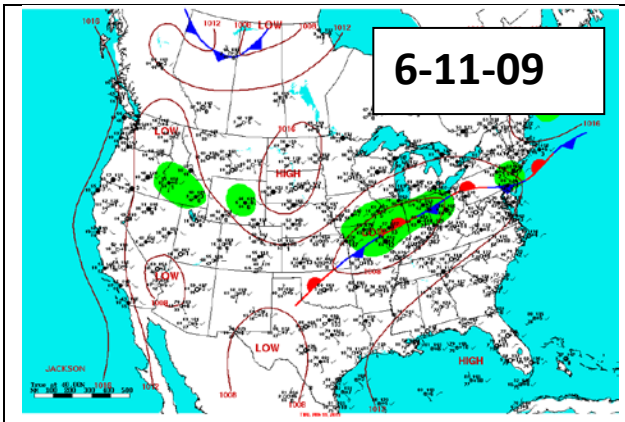
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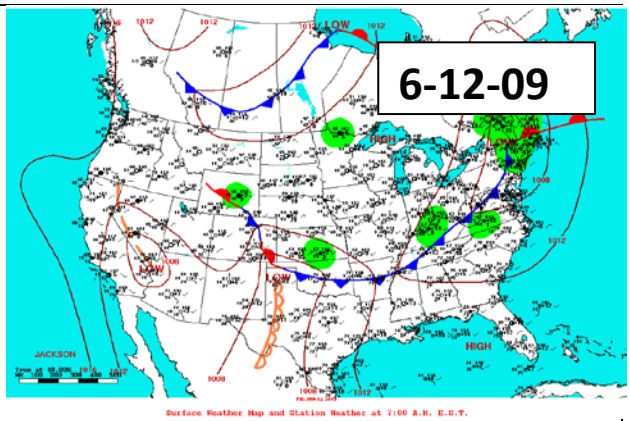
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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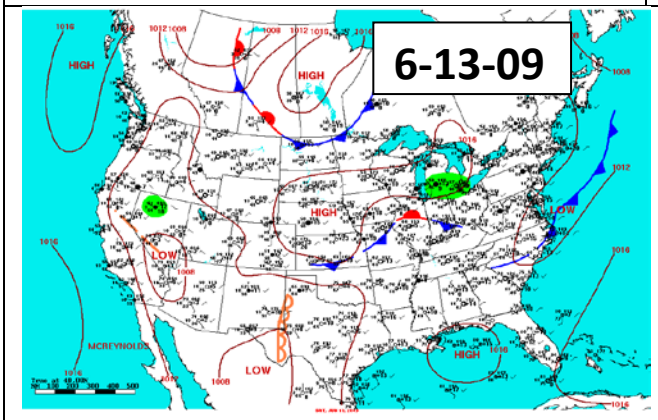
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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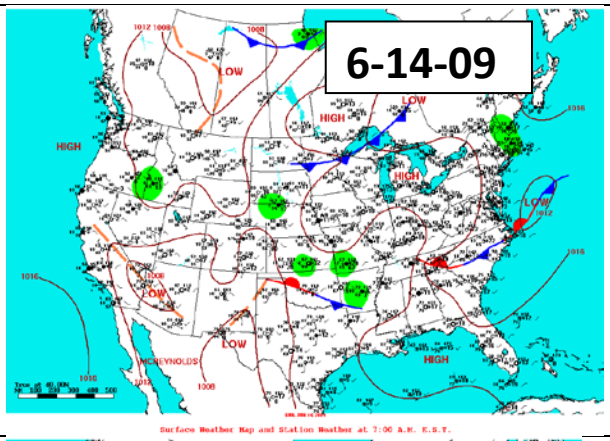
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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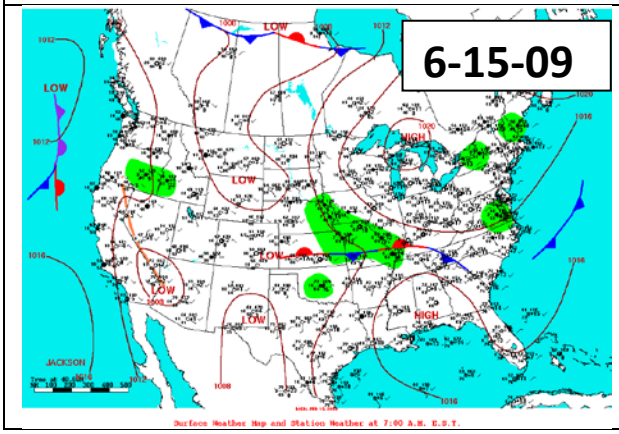
HIGH
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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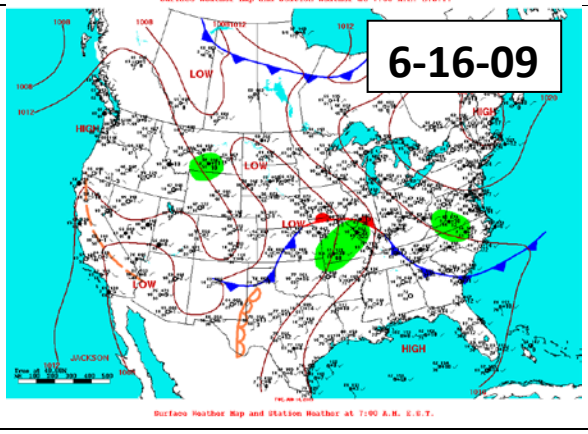
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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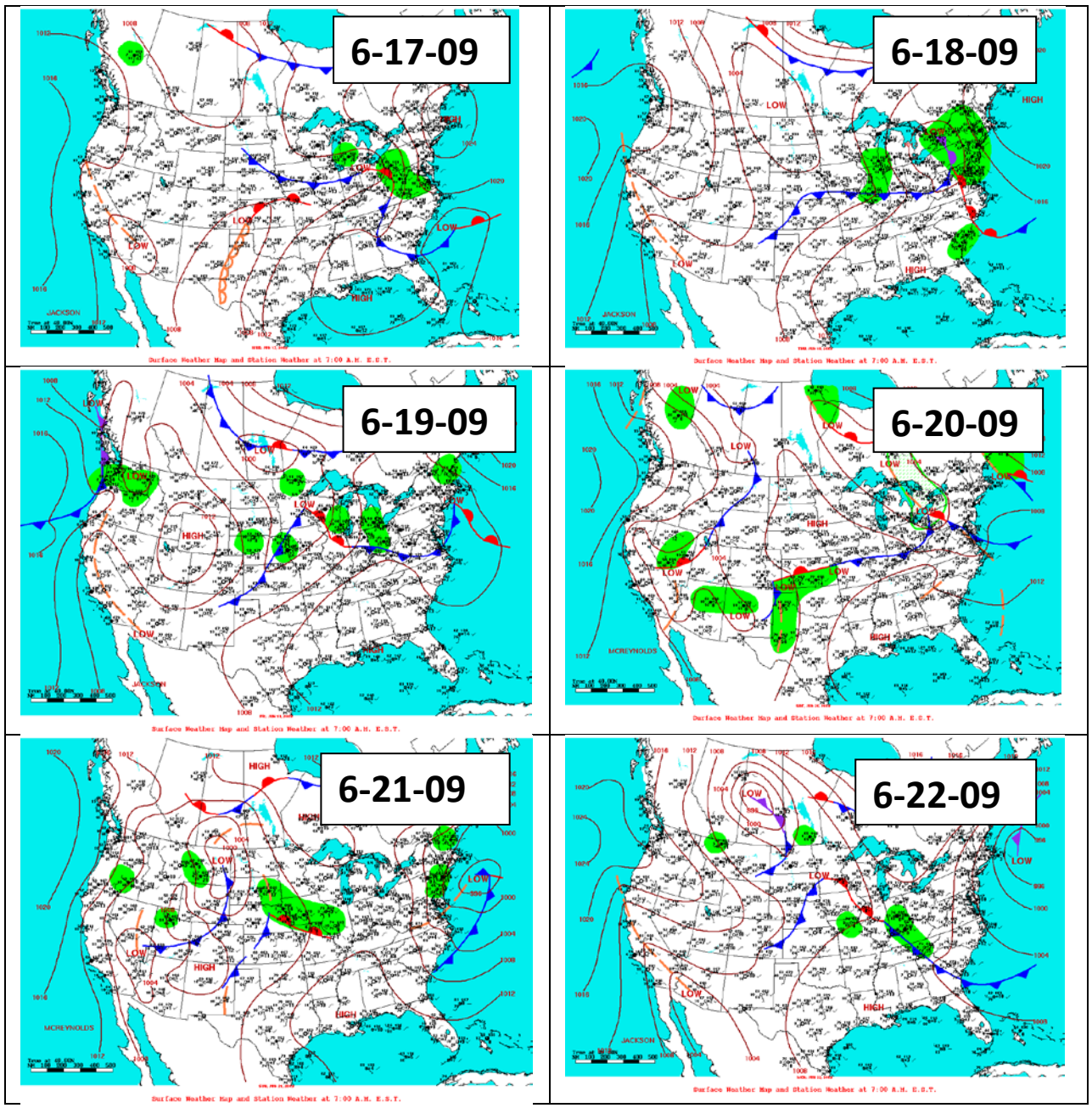
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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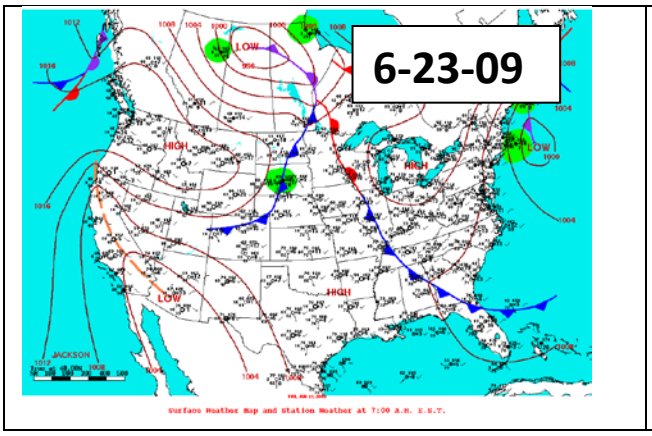
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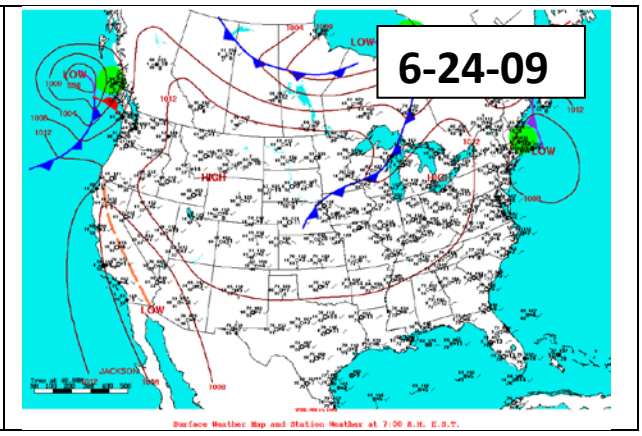
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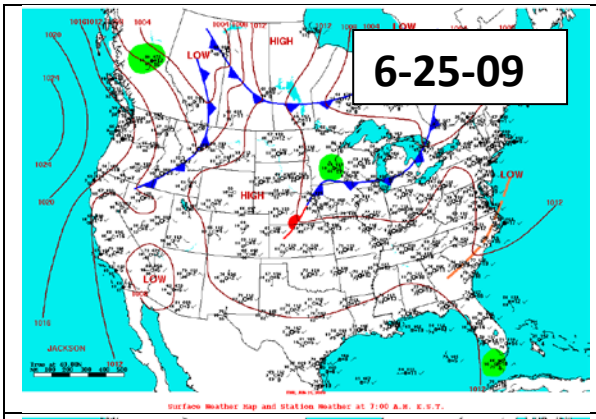
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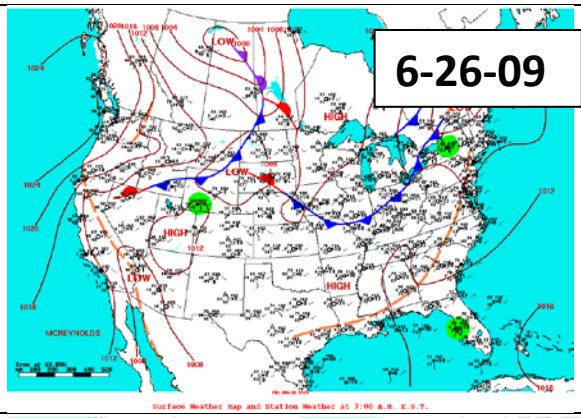
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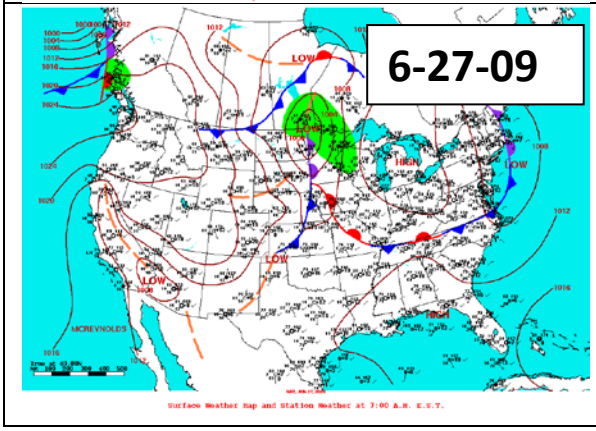
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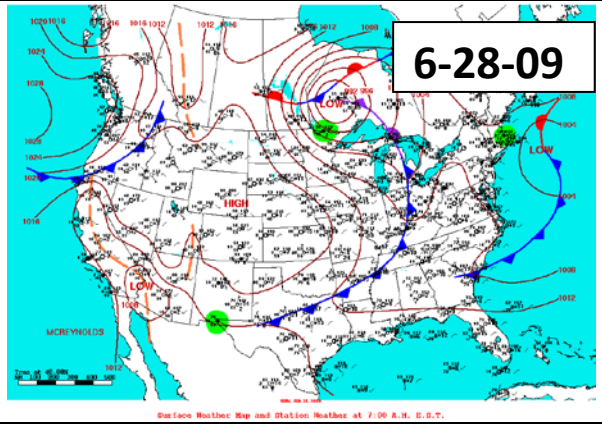
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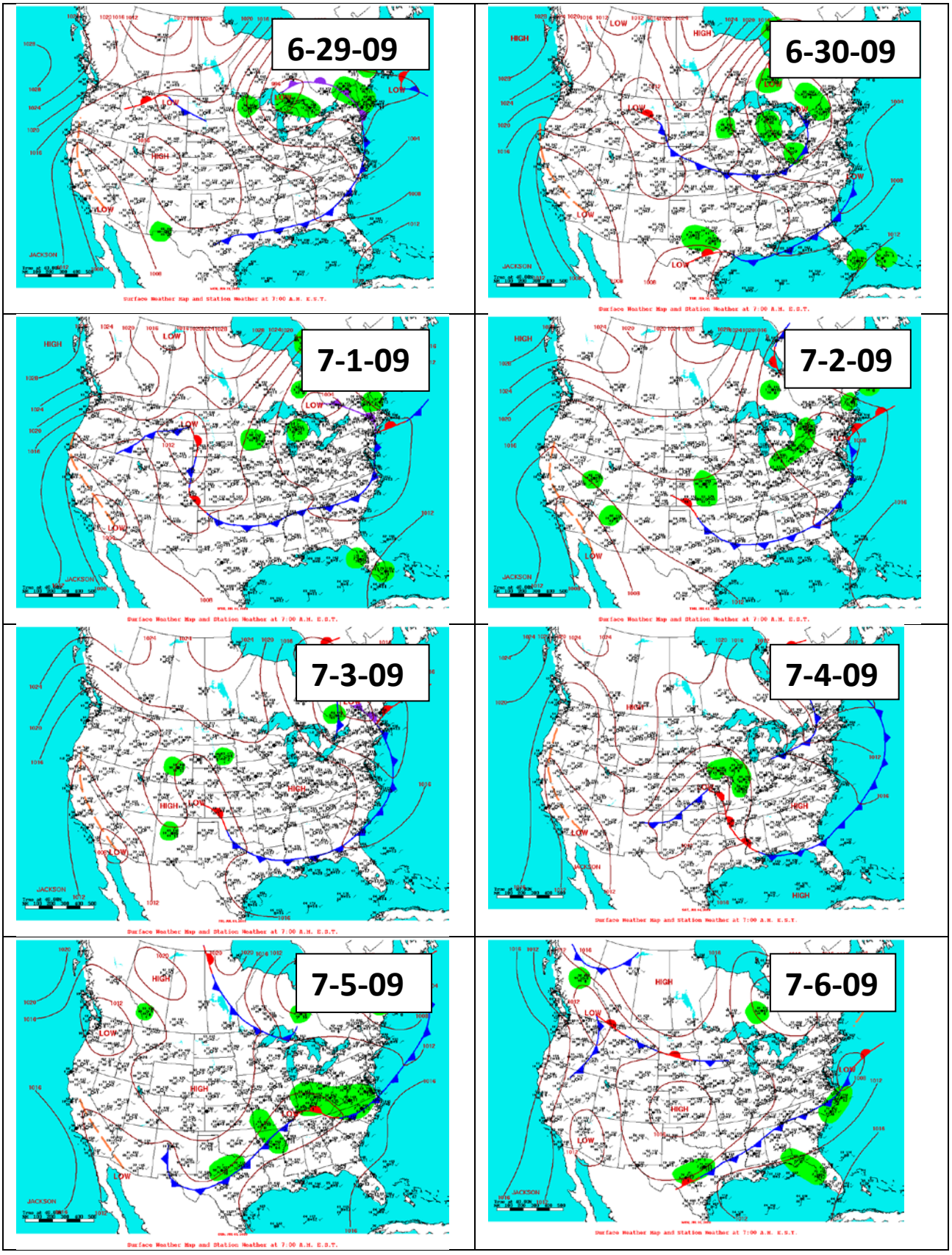
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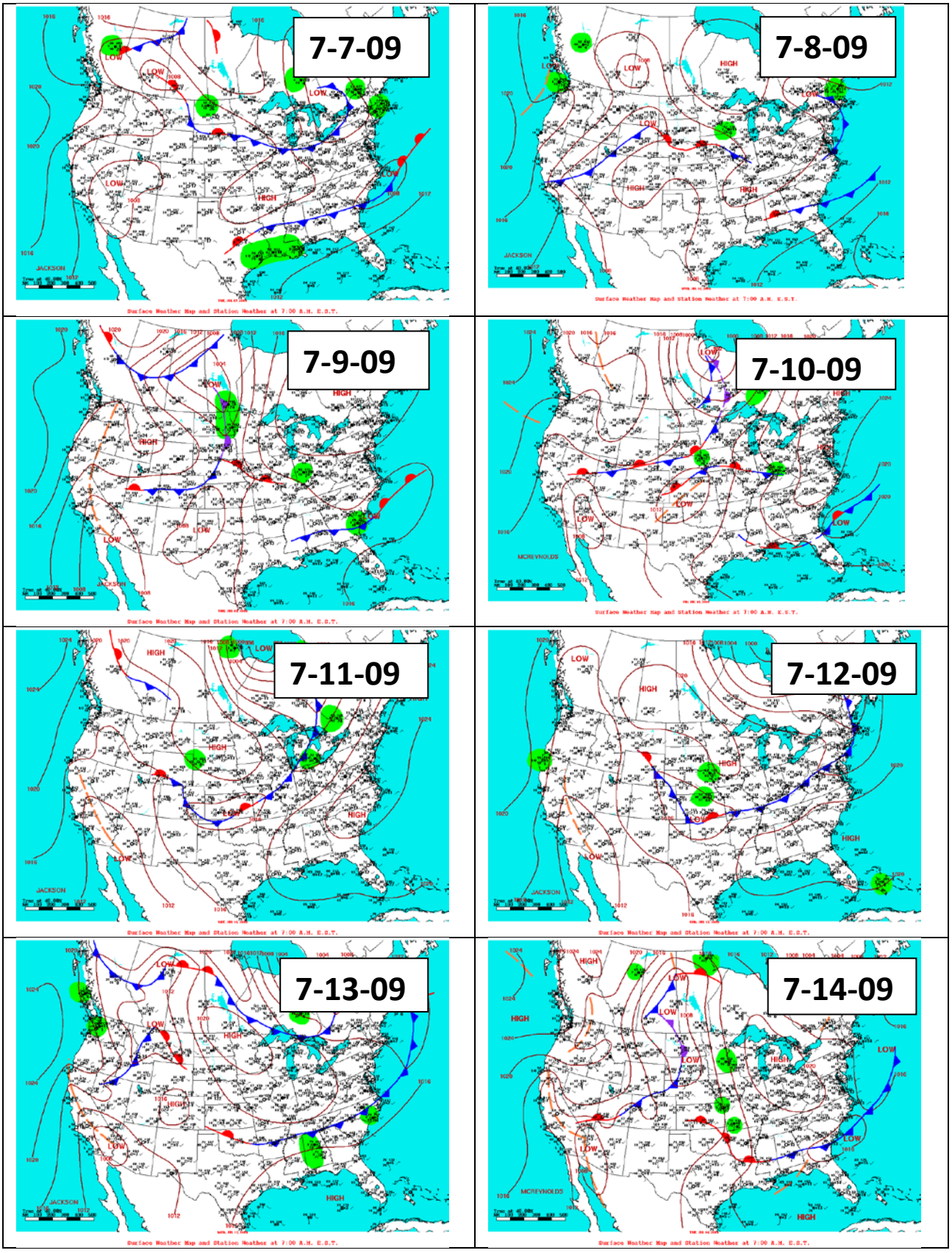
7-6-09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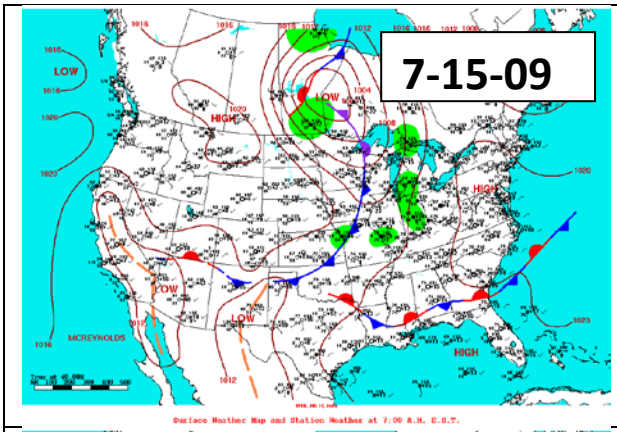
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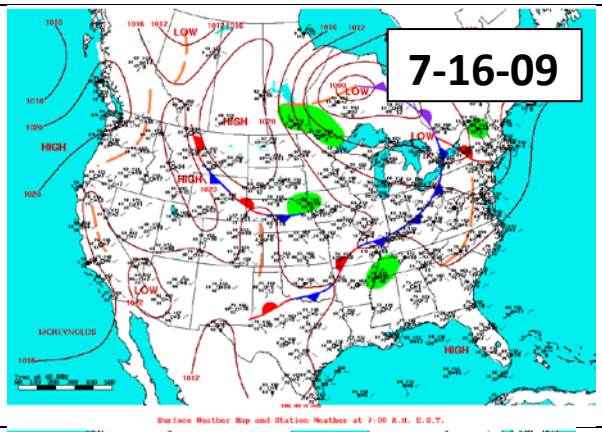
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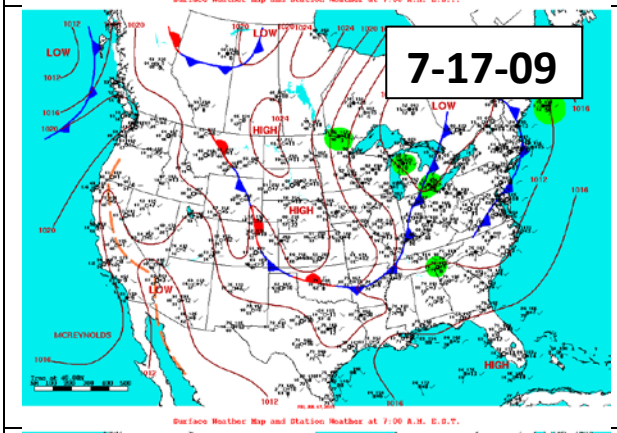
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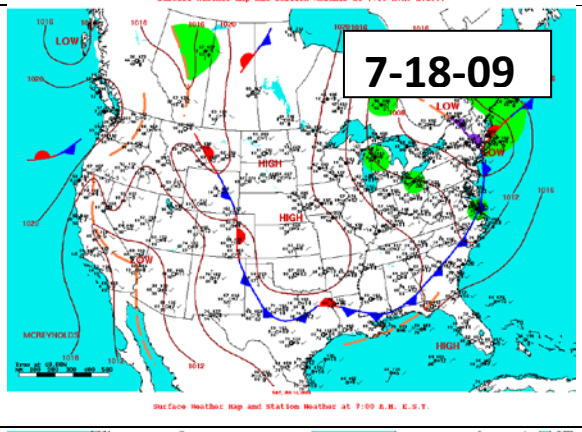
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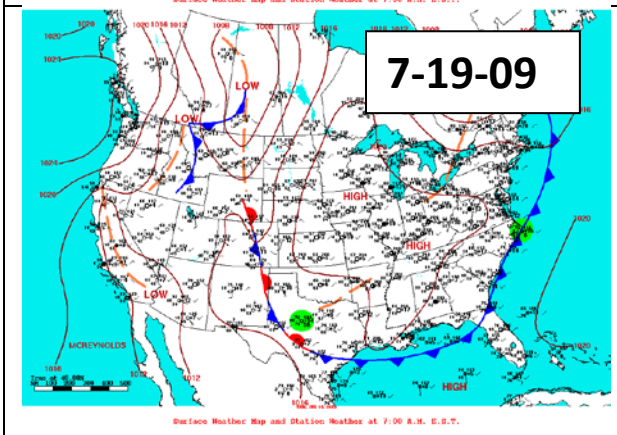
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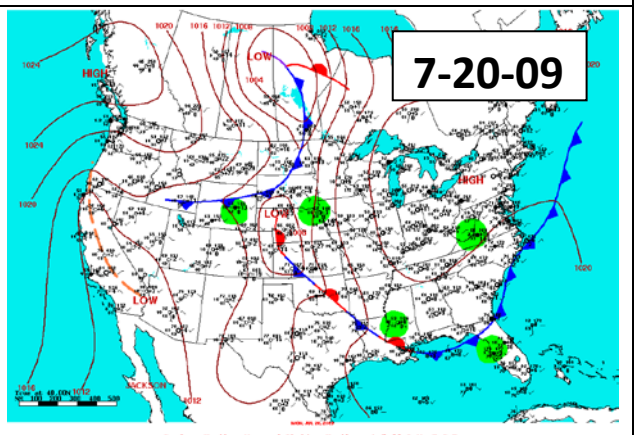
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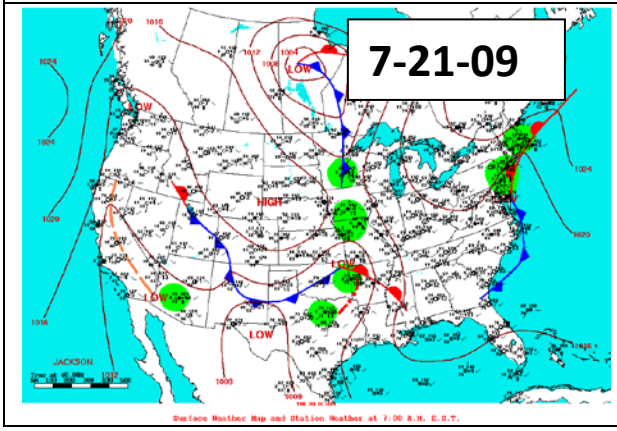
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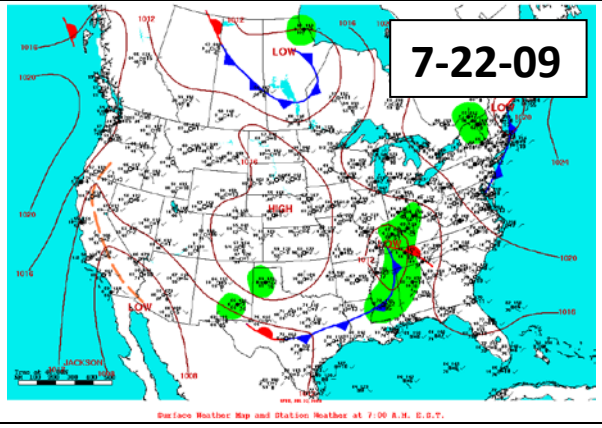
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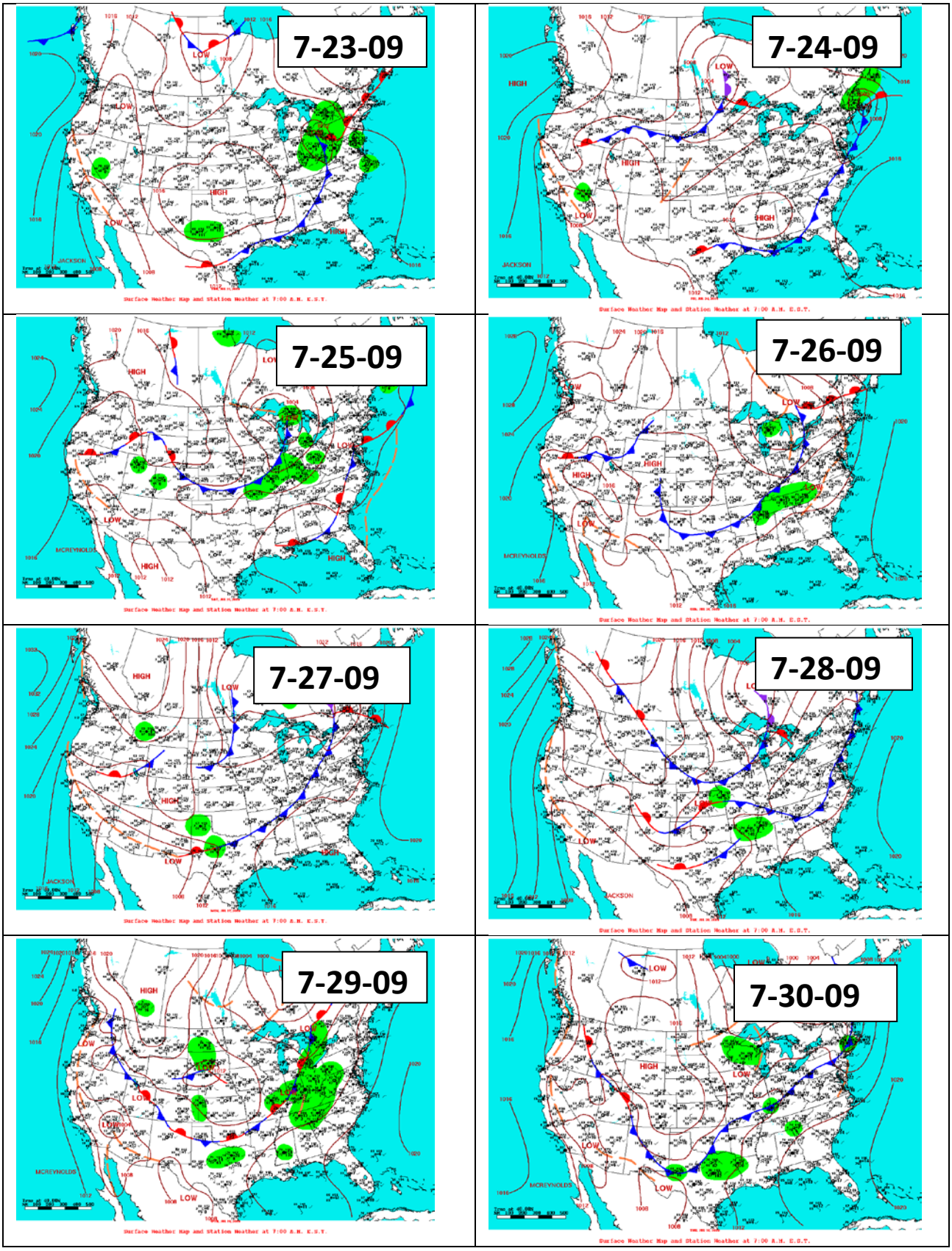
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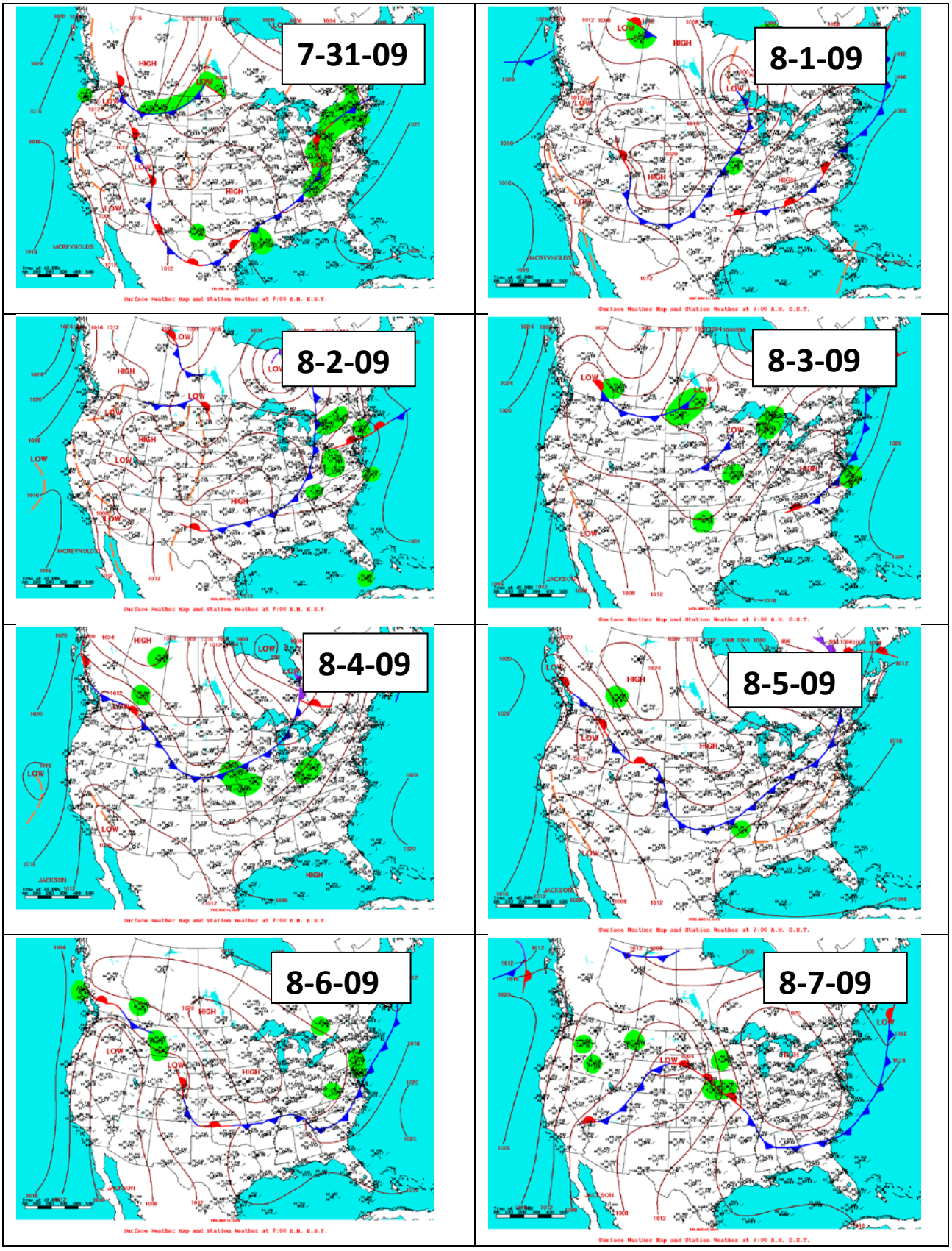
7-30-09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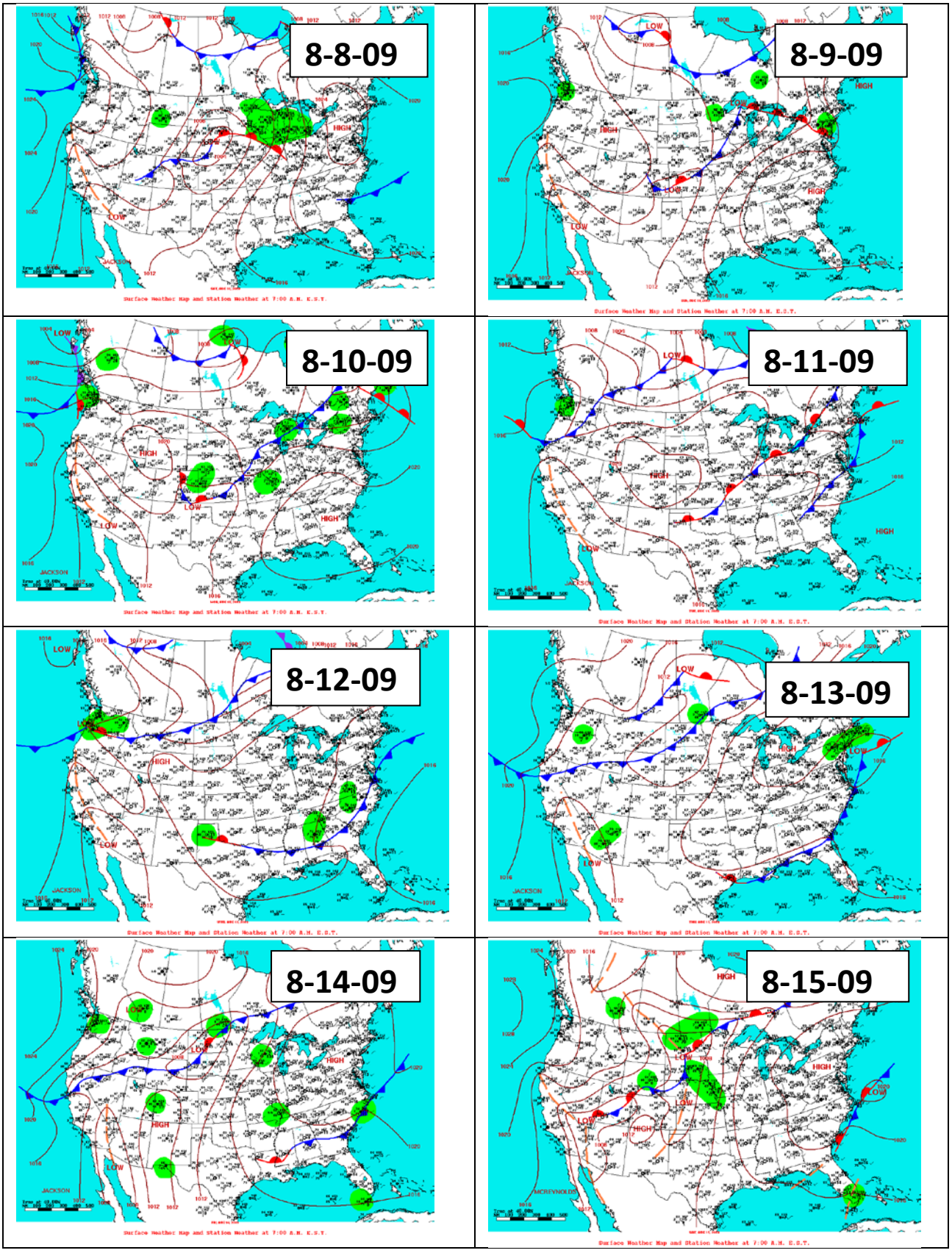
8-7-09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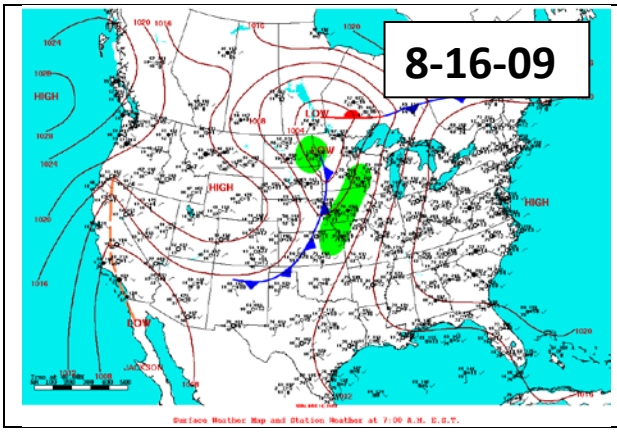
8-15-09


8-16-09
HIGH
LOW
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HIGH
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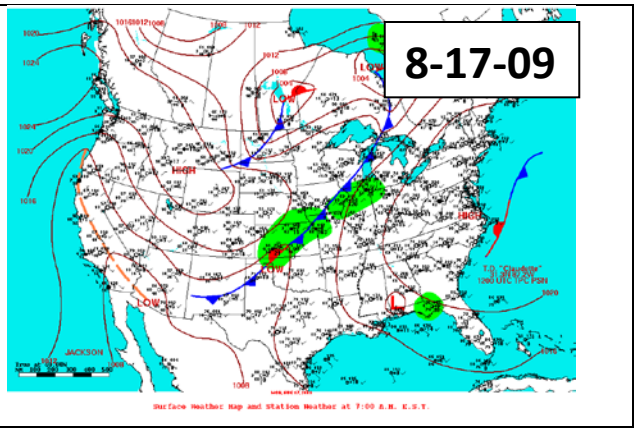
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-17-09
HIGH
LOW
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

6.10 Daily Weather conditions

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
Period 6				
9/10/2008	99.33	704	N/A	21.7
9/11/2008	99.32	915	N/A	16.8
9/12/2008	98.85	331	N/A	20.8
9/13/2008	98.30	833	N/A	23.8
9/14/2008	97.37	257	N/A	22.1
9/15/2008	98.38	998	N/A	16.2
9/16/2008	99.15	1030	N/A	16.0
9/17/2008	99.19	768	N/A	16.2
9/18/2008	99.63	764	N/A	17.6
9/19/2008	99.63	818	N/A	17.2
9/20/2008	99.36	751	N/A	18.4
9/21/2008	99.58	740	N/A	19.0
9/22/2008	99.86	717	N/A	19.7
9/23/2008	99.94	732	N/A	19.6
9/24/2008	99.75	716	N/A	19.7
9/25/2008	99.72	713	N/A	19.1
9/26/2008	99.40	745	N/A	18.4
9/27/2008	98.89	728	N/A	18.3
9/28/2008	99.07	725	N/A	17.3
9/29/2008	98.88	660	N/A	17.2
9/30/2008	98.52	926	N/A	13.8
10/1/2008	98.40	800	N/A	10.7
10/2/2008	98.58	854	N/A	11.1
10/3/2008	98.62	574	N/A	11.6
10/4/2008	99.40	699	N/A	9.6
10/5/2008	99.61	700	N/A	10.7
10/6/2008	99.58	674	N/A	15.7
10/7/2008	99.33	454	N/A	14.9
10/8/2008	98.33	246	N/A	15.2
10/9/2008	98.83	671	N/A	12.7
10/10/2008	99.35	681	N/A	13.1
10/11/2008	99.60	632	N/A	17.8
10/12/2008	99.82	658	N/A	19.2
10/13/2008	99.78	677	N/A	20.7
10/14/2008	99.52	574	N/A	18.7
10/15/2008	99.05	598	N/A	16.6
10/16/2008	99.23	820	N/A	12.5
10/17/2008	99.54	765	N/A	10.7
10/18/2008	99.66	807	N/A	10.1
10/19/2008	99.86	640	N/A	8.3

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
10/20/2008	99.40	632	N/A	10.8
10/21/2008	99.76	684	N/A	8.1
10/22/2008	100.08	631	N/A	5.6
10/23/2008	99.86	626	N/A	7.3
10/24/2008	99.02	227	N/A	10.2
10/25/2008	98.35	234	N/A	7.1
10/26/2008	98.03	614	N/A	9.5
10/27/2008	99.03	616	N/A	4.2
10/28/2008	99.72	491	N/A	2.3
10/29/2008	99.21	602	N/A	3.4
10/30/2008	99.94	568	N/A	4.0
10/31/2008	99.96	540	N/A	11.9
11/1/2008	99.80	501	N/A	12.6
11/2/2008	99.69	587	N/A	12.7
11/3/2008	99.46	525	N/A	16.5
11/4/2008	99.41	522	N/A	13.7
11/5/2008	99.01	530	N/A	12.7
11/6/2008	98.56	565	N/A	14.8
11/7/2008	98.07	529	N/A	11.9
11/8/2008	97.71	283	N/A	4.0
11/9/2008	98.25	126	N/A	1.7
11/10/2008	99.24	697	N/A	-0.3
11/11/2008	99.73	165	N/A	-1.6
11/12/2008	99.08	321	N/A	5.4
11/13/2008	98.17	501	N/A	9.4
11/14/2008	97.65	77	N/A	10.7
11/15/2008	97.86	174	N/A	5.3
11/16/2008	98.58	509	N/A	1.1
11/17/2008	99.15	296	N/A	0.1
11/18/2008	100.05	612	N/A	-3.0
11/19/2008	99.29	471	N/A	-0.6
11/20/2008	99.10	492	N/A	1.4
11/21/2008	100.01	594	N/A	-4.3
11/22/2008	100.45	375	N/A	-5.8
11/23/2008	99.83	480	N/A	-3.1
11/24/2008	98.51	157	N/A	1.3
11/25/2008	98.61	499	N/A	-0.1
11/26/2008	98.93	460	N/A	-0.8
11/27/2008	98.61	454	N/A	-0.9
11/28/2008	98.48	467	N/A	0.9
11/29/2008	98.40	560	N/A	-1.0

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
11/30/2008	96.88	124	N/A	0.5
12/1/2008	96.67	321	N/A	-0.8
12/2/2008	98.75	406	N/A	-4.4
12/3/2008	98.52	487	N/A	0.5
12/4/2008	99.31	504	N/A	-3.6
12/5/2008	99.95	574	N/A	-9.5
12/6/2008	98.39	137	N/A	-5.5
12/7/2008	99.25	484	N/A	-8.7
12/8/2008	98.98	254	N/A	-3.7
12/9/2008	98.03	34	N/A	5.2
12/10/2008	98.72	396	N/A	-0.3
Period 7				
12/11/2008	98.93	302	N/A	-4.2
12/12/2008	98.85	541	56%	-4.6
12/13/2008	99.23	174	52%	-4.6
12/14/2008	98.43	77	13%	4.3
12/15/2008	99.11	323	99%	-2.0
12/16/2008	100.35	136	94%	-9.8
12/17/2008	99.21	380	88%	-6.6
12/18/2008	99.76	332	74%	-7.8
12/19/2008	98.39	285	100%	-1.8
12/20/2008	98.79	153	94%	-4.1
12/21/2008	98.43	401	40%	-13.3
12/22/2008	99.89	445	0%	-16.8
12/23/2008	99.69	152	58%	-7.8
12/24/2008	98.21	189	94%	1.4
12/25/2008	99.91	438	15%	-9.2
12/26/2008	99.20	89	85%	-0.6
12/27/2008	98.27	103	85%	13.2
12/28/2008	98.43	519	38%	3.1
12/29/2008	98.95	426	73%	1.0
12/30/2008	98.76	421	70%	0.6
12/31/2008	99.04	450	24%	-3.1
1/1/2009	99.41	316	27%	-6.0
1/2/2009	98.25	360	13%	-0.7
1/3/2009	98.81	456	26%	-3.7
1/4/2009	98.54	73	73%	1.8
1/5/2009	99.43	482	22%	-4.7

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
1/6/2009	98.05	136	76%	-4.2
1/7/2009	96.60	282	99%	-2.3
1/8/2009	97.73	255	71%	-9.0
1/9/2009	98.84	527	75%	-6.5
1/10/2009	98.62	100	97%	-3.1
1/11/2009	99.04	336	87%	-5.5
1/12/2009	99.13	271	92%	-5.0
1/13/2009	98.64	537	73%	-4.4
1/14/2009	98.94	264	87%	-14.3
1/15/2009	100.12	490	48%	-19.7
1/16/2009	100.90	569	23%	-24.3
1/17/2009	99.20	619	37%	-12.8
1/18/2009	97.95	579	76%	-7.4
1/19/2009	98.01	610	92%	-10.2
1/20/2009	98.59	509	80%	-12.1
1/21/2009	98.85	646	72%	-10.0
1/22/2009	98.50	512	72%	-3.5
1/23/2009	98.27	639	65%	-0.3
1/24/2009	99.78	523	25%	-7.9
1/25/2009	99.94	506	5%	-14.2
1/26/2009	100.08	373	16%	-11.3
1/27/2009	99.98	156	13%	-8.9
1/28/2009	98.60	553	73%	-8.0
1/29/2009	98.53	351	92%	-8.2
1/30/2009	98.77	560	33%	-9.2
1/31/2009	98.81	543	61%	-12.0
2/1/2009	98.18	653	64%	1.6
2/2/2009	98.82	804	66%	-4.2
2/3/2009	98.80	632	65%	-9.8
2/4/2009	99.79	714	69%	-11.1
2/5/2009	100.21	570	66%	-14.0
2/6/2009	99.30	587	36%	-5.7
2/7/2009	98.65	564	99%	7.9
2/8/2009	99.54	558	80%	3.7
2/9/2009	99.51	465	98%	1.7
2/10/2009	98.28	496	72%	11.3

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
2/11/2009	97.37	427	97%	11.3
2/12/2009	98.28	609	15%	3.2
2/13/2009	99.18	628	7%	0.6
2/14/2009	98.88	706	51%	-0.3
2/15/2009	99.52	735	35%	-2.5
2/16/2009	99.94	842	39%	-2.9
2/17/2009	99.20	636	33%	-1.4
2/18/2009	97.06	266	72%	3.8
2/19/2009	98.22	826	41%	-6.5
2/20/2009	99.06	643	0%	-7.6
2/21/2009	98.54	388	40%	-4.4
2/22/2009	99.29	873	3%	-6.4
2/23/2009	100.40	797	16%	-8.6
2/24/2009	100.06	706	65%	-5.3
2/25/2009	99.38	708	5%	-0.3
Period 8				
3/11/2009	100.18	654	73%	0.2
3/12/2009	100.65	692	48%	-3.8
3/13/2009	100.21	758	56%	-2.0
3/14/2009	99.47	789	59%	1.9
3/15/2009	99.09	787	57%	6.0
3/16/2009	99.24	829	11%	9.2
3/17/2009	99.25	762	63%	11.8
3/18/2009	98.96	720	54%	12.3
3/19/2009	99.57	814	4%	6.3
3/20/2009	100.17	816	18%	-0.4
3/21/2009	100.03	809	0%	5.1
3/22/2009	99.97	807	49%	8.3
3/23/2009	99.73	725	14%	7.0
3/24/2009	98.98	810	1%	11.1
3/25/2009	98.06	795	36%	13.5
3/26/2009	98.39	906	24%	7.9
3/27/2009	98.53	774	55%	7.9
3/28/2009	98.07	745	10%	4.9
3/29/2009	96.76	270	95%	3.8
3/30/2009	98.60	851	56%	3.6
3/31/2009	98.23	311	15%	8.7
4/1/2009	97.89	859	42%	7.8
4/2/2009	97.94	926	6%	12.0

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
4/3/2009	96.91	691	65%	7.3
4/4/2009	98.60	862	42%	4.3
4/5/2009	98.08	132	43%	5.9
4/6/2009	97.37	824	64%	2.5
4/7/2009	97.97	1062	7%	1.7
4/8/2009	97.77	1053	12%	4.6
4/9/2009	98.15	891	35%	7.6
4/10/2009	98.30	303	32%	7.5
4/11/2009	99.27	892	3%	5.7
4/12/2009	99.75	931	13%	5.5
4/13/2009	98.59	230	49%	3.9
4/14/2009	97.92	186	100%	5.2
4/15/2009	98.92	562	71%	5.9
4/16/2009	99.90	914	64%	9.3
4/17/2009	99.98	925	55%	11.2
4/18/2009	99.24	821	51%	13.6
4/19/2009	98.40	203	92%	13.5
4/20/2009	97.40	954	79%	8.3
4/21/2009	97.54	747	95%	5.2
4/22/2009	98.10	1041	72%	7.4
4/23/2009	98.93	907	34%	8.9
4/24/2009	98.48	908	31%	19.6
4/25/2009	98.80	989	6%	22.6
4/26/2009	99.13	907	27%	22.6
4/27/2009	99.08	920	7%	22.0
4/28/2009	99.52	274	98%	14.6
4/29/2009	99.84	384	88%	10.0
4/30/2009	98.72	633	99%	15.0
5/1/2009	98.53	831	97%	15.3
5/2/2009	98.77	1124	93%	11.6
5/3/2009	98.59	869	55%	13.5
5/4/2009	98.77	969	38%	14.2
5/5/2009	98.80	1106	7%	15.3
5/6/2009	98.35	309	84%	14.0
5/7/2009	98.09	1057	69%	15.5
5/8/2009	97.90	453	67%	15.4
5/9/2009	98.03	773	40%	13.1
5/10/2009	99.15	943	44%	10.4
5/11/2009	99.27	1091	39%	9.9
5/12/2009	99.45	926	33%	10.1
5/13/2009	98.68	388	46%	11.8

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
5/14/2009	98.43	969	28%	15.6
5/15/2009	99.18	815	56%	11.2
5/16/2009	98.52	1097	73%	11.9
5/17/2009	99.67	939	17%	N/A
5/18/2009	99.88	937	48%	N/A
5/19/2009	99.75	900	50%	N/A
5/20/2009	99.62	921	40%	N/A
5/21/2009	99.29	918	30%	N/A
5/22/2009	99.22	981	59%	N/A
5/23/2009	99.06	932	48%	N/A
5/24/2009	98.80	899	60%	N/A
5/25/2009	98.80	732	53%	N/A
5/26/2009	98.33	1018	47%	N/A
5/27/2009	97.87	1053	67%	N/A
5/28/2009	97.79	279	91%	N/A
Period 9				
5/29/2009	98.29	982	42%	16.9
5/30/2009	98.33	855	40%	16.6
5/31/2009	98.44	920	9%	17.8
6/1/2009	98.46	861	16%	19.8
6/2/2009	98.82	949	82%	18.3
6/3/2009	99.04	603	100%	15.1
6/4/2009	98.95	1018	100%	14.4
6/5/2009	98.63	942	100%	16.6
6/6/2009	98.57	1024	100%	20.0
6/7/2009	98.49	612	100%	21.2
6/8/2009	98.27	792	100%	22.6
6/9/2009	98.44	1136	77%	20.4
6/10/2009	98.44	847	0%	17.8
6/11/2009	98.02	683	0%	19.3
6/12/2009	98.45	981	0%	18.7
6/13/2009	98.65	1056	0%	19.6
6/14/2009	98.70	1045	0%	20.4
6/15/2009	98.82	818	0%	21.7
6/16/2009	98.64	384	35%	20.0
6/17/2009	98.31	970	62%	20.9
6/18/2009	98.38	922	65%	19.2
6/19/2009	98.06	875	59%	25.5
6/20/2009	97.98	1044	53%	24.3
6/21/2009	98.27	1204	67%	25.1
6/22/2009	98.22	1018	99%	24.6
6/23/2009	98.44	898	59%	25.8

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
6/24/2009	98.51	944	63%	26.2
6/25/2009	98.30	952	76%	27.3
6/26/2009	98.15	1006	100%	27.2
6/27/2009	98.41	1020	100%	23.8
6/28/2009	98.02	941	100%	25.2
6/29/2009	97.59	1052	100%	21.7
6/30/2009	97.53	934	100%	18.5
7/1/2009	97.85	903	100%	16.8
7/2/2009	98.46	809	100%	17.1
7/3/2009	98.99	1149	100%	20.4
7/4/2009	98.94	350	100%	18.4
7/5/2009	98.53	1058	100%	20.2
7/6/2009	98.41	1053	100%	21.6
7/7/2009	98.32	973	100%	21.3
7/8/2009	98.64	728	99%	19.4
7/9/2009	99.00	964	99%	20.3
7/10/2009	99.15	813	99%	22.0
7/11/2009	98.96	1019	79%	23.8
7/12/2009	99.04	1023	51%	20.9
7/13/2009	98.97	1048	44%	19.9
7/14/2009	99.19	1235	35%	18.1
7/15/2009	98.76	833	17%	21.1
7/16/2009	98.58	942	38%	22.4
7/17/2009	98.27	1052	34%	19.3
7/18/2009	98.65	963	54%	16.3
7/19/2009	99.15	1091	39%	18.0
7/20/2009	99.17	1034	56%	18.4
7/21/2009	98.98	965	51%	20.0
7/22/2009	98.73	514	98%	18.4
7/23/2009	98.51	924	99%	20.3
7/24/2009	98.51	977	100%	19.7
7/25/2009	97.96	1011	100%	21.4
7/26/2009	98.22	1006	100%	20.9
7/27/2009	98.56	926	100%	21.0
7/28/2009	98.30	983	100%	21.9
7/29/2009	98.07	1036	100%	20.8
7/30/2009	98.43	898	100%	18.6
7/31/2009	98.52	1033	100%	20.3
8/1/2009	98.76	852	100%	19.2
8/2/2009	98.59	956	100%	19.7
8/3/2009	98.62	1008	100%	19.4

Date	Barometric Pressure (kPA)	Max Solar Radiation (W m^{-2})	Wetness (%)	Air Temperature (°C)
8/4/2009	98.38	640	100%	22.6
8/5/2009	98.81	924	100%	21.5
8/6/2009	99.09	955	79%	19.0
8/7/2009	99.27	491	76%	17.7
8/8/2009	98.98	889	100%	23.1
8/9/2009	98.88	913	100%	27.1
8/10/2009	98.79	1080	76%	26.1
8/11/2009	98.72	1005	74%	23.3
8/12/2009	98.98	999	55%	19.9
8/13/2009	99.17	954	53%	21.4
8/14/2009	99.26	969	53%	21.9
8/15/2009	99.16	824	52%	22.6
8/16/2009	99.02	944	93%	25.5
8/17/2009	98.99	965	71%	24.4
8/18/2009	98.84	797	72%	21.7
8/19/2009	98.64	874	64%	21.8
8/20/2009	97.92	948	59%	21.4
8/21/2009	98.05	958	57%	19.7
8/22/2009	98.52	776	66%	16.6
8/23/2009	98.97	832	60%	16.5
8/24/2009	99.17	N/A	100%	14.3

6.11 Daily Lagoon conditions

Lagoon temperature, pH and oxidation-reduction potential

Date	Temperature, °C		Lagoon pH	Lagoon ORP (mV)
	Air	Lagoon		
Period 6				
9/10/2008	21.7	N/A	N/A	N/A
9/11/2008	16.8	N/A	N/A	N/A
9/12/2008	20.8	N/A	N/A	N/A
9/13/2008	23.8	N/A	N/A	N/A
9/14/2008	22.1	N/A	N/A	N/A
9/15/2008	16.2	N/A	N/A	N/A
9/16/2008	16.0	N/A	N/A	N/A
9/17/2008	16.2	N/A	N/A	N/A
9/18/2008	17.6	N/A	N/A	N/A
9/19/2008	17.2	21.5	8.3	-394
9/20/2008	18.4	21.2	8.3	-478
9/21/2008	19.0	21.3	8.3	-494
9/22/2008	19.7	21.6	8.3	-512
9/23/2008	19.6	21.3	8.3	-522
9/24/2008	19.7	21.2	8.3	-531
9/25/2008	19.1	21.3	8.3	-517
9/26/2008	18.4	21.6	8.3	-503
9/27/2008	18.3	21.5	8.3	-515
9/28/2008	17.3	20.9	8.3	-524
9/29/2008	17.2	20.6	8.3	-522
9/30/2008	13.8	20.0	8.3	-516
10/1/2008	10.7	19.0	8.3	-510
10/2/2008	11.1	18.4	8.4	-518
10/3/2008	11.6	18.2	8.4	-501
10/4/2008	9.6	17.5	8.4	-513
10/5/2008	10.7	17.1	8.4	-509
10/6/2008	15.7	16.5	8.4	-506
10/7/2008	14.9	16.1	8.4	-515
10/8/2008	15.2	16.2	8.4	-518
10/9/2008	12.7	16.3	8.3	-518
10/10/2008	13.1	16.3	8.2	N/A
10/11/2008	17.8	16.2	8.2	-492
10/12/2008	19.2	16.7	8.2	-491
10/13/2008	20.7	17.2	8.2	-501
10/14/2008	18.7	17.8	8.2	-501

Date	Temperature, °C		Lagoon pH	Lagoon ORP (mV)
	Air	Lagoon		
10/15/2008	16.6	17.5	8.2	-502
10/16/2008	12.5	17.5	8.2	-489
10/17/2008	10.7	16.8	8.2	-485
10/18/2008	10.1	16.3	8.2	-496
10/19/2008	8.3	15.5	8.2	-511
10/20/2008	10.8	15.1	8.2	-515
10/21/2008	8.1	15.0	8.2	-499
10/22/2008	5.6	13.9	8.2	-500
10/23/2008	7.3	12.9	8.2	-497
10/24/2008	10.2	12.6	8.2	-516
10/25/2008	7.1	12.0	8.2	-527
10/26/2008	9.5	11.3	8.2	-529
10/27/2008	4.2	10.9	8.2	-527
10/28/2008	2.3	N/A	N/A	N/A
10/29/2008	3.4	N/A	N/A	N/A
10/30/2008	4.0	N/A	N/A	N/A
10/31/2008	11.9	N/A	N/A	N/A
11/1/2008	12.6	N/A	N/A	N/A
11/2/2008	12.7	N/A	N/A	N/A
11/3/2008	16.5	N/A	N/A	N/A
11/4/2008	13.7	N/A	N/A	N/A
11/5/2008	12.7	N/A	N/A	N/A
11/6/2008	14.8	N/A	N/A	N/A
11/7/2008	11.9	N/A	N/A	N/A
11/8/2008	4.0	N/A	N/A	N/A
11/9/2008	1.7	N/A	N/A	N/A
11/10/2008	-0.3	N/A	N/A	N/A
11/11/2008	-1.6	N/A	N/A	N/A
11/12/2008	5.4	N/A	N/A	N/A
11/13/2008	9.4	N/A	N/A	N/A
11/14/2008	10.7	N/A	N/A	N/A
11/15/2008	5.3	N/A	N/A	N/A
11/16/2008	1.1	N/A	N/A	N/A
11/17/2008	0.1	N/A	N/A	N/A
11/18/2008	-3.0	N/A	N/A	N/A
11/19/2008	-0.6	N/A	N/A	N/A
11/20/2008	1.4	N/A	N/A	N/A
11/21/2008	-4.3	N/A	N/A	N/A
11/22/2008	-5.8	N/A	N/A	N/A
11/23/2008	-3.1	N/A	N/A	N/A
11/24/2008	1.3	N/A	N/A	N/A
11/25/2008	-0.1	N/A	N/A	N/A

Date	Temperature, °C		Lagoon pH	Lagoon ORP (mV)
	Air	Lagoon		
11/26/2008	-0.8	N/A	N/A	N/A
11/27/2008	-0.9	N/A	N/A	N/A
11/28/2008	0.9	N/A	N/A	N/A
11/29/2008	-1.0	N/A	N/A	N/A
11/30/2008	0.5	N/A	N/A	N/A
12/1/2008	-0.8	N/A	N/A	N/A
12/2/2008	-4.4	N/A	N/A	N/A
12/3/2008	0.5	N/A	N/A	N/A
12/4/2008	-3.6	N/A	N/A	N/A
12/5/2008	-9.5	N/A	N/A	N/A
12/6/2008	-5.5	N/A	N/A	N/A
12/7/2008	-8.7	N/A	N/A	N/A
12/8/2008	-3.7	N/A	N/A	N/A
12/9/2008	5.2	N/A	N/A	N/A
12/10/2008	-0.3	N/A	N/A	N/A
Period 7				
12/11/2008	-4.2	N/A	N/A	N/A
12/12/2008	-4.6	N/A	N/A	N/A
12/13/2008	-4.6	N/A	N/A	N/A
12/14/2008	4.3	N/A	N/A	N/A
12/15/2008	-2.0	N/A	N/A	N/A
12/16/2008	-9.8	N/A	N/A	N/A
12/17/2008	-6.6	N/A	N/A	N/A
12/18/2008	-7.8	N/A	N/A	N/A
12/19/2008	-1.8	N/A	N/A	N/A
12/20/2008	-4.1	N/A	N/A	N/A
12/21/2008	-13.3	N/A	N/A	N/A
12/22/2008	-16.8	N/A	N/A	N/A
12/23/2008	-7.8	N/A	N/A	N/A
12/24/2008	1.4	N/A	N/A	N/A
12/25/2008	-9.2	N/A	N/A	N/A
12/26/2008	-0.6	N/A	N/A	N/A
12/27/2008	13.2	N/A	N/A	N/A
12/28/2008	3.1	N/A	N/A	N/A
12/29/2008	1.0	N/A	N/A	N/A
12/30/2008	0.6	N/A	N/A	N/A
12/31/2008	-3.1	N/A	N/A	N/A
1/1/2009	-6.0	N/A	N/A	N/A
1/2/2009	-0.7	N/A	N/A	N/A
1/3/2009	-3.7	N/A	N/A	N/A
1/4/2009	1.8	N/A	N/A	N/A

Date	Temperature, °C		Lagoon pH	Lagoon ORP (mV)
	Air	Lagoon		
1/5/2009	-4.7	N/A	N/A	N/A
1/6/2009	-4.2	N/A	N/A	N/A
1/7/2009	-2.3	N/A	N/A	N/A
1/8/2009	-9.0	N/A	N/A	N/A
1/9/2009	-6.5	N/A	N/A	N/A
1/10/2009	-3.1	N/A	N/A	N/A
1/11/2009	-5.5	N/A	N/A	N/A
1/12/2009	-5.0	N/A	N/A	N/A
1/13/2009	-4.4	N/A	N/A	N/A
1/14/2009	-14.3	N/A	N/A	N/A
1/15/2009	-19.7	N/A	N/A	N/A
1/16/2009	-24.3	N/A	N/A	N/A
1/17/2009	-12.8	N/A	N/A	N/A
1/18/2009	-7.4	N/A	N/A	N/A
1/19/2009	-10.2	N/A	N/A	N/A
1/20/2009	-12.1	N/A	N/A	N/A
1/21/2009	-10.0	N/A	N/A	N/A
1/22/2009	-3.5	N/A	N/A	N/A
1/23/2009	-0.3	N/A	N/A	N/A
1/24/2009	-7.9	N/A	N/A	N/A
1/25/2009	-14.2	N/A	N/A	N/A
1/26/2009	-11.3	N/A	N/A	N/A
1/27/2009	-8.9	N/A	N/A	N/A
1/28/2009	-8.0	N/A	N/A	N/A
1/29/2009	-8.2	N/A	N/A	N/A
1/30/2009	-9.2	N/A	N/A	N/A
1/31/2009	-12.0	N/A	N/A	N/A
2/1/2009	1.6	N/A	N/A	N/A
2/2/2009	-4.2	N/A	N/A	N/A
2/3/2009	-9.8	N/A	N/A	N/A
2/4/2009	-11.1	N/A	N/A	N/A
2/5/2009	-14.0	N/A	N/A	N/A
2/6/2009	-5.7	N/A	N/A	N/A
2/7/2009	7.9	N/A	N/A	N/A
2/8/2009	3.7	N/A	N/A	N/A
2/9/2009	1.7	N/A	N/A	N/A
2/10/2009	11.3	N/A	N/A	N/A
2/11/2009	11.3	N/A	N/A	N/A
2/12/2009	2.2	N/A	N/A	N/A
Period 8				
3/11/2009	0.2	N/A	N/A	N/A
3/12/2009	-3.8	N/A	N/A	N/A

Date	Temperature, °C		Lagoon pH	Lagoon ORP (mV)
	Air	Lagoon		
3/13/2009	-2.0	N/A	N/A	N/A
3/14/2009	1.9	N/A	N/A	N/A
3/15/2009	6.0	N/A	N/A	N/A
3/16/2009	9.2	N/A	N/A	N/A
3/17/2009	11.8	N/A	N/A	N/A
3/18/2009	12.3	N/A	N/A	N/A
3/19/2009	6.3	N/A	N/A	N/A
3/20/2009	-0.4	N/A	N/A	N/A
3/21/2009	5.1	N/A	N/A	N/A
3/22/2009	8.3	N/A	N/A	N/A
3/23/2009	7.0	N/A	N/A	N/A
3/24/2009	11.1	N/A	N/A	N/A
3/25/2009	13.5	N/A	N/A	N/A
3/26/2009	7.9	N/A	N/A	N/A
3/27/2009	7.9	N/A	N/A	N/A
3/28/2009	4.9	N/A	N/A	N/A
3/29/2009	3.8	N/A	N/A	N/A
3/30/2009	3.6	N/A	N/A	N/A
3/31/2009	8.7	N/A	N/A	N/A
4/1/2009	7.8	N/A	N/A	N/A
4/2/2009	12.0	N/A	N/A	N/A
4/3/2009	7.3	N/A	N/A	N/A
4/4/2009	4.3	N/A	N/A	N/A
4/5/2009	5.9	N/A	N/A	N/A
4/6/2009	2.5	N/A	N/A	N/A
4/7/2009	1.7	N/A	N/A	N/A
4/8/2009	4.6	N/A	N/A	N/A
4/9/2009	7.6	N/A	N/A	N/A
4/10/2009	7.5	N/A	N/A	N/A
4/11/2009	5.7	N/A	N/A	N/A
4/12/2009	5.5	N/A	N/A	N/A
4/13/2009	3.9	N/A	N/A	N/A
4/14/2009	5.2	N/A	N/A	N/A
4/15/2009	5.9	N/A	N/A	N/A
4/16/2009	9.3	N/A	N/A	N/A
4/17/2009	11.2	N/A	N/A	N/A
4/18/2009	13.6	N/A	N/A	N/A
4/19/2009	13.5	N/A	N/A	N/A
4/20/2009	8.3	N/A	N/A	N/A
4/21/2009	5.2	N/A	N/A	N/A
4/22/2009	7.4	N/A	N/A	N/A

Date	Temperature, °C		Lagoon pH	Lagoon ORP (mV)
	Air	Lagoon		
4/23/2009	8.9	N/A	N/A	N/A
4/24/2009	19.6	N/A	N/A	N/A
4/25/2009	22.6	N/A	N/A	N/A
4/26/2009	22.6	N/A	N/A	N/A
4/27/2009	22.0	N/A	N/A	N/A
4/28/2009	14.6	N/A	N/A	N/A
4/29/2009	10.0	N/A	N/A	N/A
4/30/2009	15.0	N/A	N/A	N/A
5/1/2009	15.3	N/A	N/A	N/A
5/2/2009	11.6	N/A	N/A	N/A
5/3/2009	13.5	N/A	N/A	N/A
5/4/2009	14.2	N/A	N/A	N/A
5/5/2009	15.3	N/A	N/A	N/A
5/6/2009	14.0	N/A	N/A	N/A
5/7/2009	15.5	N/A	N/A	N/A
5/8/2009	15.4	N/A	N/A	N/A
5/9/2009	13.1	N/A	N/A	N/A
5/10/2009	10.4	N/A	N/A	N/A
5/11/2009	9.9	N/A	N/A	N/A
5/12/2009	10.1	N/A	N/A	N/A
5/13/2009	11.8	N/A	N/A	N/A
5/14/2009	15.6	N/A	N/A	N/A
5/15/2009	11.2	N/A	N/A	N/A
5/16/2009	11.9	N/A	N/A	N/A
5/17/2009	N/A	N/A	N/A	N/A
5/18/2009	N/A	N/A	N/A	N/A
5/19/2009	N/A	N/A	N/A	N/A
5/20/2009	N/A	N/A	N/A	N/A
5/21/2009	N/A	N/A	N/A	N/A
5/22/2009	N/A	N/A	N/A	N/A
5/23/2009	N/A	N/A	N/A	N/A
5/24/2009	N/A	N/A	N/A	N/A
5/25/2009	N/A	N/A	N/A	N/A
5/26/2009	N/A	N/A	N/A	N/A
5/27/2009	N/A	N/A	N/A	N/A
5/28/2009	N/A	N/A	N/A	N/A
Period 9				
5/29/2009	16.9	19.6	7.1	-301
5/30/2009	16.6	19.7	7.1	-357
5/31/2009	17.8	19.8	7.1	-394
6/1/2009	19.8	19.9	7.1	-400
6/2/2009	18.3	20.5	7.1	-417

Date	Temperature, °C		Lagoon pH	Lagoon ORP (mV)
	Air	Lagoon		
6/3/2009	15.1	20.3	7.0	-445
6/4/2009	14.4	20.3	7.0	-463
6/5/2009	16.6	20.3	7.0	-464
6/6/2009	20.0	20.5	7.0	-473
6/7/2009	21.2	20.7	7.0	-468
6/8/2009	22.6	20.9	7.0	-466
6/9/2009	20.4	21.5	7.0	-462
6/10/2009	17.8	21.5	7.0	-460
6/11/2009	19.3	21.5	7.0	-467
6/12/2009	18.7	21.5	7.1	-458
6/13/2009	19.6	21.8	7.1	-463
6/14/2009	20.4	22.0	7.1	-465
6/15/2009	21.7	22.3	7.1	-466
6/16/2009	20.0	N/A	7.1	-469
6/17/2009	20.9	N/A	7.1	-470
6/18/2009	19.2	22.4	7.1	-322
6/19/2009	25.5	22.8	7.1	-382
6/20/2009	24.3	23.6	7.1	-423
6/21/2009	25.1	24.2	7.1	-446
6/22/2009	24.6	24.7	7.1	-459
6/23/2009	25.8	25.3	7.1	-459
6/24/2009	26.2	26.0	7.1	-463
6/25/2009	27.3	26.6	7.1	-471
6/26/2009	27.2	27.6	7.1	-475
6/27/2009	23.8	27.5	7.1	-470
6/28/2009	25.2	27.6	7.1	-490
6/29/2009	21.7	27.1	7.1	-476
6/30/2009	18.5	26.3	7.1	-481
7/1/2009	16.8	25.4	7.1	-466
7/2/2009	17.1	24.6	7.2	-465
7/3/2009	20.4	24.3	7.2	-459
7/4/2009	18.4	24.3	7.2	-462
7/5/2009	20.2	24.0	7.2	-467
7/6/2009	21.6	24.5	7.2	-452
7/7/2009	21.3	24.9	7.2	-466
7/8/2009	19.4	24.7	7.2	-463
7/9/2009	20.3	24.4	7.2	-470
7/10/2009	22.0	24.8	7.1	-442
7/11/2009	23.8	25.2	7.1	-395
7/12/2009	20.9	25.5	7.1	-431
7/13/2009	19.9	25.6	7.1	-450

Date	Temperature, °C		Lagoon pH	Lagoon ORP (mV)
	Air	Lagoon		
7/14/2009	18.1	25.4	7.2	-465
7/15/2009	21.1	24.9	7.2	-471
7/16/2009	22.4	25.2	7.2	-487
7/17/2009	19.3	25.4	7.2	-493
7/18/2009	16.3	24.6	7.2	-485
7/19/2009	18.0	24.3	7.2	-490
7/20/2009	18.4	24.4	7.2	-487
7/21/2009	20.0	24.5	7.2	-488
7/22/2009	18.4	24.4	7.2	-485
7/23/2009	20.3	24.1	7.2	-477
7/24/2009	19.7	24.2	7.2	-487
7/25/2009	21.4	24.6	7.2	-487
7/26/2009	20.9	24.6	7.2	-490
7/27/2009	21.0	24.9	7.2	-490
7/28/2009	21.9	25.1	7.2	-486
7/29/2009	20.8	25.2	7.2	-487
7/30/2009	18.6	24.9	7.2	-477
7/31/2009	20.3	25.1	7.2	-459
8/1/2009	19.2	25.1	7.2	-436
8/2/2009	19.7	25.0	7.2	-471
8/3/2009	19.4	25.0	7.2	-489
8/4/2009	22.6	25.1	7.2	-494
8/5/2009	21.5	24.9	7.2	-506
8/6/2009	19.0	25.0	7.2	-496
8/7/2009	17.7	24.8	7.2	-505
8/8/2009	23.1	24.3	7.2	-500
8/9/2009	27.1	25.1	7.2	-505
8/10/2009	26.1	26.3	7.2	-509
8/11/2009	23.3	26.3	7.2	-509
8/12/2009	19.9	25.7	7.1	-485
8/13/2009	21.4	25.7	7.2	-482
8/14/2009	21.9	25.9	7.2	-491
8/15/2009	22.6	26.4	7.2	-483
8/16/2009	25.5	26.2	7.1	-482
8/17/2009	24.4	26.8	7.2	-482
8/18/2009	21.7	N/A	N/A	N/A
8/19/2009	21.8	N/A	N/A	N/A
8/20/2009	21.4	N/A	N/A	N/A
8/21/2009	19.7	N/A	N/A	N/A
8/22/2009	16.6	N/A	N/A	N/A
8/23/2009	16.5	N/A	N/A	N/A
8/24/2009	14.3	N/A	N/A	N/A

6.12 Daily Site Emissions and Data completeness

6.12.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid values: Number of ½ hour periods with valid emissions data
Direction limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction
Missing downwind NH_3: Number of ½ hour periods invalidated because at least 1 TDL path was either missing or else had invalid concentration values
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ hour periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ hour periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ hour periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ hour periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/16/2008	6	0	4	28.1	6.8	14.7	33.7	23.0	8.9	6.6
9/17/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/18/2008	0	0	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/19/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/20/2008	2	0	44	52.1	30.5	30.5	73.7	42.8	16.4	12.2
9/21/2008	2	0	44	51.1	9.7	44.2	57.9	41.9	16.1	11.9
9/22/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/23/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/24/2008	1	0	42	27.4	N/A	27.4	27.4	22.5	8.6	6.4
9/25/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2008	14	0	32	68.6	9.9	49.5	84.2	56.3	21.6	16.0
9/28/2008	22	0	19	41.8	19.6	17.9	81.1	34.3	13.2	9.8
9/29/2008	15	0	33	42.9	22.7	16.8	77.9	35.3	13.6	10.0
9/30/2008	27	0	15	26.8	13.4	8.4	63.2	22.0	8.5	6.3
10/1/2008	28	0	2	28.2	13.2	8.4	58.9	23.2	8.9	6.6
10/2/2008	27	0	12	24.3	6.5	13.7	37.9	20.0	7.7	5.7
10/3/2008	1	0	41	7.4	N/A	7.4	7.4	6.0	2.3	1.7
10/4/2008	9	0	34	30.8	13.7	16.8	50.5	25.2	9.7	7.2

	Valid values	Cause for invalid values		Emission						
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10/5/2008	1	0	45	0.0	N/A	0.0	0.0	0.0	0.0	0.0
10/6/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/8/2008	0	0	36	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/9/2008	0	0	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/10/2008	17	0	7	39.0	8.4	16.8	49.5	32.0	12.3	9.1
10/11/2008	43	0	0	36.1	8.0	20.0	51.6	29.6	11.4	8.4
10/12/2008	34	0	4	31.9	15.1	13.7	64.2	26.2	10.1	7.5
10/13/2008	46	0	0	33.8	17.6	10.5	70.5	27.7	10.7	7.9
10/14/2008	25	0	18	31.0	14.2	8.4	56.8	25.4	9.8	7.2
10/15/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/16/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/17/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/19/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/20/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/21/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/22/2008	14	0	33	35.6	5.5	27.4	47.4	29.3	11.3	8.3
10/23/2008	32	0	0	36.7	8.7	20.0	52.6	30.2	11.6	8.6
10/24/2008	29	0	0	28.3	10.2	11.6	44.2	23.2	8.9	6.6
10/25/2008	11	0	7	34.1	10.7	17.9	48.4	28.0	10.8	8.0
10/26/2008	26	0	1	31.1	11.7	13.7	57.9	25.5	9.8	7.3
10/27/2008	25	0	2	17.9	5.5	7.4	30.5	14.7	5.6	4.2
10/28/2008	11	0	0	13.0	5.5	6.3	21.1	10.7	4.1	3.0
10/29/2008	33	0	0	18.5	5.7	9.5	32.6	15.2	5.8	4.3
10/30/2008	23	0	3	27.5	7.1	11.6	41.1	22.5	8.7	6.4
10/31/2008	21	0	5	34.3	12.6	16.8	55.8	28.1	10.8	8.0
11/1/2008	29	0	1	10.6	23.8	-20.0	74.7	8.7	3.3	2.5
11/2/2008	19	0	0	27.4	8.4	15.8	44.2	22.5	8.7	6.4
11/3/2008	25	0	0	31.8	15.8	17.9	95.8	26.1	10.0	7.4
11/4/2008	28	0	1	19.1	9.4	6.3	45.3	15.7	6.0	4.5
11/5/2008	37	0	0	26.6	19.3	1.1	86.3	21.8	8.4	6.2
11/6/2008	45	0	0	37.3	16.1	11.6	74.7	30.6	11.8	8.7
11/7/2008	38	0	1	37.6	18.6	15.8	87.4	30.9	11.9	8.8
11/8/2008	21	0	24	27.5	3.4	18.9	32.6	22.6	8.7	6.4
11/9/2008	38	0	4	22.1	2.7	16.8	27.4	18.1	7.0	5.2
11/10/2008	10	0	1	14.3	3.8	8.4	20.0	11.8	4.5	3.3
11/11/2008	5	0	1	14.9	2.7	12.6	17.9	12.3	4.7	3.5
11/12/2008	29	0	1	20.5	6.4	10.5	33.7	16.8	6.5	4.8
11/13/2008	22	0	12	32.7	8.5	14.7	49.5	26.9	10.3	7.7
11/14/2008	5	0	27	27.4	8.8	14.7	36.8	22.5	8.6	6.4
11/15/2008	38	0	1	28.8	8.0	12.6	43.2	23.6	9.1	6.7

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11/16/2008	27	0	4	23.4	5.8	14.7	38.9	19.2	7.4	5.5
11/17/2008	13	0	16	15.4	4.0	5.3	22.1	12.6	4.9	3.6
11/18/2008	0	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/19/2008	0	0	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/20/2008	5	0	0	33.1	3.5	27.4	36.8	27.1	10.4	7.7
11/21/2008	27	0	2	15.4	5.2	5.3	29.5	12.6	4.9	3.6
11/22/2008	12	0	21	13.8	5.7	5.3	21.1	11.3	4.3	3.2
11/23/2008	1	0	11	21.1	N/A	21.1	21.1	17.3	6.6	4.9
11/24/2008	32	0	9	18.8	7.2	9.5	46.3	15.4	5.9	4.4
11/25/2008	43	0	0	16.2	4.4	7.4	26.3	13.3	5.1	3.8
11/26/2008	22	0	10	8.8	4.0	3.2	14.7	7.2	2.8	2.0
11/27/2008	6	0	14	12.8	4.8	4.2	17.9	10.5	4.0	3.0
11/28/2008	23	0	3	14.8	3.5	8.4	21.1	12.1	4.7	3.5
11/29/2008	14	0	7	10.5	8.2	1.1	28.4	8.6	3.3	2.5
11/30/2008	3	0	18	15.8	4.6	12.6	21.1	13.0	5.0	3.7
12/1/2008	16	0	7	26.1	10.1	11.6	42.1	21.4	8.2	6.1
12/2/2008	14	0	13	16.2	3.9	10.5	24.2	13.3	5.1	3.8
12/3/2008	10	0	19	29.5	9.1	22.1	47.4	24.2	9.3	6.9
12/4/2008	30	0	5	14.2	2.9	10.5	21.1	11.6	4.5	3.3
12/5/2008	11	0	11	10.5	3.5	6.3	15.8	8.6	3.3	2.5
12/6/2008	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/7/2008	4	0	38	6.1	1.6	5.3	8.4	5.0	1.9	1.4
12/8/2008	3	0	8	15.8	2.8	13.7	18.9	13.0	5.0	3.7
12/9/2008	0	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/11/2008	0	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/12/2008	3	0	1	35.1	16.4	16.8	48.4	28.8	11.1	8.2
12/13/2008	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/14/2008	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2008	6	0	20	29.5	5.9	18.9	34.7	24.2	9.3	6.9
12/16/2008	0	0	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/17/2008	1	0	8	3.2	N/A	3.2	3.2	2.6	1.0	0.7
12/18/2008	5	0	34	4.8	1.4	3.2	6.3	4.0	1.5	1.1
12/19/2008	0	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/20/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/21/2008	0	0	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/22/2008	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/23/2008	0	0	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/24/2008	1	0	25	8.4	N/A	8.4	8.4	6.9	2.7	2.0
12/25/2008	4	0	20	7.1	1.6	5.3	8.4	5.8	2.2	1.7
12/26/2008	1	0	47	31.6	N/A	31.6	31.6	25.9	10.0	7.4
12/27/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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12/28/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/29/2008	0	0	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/30/2008	2	0	2	21.6	8.2	15.8	27.4	17.7	6.8	5.0
12/31/2008	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/1/2009	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/2/2009	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/3/2009	5	0	26	23.6	19.8	2.1	42.1	19.4	7.4	5.5
1/4/2009	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/5/2009	0	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/6/2009	0	0	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/7/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/8/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/9/2009	2	0	8	17.4	2.2	15.8	18.9	14.3	5.5	4.1
1/10/2009	5	0	29	16.2	1.2	14.7	17.9	13.3	5.1	3.8
1/11/2009	0	0	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/12/2009	0	0	39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/13/2009	0	0	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/14/2009	0	0	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/15/2009	0	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/16/2009	0	0	39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/17/2009	1	0	45	1.1	N/A	1.1	1.1	0.9	0.3	0.2
1/18/2009	0	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/19/2009	4	0	19	5.3	3.7	2.1	9.5	4.3	1.7	1.2
1/20/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/21/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/22/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/23/2009	0	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/24/2009	0	0	36	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/25/2009	0	0	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/26/2009	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2009	0	0	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/28/2009	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/29/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/30/2009	0	0	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2009	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2009	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/2/2009	0	0	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/3/2009	1	0	34	12.6	N/A	12.6	12.6	10.4	4.0	3.0
2/4/2009	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2009	2	0	41	4.2	0.0	4.2	4.2	3.5	1.3	1.0
2/6/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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2/8/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/9/2009	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/11/2009	4	0	23	31.6	9.5	22.1	42.1	25.9	10.0	7.4
2/12/2009	12	0	30	16.1	4.0	9.5	21.1	13.2	5.1	3.8
2/13/2009	21	0	2	8.4	3.2	3.2	14.7	6.9	2.7	2.0
2/14/2009	17	0	28	13.5	3.9	9.5	22.1	11.1	4.3	3.2
2/15/2009	31	0	2	9.5	3.8	3.2	22.1	7.8	3.0	2.2
2/16/2009	22	0	5	9.3	4.4	3.2	21.1	7.6	2.9	2.2
2/17/2009	1	0	40	28.4	N/A	28.4	28.4	23.3	9.0	6.6
2/18/2009	12	0	27	19.5	6.1	10.5	29.5	16.0	6.1	4.6
2/19/2009	1	0	37	7.4	N/A	7.4	7.4	6.0	2.3	1.7
2/20/2009	4	0	35	8.7	3.5	6.3	13.7	7.1	2.7	2.0
2/21/2009	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/22/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/23/2009	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/24/2009	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/25/2009	0	0	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2009	0	0	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2009	1	0	27	11.6	N/A	11.6	11.6	9.5	3.7	2.7
3/13/2009	11	0	33	20.0	4.5	12.6	25.3	16.4	6.3	4.7
3/14/2009	30	0	2	17.1	5.3	9.5	26.3	14.1	5.4	4.0
3/15/2009	41	0	0	18.6	7.5	9.5	37.9	15.3	5.9	4.3
3/16/2009	23	0	0	21.3	5.4	14.7	40.0	17.5	6.7	5.0
3/17/2009	23	0	0	28.5	39.8	-21.1	120.0	23.4	9.0	6.7
3/18/2009	31	0	2	27.2	15.3	-4.2	51.6	22.3	8.6	6.4
3/19/2009	31	0	6	14.8	4.9	5.3	30.5	12.2	4.7	3.5
3/20/2009	29	0	3	18.7	7.7	6.3	34.7	15.3	5.9	4.4
3/21/2009	34	0	1	16.7	4.2	8.4	27.4	13.7	5.3	3.9
3/22/2009	39	0	0	20.1	6.8	1.1	34.7	16.5	6.3	4.7
3/23/2009	26	0	0	32.2	6.4	20.0	45.3	26.5	10.2	7.5
3/24/2009	23	0	0	34.4	9.0	23.2	52.6	28.2	10.9	8.0
3/25/2009	17	0	4	36.3	13.0	12.6	53.7	29.8	11.5	8.5
3/26/2009	22	0	2	17.2	4.5	9.5	30.5	14.1	5.4	4.0
3/27/2009	11	0	1	19.3	4.2	12.6	27.4	15.9	6.1	4.5
3/28/2009	18	0	17	42.7	9.9	22.1	58.9	35.0	13.5	10.0
3/29/2009	5	0	17	34.1	11.7	13.7	42.1	28.0	10.8	8.0
3/30/2009	5	0	37	25.1	12.1	6.3	40.0	20.6	7.9	5.9
3/31/2009	40	0	0	26.4	8.0	16.8	52.6	21.6	8.3	6.2
4/1/2009	8	0	30	19.5	7.1	12.6	30.5	16.0	6.1	4.6
4/2/2009	33	0	4	23.9	10.5	9.5	43.2	19.6	7.6	5.6
4/3/2009	5	0	33	26.9	19.7	9.5	52.6	22.1	8.5	6.3

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4/4/2009	5	0	43	8.6	2.3	6.3	11.6	7.1	2.7	2.0
4/5/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2009	3	0	30	11.9	1.6	10.5	13.7	9.8	3.8	2.8
4/7/2009	1	0	7	7.4	N/A	7.4	7.4	6.0	2.3	1.7
4/8/2009	3	0	37	17.9	2.1	15.8	20.0	14.7	5.6	4.2
4/9/2009	16	0	3	11.2	5.3	4.2	22.1	9.2	3.5	2.6
4/10/2009	4	0	33	36.3	23.0	22.1	70.5	29.8	11.5	8.5
4/11/2009	35	0	4	18.8	3.5	13.7	29.5	15.5	5.9	4.4
4/12/2009	36	0	8	23.8	11.1	-9.5	47.4	19.6	7.5	5.6
4/13/2009	25	0	11	37.5	3.6	29.5	43.2	30.8	11.8	8.8
4/14/2009	18	0	14	20.9	5.8	12.6	30.5	17.2	6.6	4.9
4/15/2009	33	0	6	16.2	3.1	8.4	25.3	13.3	5.1	3.8
4/16/2009	29	0	10	29.1	10.8	7.4	49.5	23.9	9.2	6.8
4/17/2009	28	0	1	27.0	12.3	1.1	58.9	22.2	8.5	6.3
4/18/2009	23	0	1	28.5	16.5	12.6	72.6	23.4	9.0	6.7
4/19/2009	28	0	9	30.9	12.5	3.2	61.1	25.4	9.8	7.2
4/20/2009	5	0	27	24.2	4.3	17.9	29.5	19.9	7.6	5.7
4/21/2009	0	0	36	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/22/2009	10	0	23	15.3	3.6	9.5	20.0	12.5	4.8	3.6
4/23/2009	31	0	6	24.7	7.0	15.8	41.1	20.2	7.8	5.8
4/24/2009	25	0	12	28.8	6.7	20.0	52.6	23.6	9.1	6.7
4/25/2009	12	0	1	33.0	6.3	26.3	46.3	27.1	10.4	7.7
4/26/2009	38	0	0	42.1	20.0	20.0	89.5	34.6	13.3	9.9
4/27/2009	28	0	13	40.6	7.1	29.5	56.8	33.3	12.8	9.5
4/28/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2009	1	0	42	35.8	N/A	35.8	35.8	29.4	11.3	8.4
5/1/2009	26	0	3	22.0	4.0	14.7	29.5	18.1	7.0	5.2
5/2/2009	27	0	4	25.9	6.8	8.4	33.7	21.3	8.2	6.1
5/3/2009	20	0	3	22.1	7.2	13.7	35.8	18.1	7.0	5.2
5/4/2009	17	0	10	45.1	13.7	20.0	62.1	37.0	14.2	10.5
5/5/2009	36	0	1	36.8	8.3	23.2	57.9	30.2	11.6	8.6
5/6/2009	38	0	0	25.7	5.7	13.7	37.9	21.1	8.1	6.0
5/7/2009	9	0	38	21.5	3.0	14.7	25.3	17.7	6.8	5.0
5/8/2009	15	0	29	18.5	6.4	10.5	33.7	15.1	5.8	4.3
5/9/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/11/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/12/2009	22	0	16	36.3	13.3	9.5	57.9	29.8	11.4	8.5
5/13/2009	38	0	3	29.0	6.3	18.9	41.1	23.8	9.2	6.8
5/14/2009	12	0	36	31.4	5.3	24.2	43.2	25.8	9.9	7.3
5/15/2009	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/16/2009	1	0	47	9.5	N/A	9.5	9.5	7.8	3.0	2.2
5/17/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/18/2009	13	0	31	37.9	7.7	24.2	48.4	31.1	12.0	8.9
5/19/2009	22	0	21	21.8	8.1	8.4	40.0	17.9	6.9	5.1
5/20/2009	34	0	11	31.4	16.8	7.4	56.8	25.7	9.9	7.3
5/21/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2009	3	0	43	24.6	14.3	15.8	41.1	20.2	7.8	5.7
5/24/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2009	0	0	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2009	1	0	8	21.1	N/A	21.1	21.1	17.3	6.6	4.9
5/27/2009	2	0	46	25.8	5.2	22.1	29.5	21.2	8.1	6.0
5/28/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2009	6	0	35	22.1	6.4	15.8	30.5	18.1	7.0	5.2
5/31/2009	5	0	42	26.5	7.9	15.8	33.7	21.8	8.4	6.2
6/1/2009	27	0	20	24.2	8.4	9.5	38.9	19.9	7.7	5.7
6/2/2009	1	0	28	20.0	N/A	20.0	20.0	16.4	6.3	4.7
6/3/2009	8	0	1	38.9	5.8	32.6	48.4	32.0	12.3	9.1
6/4/2009	4	0	42	29.2	10.4	16.8	42.1	24.0	9.2	6.8
6/5/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/6/2009	10	0	38	23.8	8.3	9.5	33.7	19.5	7.5	5.6
6/7/2009	26	0	17	19.5	6.4	7.4	30.5	16.0	6.1	4.6
6/8/2009	21	0	18	24.9	6.8	10.5	35.8	20.4	7.8	5.8
6/9/2009	0	0	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/10/2009	21	0	27	56.5	14.5	30.5	81.1	46.4	17.8	13.2
6/11/2009	26	0	16	38.5	19.3	10.5	68.4	31.6	12.2	9.0
6/12/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/13/2009	1	0	47	24.2	N/A	24.2	24.2	19.9	7.6	5.7
6/14/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/15/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/16/2009	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/17/2009	18	0	26	37.7	12.9	14.7	64.2	31.0	11.9	8.8
6/18/2009	7	0	40	37.1	14.9	16.8	57.9	30.5	11.7	8.7
6/19/2009	3	0	45	56.5	28.7	24.2	78.9	46.4	17.8	13.2
6/20/2009	10	0	13	28.0	12.5	6.3	46.3	23.0	8.8	6.5
6/21/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/22/2009	0	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/23/2009	6	0	39	60.7	19.0	30.5	82.1	49.8	19.2	14.2
6/24/2009	20	0	16	66.5	25.2	27.4	118.9	54.6	21.0	15.6
6/25/2009	23	0	16	64.9	27.5	31.6	135.8	53.3	20.5	15.2
6/26/2009	34	0	8	68.2	30.0	6.3	120.0	56.0	21.5	15.9

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/27/2009	13	0	21	57.7	25.4	24.2	98.9	47.3	18.2	13.5
6/28/2009	26	0	15	43.4	21.7	11.6	92.6	35.6	13.7	10.1
6/29/2009	28	0	17	39.8	13.2	22.1	64.2	32.7	12.6	9.3
6/30/2009	31	0	7	40.6	12.7	16.8	63.2	33.3	12.8	9.5
7/1/2009	29	0	4	28.4	7.7	9.5	44.2	23.3	9.0	6.6
7/2/2009	37	0	0	29.8	15.4	6.3	60.0	24.4	9.4	7.0
7/3/2009	32	0	0	37.0	12.4	14.7	68.4	30.4	11.7	8.7
7/4/2009	20	0	19	50.1	30.8	13.7	110.5	41.1	15.8	11.7
7/5/2009	10	0	38	53.2	13.5	23.2	69.5	43.6	16.8	12.4
7/6/2009	9	0	38	44.1	6.6	33.7	52.6	36.2	13.9	10.3
7/7/2009	10	0	37	68.3	30.2	25.3	108.4	56.1	21.6	16.0
7/8/2009	13	0	35	63.7	17.7	22.1	88.4	52.3	20.1	14.9
7/9/2009	19	0	26	54.6	29.0	23.2	126.3	44.8	17.2	12.8
7/10/2009	13	0	22	39.4	13.7	9.5	56.8	32.3	12.4	9.2
7/11/2009	3	0	44	23.9	8.8	16.8	33.7	19.6	7.5	5.6
7/12/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2009	14	0	30	72.9	24.4	16.8	111.6	59.8	23.0	17.0
7/14/2009	28	0	12	66.1	15.2	49.5	109.5	54.2	20.9	15.5
7/15/2009	35	0	3	45.1	14.0	15.8	78.9	37.1	14.3	10.6
7/16/2009	34	0	7	40.2	18.8	11.6	84.2	33.0	12.7	9.4
7/17/2009	22	0	0	37.7	10.4	22.1	61.1	30.9	11.9	8.8
7/18/2009	40	0	1	22.9	13.7	7.4	65.3	18.8	7.2	5.3
7/19/2009	18	0	18	51.6	24.9	20.0	92.6	42.3	16.3	12.1
7/20/2009	5	0	37	36.0	12.0	22.1	53.7	29.5	11.4	8.4
7/21/2009	31	0	1	46.9	7.6	24.2	60.0	38.5	14.8	11.0
7/22/2009	6	0	29	41.2	19.8	12.6	63.2	33.8	13.0	9.6
7/23/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/24/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/25/2009	12	0	36	43.0	8.9	30.5	64.2	35.3	13.6	10.1
7/26/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/27/2009	0	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/28/2009	2	0	13	59.5	11.2	51.6	67.4	48.8	18.8	13.9
7/29/2009	1	0	47	26.3	N/A	26.3	26.3	21.6	8.3	6.2
7/30/2009	8	0	40	26.8	4.9	17.9	32.6	22.0	8.5	6.3
7/31/2009	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/1/2009	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/2/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/3/2009	12	0	35	59.7	8.9	43.2	74.7	49.0	18.9	14.0
8/4/2009	24	0	18	34.0	9.3	10.5	54.7	27.9	10.7	7.9
8/5/2009	4	0	43	44.7	11.0	34.7	54.7	36.7	14.1	10.5
8/6/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/7/2009	23	0	14	35.8	7.1	22.1	49.5	29.4	11.3	8.4

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
8/8/2009	28	0	15	34.4	10.0	12.6	50.5	28.2	10.8	8.0
8/9/2009	5	0	43	39.8	2.7	36.8	44.2	32.7	12.6	9.3
8/10/2009	5	0	43	40.2	7.2	28.4	47.4	33.0	12.7	9.4
8/11/2009	16	0	32	63.7	12.6	44.2	88.4	52.3	20.1	14.9
8/12/2009	29	0	17	57.3	18.1	22.1	93.7	47.0	18.1	13.4
8/13/2009	17	0	25	42.0	18.8	12.6	91.6	34.5	13.3	9.8
8/14/2009	8	0	29	37.2	13.0	20.0	51.6	30.6	11.8	8.7
8/15/2009	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/16/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2009	2	0	34	38.9	3.0	36.8	41.1	32.0	12.3	9.1

6.12.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ hour periods with valid emissions data
Direction limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction
Touchdown limited: Number of ½ hour periods invalidated because fraction of source area surface covered by particle touchdowns was less than 0.1
Turbulence limited: Number of ½ hour periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m
Background (ppm): bLS model calculated daily average background concentration (ppm); average is over the ½ hour periods included in the valid column
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ hour periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ hour periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ hour periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ hour periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/16/2008	7	0	0	3	0.03	24.9	13.2	5.1	42.4	21.0	8.1	6.0
9/17/2008	16	0	1	22	0.11	38.1	16.1	3.0	70.2	32.1	12.3	9.1
9/18/2008	3	0	4	24	0.08	40.9	6.0	35.2	47.2	34.5	13.3	9.8
9/19/2008	4	0	13	25	0.16	4.7	4.1	1.4	10.7	3.9	1.5	1.1
9/20/2008	7	0	2	25	0.13	36.3	20.1	-4.9	56.3	30.6	11.8	8.7
9/21/2008	10	0	5	14	0.14	31.7	26.9	-3.1	89.0	26.7	10.3	7.6
9/22/2008	2	0	20	14	0.12	39.0	53.6	1.2	76.9	32.9	12.6	9.4
9/23/2008	0	0	11	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/24/2008	10	0	2	14	0.10	51.3	52.5	2.6	188.7	43.2	16.6	12.3
9/25/2008	10	0	4	16	0.11	65.2	46.1	-19.0	111.1	54.9	21.1	15.6
9/26/2008	15	0	6	17	0.10	60.0	19.3	13.2	89.3	50.5	19.4	14.4
9/27/2008	28	0	0	13	0.11	59.8	42.1	1.4	113.0	50.4	19.4	14.3
9/28/2008	21	0	0	15	0.04	57.1	27.5	14.1	114.5	48.1	18.5	13.7
9/29/2008	24	0	4	11	0.08	39.2	20.6	9.2	77.9	33.0	12.7	9.4
9/30/2008	28	0	0	8	0.02	25.5	20.1	0.2	65.5	21.5	8.3	6.1
10/1/2008	26	0	0	8	0.01	37.0	28.4	1.4	92.9	31.2	12.0	8.9
10/2/2008	25	0	0	12	0.05	21.3	9.4	8.3	41.7	17.9	6.9	5.1
10/3/2008	22	0	4	13	0.10	30.1	16.4	5.9	55.2	25.4	9.8	7.2
10/4/2008	21	0	1	19	0.13	23.3	15.7	-1.8	48.8	19.6	7.5	5.6
10/5/2008	5	0	10	20	0.12	23.8	12.2	6.1	38.9	20.1	7.7	5.7

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/6/2008	0	0	33	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2008	2	0	35	0	0.10	-3.7	0.9	-4.4	-3.1	-3.1	-1.2	-0.9
10/8/2008	13	0	10	0	0.11	-3.1	12.1	-25.1	29.2	-2.6	-1.0	-0.7
10/9/2008	1	0	4	1	0.37	13.5	N/A	13.5	13.5	11.4	4.4	3.3
10/10/2008	14	0	0	17	0.04	44.2	11.5	31.3	63.7	37.2	14.3	10.6
10/11/2008	20	0	0	18	0.03	42.2	28.4	9.7	108.3	35.5	13.7	10.1
10/12/2008	18	0	0	11	-0.01	61.7	40.6	4.0	127.8	52.0	20.0	14.8
10/13/2008	24	0	0	7	0.04	55.8	23.7	9.4	93.4	47.0	18.1	13.4
10/14/2008	34	0	0	5	0.02	35.9	14.4	14.2	74.1	30.3	11.6	8.6
10/15/2008	0	0	3	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/16/2008	0	0	2	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/17/2008	0	0	3	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/18/2008	0	0	2	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/19/2008	0	0	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/20/2008	0	0	0	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/21/2008	0	0	2	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/22/2008	12	0	0	18	0.03	44.4	5.8	37.1	54.5	37.4	14.4	10.6
10/23/2008	38	0	0	3	0.05	39.1	13.5	18.6	67.0	32.9	12.7	9.4
10/24/2008	37	0	0	4	0.03	24.2	12.3	1.6	49.7	20.3	7.8	5.8
10/25/2008	40	0	0	0	0.06	19.3	3.9	11.6	27.4	16.3	6.3	4.6
10/26/2008	41	0	0	0	0.06	14.6	8.2	-10.1	26.4	12.3	4.7	3.5
10/27/2008	22	0	2	0	0.06	8.7	3.7	2.1	16.7	7.3	2.8	2.1
10/28/2008	6	0	0	0	0.07	11.0	5.1	0.9	15.0	9.3	3.6	2.6
10/29/2008	35	0	0	3	0.07	7.9	6.8	0.6	22.9	6.6	2.6	1.9
10/30/2008	17	0	0	17	0.02	35.1	19.0	1.0	67.8	29.6	11.4	8.4
10/31/2008	34	0	0	5	0.04	19.9	9.7	3.8	38.9	16.7	6.4	4.8
11/1/2008	15	0	0	15	0.12	27.8	20.0	3.9	68.3	23.4	9.0	6.7
11/2/2008	36	0	0	4	0.03	31.3	7.7	13.0	50.6	26.3	10.1	7.5
11/3/2008	31	0	0	9	0.05	30.8	12.5	14.2	62.7	25.9	10.0	7.4
11/4/2008	15	0	0	17	0.04	39.7	8.2	20.7	53.9	33.4	12.9	9.5
11/5/2008	16	0	0	10	0.05	53.4	23.5	7.8	90.9	45.0	17.3	12.8
11/6/2008	36	0	0	2	0.05	33.4	22.5	0.5	75.7	28.1	10.8	8.0
11/7/2008	35	0	0	5	0.05	31.1	12.4	13.3	60.8	26.2	10.1	7.5
11/8/2008	39	0	2	0	0.06	16.2	6.3	-6.7	32.4	13.6	5.2	3.9
11/9/2008	39	0	1	0	0.06	9.9	2.6	5.0	15.7	8.3	3.2	2.4
11/10/2008	34	0	0	4	0.06	8.1	3.4	4.9	22.1	6.8	2.6	1.9
11/11/2008	20	0	0	18	0.05	10.3	4.7	0.2	19.6	8.7	3.4	2.5
11/12/2008	41	0	0	0	0.03	16.2	4.9	8.8	32.9	13.7	5.3	3.9
11/13/2008	39	0	1	0	0.04	17.9	12.8	-8.9	44.2	15.1	5.8	4.3
11/14/2008	41	0	0	0	0.03	23.5	11.3	0.0	48.8	19.7	7.6	5.6
11/15/2008	40	0	1	0	0.04	18.3	6.8	5.0	33.4	15.4	5.9	4.4
11/16/2008	40	0	0	0	0.05	11.6	3.4	5.3	19.0	9.7	3.7	2.8
11/17/2008	11	0	0	10	0.05	10.9	4.5	7.2	22.0	9.2	3.5	2.6
11/18/2008	0	0	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/19/2008	0	0	0	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
11/20/2008	11	0	0	0	0.08	6.3	1.4	3.7	8.5	5.3	2.0	1.5
11/21/2008	36	0	0	4	0.06	6.8	3.1	2.5	15.5	5.7	2.2	1.6
11/22/2008	17	0	0	22	0.03	7.3	4.9	2.4	20.3	6.1	2.4	1.7
11/23/2008	17	0	0	18	0.04	7.8	5.5	1.1	15.8	6.6	2.5	1.9
11/24/2008	30	0	1	6	0.05	4.0	3.5	-1.0	11.6	3.4	1.3	1.0
11/25/2008	39	0	0	1	0.06	4.9	2.4	1.5	11.4	4.1	1.6	1.2
11/26/2008	14	0	0	24	0.05	3.8	4.8	-3.0	9.2	3.2	1.2	0.9
11/27/2008	15	0	0	12	0.05	6.0	3.4	1.9	15.5	5.0	1.9	1.4
11/28/2008	36	0	0	5	0.06	4.2	3.0	-1.4	11.0	3.5	1.3	1.0
11/29/2008	11	0	0	18	0.09	12.3	8.9	2.0	25.2	10.3	4.0	2.9
11/30/2008	21	0	2	12	0.07	9.2	3.3	4.2	20.0	7.8	3.0	2.2
12/1/2008	41	0	0	0	0.07	3.1	4.5	-7.6	20.1	2.6	1.0	0.8
12/2/2008	41	0	0	0	0.06	4.4	4.8	-4.5	15.2	3.7	1.4	1.1
12/3/2008	39	0	2	0	0.04	16.0	8.3	-8.7	37.8	13.4	5.2	3.8
12/4/2008	39	0	0	0	0.06	0.9	4.3	-9.5	7.0	0.8	0.3	0.2
12/5/2008	40	0	0	0	0.06	-2.7	2.3	-7.1	3.1	-2.3	-0.9	-0.6
12/6/2008	33	0	0	0	0.05	3.8	5.0	-7.2	19.7	3.2	1.2	0.9
12/7/2008	37	0	0	4	0.06	-0.2	2.8	-7.8	5.0	-0.1	0.0	0.0
12/8/2008	29	0	0	0	0.03	6.4	1.9	2.0	10.4	5.4	2.1	1.5
12/9/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/11/2008	4	0	0	6	0.07	-4.4	0.3	-4.7	-4.0	-3.7	-1.4	-1.1
12/12/2008	39	0	0	2	0.08	-2.6	3.8	-10.4	10.3	-2.2	-0.9	-0.6
12/13/2008	35	0	0	6	0.05	5.1	3.2	-3.8	13.9	4.3	1.6	1.2
12/14/2008	40	0	0	0	0.04	7.4	3.7	1.3	16.1	6.2	2.4	1.8
12/15/2008	25	0	0	0	0.06	0.2	9.2	-22.1	13.9	0.2	0.1	0.0
12/16/2008	33	0	0	7	0.07	-2.1	3.4	-7.4	3.5	-1.8	-0.7	-0.5
12/17/2008	8	0	0	0	0.06	-1.9	4.0	-6.6	3.4	-1.6	-0.6	-0.5
12/18/2008	9	0	0	32	0.04	2.1	3.2	-2.4	7.5	1.7	0.7	0.5
12/19/2008	16	0	0	4	0.06	-2.1	4.0	-9.2	3.3	-1.8	-0.7	-0.5
12/20/2008	40	0	0	1	0.06	-0.5	2.0	-4.4	4.1	-0.4	-0.1	-0.1
12/21/2008	22	0	0	4	0.07	-6.8	8.1	-26.3	7.0	-5.7	-2.2	-1.6
12/22/2008	39	0	0	1	0.07	-8.5	2.3	-14.2	-2.2	-7.2	-2.8	-2.0
12/23/2008	27	0	0	6	0.07	1.3	2.9	-4.5	8.2	1.1	0.4	0.3
12/24/2008	27	0	0	0	0.06	-2.2	7.1	-13.5	8.9	-1.9	-0.7	-0.5
12/25/2008	31	0	1	9	0.06	-2.7	4.2	-8.7	7.4	-2.3	-0.9	-0.6
12/26/2008	40	0	0	1	0.06	2.4	2.1	-2.8	7.7	2.1	0.8	0.6
12/27/2008	34	0	3	0	0.05	7.9	4.0	-1.4	15.0	6.6	2.6	1.9
12/28/2008	31	0	6	2	0.06	-9.3	20.3	-42.2	36.7	-7.9	-3.0	-2.2
12/29/2008	14	0	0	9	0.07	-1.4	6.1	-11.6	6.0	-1.2	-0.4	-0.3
12/30/2008	3	0	0	1	0.03	13.4	5.0	7.6	16.7	11.3	4.3	3.2
12/31/2008	6	0	5	1	0.07	-10.7	13.7	-21.1	16.1	-9.0	-3.4	-2.6
1/1/2009	31	0	0	9	-0.02	15.2	4.8	5.7	23.4	12.8	4.9	3.6
1/2/2009	39	0	1	2	0.05	-3.4	9.7	-17.0	12.8	-2.9	-1.1	-0.8
1/3/2009	28	0	0	11	0.03	6.9	3.0	0.2	12.0	5.8	2.2	1.6

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
1/4/2009	39	0	0	1	0.02	3.6	11.8	-13.6	32.9	3.0	1.2	0.9
1/5/2009	25	0	0	8	0.06	-12.8	5.0	-22.0	-4.0	-10.8	-4.2	-3.1
1/6/2009	13	0	0	17	0.04	2.5	2.8	-2.7	7.7	2.1	0.8	0.6
1/7/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/8/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/9/2009	12	0	0	0	0.00	12.5	6.4	5.1	23.3	10.5	4.1	3.0
1/10/2009	39	0	0	0	0.04	0.9	9.2	-15.4	16.0	0.7	0.3	0.2
1/11/2009	29	0	0	10	0.06	-5.7	2.2	-10.1	-1.4	-4.8	-1.9	-1.4
1/12/2009	28	0	0	13	0.04	-0.4	6.4	-10.4	9.8	-0.3	-0.1	-0.1
1/13/2009	38	0	0	1	0.04	-6.5	11.5	-25.1	23.3	-5.5	-2.1	-1.6
1/14/2009	20	0	6	13	0.05	-2.5	7.2	-23.6	6.4	-2.1	-0.8	-0.6
1/15/2009	33	0	1	5	0.05	-8.6	4.4	-15.7	2.9	-7.2	-2.8	-2.1
1/16/2009	19	0	1	19	0.04	-4.2	7.1	-22.9	4.1	-3.6	-1.4	-1.0
1/17/2009	31	0	0	2	0.01	6.1	9.6	-18.4	20.4	5.2	2.0	1.5
1/18/2009	3	0	2	3	0.07	-13.6	7.2	-21.9	-8.9	-11.4	-4.4	-3.3
1/19/2009	16	0	0	23	0.06	-4.7	3.2	-8.9	3.1	-4.0	-1.5	-1.1
1/20/2009	0	0	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/21/2009	0	0	1	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/22/2009	0	0	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/23/2009	7	0	0	10	0.07	-19.4	3.5	-23.3	-14.5	-16.3	-6.3	-4.6
1/24/2009	37	0	0	3	0.06	-10.9	3.9	-21.3	-4.7	-9.1	-3.5	-2.6
1/25/2009	27	0	0	14	0.05	-6.1	1.9	-9.6	-2.7	-5.2	-2.0	-1.5
1/26/2009	2	0	0	36	0.08	-7.1	3.0	-9.2	-5.0	-6.0	-2.3	-1.7
1/27/2009	16	0	0	27	0.04	0.6	4.2	-10.0	5.6	0.5	0.2	0.1
1/28/2009	29	0	0	7	0.06	-7.3	8.0	-31.6	6.4	-6.2	-2.4	-1.8
1/29/2009	36	0	0	3	0.04	1.3	8.6	-26.2	18.7	1.1	0.4	0.3
1/30/2009	18	0	0	0	0.02	-5.4	6.5	-17.7	0.9	-4.5	-1.7	-1.3
1/31/2009	20	0	0	21	-0.04	17.9	6.4	-1.7	27.0	15.1	5.8	4.3
2/1/2009	33	0	0	8	-0.02	6.2	6.0	-2.2	16.8	5.2	2.0	1.5
2/2/2009	20	0	0	19	-0.01	3.2	2.9	-1.9	7.9	2.7	1.0	0.8
2/3/2009	30	0	0	8	0.03	-8.0	7.7	-21.3	6.2	-6.7	-2.6	-1.9
2/4/2009	22	0	0	15	0.01	-3.0	3.7	-10.9	4.2	-2.5	-1.0	-0.7
2/5/2009	15	0	0	20	0.00	9.8	1.6	7.1	12.3	8.3	3.2	2.4
2/6/2009	23	0	0	11	0.00	7.0	1.8	4.0	10.0	5.9	2.3	1.7
2/7/2009	33	0	0	0	0.00	12.1	10.5	5.3	62.3	10.2	3.9	2.9
2/8/2009	0	0	2	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/9/2009	9	0	0	12	0.01	9.8	2.8	5.1	13.1	8.3	3.2	2.4
2/10/2009	41	0	0	0	0.03	8.6	3.6	-0.8	21.8	7.2	2.8	2.1
2/11/2009	40	0	0	0	0.02	14.4	7.8	-11.1	31.4	12.2	4.7	3.5
2/12/2009	41	0	0	0	0.06	0.8	6.8	-23.5	7.1	0.7	0.3	0.2
2/13/2009	28	0	0	12	0.06	3.7	2.5	-1.4	9.4	3.1	1.2	0.9
2/14/2009	24	0	1	4	0.07	7.6	1.6	4.2	11.2	6.4	2.5	1.8
2/15/2009	23	0	0	16	0.07	3.4	3.6	-5.0	9.7	2.8	1.1	0.8
2/16/2009	24	0	0	17	0.07	3.6	4.8	-6.8	10.2	3.1	1.2	0.9
2/17/2009	30	0	0	12	0.03	9.1	6.4	2.0	22.0	7.6	2.9	2.2

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
2/18/2009	35	0	4	0	0.04	13.4	6.2	-0.6	23.4	11.3	4.3	3.2
2/19/2009	4	0	1	1	0.06	5.7	3.5	3.0	10.6	4.8	1.9	1.4
2/20/2009	10	0	1	7	0.05	-2.2	3.6	-9.2	2.3	-1.9	-0.7	-0.5
2/21/2009	19	0	2	9	0.04	6.8	4.8	-2.0	13.3	5.8	2.2	1.6
2/22/2009	44	0	0	0	0.06	1.8	5.8	-5.6	21.4	1.5	0.6	0.4
2/23/2009	17	0	0	30	0.06	-0.7	2.5	-4.2	3.6	-0.5	-0.2	-0.2
2/24/2009	22	0	0	23	0.03	6.3	2.6	0.6	11.0	5.3	2.1	1.5
2/25/2009	27	0	0	1	0.03	3.9	1.4	2.2	6.7	3.3	1.3	0.9
3/11/2009	9	0	0	0	0.05	12.1	2.2	8.8	15.8	10.1	3.9	2.9
3/12/2009	45	0	2	1	0.05	13.7	5.1	4.6	31.0	11.6	4.4	3.3
3/13/2009	24	0	7	17	0.06	9.1	5.1	-4.5	18.8	7.7	3.0	2.2
3/14/2009	8	0	0	38	0.03	18.6	2.5	14.3	20.8	15.7	6.0	4.5
3/15/2009	15	0	0	33	0.02	23.9	5.5	13.3	35.5	20.1	7.7	5.7
3/16/2009	25	0	0	21	0.04	23.8	13.2	3.6	50.6	20.0	7.7	5.7
3/17/2009	23	0	0	11	0.09	17.9	4.1	10.6	29.5	15.1	5.8	4.3
3/18/2009	33	0	0	13	0.08	26.7	15.2	-5.4	82.1	22.5	8.7	6.4
3/19/2009	32	0	0	15	0.03	23.9	8.2	9.7	42.8	20.1	7.7	5.7
3/20/2009	33	0	0	15	0.06	17.7	5.8	9.2	42.1	14.9	5.7	4.2
3/21/2009	30	0	0	17	0.07	17.2	9.7	1.6	53.0	14.5	5.6	4.1
3/22/2009	20	0	0	22	0.06	37.4	14.5	11.7	75.7	31.5	12.1	9.0
3/23/2009	44	0	0	3	0.06	23.4	5.7	12.0	37.1	19.7	7.6	5.6
3/24/2009	48	0	0	0	0.07	18.6	3.2	8.4	25.4	15.7	6.0	4.5
3/25/2009	44	0	0	4	0.05	26.2	9.7	1.0	47.8	22.0	8.5	6.3
3/26/2009	32	0	0	15	0.04	25.4	17.4	7.1	96.2	21.4	8.2	6.1
3/27/2009	18	0	0	23	0.06	25.8	12.9	3.6	46.2	21.7	8.3	6.2
3/28/2009	48	0	0	0	0.07	21.5	7.4	9.0	36.9	18.1	7.0	5.2
3/29/2009	46	0	1	0	0.05	15.8	13.3	-43.3	57.1	13.3	5.1	3.8
3/30/2009	36	0	0	12	0.04	21.6	21.5	-0.2	91.0	18.2	7.0	5.2
3/31/2009	47	0	0	1	0.07	16.3	7.7	-1.3	32.3	13.7	5.3	3.9
4/1/2009	45	0	0	3	0.05	18.5	8.6	7.1	37.5	15.6	6.0	4.4
4/2/2009	31	0	0	13	0.07	19.3	8.0	7.1	36.3	16.3	6.3	4.6
4/3/2009	47	0	0	0	0.04	25.8	9.7	8.8	48.7	21.7	8.4	6.2
4/4/2009	4	0	9	23	0.02	9.0	6.3	0.0	14.6	7.6	2.9	2.2
4/5/2009	0	0	0	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2009	24	0	1	0	0.00	30.4	8.0	15.0	46.2	25.6	9.9	7.3
4/7/2009	35	0	0	0	0.01	20.8	5.3	10.1	31.1	17.5	6.7	5.0
4/8/2009	43	0	0	5	0.04	13.2	7.0	2.9	25.3	11.1	4.3	3.2
4/9/2009	16	0	0	29	0.02	37.6	12.5	8.1	60.6	31.7	12.2	9.0
4/10/2009	43	0	0	5	0.06	18.9	5.3	6.1	28.8	15.9	6.1	4.5
4/11/2009	46	0	0	2	0.06	17.4	5.2	10.2	33.1	14.7	5.6	4.2
4/12/2009	34	0	0	14	0.05	23.0	7.1	10.5	41.7	19.4	7.5	5.5
4/13/2009	47	0	1	0	0.06	20.2	4.7	12.1	29.7	17.0	6.5	4.8
4/14/2009	36	0	2	10	0.05	13.5	4.3	-0.8	19.5	11.4	4.4	3.2
4/15/2009	47	0	0	1	0.07	13.6	2.1	9.1	18.4	11.4	4.4	3.3
4/16/2009	19	0	0	23	0.06	33.3	7.7	22.4	49.0	28.0	10.8	8.0

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
4/17/2009	17	0	0	21	0.06	51.2	24.7	8.5	105.9	43.1	16.6	12.3
4/18/2009	11	0	0	29	0.07	52.6	22.7	15.0	95.5	44.3	17.0	12.6
4/19/2009	21	0	1	21	0.07	26.1	7.7	13.2	43.3	22.0	8.5	6.3
4/20/2009	40	0	2	4	0.04	15.3	6.3	-0.1	29.5	12.9	5.0	3.7
4/21/2009	47	0	1	0	0.05	9.4	4.0	0.2	21.8	7.9	3.1	2.3
4/22/2009	40	0	0	7	0.03	16.6	6.1	6.9	27.5	14.0	5.4	4.0
4/23/2009	25	0	0	22	0.06	30.7	7.0	17.1	42.0	25.9	9.9	7.4
4/24/2009	48	0	0	0	0.06	32.2	14.0	14.9	69.4	27.1	10.4	7.7
4/25/2009	48	0	0	0	0.05	40.2	9.0	25.8	70.2	33.8	13.0	9.6
4/26/2009	43	0	0	5	0.10	44.8	30.9	-110.3	91.4	37.7	14.5	10.7
4/27/2009	35	0	1	1	0.08	53.4	13.4	23.1	78.8	44.9	17.3	12.8
4/28/2009	0	0	1	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2009	11	0	1	2	0.05	25.9	8.6	17.9	41.4	21.8	8.4	6.2
5/1/2009	41	0	0	7	0.04	26.4	7.8	15.7	45.9	22.2	8.5	6.3
5/2/2009	28	0	0	19	0.03	39.5	13.6	17.2	62.2	33.3	12.8	9.5
5/3/2009	15	0	0	24	0.01	60.8	21.6	17.9	84.4	51.2	19.7	14.6
5/4/2009	18	0	0	29	0.07	41.4	16.1	11.1	75.1	34.9	13.4	9.9
5/5/2009	20	0	0	16	0.07	43.0	18.4	25.4	101.2	36.2	13.9	10.3
5/6/2009	27	0	0	11	0.01	36.5	13.7	6.3	70.5	30.7	11.8	8.8
5/7/2009	33	0	3	10	0.04	55.6	78.0	0.9	480.8	46.8	18.0	13.3
5/8/2009	18	0	1	25	0.03	40.1	23.0	1.4	95.1	33.8	13.0	9.6
5/9/2009	15	0	7	10	0.05	33.4	15.6	6.0	63.3	28.1	10.8	8.0
5/10/2009	14	0	6	18	0.04	58.7	18.3	21.8	85.2	49.4	19.0	14.1
5/11/2009	16	0	10	15	0.05	19.8	18.1	-23.2	54.6	16.7	6.4	4.8
5/12/2009	27	0	0	20	0.03	43.1	21.4	8.9	87.8	36.3	14.0	10.3
5/13/2009	39	0	0	8	0.01	34.2	16.2	10.7	78.4	28.8	11.1	8.2
5/14/2009	29	0	18	0	0.02	41.3	17.0	-5.5	60.5	34.8	13.4	9.9
5/15/2009	20	0	0	25	0.04	53.5	19.4	0.8	78.3	45.1	17.3	12.8
5/16/2009	22	0	5	3	0.03	18.7	15.1	0.0	58.0	15.8	6.1	4.5
5/17/2009	0	0	19	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/18/2009	20	0	2	12	0.00	68.7	31.7	23.0	127.7	57.9	22.3	16.5
5/19/2009	40	0	0	7	0.03	66.5	39.6	12.4	143.6	56.0	21.5	16.0
5/20/2009	36	0	1	7	0.03	75.8	48.5	11.0	174.9	63.8	24.5	18.2
5/21/2009	0	0	1	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	11	0	1	24	0.03	58.9	51.6	0.0	134.1	49.6	19.1	14.1
5/23/2009	35	0	1	12	0.05	39.7	21.0	2.3	87.5	33.4	12.9	9.5
5/24/2009	27	0	0	14	0.10	61.8	25.6	1.0	107.5	52.0	20.0	14.8
5/25/2009	12	0	3	6	0.02	61.1	6.4	50.0	72.7	51.5	19.8	14.7
5/26/2009	9	0	0	0	0.06	89.7	52.9	16.1	160.3	75.5	29.0	21.5
5/27/2009	43	0	0	5	0.05	77.1	48.9	1.1	158.6	64.9	25.0	18.5
5/28/2009	6	0	13	9	0.04	49.7	31.5	-0.5	83.7	41.9	16.1	11.9
5/29/2009	5	0	16	14	0.02	14.5	6.1	5.7	21.9	12.2	4.7	3.5
5/30/2009	17	0	3	27	0.02	79.6	27.9	27.6	117.9	67.0	25.8	19.1
5/31/2009	25	0	7	13	0.02	36.3	28.2	-4.7	100.9	30.6	11.8	8.7

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/1/2009	41	0	1	6	0.03	48.7	47.5	-16.2	142.3	41.0	15.8	11.7
6/2/2009	5	0	1	17	0.04	17.9	9.7	5.8	30.4	15.1	5.8	4.3
6/3/2009	16	0	0	1	0.01	38.4	6.0	26.5	50.5	32.3	12.4	9.2
6/4/2009	25	0	1	20	0.01	58.0	20.4	2.6	94.1	48.8	18.8	13.9
6/5/2009	15	0	7	17	0.02	37.6	24.8	7.6	97.8	31.7	12.2	9.0
6/6/2009	33	0	0	13	0.03	67.1	32.7	7.9	152.7	56.5	21.7	16.1
6/7/2009	42	0	0	4	0.02	45.3	28.9	1.5	97.9	38.2	14.7	10.9
6/8/2009	38	0	0	8	0.03	63.4	39.2	7.8	148.3	53.3	20.5	15.2
6/9/2009	18	0	10	11	0.06	30.1	21.0	2.5	66.3	25.3	9.7	7.2
6/10/2009	34	0	2	12	0.04	52.7	14.4	13.2	76.7	44.4	17.1	12.6
6/11/2009	35	0	6	5	0.02	27.9	17.0	6.8	61.0	23.5	9.0	6.7
6/12/2009	18	0	28	2	0.03	49.6	25.2	8.8	97.2	41.7	16.0	11.9
6/13/2009	20	0	5	17	0.01	39.9	21.3	13.1	85.9	33.6	12.9	9.6
6/14/2009	24	0	11	13	0.02	44.1	18.1	21.0	107.4	37.1	14.3	10.6
6/15/2009	14	0	7	27	0.02	77.0	13.7	53.1	99.1	64.8	24.9	18.5
6/16/2009	35	0	1	8	0.02	53.7	17.3	14.3	90.4	45.2	17.4	12.9
6/17/2009	29	0	7	10	0.02	47.4	33.2	2.7	108.8	39.9	15.4	11.4
6/18/2009	17	0	9	17	0.08	32.0	23.9	-8.1	83.3	26.9	10.4	7.7
6/19/2009	24	0	7	6	0.07	51.9	25.7	-2.9	95.9	43.7	16.8	12.4
6/20/2009	31	0	1	0	0.02	33.5	26.2	0.7	93.2	28.2	10.8	8.0
6/21/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/22/2009	2	0	6	3	0.12	59.0	77.9	3.8	114.1	49.6	19.1	14.1
6/23/2009	14	0	4	18	0.13	56.5	37.3	-13.1	102.1	47.5	18.3	13.5
6/24/2009	18	0	0	17	0.12	92.3	43.5	4.7	173.1	77.7	29.9	22.1
6/25/2009	20	0	0	14	0.11	62.0	40.4	0.2	158.2	52.2	20.1	14.9
6/26/2009	25	0	0	13	0.06	121.9	54.6	5.8	209.3	102.6	39.5	29.2
6/27/2009	19	0	0	16	0.10	64.4	42.4	5.5	145.6	54.2	20.9	15.5
6/28/2009	31	0	0	7	0.03	46.7	34.8	1.3	139.3	39.3	15.1	11.2
6/29/2009	40	0	0	0	0.02	23.8	14.1	2.8	58.2	20.1	7.7	5.7
6/30/2009	28	0	0	11	0.02	46.5	24.9	0.3	87.4	39.1	15.0	11.1
7/1/2009	27	0	0	15	0.03	29.0	13.2	5.1	63.3	24.4	9.4	7.0
7/2/2009	29	0	0	5	0.03	32.8	21.2	4.1	82.8	27.6	10.6	7.9
7/3/2009	22	0	0	17	0.04	48.3	24.9	17.9	115.9	40.7	15.7	11.6
7/4/2009	25	0	0	13	0.04	26.5	17.9	2.4	74.8	22.3	8.6	6.4
7/5/2009	22	0	0	18	0.04	70.3	30.6	11.0	113.6	59.2	22.8	16.9
7/6/2009	19	0	0	18	0.03	64.4	26.8	18.8	106.6	54.2	20.9	15.4
7/7/2009	20	0	0	16	0.05	81.9	32.7	19.7	156.0	69.0	26.5	19.6
7/8/2009	21	0	1	20	0.06	56.7	25.6	20.2	108.3	47.7	18.4	13.6
7/9/2009	25	0	0	14	0.06	43.9	13.6	16.3	67.4	37.0	14.2	10.5
7/10/2009	13	0	0	14	0.05	45.9	33.0	3.0	110.5	38.6	14.8	11.0
7/11/2009	11	0	10	13	0.02	53.2	20.8	29.4	92.7	44.8	17.2	12.8
7/12/2009	0	0	17	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2009	22	0	1	16	0.03	71.0	47.0	7.0	145.0	59.8	23.0	17.0
7/14/2009	27	0	0	16	0.07	62.0	28.8	21.9	124.5	52.2	20.1	14.9
7/15/2009	41	0	0	6	0.02	35.2	24.8	4.0	94.4	29.6	11.4	8.4

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/16/2009	26	0	0	10	0.02	40.9	24.1	12.5	89.3	34.4	13.2	9.8
7/17/2009	22	0	0	0	0.01	33.6	12.5	13.5	57.4	28.3	10.9	8.1
7/18/2009	41	0	0	7	0.01	19.5	14.6	3.4	53.9	16.4	6.3	4.7
7/19/2009	19	0	0	18	0.06	39.9	29.0	0.2	105.5	33.6	12.9	9.6
7/20/2009	21	0	1	19	0.06	30.1	18.2	9.7	86.6	25.4	9.8	7.2
7/21/2009	24	0	0	18	0.03	42.8	25.6	4.9	116.4	36.0	13.8	10.3
7/22/2009	21	0	0	25	0.02	39.9	25.8	0.1	76.6	33.6	12.9	9.6
7/23/2009	1	0	6	14	0.01	4.5	N/A	4.5	4.5	3.8	1.4	1.1
7/24/2009	23	0	0	17	0.04	87.0	27.9	2.7	130.3	73.2	28.2	20.9
7/25/2009	17	0	25	3	0.04	46.1	10.2	16.5	59.6	38.9	14.9	11.1
7/26/2009	30	0	16	2	0.01	24.1	12.7	6.0	59.8	20.3	7.8	5.8
7/27/2009	8	0	0	19	0.00	61.9	23.2	31.0	97.0	52.1	20.0	14.8
7/28/2009	12	0	1	0	0.04	72.2	43.3	5.1	124.0	60.8	23.4	17.3
7/29/2009	2	0	18	19	0.03	23.0	13.5	13.5	32.6	19.4	7.5	5.5
7/30/2009	14	0	4	23	0.03	34.3	14.1	6.1	55.2	28.9	11.1	8.2
7/31/2009	1	0	15	13	0.03	-4.8	N/A	-4.8	-4.8	-4.0	-1.6	-1.2
8/1/2009	22	0	1	18	0.02	65.4	19.5	33.0	100.7	55.1	21.2	15.7
8/2/2009	2	0	12	9	0.06	10.2	2.0	8.8	11.6	8.6	3.3	2.4
8/3/2009	30	0	5	9	0.02	89.0	44.3	20.0	165.0	75.0	28.8	21.4
8/4/2009	29	0	1	12	0.02	51.5	20.5	2.3	84.2	43.3	16.7	12.3
8/5/2009	23	0	7	14	0.04	34.1	15.5	13.8	66.5	28.7	11.1	8.2
8/6/2009	1	0	17	17	0.03	11.0	N/A	11.0	11.0	9.2	3.6	2.6
8/7/2009	19	0	1	27	0.02	30.5	14.8	7.5	55.9	25.7	9.9	7.3
8/8/2009	43	0	0	5	0.02	61.6	41.0	6.3	135.9	51.9	20.0	14.8
8/9/2009	48	0	0	0	0.04	89.4	28.4	46.3	145.8	75.3	29.0	21.5
8/10/2009	26	0	10	8	0.02	54.7	22.3	9.3	94.5	46.1	17.7	13.1
8/11/2009	19	0	5	17	0.05	48.9	30.2	7.3	115.8	41.2	15.8	11.7
8/12/2009	40	0	0	7	0.06	35.6	19.2	9.1	86.5	30.0	11.5	8.5
8/13/2009	24	0	0	13	0.07	34.3	18.7	9.2	75.6	28.9	11.1	8.2
8/14/2009	21	0	0	18	0.10	34.3	25.5	1.1	83.9	28.9	11.1	8.2
8/15/2009	7	0	12	15	0.08	21.6	9.7	10.0	36.0	18.2	7.0	5.2
8/16/2009	20	0	4	14	0.07	31.2	13.7	4.3	65.2	26.2	10.1	7.5
8/17/2009	5	0	3	3	0.01	20.5	4.0	16.2	25.2	17.3	6.7	4.9

6.12.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ hour periods with valid emissions data
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ hour periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ hour periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ hour periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ hour periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/20/2008	1	0.7	0.0	0.7	0.7	0.6	0.2	0.2
9/21/2008	1	2.5	0.0	2.5	2.5	2.0	0.8	0.6
9/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2008	11	8.9	30.8	-5.4	21.6	7.3	2.8	2.1
9/28/2008	17	2.4	16.2	0.1	7.6	2.0	0.8	0.6
9/29/2008	6	9.2	32.8	4.1	14.2	7.6	2.9	2.2
9/30/2008	9	9.4	32.0	3.2	14.3	7.8	3.0	2.2
10/1/2008	15	7.6	28.3	1.6	14.7	6.3	2.4	1.8
10/2/2008	6	4.0	22.1	2.0	5.9	3.3	1.3	0.9
10/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/4/2008	5	2.0	15.9	-0.5	6.5	1.6	0.6	0.5
10/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($gd^{-1} hd^{-1}$)	Emission average ($gd^{-1} AU^{-1}$)
10/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/11/2008	12	1.9	14.5	0.2	4.7	1.5	0.6	0.4
10/12/2008	17	4.4	21.7	0.3	12.7	3.6	1.4	1.0
10/13/2008	33	7.3	27.2	-3.7	23.9	6.0	2.3	1.7
10/14/2008	21	5.0	22.9	0.1	17.3	4.1	1.6	1.2
10/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/24/2008	11	10.3	32.8	1.7	32.3	8.5	3.3	2.4
10/25/2008	8	20.4	44.8	6.8	42.6	16.8	6.4	4.8
10/26/2008	12	18.6	42.1	12.2	34.5	15.2	5.9	4.3
10/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/29/2008	6	10.2	34.2	2.9	19.6	8.4	3.2	2.4
10/30/2008	20	6.8	26.6	2.9	14.3	5.6	2.1	1.6
10/31/2008	17	8.1	29.0	1.7	20.6	6.7	2.6	1.9
11/1/2008	23	0.1	3.9	-7.8	7.9	0.1	0.0	0.0
11/2/2008	11	2.4	16.4	1.0	5.8	1.9	0.7	0.6
11/3/2008	20	4.7	22.3	1.7	16.9	3.8	1.5	1.1
11/4/2008	16	4.6	22.3	0.2	12.9	3.8	1.5	1.1
11/5/2008	17	6.4	26.0	-0.7	19.9	5.3	2.0	1.5
11/6/2008	33	8.5	29.1	-19.0	28.2	7.0	2.7	2.0
11/7/2008	26	8.2	28.9	2.2	30.3	6.8	2.6	1.9
11/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/12/2008	14	13.5	36.9	1.5	58.2	11.1	4.3	3.2
11/13/2008	14	11.3	34.3	2.1	25.3	9.3	3.6	2.6
11/14/2008	5	6.9	29.2	1.8	13.6	5.7	2.2	1.6
11/15/2008	32	11.0	32.7	2.9	32.3	9.0	3.5	2.6
11/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/17/2008	6	1.0	11.3	0.2	1.8	0.8	0.3	0.2
11/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/20/2008	4	15.8	44.2	12.8	19.2	13.0	5.0	3.7
11/21/2008	16	3.4	19.2	0.4	12.5	2.8	1.1	0.8
11/22/2008	5	2.3	17.1	1.0	3.9	1.9	0.7	0.5

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
11/23/2008	1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
11/24/2008	13	3.3	19.3	0.1	14.8	2.7	1.0	0.8
11/25/2008	5	3.9	22.3	3.1	4.7	3.2	1.2	0.9
11/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/27/2008	1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
11/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/29/2008	7	1.3	12.4	0.0	2.9	1.0	0.4	0.3
11/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2008	1	9.7	0.0	9.7	9.7	8.0	3.1	2.3
12/2/2008	1	8.3	0.0	8.3	8.3	6.8	2.6	2.0
12/3/2008	9	7.5	28.8	4.6	12.2	6.1	2.4	1.7
12/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/8/2008	1	0.8	0.0	0.8	0.8	0.6	0.2	0.2
12/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/26/2008	1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
12/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/30/2008	2	2.4	22.5	2.1	2.8	2.0	0.8	0.6
12/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/3/2009	1	-0.2	0.0	-0.2	-0.2	-0.1	-0.1	0.0
1/4/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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1/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/11/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/13/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/14/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/16/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/18/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/19/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/20/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/22/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/23/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/3/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/4/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/11/2009	4	0.3	6.7	-0.1	0.6	0.3	0.1	0.1
2/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/13/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/14/2009	13	0.6	8.6	0.3	1.1	0.5	0.2	0.2
2/15/2009	16	0.2	4.5	-0.2	0.9	0.1	0.1	0.0
2/16/2009	14	0.5	7.2	-0.1	1.7	0.4	0.1	0.1
2/17/2009	1	1.1	0.0	1.1	1.1	0.9	0.4	0.3
2/18/2009	5	2.0	16.3	1.0	3.5	1.7	0.6	0.5
2/19/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/20/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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2/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/22/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/23/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2009	1	3.1	0.0	3.1	3.1	2.5	1.0	0.7
3/13/2009	1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
3/14/2009	1	1.0	0.0	1.0	1.0	0.8	0.3	0.2
3/15/2009	2	1.6	18.4	0.3	2.9	1.3	0.5	0.4
3/16/2009	1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
3/17/2009	12	7.8	28.9	-1.0	30.0	6.4	2.5	1.8
3/18/2009	25	3.4	19.0	-0.8	9.4	2.8	1.1	0.8
3/19/2009	24	1.0	10.3	0.0	4.4	0.8	0.3	0.2
3/20/2009	10	3.1	18.8	0.5	9.4	2.5	1.0	0.7
3/21/2009	11	1.3	12.3	0.1	3.2	1.1	0.4	0.3
3/22/2009	17	0.4	7.0	0.1	1.3	0.4	0.1	0.1
3/23/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2009	14	14.6	38.1	7.3	24.1	12.0	4.6	3.4
3/25/2009	17	19.5	42.1	0.3	40.0	16.0	6.2	4.6
3/26/2009	13	1.3	12.2	0.4	2.9	1.1	0.4	0.3
3/27/2009	9	1.1	11.5	-0.1	4.8	0.9	0.3	0.3
3/28/2009	2	6.7	36.9	6.6	6.8	5.5	2.1	1.6
3/29/2009	1	5.2	0.0	5.2	5.2	4.3	1.6	1.2
3/30/2009	4	0.8	10.8	0.0	1.6	0.7	0.3	0.2
3/31/2009	10	26.2	48.9	5.8	71.8	21.5	8.3	6.1
4/1/2009	8	13.3	37.6	4.5	45.3	10.9	4.2	3.1
4/2/2009	14	2.7	17.4	0.6	5.7	2.2	0.9	0.6
4/3/2009	3	7.0	32.3	3.8	11.9	5.8	2.2	1.6
4/4/2009	5	2.2	16.8	1.2	3.6	1.8	0.7	0.5
4/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2009	3	6.2	30.8	4.7	7.8	5.1	1.9	1.4
4/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/9/2009	3	4.4	26.4	0.9	7.1	3.6	1.4	1.0
4/10/2009	1	10.6	0.0	10.6	10.6	8.7	3.3	2.5
4/11/2009	31	9.9	31.2	1.7	22.8	8.1	3.1	2.3
4/12/2009	6	7.5	29.9	-9.0	15.0	6.2	2.4	1.8
4/13/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2009	4	10.0	36.1	8.0	11.5	8.2	3.1	2.3
4/15/2009	30	12.1	34.3	4.6	24.3	10.0	3.8	2.8
4/16/2009	1	2.6	0.0	2.6	2.6	2.1	0.8	0.6
4/17/2009	14	1.0	10.6	-0.1	2.3	0.8	0.3	0.2
4/18/2009	9	1.8	14.4	0.5	5.8	1.5	0.6	0.4
4/19/2009	4	0.9	11.4	-0.1	2.3	0.8	0.3	0.2

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4/20/2009	1	4.4	0.0	4.4	4.4	3.6	1.4	1.0
4/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/22/2009	1	10.4	0.0	10.4	10.4	8.5	3.3	2.4
4/23/2009	26	9.2	30.4	4.2	22.0	7.5	2.9	2.1
4/24/2009	25	17.3	39.8	3.9	46.2	14.2	5.5	4.1
4/25/2009	12	15.8	39.4	11.1	22.8	12.9	5.0	3.7
4/26/2009	37	15.2	37.6	3.4	55.5	12.5	4.8	3.6
4/27/2009	28	16.3	39.5	3.2	36.7	13.4	5.2	3.8
4/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2009	10	10.6	33.4	2.6	34.2	8.7	3.3	2.5
5/2/2009	8	5.8	25.7	2.0	10.1	4.8	1.8	1.4
5/3/2009	11	1.3	12.3	0.1	7.8	1.1	0.4	0.3
5/4/2009	2	6.8	37.2	5.8	7.9	5.6	2.2	1.6
5/5/2009	8	5.5	25.0	2.1	14.7	4.5	1.7	1.3
5/6/2009	16	7.6	28.1	2.6	17.0	6.2	2.4	1.8
5/7/2009	9	7.3	28.5	3.0	9.8	6.0	2.3	1.7
5/8/2009	12	8.1	29.3	0.4	34.6	6.7	2.6	1.9
5/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/11/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/12/2009	17	4.2	21.3	0.4	9.2	3.4	1.3	1.0
5/13/2009	27	28.8	48.0	3.9	88.5	23.6	9.1	6.7
5/14/2009	12	40.0	58.5	15.0	79.5	32.9	12.6	9.4
5/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/18/2009	13	4.7	22.6	1.0	8.2	3.8	1.5	1.1
5/19/2009	21	3.9	20.3	2.7	7.6	3.2	1.2	0.9
5/20/2009	32	-8.4	0.0	-417.5	11.2	-6.9	-2.6	-2.0
5/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2009	2	4.3	29.6	3.2	5.4	3.5	1.4	1.0
5/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2009	2	2.2	21.5	2.1	2.3	1.8	0.7	0.5
5/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2009	6	1.9	15.6	0.6	3.9	1.6	0.6	0.5
5/31/2009	2	1.6	18.5	1.3	1.9	1.3	0.5	0.4
6/1/2009	26	5.9	24.8	1.0	17.5	4.9	1.9	1.4
6/2/2009	1	9.2	0.0	9.2	9.2	7.6	2.9	2.2
6/3/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/4/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/6/2009	9	8.6	30.5	3.8	13.6	7.0	2.7	2.0
6/7/2009	26	4.9	22.5	-1.1	9.4	4.0	1.5	1.1
6/8/2009	17	4.7	22.6	-2.9	11.7	3.9	1.5	1.1
6/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/11/2009	8	5.8	25.8	3.2	12.1	4.8	1.8	1.4
6/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/13/2009	1	2.6	0.0	2.6	2.6	2.1	0.8	0.6
6/14/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/16/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/17/2009	6	6.8	28.5	0.4	9.5	5.6	2.2	1.6
6/18/2009	7	4.5	23.1	2.6	7.3	3.7	1.4	1.1
6/19/2009	2	22.5	63.9	18.7	26.3	18.5	7.1	5.3
6/20/2009	1	16.3	0.0	16.3	16.3	13.3	5.1	3.8
6/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/22/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/23/2009	4	1.9	16.1	1.4	2.2	1.5	0.6	0.4
6/24/2009	12	4.1	21.5	1.1	9.6	3.4	1.3	1.0
6/25/2009	3	2.8	21.0	1.1	4.8	2.3	0.9	0.7
6/26/2009	23	4.5	21.9	1.0	9.9	3.7	1.4	1.1
6/27/2009	10	2.9	18.2	-1.0	7.5	2.4	0.9	0.7
6/28/2009	8	5.8	25.8	1.9	8.4	4.8	1.8	1.4
6/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/30/2009	13	3.9	20.6	0.8	5.8	3.2	1.2	0.9
7/1/2009	13	2.1	15.4	0.2	3.1	1.7	0.7	0.5
7/2/2009	16	3.2	18.6	1.2	6.6	2.6	1.0	0.7
7/3/2009	15	2.2	15.5	0.9	5.1	1.8	0.7	0.5
7/4/2009	16	2.7	17.2	0.1	6.9	2.2	0.8	0.6
7/5/2009	7	0.6	8.3	-0.4	0.9	0.5	0.2	0.1
7/6/2009	7	1.2	12.0	0.6	2.7	1.0	0.4	0.3
7/7/2009	8	1.9	15.1	0.1	3.1	1.6	0.6	0.4
7/8/2009	9	2.8	18.3	-0.4	9.0	2.3	0.9	0.7
7/9/2009	16	3.4	19.1	0.5	7.2	2.8	1.1	0.8
7/10/2009	9	1.5	13.4	-0.2	2.7	1.3	0.5	0.4
7/11/2009	3	1.7	16.2	0.4	2.9	1.4	0.5	0.4
7/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2009	12	3.1	18.7	0.5	8.2	2.5	1.0	0.7
7/14/2009	13	2.7	17.2	0.5	6.0	2.2	0.8	0.6
7/15/2009	14	3.8	20.3	0.1	14.7	3.1	1.2	0.9
7/16/2009	3	2.3	19.0	1.4	2.9	1.9	0.7	0.5
7/17/2009	6	7.3	29.8	3.4	11.5	6.0	2.3	1.7
7/18/2009	7	3.4	20.2	0.3	6.3	2.8	1.1	0.8

Date	Valid	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} h d^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
7/19/2009	10	3.8	20.9	1.1	7.5	3.2	1.2	0.9
7/20/2009	5	1.3	13.3	0.0	2.4	1.1	0.4	0.3
7/21/2009	14	2.7	17.4	0.5	5.1	2.2	0.9	0.6
7/22/2009	6	4.1	22.4	0.8	8.2	3.4	1.3	1.0
7/23/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/25/2009	10	8.6	31.0	3.2	18.2	7.1	2.7	2.0
7/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/28/2009	2	34.7	91.6	10.4	59.1	28.5	11.0	8.1
7/29/2009	1	5.0	0.0	5.0	5.0	4.1	1.6	1.2
7/30/2009	8	2.3	16.5	0.2	4.6	1.9	0.7	0.5
7/31/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/3/2009	12	14.4	37.9	6.8	20.0	11.8	4.5	3.4
8/4/2009	22	7.8	28.2	1.9	15.8	6.4	2.5	1.8
8/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/7/2009	10	2.6	17.3	1.1	5.2	2.1	0.8	0.6
8/8/2009	22	4.2	21.1	0.3	10.1	3.4	1.3	1.0
8/9/2009	5	5.4	26.1	3.8	6.8	4.4	1.7	1.3
8/10/2009	5	2.1	16.3	1.6	3.1	1.7	0.7	0.5
8/11/2009	10	5.8	25.3	2.7	16.3	4.7	1.8	1.3
8/12/2009	25	2.5	16.4	0.3	5.9	2.0	0.8	0.6
8/13/2009	14	2.4	16.4	0.0	4.7	2.0	0.8	0.6
8/14/2009	8	3.8	21.1	0.2	15.9	3.1	1.2	0.9
8/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/16/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ hour periods with valid emissions data
Direction limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ hour periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ hour periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ hour periods included in the valid column
Emission average (μgm^{-2}s^{-1}): Daily average emission calculated from the valid ½ hour periods
Emissions SD (μgm^{-2}s^{-1}): Daily emission standard deviation of the valid ½ hour periods
Emission minimum (μgm^{-2}s^{-1}): Daily minimum emission of the valid ½ hour periods
Emission maximum (μgm^{-2}s^{-1}): Daily maximum emission of the valid ½ hour periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area
Emission average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis
Emission average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average (μgm^{-2}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd^{-1}AU^{-1})
9/12/2008	36	0	0	4	-1.0	17.7	18.9	3.4	112.4	14.3	5.5	4.1
9/13/2008	34	0	5	8	0.0	21.9	14.9	0.2	61.0	17.6	6.8	5.0
9/14/2008	29	0	8	11	-1.4	24.7	37.4	3.2	184.7	19.9	7.6	5.7
9/15/2008	24	0	16	0	-0.1	5.7	3.3	0.9	12.6	4.6	1.8	1.3
9/16/2008	13	0	11	22	4.1	4.7	3.6	0.0	10.1	3.8	1.5	1.1
9/17/2008	8	0	8	26	-1.2	9.3	5.2	3.8	15.9	7.5	2.9	2.1
9/18/2008	0	0	6	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/19/2008	9	0	13	25	-0.6	1.1	1.1	0.0	2.8	0.9	0.4	0.3
9/20/2008	8	0	2	35	0.8	0.6	0.3	0.0	1.0	0.5	0.2	0.1
9/21/2008	5	0	10	26	6.2	2.2	3.1	-0.5	7.5	1.7	0.7	0.5
9/22/2008	0	0	24	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/23/2008	3	0	19	19	-1.4	8.2	0.9	7.3	9.2	6.6	2.5	1.9
9/24/2008	3	0	4	25	14.0	1.8	1.9	-0.2	3.5	1.5	0.6	0.4
9/25/2008	7	0	7	24	1.2	3.9	3.3	0.6	10.2	3.1	1.2	0.9
9/26/2008	12	0	9	20	9.0	13.9	11.4	-2.1	38.8	11.2	4.3	3.2
9/27/2008	26	0	2	13	5.8	10.1	10.0	-0.5	37.2	8.2	3.1	2.3
9/28/2008	17	0	3	21	4.6	2.1	2.0	0.1	7.3	1.7	0.6	0.5
9/29/2008	18	0	8	11	3.9	6.9	5.5	0.3	19.2	5.6	2.1	1.6
9/30/2008	12	0	16	13	0.0	8.4	4.7	0.0	15.5	6.8	2.6	1.9

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/1/2008	18	0	6	12	0.2	7.9	6.8	0.2	21.3	6.4	2.5	1.8
10/2/2008	9	0	15	15	4.7	5.2	5.3	-1.2	15.7	4.2	1.6	1.2
10/3/2008	16	0	8	13	4.0	2.9	3.3	-1.4	11.2	2.3	0.9	0.7
10/4/2008	20	0	2	19	9.2	1.4	3.8	-3.8	12.4	1.1	0.4	0.3
10/5/2008	6	0	11	23	6.8	3.5	5.3	-3.5	9.9	2.8	1.1	0.8
10/6/2008	0	0	33	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2008	6	0	33	0	-0.5	17.3	14.7	3.1	37.5	13.9	5.3	4.0
10/8/2008	24	0	0	0	-0.7	19.0	15.0	1.2	68.2	15.3	5.9	4.4
10/9/2008	7	0	0	1	1.7	3.1	1.4	1.6	5.7	2.5	1.0	0.7
10/10/2008	3	0	6	27	0.0	4.2	1.3	3.0	5.7	3.4	1.3	1.0
10/11/2008	12	0	8	21	-0.2	2.5	2.9	0.1	10.5	2.0	0.8	0.6
10/12/2008	15	0	2	23	1.4	3.8	3.1	0.1	8.9	3.0	1.2	0.9
10/13/2008	22	0	0	16	0.7	12.6	8.8	1.1	37.4	10.1	3.9	2.9
10/14/2008	33	0	0	5	0.1	10.6	8.7	-0.1	40.8	8.6	3.3	2.4
10/15/2008	11	0	7	21	0.7	9.7	9.6	-0.5	32.2	7.8	3.0	2.2
10/16/2008	33	0	4	2	1.6	13.3	12.6	-9.3	51.4	10.7	4.1	3.0
10/17/2008	15	0	12	14	5.8	7.3	5.5	0.0	15.8	5.9	2.3	1.7
10/18/2008	19	0	3	16	5.1	5.9	3.9	-2.2	15.5	4.7	1.8	1.3
10/19/2008	18	0	0	22	0.3	10.1	5.5	0.2	22.7	8.1	3.1	2.3
10/20/2008	20	0	2	18	-0.4	18.1	9.3	4.7	33.3	14.6	5.6	4.2
10/21/2008	26	0	0	15	3.6	18.4	11.0	5.2	51.8	14.8	5.7	4.2
10/22/2008	3	0	21	18	7.4	7.9	0.5	7.5	8.5	6.3	2.4	1.8
10/23/2008	0	0	36	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/24/2008	21	0	13	4	-0.8	14.5	16.7	3.3	79.0	11.6	4.5	3.3
10/25/2008	37	0	1	0	-1.2	22.5	10.8	6.3	50.7	18.1	7.0	5.2
10/26/2008	25	0	15	0	-1.3	26.7	11.0	8.8	63.3	21.4	8.2	6.1
10/27/2008	0	0	23	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/28/2008	0	0	3	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/29/2008	8	0	23	3	-1.3	12.3	6.4	4.8	22.4	9.9	3.8	2.8
10/30/2008	16	0	1	21	-0.4	8.7	5.2	2.2	17.9	7.0	2.7	2.0
10/31/2008	33	0	1	6	-0.3	6.7	6.5	1.0	27.7	5.4	2.1	1.5
11/1/2008	14	0	1	24	1.3	2.6	2.8	-0.1	8.5	2.1	0.8	0.6
11/2/2008	12	0	23	4	-0.7	3.2	1.8	1.4	8.3	2.5	1.0	0.7
11/3/2008	31	0	0	9	-0.7	6.6	4.9	1.4	18.2	5.3	2.0	1.5
11/4/2008	15	0	0	27	-0.9	7.9	4.9	2.6	16.6	6.3	2.4	1.8
11/5/2008	16	0	0	25	3.8	9.3	7.0	-0.2	21.3	7.5	2.9	2.1
11/6/2008	33	0	2	3	1.3	8.7	8.3	-1.0	25.4	7.0	2.7	2.0
11/7/2008	27	0	7	6	-1.0	10.4	7.6	3.1	33.2	8.4	3.2	2.4
11/8/2008	14	0	26	0	-1.7	14.5	4.6	8.5	23.5	11.7	4.5	3.3
11/9/2008	0	0	39	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/10/2008	0	0	33	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/11/2008	11	0	9	19	-1.1	1.9	1.3	0.1	4.5	1.6	0.6	0.4
11/12/2008	19	0	21	0	-1.4	9.3	10.9	0.8	37.5	7.4	2.9	2.1
11/13/2008	31	0	6	0	-1.6	9.3	5.3	1.4	21.1	7.5	2.9	2.1
11/14/2008	41	0	0	0	-1.4	15.2	13.0	1.6	65.6	12.2	4.7	3.5

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
11/15/2008	41	0	0	0	0.4	8.4	4.6	1.5	25.5	6.8	2.6	1.9
11/16/2008	1	0	37	0	-1.2	4.4	N/A	4.4	4.4	3.5	1.3	1.0
11/17/2008	5	0	15	10	-1.2	2.0	1.8	0.8	5.1	1.6	0.6	0.5
11/18/2008	6	0	5	4	-1.5	0.7	0.4	0.1	1.2	0.6	0.2	0.2
11/19/2008	14	0	0	12	-1.4	4.5	3.1	0.6	9.6	3.7	1.4	1.0
11/20/2008	10	0	0	0	-1.1	7.5	1.7	5.4	10.0	6.0	2.3	1.7
11/21/2008	23	0	13	4	-1.1	3.0	1.8	0.7	7.3	2.4	0.9	0.7
11/22/2008	17	0	0	23	-1.4	1.2	0.8	0.2	2.6	1.0	0.4	0.3
11/23/2008	17	0	0	22	-1.3	2.5	2.9	0.0	9.6	2.0	0.8	0.6
11/24/2008	18	0	15	7	-1.2	1.8	1.5	0.2	5.8	1.5	0.6	0.4
11/25/2008	7	0	32	1	-1.0	4.0	2.0	1.3	7.1	3.2	1.2	0.9
11/26/2008	3	0	11	27	-1.3	0.0	0.9	-0.5	1.1	0.0	0.0	0.0
11/27/2008	6	0	7	26	-0.4	2.7	3.1	0.3	8.4	2.2	0.8	0.6
11/28/2008	0	0	34	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/29/2008	9	0	2	29	-1.3	1.2	0.8	0.1	2.2	1.0	0.4	0.3
11/30/2008	2	0	25	12	-1.0	1.2	0.4	0.9	1.5	1.0	0.4	0.3
12/1/2008	16	0	23	0	-1.3	6.2	1.8	3.3	10.5	5.0	1.9	1.4
12/2/2008	18	0	22	0	-1.5	7.1	3.0	1.6	13.6	5.7	2.2	1.6
12/3/2008	40	0	1	0	-1.4	6.0	2.2	2.1	9.8	4.8	1.9	1.4
12/4/2008	1	0	36	0	-1.4	4.8	N/A	4.8	4.8	3.8	1.5	1.1
12/5/2008	3	0	37	0	-1.7	0.0	0.8	-0.8	0.5	0.0	0.0	0.0
12/6/2008	30	0	7	0	-1.5	0.3	0.7	-0.7	2.8	0.2	0.1	0.1
12/7/2008	6	0	29	4	-1.5	0.0	0.5	-0.9	0.6	0.0	0.0	0.0
12/8/2008	26	0	2	0	-1.6	0.2	0.3	-0.3	1.2	0.2	0.1	0.1
12/12/2008	5	0	33	2	-1.0	0.0	0.2	-0.1	0.4	0.0	0.0	0.0
12/13/2008	33	0	1	6	-1.5	0.0	0.3	-0.7	0.6	0.0	0.0	0.0
12/14/2008	40	0	0	0	-1.6	0.2	0.4	-0.6	0.9	0.2	0.1	0.0
12/15/2008	12	0	10	0	-1.3	1.1	0.7	-0.6	2.0	0.8	0.3	0.2
12/16/2008	6	0	27	7	-1.1	-0.2	1.0	-1.7	1.1	-0.1	-0.1	0.0
12/17/2008	1	0	7	0	-1.9	0.8	N/A	0.8	0.8	0.7	0.3	0.2
12/18/2008	3	0	6	32	-1.7	0.0	0.1	-0.1	0.1	0.0	0.0	0.0
12/19/2008	5	0	10	4	-1.1	-0.1	0.3	-0.4	0.2	-0.1	0.0	0.0
12/20/2008	11	0	29	1	-1.1	0.0	0.3	-0.6	0.4	0.0	0.0	0.0
12/21/2008	0	0	22	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/22/2008	0	0	38	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/23/2008	28	0	0	6	4.5	-0.8	2.5	-10.3	1.2	-0.6	-0.2	-0.2
12/24/2008	16	0	11	0	-1.4	0.0	0.2	-0.3	0.7	0.0	0.0	0.0
12/25/2008	8	0	23	9	-1.9	0.1	0.1	0.0	0.4	0.1	0.0	0.0
12/26/2008	31	0	8	1	-1.5	0.0	0.3	-0.6	0.5	0.0	0.0	0.0
12/27/2008	38	0	3	0	-1.5	0.0	0.2	-0.3	0.7	0.0	0.0	0.0
12/28/2008	10	0	28	2	-1.9	0.5	0.8	0.0	2.7	0.4	0.2	0.1
12/29/2008	14	0	0	11	-1.8	0.1	0.3	-0.5	0.5	0.0	0.0	0.0
12/30/2008	3	0	0	1	-1.3	2.2	1.4	0.7	3.6	1.8	0.7	0.5
12/31/2008	24	0	12	1	-1.4	6.3	6.5	-0.2	18.8	5.1	2.0	1.4
1/1/2009	29	0	0	11	-1.5	0.0	0.3	-0.8	0.4	0.0	0.0	0.0

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
1/2/2009	15	0	24	2	-1.7	0.1	0.6	-1.1	1.6	0.1	0.0	0.0
1/3/2009	1	0	26	13	-1.3	0.0	N/A	0.0	0.0	0.0	0.0	0.0
1/4/2009	5	0	33	1	-1.1	-0.1	0.2	-0.3	0.1	0.0	0.0	0.0
1/5/2009	6	0	17	8	-1.6	0.0	0.3	-0.3	0.3	0.0	0.0	0.0
1/6/2009	1	0	12	17	-1.1	0.3	N/A	0.3	0.3	0.3	0.1	0.1
1/7/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/8/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/9/2009	5	0	7	0	-1.3	0.5	0.7	-0.4	1.4	0.4	0.2	0.1
1/10/2009	13	0	26	0	-0.8	-0.1	0.4	-1.0	0.4	-0.1	0.0	0.0
1/11/2009	9	0	20	10	-1.6	0.0	0.2	-0.3	0.5	0.0	0.0	0.0
1/12/2009	14	0	12	13	-1.3	0.0	0.2	-0.4	0.3	0.0	0.0	0.0
1/13/2009	16	0	25	1	-1.9	0.1	0.3	-0.4	0.7	0.1	0.0	0.0
1/14/2009	14	0	15	13	-1.0	-0.1	0.5	-0.8	0.9	-0.1	0.0	0.0
1/15/2009	0	0	32	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/16/2009	7	0	13	20	-1.6	0.2	0.3	-0.2	0.7	0.1	0.0	0.0
1/17/2009	29	0	2	8	-1.7	0.0	0.4	-1.0	1.0	0.0	0.0	0.0
1/18/2009	0	0	11	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/19/2009	0	0	14	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/20/2009	12	0	7	21	-1.8	0.1	0.2	-0.2	0.4	0.0	0.0	0.0
1/21/2009	10	0	8	7	-0.9	0.0	0.4	-1.0	0.4	0.0	0.0	0.0
1/22/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/23/2009	4	0	1	0	-1.9	0.0	0.2	-0.2	0.2	0.0	0.0	0.0
1/24/2009	10	0	24	3	-2.1	0.2	0.3	-0.2	0.8	0.1	0.1	0.0
1/25/2009	0	0	27	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/26/2009	2	0	0	40	-1.1	0.0	0.2	-0.1	0.2	0.0	0.0	0.0
1/27/2009	8	0	8	27	-1.8	-0.1	0.6	-1.1	0.6	-0.1	0.0	0.0
1/28/2009	15	0	19	7	-1.5	0.0	0.2	-0.4	0.3	0.0	0.0	0.0
1/29/2009	30	0	4	4	-1.4	-0.1	0.7	-2.2	1.5	-0.1	0.0	0.0
1/30/2009	0	0	18	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2009	19	0	1	22	-1.7	0.1	0.4	-0.6	0.8	0.0	0.0	0.0
2/1/2009	11	0	20	8	-2.3	0.5	0.6	-0.3	1.5	0.4	0.2	0.1
2/2/2009	1	0	18	20	-1.4	-0.3	N/A	-0.3	-0.3	-0.2	-0.1	-0.1
2/3/2009	16	0	14	12	-1.4	0.0	0.2	-0.7	0.3	0.0	0.0	0.0
2/4/2009	7	0	15	15	-1.2	0.0	0.1	-0.2	0.1	0.0	0.0	0.0
2/5/2009	14	0	0	24	-1.7	0.0	0.3	-0.5	0.4	0.0	0.0	0.0
2/6/2009	22	0	0	17	-1.6	0.0	0.2	-0.4	0.3	0.0	0.0	0.0
2/7/2009	40	0	0	0	-1.8	0.2	0.5	-1.1	1.1	0.2	0.1	0.1
2/8/2009	14	0	12	17	-1.6	-0.1	0.3	-0.9	0.3	-0.1	0.0	0.0
2/9/2009	10	0	7	15	-1.3	0.0	0.3	-0.3	0.5	0.0	0.0	0.0
2/10/2009	41	0	0	0	-1.4	0.2	0.6	-1.0	1.8	0.2	0.1	0.1
2/11/2009	35	0	3	0	-1.3	1.9	4.4	-0.1	17.7	1.5	0.6	0.4
2/12/2009	0	0	40	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/13/2009	0	0	14	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/14/2009	32	0	0	4	-1.2	0.9	0.5	0.3	2.8	0.7	0.3	0.2
2/15/2009	22	0	0	18	-1.0	0.2	0.3	-0.2	0.8	0.2	0.1	0.0

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
2/16/2009	16	0	8	17	-1.3	0.5	0.5	-0.1	1.5	0.4	0.2	0.1
2/17/2009	29	0	0	12	-1.6	1.1	1.7	-0.5	5.9	0.9	0.3	0.3
2/18/2009	29	0	10	0	-1.1	2.2	1.0	0.7	5.2	1.7	0.7	0.5
2/19/2009	0	0	25	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/20/2009	0	0	32	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/21/2009	12	0	17	10	-1.6	0.1	0.6	-0.7	1.0	0.1	0.0	0.0
2/22/2009	0	0	42	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/23/2009	2	0	15	31	-1.7	0.1	0.0	0.1	0.1	0.1	0.0	0.0
2/24/2009	21	0	1	26	-1.6	0.4	0.5	-0.3	1.4	0.3	0.1	0.1
2/25/2009	20	0	0	1	-1.7	0.2	0.2	-0.1	0.7	0.2	0.1	0.1
3/12/2009	32	0	14	1	-1.4	2.0	1.2	0.1	5.6	1.6	0.6	0.5
3/13/2009	21	0	9	17	-1.3	1.9	1.3	-0.1	4.4	1.5	0.6	0.4
3/14/2009	0	0	8	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2009	1	0	14	33	-3.0	4.5	N/A	4.5	4.5	3.6	1.4	1.0
3/16/2009	5	0	18	22	-0.3	0.0	0.3	-0.5	0.2	0.0	0.0	0.0
3/17/2009	21	0	0	25	-0.5	7.5	5.4	0.1	16.7	6.0	2.3	1.7
3/18/2009	26	0	7	15	-0.7	4.3	2.9	0.0	11.9	3.5	1.3	1.0
3/19/2009	31	0	0	16	-1.3	3.2	2.5	0.3	8.8	2.5	1.0	0.7
3/20/2009	15	0	17	15	-1.2	3.8	3.0	0.0	9.5	3.1	1.2	0.9
3/21/2009	18	0	12	17	-1.7	1.8	1.3	0.0	4.2	1.4	0.5	0.4
3/22/2009	17	0	3	28	-1.4	0.8	0.4	0.1	1.7	0.7	0.3	0.2
3/23/2009	0	0	42	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2009	20	0	25	0	-1.1	11.0	4.0	6.8	22.5	8.8	3.4	2.5
3/25/2009	32	0	11	4	-0.9	15.0	16.5	0.6	94.0	12.0	4.6	3.4
3/26/2009	11	0	18	15	-0.6	1.3	0.7	0.5	2.5	1.0	0.4	0.3
3/27/2009	16	0	2	29	-0.2	1.7	3.0	0.0	10.8	1.4	0.5	0.4
3/28/2009	27	0	20	0	-0.6	10.1	3.0	5.2	15.3	8.1	3.1	2.3
3/29/2009	20	0	25	0	-1.4	12.6	5.4	2.6	24.7	10.1	3.9	2.9
3/30/2009	8	0	25	12	-1.0	1.2	1.2	0.1	3.9	1.0	0.4	0.3
3/31/2009	21	0	26	1	-0.6	18.0	11.0	7.3	54.6	14.5	5.6	4.1
4/1/2009	19	0	24	3	-0.8	13.4	9.8	2.9	45.7	10.8	4.2	3.1
4/2/2009	9	0	18	17	-1.0	4.1	3.2	1.4	11.0	3.3	1.3	0.9
4/3/2009	43	0	4	0	-0.6	19.8	15.2	6.2	98.9	15.9	6.1	4.5
4/4/2009	21	0	2	23	-1.1	2.9	1.2	1.4	6.7	2.3	0.9	0.7
4/5/2009	3	0	31	13	-0.9	5.2	1.3	4.3	6.7	4.2	1.6	1.2
4/6/2009	38	0	1	0	-1.1	22.2	13.5	6.5	81.8	17.8	6.9	5.1
4/7/2009	22	0	15	0	-1.1	8.1	3.2	3.2	16.5	6.5	2.5	1.8
4/8/2009	0	0	33	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/9/2009	1	0	15	32	-0.7	0.3	N/A	0.3	0.3	0.3	0.1	0.1
4/10/2009	31	0	12	5	-0.9	32.0	26.8	7.2	105.5	25.7	9.9	7.3
4/11/2009	42	0	0	2	-0.9	15.0	5.7	1.9	23.0	12.0	4.6	3.4
4/12/2009	13	0	20	14	-0.5	14.1	3.5	7.2	18.0	11.3	4.3	3.2
4/13/2009	0	0	44	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2009	24	0	13	10	-0.4	15.9	8.4	8.2	40.0	12.8	4.9	3.6
4/15/2009	45	0	1	1	-0.4	15.0	4.9	5.4	28.0	12.0	4.6	3.4

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4/16/2009	0	0	17	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/17/2009	15	0	2	30	-0.7	2.0	1.6	-0.1	4.5	1.6	0.6	0.5
4/18/2009	9	0	1	37	-0.1	3.5	3.3	0.5	8.4	2.8	1.1	0.8
4/19/2009	0	0	22	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/20/2009	12	0	29	4	-1.0	12.7	10.9	3.2	39.4	10.2	3.9	2.9
4/21/2009	8	0	39	0	-1.3	34.8	35.3	10.6	121.0	28.0	10.8	8.0
4/22/2009	8	0	31	7	-0.5	21.3	9.0	12.1	37.7	17.2	6.6	4.9
4/23/2009	23	0	2	23	-0.1	16.1	6.8	6.4	26.5	13.0	5.0	3.7
4/24/2009	46	0	0	0	0.0	26.2	14.3	6.9	57.6	21.0	8.1	6.0
4/25/2009	48	0	0	0	0.1	41.5	20.9	15.9	97.2	33.3	12.8	9.5
4/26/2009	41	0	0	5	0.1	28.2	24.9	3.4	84.6	22.6	8.7	6.5
4/27/2009	41	0	6	1	0.3	34.6	22.7	3.0	95.9	27.8	10.7	7.9
4/28/2009	27	0	18	3	-0.1	12.2	7.4	2.7	27.8	9.8	3.8	2.8
4/29/2009	0	0	46	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2009	9	0	26	2	-0.2	99.7	107.2	30.6	355.6	80.1	30.8	22.8
5/1/2009	22	0	19	7	-0.1	12.5	11.2	3.8	55.8	10.1	3.9	2.9
5/2/2009	6	0	22	20	0.7	4.8	2.0	2.2	6.7	3.8	1.5	1.1
5/3/2009	10	0	5	33	-1.6	1.4	0.9	0.4	3.0	1.1	0.4	0.3
5/4/2009	7	0	11	30	-1.1	4.4	5.4	0.0	14.7	3.5	1.4	1.0
5/5/2009	7	0	12	19	0.4	4.8	2.6	1.4	9.7	3.8	1.5	1.1
5/6/2009	19	0	8	21	0.0	9.4	6.6	2.4	24.9	7.6	2.9	2.2
5/7/2009	23	0	13	12	0.0	27.0	53.2	5.3	268.7	21.7	8.3	6.2
5/8/2009	15	0	5	28	0.1	16.2	19.9	0.6	60.9	13.0	5.0	3.7
5/9/2009	18	0	17	11	0.4	20.1	10.4	5.1	40.0	16.2	6.2	4.6
5/10/2009	17	0	8	22	0.6	10.2	10.2	2.8	38.3	8.2	3.2	2.3
5/11/2009	32	0	0	15	0.9	12.4	6.8	4.1	26.0	10.0	3.8	2.8
5/12/2009	23	0	4	21	1.6	6.9	6.4	0.4	24.0	5.5	2.1	1.6
5/13/2009	36	0	2	8	3.4	53.3	47.1	2.5	219.8	42.9	16.5	12.2
5/14/2009	18	0	28	0	1.1	73.4	65.5	9.6	279.9	59.0	22.7	16.8
5/15/2009	8	0	11	27	0.6	10.6	7.1	3.7	24.7	8.5	3.3	2.4
5/16/2009	25	0	15	3	-4.9	72.1	185.0	3.2	775.4	58.0	22.3	16.5
5/17/2009	27	0	0	18	0.8	11.8	6.3	3.2	24.8	9.5	3.7	2.7
5/18/2009	19	0	3	19	0.3	8.6	4.8	1.1	17.7	6.9	2.7	2.0
5/19/2009	38	0	0	8	-0.1	17.9	14.5	2.5	48.9	14.4	5.5	4.1
5/20/2009	34	0	0	11	1.0	10.5	7.2	2.1	28.4	8.4	3.2	2.4
5/21/2009	30	0	1	17	-0.2	11.1	8.7	2.1	38.0	8.9	3.4	2.5
5/22/2009	7	0	6	31	2.5	0.5	0.6	0.1	1.7	0.4	0.2	0.1
5/23/2009	14	0	20	12	0.4	2.8	2.4	-0.1	8.3	2.3	0.9	0.6
5/24/2009	16	0	11	21	1.7	12.4	11.7	0.0	35.0	10.0	3.8	2.8
5/25/2009	5	0	10	8	1.9	17.7	3.1	13.3	20.7	14.2	5.5	4.1
5/26/2009	6	0	2	0	0.3	7.0	7.0	1.6	19.9	5.7	2.2	1.6
5/27/2009	35	0	6	5	1.2	8.2	7.6	-0.1	28.8	6.6	2.5	1.9
5/28/2009	21	0	10	9	-0.5	7.9	5.7	0.8	19.2	6.3	2.4	1.8
5/29/2009	15	0	15	16	0.3	13.7	11.0	1.0	36.2	11.0	4.2	3.1
5/30/2009	19	0	1	28	-0.9	8.9	6.5	0.3	25.7	7.2	2.8	2.0

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/31/2009	24	0	8	13	0.6	9.9	12.7	-3.6	56.0	7.9	3.1	2.3
6/1/2009	40	0	2	6	-0.7	14.5	14.8	-1.0	69.0	11.6	4.5	3.3
6/2/2009	6	0	1	20	-0.4	39.5	37.9	4.5	95.1	31.7	12.2	9.0
6/3/2009	0	0	16	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/4/2009	10	0	15	22	0.0	21.7	14.3	3.7	53.8	17.4	6.7	5.0
6/5/2009	17	0	4	23	-0.5	6.2	6.5	-0.6	24.3	5.0	1.9	1.4
6/6/2009	27	0	5	15	0.0	17.0	10.5	3.3	43.8	13.7	5.3	3.9
6/7/2009	40	0	1	5	5.5	9.6	8.2	-0.9	42.5	7.8	3.0	2.2
6/8/2009	34	0	1	10	7.5	13.4	9.7	-2.2	37.0	10.7	4.1	3.1
6/9/2009	26	0	1	11	1.2	10.5	10.0	-1.1	36.2	8.5	3.3	2.4
6/10/2009	11	0	23	12	1.5	8.0	5.3	1.4	16.8	6.4	2.5	1.8
6/11/2009	27	0	16	5	0.3	15.8	16.7	2.0	81.9	12.7	4.9	3.6
6/12/2009	34	0	8	2	0.5	13.8	6.9	0.4	27.5	11.1	4.3	3.2
6/13/2009	9	0	14	22	1.3	3.6	3.7	0.1	12.4	2.9	1.1	0.8
6/14/2009	19	0	16	13	-0.6	8.4	7.4	-3.9	24.4	6.7	2.6	1.9
6/15/2009	6	0	7	24	1.9	6.6	1.8	4.2	8.6	5.3	2.0	1.5
6/16/2009	1	0	19	8	-0.2	3.5	N/A	3.5	3.5	2.8	1.1	0.8
6/17/2009	12	0	20	12	-0.4	8.1	5.4	0.0	17.4	6.5	2.5	1.9
6/18/2009	18	0	9	17	1.5	6.9	6.5	0.9	20.5	5.6	2.1	1.6
6/19/2009	35	0	7	6	1.5	12.4	8.4	0.7	34.1	10.0	3.8	2.8
6/20/2009	13	0	19	0	0.4	22.6	23.2	7.0	95.0	18.2	7.0	5.2
6/21/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/22/2009	15	0	2	3	0.6	2.5	1.9	0.1	6.5	2.0	0.8	0.6
6/23/2009	8	0	6	20	9.6	1.6	1.6	-1.6	3.4	1.3	0.5	0.4
6/24/2009	12	0	3	21	-0.5	8.0	6.0	3.2	20.7	6.5	2.5	1.8
6/25/2009	2	0	17	20	0.9	6.3	2.4	4.6	8.0	5.1	1.9	1.4
6/26/2009	21	0	2	17	1.4	5.8	2.8	2.0	10.7	4.7	1.8	1.3
6/27/2009	14	0	4	18	2.2	2.6	3.9	-2.4	9.7	2.1	0.8	0.6
6/28/2009	17	0	12	8	-0.1	4.7	5.1	0.8	21.1	3.8	1.5	1.1
6/29/2009	15	0	25	1	-1.4	2.5	1.2	0.5	4.8	2.0	0.8	0.6
6/30/2009	14	0	5	12	-1.0	3.8	2.1	0.0	7.5	3.1	1.2	0.9
7/1/2009	13	0	13	15	-0.8	1.9	1.2	0.1	4.8	1.5	0.6	0.4
7/2/2009	20	0	5	6	-0.9	2.3	1.8	0.1	6.3	1.8	0.7	0.5
7/3/2009	13	0	8	17	-0.4	2.2	1.4	0.3	4.6	1.8	0.7	0.5
7/4/2009	22	0	3	14	-0.2	2.5	2.1	0.3	8.8	2.0	0.8	0.6
7/5/2009	11	0	9	18	2.9	0.7	0.6	-0.2	1.5	0.5	0.2	0.2
7/6/2009	18	0	0	21	-0.3	1.5	1.1	0.1	3.6	1.2	0.5	0.3
7/7/2009	20	0	0	20	0.2	2.0	1.9	0.1	6.6	1.6	0.6	0.5
7/8/2009	13	0	3	20	1.0	2.6	2.6	-0.4	9.8	2.1	0.8	0.6
7/9/2009	20	0	3	15	0.7	3.1	1.8	0.7	7.6	2.5	0.9	0.7
7/10/2009	8	0	1	18	1.7	2.7	2.5	-0.2	7.2	2.2	0.8	0.6
7/11/2009	13	0	14	15	-1.1	4.9	5.9	0.3	21.6	3.9	1.5	1.1
7/12/2009	22	0	1	20	0.1	3.3	2.5	0.5	8.5	2.6	1.0	0.8
7/13/2009	15	0	7	20	-0.3	3.1	2.9	0.1	9.4	2.5	1.0	0.7
7/14/2009	12	0	14	19	0.9	1.9	1.0	0.3	3.4	1.5	0.6	0.4

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/15/2009	20	0	15	6	-0.6	1.7	2.0	0.0	6.4	1.3	0.5	0.4
7/16/2009	2	0	23	16	-1.7	4.3	1.9	3.0	5.6	3.5	1.3	1.0
7/17/2009	8	0	13	0	0.3	5.6	1.3	4.1	7.9	4.5	1.7	1.3
7/18/2009	8	0	32	7	-0.4	2.3	1.5	0.7	4.4	1.9	0.7	0.5
7/19/2009	11	0	6	26	-1.0	3.1	4.0	0.1	14.0	2.5	0.9	0.7
7/20/2009	13	0	6	24	-0.3	1.1	1.4	0.0	4.2	0.9	0.3	0.3
7/21/2009	13	0	10	22	0.1	2.9	1.5	0.6	7.2	2.3	0.9	0.7
7/22/2009	8	0	7	24	2.1	3.1	3.5	0.0	9.1	2.5	1.0	0.7
7/23/2009	14	0	8	14	0.0	4.6	3.1	1.1	11.1	3.7	1.4	1.0
7/24/2009	21	0	2	25	0.8	8.3	5.9	0.8	19.7	6.7	2.6	1.9
7/25/2009	25	0	16	3	0.6	14.2	25.2	1.3	125.9	11.4	4.4	3.2
7/26/2009	12	0	30	2	-0.4	3.9	2.9	0.2	9.7	3.1	1.2	0.9
7/27/2009	7	0	2	25	-1.4	2.4	1.7	1.3	6.1	2.0	0.8	0.6
7/28/2009	11	0	2	1	3.1	13.7	18.5	2.8	67.5	11.0	4.2	3.1
7/29/2009	24	0	2	20	2.2	3.7	2.2	0.6	8.4	3.0	1.1	0.8
7/30/2009	10	0	6	27	1.0	2.6	2.0	0.4	5.8	2.1	0.8	0.6
7/31/2009	11	0	16	19	0.9	2.0	0.8	0.8	3.7	1.6	0.6	0.5
8/1/2009	21	0	2	25	-0.2	14.1	7.8	3.0	33.2	11.3	4.4	3.2
8/2/2009	15	0	22	9	0.3	2.7	1.9	0.8	8.5	2.2	0.8	0.6
8/3/2009	35	0	0	13	0.1	18.6	10.2	2.3	36.4	14.9	5.7	4.2
8/4/2009	22	0	7	13	2.6	9.5	7.2	-1.2	23.8	7.6	2.9	2.2
8/5/2009	18	0	5	14	3.6	3.7	3.2	-0.8	11.1	3.0	1.1	0.8
8/6/2009	19	0	1	23	0.2	1.9	1.8	0.0	6.0	1.5	0.6	0.4
8/7/2009	11	0	9	28	-0.4	1.9	1.4	0.6	4.2	1.5	0.6	0.4
8/8/2009	37	0	4	5	-0.5	9.7	9.4	0.1	34.6	7.8	3.0	2.2
8/9/2009	46	0	2	0	0.0	11.1	4.3	3.9	22.3	8.9	3.4	2.5
8/10/2009	18	0	19	9	-0.6	13.1	14.7	1.5	57.4	10.5	4.0	3.0
8/11/2009	10	0	17	18	1.5	5.7	3.8	1.8	13.5	4.6	1.8	1.3
8/12/2009	38	0	0	8	0.4	1.6	1.3	0.0	6.8	1.3	0.5	0.4
8/13/2009	17	0	8	21	0.2	2.4	2.9	0.0	12.3	1.9	0.7	0.5
8/14/2009	20	0	1	26	-0.9	2.3	2.2	0.2	6.7	1.8	0.7	0.5
8/15/2009	23	0	0	24	-0.5	6.1	4.2	0.9	18.3	4.9	1.9	1.4
8/16/2009	27	0	0	21	0.2	11.7	7.2	0.3	27.8	9.4	3.6	2.7
8/17/2009	16	0	8	5	6.9	4.7	4.2	-2.9	13.3	3.8	1.5	1.1

Final Report
Site NC3A
Pork Production Facility
for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
Site NC3A
Pork Production Facility

for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on the location (relative to climate and typical practice), method of manure collection, manure storage and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3), hydrogen sulfide (H_2S) emissions from the wastewater lagoon open source at the southeastern finisher facility. Within that objective, this report will:

- Describe the farm and the lagoon/basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the lagoon were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Lagoon emissions were measured for up to 21 d each season over two years. The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the lagoon were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using

two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc,, Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*WindTrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the lagoon pH, oxidation-reduction potential, and temperature at 0.3 m depth were also measured from a float located at least 30 m from the lagoon inlet (Table 1-2). Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the lagoon berm (Table 1-2).

Table 1-1: Critical measurements

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder 2.0	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind Speed	3D Sonic anemometer/ RM Young 81000	0-60 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
Wind Direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
3D Turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min
Temperature Variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01°C	160 Hz sampling/ 16 Hz averaging	30 min
GSS sample flow rate	GSS/SOP-S	10 L min^{-1}	0.1 L min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/SOP-S	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to RPM Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the lagoon (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation, lagoon pH, lagoon oxidation-reduction potential, lagoon temperature, and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure, flow, temperature and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer that was downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Additional information concerning farm operations and the United States Department of Agriculture National Resource Conservation Service (USDA NRCS)-required analysis of wastewater used to irrigate nearby fields was routinely collected from the producers.

Table 1-2: Non-critical measurements

Measurement	Method/Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
Ambient Temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50 ^{o} C	0.1 ^{o} C	5 min	30 min, 24 h
Relative Humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric Pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min, 24 h
Solar Radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 Wm^{-2}	10 Wm^{-2}	5 min	30 min, 24 h
Lagoon solids depth	Sludge level detector/ SludgeGun 10HD, Markland Specialty Eng.	0-10 m	0.05 m	1/ measurement period	1 time
Lagoon/ basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	0-14 units	0.2 unit	5 min	30 min, 24 h
Lagoon/ basin Oxidation-reduction potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	-800 - +1100 mV	20 mV	5 min	30 min, 24 h
Lagoon/ basin Temperature	Thermistor/ Campbell Scientific Inc 107-L	-35 - +50 ^{o}C	0.5 ^{o}C	5 min	30 min, 24 h

1.3 Farm description and operation

The southeastern finisher lagoon facility was located in North Carolina. The elevation at the farm is 36 m. The farm consisted of five barns (Fig. 1-1) and an office, in addition to the lagoon itself. The facility had a capacity of 8000 finishing pigs in five units. Construction of the farm was completed in 1996.

Manure from the barns was transferred daily to the lagoon by pull plug and lagoon water recharge. Waste water combined into one inlet (Fig. 1-1). The rectangular waste lagoon was located to the east and was separated by a drainage swale from the barns. The clay-lined lagoon was 113 m wide and 173 m long and was oriented east-west. The lagoon area was 18,987 m^2

and volume was 45,973 m^3. Maximum liquid depth was 3.3 m. Wastewater was removed for irrigation as weather permitted. Sludge from the lagoon had not been removed since construction (15-year sludge removal cycle).

Figure 1-1: Configuration of the NC3A farm.

1.4 Measurement layout

The NH_3 emissions from the basin were monitored for 8 to 20 days each quarter of the year for two years using scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*) and backward Lagrangian Stochastic (bLS) emissions models. The H_2S emissions from the lagoon were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments

(TDLAS/scanner) were mounted at 1-m height above the lagoon berm (abl) at the northeast and southwest corners (Figure 1-2). Towers for mounting retro-reflectors were located off the northwest and southeast corners of the lagoon (Figure 1-2). A description of the position and path length of the optical paths along each side of the lagoon follows:

- North side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 60.5 m and 112 m from the northeast TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 207.5 m from the TDLAS/scanner at heights of 1.2 m, 7.4 m and 15.3 m abl.
- East side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 40.5 m and 77.5 m from the northeast TDLAS/scanner. Three retro-reflectors were mounted on the southeast tower 130 m from the TDLAS/scanner at heights of 1.5 m, 7.1 m and 15.5 m abl.
- South side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 54.5 m and 108.0 m E from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the southeast tower 181.5 m from the TDLAS/scanner at heights of 1.5 m, 7.1 m and 15.5 m abl.
- West side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 52.5 m and 89.5 m from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 134.5 m from the TDLAS/scanner at heights of 1.2 m, 7.4 m and 15.3 m abl.

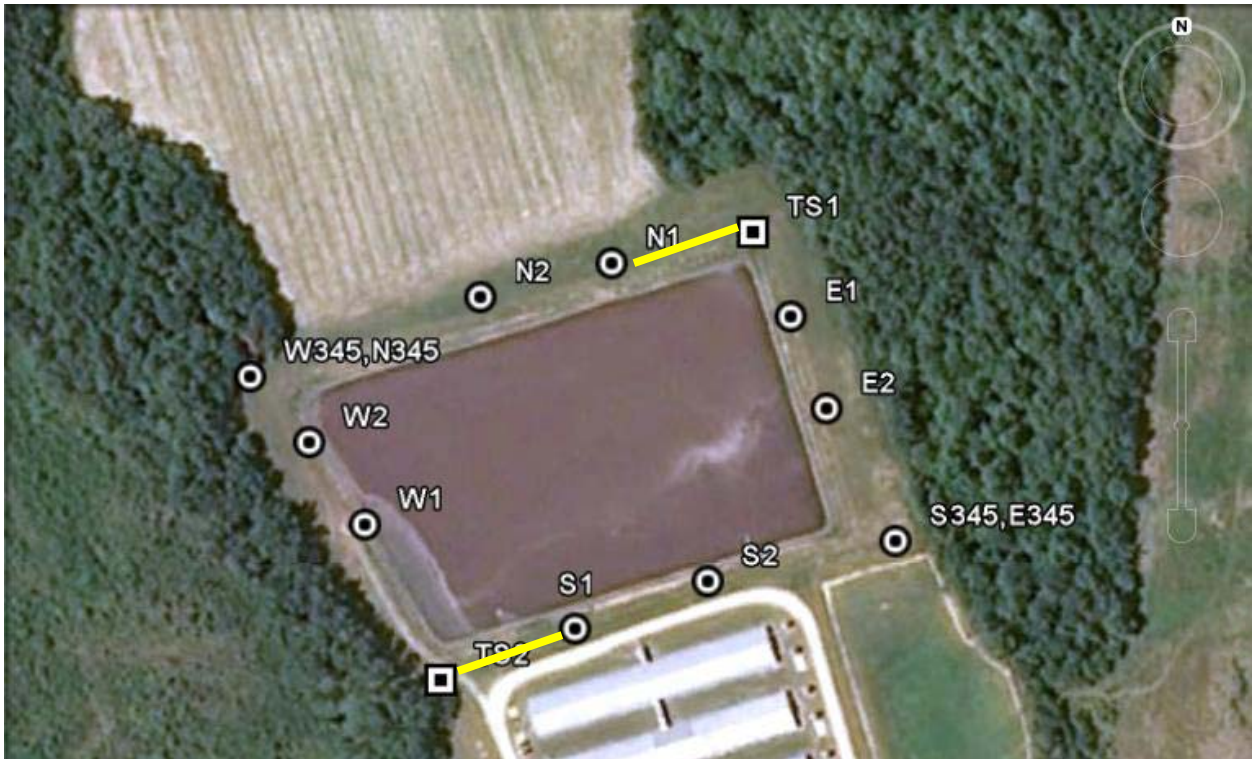

Figure 1-2: Locations of instrumentation around the lagoon under measurement. Retro-reflectors are indicated according to side (north, south, east, and west) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The location of the two S-OPS are indicated by the solid yellow lines. The instrumentation trailer was located near the SE corner of the lagoon.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1-m abl. A 50-m long S-OPS path was parallel to and 5 m north of the north berm and began at the northeast berm corner and extended west (Figure 1-2). The second 50-m S-OPS path began at southwest berm corner and extended east (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Meteorological measurement sensors, including barometric pressure, air temperature, relative humidity, solar radiation, and surface wetness, were located on the berm, 10 m west of the northeast berm corner (Fig. 1-2). The meteorological measurement data were collected by the data logger. The 3D sonic anemometers were located on the meteorological towers at 2.9 m height and on the southeast tower at 5.7 m and 16.3 m abl (Fig. 1-2).

The barns 20 m to the south of the lagoon berm had an approximate ridge height of 6 m agl (above ground level), resulting in a fetch ratio to the west of 3:10 to the lagoon. Fetch to forest to the east for the wind measurements was 3.5:1 for the 16-m measurement height, 1.3:1 for the 4-m measurement height, and 2.8:1 for the 2-m measurement, with the obstruction to the east of a 23-m deciduous forest canopy. The west obstruction for the 2-m wind measurement was a

similar forest, 140 m away, with a fetch of 6:1. Obstructions to the west for the other wind measurements were the 5.5-m high farm barns at a 50 m distance. The 16-m measurement heights were unaffected by the barns. However, the fetch was 33:1 for the 4-m measurement height, which indicated a small influence on the westerly flow by the buildings. As result of the proximity of the barns, all measurements when the wind was from 135° through 225° were excluded from analysis.

Lagoon measurements (pH, oxidation-reduction potential, and temperature) were made from a float located in the northeast corner of the lagoon.

2 Monitoring activities

2.1 Measurement periods

This location was measured as part of an approximately 20-day rotation between three other farms. The equipment was on site a total of 202 d over eight measurement periods (Table 2.1-1). Setup calibrations and site takedowns reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 198 d and H_2S emissions were measured 177 d.

Table 2-1: Days on site

Period	Start date	End date	# days
2	10/24/2007	11/7/2007	14
3	2/13/2008	3/5/2008	21
4	3/6/2008	3/26/2008	20
6	9/25/2008	10/14/2008	19
7	2/4/2009	2/23/2009	19
8	5/12/2009	6/2/2009	21
9	6/2/2009	6/22/2009	20
10	9/24/2009	12/1/2009	68

2.2 Site visits

The field operation team visited this farm 32 d (Table 2-2). Visits to set up the site instrumentation and conduct calibration verification checks of instruments typically lasted 3 d while visits for calibration verifications and take-down of the equipment on site typically lasted 2 d. The summer 2008 measurement period was bypassed so that all of the TDLAS units could be modified and inter-calibrated at PAML by Boreal Laser and PAML staff.

Table 2-2: Dates of site visits

Year	Spring	Summer	Fall	Winter
2007			Oct 24,25,26,	Feb 13,14
2008	Mar 3,26,27		Sep 24,25;Oct 14	Feb 4,5,6,23,24
2009	May 12,13,14	Jun 2,3,22,23	Sep 22,23,24 Oct 13,26,27 Nov 10,11	Dec 2

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21 d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder 2.0™ NH3 TDLAS serial number (s/n) 1026, 1027, 1028 and 1030 (Section 6.1)
- TEC 450i H_2S Analyzer s/n 0733825129 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1920, 1926, 1927, 1928, 1932, 1933 and 1945 (Section 6.3)
- Lagoon pH probes s/n 001, 004 and 007 (Section 6.4)
- Lagoon ORP probe s/n 020 and 050 (Section 6.5)
- GSS/ S-OPS s/n 4-0018 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multipoint calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers (Section 6.3) with three unused 'standard' anemometers. An inter-comparison of two TDLAS units (s/n 1026 and 1030) was conducted at this location on June 2, 2009.

2.4 Audits

Two internal audits were conducted at this location: 1) on 3/5/2008 with particular attention to the S-OPS operation and TDLAS calibration verifications, and 2) on 2/23/2009 with particular attention to the S-OPS operation and TDLAS calibration verification. An external USEPA Technical Systems Audit was conducted at this location on 9/23/2009.

2.5 Remote site checks

Over the course of measurements, there were 89 remote checks made through the computer for instruments operating at this location.

2.6 Measurement data acquisition

Data from the TDLAS units (Model GasFinder2™ NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather and lagoon data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *Loggernet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *Loggernet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA) were downloaded in real-time through a serial cable to the trailer computer using the *iPort* (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built *Visual Basic* software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic anemometer temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory "FTP" and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory "Data". The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the "FTP" directory.

3 Data processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic anemometer parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDL. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes needed to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site , data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software that was used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer and caused the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period, unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one minute off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the lagoon and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream may depend on one or more of the preceding streams, but not on following data streams. For

each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment and calibration failures, and because calibration checks were in progress. Periods of invalidated measurements associated with the calibration check failures are documented in the calibration reports in Section 6. Significant data exclusions of greater than one-day duration are indicated below by instrument with all time references in Coordinated Universal Time (UTC):

TDLAS measurement exclusions: Excluded measurements due to either the TDLAS or the scanner are summarized in Table 3.2-1.

Table 3.2-1: TDLAS measurement exclusions

Begin		End		Reason
10/27/2007	15:00	11/7/2007	13:35	TDLAS 2 centerline duty cycle over maximum allowed value
9/24/2007	22:28	10/13/2007	13:37:03	TDLAS 2 scanner power supply failed
10/26/2009	20:10	10/27/2009	20:25:51	Gap in both TDLAS records. Taken down for calibration
11/3/2009	17:54	11/11/2009	15:39:31	TDLAS 2 computer stopped.
11/12/2009	07:37	11/15/2009	18:34	TDLAS 1 centerline duty cycle over maximum allowed value

TEC 450i measurement exclusions: Excluded measurements are summarized in Table 3.2-2.

Table 3.2-2: Sonic anemometer measurement exclusions

Begin		End		Reason
9/29/2009	17:15	9/29/2009	20:45	Gap in data
10/13/2009	13:45	10/13/2009	19:15	Calibration check
10/26/2009	19:15	10/27/2009	22:15	Calibration check
11/5/2009	07:15	11/5/2009	15:15	Calibration check
11/11/2009	15:45	11/11/2009	20:15	Calibration check

Air temperature and relative humidity measurement exclusions: Excluded measurements are summarized in Table 3.2-3.

Table 3.2-1: Air temperature and relative humidity measurement exclusions

Begin		End		Reason
2/6/2009	00:15:00	2/6/2009	17:40:00	Data logger unplugged

Wetness measurement exclusions: Excluded measurements are summarized in Table 3.2-4.

Table 3.2-4: Wetness measurement exclusions

Begin		End		Reason
10/25/2007	18:35:00	11/7/2007	16:25:00	Corrosion, reads wet entire period
6/5/2009	23:55:00	6/22/2009	22:20:00	Corrosion, reads wet entire period

Pressure measurement exclusions: Excluded measurements are summarized in Table 3.2-5.

Table 3.2-5: Pressure measurement exclusions

Begin		End		Reason
3/5/2008	17:40:00	3/26/2009	17:35:00	Sensor failed. Removed for repair.

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-6.

Table 3.2-6: Sonic anemometer measurement exclusions

Begin		End		Reason
9/25/2008	15:34	10/14/2008	12:49	Sonic 2 operations failure.
3/19/2008	04:15	3/22/2008	13:30	All Sonics program failure
10/13/2009	12:39	10/13/2009	19:15	Calibration check
10/24/2009	16:24	10/27/2009	16:09	Calibration check

Lagoon temperature, pH, and ORP measurement exclusions: Excluded measurements are summarized in Table 3.2-7.

Table 3.2-7: Lagoon temperature, pH, and ORP measurement exclusions

Begin		End		Reason
Lagoon Temperature Exclusion Times				
10/25/2007	18:35:00	11/7/2007	16:25:00	Temp probe failure
9/25/2008	21:35:00	10/14/2008	15:15:00	Lagoon temp unreasonable data
9/24/2009	22:10:00	10/27/2009	17:45:00	Lagoon probe float stuck in sludge
Lagoon pH Exclusion Times				
9/24/2009	22:10:00	10/27/2009	17:45:00	Lagoon probe float stuck in sludge
Lagoon ORP Exclusion Times				
9/24/2009	22:10:00	10/27/2009	17:45:00	Lagoon probe float stuck in sludge
11/25/2009	07:30:00	12/2/2009	14:10:00	ORP probe not reading zeros

GSS/S-OPS measurement exclusions: Excluded measurements are summarized in Table 3.2-8.

Table 3.2-8: GSS/S-OPS measurement exclusions

Begin		End		Reason
10/13/2009	14:00	10/13/2007	17:30	Calibration check
10/27/2009	12:45	10/27/2009	17:15	Calibration check
11/11/2009	17:15	11/11/2009	20:15	Calibration check

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20°C (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in super-saturated "holes" in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a super-saturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maximized light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably super-saturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-s value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the

occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be super-saturated were flagged as super-saturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not super-saturated. To determine which points truly were super-saturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest PIC corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be super-saturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as super-saturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the S-OPS changed from one line to the other line. This array was later used when separating the H_2S data according to which S-OPS line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic anemometer software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax*

during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic anemometer temperature variance of greater than 2.5 K^2, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic temperature variance had to be less than 2.5 K^2. To be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH_3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be *RPM* processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH_3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigned values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the

approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *WindTrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3} \frac{34.0818\left([H_2S]_{downwind} - [H_2S]_{upwind}\right)}{17030.4[NH_3]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H_2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigned values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths. All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the lagoon include transfer of waste from barns into the lagoon and lagoon pump-outs for irrigation (Table 4.1-1).

Table 4.1-1 Producer activities

Period	Activity	Animal Inventory
2: 10/24 - 11/7/2007	No events	6963
3: 2/13 - 3/5/2008	No events	5004
4: 3/6 - 3/26/2008	No events	6425
	4/17 - 05/01/2008 lagoon pump-out 9/15 - 9/23/2008 lagoon pump-out	
6: 9/25 - 10/14/2008	9/29 - 9/30/2008 lagoon pump-out	3533
7: 2/4 - 2/23/2009	No animals present due to disease	0
8: 5/12 - 6/2/2009	No events	7126
9: 6/2 - 6/22/2009	No events	7063
10: 9/24 - 12/2/2009	No events	8702

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for mid-latitude climates (Table 4.2-1). Twenty-three percent of the days had extra-tropical frontal systems overhead while 77% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Period	# days	# warm front passages	# cold front passages	# days stationary front	# days tropical storms
2	14	0	5	2	0
3	21	2	4	2	0
4	20	0	4	0	0
6	19	1	3	0	0
7	19	2	3	0	0
8	21	0	2	0	0
9	20	1	4	0	0
10	68	0	4	0	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from -2.9^{o}C to 28.5^{o}C while the barometric pressure varied from 99.56 kPa to 102.77 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ hr solar irradiance of 1150Wm^{-2} to overcast conditions with maximum ½ hr solar irradiance of 76 Wm^{-2} (Section 6.10).

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared with the monthly climatology is indicated in Figure 4.2-1. Temperatures were generally within the climatological normal conditions throughout the study measurement periods at this location.

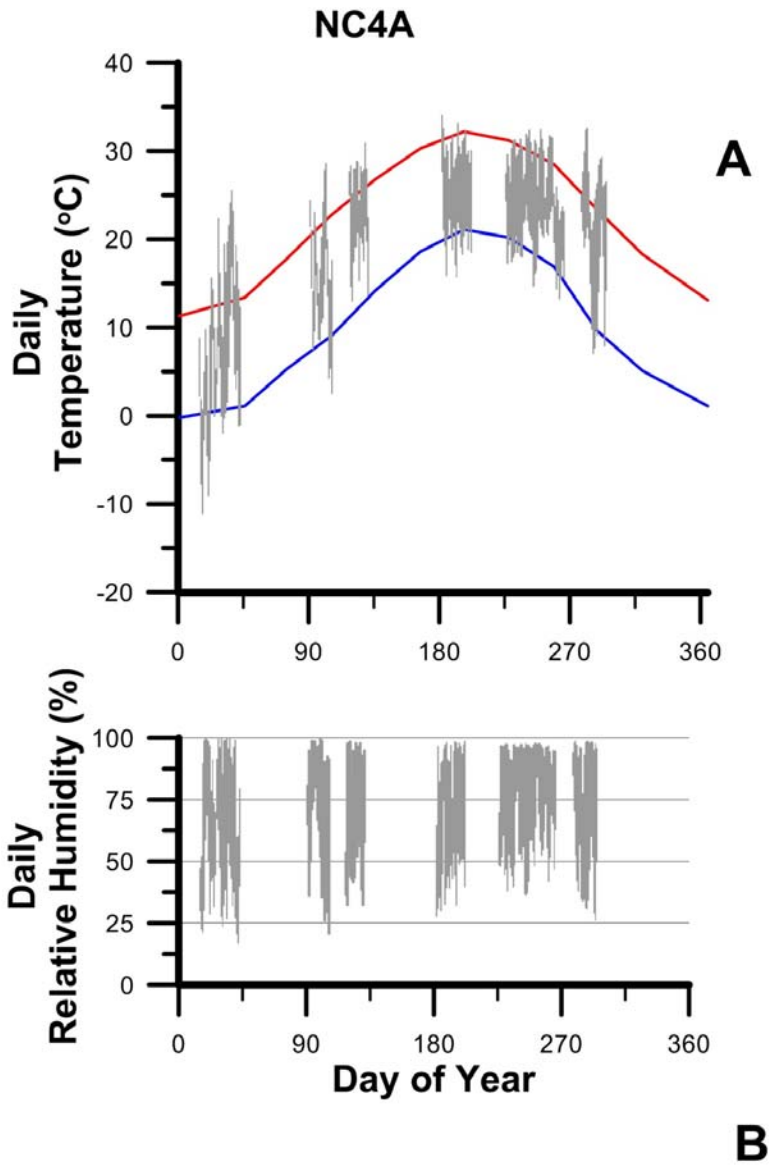

Figure 4.2-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line) temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidities for measurement days are indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figures 4.2-2 through 4.2-5. Emission calculation exclusion regions due to surrounding sources (wind directions of 135° through 225°) are indicated as a grayed region in the figures. Winds were generally from the north-northwest during measurement periods 2, 6, 9, and 10.

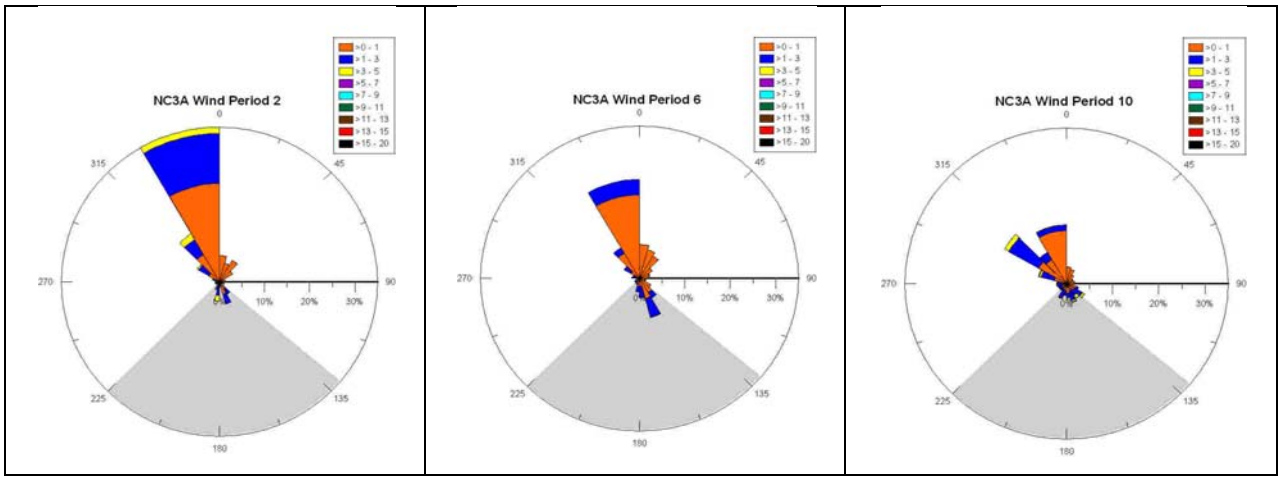

Figure 4.2-2: Wind roses for ½ hourly wind measurements during the Fall Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

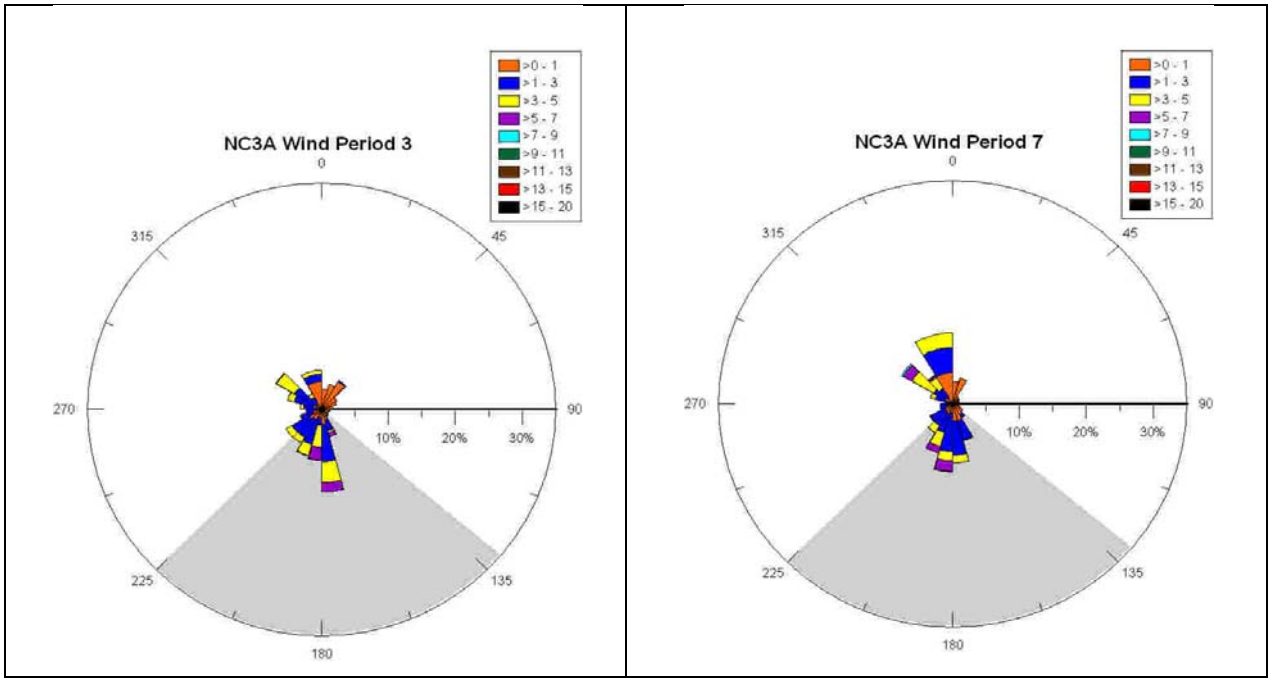

Figure 4.2-3: Wind roses for ½ hourly wind measurements during the Winter Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

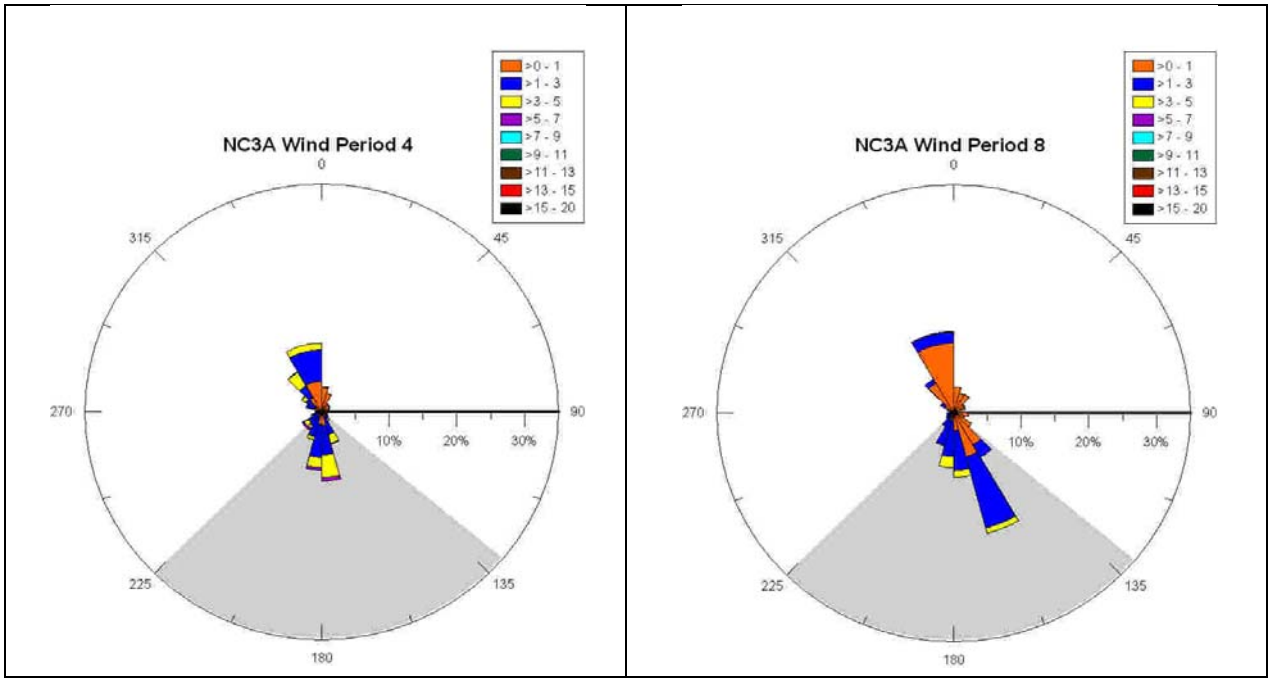

Figure 4.2-4: Wind roses for ½ hourly wind measurements during the Spring Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

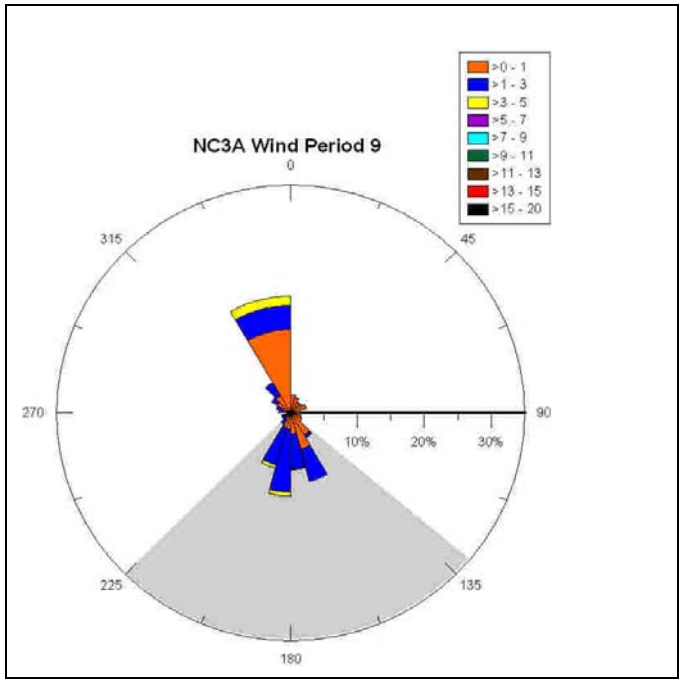

Figure 4.2-5: Wind rose for ½ hourly wind measurements during the Summer Measurement Period. The period in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

4.3 Lagoon conditions

4.3.1 Lagoon appearance, liquid depth and sludge depth

The appearance of the lagoon was recorded on almost every site visit (Table 4.3-1). The lagoon generally appeared red with no crust or scum. Scum was evident at times during the spring and summer.

Table 4.3-1: Lagoon physical characteristics

Period	Appearance	Liquid Depth	Sludge Depth	Source of Meas.*
	color/crust	(m)	(m)	
2: 10/24 - 11/7/2007	10/24/2007 - dark/no crust or scum 10/25/2007 - dark/no crust or scum 10/26/2007 - black/no crust or scum 11/7/2007 - brown/red/no crust or scum	1.98	N/A	Producer
3: 2/13 - 3/5/2008	2/13/2008 - black/no crust or scum 2/14/2008 - black/no crust or scum 3/5/2008 - black/partial scum	2.45	N/A	Producer

Period	Appearance	Liquid Depth	Sludge Depth	Source of Meas.*
	color/crust	(m)	(m)	
4: 3/6 - 3/26/2008	3/6/2008 - black/80% scum 3/26/2008 - brown/black/no crust or scum 3/27/2008 - brown/black/30% scum	2.57	N/A	Producer
6: 9/25 - 10/14/2008	9/24/2008 - reddish/no crust or scum 9/25/2008 - reddish/black/no crust 10/14/2008 - reddish/brown/50% Film	N/A	N/A	N/A
7: 2/4 - 2/23/2009	2/4/2009 - clear/no crust 2/5/2009 - light black/no crust 2/6/2009 - blackish/no crust 2/23/2009 - black w/ pink in corner/slight scum 2/24/2009 - black w/ pink in corner/no Crust or scum	2.21 1.49	0.78	Producer sludge gun
8: 5/12 - 6/2/2009	5/12/2009 - black/25% scum 5/13/2009 - black/20% scum 5/14/2009 - black/30% scum 6/2/2009 - red/thick scum	2.33 1.8	0.3	Producer sludge gun
9: 6/2 - 6/22/2009	6/3/2009 - brown/red/80% scum 6/22/2009 - black/50% scum 6/23/2009 - black/40% scum	2.46	N/A	Producer
10: 9/24 - 12/2/2009	9/22/2009 - brown/red/no crust or scum 9/23/2009 - brown/red/no crust or scum 9/24/2009 - brown/red/no crust or scum 10/13/2009 - black/90% scum 10/26/2009 - red/5% crust 10/27/2009 - red/5% crust 11/10/2009 - red/no crust or scum 11/11/2009 - red/no crust or scum 12/2/2009 - red/5% crust	N/A	N/A	N/A

4.3.2 Temperature, pH and oxidation-reduction potential

The measured lagoon liquid temperature varied from 9.0^{o}C to 30.2^{o}C (Section 6.11). The measured lagoon pH varied from 7.1 to 8.4 (Section 6.11) while the oxidation-reduction potentials varied from -108 mV to -558 mV over the entire study period (Section 6.11).

4.3.3 Lagoon chemistry

Lagoon water chemical analyses were not conducted by the project but commercial analyses required by the USDA NRCS at the time of water removal for field application was available for applications during the overall project period (Table 4.3-3).

Table 4.3-3: Record of lagoon chemistry

			Percent (wet weight basis)			
Date	**n**	**pH**	**Nitrogen**	**Solids**	**Ammonia**	**Sulfur**
9/1/2009	1	7.64	0.29	N/A	N/A	0.03
7/13/2009	1	7.56	0.51	N/A	N/A	0.03
5/21/2009	1	7.45	0.40	N/A	N/A	0.05
3/31/2009	1	7.94	0.24	N/A	N/A	0.04
2/18/2009	1	6.87	0.17	N/A	N/A	0.03
12/16/2008	1	7.81	0.32	N/A	N/A	0.04
10/15/2008	1	7.61	0.32	N/A	N/A	0.04
8/26/2008	1	7.88	0.34	N/A	N/A	0.04
7/10/2008	1	7.82	0.49	N/A	N/A	0.05
5/16/2008	1	7.75	0.67	N/A	N/A	0.05
3/25/2008	1	7.46	0.68	N/A	N/A	0.05
1/23/2008	1	7.36	0.56	N/A	N/A	0.05
11/20/2007	1	7.29	0.36	N/A	N/A	0.05
9/27/2007	1	7.89	0.30	N/A	N/A	0.05
8/6/2007	1	7.94	0.47	N/A	N/A	0.04
6/15/2007	1	7.68	0.59	N/A	N/A	0.05
4/19/2007	1	7.82	0.53	N/A	N/A	0.04
3/22/2007	1	7.71	0.59	N/A	N/A	0.05
1/24/2007	1	7.79	0.40	N/A	N/A	0.04
12/1/2006	1	6.80	0.23	N/A	N/A	0.03

4.4 Emissions measurements

Emissions data were calculated on a ½ h basis since this was the interval over which the S-OPS system sampled both sides of the lagoon and since this interval is in the range over which turbulence statistics are often calculated. Emissions reported on a head basis were scaled by the design animal population and not the animal population at the time of measurements to account for the longer term manure storage of the lagoon or basin. Emissions reported on an animal unit (1 AU = 500 lb) basis assumed the typical animal weight values reported by the producer. Emissions reported on an area basis are based on the surface area of the lagoon.

Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison was based on 561 ½ h measurement periods over the entire measurement time at this location. Results show that the bLS emissions had a significantly difference precision (F=1.08, critical F 1.0) and a significant bias over the *RPM* emissions (t=-5.75, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 0.84 (Table 4.4-1). Consequently the ½ h bLS emissions measurements are biased low by 16% compared to the *RPM* measurements.

Table 4.4-1: Comparison of the bLS and *RPM* NH_3 emissions

	RPM	bLS	bLS-RPM
Mean emission (gs^{-1})	0.434	0.366	-0.068
Standard deviation (gs^{-1})	0.327	0.340	—
Variance of the mean (gs^{-1})	0.107	0.116	—

4.4.1 NH_3 emissions

4.4.1.1 Mean daily NH_3 emissions

An annual trend in the daily NH_3 emissions based on the *RPM* model was indicated (Figure 4.4.1-1) with an early summer maximum emission of approximately 15 g $NH_3d^{-1}hd^{-1}$. The fall and winter lagoon emissions were similar at between 0 g and 7 g $NH_3d^{-1}hd^{-1}$. There were only a small number of measurements with more than 75% of the day's emissions measured. The wide variability during the spring and fall in combination with the few 'complete' days of measurements limits confidence in the magnitude of the emissions. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

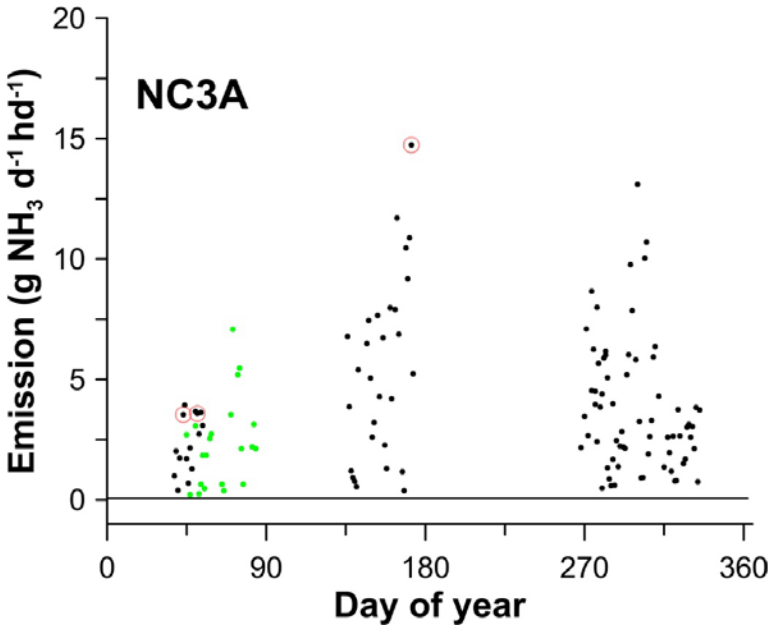

Figure 4.4.1-1: Annual variation in RPM-calculated daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH^3 concentration measurement.

An annual trend in the daily NH_3 emissions based on the bLS model was indicated (Figure 4.4.1-2); again with a relatively constant emission of approximately 5 g $NH_3d^{-1}hd^{-1}$. Measurements with more than 75% of the day's emissions measured only include days in spring and fall

providing less confidence in the mid-summer emission measurements than spring and fall. There was a relatively wide range in emissions from day-to-day throughout the year. Light and variable winds result in negative emissions seen during several days. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

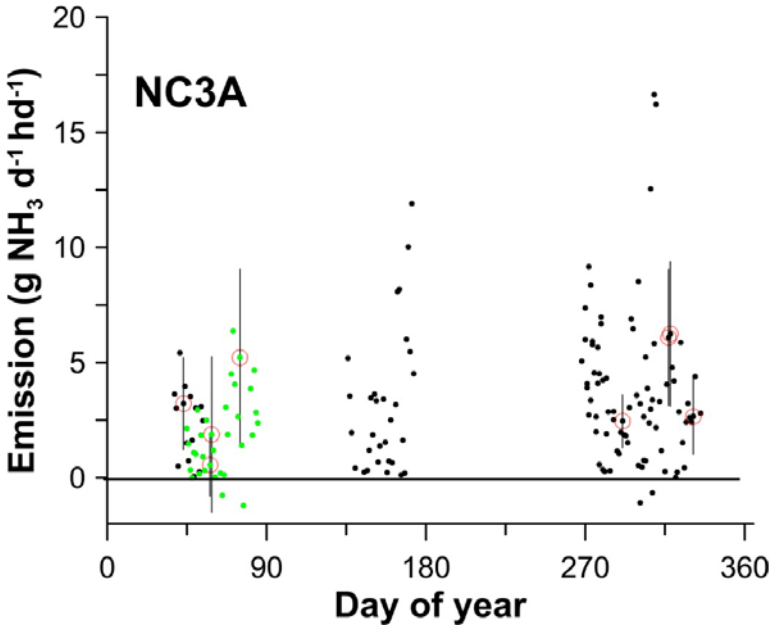

Figure 4.4.1-2: Annual variation in bLS-calculated daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH^3 concentration measurement. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS model is influenced by the calculated background concentrations. Results indicate that the background concentration of NH_3 was generally less than 0.2 ppm (Figure 4.4.1-3). Given that the typical path length around the lagoon was 100 m and the typical background concentration is less than 0.2 ppm, this corresponds to a background PIC of less than 20 ppm-m. This is approximately ten times the MDL for the TDLAS instruments of 2 ppm-m (Section 6.1) and therefore represents a real background for this location.

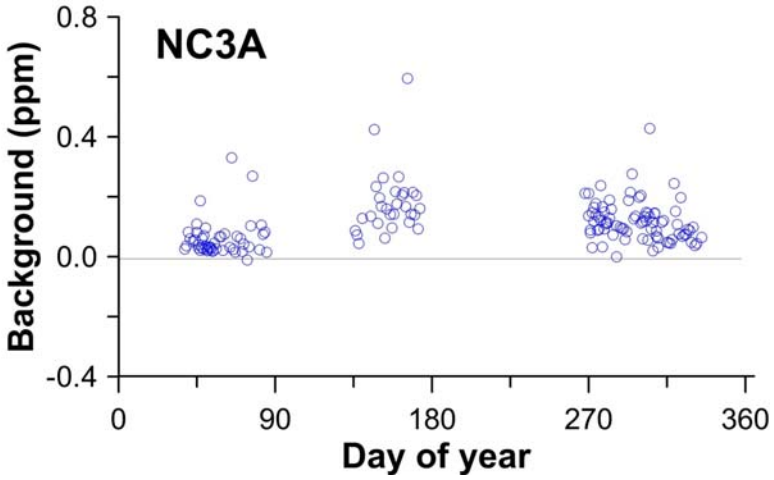

Figure 4.4.1-3: Annual variation in bLS-calculated mean daily background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

A distinct diurnal pattern of emissions was evident with the emissions highest during the day time (Figure 4.4.1-4). The pattern was evident in all measurement periods. The negative emissions near sunrise (at approximately 0.5 in the Figure) is probably a result of the light and variable winds common during the early morning hours.

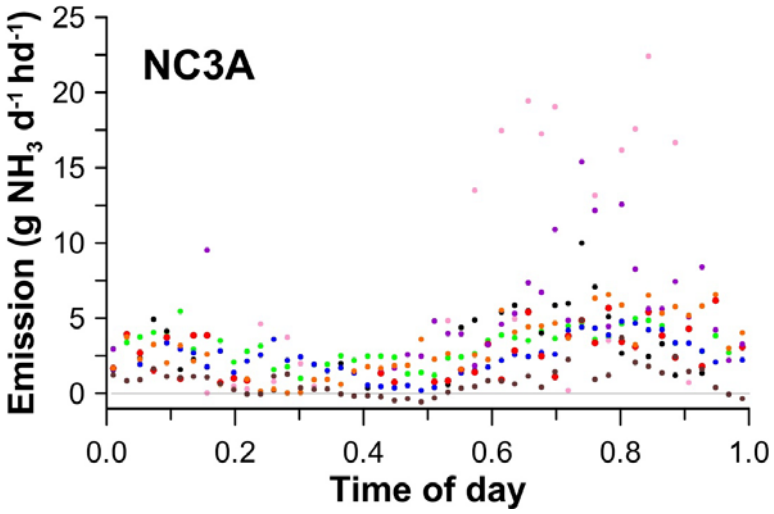

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 2-Fall (pink), Period3-Winter (brown), Period 4-Spring (orange), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple), and Period 10 (green)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ h periods (corresponding to 75% completeness on a daily basis) is given. Because of the requirement of 5 to 10 valid TDLAS measurements before an *RPM* emission measurement is possible, the number of valid ½ h periods with *RPM* emissions was greatly limited. The wind conditions and wind direction exclusion region did not greatly reduce the yield of valid bLS emission measurements. The completeness statistics are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

	Measurement period								
	2	**3**	**4**	**6**	**7**	**8**	**9**	**10**	**Total**
NH_3 RPM model									
Valid 1/2 h measurements (d)	0.3	1.0	2.5	1.7	5.5	2.0	3.3	7.3	**23.6**
Measurements excluded due to wind direction (d)	0.3	0.0	0.2	1.1	3.6	5.0	4.3	5.6	**20.1**
Measurements excluded because at least one downwind path is missing or invalid (d)	10.9	16.7	9.7	12.4	1.1	7.2	5.5	34.4	**97.8**
Number of d with ≥ 36 valid 1/2 h periods	0.0	0.0	0.0	0.0	2.0	0.0	1.0	0.0	**3.0**
NH_3 bLS model									
Valid 1/2 h measurements (d)	0.9	5.4	4.6	2.3	4.8	1.5	3.4	15.9	**38.7**
Measurements excluded due to wind direction (d)	1.1	5.1	4.0	1.4	3.5	5.8	3.8	5.4	**30.1**
Measurements excluded because touchdown fraction < 0.1 (d)	2.2	0.1	0.0	0.2	0.0	0.1	0.0	2.4	**5.1**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| < 2$ m (d)	3.7	5.3	4.4	8.0	6.7	5.7	7.6	20.0	**61.5**
Number of d with ≥ 36 valid 1/2 h periods (d)	0.0	2.0	1.0	0.0	1.0	0.0	0.0	4.0	**8.0**

In total, 23 d of valid NH_3 emissions were determined from the 143 measurement d using the *RPM* model, with only 3 d having at least 36 valid ½ h NH_3 emissions. The absence or invalidation of at least one downwind path led to 98 d for which emissions could not be calculated.

Thirty eight d of valid NH_3 emissions were determined from the 143 measurement d using the bLS model, with only 8 d having at least 36 valid ½ h NH_3 emissions. The exclusion wind directions due to the location of the barns relative to the lagoon resulted in the loss of 30 d of

measurements. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m), of which the majority were due to low wind speeds, led to 62 d for which emissions could not be calculated. A touchdown fraction of less than 0.1 led to the exclusion of 5 d of data. Low touchdown fractions indicated that little, if any, downwind data were available. This corresponded to either when the downwind TDLAS was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ h interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ h mean wind speed and direction, in contrast to the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times that the *RPM* model produces a valid emission while the bLS model does not. However, these times are overwhelmed by the times that the *RPM* model is missing concentration data for one or more paths, while the bLS model is able to run.

4.4.2 H_2S emissions

4.4.2.1 Mean daily H_2S emissions

The average concentrations of H_2S measured from the two S-OPS were nearly always at the MDL for the 450i H_2S analyzer. Consequently the emissions measurements reported are essentially the MDL of the emissions method under the wind conditions at this location.

Emissions of H_2S determined using the Ratiometric model suggested that emissions during the winter and spring are highest at approximately 1 g H_2S d^{-1} hd^{-1} with the emissions decreasing throughout the rest of the year (Figure 4.4.2-1). A near-zero emission during the fall and winter is strongly indicated. The variable daily emissions (positive and negative) between days 135 and 180 correspond with highly variable low wind conditions resulting in no distinct upwind or downwind S-OPS throughout the 30-min measurement period. The negative emissions result from this wind variability: the chosen upwind path becomes the downwind path within the averaging period. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

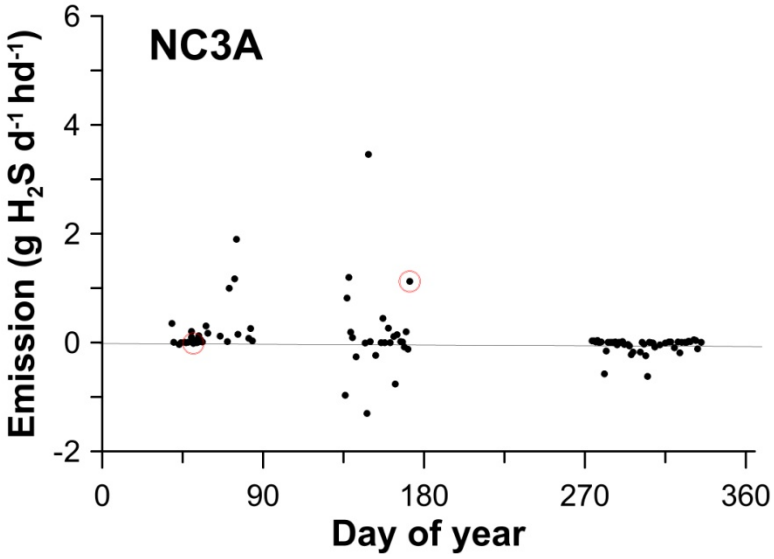

Figure 4.4.2-1: Annual variation in Ratiometric-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

Emissions of H_2S determined using the bLS model suggested that emissions during the winter and spring are highest at approximately 2 g H_2S d^{-1} hd^{-1} with the emissions decreasing throughout the rest of the year (Figure 4.4.2-2). One value (13.3 g H_2S d^{-1} hd^{-1}) is not plotted. A near-zero emission during the fall and winter is strongly indicated. The variable daily emissions (positive and negative) between days 135 and 180 correspond with highly variable low wind conditions resulting no distinct upwind or downwind S-OPS throughout the 30-min measurement period. The negative emissions result from this wind variability: the chosen upwind path becomes the downwind path within the averaging period. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

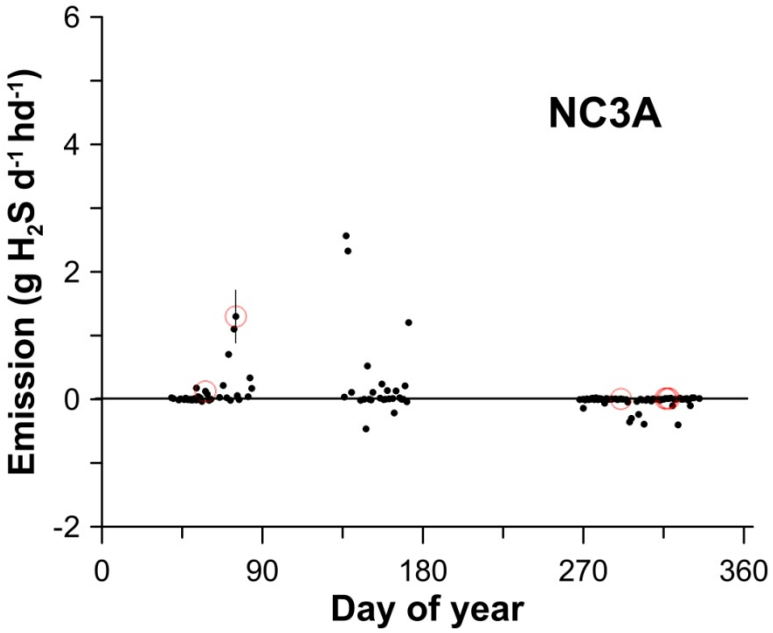

Figure 4.4.2-2: Annual variation in bLS-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS emission model depends on a good estimate of the background H_2S concentration. Results indicate that the background concentration was generally less than ±2.5 ppb (Figure 4.4.2-3). The high variability in background concentrations between day 135 and 180 corresponded with the highly variable emissions and suggests that the values reported for the period are likely in error. The high backgrounds occurred when the winds were light and variable resulting in no distinct upwind or downwind S-OPS throughout the measurement period.

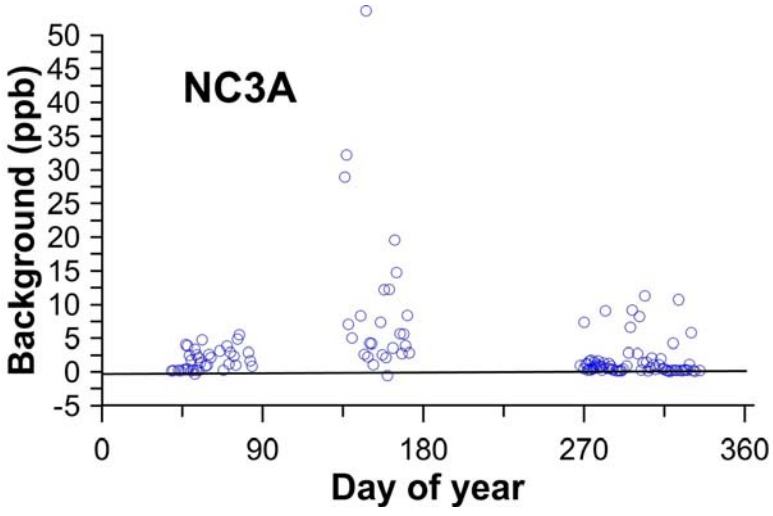

Figure 4.4.2-3: Annual variation in bLS-computed mean daily background concentration of H_2S.

4.4.2.2 Diurnal variation in H_2S emissions

The H_2S emissions calculated using the bLS model generally did not show a diurnal trend (Figure 4.4.2-4).

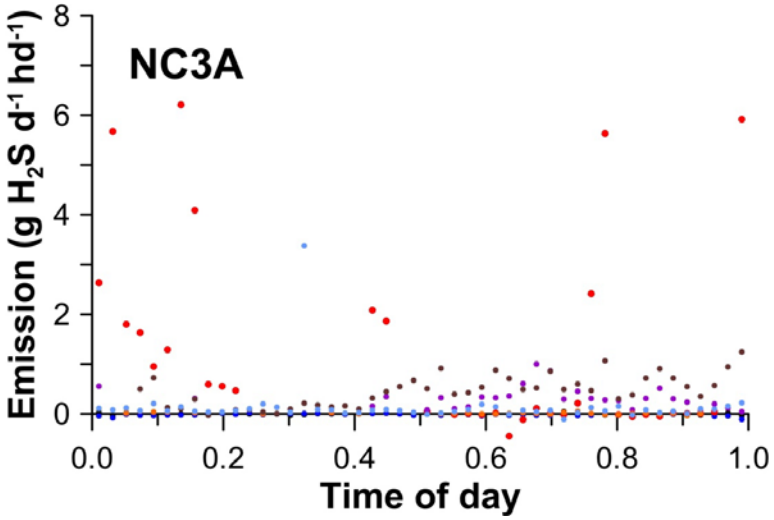

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 3-Winter (light blue), Period 4-Spring (brown), Period 6-Fall (orange), Period 7-Winter (black), Period 8-Spring (red), and Period 9-Summer (purple), Period 10-Fall (blue)) are indicated.

4.4.2.3 H_2S emissions data completeness

H_2S Measurements were begun in Period 3. Consequently there were no measurements possible for Fall 2007. As described for the NH_3 emissions, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics are summarized in Table 4.4.2-1.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

	Measurement period								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
H_2S Ratiometric model									
Valid 1/2 h measurements (d)		0.6	2.3	1.4	4.2	1.8	2.8	4.9	**18.0**
Number of d with ≥ 36 valid 1/2 h periods (d)		0.0	0.0	0.0	1.0	0.0	1.0	0.0	**2.0**
H_2S bLS model									
Valid 1/2 h measurements (d)		3.1	3.4	1.8	3.5	1.1	2.5	15.1	**30.6**
Measurements excluded due to wind direction (d)		5.1	3.8	1.6	3.2	5.5	3.6	5.5	**28.3**
Measurements excluded because angle of attack > 60 degrees (d)		2.1	1.0	0.4	1.2	0.4	0.7	3.3	**9.1**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| < 2$ m (d)		6.8	5.6	10.9	8.2	7.8	9.5	30.4	**79.1**
Number of d with ≥ 36 valid 1/2 h periods (d)		1.0	1.0	0.0	0.0	0.0	0.0	4.0	**6.0**

The H_2S emissions were measured a total of 177.7 d at this location. The majority of measurements were invalidated as a result of inconsistent turbulence statistics- probably a result of the proximity of the wooded areas to the lagoon (Figure 1-2). Because there were few valid ½ measurements of the NH_3 emissions based on the *RPM* model (Table 4.4.1-2), the number of valid ½ periods of valid Ratiometric emissions measurements of H_2S is small. The majority of bLS emissions measurements were invalidated due to wind conditions. In total, 18 d of valid H_2S emissions were determined using the Ratiometric emission method, with only 2 d having at least 36 valid ½ h H_2S emissions. Thirty d of valid H_2S emissions were determined using the bLS model, with again only 6 d having at least 36 valid ½ h H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) excluded 79 d, largely due to low winds speeds. Wind direction exclusions invalidated 28 d of measurements.

4.4.3 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of the TDLAS serial numbers 1026, 1027, and 1028 prior to 7/21/2008. TDLAS 1027 was used at NC3A from 2/13/2008 to 3/26/2008 (Measurement periods 3 and 4). TDLAS 1028 was used at NC3A from 2/13/2008 to 3/26/2008 (Measurement periods 3 and 4). Under the calibration verification checks, the TDLAS error of all units was 10% accuracy. However due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and units without apparent

interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from dew point temperatures of -2°C to 20°C. A conservative estimate of the accuracy of all of the above TDLAS units with evident moisture interference was estimated at 40%.

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions, underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%. Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was -16% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -56% for TDLAS NH_3 measurements made by units with moisture interference and a bias of -16% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the Ratiometric measurement of H_2S emissions was ± 18%.

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6 Appendices

6.1 TDLAS NH_3 calibrations

Five TDLAS units (Model GasFinder 2.0™ NH3OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used at this location: serial numbers 1026, 1027, 1028, 1030, and 1031.

TDLAS 1026 was multipoint calibrated seven times during the study (Figure 6.1-1). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 1/17/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3,$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in any correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and 11/10/2009 bias exceedances were followed the same or next day with a passing verification and

were deemed to be a result of operator error. The negative bias over the period 4/2/2008 through 7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used). During operations the bias was only intermittently evident because to different multipoint calibration was applied to the calibration verification measurements during the progress of the study than finally applied during the analysis. Repeated calibrations within 24 h often showed biases differing by more than 10 ppm-m suggesting operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period are considered valid and the error assumed to be due to the calibration verification operator.

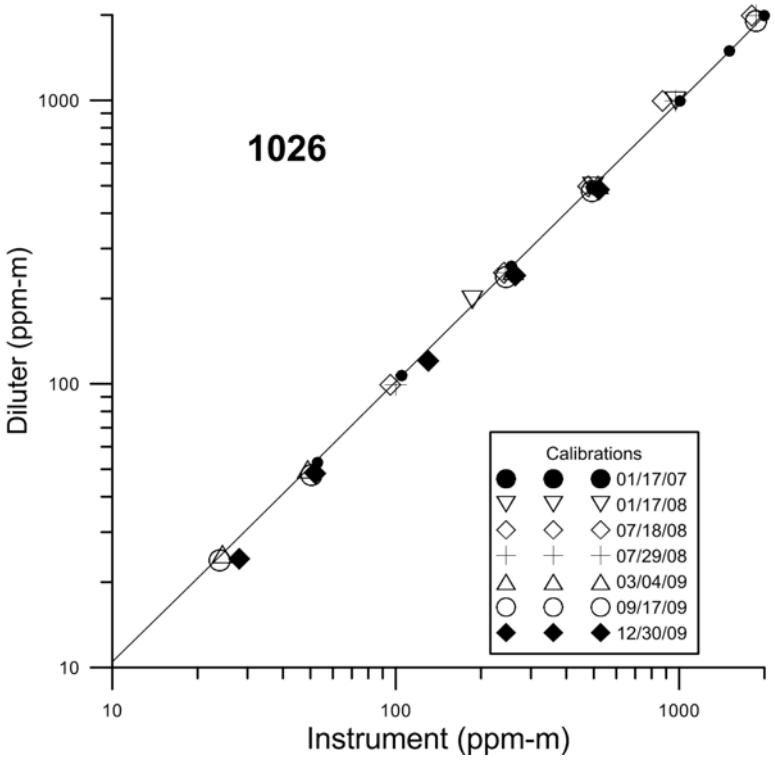


Figure 6.1-1: Multipoint calibrations of the GasFinder 2.0 ^{TM} s/n NH3OP-1026. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

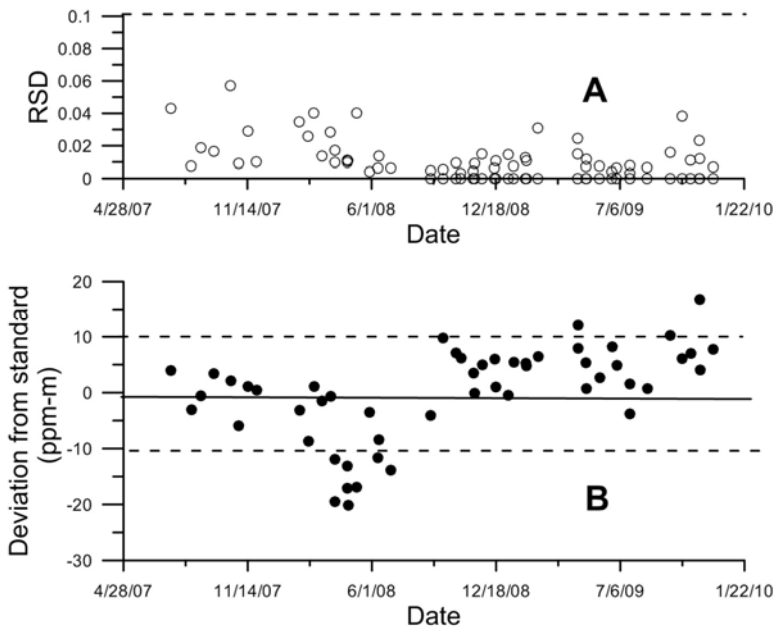


Figure 6.1-2: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1026

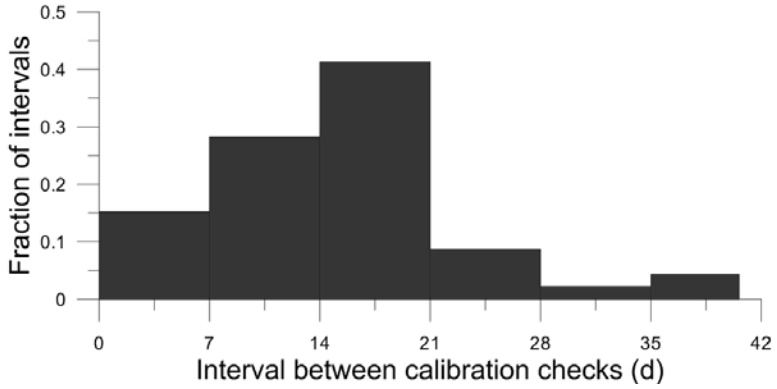


Figure 6.1-3: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1026

TDLAS 1027 was multipoint calibrated eight times (Figure 6.2-4). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 6/18/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 2.24 + 0.9936 * X - 3.59E\text{-}5 * X^2 + 6.230E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window.

At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.13 ppm-m prior to the July 2008 modification and 1.83 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 5.36 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 9/26/2008 and 9/24/2009 (Figure 1). No negative biases exceeded the DQI. Since both positive bias exceedances were followed by a DQI compliant verification on the subsequent calibration verification without intervention, it is assumed that operator error was the cause for the non-compliance.

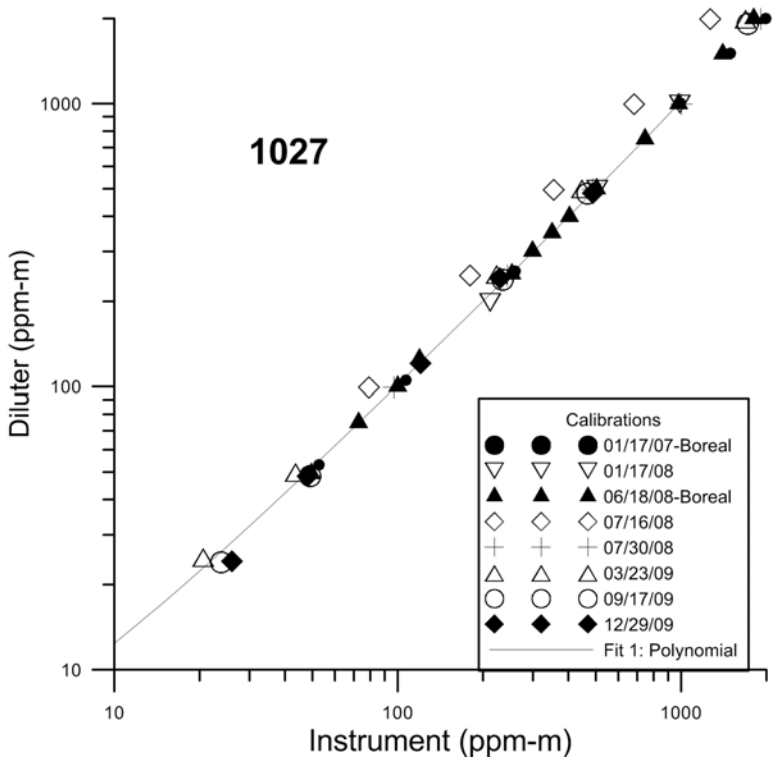


Figure 6.1-4: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1027. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

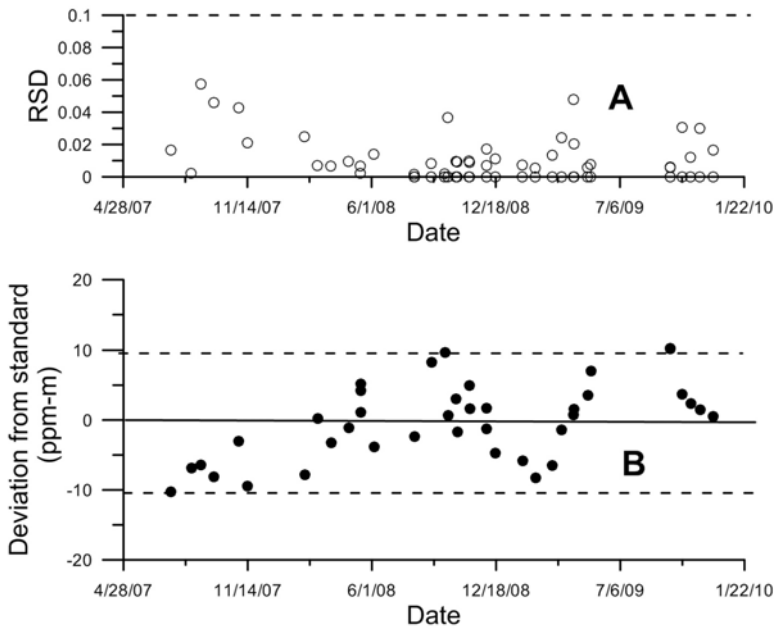


Figure 6.1-5: Control charts of the GasFinder 2.0 [TM] s/n NH3OP-1027

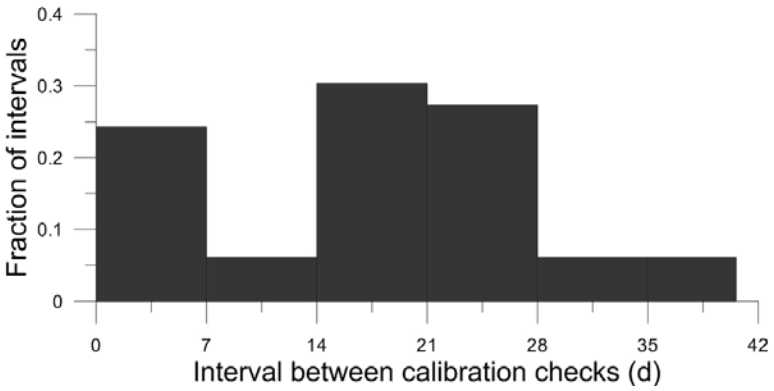


Figure 6.1-6: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1027

TDLAS 1028 was multipoint calibrated six times during the study (Figure 6.1-7). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/23/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 1.46 + 0.985 * X + 8.465E\text{-}6 * X^2 + 3.879E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d was the result of calibration checks made at the

end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-8) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 2). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

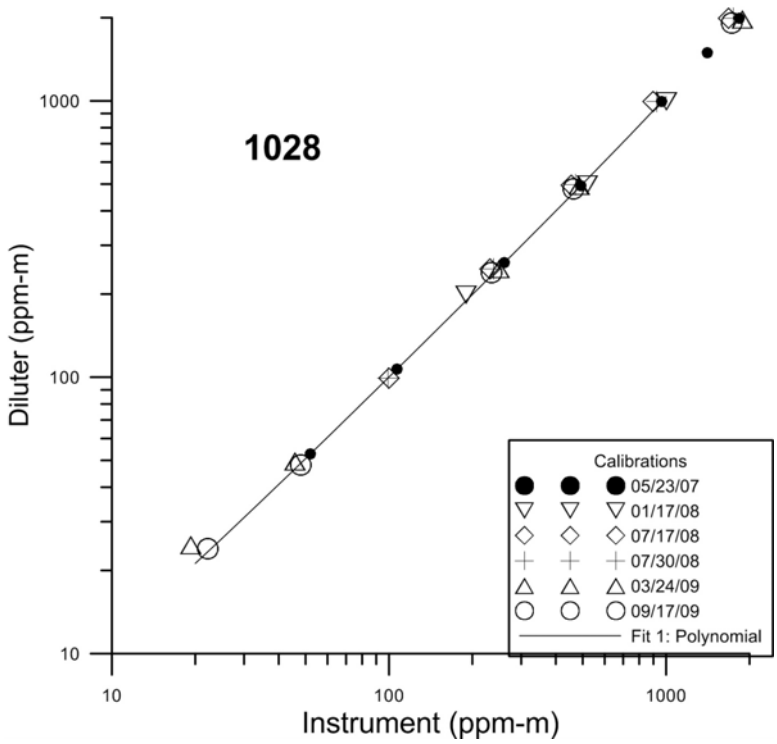


Figure 6.1-7: Multipoint calibrations of the GasFinder 2.0 ™ s/n NH3OP-1028. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

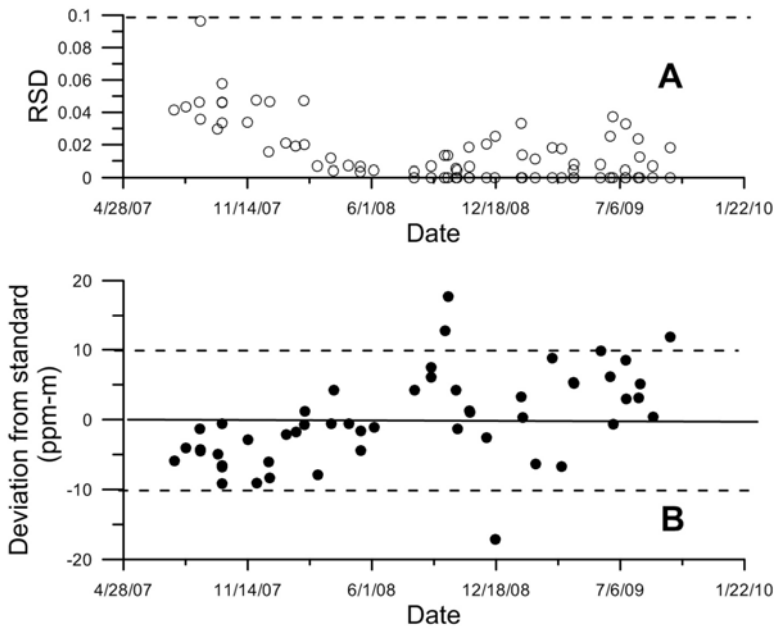


Figure 6.1-8: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1028

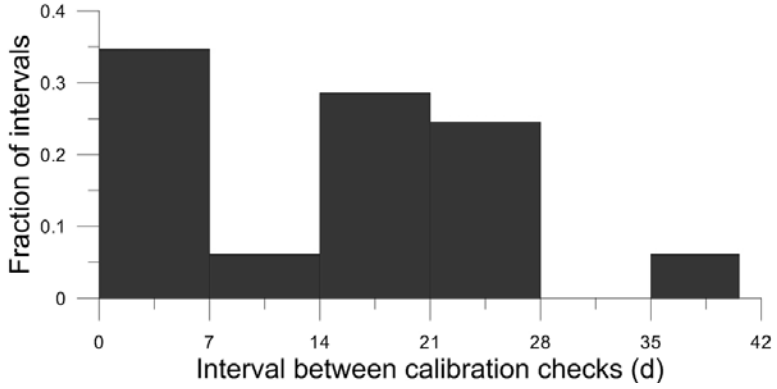


Figure 6.1-9: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1028

TDLAS 1030 was multipoint calibrated eight times (Figure 6.1-10). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 3/26/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 0.13 + 0.9974 * X - 2.1056E\text{-}005 * X^2 + 3.050E\text{-}008 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window.

At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. The adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 3.05 ppm-m prior to the July 2008 modification and 0.685 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-12). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 7.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m except on 8/30/2007 (Figure 6.1-11) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 8/14/2008 and 9/23/2008 while negative biases exceeding the DQI occurred on 10/4/2007, 9/23/2008, and 4/28/2009 (Figure 6.1-11). In all cases, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

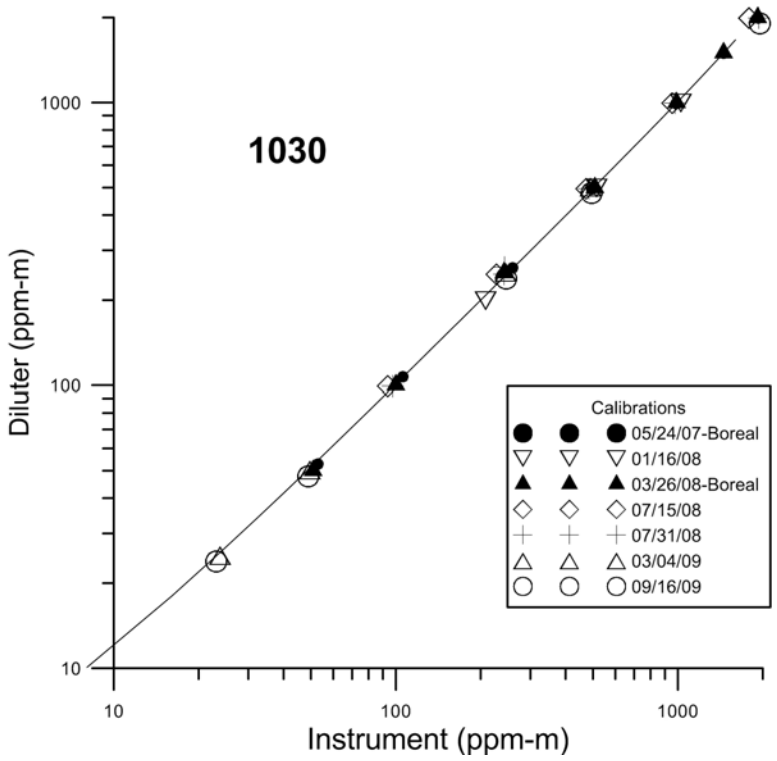


Figure 6.1-10: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1030. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

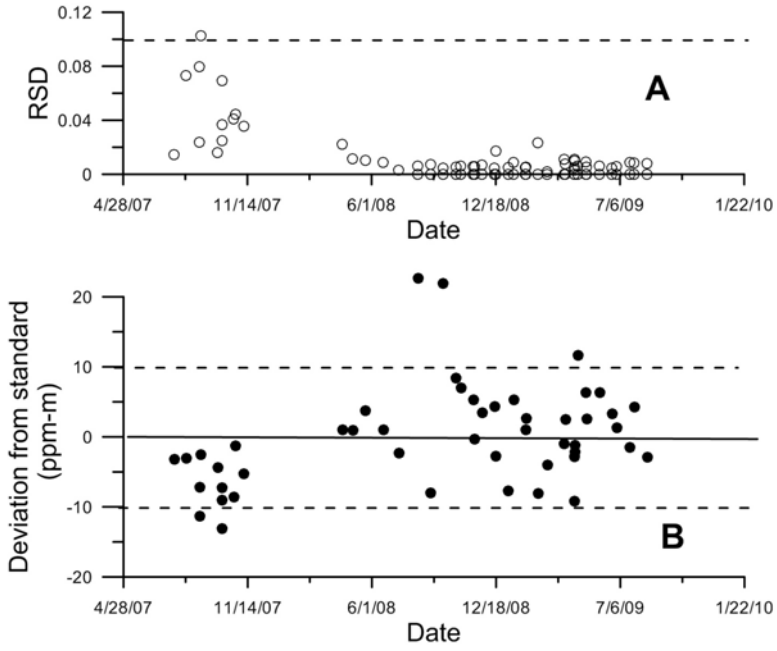


Figure 6.1-11: Control charts of the GasFinder 2.0 [TM] s/n NH3OP-1030

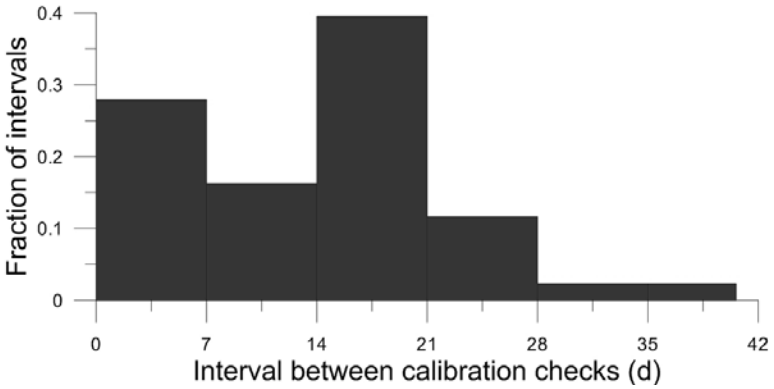


Figure 6.1-12: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1030

TDLAS 1031 was multipoint calibrated six times during the study (Figure 6.1-13). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/30/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

ppm-m = -4.43 + 1.0120 * X - 5.7496E-005 * X^2 + 6.0196E-008 * X^3

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 5.70 ppm-m prior to the July 2008 modification and 1.92 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The average MDL was approximately equal to the offset indicated in the calibration regression. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-14) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-15). The large fraction of checks made within 7 d ws the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 15.60 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-14) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI occurred in the

calibration verifications between 8/2/07 and 9/18/07 (Figure 6.1-14). Positive DQI bias exceedances occurred on 6/28/2007, 9/11/2008, 4/8/2009 and 8/12/2009. Verification failures in the 6/28/07 to 9/18/07 interval were a result of un-anticipated optical noise in the calibration procedure which was later corrected. The 4/8/2009 exceedance was preceded and followed by DQI-compliant verifications and the 8/12/2009 verification was preceded by a compliant verification and followed by a multipoint indicating no problem with instrument performance. The instrument was taken out of service between 9/11/2008 and 12/31/2008.

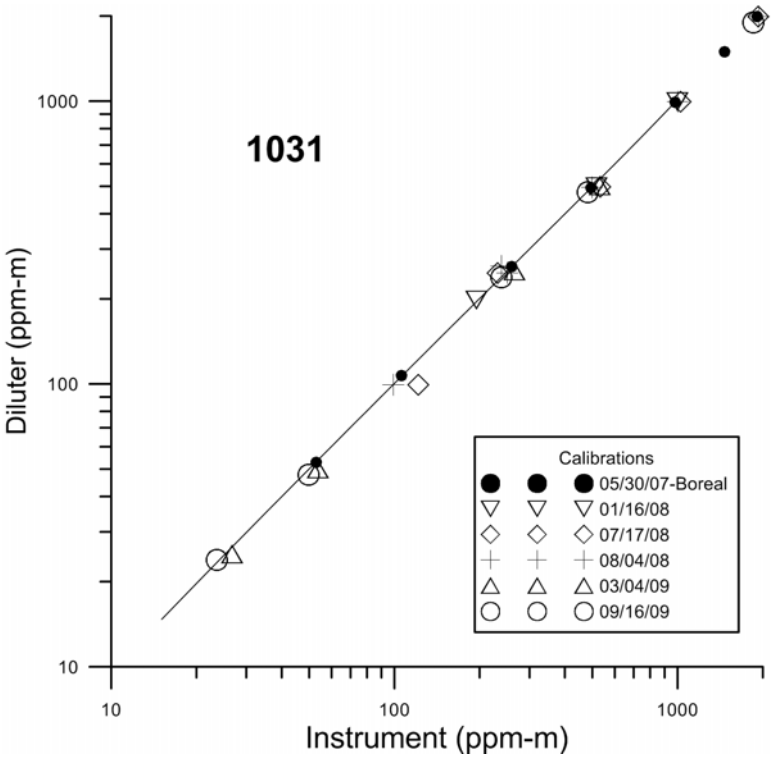


Figure 6.1-13: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1031. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

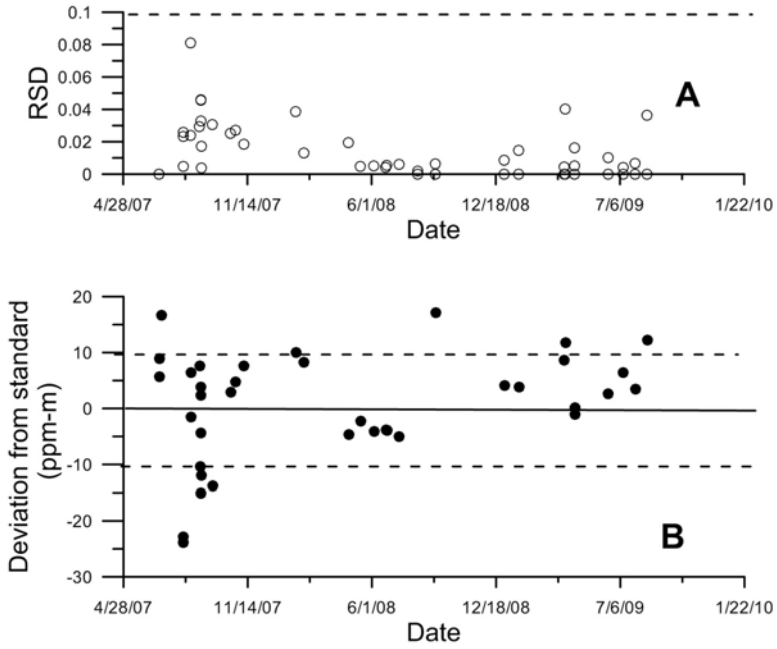


Figure 6.1-14: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1031

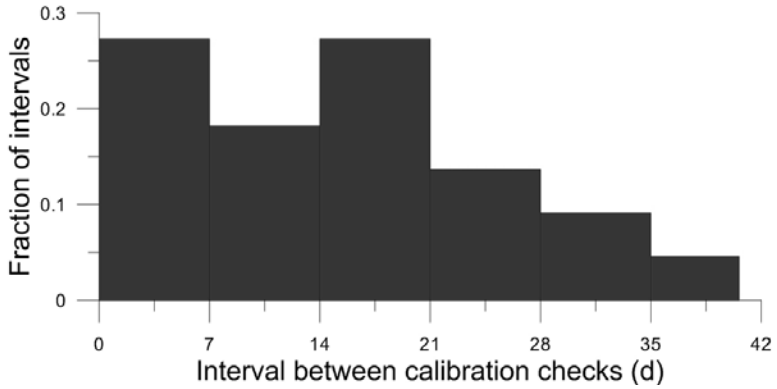


Figure 6.1-15: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1031

6.2 TEC 450i analyzer H_2S calibrations

Two TEC 450i SO_2/H_2S Analyzers (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA) were used at this location, serial numbers 0733825128 and 0733825129.

TEC 450i SO_2/H_2S Analyzer serial number 0733825128 was multipoint calibrated eight times during the study (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.73 to 1.38 (Table 6.2-1). Part of the variation in slope was a result of the H_2S calibration cylinders used. The initial multipoint calibration was conducted prior to the complete burn-in of the converter and consequently differs greatly from the other calibrations.

Table 6.2-1: Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
12/12/2007	1.38	-0.0220	0.999
7/11/2008	0.99	0.0034	0.999
8/13/2008	1.18	-0.0045	0.999
9/4/2008	1.22	0.0065	0.999
3/25/2009	0.73	0.0068	0.999
6/19/2009	1.14	-0.0037	0.999
6/24/2009	0.75	0.0075	0.999
9/9/2009	1.14	-0.0052	0.999

The standard deviation of instrument response with CEM zero air measured over a one h period was 0.83 ppb (10/19/2009). The instrument MDL, defined as 3σ was 2.5 ppb and is indicated in Figure 6.1-2A with dashed lines. This is much less than the mean absolute multipoint calibration intercept concentration of 7.5 ppb.

Instrument performance calibration checks (Figures 6.2-2 and 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.2-4). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.788. The mean zero concentration was +1.7 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). Three major periods of instrument bias that exceeded the ± 10% of FS are evident (Figure 6.2-2). The first period extends from the beginning of the measurements until 9/5/2008. Based on the correlation of instrument performance and the calibration cylinder used, it was determined that the concentration of H_2S in the SGAL053 cylinder, which could not be independently verified, was significantly below indicated specification. This resulted in unusually high ratios of diluter concentration versus instrument response (1.01 to 1.18) up until the cylinder was replaced. The second period was from 11/4/2008 to 12/16/2008 when the calibration checks were inconsistent.

Checks conducted on 11/4/2008 and 12/16/2008 at the end of measurement periods failed while checks made two d later at the set up of the next site passed. Since no modifications/repairs of the instruments were done in the interim between these calibrations, we assume that the FOS must have erred in their procedures.

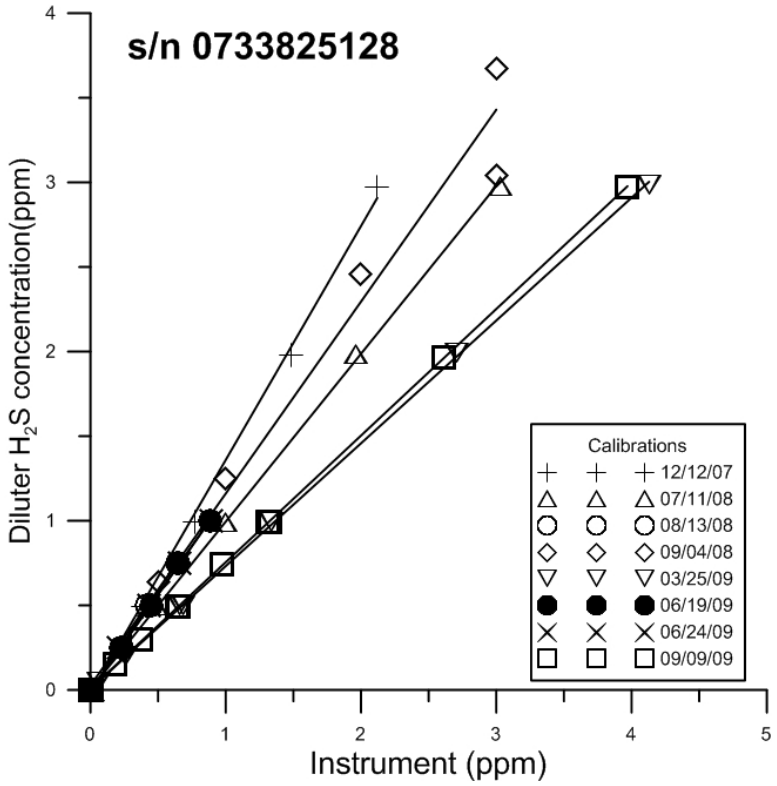


Figure 6.2-1: Multipoint calibrations of the 450i SO_2/H_2S Analyzer

The third period of calibration check failures occurred after April 2009. High zero checks (Figure 6.2-2A) and low reference checks (Figure 6.2-2B) occurred throughout this time. The instrument response time was found to be unusually long (11 min versus typical 5 min) when specifically checked in July 2009. After the prescribed 10 min interval specified in the SOP the response was only 59% of the span value when the long time constant was discovered. Given the SOP reference value of 0.5 ppm, the 59% response after 10 min corresponds to approximately 0.2 ppm less than the stabilized reference value. The control chart of the calibration checks (Figure 6.2-2) showed a shift in response of approximately -0.2 ppm, which occurred in May 2009 and continued through July 2009 but appeared to return to normal operation in August 2009. This change in time response occurred during dusty conditions when the equipment was at WA5A. The change in response resulted in two multipoint calibrations in the field (Table 6.2-1).

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedances (Figure 6.2-3) occurred on 9/5/2008, 6/4/2009 and 8/4/2009. The failure on 9/5/2008 was associated with a change in calibration cylinder (from SGAL053 to FF27944). As previously discussed, it is

believed that the certified concentration in SGAL053 was low, resulting in a significant shift in the measured diluter concentration when the new cylinder was began use. The failures on 6/4/2009 and 8/4/2009 were probably associated with variable response the instrument during the period of the shift in response time of the instrument.

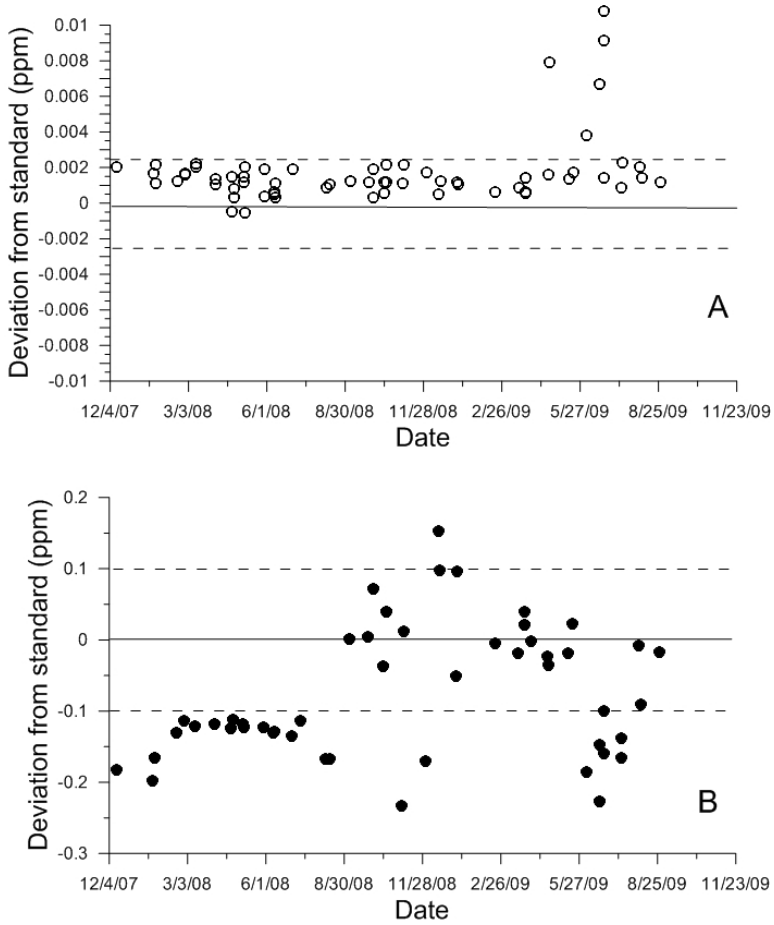


Figure 6.2-2: Instrument Control Charts.

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

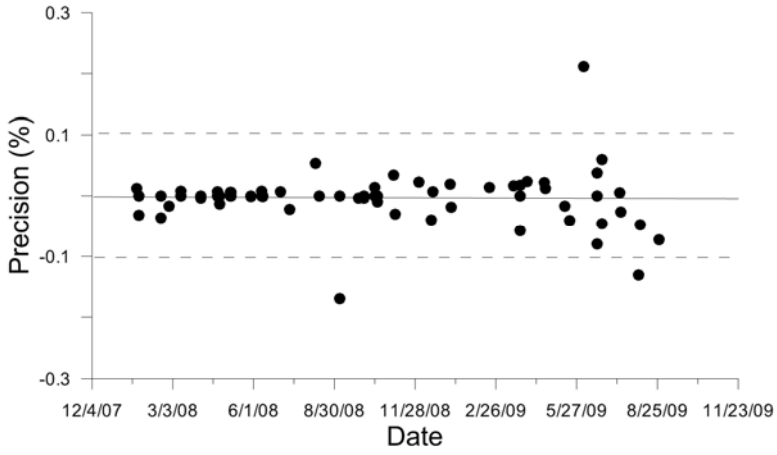


Figure 6.2-3: Instrument Precision

The precision of span checks are indicated. The dashed lines represent 10% of the Full Scale value (1 ppm).

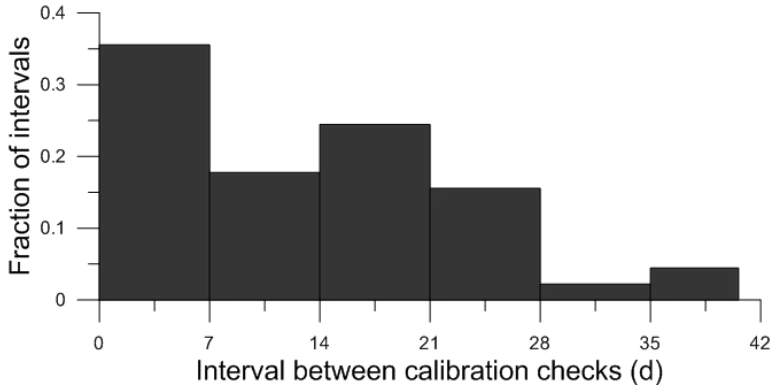


Figure 6.2-4: Calibration check intervals

TEC 450i SO_2/H_2S Analyzer serial number 0733825129 was multipoint calibrated seven times (Figure 6.2-5). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.67 to 0.94 (Table 6.2-2). The initial 12/30/2007 multipoint calibration records were lost.

Table 6.2-2: Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
7/21/2008	0.67	0.0100	0.999
11/25/2008	0.81	0.0070	0.999
3/5/2009	0.94	0.0165	0.999
4/23/2009	0.73	0.0263	0.999
4/29/2009	0.78	0.0206	0.999
9/1/2009	0.75	0.0054	0.999
12/29/2009	0.81	0.0083	0.999

The standard deviation of instrument response with CEM zero air measured over a one h period was 0.81 ppb (12/29/2009). The instrument MDL, defined as 3σ was 2.4 ppb and is indicated in Figure 6.2-6A with dashed lines. This is much less than the mean absolute value of the multipoint calibration intercept of 13.4 ppb.

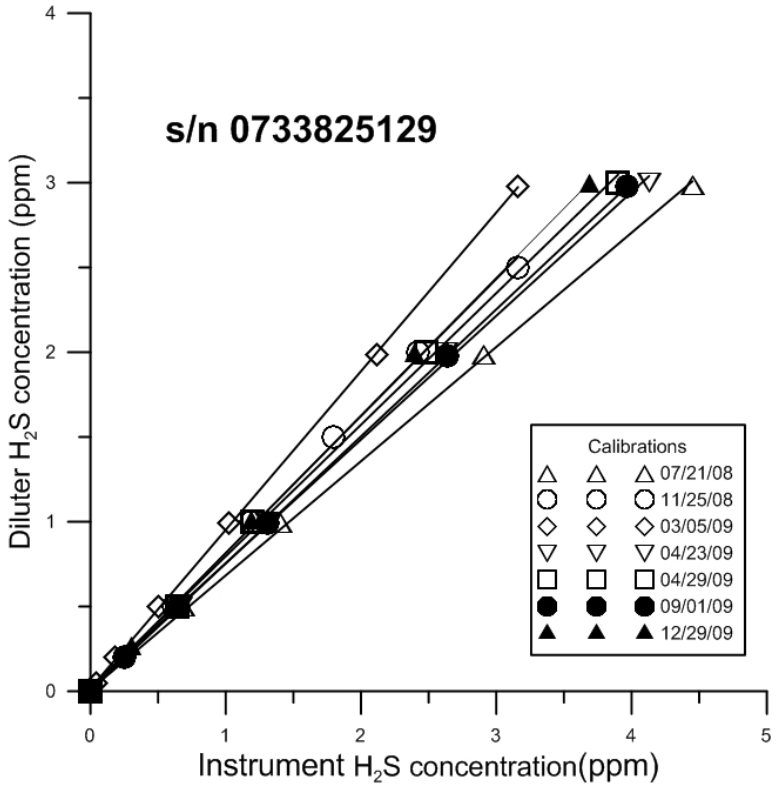


Figure 6.2-5: Multipoint calibrations of the 450i SO_2/H_2S Analyzer

Instrument performance calibration checks (Figures 6.2-6 and 6.2-7) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 25 d (Figure 6.2-8). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.800. The mean zero concentration was +0.3 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). The initial calibration check (1/15/2008) was conducted prior to the complete burn-in of the converter and consequently differs from the other calibrations and indicated a failed check in the post-study response check (Figure 6.2-6B). Post-study response checks in August and September 2008 also indicated check failures (Figure 6.2-6B), although all of these failures are associated with a non-diluted calibration cylinder where the balance gas was N_2 and consequently the 450i converter was unable to function properly.

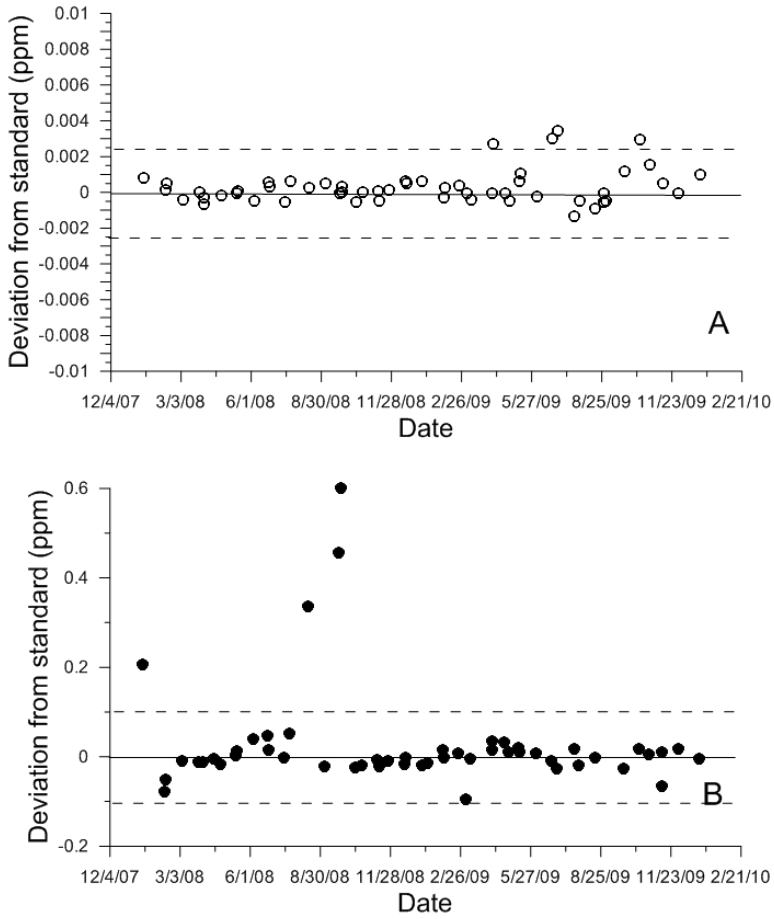


Figure 6.2-6: Instrument Control Charts

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1ppm).

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedances (Figure 6.2-7) occurred on 2/12/2008 and 3/5/2009. The 2/2/2008 failure was likely due to the burn-in of the converter and signals changes in the instrument response as the instrument is conditioned. The failure on 3/5/2009 was likely a result of the use of a out-of-certification range calibration cylinder (although within certification period; FF44447). This cylinder was 38% below the mean concentration of nine cylinder inter-compared on 8/28,31/2009. Calibration certification before and after this date were valid.

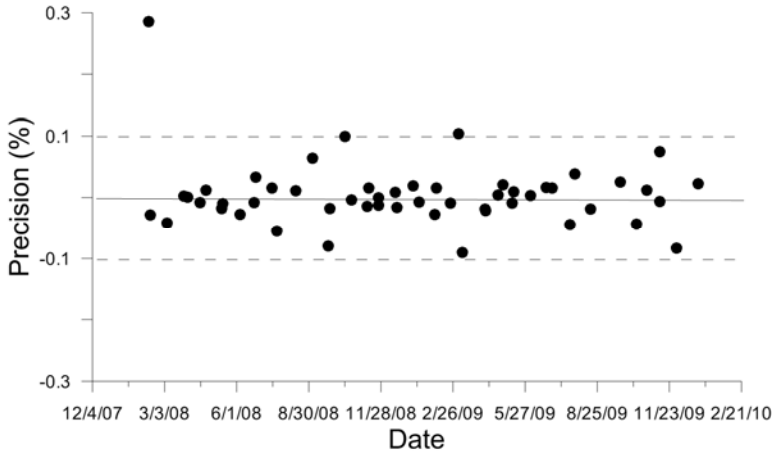


Figure 6.2-7: Instrument Precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

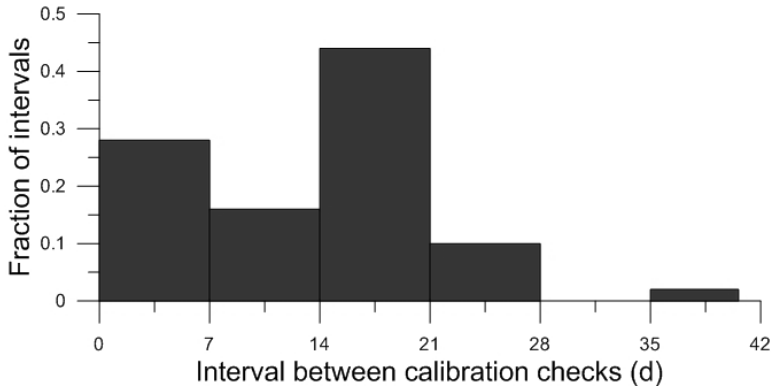


Figure 6.2-8: Calibration check intervals

6.3 Sonic anemometer calibrations

Nine sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were used at this location: serial numbers 1927, 1926, 1925, 1933, 1920, 1928, 1945, 1921, and 1932.

Sonic anemometer serial number 1927 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-1). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check on all checks except 9/23-25/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back to use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-1: Standards inter-comparisons

Calibration dates		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.025	-0.043
1/21/2008	1/23/2008	-0.051	-0.033
7/16-17/2008	7/17-18/2008	+0.042	+0.029
3/23-25/2009	3/25-27/2009	-0.050	-0.028
9/1-2/2009	9/2-3/2009	-0.035	-0.023

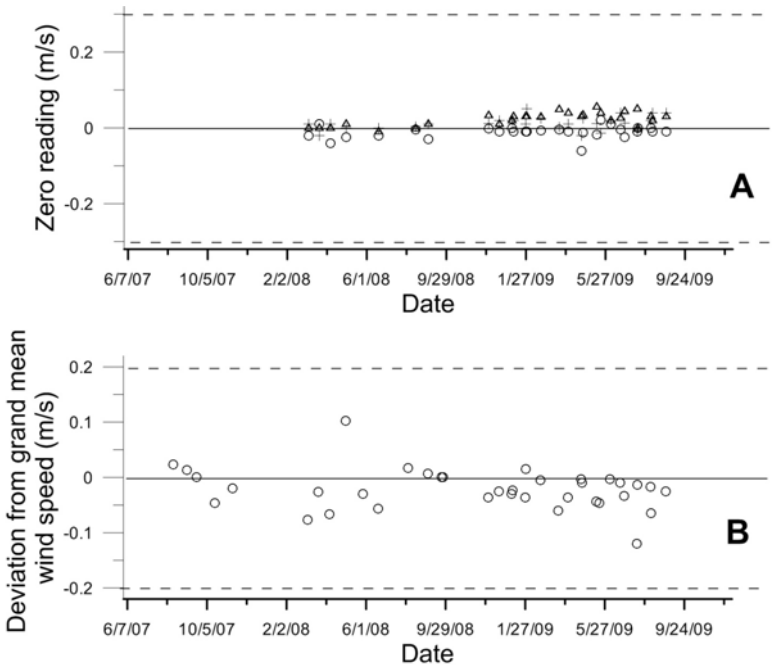


Figure 6.3-1: On-site quality assurance of s/n 1927. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

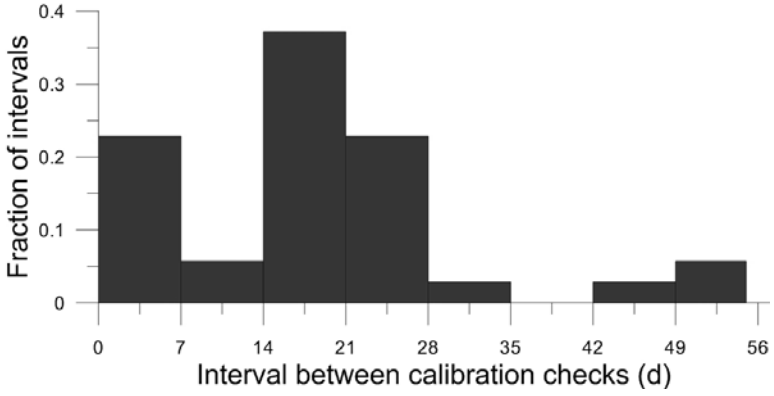


Figure 6.3-2: Inter-comparison check intervals for s/n 1927.

Sonic anemometer serial number 1926 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-2). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-3). The majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of checks

made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 1B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-31A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-2: Standards inter-comparisons

Calibration dates		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29-7/2/2007	-0.005	-0.033
1/17-18/2008	1/20-21/2008	-0.013	-0.032
7/16-17/2008	7/17-18/2008	+0.037	+0.059
3/6-7/2009	3/7-9/2009	+0.004	+0.048
9/16-17/2009	9/17-18/2009	+0.059	+0.001

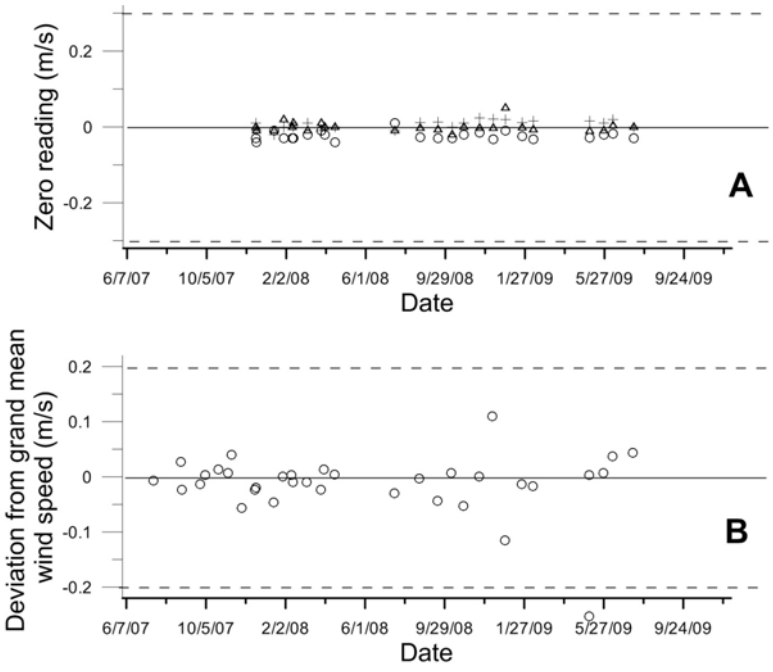


Figure 6.3-3: On-site quality assurance of s/n 1926. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

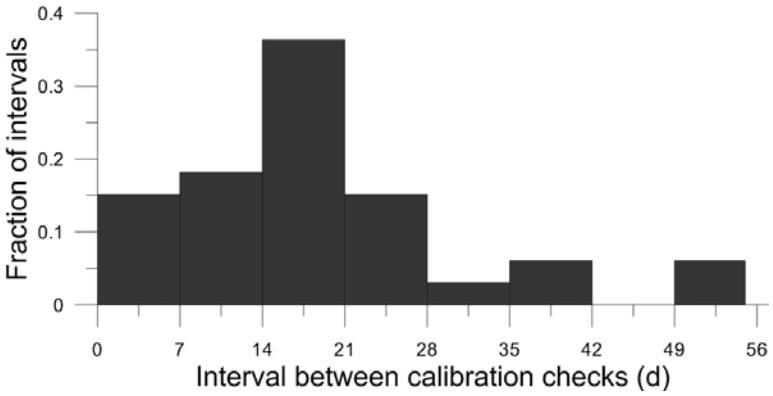


Figure 6.3-4: Inter-comparison check intervals for s/n 1926.

Sonic anemometer 1925 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-3). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 26 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-5B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-3: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.013	-0.022
1/21-22/2008	1/23/2008	-0.053	-0.075
7/16-17/2008	7/17-18/2008	+0.023	+0.004
3/6-7/2009	3/7-9/2009	-0.018	-0.058
9/8-14/2009	9/15-16/2009	-0.013	-0.022
12/18-19/2009	12/21-23/2009	+0.095	-0.084

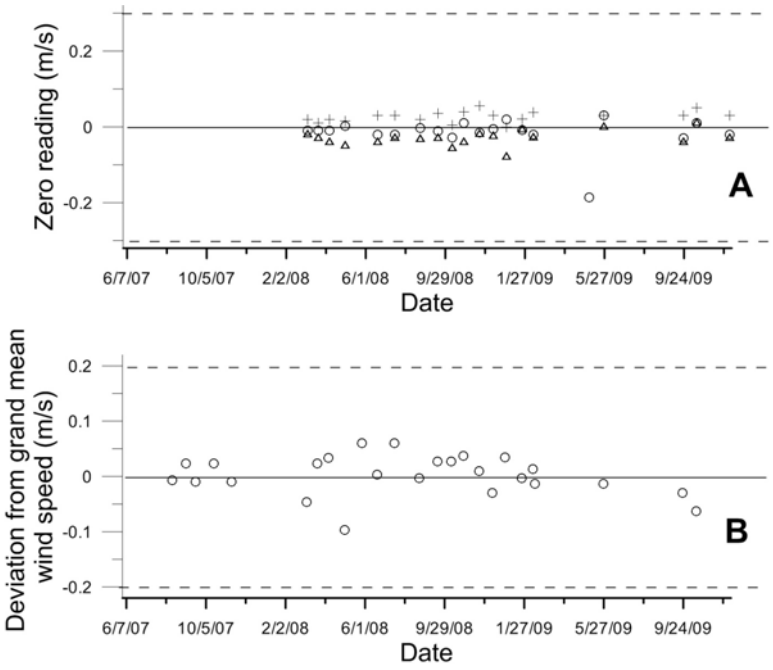


Figure 6.3-5: On-site quality assurance of s/n 1925. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

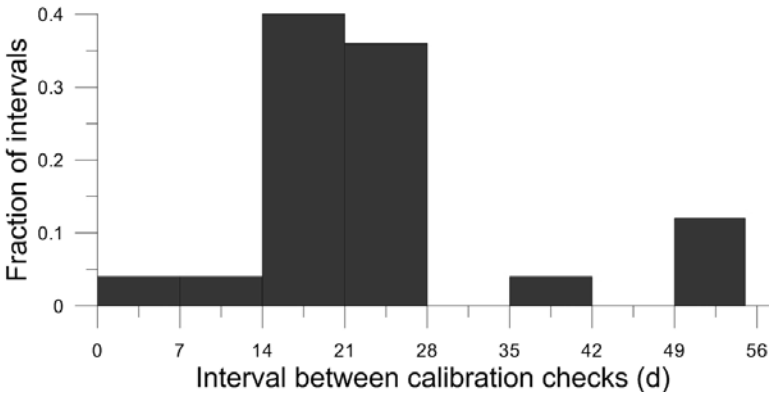


Figure 6.3-6: Inter-comparison check intervals for s/n 1925.

Sonic anemometer serial number 1933 was inter-compared with three standard anemometers of identical design three times during the study (Table 6.3-4). This instrument was used as a standard prior to use in the on-site measurements beginning 4/23/2008. No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 23 times (Figure 6.3-7). The

majority of calibration checks were made within 21 d (Figure 6.3-8). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-7B). This instrument passed this check on all checks except 7/21/2009 and was taken out of service. The last standard inter-comparison (1/2010) failed due to loss of communications.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-7A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-4: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
7/18-19/2008	7/21-22/2008	+0.012	+0.014
3/3-5/2009	3/5-6/2009	-0.016	-0.004
1/7-9/2010	1/23-25/2010	-3.733	-3.93

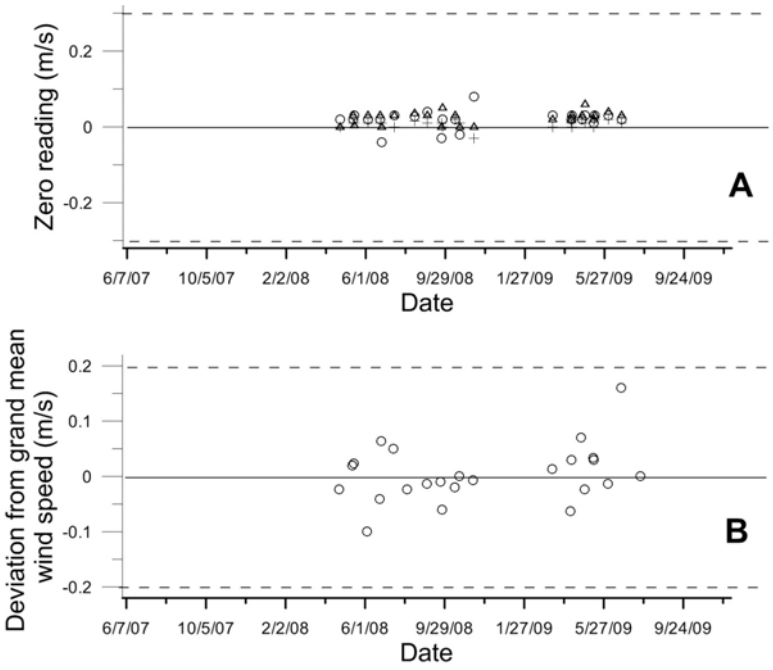


Figure 6.3-7: On-site quality assurance of s/n 1933. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

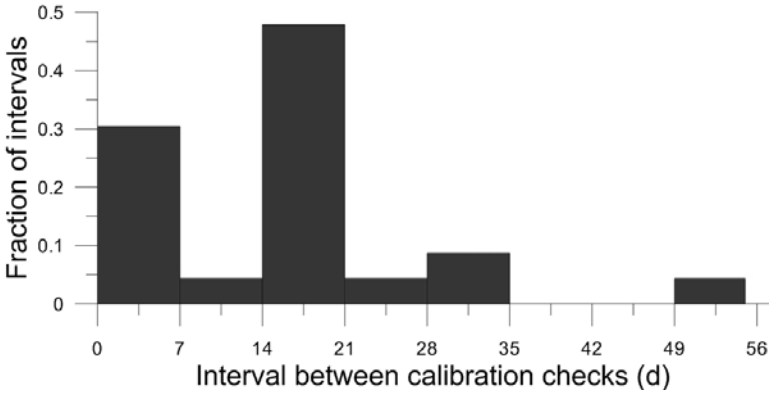


Figure 6.3-8: Inter-comparison check intervals for s/n 1933.

Sonic anemometer serial number 1920 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-5). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 51 times (Figure 6.3-9). The majority of calibration checks were made within 21 d (Figure 6.3-10). The large fraction of

checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-9B). This instrument passed this check at all times. However, this instrument developed intermittent problems during operation and was sent to the factory for repair 10/10/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-9A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-5: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29-7/2/2007	+0.001	+0.002
1/17-19/2008	1/20-21/2008	+0.045	+0.003
7/18-21/2008	7/21-22/2008	+0.017	-0.006
3/23-25/2009	3/25-27/2009	-0.036	-0.033
9/1-2/2009	9/2-3/2009	-0.046	-0.025

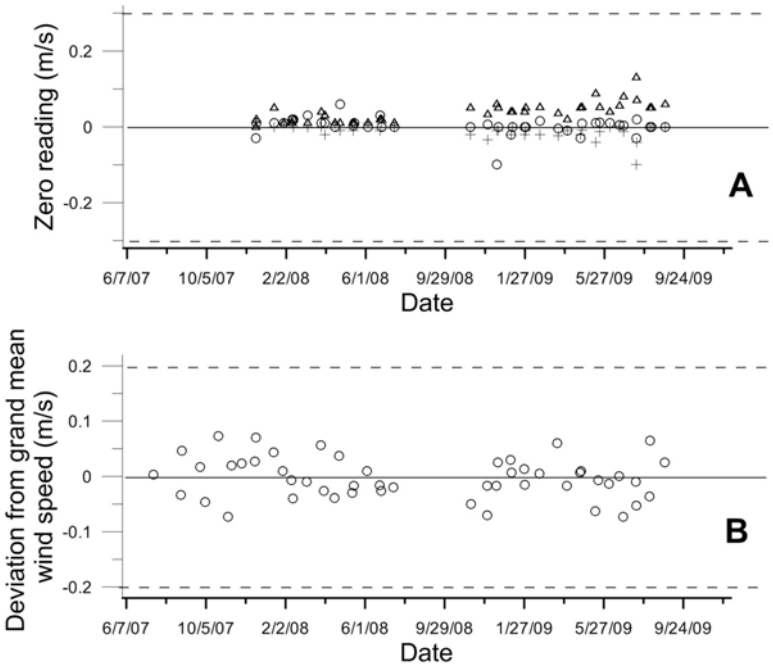


Figure 6.3-9: On-site quality assurance of s/n 1920. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

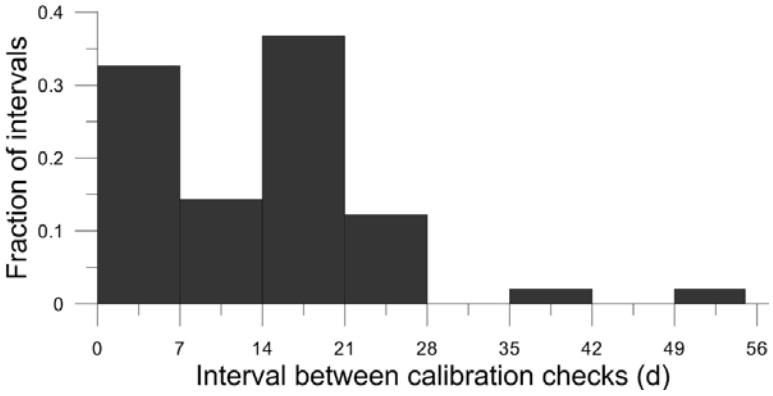


Figure 6.3-10: Inter-comparison check intervals for s/n 1920.

Sonic anemometer serial number 1928 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-6). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 48 times (Figure 6.3-11). The majority of calibration checks were made within 21 d (Figure 6.3-12). The large fraction of

checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments(Figure 6.3-11B). This instrument passed this check all but one time. On this one date, the inter-comparison was rerun and the instrument passed the check.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-11A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-6: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.004	+0.019
12/27-28/2007	12/29-31/2007	+0.003	-0.005
7/10-11/2008	7/11-14/2008	+0.022	+0.007
3/3-4/2009	3/5-6/2009	+0.070	-0.027
9/16-17/2009	9/17-18/2009	+0.056	+0.022
12/18-19/2009	12/21-23/2009	+0.094	-0.077

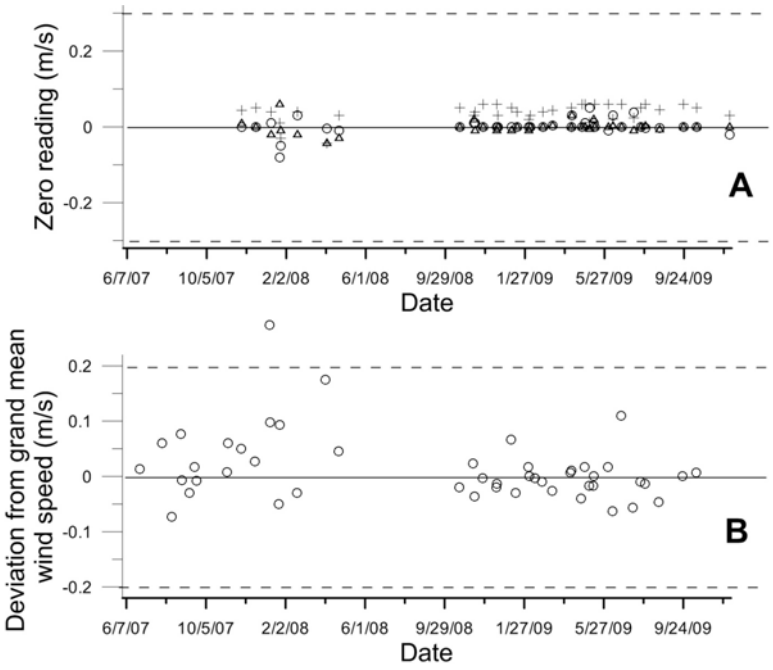


Figure 6.3-11: On-site quality assurance of s/n 1928. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

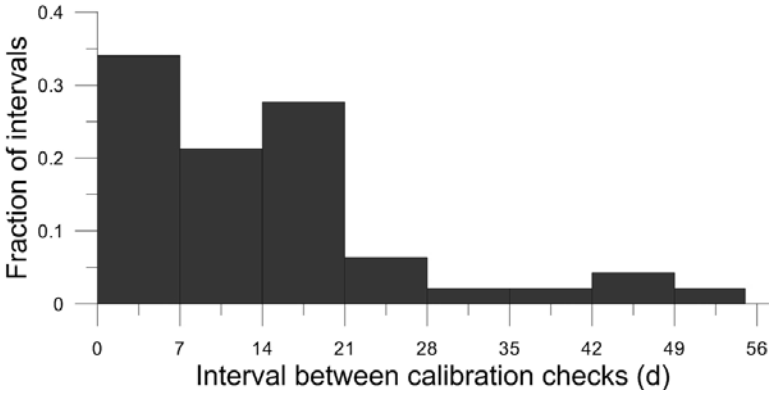


Figure 6.3-12: Inter-comparison check intervals for s/n 1928.

Sonic anemometer serial number 1945 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-7). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 45 times (Figure 6.3-13). The majority of calibration checks were made within 21 d (Figure 6.3-14). The large fraction of

checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-13B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-13A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-7: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/27-7/2/2007	+0.001	-0.051
1/17-19/2008	1/20-21/2008	-0.023	-0.037
7/18-21/2008	7/21-22/2008	+0.023	+0.026
3/3-4/2009	3/5-6/2009	+0.014	+0.171
9/16-17/2009	9/17-18/2009	+0.028	-0.012

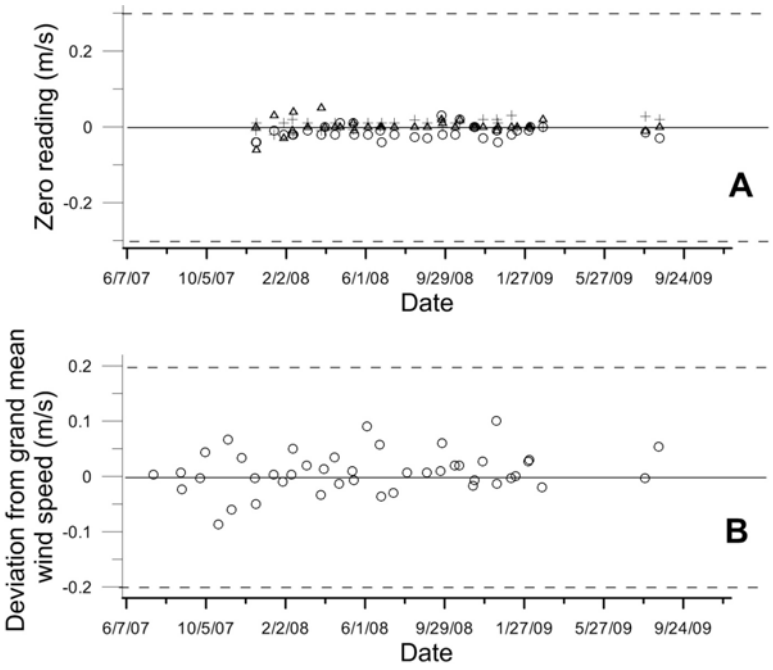


Figure 6.3-13: On-site quality assurance of s/n 1945. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

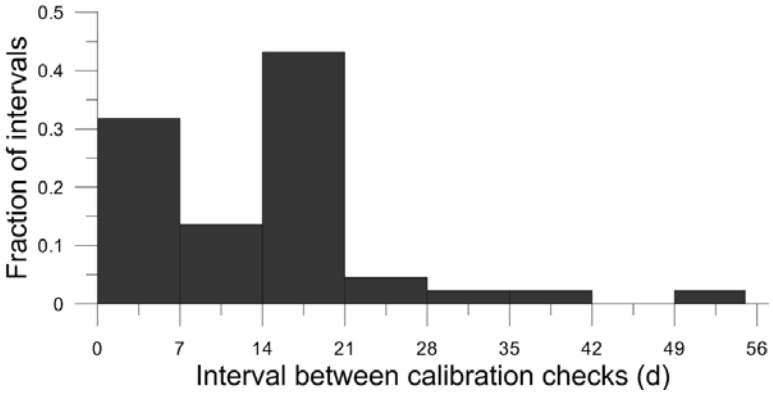


Figure 6.3-14: Inter-comparison check intervals for s/n 1945.

Sonic anemometer serial number 1921 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-8). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 43 times (Figure 6.3-15). The majority of calibration checks were made within 21 d (Figure 6.3-16). The large fraction of

checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-15B). This instrument passed this check at all times. However, this instrument developed intermittent problems during operation and was sent to the factory for repair 12/9/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-15A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-8: Standards inter-comparisons

Calibration dates		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.008	-0.003
12/27-28/2007	12/29-31/2007	-0.034	+0.001
7/10-11/2008	7/11-14/2008	+0.029	-0.022
3/23-25/2009	3/25-27/2009	-0.021	-0.040
9/8-14/2009	9/15-16/2009	+0.028	+0.038
12/18-19/2009	12/21-23/2009	+0.078	+0.002

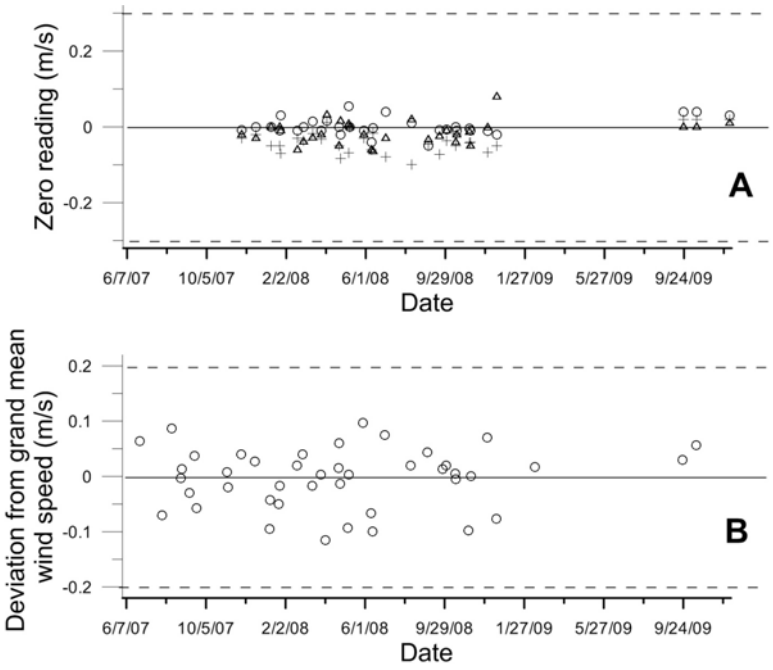


Figure 6.3-15: On-site quality assurance of s/n 1921. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

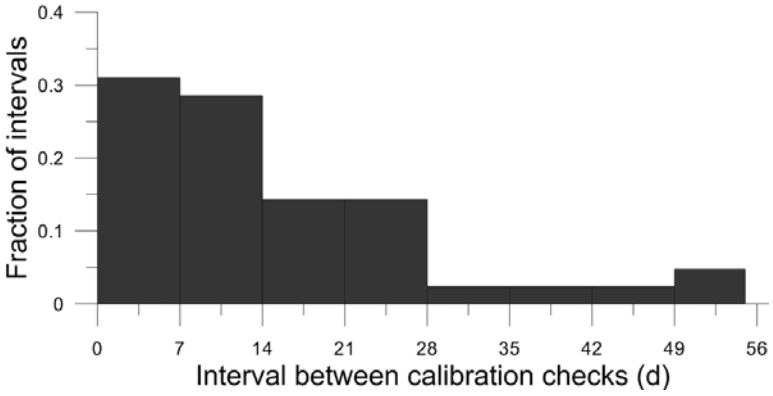


Figure 6.3-16: Inter-comparison check intervals for s/n 1921.

Sonic anemometer serial number 1932 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-9). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 55 times (Figure 6.3-17). The majority of calibration checks were made within 21 d (Figure 6.3-18). The large fraction of

checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-17B). This instrument passed this check on all checks except 10/15-16/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back in use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-17B). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-9: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-17/2007	6/18-19/2007	+0.004	+0.160
12/27-28/2007	12/29-31/2007	+0.014	-0.009
7/10-11/2008	7/11-14/2008	+0.008	+0.031
3/3-5/2009	3/5-6/2009	-0.024	-0.005
9/8-14/2009	9/15-16/2009	-0.025	-0.044
1/7-9/2010	1/23-24/2010	+0.020	-0.016

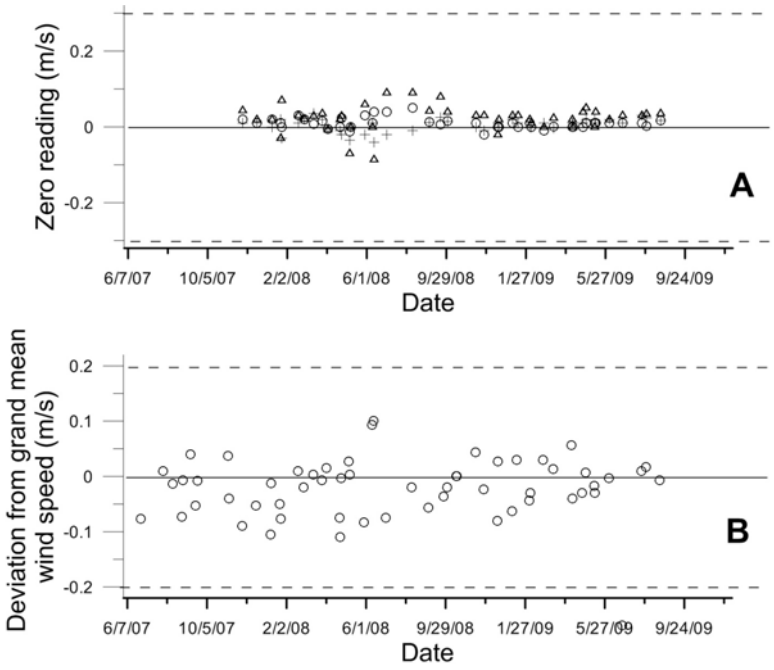


Figure 6.3-17: On-site quality assurance of s/n 1932. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

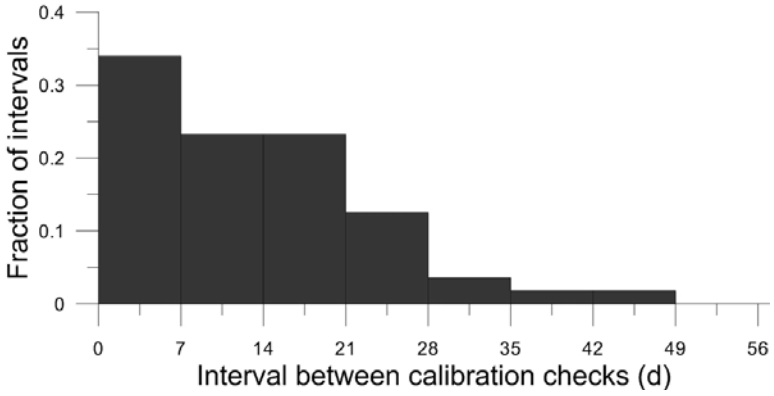


Figure 6.3-18: Inter-comparison check intervals for s/n 1932.

6.4 pH probe calibrations

Three pH probes (Model CSIMM-ph, Innovative Sensors, Inc., Anaheim, CA) were used at this location: The Innovative Sensors, Inc. CSIM11-pH probe, serial numbers 001, 004, and 007.

The Innovative Sensors, Inc. CSIM11-pH probe, s/n 001, was first used 7/18/2007 and last used 4/30/2008. The probe was calibrated 17 times. Since freezing conditions damage the probe, the probes were not used during the winter at many locations. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-1A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed both the accuracy DQI and the stability checks.

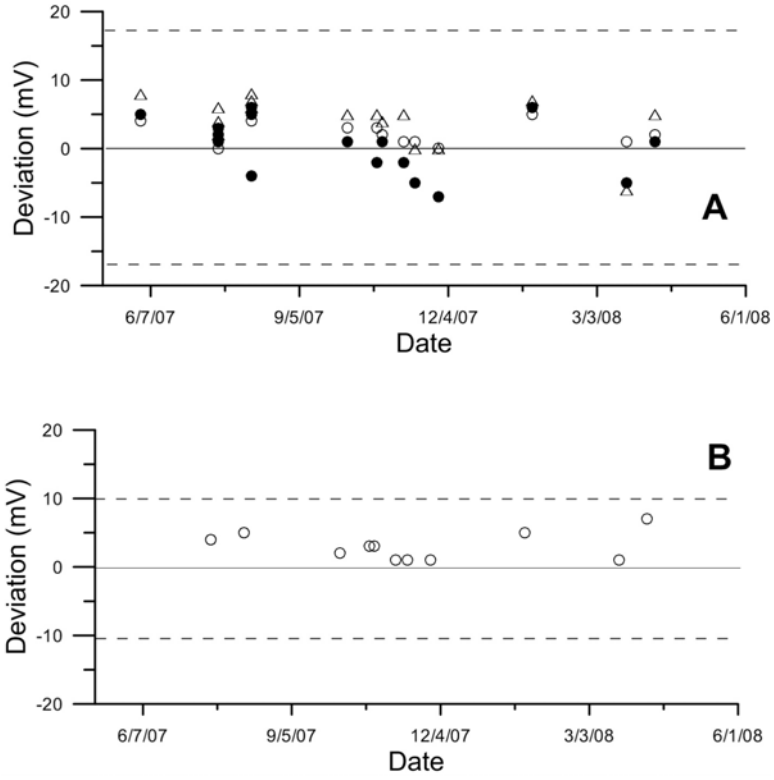


Figure 6.4-1: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 001. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

Probe 004 was first used 7/8/2007 and last used 2/3/2009. The probe was calibrated 27 times. Since freezing conditions damage the probe, the probes were not used during the winter at many locations. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-2A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe passed the accuracy DQI on all checks but 2/3/09 but failed the stability checks 9/23/08, 9/25/08, and 2/3/09. Since the sensor passed checks subsequent to the 9/2008 checks, these failures were likely due to operator error. The last check on 2/3/2009 indicated a faulty sensor.

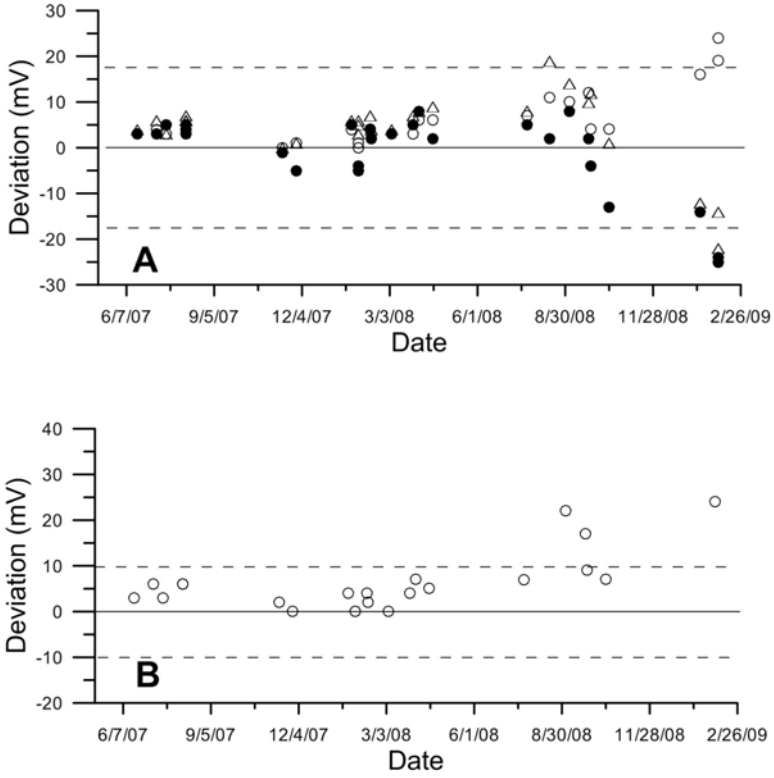


Figure 6.4-2: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 004. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

Probe 007 was first used 2/5/2009 and last used 12/2/2009. The probe was calibrated 14 times. Since freezing conditions damage the probe, the probes were not used during the winter at many locations. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-3A

illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-3B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed both the accuracy DQI and the stability checks.

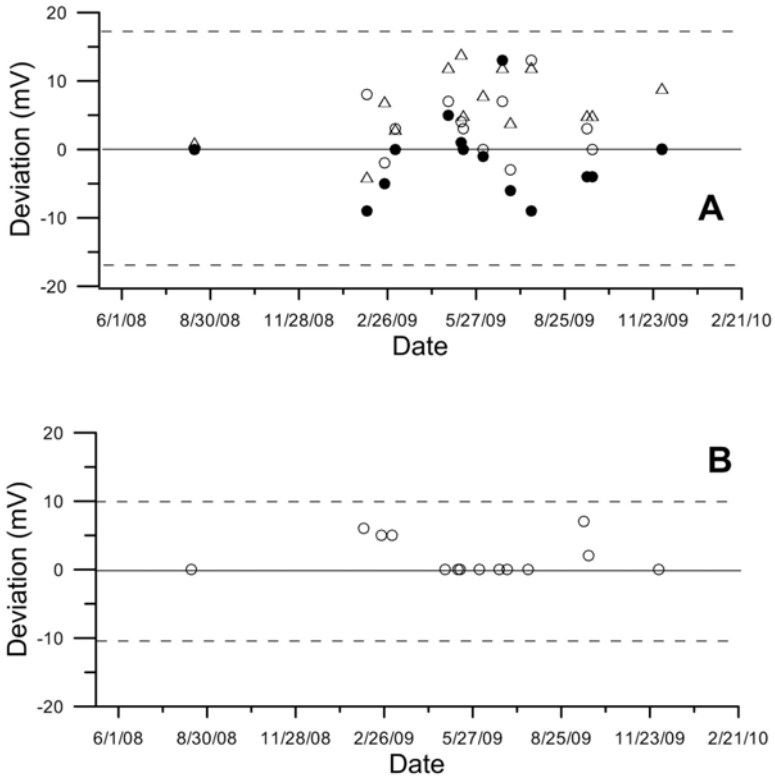


Figure 6.4-3: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 007. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since lagoon pH measurements were not made at several locations, the interval between calibrations can be large such that locations that did not have lagoon pH measurements were visited between locations where the measurements were made.

6.5 ORP probe calibrations

Two ORP probes (Model CSIM11-ORP, Innovative Sensors Inc., Anaheim, California) were used at this location: The Innovative Sensors, Inc. CSIM11-ORP probe, serial numbers 020 and 050.

Probe 020 was first used 7/18/2007 and last used 9/3/2008. The probe was calibrated 16 times. Since freezing conditions damage the probe, the probes were not used during the winter at many locations. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-1A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe passed the accuracy check DQI on all but 3/27/2008, 4/2/2008, and 8/14/2008. Subsequent accuracy check however, met the accuracy DQI without probe modification so the prior failures were assumed to be due to operator error. The stability deviated significantly from the normal range on 4/2/2008 and 8/14/2008 indicating a possible partially-plugged probe.

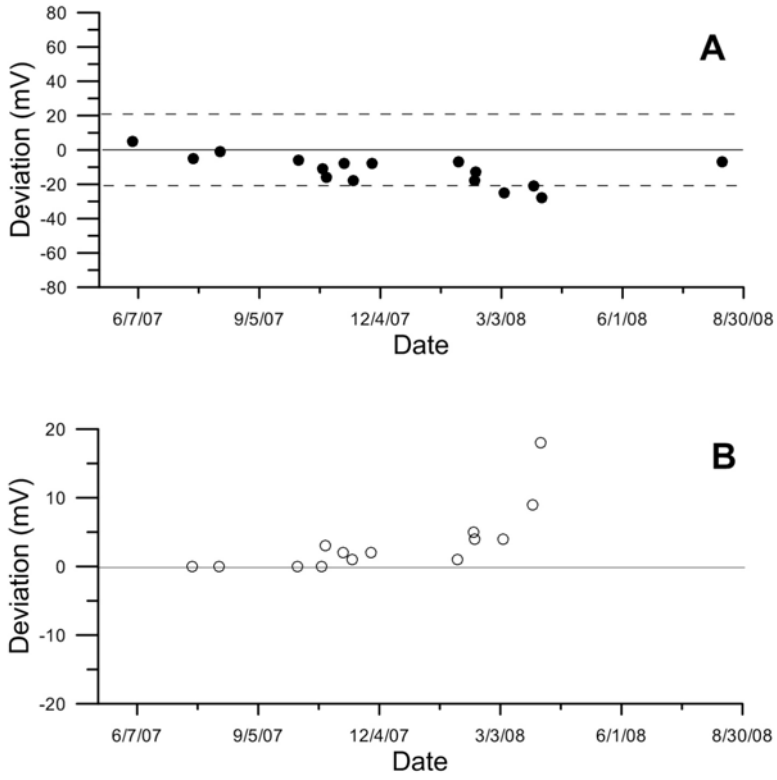


Figure 6.5-2: Accuracy and stability calibration checks of CSIM11 ORP probe, s/n 020. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

Probe 050 was first used 4/24/2008 and last used 2/23/2009. The probe was calibrated 11 times. Since freezing conditions damage the probe, the probes were not used during the winter at many locations. The ORP probe DQI specified an accuracy of ± 20 mV (Figure6.5-2A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the accuracy DQI although it showed wide response variation to the stability check. The cause of this instability is unknown.

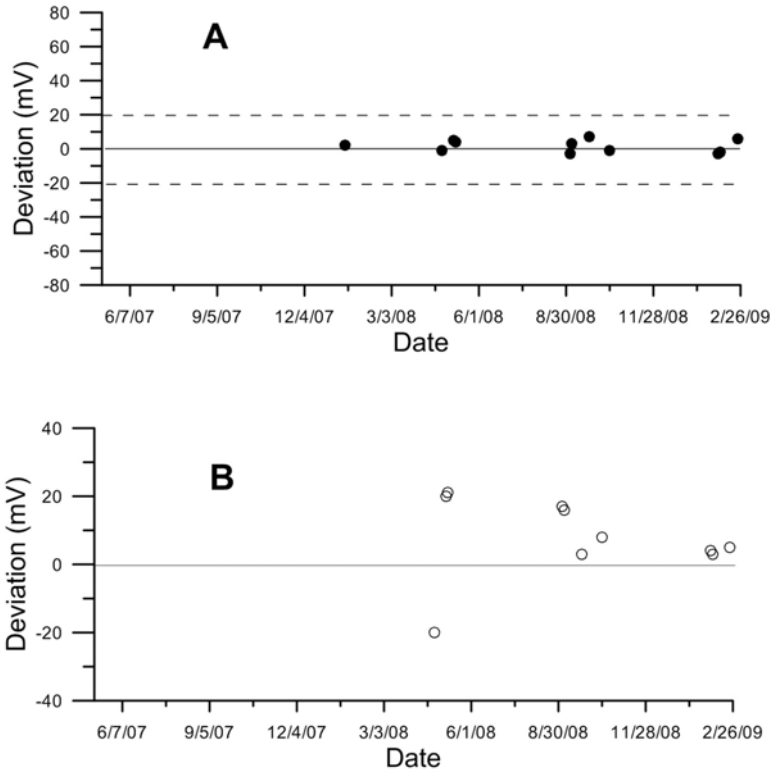


Figure 6.5-2: Accuracy and stability calibration checks of CSIM11 ORP probe s/n 050. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since lagoon ORP measurements were not made at several locations, the interval between calibrations can be large such that locations that did not have lagoon ORP measurements were visited between locations where the measurements were made.

6.6 S-OPS operational checks

Two Synthetic Open Path Systems were used at this location: (1) Synthetic Open Path Systems (S-OPS; s/n D and F) and the Gas Sampling System (GSS s/n 4-0018) and (2) Synthetic Open Path Systems (S-OPS; s/n B and E) and the Gas Sampling System (GSS s/n 4-0017).

The Synthetic Open Path Systems (S-OPS; s/n D and F) and the Gas Sampling System (GSS s/n 4-0018) were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results for the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 6.6-1. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Often GSS leak check failures corresponded to successful S-OPS leak checks that included the GSS within the system check (Table 6.6-1). Leaks in the GSS generally were a result of pump problems or incorrect zero offset determinations. Leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 6/26/2008, 7/15/2008, 12/17/2008, 1/15/2009, 2/3/2009, 2/6/2009, and both lines on 10/22/2008 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on subsequent visits.
- GSS leak check failures that paired with S-OPS leak check passes indicated that the GSS leak check test may have been in error.
- GSS leak check failure on 10/14/2008 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 6.6-1).

Table 6.6-1 - Record of leak checks for GSS s/n 4-0018 and GSS/S-OPS s/n D and F

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
4/1/2008	NC4A	2	0.04	-38.42	Pass	9.7	0.49	-35.63	Pass
		3	0.07	-38.12	Pass	9.8	0.62	-37.59	Pass
4/15/2008	NC4A	2	0.04	-36.59	Pass	6.5	0.54	-38.45	Pass
		3	0.04	-36.36	Pass	9.6	0.68	-36.38	Pass
4/24/2008	WI5A	2	0.07	-35.13	Pass	8.3	0.62	-35.39	Pass
		3	0.09	-37.54	Pass	8	0.61	-35.54	Pass
5/13/2008	WI5A	2	0.08	-34.5	Pass	7.7	0.69	-36.06	Pass
		3	0.07	-37.35	Pass	10	0.65	-37	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
5/15/2008	IA3A	2	0.01	-37.16	Pass	8.2	0.51	-36.29	Pass
		3	0.04	-36.72	Pass	10	0.65	-35.9	Pass
6/4/2008	IA3A	2	0.08	-38.67	Pass	9.9	0.32	-37.49	Pass
		3	0.07	-23.71	Pass	10	0.47	-20.66	Pass
6/23/2008	IA3A	2	0.01	-35.74	Pass	10	0.38	-36.45	Pass
		3	0.05	-34.5	Pass	10	1.00	-37.66	Pass
6/25/2008	WI5A	2	0.05	-35.75	Pass	10	0.31	-34.95	Pass
		3	-0.01	-35.63	Pass	10	1.07	-36.71	Fail
7/15/2008	WI5A	2	0.05	-37.52	Pass	10	0.39	-36.92	Pass
		3	0.08	-34.45	Pass	8	0.90	-34.97	Fail
8/13/2008	NC4A	2	0.11	-36.28	Pass	10.1	0.38	-36.27	Pass
		3	0.08	-35.29	Pass	10	1.03	-36.16	Fail
9/3/2008	NC4A	2	-0.01	-35.49	Pass	9.8	0.46	-35.83	Pass
		3	-0.01	-37.07	Pass	9.5	0.62	-35.51	Pass
9/22/2008	NC4A	2	0.07	-37.58	Pass	10	0.61	-35.03	Pass
		3	0.04	-36.9	Pass	9.8	0.89	-35.95	Pass
9/25/2008	NC3A	2	0.08	-38.32	Pass	10	0.59	-35.9	Pass
		3	0.12	-37.84	Pass	10	0.96	-35.15	Pass
10/14/2008	NC3A	2	0.23	2.01	Fail	9.9	0.85	2.24	Pass
		3	0.24	2.76	Fail	9.8	0.82	3.74	Pass
10/22/2008	WI5A	2	0.03	-37.7	Pass	9.1	1.01	-37.55	Fail
		3	0.05	-36.53	Pass	8.3	0.93	-35.01	Fail
11/11/2008	WI5A	2	0.23	-38.84	Fail	9	0.32	-36.7	Pass
		3	0.09	-40.18	Pass	10	0.18	-39.43	Pass
11/13/2008	IA3A	2	0.14	-35.89	Pass	10	0.31	-33.84	Pass
		3	0.15	-36	Fail	10	0.32	-37.98	Pass
11/25/2008	IA3A	2	0.09	-32.04	Pass	9.9	0.63	-32.86	Pass
		3	0.09	-32.17	Pass	9.8	0.81	-32.56	Pass
12/16/2008	IA3A	2	0.18	-34.49	Fail	10	0.84	-35.46	Pass
		3	0.16	-32.41	Fail	10	0.51	-31.94	Pass
12/17/2009	WI5A	2	0.15	-36.18	Fail	8	0.82	-35.46	Fail
		3	0.18	-37.68	Fail	9.2	0.69	-35.44	Pass
1/6/2009	WI5A	2	0.20	-35.97	Fail	7	0.65	-35.46	Pass
		3	0.24	-23.82	Fail	9.1	0.68	-36.42	Pass
1/15/2009	NC4A	2	-0.05	-44.56	Pass	9.2	0.63	-43.36	Pass
		3	0.12	-43.57	Pass	8.5	1.03	-42.33	Fail
2/3/2009	NC4A	2	-0.03	-32.52	Pass	9	0.66	-31.73	Pass
		3	0.16	-32.07	Fail	8.5	1.07	-30.71	Fail
2/6/2009	NC3A	2	-0.28	-46.68	Pass	9.9	1.43	-33.54	Fail
		3	-0.01	-34.92	Pass	9.7	0.78	-33.01	Pass
2/23/2009	NC3A	2	0.05	-35.36	Pass	9.9	0.85	-35.24	Pass
		3	0.05	-35.51	Pass	9.7	0.43	-36.15	Pass
3/10/2009	WI5A	2	0.00	-36.55	Pass	8.2	0.39	-36.06	Pass
		3	0.03	-34.443	Pass	9.2	0.34	-36.32	Pass
4/7/2009	WI5A	2	0.12	-34.35	Pass	8.3	0.20	-32.15	Pass
		3	0.12	-32.31	Pass	9.4	0.24	-32.25	Pass
4/9/2009	IA3A	2	0.03	-33.32	Pass	10	0.23	-34.89	Pass
		3	0.11	-34.66	Pass	10	0.22	-36.33	Pass
4/23/2009	IA3A	2	0.01	-34.49	Pass	10.01	0.16	-34.9	Pass
		3	0.03	-36.36	Pass	10.01	0.15	-36.06	Pass
4/29/2009	NC4A	2	0.04	-33.83	Pass	9.8	0.14	-33.81	Pass
		3	0.00	-34.77	Pass	9.7	0.15	-34.79	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
5/11/2009	NC4A	2	0.03	-34.5	Pass	9.7	0.20	-34.34	Pass
		3	0.04	-32.88	Pass	9.7	0.20	-35.06	Pass
5/13/2009	NC3A	2	0.04	-34.4	Pass	9.3	0.30	-34.94	Pass
		3	0.03	-35.18	Pass	9.7	0.23	-34.04	Pass
6/2/2009	NC3A	2	0.04	-37.94	Pass	9.6	0.14	-37.45	Pass
		3	0.04	-35.54	Pass	9.5	0.22	-35.11	Pass
6/22/2009	NC3A	2	0.01	-35.46	Pass	9.8	0.20	-37.18	Pass
		3	0.03	-35.24	Pass	9.7	0.22	-37.89	Pass
7/1/2009	NC4A	2	0.03	-35.48	Pass	9.7	0.14	-36.58	Pass
		3	0.01	-34.46	Pass	9.5	0.14	-34.58	Pass
7/21/2009	NC4A	2	0.01	-35.69	Pass	9.8	0.11	-36.99	Pass
		3	0.03	-35.72	Pass	9.6	0.15	-35.37	Pass
7/28/2009	IA3A	2	0.01	-34.9	Pass	10	0.20	-33.94	Pass
		3	0.04	-34.55	Pass	10	0.31	-34.19	Pass
8/17/2009	IA3A	2	0.07	-42.67	Pass	10.05	0.14	-42.19	Pass
		3	0.07	-42.05	Pass	10.05	0.18	-41.85	Pass

The inlet flow balance checks are summarized in sequence in Tables 6.6-2A and 6.6-2B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A - Record of flow balancing- Side 1 (s/n D)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	End date	Site	1	2	3	4	5	6	7	8	9	10	Check results
3/26/08	4/1/2008	NC3A	0.00	0.02	0.00	-0.01	0.19	-0.03	-0.01	-0.03	-0.07	-0.09	**Fail**
4/1/2008	4/15/2008	NC4A	0.03	0.01	0.02	0.09	0.03	0.04	-0.07	0.20	0.28	-0.06	**Fail**
4/15/2008	4/24/2008	NC4A	-0.13	-0.14	-0.15	-0.12	-0.21	-0.26	-0.32	-0.31	-0.33	-0.36	**Fail**
4/24/2008	5/13/2008	WI5A	-0.04	-0.03	-0.03	-0.06	-0.03	-0.02	-0.02	-0.02	-0.03	-0.03	**Pass**
5/15/2008	6/4/2008	IA3A	0.00	-0.05	-0.02	-0.03	-0.01	-0.07	-0.02	-0.03	0.01	0.02	**Pass**
6/4/2008	6/23/2008	IA3A	0.05	0.02	0.00	0.05	0.00	0.08	0.01	0.01	-0.01	-0.03	**Pass**

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
6/25/2008	7/15/2008	WI5A	0.05	0.02	0.07	-0.03	-0.01	-0.05	0.02	-0.03	-0.02	-0.01	**Pass**
7/15/2008	8/13/2008	WI5A	-0.05	0.10	-0.02	0.03	0.08	-0.09	0.00	0.06	-0.01	0.04	**Pass**
8/13/2008	9/3/2008	NC4A	-0.27	-0.12	-0.17	-0.13	-0.14	-0.29	-0.20	-0.21	-0.25	-0.22	**Pass**
9/3/2008	9/22/2008	NC4A	-0.12	-0.13	-0.11	-0.10	-0.15	-0.09	-0.10	-0.06	-0.10	-0.11	**Pass**
9/25/2008	10/14/2008	NC3A	-0.12	-0.09	-0.11	-0.12	-0.17	-0.16	-0.17	-0.22	-0.17	-0.23	**Pass**
10/14/2008	10/22/2008	NC3A	-0.32	-0.18	-0.23	-0.31	-0.19	-0.31	-0.29	-0.24	-0.22	-0.13	**Pass**
10/22/2008	11/11/2008	WI5A	-0.07	-0.10	-0.10	-0.13	-0.10	-0.10	-0.09	-0.13	-0.12	-0.15	**Pass**
11/13/2008	11/25/2008	IA3A	-0.10	-0.17	-0.18	-0.17	-0.13	-0.06	-0.15	-0.13	-0.15	-0.17	**Pass**
11/25/2008	12/16/2008	IA3A	-0.22	-0.18	-0.17	-0.18	-0.17	-0.20	-0.20	-0.16	-0.19	-0.16	**Pass**
12/17/2008	1/6/2009	WI5A	-0.30	-0.41	-0.27	-0.62	-0.15	-0.22	-0.29	-0.15	-0.23	-0.05	**Fail**
1/6/2009	1/15/2009	WI5A	-0.10	0.17	-0.17	0.34	-0.20	-0.12	-0.02	-0.18	-0.11	-0.17	**Fail**
1/15/2009	2/3/2009	NC4A	-0.27	-0.32	0.14	-0.07	-0.25	-0.32	-0.13	0.04	-0.40	-0.29	**Fail**
2/5/2009	2/23/2009	NC3A	-0.11	-0.13	-0.12	-0.12	-0.13	-0.11	-0.13	-0.16	-0.16	-0.09	**Pass**
2/23/2009	3/10/2009	NC3A	-0.11	-0.07	-0.12	-0.17	-0.15	-0.18	-0.19	-0.03	-0.19	-0.21	**Pass**
3/10/2009	4/7/2009	WI5A	-0.17	-0.17	-0.16	-0.19	-0.11	-0.08	-0.06	-0.22	-0.07	-0.11	**Pass**
4/9/2009	4/23/2009	IA3A	-0.15	-0.13	-0.11	-0.14	-0.15	-0.13	-0.13	-0.09	-0.11	-0.10	**Pass**
4/23/2009	4/29/2009	IA3A	-0.13	-0.11	-0.14	-0.14	-0.14	-0.16	-0.15	-0.20	-0.22	-0.20	**Pass**
4/29/2009	5/11/2009	NC4A	-0.26	-0.19	-0.16	-0.14	-0.15	-0.13	-0.14	-0.14	-0.11	-0.10	**Fail**
5/13/2009	6/2/2009	NC3A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.14	-0.14	-0.15	-0.15	-0.14	**Pass**
6/2/2009	6/22/2009	NC3A	-0.12	-0.10	-0.11	-0.11	-0.11	-0.13	-0.09	-0.14	-0.13	-0.14	**Pass**
6/22/2009	6/30/2009	NC3A	-0.15	-0.13	-0.13	-0.13	-0.13	-0.11	-0.13	-0.13	-0.12	-0.12	**Pass**
6/30/2009	7/21/2009	NC4A	-0.09	-0.13	-0.10	-0.11	-0.09	-0.11	-0.11	-0.08	-0.10	-0.10	**Pass**
7/21/2009	7/28/2009	NC4A	-0.08	-0.06	-0.08	-0.07	-0.06	-0.06	-0.05	-0.06	-0.06	-0.02	**Pass**
7/28/2009	8/17/2009	IA3A	-0.14	-0.14	-0.15	-0.13	-0.14	-0.15	-0.13	-0.12	-0.11	-0.15	**Pass**

Table 6.6-2B - Record of flow balancing- Side 2 (s/n F)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/26/2008	4/1/2008	NC3A	0.09	0.03	0.02	0.04	0.00	0.06	0.06	0.05	0.04	0.02	**Pass**
4/1/2008	4/15/2008	NC4A	0.05	0.21	0.05	0.04	0.10	0.03	0.27	0.00	0.08	0.13	**Fail**
4/15/2008	4/24/2008	NC4A	0.09	0.24	0.26	0.26	0.21	0.29	0.22	0.25	0.30	0.22	**Fail**
4/24/2008	5/13/2008	WI5A	-0.04	-0.03	-0.02	-0.02	0.12	-0.02	-0.04	-0.04	-0.07	0.03	**Fail**
5/15/2008	6/4/2008	IA3A	-0.09	-0.12	-0.08	-0.10	0.34	-0.02	-0.05	0.88	-0.06	-0.08	**Fail**
6/4/2008	6/23/2008	IA3A	0.05	0.06	0.04	0.02	0.03	-0.01	0.00	-0.01	0.07	-0.01	**Pass**
6/26/2008	7/15/2008	WI5A	0.03	0.03	0.02	0.02	-0.02	0.05	0.06	-0.01	0.00	0.01	**Pass**
7/15/2008	8/13/2008	WI5A	-0.27	-0.25	-0.30	-0.29	-0.23	-0.34	-0.36	-0.17	-0.27	-0.26	**Pass**
8/13/2008	9/3/2008	NC4A	0.02	0.02	0.06	0.05	0.00	0.09	0.06	-0.07	0.03	0.08	**Pass**
9/3/2008	9/22/2008	NC4A	0.00	0.02	0.00	-0.01	-0.02	-0.06	-0.02	-0.01	-0.06	-0.03	**Pass**
9/25/2008	10/14/2008	NC3A	0.00	0.02	0.02	0.00	0.02	-0.01	-0.06	0.03	0.04	0.08	**Fail**
10/14/2008	10/22/2008	NC3A	0.22	0.16	0.17	0.20	0.23	0.24	0.20	0.19	0.23	0.14	**Fail**
10/22/2008	11/11/2008	WI5A	-0.02	0.03	0.02	-0.01	0.00	-0.07	-0.09	-0.01	-0.02	0.00	**Fail**
11/13/2008	11/25/2008	IA3A	-0.23	-0.06	-0.11	-0.09	-0.06	-0.17	-0.16	-0.21	-0.12	-0.10	**Pass**
11/25/2008	12/16/2008	IA3A	-0.14	-0.23	-0.19	-0.18	-0.21	-0.17	-0.10	-0.07	-0.11	-0.13	**Fail**
12/17/2008	1/6/2009	WI5A	-0.26	-0.36	-0.28	-0.31	-0.31	-0.33	-0.35	-0.11	-0.26	-0.36	**Fail**
1/6/2009	1/15/2009	WI5A	0.02	-0.28	0.09	0.12	0.08	0.21	0.24	-0.97	0.20	0.20	**Fail**
1/16/2009	2/3/2009	NC4A	-0.29	-0.32	-0.20	0.34	-0.42	0.63	0.50	-0.51	0.23	0.23	**Fail**
2/5/2009	2/23/2009	NC3A	-0.11	-0.11	-0.13	-0.13	-0.15	-0.14	-0.17	-0.16	-0.16	-0.11	**Pass**
2/23/2009	3/10/2009	NC3A	-0.16	-0.16	-0.18	-0.19	-0.15	-0.19	-0.22	-0.15	-0.17	-0.12	**Pass**

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/10/2009	4/7/2009	WI5A	-0.21	-0.24	-0.21	-0.21	-0.24	-0.22	-0.23	-0.23	-0.20	-0.32	**Pass**
4/9/2009	4/23/2009	IA3A	0.00	0.00	0.00	-0.01	-0.03	-0.02	0.00	-0.04	-0.03	-0.05	**Pass**
4/23/2009	4/29/2009	IA3A	-0.15	-0.16	-0.15	-0.16	-0.16	-0.17	-0.18	-0.18	-0.20	-0.17	**Pass**
4/29/2009	5/11/2009	NC4A	-0.14	-0.10	-0.14	-0.13	-0.16	-0.11	-0.14	-0.11	-0.09	-0.11	**Pass**
5/13/2009	6/2/2009	NC3A	-0.12	-0.14	-0.14	-0.14	-0.19	-0.14	-0.22	-0.11	-0.15	-0.21	**Pass**
6/2/2009	6/22/2009	NC3A	-0.10	-0.77	-0.09	-0.10	-0.04	-0.05	-0.03	-0.04	-0.05	-0.03	**Fail**
6/22/2009	6/30/2009	NC3A	-0.14	0.53	-0.16	-0.15	-0.22	-0.18	-0.25	-0.20	-0.19	-0.22	**Fail**
6/30/2009	7/21/2009	NC4A	-0.14	-0.12	-0.11	-0.12	-0.14	-0.10	-0.06	-0.09	-0.10	-0.09	**Pass**
7/21/2009	7/28/2009	NC4A	-0.08	-0.08	-0.08	-0.10	-0.03	-0.06	-0.06	-0.05	-0.03	-0.03	**Fail**
7/28/2009	8/17/2009	IA3A	-0.04	-1.01	-0.07	-0.05	-0.04	-0.07	0.01	-0.09	-0.06	-0.05	**Fail**

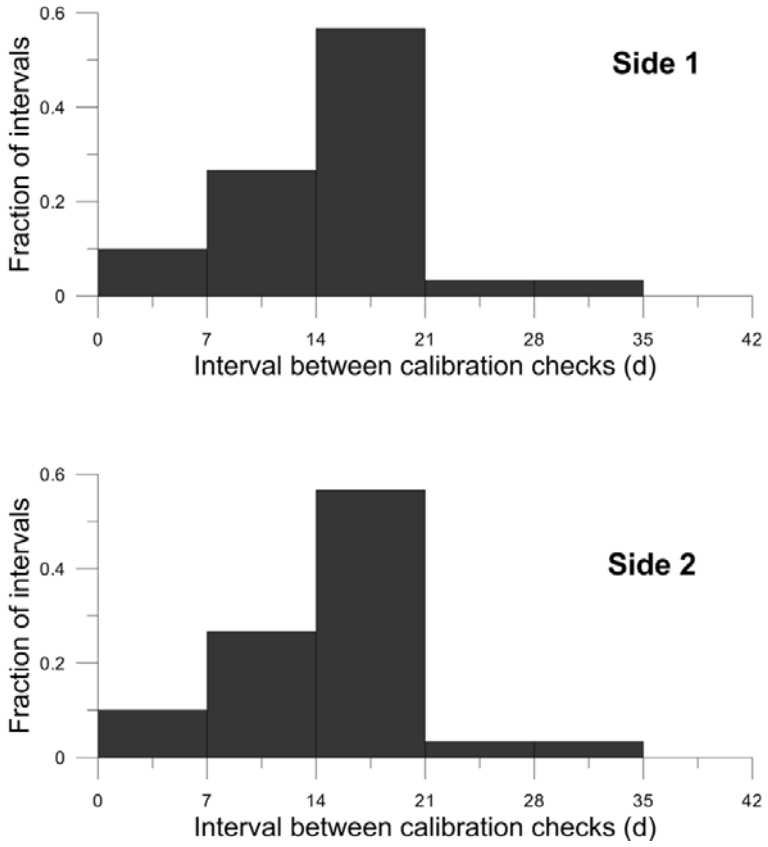


Figure 6.6-1 – Intervals between checks for GSS s/n 4-0018 and GSS/S-OPS s/n D and F

The Synthetic Open Path Systems (S-OPS; s/n B and E) and the Gas Sampling System (GSS s/n 4-0017) were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results for the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 6.6-3. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Leaks in the GSS rarely occurred, however leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 9/3/2008, 10/2/2008, 12/6/2008, 5/14/2009, 8/4/2009, 10/29/2009 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on the subsequent visit.
- GSS leak check failure on 1/6/2009 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 6.6-3).

Table 6.6-3 - Record of leak checks for GSS s/n 4-0017 and GSS/S-OPS s/n B and E

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
3/13/2008	WA5A	2	0.08	-41.29	Pass	8	0.56	-41.19	Pass
		3	0.01	-41.46	Pass	10.1	0.43	-39.25	Pass
4/3/2008	TX5A	2	0.00	-37.94	Pass	9.3	0.46	-40.07	Pass
		3	-0.01	-40.41	Pass	9.7	0.34	-40.19	Pass
4/22/2008	TX5A	2	0.09	-31.84	Pass	9.2	0.50	-32.48	Pass
		3	0.04	-40.85	Pass	9.6	0.36	-39.59	Pass
4/24/2008	OK4A	2	0.07	-30.69	Pass	8.4	0.44	-31.03	Pass
		3	0.01	-28.52	Pass	9.7	0.63	-28.7	Pass
5/6/2008	OK4A	2	0.14	-24.42	Pass	8.5	0.65	-26.2	Pass
		3	0.17	-24.74	Fail	9.8	0.66	-23.07	Pass
5/8/2008	OK3A	2	-0.14	-32.28	Pass	9.7	0.11	-30.99	Pass
		3	-0.14	-31.16	Pass	9.2	0.51	-30.83	Pass
5/29/2008	OK3A	2	0.15	-30.98	Fail	9.8	0.31	-32.07	Pass
		3	0.27	-30.89	Fail	9.2	0.58	-32.37	Pass
6/10/2008	OK3A	2	0.07	-39.64	Pass	9.7	0.37	-38.89	Pass
		3	0.06	-40.66	Pass	N/A	N/A	N/A	N/A
6/11/2008	TX5A	2	0.19	-39.52	Fail	9.4	0.19	-38.31	Pass
		3	0.00	-38.5	Pass	9.5	0.77	-38.43	Pass
7/1/2008	TX5A	2	0.15	-31.62	Fail	9.3	0.28	-31.17	Pass
		3	0.15	-31.69	Fail	9.3	1.00	-32.02	Pass
8/10/2008	WA5A	2	0.09	-40.9	Pass	7.5	0.44	-40.5	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
		3	0.07	-40.35	Pass	10.5	0.75	-38.31	Pass
9/3/2008	WA5A	2	0.27	-32.88	Fail	8	6.86	-23.56	Fail
		3	0.30	-32.92	Fail	10.5	0.53	-34.62	Pass
9/3/2008	WA5A	2	0.20	-32.22	Fail	8	0.43	-32.51	Pass
		3	0.30	-32.36	Fail	10.5	0.52	-32.73	Pass
9/26/2008	WA5A	2	0.53	-38.99	Fail	8.1	0.33	-40.01	Pass
		3	0.19	-37.03	Fail	10.5	0.41	-39.44	Pass
10/2/2008	OK4A	2	0.23	-40.69	Fail	9.6	0.95	-0.43	Pass
		3	0.23	-39.56	Fail	8.6	0.87	-0.04	Fail
10/15/2008	OK4A	2	0.17	-41.03	Fail	9.8	0.32	-38.14	Pass
		3	0.18	-38.71	Fail	8.5	0.32	-38.9	Pass
10/16/2008	TX5A	2	0.20	-39.65	Fail	9.7	0.28	-39.72	Pass
		3	0.23	-40.98	Fail	9.5	0.59	-39.55	Pass
11/4/2008	TX5A	2	0.33	-41.59	Fail	9.4	0.31	-39.62	Pass
		3	0.32	-41.56	Fail	9.3	0.50	-40.62	Pass
11/6/2008	OK3A	2	0.33	-39.79	Fail	8.7	0.73	-42.34	Pass
		3	0.32	-38.77	Fail	9.3	0.47	-39.46	Pass
12/3/2008	OK3A	2	0.79	-40.32	Fail	8.4	0.65	-39.24	Pass
		3	0.83	-39.05	Fail	9.2	0.43	-40.53	Pass
12/16/2008	OK3A	2	0.72	-37.7	Fail	8.6	1.05	-40.13	Fail
		3	0.79	-36.81	Fail	9.5	0.91	-40.65	Pass
12/18/2008	TX5A	2	1.98	-38.41	Fail	9.4	0.92	-37.74	Pass
		3	2.09	-38.03	Fail	9.4	0.90	-37.46	Pass
1/6/2009	TX5A	2	0.12	-40.6	Pass	9.1	2.09	-37.63	Fail
		3	0.13	-40.35	Pass	8.9	2.12	-37.72	Fail
1/8/2009	OK4A	2	0.11	-38.95	Pass	9.8	0.41	-39.67	Pass
		3	0.11	-37.59	Pass	7.2	0.30	-41.91	Pass
1/27/2009	OK4A	2	0.09	-38.64	Pass	9.4	0.36	-40.34	Pass
		3	0.09	-38.15	Pass	8.3	0.20	-41.46	Pass
1/29/2009	TX5A	2	0.05	-37.73	Pass	9.8	0.37	-38.37	Pass
		3	0.17	-38.46	Fail	9.6	0.24	-37.24	Pass
2/19/2009	TX5A	2	0.19	-36.64	Fail	9.9	0.92	-39.35	Pass
		3	0.04	-36.77	Pass	9.7	0.64	-38.72	Pass
3/18/2009	TX5A	2	0.15	-38.19	Fail	9.3	0.65	-37.14	Pass
		3	0.07	-39.28	Pass	9.8	0.45	-37.54	Pass
4/21/2009	OK4A	2	0.15	0.06	Fail	10.2	0.55	-40.07	Pass
		3	0.01	-39.72	Pass	9	0.24	-37.98	Pass
4/22/2009	OK3A	2	0.14	-40.11	Pass	9.7	0.30	-38.44	Pass
		3	0.05	-38.69	Pass	8.8	0.77	-27.92	Pass
5/14/2009	OK3A	2	0.20	-39.22	Fail	9.7	0.26	-38.46	Pass
		3	0.09	-39.13	Pass	8.6	0.88	-38.07	Fail
5/21/2009	WA5A	2	0.17	-37.7	Fail	7.9	0.18	-39.69	Pass
		3	0.02	-39.6	Pass	10.5	0.96	-39.37	Pass
6/4/2009	WA5A	2	0.18	-40.86	Fail	8.6	0.24	-40.49	Pass
		3	0.04	-38.48	Pass	10.5	0.97	-38.07	Pass
6/19/2009	WA5A	2	0.33	-39.5	Fail	8.7	0.25	-38.74	Pass
		3	0.14	-39.6	Pass	10.5	0.95	-37.89	Pass
6/23/2009	OK4A	2	0.07	-39.89	Pass	9.7	0.37	-39.37	Pass
		3	0.04	-38.56	Pass	8.8	0.60	-40.96	Pass
7/14/2009	OK4A	2	0.25	-39.85	Fail	8.5	0.14	-40.79	Pass
		3	0.08	-38.49	Pass	9.7	0.13	-39.51	Pass
7/15/2009	OK3A	2	0.02	-38.14	Pass	8.7	0.63	-38.59	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
		3	0.04	-36.71	Pass	9.9	0.08	-39.75	Pass
8/4/2009	OK3A	2	0.06	-38.09	Pass	8.5	2.25	-37.22	Fail
		3	0.11	-34.41	Pass	9.7	0.09	-39.78	Pass
8/6/2009	TX5A	2	0.05	-38.3	Pass	9.8	0.75	-39.4	Pass
		3	0.00	-40.36	Pass	9.9	0.14	-38.93	Pass
8/27/2009	TX5A	2	0.02	-39.89	Pass	9.7	0.65	-37.52	Pass
		3	0.05	-40.26	Pass	9.5	0.11	-38.95	Pass
9/23/2009	NC3A	2	0.06	-40.15	Pass	10.1	0.34	-39.61	Pass
		3	0.07	-38.33	Pass	0	-0.60	-0.05	Pass
10/13/2009	NC3A	2	0.17	-39.38	Fail	9.6	0.41	-39.03	Pass
		3	0.04	-37.77	Pass	10	0.20	-41.33	Pass
10/27/2009	NC3A	2	0.08	-41.29	Pass	10	0.26	-39.3	Pass
		3	0.01	-41.46	Pass	9.3	1.45	0.11	Fail
10/27/2009	NC3A	2	0.00	-37.94	Pass	10	0.26	-39.3	Pass
		3	-0.01	-40.41	Pass	9.3	0.51	-40.26	Pass
11/11/2009	NC3A	2	0.04	-39.92	Pass	10	0.79	-40.71	Pass
		3	0.04	-39.74	Pass	9.6	0.27	-40.26	Pass

The inlet flow balance checks are summarized in sequence in Tables 6.6-4A and 6.6-4B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-4A - Record of flow balancing- Side 1 (s/n B)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	End date	Site	1	2	3	4	5	6	7	8	9	10	Check results
3/13/2008	4/3/2008	WA5A	-0.20	-0.21	-0.06	-0.14	-0.20	-0.24	-0.21	-0.04	-0.20	-0.23	**Fail**
4/3/2008	4/22/2008	TX5A	-0.08	-0.07	-0.08	-0.09	-0.07	-0.09	-0.13	-0.09	-0.12	-0.14	**Pass**
4/24/2008	5/6/2008	OK4A	-0.02	-0.04	-0.01	-0.14	-0.02	-0.03	-0.09	-0.10	-0.07	-0.12	**Fail**
5/8/2008	5/29/2008	OK3A	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.03	0.01	0.04	**Pass**
5/29/2008	6/10/2008	OK3A	M	M	M	M	M	M	M	M	M	M	**M**

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
6/11/2008	7/1/2008	TX5A	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	**Pass**
7/1/2008	8/10/2008	TX5A	0.35	0.38	0.11	0.39	0.27	0.31	0.30	0.18	0.34	0.31	**Pass**
8/10/2008	9/3/2008	WA5A	0.00	-0.10	0.11	-0.20	0.00	0.00	-0.10	0.00	-0.10	0.00	**Fail**
9/3/2008	9/26/2008	WA5A	0.00	-0.10	-0.10	0.10	0.00	-0.20	-0.10	0.10	0.00	0.00	**Fail**
10/2/2008	10/15/2008	OK4A	0.02	-0.02	0.01	0.01	-0.03	0.06	0.06	0.05	0.04	0.02	**Fail**
10/16/2008	11/4/2008	TX5A	0.02	0.00	0.00	-0.01	-0.02	-0.05	-0.05	0.00	0.01	0.03	**Pass**
11/6/2008	12/3/2008	OK3A	0.03	0.00	0.00	0.01	-0.02	0.03	0.04	0.05	0.05	0.05	**Pass**
12/3/2008	12/16/2008	OK3A	-0.02	-0.01	-0.01	0.00	0.04	-0.06	0.04	-0.04	-0.03	-0.03	**Pass**
12/18/2008	1/6/2009	TX5A	-0.02	-0.06	-0.03	0.00	-0.04	-0.02	-0.02	0.00	0.01	-0.01	**Fail**
1/8/2009	1/27/2009	OK4A	-0.02	-0.04	-0.04	0.00	-0.05	-0.01	0.00	0.00	0.00	0.01	**Pass**
1/29/2009	2/19/2009	TX5A	-0.04	-0.02	0.00	0.06	0.00	-0.06	0.00	-0.02	-0.02	0.00	**Pass**
2/19/2009	3/18/2009	TX5A	0.01	-0.02	0.01	0.01	0.01	-0.02	0.00	0.00	0.00	-0.01	**Fail**
3/18/2009	4/2/2009	TX5A	0.06	0.06	0.05	0.06	0.04	0.08	0.06	0.10	0.05	0.11	**Pass**
4/2/2009	4/21/2009	OK4A	0.02	0.05	0.04	0.04	-0.03	0.01	0.02	0.01	-0.01	-0.01	**Pass**
4/22/2009	5/14/2009	OK4A	-0.03	-0.04	-0.02	-0.03	-0.02	-0.14	-0.02	-0.01	-0.02	-0.03	**Pass**
5/14/2009	5/21/2009	OK4A	0.23	0.24	0.27	0.28	0.17	0.28	0.23	0.26	0.17	0.29	**Pass**
5/21/2009	6/4/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/23/2009	7/14/2009	OK4A	0.00	-0.02	-0.03	-0.01	-0.04	0.01	0.01	0.00	-0.01	-0.04	**Pass**
7/15/2009	8/4/2009	OK3A	0.05	0.04	0.13	0.09	0.13	0.20	0.16	0.14	0.14	0.18	**Pass**
8/6/2009	8/27/2009	TX5A	0.05	0.05	0.01	0.00	0.01	0.03	0.02	0.03	0.06	0.04	**Pass**
8/27/2009	9/24/2009	TX5A	-0.10	-0.06	-0.05	-0.06	-0.08	-0.01	-0.04	-0.05	-0.14	-0.01	**Pass**
9/24/2009	10/13/2009	NC3A	0.00	-0.03	0.00	-0.05	-0.03	-0.08	87.39	-0.11	-0.12	0.06	**Pass**
10/13/2009	10/27/2009	NC3A	-0.02	-0.05	-0.04	-0.03	-0.04	-0.04	-0.03	-0.03	-0.05	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.00	-0.02	-0.01	-0.01	-0.01	0.00	-0.02	0.00	-0.04	0.02	**Pass**
11/11/2009	12/2/2009	NC3A	0.02	0.04	-0.11	-0.01	0.01	0.00	-0.03	-0.08	0.37	0.03	**Fail**

M: missing measurements.

Table 6.6-4B - Record of flow balancing- Side 2 (s/n E)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	0.19	0.18	0.11	0.19	0.14	0.14	0.15	0.17	0.15	0.21	**Fail**
4/3/2008	4/22/2008	TX5A	-0.03	-0.03	0.01	-0.04	-0.09	-0.06	0.00	0.01	0.00	0.00	**Pass**
4/24/2008	5/6/2008	OK4A	0.00	0.00	0.00	-0.03	-0.02	-0.05	0.06	-0.01	-0.03	0.06	**Fail**
5/8/2008	5/29/2008	OK3A	0.02	0.01	0.04	0.00	0.05	0.02	0.01	0.04	0.02	0.02	**Pass**
5/29/2008	6/10/2008	OK3A	-0.01	-0.01	-0.02	0.00	0.00	-0.02	0.01	-0.04	-0.02	0.00	**Pass**
6/11/2008	7/1/2008	TX5A	0.01	0.00	0.00	0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.03	**Pass**
7/1/2008	7/29/08	TX5A	-0.03	-0.09	0.00	-0.05	-0.03	-0.06	0.02	-0.03	-0.02	0.00	**Pass**
8/10/2008	9/3/2008	WA5A	0.05	0.14	0.09	0.10	0.16	0.14	0.12	0.15	0.18	0.15	**Pass**
9/3/2008	9/26/2008	WA5A	-0.04	-0.06	-0.02	-0.01	0.00	0.00	0.02	-0.04	0.02	0.00	**Pass**
10/2/2008	10/15/2008	OK4A	0.00	0.01	-0.02	0.00	-0.01	0.01	0.03	0.03	0.11	0.00	**Pass**
10/16/2008	11/4/2008	TX5A	-0.02	-0.05	-0.03	-0.04	0.00	0.00	-0.04	-0.04	-0.01	-0.02	**Pass**
11/6/2008	12/3/2008	OK3A	-0.01	0.01	0.00	-0.02	0.14	-0.07	0.01	0.02	0.02	0.02	**Fail**
12/3/2008	12/16/2008	OK3A	0.01	-0.02	-0.01	-0.02	-0.01	0.02	0.00	0.00	-0.02	-0.01	**Pass**
12/18/2008	1/6/2009	TX5A	-0.03	-0.08	-0.05	-0.05	-0.06	-0.05	-0.06	-0.04	-0.07	-0.02	**Pass**
1/8/2009	1/27/2009	OK4A	-0.04	-0.03	-0.03	-0.04	-0.04	-0.02	-0.03	-0.02	-0.02	-0.01	**Pass**
1/29/2009	2/19/2009	TX5A	0.00	-0.05	0.00	0.01	-0.02	-0.05	0.02	0.02	0.12	-0.01	**Pass**
2/19/2009	3/18/2009	TX5A	0.03	0.03	0.04	0.03	0.02	0.04	0.01	0.02	0.03	0.01	**Fail**
3/18/2009	4/2/2009	TX5A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.16	-0.14	-0.12	-0.15	-0.14	**Pass**

4/2/2009	4/21/2009	OK4A	0.00	0.05	0.05	0.04	0.04	0.07	0.05	0.03	0.01	0.02	**Pass**
4/22/2009	5/14/2009	OK3A	-0.06	0.00	0.00	-0.01	0.01	0.02	0.01	0.03	0.03	0.00	**Pass**
5/14/2009	5/21/2009	OK3A	-0.07	-0.11	-0.13	-0.11	-0.21	-0.10	-0.19	-0.16	-0.17	-0.18	**Pass**
5/21/2009	6/4/2009	WA5A	0.01	0.00	0.00	0.01	0.07	-0.03	0.05	0.02	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.01	0.01	-0.04	-0.03	-0.03	-0.03	-0.02	-0.01	-0.02	0.00	**Pass**
6/23/2009	7/14/2009	OK3A	-0.02	-0.02	0.00	-0.02	-0.02	0.03	-0.03	-0.02	-0.02	0.01	**Pass**
7/15/2009	8/4/2009	OK3A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
8/4/2009	8/6/2009	OK3A	0.00	-0.01	0.01	0.01	-0.01	0.01	-0.01	0.02	0.01	0.00	**Pass**
8/6/2009	8/27/2009	TX5A	0.00	-0.03	-0.05	-0.04	-0.02	-0.02	-0.01	0.01	0.01	0.03	**Pass**
8/27/2009	9/23/2009	TX5A	0.05	0.05	0.08	0.11	0.22	0.22	0.21	0.25	0.22	0.21	**Fail**
9/24/2009	10/13/2009	NC3A	0.02	0.03	0.00	0.02	0.00	0.00	0.00	-0.03	0.00	0.16	**Fail**
10/13/2009	10/27/09	NC3A	0.00	-0.01	0.12	-0.05	-0.02	-0.12	-0.04	-0.05	-0.06	0.00	**Pass**
10/27/09	11/11/2009	NC3A	0.15	0.06	0.18	0.10	-0.05	0.25	0.25	0.05	0.21	-0.60	**Fail**

The nominal planned interval between S-OPS checks was 20 days (three weeks). S-OPS checks were conducted at this long-term measurement location a relatively few times with the period of time between checks varying from one to three weeks (Figure 6.6-2). Shorter intervals between checks occurred due to work on the systems.

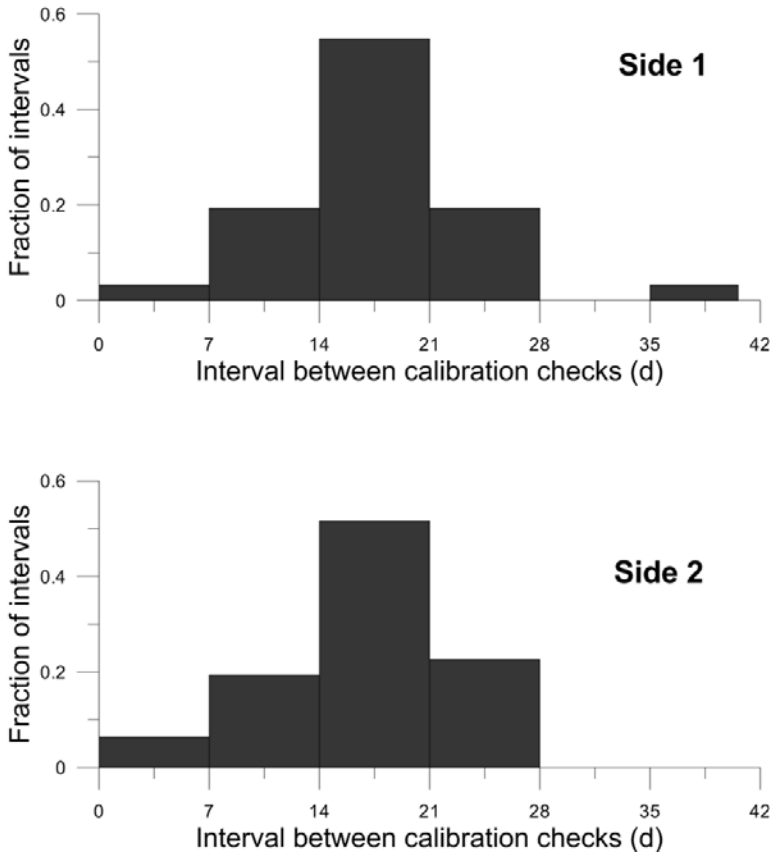


Figure 6.6-2 – Intervals between checks for GSS s/n 4-0017 and GSS/S-OPS s/n B and E

6.7 Miscellaneous meteorological and lagoon calibrations

6.7.1 Air temperature/ humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n 4410027

Relative humidity (RH)					
Calibration date	**Temperature (°C)**	**Expected RH (%)**	**Deviation from expected RH (%)**	**Average deviation RH (%)**	**Action**
3/8/2010	24.7	25	1.9		Accept
	24.7	50	1.4		Accept
	24.7	95	2.3		Accept
				1.9	Accept
3/6/2010	N/A	39.6	1.2	1.2	Accept
8/1/2008	27.8	11.0	-0.7		Accept
	27.5	50.8	2.5		Accept
	27.8	96.4	7.6		Accept
				3.1	Accept
Temperature (T)					
Calibration date	**Expected T (°C)**	**Measured T (°C)**	**Deviation from expected T (°C)**		**Action**
3/8/2010	25.6	24.7	0.9		Accept
3/6/2009	25.3	25.2	0.2		Accept
8/1/2008	27.5	27.3	0.2		Accept

6.7.2 Barometric pressure

Two aneroid barometers (Model 278, Setra Inc., Boxborough, MA) serial numbers 3051828 and 3033740 were used to measure barometric pressure. Calibration of these sensors was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks is documented in Tables 6.7-2 and 6.7-3.

Table 6.7-2: Calibration record of Setra 278, s/n 3051828

Calibration date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
3/4-8/2010	997-1004	4	0.1	Pass
2/27 - 3/2/2009	990.9-1007.1	6	1.6	Pass
7/23-27/2008	995.3-996.5	6	0.9	Pass
1/17-18/2008	984.9-996.9	6	0.8	Pass

Table 6.7-3: Calibration record of Setra 278 s/n 3033740

Calibration date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
2/11-12/2010	998.6-992.5	5	1.5	Pass
9/16-17/2009	997.5-1000.1	6	0.9	Pass
3/24-25/2009	986.0-992.0	6	1.4	Pass
7/9-11/2008	993.1-996.8	6	1.5	Pass
1/3-4/2008	1018.4-1001.7	6	2.5	Pass

6.7.3 Solar radiation

Two LiCOR pyranometers were used to measure solar radiation. Calibration of these sensors was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks is documented in Tables 6.7-4 and 6.7-5.

Table 6.7-4: Calibration record of LiCOR 200SB Pyranometer, s/n PY554448

Calibration date	Mean difference from reference (Wm^{-2})	Mean difference from reference (%)	Action
3/5-3/8 2010	-3.8	0.7	Pass
8/30/2006	—	—	Pass, Factory Calibration

Table 6.7-5: Calibration record of LiCOR 200SB Pyranometer s/n PY554449

Calibration date	Mean difference from reference (Wm^{-2})	Mean difference from reference (%)	Action
3/5/2010	4.8	0.9	Retry
3/6/2010	1.4	0.4	Pass
8/30/2006	—	—	Pass, Factory Calibration

6.7.4 Lagoon water temperature

A thermistor (Model 107-L, Campbell Scientific Inc, Logan, Utah) was used to measure lagoon temperature. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks is documented in Tables 6.7-6 through 6.7-7.

Table 6.7-6: Calibration record of thermistor CSI 107-L (0010)

Calibration date	Expected value (°C)	Difference from expected (°C)	Action
1/25/2008	0	0.0	Accept
6/18/2007	25	0.1	Accept
	24	0.2	Accept
	24	0.4	Accept

Table 6.7-7: Calibration record of thermistor CSI 107-L (III)

Calibration date	Expected value (°C)	Difference from expected (°C)	Action
2/15/2010	1.1	18.4	Replace
9/14/2009	0	0	Accept
3/06/2009	0	0	Accept

6.7.5 Sludge gun

The Marklin 20176 Sludge gun was used to measure sludge depth in the lagoon. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-8.

Table 6.7-8: Calibration record of Marklin sludge gun s/n 20176B

Calibration date	Mean (mm)	Standard deviation (mm)	Accuracy (mm)	Action
2/26/2010	69.0	0.8	1.0	Accept
3/6/2009	71.8	0.8	0.9	Accept
7/23/2008	73.3	0.4	1.1	Accept
7/27/2008	79.9	0.8	0.9	Accept
2/23/2007	81.2	1.0	1.2	Accept

6.7.6 CR1000 data logger

The CR1000 data logger (Campbell Scientific Inc., Logan, UT) was used to log all lagoon measurements (pH, oxidation-reduction potential, and temperature) and air temperature, relative humidity, barometric pressure, and wetness. Calibration checks of this unit were conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. Two loggers were used. The record of calibration checks are documented in Tables 6.7-9 and Table 6.7-10.

Table 6.7-9: Calibration record of Campbell Scientific CR1000 data logger, s/n 7886 (7675)

Factory calibration						
Calibration date: 1/18/2007			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance (mV)**	**Measured mV**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
11	5000	± 3	5001.25	-1.25	5001.35	-1.35
11	-5000	± 3	-5001.48	-1.48	-5001.69	-1.69
11	2500	± 1.5	—	—	2500.3	-0.3
11	250	± 0.15	—	—	249.999	0.001
11	25	± 0.015	—	—	25.0032	-0.0032
11	7.5	± 0.0045	—	—	7.49571	0.00429
11	2.5	± 0.0015	—	—	2.50062	-0.00062
11	-2.5	± 0.0015	—	—	-2.49924	0.00024
11	5000	± 6	4999.45	0.45	4999.32	0.32
11	5000	± 6	5001.96	-1.96	5001.69	-1.69
11	5000	± 6	—	—	—	—
11	5000	± 6	—	—	—	—

PAML calibration						
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
SE channel	**Input (mV)**	**Tolerance SE|DE (mV)**	**Measured mV (mean value)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
2	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
3	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
4	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
5	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
6	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
7	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
8	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
9	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
10	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
12	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
13	4950	± 6.96 | 4.97	4950.5	-0.5	—	—

PAML calibration						
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
SE channel	**Input (mV)**	**Tolerance SE|DE (mV)**	**Measured mV (mean value)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
14	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
15	4950	± 6.96 | 4.97	4950.5	-0.5	—	—
16	4950	± 6.96 | 4.97	4950.5	-0.5	—	—

Calibration date: 5/28/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.06 | 1.06	99.49	0.51	—	—
2	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
3	100	± 2.06 | 1.06	99.49	0.51	—	—
4	100	± 2.06 | 1.06	99.49	0.51	—	—
5	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
6	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
7	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
8	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
9	100	± 2.06 | 1.06	99.49	0.51	—	—
10	100	± 2.06 | 1.06	99.49	0.51	—	—
11	100	± 2.06 | 1.06	99.49	0.51	—	—
12	100	± 2.06 | 1.06	99.49	0.51	—	—
13	100	± 2.06 | 1.06	99.49	0.51	—	—
14	100	± 2.06 | 1.06	99.49	0.51	—	—
15	100	± 2.06 | 1.06	99.49	0.51	—	—
16	100	± 2.06 | 1.06	99.49	0.51	—	—
Calibration date: 5/28/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.06 | 1.06	0	0	—	—
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0	—	—
4	0	± 2.06 | 1.06	0	0	—	—
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0	—	—
10	0	± 2.06 | 1.06	0	0	—	—

Calibration date: 5/28/2010			Single-ended		Differential	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
11	0	± 2.06 | 1.06	0	0	—	—
12	0	± 2.06 | 1.06	0	0	—	—
13	0	± 2.06 | 1.06	0	0	—	—
14	0	± 2.06 | 1.06	0	0	—	—
15	0	± 2.06 | 1.06	0	0	—	—
16	0	± 2.06 | 1.06	0	0	—	—

Table 6.7-10: Calibration record of Campbell Scientific CR1000 data logger, s/n 7752

PAML calibration						
Calibration date: 3/1/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.06 | 1.06	99.23	0.77	—	—
2	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
3	100	± 2.06 | 1.06	99.23	0.77	—	—
4	100	± 2.06 | 1.06	99.23	0.77	—	—
5	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
6	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
7	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
8	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
9	100	± 2.06 | 1.06	99.23	0.77	—	—
10	100	± 2.06 | 1.06	99.23	0.77	—	—
11	100	± 2.06 | 1.06	99.23	0.77	—	—
12	100	± 2.06 | 1.06	99.23	0.77	—	—
13	100	± 2.06 | 1.06	99.23	0.77	—	—
14	100	± 2.06 | 1.06	99.23	0.77	—	—
15	100	± 2.06 | 1.06	99.23	0.77	—	—
16	100	± 2.06 | 1.06	99.23	0.77	—	—
Calibration date: 3/1/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.06 | 1.06	0	0	—	—
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0	—	—
4	0	± 2.06 | 1.06	0	0	—	—

PAML calibration						
Calibration date: 3/1/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0	—	—
10	0	± 2.06 | 1.06	0	0	—	—
11	0	± 2.06 | 1.06	0	0	—	—
12	0	± 2.06 | 1.06	0	0	—	—
13	0	± 2.06 | 1.06	0	0	—	—
14	0	± 2.06 | 1.06	0	0	—	—
15	0	± 2.06 | 1.06	0	0	—	—
16	0	± 2.06 | 1.06	0	0	—	—

6.7.7 CR800 Data logger

The CR800 data logger (Campbell Scientific Inc., Logan, UT) was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration checks were conducted only at end of the study. Initial calibrations were conducted by the factory. Two data loggers were used. The record of calibration checks is documented in Tables 6.7-11 and 6.7-12.

Table 6.7-11: Calibration record of Campbell Scientific CR800 data logger s/n 3697

Calibration date: 3/8/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.061	99.29	0.71
2	100	± 2.061	99.29	0.71
3	100	± 2.061	99.29	0.71
4	100	± 2.061	99.29	0.71
5	100	± 2.061	99.29	0.71
6	100	± 2.061	99.29	0.71

Calibration date: 3/8/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.061	0	0
2	0	± 2.061	0	0
3	0	± 2.061	0	0
4	0	± 2.061	0	0
5	0	± 2.061	0	0
6	0	± 2.061	0	0

Table 6.7-12: Calibration record of Campbell Scientific CR800 data logger s/n 3698

Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (%)**
1	100	± 2.061	99.23	0.77
2	100	± 2.061	99.23	0.77
3	100	± 2.061	99.23	0.77
4	100	± 2.061	99.23	0.77
5	100	± 2.061	99.23	0.77
6	100	± 2.061	99.23	0.77
Calibration date: 3/10/2010			**Single-ended**	
1	0	± 2.061	0	0

Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (%)**
2	0	± 2.061	0	0
3	0	± 2.061	0	0
4	0	± 2.061	0	0
5	0	± 2.061	0	0
6	0	± 2.061	0	0

6.8 Site activity

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
	10/24/2007	Setup	NW and SE tower heights taken.
	10/24/2007	Setup	Problem with sonic anemometer calibration. The dip switch w in the wrong position. Tried to rectify which took 3 h.
	10/24/2007	Setup	Received 500 ppm NH_3 cylinder. Brought scanners from Murphy Brown office.
	10/24/2007	Setup	Position with trailer was adjusted from original plan as trailer was going to come in between TDLAS path. Additionally, EDM was not working properly, so only two tie downs were used.
	10/24/2007	Setup	Evidence of 3 brief power failures in succession.
18:15-19:15	10/24/2007	Setup	Sonic inter-comparison: Sensor 1: 4.68, Sensor 2: 4.62, Sensor 3: 4.78
19:35	10/24/2007	Setup	Zero calibration on sonic anemometers. All pass.
	10/25/2007	Setup	Lower retro-reflectors on SE tower were raised because west facing was not visible from the scanner otherwise.
	10/25/2007	Setup	Scanner 2 was placed at UVDOAS stake. New distances were measured and used in *GasView MP*.
	10/25/2007	Setup	Lagoon temp probe reading about 37.5C. This is higher than we have previously observed.
	10/25/2007	Setup	pH probe: calibration, QA, and acceptance done.
	10/25/2007	Setup	ORP probe: calibration and acceptance done.
14:04-14:09	10/25/2007	Setup	Calibrated TDLAS 1031: Mean: 53.11 SD: 1.44
14:47-14:52	10/25/2007	Setup	Calibrated TDLAS 1030: Mean: 50.20 SD: 2.23
19:49	10/25/2007	Setup	Barometer audit: accepted.
22:40	10/25/2007	Setup	Reset Table 1 on CR1000. Changed card after the table was reset (may have been mistake). Entire table was collected on East laptop before reset.
	10/26/2007	Setup	Could not find camera for pictures.
	10/26/2007	Setup	Checked *Loggernet*. Downloaded data from *Loggernet* (CR1000) seems to be good. Could not get *Loggernet* connected
	10/26/2007	Setup	Heavy rain prevented work on antennas.
	10/26/2007	Setup	Downloaded TDLAS data (just for one day). TDLAS working well.
	10/31/2007	Remote	Check instrument status. TDLAS-1 path 10 was not aimed correctly with light values around 112. Lost path on same day after optimization around 16:53. Decreased obstruction level from 500 to 50 on both TDLAS-1 and TDLAS-2 at 19:26.
	11/7/2007	Takedown	Everything went well other than TDLAS calibration (took four h).
	11/7/2007	Takedown	Sonic inter-comparison: Sensor 1: 1.56, Sensor 2: 1.64, Sensor 3: 1.50
	11/7/2007	Takedown	Zero calibration on sonic anemometers. All pass.
	11/7/2007	Takedown	pH probe: calibration, QA, and acceptance done.
	11/7/2007	Takedown	ORP probe: calibration and acceptance done.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
	11/7/2007	Takedown	Wetness Sensor calibration: accepted.
	11/7/2007	Takedown	Barometer audit: accepted.
22:44-22:49	11/7/2007	Takedown	Calibrated TDLAS 1031: Mean: 25.1 SD: 1.9
23:34-23:39	11/7/2007	Takedown	Calibrated TDLAS 1030: Mean: 27.1 SD: 3.6%
	2/13/2008	Setup	No comments reported.
17:00-18:00	2/13/2008	Setup	Sonic inter-comparison: Sensor 1: 3.44, Sensor 2: 3.47, Sensor 3: 3.38 Action: pass.
18:35	2/13/2008	Setup	Zero calibration on sonic anemometers. All pass.
23:50	2/13/2008	Setup	pH probe: calibration, QA, and acceptance done.
19:00	2/13/2008	Setup	Barometer audit: accepted.
21:33-21:38	2/13/2008	Setup	Calibrated TDLAS 1027: Mean: 100.9 SD: 2.5 RSD: 2.5% Bias: 0.8% Note: Calibration at 100 ppm since attempt at 50 pmm was very "bouncy."
23:07-23:12	2/13/2008	Setup	Calibrated TDLAS 1028: Mean: 93.9 SD: 1.97 RSD: 2.0% Bias: -6.2% Note: Calibration at 100 ppm since attempt at 50 pmm was very "bouncy."
00:10-00:15	2/14/2008	Setup	ORP probe: calibration and acceptance done.
0:50	2/14/2008	Setup	TFC 450i Calibration Verification
1:15	2/14/2008	Setup	TFC 450i Reference Precision Check
	2/14/2008	Setup	Leakage problem in S-OPS took at least 3-4 h to correct.
	2/14/2008	Setup	GSS acceptance
	2/14/2008	Setup	S-OPS acceptance
20:00	2/14/2008	Setup	Wetness Sensor calibration: accepted.
	2/24/2008-2/25/2008	Remote	Restart I-Port and download H_2S data to fill in the gap. Check time synchronization.
	3/5/2008	Calibration	Changed plastic optical window from the calibration cell to thin poly-carbonated optical window.
	3/5/2008	Calibration	Used 100ppm during TDLAS 1028 to get r^2 values above 0.85 instead of 50ppm.
	3/5/2008	Calibration	ORP connected incorrectly to CR1000 data logger.
	3/5/2008	Calibration	Open-path Sensor Installation
	3/5/2008	Calibration	Lagoon site open path sensor installation
	3/5/2008	Calibration	S-OPS Inlet Flow Verification
11:40	3/5/2008	Calibration	Wetness Sensor calibration: accepted.
15:45	3/5/2008	Calibration	pH probe: calibration, QA, and acceptance done.
16:10-16:15	3/5/2008	Calibration	ORP probe: calibration and acceptance done.
16:50	3/5/2008	Calibration	Barometer audit: accepted.
14:45-15:45	3/5/2008	Calibration	Sonic inter-comparison: Sensor 1: 2.73, Sensor 2: 2.73, Sensor 3: 2.70 Action: pass.
16:43	3/5/2008	Calibration	Zero calibration on sonic anemometers. All pass.
22:03-22:08	3/5/2008	Calibration	Calibrated TDLAS 1028: Mean: 54.31 SD: 0.38 RSD: 0.7% Bias: 8.4%
23:41-23:46	3/5/2008	Calibration	Calibrated TDLAS 1028: Mean: 93.03 SD: 0.65 RSD: 0.7% Bias: -7.1% Note: In order to get r^2 values about 0.85, passed 100 ppm of NH_3 instead of 50 ppm.
	3/6/2008	Calibration	S-OPS acceptance
	3/6/2008	Calibration	Removed barometer cable for repair.
	3/6/2008	Calibration	Missing screw at SE tower (3rd down from 2nd retro-reflector) was replaced by new one.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
	3/6/2008	Calibration	In morning, scum covered 80% of lagoon.
14:00	3/6/2008	Calibration	Sludge Depth Measurements taken
16:50	3/6/2008	Calibration	TFC 450i Calibration Verification
17:09	3/6/2008	Calibration	TFC 450i Reference Precision Check
	3/10/2008	Remote	Checked status. Sonic program stopped on 3/9/2008 at 17:20 because of overflow error caused by long integer wraparound. Had to restart sonic anemometer program.
	3/12/2008	Remote	Check site status. Re-sync clocks.
	3/13/2008	Remote	Checked time synchronizations.
	3/13/2008	Remote	Checked status. Re-sync clocks.
	3/13/2008	Remote	Checked status/time-sync.
	3/17/2008	Remote	Checked status. Restarted *iPort* and downloaded data to fill gap since 3/16/2008 at 19:50.
15:35	3/20/2008	Remote	Daily Status Check from PAML Notes: No communication with CR1000. Sonic 1 flagged a small amount of data from 440.9-441.3.
14:00	3/21/2008	Remote	Daily Status Check from PAML Notes: Cannot connect to East trailer; no data sent back since yesterday's status check.
15:45	3/24/2008	Remote	Daily Status Check from PAML Notes: New QC software not installed on computer for H_2S analyzer. No communications with CR1000; no QC files to check. Cannot connect to TDLAS 2 Panasonic.
	3/25/2008	Remote	Determine issue with GSS/CR800 data.
14:30	3/25/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 has one period with 367 flagged on day 448.64 as well as a number of periods with around 10 flags. GSS data starts on 2008-3-19 at 545 UTC. Data from 2008-3-6 to 2008-3-19 appears to have disappeared from the saved data file over the weekend. No communication with CR 1000. Unable to communicate with TDLAS 2 laptop.
	3/26/2008	Takedown	TDLAS 2 lost internet connection; it was still collecting data. IP settings were invalid; clicked on repair and it reconnected.
	3/26/2008	Takedown	S-OPS Inlet Flow Verification
	3/26/2008	Takedown	GSS No Flow Test: Pass
17:20-18:20	3/26/2008	Takedown	Sonic inter-comparison: Sensor 1: 3.18, Sensor 2: 3.10, Sensor 3: 3.19 Action: pass.
17:30	3/26/2008	Takedown	Wetness Sensor calibration: accepted.
19:20	3/26/2008	Takedown	Zero calibration on sonic anemometers. All pass.
	3/27/2008	Takedown	Clock on UPS is wrong. Actual (LAN) at 3/27 at 21:49 UTC. UPS at 3/28 at 6:07 UTC. Corrected time on UPS to sync with LAN.
14:15-14:20	3/27/2008	Takedown	Calibrated TDLAS 1028: Mean: 48.5 SD: 0.5 RSD: 1.2% Bias: -3.0%
15:06-15:11	3/27/2008	Takedown	Calibrated TDLAS 1027: Mean: 48.3 SD: 0.3 RSD: 0.7% Bias: -3.4%
17:58	3/27/2008	Takedown	TFC 450i Calibration Verification
18:12	3/27/2008	Takedown	TFC 450i Reference Precision Check
21:00	3/27/2008	Takedown	pH probe: calibration, QA, and acceptance done.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
21:25-21:30	3/27/2008	Takedown	ORP probe: calibration and acceptance done.
	9/24/2008	Setup	Hooked up power to trailer (broken connection in box).
	9/24/2008	Setup	Weather station power receptacle destroyed. Had to run power from corner.
	9/24/2008	Setup	Distribution retro-reflector and scanners around lagoon.
	9/25/2008	Setup	Calibration of TDLAS were not done as there was not enough gas pressure in NH_3 cylinders (psi was too low).
	9/25/2008	Setup	TEC 450i (S/N: 129) low flow=0.68 L min^{-1}. Leak test shows flow of 0.00 L min^{-1} within 305. Flow meter on inlet shows comparable flow to 450i. Pump needs to be replaced/rebuilt.
	9/25/2008	Setup	Filter paper replaced in SOP inlets F5 and F6 because they were wet (low flow). Also replaced inlet D7 because of spider webs and blockage in filter paper and water vapor.
	9/25/2008	Setup	Lagoon site layout form completed. Note: Plastics are the same as NC4A.
	9/25/2008	Setup	Maintenance and Inspection list completed.
	9/25/2008	Setup	S-OPS/GSS Leak Test
	9/25/2008	Setup	S-OPS Max Flow Test
	9/25/2008	Setup	GSS Max Flow Test
	9/25/2008	Setup	GSS No Flow Test
	9/25/2008	Setup	GSS Leak Test
	9/25/2008	Setup	S-OPS Balance: F
	9/25/2008	Setup	S-OPS Balance: D
	9/25/2008	Setup	pH probe: calibration, QA, and acceptance done.
12:00-13:25	9/25/2008	Setup	Sonic anemometer inter-comparison. Notes: Sonic anemometer 2 (1927) not functioning. Ran sonic anemometers on calibration stand all night.
13:48	9/25/2008	Setup	Zero calibration on sonic anemometers. Sonic anemometer 2 (1927) not functioning.
16:10	9/25/2008	Setup	ORP probe: calibration and acceptance done.
20:08	9/25/2008	Setup	TEC 450i Reference Precision Check
20:22	9/25/2008	Setup	TEC 450i Instrument Operating Parameters
20:22	9/25/2008	Setup	TEC 450i Calibration Verification Check
20:45	9/25/2008	Setup	TEC 450i SO2 Calibration
13:00	9/29/2008	Remote	Daily Status Check from PAML Notes: Number of unflagged points dropped at the end of the retrieved data. Sonic anemometer 2 not present. Day 635 shows a period of bad data for sonic anemometer 1. No communication with CR 1000. Lost paths on both TDLAS's. See report for details.
17:00	9/30/2008	Remote	Daily Status Check from PAML Notes: Check not done this morning because of fog. Changed optimum level on TDLAS 1 from 3000 to 1000 to reduce optimization on path3. Flag 2 in H_2S data from 630.84 to 638.97 (chamber temperature outside of range of 43C-47C or converter temperature outside range of 300K-400K; GSS panel temp reached 40C as AC is off). No communication with CR 1000.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
13:00	10/1/2008	Remote	Daily Status Check from PAML Notes: Sonic anemometer 2 not present. No communication with CR1000. Looks like data file (H_2S) stops about 640.05. Check when logging in; data still there.
12:10	10/2/2008	Remote	Daily Status Check from PAML Notes: TDLAS 2 paths 2 and 3 needed slight reaiming. "XXXX" errors reappearing, especially when reaiming paths. No communication with CR 1000. Sonic anemometer 2 not present. GSS/ H_2S /Innova QC charts not up to date.
13:15	10/3/2008	Remote	Daily Status Check from PAML Notes: On TDLAS 1, path 7 had a light value of zero; tried to set up to 2400. Now all paths are working. TDLAS 2 showing "xxx" problem for a short period of time but regularly. Sonic anemometer 2 is not working. No communication with CR 1000.
12:00	10/6/2008	Remote	Daily Status Check from PAML Notes: Foggy conditions causing TDLAS paths to be lost. As of 16:30 UTC all paths had been restored except S2R7, which may be blocked by pump. Reloaded H_2S data from 10/2/2008 at 15:00 since the GSSQC showed gaps in the H_2S data (flag 1). Sonic anemometer 2 is not working. No communication with CR 1000.
12:30	10/7/2008	Remote	Daily Status Check from PAML Notes: Foggy/damp conditions causing lost TDLAS paths. Error message on *iPort* screen: "error: Timeout error while reading response from instrument at address 173." Tried pulling for instrument 45. Console screen went crazy repeating a series of messages. Clicked on "Comm" and it settled down and the screen came up for 450i. Looked at the most recent file and found long break in H_2S data from 14:02 to 17:00 yesterday and then data stopped at 17:33. Tried to produce fill data starting at 14:00. It downloaded, and then the instrument screen went away and said: "error: Bad command: 'iScreen.'" Successfully filled starting at 16:20 to present and restarted realtime. Sonic anemometer 2 not present. H_2S temperature graphs variable due to AC being off and sometimes chamber temperature being too high. H_2S sample flow about 0.7 L min^{-1}. Gaps in H_2S data download seem to be becoming more prevalent. No communication with CR 1000.
	10/14/2008	Takedown	Tower retro-reflectors had dew on windows; TDLAS were not getting good light values for these retro-reflectors.
	10/14/2008	Takedown	S-OPS inlet filters had a lot of spiders and nests inside.
	10/14/2008	Takedown	At 08:50:33 on 10/12/2008, UPS switched to battery power. (Does not have any info after this log).
	10/14/2008	Takedown	TEC 450i error: "Timeout error while reading response from instrument at address 173."
	10/14/2008	Takedown	During TDLAS 1026 calibration, did not change distance to 1.0 m, so it was changed in the calibration file.
	10/14/2008	Takedown	Lagoon 50% covered in film; no sludge depth measurements possible.
	10/14/2008	Takedown	TDLAS 1030 accuracy -10.01%; 1026 -9.98%

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
	10/14/2008	Takedown	Maintenance and Inspection list completed.
	10/14/2008	Takedown	GSS No Flow Test
	10/14/2008	Takedown	S-OPS Balance--F: Fail
	10/14/2008	Takedown	S-OPS Balance--D: Pass
	10/14/2008	Takedown	S-OPS/GSS Leak Test
	10/14/2008	Takedown	S-OPS Max Flow Test
	10/14/2008	Takedown	GSS Max Flow Test
13:35-14:35	10/14/2008	Takedown	Sonic anemometer inter-comparison; all pass. Note: Sonic anemometer 2 was not present because it had not been working properly.
14:15	10/14/2008	Takedown	Pulled out lagoon/disconnected wires from CR 1000.
14:57	10/14/2008	Takedown	Wetness Sensor calibration: accepted.
14:58	10/14/2008	Takedown	Barometer audit: accepted.
15:05	10/14/2008	Takedown	Zero sonic anemometer calibration; all pass. Note: Sonic anemometer 2 not working (no sonic anemometer 2 in NC 3A period 6).
15:40	10/14/2008	Takedown	pH probe: calibration, QA, and acceptance done.
15:45	10/14/2008	Takedown	ORP probe: calibration and acceptance done.
17:11	10/14/2008	Takedown	TEC 450i Instrument Operating Parameters
17:11	10/14/2008	Takedown	TEC 450i Calibration Verification Check
17:27	10/14/2008	Takedown	TEC 450i Reference Precision Check
17:47	10/14/2008	Takedown	SO2 calibration
20:04	10/14/2008	Takedown	Calibrated TDLAS 1026
20:45	10/14/2008	Takedown	Calibrated TDLAS 1030
	2/4/2009	Setup	Reached site at 9:30 AM local time. The gate was locked upon arrival; called the farm person and was told that there are no pigs in the farm or electrical power for the past two weeks. Had to wait two or three h to get the electricity turned on. According to the farm person (Kraig) the farm will have pigs within a week.
21:52	2/4/2009	Setup	Calibrated TDLAS 1030
22:22	2/4/2009	Setup	Calibrated TDLAS 1026.
22:30-23:25	2/4/2009	Setup	Sonic anemometer inter-comparison; all pass.
23:45	2/4/2009	Setup	Zero sonic anemometer calibration; all pass.
	2/5/2009	Setup	Took 6-7 h to do S-OPS balancing and leak test. Had to change diaphragm of pump.
	2/5/2009	Setup	Innova is still not calibrating well.
	2/5/2009	Setup	Maintenance and Inspection list completed.
14:11-14:39	2/5/2009	Setup	TEC 450i Single Point Calibrations: all pass.
16:17-17:30	2/5/2009	Setup	Innova calibration. Notes: While calibrating NH_3, clicked 100 ppm in diluter for the first time. Did five min zero and again started 50 ppm NH_3. Calibrating CH_4 has improved as compared to NC4A; will check once again at takedown (will try to improve CHAD).
16:35-22:35	2/5/2009	Setup	S-OPS/GSS Calibration Verification: all tests pass.
18:24	2/5/2009	Setup	Barometer audit: accepted.
21:00	2/5/2009	Setup	ORP probe: calibration and acceptance done.
21:15	2/5/2009	Setup	pH probe: calibration, QA, and acceptance done.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
	2/6/2009	Setup	Checked Innova for CH_4 calibration. Used diluter to dilute CH_4 (9.85 ppm) to 2.00 ppm. Using Nafion tube, results were about 4-5 ppm. Not using the Nafion tubing yielded results of about 2.1 ppm. Talked with Prof. Grant about this, and he has asked us to keep the Innova at the site. Still trying to resolve issue.
	2/6/2009	Setup	Lagoon site layout completed
22:00	2/6/2009	Setup	Wetness Sensor calibration: accepted.
16:00	2/9/2009	Remote	Daily Status Check from PAML Notes: Limited connection with CR 1000. No Innova QC. Isolated flag 4 in H_2S data.
13:25	2/10/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 path 3 was initially off, but problem corrected itself. TDLAS 2 was optimizing a lot; changed the pan/tilt unit options as follows--Optimization Light Requirements: Min. acceptable changed from 3000 to 1000; optimum level changed from 8000 to 3000. Some flag 4 in H_2S data. No Innova QC graphs yet, but Innova is at site. Limited communication with CR 1000.
13:32	2/11/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 path 3 was initially off, but problem corrected itself. Probably was dew on the retro-reflector-reflector. Some flag 4 in H_2S data. Innova dew point graph has two sharp, lasting spikes. No connection to CR 1000.
13:20	2/12/2009	Remote	Daily Status Check from PAML Notes: H_2S is 1 min 18 s behind LAN. Average w on sonic anemometer 1 is about 0.1 ms^{-1}. On sonic anemometer 2, it is about -0.2 ms^{-1}. Sharp spikes on Innova dew point graph. No connection to CR 1000.
13:30	2/13/2009	Remote	Daily Status Check from PAML Notes: No communication with CR1000.
13:40	2/16/2009	Remote	Daily Status Check from PAML Notes: Some flag 4 in H_2S data. No communication with CR 1000.
13:45	2/17/2009	Remote	Daily Status Check from PAML Notes: Some flag 4 in H_2S data. No communication with CR 1000.
13:10	2/18/2009	Remote	Daily Status Check from PAML Notes: TDLAS supply voltage dropping. No communication with CR 1000.
13:30	2/19/2009	Remote	Daily Status Check from PAML Notes: Connect to CR 1000 for only a few seconds. Still poor communication.
17:10	2/20/2009	Remote	Daily Status Check from PAML Notes: Some flag 4 in H_2S data. No communication with CR 1000.
	2/23/2009	Takedown	Reached site at 9:00 AM local time. Gate was locked; entered site by walking. Currently no pigs at the site.
	2/23/2009	Takedown	Johnny Cain unlocked gate. He is in charge of pumping lagoon at site, but has not done so since October. Farm has had disease problems, so all the pigs were removed. Another company had expressed interest in placing cull pigs at site but decided not to. Murphy Brown may place pigs here again, but not for sure and not sure when.
	2/23/2009	Takedown	Found scratches on the plastic window of TDLAS 1031.
	2/23/2009	Takedown	Crank up tripod is broken and needs to be repaired.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
	2/23/2009	Takedown	Found the GSS pump was loose upon arrival.
	2/23/2009	Takedown	Made a new control chart for pH sensor 7.
	2/23/2009	Takedown	Checked the Innova calibration; concluded that the instrument is not working for humidifaction. Will send the instrument to company for repair.
	2/23/2009	Takedown	Prof. Rich Grant audited the site.
	2/23/2009	Takedown	S-OPS installation report completed. Will keep with Open Site Notes for 2/23/2009.
	2/23/2009	Takedown	pH probe: calibration, QA, and acceptance done.
	2/23/2009	Takedown	ORP probe: calibration and acceptance done.
12:05-2:00	2/23/2009	Takedown	S-OPS/GSS Calibration Verification: all tests pass.
15:06	2/23/2009	Takedown	Barometer audit: accepted.
15:08	2/23/2009	Takedown	Wetness Sensor calibration: accepted.
16:45-17:15	2/23/2009	Takedown	Sonic inter-comparison; all pass.
16:57-17:21	2/23/2009	Takedown	Calibrated TDLAS 1030
17:50-18:05	2/23/2009	Takedown	Calibrated TDLAS 1026
19:08	2/23/2009	Takedown	Zero sonic anemometer calibration; all pass.
21:26-22:38	2/23/2009	Takedown	Innova calibration Notes: CH_4 calibration fails. Will return instrument to company.
22:56-00:53	2/23/2009	Takedown	TEC 450i Single Point Calibrations--all pass. Notes: Stopped doing calibration and went to perform tower work as it was getting dark. Returned and completed calibration.
	2/24/2009	Takedown	UPS activity: 2/7/2009 22:07 UTC: UPS switched to battery power. 2/10/2009 22:36 UTC: UPS switched to battery power.
	2/24/2009	Takedown	Completed taking down site. Heading to PAML.
	2/24/2009	Takedown	Maintenance and Inspection list completed.
16:30	2/24/2009	Takedown	Sludge Depth Measurements taken
	5/12/2009	Setup	Reached site at 1:00 PM local time. Hooked up the trailer and turned on the power.
	5/12/2009	Setup	Saw that 10-12 fence posts for the S-OPS were missing; will replace them.
21:00-22:00	5/12/2009	Setup	Sonic anemometer inter-comparison; all pass.
21:38-21:51	5/12/2009	Setup	Calibrated TDLAS 1026.
22:04-22:20	5/12/2009	Setup	Calibrated TDLAS 1030.
22:25	5/12/2009	Setup	Zero sonic anemometer calibration; all pass.
	5/13/2009	Setup	Prof. Rich Grant audited the site. He also brought the fense posts for the S-OPS.
	5/13/2009	Setup	Mounting arm for sonic anemometer 2 on tower was tilted; now fixed.
	5/13/2009	Setup	Lagoon site layout completed
	5/13/2009	Setup	Maintenance and Inspection list completed.
19:00-21:00	5/13/2009	Setup	S-OPS/GSS calibrations
20:15-20:44	5/13/2009	Setup	TEC 450i single point calibration
20:45	5/13/2009	Setup	Started H_2S measurement.
	5/14/2009	Setup	Raised the ground retro-reflectors a bit over one meter to make sure the tall grass will not obstruct any paths in the future.
	5/14/2009	Setup	ORP probe: calibration and acceptance done.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
	5/14/2009	Setup	pH probe: calibration, QA, and acceptance done.
13:00	5/14/2009	Setup	Barometer audit: accepted.
13:14	5/14/2009	Setup	Wetness Sensor calibration: accepted.
13:30	5/18/2009	Remote	Daily Status Check from PAML Notes: Last CR 1000 update was on 5/17/2009 at 20:30 UTC.
12:30	5/19/2009	Remote	Daily Status Check from PAML Notes: CR 1000 data not incrementing. Last data was sent on 11:01 UTC on 5/19/2009.
12:00	5/19/2009	Remote	Daily Status Check from PAML Notes: CR 800 not connected; restarted *Loggernet* to correct problem. Last CR 800 data point was on 5/19/2009 at 13:03. No CR 1000 connection. Last data point was at 18:05 UTC on 5/18/2009.
12:15	5/21/2009	Remote	Daily Status Check from PAML Notes: CR 1000 data not incrementing. Last data was sent on 00:55 UTC on 5/20/2009. Found two excessive spike counts on sonic anemometer 3.
12:15	5/22/2009	Remote	Daily Status Check from PAML Notes: TDLAS paths appear to recovering from fog/dew. TDLAS 1 path 3 optimizing a lot (light level reading are about 400). CR 1000 data not incrementing. Last data was sent on 7:05 UTC on 5/20/2009.
12:15	5/26/2009	Remote	Daily Status Check from PAML Notes: No communication with CR 1000 since 16:01 UTC on 2009-5-24. Foggy/damp conditions causing TDLAS paths to be lost; will check later.
12:15	5/27/2009	Remote	Daily Status Check from PAML Notes: No communication with CR 1000 since 16:01 UTC on 2009-5-24. Foggy/damp conditions causing TDLAS paths to be lost. TDLAS 1 had low light levels on paths 6, 7, and 9. Found path 7 only. TDLAS 2 had low light levels on paths 4 and 5; could not find any paths. Will check later for any improvements.
18:45	5/28/2009	Remote	Daily Status Check from PAML Notes: No QC update available as the modeling computer was accidentally turned off. No connection to CR 1000.
12:30	5/29/2009	Remote	Daily Status Check from PAML Notes: Reaimed TDLAS 2 path 9; unable to get higher light levels than 70. Similar break occurred in this retro-reflector yesterday; probably become wet inside or else heater has failed.
12:10	6/1/2009	Remote	Daily Status Check from PAML Notes: One path on TDLAS 1 was not aligned, unable to find. No CR 1000 connection since 5/21/2009 at 10:50 UTC.
	6/2/2009	Calibration	Upon arrival found some TDLAS paths were off because of heavy dew.
	6/2/2009	Calibration	Checked TEC 450i for brown residue in converter tee; none present.
14:30-16:30	6/2/2009	Calibration	S-OPS/GSS calibrations Note: Changed all inlet filters because they looked dirty. This did not affect the inlet balancing. See Open Site Notes for 6/2/2009 for an example filter.
14:37	6/2/2009	Calibration	Barometer audit: accepted.
14:38	6/2/2009	Calibration	Wetness Sensor calibration: accepted.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
14:55-15:55	6/2/2009	Calibration	Sonic anemometer inter-comparison; all pass.
16:28	6/2/2009	Calibration	Sonic anemometer bias/zero calibration; all pass.
17:42-19:11	6/2/2009	Calibration	Performed TDLAS inter-comparison between TDLAS 1026 and TDLAS 1030. See Open Site Notes for 6/2/2009 for details.
20:36-20:53	6/2/2009	Calibration	Calibrated TDLAS 1026
21:08-21:26	6/2/2009	Calibration	Calibrated TDLAS 1030
	6/3/2009	Calibration	Changed filter in HVAC unit. The old filter looked dirty.
	6/3/2009	Calibration	Probe float instrument were removed and calibrated this morning.
	6/3/2009	Calibration	LAN and the TDLAS laptops are all unable to access the internet through URL's. However, the IP's still work, so data can be shipped, and the computers can still be remotely accessed.
	6/3/2009	Calibration	Maintenance and Inspection list completed.
	6/3/2009	Calibration	ORP probe: calibration and acceptance done.
	6/3/2009	Calibration	pH probe: calibration, QA, and acceptance done.
19:10-19:38	6/3/2009	Calibration	TEC 450i single point calibration
19:42-19:44	6/3/2009	Calibration	TEC 450i leak test. Flow: 0.000 Pressure: 156.7
13:00	6/5/2009	Remote	Daily Status Check from PAML Notes: Reaimed TDLAS 2 path 9 (probably recovering from moisture). TDLAS 1 DCD increasing by 5 during heat of the day. Internal temperature to 50C at times. CDC sometimes drops by 20 for a short time. TDLAS 2 CDC increases by 4 during the heat of the day. Sometimes decreases by 40 for a short time. Internal temperature to 50C at times.
12:40	6/8/2009	Remote	Daily Status Check from PAML Notes: Many TDLAS paths were not aligned in the morning because of dense fog. All paths have since recovered. TDLAS 2 centerline duty cycle briefly dropped from 173 to 133 a couple of days ago. Brief periods of flagged data on sonic anemometers 1 and 3. No communication with CR 1000.
12:15	6/9/2009	Remote	Daily Status Check from PAML Notes: Sonic anemometer one w graph looks slightly different than the other sonic anemometer graphs. Will check tomorrow to see if it behaves the same. Poor communication with the CR 1000. Many TDLAS paths had low light levels this morning, probably caused by fog/dew. All paths had recovered after about two h after check was performed.
12:10	6/10/2009	Remote	Daily Status Check from PAML Notes: Both TDLAS units have low light levels; probably caused by fog/dew. Will wait for moisture to clear before checking again. Last CR 1000 data was sent on 6/4/2009 at 13:01 UTC.
13:00	6/11/2009	Remote	Daily Status Check from PAML Notes: Wind data not present in QC data. Last CR 1000 data was sent on 6/4/2009 at 13:01 UTC. TDLAS 2 path 9 had low light levels (around 700), but it seems to be recovering from moisture. TDLAS 2 CDC drops by about 40 during the heat of the day.

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
12:15	6/12/2009	Remote	Daily Status Check from PAML Notes: Last CR 1000 data was sent on 6/4/2009 at 13:01 UTC. TDLAS 2 path 9 had low light levels (around 700), but it seems to be recovering from moisture. TDLAS 2 CDC drops from ~171 to ~133 when the internal temperature is greater than 50C.
12:30	6/15/2009	Remote	Daily Status Check from PAML Notes: Many TDLAS paths were not aligned in the morning because of dense fog/moisture. They seem to be recovering. No communication with CR 1000. TDLAS 2 CDC drops by about 40 during the heat of the day.
12:50	6/16/2009	Remote	Daily Status Check from PAML Notes: Re-aimed TDLAS 1 path 6. Upon remote login, found three Mcshield Exe Application errors. No connection to CR 1000; last data modified at 20:00 UTC 6/14/2009.
11:40	6/17/2009	Remote	Daily Status Check from PAML Notes: Several TDLAS paths have low light levels, probably caused by fog/moisture, and they will recover later in the morning. Re-aimed TDLAS 1 path 2. Light levels for this path appear to be at the maximum value; will check later. No connection to CR 1000; last data modified at 20:00 UTC 6/14/2009.
12:00	6/18/2009	Remote	Daily Status Check from PAML Notes: No connection to CR 1000; last data modified at 20:00 UTC 6/14/2009. Several TDLAS paths have low light levels, probably caused by fog/moisture, and they are recovering slowly. Re-aimed TDLAS 2 path 9. Added DoEvents statement to sonic anemometer program at 16:44 UTC.
12:00	6/19/2009	Remote	Daily Status Check from PAML Notes: No connection to CR 1000; last data modified at 20:00 UTC 6/14/2009. Several TDLAS paths have low light levels, probably caused by fog/moisture, and they are recovering slowly.
	6/22/2009	Takedown	Found the sonic anemometers at the following positions: Sonic anemometer 1: square with lagoon; Sonic anemometer 2: at the green pump on the middle of the west side of the lagoon; Sonic anemometer 3: down the driveway (square with the lagoon).
	6/22/2009	Takedown	TDLAS 1026 failed during calibration. Wetness sensor also failed during calibration (paint on sensor was almost completely gone).
18:55-19:50	6/22/2009	Takedown	Sonic anemometer inter-comparison performed; all sonic anemometers passed.
19:00-20:45	6/22/2009	Takedown	S-OPS/GSS calibrations
19:12-19:17	6/22/2009	Takedown	Calibrated TDLAS 1026. Instrument failed calibration with -11.79% bias.
19:34-19:51	6/22/2009	Takedown	Calibrated TDLAS 1030.
20:22-20:54	6/22/2009	Takedown	Calibrated TEC 450i
20:28-20:30	6/22/2009	Takedown	Zero sonic anemometer calibration; all pass.
20:30	6/22/2009	Takedown	Barometer audit: accepted.
20:32	6/22/2009	Takedown	Calibrated wetness sensor: Failed. Note: paint was completely gone

Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
	6/23/2009	Takedown	Marked extension tubing with pieces of tape. Put 3-4 pieces on the near side and five pieces on the far side.
	6/23/2009	Takedown	UPS history: 6/4/2009 18:10: UPS switched to battery power. 6/10/2009 9:09:00: UPS switched to battery power. 9:09:58: UPS bypass unavailable
	6/23/2009	Takedown	pH probe: calibration, QA, and acceptance done.
	6/23/2009	Takedown	ORP probe: calibration and acceptance done.
	6/23/2009	Takedown	Maintenance and Inspection list completed.
	9/22/2009	Setup	Set out scanners, retro-reflectors, and met station.
21:30	9/22/2009	Setup	pH probe: calibration, QA, and acceptance done.
21:40	9/22/2009	Setup	ORP probe: calibration and acceptance done.
	9/22/2009	Setup	Lagoon water level very low--below NRCS gauge bottom.
	9/23/2009	Setup	EPA Audit (Larry, Elmore, Bill)
	9/23/2009	Setup	Lagoon site layout completed
	9/23/2009	Setup	Maintenance and Inspection list completed.
	9/23-9/24/2009	Setup	S-OPS/GSS calibrations Notes: Found dust/dirt in 25mm plastic filters, damaging the filters and ruining the plastic/plastic seals.
12:40-13:40	9/23/2009	Setup	Sonic anemometer inter-comparison performed; all sonic anemometers passed.
14:11	9/23/2009	Setup	Sonic anemometer zero/bias check; all pass.
22:48-00:15	9/23/2009	Setup	TEC 450i single point calibration.
	9/24/2009	Setup	Scanner #5 power supply failed.
	9/24/2009	Setup	Lagoon sensors not installed. Lagoon too low for cables and probes.
16:04-16:43	9/24/2009	Setup	Calibrated TDLAS 1027 Note: Zero N_2 CC92283. This does not newest MP calibration equation
17:15-17:36	9/24/2009	Setup	Calibrated TDLAS 1028 Note: Zero N_2 CC92283. This does not newest MP calibration equation. This TDLAS unit has considerable noise.
18:08-18:26	9/24/2009	Setup	Calibrated TDLAS 1026 Note: Zero N_2 CC92283. This does not newest MP calibration equation
22:14	9/24/2009	Setup	Barometer audit: accepted.
22:15	9/24/2009	Setup	Wetness Sensor calibration: accepted.
15:10	9/28/2009	Remote	Daily Status Check from PAML Notes: Changed optimization requirements: Minimum acceptable from 3000 to 1000. Optimum level from 8000 to 3000. Left max acceptable at 11000 and obstruction at 500. TDLAS 2 not present due to bad power supply. No lagoon float present. Humidity flat lines at 100% for long periods of time and sometimes spends long times at 108%.
12:06	9/29/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 not present due to bad power supply.
12:05	9/30/2009	Remote	Daily Status Check from PAML Notes: Tons of messages from UPS related to power failure. Sonic anemometers stopped incrementing at 17:21 UTC 9/29/2009. Last H_2S update was at 17:20 9/29; last data was at 17:19. Filled missing H_2S data from 17:27 to 20:06 and restarted sonic anemometers.

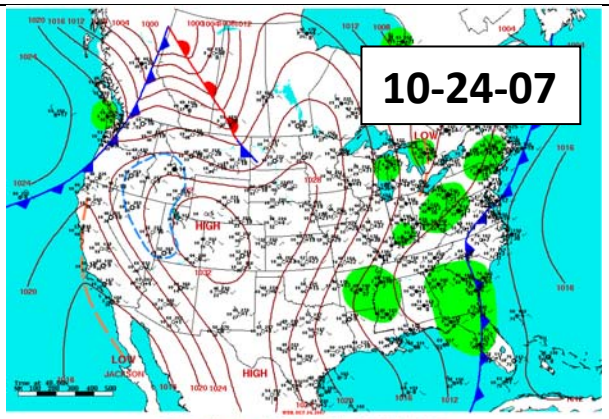
Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
12:30	10/1/2009	Remote	Daily Status Check from PAML Notes: Relative humidity probe is maxing out. TDLAS 2 not present due to bad power supply. No lagoon probes.
14:00	10/2/2009	Remote	Daily Status Check from PAML Notes: Relative humidity probe is maxing out. TDLAS 2 not present due to bad power supply. No lagoon probes.
14:00	10/5/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 not present due to bad power supply. No lagoon probes.
15:30	10/6/2009	Remote	Daily Status Check from PAML Notes: *iPort* error encountered with H_2S analyzer. Stopped sonic anemometers and restarted H_2S. Both programs are now running. TDLAS 2 not present due to bad power supply.
15:45	10/7/2009	Remote	Daily Status Check from PAML Notes: Tried reaiming path 4 on TDLAS 1. Could not get good light levels. TDLAS 2 not present due to bad power supply.
12:45	10/8/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 not present due to bad power supply.
12:24	10/9/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 not present due to bad power supply.
12:50	10/12/2009	Remote	Daily Status Check from PAML Notes: *iPort* error encountered with H_2S analyzer. Stopped sonic anemometers and restarted H_2S. Both programs are now running. TDLAS 2 not present due to bad power supply. Relative humidity probe is maxing out. No lagoon probes.
	10/13/2009	Calibration	Lagoon level is too low for the probe float.
	10/13/2009	Calibration	Used expired H_2S cylinder (9/16/2009) for calibrating TEC 450i H_2S analyzer.
	10/13/2009	Calibration	Used larger scale rotometer to balance south line S-OPS. All inlets passed with a range of 1.00 to 1.20. Changed nozzles on inlets 4, 5, 9, and 10 to bring leak down to passing range.
	10/13/2009	Calibration	UPS history file is located with the Open Site Notes.
14:00-16:45	10/13/2009	Calibration	S-OPS/GSS calibrations
14:02-14:45	10/13/2009	Calibration	TEC 450i single point calibration. Notes: H_2S accuracy is good but precision is bad. Used expired H_2S cylinder (9/16/2009).
14:05-15:05	10/13/2009	Calibration	Sonic anemometer inter-comparison; all pass.
16:15	10/13/2009	Calibration	Barometer audit: accepted.
16:18	10/13/2009	Calibration	Wetness Sensor calibration: accepted.
16:20	10/13/2009	Calibration	Zero sonic anemometer calibration; all pass.
19:00-19:18	10/13/2009	Calibration	Calibrated TDLAS 1026.
19:30-19:48	10/13/2009	Calibration	Calibrated TDLAS 1027.
14:20	10/14/2009	Remote	Daily Status Check from PAML Notes: Yesterday was calibration check at site. Started new QC file and added TDLAS 2. Reaimed TDLAS 2 paths 2 and 3. No lagoon probes.
13:15	10/15/2009	Remote	Daily Status Check from PAML Notes: Dense fog in area. No lagoon probes.
13:01	10/16/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 path 2 is not aligned. No lagoon probes.
12:40	10/19/2009	Remote	Daily Status Check from PAML Notes: No lagoon probes.

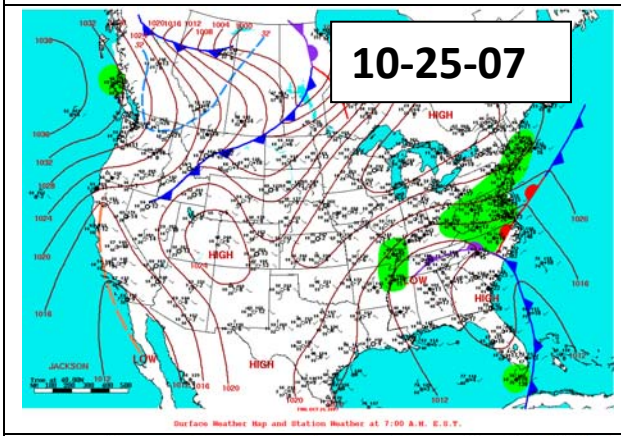
Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
12:45	10/20/2009	Remote	Daily Status Check from PAML Notes: Reaimed TDLAS 2 path 7. No lagoon probes.
14:15	10/22/2009	Remote	Daily Status Check from PAML Notes: Some optimization occurring on TDLAS 2. No lagoon probes. RH sometimes exceeds 100%.
12:12	10/23/2009	Remote	Daily Status Check from PAML Notes: TDLAS paths are not aligned. Dense fog reported in the area.
12:20	10/26/2009	Remote	Daily Status Check from PAML Notes: Sonic anemometer program had an "overflow" error. Sonic anemometers stopped due to wraparound of long data type. No lagoon probes.
12:25	10/28/2009	Remote	Daily Status Check from PAML Notes: TDLAS 1 path 1 and TDLAS 2 path 1 were not aligned. Could not fix TDLAS 1 path 1 (probably wet). TDLAS 2 optimization was not enabled; turned optimize on. Got TDLAS 2 light levels to about 800 (good enough for optimization to work on). Calibration done on sonic anemometers yesterday. Flag 1 in H_2S data (data missing during calibration yesterday).
12:40	10/29/2009	Remote	Daily Status Check from PAML Notes: TDLAS paths are not aligned. Dense fog reported in the area.
12:44	10/30/2009	Remote	Daily Status Check from PAML
13:38	11/2/2009	Remote	Daily Status Check from PAML
12:12	11/3/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 laptop has stopped running. Stopped at 14:51 UTC on 11/2.
13:00	11/4/2009	Remote	Daily Status Check from PAML Notes: Unable to connect to TDLAS 2 laptop. TDLAS data stopped collecting at 11/3 at 9:06 UTC.
12:28	11/5/2009	Remote	Daily Status Check from PAML Notes: Upon login, found *iPort* runtime error. Stopped sonic anemometers to restart *iPort*. Restarted *iPort* program and loaded records back 1300. TDLAS 2 will not connect remotely.
14:19	11/6/2009	Remote	Daily Status Check from PAML
13:40	11/6/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 laptop has apparently frozen up.
	11/10/2009	Calibration	TDLAS 2 had parser message: "Value creation failed at line 422." Restarted the computer. Last data recorded on Nov. 3. Calibrated TDLAS 2 (failed); will try again tomorrow.
22:44-23:01	11/10/2009	Calibration	Calibrated TDLAS 1026: Failed (-19.8% bias)
	11/11/2009	Calibration	Unable to calibrate sonic anemometers and lagoon probes because of wet and windy conditions. Instruments appear to be reading properly today and at the last QC check.
	11/11/2009	Calibration	Balancing of S-OPS lines affected by damp conditions.
	11/11/2009	Calibration	TDLAS 2 laptop may be developing issue with switching paths unexpectedly.
	11/11/2009	Calibration	Maintenance and Inspection list completed.
14:06-14:25	11/11/2009	Calibration	Calibrated TDLAS 1026
14:50-15:08	11/11/2009	Calibration	Calibrated TDLAS 1027
15:55-18:21	11/11/2009	Calibration	TEC 450i Single Point calibration Notes: H_2S tank was expired. Ran with expired tank first then ran new H_2S tank.

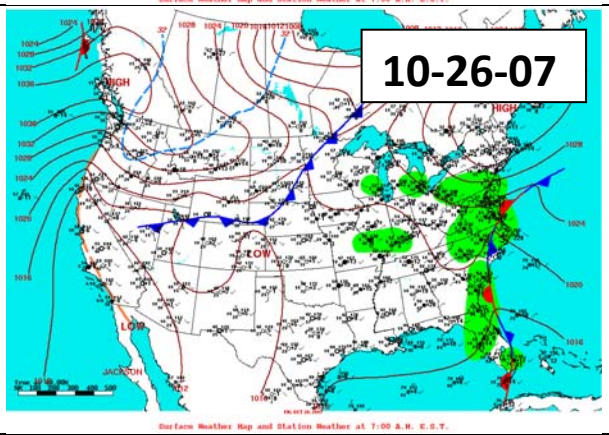
Time HH:MM (UTC)	Date	Activity (setup, takedown, repair, calibration, or remote)	Event description
19:00	11/11/2009	Calibration	S-OPS/GSS calibrations Notes: South side line nozzle 10 had water inside, so the inlet balancing failed. North side line nozzles 1 and 2 had water inside as well. Failed balancing twice.
19:33	11/11/2009	Calibration	Barometer audit: accepted.
13:40	11/13/2009	Remote	Daily Status Check from PAML
14:20	11/16/2009	Remote	Daily Status Check from PAML Notes: TDLAS's are recovering from a couple of days of damp conditions. Reaimed TDLAS 2 paths 2 and 3. Reaimed path 10 on TDLAS 1. CDC on TDLAS 1 jumped to 255 for a couple of days, but it has now returned to normal.
13:40	11/17/2009	Remote	Daily Status Check from PAML Notes: TDLAS paths are not aligned due to fog/mist in area.
14:10	11/18/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 path 2 is optimizing. Unable to improve light levels; retro-reflector is probably wet inside but appears to be gradually drying.
14:55	11/19/2009	Remote	Daily Status Check from PAML Notes: TDLAS 2 path 2 cannot be found. Water could possibly be in the retro-reflector.
13:42	11/20/2009	Remote	Daily Status Check from PAML Notes: Cannot find TDLAS 1 path 10. Cannot find TDLAS 2 path 2.
13:15	11/23/2009	Remote	Daily Status Check from PAML Notes: H_2S analyzer stopped data collection at 21:03 UTC on 11/20. Restarted the H_2S analyzer and filled missing data. Stopped and restarted the sonic anemometers as well.
13:45	11/24/2009	Remote	Daily Status Check from PAML Notes: Cannot find TDLAS 1 path 10. TDLAS 2 path 2 is optimizing.
13:16	11/25/2009	Remote	Daily Status Check from PAML Notes: H_2S data files were missing from the record. Went back and filled last 9000 records to fill in the missing data from 11/20. ORP spiked to 82.
13:10	11/30/2009	Remote	Daily Status Check from PAML Notes: ORP has spiked over 1000, and the wetness sensor seems to have failed and needs cleaned.
	12/2/2009	Takedown	Open site notes completed.
	12/2/2009	Takedown	Maintenance and Inspection list completed.
14:13	12/2/2009	Takedown	Barometer audit: accepted.
14:15-15:20	12/2/2009	Takedown	Sonic anemometer inter-comparison; all pass.
15:30-16:07	12/2/2009	Takedown	TEC 450i single point calibration
15:45	12/2/2009	Takedown	S-OPS/GSS calibrations Notes: Inlets 8, 9, and 10 were off due to rain.
16:43	12/2/2009	Takedown	Zero sonic anemometer calibration; all pass.
17:01	12/2/2009	Takedown	pH probe: calibration and QA done.
18:13-18:30	12/2/2009	Takedown	Calibrated TDLAS 1026
18:43-19:00	12/2/2009	Takedown	Calibrated TDLAS 1027
22:40	12/2/2009	Takedown	ORP probe: calibration done.

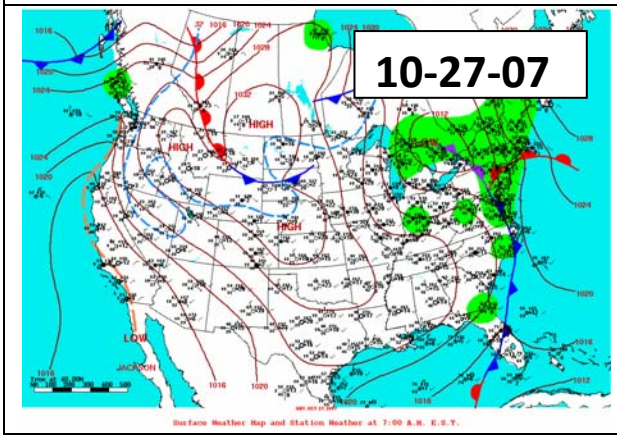
6.9 Site weather

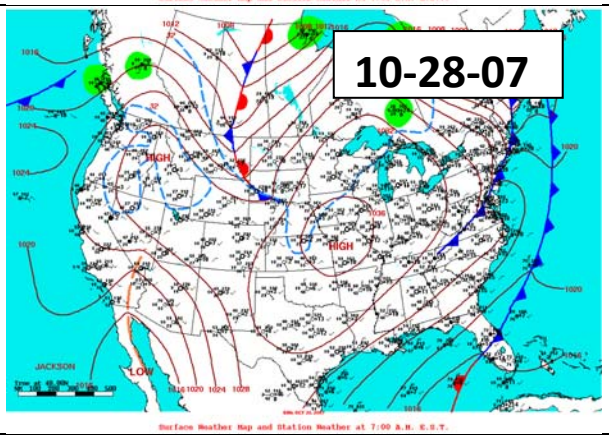
Period 2

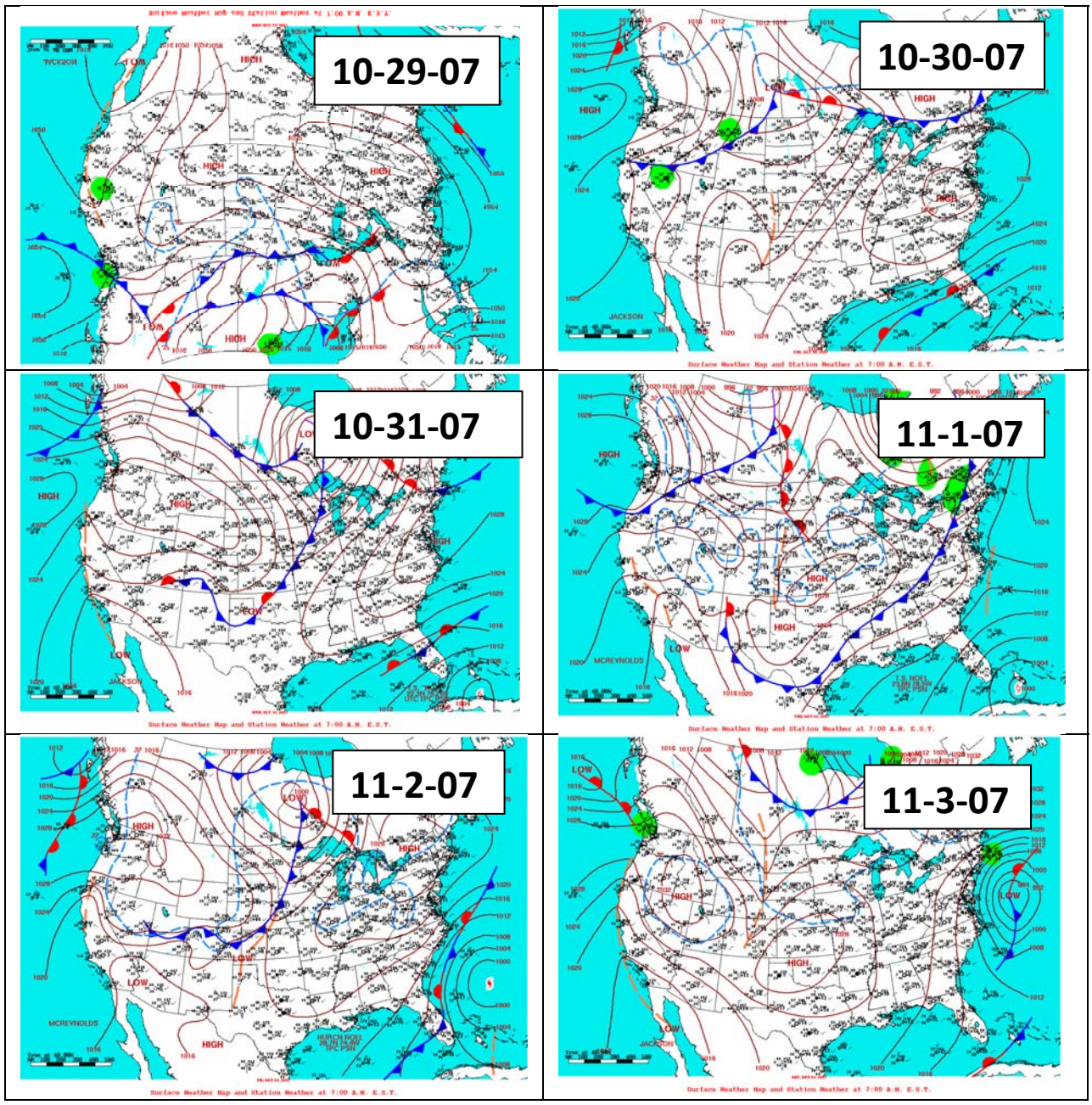








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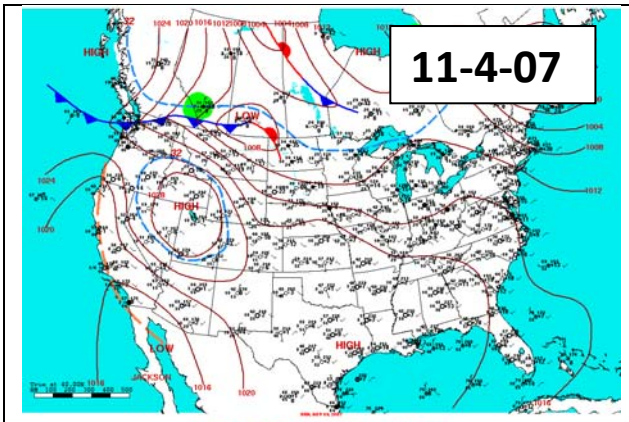
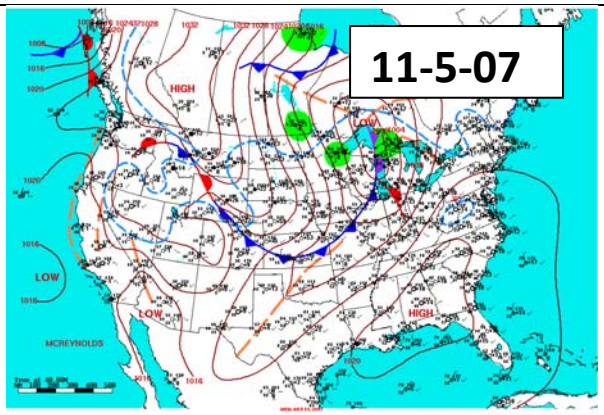
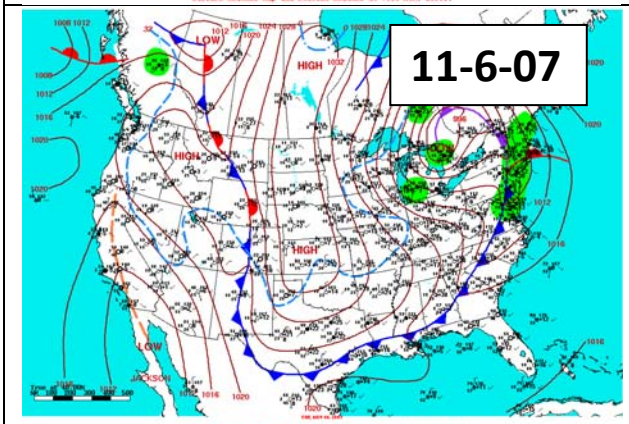
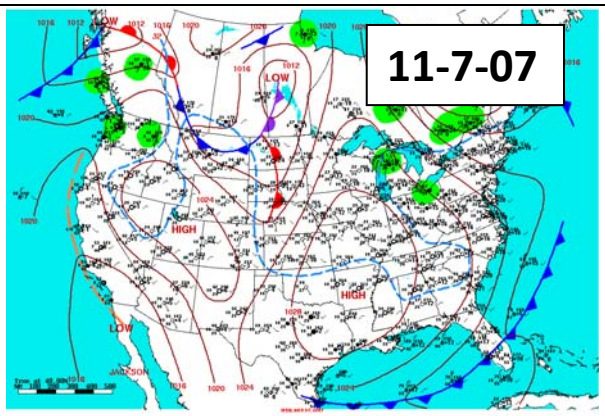
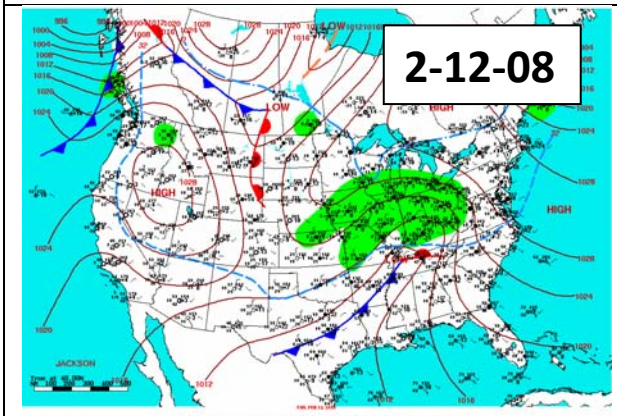


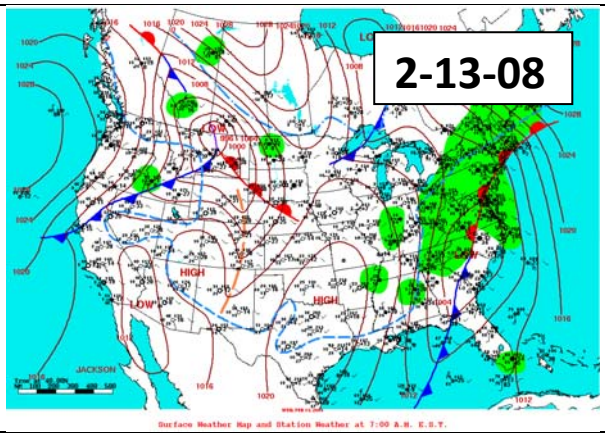


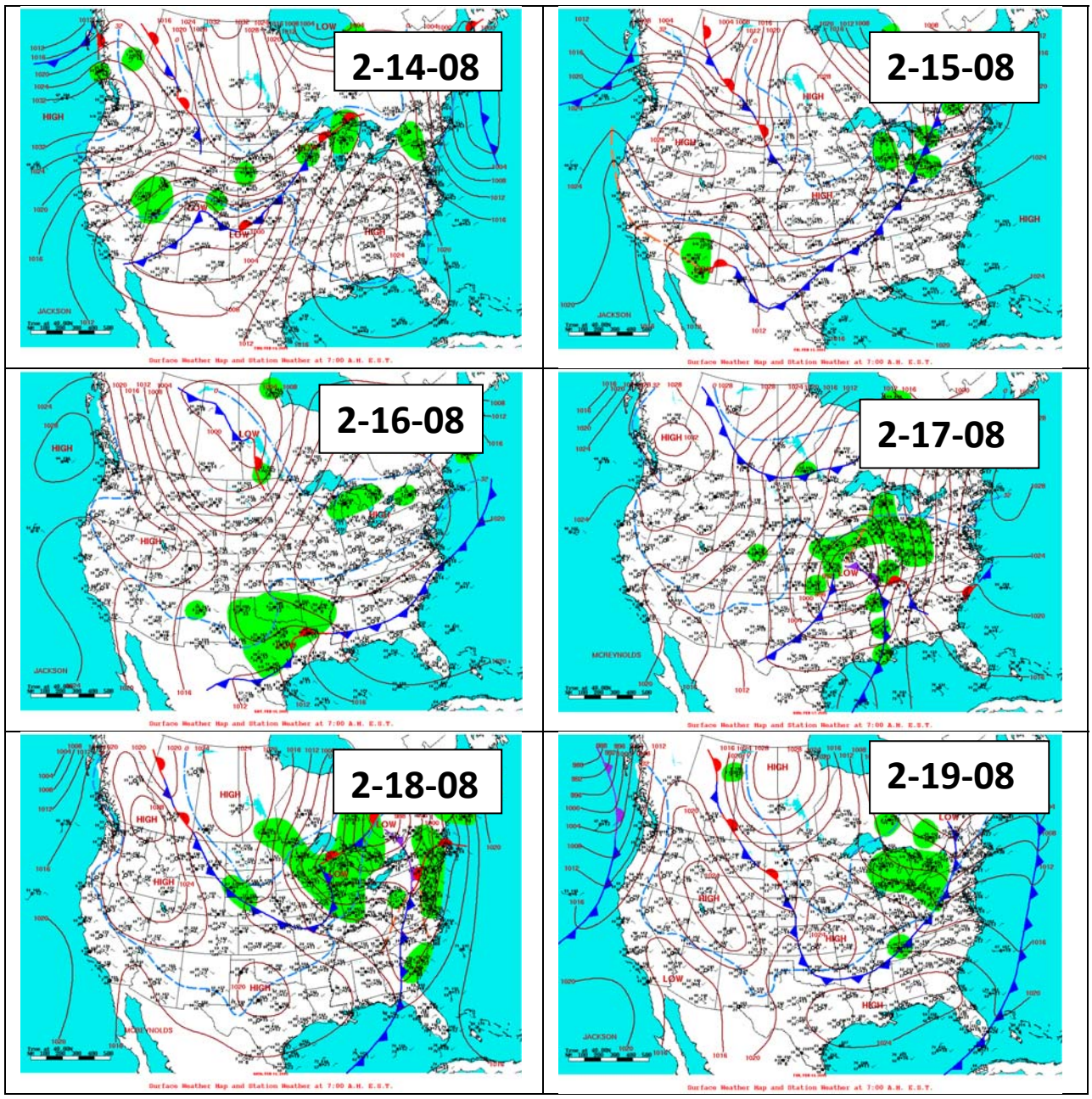




Period 3



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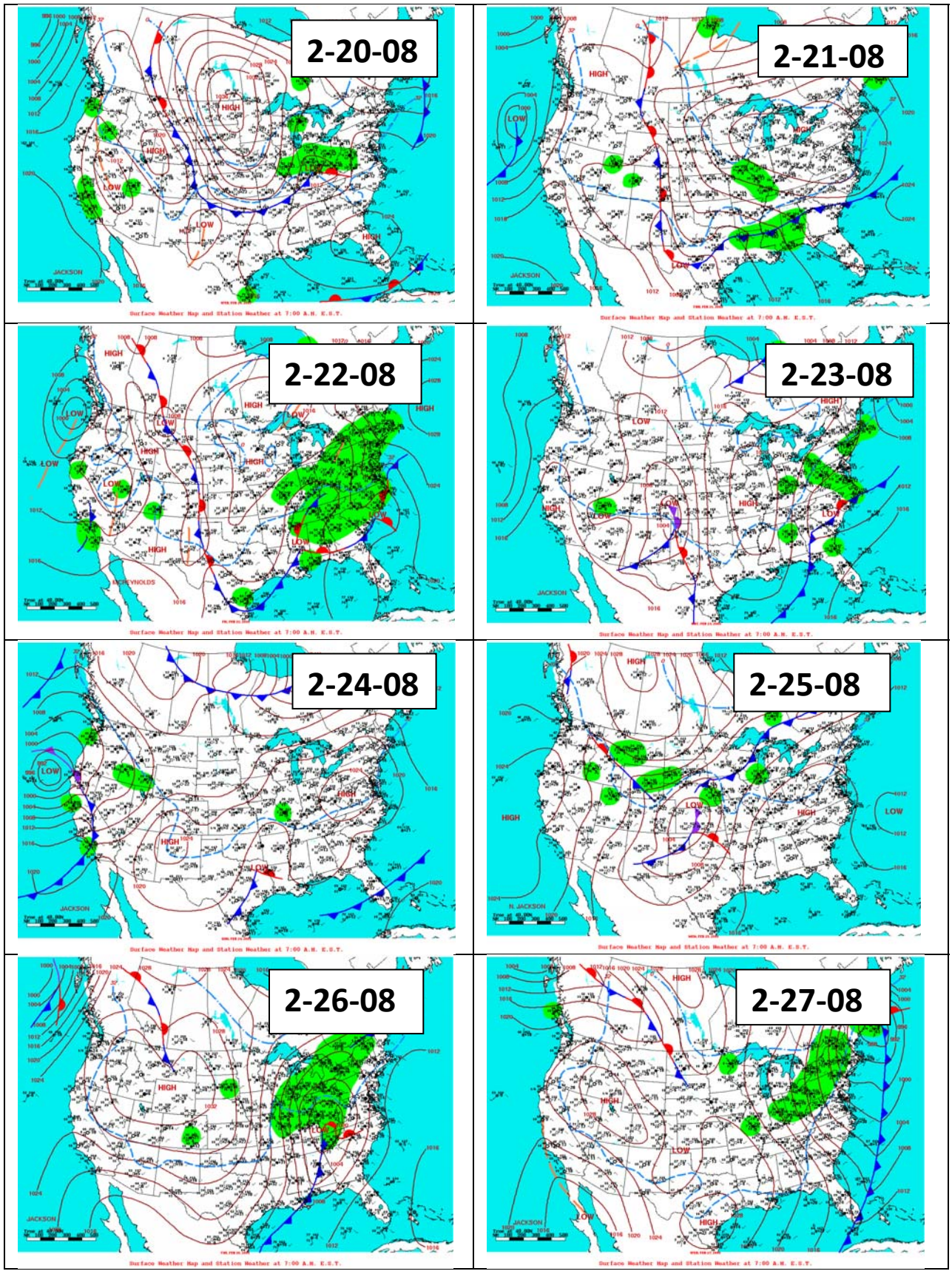
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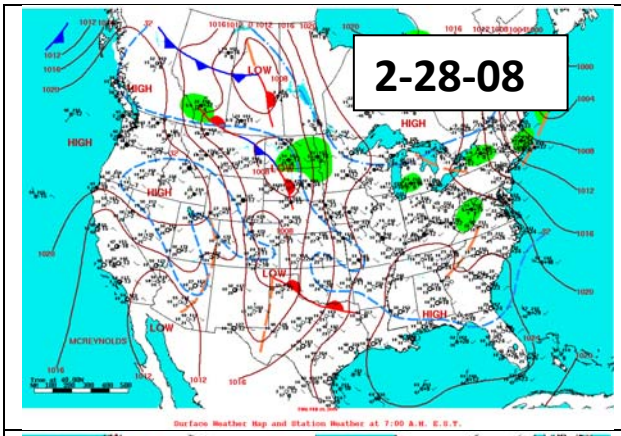
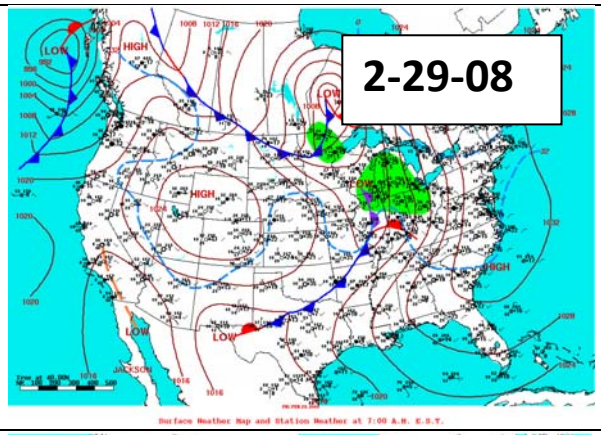
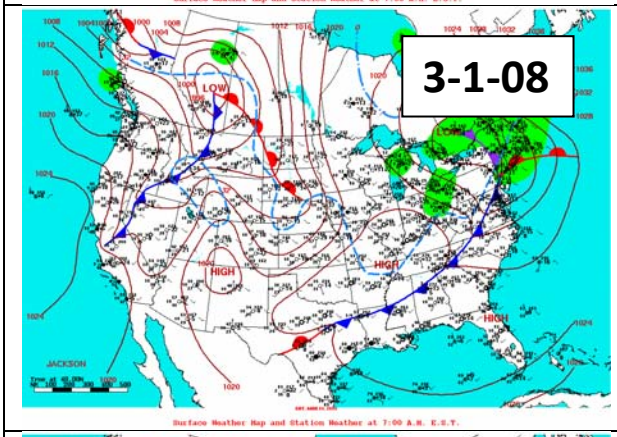
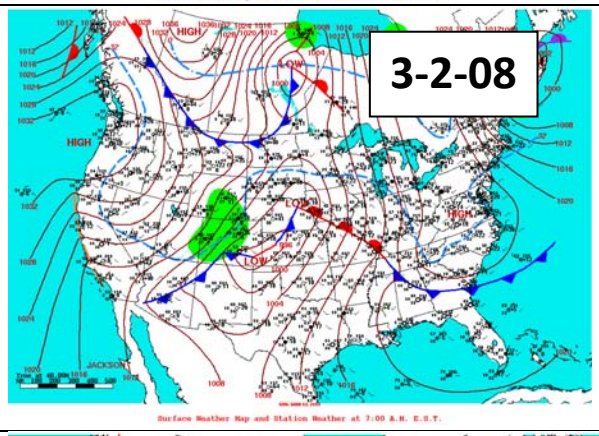
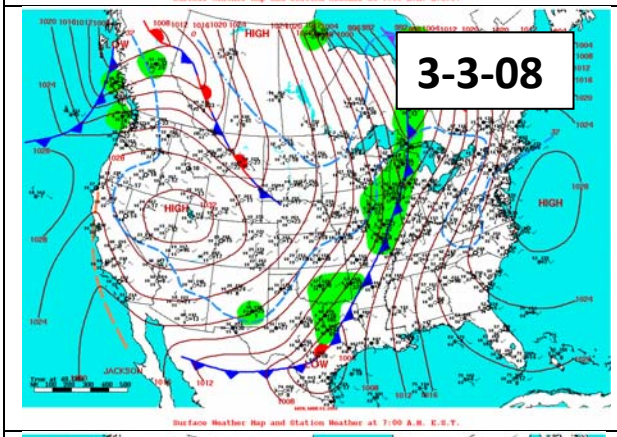
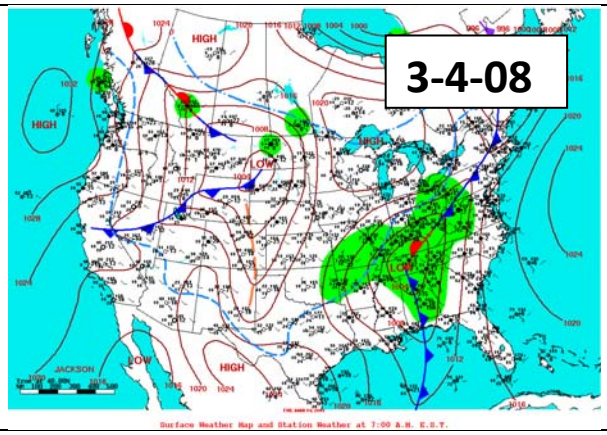


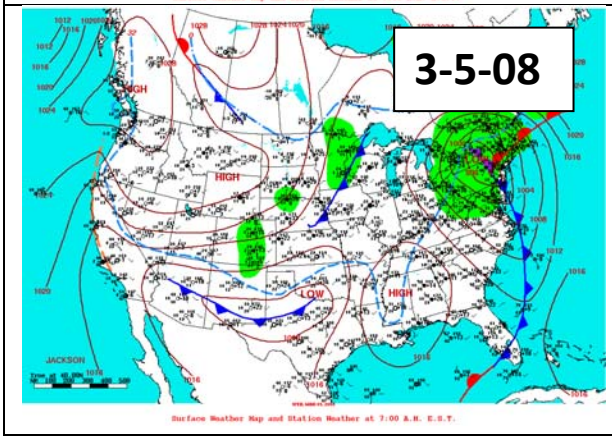




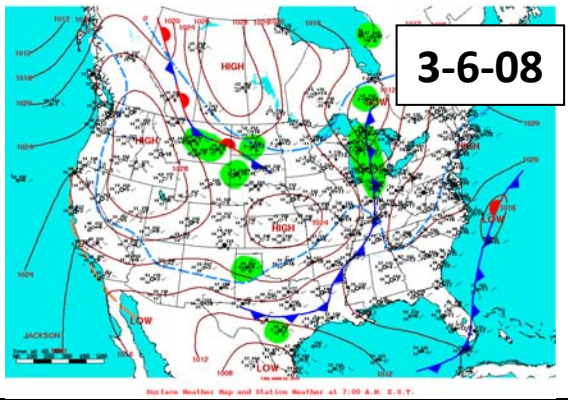


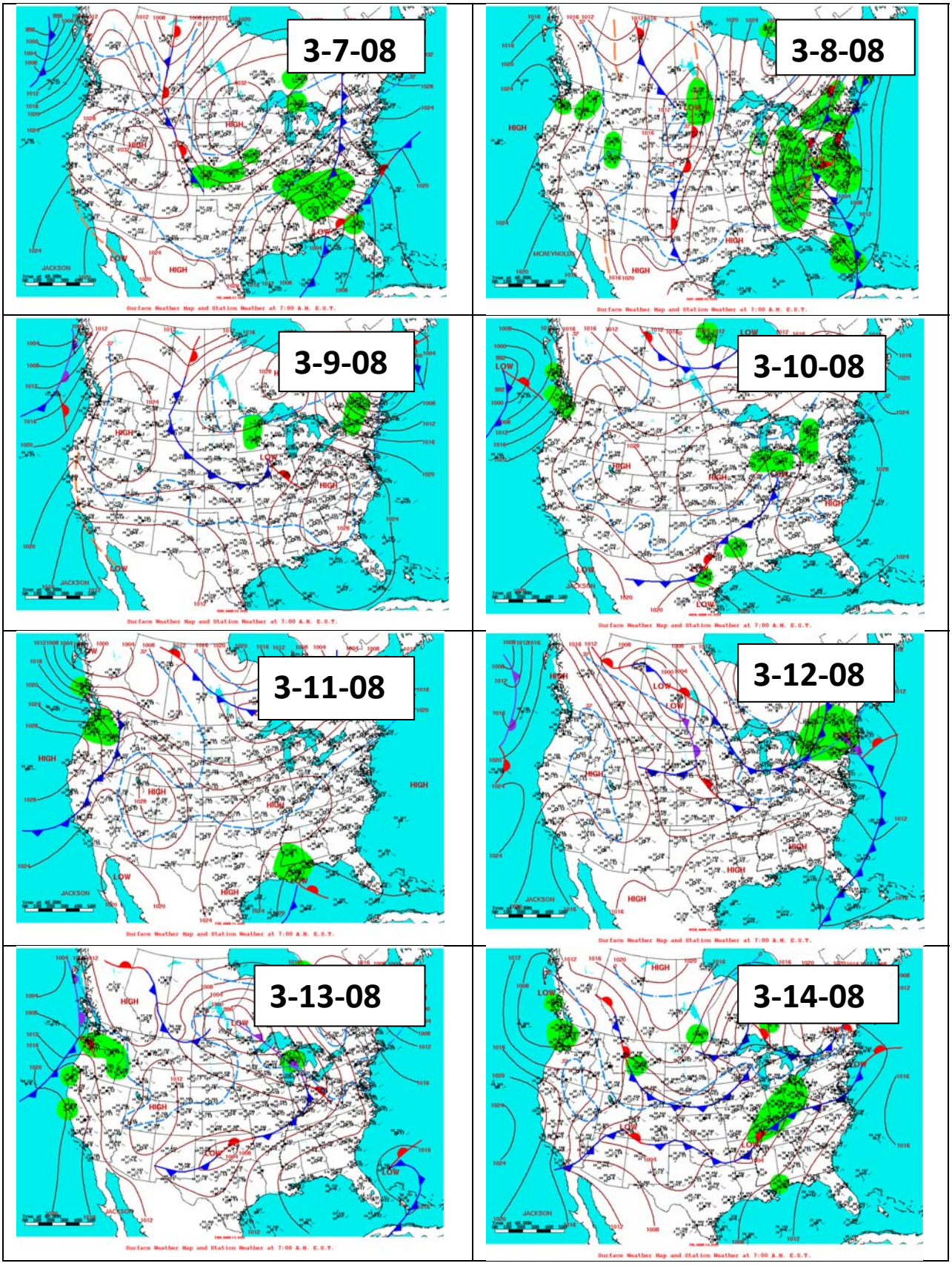






Period 4

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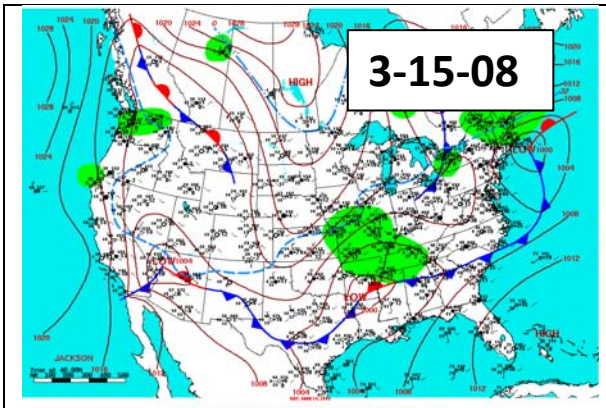
3-14-08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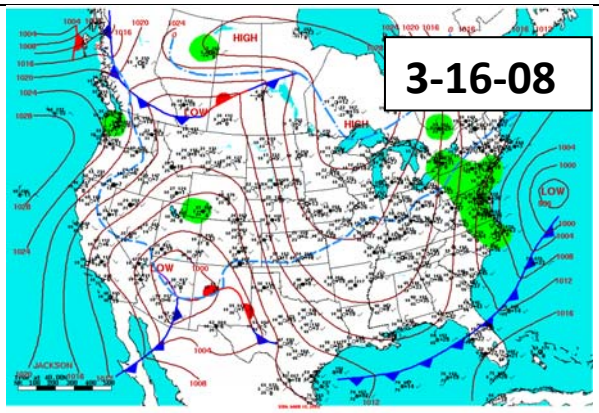
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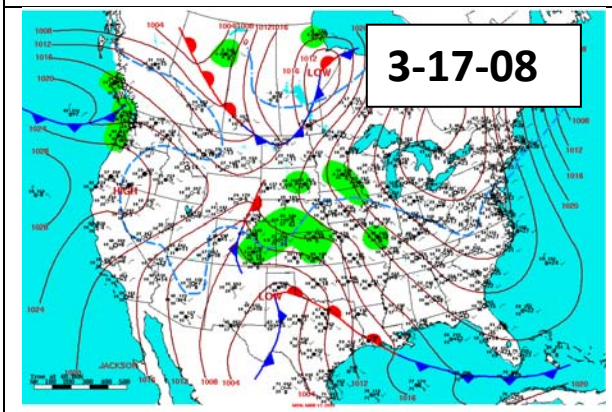
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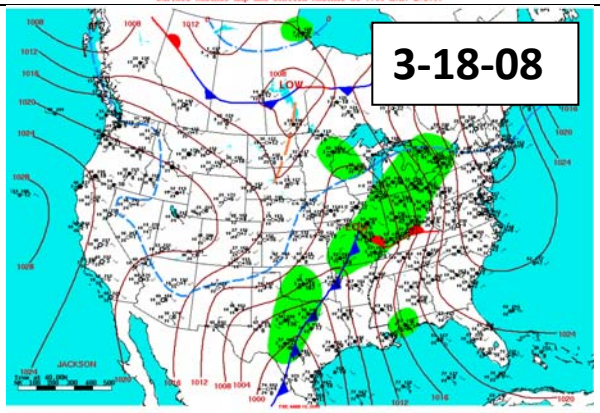
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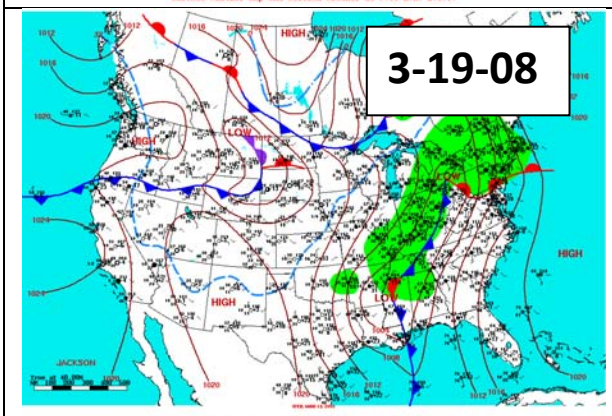
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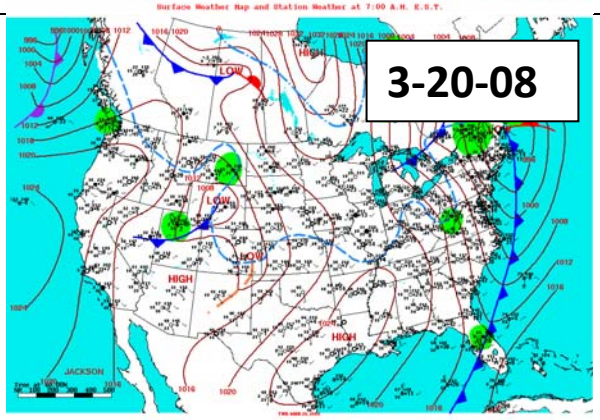
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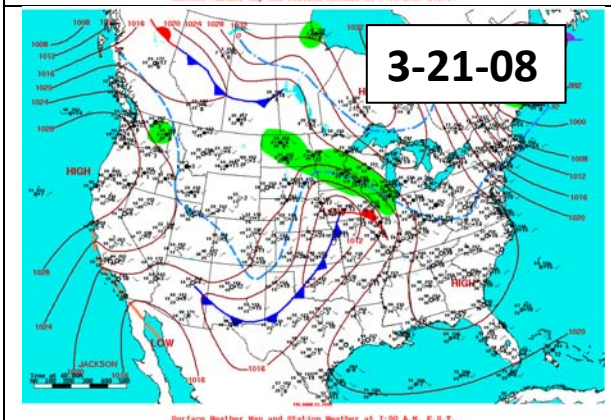
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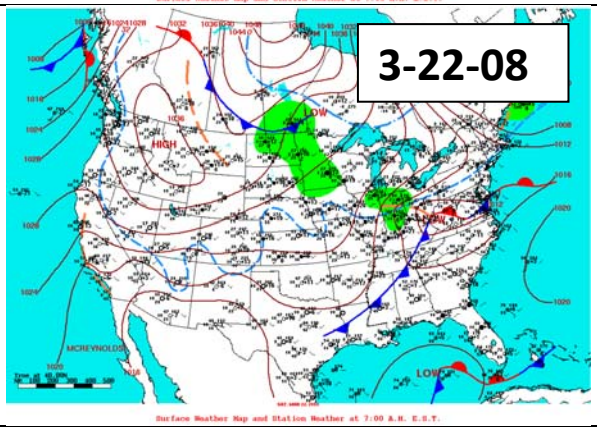
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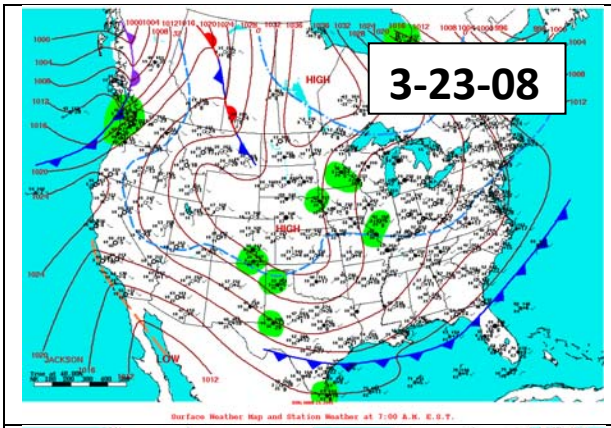

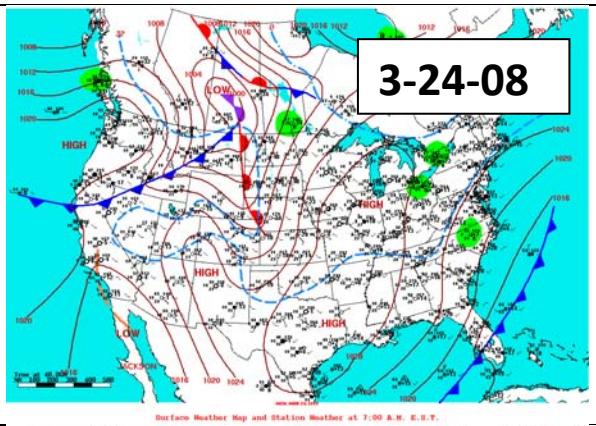

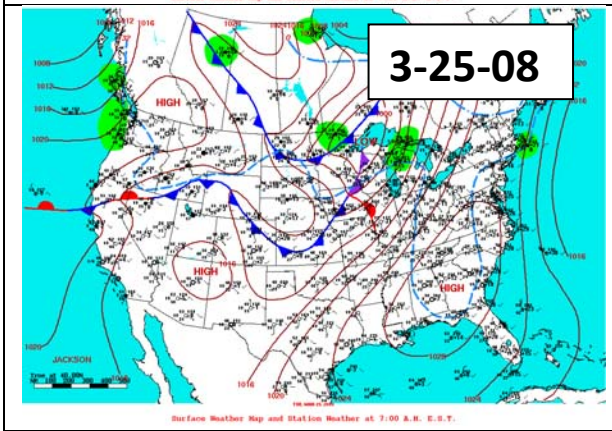

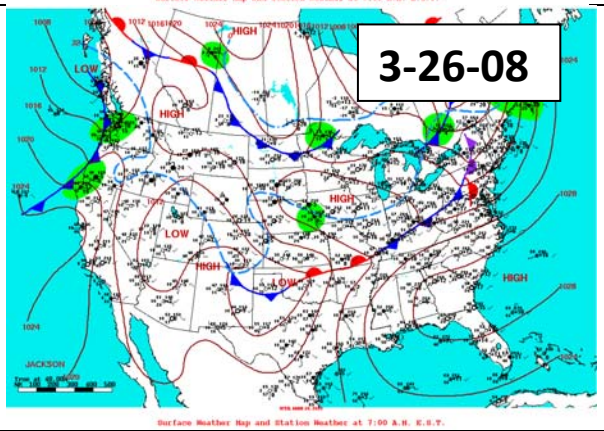

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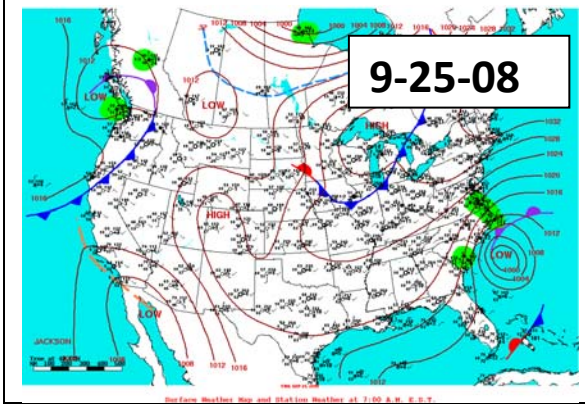

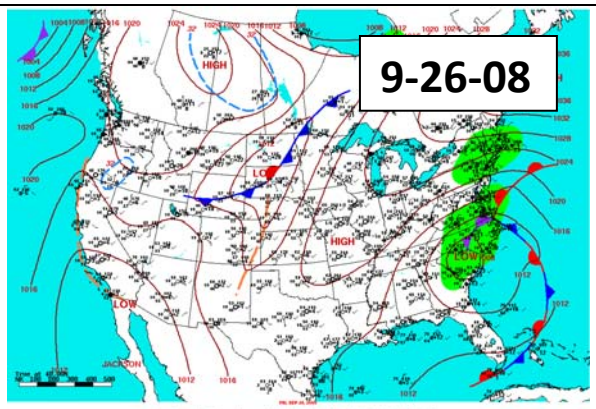

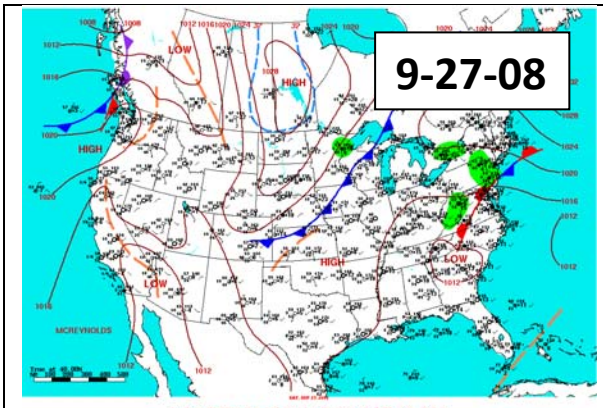
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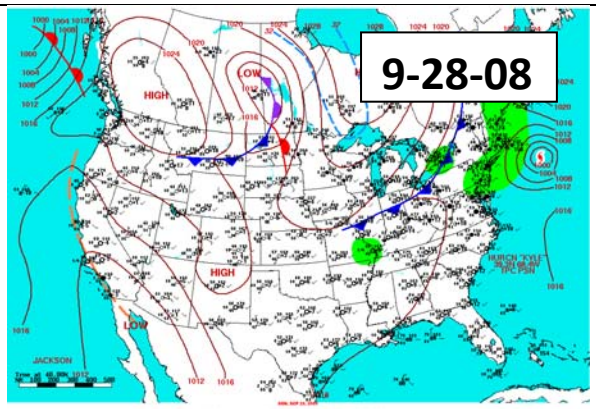
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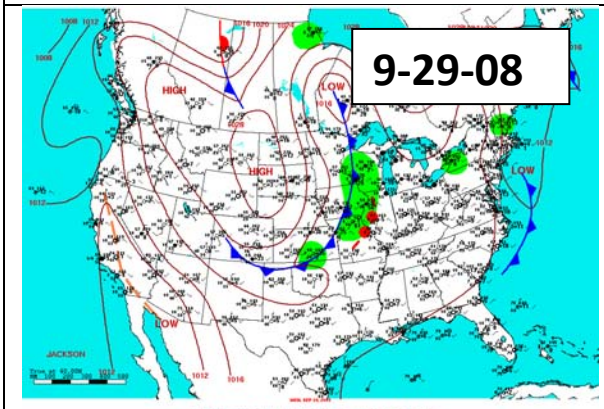
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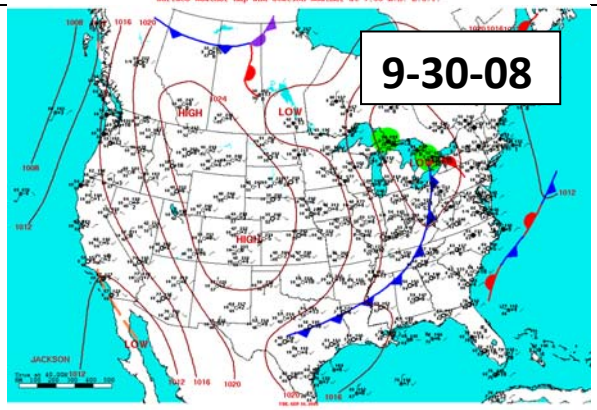
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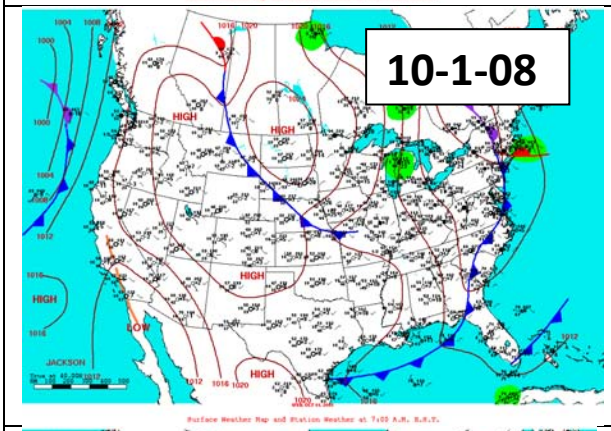
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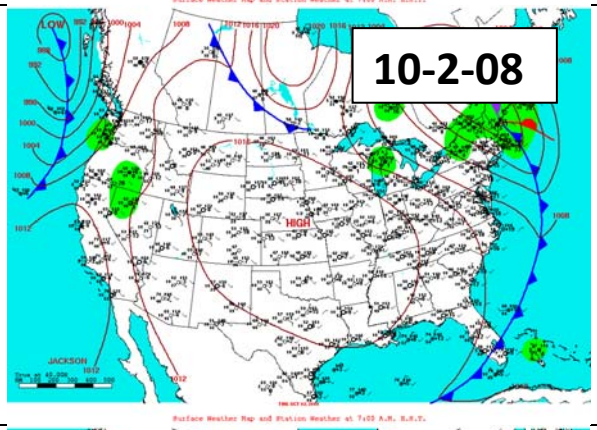
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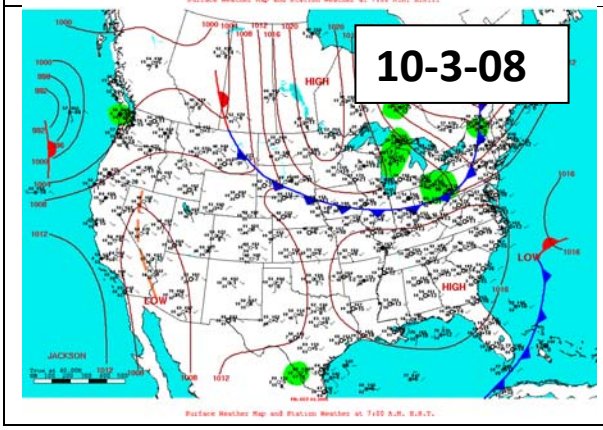
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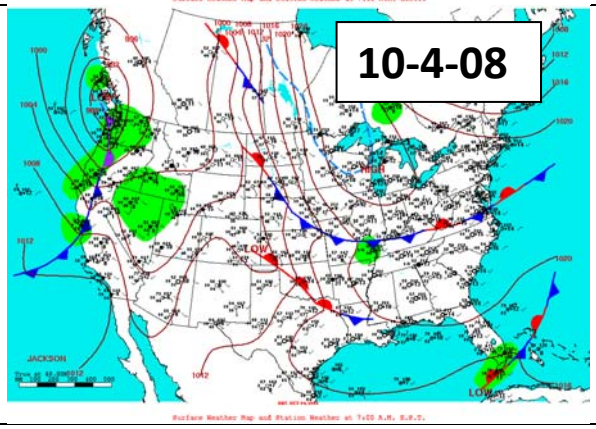
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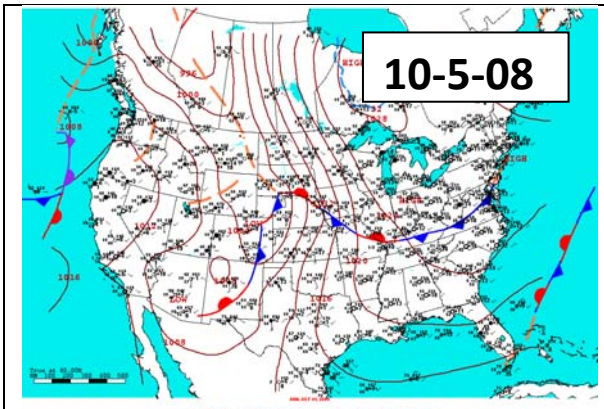
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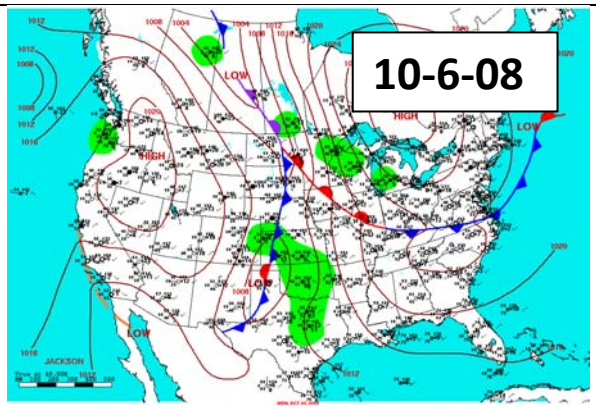
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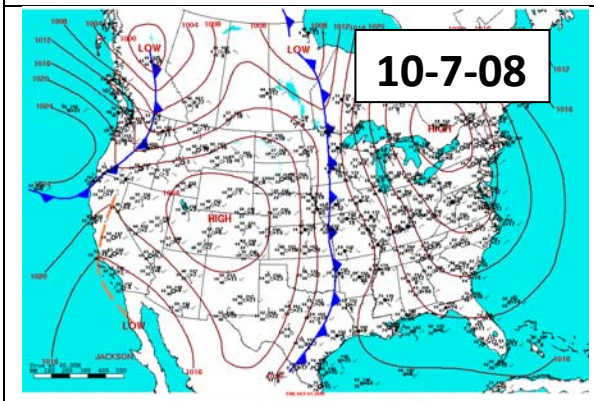
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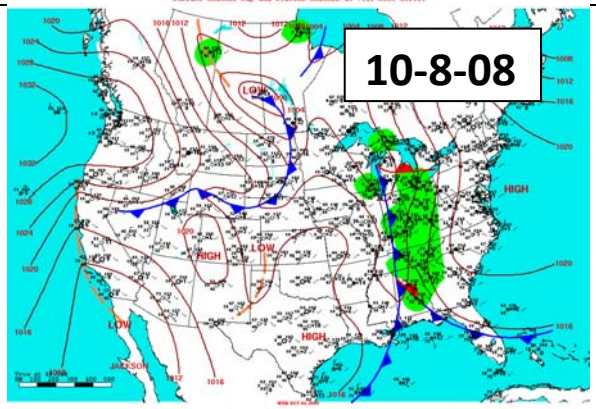
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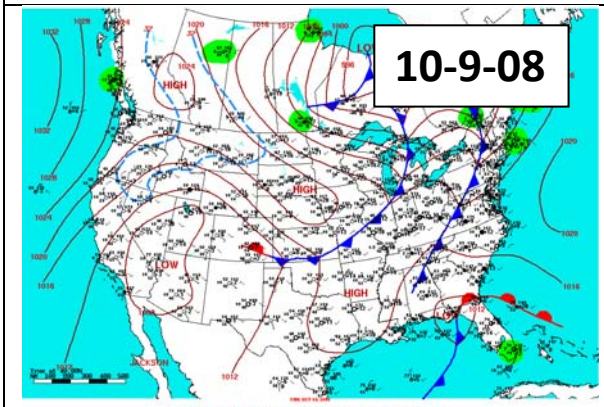
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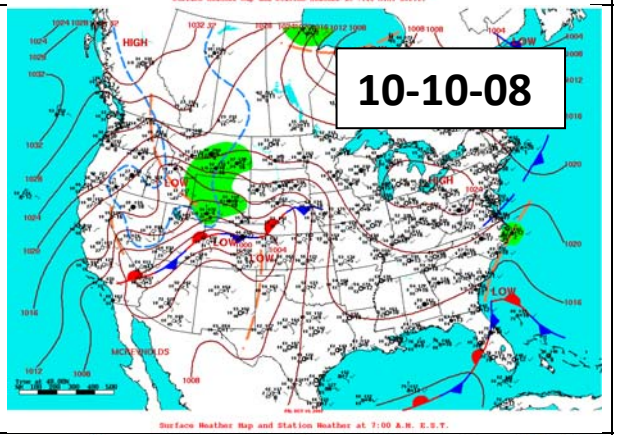
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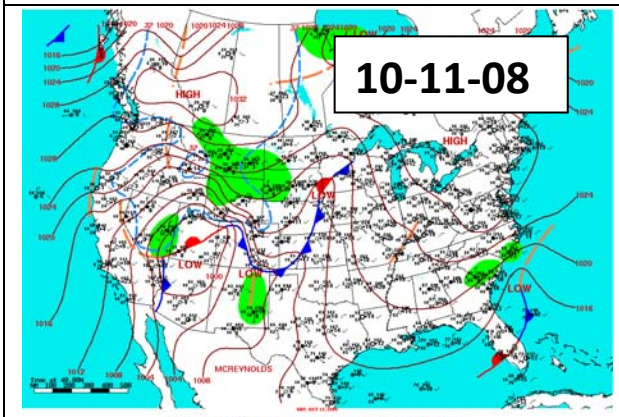
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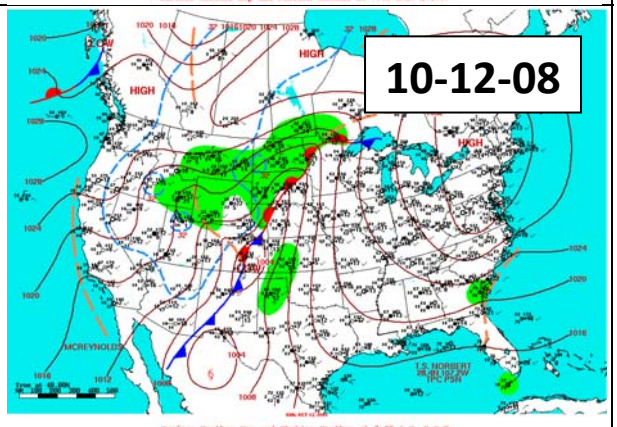
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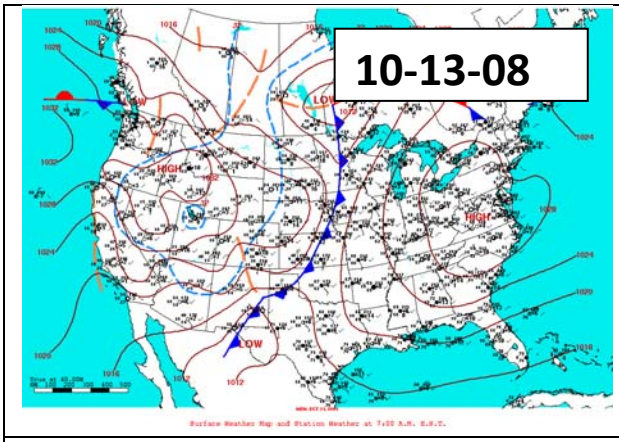
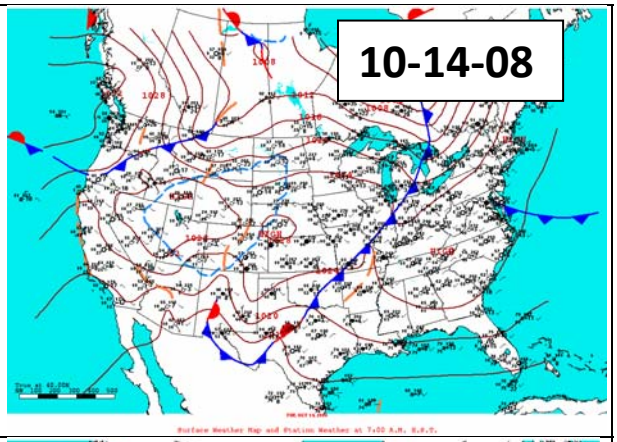
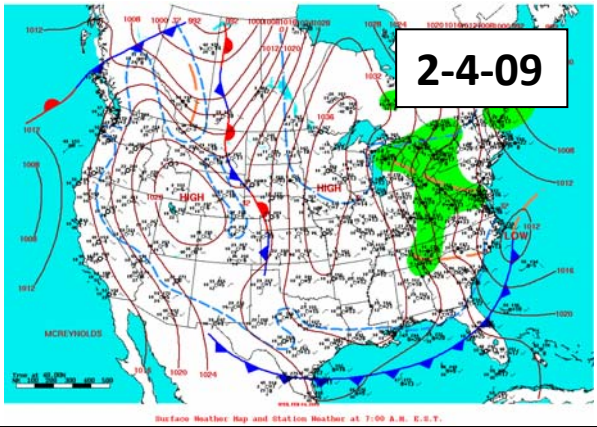
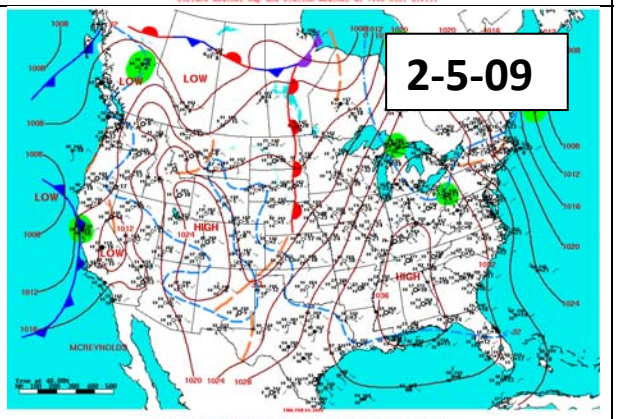
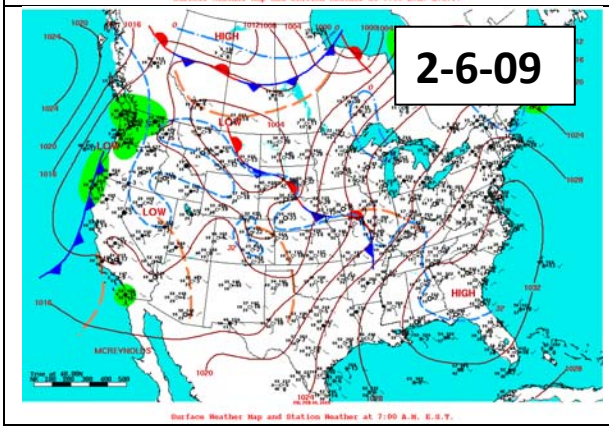


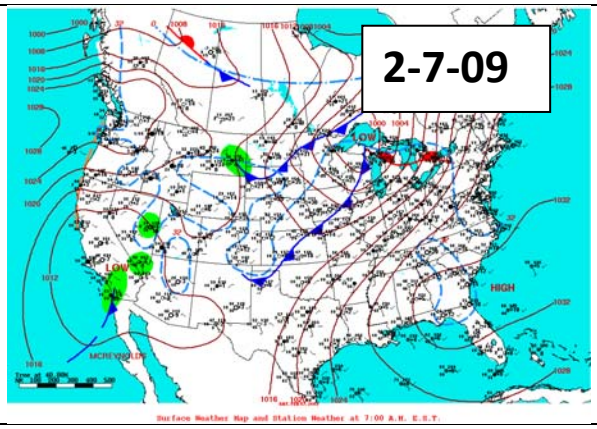


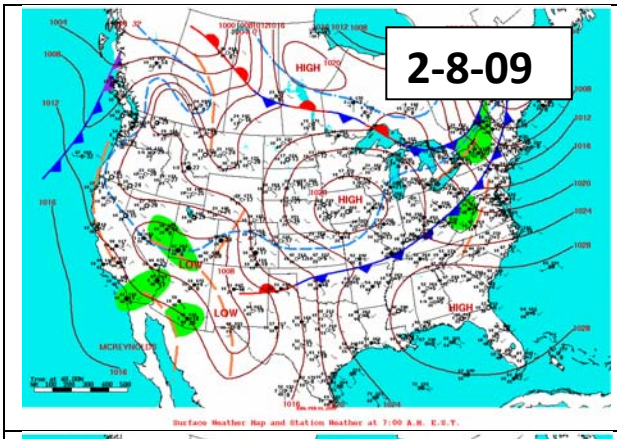
Period 7







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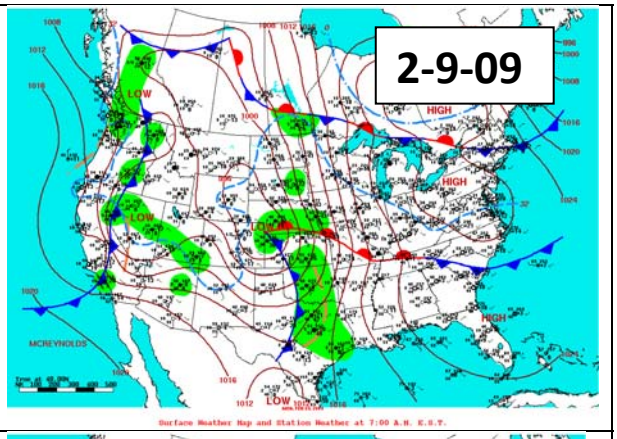
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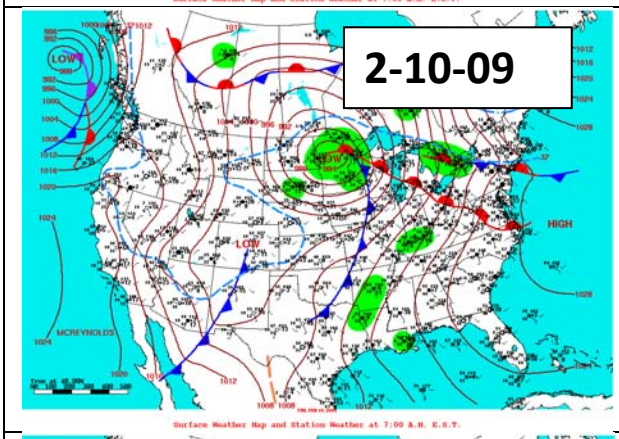
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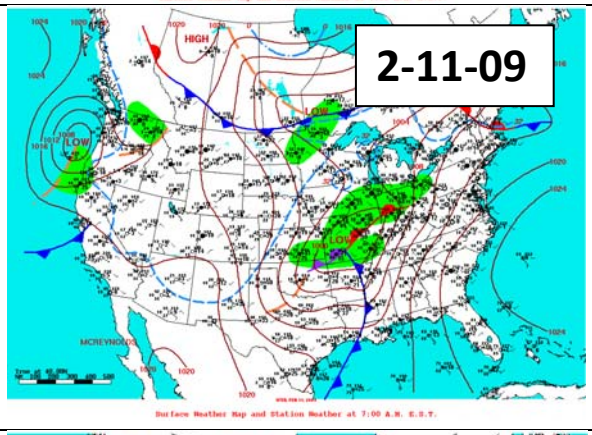
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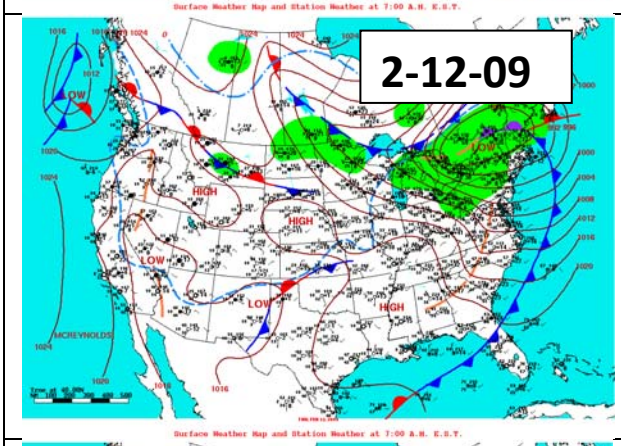
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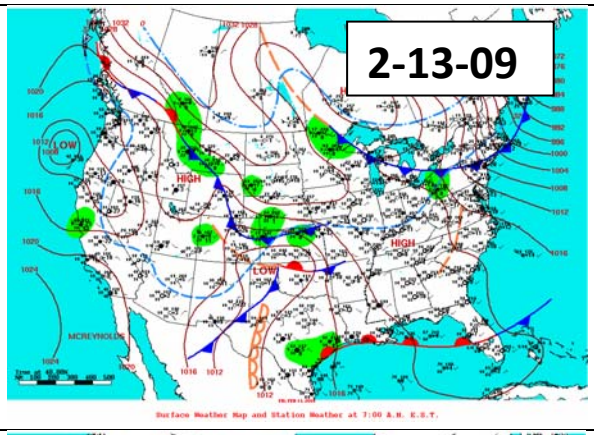
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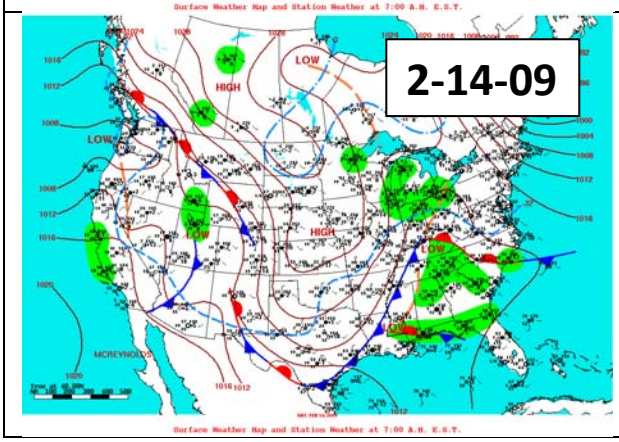
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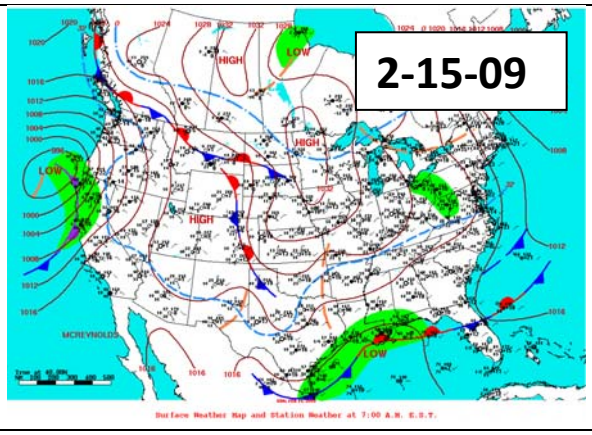
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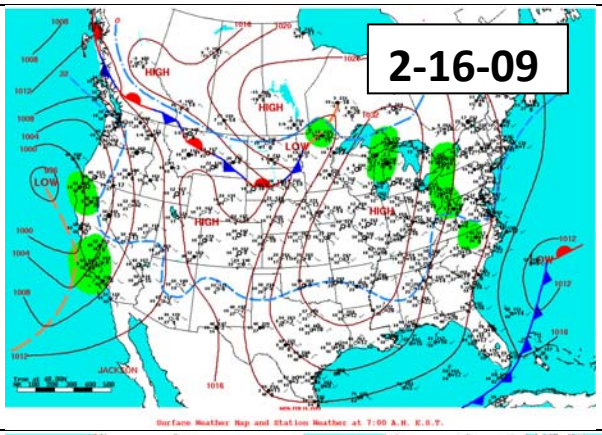
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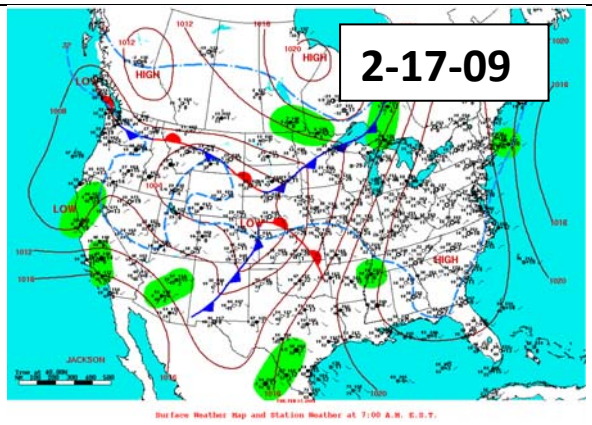
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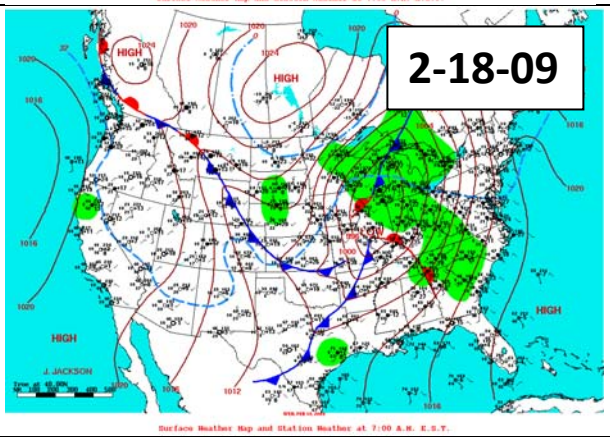
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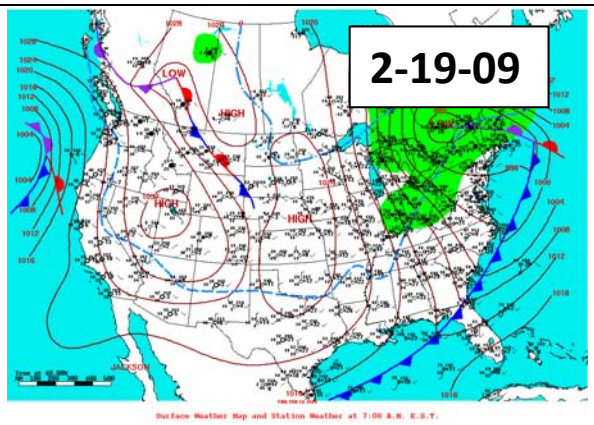
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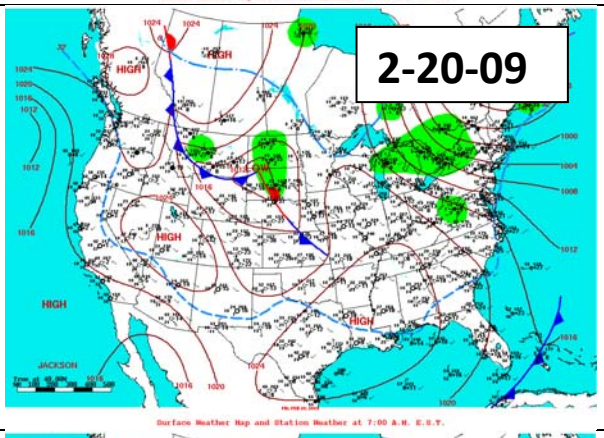
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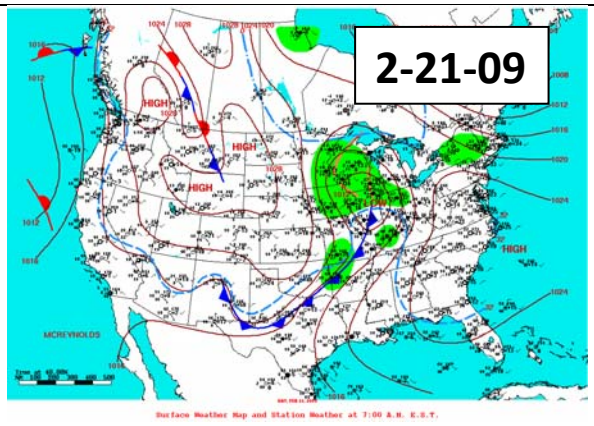
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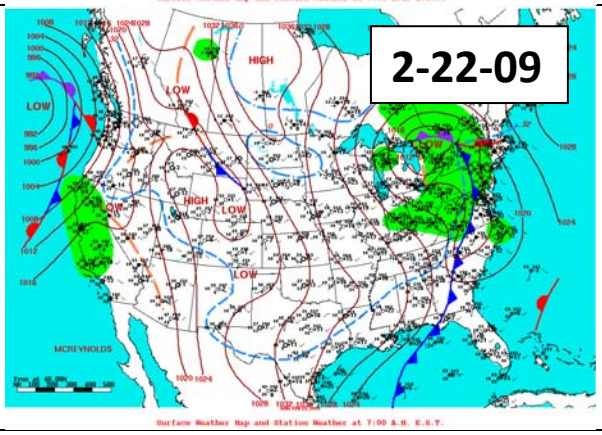
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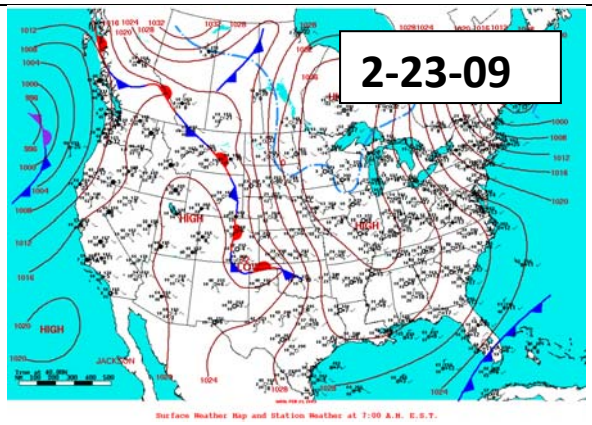
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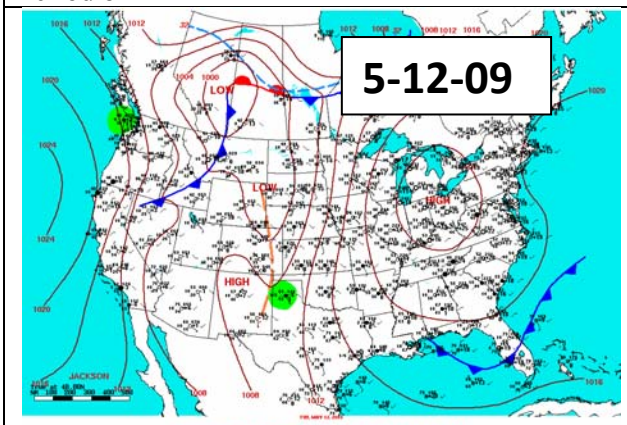
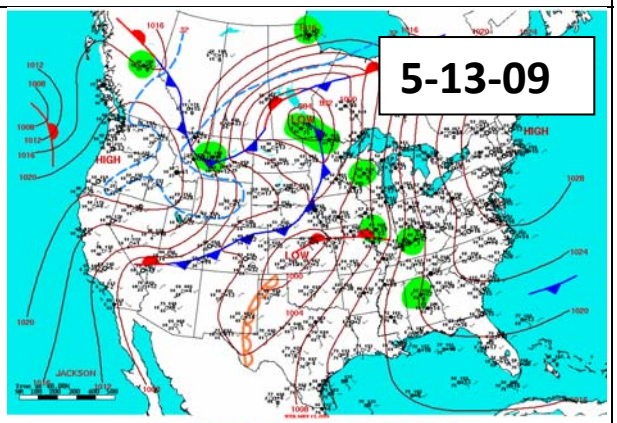
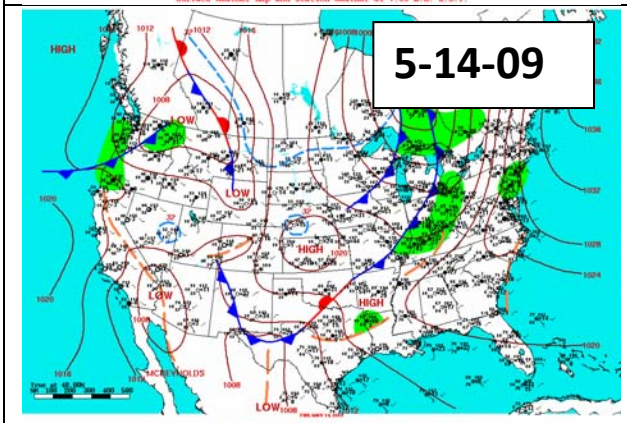
Period 8


5-12-09
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


5-13-09
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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LOW
MCREYNOLDS
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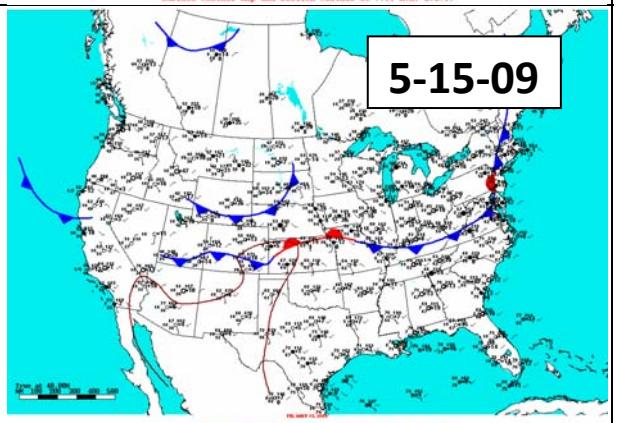
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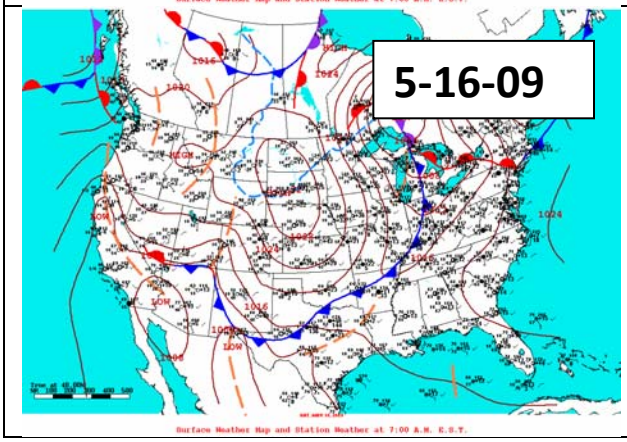
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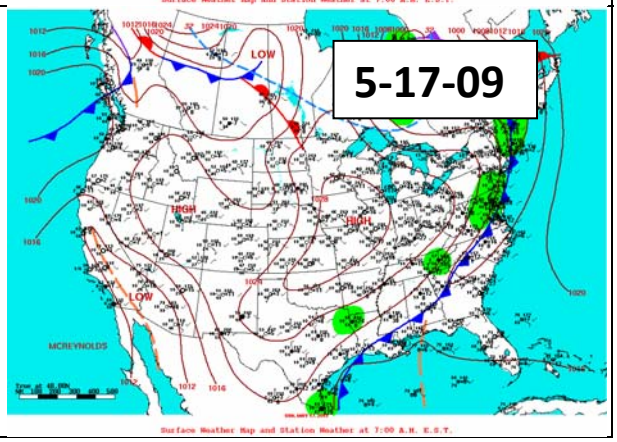
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HIGH
MCREYNOLDS
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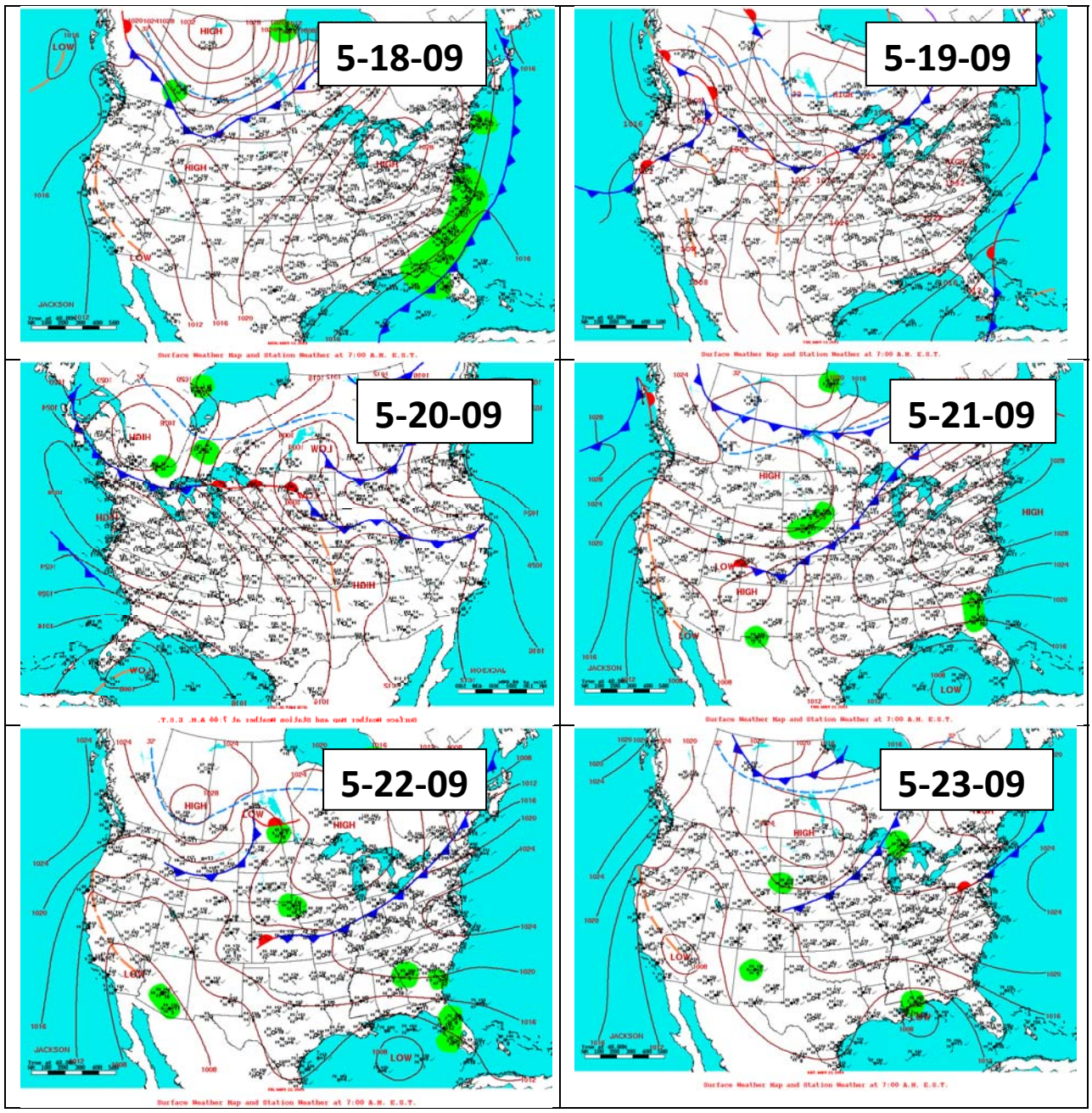
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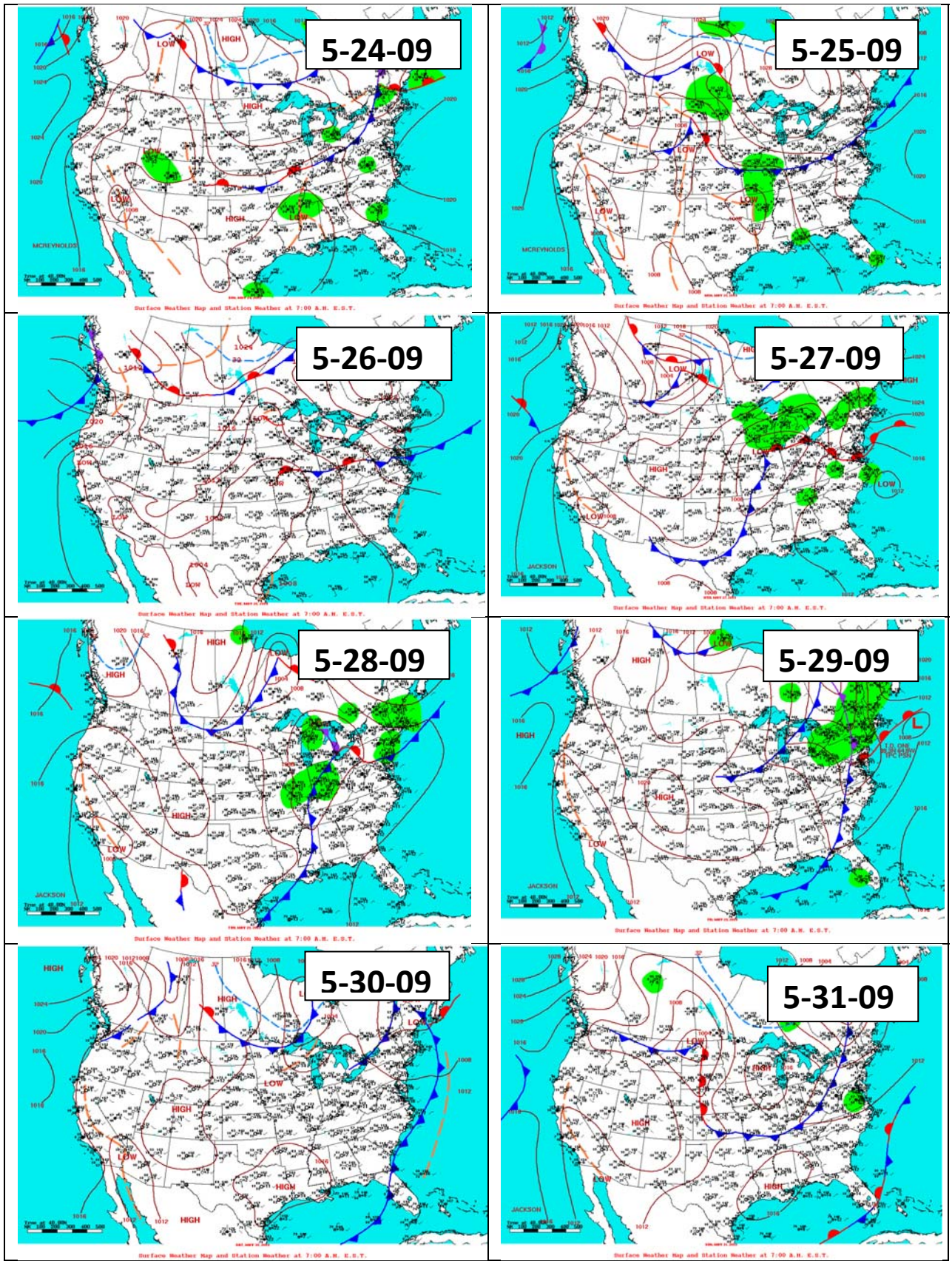
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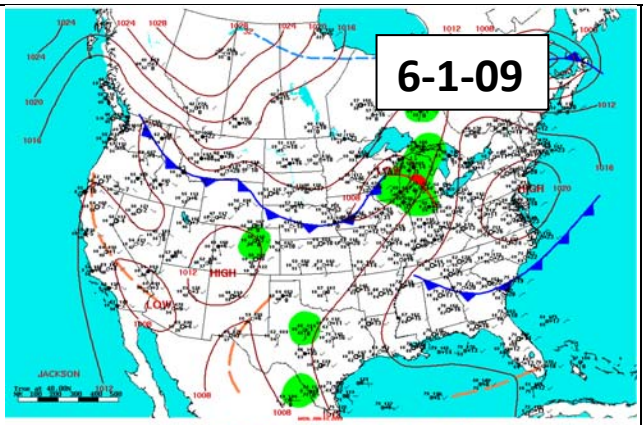
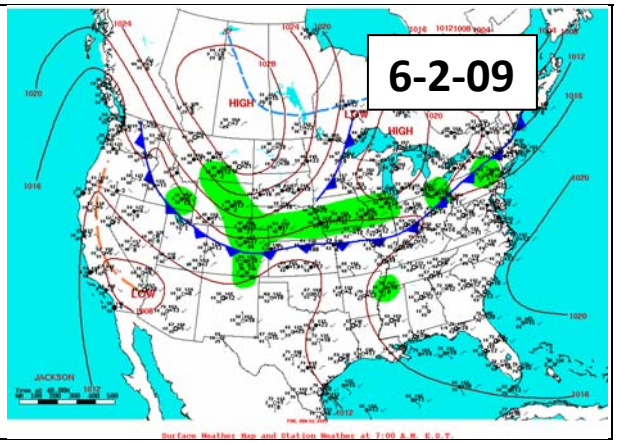
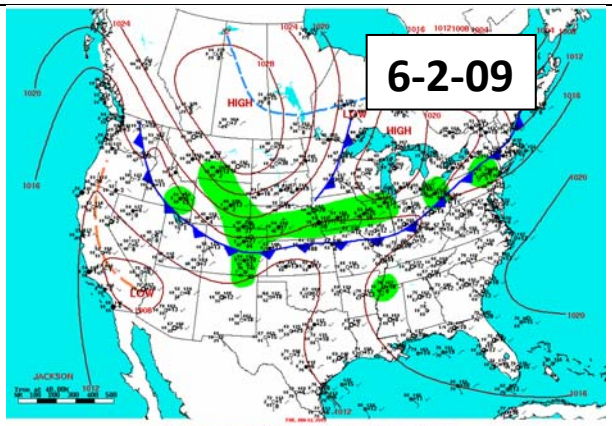
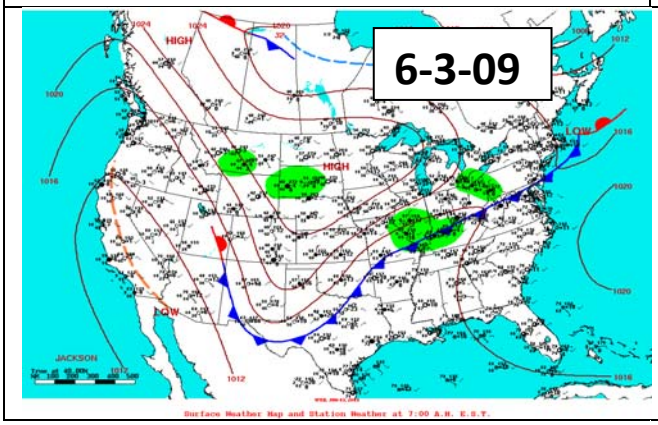
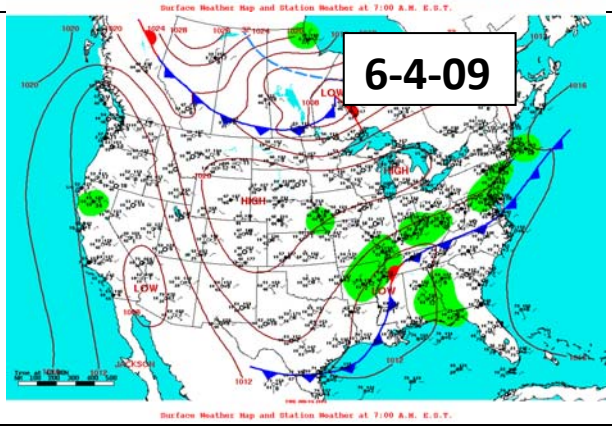


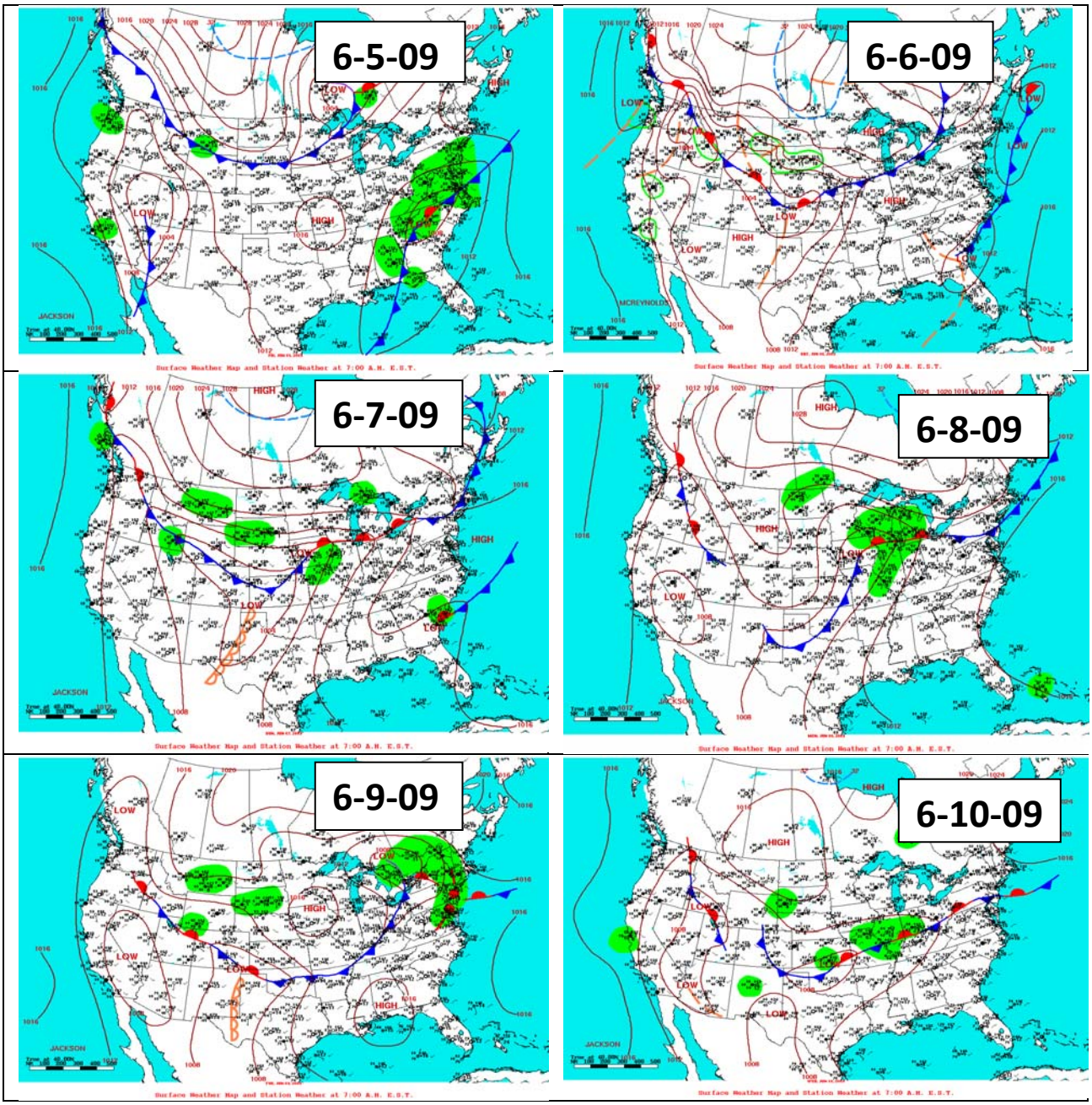


Period 9





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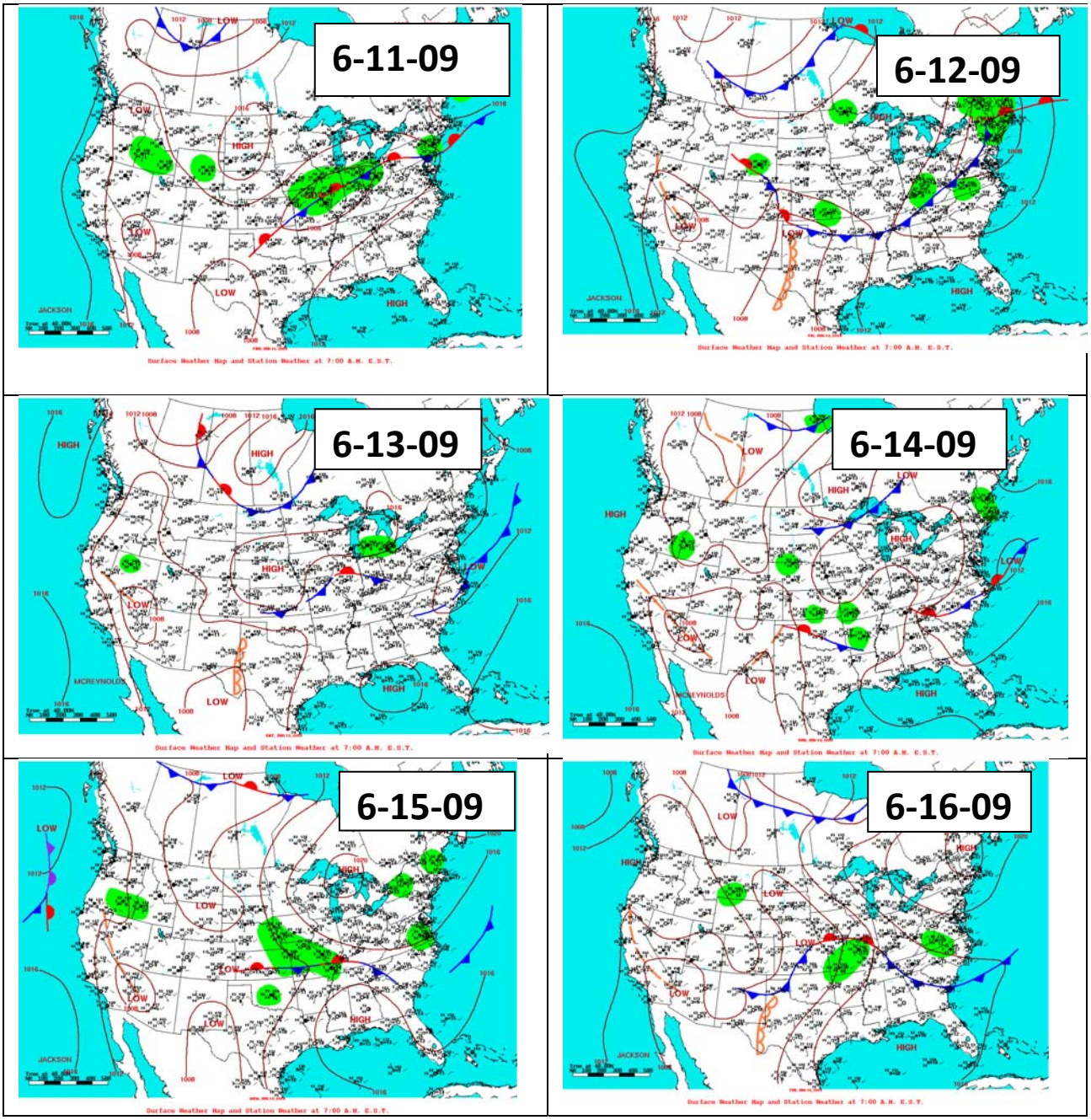
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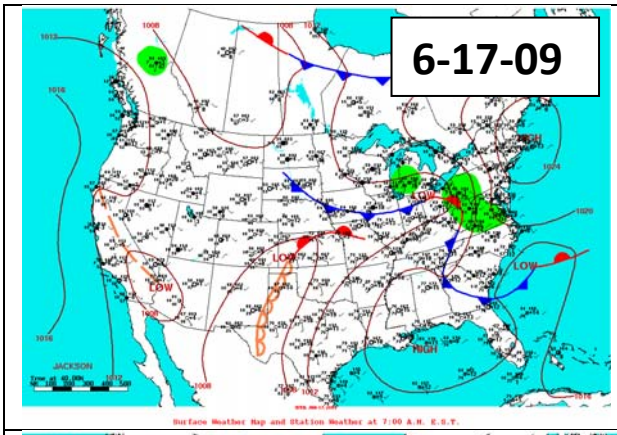
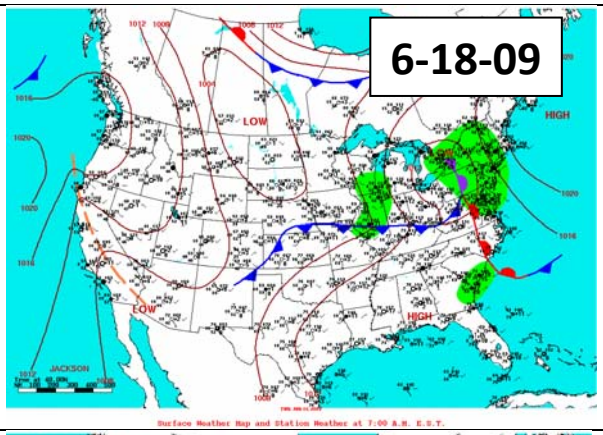
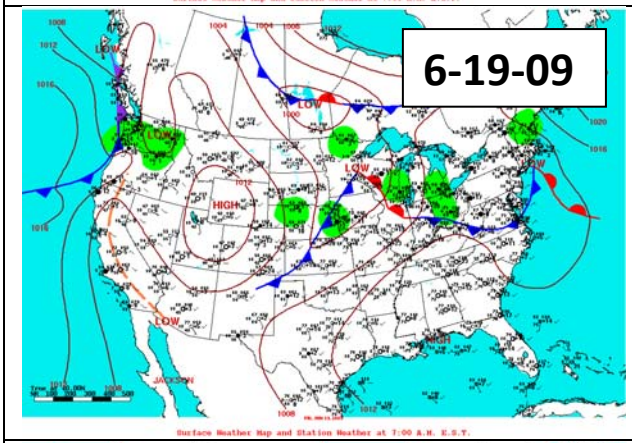
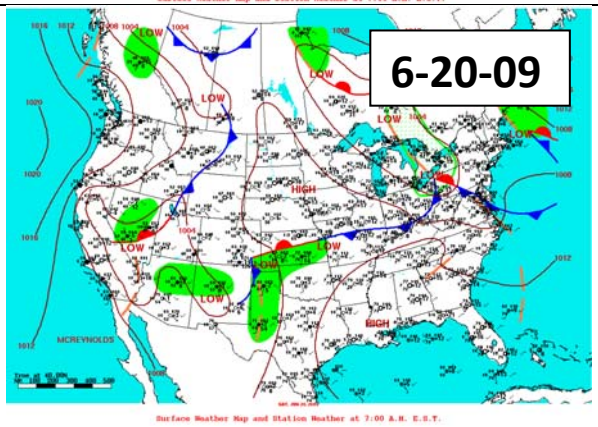
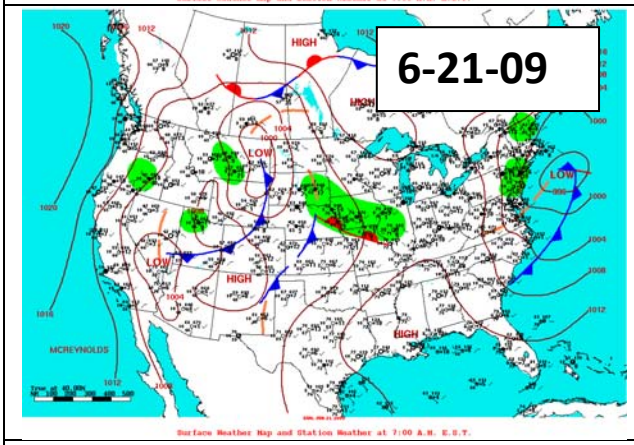
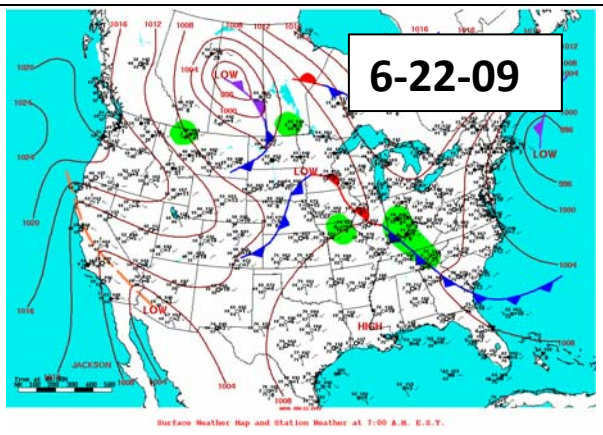




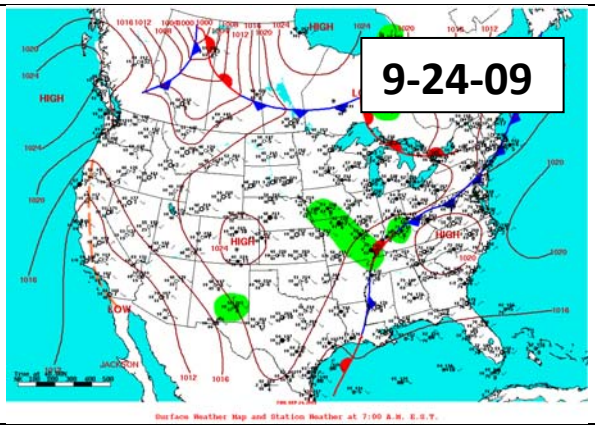


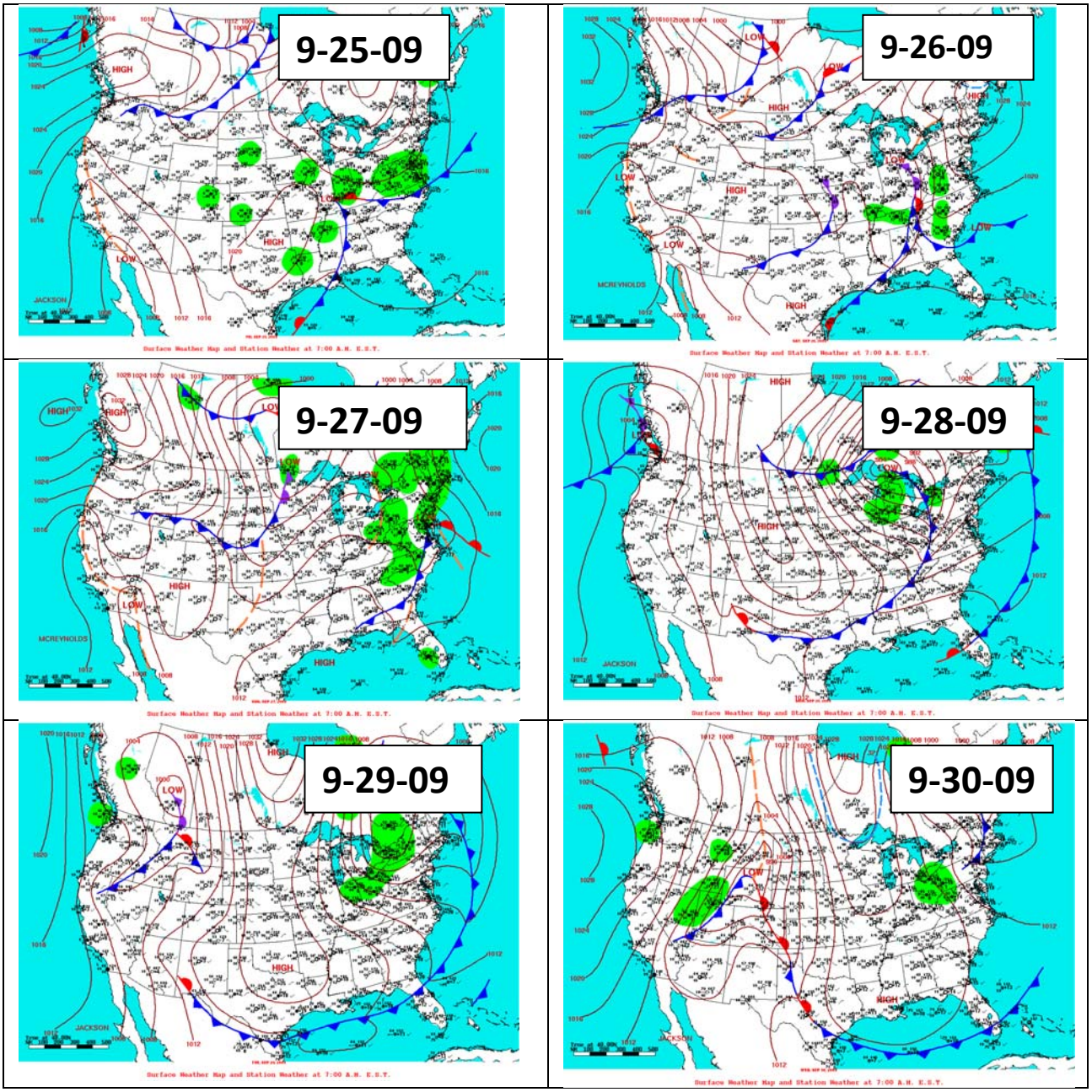






Period 10

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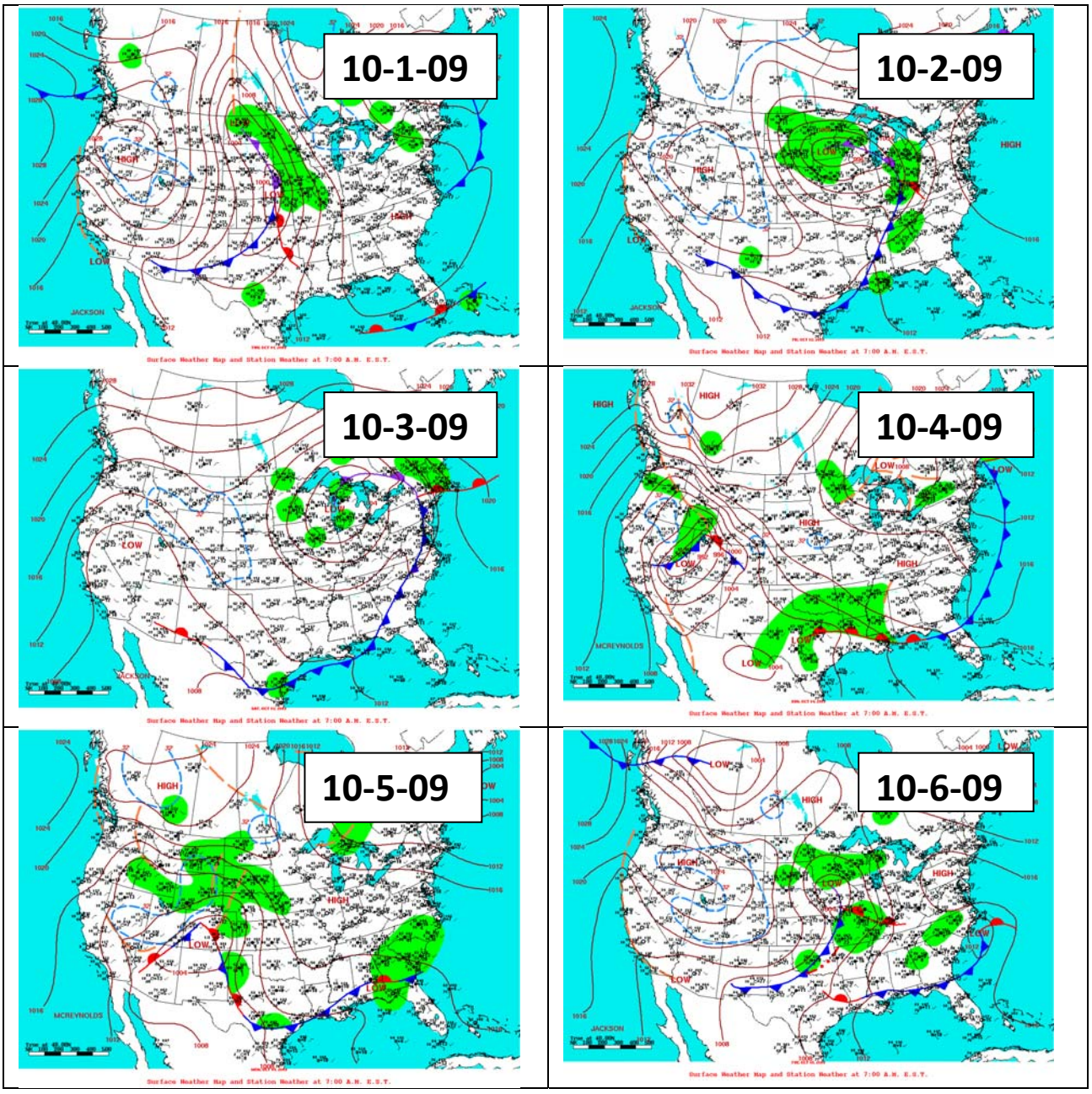
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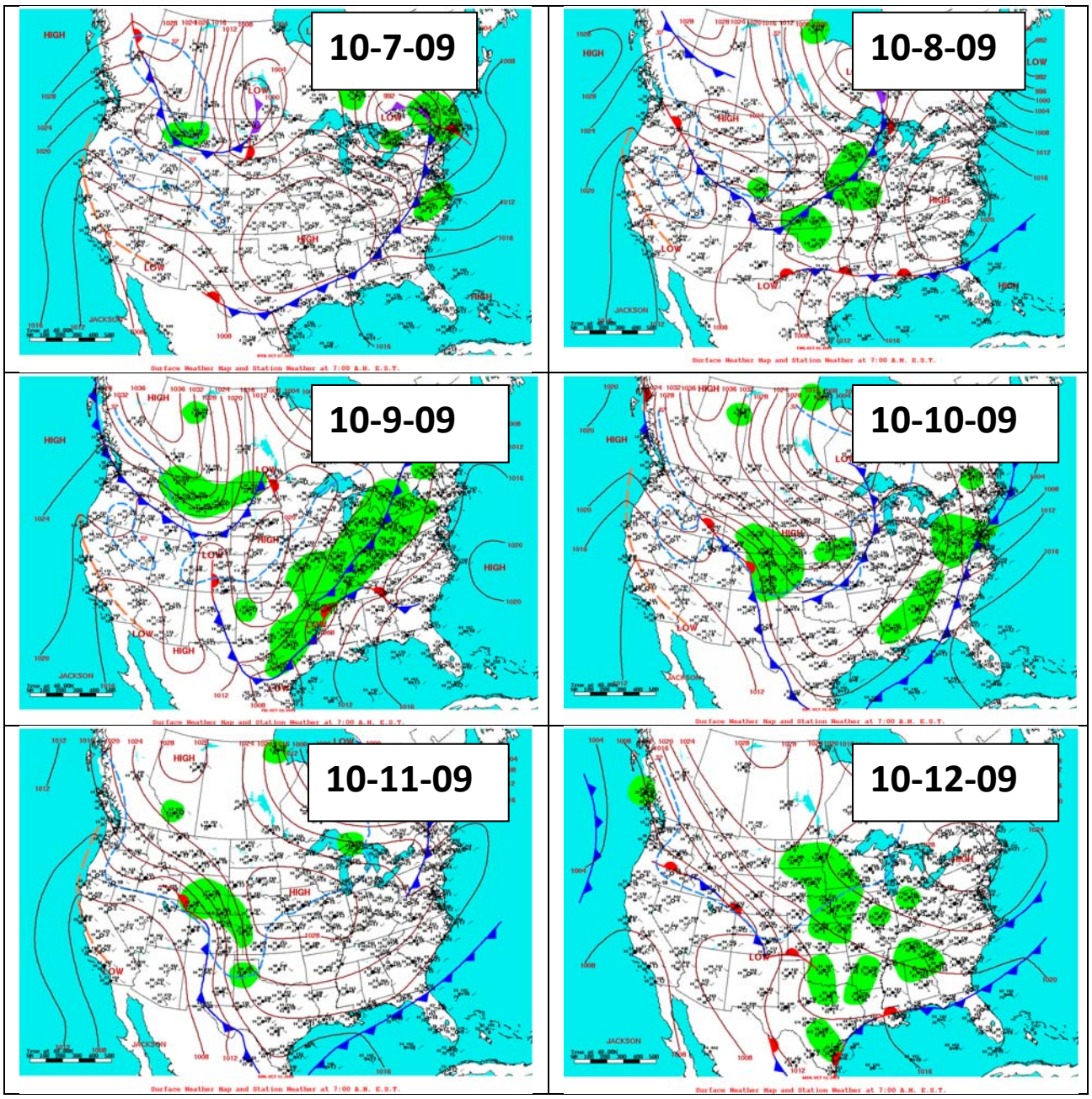
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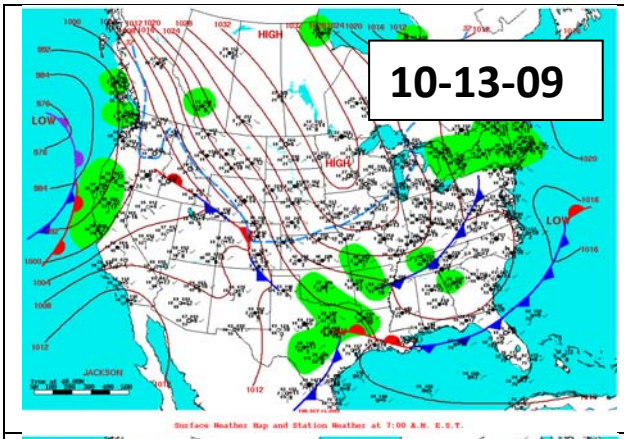
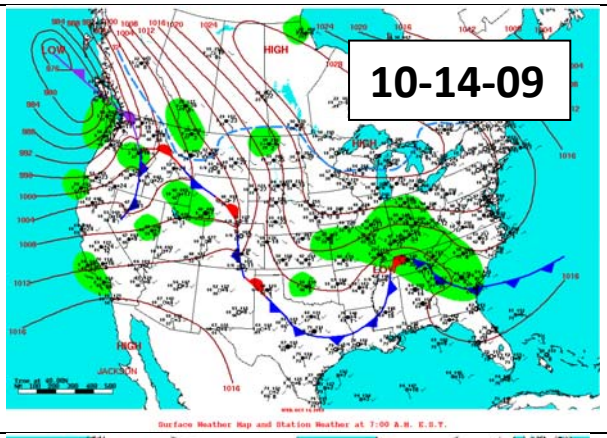
10-12-09


10-13-09
HIGH
LOW
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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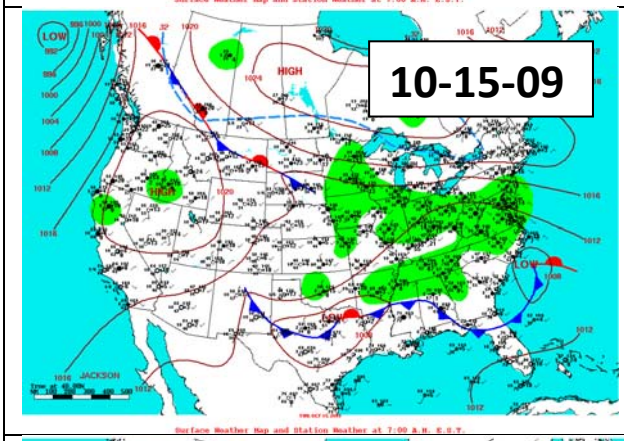
HIGH
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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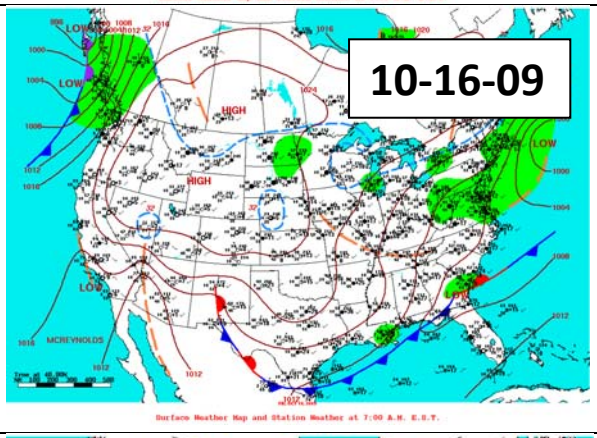
HIGH
LOW
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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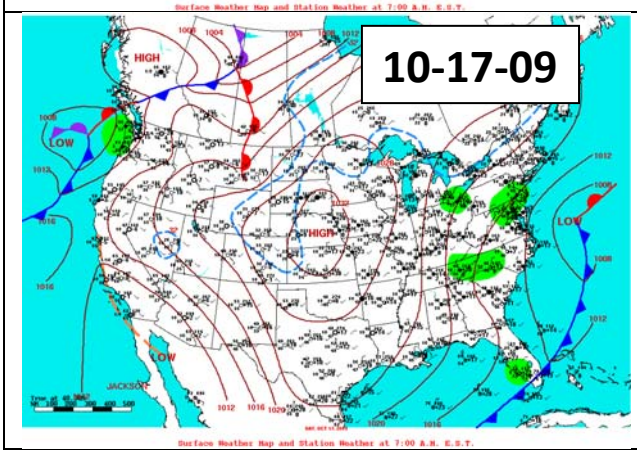
LOW
LOW
HIGH
HIGH
LOW
LOW
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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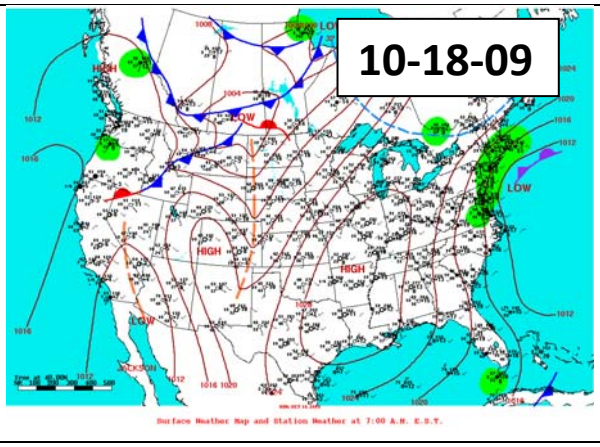
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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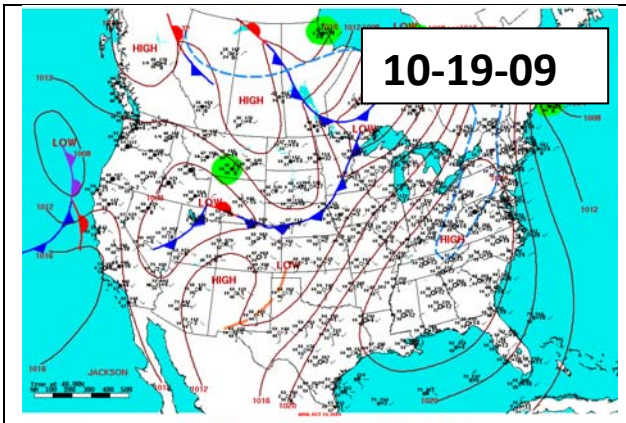
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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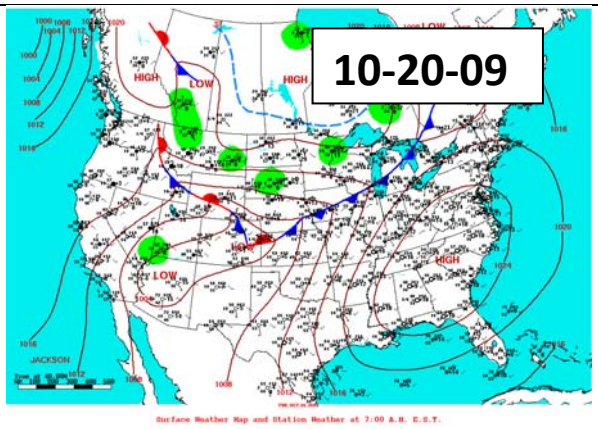
JACKSON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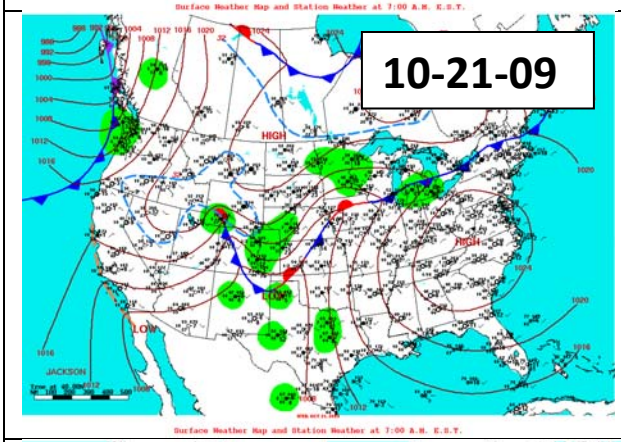
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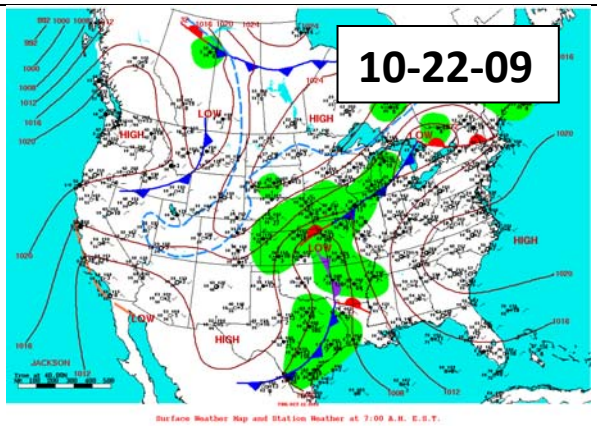
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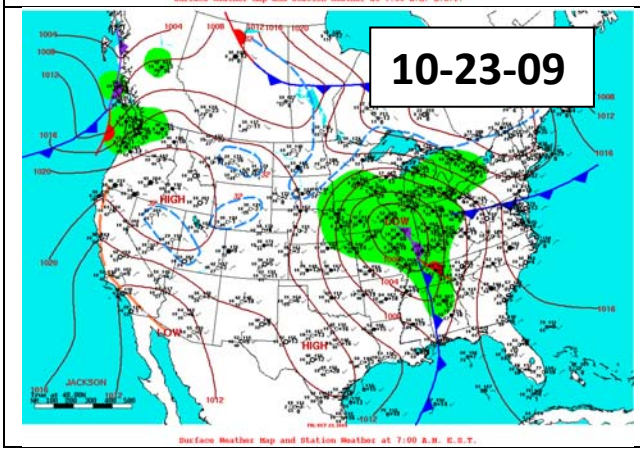
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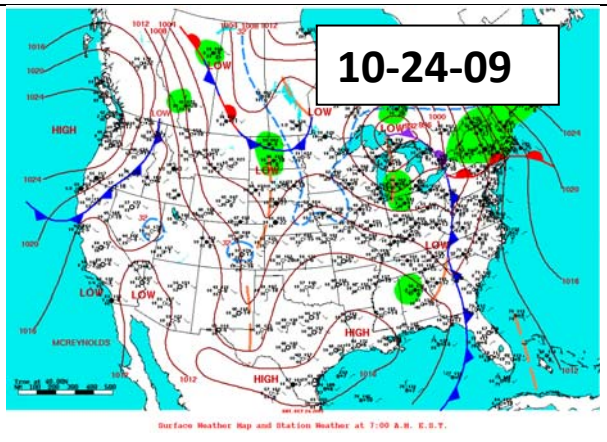
JACKSON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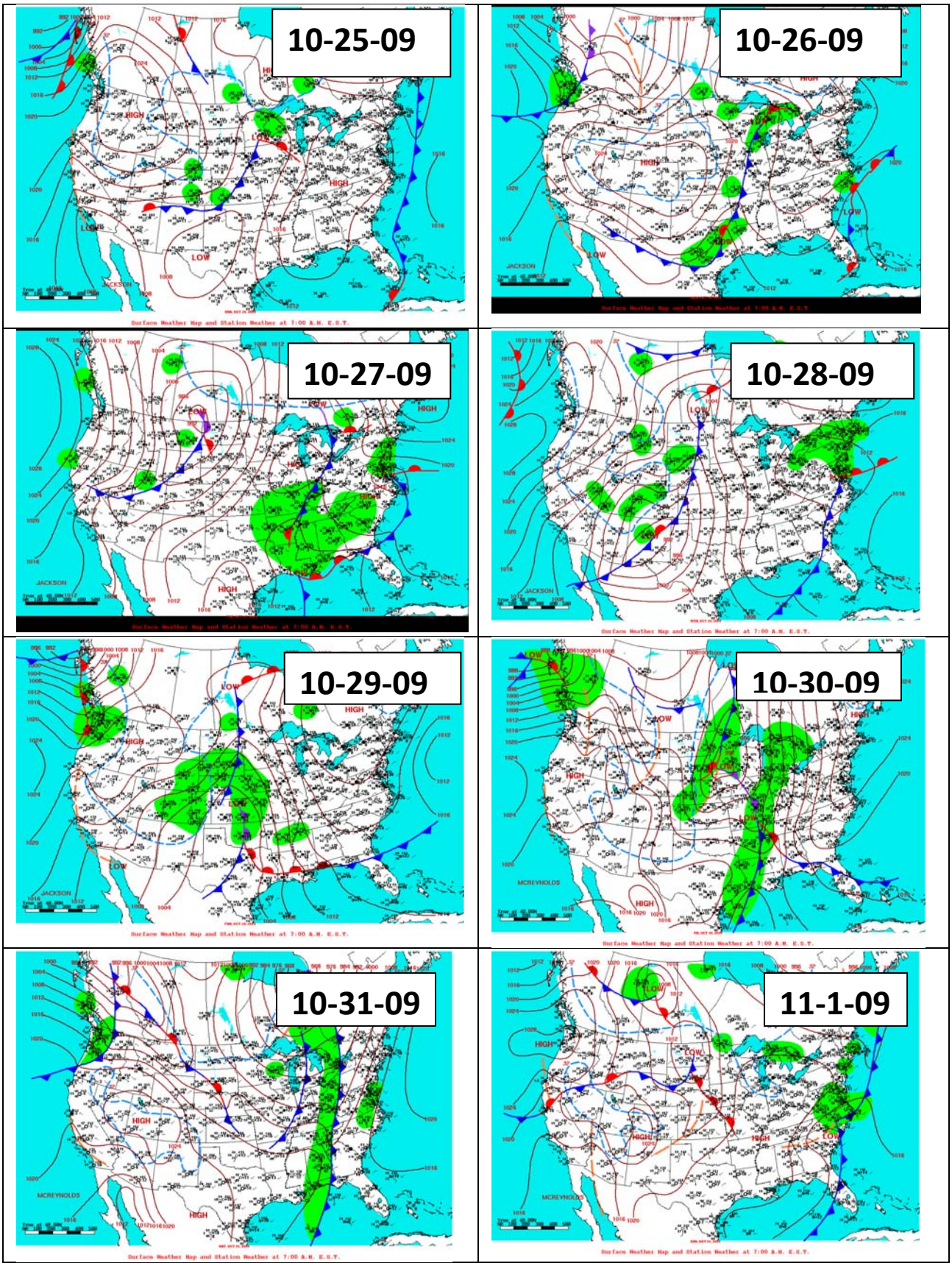
MCREYNOLDS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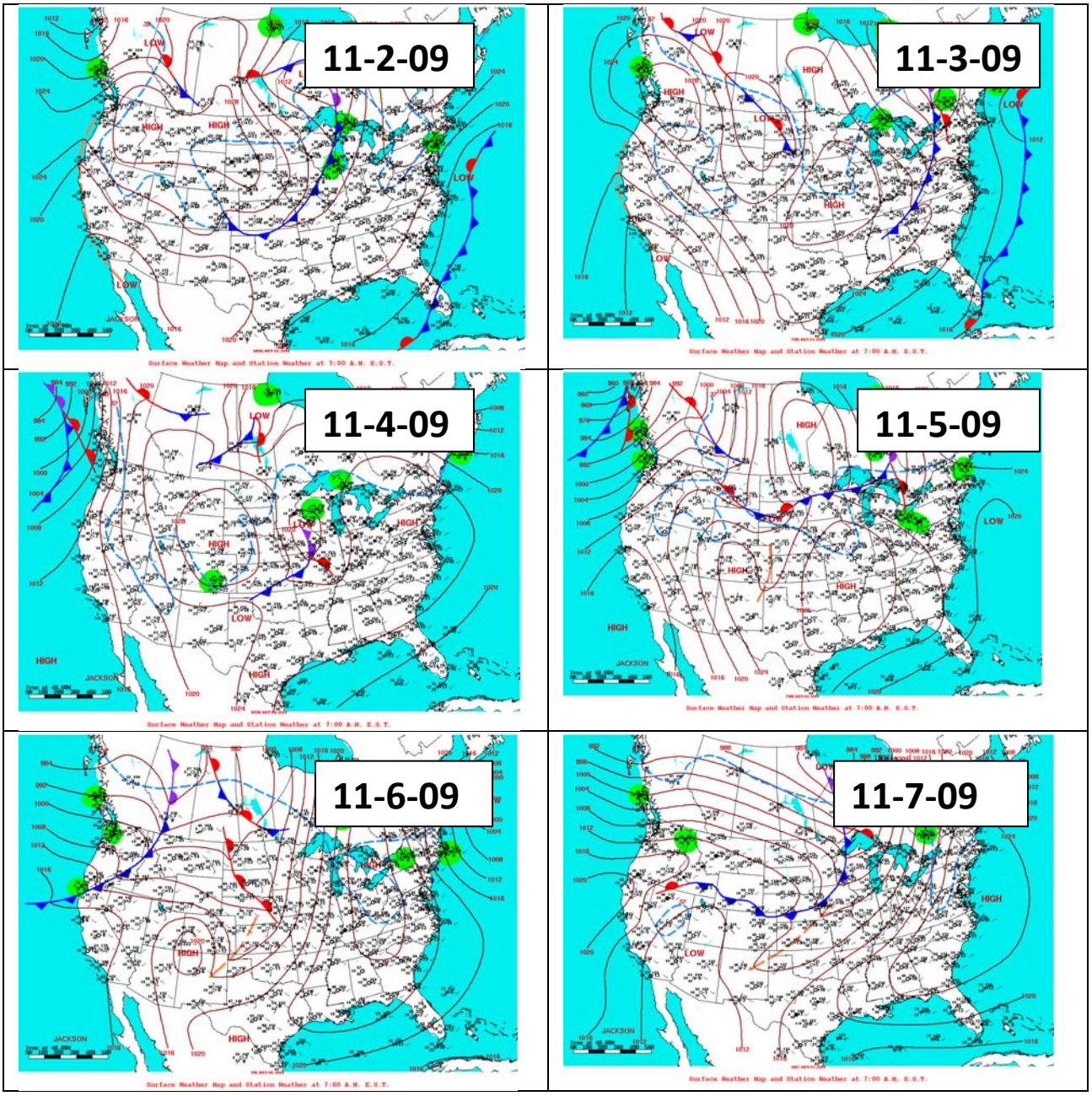
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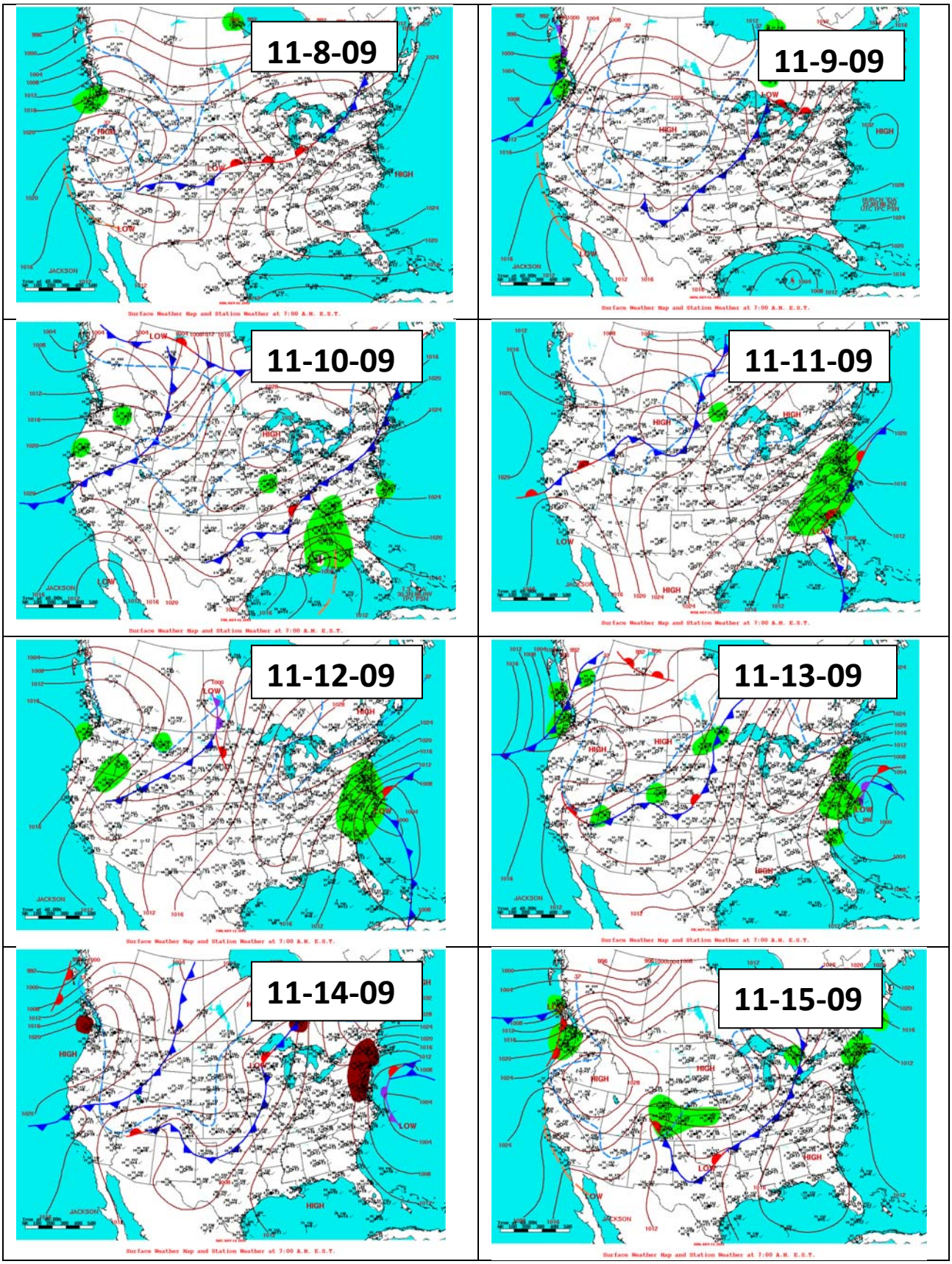
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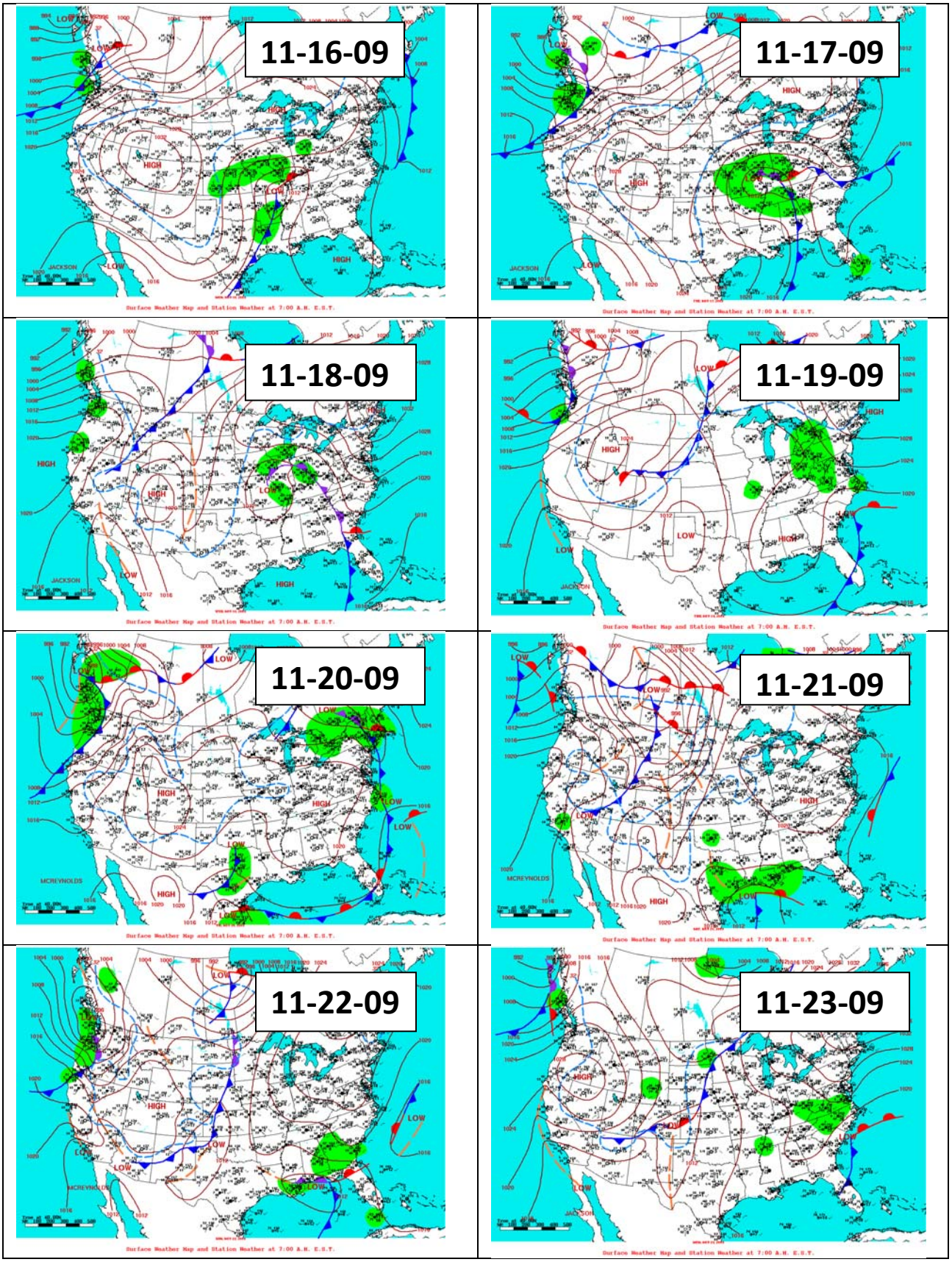
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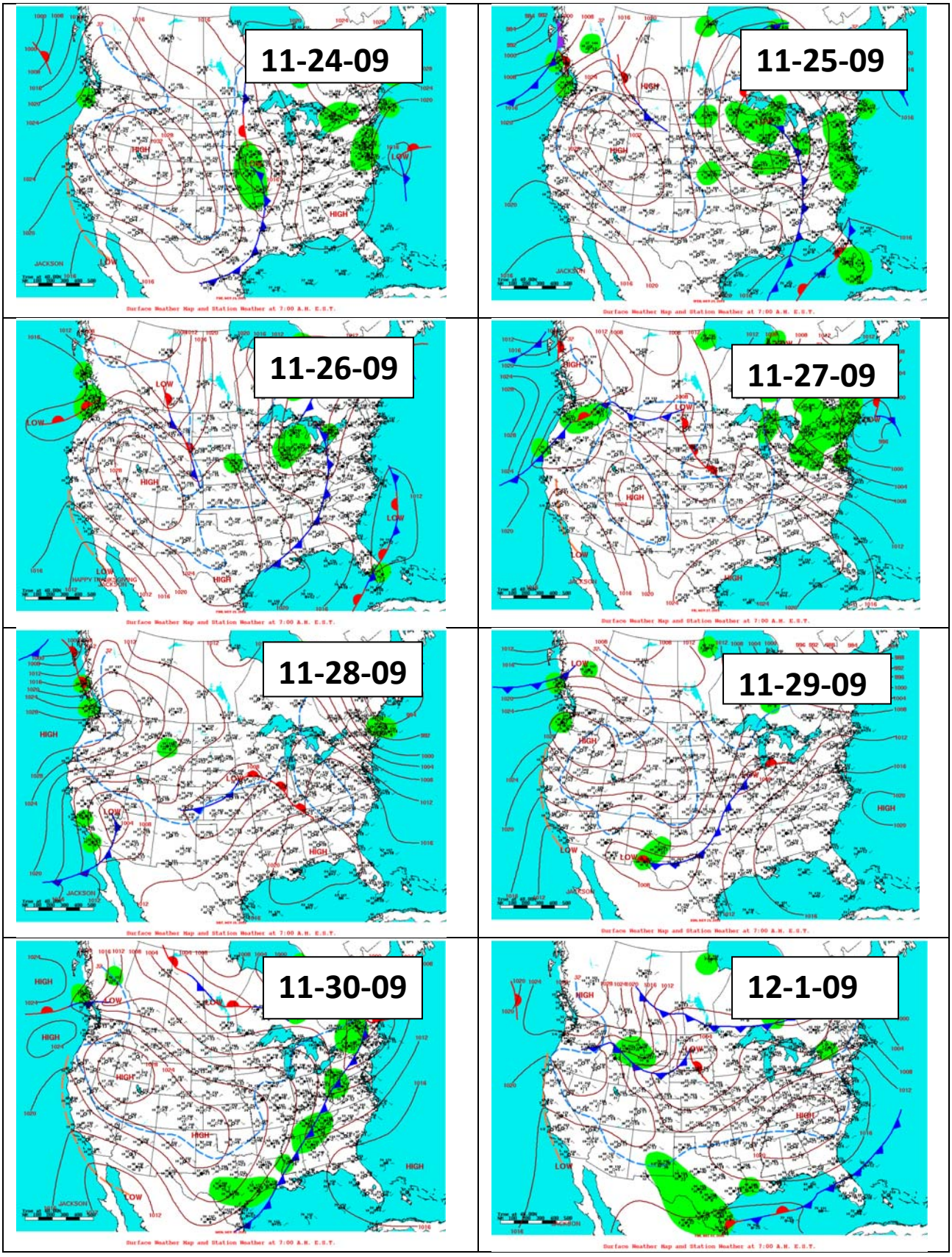
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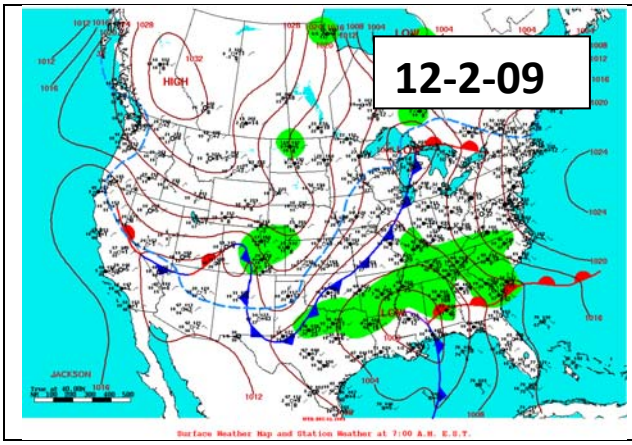
12-2-09
HIGH
LOW
JACKSON

6.10 Daily weather conditions

Date (DD/MM/YYYY)	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 2				
10/25/2007	101.13	255	N/A	21.7
10/26/2007	101.43	287	N/A	20.3
10/27/2007	101.58	739	N/A	19.3
10/28/2007	102.11	859	N/A	15.2
10/29/2007	102.68	693	N/A	10.8
10/30/2007	102.60	700	N/A	9.3
10/31/2007	102.19	678	N/A	13.4
11/1/2007	101.48	671	N/A	16.7
11/2/2007	101.32	656	N/A	14.9
11/3/2007	101.05	684	N/A	11.9
11/4/2007	101.12	667	N/A	9.1
11/5/2007	101.32	657	N/A	9.5
11/6/2007	100.99	754	N/A	14.2
11/7/2007	101.68	650	N/A	4.9
Period 3				
2/13/2008	99.56	219	100%	16.0
2/14/2008	101.28	741	98%	5.6
2/15/2008	102.02	544	70%	6.2
2/16/2008	101.79	692	62%	10.5
2/17/2008	101.58	768	78%	10.6
2/18/2008	100.31	716	77%	18.6
2/19/2008	101.20	754	24%	9.4
2/20/2008	101.56	765	47%	8.3
2/21/2008	102.00	495	4%	7.2
2/22/2008	101.26	261	100%	3.4
2/23/2008	100.78	444	93%	10.2
2/24/2008	101.49	719	54%	8.8
2/25/2008	101.18	764	55%	7.8
2/26/2008	100.23	596	87%	12.1
2/27/2008	100.07	944	17%	8.5
2/28/2008	101.79	793	0%	1.4
2/29/2008	102.60	775	59%	3.6
3/1/2008	101.83	777	60%	12.5
3/2/2008	101.96	785	57%	9.3
3/3/2008	102.04	889	52%	11.3
3/4/2008	101.11	432	93%	17.5
3/5/2008	99.90	802	49%	14.9
Period 4				
3/6/2008	NA	811	61%	11.5
3/7/2008	NA	221	98%	12.5

Date (DD/MM/YYYY)	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
3/8/2008	NA	997	58%	15.9
3/9/2008	NA	842	0%	5.3
3/10/2008	NA	830	58%	7.2
3/11/2008	NA	795	36%	10.7
3/12/2008	NA	834	17%	13.7
3/13/2008	NA	846	47%	12.7
3/14/2008	NA	728	0%	16.0
3/15/2008	NA	817	40%	16.3
3/16/2008	NA	943	47%	14.0
3/17/2008	NA	875	8%	9.6
3/18/2008	NA	664	43%	8.7
3/19/2008	NA	911	40%	18.0
3/20/2008	NA	887	38%	16.2
3/21/2008	NA	910	28%	10.3
3/22/2008	NA	995	8%	15.6
3/23/2008	NA	881	0%	12.1
3/24/2008	NA	1070	17%	8.2
3/25/2008	NA	888	43%	6.6
3/26/2008	NA	915	0%	9.1
Period 6				
9/25/2008	100.62	136	44%	17.5
9/26/2008	100.37	390	66%	20.1
9/27/2008	100.80	775	67%	20.9
9/28/2008	100.91	856	58%	22.1
9/29/2008	101.10	808	66%	21.7
9/30/2008	100.86	644	70%	21.3
10/1/2008	100.27	765	78%	20.5
10/2/2008	100.71	750	39%	15.2
10/3/2008	101.18	726	60%	14.8
10/4/2008	101.66	757	66%	16.7
10/5/2008	101.93	764	67%	18.3
10/6/2008	101.91	701	60%	18.0
10/7/2008	102.05	673	60%	17.6
10/8/2008	101.69	797	67%	16.7
10/9/2008	101.16	740	53%	20.6
10/10/2008	101.36	750	61%	21.0
10/11/2008	101.77	279	91%	20.0
10/12/2008	102.26	868	55%	19.6
10/13/2008	102.43	782	68%	19.0
10/14/2008	102.12	559	94%	14.1
Period 7				
2/3/2009	N/A	N/A	N/A	N/A

Date (DD/MM/YYYY)	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
2/4/2009	101.93	N/A	0%	0.8
2/5/2009	102.65	689	1%	-2.9
2/6/2009	102.77	658	52%	9.1
2/7/2009	102.52	668	24%	8.4
2/8/2009	102.09	652	1%	14.5
2/9/2009	102.20	681	58%	11.2
2/10/2009	102.12	746	55%	13.1
2/11/2009	101.57	638	60%	16.5
2/12/2009	100.86	866	4%	17.7
2/13/2009	101.34	695	13%	12.7
2/14/2009	100.99	463	22%	10.5
2/15/2009	101.21	701	77%	8.7
2/16/2009	101.57	826	72%	5.3
2/17/2009	102.15	733	59%	1.9
2/18/2009	101.16	285	78%	6.5
2/19/2009	99.90	833	50%	14.0
2/20/2009	101.24	752	0%	3.4
2/21/2009	102.02	753	45%	2.2
2/22/2009	101.46	846	19%	7.9
2/23/2009	102.37	765	1%	1.0
Period 8				
5/12/2009	101.70	385	N/A	21.2
5/13/2009	102.03	1034	N/A	17.2
5/14/2009	101.92	976	N/A	18.9
5/15/2009	101.79	1079	N/A	21.8
5/16/2009	101.56	1025	N/A	22.5
5/17/2009	101.17	1050	N/A	20.3
5/18/2009	101.72	718	N/A	12.0
5/19/2009	102.15	1134	N/A	13.2
5/20/2009	102.22	1094	N/A	16.2
5/21/2009	102.04	1005	N/A	20.7
5/22/2009	101.78	1059	N/A	21.1
5/23/2009	101.61	1123	N/A	21.7
5/24/2009	101.40	1149	N/A	22.6
5/25/2009	101.17	962	N/A	21.5
5/26/2009	101.07	762	N/A	21.8
5/27/2009	100.85	1138	N/A	22.7
5/28/2009	100.57	1057	N/A	23.6
5/29/2009	100.45	1071	N/A	23.8
5/30/2009	100.55	1150	N/A	22.0
5/31/2009	100.69	937	N/A	23.4
6/1/2009	101.11	1074	N/A	24.0

Date (DD/MM/YYYY)	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
6/2/2009	101.41	697	N/A	20.7
Period 9				
6/3/2009	101.27	996	N/A	24.6
6/4/2009	100.94	1115	N/A	23.5
6/4/2009	100.40	1054	N/A	23.6
6/5/2009	100.86	1013	N/A	20.2
6/6/2009	101.22	1089	N/A	22.5
6/7/2009	101.07	1098	N/A	23.9
6/8/2009	100.90	1048	N/A	24.6
6/9/2009	100.90	1038	N/A	22.6
6/10/2009	100.72	1011	N/A	25.0
6/11/2009	100.54	996	N/A	25.3
6/12/2009	100.62	1012	N/A	26.7
6/13/2009	100.77	1021	N/A	25.7
6/14/2009	101.01	1048	N/A	24.5
6/15/2009	101.14	965	N/A	21.9
6/16/2009	101.33	889	N/A	22.7
6/17/2009	100.92	1000	N/A	25.2
6/18/2009	100.64	1075	N/A	27.2
6/19/2009	100.46	1094	N/A	28.5
6/20/2009	100.14	1030	N/A	28.5
6/21/2009	100.12	1064	N/A	24.7
6/22/2009	100.15	673	N/A	21.0
Period 10				
9/24/2009	101.30	77	85%	26.7
9/25/2009	101.36	877	72%	24.8
9/26/2009	101.50	308	76%	20.0
9/27/2009	100.46	822	61%	23.1
9/28/2009	100.31	783	56%	21.4
9/29/2009	100.53	833	14%	19.6
9/30/2009	101.04	830	52%	15.0
10/1/2009	101.32	801	59%	15.2
10/2/2009	101.07	788	63%	16.8
10/3/2009	100.81	788	60%	21.4
10/4/2009	101.19	853	56%	17.1
10/5/2009	101.43	211	93%	15.5
10/6/2009	101.04	208	98%	17.3
10/7/2009	100.79	870	64%	21.7
10/8/2009	101.60	774	54%	16.6
10/9/2009	101.37	764	61%	19.8
10/10/2009	100.96	828	64%	25.2
10/11/2009	101.68	564	54%	18.1

Date (DD/MM/YYYY)	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
10/12/2009	101.93	226	80%	15.7
10/13/2009	101.65	732	64%	17.4
10/14/2009	101.55	173	91%	13.5
10/15/2009	100.77	480	75%	11.3
10/16/2009	100.44	687	68%	13.0
10/17/2009	100.93	971	52%	11.5
10/18/2009	101.37	712	25%	8.5
10/19/2009	102.01	726	41%	9.5
10/20/2009	102.09	720	64%	9.2
10/21/2009	102.02	719	65%	11.9
10/22/2009	101.69	735	66%	14.1
10/23/2009	101.20	926	62%	19.6
10/24/2009	100.64	607	69%	23.0
10/25/2009	101.11	580	55%	16.3
10/26/2009	101.67	198	80%	11.6
10/27/2009	101.42	374	86%	14.6
10/28/2009	100.83	801	62%	22.1
10/29/2009	101.61	686	64%	15.9
10/30/2009	101.84	562	66%	15.7
10/31/2009	101.22	601	89%	19.6
11/1/2009	100.98	147	100%	18.2
11/2/2009	101.49	320	66%	12.1
11/3/2009	101.66	644	66%	12.0
11/4/2009	102.02	627	64%	12.1
11/5/2009	101.84	645	59%	12.5
11/6/2009	102.19	660	59%	8.2
11/7/2009	102.25	631	63%	7.5
11/8/2009	102.13	619	62%	11.8
11/9/2009	102.40	661	66%	13.1
11/10/2009	101.95	404	85%	16.6
11/11/2009	100.89	301	100%	14.9
11/12/2009	100.14	157	100%	10.1
11/13/2009	100.11	299	77%	10.6
11/14/2009	100.65	490	55%	14.0
11/15/2009	101.11	622	70%	12.9
11/16/2009	101.31	606	71%	12.8
11/17/2009	101.48	709	68%	11.9
11/18/2009	101.69	327	97%	13.9
11/19/2009	101.49	630	73%	19.1
11/20/2009	101.46	589	67%	16.2
11/21/2009	101.60	562	61%	10.6
11/22/2009	101.76	651	79%	8.5

Date (DD/MM/YYYY)	**Barometric pressure** (kPA)	**Max solar radiation** (Wm^{-2})	**Wetness** (%)	**Air temperature** (°C)
11/23/2009	101.58	135	100%	11.5
11/24/2009	101.65	104	80%	11.1
11/25/2009	101.43	273	80%	10.3
11/26/2009	100.87	585	79%	8.8
11/27/2009	100.70	555	28%	8.1
11/28/2009	101.24	559	61%	5.4
11/29/2009	101.37	584	51%	10.0
11/30/2009	100.86	578	29%	13.5
12/1/2009	101.46	657	59%	7.5
12/1/2009	101.49	155	71%	6.8
12/1/2009	101.49	155	71%	6.8

6.11 Daily lagoon conditions

Date (MM/DD/YYYY)	Air Temperature (°C)	Lagoon Temp (°C)	Lagoon pH	ORP (mV)
Period 2				
10/25/2007	21.7	NA	7.93	-473
10/26/2007	20.3	NA	7.95	-497
10/27/2007	19.3	NA	8.00	-451
10/28/2007	15.2	NA	7.99	-543
10/29/2007	10.8	NA	8.02	-548
10/30/2007	9.3	NA	8.06	-542
10/31/2007	13.4	NA	8.07	-546
11/1/2007	16.7	NA	8.06	-550
11/2/2007	14.9	NA	8.10	-545
11/3/2007	11.9	NA	8.12	-542
11/4/2007	9.1	NA	8.10	-546
11/5/2007	9.5	NA	8.10	-554
11/6/2007	14.2	NA	8.08	-540
11/7/2007	4.9	NA	8.04	-558
Period 3				
2/13/2008	16.0	N/A	N/A	N/A
2/14/2008	5.6	14.1	7.52	-377
2/15/2008	6.2	13.5	7.52	-449
2/16/2008	10.5	13.3	7.50	-481
2/17/2008	10.6	13.3	7.53	-472
2/18/2008	18.6	14.8	7.56	-415
2/19/2008	9.4	14.9	7.54	-489
2/20/2008	8.3	14.7	7.53	-492
2/21/2008	7.2	13.9	7.50	-500
2/22/2008	3.4	12.3	7.53	-486
2/23/2008	10.2	11.8	7.55	-491
2/24/2008	8.8	12.1	7.54	-502
2/25/2008	7.8	12.3	7.55	-478
2/26/2008	12.1	13.0	7.53	-464
2/27/2008	8.5	12.6	7.54	-480
2/28/2008	1.4	11.5	7.57	-480
2/29/2008	3.6	11.7	7.57	-473
3/1/2008	12.5	12.2	7.56	-488
3/2/2008	9.3	13.1	7.55	-486
3/3/2008	11.3	13.5	7.55	-463
3/4/2008	17.5	14.2	7.53	-461
3/5/2008	14.9	15.3	7.56	-441
Period 4				
3/6/2008	11.5	16.2	7.46	-490
3/7/2008	12.5	16.2	7.47	-484

Date (MM/DD/YYYY)	Air Temperature (°C)	Lagoon Temp (°C)	Lagoon pH	ORP (mV)
3/8/2008	15.9	16.8	7.50	-476
3/9/2008	5.3	16.2	7.49	-515
3/10/2008	7.2	16.4	7.49	-506
3/11/2008	10.7	16.4	7.48	-524
3/12/2008	13.7	16.4	7.47	-522
3/13/2008	12.7	17.2	7.47	-505
3/14/2008	16.0	17.1	7.47	-532
3/15/2008	16.3	17.3	7.46	-533
3/16/2008	14.0	17.6	7.48	-509
3/17/2008	9.6	17.5	7.48	-507
3/18/2008	8.7	17.0	7.50	-496
3/19/2008	18.0	17.3	7.50	-480
3/20/2008	16.2	18.0	7.51	-497
3/21/2008	10.3	18.1	7.49	-507
3/22/2008	15.6	18.3	7.48	-529
3/23/2008	12.1	18.1	7.48	-522
3/24/2008	8.2	17.5	7.49	-511
3/25/2008	6.6	16.7	7.51	-505
3/26/2008	9.1	16.5	7.51	-520
Period 6				
9/25/2008	17.5	N/A	7.73	-345
9/26/2008	20.1	N/A	7.76	-405
9/27/2008	20.9	N/A	7.75	-511
9/28/2008	22.1	N/A	7.77	-525
9/29/2008	21.7	N/A	7.76	-540
9/30/2008	21.3	N/A	7.76	-538
10/1/2008	20.5	N/A	7.71	-536
10/2/2008	15.2	N/A	7.75	-533
10/3/2008	14.8	N/A	7.73	-503
10/4/2008	16.7	N/A	7.74	-312
10/5/2008	18.3	N/A	7.78	-430
10/6/2008	18.0	N/A	7.76	-492
10/7/2008	17.6	N/A	7.76	-432
10/8/2008	16.7	N/A	7.77	-402
10/9/2008	20.6	N/A	7.76	-498
10/10/2008	21.0	N/A	7.73	-509
10/11/2008	20.0	N/A	7.72	-488
10/12/2008	19.6	N/A	7.68	-489
10/13/2008	19.0	N/A	7.67	-498
10/14/2008	14.1	N/A	7.69	-484
Period 7				
2/3/2009	N/A	N/A	N/A	N/A

Date (MM/DD/YYYY)	Air Temperature (°C)	Lagoon Temp (°C)	Lagoon pH	ORP (mV)
2/4/2009	0.8	N/A	N/A	N/A
2/5/2009	-2.9	N/A	N/A	N/A
2/6/2009	9.1	12.3	8.36	-108
2/7/2009	8.4	13.5	8.33	-122
2/8/2009	14.5	9.0	8.34	-129
2/9/2009	11.2	9.7	8.31	-271
2/10/2009	13.1	12.3	8.30	-183
2/11/2009	16.5	14.1	8.28	-209
2/12/2009	17.7	13.9	8.26	-229
2/13/2009	12.7	13.5	8.26	-359
2/14/2009	10.5	13.7	8.27	-307
2/15/2009	8.7	12.5	8.28	-420
2/16/2009	5.3	12.0	8.29	-410
2/17/2009	1.9	10.3	8.32	-435
2/18/2009	6.5	10.1	8.34	-283
2/19/2009	14.0	11.2	8.31	-312
2/20/2009	3.4	10.7	8.31	-486
2/21/2009	2.2	10.3	8.32	-410
2/22/2009	7.9	10.2	8.33	-406
2/23/2009	1.0	8.9	8.36	-488
Period 8				
5/12/2009	21.2	N/A	N/A	N/A
5/13/2009	17.2	N/A	N/A	N/A
5/14/2009	18.9	24.4	7.42	-448
5/15/2009	21.8	24.4	7.42	-473
5/16/2009	22.5	25.2	7.40	-494
5/17/2009	20.3	25.4	7.41	-502
5/18/2009	12.0	22.5	7.55	-513
5/19/2009	13.2	21.0	7.59	-518
5/20/2009	16.2	20.6	7.61	-516
5/21/2009	20.7	21.5	7.59	-522
5/22/2009	21.1	22.6	7.57	-526
5/23/2009	21.7	23.8	7.53	-530
5/24/2009	22.6	24.9	7.53	-530
5/25/2009	21.5	25.0	7.53	-533
5/26/2009	21.8	25.0	7.53	-537
5/27/2009	22.7	25.1	7.52	-538
5/28/2009	23.6	26.0	7.47	-543
5/29/2009	23.8	26.4	7.43	-537
5/30/2009	22.0	26.0	7.49	-534
5/31/2009	23.4	26.8	7.48	-539
6/1/2009	24.0	27.3	7.47	-539

Date (MM/DD/YYYY)	Air Temperature (°C)	Lagoon Temp (°C)	Lagoon pH	ORP (mV)
6/2/2009	20.7	27.5	7.44	-540
Period 9				
6/3/2009	24.6	27.7	7.37	-497
6/4/2009	23.5	28.3	7.34	-505
6/4/2009	23.6	27.8	7.39	-512
6/5/2009	20.2	27.2	7.43	-523
6/6/2009	22.5	26.8	7.46	-527
6/7/2009	23.9	27.3	7.47	-533
6/8/2009	24.6	27.9	7.44	-540
6/9/2009	22.6	27.4	7.49	-534
6/10/2009	25.0	27.6	7.49	-540
6/11/2009	25.3	28.0	7.46	-549
6/12/2009	26.7	28.3	7.42	-550
6/13/2009	25.7	28.9	7.43	-546
6/14/2009	24.5	29.1	7.45	-536
6/15/2009	21.9	28.4	7.48	-545
6/16/2009	22.7	28.0	7.51	-548
6/17/2009	25.2	28.2	7.51	-549
6/18/2009	27.2	28.9	7.49	-550
6/19/2009	28.5	29.7	7.46	-548
6/20/2009	28.5	30.2	7.46	-547
6/21/2009	24.7	30.1	7.46	-546
6/22/2009	21.0	N/A	N/A	N/A
Period 10				
9/24/2009	26.7	N/A	N/A	N/A
9/25/2009	24.8	N/A	N/A	N/A
9/26/2009	20.0	N/A	N/A	N/A
9/27/2009	23.1	N/A	N/A	N/A
9/28/2009	21.4	N/A	N/A	N/A
9/29/2009	19.6	N/A	N/A	N/A
9/30/2009	15.0	N/A	N/A	N/A
10/1/2009	15.2	N/A	N/A	N/A
10/2/2009	16.8	N/A	N/A	N/A
10/3/2009	21.4	N/A	N/A	N/A
10/4/2009	17.1	N/A	N/A	N/A
10/5/2009	15.5	N/A	N/A	N/A
10/6/2009	17.3	N/A	N/A	N/A
10/7/2009	21.7	N/A	N/A	N/A
10/8/2009	16.6	N/A	N/A	N/A
10/9/2009	19.8	N/A	N/A	N/A
10/10/2009	25.2	N/A	N/A	N/A
10/11/2009	18.1	N/A	N/A	N/A

Date (MM/DD/YYYY)	Air Temperature (°C)	Lagoon Temp (°C)	Lagoon pH	ORP (mV)
10/12/2009	15.7	N/A	N/A	N/A
10/13/2009	17.4	N/A	N/A	N/A
10/14/2009	13.5	N/A	N/A	N/A
10/15/2009	11.3	N/A	N/A	N/A
10/16/2009	13.0	N/A	N/A	N/A
10/17/2009	11.5	N/A	N/A	N/A
10/18/2009	8.5	N/A	N/A	N/A
10/19/2009	9.5	N/A	N/A	N/A
10/20/2009	9.2	N/A	N/A	N/A
10/21/2009	11.9	N/A	N/A	N/A
10/22/2009	14.1	N/A	N/A	N/A
10/23/2009	19.6	N/A	N/A	N/A
10/24/2009	23.0	N/A	N/A	N/A
10/25/2009	16.3	N/A	N/A	N/A
10/26/2009	11.6	N/A	N/A	N/A
10/27/2009	14.6	18.9	7.17	-412
10/28/2009	22.1	19.1	7.13	-483
10/29/2009	15.9	19.7	7.20	-517
10/30/2009	15.7	19.9	7.26	-531
10/31/2009	19.6	20.0	7.17	-521
11/1/2009	18.2	20.4	7.14	-515
11/2/2009	12.1	20.0	7.43	-535
11/3/2009	12.0	19.1	7.20	-527
11/4/2009	12.1	18.7	7.32	-530
11/5/2009	12.5	18.4	7.38	-528
11/6/2009	8.2	18.1	7.44	-528
11/7/2009	7.5	17.7	7.40	-509
11/8/2009	11.8	17.6	7.28	-514
11/9/2009	13.1	17.3	7.39	-524
11/10/2009	16.6	17.2	7.46	-521
11/11/2009	14.9	16.8	7.69	-405
11/12/2009	10.1	15.1	7.79	-490
11/13/2009	10.6	13.4	7.84	-504
11/14/2009	14.0	13.3	7.82	-523
11/15/2009	12.9	13.9	7.77	-524
11/16/2009	12.8	14.5	7.73	-523
11/17/2009	11.9	14.8	7.71	-522
11/18/2009	13.9	15.1	7.69	-517
11/19/2009	19.1	15.9	7.69	-521
11/20/2009	16.2	16.8	7.63	-524
11/21/2009	10.6	16.7	7.61	-523
11/22/2009	8.5	16.0	7.60	-520

Date (MM/DD/YYYY)	Air Temperature (°C)	Lagoon Temp (°C)	Lagoon pH	ORP (mV)
11/23/2009	11.5	15.3	7.64	-458
11/24/2009	11.1	14.8	7.63	-358
11/25/2009	10.3	14.5	7.62	-171
11/26/2009	8.8	N/A	N/A	N/A
11/27/2009	8.1	N/A	N/A	N/A
11/28/2009	5.4	N/A	N/A	N/A
11/29/2009	10.0	N/A	N/A	N/A
11/30/2009	13.5	N/A	N/A	N/A
12/1/2009	7.5	N/A	N/A	N/A
12/2/2009	6.8	N/A	N/A	N/A
12/3/2009	6.8	N/A	N/A	N/A

6.12 Daily site emissions and data completeness

6.12.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid values: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Missing downwind NH_3: Number of ½ h periods invalidated because at least 1 TDL path was either missing or else had invalid concentration values
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

	Valid	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 2										
10/25/2007	0	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/26/2007	9	8	5	29.9	12.8	12.8	51.1	46.6	5.8	47.9
10/27/2007	4	8	29	67.4	38.5	36.1	119.4	104.8	13.1	107.8
10/28/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/29/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/30/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/31/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/1/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/2/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/3/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/4/2007	0	0	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/5/2007	0	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/6/2007	1	0	45	32.8	N/A	32.8	32.8	51.0	6.4	52.4
11/7/2007	0	0	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 3										
2/14/2008	1	0	14	13.9	N/A	13.9	13.9	21.6	2.7	22.2
2/15/2008	0	0	39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/16/2008	1	0	43	1.1	N/A	1.1	1.1	1.7	0.2	1.8
2/17/2008	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
2/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/19/2008	2	0	43	15.8	14.5	5.6	26.1	24.6	3.1	25.3
2/20/2008	0	1	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/21/2008	8	0	31	1.3	0.3	1.1	1.7	1.9	0.2	2.0
2/22/2008	2	0	40	3.3	1.6	2.2	4.4	5.2	0.6	5.3
2/23/2008	4	0	41	9.4	3.2	6.1	13.9	14.7	1.8	15.1
2/24/2008	9	0	31	2.4	2.5	0.0	7.2	3.7	0.5	3.9
2/25/2008	1	0	33	9.4	N/A	9.4	9.4	14.7	1.8	15.1
2/26/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/27/2008	4	0	40	13.1	5.1	6.1	17.8	20.3	2.5	20.9
2/28/2008	14	0	30	14.0	3.7	8.3	22.2	21.8	2.7	22.5
2/29/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	0	1	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/3/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4										
3/6/2008	1	0	7	3.3	N/A	3.3	3.3	5.2	0.6	5.3
3/7/2008	2	0	17	1.9	0.4	1.7	2.2	3.0	0.4	3.1
3/8/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/9/2008	0	0	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	1	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	3	2	23	18.1	10.9	6.1	27.2	28.2	3.5	29.0
3/12/2008	2	3	34	36.4	10.6	28.9	43.9	56.6	7.1	58.2
3/13/2008	0	0	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	1	0	46	26.7	N/A	26.7	26.7	41.5	5.2	42.7
3/16/2008	22	0	22	28.1	9.5	5.0	46.1	43.7	5.5	45.0
3/17/2008	26	0	9	10.9	9.4	1.1	32.8	17.0	2.1	17.5
3/18/2008	1	0	40	3.3	N/A	3.3	3.3	5.2	0.6	5.3
3/19/2008	0	0	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	0	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2008	14	0	11	11.3	8.2	2.2	24.4	17.6	2.2	18.1
3/24/2008	34	0	7	16.1	12.3	1.7	53.3	25.1	3.1	25.8
3/25/2008	15	2	20	10.9	5.2	2.8	20.6	17.0	2.1	17.5
3/26/2008	0	0	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6										
9/25/2008	0	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/28/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/29/2008	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/30/2008	0	9	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/1/2008	9	1	34	44.6	19.6	16.1	72.2	69.3	8.7	71.3
10/2/2008	26	0	13	32.2	10.7	15.0	66.1	50.0	6.3	51.5
10/3/2008	4	8	26	20.4	6.9	12.2	28.9	31.8	4.0	32.7
10/4/2008	6	2	23	41.1	22.5	17.8	82.8	63.9	8.0	65.8
10/5/2008	2	1	37	29.2	2.0	27.8	30.6	45.4	5.7	46.7
10/6/2008	6	0	33	19.8	10.0	6.7	33.9	30.8	3.9	31.7
10/7/2008	2	3	39	2.5	0.4	2.2	2.8	3.9	0.5	4.0
10/8/2008	2	13	27	30.3	3.5	27.8	32.8	47.1	5.9	48.4
10/9/2008	5	12	7	30.9	12.6	20.6	52.2	48.0	6.0	49.4
10/10/2008	8	2	16	6.9	4.1	1.7	12.8	10.7	1.3	11.0
10/11/2008	3	0	40	4.4	1.5	2.8	5.6	6.9	0.9	7.1
10/12/2008	7	2	31	3.0	1.7	1.7	6.1	4.7	0.6	4.8
10/13/2008	2	0	32	8.6	0.4	8.3	8.9	13.4	1.7	13.8
10/14/2008	0	0	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7										
2/5/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2009	0	9	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2009	6	30	1	5.1	1.6	3.3	7.2	7.9	1.0	8.1
2/8/2009	15	21	0	10.3	5.1	5.0	23.3	16.1	2.0	16.5
2/9/2009	3	7	15	2.0	0.6	1.7	2.8	3.2	0.4	3.3
2/10/2009	1	19	3	8.9	N/A	8.9	8.9	13.8	1.7	14.2
2/11/2009	0	24	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/12/2009	36	0	0	18.2	11.6	5.0	44.4	28.3	3.5	29.1
2/13/2009	31	0	0	20.3	8.2	6.7	34.4	31.5	3.9	32.4
2/14/2009	5	10	0	8.8	1.6	7.2	10.6	13.7	1.7	14.0
2/15/2009	12	5	17	3.5	1.2	1.7	5.0	5.5	0.7	5.6
2/16/2009	23	0	0	11.1	6.8	3.9	25.0	17.2	2.2	17.7
2/17/2009	22	0	0	6.6	2.8	1.1	11.1	10.3	1.3	10.6
2/18/2009	0	19	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/19/2009	18	9	0	18.9	8.3	2.2	31.1	29.4	3.7	30.2
2/20/2009	43	0	0	18.4	4.8	9.4	26.7	28.6	3.6	29.4
2/21/2009	3	7	11	14.1	9.9	2.8	21.1	21.9	2.7	22.5
2/22/2009	16	13	0	18.7	8.6	3.9	33.9	29.1	3.6	29.9
2/23/2009	28	0	1	15.9	5.3	7.8	28.9	24.7	3.1	25.4
Period 8										
5/13/2009	0	13	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/14/2009	0	17	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/15/2009	0	16	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2009	6	25	11	34.9	14.9	16.1	53.3	54.3	6.8	55.9
5/17/2009	11	5	18	19.8	19.9	-3.9	58.3	30.9	3.9	31.8

	Valid	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/18/2009	22	0	7	6.2	3.6	1.7	16.7	9.6	1.2	9.9
5/19/2009	16	0	6	4.8	1.5	1.7	7.2	7.5	0.9	7.7
5/20/2009	17	9	0	4.0	2.4	-2.2	7.2	6.1	0.8	6.3
5/21/2009	1	21	7	2.8	N/A	2.8	2.8	4.3	0.5	4.4
5/22/2009	1	18	4	27.8	N/A	27.8	27.8	43.2	5.4	44.4
5/23/2009	0	4	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2009	0	20	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2009	0	23	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2009	0	23	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2009	1	5	23	33.3	N/A	33.3	33.3	51.8	6.5	53.3
5/28/2009	1	16	20	38.3	N/A	38.3	38.3	59.6	7.5	61.3
5/29/2009	6	9	19	26.0	12.2	13.3	48.9	40.5	5.1	41.6
5/30/2009	9	1	29	13.4	8.5	5.0	32.8	20.8	2.6	21.4
5/31/2009	3	2	39	16.5	3.8	12.2	19.4	25.6	3.2	26.4
6/1/2009	0	13	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/2/2009	1	2	20	39.4	N/A	39.4	39.4	61.3	7.7	63.1
Period 9										
6/3/2009	3	20	18	22.0	9.8	11.7	31.1	34.3	4.3	35.3
6/4/2009	0	17	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/5/2009	7	23	2	34.6	8.0	22.8	46.1	53.8	6.7	55.4
6/6/2009	11	4	2	11.7	6.5	2.8	26.7	18.1	2.3	18.7
6/7/2009	2	11	0	6.7	2.4	5.0	8.3	10.4	1.3	10.7
6/8/2009	0	15	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	5	11	18	41.0	13.4	25.0	60.6	63.8	8.0	65.6
6/10/2009	1	5	11	21.7	N/A	21.7	21.7	33.7	4.2	34.7
6/11/2009	0	20	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/12/2009	10	14	11	40.7	12.8	27.8	63.3	63.2	7.9	65.1
6/13/2009	3	3	25	60.2	5.6	56.7	66.7	93.6	11.7	96.3
6/14/2009	19	1	15	35.3	19.5	15.0	81.1	54.9	6.9	56.5
6/15/2009	0	9	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/16/2009	10	8	19	6.0	5.3	-0.6	13.3	9.3	1.2	9.6
6/17/2009	2	20	7	1.9	0.4	1.7	2.2	3.0	0.4	3.1
6/18/2009	6	12	18	53.8	13.3	34.4	70.6	83.7	10.5	86.1
6/19/2009	18	8	16	47.3	23.6	18.9	85.6	73.5	9.2	75.6
6/20/2009	14	3	17	56.0	27.8	17.2	115.6	87.0	10.9	89.5
6/21/2009	41	0	1	75.8	23.9	27.2	123.3	117.8	14.7	121.2
6/22/2009	8	0	9	26.9	9.4	7.2	36.7	41.9	5.2	43.1
Period 10										
9/24/2009	0	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2009	1	10	36	11.1	N/A	11.1	11.1	17.3	2.2	17.8
9/26/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2009	1	0	47	17.8	N/A	17.8	17.8	27.6	3.5	28.4
9/28/2009	3	12	27	36.5	6.5	31.7	43.9	56.7	7.1	58.4

	Valid	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/29/2009	3	0	24	13.7	3.8	9.4	16.7	21.3	2.7	21.9
9/30/2009	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/1/2009	1	5	34	23.3	N/A	23.3	23.3	36.3	4.5	37.3
10/2/2009	0	16	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/3/2009	10	2	23	23.2	12.7	10.6	51.7	36.0	4.5	37.1
10/4/2009	3	1	39	12.4	5.2	8.9	18.3	19.3	2.4	19.9
10/5/2009	0	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/6/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2009	4	0	42	22.6	5.5	17.8	30.6	35.2	4.4	36.2
10/8/2009	0	8	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/9/2009	5	13	7	31.8	4.4	25.6	37.2	49.4	6.2	50.8
10/10/2009	3	18	19	26.1	3.1	22.8	28.9	40.6	5.1	41.8
10/11/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/12/2009	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/13/2009	2	0	28	20.6	0.0	20.6	20.6	32.0	4.0	32.9
10/14/2009	4	0	34	3.1	3.6	0.6	8.3	4.8	0.6	4.9
10/15/2009	4	3	35	12.6	7.7	6.1	22.8	19.7	2.5	20.2
10/16/2009	5	0	27	7.1	3.2	3.9	12.2	11.1	1.4	11.4
10/17/2009	15	0	4	11.4	4.1	5.6	18.3	17.7	2.2	18.3
10/18/2009	10	0	7	14.6	3.0	9.4	18.9	22.6	2.8	23.3
10/19/2009	20	0	3	11.3	4.3	1.7	18.3	17.5	2.2	18.0
10/20/2009	6	8	0	11.0	3.0	7.8	15.0	17.1	2.1	17.6
10/21/2009	4	7	3	26.7	17.1	6.1	46.7	41.5	5.2	42.7
10/22/2009	5	12	1	31.0	23.9	5.0	67.8	48.2	6.0	49.6
10/23/2009	16	8	21	50.2	22.7	-15.6	75.6	78.0	9.8	80.3
10/24/2009	17	15	0	40.4	6.0	30.6	52.2	62.8	7.9	64.6
10/25/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/26/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/27/2009	0	0	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/28/2009	23	7	9	16.7	6.7	3.9	36.1	26.0	3.2	26.7
10/29/2009	12	0	22	4.7	2.8	0.6	8.9	7.3	0.9	7.6
10/30/2009	3	0	2	4.8	2.6	3.3	7.8	7.5	0.9	7.7
10/31/2009	6	13	10	51.6	11.4	38.3	67.8	80.2	10.0	82.5
11/1/2009	1	0	44	55.0	N/A	55.0	55.0	85.5	10.7	88.0
11/2/2009	14	0	12	9.7	1.7	7.2	13.3	15.1	1.9	15.6
11/3/2009	9	1	25	13.5	6.7	6.7	27.8	21.0	2.6	21.6
11/4/2009	4	8	27	16.9	9.6	4.4	24.4	26.4	3.3	27.1
11/5/2009	1	1	39	30.6	N/A	30.6	30.6	47.5	5.9	48.9
11/6/2009	0	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/7/2009	0	16	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/8/2009	6	5	6	22.1	15.9	8.9	49.4	34.4	4.3	35.4
11/9/2009	0	0	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/10/2009	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
11/11/2009	7	0	37	7.0	1.4	5.0	8.9	10.9	1.4	11.2
11/12/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/13/2009	3	0	44	13.3	1.0	12.2	13.9	20.7	2.6	21.3
11/14/2009	6	0	39	10.1	3.2	6.1	13.9	15.7	2.0	16.1
11/15/2009	1	0	46	6.1	N/A	6.1	6.1	9.5	1.2	9.8
11/16/2009	4	0	35	13.6	11.0	-1.1	25.6	21.2	2.6	21.8
11/17/2009	5	0	40	4.0	1.5	2.2	5.6	6.2	0.8	6.4
11/18/2009	8	0	33	4.1	2.6	2.2	10.0	6.4	0.8	6.6
11/19/2009	13	2	16	19.3	11.3	5.0	39.4	30.0	3.7	30.8
11/20/2009	5	0	42	13.7	3.2	9.4	16.7	21.3	2.7	21.9
11/21/2009	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/22/2009	4	0	31	7.8	4.6	4.4	14.4	12.1	1.5	12.4
11/23/2009	15	0	10	8.7	4.3	1.7	18.3	13.5	1.7	13.9
11/24/2009	7	0	13	15.5	5.9	7.8	22.8	24.1	3.0	24.8
11/25/2009	4	5	7	16.1	6.8	10.0	23.3	25.1	3.1	25.8
11/26/2009	2	3	26	13.3	1.6	12.2	14.4	20.7	2.6	21.3
11/27/2009	17	0	0	15.7	8.1	5.6	35.6	24.3	3.0	25.0
11/28/2009	12	0	11	10.9	5.2	6.1	26.1	17.0	2.1	17.5
11/29/2009	10	27	0	19.7	7.6	8.3	29.4	30.7	3.8	31.6
11/30/2009	1	41	0	3.9	N/A	3.9	3.9	6.0	0.8	6.2
12/1/2009	7	1	28	19.2	9.5	6.1	32.2	29.9	3.7	30.7

6.12.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Touchdown limited: Number of ½ h periods invalidated because fraction of source area surface covered by particle touchdowns was less than 0.1
Turbulence Limited: Number of ½ h periods that the bLS model was not run because either u_* < 0.15 ms^{-1} or |L| < 2 m
Background (ppm): bLS model calculated daily average background concentration (ppm); average is over the ½ h periods included in the valid column
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 2												
10/25/2007	0	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/26/2007	4	13	0	10	0.20	18.1	33.5	0.2	68.4	28.6	3.6	29.5
10/27/2007	14	8	8	14	0.20	43.1	48.6	1.5	143.0	68.1	8.5	70.0
10/28/2007	1	0	8	4	0.06	-5.5	N/A	-5.5	-5.5	-8.7	-1.1	-8.9
10/29/2007	0	0	2	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/30/2007	1	1	4	22	0.12	13.4	N/A	13.4	13.4	21.1	2.6	21.7
10/31/2007	1	8	1	21	0.06	3.8	N/A	3.8	3.8	5.9	0.7	6.1
11/1/2007	3	0	11	23	0.43	-137.0	253.0	-299.0	155.0	-216.2	-27.0	-222.5
11/2/2007	0	0	11	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/3/2007	2	0	34	4	0.02	63.6	37.4	37.1	90.0	100.3	12.5	103.2
11/4/2007	9	0	6	23	0.14	-3.3	219.0	-581.0	133.0	-5.3	-0.7	-5.4
11/5/2007	3	3	7	29	0.08	84.3	74.7	1.0	145.0	133.1	16.6	137.0
11/6/2007	5	18	12	10	0.03	82.2	58.1	20.9	156.0	129.7	16.2	133.4
11/7/2007	0	0	3	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 3												
2/14/2008	3	0	3	6	0.11	10.9	20.2	-7.7	32.4	17.1	2.1	17.6
2/15/2008	11	4	0	27	0.03	7.5	3.3	4.1	14.8	11.8	1.5	12.1
2/16/2008	9	0	0	24	0.19	1.7	3.1	-1.4	8.4	2.7	0.3	2.8
2/17/2008	4	18	0	12	0.06	-0.1	0.2	-0.4	0.2	-0.1	0.0	-0.1
2/18/2008	12	35	0	0	0.03	5.5	4.8	0.0	13.4	8.6	1.1	8.9
2/19/2008	34	0	0	10	0.10	5.2	12.1	-17.4	54.0	8.2	1.0	8.4

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
2/20/2008	12	9	0	20	0.02	14.9	3.5	8.2	19.2	23.5	2.9	24.2
2/21/2008	10	10	0	6	0.03	0.8	1.1	0.0	2.8	1.3	0.2	1.4
2/22/2008	16	1	0	6	0.03	9.4	14.3	-2.7	45.5	14.8	1.8	15.2
2/23/2008	11	10	2	24	0.02	4.6	6.4	0.1	19.7	7.3	0.9	7.5
2/24/2008	10	2	0	7	0.05	1.6	3.7	-0.1	11.7	2.5	0.3	2.6
2/25/2008	13	2	0	22	0.03	12.6	11.9	0.6	44.5	19.8	2.5	20.4
2/26/2008	0	24	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/27/2008	43	5	0	0	0.07	2.8	6.8	-8.3	18.0	4.4	0.5	4.5
2/28/2008	36	0	0	10	0.07	9.5	17.2	-9.7	73.4	15.0	1.9	15.5
2/29/2008	0	18	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	20	21	0	5	0.02	6.1	5.0	0.7	17.3	9.6	1.2	9.8
3/2/2008	2	8	0	16	0.08	0.1	0.1	0.0	0.2	0.2	0.0	0.2
3/3/2008	0	26	0	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	41	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	13	11	0	0	0.03	1.0	2.1	-1.1	7.5	1.5	0.2	1.6
Period 4												
3/6/2008	1	3	0	2	0.33	-4.0	N/A	-4.0	-4.0	-6.3	-0.8	-6.4
3/7/2008	1	8	0	8	0.02	0.6	N/A	0.6	0.6	0.9	0.1	1.0
3/8/2008	15	33	0	0	0.01	15.5	13.7	3.3	44.5	24.5	3.1	25.2
3/9/2008	27	1	0	6	0.07	9.5	7.8	-2.4	26.2	15.0	1.9	15.4
3/10/2008	0	17	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	6	5	0	33	0.06	22.8	14.1	0.7	34.4	36.0	4.5	37.0
3/12/2008	22	0	0	15	0.02	32.3	21.1	2.0	75.9	51.0	6.4	52.5
3/13/2008	1	14	0	27	0.04	20.5	N/A	20.5	20.5	32.4	4.0	33.3
3/14/2008	0	26	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	6	26	0	12	-0.01	13.4	10.5	3.4	31.7	21.2	2.6	21.8
3/16/2008	38	0	0	3	0.03	26.4	19.5	0.7	70.2	41.7	5.2	42.9
3/17/2008	17	0	0	13	0.10	7.2	7.9	0.2	25.2	11.3	1.4	11.6
3/18/2008	3	19	0	14	0.27	-6.2	6.6	-13.0	0.2	-9.7	-1.2	-10.0
3/19/2008	0	9	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	10	8	0	1	0.02	19.6	9.6	9.9	40.6	30.9	3.9	31.8
3/23/2008	19	1	0	10	0.11	9.4	19.7	0.1	87.5	14.8	1.9	15.2
3/24/2008	31	0	0	13	0.07	23.6	19.0	-0.3	61.5	37.3	4.7	38.4
3/25/2008	18	6	0	16	0.08	14.4	8.9	0.1	29.0	22.7	2.8	23.3
3/26/2008	4	15	2	11	0.01	12.1	11.2	4.5	28.3	19.1	2.4	19.6
Period 6												
9/25/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	15	5	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2008	1	7	1	29	0.21	30.4	N/A	30.4	30.4	47.9	6.0	49.3
9/28/2008	19	0	0	21	0.08	19.8	17.0	3.2	64.4	31.3	3.9	32.2
9/29/2008	5	3	2	26	0.03	46.4	62.2	9.2	155.0	73.3	9.2	75.4
9/30/2008	6	3	0	37	0.16	17.0	19.7	0.2	54.1	26.9	3.4	27.7
10/1/2008	12	4	0	24	0.14	29.3	25.2	7.5	95.4	46.2	5.8	47.6
10/2/2008	25	0	0	18	0.09	23.0	16.3	4.5	59.3	36.3	4.5	37.4

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/3/2008	6	11	0	22	0.13	10.1	4.2	2.3	13.6	15.9	2.0	16.3
10/4/2008	8	1	0	25	0.24	28.6	28.9	0.0	89.3	45.2	5.7	46.5
10/5/2008	4	2	0	28	0.17	22.8	21.6	2.7	53.0	36.1	4.5	37.1
10/6/2008	8	0	0	32	0.09	35.3	32.6	3.8	100.0	55.8	7.0	57.4
10/7/2008	1	1	0	18	0.11	1.7	N/A	1.7	1.7	2.7	0.3	2.8
10/8/2008	1	16	0	19	0.11	1.4	N/A	1.4	1.4	2.2	0.3	2.3
10/9/2008	3	4	0	31	0.19	9.7	4.5	5.0	14.0	15.3	1.9	15.7
10/10/2008	0	0	0	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/11/2008	3	0	0	0	0.07	1.5	0.4	1.1	1.9	2.4	0.3	2.5
10/12/2008	0	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/13/2008	7	0	0	9	0.10	12.7	25.8	0.1	70.8	20.1	2.5	20.7
10/14/2008	0	0	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7												
2/5/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2009	0	14	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2009	9	11	1	19	0.03	18.4	7.5	10.7	30.4	29.0	3.6	29.8
2/8/2009	19	11	0	17	0.04	15.3	5.5	7.9	25.1	24.1	3.0	24.8
2/9/2009	2	10	0	22	0.08	2.5	2.4	0.9	4.2	4.0	0.5	4.1
2/10/2009	1	15	0	23	0.06	27.5	N/A	27.5	27.5	43.4	5.4	44.6
2/11/2009	0	24	0	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/12/2009	37	11	0	0	0.05	16.3	10.2	1.0	36.1	25.8	3.2	26.5
2/13/2009	18	0	0	19	0.05	20.1	9.1	0.1	32.3	31.8	4.0	32.7
2/14/2009	5	11	0	25	0.08	7.6	4.1	2.2	11.4	12.0	1.5	12.4
2/15/2009	16	4	0	17	0.04	3.8	4.6	-2.6	12.9	5.9	0.7	6.1
2/16/2009	20	0	0	24	0.02	17.9	13.4	1.7	39.0	28.3	3.5	29.1
2/17/2009	10	1	0	26	0.03	8.2	10.3	0.2	30.0	13.0	1.6	13.4
2/18/2009	2	21	0	23	0.07	0.2	0.4	0.0	0.5	0.4	0.0	0.4
2/19/2009	24	10	0	13	0.03	15.4	8.3	1.0	30.4	24.2	3.0	24.9
2/20/2009	32	0	0	14	0.02	14.9	6.2	3.2	27.1	23.6	2.9	24.3
2/21/2009	1	19	0	18	0.03	1.3	N/A	1.3	1.3	2.1	0.3	2.2
2/22/2009	19	6	0	23	0.03	15.7	4.0	9.5	22.2	24.7	3.1	25.4
2/23/2009	13	0	0	15	0.02	12.5	3.9	7.1	19.2	19.8	2.5	20.3
Period 8												
5/13/2009	0	13	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/14/2009	0	23	0	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/15/2009	0	22	0	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2009	6	13	0	27	0.09	26.2	28.9	1.9	72.4	41.4	5.2	42.6
5/17/2009	9	13	1	16	0.07	18.0	19.9	2.2	63.0	28.3	3.5	29.2
5/18/2009	13	0	0	0	0.04	9.9	6.2	3.7	19.9	15.7	2.0	16.1
5/19/2009	0	0	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/20/2009	1	4	0	0	0.13	2.1	N/A	2.1	2.1	3.3	0.4	3.4
5/21/2009	0	13	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	0	26	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2009	0	23	0	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2009	0	21	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2009	1	16	0	24	0.14	1.2	N/A	1.2	1.2	1.9	0.2	2.0

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/26/2009	0	26	0	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2009	2	9	0	19	0.42	1.6	2.2	0.0	3.1	2.5	0.3	2.6
5/28/2009	5	14	3	19	0.23	6.0	6.0	-0.4	13.3	9.5	1.2	9.8
5/29/2009	6	20	1	13	0.11	17.6	11.7	1.0	30.6	27.7	3.5	28.5
5/30/2009	10	6	0	5	0.20	9.4	9.7	0.7	34.7	14.9	1.9	15.3
5/31/2009	17	2	0	16	0.17	18.4	10.6	1.7	35.8	29.0	3.6	29.8
6/1/2009	1	11	0	13	0.26	16.9	N/A	16.9	16.9	26.7	3.3	27.5
6/2/2009	1	4	0	16	0.06	3.4	N/A	3.4	3.4	5.4	0.7	5.5
Period 9												
6/3/2009	5	15	0	24	0.16	7.0	5.5	1.2	15.9	11.1	1.4	11.4
6/4/2009	0	17	0	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/5/2009	9	18	0	20	0.14	17.3	8.5	3.6	31.5	27.2	3.4	28.0
6/6/2009	5	2	0	10	0.10	7.8	4.7	3.4	15.0	12.3	1.5	12.7
6/7/2009	2	13	0	4	0.14	1.1	0.6	0.7	1.5	1.8	0.2	1.8
6/8/2009	2	14	0	22	0.22	3.6	0.6	3.2	4.1	5.7	0.7	5.9
6/9/2009	10	6	0	26	0.18	12.7	13.8	-1.2	48.7	20.1	2.5	20.6
6/10/2009	5	6	1	19	0.27	3.3	4.3	0.3	10.7	5.2	0.6	5.3
6/11/2009	0	19	0	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/12/2009	13	16	0	15	0.20	16.1	12.9	4.6	50.9	25.4	3.2	26.2
6/13/2009	12	6	0	16	0.21	40.9	40.2	0.1	144.0	64.5	8.1	66.4
6/14/2009	14	0	0	18	0.17	41.5	41.5	1.0	141.0	65.5	8.2	67.4
6/15/2009	1	14	0	18	0.60	0.6	N/A	0.6	0.6	0.9	0.1	0.9
6/16/2009	2	9	0	14	0.11	8.3	11.1	0.4	16.1	13.1	1.6	13.5
6/17/2009	1	20	0	10	0.14	1.0	N/A	1.0	1.0	1.6	0.2	1.6
6/18/2009	9	9	1	23	0.21	30.5	25.4	0.9	82.7	48.1	6.0	49.5
6/19/2009	16	0	0	23	0.14	50.8	27.9	13.1	96.3	80.2	10.0	82.5
6/20/2009	24	0	0	16	0.20	27.7	28.9	1.4	117.0	43.7	5.5	45.0
6/21/2009	27	0	0	15	0.09	60.4	24.7	12.2	109.0	95.3	11.9	98.0
6/22/2009	7	0	0	14	0.16	22.8	17.9	1.2	53.0	36.1	4.5	37.1
Period 10												
9/24/2009	0	1	0	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2009	6	0	8	24	0.21	25.7	7.5	14.0	35.8	40.5	5.1	41.7
9/26/2009	0	0	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2009	16	4	5	20	0.14	37.4	34.3	2.1	127.0	59.0	7.4	60.7
9/28/2009	7	16	0	20	0.09	20.6	8.3	13.3	37.6	32.6	4.1	33.5
9/29/2009	11	0	6	10	0.15	13.7	12.9	2.0	40.8	21.7	2.7	22.3
9/30/2009	3	0	14	3	0.12	42.4	15.7	26.4	57.9	67.0	8.4	68.9
10/1/2009	7	7	1	20	0.18	30.0	27.4	0.2	79.2	47.4	5.9	48.7
10/2/2009	0	15	0	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/3/2009	12	4	2	16	0.09	13.4	8.5	0.9	30.7	21.2	2.6	21.8
10/4/2009	4	0	8	18	0.12	20.7	23.7	0.0	54.7	32.7	4.1	33.6
10/5/2009	1	4	0	18	0.03	2.9	N/A	2.9	2.9	4.5	0.6	4.7
10/6/2009	1	0	8	6	0.15	33.9	N/A	33.9	33.9	53.5	6.7	55.0
10/7/2009	12	16	8	8	0.12	21.4	21.1	0.4	61.5	33.8	4.2	34.8
10/8/2009	0	6	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/9/2009	5	11	0	17	0.13	21.9	6.8	12.7	30.8	34.5	4.3	35.5

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/10/2009	7	22	6	9	0.16	14.5	9.2	5.6	29.5	22.9	2.9	23.5
10/11/2009	0	0	2	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/12/2009	0	0	1	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/13/2009	4	2	7	7	0.00	14.6	10.7	0.0	25.6	23.1	2.9	23.7
10/14/2009	0	0	0	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/15/2009	28	3	0	5	0.10	5.9	7.1	-5.0	20.5	9.2	1.2	9.5
10/16/2009	16	0	1	10	0.09	5.2	4.6	0.0	13.2	8.3	1.0	8.5
10/17/2009	26	0	0	4	0.09	10.0	11.4	0.1	42.2	15.8	2.0	16.3
10/18/2009	41	0	0	4	0.06	12.4	5.8	1.6	30.9	19.6	2.5	20.2
10/19/2009	25	0	0	13	0.08	9.4	6.3	0.9	28.4	14.9	1.9	15.3
10/20/2009	6	10	0	15	0.19	9.2	12.6	2.6	34.7	14.5	1.8	14.9
10/21/2009	3	8	0	15	0.21	7.7	4.0	5.3	12.2	12.1	1.5	12.5
10/22/2009	5	9	0	20	0.28	15.5	17.9	0.5	41.3	24.4	3.1	25.1
10/23/2009	13	5	0	21	0.13	34.9	3.5	28.2	40.6	55.0	6.9	56.6
10/24/2009	6	14	0	13	0.14	32.8	6.0	25.5	38.8	51.7	6.5	53.2
10/25/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/26/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/27/2009	2	0	1	2	0.11	2.7	3.7	0.1	5.3	4.3	0.5	4.4
10/28/2009	25	15	0	3	0.12	16.3	11.2	0.4	44.1	25.7	3.2	26.4
10/29/2009	2	0	0	10	0.13	2.3	1.1	1.5	3.1	3.7	0.5	3.8
10/30/2009	4	0	0	7	0.15	3.8	4.3	0.8	10.0	6.0	0.7	6.2
10/31/2009	4	13	0	19	0.14	26.6	11.6	17.3	43.4	41.9	5.2	43.1
11/1/2009	25	6	3	14	0.13	19.6	22.1	0.7	78.8	31.0	3.9	31.9
11/2/2009	34	0	0	3	0.09	12.0	15.0	0.0	65.5	19.0	2.4	19.5
11/3/2009	13	1	0	25	0.11	15.1	12.1	1.0	37.9	23.8	3.0	24.5
11/4/2009	5	7	1	17	0.14	17.1	19.5	0.2	43.1	26.9	3.4	27.7
11/5/2009	17	0	0	15	0.07	29.5	10.8	15.4	47.1	46.6	5.8	47.9
11/6/2009	15	0	1	17	0.06	11.0	8.3	0.9	27.8	17.4	2.2	17.9
11/7/2009	0	11	0	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/8/2009	8	6	0	26	0.12	16.8	14.0	0.1	42.0	26.5	3.3	27.2
11/9/2009	5	0	1	15	0.12	5.9	8.8	0.1	21.5	9.3	1.2	9.6
11/10/2009	0	0	1	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/11/2009	9	0	2	0	0.05	1.4	1.3	-1.4	2.8	2.2	0.3	2.3
11/12/2009	33	0	14	0	0.05	20.5	16.5	-12.5	55.8	32.4	4.0	33.3
11/13/2009	41	0	7	0	0.04	30.8	15.0	6.9	59.9	48.7	6.1	50.1
11/14/2009	41	0	1	2	0.06	31.7	15.9	3.1	72.9	50.0	6.2	51.4
11/15/2009	11	0	0	30	0.24	24.3	37.2	-5.1	109.0	38.3	4.8	39.4
11/16/2009	8	0	0	26	0.15	21.3	14.2	4.2	46.5	33.6	4.2	34.5
11/17/2009	1	0	0	23	0.11	0.1	N/A	0.1	0.1	0.1	0.0	0.1
11/18/2009	5	0	0	16	0.08	1.2	1.1	0.0	2.5	1.9	0.2	2.0
11/19/2009	17	2	0	21	0.20	14.5	11.0	0.6	32.7	22.8	2.9	23.5
11/20/2009	25	0	1	16	0.07	29.8	17.7	7.2	70.8	47.0	5.9	48.4
11/21/2009	11	0	0	12	0.07	7.7	8.1	0.0	21.6	12.1	1.5	12.5
11/22/2009	6	0	0	25	0.07	2.1	2.0	0.3	5.1	3.4	0.4	3.5
11/23/2009	16	0	0	12	0.09	12.2	6.8	0.2	24.6	19.3	2.4	19.8
11/24/2009	29	0	0	19	0.09	16.3	6.8	3.9	28.0	25.7	3.2	26.4

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
11/25/2009	9	2	0	31	0.05	13.2	10.8	3.8	35.3	20.8	2.6	21.4
11/26/2009	4	5	0	29	0.10	12.2	7.2	5.1	18.5	19.3	2.4	19.8
11/27/2009	41	0	0	6	0.04	13.5	8.4	0.9	32.1	21.3	2.7	21.9
11/28/2009	17	0	0	18	0.04	22.3	10.9	5.5	39.9	35.2	4.4	36.2
11/29/2009	0	10	0	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/30/2009	0	24	0	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2009	15	0	4	13	0.06	14.2	11.0	1.3	31.2	22.4	2.8	23.0

6.12.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 3								
2/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/19/2008	2	1.0	10.7	0.9	1.2	1.6	0.2	1.7
2/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/22/2008	2	0.2	4.8	0.2	0.3	0.3	0.0	0.3
2/23/2008	4	0.6	6.8	0.1	1.5	1.0	0.1	1.0
2/24/2008	4	0.2	4.2	0.2	0.4	0.4	0.0	0.4
2/25/2008	1	0.1	0.0	0.1	0.1	0.1	0.0	0.1
2/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/27/2008	4	1.6	10.6	0.4	2.8	2.4	0.3	2.5
2/28/2008	14	0.9	7.2	0.1	3.4	1.4	0.2	1.4
2/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4								
3/7/2008	2	0.6	8.2	0.6	0.6	0.9	0.1	1.0
3/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	3	0.1	2.5	-0.3	0.5	0.1	0.0	0.1

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
3/12/2008	2	5.1	23.2	4.7	5.6	8.0	1.0	8.2
3/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	1	6.0	0.0	6.0	6.0	9.4	1.2	9.6
3/16/2008	22	9.8	21.7	0.5	29.7	15.2	1.9	15.6
3/17/2008	23	0.8	6.7	-0.1	4.8	1.2	0.2	1.3
3/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2008	14	0.4	4.9	-0.1	1.1	0.6	0.1	0.6
3/24/2008	34	1.3	8.6	0.1	4.0	2.1	0.3	2.1
3/25/2008	11	0.2	3.1	0.0	0.5	0.2	0.0	0.3
3/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6								
9/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/1/2008	7	0.1	3.1	-0.2	0.5	0.2	0.0	0.2
10/2/2008	22	0.2	3.0	-0.2	0.8	0.2	0.0	0.2
10/3/2008	2	0.1	2.5	0.0	0.1	0.1	0.0	0.1
10/4/2008	5	0.2	3.5	-0.1	0.6	0.3	0.0	0.3
10/5/2008	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/6/2008	6	0.0	1.6	0.0	0.1	0.1	0.0	0.1
10/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/8/2008	2	-3.0	0.0	-3.4	-2.6	-4.6	-0.6	-4.8
10/9/2008	5	-0.8	0.0	-3.0	0.2	-1.3	-0.2	-1.3
10/10/2008	8	0.0	0.5	0.0	0.0	0.0	0.0	0.0
10/11/2008	3	0.0	1.5	0.0	0.1	0.0	0.0	0.0
10/12/2008	4	0.0	0.2	0.0	0.0	0.0	0.0	0.0
10/13/2008	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7								
2/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/8/2009	5	1.8	11.0	-0.8	7.4	2.8	0.4	2.9
2/9/2009	2	0.0	1.0	0.0	0.0	0.0	0.0	0.0
2/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/11/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/12/2009	17	-0.2	0.0	-1.7	0.5	-0.3	0.0	-0.3

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
2/13/2009	31	0.0	0.0	-1.1	0.8	0.0	0.0	0.0
2/14/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/15/2009	10	0.0	0.4	-0.1	0.1	0.0	0.0	0.0
2/16/2009	23	0.0	0.0	-0.2	0.2	0.0	0.0	0.0
2/17/2009	19	0.0	1.4	-0.1	0.2	0.1	0.0	0.1
2/18/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/19/2009	16	0.5	5.4	-0.8	9.5	0.8	0.1	0.8
2/20/2009	43	-0.1	0.0	-1.0	0.5	-0.1	0.0	-0.1
2/21/2009	2	0.0	0.7	-0.1	0.1	0.0	0.0	0.0
2/22/2009	11	0.0	0.0	-0.7	0.9	0.0	0.0	0.0
2/23/2009	24	0.1	1.7	-0.7	0.8	0.1	0.0	0.1
Period 8								
5/13/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/14/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2009	4	-5.0	0.0	-30.9	11.0	-7.8	-1.0	-8.0
5/17/2009	10	4.2	18.1	-30.4	28.0	6.5	0.8	6.7
5/18/2009	22	6.1	17.8	0.0	32.0	9.6	1.2	9.8
5/19/2009	16	1.0	7.5	0.2	2.6	1.5	0.2	1.5
5/20/2009	17	0.5	5.3	-0.1	1.6	0.7	0.1	0.8
5/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	1	-1.4	0.0	-1.4	-1.4	-2.1	-0.3	-2.2
5/23/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2009	1	-0.1	0.0	-0.1	-0.1	-0.1	0.0	-0.1
5/28/2009	1	-6.7	0.0	-6.7	-6.7	-10.4	-1.3	-10.7
5/29/2009	3	17.8	45.6	0.0	46.3	27.7	3.5	28.5
5/30/2009	8	0.1	2.4	-0.1	0.4	0.1	0.0	0.1
5/31/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/2/2009	1	-1.2	0.0	-1.2	-1.2	-1.9	-0.2	-2.0
6/3/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 9								
6/4/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/5/2009	6	0.0	0.0	-2.9	2.1	0.0	0.0	0.0
6/6/2009	10	2.3	11.6	0.6	7.6	3.5	0.4	3.6
6/7/2009	2	0.0	0.0	-0.1	0.1	0.0	0.0	0.0
6/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	5	1.4	9.6	0.1	3.2	2.1	0.3	2.2
6/10/2009	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/11/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/12/2009	2	0.5	7.8	0.5	0.6	0.9	0.1	0.9
6/13/2009	3	-3.9	0.0	-11.6	0.0	-6.1	-0.8	-6.3

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/14/2009	19	0.8	6.6	-0.9	3.5	1.2	0.1	1.2
6/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/16/2009	9	0.1	2.5	-0.1	0.5	0.2	0.0	0.2
6/17/2009	1	0.1	0.0	0.1	0.1	0.1	0.0	0.1
6/18/2009	6	-0.4	0.0	-1.7	0.5	-0.7	-0.1	-0.7
6/19/2009	18	1.0	7.6	-0.2	3.5	1.6	0.2	1.6
6/20/2009	9	-0.7	0.0	-3.8	0.4	-1.0	-0.1	-1.0
6/21/2009	41	5.8	17.2	0.1	21.4	9.0	1.1	9.3
6/22/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 10								
9/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/3/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/4/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/11/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/13/2009	2	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
10/14/2009	3	0.1	2.1	0.0	0.2	0.1	0.0	0.1
10/15/2009	1	-0.2	0.0	-0.2	-0.2	-0.3	0.0	-0.3
10/16/2009	5	0.0	0.8	0.0	0.1	0.0	0.0	0.0
10/17/2009	15	0.0	0.4	0.0	0.0	0.0	0.0	0.0
10/18/2009	10	0.1	2.2	-0.7	0.6	0.1	0.0	0.1
10/19/2009	18	-0.2	0.0	-2.4	0.2	-0.3	0.0	-0.3
10/20/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/21/2009	3	-0.2	0.0	-0.5	0.0	-0.3	0.0	-0.3
10/22/2009	5	-0.3	0.0	-0.7	-0.1	-0.5	-0.1	-0.5
10/23/2009	16	-1.2	0.0	-2.6	0.5	-1.8	-0.2	-1.8
10/24/2009	17	-0.9	0.0	-1.9	-0.3	-1.4	-0.2	-1.4
10/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/28/2009	5	-0.9	0.0	-1.5	-0.3	-1.4	-0.2	-1.4

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/29/2009	12	0.0	0.4	0.0	0.1	0.0	0.0	0.0
10/30/2009	2	-0.2	0.0	-0.3	0.0	-0.3	0.0	-0.3
10/31/2009	6	-1.2	0.0	-2.2	-0.6	-1.9	-0.2	-2.0
11/1/2009	1	-3.2	0.0	-3.2	-3.2	-5.0	-0.6	-5.1
11/2/2009	14	0.0	1.1	-0.1	0.1	0.0	0.0	0.0
11/3/2009	3	0.0	0.0	-0.1	0.1	0.0	0.0	0.0
11/4/2009	4	0.0	0.0	-0.2	0.1	-0.1	0.0	-0.1
11/5/2009	1	-0.4	0.0	-0.4	-0.4	-0.7	-0.1	-0.7
11/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/8/2009	3	-0.2	0.0	-0.6	0.1	-0.3	0.0	-0.3
11/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/11/2009	6	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1
11/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/13/2009	3	0.1	2.3	0.0	0.2	0.1	0.0	0.1
11/14/2009	6	0.0	1.7	0.0	0.1	0.1	0.0	0.1
11/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/16/2009	4	-0.5	0.0	-1.4	0.0	-0.8	-0.1	-0.8
11/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/18/2009	8	0.1	1.9	0.0	0.1	0.1	0.0	0.1
11/19/2009	10	-1.0	0.0	-1.7	-0.5	-1.5	-0.2	-1.5
11/20/2009	4	0.0	1.0	0.0	0.1	0.0	0.0	0.0
11/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/22/2009	4	0.0	1.5	0.0	0.1	0.0	0.0	0.1
11/23/2009	15	0.0	1.1	-0.2	0.1	0.0	0.0	0.0
11/24/2009	7	0.1	2.8	-0.1	0.4	0.2	0.0	0.2
11/25/2009	2	0.1	2.8	0.0	0.2	0.1	0.0	0.1
11/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/27/2009	3	0.2	4.6	-0.1	0.7	0.4	0.0	0.4
11/28/2009	1	0.2	0.0	0.2	0.2	0.3	0.0	0.3
11/29/2009	10	-0.6	0.0	-1.0	-0.1	-1.0	-0.1	-1.0
11/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2009	7	0.0	0.8	-0.2	0.2	0.0	0.0	0.0

6.12.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average (μgm^{-2}s^{-1}): Daily average emission calculated from the valid ½ h periods
Emissions SD (μgm^{-2}s^{-1}): Daily emission standard deviation of the valid ½ h periods
Emission minimum (μgm^{-2}s^{-1}): Daily minimum emission of the valid ½ h periods
Emission maximum (μgm^{-2}s^{-1}): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission Average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission Average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average (μgm^{-2}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd^{-1}AU^{-1})
Period 3												
2/15/2008	0	4	11	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/16/2008	8	0	1	30	4.0	0.1	0.1	0.0	0.4	0.2	0.0	0.2
2/17/2008	4	18	0	19	3.9	0.0	0.1	0.0	0.1	0.0	0.0	0.0
2/18/2008	1	35	11	0	-18.8	68.5	N/A	68.5	68.5	106.4	13.3	109.5
2/19/2008	19	0	15	14	1.7	0.0	0.4	-0.7	0.6	-0.1	0.0	-0.1
2/20/2008	0	9	12	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/21/2008	9	10	1	7	3.3	0.1	0.1	0.0	0.3	0.1	0.0	0.1
2/22/2008	10	1	6	7	2.6	0.9	1.8	-0.6	5.9	1.4	0.2	1.5
2/23/2008	2	12	9	25	2.2	0.2	0.3	0.0	0.4	0.3	0.0	0.3
2/24/2008	9	2	1	16	1.4	0.1	0.2	0.0	0.6	0.2	0.0	0.2
2/25/2008	2	2	11	31	4.7	-0.2	0.4	-0.4	0.1	-0.3	0.0	-0.3
2/26/2008	0	24	0	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/27/2008	38	5	5	0	0.9	0.7	0.5	-0.3	2.3	1.0	0.1	1.0
2/28/2008	33	0	3	12	1.0	0.4	0.6	-1.1	2.4	0.7	0.1	0.7
2/29/2008	0	18	0	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	12	21	8	7	2.6	-0.1	0.9	-2.4	1.2	-0.1	0.0	-0.1
3/2/2008	2	8	0	28	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3/3/2008	0	26	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	41	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	11	9	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}1hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 4												
3/7/2008	1	8	0	12	3.1	0.1	N/A	0.1	0.1	0.2	0.0	0.2
3/8/2008	0	33	15	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/9/2008	18	1	9	7	0.3	1.1	1.5	-0.1	4.6	1.7	0.2	1.8
3/10/2008	0	17	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	6	5	0	36	3.8	0.1	0.4	-0.2	0.8	0.2	0.0	0.2
3/12/2008	20	0	2	26	1.1	3.6	3.3	-0.1	9.6	5.6	0.7	5.8
3/13/2008	1	14	0	33	2.9	-0.1	N/A	-0.1	-0.1	-0.1	0.0	-0.1
3/14/2008	0	26	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	3	26	3	15	2.4	5.7	4.8	0.6	10.1	8.8	1.1	9.1
3/16/2008	36	0	2	4	1.0	6.7	5.6	0.0	21.9	10.4	1.3	10.7
3/17/2008	17	0	0	21	4.8	0.3	0.4	0.0	1.1	0.5	0.1	0.5
3/18/2008	2	19	1	24	5.5	0.0	1.0	-0.7	0.7	0.0	0.0	0.0
3/19/2008	0	9	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	0	8	9	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2008	18	0	0	15	2.9	0.2	0.3	0.0	1.2	0.3	0.0	0.3
3/24/2008	31	0	0	17	1.6	1.7	1.5	-0.3	4.7	2.7	0.3	2.7
3/25/2008	12	4	5	21	0.8	0.9	1.2	0.0	3.7	1.4	0.2	1.4
3/26/2008	0	12	0	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6												
9/26/2008	0	21	0	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2008	1	8	0	38	7.3	-0.7	N/A	-0.7	-0.7	-1.1	-0.1	-1.1
9/28/2008	11	0	8	29	1.2	-0.1	0.1	-0.3	0.0	-0.1	0.0	-0.1
9/29/2008	6	5	0	34	1.2	0.0	0.2	-0.3	0.4	0.1	0.0	0.1
9/30/2008	4	3	2	38	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/1/2008	10	4	2	30	1.8	0.0	0.2	-0.3	0.2	0.1	0.0	0.1
10/2/2008	21	0	3	22	0.5	0.1	0.1	-0.1	0.3	0.1	0.0	0.1
10/3/2008	3	11	3	30	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/4/2008	6	1	2	37	1.1	0.1	0.2	-0.1	0.5	0.2	0.0	0.2
10/5/2008	3	2	1	35	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/6/2008	8	0	0	35	0.9	0.1	0.1	0.0	0.3	0.1	0.0	0.1
10/7/2008	1	1	0	26	0.8	0.0	N/A	0.0	0.0	0.0	0.0	0.0
10/8/2008	1	16	0	30	1.3	0.0	N/A	0.0	0.0	-0.1	0.0	-0.1
10/9/2008	3	4	0	39	9.1	-0.3	0.3	-0.6	0.0	-0.5	-0.1	-0.5
10/10/2008	0	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/11/2008	3	0	0	1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/12/2008	0	0	0	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/13/2008	7	0	0	30	0.3	0.0	0.1	0.0	0.3	0.1	0.0	0.1
10/14/2008	0	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7												
2/7/2009	0	11	10	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/8/2009	8	11	11	18	0.2	0.1	0.5	-0.4	1.2	0.2	0.0	0.2
2/9/2009	2	10	0	31	0.2	0.1	0.1	0.0	0.1	0.1	0.0	0.1

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
2/10/2009	0	15	1	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/11/2009	0	24	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/12/2009	17	11	20	0	0.2	-0.1	0.2	-0.4	0.4	-0.1	0.0	-0.1
2/13/2009	18	0	0	30	0.1	0.0	0.3	-0.5	0.5	0.0	0.0	0.1
2/14/2009	0	11	5	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/15/2009	16	4	0	23	0.4	0.0	0.0	-0.2	0.0	0.0	0.0	0.0
2/16/2009	20	0	0	28	0.3	0.0	0.1	-0.2	0.3	0.0	0.0	0.0
2/17/2009	7	1	3	34	0.4	0.0	0.1	-0.1	0.0	0.0	0.0	0.0
2/18/2009	1	21	1	24	2.5	0.0	N/A	0.0	0.0	0.0	0.0	0.0
2/19/2009	21	10	3	14	0.2	0.0	0.2	-0.3	0.4	0.0	0.0	0.0
2/20/2009	32	0	0	16	0.2	-0.1	0.2	-0.4	0.6	-0.1	0.0	-0.1
2/21/2009	1	19	0	24	-0.3	0.0	N/A	0.0	0.0	0.0	0.0	0.0
2/22/2009	15	6	4	23	0.3	-0.1	0.5	-1.2	0.6	-0.1	0.0	-0.1
2/23/2009	11	0	0	13	0.2	0.0	0.2	-0.2	0.3	0.0	0.0	0.0
Period 8												
5/14/2009	0	14	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/15/2009	0	22	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/16/2009	4	13	2	28	28.9	0.2	7.0	-7.7	9.3	0.3	0.0	0.3
5/17/2009	6	13	4	16	32.2	13.2	16.7	-7.3	30.4	20.5	2.6	21.1
5/18/2009	13	0	0	1	7.1	12.0	9.6	2.4	31.9	18.6	2.3	19.1
5/19/2009	0	0	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/20/2009	1	4	0	7	5.0	0.5	N/A	0.5	0.5	0.8	0.1	0.9
5/21/2009	0	13	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	0	26	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2009	0	23	0	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2009	0	21	0	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2009	1	16	0	31	8.3	-0.1	N/A	-0.1	-0.1	-0.1	0.0	-0.1
5/26/2009	0	26	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2009	2	9	0	27	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/28/2009	1	17	4	25	53.6	-2.4	N/A	-2.4	-2.4	-3.7	-0.5	-3.8
5/29/2009	1	23	5	13	2.2	2.7	N/A	2.7	2.7	4.2	0.5	4.3
5/30/2009	9	6	1	16	4.2	0.0	0.1	-0.1	0.2	0.0	0.0	0.0
5/31/2009	13	4	4	25	4.2	-0.1	0.2	-0.7	0.2	-0.1	0.0	-0.1
6/1/2009	1	11	0	22	1.0	0.6	N/A	0.6	0.6	0.9	0.1	0.9
6/2/2009	0	3	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 9												
6/4/2009	0	17	0	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/5/2009	7	18	2	21	7.4	0.1	0.9	-1.3	1.6	0.1	0.0	0.2
6/6/2009	5	2	0	21	2.6	1.2	1.1	0.2	2.8	1.9	0.2	2.0
6/7/2009	2	13	0	21	12.2	0.0	0.1	-0.1	0.0	0.0	0.0	0.0
6/8/2009	1	14	1	28	2.1	0.0	N/A	0.0	0.0	0.0	0.0	0.0
6/9/2009	8	6	2	31	-0.6	0.7	1.6	-0.2	4.6	1.1	0.1	1.1
6/10/2009	5	6	1	20	12.2	0.0	0.4	-0.5	0.6	0.0	0.0	0.0
6/11/2009	0	19	0	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/12/2009	3	16	10	17	3.5	0.1	0.1	0.0	0.1	0.1	0.0	0.1

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}1hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/13/2009	9	6	3	24	19.6	-1.1	2.3	-7.1	0.1	-1.7	-0.2	-1.8
6/14/2009	14	0	0	28	14.8	0.7	1.0	-1.1	2.4	1.0	0.1	1.1
6/15/2009	0	14	1	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/16/2009	2	9	0	18	5.6	0.1	0.2	0.0	0.2	0.2	0.0	0.2
6/17/2009	1	20	0	24	2.7	0.0	N/A	0.0	0.0	0.0	0.0	0.0
6/18/2009	7	11	3	27	5.6	0.0	0.2	-0.3	0.3	0.0	0.0	0.0
6/19/2009	16	0	0	26	3.9	1.1	1.3	-0.2	4.1	1.7	0.2	1.7
6/20/2009	15	0	9	23	8.4	-0.2	0.4	-1.5	0.1	-0.3	0.0	-0.3
6/21/2009	27	0	0	21	2.8	6.2	4.7	0.0	17.6	9.6	1.2	9.9
6/22/2009	0	0	0	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 10												
9/25/2009	14	0	2	25	0.9	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
9/26/2009	0	0	0	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/27/2009	18	4	3	23	0.5	0.0	0.1	-0.2	0.2	0.0	0.0	0.0
9/28/2009	0	16	7	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/29/2009	15	0	4	14	0.2	0.0	0.1	-0.1	0.4	0.0	0.0	0.0
9/30/2009	19	0	0	5	0.4	0.0	0.1	-0.2	0.1	0.0	0.0	0.0
10/1/2009	5	7	3	29	0.3	0.0	0.1	-0.1	0.1	0.0	0.0	0.0
10/2/2009	0	15	0	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/3/2009	4	4	10	27	0.8	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
10/4/2009	12	0	2	31	0.6	0.0	0.1	-0.1	0.2	0.0	0.0	0.0
10/5/2009	0	4	1	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/6/2009	9	0	0	19	0.6	0.0	0.1	-0.1	0.1	0.0	0.0	0.0
10/7/2009	14	16	6	10	0.2	0.0	0.1	-0.1	0.2	0.0	0.0	0.0
10/8/2009	0	6	0	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/9/2009	0	11	5	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/10/2009	12	22	3	11	0.5	0.1	0.2	-0.1	0.3	0.1	0.0	0.1
10/11/2009	2	0	0	16	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/12/2009	2	0	0	28	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/13/2009	21	2	0	8	0.4	0.0	0.1	-0.2	0.1	0.0	0.0	0.0
10/14/2009	0	0	0	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/15/2009	23	3	5	5	0.1	0.0	0.1	-0.3	0.4	0.0	0.0	0.0
10/16/2009	17	0	0	15	0.1	0.0	0.1	-0.2	0.1	0.0	0.0	0.0
10/17/2009	26	0	0	12	0.2	0.0	0.0	-0.1	0.1	0.0	0.0	0.0
10/18/2009	41	0	0	7	0.1	0.0	0.1	-0.2	0.4	0.0	0.0	0.0
10/19/2009	22	0	1	18	0.4	0.0	0.1	-0.2	0.2	0.0	0.0	0.0
10/20/2009	0	10	6	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/21/2009	2	8	1	33	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/22/2009	5	9	0	33	2.8	-0.2	0.5	-1.1	0.1	-0.4	0.0	-0.4
10/23/2009	13	5	0	30	6.6	-1.8	0.6	-2.9	-0.8	-2.8	-0.4	-2.9
10/24/2009	6	14	0	13	9.2	-1.6	0.7	-2.6	-0.6	-2.4	-0.3	-2.5
10/25/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/26/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/27/2009	2	0	0	0	2.7	-0.2	0.2	-0.3	0.0	-0.3	0.0	-0.3
10/28/2009	7	15	18	5	8.2	-1.2	0.7	-2.3	0.0	-1.9	-0.2	-2.0

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/29/2009	2	0	0	28	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/30/2009	3	0	0	22	1.4	0.0	0.1	-0.1	0.0	-0.1	0.0	-0.1
10/31/2009	4	13	0	30	11.3	-2.0	1.1	-3.2	-1.0	-3.1	-0.4	-3.2
11/1/2009	24	9	1	13	1.4	-0.1	0.6	-2.8	0.3	-0.1	0.0	-0.1
11/2/2009	34	0	0	4	0.1	0.0	0.1	-0.2	0.3	0.0	0.0	0.0
11/3/2009	6	1	7	34	0.6	0.0	0.2	-0.2	0.2	0.0	0.0	0.0
11/4/2009	6	7	0	32	2.1	-0.2	0.4	-0.9	0.1	-0.2	0.0	-0.2
11/5/2009	13	0	0	18	1.1	0.0	0.4	-0.5	0.6	0.0	0.0	0.0
11/6/2009	15	0	1	31	0.4	0.0	0.2	-0.4	0.4	0.0	0.0	0.0
11/7/2009	0	11	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/8/2009	1	6	7	32	1.1	0.0	N/A	0.0	0.0	0.0	0.0	0.0
11/9/2009	6	0	1	37	2.0	-0.1	0.1	-0.3	0.0	-0.1	0.0	-0.1
11/10/2009	2	0	0	34	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11/11/2009	7	0	0	0	0.4	0.0	0.0	0.0	0.1	0.0	0.0	0.0
11/12/2009	47	0	0	0	0.2	0.1	0.2	-0.5	0.6	0.1	0.0	0.1
11/13/2009	48	0	0	0	0.1	0.1	0.2	-0.5	0.5	0.1	0.0	0.1
11/14/2009	42	0	0	6	0.0	0.0	0.2	-0.4	0.7	0.1	0.0	0.1
11/15/2009	8	0	3	36	0.2	0.1	0.1	0.0	0.3	0.1	0.0	0.1
11/16/2009	8	0	0	38	4.2	-0.5	0.4	-1.2	0.1	-0.8	-0.1	-0.9
11/17/2009	1	0	0	35	0.3	0.0	N/A	0.0	0.0	0.0	0.0	0.0
11/18/2009	5	0	0	31	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11/19/2009	15	2	2	29	10.7	-2.1	1.1	-3.8	-0.4	-3.2	-0.4	-3.3
11/20/2009	26	0	0	22	0.2	0.1	0.2	-0.4	0.4	0.1	0.0	0.2
11/21/2009	11	0	0	31	0.1	0.0	0.1	-0.1	0.1	0.0	0.0	0.0
11/22/2009	6	0	0	36	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11/23/2009	16	0	0	12	0.3	0.0	0.1	-0.1	0.2	0.0	0.0	0.0
11/24/2009	29	0	0	19	0.2	0.0	0.1	-0.3	0.5	0.1	0.0	0.1
11/25/2009	2	2	7	37	1.1	-0.1	0.1	-0.1	0.0	-0.1	0.0	-0.2
11/26/2009	1	5	3	39	5.8	-0.5	N/A	-0.5	-0.5	-0.8	-0.1	-0.8
11/27/2009	6	0	35	7	0.2	0.1	0.3	-0.2	0.5	0.2	0.0	0.2
11/28/2009	4	0	13	30	0.1	0.1	0.1	0.0	0.2	0.2	0.0	0.2
11/29/2009	0	10	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/30/2009	0	24	0	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2009	15	1	2	18	0.2	0.0	0.1	-0.2	0.3	0.1	0.0	0.1

Final Report
Site NC4A
Pork Production Facility
for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
Site NC4A
Pork Production Facility

for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on the location (relative to climate and typical practice), method of manure collection, manure storage and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3) and hydrogen sulfide (H_2S) emissions from the wastewater lagoon open source at the southeastern sow facility. Within that objective, this report will:

- Describe the farm and the lagoon/basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the lagoon were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Lagoon emissions were measured for up to 21 d each season over two years. The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the lagoon were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using

two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc,, Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*WindTrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the lagoon pH, oxidation-reduction potential, and temperature at 0.3 m depth were also measured from a float located at least 30 m from the lagoon inlet (Table 1-2). Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the lagoon berm (Table 1-2).

Table 1-1: Critical measurements

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder 2.0	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind speed	3D Sonic anemometer/ RM Young 81000	0-60 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
Wind direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
3D turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min
Temperature variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01^{o}C	160 Hz sampling/ 16 Hz averaging	30 min
GSS sample flow rate	GSS/SOP-S	10 L min^{-1}	0.1 L min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/SOP-S	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to RPM Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the lagoon (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation, lagoon pH, lagoon oxidation-reduction potential, lagoon temperature, and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure, flow, temperature and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer that was downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Additional information concerning farm operations and the United States Department of Agriculture National Resource Conservation Service (USDA NRCS)-required analysis of wastewater used to irrigate nearby fields was routinely collected from the producers.

Table 1-2: Non-critical measurements

Measurement	Method/Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
Ambient temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50 ^{o} C	0.1 ^{o} C	5 min	30 min, 24 h
Relative humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min & 24 h
Solar radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 Wm^{-2}	10 Wm^{-2}	5 min	30 min & 24 h
Lagoon solids depth	Sludge level detector/ SludgeGun 10HD, Markland Specialty Eng.	0-10 m	0.05 m	1/ measurement period	1 time
Lagoon/ basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	0-14 units	0.2 unit	5 min	30 min & 24 h
Lagoon/ basin oxidation-reduction potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	-800 - +1100 mV	20 mV	5 min	30 min & 24 h
Lagoon/ basin temperature	Thermistor/ Campbell Scientific Inc 107-L	-35 - +50 ^{o}C	0.5 ^{o}C	5 min	30 min & 24 h

1.3 Farm description and operation

The southeastern sow facility was located in North Carolina. The elevation at the farm was 59 m. The farm consisted of three barns, one each of gestation, breeding, and farrowing, and an office (Fig. 1-1). The facility had a capacity of 2000 sows in three units. Construction of the farm was completed in 1994.

Manure from the barns was transferred once a week from the gestation, farrowing, and breeding barns to the lagoon by pull plug with lagoon water recharge of the pits. Waste water from all three buildings combined into one inlet (SW corner of lagoon- Fig. 1-1). The waste lagoon was located to the north of the barns. The clay-lined, trapezoidal-shaped lagoon was 123 m wide and 187 m long, and was oriented east-west. The lagoon bank was clay, with a berm slope of 3:1. The lagoon had a surface area of 23,195 m^2 and a volume of 56,851 m^3. At the beginning of the study the sludge depth was approximately 0.7 m. Liquid was removed as weather permitted. Sludge from the lagoon had not been removed since construction (15-yr sludge removal cycle).

Figure 1-1: Configuration of the NC4A farm.

1.4 Measurement layout

The NH_3 emissions from the basin were monitored for 8 to 20 d each quarter of the year for two years using scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*) and backward Lagrangian Stochastic (bLS) emissions models. The H_2S emissions from the lagoon were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments

(TDLAS/scanner) were mounted at 1-m height above the lagoon berm (abl) at the northeast and southwest corners (Figure 1-2). Towers for mounting retro-reflectors were located off the northwest and southeast corners of the lagoon (Figure 1-2). A description of the position and path length of the optical paths along each side of the lagoon follows:

- North side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 58.5 m and 116 m from the northeast TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 184 m from the TDLAS/scanner at heights of 1.1 m, 7.2 m, and 15.6 m abl.
- East side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 43.5 m and 83 m south of the northeast TDLAS/scanner. Three retro-reflectors were mounted on the southeast tower 134.5 m from the TDLAS/scanner at heights of 1.4 m, 7 m, and 15.4 m abl.
- South side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 61.5 m and 126 m from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the southeast tower 218.5 m from the TDLAS/scanner at heights of 1.4 m, 7 m, and 15.4 m abl.
- West side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 46 m and 90.5 m north from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 163.5 m from the TDLAS/scanner at heights of 1.1 m, 7.2 m, and 15.6 m abl.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1 m abl. A 50-m long S-OPS path was parallel to and 5 m north of the north berm and began at the northeast berm corner and extended west (Figure 1-2). The second 50-m long S-OPS was parallel to and 5 m south of the south lagoon berm and began at retro-reflector S2 and extended west 50 m towards retro-reflector S1 (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Meteorological measurements (barometric pressure, air temperature and relative humidity, solar radiation, and surface wetness) were made 10 m south of the northeast berm corner (Figure 1-2). The 3D sonic anemometers were located on the meteorological tower at 2.8 m abl and on the southwest corner tower (Figure 1-2) at 4.5 m and 16.3 m abl.

The barns located 20 m south of the lagoon berm had an approximate ridge height of 6 m agl, resulting in a fetch ratio to the south of 10:3 to the surface of the lagoon. Fetch for wind measurements from the east (cropland) was 100:1 for the all measurement heights. Fetch for the wind measurements to the west was limited by a 23-m deciduous tree line. The fetch to the west for the 2-m wind measurement was 100:1. Fetch to the west for the 4-m wind measurement (influenced by the 5.5-m high breeding building) was 100:2.4. Fetch to the west for the 16-m height wind measurement (influenced by the 23-m high tree line at a 287-mdistance) was 100:2. Consequently, all wind measurements were relatively unaffected by upwind conditions. The fan exhaust from the northernmost barn was to both the east and west. The fan exhaust from the middle barn was to the west. As a result of the proximity of the barns, winds from 225° through 315° were excluded from analysis.

Lagoon measurements (pH, oxidation-reduction potential, and temperature) were made from a float located in the northeast corner of the lagoon.

Figure 1-2: Locations of instrumentation around the lagoon under measurement. Retro-reflectors are indicated according to side (N,S,E,W) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The location of the two S-OPS are indicated by the solid yellow lines. The instrumentation trailer was located near the SW corner of the lagoon.

2 Monitoring activities

2.1 Measurement periods

This location was measured as part of an approximate 20-d rotation between three other farms. The equipment was on site a total of 138 d over eight measurement periods (Table 2.1-1). Setup calibrations and site takedowns reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 131 d and H_2S emissions were measured 108 d.

Table 2-1: Dates on site

Period	Start date	End date	# d
2	10/04/2007	10/22/2007	18
3	01/29/2008	02/11/2008	13
4	03/31/2008	04/16/2008	16
5	08/13/2008	09/02/2008	20
6	09/04/2008	09/23/2008	19
7	01/14/2009	02/02/2009	19
8	04/28/2009	05/11/2009	13
9	07/01/2009	07/21/2009	20

2.2 Site visits

The Field operation team visited this farm 40 d (Table 2.2). Visits to set up the site instrumentation and conduct calibration verification checks of instruments typically lasted 3 d while visits for calibration verifications and take-down of the equipment on site typically lasted 2 d.

Table 2-2: Dates of site visits

Year	Spring	Summer	Fall	Winter
2007			Oct 2,3,4,5,22	Jan 29,30,31 Feb 1,11,12
2008	Mar 31, Apr 1,2,14,15,16,17	Aug 12,13,14,26	Sep 2,3,4,22,23	Jan 14,15,16,21 Feb 2,3
2009	Apr 28,29 May 11,12	Jun 30 Jul 1,21,22		

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21 day intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder 2.0™ NH3 TDLAS serial number (s/n) 1026, 1027, 1028 and 1030 (Section 6.1)

- TEC 450i H2S Analyzer s/n 0733825129 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1920, 1926, 1927, 1928, 1932, 1933 and 1945 (Section 6.3)
- lagoon pH probes s/n 001, 004 and 007 (Section 6.4)
- lagoon ORP probe s/n 020 and 050 (Section 6.5)
- GSS/ S-OPS s/n 4-0018 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multi-point calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers (Section 6.3) with three unused 'reference' anemometers.

2.4 Audits

Two internal audits were conducted at this location: 1) on 1/15/2009 with particular attention to the H_2S and TDLAS calibration verification and the checks on the meteorological sensors, and 2) on 5/13/2009 with particular attention to the documentation and lagoon probe calibrations.

2.5 Repair trips

Three repair trips were made to this location: 10/16/2007, 1/29/2008 and 8/26/2008.

2.6 Remote site checks

Over the course of measurements, there were 58 remote checks made through the computer for instruments operating at this location.

2.7 Measurement data acquisition

Data from the TDLAS units (Model GasFinder 2.0™ NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather and lagoon data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *Loggernet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *Loggernet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA) were downloaded in real-time through a serial cable to the trailer computer using the *iPort* (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built *Visual Basic* software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory “FTP” and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory “Data”. The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the “FTP” directory.

3 Data Processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic anemometer parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDLAS. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes need to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site , data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer causing data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period, unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one minute off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the lagoon and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream may depend on one or more of the preceding streams, but not on following data streams. For

each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment failures, calibration failures, and calibration checks in progress. Periods of invalidated measurements associated with the calibration check failures is documented in the calibration reports in Section 6. Significant data exclusions of greater than one-day duration are indicated below by instrument. All time references are in Coordinated Universal Time (UTC):

TDLAS measurement exclusions: Excluded measurements due to either the TDLAS or scanner are summarized in Table 3.2-1.

Table 3.2-1: Air temperature and relative humidity measurement exclusions

Begin		End		Reason
10/5/2007	20:00	10/22/2007	16:00	TDLAS 2 did not calibrate; all paths lost nearly entire period. Equipment returned to PAML for replacement and repair by manufacturer
10/17/2007	17:00	10/22/2007	16:00	Communications failure with controller computer
2/1/2008	06:00	2/11/2008	17:22	TDLAS 2 centerline duty cycle maxed out nearly entire period. Equipment returned to PAML for replacement and repair by manufacturer
8/15/2008	17:00	8/27/2008	1:45	TDLAS 1 centerline duty cycle maxed out; scanner found pointing straight down with water inside TDLAS. Equipment returned to PAML for replacement and repair by manufacturer
1/26/2009	17:00	2/2/2009	18:00	TDLAS 2 scanner found pointing down; TDLAS vital signs continued to look good, though data were missing intermittently. Scanner returned to PAML for replacement and repair by manufacturer
7/11/2009	02:00	7/20/2009	23:00	TDLAS 1 scanner found pointing down; TDLAS 1026 wet inside and stopped working from 7/14 until end of period. . Equipment returned to PAML for replacement and repair by manufacturer

In addition, very wet weather and some deflective seals caused several retro-reflector boxes to become moist or wet inside resulting in loss of TDLAS signal from those retro-reflectors. This retro-reflector moisture did not dry out since the heaters designed to dry out the retro-reflector only heat up to 20 °C and the weather in NC at the time was well above 20°C. One TDLAS path was often blocked by equipment involved in the pumping out of the lagoon.

Air temperature and relative humidity measurement exclusions: Excluded measurements are summarized in Table 3.2-2.

Table 3.2-2: Air temperature and relative humidity measurement exclusions

Begin		End		Reason
4/2/2008	15:35	4/2/2008	17:00	Wires were switched

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-3.

Table 3.2-3: Sonic anemometer measurement exclusions

Begin		End		Reason
9/8/2008	23:00	9/23/2008	23:55	Sonic anemometer 2 stopped functioning
7/18/2009	00:15	7/21/2009	18:20	Sonic anemometer 3 stopped functioning

Lagoon temperature, pH, and ORP measurement exclusions: Excluded measurements are summarized in Table 3.2-4.

Table 3.2-4: Lagoon temperature, pH, and ORP measurement exclusions

Lagoon temperature exclusion times				
Begin		**End**		**Reason**
9/3/2008	13:55	9/3/2008	16:35	Calibration check
Lagoon pH exclusion times				
9/3/2008	13:55	9/3/2008	16:35	Calibration check
1/15/2009	15:55	2/2/2009	22:10	pH sensor failed at end of calibration, data cannot be validated
Lagoon ORP exclusion times				
9/3/2008	13:55	9/3/2008	16:35	Calibration check

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20°C (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in supersaturated "holes" in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a supersaturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maximized light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably supersaturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-s value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be supersaturated were flagged as supersaturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not supersaturated. To determine which points truly were supersaturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest path integrated concentrations corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be supersaturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as supersaturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells were averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the SOPs changed from one line to the other line. This array was later used when separating the H_2S data according to which SOPs line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic anemometer software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic temperature variance of greater than 2.5 $m^2\ s^{-2}$, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic temperature variance had to be less than 2.5 $m^2\ s^{-2}$ To be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan

through all the paths). To make *RPM* processing much quicker and efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be *RPM* processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH_3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *WindTrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of

measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3}\frac{34.0818\left(\left[H_2S\right]_{downwind} - \left[H_2S\right]_{upwind}\right)}{17030.4\left[NH_3\right]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H_2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and tells the model to run depending on whether or not the u_* and L values are acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths. All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the lagoon include transfer of waste from barns into the lagoon and lagoon pump-outs for irrigation (Table 4.1-1).

Table 4.1-1: Producer activities

Period	Events during period
2: 10/2 - 10/22/2007	Lagoon below stop pump level entire period
3: 1/29 - 2/12/2008	Lagoon below stop pump level entire period
4: 3/31 - 4/17/2008	4/16/2008 9:25 AM-2:40 PM pump out
5: 8/12 - 9/3/2008	8/23/2008 9:55 AM-2:00 PM pump out.
6: 9/3 - 9/23/2008	9/22/2008 9:30 AM-12:15 PM pump out 9/23/2008 8 AM-9:45 AM pump out 9/2420/08 6:30 AM-7:45 AM pump out
7: 1/14 - 2/3/2009	2/7/2009 9:30 AM-5:30 PM pump out.
8: 4/27 - 5/11/2009	no events
9: 6/30 - 7/22/2009	no events

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for midlatitude climates (Table 4.2-1). Twenty seven percent of the days had extra-tropical frontal systems overhead while 73% of the days were under the general influence of extra-tropical high pressure. One tropical cyclone influenced the weather at this location. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Period	# days	# Warm front passages	# Cold front passages	# days stationary front	# days tropical storms
2	18	0	2	0	0
3	13	2	4	0	0
4	16	0	3	0	0
5	20	0	3	2	0
6	19	0	2	2	1
7	19	1	5	1	0
8	13	0	3	3	0
9	20	0	4	0	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from -5.1 ^{o}C to 32.4 ^{o}C while the barometric pressure varied from 99.74 kPa to 102.85 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ h solar irradiance of 1186 Wm^{-2} to overcast conditions with maximum ½ h solar irradiance of 117 Wm^{-2} (Section 6.10).

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared to the monthly climatology is indicated in Figure 4.2-1. Temperatures were generally within the climatological normal conditions throughout the study measurement periods at this location except for the measurements made during the beginning of the year (Period 7) when temperatures were below normal.

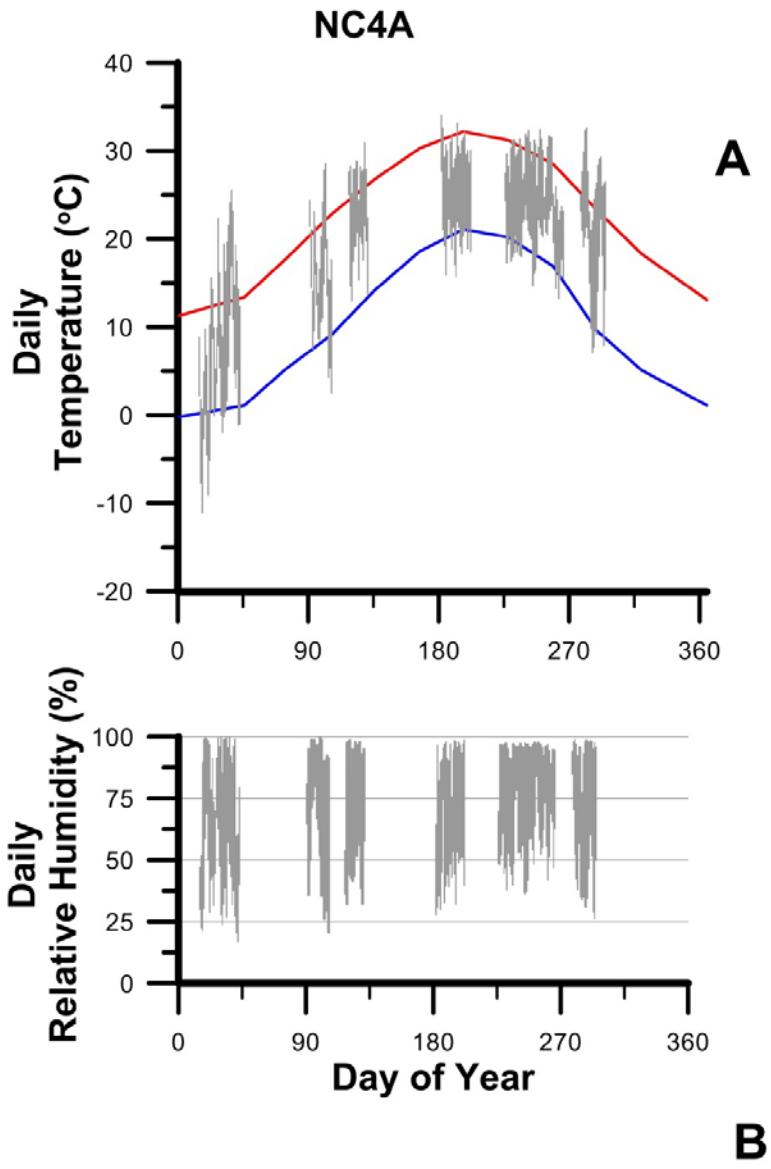

Figure 4.2-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line) temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidity for measurement days is indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figure 4.2-2 through 4.2-5. Emission calculation exclusion regions due to surrounding sources (wind directions of 135° through 225°) are indicated as a grayed region in the figures. Winds were generally from the southwest during measurement periods 3, 8 and 9 and from the north-northeast during measurement periods 4, 5, and 6 (Figure 4.2-2 through 4.2-5).

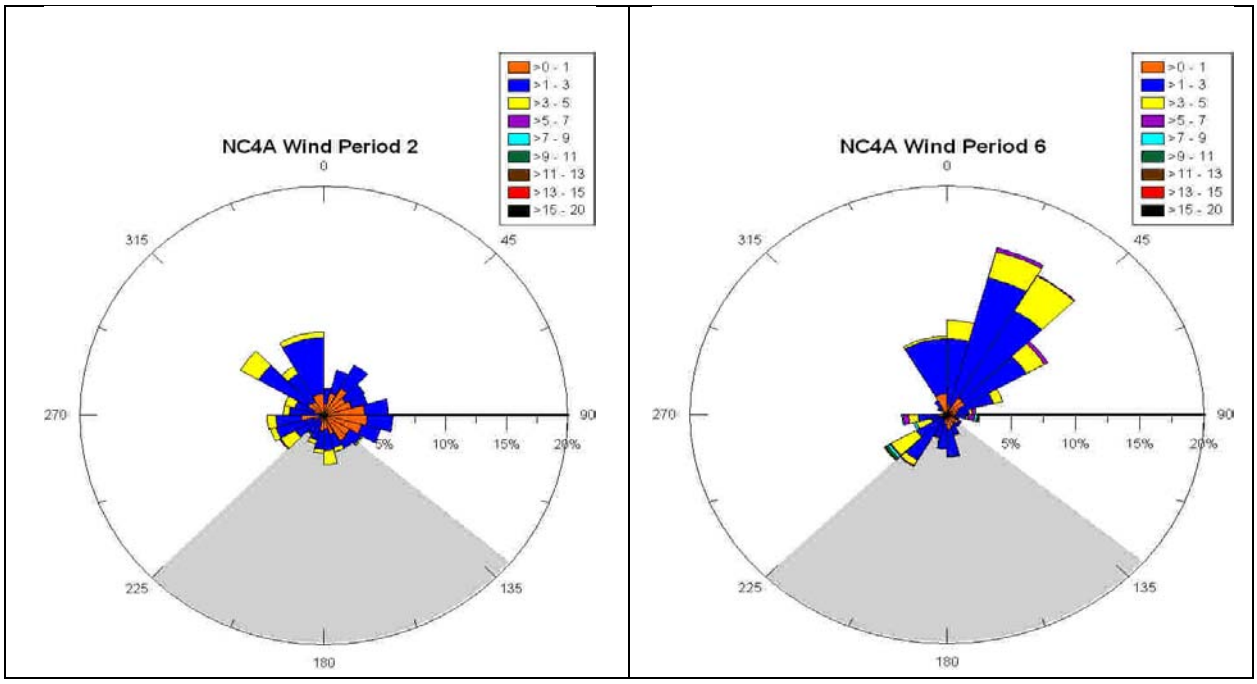

Figure 4.2-2: Wind roses for ½ hourly wind measurements during the Fall Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

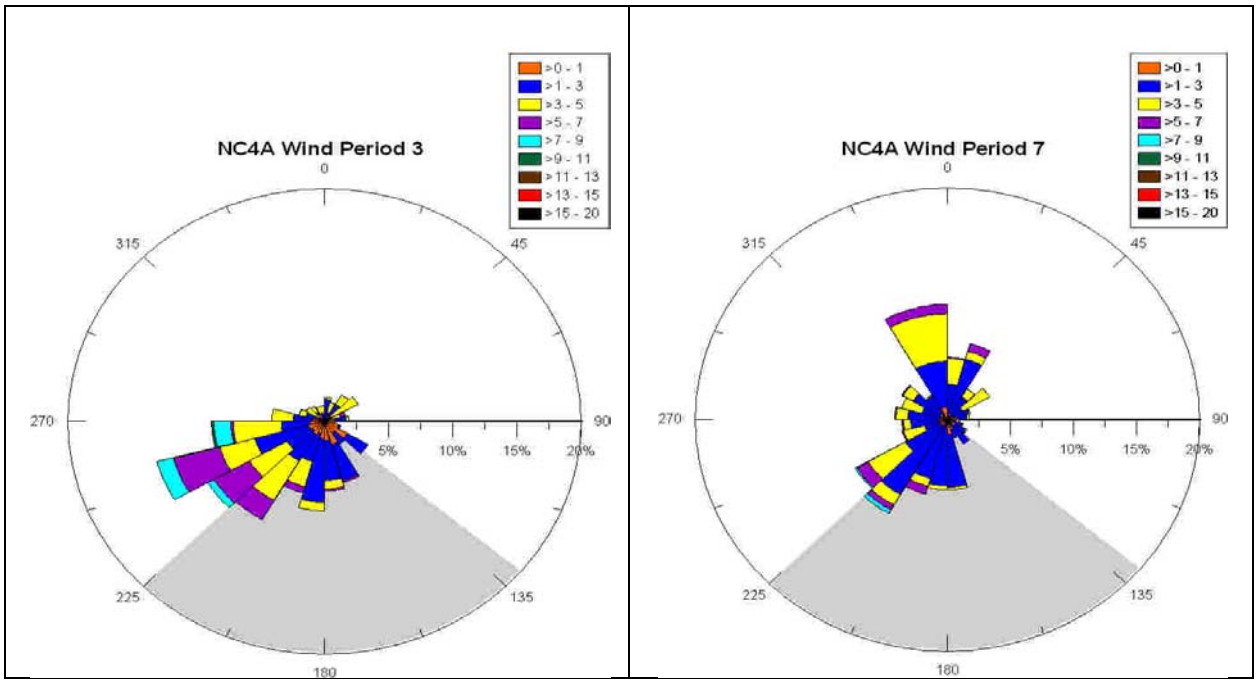

Figure 4.2-3: Wind roses for ½ hourly wind measurements during the Winter Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

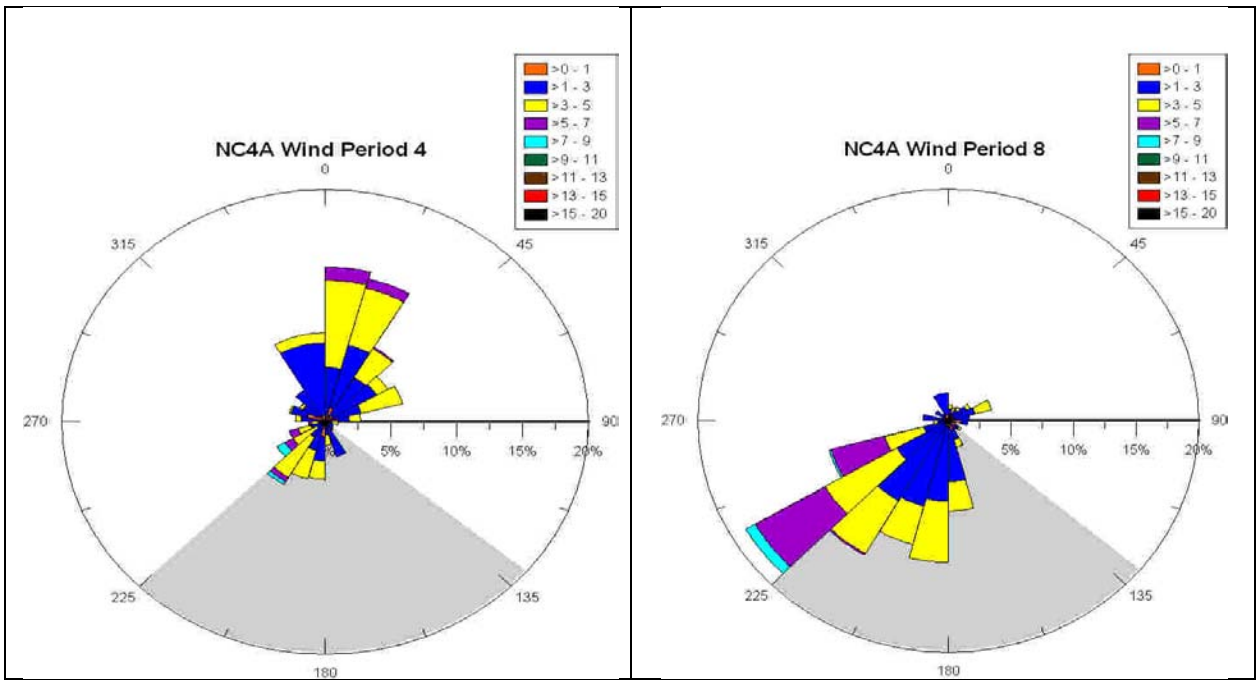

Figure 4.2-4: Wind roses for ½ hourly wind measurements during the Spring Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

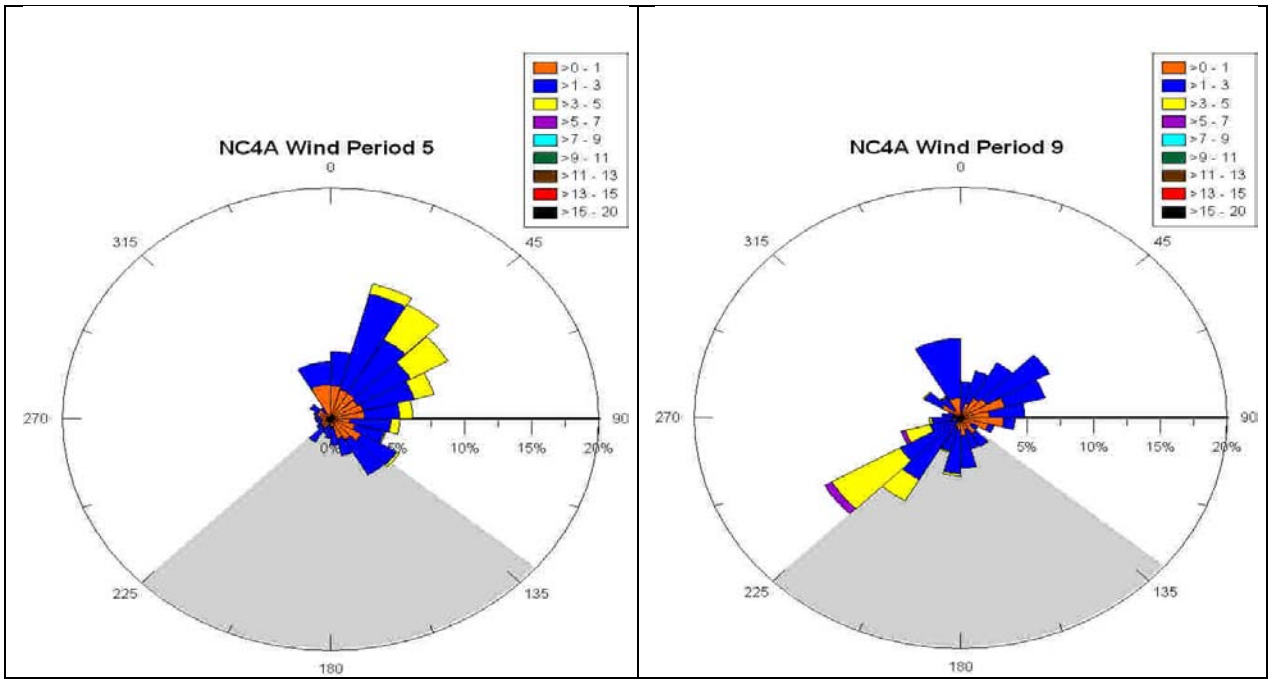

Figure 4.2-5: Wind roses for ½ hourly wind measurements during the Summer Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

4.3 Lagoon conditions

4.3.1 Lagoon appearance, liquid depth and sludge depth

The appearance of the lagoon was recorded on almost every site visit (Table 4.3-1). The lagoon generally appeared red with no crust or scum. Scum was evident at times during the spring and summer.

Table 4.3-1: Lagoon physical characteristics

Period	Appearance	Liquid depth	Sludge depth	Source of meas.
	Color/crust	(m)	(m)	
2; 10/02 - 10/22/2007	10/2/07 light red/no crust or scum 10/3/07 light red/no crust or scum 10/4/07 light red/no crust or scum 10/5/07 light red/no crust or scum 10/22/07 light red/15% scum	2.35		Producer
3: 01/29 - 02/12/2008	1/29/08 red/no crust or scum 1/30/08 red/no crust or scum 1/31/08 red/no crust or scum 2/1/08 red/no crust or scum 2/11/08 red/no crust or scum 2/12/08 red/no crust or scum	2.05		Producer
4: 03/31 - 04/17/2008	3/31/08 red/no crust or scum 4/1/08 red/no crust or scum 4/2/08 red/no crust or scum 4/14/08 red/no crust or scum 4/15/08 red/no crust or scum 4/16/08 red/5% scum 4/17/08 red/8% scum	2.27 1.76 (4/16/08)	0.2	Producer Sludge Gun
5: 08/12 - 09/03/2008	8/12/08 red/no crust or scum 8/13/08 red/no crust or scum 8/14/08 red/5% scum 8/26/08 red/no crust or scum 9/2/08 pink/no crust or scum	2.87		Producer
6: 09/03 - 09/23/2008	9/3/08 red/no crust or scum 9/4/08 red/no crust or scum 9/22/08 red/no crust or scum 9/23/08 red/no crust or scum	1.42 (9/3/08)	0.61	Sludge Gun
7: 01/14 - 02/03/2009	1/14/09 red/no crust or scum 1/15/09 red/no crust or scum 1/16/09 red/no crust or scum 2/2/09 pink/no crust or scum 2/3/09 pink/no crust or scum	2.22 1.69 (2/2/09)	0.16	Producer Sludge Gun
8: 04/27 - 05/11/2009	4/28/09 pink/no crust or scum 4/29/09 pink/no crust or scum 5/11/09 pink/no crust or scum 5/12/09 pink/5% scum	2.06		Producer
9: 06/30 - 07/22/2009	6/30/09 pink/no crust or scum 7/1/09 dark pink/15% crust 7/21/09 red/2% scum 7/22/09 red/1% scum	1.87 1.33 (7/1/09)	0.885	Producer Sludge Gun

4.3.2 Temperature, pH and oxidation-reduction potential

The measured lagoon liquid temperature varied from 3.2^{o} C to 32.4^{o} C (Section 6.11). The measured lagoon pH varied from 7.6 to 8.1 (Section 6.11) while the oxidation-reduction potentials varied from -245 mV to -553 mV over the entire study period (Section 6.11).

4.3.3 Lagoon Chemistry

Lagoon water chemical analyses were not conducted by the project but analyses required by the NRCS at the time of water removal for field application was available for applications during the overall project period. Due to the drought conditions present at the site, water was only removed once (Table 4.3-3).

Table 4.3-3: Record of lagoon chemistry

				Percent (wet weight basis)		
Date	**n**	**pH (SU)**	**Nitrogen**	**Solids**	**Ammonia**	**Sulfur**
8/31/2009	1	7.40	0.20	N/A	N/A	0.08
7/17/2009	1	7.66	0.30	N/A	N/A	0.08
5/26/2009	1	7.46	0.36	N/A	N/A	0.01
4/3/2009	1	7.30	0.30	N/A	N/A	0.07
4/3/2009	1	7.30	0.30	N/A	N/A	0.07
2/18/2009	1	7.31	0.32	N/A	N/A	0.07
12/16/2009	1	7.63	0.24	N/A	N/A	0.07
10/15/2008	1	7.56	0.24	N/A	N/A	0.07
8/26/2008	1	7.68	0.26	N/A	N/A	0.08
7/9/2008	1	7.42	0.30	N/A	N/A	0.09
7/9/2008	1	7.42	0.30	N/A	N/A	0.09
5/16/2008	1	7.79	0.33	N/A	N/A	0.07
5/25/2009	1	7.49	0.38	N/A	N/A	0.08
1/24/2008	1	7.51	0.29	N/A	N/A	0.08
11/20/2007	1	7.41	0.29	N/A	N/A	0.08
9/25/2007	1	7.68	0.26	N/A	N/A	0.08
8/1/2007	1	7.68	0.27	N/A	N/A	0.07
6/15/2007	1	7.22	0.28	N/A	N/A	0.07
4/19/2007	1	7.50	0.39	N/A	N/A	0.07
3/22/2007	1	7.54	0.31	N/A	N/A	0.06
1/24/2007	1	7.59	0.23	N/A	N/A	0.04
12/1/2006	1	7.41	0.20	N/A	N/A	0.05

4.4 Emissions measurements

Emissions data were calculated on a ½ h basis since this was the interval over which the S-OPS system sampled both sides of the lagoon and since this interval is in the range over which turbulence statistics are often calculated. Emissions reported on a head basis were scaled by the design animal population and not the animal population at the time of measurements to account for the longer term manure storage of the lagoon or basin. Emissions reported on an animal unit (1 AU = 500 lb) basis assumed the typical animal weight values reported by the producer. Piglets were not included in the populations or AU determinations. Emissions reported on an area basis are based on the surface area of the lagoon.

Validation of bLS

The Method 301 validation method for the bLS emissions measurement was based on 829 ½ h measurement periods over the entire measurement time at this location. Results show that the bLS emissions had a significantly difference precision (F=3.14, critical F 1.0) and a significant bias over the *RPM* emissions (t=21.59, $t_{0.2}$=1.29) with a corresponding correction factor for the

bLS of 1.55 (Table 4.4.1-1). Consequently the ½ h bLS emissions measurements are biased high by 64% compared to the *RPM* measurements.

Table 4.4.1-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	bLS	bLS-RPM
Mean emission (gs^{-1})	0.793	1.227	0.434
Standard Deviation (gs^{-1})	0.443	0.785	
Variance of the mean (gs^{-1})	0.196	0.617	

4.4.1 NH_3 Emissions

4.4.1.1 Mean daily NH_3 emissions

An annual trend in the daily NH_3 emissions based on the *RPM* model was indicated (Figure 4.4.1-1) with a highly variable summer emission of between approximately 20 g and 80 g $NH_3 d^{-1} hd^{-1}$. The daily emissions during the winter decreased to approximately 5 g to 20g $NH_3 d^{-1} hd^{-1}$; however most of the winter emissions measurements may be overestimated by 64% due to the interference of atmospheric moisture. There are only a small number of daily emissions measurements estimated with more than 75% of the day's emissions. Considering only those emission values reduces the summer emission maximum to between approximately 30 and 60 g $NH_3 d^{-1} hd^{-1}$. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

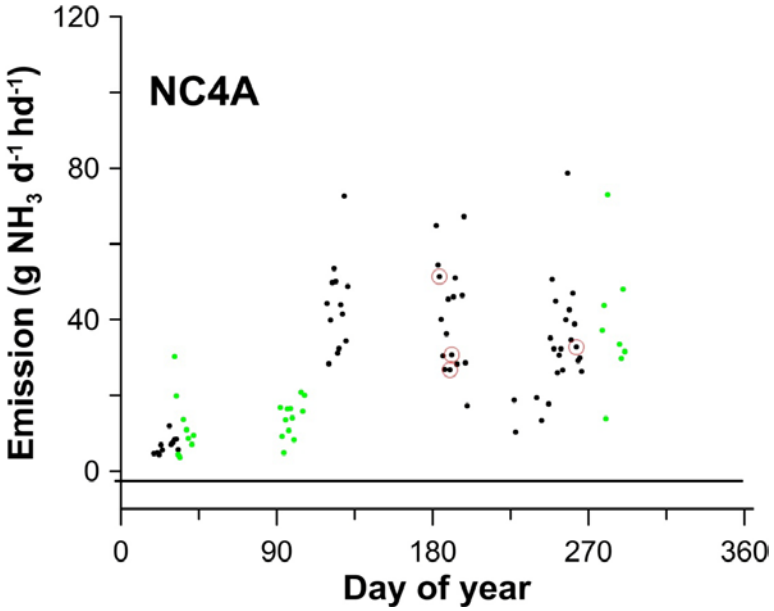

Figure 4.4.1-1: Annual variation in RPM-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

An annual trend in the daily NH_3 emissions based on the bLS model was indicated (Figure 4.4.1-2) with a highly variable summer emission of between approximately -20 and 200 g $NH_3 d^{-1} hd^{-1}$.

The daily emissions during the winter decreased to approximately 10 g to 20 g NH_3 $d^{-1}hd^{-1}$; however most of the winter emissions measurements may be overestimated by 64% due to the interference of atmospheric moisture. There were more daily measurements estimated with more than 75% of the day's emissions than using the *RPM* emissions model. Considering only those emission values reduces the summer emission maximum to between approximately 40 and 75 g NH_3 $d^{-1}hd^{-1}$. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

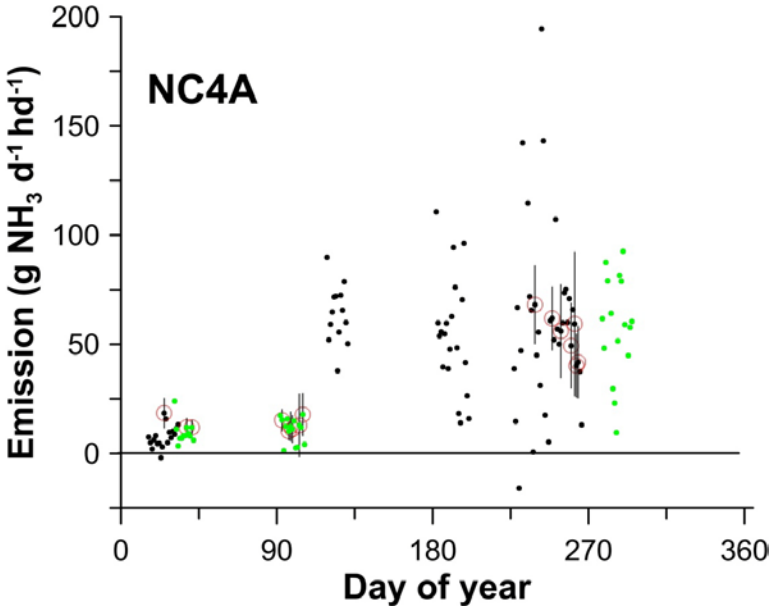

Figure 4.4.1-2: Annual variation in bLS-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

The bLS model is influenced by the calculated background concentrations. Results indicate that the background concentration of NH_3 was generally less than 0.1 ppm (Figure 4.4.1-3). Given that the typical path length around the lagoon was 100 m and the typical background concentration is less than 0.1 ppm, this corresponds to a background PIC of less than 10 ppm-m. This is approximately five times the MDL for the TDLAS instruments of 2 ppm-m (Section 8.1) and therefore represents a real background for this location. Negative background concentrations occur when the winds are variable resulting in no distinct upwind or downwind measurements.

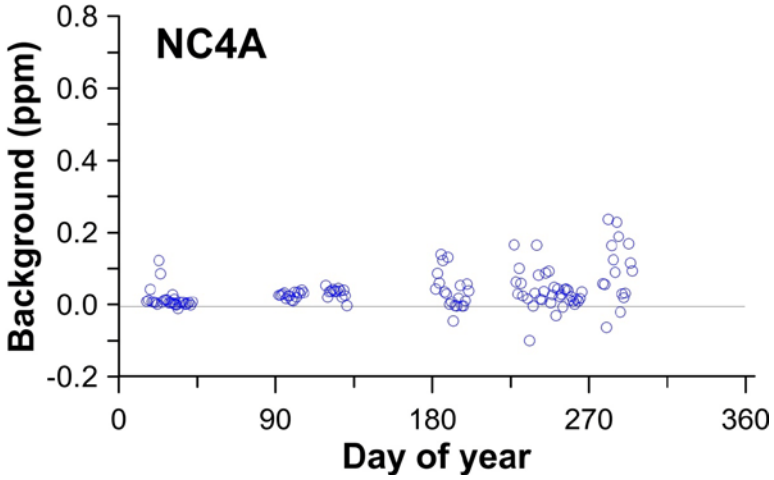

Figure 4.4.1-3: Annual variation in bLS-computed mean daily background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

In general, there was a strong diurnal pattern to the NH_3 emissions during all but the winter and early spring measurement periods (Figure 4.4.1-4).

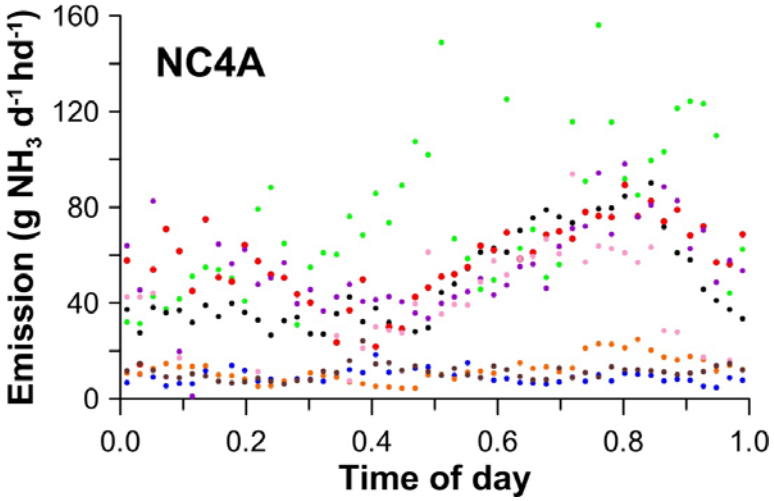

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 2-Fall (pink), Period3-Winter (brown), Period 4-Spring (orange), Period 5-Summer (green), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ h periods (corresponding to 75% completeness on a daily basis) is given. Because of the requirement of 5 to 10 valid TDLAS measurements before an *RPM* emission measurement is possible, the number of valid ½ h periods with *RPM* emissions was greatly limited. The wind conditions and wind direction exclusion region did not greatly reduce the yield of valid bLS emission measurements. The completeness statistics are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

	Measurement Period								
	2	**3**	**4**	**6**	**7**	**8**	**9**	**10**	**Total**
NH_3 RPM model									
Valid 1/2 h measurements (d)	1.3	1.5	1.5	0.3	6.9	1.9	4.4	7.0	**24.7**
Measurements excluded due to wind direction (d)	0.0	1.5	0.0	0.9	0.5	1.0	5.3	3.0	**12.0**
Measurements excluded because at least one downwind path is missing or invalid (d)	13.9	6.8	12.1	17.0	11.2	10.1	2.0	7.6	**80.8**
Number of d with≥36 valid 1/2 h periods (d)	0	0	0	0	1	0	0	3	**4**
NH_3 bLS model									
Valid 1/2 h measurements (d)	4.3	3.9	8.9	4.1	10.6	6.1	4.5	6.3	**48.7**
Measurements excluded due to wind direction (d)	0.7	2.0	2.6	1.8	1.6	2.8	5.1	3.0	**19.6**
Measurements excluded because touchdown fraction < 0.1 (d)	1.1	0.3	0.1	3.8	0.1	1.3	0.0	2.0	**8.6**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| < 2$ m (d)	8.5	4.1	2.7	8.0	6.0	6.8	2.1	7.4	**45.5**
Number of d with ≥36 valid 1/2 h periods (d)	0	2	6	1	6	1	0	0	**16**

In total, 24 d of valid NH_3 emissions were determined from the 138 measurement d using the *RPM* model, with only 4 d having at least 36 valid ½ h NH_3 emissions. The absence or invalidation of at least one downwind path led to 81 d for which emissions could not be calculated.

Forty eight d of valid NH_3 emissions were determined from the 138 measurement d using the bLS model, with 16 d having at least 36 valid ½ h NH_3 emissions. The exclusion wind directions due to the location of the barns relative to the lagoon resulted in the loss of 20 d of measurements. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) led to 46 d for which emissions could not be calculated. A touchdown fraction of less than 0.1 led to the exclusion of 8 d of data. Low touchdown fractions indicated that little, if any, downwind data was available.

This corresponded to either when the downwind TDLAS was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ h interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ h mean wind speed and direction, in contrast to the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times that the *RPM* model produces a valid emission while the bLS model does not. However, these times are overwhelmed by the times that the *RPM* model is missing concentration data for one or more paths, while the bLS model is able to run.

4.4.2 H_2S Emissions

4.4.2.1 Mean daily H_2S emissions

The average concentrations of air measured from the two S-OPS were nearly always at the MDL for the 450i H_2S analyzer. Consequently the Ratiometric model emissions measurements reported are essentially the MDL of the emissions method under the wind conditions at this location. There was no distinct annual pattern to the Ratiometric H_2S emissions measurements at this location based on the Ratiometric emissions model. One value is not plotted (48.6 g H_2S d^{-1} hd^{-1} on DOY 125). This extremely high value is a result of highly variable winds. The negative emissions correspond to light and variable winds making an indistinct upwind and downwind S-OPS path. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

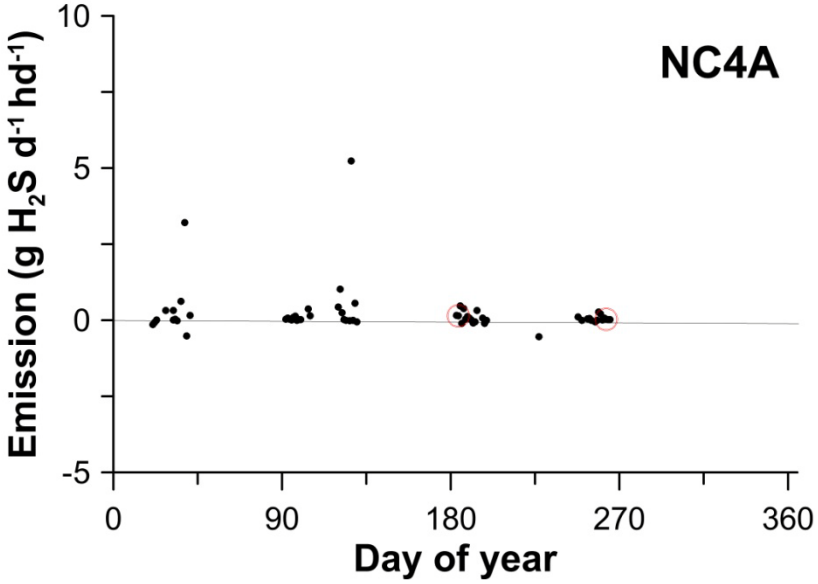

Figure 4.4.2-1: Annual variation in Ratiometric-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

As stated above, the average concentrations of air measured from the two S-OPS were nearly always at the MDL for the 450i H_2S analyzer and consequently the emissions measurements reported are essentially the MDL of the bLS emissions method under the wind conditions at this location. There is no distinct annual pattern to the H_2S emissions measurements at this location based on the bLS emissions model. One value (the same one as in the Ratiometric emissions estimate) is not plotted (26.1 g H_2S d^{-1} hd^{-1} on DOY 125). This extremely high value is a result of highly variable winds. The negative emissions correspond to light and variable winds making an indistinct upwind and downwind S-OPS path. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

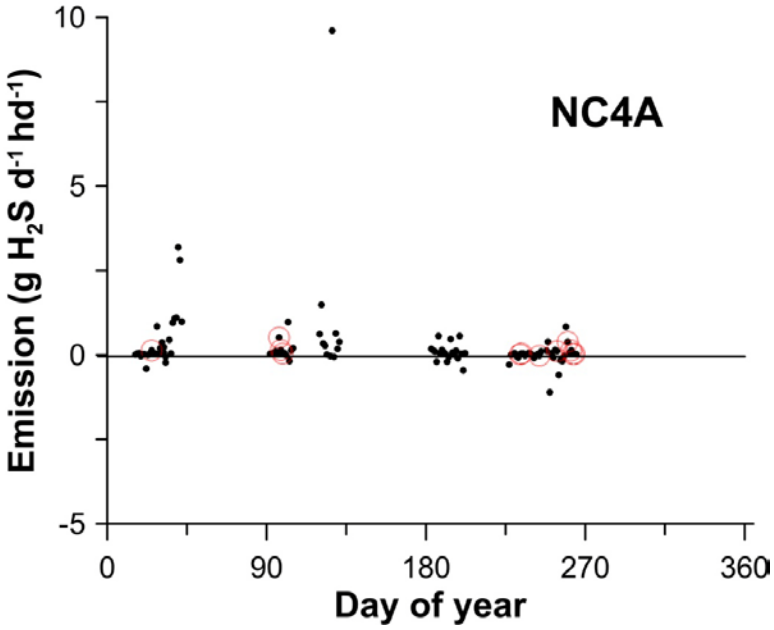

Figure 4.4.2-2: Annual variation in bLS-Computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS emission model depends on a good estimate of the background H_2S concentration. Results indicate that the background concentration was generally less than ± 2.5 ppb (Figure 4.4.3-3). This background is consistent with an equivalent zero value where the instrument MDL was 3.4 ppb (Section 6.2).

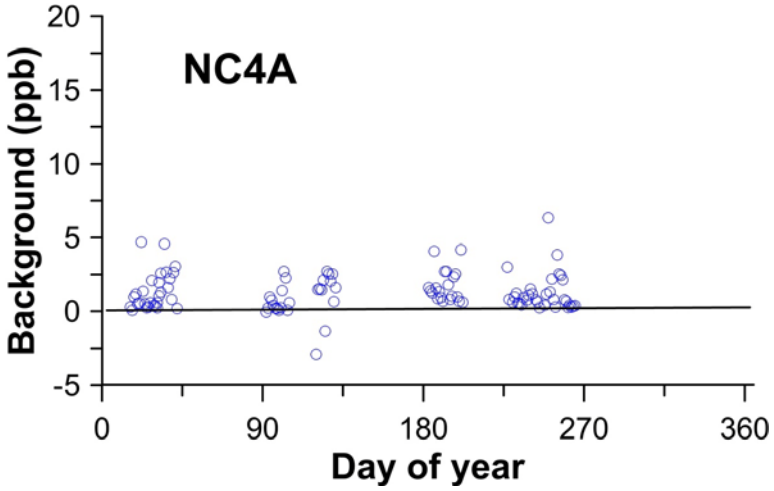

Figure 4.4.3-3: Annual variation in bLS-computed mean daily background concentration of H_2S.

4.4.2.2 Diurnal variation in H_2S emissions

There was no distinct diurnal periodicity in the H_2S emissions measurements (Figure 4.4.2-4).

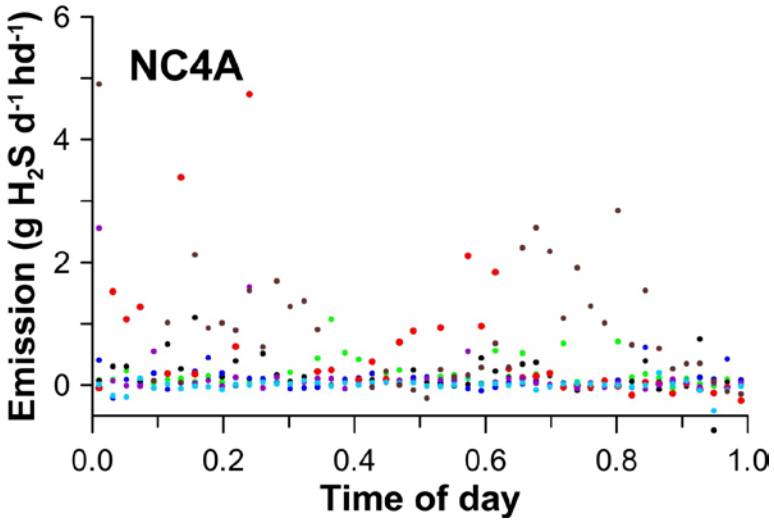

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 3-Winter (brown), Period 4-Spring (green), Period 5-Summer (light blue), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.2.3 H_2S emissions data completeness

H_2S measurements were begun in Period 3. Consequently there were no measurements possible for Fall 2007. As described for the NH_3 emissions, emissions completeness and failure totals are

given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics are summarized in Table 4.4.2-1.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

	Measurement Period								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
H_2S Ratiometric model									
Valid 1/2 h measurements (d)		0.6	1.1	0.0	5.1	0.5	2.7	4.7	**14.7**
Number of d with ≥36 valid 1/2 h periods (d)		0	0	0	1	0	0	1	**2**
H_2S bLS model									
Valid 1/2 h measurements (d)		2.6	5.9	5.4	8.3	5.0	3.0	6.4	**36.6**
Measurements excluded due to wind direction (d)		2.0	2.3	1.8	1.6	3.0	5.2	3.0	**18.7**
Measurements excluded because angle of attack > 60 degrees (d)		1.5	1.8	2.6	1.7	2.0	1.1	2.2	**12.9**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| <$ 2 m (d)		5.0	2.5	8.8	6.0	7.1	2.0	7.9	**39.4**
Number of d with ≥36 valid 1/2 h periods (d)		0	3	3	5	1	0	0	**12**

The H_2S emissions were measured a total of 108.8 d at this location. The majority of measurements were invalidated as a result of inconsistent turbulence statistics- probably a result of the proximity of the wooded areas to the lagoon (Figure 1-2). Because there were few valid ½ measurements of the NH_3 emissions based on the *RPM* model (Table 4.4.1-2), the number of valid ½ periods of valid Ratiometric emissions measurements of H_2S is small. The majority of bLS emissions measurements were invalidated due to wind conditions. In total, 14 d of valid H_2S emissions were determined using the Ratiometric emission method, with only 2 d having at least 36 valid ½ h H2S emissions. Thirty six d of valid H_2S emissions were determined using the bLS model, with 12 d having at least 36 valid ½ h H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) excluded 39 d, largely due to low winds speeds. Wind direction exclusions invalidated 19 d of measurements.

4.4.3 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of the TDLAS serial numbers 1026, 1027, and 1028 prior to July 21, 2008. TDLAS 1027 was used at NC4A from 3/31/2008 to 4/16/2008 (Measurement period 4). TDLAS 1028 was used at NC4A from 10/4/2007 to 10/22/2007, 1/29/2008 to 2/11/2008, 3/31/2008 to 4/16/2008 (Measurement periods 2, 3 and 4). Under the calibration verification checks, the TDLAS error of all units was 10% accuracy. However due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and units without apparent interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from

dewpoint temperatures of -2°C to 20°C. A conservative estimate of the bias of all of the above TDLAS units with evident moisture interference was estimated at -40%.

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions, underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%. Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was +55% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of +15% for TDLAS NH_3 measurements made by units with moisture interference and a bias of +55% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the Ratiometric measurement of H_2S emissions was ±18%.

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6 Appendices

6.1 TDLAS NH_3 calibrations

Six TDLAS units Model GasFinder 2.0^{TM} NH3OP (Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used at this location: serial numbers 1026, 1027, 1028, 1030, 1031, and 1032

TDLAS 1026 was multipoint calibrated seven times (Figure 6.1-1). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 1/17/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3,$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and

11/10/2009 bias exceedances were followed the same or next day with a passing verification and were deemed to be a result of operator error. The negative bias over the period 4/2/2008 through 7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used). During operations the bias was only intermittently evident because two different multipoint calibrations were applied to the calibration verification measurements during the progress of the study. Repeated calibrations within 24 hours often showed biases differing by more than 10 ppm-m, which suggested operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period are considered valid and the error assumed to be due to the calibration verification operator.

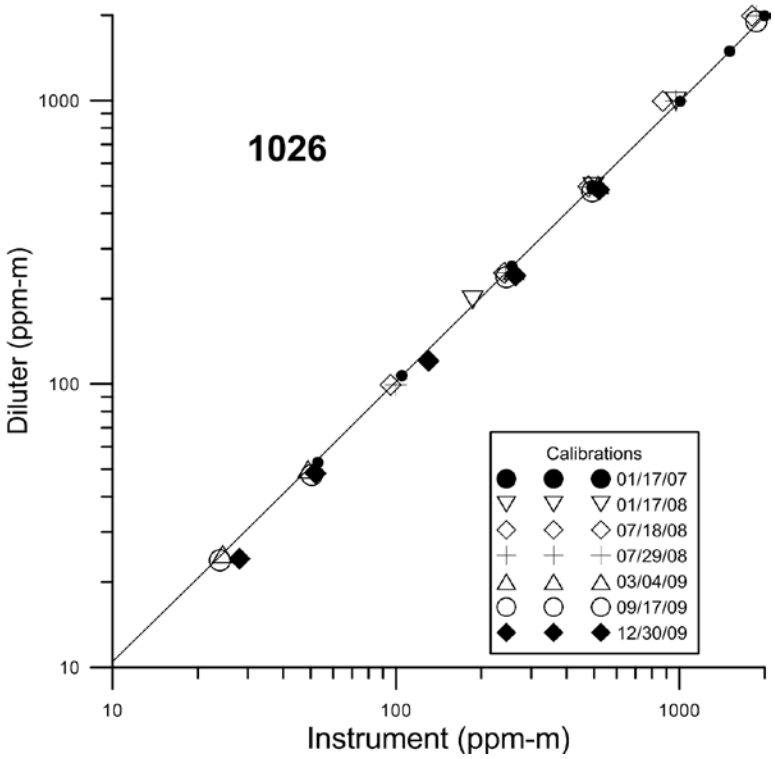


Figure 6.1-1: Multipoint calibrations of the GasFinder 2.0 ^{TM} s/n NH3OP-1026. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

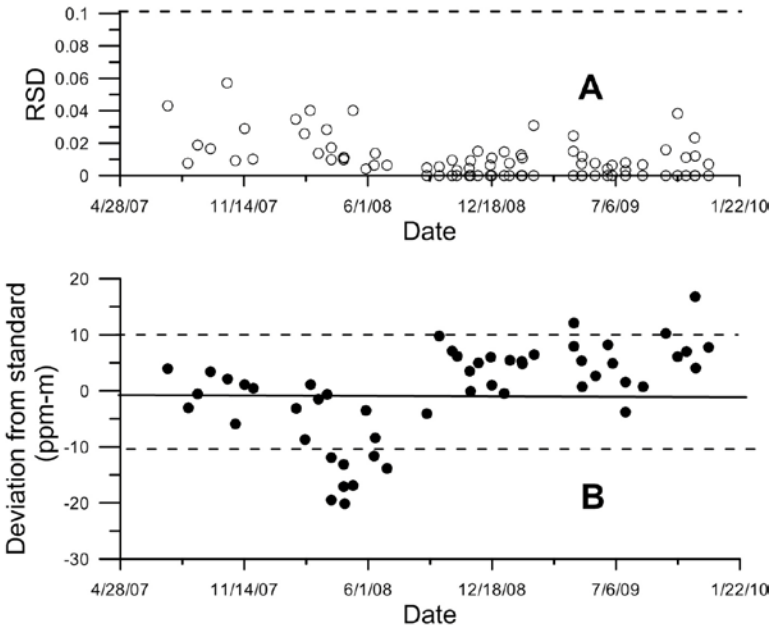


Figure 6.1-2: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1026

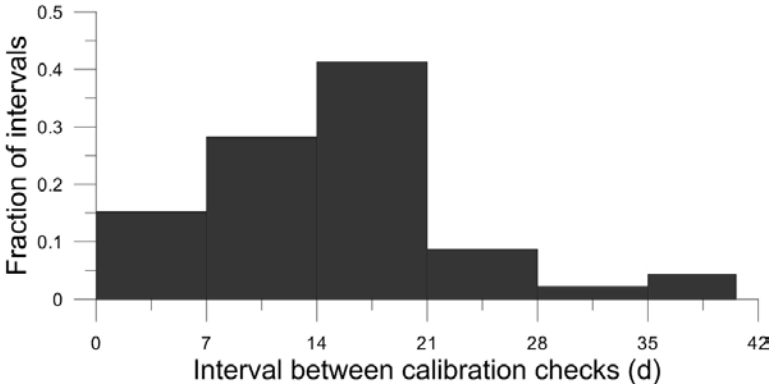


Figure 6.1-3: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1026

TDLAS 1027 was multipoint calibrated eight times (Figure 6.1-4). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 6/18/08 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 2.24 + 0.9936 * X - 3.59E\text{-}5 * X^2 + 6.230E\text{-}8 * X^3,$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.13 ppm-m prior to the July 2008 modification and 1.83 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 5.36 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 9/26/2008 and 9/24/2009 (Figure 6.1-4). No negative biases exceeding the DQI occurred. Since both positive bias exceedances were followed by a DQI compliant verification on the subsequent calibration verification without intervention, it is assumed that operator error was the cause for the non-compliance.

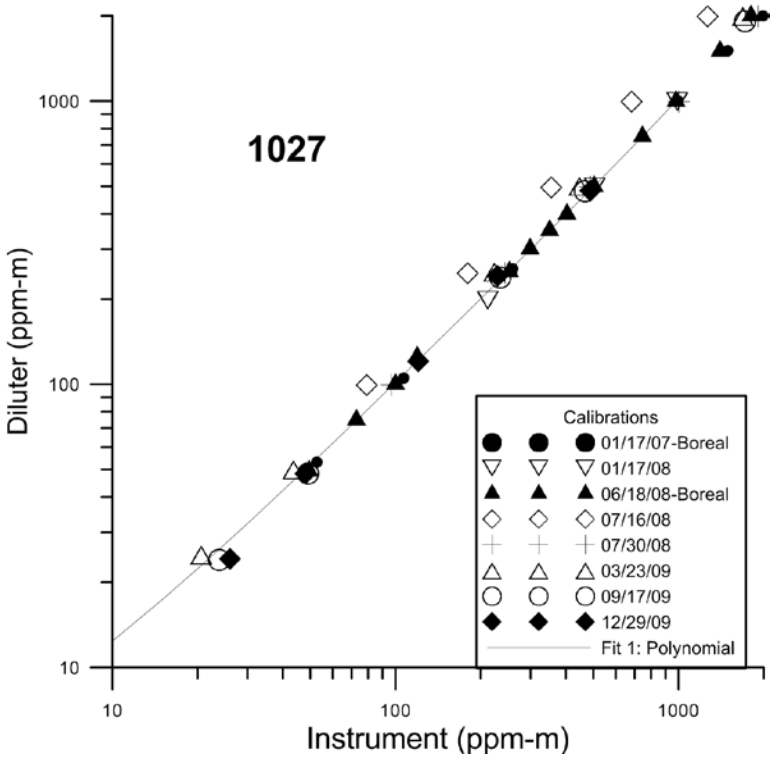


Figure 6.1-4: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1027. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

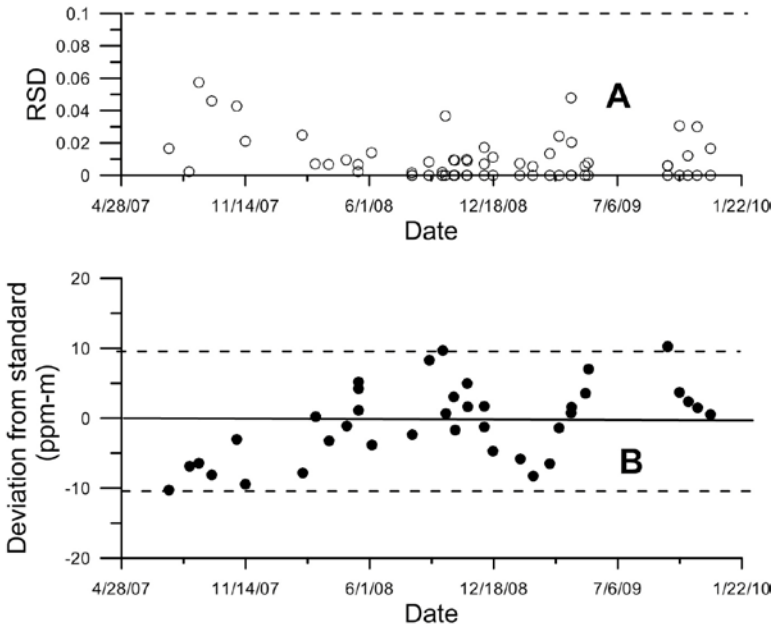


Figure 6.1-5: Control charts of the GasFinder 2.0 [TM] s/n NH3OP-1027

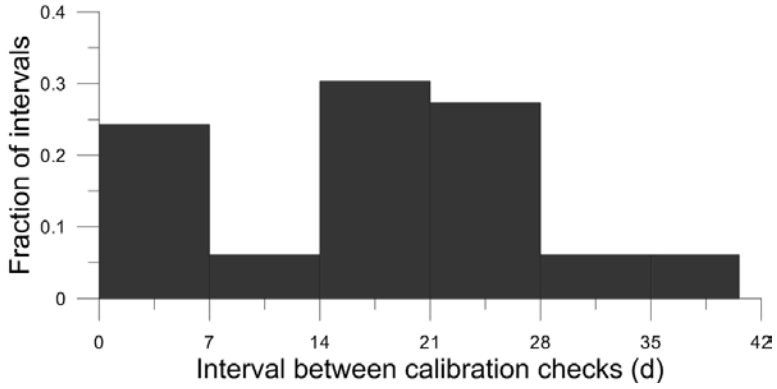


Figure 6.1-6: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1027

TDLAS 1028 was multipoint calibrated six times (Figure 6.1-7). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 5/23/07 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 1.46 + 0.985 * X + 8.465E\text{-}6 * X^2 + 3.879E\text{-}8 * X^3,$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-8) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 6.1-8). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

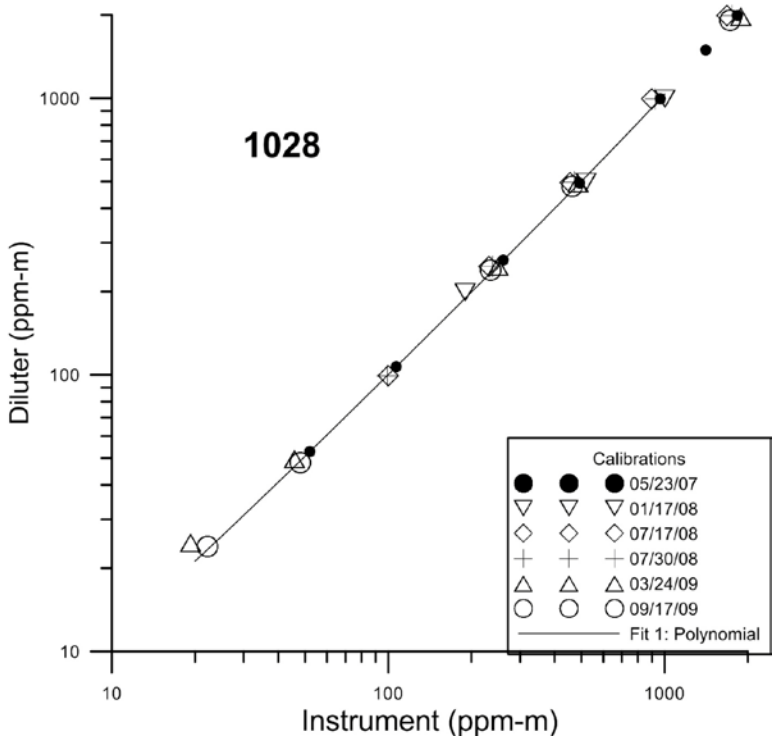


Figure 6.1-7: Multipoint calibrations of the GasFinder 2.0 ™ s/n NH3OP-1028. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

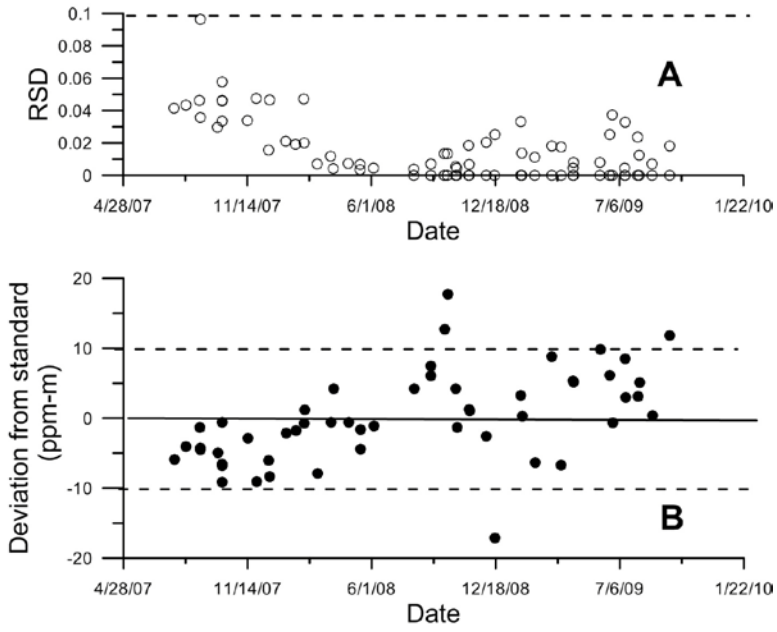


Figure 6.1-8: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1028

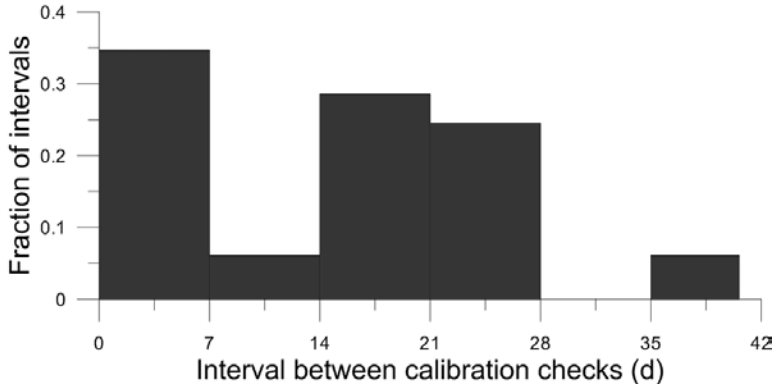


Figure 6.1-9: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1028

TDLAS 1030 was multipoint calibrated eight times (Figure 6.1-10). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 3/26/08 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$ppm\text{-}m = 0.13 + 0.9974 * X - 2.1056E\text{-}005 * X^2 + 3.050E\text{-}008 * X^3$,

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. The adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 3.05 ppm-m prior to the July 2008 modification and 0.685 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-12). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 7.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m except on 8/30/2007 (Figure 6.1-11) and well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 8/14/2008 and 9/23/2008 while negative biases exceeding the DQI occurred on 10/4/2007, 9/23/2008, and 4/28/2009 (Figure 6.1-11). In all cases, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

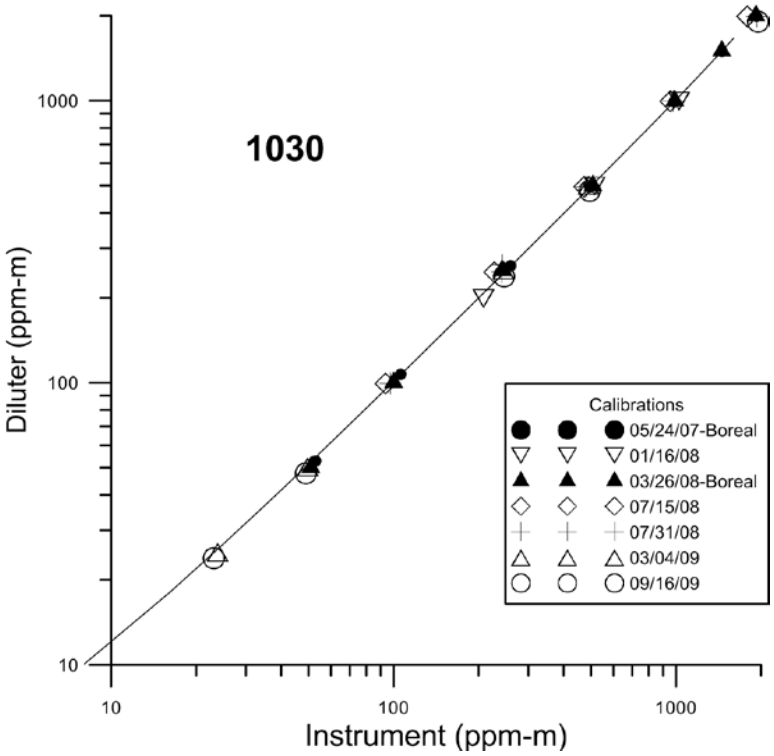


Figure 6.1-10: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1030. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

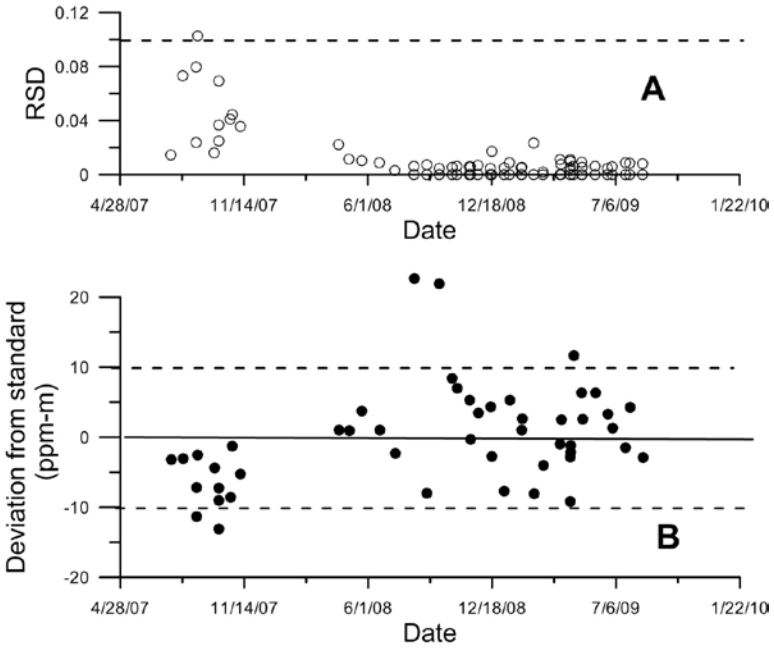


Figure 6.1-11: Control charts of the GasFinder 2.0 [TM] s/n NH3OP-1030

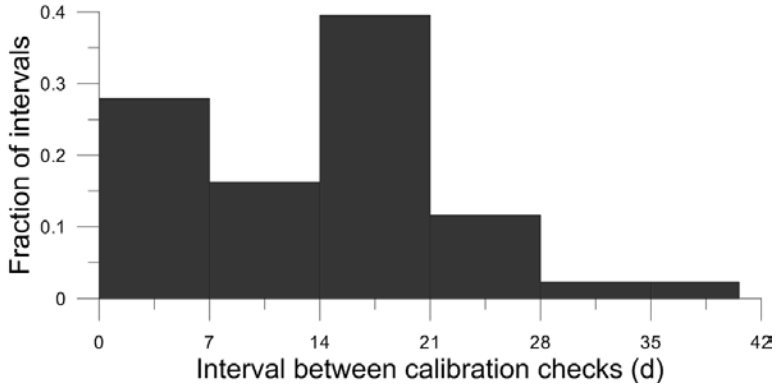


Figure 6.1-12: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1030

TDLAS 1031 was multipoint calibrated six times (Figure 6.1-13). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 5/30/07 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -4.43 + 1.0120 * X - 5.7496E\text{-}005 * X^2 + 6.0196E\text{-}008 * X^3,$$

where X was the instrument response. In July 2008, factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 5.70 ppm-m prior to the July 2008 modification and 1.92 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The average MDL was approximately equal to the offset indicated in the calibration regression. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-14) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-15). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 15.60 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-14) and were well within the precision DQI. The accuracy DQI was ± 10%

of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI occurred in the calibration verifications between 8/2/2007 and 9/18/2007 (Figure 6.1-14). Positive DQI bias exceedances occurred on 6/28/2007, 9/11/2008, 4/8/2009 and 8/12/2009. Verification failures in the 6/28/2007 to 9/18/2007 interval were a result of un-anticipated optical noise in the calibration procedure which was later corrected. The 4/8/2009 exceedance was preceeded and followed by DQI-compliant verifications and the 8/12/2009 verification was preceeded by a compliant verification and followed by a multi-point indicating no problem with instrument performance. The instrument was taken out of service between 9/11/2008 and 12/31/2008 due to damage from moisture in the instrument.

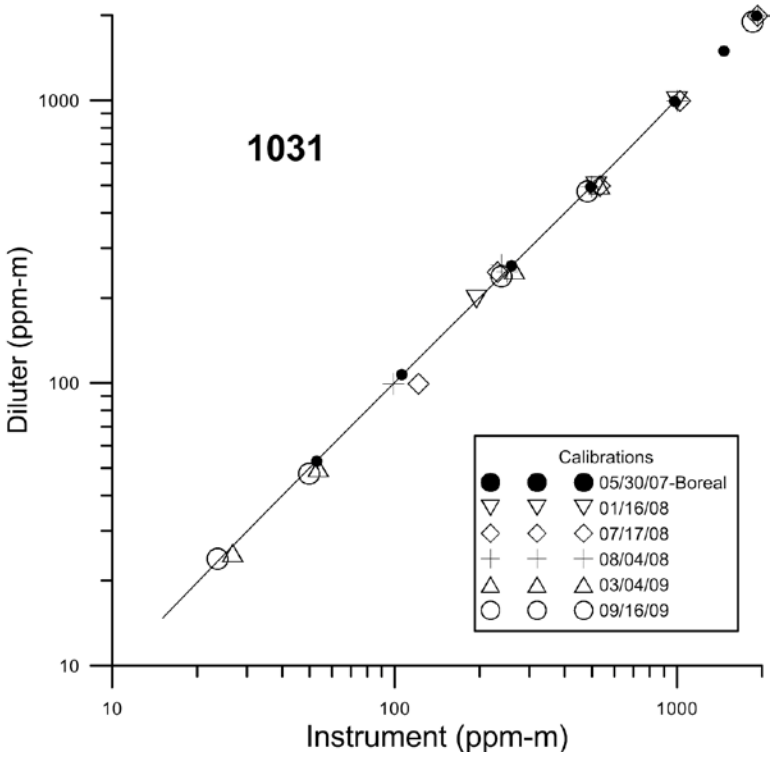


Figure 6.1-13: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1031. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

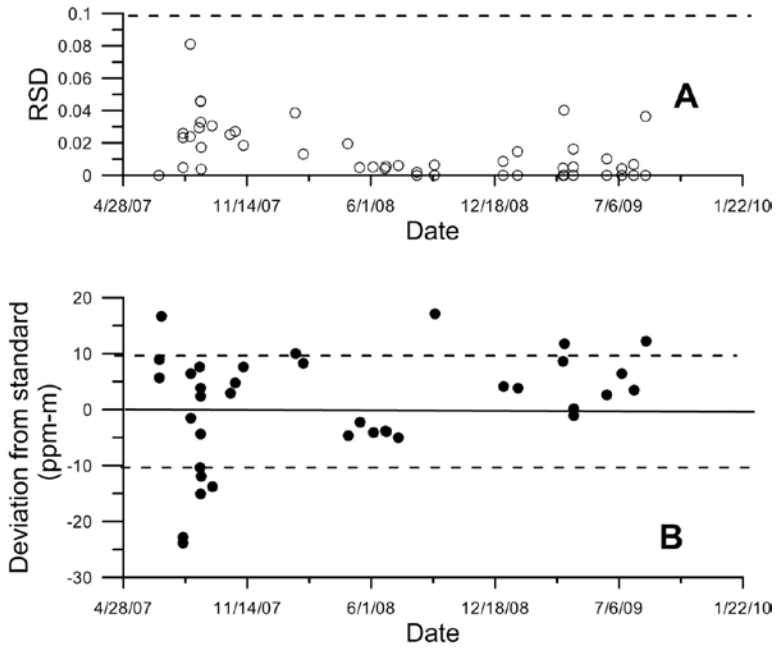


Figure 6.1-14: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1031

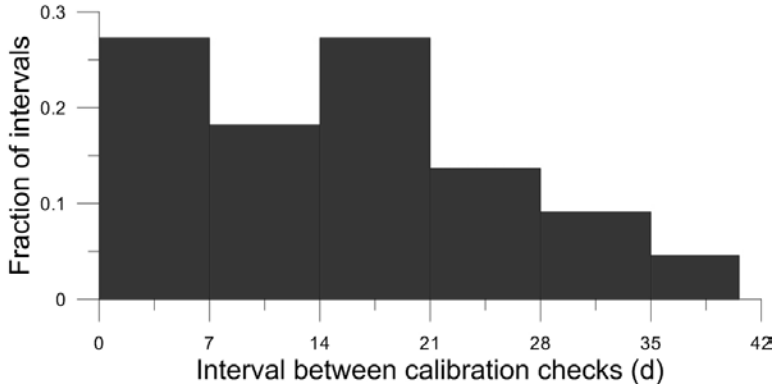


Figure 6.1-15: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1031

The Boreal GasFinder 2.0 ^{TM}, serial number NH3OP-1032, was multipoint calibrated six times (Figure 6.1-16). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-1 indicated the multi-point calibrations used during different periods in the study.

Table 6.1-1: Multi-point calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
9/21/2007	8/1/2008	9/12/2007
8/27/2008	8/18/2009	3/4/2009

The offset of the calibration equation was determined from a least squares fit of the appropriate period (Table 6.1-1) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

9/12/07: ppm-m = -4.35 + 1.005 * X + 3.563 E-005 * X^2 - 2.618 E-008 * X^3

3/4/09: ppm-m = -0.69 + 0.995 * X - 2.3298 E-004 * X^2 + 2.891 E-007 * X^3

where X was the instrument response. In July 2008, factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments). The laser was found on 7/21/2008 to not be internally grounded properly, resulting is the inclusion of responses at very low light levels. The reportable instrument response was above the minimum light level threshold considered for a valid instrument measurement.

A zero concentration was not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.60 ppm-m prior to the July 2008 modification and 1.36 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL was greater than the offset in the calibration equation for measurements prior to July 2008 and less than that after July 2008. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-17) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-18). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the

verifications about that predicted by the calibration equation was 6.13 and 5.61 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-17) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias exceeding the DQI occurred on 3/26/2008 and 9/10/2008 (Figure 6.1-17). These exceedances were preceeded and followed by valid calibration verifications and it is assumed that since no modifications of the instrument were made that the exceedances are due to operator error. A negative bias exceeding the DQI was indicated in the calibration verifications on 5/6/2008 (Figure 6.1-17). The grounding problem found on 7/21/2008 (described above) may have been the cause for the period of consistently negative verifications after 4/21/2008 when the background light levels exceeded the minimum acceptable light level. However since the 5/6/2008 exceedance was followed by compliant verifications (although low) without correction of the grounding problem it is assumed that the measurements are valid throughout the period of the grounding problem.

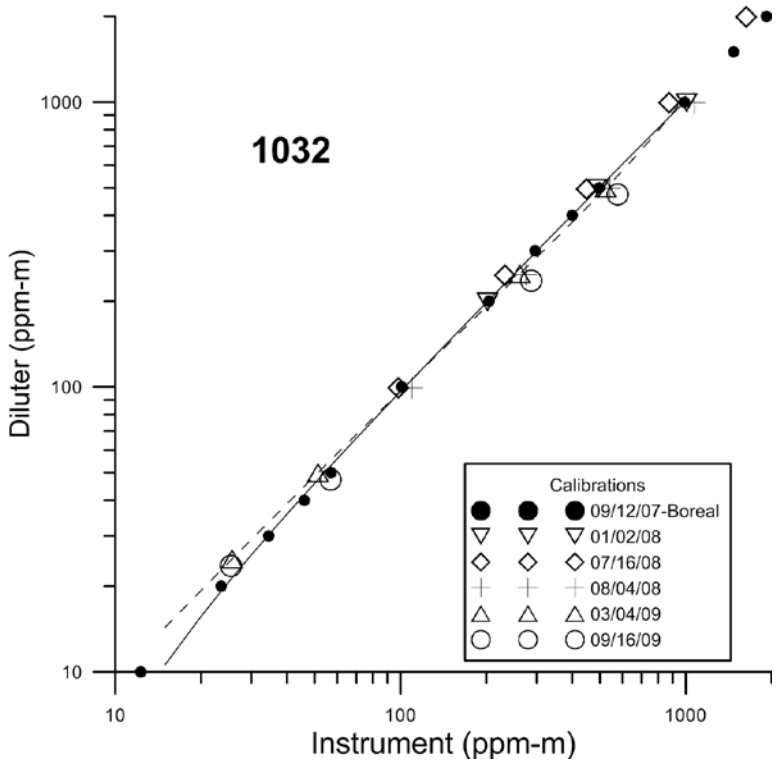


Figure 6.1-16: Multipoint calibrations of the GasFinder 2.0 [TM] s/n NH3OP-1032. The solid (9/12/07) and dashed (3/4/09) lines are the 3rd order polynomial regressions for the chosen multipoint calibration.

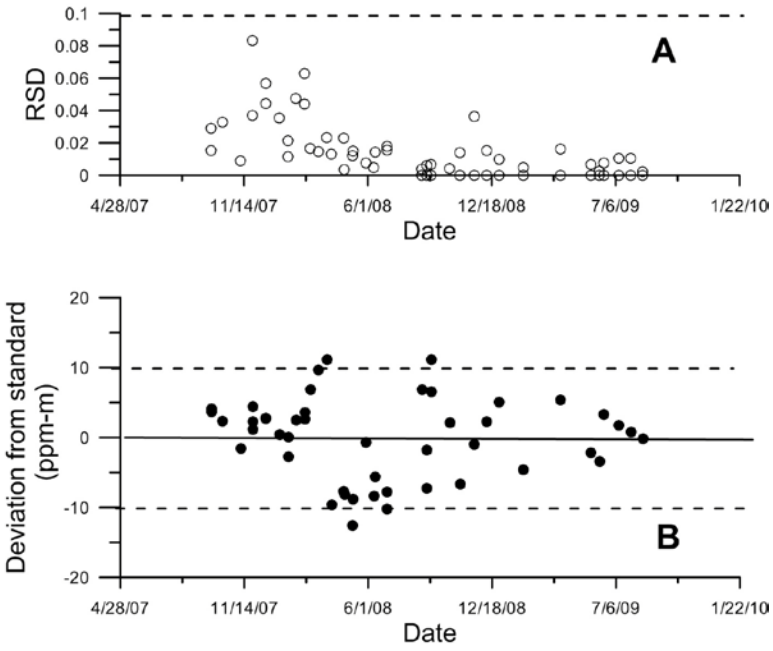


Figure 6.1-17: Control charts of the GasFinder 2.0 ™ s/n NH3OP-1032

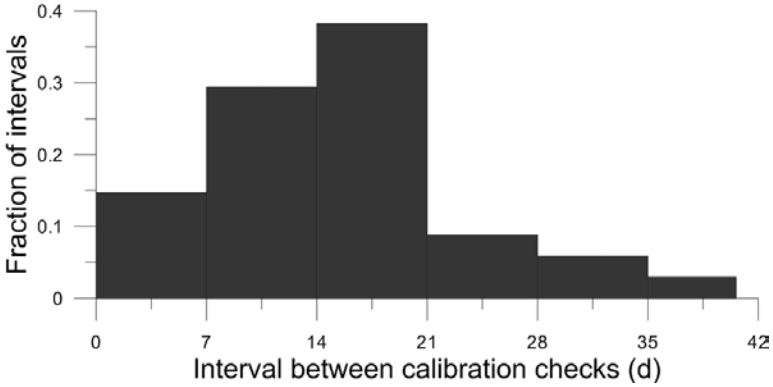


Figure 6.1-18: Calibration check intervals of the GasFinder 2.0 ™ s/n NH3OP-1032

6.2 TEC 450i analyzer H_2S calibrations

The SO_2/H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA) (serial number 0733825130) (serial number 0733825129) was multipoint calibrated seven times (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.67 to 0.94 (Table 6.2-1). The initial 12/30/2007 multipoint calibration records were lost.

Table 6.2-1: Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
07/21/2008	0.67	0.0100	0.999
11/25/2008	0.81	0.0070	0.999
03/05/2009	0.94	0.0165	0.999
04/23/2009	0.73	0.0263	0.999
04/29/2009	0.78	0.0206	0.999
09/01/2009	0.75	0.0054	0.999
12/29/2009	0.81	0.0083	0.999

The standard deviation of instrument response with CEM zero air measured over a one hour period was 0.81 ppb (12/29/2009). The instrument MDL, defined as 3σ was 2.4 ppb and is indicated in Figure 6.2-2A with dashed lines. This is much less than the mean absolute value of the multipoint calibration intercept of 13.4 ppb.

Instrument performance calibration checks (Figure 6.2-2, 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 25 d (Figure 6.2-4). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas to instrument reading. The long-term mean ratio for this instrument was 0.800. The mean zero concentration was +0.3 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). The initial calibration check (1/15/2008) was conducted prior to the complete burn-in of the converter and consequently differs from the other calibrations and indicated a failed check in the post-study response check (Figure 6.2-2B). Post-study response checks in August and September 2008 also indicated check failures (Figure 6.2-2B), although all of these failures are associated with a non-diluted calibration cylinder where the balance gas was N_2 and consequently, the 450i converter was unable to function properly.

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedances (Figure 6.2-3) occurred on 2/12/2008 and 3/5/2009. The 2/2/2008 failure was likely due to the burn-in of the converter and signal changes in the instrument response as the instrument is conditioned. The failure on 3/5/2009 was likely a result of the use of an out-of-certification range calibration cylinder (although within certification period; FF44447). This cylinder was 38% below the mean concentration of nine cylinders inter-compared on 8/28,31/2009. Calibration certifications before and after this date were valid.

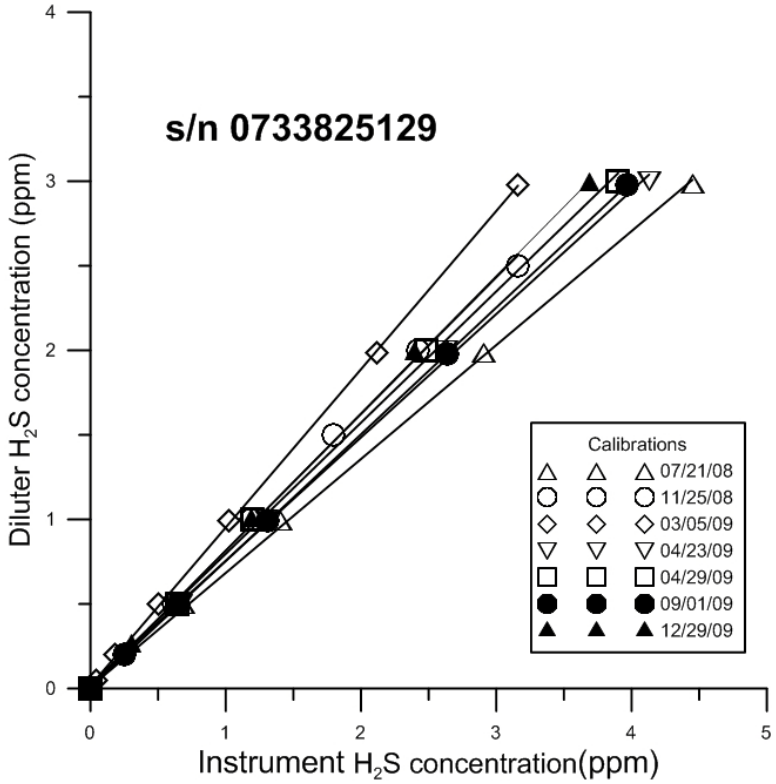


Figure 6.2-1: Multipoint calibrations of the 450i SO_2/H_2S Analyzer

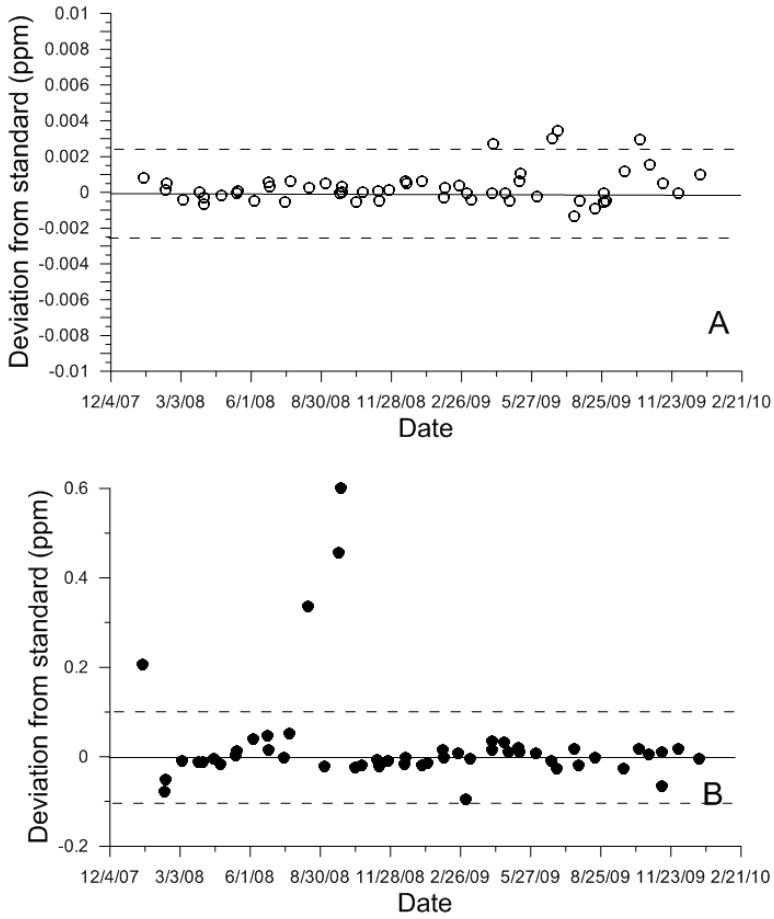


Figure 6.2-2: Instrument Control Charts

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

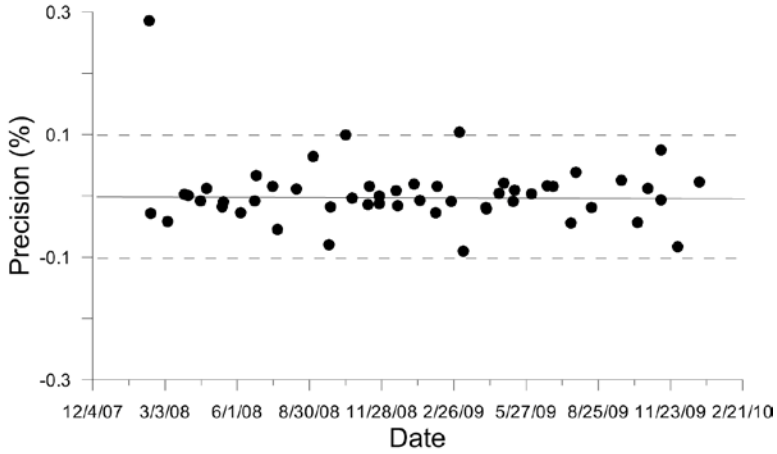


Figure 6.2-3: Instrument Precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

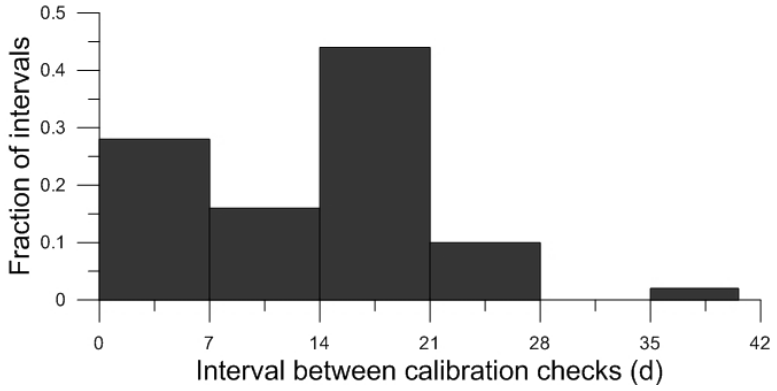


Figure 6.2-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Seven sonic anemometers (Model 81000, RM Young Inc, Traverse City, MI) were used at this location: serial numbers 1927, 1926, 1933, 1920, 1928, 1945, and 1932.

The sonic anemometer 1927 was inter-compared with three reference anemometers of identical design five times (Table 6.3-1). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check on all checks except 9/23-25/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back to use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-1: Reference inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.025	-0.043
1/21/2008	1/23/2008	-0.051	-0.033
7/16-17/2008	7/17-18/2008	+0.042	+0.029
3/23-25/2009	03/25-27/2009	-0.050	-0.028
9/1-2/2009	9/2-03/2009	-0.035	-0.023

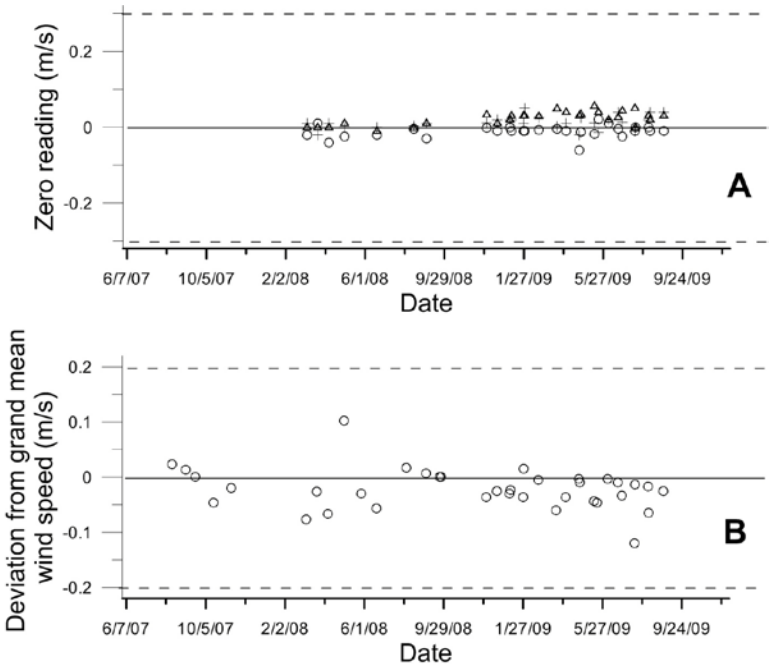


Figure 6.3-1: On-site quality assurance of s/n 1927. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

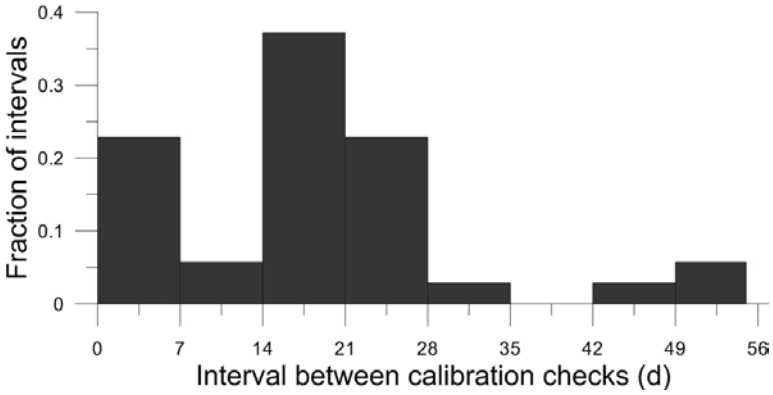


Figure 6.3-2: Inter-comparison check intervals for s/n 1927.

The sonic anemometer 1926 was inter-compared with three reference anemometers of identical design five times (Table 6.3-2). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-3). The majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of checks made within 7 d was

the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-3B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 1A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-2: Reference inter-comparisons

Calibration dates		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29-7/2/2007	-0.005	-0.033
1/17-18/2008	1/20-21/2008	-0.013	-0.032
7/16-17/2008	7/17-18/2008	+0.037	+0.059
3/6-7/2009	3/7-9/2009	+0.004	+0.048
9/16-17/2009	9/17-18/2009	+0.059	+0.001

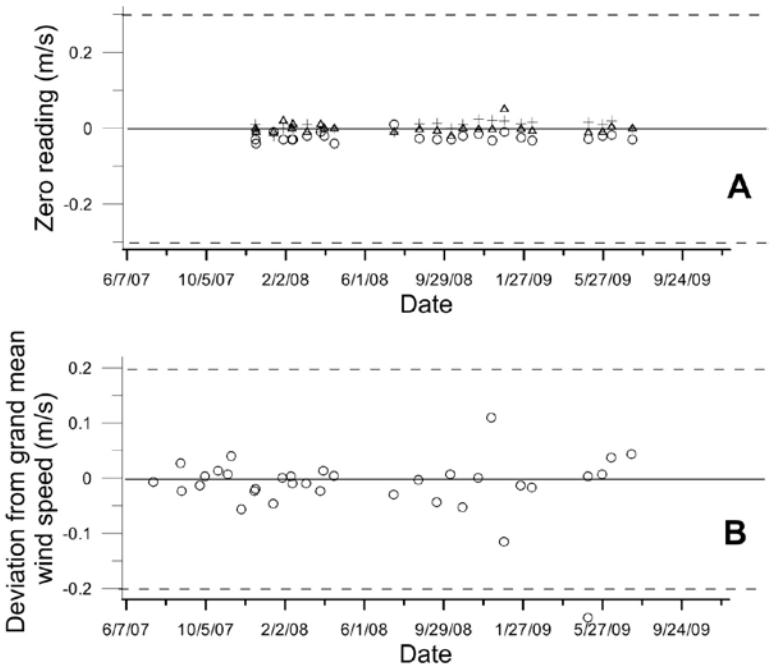


Figure 6.3-3: On-site quality assurance of s/n 1926. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

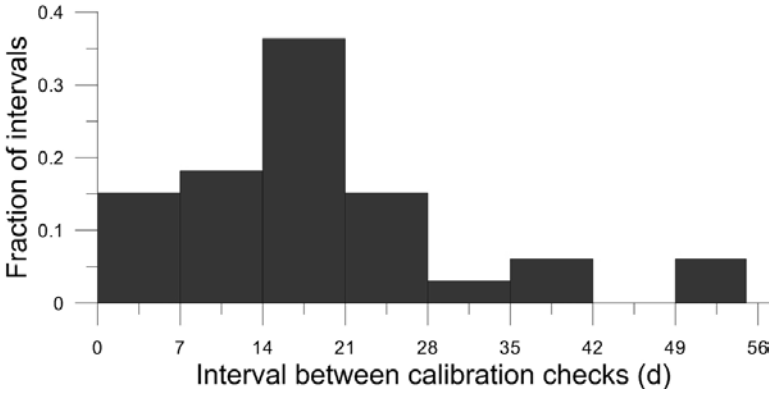


Figure 6.3-4: Inter-comparison check intervals for s/n 1926.

The sonic anemometer 1933 was inter-compared with three reference anemometers of identical design three times (Table 6.3-3). This instrument was used as a reference prior to use in the on-site measurements beginning 4/23/2008. No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 23 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-5B). This instrument passed this check on all checks except 7/21/2009 and was taken out of service. The last reference inter-comparison (1/2010) failed due to loss of communications.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-3: Reference inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
7/18-19/2008	7/21-22/2008	+0.012	+0.014
3/3-5/2009	3/5-6/2009	-0.016	-0.004
1/7-9/2010	1/23-25/2010	-3.733	-3.93

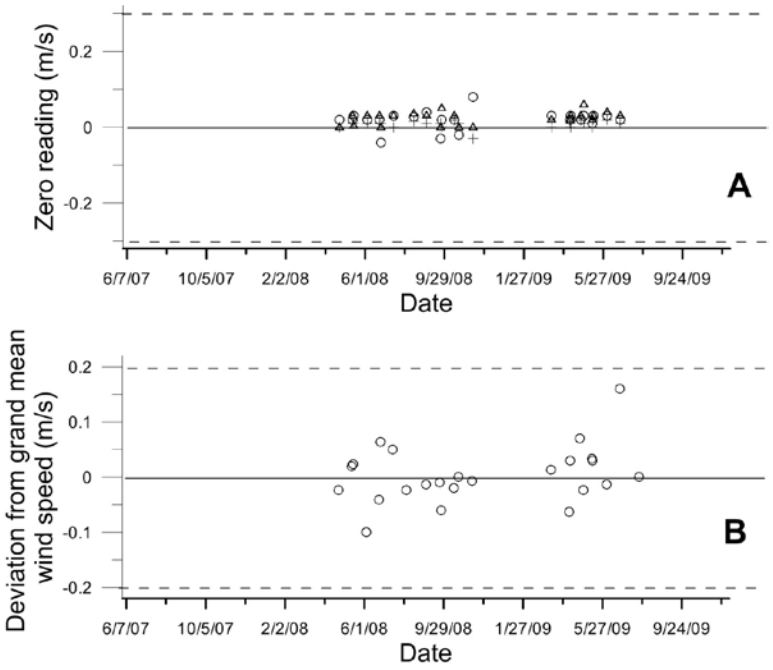


Figure 6.3-5: On-site quality assurance of s/n 1933. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

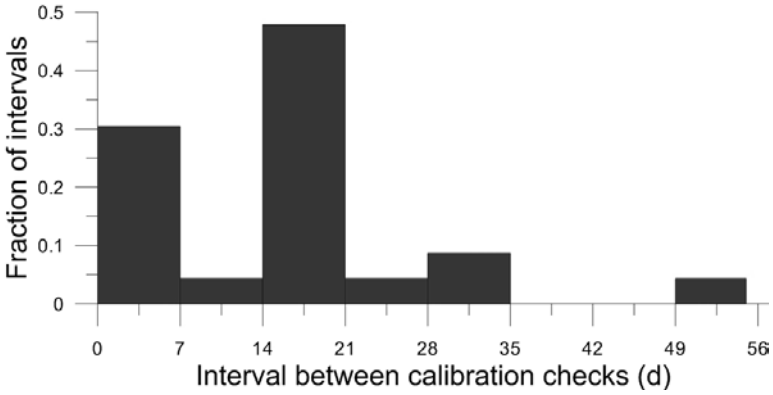


Figure 6.3-6: Inter-comparison check intervals for s/n 1933.

The sonic anemometer 1920 was inter-compared with three reference anemometers of identical design five times (Table 6.3-4). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 51 times (Figure 6.3-7). The majority of calibration checks were made within 21 d (Figure 6.3-8). The large fraction of checks made within 7 d was

the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-7B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 10/10/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-7A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-4: Reference inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29-7/2/2007	+0.001	+0.002
1/17-19/2008	1/20-21/2008	+0.045	+0.003
7/18-21/2008	7/21-22/2008	+0.017	-0.006
3/23-25/2009	3/25-27/2009	-0.036	-0.033
9/1-2/2009	9/2-3/2009	-0.046	-0.025

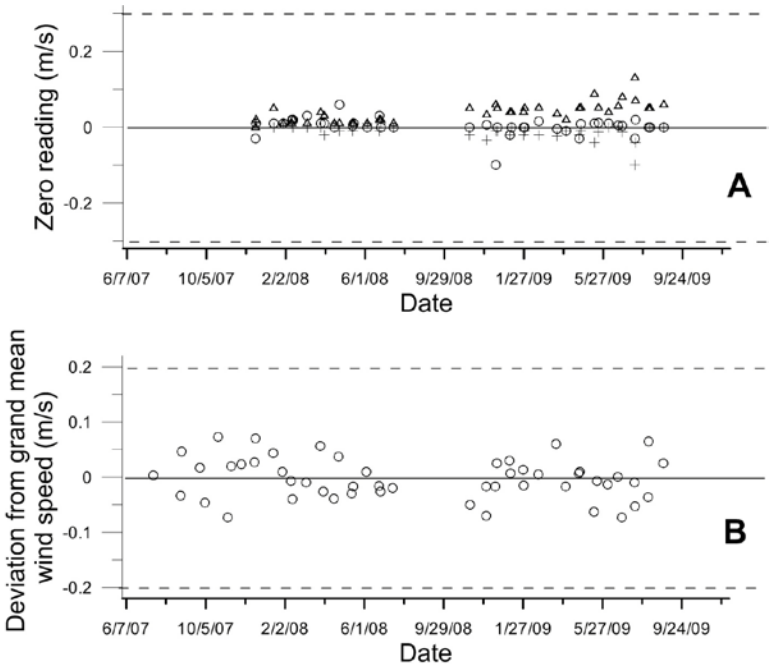


Figure 6.3-7: On-site quality assurance of s/n 1920. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

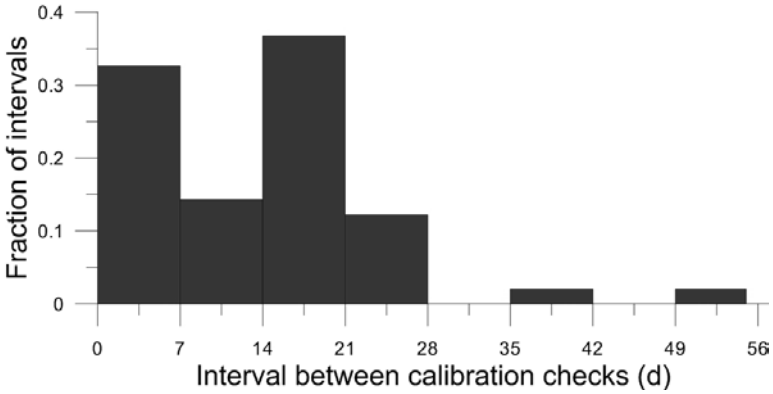


Figure 6.3-8: Inter-comparison check intervals for s/n 1920.

The sonic anemometer 1928 was inter-compared with three reference anemometers of identical design six times (Table 6.3-5). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 48 times (Figure 6.3-9). The majority of calibration checks were made within 21 d (Figure 6.3-10). The large fraction of checks made within 7 d was

the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-9B). This instrument passed this check all but one time. On this one date, the inter-comparison was rerun and the instrument passed the check.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-9A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-5: Reference inter-comparisons

Calibration dates		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.004	+0.019
12/27-28/2007	12/29-31/2007	+0.003	-0.005
7/10-11/2008	7/11-14/2008	+0.022	+0.007
3/3-4/2009	3/5-6/2009	+0.070	-0.027
9/16-17/2009	9/17-18/2009	+0.056	+0.022
12/18-19/2009	12/21-23/2009	+0.094	-0.077

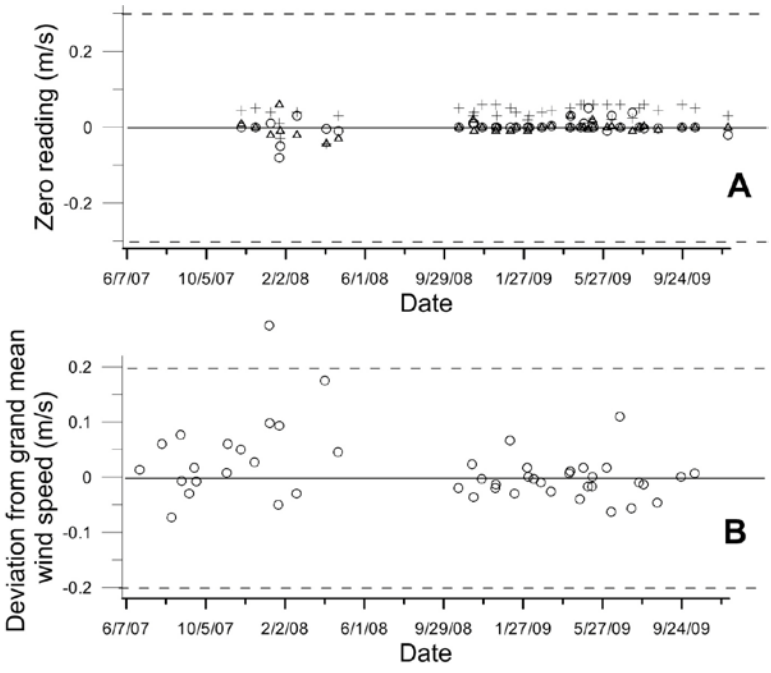


Figure 6.3-9: On-site quality assurance of s/n 1928. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

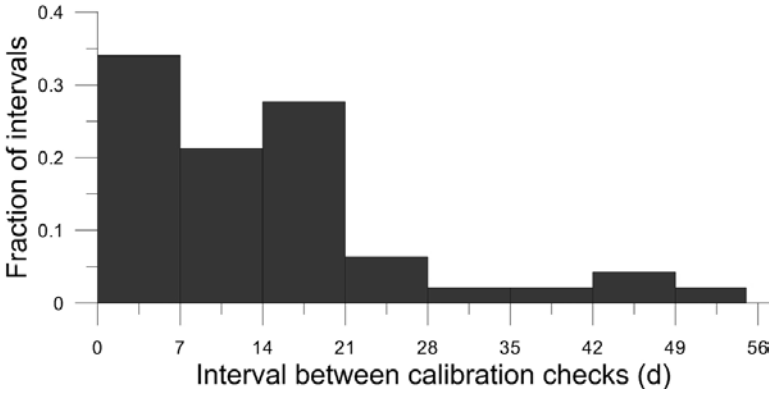


Figure 6.3-10: Inter-comparison check intervals for s/n 1928.

The sonic anemometer 1945 was inter-compared with three reference anemometers of identical design five times (Table 6.3-6). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 45 times (Figure 6.3-11). The majority of calibration checks were made within 21 d (Figure 6.3-12). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-11B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-11A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-6: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/27-7/2/2007	+0.001	-0.051
1/17-19/2008	1/20-21/2008	-0.023	-0.037
7/18-21/2008	7/21-22/2008	+0.023	+0.026
3/3-4/2009	3/5-6/2009	+0.014	+0.171
9/16-17/2009	9/17-18/2009	+0.028	-0.012

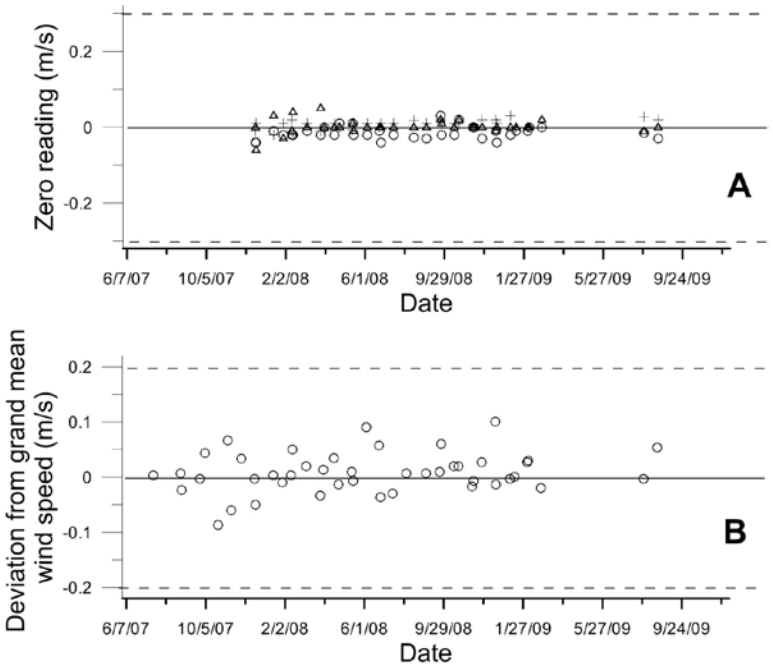


Figure 6.3-11: On-site quality assurance of s/n 1945. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

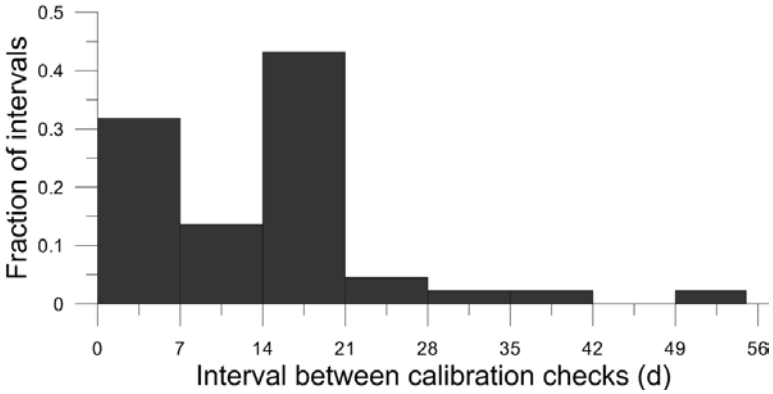


Figure 6.3-12: Inter-comparison check intervals for s/n 1945.

The sonic anemometer 1932 was inter-compared with three reference anemometers of identical design six times (Table 6.3-7). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 55 times (Figure 6.3-13). The majority of calibration checks were made within 21 d (Figure 6.3-14). The large fraction of checks made within 7 d was

the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-13B). This instrument passed this check on all checks except 10/15-16/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back to use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-13B). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-7: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-17/2007	6/18-19/2007	+0.004	+0.160
12/27-28/2007	12/29-31/2007	+0.014	-0.009
7/10-11/2008	7/11-14/2008	+0.008	+0.031
3/3-5/2009	3/5-6/2009	-0.024	-0.005
9/8-14/2009	9/15-16/2009	-0.025	-0.044
1/7-9/2010	1/23-24/2010	+0.020	-0.016

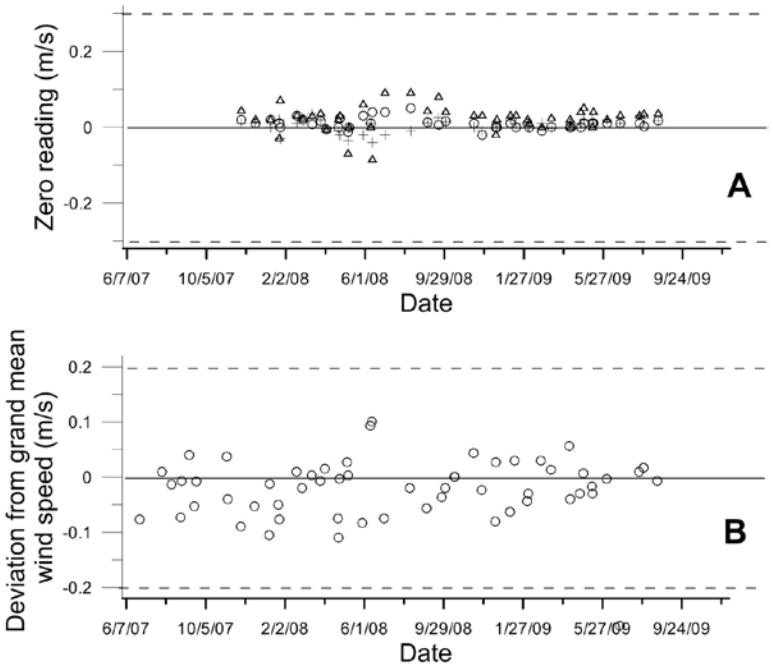


Figure 6.3-13: On-site quality assurance of s/n 1932. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

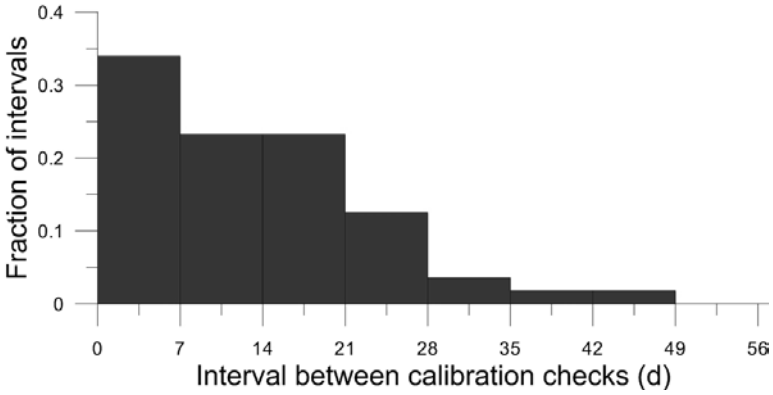


Figure 6.3-14: Inter-comparison check intervals for s/n 1932.

6.4 pH probe calibrations

Three probes (Model CSIMM-ph, Innovative Sensors Inc., Anaheim, California) were used at this location with serial numbers 001, 004, and 007.

Probe 001, was used between 7/18/2007 and 4/30/2008. The probe was calibrated 17 times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-1A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed both the accuracy DQI and the stability checks.

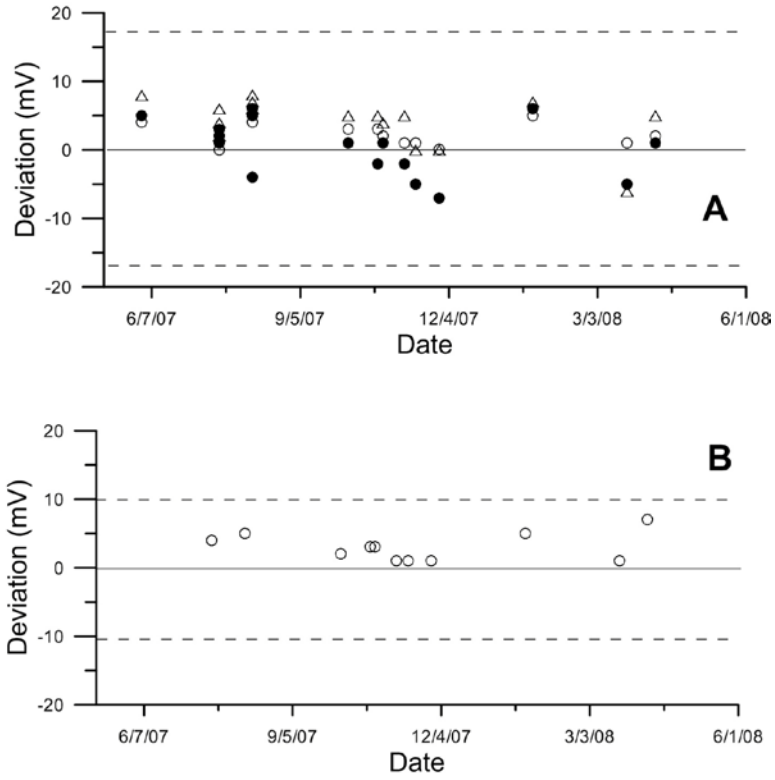


Figure 6.4-1: Accuracy and stability calibration checks of CSIM11 pH probe s/n 001. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

Probe 004, was used between 7/8/2007 and 2/3/2009. The probe was calibrated 27 times. Since freezing conditions damage the probe, the probes were not used during the winter at many locations. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-2A

illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe passed the accuracy DQI on all checks but 2/3/2009 but failed the stability checks 9/23/2008, 9/25/2008, and 2/3/2009. Since the sensor passed checks subsequent to the 9/2008 checks, these failures were likely due to operator error. The last check on 2/3/2009 indicated a faulty sensor.

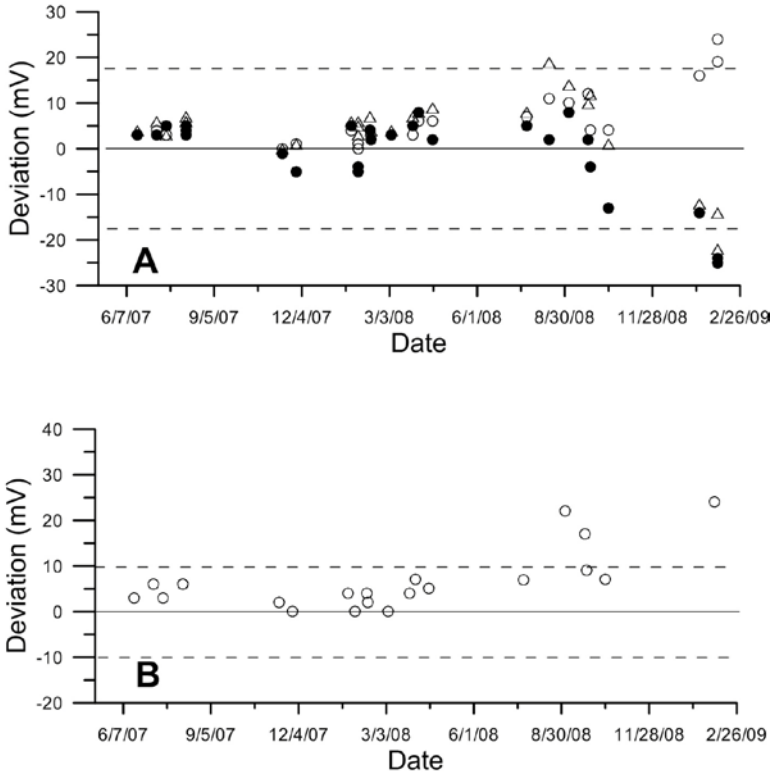


Figure 6.4-2: Accuracy and stability calibration checks of CSIM11 pH probe s/n 004. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

Probe 007, was used between 2/5/2009 and 12/2/2009. The probe was calibrated 14 times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-3A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-3B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the

frequency of these checks. The probe always passed both the accuracy DQI and the stability checks.

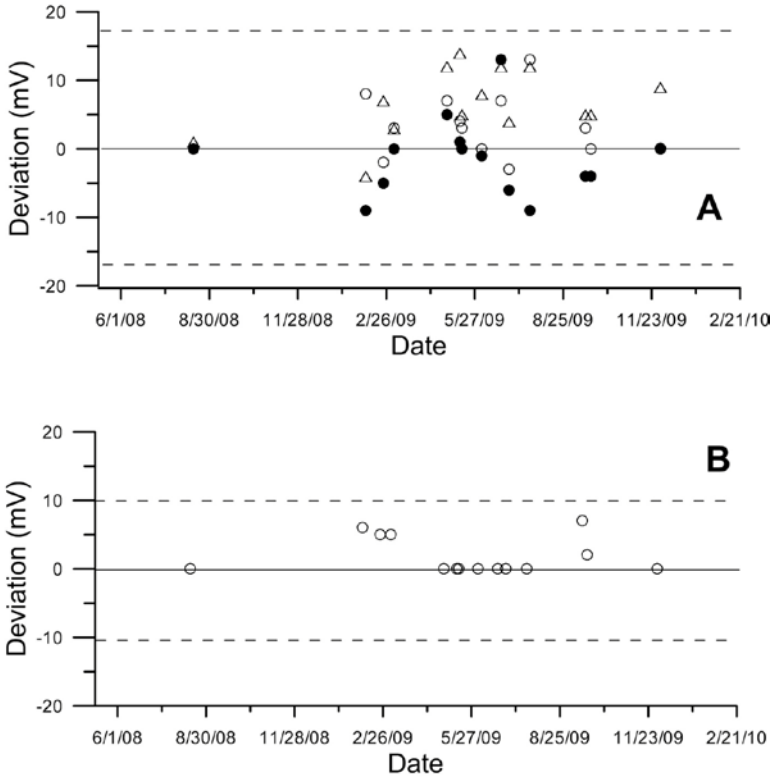


Figure 6.4-3: Accuracy and stability calibration checks of CSIM11 pH probe s/n 007. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since freezing conditions damaged the probes, the probes were not used during the winter at many locations. Since lagoon pH measurements were not made at several locations the interval between calibrations can be large when locations that did not have lagoon pH measurements were visited between locations where the measurements were made.

6.5 ORP probe calibrations

Two oxidation-reduction potential (ORP) probes (Model CSIM11-ORP, Innovative Sensors Inc., Anaheim, California) were used at this location with serial numbers 020 and 050

ORP probe s/n 020 was used between 7/18/2007 and 9/3/2008. The probe was calibrated 16 times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-1A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe passed the accuracy check DQI on all but 3/27/2008, 4/2/2008, and 8/14/2008. Subsequent accuracy check however met the accuracy DQI without probe modification so the prior failures were assumed to be due to operator error. The stability deviated significantly from the normal range on 4/2/2008 and 8/14/2008 indicating a possible partially-plugged probe.

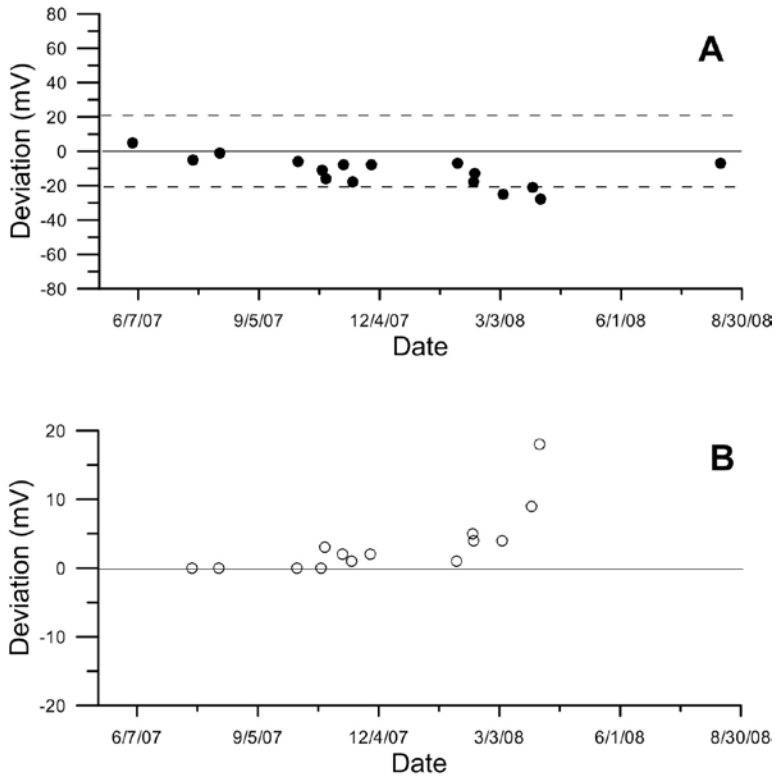


Figure 6.5-1: Accuracy and stability calibration checks of CSIM11 ORP probe s/n 020. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

ORP probe s/n 020 was used between 4/24/2008 and 2/23/2009. The probe was calibrated 11 times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-2A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced

the frequency of these checks. The probe always passed the accuracy DQI although showed wide response variation to the stability check. The cause of this instability is unknown.

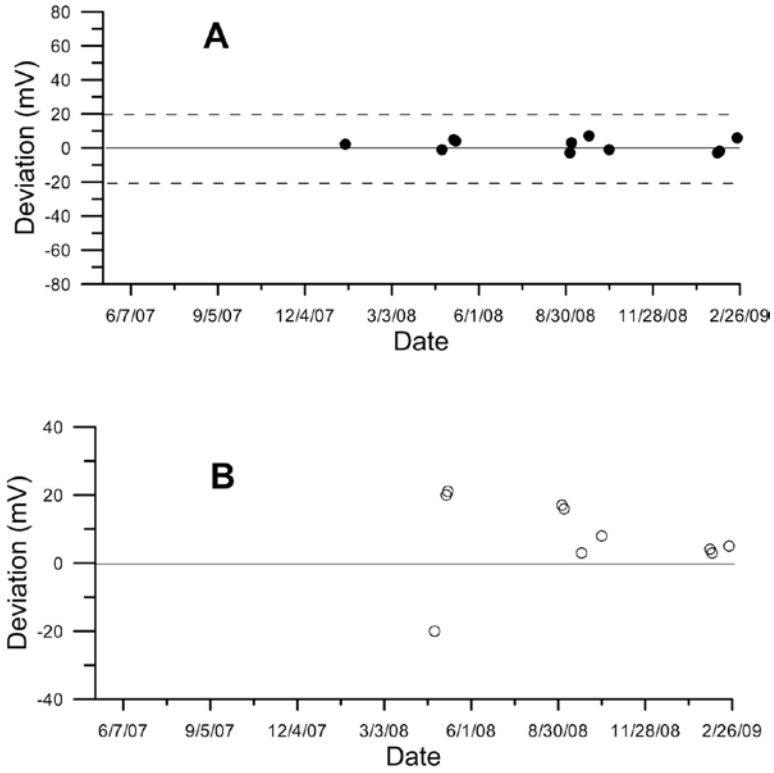


Figure 6.5-2: Accuracy and stability calibration checks of CSIM11 ORP probe s/n 050. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since freezing conditions damaged the probes, the probes were not used during the winter at many locations. Since lagoon ORP measurements were not made at several locations the interval between calibrations can be large when locations that did not have lagoon ORP measurements were visited between locations where the measurements were made.

6.6 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n D and F) and the Gas Sampling System (GSS s/n 4-0018) were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results for the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 6.6-1. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Often GSS leak check failures corresponded to successful S-OPS leak checks that included the GSS within the system check (Table 6.6-1). Leaks in the GSS generally were a result of pump problems or incorrect zero offset determinations. Leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 6/26/2008, 7/15/2008, 12/17/2008, 1/15/2009, 2/3/2009, 2/6/2009, and both lines on 10/22/2008 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on subsequent visits.
- GSS leak check failures that paired with S-OPS leak check passes indicated that the GSS leak check test may have been in error.
- GSS leak check failure on 10/14/2008 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 6.6-1).

Table 6.6-1 - Record of Leak checks for GSS s/n 4-0018 and GSS/S-OPS s/n D and F

Date	Site	GSS Solenoid	GSS Mass Flow (L min^{-1})	GSS Pressure (kPa)	GSS Check result	S-OPS Max Flow (L min^{-1})	S-OPS Mass Flow (L min^{-1})	S-OPS Pressure (kPa)	S-OPS Check result
4/1/2008	NC4A	2	0.04	-38.42	Pass	9.7	0.49	-35.63	Pass
		3	0.07	-38.12	Pass	9.8	0.62	-37.59	Pass
4/15/2008	NC4A	2	0.04	-36.59	Pass	6.5	0.54	-38.45	Pass
		3	0.04	-36.36	Pass	9.6	0.68	-36.38	Pass
4/24/2008	WI5A	2	0.07	-35.13	Pass	8.3	0.62	-35.39	Pass
		3	0.09	-37.54	Pass	8	0.61	-35.54	Pass
5/13/2008	WI5A	2	0.08	-34.5	Pass	7.7	0.69	-36.06	Pass
		3	0.07	-37.35	Pass	10	0.65	-37	Pass
5/15/2008	IA3A	2	0.01	-37.16	Pass	8.2	0.51	-36.29	Pass
		3	0.04	-36.72	Pass	10	0.65	-35.9	Pass
6/4/2008	IA3A	2	0.08	-38.67	Pass	9.9	0.32	-37.49	Pass
		3	0.07	-23.71	Pass	10	0.47	-20.66	Pass

Date	Site	GSS Solenoid	GSS Mass Flow (L min^{-1})	GSS Pressure (kPa)	GSS Check result	S-OPS Max Flow (L min^{-1})	S-OPS Mass Flow (L min^{-1})	S-OPS Pressure (kPa)	S-OPS Check result
6/23/2008	IA3A	2	0.01	-35.74	Pass	10	0.38	-36.45	Pass
		3	0.05	-34.5	Pass	10	1.00	-37.66	Pass
6/25/2008	WI5A	2	0.05	-35.75	Pass	10	0.31	-34.95	Pass
		3	-0.01	-35.63	Pass	10	1.07	-36.71	Fail
7/15/2008	WI5A	2	0.05	-37.52	Pass	10	0.39	-36.92	Pass
		3	0.08	-34.45	Pass	8	0.90	-34.97	Fail
8/13/2008	NC4A	2	0.11	-36.28	Pass	10.1	0.38	-36.27	Pass
		3	0.08	-35.29	Pass	10	1.03	-36.16	Fail
9/3/2008	NC4A	2	-0.01	-35.49	Pass	9.8	0.46	-35.83	Pass
		3	-0.01	-37.07	Pass	9.5	0.62	-35.51	Pass
9/22/2008	NC4A	2	0.07	-37.58	Pass	10	0.61	-35.03	Pass
		3	0.04	-36.9	Pass	9.8	0.89	-35.95	Pass
9/25/2008	NC3A	2	0.08	-38.32	Pass	10	0.59	-35.9	Pass
		3	0.12	-37.84	Pass	10	0.96	-35.15	Pass
10/14/2008	NC3A	2	0.23	2.01	Fail	9.9	0.85	2.24	Pass
		3	0.24	2.76	Fail	9.8	0.82	3.74	Pass
10/22/2008	WI5A	2	0.03	-37.7	Pass	9.1	1.01	-37.55	Fail
		3	0.05	-36.53	Pass	8.3	0.93	-35.01	Fail
11/11/2008	WI5A	2	0.23	-38.84	Fail	9	0.32	-36.7	Pass
		3	0.09	-40.18	Pass	10	0.18	-39.43	Pass
11/13/2008	IA3A	2	0.14	-35.89	Pass	10	0.31	-33.84	Pass
		3	0.15	-36	Fail	10	0.32	-37.98	Pass
11/25/2008	IA3A	2	0.09	-32.04	Pass	9.9	0.63	-32.86	Pass
		3	0.09	-32.17	Pass	9.8	0.81	-32.56	Pass
12/16/2008	IA3A	2	0.18	-34.49	Fail	10	0.84	-35.46	Pass
		3	0.16	-32.41	Fail	10	0.51	-31.94	Pass
12/17/2009	WI5A	2	0.15	-36.18	Fail	8	0.82	-35.46	Fail
		3	0.18	-37.68	Fail	9.2	0.69	-35.44	Pass
1/6/2009	WI5A	2	0.20	-35.97	Fail	7	0.65	-35.46	Pass
		3	0.24	-23.82	Fail	9.1	0.68	-36.42	Pass
1/15/2009	NC4A	2	-0.05	-44.56	Pass	9.2	0.63	-43.36	Pass
		3	0.12	-43.57	Pass	8.5	1.03	-42.33	Fail
2/3/2009	NC4A	2	-0.03	-32.52	Pass	9	0.66	-31.73	Pass
		3	0.16	-32.07	Fail	8.5	1.07	-30.71	Fail
2/6/2009	NC3A	2	-0.28	-46.68	Pass	9.9	1.43	-33.54	Fail
		3	-0.01	-34.92	Pass	9.7	0.78	-33.01	Pass
2/23/2009	NC3A	2	0.05	-35.36	Pass	9.9	0.85	-35.24	Pass
		3	0.05	-35.51	Pass	9.7	0.43	-36.15	Pass
3/10/2009	WI5A	2	0.00	-36.55	Pass	8.2	0.39	-36.06	Pass
		3	0.03	-34.443	Pass	9.2	0.34	-36.32	Pass
4/7/2009	WI5A	2	0.12	-34.35	Pass	8.3	0.20	-32.15	Pass
		3	0.12	-32.31	Pass	9.4	0.24	-32.25	Pass
4/9/2009	IA3A	2	0.03	-33.32	Pass	10	0.23	-34.89	Pass
		3	0.11	-34.66	Pass	10	0.22	-36.33	Pass
4/23/2009	IA3A	2	0.01	-34.49	Pass	10.01	0.16	-34.9	Pass
		3	0.03	-36.36	Pass	10.01	0.15	-36.06	Pass
4/29/2009	NC4A	2	0.04	-33.83	Pass	9.8	0.14	-33.81	Pass
		3	0.00	-34.77	Pass	9.7	0.15	-34.79	Pass
5/11/2009	NC4A	2	0.03	-34.5	Pass	9.7	0.20	-34.34	Pass
		3	0.04	-32.88	Pass	9.7	0.20	-35.06	Pass
5/13/2009	NC3A	2	0.04	-34.4	Pass	9.3	0.30	-34.94	Pass

Date	Site	GSS Solenoid	GSS Mass Flow (L min^{-1})	GSS Pressure (kPa)	GSS Check result	S-OPS Max Flow (L min^{-1})	S-OPS Mass Flow (L min^{-1})	S-OPS Pressure (kPa)	S-OPS Check result
		3	0.03	-35.18	Pass	9.7	0.23	-34.04	Pass
6/2/2009	NC3A	2	0.04	-37.94	Pass	9.6	0.14	-37.45	Pass
		3	0.04	-35.54	Pass	9.5	0.22	-35.11	Pass
6/22/2009	NC3A	2	0.01	-35.46	Pass	9.8	0.20	-37.18	Pass
		3	0.03	-35.24	Pass	9.7	0.22	-37.89	Pass
7/1/2009	NC4A	2	0.03	-35.48	Pass	9.7	0.14	-36.58	Pass
		3	0.01	-34.46	Pass	9.5	0.14	-34.58	Pass
7/21/2009	NC4A	2	0.01	-35.69	Pass	9.8	0.11	-36.99	Pass
		3	0.03	-35.72	Pass	9.6	0.15	-35.37	Pass
7/28/2009	IA3A	2	0.01	-34.9	Pass	10	0.20	-33.94	Pass
		3	0.04	-34.55	Pass	10	0.31	-34.19	Pass
8/17/2009	IA3A	2	0.07	-42.67	Pass	10.05	0.14	-42.19	Pass
		3	0.07	-42.05	Pass	10.05	0.18	-41.85	Pass

The inlet flow balance checks are summarized in sequence in Tables 6.6-2A and 6.6-2B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A - Record of flow balancing- Side 1 (s/n D)

			Delta Inlet Flow (Beginning-End) (L min^{-1})										
Start Date	**End Date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/26/2008	4/1/2008	NC3A	0.00	0.02	0.00	-0.01	0.19	-0.03	-0.01	-0.03	-0.07	-0.09	**Fail**
4/1/2008	4/15/2008	NC4A	0.03	0.01	0.02	0.09	0.03	0.04	-0.07	0.20	0.28	-0.06	**Fail**
4/15/2008	4/24/2008	NC4A	-0.13	-0.14	-0.15	-0.12	-0.21	-0.26	-0.32	-0.31	-0.33	-0.36	**Fail**
4/24/2008	5/13/2008	WI5A	-0.04	-0.03	-0.03	-0.06	-0.03	-0.02	-0.02	-0.02	-0.03	-0.03	**Pass**
5/15/2008	6/4/2008	IA3A	0.00	-0.05	-0.02	-0.03	-0.01	-0.07	-0.02	-0.03	0.01	0.02	**Pass**
6/4/2008	6/23/2008	IA3A	0.05	0.02	0.00	0.05	0.00	0.08	0.01	0.01	-0.01	-0.03	**Pass**
6/25/2008	7/15/2008	WI5A	0.05	0.02	0.07	-0.03	-0.01	-0.05	0.02	-0.03	-0.02	-0.01	**Pass**
7/15/2008	8/13/2008	WI5A	-0.05	0.10	-0.02	0.03	0.08	-0.09	0.00	0.06	-0.01	0.04	**Pass**
8/13/2008	9/3/2008	NC4A	-0.27	-0.12	-0.17	-0.13	-0.14	-0.29	-0.20	-0.21	-0.25	-0.22	**Pass**
9/3/2008	9/22/2008	NC4A	-0.12	-0.13	-0.11	-0.10	-0.15	-0.09	-0.10	-0.06	-0.10	-0.11	**Pass**
9/25/2008	10/14/2008	NC3A	-0.12	-0.09	-0.11	-0.12	-0.17	-0.16	-0.17	-0.22	-0.17	-0.23	**Pass**
10/14/2008	10/22/2008	NC3A	-0.32	-0.18	-0.23	-0.31	-0.19	-0.31	-0.29	-0.24	-0.22	-0.13	**Pass**
10/22/2008	11/11/2008	WI5A	-0.07	-0.10	-0.10	-0.13	-0.10	-0.10	-0.09	-0.13	-0.12	-0.15	**Pass**
11/13/2008	11/25/2008	IA3A	-0.10	-0.17	-0.18	-0.17	-0.13	-0.06	-0.15	-0.13	-0.15	-0.17	**Pass**
11/25/2008	12/16/2008	IA3A	-0.22	-0.18	-0.17	-0.18	-0.17	-0.20	-0.20	-0.16	-0.19	-0.16	**Pass**
12/17/2008	1/6/2009	WI5A	-0.30	-0.41	-0.27	-0.62	-0.15	-0.22	-0.29	-0.15	-0.23	-0.05	**Fail**
1/6/2009	1/15/2009	WI5A	-0.10	0.17	-0.17	0.34	-0.20	-0.12	-0.02	-0.18	-0.11	-0.17	**Fail**
1/15/2009	2/3/2009	NC4A	-0.27	-0.32	0.14	-0.07	-0.25	-0.32	-0.13	0.04	-0.40	-0.29	**Fail**
2/5/2009	2/23/2009	NC3A	-0.11	-0.13	-0.12	-0.12	-0.13	-0.11	-0.13	-0.16	-0.16	-0.09	**Pass**
2/23/2009	3/10/2009	NC3A	-0.11	-0.07	-0.12	-0.17	-0.15	-0.18	-0.19	-0.03	-0.19	-0.21	**Pass**
3/10/2009	4/7/2009	WI5A	-0.17	-0.17	-0.16	-0.19	-0.11	-0.08	-0.06	-0.22	-0.07	-0.11	**Pass**
4/9/2009	4/23/2009	IA3A	-0.15	-0.13	-0.11	-0.14	-0.15	-0.13	-0.13	-0.09	-0.11	-0.10	**Pass**
4/23/2009	4/29/2009	IA3A	-0.13	-0.11	-0.14	-0.14	-0.14	-0.16	-0.15	-0.20	-0.22	-0.20	**Pass**
4/29/2009	5/11/2009	NC4A	-0.26	-0.19	-0.16	-0.14	-0.15	-0.13	-0.14	-0.14	-0.11	-0.10	**Fail**
5/13/2009	6/2/2009	NC3A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.14	-0.14	-0.15	-0.15	-0.14	**Pass**
6/2/2009	6/22/2009	NC3A	-0.12	-0.10	-0.11	-0.11	-0.11	-0.13	-0.09	-0.14	-0.13	-0.14	**Pass**
6/22/2009	6/30/2009	NC3A	-0.15	-0.13	-0.13	-0.13	-0.13	-0.11	-0.13	-0.13	-0.12	-0.12	**Pass**
6/30/2009	7/21/2009	NC4A	-0.09	-0.13	-0.10	-0.11	-0.09	-0.11	-0.11	-0.08	-0.10	-0.10	**Pass**
7/21/2009	7/28/2009	NC4A	-0.08	-0.06	-0.08	-0.07	-0.06	-0.06	-0.05	-0.06	-0.06	-0.02	**Pass**
7/28/2009	8/17/2009	IA3A	-0.14	-0.14	-0.15	-0.13	-0.14	-0.15	-0.13	-0.12	-0.11	-0.15	**Pass**

Table 6.6-2B - Record of flow balancing- Side 2 (s/n F)

			Delta Inlet Flow (Beginning-End) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/26/2008	4/1/2008	NC3A	0.09	0.03	0.02	0.04	0.00	0.06	0.06	0.05	0.04	0.02	**Pass**
4/1/2008	4/15/2008	NC4A	0.05	0.21	0.05	0.04	0.10	0.03	0.27	0.00	0.08	0.13	**Fail**
4/15/2008	4/24/2008	NC4A	0.09	0.24	0.26	0.26	0.21	0.29	0.22	0.25	0.30	0.22	**Fail**
4/24/2008	5/13/2008	WI5A	-0.04	-0.03	-0.02	-0.02	0.12	-0.02	-0.04	-0.04	-0.07	0.03	**Fail**
5/15/2008	6/4/2008	IA3A	-0.09	-0.12	-0.08	-0.10	0.34	-0.02	-0.05	0.88	-0.06	-0.08	**Fail**
6/4/2008	6/23/2008	IA3A	0.05	0.06	0.04	0.02	0.03	-0.01	0.00	-0.01	0.07	-0.01	**Pass**
6/26/2008	7/15/2008	WI5A	0.03	0.03	0.02	0.02	-0.02	0.05	0.06	-0.01	0.00	0.01	**Pass**
7/15/2008	8/13/2008	WI5A	-0.27	-0.25	-0.30	-0.29	-0.23	-0.34	-0.36	-0.17	-0.27	-0.26	**Pass**
8/13/2008	9/3/2008	NC4A	0.02	0.02	0.06	0.05	0.00	0.09	0.06	-0.07	0.03	0.08	**Pass**
9/3/2008	9/22/2008	NC4A	0.00	0.02	0.00	-0.01	-0.02	-0.06	-0.02	-0.01	-0.06	-0.03	**Pass**
9/25/2008	10/14/2008	NC3A	0.00	0.02	0.02	0.00	0.02	-0.01	-0.06	0.03	0.04	0.08	**Fail**
10/14/2008	10/22/2008	NC3A	0.22	0.16	0.17	0.20	0.23	0.24	0.20	0.19	0.23	0.14	**Fail**
10/22/2008	11/11/2008	WI5A	-0.02	0.03	0.02	-0.01	0.00	-0.07	-0.09	-0.01	-0.02	0.00	**Fail**
11/13/2008	11/25/2008	IA3A	-0.23	-0.06	-0.11	-0.09	-0.06	-0.17	-0.16	-0.21	-0.12	-0.10	**Pass**
11/25/2008	12/16/2008	IA3A	-0.14	-0.23	-0.19	-0.18	-0.21	-0.17	-0.10	-0.07	-0.11	-0.13	**Fail**
12/17/2008	1/6/2009	WI5A	-0.26	-0.36	-0.28	-0.31	-0.31	-0.33	-0.35	-0.11	-0.26	-0.36	**Fail**
1/6/2009	1/15/2009	WI5A	0.02	-0.28	0.09	0.12	0.08	0.21	0.24	-0.97	0.20	0.20	**Fail**
1/16/2009	2/3/2009	NC4A	-0.29	-0.32	-0.20	0.34	-0.42	0.63	0.50	-0.51	0.23	0.23	**Fail**
2/5/2009	2/23/2009	NC3A	-0.11	-0.11	-0.13	-0.13	-0.15	-0.14	-0.17	-0.16	-0.16	-0.11	**Pass**
2/23/2009	3/10/2009	NC3A	-0.16	-0.16	-0.18	-0.19	-0.15	-0.19	-0.22	-0.15	-0.17	-0.12	**Pass**
3/10/2009	4/7/2009	WI5A	-0.21	-0.24	-0.21	-0.21	-0.24	-0.22	-0.23	-0.23	-0.20	-0.32	**Pass**
4/9/2009	4/23/2009	IA3A	0.00	0.00	0.00	-0.01	-0.03	-0.02	0.00	-0.04	-0.03	-0.05	**Pass**
4/23/2009	4/29/2009	IA3A	-0.15	-0.16	-0.15	-0.16	-0.16	-0.17	-0.18	-0.18	-0.20	-0.17	**Pass**
4/29/2009	5/11/2009	NC4A	-0.14	-0.10	-0.14	-0.13	-0.16	-0.11	-0.14	-0.11	-0.09	-0.11	**Pass**
5/13/2009	6/2/2009	NC3A	-0.12	-0.14	-0.14	-0.14	-0.19	-0.14	-0.22	-0.11	-0.15	-0.21	**Pass**
6/2/2009	6/22/2009	NC3A	-0.10	-0.77	-0.09	-0.10	-0.04	-0.05	-0.03	-0.04	-0.05	-0.03	**Fail**
6/22/2009	6/30/2009	NC3A	-0.14	0.53	-0.16	-0.15	-0.22	-0.18	-0.25	-0.20	-0.19	-0.22	**Fail**
6/30/2009	7/21/2009	NC4A	-0.14	-0.12	-0.11	-0.12	-0.14	-0.10	-0.06	-0.09	-0.10	-0.09	**Pass**
7/21/2009	7/28/2009	NC4A	-0.08	-0.08	-0.08	-0.10	-0.03	-0.06	-0.06	-0.05	-0.03	-0.03	**Fail**
7/28/2009	8/17/2009	IA3A	-0.04	-1.01	-0.07	-0.05	-0.04	-0.07	0.01	-0.09	-0.06	-0.05	**Fail**

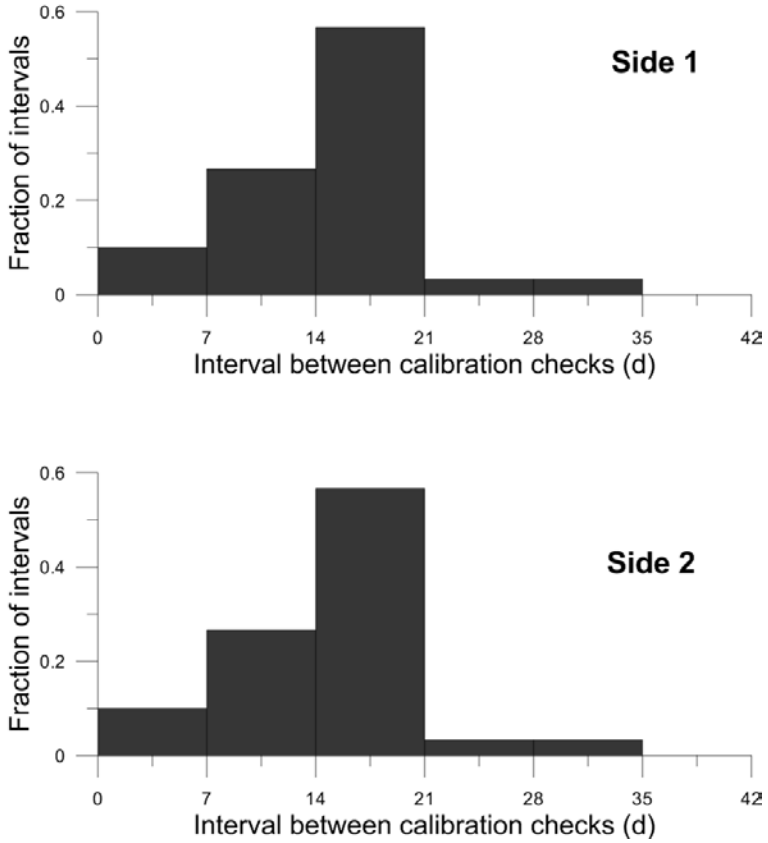


Figure 6.6-1 – Intervals between checks for GSS s/n 4-0018 and GSS/S-OPS s/n D and F

6.7 Miscellaneous meteorological and lagoon calibrations

6.7.1 Air temperature/ humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration check is documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n: 4410027

Relative Humidity (RH)					
Calibration Date (mm/dd/yyyy)	**Temperature (°C)**	**Expected RH (%)**	**Difference from expected RH (%)**	**Average Difference RH (%)**	**Action**
3/8/2010	24.7	25	2		Accept
	24.7	50	1		Accept
	24.7	95	2		Accept
				2	Accept
3/6/2010	N/A	40	1	1	Accept
8/1/2008	27.8	11	-1		Accept
	27.5	51	2		Accept
	27.8	96	8		Accept
				3	Accept

Temperature (T)				
Calibration Date (mm/dd/yyyy)	**Expected T (°C)**	**Measured T (°C)**	**Difference from expected T (°C)**	**Action**
3/8/2010	25.6	24.7	0.9	Accept
3/6/2009	25.3	25.2	0.2	Accept
8/1/2008	27.5	27.3	0.2	Accept

6.7.2 Barometric Pressure

An aneroid barometer (Model 278, Setra Inc, Boxborough, MA) was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278 s/n 3051828

Calibration date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
3/4-8/2010	997-1004	4	0.10	Pass
2/27 - 3/2/2009	990.9-1007.1	6	1.60	Pass
7/23-27/2008	995.3-996.5	6	0.90	Pass
1/17-18/2008	984.9-996.9	6	0.80	Pass

6.7.3 Solar radiation

A pyranometer (Model 200SB, LiCOR Inc., Lincoln, NE) was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks is documented in Table 6.7-3.

Table 6.7-3: Calibration record of LiCOR 200SB Pyranometer s/n PY55448

Calibration Date (mm/dd/yyyy)	Mean Difference from standard (W/m^2)	Mean Difference from standard (%)	Action
3/5-8/2010	-3.8	0.7	Pass
8/30/2006	N/A	N/A	Pass (factory calibr.)

6.7.4 Lagoon water temperature

A thermistor (Model 107-L, Campbell Scientific Inc, Logan, Utah) was used to measure lagoon temperature. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks is documented in Tables 6.7-4 through Table 6.7-6.

Table 6.7-4: Calibration record of Thermistor CSI 107-L (0010)

Calibration Dates	Expected value (°C)	Deviation from expected (°C)	Action
1/25/2008	0.0	0.0	Accept
6/18/2007	25.0	0.1	Accept
	24.5	0.2	Accept
	24.0	0.4	Accept

Table 6.7-5: Calibration record of Thermistor CSI 107-L (III)

Calibration Date	Expected value (°C)	Difference from expected (°C)	Action
2/15/2010	1.1	18.4	Replace
9/14/2009	0.0	-0.1	Accept
3/6/2009	0.0	0.0	Accept

Table 6.7-6: Calibration record of Thermistor CSI 107-L (V)

Calibration Date	Expected value (°C)	Difference from expected (°C)	Action
2/15/2010	1.1	1.2	Accept
2/15/2010	35.7	2.9	Accept
9/14/2009	0.1	-0.1	Accept
3/6/2009	0.0	0.1	Accept

6.7.5 Sludge Gun

A sludge gun (Model 10, Marklin Specialty Engineering, Toronto, Ontario, Canada) with serial number 20176A was used to measure sludge depth in the lagoon. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks is documented in Table 6.7-7.

Table 6.7-7: Calibration record of Marklin Sludge Gun s/n 20176B

Calibration Date	Mean	Standard deviation	Accuracy	Action
2/26/2010	69.0	0.75	1	Accept
3/6/2009	71.8	0.75	0.937	Accept
7/23/2008	73.3	0.35	1.11	Accept
7/27/2008	79.9	0.78	0.88	Accept
2/23/2007	81.2	0.97	1.22	Accept

6.7.6 CR1000 Data logger

The CR1000 data logger (Campbell Scientific Inc., Lagan, UT) was used to log all lagoon measurements (pH, oxidation-reduction potential, and temperature) and air temperature, relative humidity, barometric pressure, and wetness. Calibration checks of this unit were conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. Two different loggers were used. The record of calibration checks are documented in Table 6.7-8 and Table 6.7-9.

Table 6.7-8: Calibration record of Campbell Scientific CR1000 data logger, s/n 7886 (7675)

Factory Calibration						
Calibration Date: 1/18/2007			Single-Ended		Differential	
Channel	**Input (mV)**	**Tolerance (mV)**	**Measured mV**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
11	5000	± 3	5001.25	-1.25	5001.35	-1.35
11	-5000	± 3	-5001.48	-1.48	-5001.69	-1.69
11	2500	± 1.5			2500.3	-0.3
11	250	± 0.15			249.999	0.001
11	25	± 0.015			25.0032	-0.0032
11	7.5	± 0.0045			7.49571	0.00429
11	2.5	± 0.0015			2.50062	-0.00062
11	-2.5	± 0.0015			-2.49924	0.00024
11	5000	± 6	4999.45	0.45	4999.32	0.32
11	5000	± 6	5001.96	-1.96	5001.69	-1.69
11	5000	± 6				
11	5000	± 6				

PAML Calibration						
Calibration Date: 2/5/2007			Single Ended		Differential	
SE Channel	**Input (mV)**	**Tolerance SE|DE (mV)**	**Measured mV Mean Value**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	4950	± 6.96| 4.97	4950.5	-0.5		
2	4950	± 6.96| 4.97	4950.5	-0.5		
3	4950	± 6.96| 4.97	4950.5	-0.5		
4	4950	± 6.96| 4.97	4950.5	-0.5		
5	4950	± 6.96| 4.97	4950.5	-0.5		
6	4950	± 6.96| 4.97	4950.5	-0.5		
7	4950	± 6.96| 4.97	4950.5	-0.5		
8	4950	± 6.96| 4.97	4950.5	-0.5		
9	4950	± 6.96| 4.97	4950.5	-0.5		
10	4950	± 6.96| 4.97	4950.5	-0.5		
12	4950	± 6.96| 4.97	4950.5	-0.5		

13	4950	± 6.96| 4.97	4950.5	-0.5		
14	4950	± 6.96| 4.97	4950.5	-0.5		
15	4950	± 6.96| 4.97	4950.5	-0.5		
16	4950	± 6.96| 4.97	4950.5	-0.5		

Calibration Date: 5/28/2010			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.06 | 1.06	99.49	0.51		
2	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
3	100	± 2.06 | 1.06	99.49	0.51		
4	100	± 2.06 | 1.06	99.49	0.51		
5	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
6	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
7	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
8	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
9	100	± 2.06 | 1.06	99.49	0.51		
10	100	± 2.06 | 1.06	99.49	0.51		
11	100	± 2.06 | 1.06	99.49	0.51		
12	100	± 2.06 | 1.06	99.49	0.51		
13	100	± 2.06 | 1.06	99.49	0.51		
14	100	± 2.06 | 1.06	99.49	0.51		
15	100	± 2.06 | 1.06	99.49	0.51		
16	100	± 2.06 | 1.06	99.49	0.51		
Calibration Date: 5/28/2010			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.06 | 1.06	0	0		
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0		
4	0	± 2.06 | 1.06	0	0		
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0		
10	0	± 2.06 | 1.06	0	0		
11	0	± 2.06 | 1.06	0	0		
12	0	± 2.06 | 1.06	0	0		
13	0	± 2.06 | 1.06	0	0		
14	0	± 2.06 | 1.06	0	0		
15	0	± 2.06 | 1.06	0	0		
16	0	± 2.06 | 1.06	0	0		

Table 6.7-9: Calibration record of Campbell Scientific CR1000 data logger, s/n 7752

Calibration Date: 3/1/2010			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.06 | 1.06	99.23	0.77		
2	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
3	100	± 2.06 | 1.06	99.23	0.77		
4	100	± 2.06 | 1.06	99.23	0.77		
5	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
6	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
7	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
8	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
9	100	± 2.06 | 1.06	99.23	0.77		
10	100	± 2.06 | 1.06	99.23	0.77		
11	100	± 2.06 | 1.06	99.23	0.77		
12	100	± 2.06 | 1.06	99.23	0.77		
13	100	± 2.06 | 1.06	99.23	0.77		
14	100	± 2.06 | 1.06	99.23	0.77		
15	100	± 2.06 | 1.06	99.23	0.77		
16	100	± 2.06 | 1.06	99.23	0.77		
Calibration Date: 3/1/2010			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerence SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.06 | 1.06	0	0		
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0		
4	0	± 2.06 | 1.06	0	0		
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0		
10	0	± 2.06 | 1.06	0	0		
11	0	± 2.06 | 1.06	0	0		
12	0	± 2.06 | 1.06	0	0		
13	0	± 2.06 | 1.06	0	0		
14	0	± 2.06 | 1.06	0	0		
15	0	± 2.06 | 1.06	0	0		
16	0	± 2.06 | 1.06	0	0		

6.7.7 CR800 Data logger

The CR800 data logger (Campbell Scientific Inc., Logan, Utah) was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration check of this unit was conducted only at end of the study. Initial calibrations were conducted by the factory. The record of calibration checks is documented in Table 6.7-10.

Table 6.7-10: Calibration record of Campbell Scientific CR800 data logger s/n 3697

Calibration Date: **3/8/2010**			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerence SE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	100	+ / - 2.061	99.29	0.71		
2	100	+ / - 2.061	99.29	0.71		
3	100	+ / - 2.061	99.29	0.71		
4	100	+ / - 2.061	99.29	0.71		
5	100	+ / - 2.061	99.29	0.71		
6	100	+ / - 2.061	99.29	0.71		

Calibration Date: **3/8/2010**			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerence SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	0	+ / - 2.061	0	0		
2	0	+ / - 2.061	0	0		
3	0	+ / - 2.061	0	0		
4	0	+ / - 2.061	0	0		
5	0	+ / - 2.061	0	0		
6	0	+ / - 2.061	0	0		

6.8 Site Activity

Time	Date MM DD YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	10/2/2007	Setup	Reached site by afternoon, messed up with electricity. Called the electrician (He didn't respond the same day).
	10/2/2007	Setup	Carried all retro-reflectors and placed up on their respective sites. Tried to do tower but could not complete. Purchased extension cords for 6 retro-reflectors.
	10/3/2007	Setup	Did anchoring for trailer. Got trailer steady.
	10/3/2007	Setup	Spent hours on TDLAS calibrations as we were getting high values with too much fluctuation.
	10/3/2007	Setup	It was raining heavily, so could not do additional stuff, but still got retro work done.
23:55-00:00	10/3/2007	Setup	Calibrated TDLAS 1030: Mean: 57.98 SD: 4.77
	10/4/2007	Setup	Tried to calibrate TDLAS 1030 but could not do so as it was giving very high values with high SD.
	10/4/2007	Setup	Did the towers and electricity on towers.
14:00-15:00	10/4/2007	Setup	Sonic anemometer inter-comparison: all pass.
14:12	10/4/2007	Setup	ORP sensor: calibration and acceptance accepted
15:28	10/4/2007	Setup	pH sensor: calibration, acceptance, QA accepted
16:13-16:16	10/4/2007	Setup	Zero calibration on sonic anemometers; all pass.
01:29-01:34	10/5/2007	Setup	Calibrated TDLAS 1028: Mean: 47.38 SD: 1.58 RSD: 3.2%
01:57-02:02	10/5/2007	Setup	Calibrated TDLAS 1030: Mean: 62.05 SD: 1.55
	10/5/2007	Setup	Did time check on PC's.
	10/5/2007	Setup	Took retro and sonic anemometer heights.
	10/10/2007	Remote	Check status of PC's and instruments after set up last week.
	10/10/2007	Remote	Check site status.
	10/11/2007	Remote	Install new version of sonic anemometer program (V3).
	10/12/2007	Remote	Check out site operations.
	10/22/2007	Takedown	Arrived at 11:15 a.m. Took down all instruments and did all calibrations by 8:30 p.m.
	10/22/2007	Takedown	Dropped retro from top of tower. Minimal damage.
	10/22/2007	Takedown	Recorded locations of retro-reflectors relative to electric posts. See notes.
	10/22/2007	Takedown	500 ppm NH3 cylinder has expired; according to Praxair it was delivered on 10/8/2007, but Murphy Brown does not know where it is. It is missing.
	10/22/2007	Takedown	Barometer audit: accepted.
15:00	10/22/2007	Takedown	Wetness Sensor calibration: accepted.
18:56	10/22/2007	Takedown	Zero calibration on sonic anemometers; all pass.
23:16-23:21	10/22/2007	Takedown	Calibrated TDLAS 1030: Mean: 57.54 SD: 2.32 notes: Continued passing NH3 from 2321 UTC-2327 UTC during the calculations. During initial background, the program was set in scanning mode with varying distances in the log file.

23:52	10/22/2007	Takedown	pH sensor: calibration, acceptance, QA accepted
00:20	10/23/2007	Takedown	ORP sensor: calibration and acceptance accepted
	1/29/2008	Setup	Dried tower retro-reflectors; calibrated sonic anemometers; started S-OPS.
17:45-18:45	1/29/2008	Setup	Sonic anemometer inter-comparison: all pass.
19:30	1/29/2008	Setup	Zero calibration on sonic anemometers; all pass.
	1/30/2008	Setup	Started S-OPS. Found some leakage in 2nd and 9th inlets of north side S-OPS. Corrected it and started.
	1/30/2008	Setup	GSS acceptance
22:30	1/30/2008	Setup	Barometer audit: accepted.
22:30-23:45	1/30/2008	Setup	Wetness Sensor calibration: accepted.
22:35-22:40	1/30/2008	Setup	Calibrated TDLAS 1028: Mean: 49.15 SD: 0.94 RSD: 1.9% Bias: -1.9%
23:32	1/30/2008	Setup	Calibrated TDLAS 1031 Mean: 48.35 SD: 1.86 RSD: 3.9% Bias: -3.5%
	1/30/2008	Setup	Did not have 590 gas regulator, so H2S single check calibration was not done.
	1/31/2008	Setup	Having some communication problems with TDLAS 1028. Checked cable, pin 4 and 12 are already connected. System is still functioning even with the error. Moved the modem/power supply box to different leg of tripod higher up.
	1/31/2008	Setup	pH sensor: calibration, acceptance, QA accepted
	1/31/2008	Setup	Sludge Depth measurements taken.
	1/31/2008	Setup	S-OPS installation report made
13:55	1/31/2008	Setup	ORP sensor: calibration and acceptance accepted
	2/1/2008	Setup	At 0733 UTC, found out that TDLAS 2 (1031) stopped sending data. Found that back of GasFinder 2.0™ said "centering" and that centerline data cycle was increasing above 200 and r^2 was decreasing. Problem was "fixed" by powering off and powering on the GasFinder 2.0™. Initially, the CDC and reference r^2 were bad, but in a few moments the values looked good. System appears to be working.
	2/4/2008	Remote	Fix problems with TDLAS system 2
	2/8/2008	Remote	Fix corrupt paths on TDLAS 2 (1031).
	2/11/2008	Takedown	Need black printer cartridge.
	2/11/2008	Takedown	S-OPS acceptance
	2/11/2008	Takedown	S-OPS Inlet Flow Verification
18:30-19:30	2/11/2008	Takedown	Sonic anemometer inter-comparison: all pass.
20:10	2/11/2008	Takedown	Barometer audit: accepted.
20:10	2/11/2008	Takedown	Wetness Sensor calibration: accepted.
20:25	2/11/2008	Takedown	Zero calibration on sonic anemometers; all pass.
	2/12/2008	Takedown	TDLAS 1031 is not working well. Replaced with different unit.
	2/12/2008	Takedown	pH sensor: calibration, acceptance, QA accepted
17:52-17:57	2/12/2008	Takedown	Calibrated TDLAS 1028: Mean: 49.85 SD: 3.35 RSD: 4.77% Bias: -0.8%
16:38-16:51	2/12/2008	Takedown	Calibrated TDLAS 1031: Mean: 50.22 SD: 0.65 RSD: 1.3% Bias: -0.2% notes: During the measurement period, the TDLAS was giving 401(calibration) errors most of the time. At start of calibration, the background test gave some wild numbers (ex. 170 ppm with r^2 of 0.65). This settled down. After NH3 was passed into cell, got values

			of 0, 0.000 for 10+ min. Powered off and back on again and got better values (~22 ppm, 0.95) Also error code of 5. Moved cell slightly and got great results even with error code.
	3/31/2008	Setup	Threads were damaged on new NH3 cylinder and on associated gas regulator.
20:00-21:00	3/31/2008	Setup	Sonic anemometer inter-comparison: all pass.
20:20-20:25	3/31/2008	Setup	Calibrated TDLAS 1028: Mean: 46.15 SD: 0.18 RSD: 0.4% Bias: -3.0%
22:18	3/31/2008	Setup	Zero calibration on sonic anemometers; all pass.
	4/1/2008	Setup	Replaced filter on SOP inlet D5.
	4/1/2008	Setup	Replaced one rivet on SE tower.
	4/1/2008	Setup	S-OPS Max Flow test
	4/1/2008	Setup	S-OPS Inlet flow Verification: Pass (second attempt)
	4/1/2008	Setup	S-OPS/GSS Leak Test: Pass
	4/1/2008	Setup	GSS Leak Test: Pass
	4/1/2008	Setup	GSS no Flow Test
18:16	4/1/2008	Setup	TFC 450i calibration check
21:15	4/1/2008	Setup	Wetness Sensor calibration: accepted.
21:15	4/1/2008	Setup	Barometer audit: accepted.
21:58	4/1/2008	Setup	TFC 450i calibration check
22:16	4/1/2008	Setup	TFC 450i Reference precision check
	4/2/2008	Setup	Talked to Thermo about 450i motherboard error. When booting, unable to find motherboard. No answers. Decided to leave here.
	4/2/2008	Setup	Connecting/disconnecting ground for temp. probe and RH probe changes values measured by pH and ORP probes by about 0.3 pH and 200 ORP (i.e., if Air Temp/RH is unhooked we get lower values for ORP and higher values for pH).
	4/2/2008	Setup	pH sensor: calibration, acceptance, QA accepted
13:50	4/2/2008	Setup	ORP sensor: calibration and acceptance accepted
14:30	4/4/2008	Remote	Daily Status Check from PAML notes: Sonic anemometer 2 has 6 five-min intervals with >1000 flagged points.
12:00	4/7/2008	Remote	Daily Status Check from PAML notes: Spikes >160 in sonic anemometer 1 are related to sonic anemometer flagged data due to rain.
12:31	4/8/2008	Remote	Daily Status Check from PAML notes: TDLAS 1 reference r^2 varies from 96-99. Reference status 10 for a period on day 462. TDLAS 2 reference status is sometimes 10 or 30.
12:00	4/9/2008	Remote	Daily Status Check from PAML notes: Wetness sensor does not appear to be responding normally to dry condition.
	4/10/2008	Remote	Fix corrupt path on TDLAS 2
12:30	4/10/2008	Remote	Daily Status Check from PAML notes: Dense fog causing TDLAS 2 to optimize.
	4/11/2008	Remote	Fix corrupt path on TDLAS 2
12:20	4/11/2008	Remote	Daily Status Check from PAML notes: Most 5 min periods have 10-40 flagged points for sonic anemometer 1. Also, for last day or so we are often losing several hundred points for sonic anemometer 1 per five min. Lagoon temperature jumped from 16c to 22C yesterday. More variable since at about 19C. TDLAS 2 has corrupt path and pan/tilt errors.
	4/12/2008	Remote	Check operation
	4/13/2008	Remote	Check operation
	4/14/2008	Takedown	Zoebell's solution stored in refrigerator has turned blue. This is due

			to reaction with metal rod used during mixing; we have to use glass rod.
	4/14/2008	Takedown	Path 6 on TDLAS 2 (1028) had corrupt pan/tilt values upon arrival. Reaimed at about 21 UTC.
	4/14/2008	Takedown	Tubing added to barometer.
	4/15/2008	Takedown	S-OPS Max Flow test
	4/15/2008	Takedown	S-OPS Inlet flow Verification: Fail (several attempts) note: Tried several times to balance the air but could not do so; spent almost one day.
	4/15/2008	Takedown	S-OPS/GSS Leak Test: Pass
	4/15/2008	Takedown	GSS Leak Test: Pass
	4/15/2008	Takedown	GSS no Flow Test
	4/15/2008	Takedown	While doing S-OPS inlet verification for #F we found water droplets in new orifices connecting tubes (orifices #1, 2, 4, 8, and 9 and nos. 1 and 9 also had spider webs). When reading flow rate on orifice 2, the values were fluctuating from 6.3 to 8 L min^{-1}.
	4/16/2008	Takedown	Spent almost 8+ hours in balancing air flow on S-OPS "D." Was able to get rid of leaks but not able to balance.
	4/16/2008	Takedown	Pumping out lagoon and spraying to nearby field from 8:40 am to 3:00 pm
	4/16/2008	Takedown	Dipped ORP probe in Zoebell's solution. It was supposed to read 224 ± 30, but instead it gave 160 ± 50.
	4/16/2008	Takedown	Barometer audit: accepted.
14:05	4/16/2008	Takedown	Wetness Sensor calibration: accepted.
14:30-15:30	4/16/2008	Takedown	Sonic anemometer inter-comparison: all pass.
16:11	4/16/2008	Takedown	Zero calibration on sonic anemometers; all pass.
18:35	4/16/2008	Takedown	TFC 450i Reference precision check
22:10	4/16/2008	Takedown	ORP sensor: calibration and acceptance accepted
22:30	4/16/2008	Takedown	pH sensor: calibration, acceptance, QA accepted
23:30	4/16/2008	Takedown	Sludge Depth measurements taken. Avg. Depth to sludge layer: 1.56 m.
	4/17/2008	Takedown	Lagoon 8% crusted.
18:08-18:13	4/18/2008	Takedown	Calibrated TDLAS 1027: Mean: 90.94 SD: 1.34 RSD: 1.3% Bias: -0.9%
19:03-19:08	4/18/2008	Takedown	Calibrated TDLAS 1028: Mean: 109.74 SD: 5.46 RSD: 4.98% Bias: 11.0% After offset bias of 15.4: -4.6% note: During second background, many large concentrations were obtained but no r^2 >0.85
	8/12/2008	Setup	Tied down trailer and hooked up power.
	8/13/2008	Setup	Had problems connecting to internet--had to reinstall software on LAN (needed because new radio is being used).
	8/13/2008	Setup	146i diluter not working properly. Call Thermo--said flow controller must have recently been calibrated and perhaps rushed or connection is loose. Called Juan Carlos from barn source and sent diagram of diluter that displayed connections they may have disconnected. Will check in morning.
	8/13/2008	Setup	Current IP address is 75.203.33.222 (Sierra Wireless Program) Dyn DNS Current IP: 75.203.33.222 (same as yesterday).
	8/13/2008	Setup	GSS Leak Test: Pass
	8/13/2008	Setup	GSS Max Flow Test
	8/13/2008	Setup	GSS no Flow Test
	8/13/2008	Setup	S-OPS Balance: D

	8/13/2008	Setup	S-OPS Balance: F
	8/13/2008	Setup	S-OPS/GSS Leak Test
	8/13/2008	Setup	S-OPS Max Flow Test
19:55-20:55	8/13/2008	Setup	Sonic anemometer inter-comparison: all pass.
	8/14/2008	Setup	Diluter connections appear secure--will ship back to PAML to assess problems.
	8/14/2008	Setup	Yesterday's S-OPS calibration was on a file from WI5A.
	8/14/2008	Setup	Made KCl, QCCS, and Zobells solutions.
	8/14/2008	Setup	Could not perform pH/ORP stability/reference check because of broken reference electrode during ORP calibration. Both probes passed calibration.
	8/14/2008	Setup	Mounted TDLAS 1030/PTU 4 power/communication box on pole so communication Signal can be above pump (lagoon pump metal).
	8/14/2008	Setup	Used extension cords to some retro-reflectors when power cords could not reach outlets,
	8/14/2008	Setup	Could not find lagoon calibration control charts.
	8/14/2008	Setup	Changed the following inlet filters: D--1, 2, 4, and 5 F--1, 2, 5, 6, and 10.
	8/14/2008	Setup	Lagoon site layout made
	8/14/2008	Setup	Maintenance list made
1313	8/14/2008	Setup	Zero calibration on sonic anemometers; all pass.
15:34	8/14/2008	Setup	Wetness Sensor calibration: accepted.
15:45	8/14/2008	Setup	Barometer audit: accepted.
15:20	8/14/2008	Setup	TEC 450i Calibration Verification Check
15:34	8/14/2008	Setup	TEC 450i Instrument Operating Parameters
15:34	8/14/2008	Setup	TEC 450i Reference Precision Check
22:00	8/14/2008	Setup	ORP sensor 020: calibration. Could not perform acceptance because of broken reference electrode.
22:05	8/14/2008	Setup	pH sensor: calibration, and QA accepted Could not do QA because of broken reference electrode.
12:41	8/20/2008	Remote	Daily Status Check from PAML notes: Stopped sonic anemometer program to try and update H2S data. Connected to H2S analyzer successfully. H2S analyzer not staying connected--no data to process in QC check. Filled 1000 records back--only from 8/19/2008. Filled again from 8/14/2008 at 12:00 UTC. Sonic anemometer 1 mostly below 160 in flagging data...some greater than 160. On TDLAS's centerline duty cycle jumped from approximately. 150 to 250 at NAEMS day 494.7. TDLAS 1 paths are not all aimed correctly. Paths on optimize sheet seem to be in the correct spot relative to each other.
14:45	8/21/2008	Remote	Daily Status Check from PAML notes: no data received during this time.
	8/26/2008	Repair	no internet upon arrival. Updated DynDNS--green checkmark temporarily. Power-cycled radio and router--internet slow and intermittent.
	8/14/2008	Repair	Scanner on SW corner pointing straight down--still no communication with TDLAS 1031.
	8/14/2008	Repair	Calibrated TDLAS 1032 with oscilloscope--seemed to work successfully.
	8/14/2008	Repair	New diluter seems to work well PU# 1040240 SN# 079220664
	8/14/2008	Repair	TDLAS 1032: when using new control charts to account for temperature and pressure--cal curve, unable to pass (100 ppm, 200

			ppm, 50 ppm-m, 100 ppm-m, 125 ppm-m, 25 ppm-m respectively).
	8/14/2008	Repair	TDLAS 1031 had water inside window plastic. Serial controller rusted and wet when disconnected in field.
	8/14/2008	Repair	SW scanner grinding briefly during first initialization; new commands seem to make resets and initializations go very slowly (~20-25 min), but "home" is in same spot and paths stay aligned. Giving pan/tilt errors after every move, but still moving to each path successfully.
18:34-21:06	8/14/2008	Repair	Calibrated TDLAS 1032 See calibration sheet for full details.
	9/2/2008	Calibration	When arrived LAN said M drive was not accessible.
	9/2/2008	Calibration	TDLAS 1 only had paths 8 and 9--lost all other paths. TDLAS 2 lost path 8 and was optimizing until time-out on path 8 because obstruction level was set to 100; changed obstruction level to 300.
	9/2/2008	Calibration	H2S program stopped on 8/29/2008 at 2:26 UTC. Will make a fill file.
	9/2/2008	Calibration	TDLAS 1 kept getting a pan/tilt error on *GasView MP*. Tried restarting computer but it did not help.
	9/2/2008	Calibration	Switched out internet radio from 0724312186 to 0721320042. Internet is now working very well.
	9/2/2008	Calibration	Reaimed all paths on TDLAS 1 except path 7 and all paths on TDLAS 2 except path 8 from inside. We will see if anything is blocking these paths and aim them from the outside.
	9/2/2008	Calibration	Retro-reflector 8 on TDLAS 2 had quite a lot of water in it. Drained water out, and it is fine now. Will re-silicone it tomorrow.
	9/2/2008	Calibration	Retro-reflector 7 on TDLAS 1 was very low and grass was blocking the path. Raised up the retro-reflector, and it is fine now. Also raised retro-reflector 2 and TDLAS 1 since grass was starting to block the path as well.
21:23	9/2/2008	Calibration	Zero calibration on sonic anemometers; all pass.
21:35-22:35	9/2/2008	Calibration	Sonic anemometer inter-comparison: all pass.
	9/3/2008	Calibration	When conducting the S-OPS leak test, there was a leak of 1.66 L min^{-1}. Fixed the leak and balanced the inlets.
	9/3/2008	Calibration	Raised scanner/TDLAS 1 because it was low and the grass was getting in the way. Reaimed the paths.
	9/3/2008	Calibration	The ORP probe would not calibrate properly (S/N: 020). Replaced it with new ORP probe (S/N: 050).
	9/3/2008	Calibration	Initially the diluter was flowing very slowly. Open case and rejected the cable, and it works fine now.
	9/3/2008	Calibration	Remainder of zero air was lost due to high flow rate for TDLAS calibration and a leak in the T used to split the zero air stream going into the diluter. Zero air was used instead of N2 because N2 tank is empty.
	9/3/2008	Calibration	Replaced broken retro-reflector box.
	9/3/2008	Calibration	Added silicone sealing to bottom retro-reflector on N side of SE tower. It was wet yesterday upon arrival.
	9/3/2008	Calibration	pH sensor: calibration, acceptance, QA accepted
	9/3/2008	Calibration	ORP sensor 020: calibration and acceptance. Acceptance fails. Will replace probe.
	9/3/2008	Calibration	ORP sensor 050: calibration and acceptance accepted.
	9/3/2008	Calibration	Sludge Depth measurements taken. Avg. Depth to sludge layer: 0.86 m.

	9/3/2008	Calibration	Wetness Sensor calibration: accepted.
	9/3/2008	Calibration	Barometer audit: accepted.
	9/3/2008	Calibration	GSS Leak Test: Pass
	9/3/2008	Calibration	GSS Max Flow Test
	9/3/2008	Calibration	GSS no Flow Test
	9/3/2008	Calibration	S-OPS Balance: D
	9/3/2008	Calibration	S-OPS Balance: F
	9/3/2008	Calibration	S-OPS/GSS Leak Test
	9/3/2008	Calibration	S-OPS Max Flow Test
23:12	9/3/2008	Calibration	Calibrated TDLAS 1030 Mean: 51.42 SD: 0.38 RSD: 0.7% Bias: 3.6% notes: There were scratches in the front window of the TDLAS. Had to restart calibration because of trouble with diluter.
23:58	9/3/2008	Calibration	Calibrated TDLAS 1026 Mean: 49.71 SD: 0.76 RSD: 1.5% Bias: 0.16%
	9/4/2008	Calibration	TDLAS 1 retro-reflector 6: removed 1/8 plastic; now just 1/4 plastic.
	9/4/2008	Calibration	Maintenance list made
	9/4/2008	Calibration	Electronic Data Chain of Custody form made.
00:41	9/4/2008	Calibration	Calibrated TDLAS 1032 Mean: 46.58 SD: 0.27 RSD: 0.6% Bias: -6.1% notes: Could not get a smooth reading on the oscilloscope. It always had a very deep wave. Will bring it back to PAML to investigate. Later, recheck oscilloscope; got a smooth waveform but not ideal.
03:34	9/4/2008	Calibration	TEC 450i Calibration Verification Check
03:54	9/4/2008	Calibration	TEC 450i Instrument Operating Parameters
03:54	9/4/2008	Calibration	TEC 450i Reference Precision Check
04:18	9/4/2008	Calibration	SO2 calibration
13:10	9/5/2008	Remote	Daily Status Check from PAML notes: Last evening around 10pm EDT, I (MJB) logged in from home and found that sonic anemometer program was not running. It had been shut down during the final on-site check to allow *iPort* to run. Sonic anemometer data missing from 613.56-614.11. Sonic anemometer 1 has a quite a few 5-min periods with 1-20 sonic anemometer flagged points. Sonic anemometers 1 and 2 have a few periods with over 160 spike counts. Period 6 started yesterday. Many TDLAS paths are losing some data probably because of dew.
12:30	9/8/2008	Remote	Daily Status from PAML notes: Tropical Storm Hanna impacted site on Saturday morning (9/6/2008). Very few paths getting valid light levels at this time. Valid paths on TDLAS 1: 3, 4, 8, and 10. Valid paths on TDLAS 2: 1, 2, and 4. Possibly caused by a combination of dew/fog and possibly wet plastic inside retro-reflectors. CR 1000 RH is 90% and T=24.4 C.
11:50	9/9/2008	Remote	Daily Status Check from PAML notes: At 13:00 EDT reaimed TDLAS paths: TDLAS 1 R5 and TDLAS 2 R9. See form for details. Unable to find TDLAS 2 R10 yet. May be caused by fog or mist. FTP server was off (unknown cause), so no data were received this morning. Turned on FTP server and reset data. Flagged data in sonic anemometers 2 and 3 around 617.95-618. Sonic anemometer 2 stopped sending data around 618.0. Since about 618.0 both side on GSS mass flow data have similar readings. Will keep checking. Change (step) in H2S sample flow from 0.77 to 0.66 at 618.1.
12:00	9/10/2008	Remote	Daily Status Check from PAML notes: Very humid conditions for long periods; none of the paths valid. Sonic anemometer 2 not functioning. H2S sample flow had a step drop around day 618. SO2 has been around 10 ppb entire period. H2S has rarely reached 5 ppb.

12:30	9/11/2008	Remote	Daily Status Check from PAML notes: AT 18:20, moved TDLAS 2 R10. Still have not realigned path, but new location is closer to where it should be. Sonic anemometer 2 is still not working. H2S chamber pressure jumped from 698 to 710 about 2 d ago (618.1) (at that same time that sample flow decreased).
12:15	9/12/2008	Remote	Daily Status Check from PAML notes: Last 450I data point was on 9/12/2008 at 07:37 UTC. Stopped sonic anemometer program; created data fill file; restarted real-time file; restarted sonic anemometer program. Only one TDLAS path getting valid light levels out of 20. Continued fog/mist/dew. Sonic anemometer 2 still not working. H2S sample flow is still low at 0.66 L min^{-1}.
12:00	9/15/2008	Remote	Daily Status Check from PAML notes: Tried to reaim path 5 on TDLAS 2. See form for details. Paths 5 and 10 on TDLAS 2 are lost. Sonic anemometer 2 still not working. H2S sample flow has been steady at 0.66 L min^{-1} for past few days.
11:50	9/16/2008	Remote	Daily Status Check from PAML notes: Still very humid. Path TDLAS paths with relatively low light levels on TDLAS 1. Path 10 on TDLAS 2 is completely lost. Sonic anemometer 2 still not working. Sonic anemometer 3 has four 5-min periods with over 1500 flags. H2S sample flow is still not normal with a reading of 0.66 L min^{-1}.
12:30	9/17/2008	Remote	Daily Status Check from PAML notes: Reaimed TDLAS 2 paths 5 and 10. Paths are still wet probably as light levels are still low. See forms for details. Sonic anemometer 2 still not working. H2S sample flow is still low at 0.66 L min^{-1}.
12:00	9/18/2008	Remote	Daily Status Check from PAML notes: Fog/mist still causing low light levels on some paths. Paths 5 and 10 on TDLAS 2 still have low light levels most of the time. Sonic anemometer 2 still not functioning. Sample flow on H2S analyzer still low at 0.66 L min^{-1}.
	9/22/2008	Takedown	Arrived at site around 20:00 UTC. Opened up retro-reflector door on TDLAS 2 retro-reflector 10 since the plastic was wet. Retro-reflector seal appears bad. Path 10 was saturated, so moved to a good location and restarted.
	9/22/2008	Takedown	At orifice 3 on F-S-OPS, lower "T" was covered by a fire ant nest. When the "T" was removed the ants came out of the nest. Saw a lot of tape attached to the "T" also; must have leaked the last time as well.
	9/22/2008	Takedown	Plastic in TDLAS 2 retro-reflector 10 still slightly damp at 23:00 UTC. Took out and dried in the breeze, and placed back in retro-reflector box.
	9/22/2008	Takedown	GSS Leak Test: Pass
	9/22/2008	Takedown	GSS Max Flow Test
	9/22/2008	Takedown	GSS no Flow Test
	9/22/2008	Takedown	S-OPS Max Flow test
	9/22/2008	Takedown	S-OPS/GSS Leak Test: Pass
	9/22/2008	Takedown	S-OPS Balance: D
20:35	9/22/2008	Takedown	Barometer audit: accepted.
	9/22/2008	Takedown	S-OPS Balance: F
	9/23/2008	Takedown	Received nitrogen and zero air cylinders.
	9/23/2008	Takedown	Retro-reflector plastic information taken. See site notes for details.
	9/23/2008	Takedown	Maintenance list made
	9/23/2008	Takedown	pH sensor: Calibration, Acceptance, Stability, and QA accepted.
	9/23/2008	Takedown	ORP sensor: calibration and acceptance accepted
16:10-	9/23/2008	Takedown	Sonic anemometer inter-comparison: Sonic anemometer 2 fails

17:10			
17:28	9/23/2008	Takedown	Zero calibration on sonic anemometers. Notes: Sonic anemometer 2 is not working. All values are zero with a flag 2.
20:03-20:17	9/23/2008	Takedown	TEC 450i Calibration Verification Check
20:19	9/23/2008	Takedown	TEC 450i Instrument Operating Parameters
20:19	9/23/2008	Takedown	TEC 450i Reference Precision Check
22:30	9/23/2008	Takedown	Calibrated TDLAS 1030 notes: Diluter only being used to control flow.
23:09	9/23/2008	Takedown	Calibrated TDLAS 1026 notes: Diluter only being used to control flow.
	1/14/2009	Setup	Reached site at 2:30 pm local time.
	1/14/2009	Setup	Hooked up trailer and power supply.
	1/14/2009	Setup	Set up all ground retro-reflectors and scanners.
	1/14/2009	Setup	Scissor jack at right side of the trailer got damaged while driving from PAML to NC4A. Have to use blocks to give support.
	1/14/2009	Setup	Glass reference electrode got broken (it may have broke while traveling). Could not perform acceptance or pH and ORP probes. Will only do calibration.
	1/14/2009	Setup	Truck got stuck in evening hours.
21:55-22:50	1/14/2009	Setup	Sonic anemometer inter-comparison; all pass.
23:25	1/14/2009	Setup	Zero sonic anemometer calibration; all pass.
	1/15/2009	Setup	One scanner is completely dead. Power supply is outputting 24.6 V as verified by "test box," but scanner fails to do "initialization dance" or any sort of measures in start up. Will return to DP tomorrow.
	1/15/2009	Setup	During Innova calibration, NH3 looks good and passes. Methane, however, had values ten times higher than NH3. Found an error in calculation (calculating using C3H8 instead of CH4). CH4 still not passing with accuracy of -36.4%.
	1/15/2009	Setup	While balance S-OPS side F filter paper on orifices #2 and #8 had to be changed. There is a leak somewhere in the F side. Will try to fix leak tomorrow.
	1/15/2009	Setup	Maintenance list made
14:18	1/15/2009	Setup	pH sensor: QA and inspection/maintenance completed. Note: Glass reference electrode got broken (it may have broke while traveling). Could not perform acceptance or pH and ORP probes.
14:28	1/15/2009	Setup	ORP calibration note: Glass reference electrode got broken (it may have broke while traveling). Could not perform acceptance or pH and ORP probes.
15:50	1/15/2009	Setup	Installed lagoon probes.
17:14	1/15/2009	Setup	TEC 450i calibration
17:28	1/15/2009	Setup	Wetness Sensor calibration: accepted.
17:31	1/15/2009	Setup	Wetness Sensor calibration: accepted.
19:05	1/15/2009	Setup	Calibrated TDLAS 1026
20:21	1/15/2009	Setup	Calibrated TDLAS 1030
	1/16/2009	Setup	Since SW scanner was not working, TDLAS 1026 was fixed on a single path.
	1/16/2009	Setup	Took about one h to balance S-OPS "D" side. Changed nozzle for orifice number 2.
	1/16/2009	Setup	Spent about two hours to find leaks in S-OPS. Found orifices 2 and 8 leaking. Managed to drop leak by 0.3 L min^{-1}. Still not good enough to pass; failing by 0.04 L min^{-1}. Will keep like that.

	1/16/2009	Setup	Lagoon site layout made
14:00	1/20/2009	Remote	Daily Status Check from PAML notes: Unable to find paths on TDLAS 1 due to snow. Extensive communication problems with TDLAS 1. Innova present, but QC not working at PAML. GSS mass flow and pressure on one line dropped for a while yesterday. Single path on TDLAS 2.
	1/21/2009	Repair	Flight to site was delayed, so did not arrive on site until 6:00 P.M. local time. Gate was locked upon arrive so had to walk the scanner to the trailer.
	1/21/2009	Repair	Set up the scanner and aimed the paths using the halogen work lights. When the laptop was brought back into the trailer, the *GasView MP* program kept showing pan/tilt errors. Tried moving antennas on the trailer roof and also took a spare tripod over the scanner and mounted the modem box as high as possible. Restarted program the scanner and TDLAS modems, and it seems to be running better. However, some pan/tilt errors occur sporadically.
	1/21/2009	Repair	Performed CH4 span check on Innova. Recorded the results in the Innova control chart. With the Humidifier canister in the line, got similar results to the calibration on 1/15/2009 (6.55 ppm CH_4). Then ran calibration span without the Humidifier in the line and got very different results (11.88 ppm CH4). Hooked the sampling tube from the GSS back to the Innova at 1:38 UTC on 1/22/2009.
13:15	1/21/2009	Remote	Daily Status Check from PAML notes: Restarted GasViewMP program and reloaded setup files for TDLAS 1. System is attempting to reaim/optimize paths. Some light values at 16,368 to start out. GSS mass flow has been gradually decreasing. Flag 4 (valve constant) in H2S data. Innova QC not working. TDLAS 2 is on a single path.
13:10	1/22/2009	Remote	Daily Status Check from PAML notes: On TDLAS 2, paths 4, 9, and 10 have red box errors. Placed correct values in repair file. When in Aim screen, all ten paths have good light level values. However, when running, the indicator goes to "moving" for long periods of time and then "pan-tilt error." Some paths go to correct spots and others do not. Pan-tilt unit seems to struggle to send data back to trailer. Innova QC not working. TDLAS 2 is on a single path.
15:07	1/23/2009	Remote	Daily Status Check from PAML notes: TDLAS 2 is not working properly. Scanner keeps giving pan-tilt errors.
14:10	1/26/2009	Remote	Daily Status Check from PAML notes: Scanner 2 is not working (pan-tilt errors). Found that path 8 on TDLAS 2 had a dwell time of zero sec since set up occurred. Set this path up as a "single path" by changing dwell to 600s and all other paths' dwell to zero sec. Left system aimed at path 9 by not pressing run button. This is tower path on west side of lagoon since winds should be from the east for the next day or so.
13:00	1/27/2009	Remote	Daily Status Check from PAML notes: TDLAS 2 is set to a single path on path 8. QC program cannot handle this. GSS mass flow still fluctuating. No Innova QC.
14:50	1/28/2009	Remote	Daily Status Check from PAML notes: Moved TDLAS 2 from pointing at retro-reflector 8 (west side) to retro-reflector 3 (south side) at 16:08 since winds have shifted to the south. No Innova QC. GSS mass flow fluctuating.
13:05	1/29/2009	Remote	Daily Status Check from PAML notes: TDLAS 2 is on a fixed path (path 3). TDLAS 2 path 3 has low light values (~832). TDLAS 2 has extensive "xxxx" error values. No QC file for GSS/H2S/Innova. GSS mass flow pink line still variable. No Innova QC available.

16:30	1/30/2009	Remote	Daily Status Check from PAML notes: TDLAS 2 is on a fixed path (path 3). TDLAS 2 also has continuous communication problems ("xxxx" displayed as values). No TDLAS 2 QC because of single path; values look good. GSS mass flow/pressure still varying. No Innova QC.
	2/2/2009	Takedown	Reached site at 2:15 pm local time.
	2/2/2009	Takedown	Everything was working well; even TDLAS 2 (1026) was working. It was not showing communication (xxxx) error.
	2/2/2009	Takedown	Scanner seems to be not working. TDLAS is stuck in one direction that is opposite to the lagoon facing downwards.
20:35-21:29	2/2/2009	Takedown	Sonic anemometer inter-comparison; all pass.
21:30-22:00	2/2/2009	Takedown	Sludge Depth measurements taken. Notes: Did measurements in two different ways. The first was recording the depth when the gun begins to squeal when lowering. The second was recording the depth when the sludge gun stops squealing when raised. The two depths were very different, varying by more than one meter. See worksheet for details.
22:02	2/2/2009	Takedown	Removed probe float from lagoon.
22:51	2/2/2009	Takedown	Zero sonic anemometer calibration; all pass.
23:08	2/2/2009	Takedown	Barometer audit: accepted.
	2/3/2009	Takedown	CH4 calibration fails for Innova; it initially gave a good reading, but after one minute it started giving lower values. The cylinder may be bad.
	2/3/2009	Takedown	S-OPS "F" balancing failed. Had to change filter paper for orifices 1 and 8 (before changing filter paper leak test was failing but after change it passed).
	2/3/2009	Takedown	S-OPS "D" balanced failed too. Will check at NC3A. Filter holder for #1 is leaking, but do not have replacement available. Water is in the liner of the inlets with leaking filer paper holders.
	2/3/2009	Takedown	pH sensor failed during calibration. It was giving more basic values than reference solution. Changed reference solution and cleaned probe with soap. Readings improved slightly, but still failing. Will replace with a new sensor.
	2/3/2009	Takedown	Maintenance list made
14:32-16:34	2/3/2009	Takedown	S-OPS/GSS calibrations: See Open Site notes for details on S-OPS balancing.
15:34-16:44	2/3/2009	Takedown	Innova single point calibration notes: It initially gave a good reading, but after 2-3 min it started giving lower values. Did CH4 calibration again with Teflon tubing, but got same result.
17:42	2/3/2009	Takedown	Calibrated TDLAS 1026
18:10	2/3/2009	Takedown	Calibrated TDLAS 1030
19:28	2/3/2009	Takedown	Wetness Sensor calibration: accepted.
22:00	2/3/2009	Takedown	ORP sensor: calibration and acceptance accepted
22:28	2/3/2009	Takedown	pH sensor: QA and inspection/maintenance completed.
	4/28/2009	Setup	TDLAS 1026 failed calibration (bias -15.34%). Tried calibrating the TDLAS a second time, but it failed again (bias -11.43%).
17:20	4/28/2009	Setup	Zero sonic anemometer calibration; all pass.
17:40	4/28/2009	Setup	Sonic anemometer inter-comparison; all pass.
21:32-23:21	4/28/2009	Setup	Calibrated TDLAS 1026 notes: TDLAS 1026 failed calibration (bias -15.34%). Tried calibrating the TDLAS a second time, but it failed again (bias -11.43%).
22:05	4/28/2009	Setup	Calibrated TDLAS 1030

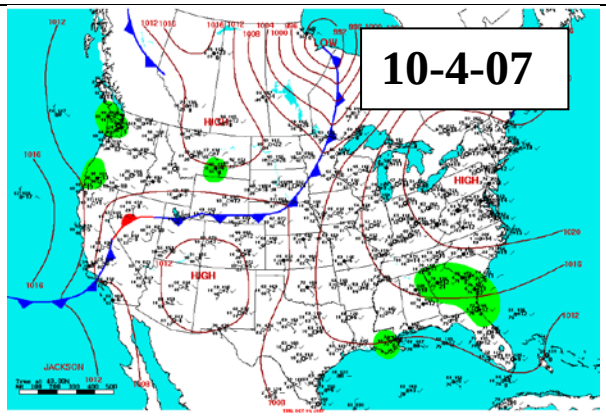
	4/29/2009	Setup	While aiming TDLAS 1030 (SW corner), the machine displayed communication errors (“xxxx”) most of the time. Some improvement when we started running. Placed grad modem/power supply box on top of the tall tripod and communication errors went away.
	4/29/2009	Setup	Maintenance list made
	4/29/2009	Setup	Lagoon site layout made
	4/29/2009	Setup	S-OPS/GSS calibrations
	4/29/2009	Setup	ORP sensor: calibration and acceptance accepted
15:32	4/29/2009	Setup	Wetness Sensor calibration: accepted.
15:34	4/29/2009	Setup	Barometer audit: accepted.
15:46-16:55	4/29/2009	Setup	TEC 450i multipoint calibration
16:40	4/29/2009	Setup	pH sensor: QA, calibration, and inspection and maintenance completed
14:15	4/30/2009	Remote	Daily Status Check from PAML notes: no QC data.
14:10	5/1/2009	Remote	Daily Status Check from PAML notes: no Innova at site.
13:10	5/4/2009	Remote	Daily Status Check from PAML notes: *iPort* error; had to stop sonic anemometers to restart *iPort*. Filled missing data from 5/2/2009 00:11 to 5/4/2009 02:29 and from 5/4/2009 2:40 to 5/4/2009 13:01. Sonic anemometer 1 average w is slightly higher than zero. Sonic anemometer u, v, and w graphs look different.
12:05	5/5/2009	Remote	Daily Status Check from PAML notes: On TDLAS 2, paths 2, 3, and 8 were off. Weather is bad; will check again later. Not able to connect to CR 800. Later, restarted *Loggernet* and was able to connect. Sonic anemometer 1 w looks different from the other sonic anemometers' graphs.
13:00	5/6/2009	Remote	Daily Status Check from PAML notes: Unable to connect to CR 800; restarted *Loggernet* to be able to connect to CR 800. Checked GSS (CR 800) data collection and TDLAS 2 alignment later in the day. Found that date was set one day behind on "Date and Time Properties." Corrected from 5/5/2009 to 5/6/2009, and *Loggernet* appears to be downloading data again. Does not appear to have affected any data streams. At least two paths on TDLAS 2 have low light levels (path 8 optimizing the most). Handful of five-min intervals for sonic anemometer 3 has flagging (only two are greater than 500).
12:50	5/7/2009	Remote	Daily Status Check from PAML notes: Around day 856.6 there is some period of time that is repeated, probably due to the date error noticed yesterday. The data with the incorrect time stamps is from 5/6 13:39 to 5/6 15:00.
13:00	5/8/2009	Remote	Daily Status Check from PAML notes: *iPort* error; had to stop sonic anemometers to restart *iPort*. Filled missing data from 5/7/2009 22:29 to 5/8/2009 05:38. Data is now complete. Tried to reaim TDLAS 2 path 5 but was not successful. Spent about 30 min trying to re-aim; will try again later.
	5/11/2009	Takedown	Fifth paths on SW TDLAS (the path that which was unable to be found in Daily Status Check for 5/8/2009) was found to be filled with water, and the plastic was found to be stuck to the window due to water. Resealed the window with putty.
17:51-18:19	5/11/2009	Takedown	TEC 450i single point calibration
18:45-19:02	5/11/2009	Takedown	Calibrated TDLAS 1030
19:00-	5/11/2009	Takedown	Sonic anemometer inter-comparison; all pass.

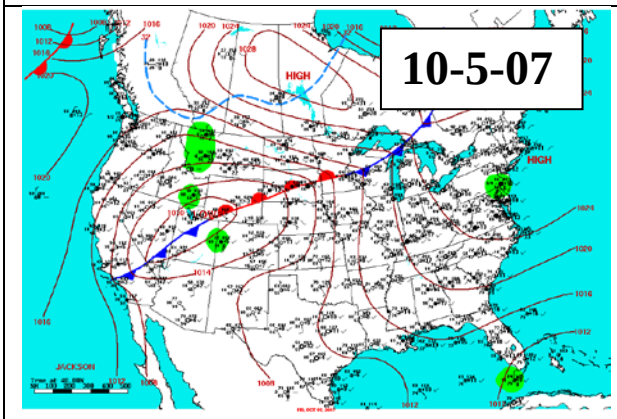
19:54			
19:21-19:35	5/11/2009	Takedown	Calibrated TDLAS 1026
20:13	5/11/2009	Takedown	Zero sonic anemometer calibration; all pass.
20:30	5/11/2009	Takedown	S-OPS/GSS calibrations notes: Inlet balance failed; will check "D" side at NC3A.
21:45	5/11/2009	Takedown	Barometer audit: accepted.
22:00	5/11/2009	Takedown	Wetness Sensor calibration: accepted.
	5/12/2009	Takedown	no lagoon boating for sludge depth due to breezy conditions and injured boater (MTB pulled chest muscle while removing probe float).
	5/12/2009	Takedown	Maintenance list made
	5/12/2009	Takedown	ORP sensor: calibration and acceptance accepted
13:15	5/12/2009	Takedown	pH sensor: QA, calibration, and inspection and maintenance completed
	6/30/2009	Setup	Replaced broken retro-reflector box with a new one.
	6/30/2009	Setup	New QCCS and Zobell's solution made.
	6/30/2009	Setup	New wetness sensor installed.
18:37	6/30/2009	Setup	Calibrated wetness sensor: accepted. Notes: New wetness sensor (s/n: 6)
18:48	6/30/2009	Setup	Barometer audit: accepted.
	7/1/2009	Setup	Sludge depth measurements taken
	7/1/2009	Setup	ORP sensor: calibration and acceptance accepted
	7/1/2009	Setup	Lagoon site layout made
	7/1/2009	Setup	Maintenance list made
15:55-17:25	7/1/2009	Setup	S-OPS/GSS calibrations
17:15	7/1/2009	Setup	pH sensor: QA, calibration, and inspection and maintenance completed
18:08	7/1/2009	Setup	Started H2S measurement
19:55	7/1/2009	Setup	Installed lagoon probes.
13:20	7/6/2009	Remote	Daily Status Check from PAML
13:20	7/7/2009	Remote	Daily Status Check from PAML notes: When connecting to the TDLAS 1 laptop, found that the aiming screen was still there from yesterday. It was aimed at path 6. Clicked OK, and it started scanning again as it was already in run mode. Stopped scanning at 13:29 UTC 7/6/2009. Started scanning at 13:49 UTC 7/7/2009.
12:55	7/8/2009	Remote	Daily Status Check from PAML notes: Paths on both TDLs have low light levels, probably caused by fog in the area.
16:12	7/9/2009	Remote	Daily Status Check from PAML
12:00	7/10/2009	Remote	Daily Status Check from PAML
12:20	7/13/2009	Remote	Daily Status Check from PAML notes: Sonic anemometers' 2 and 3 w values are on either side of the zero line. TDLAS 1 had a fraction of all ten paths aligned as zero for the previous day and is continuing today. Unable to aim any TDLAS 1 paths.
12:20	7/14/2009	Remote	Daily Status Check from PAML notes: Sonic anemometer 1 w is on the positive side of the zero line. CDC for TDLAS 1 went to 255 and quit; unable to connect to TDLAS 1.
12:20	7/15/2009	Remote	Daily Status Check from PAML notes: Sonic anemometer 1 average w is biased to the positive. TDLAS 1 is no longer work or collecting data. Many paths with low light levels on TDLAS 2 probably caused by dense fog at site.
	7/16/2009	Remote	Daily Status Check from PAML notes: TDLAS 1 is offline.

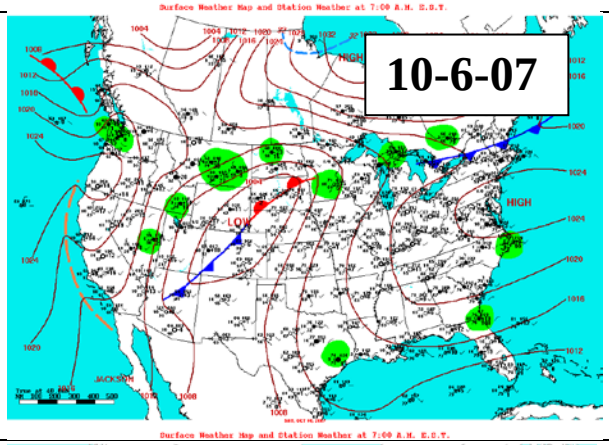
	7/17/2009	Remote	Daily Status Check from PAML notes: Sonic anemometer 1 is biased to the positive. TDLAS 1 is not working. Morning fog/dew in area probably cause low light levels on TDLAS 2.
	7/20/2009	Remote	Daily Status Check from PAML notes: TDLAS 1 is offline. Sonic anemometer 3 has stopped sending data for unflagged data points and for number of spike data points. Checked 300 sec data, and it was all zeros. Sonic anemometer 3 has not sent any w data since day 930.
	7/21/2009	Remote	Daily Status Check from PAML notes: N:\ is not accessible. Associated error message upon remote login: "not enough server space to process this command." no data for sonic anemometer 3. TDLAS 2 stopped at 13:07:01 UTC on 7/20/2009. Cannot connect to TDLAS laptops. FOS on site.
	7/21/2009	Takedown	Value 10 Error at line 422; computers messed up. Scanner 1202 failed, pointing down. TDLAS 1026 was wet inside, pointing down as well. Let TDLAS dry in the sun. Its connector was badly corroded.
	7/21/2009	Takedown	Sonic anemometer 3 (1933) stopped working on 7/18 at about 00:15 UTC.
13:27-14:21	7/21/2009	Takedown	Calibrated TEC 450i notes: fail precision; 8.47%
19:55-20:55	7/21/2009	Takedown	Sonic anemometer inter-comparison note: Sonic anemometer 3 (1933) stopped working on 7/18/2009 at about 00:15 UTC.
20:08-20:32	7/21/2009	Takedown	Calibrated TDLAS 1030
21:11	7/21/2009	Takedown	Zero sonic anemometer calibration note: Sonic anemometer 3 (1933) stopped working on 7/18 at about 00:15 UTC.
21:30	7/21/2009	Takedown	S-OPS/GSS calibrations
21:42-22:02	7/21/2009	Takedown	Calibrated TDLAS 1026
	7/22/2009	Takedown	Open site notes completed.
	7/22/2009	Takedown	Maintenance list made
	7/22/2009	Takedown	ORP sensor: calibration accepted
14:12	7/22/2009	Takedown	Barometer audit: accepted.
14:16	7/22/2009	Takedown	Wetness Sensor calibration: accepted.
15:05	7/22/2009	Takedown	pH sensor: QA accepted

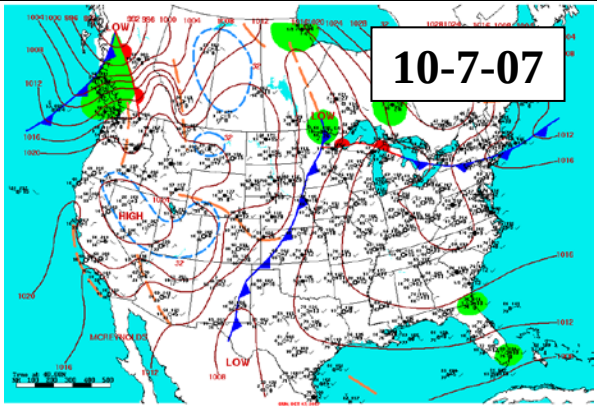
6.9 Site Weather

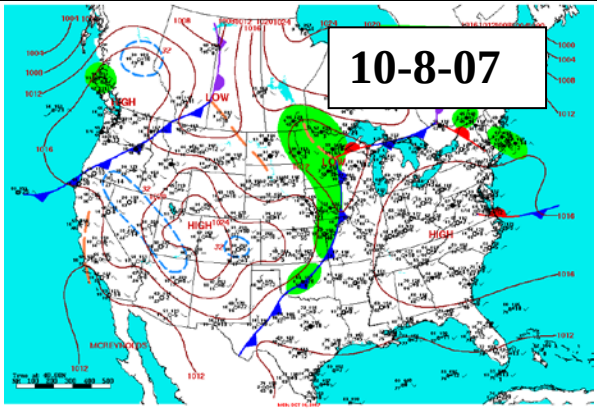
Period 2

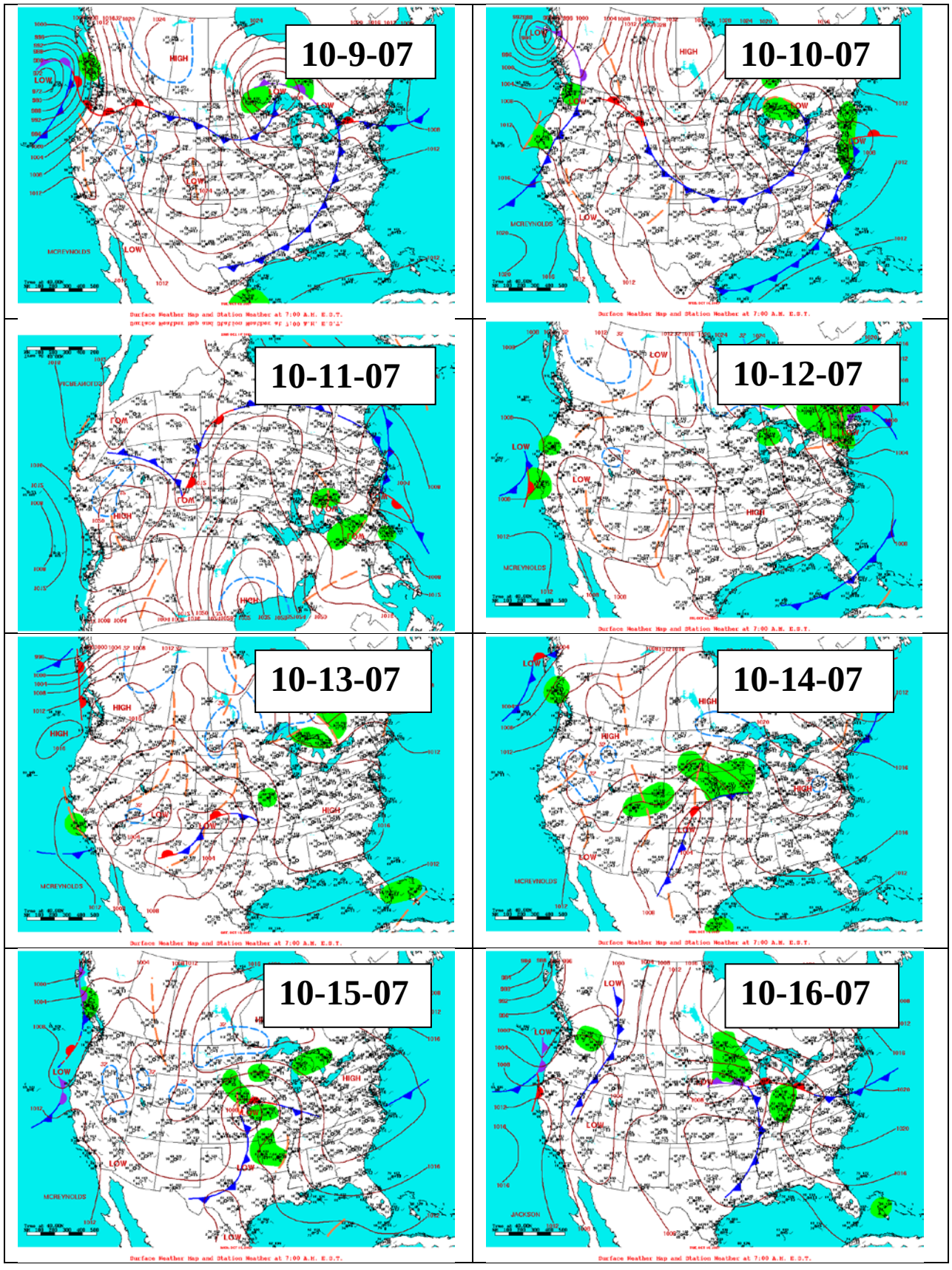








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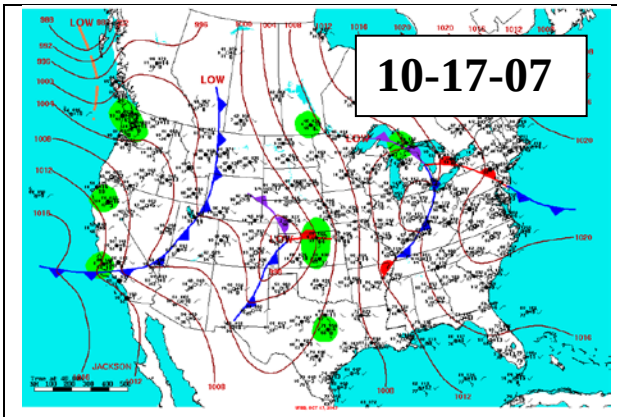

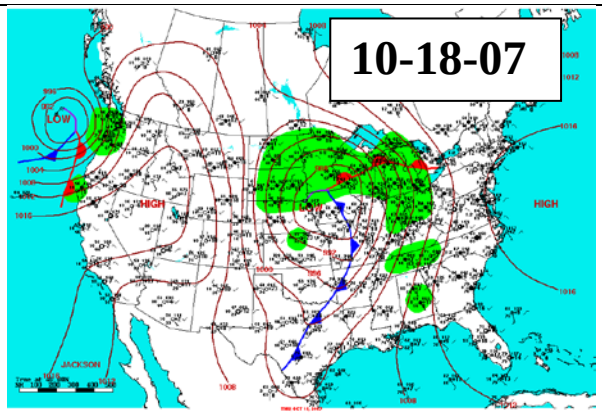

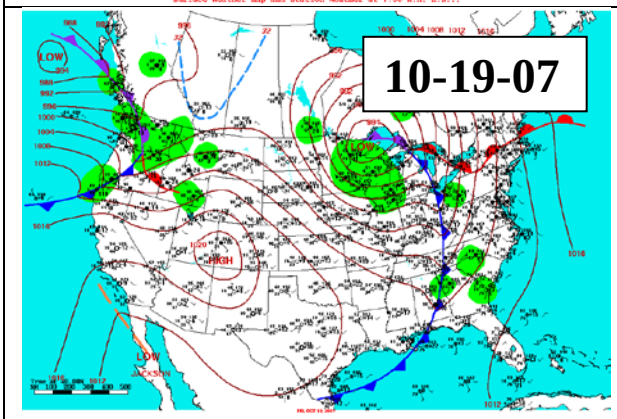

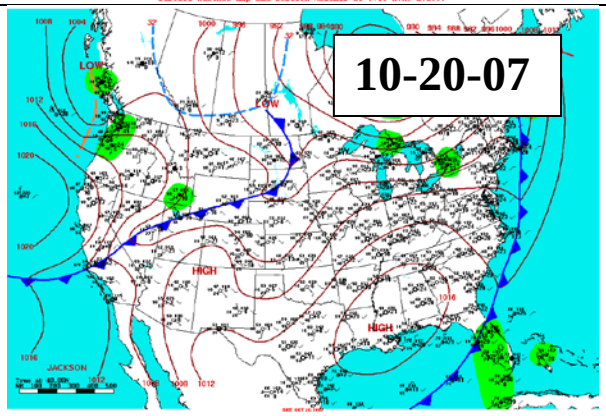

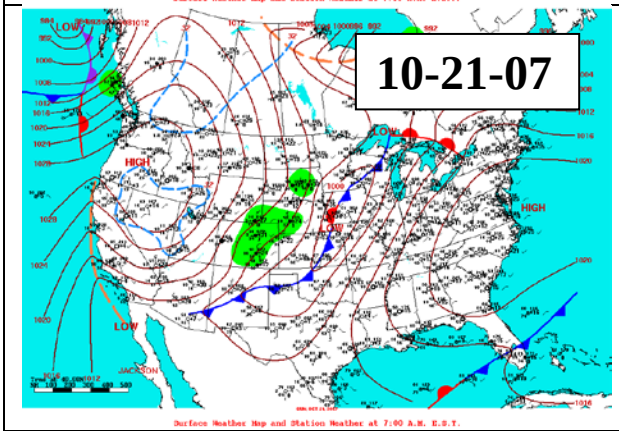

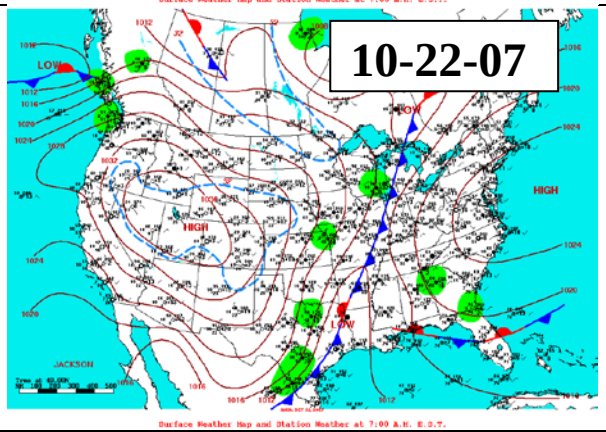

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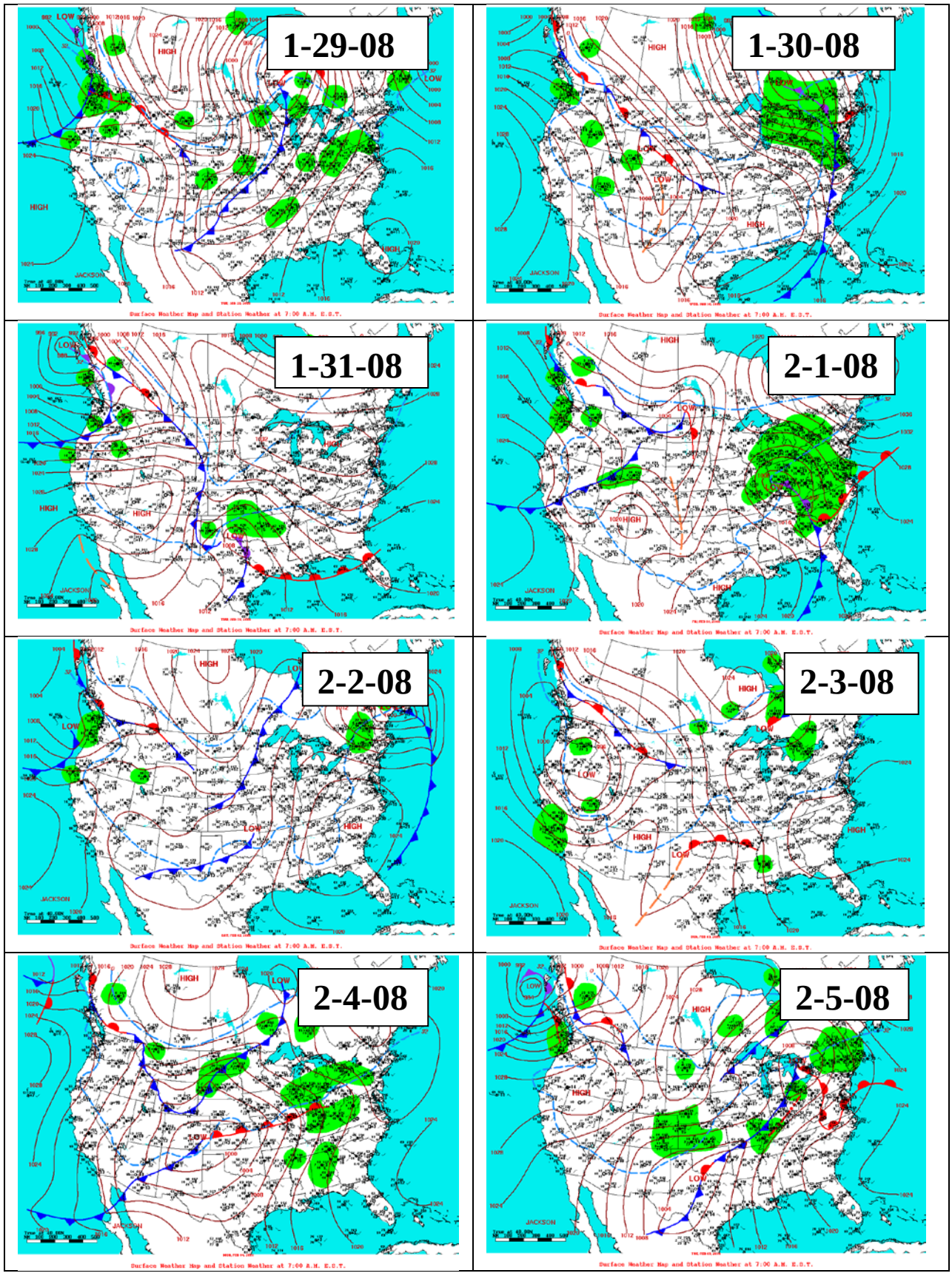
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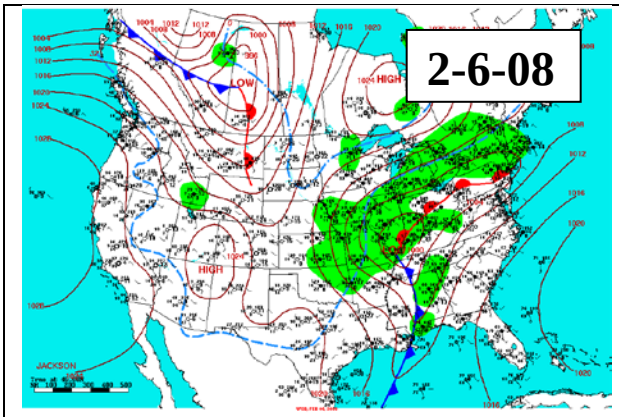

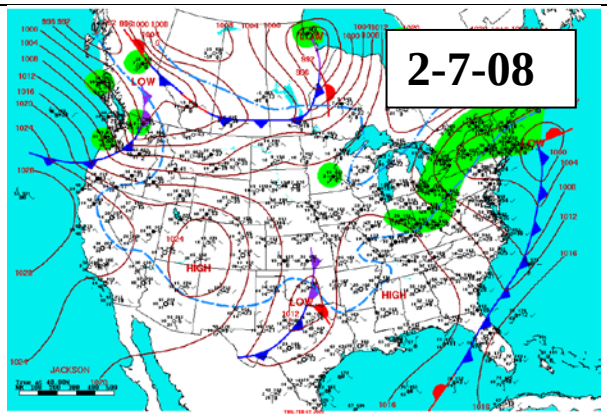

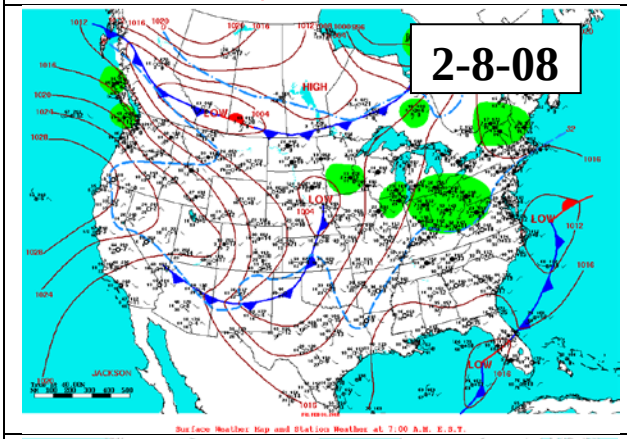

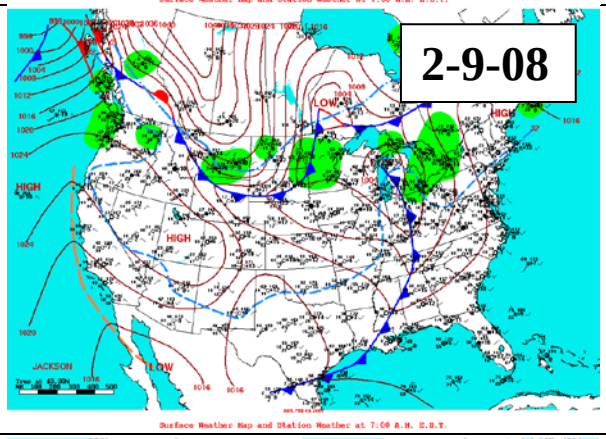

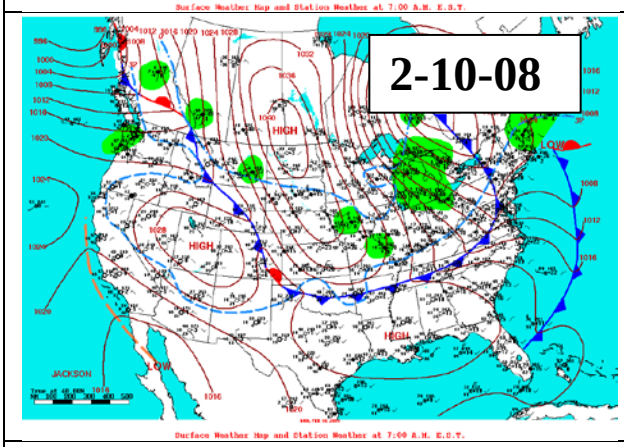

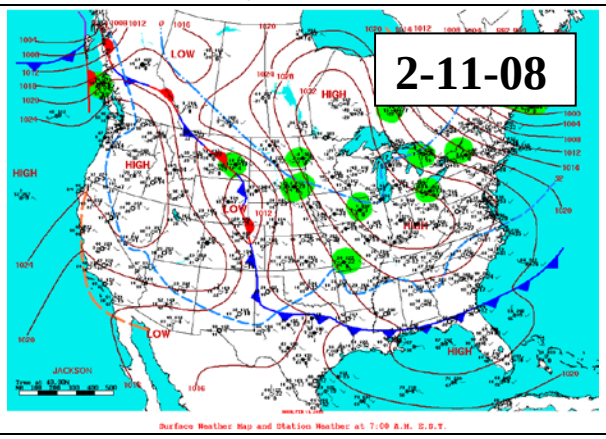

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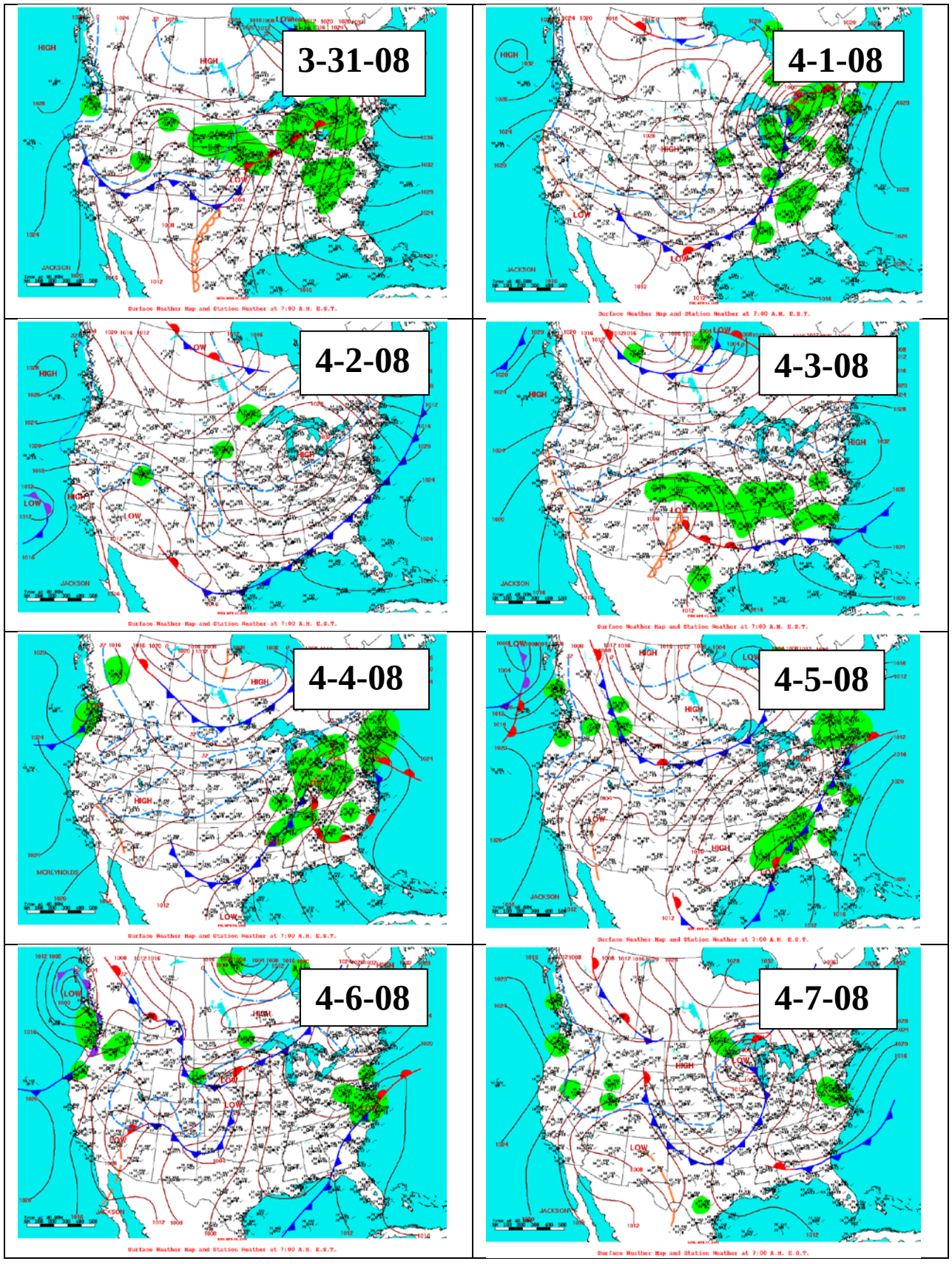
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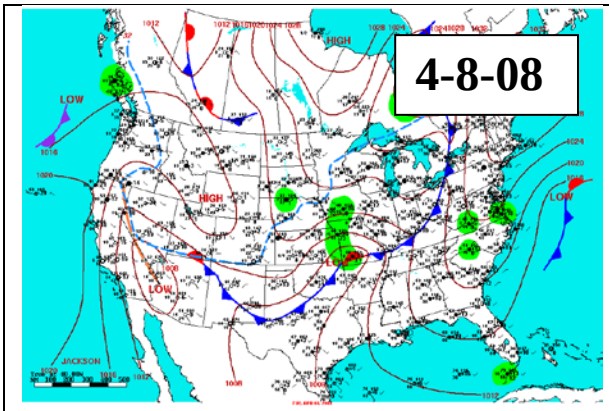
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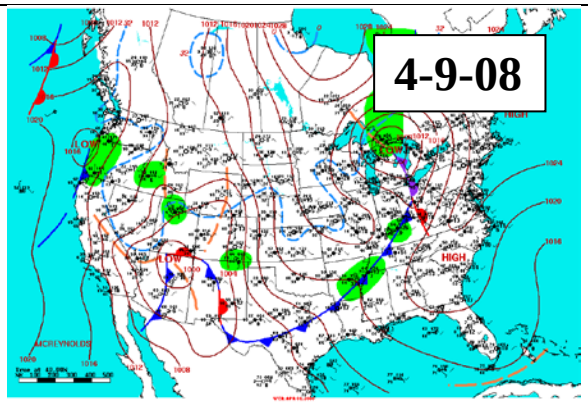
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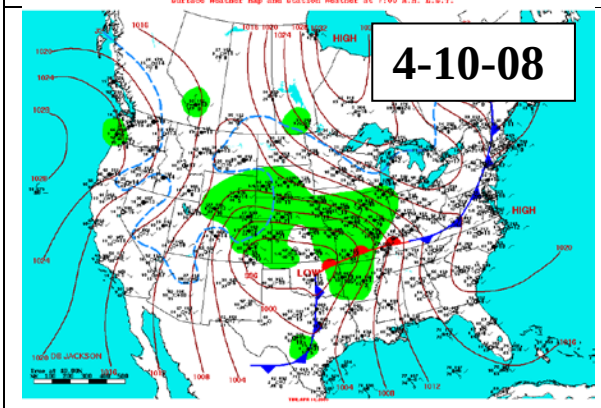
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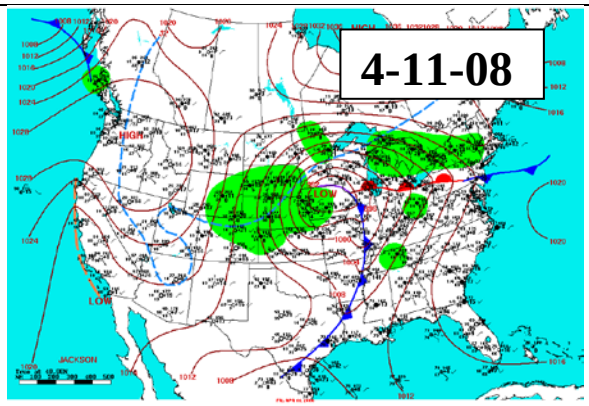
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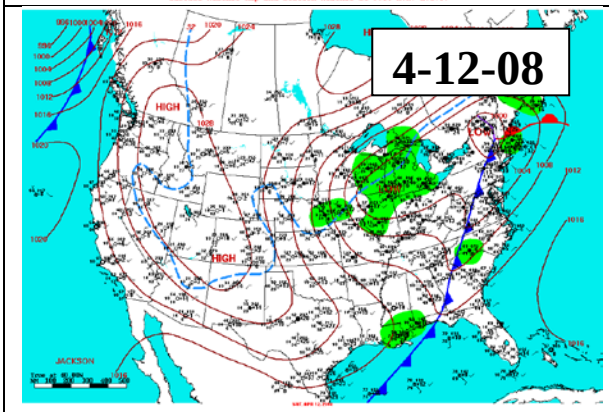
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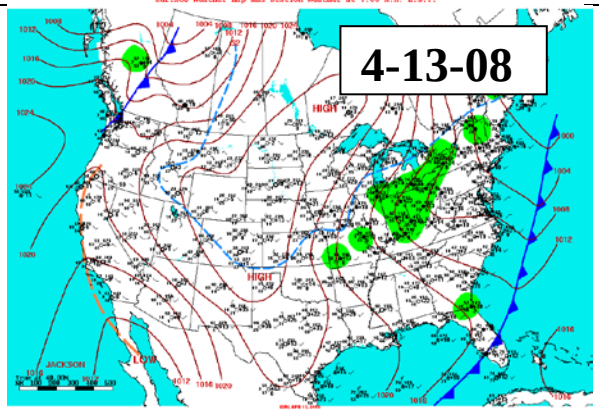
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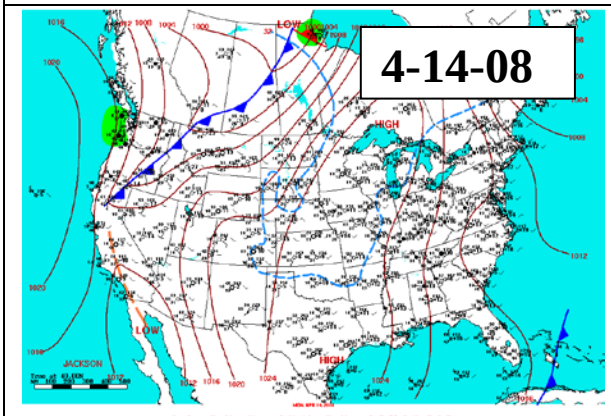
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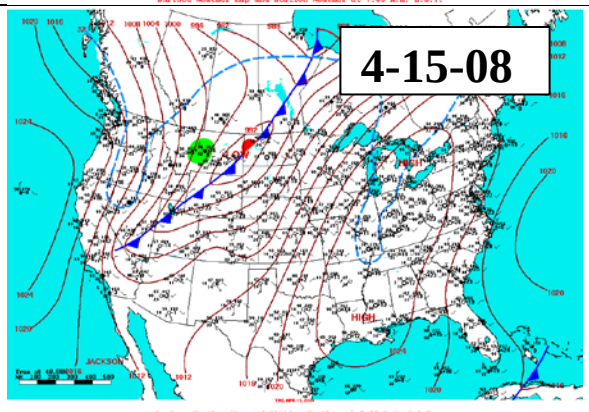
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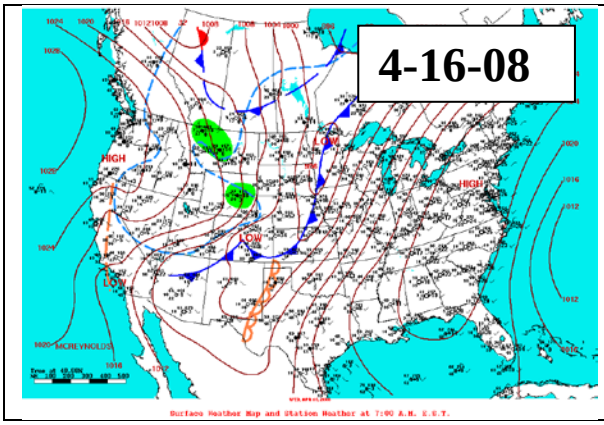

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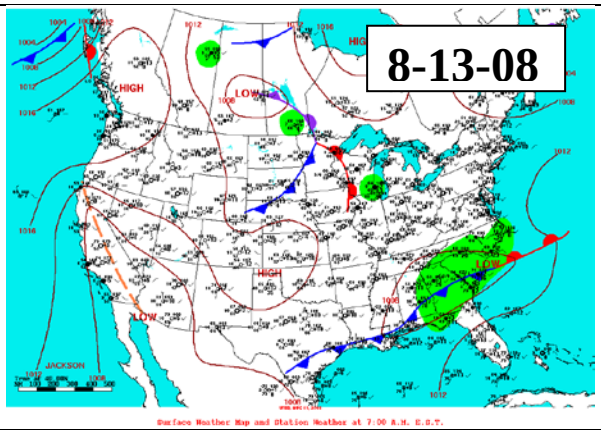

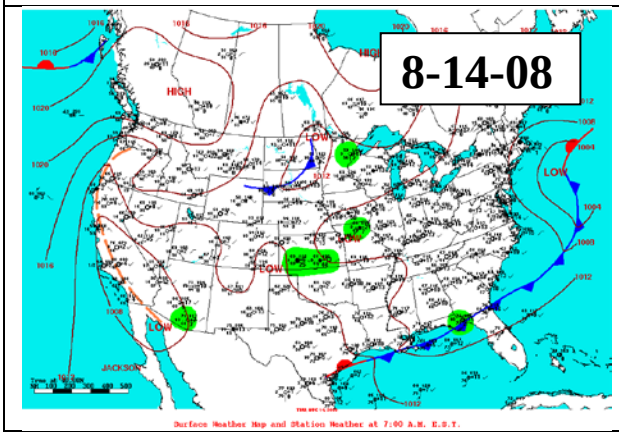

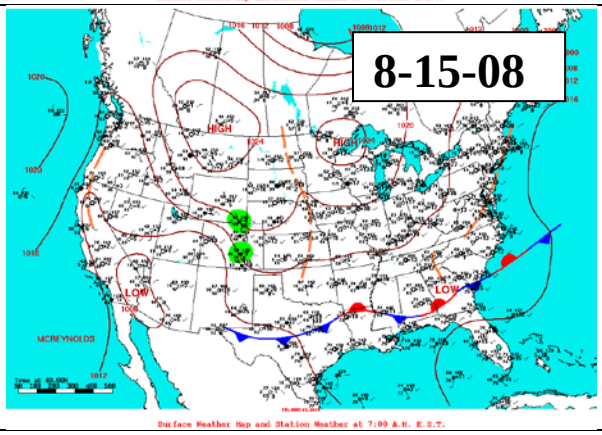

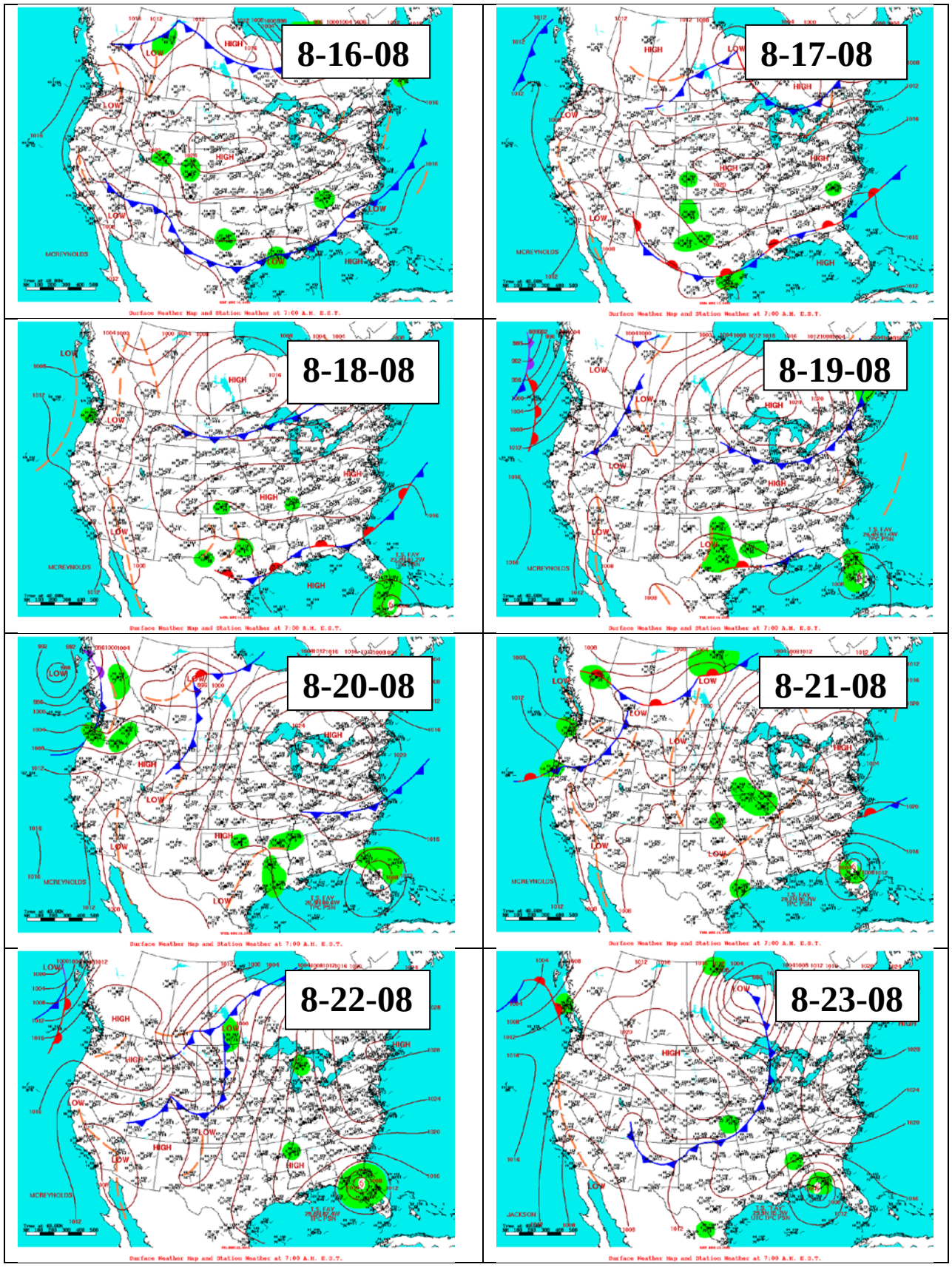
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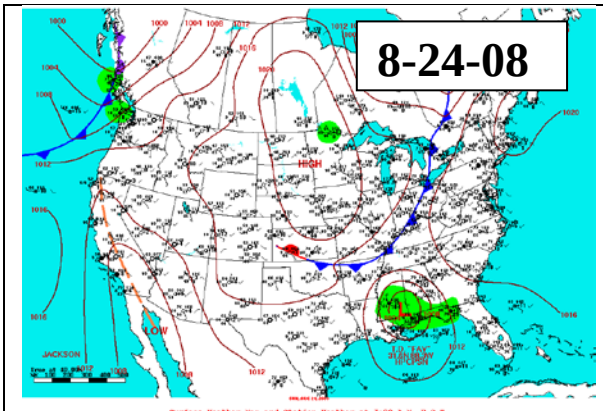
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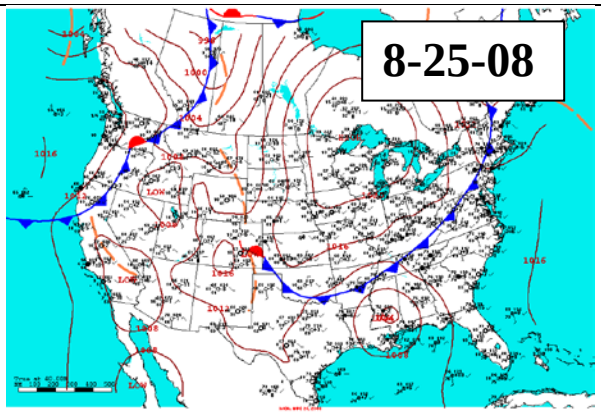
HIGH
LOW
JACKSON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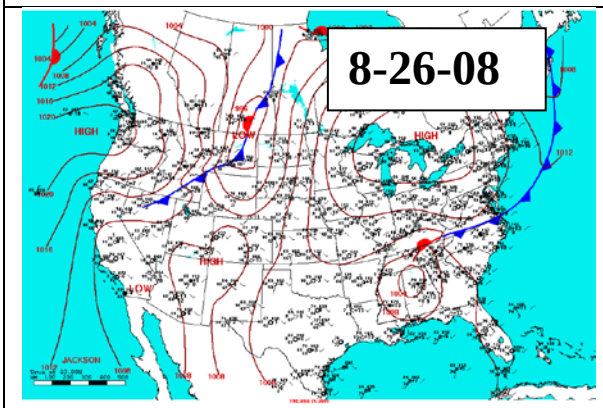
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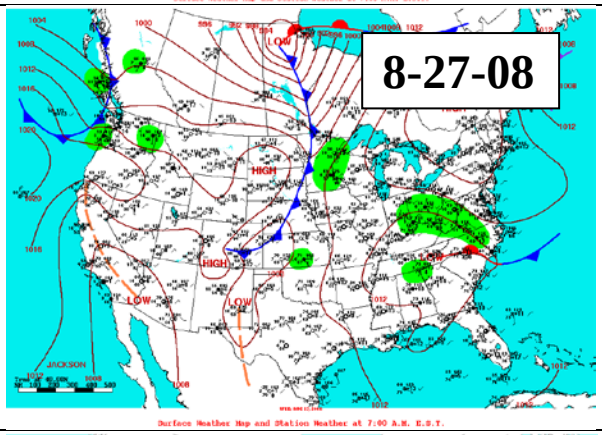
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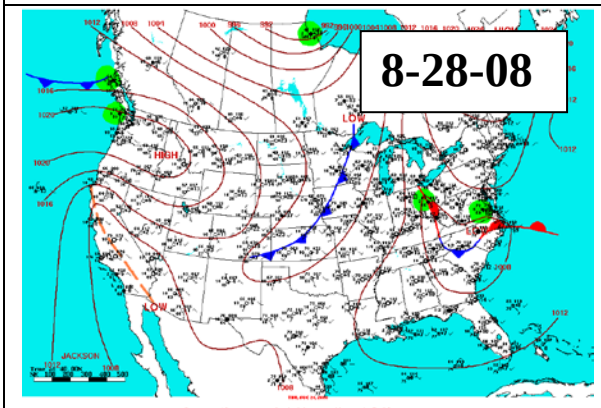
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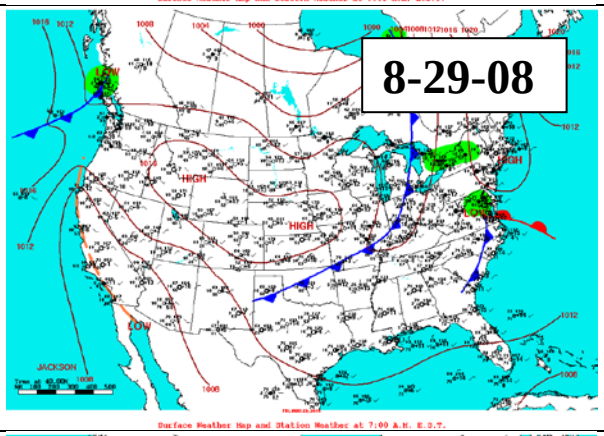
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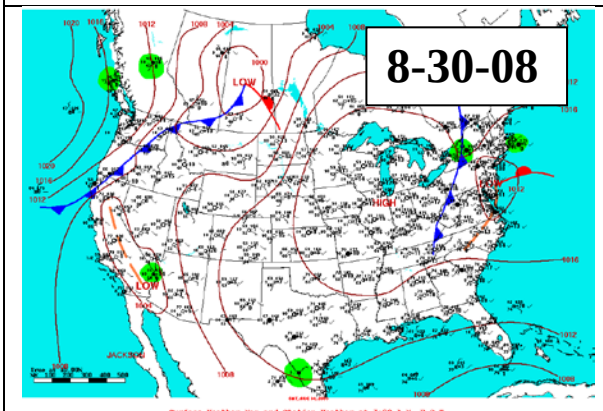
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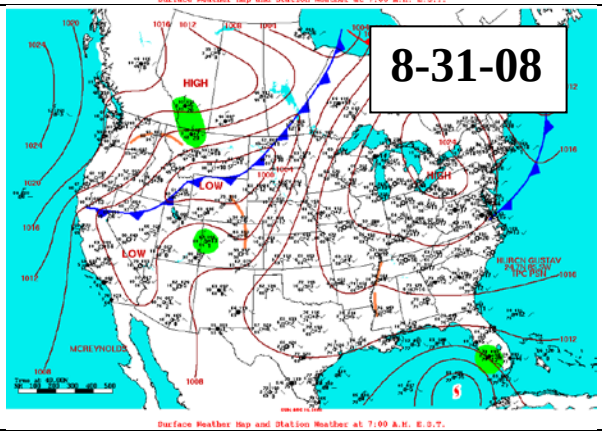
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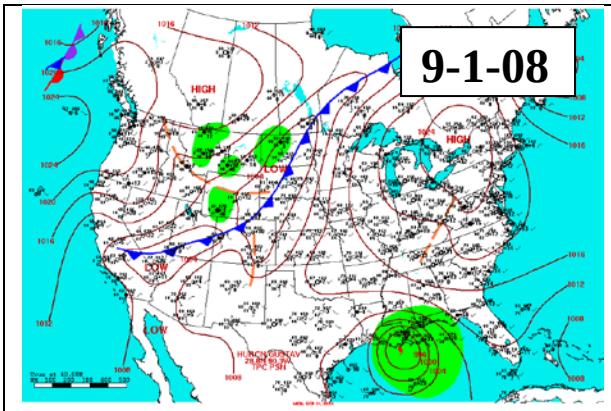
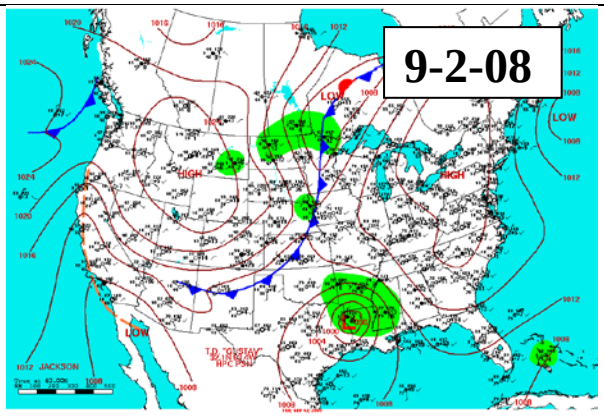
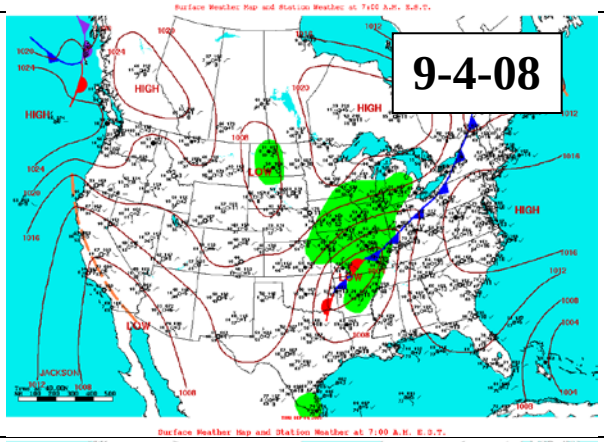
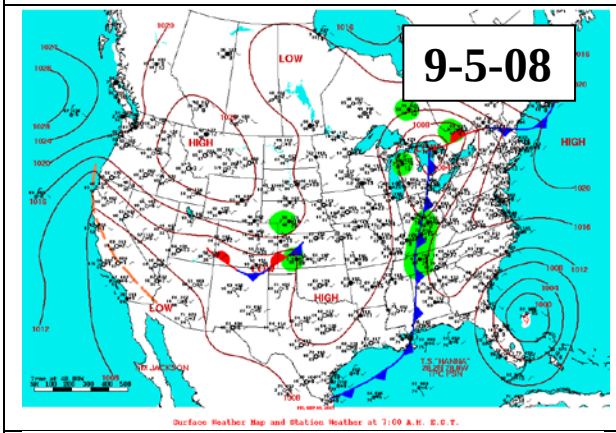
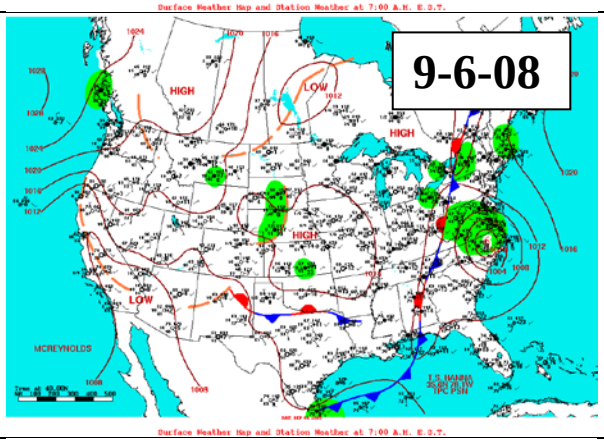


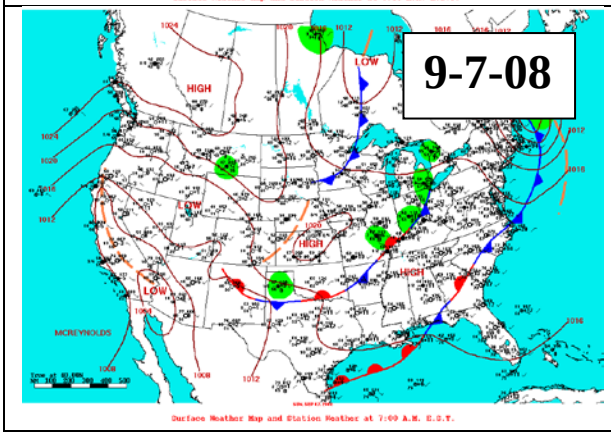


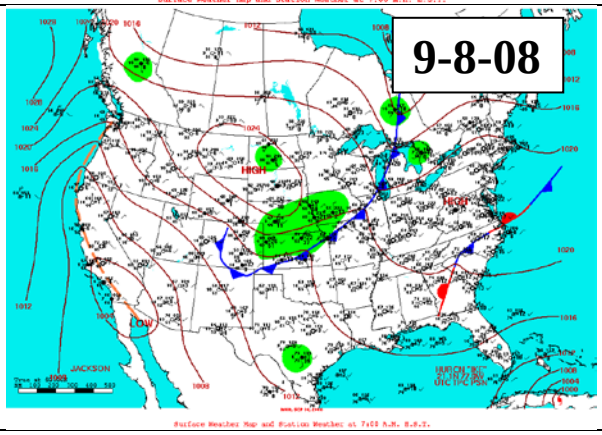
Period 6

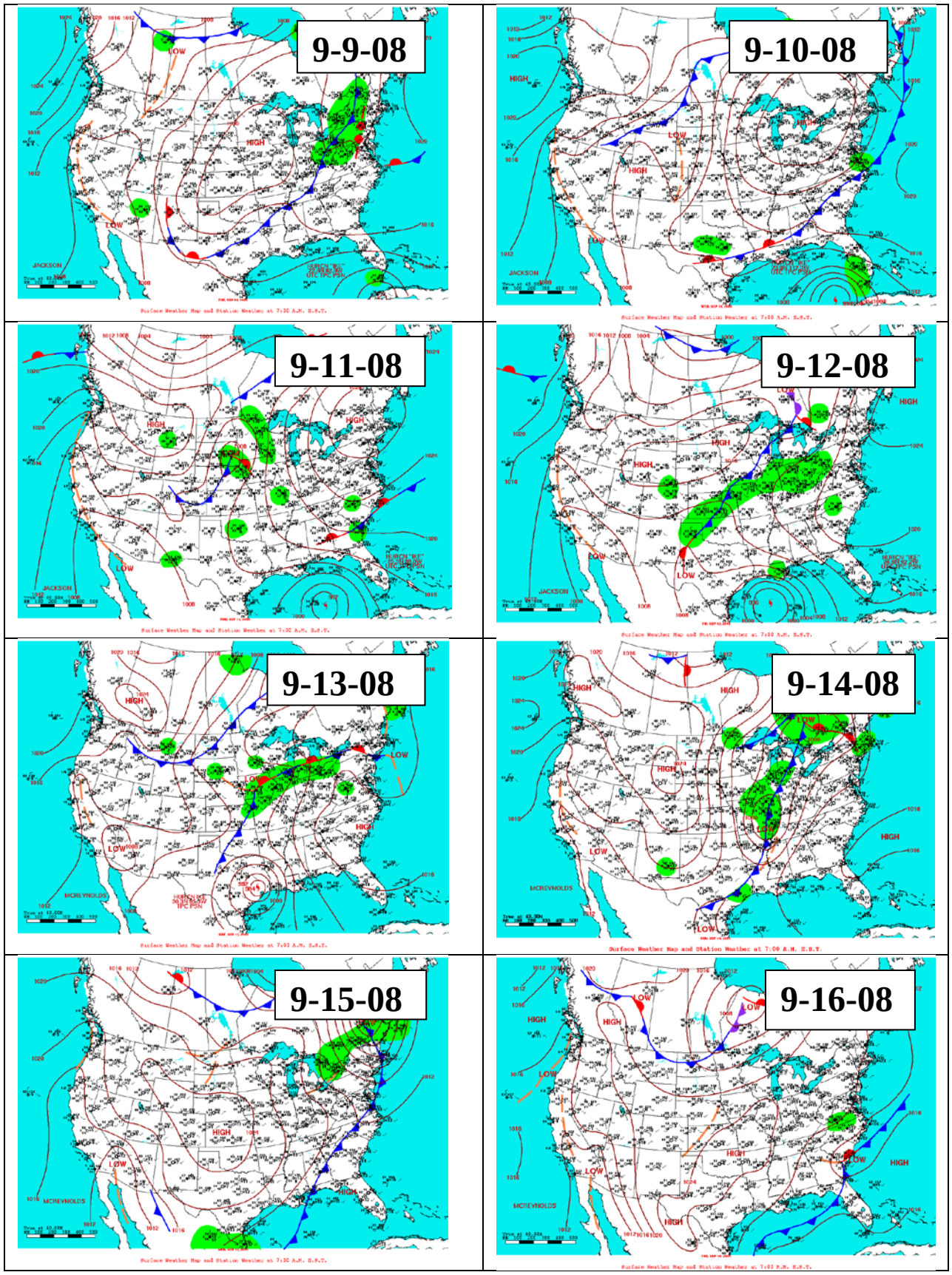








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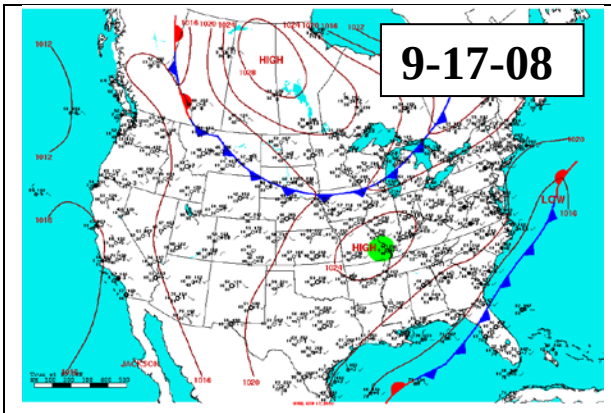
9-16-08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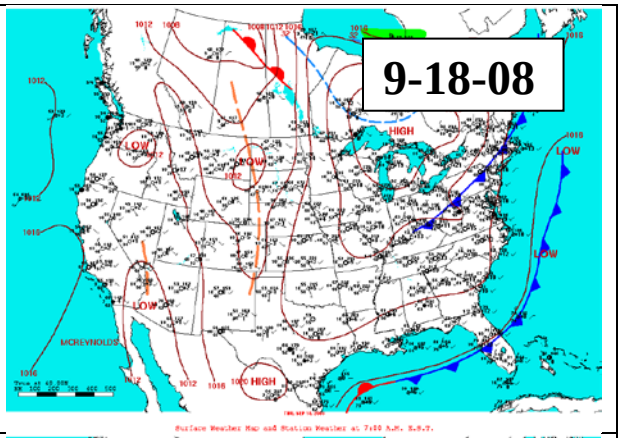
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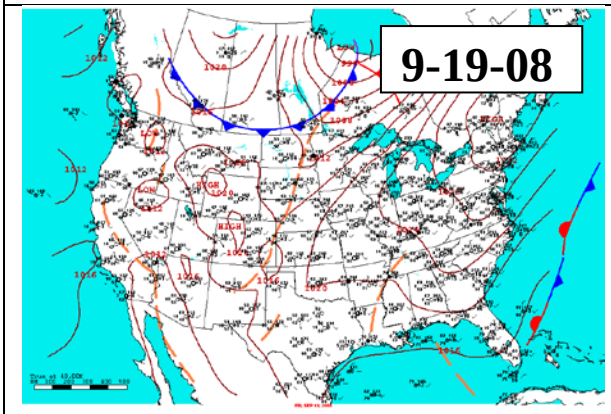
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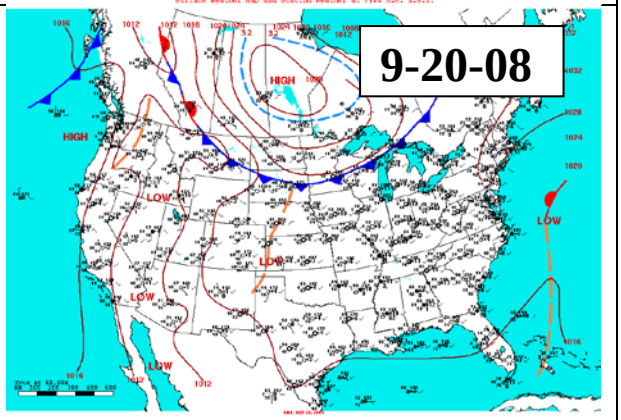
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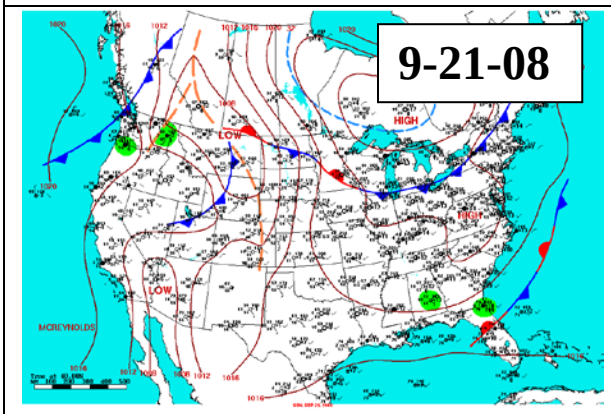
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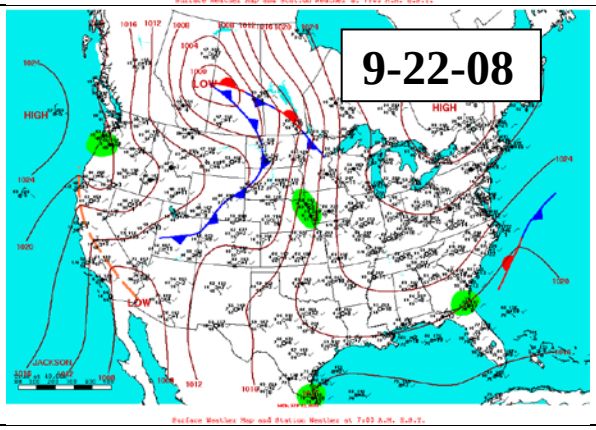
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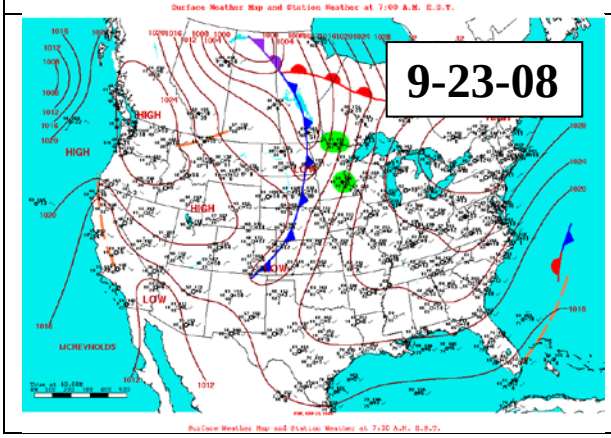
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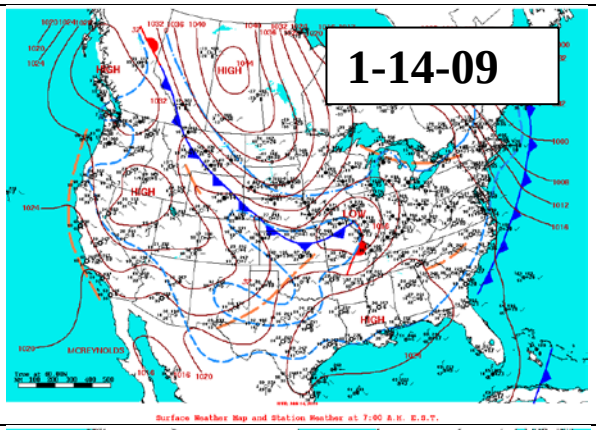

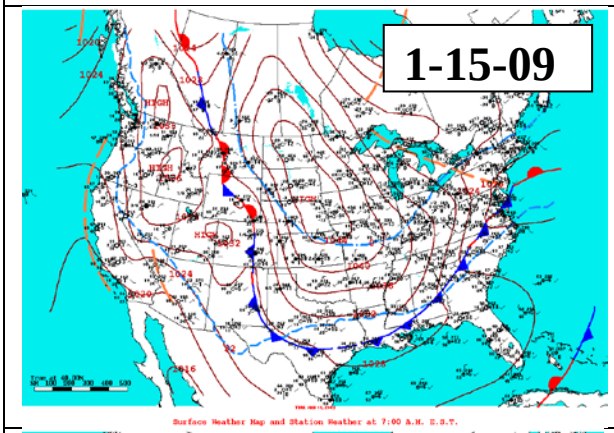

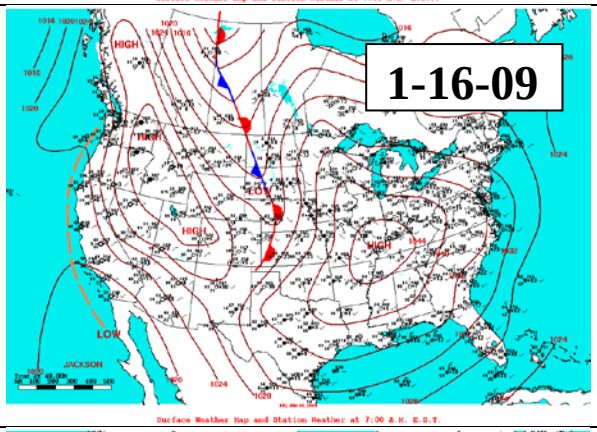

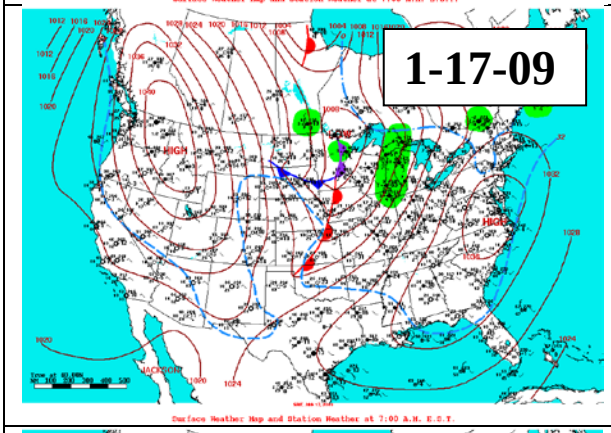

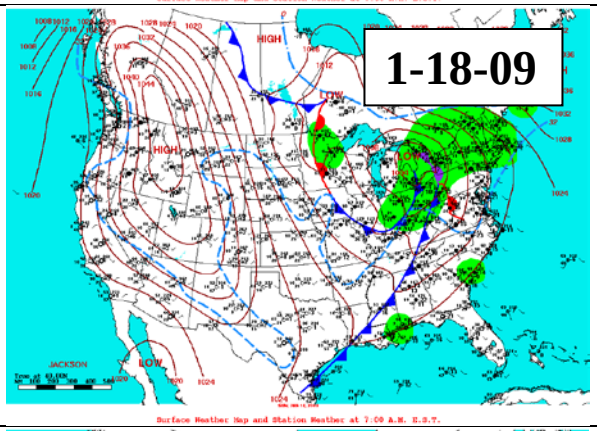

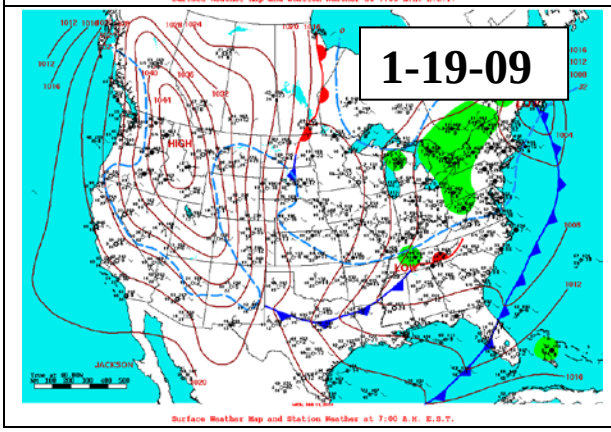

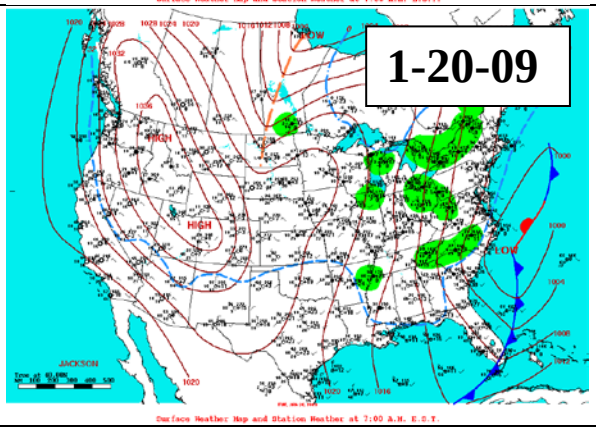

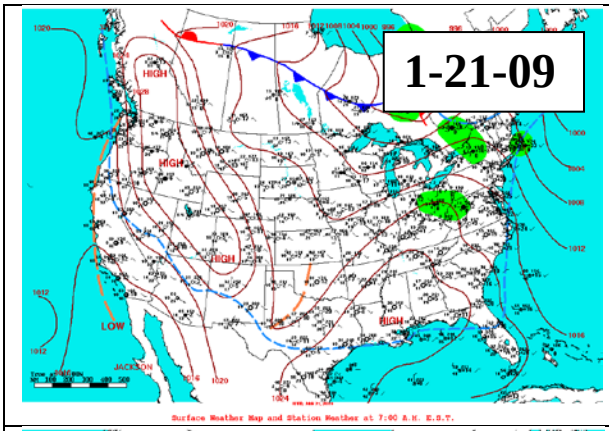
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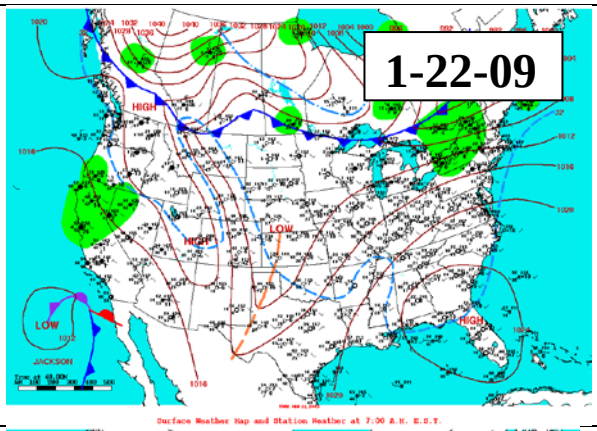
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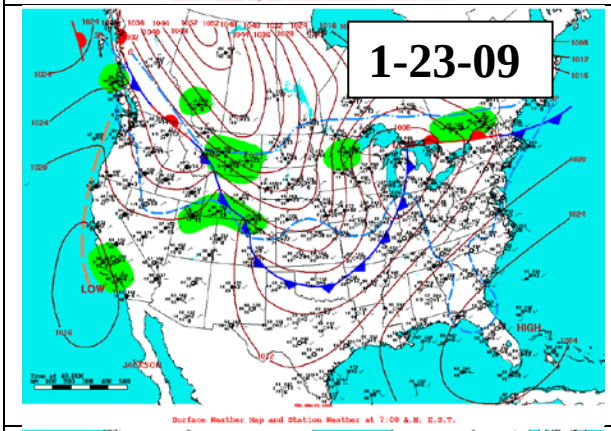
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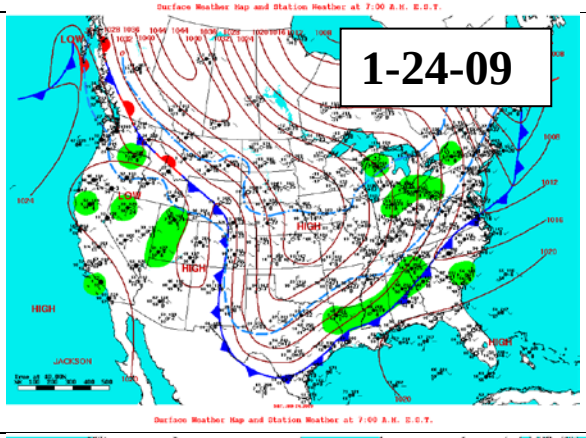
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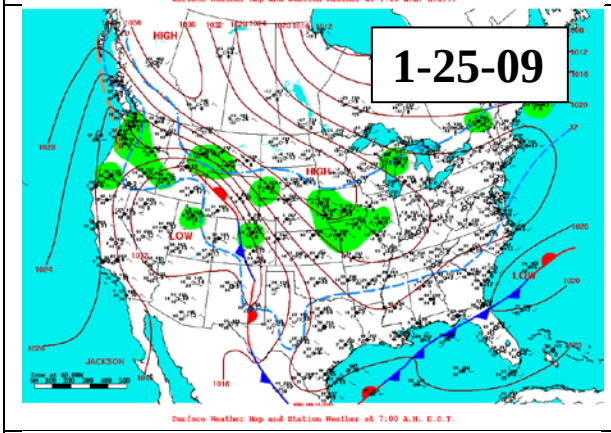
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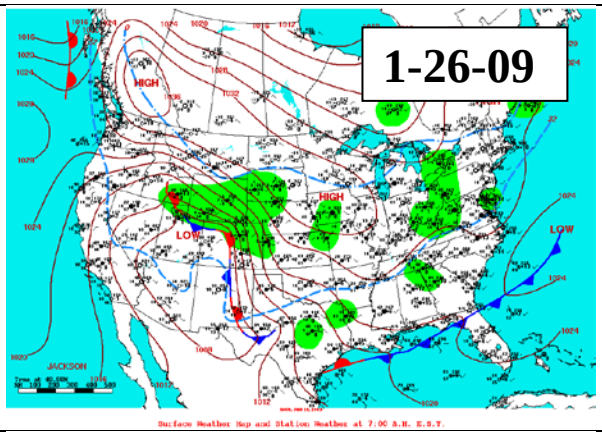
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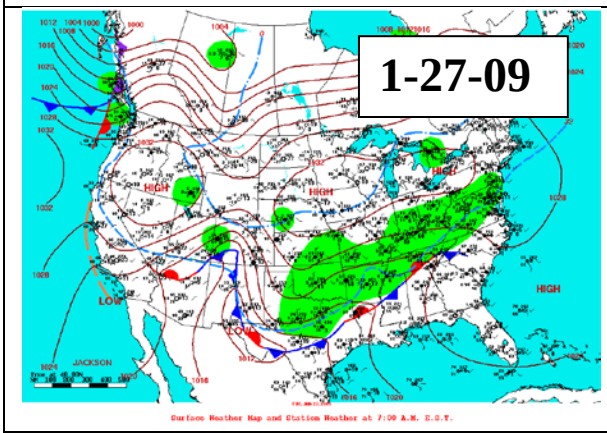
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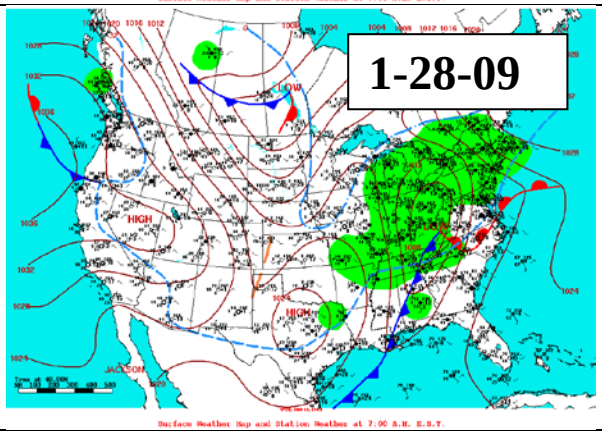
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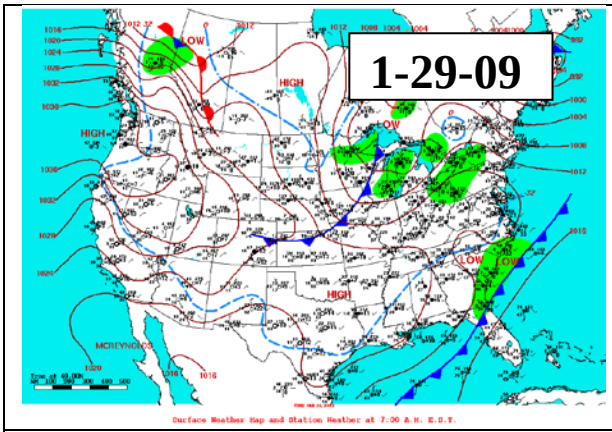
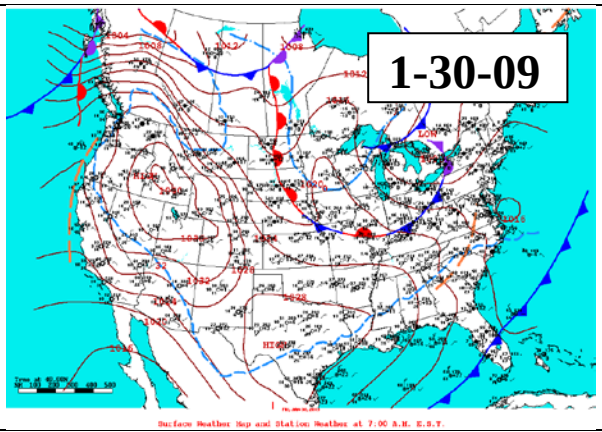
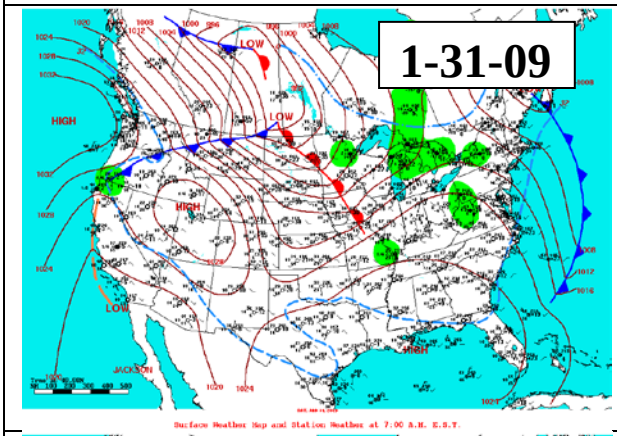
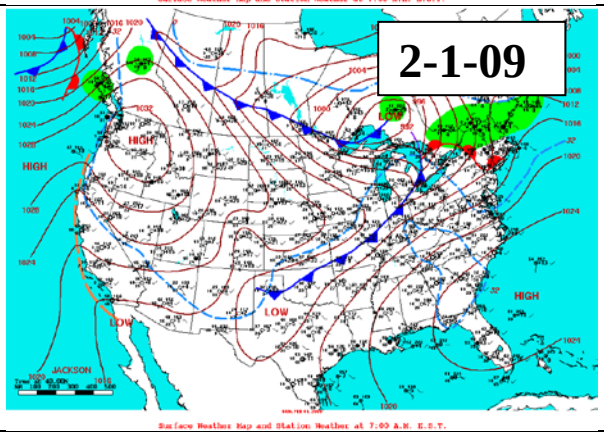
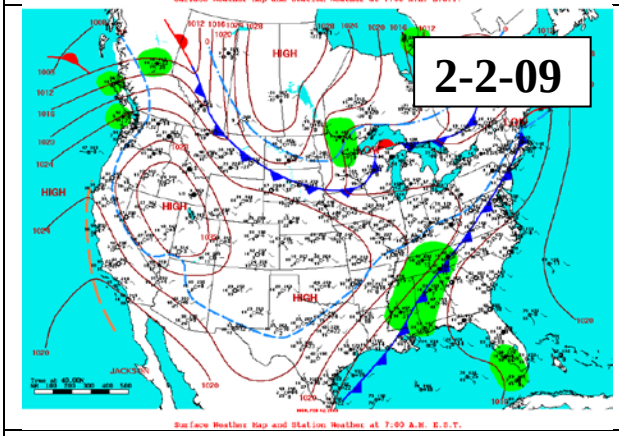


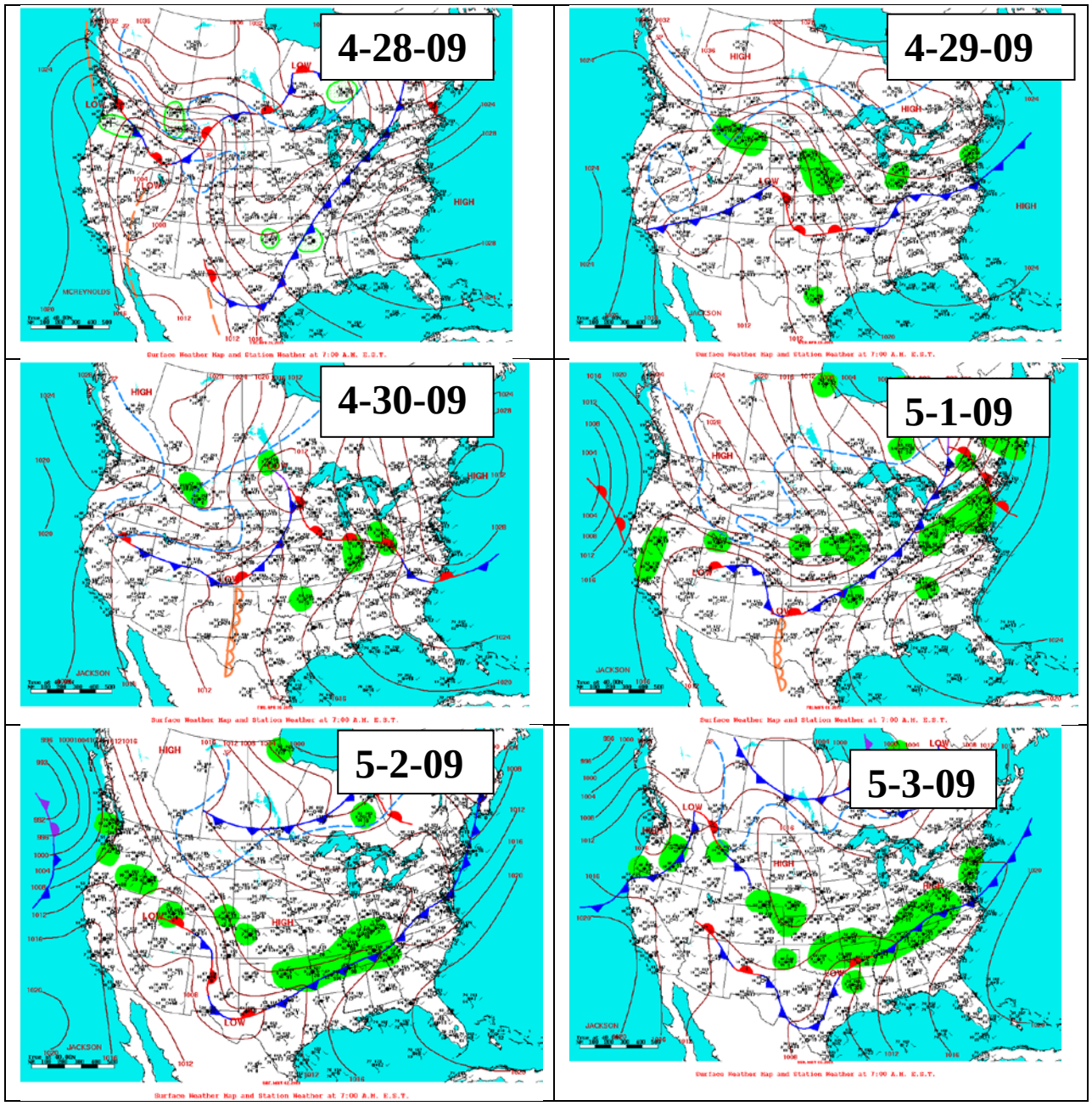








Period 8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4-30-09
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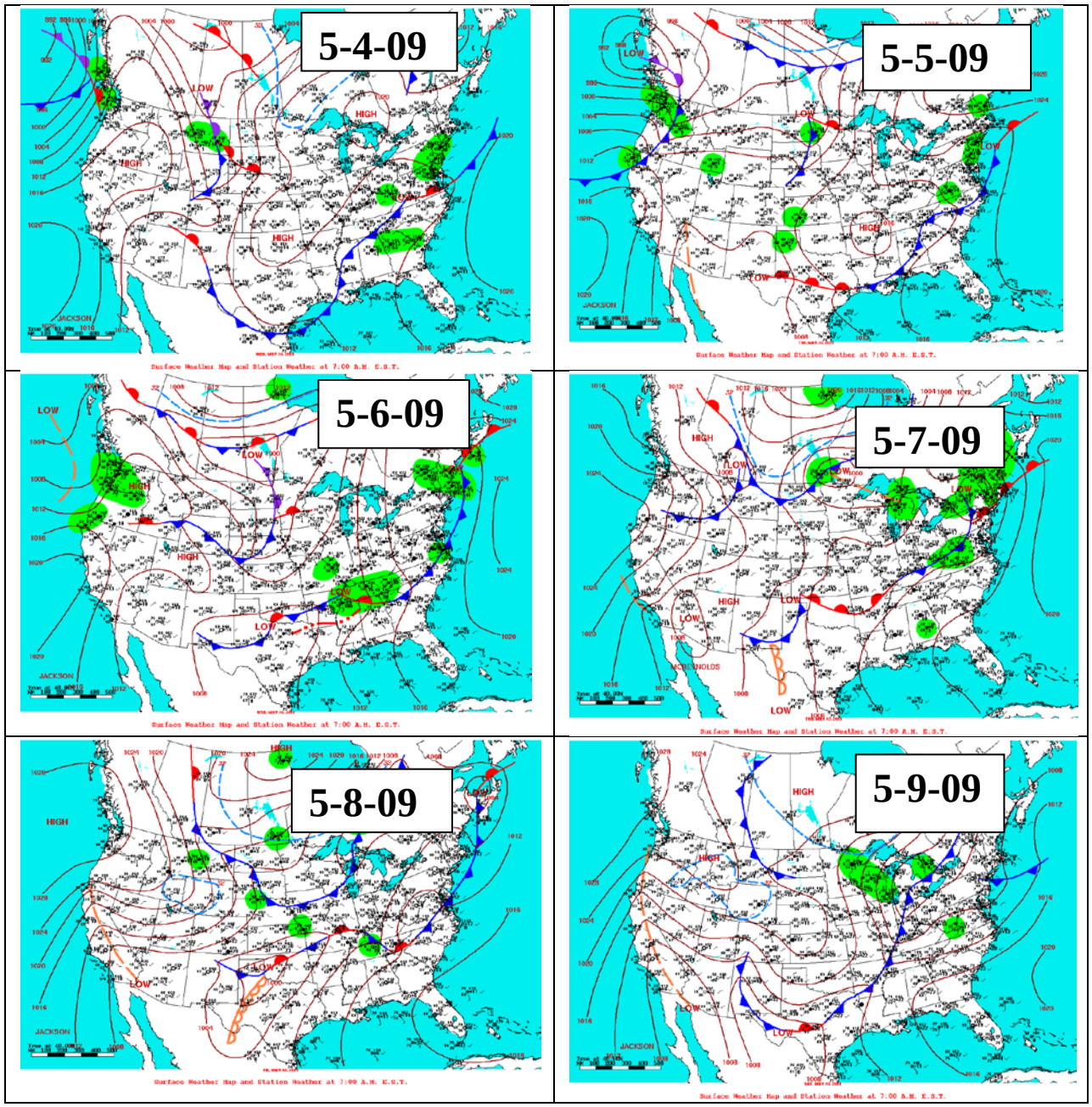
5-2-09
5-3-09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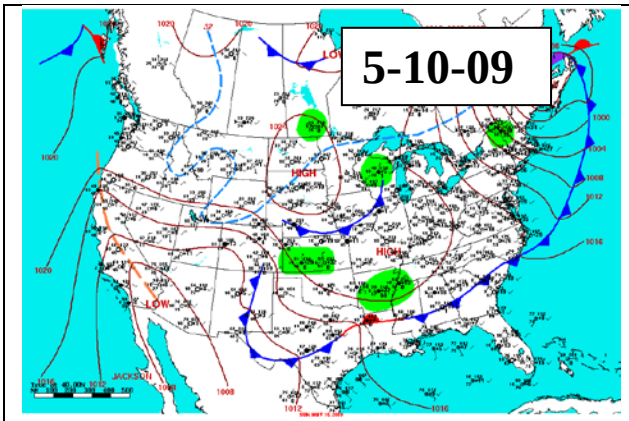
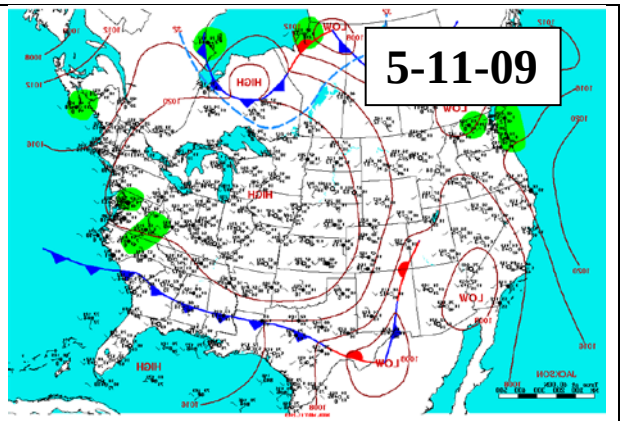
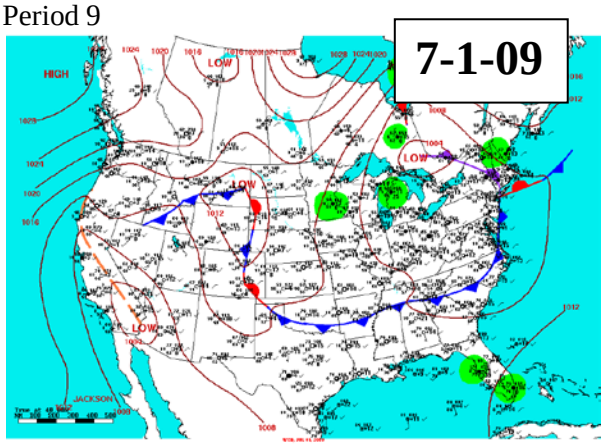
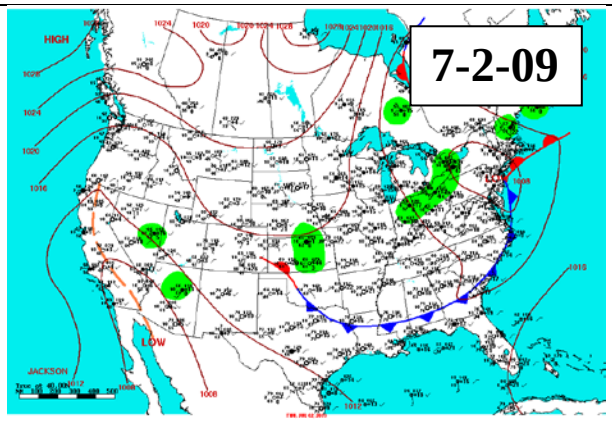
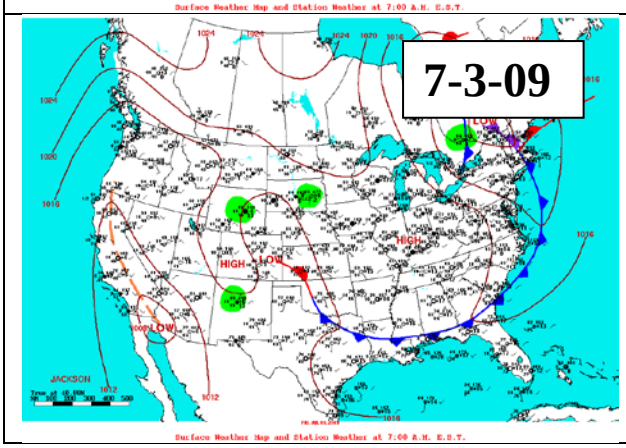


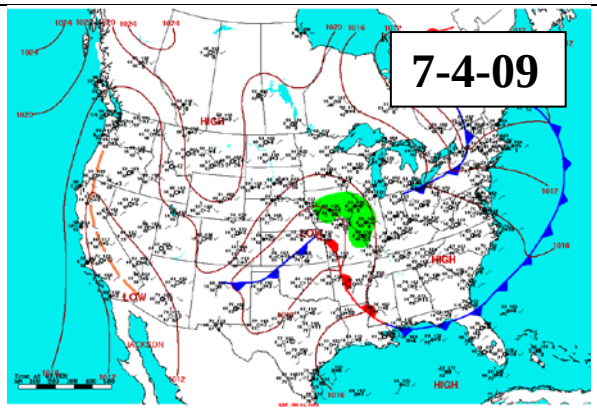


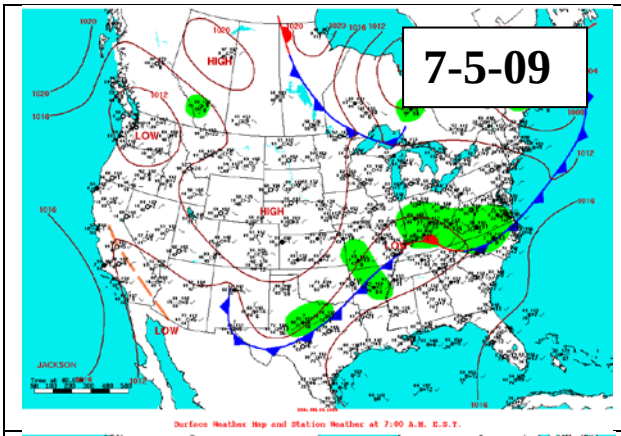
Period 9










7-5-09
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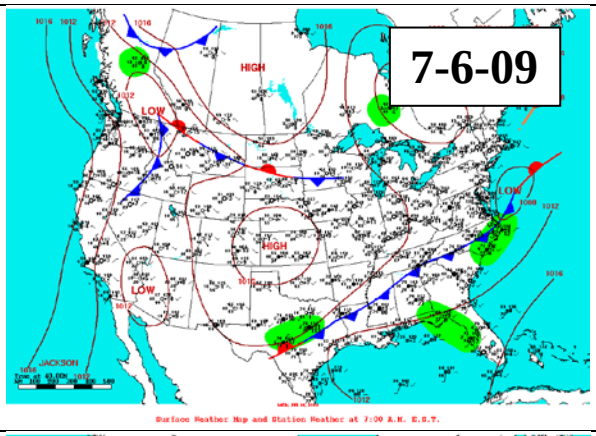
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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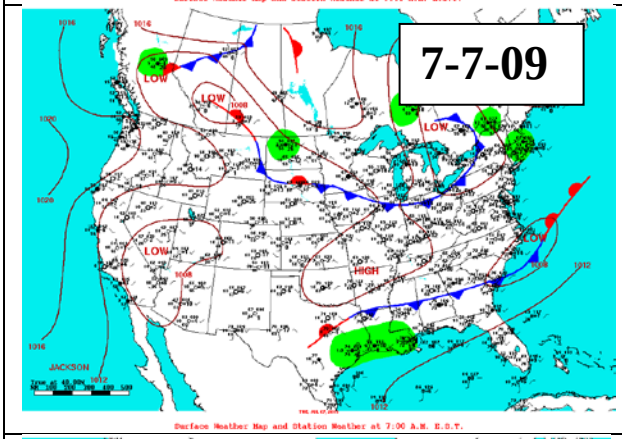
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-7-09
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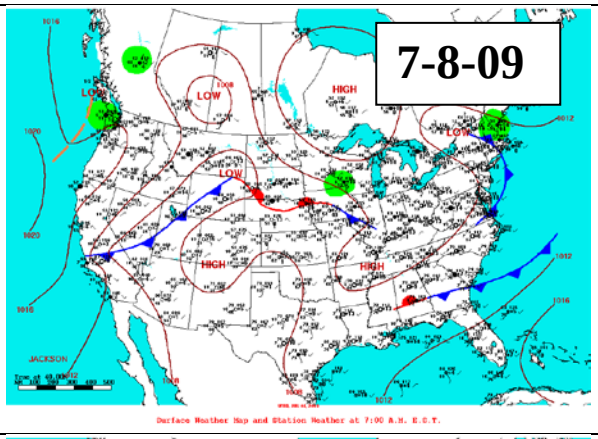
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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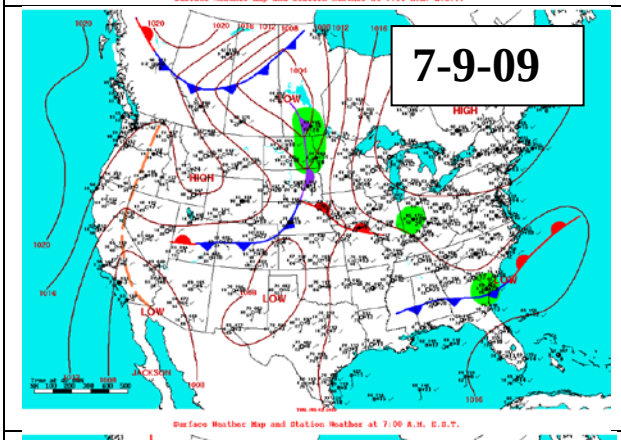
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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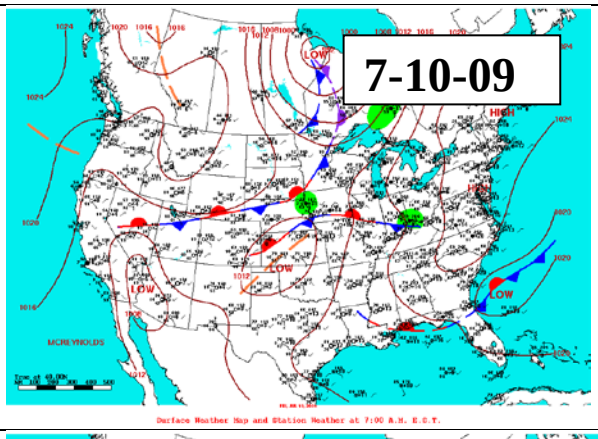
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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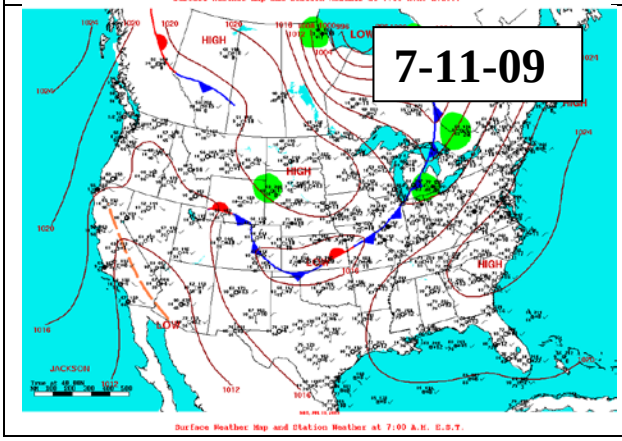
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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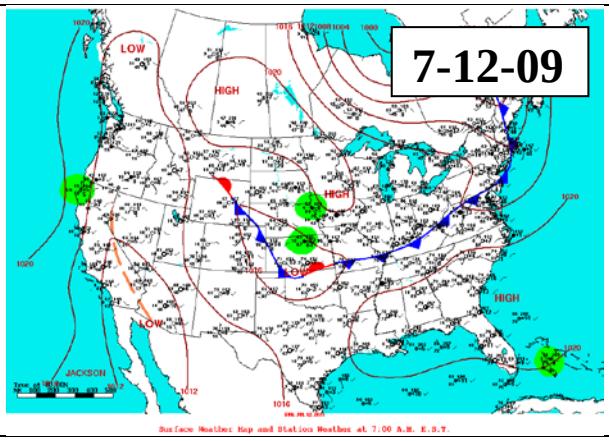
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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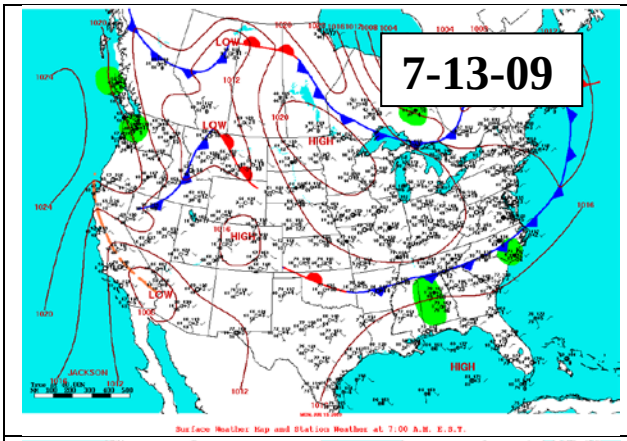
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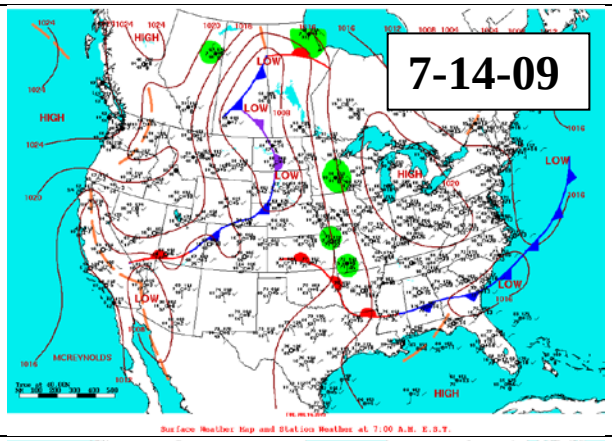
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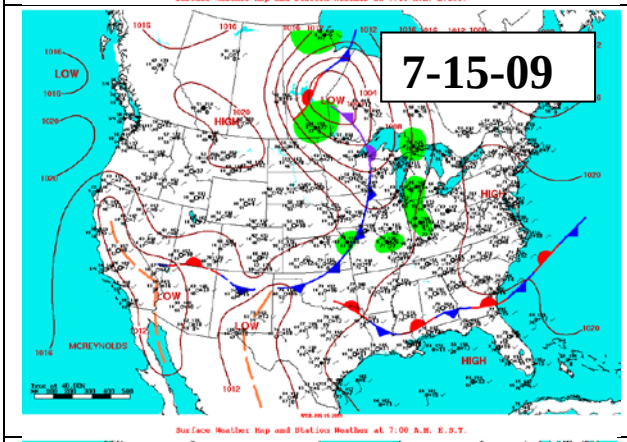
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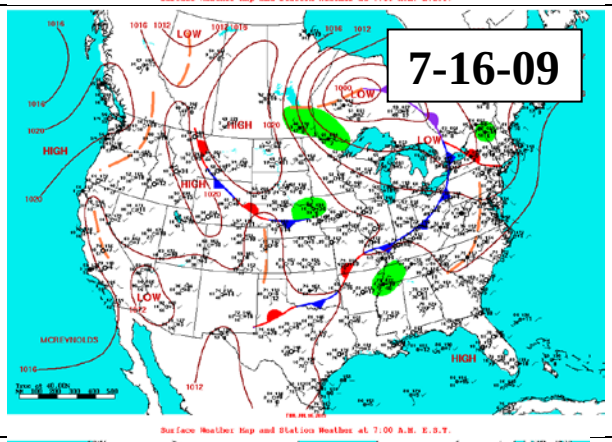
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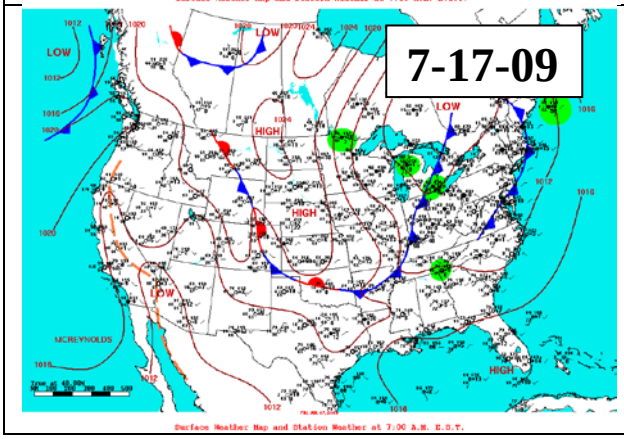
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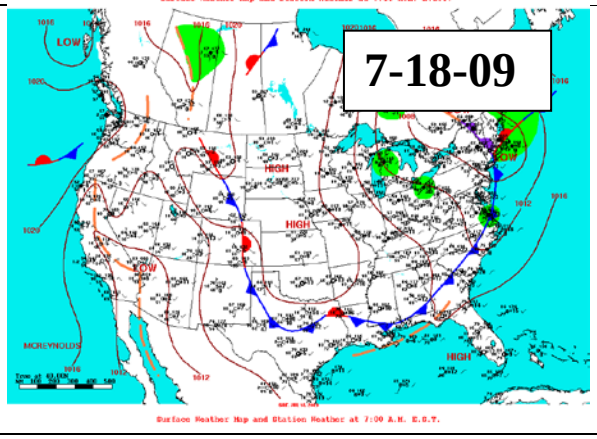
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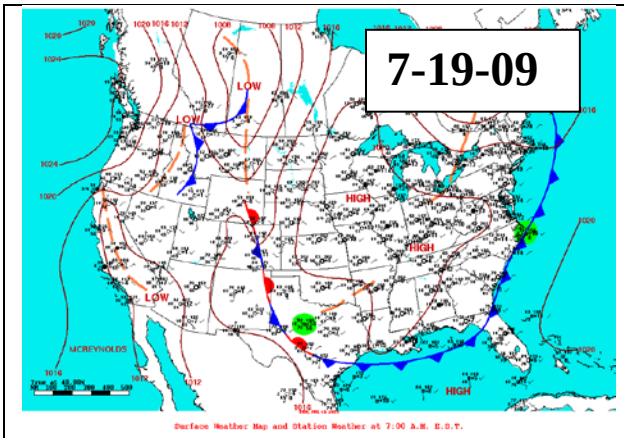
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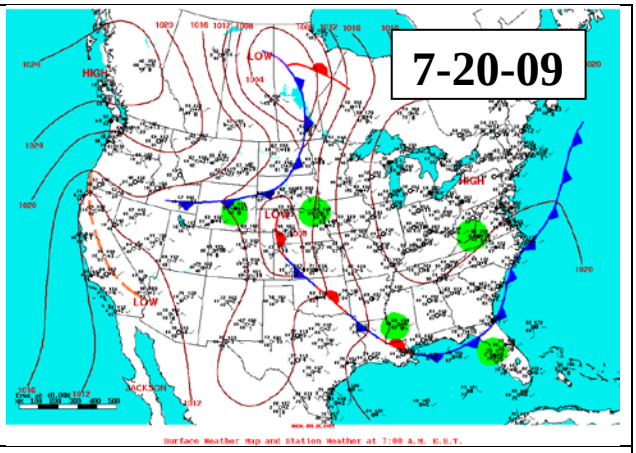
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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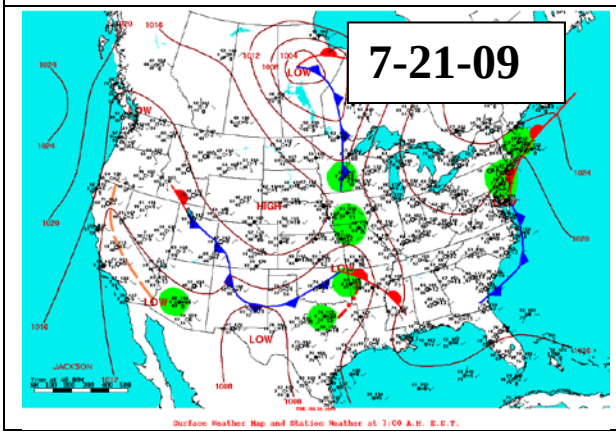
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-21-09
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LOW
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LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

6.10 Daily Weather conditions

Date (MM/DD/YYYY)	Barometric pressure (kPA)	Max Solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 2				
10/5/2007	101.65	259	N/A	24.4
10/6/2007	101.55	722	N/A	22.7
10/7/2007	101.30	878	N/A	23.4
10/8/2007	101.10	756	N/A	25.0
10/9/2007	100.73	728	N/A	25.8
10/10/2007	100.28	829	N/A	24.0
10/11/2007	99.98	763	N/A	19.2
10/12/2007	100.53	768	N/A	14.7
10/13/2007	101.02	745	N/A	14.8
10/14/2007	101.28	723	N/A	15.4
10/15/2007	101.57	724	N/A	17.1
10/16/2007	101.48	713	N/A	17.6
10/17/2007	101.36	844	N/A	20.4
10/18/2007	100.94	782	N/A	22.4
10/19/2007	100.31	695	N/A	24.6
10/20/2007	100.50	766	N/A	22.4
10/21/2007	101.63	794	N/A	16.2
10/22/2007	101.91	774	N/A	17.5
Period 3				
1/30/2008	101.25	N/A	N/A	8.9
1/31/2008	102.09	695	N/A	4.2
2/1/2008	101.31	399	N/A	10.1
2/2/2008	101.70	692	N/A	8.7
2/3/2008	101.76	642	N/A	9.5
2/4/2008	101.70	668	N/A	13.3
2/5/2008	101.50	674	N/A	16.8
2/6/2008	100.74	718	N/A	20.1
2/7/2008	100.37	682	N/A	16.1
2/8/2008	100.72	671	N/A	8.8
2/9/2008	100.92	681	N/A	9.9
2/10/2008	101.01	701	N/A	12.4
2/11/2008	101.89	698	N/A	5.4
2/12/2008	102.02	330	N/A	1.9
Period 4				
4/1/2008	101.13	407	100%	23.0
4/2/2008	101.60	997	62%	18.1
4/3/2008	102.18	285	52%	10.5
4/4/2008	101.19	945	73%	14.1
4/5/2008	100.77	276	96%	18.2
4/6/2008	100.88	307	93%	15.2
4/7/2008	101.46	782	92%	10.6

Date (MM/DD/YYYY)	Barometric pressure (kPA)	Max Solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
4/8/2008	101.65	1085	92%	11.5
4/9/2008	101.63	561	65%	14.4
4/10/2008	101.46	1054	66%	16.3
4/11/2008	101.03	998	60%	20.1
4/12/2008	100.25	998	13%	21.7
4/13/2008	100.20	1014	1%	17.1
4/14/2008	100.79	1145	34%	10.4
4/15/2008	101.23	1101	31%	10.3
4/16/2008	101.77	977	37%	8.6
Period 5				
8/14/2008	100.64	414	0%	26.8
8/15/2008	100.88	1103	52%	23.6
8/16/2008	101.07	960	54%	22.7
8/17/2008	101.10	582	63%	23.0
8/18/2008	101.03	1058	55%	22.9
8/19/2008	101.04	1034	55%	24.5
8/20/2008	101.22	1080	51%	25.0
8/21/2008	101.49	1084	49%	24.5
8/22/2008	101.65	1109	34%	23.6
8/23/2008	101.61	1059	38%	24.0
8/24/2008	101.23	1133	66%	24.1
8/25/2008	100.90	1050	65%	24.6
8/26/2008	100.87	648	95%	24.0
8/27/2008	100.75	588	84%	24.0
8/28/2008	100.53	1043	57%	26.5
8/29/2008	100.66	996	62%	25.2
8/30/2008	101.02	1009	59%	25.3
8/31/2008	101.27	944	46%	25.7
9/1/2008	101.47	886	45%	24.4
9/2/2008	101.32	895	43%	22.3
9/3/2008	100.99	881	49%	23.3
9/4/2008	100.88	0	71%	21.6
Period 6				
9/5/2008	100.77	531	76%	22.0
9/6/2008	99.75	877	63%	25.5
9/7/2008	101.00	991	51%	26.3
9/8/2008	101.38	852	62%	25.0
9/9/2008	101.27	1084	67%	23.7
9/10/2008	101.38	413	74%	23.1
9/11/2008	101.73	703	74%	23.0
9/12/2008	101.60	935	64%	24.4
9/13/2008	101.15	858	62%	26.2
9/14/2008	100.86	793	60%	27.1
9/15/2008	100.67	834	57%	26.7
9/16/2008	101.08	528	84%	22.0

Date (MM/DD/YYYY)	Barometric pressure (kPA)	Max Solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
9/17/2008	101.42	914	53%	19.8
9/18/2008	101.46	792	47%	19.9
9/19/2008	101.76	823	N/A	19.6
9/20/2008	101.70	734	N/A	17.5
9/21/2008	101.71	819	N/A	19.4
9/22/2008	101.79	618	N/A	20.1
9/23/2008	101.90	671	N/A	18.0
Period 7				
1/15/2009	101.81	570	3%	7.0
1/16/2009	102.84	592	0%	-4.2
1/17/2009	102.85	588	32%	-5.1
1/18/2009	101.28	117	61%	1.7
1/19/2009	100.06	567	69%	4.0
1/20/2009	99.74	233	93%	0.5
1/21/2009	101.15	607	63%	-4.4
1/22/2009	101.54	599	54%	0.4
1/23/2009	101.37	679	57%	6.7
1/24/2009	101.08	266	73%	10.5
1/25/2009	101.85	487	0%	3.1
1/26/2009	102.12	377	0%	2.3
1/27/2009	102.20	538	81%	5.8
1/28/2009	101.11	507	74%	13.7
1/29/2009	100.84	684	28%	8.9
1/30/2009	100.93	662	64%	4.5
1/31/2009	101.41	645	0%	2.7
2/1/2009	101.66	636	17%	6.4
2/2/2009	101.12	558	41%	8.9
2/3/2009	100.46	762	59%	5.5
Period 8				
4/28/2009	102.11	953	0%	26.6
4/29/2009	102.01	1026	37%	20.9
4/30/2009	102.07	1186	42%	17.7
5/1/2009	101.56	1061	50%	21.5
5/2/2009	100.97	993	39%	22.7
5/3/2009	100.84	1058	34%	23.7
5/4/2009	100.84	1026	31%	23.9
5/5/2009	101.07	950	81%	19.5
5/6/2009	101.09	955	64%	23.1
5/7/2009	100.78	955	54%	22.6
5/8/2009	100.68	984	42%	22.5
5/9/2009	100.59	949	41%	25.7
5/10/2009	100.94	1077	26%	22.8
5/12/2009	101.17	622	64%	16.7
Period 9				
7/1/2009	99.97	1044	9%	32.4

Date (MM/DD/YYYY)	Barometric pressure (kPA)	Max Solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
7/2/2009	100.35	1061	45%	26.5
7/3/2009	100.81	1147	39%	24.4
7/4/2009	101.07	982	31%	23.9
7/5/2009	100.73	924	66%	24.7
7/6/2009	100.27	822	77%	24.5
7/7/2009	100.29	1072	50%	25.0
7/8/2009	100.51	1118	48%	24.9
7/9/2009	101.06	1088	55%	23.5
7/10/2009	101.73	993	34%	22.7
7/11/2009	101.75	1059	38%	22.9
7/12/2009	101.21	935	0%	26.6
7/13/2009	100.82	300	63%	23.9
7/14/2009	101.08	1006	52%	23.3
7/15/2009	101.47	978	49%	24.3
7/16/2009	101.02	999	53%	24.7
7/17/2009	100.51	965	57%	25.6
7/18/2009	100.58	1025	55%	24.7
7/19/2009	101.13	1077	42%	24.3
7/20/2009	101.12	1009	62%	24.2
7/21/2009	101.25	968	63%	22.5

6.11 Daily lagoon conditions

Lagoon temperature, pH and oxidation-reduction potential

Date (MM/DD/YYYY)	Air temperature (°C)	Lagoon temperature (°C)	Lagoon (pH)	Lagoon ORP (mV)
Period 2				
10/5/2007	24.4	25.72	7.87	-394
10/6/2007	22.7	25.63	7.84	-435
10/7/2007	23.4	26.27	7.90	-405
10/8/2007	25.0	26.98	7.87	-455
10/9/2007	25.8	28.08	7.90	-425
10/10/2007	24.0	27.76	7.86	-433
10/11/2007	19.2	25.72	7.85	-465
10/12/2007	14.7	23.07	7.85	-460
10/13/2007	14.8	21.33	7.89	-457
10/14/2007	15.4	20.14	7.90	-481
10/15/2007	17.1	19.53	7.93	-489
10/16/2007	17.6	19.55	7.91	-503
10/17/2007	20.4	20.07	7.92	-502
10/18/2007	22.4	21.88	7.90	-457
10/19/2007	24.6	24.50	7.94	-415
10/20/2007	22.4	24.53	7.90	-455
10/21/2007	16.2	21.82	7.87	-512
10/22/2007	17.5	20.87	7.89	-520
Period 3				
1/30/2008	8.9	N/A	N/A	N/A
1/31/2008	4.2	8.23	7.94	-395
2/1/2008	10.1	8.41	8.00	-370
2/2/2008	8.7	9.00	8.05	-411
2/3/2008	9.5	9.75	8.08	-454
2/4/2008	13.3	10.84	8.06	-479
2/5/2008	16.8	13.36	8.07	-466
2/6/2008	20.1	14.63	7.99	-495
2/7/2008	16.1	15.51	7.91	-507
2/8/2008	8.8	14.75	7.90	-517
2/9/2008	9.9	13.98	7.90	-510
2/10/2008	12.4	13.19	7.89	-502
2/11/2008	5.4	12.01	7.88	-514
2/12/2008	1.9	10.73	7.83	-514
Period 4				
4/1/2008	23.0	N/A	N/A	N/A
4/2/2008	18.1	18.08	7.73	-403
4/3/2008	10.5	16.23	7.72	-470
4/4/2008	14.1	15.95	7.74	-458
4/5/2008	18.2	17.17	7.75	-473
4/6/2008	15.2	17.09	7.73	-544
4/7/2008	10.6	16.06	7.67	-545

Date (MM/DD/YYYY)	Air temperature (°C)	Lagoon temperature (°C)	Lagoon (pH)	Lagoon ORP (mV)
4/8/2008	11.5	15.45	7.71	-549
4/9/2008	14.4	16.05	7.72	-553
4/10/2008	16.3	17.25	7.73	-543
4/11/2008	20.1	20.80	7.77	-521
4/12/2008	21.7	21.16	7.72	-511
4/13/2008	17.1	20.94	7.72	-514
4/14/2008	10.4	18.72	7.71	-529
4/15/2008	10.3	17.02	7.63	-522
4/16/2008	8.6	16.19	7.65	-521
Period 5				
8/14/2008	26.8	23.91	7.58	-428
8/15/2008	23.6	24.18	7.62	-456
8/16/2008	22.7	24.59	7.69	-415
8/17/2008	23.0	25.17	7.67	-428
8/18/2008	22.9	24.64	7.67	-461
8/19/2008	24.5	25.65	7.65	-442
8/20/2008	25.0	26.11	7.66	-428
8/21/2008	24.5	26.66	7.64	-441
8/22/2008	23.6	25.80	7.65	-422
8/23/2008	24.0	26.31	7.66	-390
8/24/2008	24.1	26.47	7.64	-337
8/25/2008	24.6	26.44	7.64	-281
8/26/2008	24.0	26.26	7.65	-245
8/27/2008	24.0	25.33	7.63	-281
8/28/2008	26.5	25.64	7.69	-339
8/29/2008	25.2	26.78	7.65	-371
8/30/2008	25.3	26.26	7.61	-398
8/31/2008	25.7	26.51	7.62	-399
9/1/2008	24.4	27.33	7.64	-397
9/2/2008	22.3	26.61	7.65	-394
9/3/2008	23.3	25.93	7.62	-405
9/4/2008	21.6	26.26	7.59	-443
Period 6				
9/5/2008	22.0	25.19	7.65	-459
9/6/2008	25.5	25.73	7.74	-304
9/7/2008	26.3	26.59	7.69	-447
9/8/2008	25.0	27.05	7.68	-489
9/9/2008	23.7	27.65	7.73	-485
9/10/2008	23.1	26.78	7.71	-542
9/11/2008	23.0	25.85	7.68	-548
9/12/2008	24.4	25.86	7.71	-548
9/13/2008	26.2	27.23	7.75	-505
9/14/2008	27.1	28.79	7.76	-451
9/15/2008	26.7	27.92	7.73	-512
9/16/2008	22.0	26.52	7.67	-543

Date (MM/DD/YYYY)	Air temperature (°C)	Lagoon temperature (°C)	Lagoon (pH)	Lagoon ORP (mV)
9/17/2008	19.8	24.54	7.75	-537
9/18/2008	19.9	23.89	7.77	-540
9/19/2008	19.6	23.52	7.77	-515
9/20/2008	17.5	22.39	7.79	-508
9/21/2008	19.4	21.83	7.77	-521
9/22/2008	20.1	22.01	7.77	-521
9/23/2008	18.0	N/A	N/A	N/A
Period 7				
1/15/2009	7.0	7.67	N/A	-355
1/16/2009	-4.2	6.13	N/A	-390
1/17/2009	-5.1	4.53	N/A	-410
1/18/2009	1.7	3.84	N/A	-349
1/19/2009	4.0	4.42	N/A	-319
1/20/2009	0.5	4.54	N/A	-390
1/21/2009	-4.4	3.15	N/A	-378
1/22/2009	0.4	3.52	N/A	-414
1/23/2009	6.7	3.96	N/A	-377
1/24/2009	10.5	5.31	N/A	-418
1/25/2009	3.1	5.28	N/A	-450
1/26/2009	2.3	4.97	N/A	-468
1/27/2009	5.8	5.21	N/A	-473
1/28/2009	13.7	7.05	N/A	-452
1/29/2009	8.9	9.37	N/A	-474
1/30/2009	4.5	9.15	N/A	-492
1/31/2009	2.7	8.37	N/A	-485
2/1/2009	6.4	7.83	N/A	-469
2/2/2009	8.9	8.24	N/A	-476
2/3/2009	5.5	N/A	N/A	N/A
Period 8				
4/28/2009	26.6	N/A	N/A	N/A
4/29/2009	20.9	24.24	7.60	-455
4/30/2009	17.7	21.63	7.62	-507
5/1/2009	21.5	22.74	7.81	-519
5/2/2009	22.7	23.38	7.78	-523
5/3/2009	23.7	24.40	7.76	-527
5/4/2009	23.9	24.59	7.78	-531
5/5/2009	19.5	23.69	7.76	-532
5/6/2009	23.1	24.06	7.84	-523
5/7/2009	22.6	24.64	7.84	-534
5/8/2009	22.5	25.65	7.81	-538
5/9/2009	25.7	26.06	7.82	-539
5/10/2009	22.8	25.81	7.69	-538
5/11/2009	16.7	24.32	7.66	-531
Period 9				
7/1/2009	32.4	31.36	7.75	-317

Date (MM/DD/YYYY)	Air temperature (°C)	Lagoon temperature (°C)	Lagoon (pH)	Lagoon ORP (mV)
7/2/2009	26.5	27.23	7.77	-442
7/3/2009	24.4	26.66	7.79	-490
7/4/2009	23.9	25.99	7.80	-464
7/5/2009	24.7	26.82	7.86	-432
7/6/2009	24.5	26.14	7.85	-509
7/7/2009	25.0	25.78	7.80	-524
7/8/2009	24.9	26.62	7.80	-524
7/9/2009	23.5	25.87	7.75	-525
7/10/2009	22.7	25.57	7.83	-528
7/11/2009	22.9	26.07	7.79	-504
7/12/2009	26.6	27.41	7.84	-435
7/13/2009	23.9	26.47	7.84	-479
7/14/2009	23.3	25.27	7.82	-531
7/15/2009	24.3	26.63	7.77	-529
7/16/2009	24.7	27.40	7.82	-474
7/17/2009	25.6	28.27	7.84	-448
7/18/2009	24.7	26.98	7.81	-476
7/19/2009	24.3	26.95	7.76	-535
7/20/2009	24.2	27.31	7.76	-536
7/21/2009	22.5	26.28	7.77	-536

6.12 Daily Site Emissions and Data completeness

6.12.1 Daily NH_3 emission using RPM emissions model

Date: Month/Day/Year

Valid values: Number of ½ h periods with valid emissions data

Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction

Missing downwind NH_3: Number of ½ h periods invalidated because at least 1 TDLAS path was either missing or else had invalid concentration values

Emission average ($\mu g m^{-2} s^{-1}$): Daily average emission calculated from the valid ½ h periods

Emissions SD ($\mu g m^{-2} s^{-1}$): Daily emission standard deviation of the valid ½ h periods

Emission minimum ($\mu g m^{-2} s^{-1}$): Daily minimum emission of the valid ½ h periods

Emission maximum ($\mu g m^{-2} s^{-1}$): Daily maximum emission of the valid ½ h periods

Emission average ($g d^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area

Emission average ($g d^{-1} hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis

Emission average ($g d^{-1} AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} hd^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
Period 2										
10/5/2007	4	0	6	36.6	5.5	28.5	40.0	74.3	37.2	95.3
10/6/2007	9	0	38	43.0	10.9	26.4	54.0	87.4	43.7	112.1
10/7/2007	1	0	45	13.6	N/A	13.6	13.6	27.6	13.8	35.5
10/8/2007	2	0	46	71.9	16.2	60.4	83.4	146.0	73.0	187.3
10/9/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/10/2007	0	0	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/11/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/12/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/13/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/14/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/15/2007	20	0	22	33.0	11.2	16.6	54.9	67.0	33.5	85.9
10/16/2007	13	0	16	29.3	9.8	13.2	49.4	59.4	29.7	76.2
10/17/2007	11	0	21	47.4	16.2	17.0	68.5	96.1	48.1	123.4
10/18/2007	2	0	42	31.1	2.4	29.4	32.8	63.1	31.5	80.9
10/19/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/20/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/21/2007	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/22/2007	0	0	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 3										
1/31/2008	1	0	17	29.8	N/A	29.8	29.8	60.5	30.2	77.6
2/1/2008	5	2	37	19.5	7.5	6.8	26.0	39.6	19.8	50.8
2/2/2008	2	5	37	4.3	0.6	3.8	4.7	8.6	4.3	11.1

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu g\ m^{-2}\ s^{-1}$)	Emission SD ($\mu g\ m^{-2}\ s^{-1}$)	Emission minimum ($\mu g\ m^{-2}\ s^{-1}$)	Emission maximum ($\mu g\ m^{-2}\ s^{-1}$)	Emission average ($kg\ d^{-1}$)	Emission average ($g\ d^{-1}\ hd^{-1}$)	Emission average ($g\ d^{-1}\ AU^{-1}$)
2/3/2008	5	6	27	3.6	1.2	1.7	5.1	7.3	3.6	9.3
2/4/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2008	4	12	26	13.4	4.7	9.8	20.0	27.2	13.6	34.9
2/6/2008	0	33	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2008	22	8	6	10.7	4.8	5.1	21.3	21.8	10.9	28.0
2/8/2008	10	3	19	8.5	3.1	3.4	12.8	17.2	8.6	22.1
2/9/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2008	15	2	22	6.9	2.4	3.4	11.1	13.9	7.0	17.9
2/11/2008	7	0	28	9.2	3.1	6.0	14.0	18.8	9.4	24.1
Period 4										
4/1/2008	0	0	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2008	6	0	40	16.5	6.4	8.5	26.8	33.6	16.8	43.0
4/3/2008	5	0	26	9.0	3.9	3.4	12.3	18.3	9.2	23.5
4/4/2008	3	0	45	4.7	2.0	2.6	6.4	9.5	4.8	12.2
4/5/2008	6	0	38	13.3	3.6	6.0	15.3	27.1	13.5	34.7
4/6/2008	11	0	28	16.1	4.4	6.0	22.6	32.8	16.4	42.0
4/7/2008	3	0	39	10.5	3.0	7.2	13.2	21.3	10.7	27.3
4/8/2008	4	0	43	16.3	3.7	13.2	21.7	33.0	16.5	42.4
4/9/2008	10	0	36	13.8	3.2	9.4	18.3	28.1	14.0	36.0
4/10/2008	2	0	45	8.1	2.4	6.4	9.8	16.4	8.2	21.1
4/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/12/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2008	3	0	45	20.6	15.2	9.4	37.9	41.8	20.9	53.6
4/15/2008	15	0	30	15.5	4.9	8.5	28.9	31.5	15.8	40.4
4/16/2008	3	0	20	19.7	5.0	14.0	23.4	40.0	20.0	51.4
Period 5										
8/14/2008	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/15/2008	8	4	27	18.5	4.4	10.2	23.8	37.5	18.7	48.1
8/16/2008	1	0	47	10.2	N/A	10.2	10.2	20.7	10.4	26.6
8/17/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/19/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/20/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/21/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/23/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/24/2008	0	5	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/25/2008	0	15	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/26/2008	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/27/2008	0	1	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/28/2008	4	3	39	19.0	6.5	13.2	27.2	38.7	19.3	49.6
8/29/2008	0	7	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu g\ m^{-2}\ s^{-1}$)	Emission SD ($\mu g\ m^{-2}\ s^{-1}$)	Emission minimum ($\mu g\ m^{-2}\ s^{-1}$)	Emission maximum ($\mu g\ m^{-2}\ s^{-1}$)	Emission average ($kg\ d^{-1}$)	Emission average ($g\ d^{-1}\ hd^{-1}$)	Emission average ($g\ d^{-1}\ AU^{-1}$)
8/30/2008	0	4	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	1	3	44	13.2	N/A	13.2	13.2	26.8	13.4	34.4
9/1/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/2/2008	0	0	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/3/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6										
9/4/2008	3	7	12	17.4	0.4	17.0	17.9	35.4	17.7	45.5
9/5/2008	17	0	22	34.6	11.2	2.6	48.9	70.2	35.1	90.1
9/6/2008	10	0	38	49.8	15.2	33.6	71.5	101.2	50.6	129.8
9/7/2008	5	3	36	31.7	7.5	20.0	38.7	64.5	32.2	82.7
9/8/2008	13	0	34	44.2	15.4	13.6	72.3	89.7	44.9	115.1
9/9/2008	8	6	33	25.5	13.0	5.1	43.0	51.7	25.9	66.4
9/10/2008	21	0	27	30.2	7.4	17.0	39.6	61.2	30.6	78.5
9/11/2008	34	0	14	31.8	6.8	13.2	44.7	64.5	32.2	82.7
9/12/2008	14	6	26	26.3	9.3	13.6	40.9	53.3	26.7	68.4
9/13/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/14/2008	2	1	45	39.4	1.5	38.3	40.4	79.9	40.0	102.5
9/15/2008	3	0	45	77.4	11.4	68.1	90.2	157.2	78.6	201.8
9/16/2008	13	0	35	41.9	11.2	14.0	57.9	85.1	42.6	109.2
9/17/2008	27	0	21	34.2	9.6	16.6	54.0	69.3	34.7	89.0
9/18/2008	24	0	23	46.2	10.4	29.4	70.2	93.8	46.9	120.4
9/19/2008	30	0	18	38.2	8.5	22.1	59.1	77.6	38.8	99.6
9/20/2008	39	0	9	32.2	5.2	20.0	41.3	65.4	32.7	84.0
9/21/2008	32	0	16	28.7	4.6	19.6	37.4	58.2	29.1	74.7
9/22/2008	27	0	16	29.4	5.6	18.3	39.6	59.7	29.9	76.7
9/23/2008	8	0	18	25.9	4.0	19.1	29.8	52.6	26.3	67.5
Period 7										
1/16/2009	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/17/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/18/2009	0	6	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/19/2009	7	1	36	4.6	1.5	2.6	6.8	9.3	4.6	11.9
1/20/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/21/2009	9	0	32	4.7	1.0	3.0	6.4	9.5	4.8	12.2
1/22/2009	6	6	0	4.3	2.2	1.7	7.7	8.6	4.3	11.1
1/23/2009	5	2	0	6.8	3.1	3.4	10.2	13.8	6.9	17.7
1/24/2009	8	0	13	5.5	1.0	3.4	6.8	11.1	5.6	14.3
1/25/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/26/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2009	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/28/2009	2	9	27	11.7	8.1	6.0	17.4	23.8	11.9	30.5
1/29/2009	4	2	38	6.9	5.4	2.6	14.0	14.0	7.0	18.0
1/30/2009	7	0	35	7.5	0.9	6.4	8.9	15.2	7.6	19.5
1/31/2009	35	0	12	8.2	1.7	4.3	12.3	16.6	8.3	21.3

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Emission average ($\mu g\ m^{-2}\ s^{-1}$)	Emission SD ($\mu g\ m^{-2}\ s^{-1}$)	Emission minimum ($\mu g\ m^{-2}\ s^{-1}$)	Emission maximum ($\mu g\ m^{-2}\ s^{-1}$)	Emission average ($kg\ d^{-1}$)	Emission average ($g\ d^{-1}\ hd^{-1}$)	Emission average ($g\ d^{-1}\ AU^{-1}$)
2/1/2009	5	13	2	8.3	2.3	5.5	11.1	16.8	8.4	21.5
2/2/2009	1	7	7	5.5	N/A	5.5	5.5	11.2	5.6	14.4
Period 8										
4/29/2009	14	1	5	43.6	11.5	26.0	58.3	88.6	44.3	113.6
4/30/2009	32	11	0	27.8	15.3	9.8	79.1	56.5	28.3	72.5
5/1/2009	19	15	14	39.3	10.9	23.4	54.5	79.7	39.9	102.3
5/2/2009	21	27	0	49.0	10.5	28.1	68.1	99.5	49.8	127.7
5/3/2009	20	24	4	52.7	16.7	24.3	78.7	107.0	53.5	137.3
5/4/2009	20	28	0	49.3	13.0	27.2	67.7	100.1	50.0	128.4
5/5/2009	7	21	16	30.7	8.3	22.6	42.6	62.3	31.2	80.0
5/6/2009	1	45	0	31.9	N/A	31.9	31.9	64.8	32.4	83.1
5/7/2009	11	37	0	43.2	16.1	26.4	65.1	87.8	43.9	112.7
5/8/2009	18	17	9	40.9	17.1	8.5	69.8	83.0	41.5	106.5
5/9/2009	24	23	0	71.6	12.8	47.2	90.2	145.4	72.7	186.5
5/10/2009	24	0	24	33.9	9.0	17.4	56.6	68.9	34.4	88.4
5/11/2009	1	3	22	48.1	N/A	48.1	48.1	97.6	48.8	125.3
Period 9										
7/1/2009	13	5	2	63.9	17.4	36.2	99.1	129.7	64.8	166.4
7/2/2009	23	10	7	53.6	22.9	17.4	103.0	108.8	54.4	139.5
7/3/2009	37	1	0	50.6	11.3	32.3	79.1	102.8	51.4	131.9
7/4/2009	27	2	1	39.4	15.5	7.7	65.1	80.0	40.0	102.6
7/5/2009	9	22	0	29.9	13.0	6.8	51.1	60.8	30.4	78.0
7/6/2009	17	11	18	26.4	12.0	11.5	48.5	53.7	26.8	68.9
7/7/2009	18	0	28	35.7	10.6	20.0	52.3	72.4	36.2	92.9
7/8/2009	12	16	14	44.7	17.1	17.4	73.6	90.7	45.4	116.4
7/9/2009	38	4	0	26.3	8.7	13.2	44.7	53.4	26.7	68.5
7/10/2009	44	0	0	30.3	9.1	17.4	50.6	61.5	30.7	78.9
7/11/2009	14	11	21	45.3	14.8	23.8	69.8	92.0	46.0	118.1
7/12/2009	34	14	0	50.3	19.0	20.0	84.7	102.1	51.0	130.9
7/13/2009	15	13	17	27.8	10.0	7.7	46.0	56.4	28.2	72.4
7/14/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/15/2009	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/16/2009	15	14	16	45.7	15.9	14.5	65.1	92.8	46.4	119.1
7/17/2009	11	14	22	66.2	23.3	32.3	91.9	134.5	67.2	172.5
7/18/2009	7	6	33	28.1	6.6	18.7	36.2	57.1	28.6	73.3
7/19/2009	1	0	47	17.0	N/A	17.0	17.0	34.6	17.3	44.3
7/20/2009	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data

Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction

Touchdown limited: Number of ½ h periods invalidated because fraction of source area surface covered by particle touchdowns was less than 0.1

Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m

Background (ppm): bLS model calculated daily average background concentration (ppm); average is over the ½ h periods included in the valid column

Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods

Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods

Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods

Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods

Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area

Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis

Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction Limited	Touchdown Limited	Turbulence Limited	Background (ppm)	Emission Average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission Minimum ($\mu gm^{-2}s^{-1}$)	Emission Maximum ($\mu gm^{-2}s^{-1}$)	Emission Average (kgd^{-1})	Emission Average ($gd^{-1}hd^{-1}$)	Emission Average ($gd^{-1}AU^{-1}$)
Period 2												
10/5/2007	3	0	0	3	0.06	61.1	14.9	48.2	77.5	123.5	61.7	158.4
10/6/2007	27	0	0	21	0.06	47.7	18.0	-2.1	88.6	96.3	48.2	123.6
10/7/2007	10	0	0	30	-0.06	86.5	46.4	12.1	176.5	174.9	87.4	224.3
10/8/2007	9	0	1	37	0.24	78.2	31.8	8.7	107.9	158.0	79.0	202.8
10/9/2007	0	0	12	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/10/2007	5	0	9	13	0.16	63.5	58.7	2.4	155.3	128.2	64.1	164.5
10/11/2007	28	1	6	8	0.12	29.3	27.1	-34.0	75.7	59.2	29.6	76.0
10/12/2007	24	0	1	21	0.09	22.8	43.8	-44.6	201.8	46.0	23.0	59.0
10/13/2007	15	0	0	28	0.23	9.4	41.2	-75.8	93.6	19.0	9.5	24.4
10/14/2007	15	0	1	28	0.19	51.0	52.1	4.2	199.8	103.1	51.5	132.3
10/15/2007	13	0	0	28	-0.02	80.7	32.4	32.2	130.7	163.1	81.6	209.3
10/16/2007	14	1	0	28	0.03	77.9	30.6	0.4	115.7	157.5	78.7	202.0
10/17/2007	9	4	0	29	0.02	91.6	23.0	56.4	128.6	185.0	92.5	237.3
10/18/2007	2	16	2	20	0.03	58.4	11.9	50.0	66.8	118.0	59.0	151.3
10/19/2007	0	6	13	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/20/2007	18	0	9	15	0.17	44.3	30.0	-11.0	114.3	89.5	44.7	114.8
10/21/2007	6	4	0	33	0.12	57.2	22.9	33.3	94.1	115.6	57.8	148.3
10/22/2007	6	0	0	23	0.09	59.8	15.9	37.3	80.3	120.9	60.4	155.1
Period 3												
1/31/2008	11	0	0	0	0.03	23.7	6.5	18.6	41.4	47.8	23.9	61.4
2/1/2008	22	8	2	11	0.02	11.1	7.9	0.1	30.6	22.3	11.2	28.7
2/2/2008	11	11	0	25	0.00	3.5	1.1	1.8	5.0	7.0	3.5	9.0
2/3/2008	8	4	0	33	-0.01	6.7	3.7	2.2	11.1	13.6	6.8	17.4
2/4/2008	4	6	0	28	0.01	6.8	2.9	3.3	10.0	13.7	6.8	17.6
2/5/2008	12	14	1	19	0.01	8.1	1.5	5.8	10.2	16.3	8.2	20.9

Date	Valid	Direction Limited	Touchdown Limited	Turbulence Limited	Background (ppm)	Emission Average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission Minimum ($\mu gm^{-2}s^{-1}$)	Emission Maximum ($\mu gm^{-2}s^{-1}$)	Emission Average (kgd^{-1})	Emission Average ($gd^{-1}hd^{-1}$)	Emission Average ($gd^{-1}AU^{-1}$)
2/6/2008	4	39	0	4	0.01	8.0	1.9	6.3	10.5	16.3	8.1	20.9
2/7/2008	36	8	0	4	0.00	11.8	4.1	5.3	23.9	23.9	12.0	30.7
2/8/2008	17	0	0	29	0.00	9.1	2.4	4.6	12.5	18.5	9.2	23.7
2/9/2008	13	7	0	24	0.01	7.8	1.4	5.2	9.8	15.8	7.9	20.3
2/10/2008	36	1	0	11	0.00	11.8	3.2	6.1	19.6	23.9	12.0	30.7
2/11/2008	15	0	12	7	0.01	5.9	5.2	0.9	17.7	12.0	6.0	15.3
Period 4												
4/1/2008	0	1	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2008	31	14	0	2	0.03	17.2	12.2	0.3	43.0	34.7	17.3	44.5
4/3/2008	47	0	0	1	0.03	15.1	4.9	5.4	25.9	30.5	15.2	39.1
4/4/2008	13	20	0	15	0.03	1.3	1.1	0.3	3.7	2.6	1.3	3.3
4/5/2008	20	20	0	7	0.03	12.2	9.5	0.1	43.5	24.7	12.3	31.7
4/6/2008	30	0	1	17	0.02	15.6	5.2	4.6	27.0	31.5	15.7	40.4
4/7/2008	48	0	0	0	0.02	10.0	4.0	2.4	18.9	20.3	10.2	26.0
4/8/2008	48	0	0	0	0.02	12.2	6.7	1.2	33.5	24.7	12.4	31.7
4/9/2008	45	0	0	3	0.01	11.1	6.2	2.3	29.8	22.4	11.2	28.7
4/10/2008	14	7	0	21	0.01	14.6	13.6	-1.5	44.4	29.6	14.8	37.9
4/11/2008	1	25	0	21	0.03	2.6	N/A	2.6	2.6	5.2	2.6	6.7
4/12/2008	13	34	0	0	0.02	2.8	3.0	-2.0	8.6	5.6	2.8	7.2
4/13/2008	42	2	0	4	0.03	12.8	14.3	-30.3	46.8	25.8	12.9	33.1
4/14/2008	31	0	1	16	0.03	11.9	10.9	-1.8	36.0	24.0	12.0	30.8
4/15/2008	39	0	0	9	0.04	17.7	9.7	2.4	44.1	35.7	17.8	45.8
4/16/2008	5	0	1	13	0.03	4.1	7.1	-2.7	16.3	8.4	4.2	10.8
Period 5												
8/14/2008	0	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/15/2008	8	11	1	24	0.16	38.3	58.5	-64.6	121.9	77.5	38.7	99.4
8/16/2008	8	1	15	21	0.06	14.5	21.7	-22.4	51.3	29.3	14.7	37.7
8/17/2008	4	0	9	34	0.03	66.2	26.3	36.6	98.0	133.7	66.9	171.5
8/18/2008	5	0	15	21	0.10	-15.8	76.6	-127.3	82.0	-31.9	-15.9	-40.9
8/19/2008	10	2	3	28	0.06	46.6	56.3	-15.4	141.1	94.2	47.1	120.8
8/20/2008	3	1	16	24	0.02	140.7	24.4	114.7	163.2	284.4	142.2	364.9
8/21/2008	0	0	32	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	0	0	38	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/23/2008	4	0	27	17	0.02	113.5	32.7	77.7	151.6	229.4	114.7	294.3
8/24/2008	8	6	6	23	-0.10	71.1	50.8	11.0	135.9	143.7	71.8	184.3
8/25/2008	1	26	0	17	-0.22	64.9	N/A	64.9	64.9	131.2	65.6	168.3
8/26/2008	1	1	9	34	0.00	0.7	N/A	0.7	0.7	1.4	0.7	1.8
8/27/2008	40	1	1	6	0.03	67.4	17.7	26.9	106.3	136.2	68.1	174.8
8/28/2008	21	13	0	14	0.16	44.5	37.4	-67.8	114.3	89.9	44.9	115.3
8/29/2008	10	11	0	26	0.08	54.9	82.2	0.4	271.2	110.9	55.4	142.3
8/30/2008	9	7	0	28	0.02	30.7	28.6	5.5	83.2	62.1	31.0	79.7
8/31/2008	21	4	2	17	0.01	192.5	129.2	4.5	529.1	389.0	194.5	499.1
9/1/2008	30	0	6	12	0.04	141.6	80.4	36.8	295.7	286.1	143.0	367.0
9/2/2008	14	0	0	18	0.09	17.4	37.8	-19.5	116.3	35.1	17.6	45.0
9/3/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6												

Date	Valid	Direction Limited	Touchdown Limited	Turbulence Limited	Background (ppm)	Emission Average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission Minimum ($\mu gm^{-2}s^{-1}$)	Emission Maximum ($\mu gm^{-2}s^{-1}$)	Emission Average (kgd^{-1})	Emission Average ($gd^{-1}hd^{-1}$)	Emission Average ($gd^{-1}AU^{-1}$)
9/4/2008	1	1	0	16	0.09	5.1	N/A	5.1	5.1	10.4	5.2	13.3
9/5/2008	25	0	0	15	0.00	60.2	24.1	18.7	103.8	121.6	60.8	156.0
9/6/2008	37	3	3	4	0.03	61.2	14.4	41.8	114.1	123.7	61.9	158.7
9/7/2008	12	9	0	24	0.05	51.5	28.2	8.3	107.1	104.1	52.1	133.6
9/8/2008	19	2	0	26	-0.03	106.2	42.2	22.6	186.7	214.6	107.3	275.3
9/9/2008	10	11	0	22	0.04	56.3	17.3	30.1	98.0	113.8	56.9	146.0
9/10/2008	20	6	0	21	0.02	49.6	21.1	1.9	74.0	100.2	50.1	128.6
9/11/2008	41	0	0	7	0.03	55.4	21.1	3.1	108.9	112.0	56.0	143.7
9/12/2008	3	10	2	28	-0.01	59.2	68.3	3.5	135.4	119.6	59.8	153.5
9/13/2008	21	0	0	27	0.04	72.8	24.8	33.2	128.9	147.0	73.5	188.6
9/14/2008	17	14	0	17	0.04	74.6	18.9	47.8	114.9	150.6	75.3	193.3
9/15/2008	23	21	0	4	0.04	59.4	16.4	34.8	100.5	120.0	60.0	154.0
9/16/2008	34	2	0	12	0.01	70.1	60.7	-5.9	373.7	141.7	70.8	181.8
9/17/2008	47	0	0	1	0.02	48.8	19.3	16.7	97.4	98.7	49.3	126.6
9/18/2008	24	0	0	23	0.01	65.3	29.7	16.3	123.1	131.9	65.9	169.2
9/19/2008	37	0	0	11	0.00	58.7	32.7	14.6	119.6	118.7	59.3	152.3
9/20/2008	46	0	0	2	0.01	39.8	14.3	8.8	78.8	80.5	40.2	103.2
9/21/2008	36	0	0	12	0.01	41.4	16.3	9.7	75.8	83.7	41.8	107.3
9/22/2008	32	0	0	15	0.02	37.1	18.7	7.1	72.0	74.9	37.5	96.2
9/23/2008	23	0	0	0	0.04	12.9	5.1	2.4	24.0	26.1	13.1	33.5
Period 7												
1/16/2009	32	0	8	2	0.01	7.5	2.7	2.2	13.8	15.1	7.5	19.3
1/17/2009	13	3	3	28	0.01	4.9	1.6	2.6	9.1	9.9	4.9	12.7
1/18/2009	1	39	0	8	0.04	2.1	N/A	2.1	2.1	4.2	2.1	5.4
1/19/2009	18	1	3	24	0.01	6.2	1.3	3.9	9.0	12.5	6.3	16.1
1/20/2009	31	0	0	12	0.01	8.0	2.7	1.3	11.5	16.1	8.0	20.6
1/21/2009	23	0	0	24	0.01	4.3	1.7	0.5	8.5	8.8	4.4	11.3
1/22/2009	13	7	0	27	0.00	4.5	3.0	0.7	8.7	9.1	4.6	11.7
1/23/2009	17	11	0	20	0.12	-1.9	4.9	-12.3	6.4	-3.8	-1.9	-4.9
1/24/2009	6	15	8	19	0.09	2.9	1.7	1.6	5.5	5.9	3.0	7.6
1/25/2009	36	0	8	4	0.01	18.3	6.7	11.6	44.8	36.9	18.5	47.4
1/26/2009	17	0	7	23	0.01	15.7	12.3	0.1	40.3	31.7	15.8	40.7
1/27/2009	7	0	9	30	0.01	4.9	1.9	1.6	6.9	9.9	4.9	12.7
1/28/2009	6	25	0	13	0.01	9.6	5.5	5.6	19.8	19.4	9.7	24.9
1/29/2009	11	0	16	20	0.00	7.1	1.7	3.9	10.6	14.4	7.2	18.4
1/30/2009	17	0	0	25	0.00	10.1	1.4	6.8	11.9	20.4	10.2	26.1
1/31/2009	33	0	0	15	0.00	8.7	2.1	5.2	13.8	17.5	8.7	22.4
2/1/2009	10	22	0	16	0.00	11.4	1.3	9.5	13.8	22.9	11.5	29.4
2/2/2009	4	12	0	18	0.00	13.0	3.5	8.2	16.7	26.3	13.2	33.8
Period 8												
4/29/2009	9	0	0	8	0.05	89.0	19.8	50.1	120.4	179.8	89.9	230.6
4/30/2009	28	12	0	8	0.02	51.5	22.2	14.2	98.9	104.1	52.0	133.5
5/1/2009	18	21	0	2	0.04	58.6	7.6	34.0	66.8	118.5	59.2	152.0
5/2/2009	21	26	0	1	0.04	64.1	11.2	38.4	83.0	129.4	64.7	166.1
5/3/2009	18	21	0	7	0.04	70.8	11.1	46.4	86.3	143.1	71.6	183.6
5/4/2009	19	27	0	1	0.04	71.2	10.6	51.4	87.9	143.8	71.9	184.5

Date	Valid	Direction Limited	Touchdown Limited	Turbulence Limited	Background (ppm)	Emission Average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission Minimum ($\mu gm^{-2}s^{-1}$)	Emission Maximum ($\mu gm^{-2}s^{-1}$)	Emission Average (kgd^{-1})	Emission Average ($gd^{-1}hd^{-1}$)	Emission Average ($gd^{-1}AU^{-1}$)
5/5/2009	8	22	0	18	0.04	37.4	12.4	13.6	49.9	75.5	37.7	96.9
5/6/2009	2	40	0	3	0.05	54.9	3.2	52.7	57.2	111.0	55.5	142.4
5/7/2009	11	37	0	0	0.04	71.6	19.6	40.7	100.3	144.7	72.4	185.7
5/8/2009	13	17	0	16	0.02	64.9	24.7	23.7	96.8	131.1	65.5	168.2
5/9/2009	24	21	0	3	0.04	77.9	11.6	60.6	98.8	157.4	78.7	202.0
5/10/2009	30	0	0	18	0.02	59.3	19.8	28.9	99.7	119.9	60.0	153.8
5/11/2009	15	0	0	18	0.00	49.7	22.4	0.5	85.0	100.3	50.2	128.7
Period 9												
7/1/2009	10	5	0	5	0.04	109.4	24.3	49.5	132.9	221.0	110.5	283.6
7/2/2009	20	12	0	14	0.09	59.3	34.5	4.2	128.1	119.8	59.9	153.7
7/3/2009	33	0	0	10	0.06	53.2	21.8	17.9	110.9	107.5	53.7	137.9
7/4/2009	17	1	0	27	0.14	55.0	38.0	0.2	126.9	111.2	55.6	142.6
7/5/2009	7	11	0	30	0.12	39.2	32.9	1.0	77.1	79.1	39.6	101.5
7/6/2009	8	11	13	15	0.04	54.1	11.0	32.7	69.8	109.4	54.7	140.3
7/7/2009	18	0	13	13	0.03	59.1	30.1	12.0	105.8	119.4	59.7	153.2
7/8/2009	12	10	0	25	0.13	38.3	24.9	1.0	79.9	77.4	38.7	99.3
7/9/2009	33	2	0	12	0.00	47.2	26.3	16.3	121.0	95.4	47.7	122.4
7/10/2009	26	0	0	21	0.01	62.1	23.4	17.9	118.0	125.4	62.7	161.0
7/11/2009	13	11	0	21	-0.05	93.4	38.7	10.2	147.8	188.6	94.3	242.0
7/12/2009	29	12	0	6	0.00	75.3	30.5	45.3	145.9	152.1	76.1	195.2
7/13/2009	18	18	2	10	0.00	47.8	26.8	-0.5	96.3	96.5	48.3	123.8
7/14/2009	1	0	22	23	0.02	18.1	N/A	18.1	18.1	36.6	18.3	47.0
7/15/2009	7	4	8	23	0.05	13.8	8.8	3.1	23.5	28.0	14.0	35.9
7/16/2009	11	15	2	19	0.00	69.7	22.6	13.8	95.7	140.8	70.4	180.6
7/17/2009	12	12	0	22	0.00	95.2	28.5	51.9	129.2	192.3	96.1	246.7
7/18/2009	20	6	4	17	0.01	41.2	17.0	12.6	81.7	83.2	41.6	106.7
7/19/2009	1	0	28	18	0.06	26.1	N/A	26.1	26.1	52.8	26.4	67.8
7/20/2009	4	15	2	23	0.04	15.8	7.7	9.3	25.6	31.9	16.0	41.0

6.12.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 3								
1/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2008	4	0.0	0.5	-0.1	0.0	0.0	0.0	0.0
2/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/3/2008	1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
2/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2008	4	0.6	5.9	0.1	1.4	1.2	0.6	1.6
2/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2008	11	3.2	11.7	-2.3	18.5	6.4	3.2	8.2
2/8/2008	6	-0.5	0.0	-3.9	1.2	-1.0	-0.5	-1.3
2/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2008	2	0.2	3.7	-0.2	0.6	0.3	0.2	0.4
2/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4								
4/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2008	1	0.0	0.0	0.0	0.0	0.1	0.0	0.1
4/3/2008	1	0.1	0.0	0.1	0.1	0.1	0.1	0.2
4/4/2008	3	0.0	1.3	0.0	0.0	0.1	0.0	0.1
4/5/2008	5	0.0	0.8	0.0	0.1	0.0	0.0	0.0
4/6/2008	9	0.1	2.1	0.0	0.2	0.2	0.1	0.2
4/7/2008	3	0.1	2.9	0.0	0.3	0.3	0.1	0.3
4/8/2008	4	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
4/9/2008	10	0.0	1.1	-0.1	0.1	0.0	0.0	0.1
4/10/2008	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/14/2008	3	0.4	4.8	0.0	0.9	0.7	0.4	0.9
4/15/2008	12	0.1	2.6	0.1	0.2	0.3	0.1	0.4

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
4/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5								
8/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/15/2008	1	-0.5	0.0	-0.5	-0.5	-1.1	-0.5	-1.4
8/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6								
9/5/2008	11	0.1	2.3	-0.1	0.3	0.2	0.1	0.3
9/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/7/2008	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/10/2008	13	0.0	1.4	-0.1	0.4	0.1	0.0	0.1
9/11/2008	32	0.1	1.6	-0.1	0.2	0.1	0.1	0.2
9/12/2008	6	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
9/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/14/2008	2	-0.1	0.0	-0.1	0.0	-0.1	-0.1	-0.1
9/15/2008	3	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
9/16/2008	12	0.3	3.5	0.0	1.2	0.5	0.3	0.7
9/17/2008	27	0.2	3.0	0.0	1.7	0.4	0.2	0.5
9/18/2008	24	0.0	0.7	-0.2	0.2	0.0	0.0	0.0
9/19/2008	30	0.1	1.7	-0.4	1.1	0.1	0.1	0.2
9/20/2008	39	0.0	1.1	-0.2	0.2	0.1	0.0	0.1
9/21/2008	32	0.0	1.0	-0.1	0.1	0.0	0.0	0.1
9/22/2008	14	0.0	0.8	-0.1	0.3	0.0	0.0	0.0
9/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7								

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
1/16/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/18/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/19/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/20/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/21/2009	3	-0.1	0.0	-0.3	0.0	-0.3	-0.1	-0.4
1/22/2009	6	-0.1	0.0	-0.2	0.1	-0.1	-0.1	-0.2
1/23/2009	5	0.0	0.7	-0.1	0.2	0.0	0.0	0.0
1/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/28/2009	2	0.3	5.2	0.2	0.4	0.6	0.3	0.8
1/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2009	5	0.3	4.1	-0.2	1.2	0.6	0.3	0.8
2/2/2009	1	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Period 8								
4/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2009	8	0.4	4.5	0.0	1.0	0.9	0.4	1.1
5/1/2009	17	1.0	6.7	0.0	7.3	2.0	1.0	2.6
5/2/2009	18	0.2	3.3	-0.3	1.7	0.5	0.2	0.6
5/3/2009	18	0.0	0.8	-0.2	0.5	0.0	0.0	0.0
5/4/2009	14	0.0	0.0	-0.3	0.1	0.0	0.0	0.0
5/5/2009	5	47.9	117.7	0.0	238.1	97.3	48.7	124.9
5/6/2009	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/7/2009	11	5.2	14.6	-0.2	50.0	10.5	5.2	13.4
5/8/2009	11	0.0	0.0	-0.2	0.2	0.0	0.0	0.0
5/9/2009	24	0.6	4.9	-0.7	5.3	1.1	0.6	1.4
5/10/2009	3	-0.1	0.0	-0.1	0.0	-0.1	-0.1	-0.1
5/11/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 9								
7/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/2/2009	18	0.2	2.7	-0.2	1.1	0.3	0.2	0.4
7/3/2009	37	0.1	2.5	-0.1	0.5	0.3	0.1	0.4
7/4/2009	18	0.5	4.5	-0.1	3.9	0.9	0.5	1.2
7/5/2009	5	-0.1	0.0	-0.2	0.0	-0.2	-0.1	-0.3
7/6/2009	10	0.4	4.2	-0.3	3.9	0.8	0.4	1.0
7/7/2009	13	0.0	1.1	-0.1	0.2	0.1	0.0	0.1
7/8/2009	4	0.1	2.5	0.1	0.2	0.2	0.1	0.3
7/9/2009	15	0.1	1.7	0.0	0.3	0.1	0.1	0.2
7/10/2009	26	0.0	0.5	-0.1	0.2	0.0	0.0	0.0
7/11/2009	10	-0.1	0.0	-0.2	0.0	-0.2	-0.1	-0.2
7/12/2009	32	-0.1	0.0	-0.4	0.2	-0.1	-0.1	-0.2

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/13/2009	13	0.3	4.0	-0.1	3.7	0.6	0.3	0.8
7/14/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/16/2009	13	0.1	1.8	-0.1	0.4	0.1	0.1	0.2
7/17/2009	11	-0.1	0.0	-0.6	0.1	-0.2	-0.1	-0.3
7/18/2009	2	0.0	0.0	-0.2	0.1	0.0	0.0	0.0
7/19/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/20/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either u_* < 0.15 ms^{-1} or |L| < 2 m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (gd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 3												
1/31/2008	19	0	0	25	0.6	0.4	0.4	-0.1	1.1	0.7	0.4	0.9
2/1/2008	20	6	7	12	1.0	0.1	0.2	-0.2	1.0	0.1	0.1	0.2
2/2/2008	1	10	10	26	1.3	-0.2	N/A	-0.2	-0.2	-0.5	-0.2	-0.6
2/3/2008	0	3	8	36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/4/2008	3	6	0	38	4.6	0.4	0.4	0.1	0.9	0.9	0.4	1.1
2/5/2008	12	16	0	19	2.7	0.0	0.4	-0.8	0.5	0.1	0.0	0.1
2/6/2008	4	37	0	5	1.6	0.9	0.5	0.2	1.4	1.9	0.9	2.4
2/7/2008	17	8	17	4	2.2	1.1	1.5	-1.5	4.8	2.2	1.1	2.8
2/8/2008	8	0	8	31	0.8	1.1	1.1	-0.2	2.9	2.2	1.1	2.8
2/9/2008	13	7	0	28	2.6	3.1	3.0	0.6	10.0	6.4	3.2	8.2
2/10/2008	8	1	21	11	3.0	2.7	3.6	-0.1	8.0	5.6	2.8	7.2
2/11/2008	18	0	0	4	0.2	1.0	1.1	0.0	4.1	2.0	1.0	2.5
Period 4												
4/2/2008	2	0	2	0	-0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1
4/3/2008	7	0	40	1	0.2	0.0	0.1	-0.1	0.1	0.1	0.0	0.1
4/4/2008	9	20	4	15	1.0	0.1	0.1	-0.1	0.2	0.1	0.1	0.1
4/5/2008	14	20	6	8	0.8	0.1	0.2	-0.1	0.8	0.2	0.1	0.3
4/6/2008	26	0	5	17	0.4	0.0	0.1	-0.1	0.2	0.1	0.0	0.1
4/7/2008	48	0	0	0	0.2	0.5	0.7	-0.1	3.8	1.0	0.5	1.3

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
4/8/2008	48	0	0	0	0.2	0.1	0.1	-0.1	0.4	0.3	0.1	0.4
4/9/2008	45	0	0	3	0.1	0.0	0.1	-0.1	0.2	0.1	0.0	0.1
4/10/2008	6	7	8	27	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.1
4/11/2008	1	25	0	21	1.4	0.0	N/A	0.0	0.0	0.0	0.0	0.0
4/12/2008	12	34	1	0	2.7	1.0	1.7	-0.4	3.7	2.0	1.0	2.5
4/13/2008	25	2	17	4	2.3	-0.2	0.3	-0.7	0.4	-0.4	-0.2	-0.5
4/14/2008	29	0	2	16	0.1	0.1	0.2	-0.2	0.6	0.3	0.1	0.3
4/15/2008	13	0	0	9	0.6	0.2	0.1	0.0	0.3	0.4	0.2	0.5
Period 5												
8/15/2008	6	11	3	28	3.0	-0.3	0.3	-0.8	0.0	-0.6	-0.3	-0.7
8/16/2008	19	2	4	22	0.8	0.0	0.1	-0.4	0.2	0.0	0.0	0.0
8/17/2008	0	0	13	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	11	0	9	28	0.6	0.1	0.1	-0.1	0.2	0.1	0.1	0.1
8/19/2008	11	2	2	31	1.0	0.0	0.1	-0.2	0.3	-0.1	0.0	-0.1
8/20/2008	7	1	12	26	1.2	-0.1	0.2	-0.5	0.2	-0.2	-0.1	-0.2
8/21/2008	37	0	0	11	0.5	0.0	0.1	-0.2	0.4	0.0	0.0	0.0
8/22/2008	36	0	6	6	0.5	0.0	0.2	-0.3	0.5	0.1	0.0	0.1
8/23/2008	22	0	9	17	0.4	0.0	0.1	-0.1	0.3	0.1	0.0	0.1
8/24/2008	6	6	8	28	0.9	0.0	0.1	-0.1	0.1	-0.1	0.0	-0.1
8/25/2008	0	26	1	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/26/2008	11	1	1	35	0.8	0.0	0.1	-0.1	0.3	0.1	0.0	0.1
8/27/2008	18	1	23	6	1.1	0.0	0.1	-0.3	0.3	0.1	0.0	0.1
8/28/2008	2	13	19	14	1.5	0.0	0.2	-0.2	0.2	0.0	0.0	0.0
8/29/2008	6	11	4	26	1.2	-0.1	0.6	-1.3	0.6	-0.2	-0.1	-0.2
8/30/2008	0	7	9	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	21	4	2	20	0.8	0.0	0.2	-0.2	0.3	0.0	0.0	0.0
9/1/2008	36	0	0	12	0.6	0.0	0.1	-0.3	0.2	-0.1	0.0	-0.1
9/2/2008	12	0	0	26	0.2	0.1	0.1	0.0	0.4	0.2	0.1	0.3
Period 6												
9/4/2008	0	0	0	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	19	0	6	18	0.4	0.1	0.2	-0.2	0.6	0.3	0.1	0.3
9/6/2008	17	3	24	4	1.2	0.4	1.5	-0.9	5.5	0.8	0.4	1.0
9/7/2008	6	9	6	27	6.3	-1.1	2.4	-5.9	0.1	-2.2	-1.1	-2.8
9/8/2008	7	2	12	27	1.3	0.0	0.2	-0.2	0.3	0.1	0.0	0.1
9/9/2008	8	11	2	27	2.2	-0.1	0.2	-0.3	0.2	-0.2	-0.1	-0.2
9/10/2008	15	6	5	22	0.8	0.1	0.4	-0.1	1.6	0.3	0.1	0.4
9/11/2008	39	0	2	7	0.3	0.1	0.2	-0.2	0.5	0.2	0.1	0.3
9/12/2008	2	10	6	30	3.8	-0.6	0.8	-1.2	0.0	-1.2	-0.6	-1.5
9/13/2008	10	0	11	27	2.5	-0.2	0.1	-0.4	0.0	-0.3	-0.2	-0.4
9/14/2008	17	14	0	17	2.4	-0.2	0.2	-0.8	0.1	-0.4	-0.2	-0.5
9/15/2008	18	21	5	4	2.2	0.0	0.5	-1.5	1.3	-0.1	0.0	-0.1
9/16/2008	31	2	3	12	0.8	0.8	1.8	-0.1	9.1	1.7	0.8	2.1
9/17/2008	47	0	0	1	0.7	0.4	0.6	-0.2	3.3	0.8	0.4	1.0
9/18/2008	24	0	0	24	0.3	0.1	0.2	-0.2	0.8	0.1	0.1	0.2
9/19/2008	36	0	1	11	0.4	0.1	0.4	-0.7	2.0	0.3	0.1	0.3

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/20/2008	46	0	0	2	0.3	0.0	0.1	-0.2	0.3	0.1	0.0	0.1
9/21/2008	36	0	0	12	0.3	0.0	0.1	-0.2	0.2	0.1	0.0	0.1
9/22/2008	19	0	0	15	0.4	0.0	0.1	-0.2	0.3	0.0	0.0	0.0
Period 7												
1/16/2009	10	0	0	2	0.3	0.0	0.2	-0.2	0.3	0.0	0.0	0.0
1/17/2009	8	3	8	29	0.1	0.0	0.1	-0.1	0.2	0.1	0.0	0.1
1/18/2009	1	39	0	8	1.0	0.0	N/A	0.0	0.0	0.1	0.0	0.1
1/19/2009	5	5	13	25	1.2	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1
1/20/2009	29	0	5	14	0.5	0.0	0.2	-0.3	0.3	0.0	0.0	0.0
1/21/2009	13	0	10	25	0.6	0.0	0.1	-0.1	0.2	0.0	0.0	0.0
1/22/2009	13	7	0	28	4.7	-0.4	0.4	-1.4	0.1	-0.8	-0.4	-1.1
1/23/2009	17	11	0	20	1.4	0.0	0.1	-0.2	0.3	0.0	0.0	0.0
1/24/2009	8	15	6	19	0.5	0.0	0.1	-0.1	0.2	0.1	0.0	0.1
1/25/2009	43	0	1	4	0.2	0.1	0.2	-0.2	0.8	0.3	0.1	0.4
1/26/2009	23	0	2	23	0.3	0.0	0.1	-0.1	0.2	0.1	0.0	0.1
1/27/2009	6	0	12	30	0.6	0.0	0.1	-0.1	0.2	0.1	0.0	0.1
1/28/2009	5	28	2	13	2.1	0.8	2.1	-1.4	4.3	1.7	0.8	2.2
1/29/2009	22	0	6	20	0.4	0.0	0.1	-0.3	0.2	0.1	0.0	0.1
1/30/2009	12	0	5	31	0.3	0.2	0.2	0.0	0.5	0.4	0.2	0.5
1/31/2009	9	0	24	15	0.2	0.2	0.1	0.1	0.4	0.5	0.2	0.6
2/1/2009	10	22	0	16	2.0	0.2	0.5	-0.4	1.1	0.5	0.2	0.6
2/2/2009	4	13	0	19	2.6	-0.1	0.2	-0.4	0.2	-0.1	-0.1	-0.2
Period 8												
4/30/2009	7	12	21	8	-2.9	0.6	0.7	-0.4	1.5	1.2	0.6	1.6
5/1/2009	18	26	2	2	1.5	1.4	2.3	0.1	7.9	3.0	1.5	3.8
5/2/2009	18	26	3	1	1.5	0.3	0.7	-0.3	2.3	0.7	0.3	0.9
5/3/2009	17	21	2	8	1.5	0.3	1.1	-0.3	4.6	0.5	0.3	0.7
5/4/2009	13	27	6	1	2.1	0.0	0.2	-0.3	0.3	0.0	0.0	0.0
5/5/2009	5	22	3	18	-1.4	25.4	56.2	-4.5	125.8	52.2	26.1	67.0
5/6/2009	1	40	0	3	2.7	0.0	N/A	0.0	0.0	-0.1	0.0	-0.1
5/7/2009	11	37	0	0	2.5	9.4	25.7	-0.3	85.2	19.2	9.6	24.6
5/8/2009	8	17	5	16	2.0	-0.1	0.2	-0.4	0.2	-0.1	-0.1	-0.1
5/9/2009	24	21	0	3	2.5	0.6	1.2	-0.7	4.8	1.3	0.6	1.6
5/10/2009	19	0	11	18	0.7	0.2	0.3	-0.2	0.8	0.3	0.2	0.4
5/11/2009	4	0	0	19	1.6	0.4	0.5	0.0	1.1	0.8	0.4	1.0
Period 9												
7/2/2009	15	12	5	15	1.6	0.2	0.3	-0.3	1.1	0.4	0.2	0.5
7/3/2009	33	0	0	14	1.4	0.1	0.2	-0.5	0.5	0.3	0.1	0.3
7/4/2009	9	1	8	29	1.2	0.1	0.2	-0.3	0.3	0.2	0.1	0.3
7/5/2009	4	11	3	30	4.1	-0.2	0.2	-0.4	0.1	-0.4	-0.2	-0.5
7/6/2009	19	11	3	15	1.6	0.5	2.1	-0.1	9.2	1.1	0.6	1.4
7/7/2009	24	0	9	13	0.9	0.0	0.1	-0.1	0.3	0.1	0.0	0.1
7/8/2009	7	10	5	26	1.3	0.1	0.2	0.0	0.5	0.3	0.1	0.4
7/9/2009	14	2	19	12	0.9	0.1	0.1	-0.1	0.3	0.2	0.1	0.2
7/10/2009	21	0	5	22	0.7	0.0	0.1	-0.1	0.3	0.1	0.0	0.1

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/11/2009	11	11	2	23	2.7	-0.2	0.2	-0.5	0.1	-0.4	-0.2	-0.5
7/12/2009	28	12	1	7	2.7	-0.1	0.2	-0.6	0.3	-0.1	-0.1	-0.2
7/13/2009	15	18	5	10	1.8	0.4	1.5	-0.1	5.8	0.9	0.5	1.2
7/14/2009	22	0	1	25	0.8	0.1	0.1	-0.1	0.2	0.1	0.1	0.2
7/15/2009	2	4	15	26	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7/16/2009	10	15	3	20	2.3	0.1	0.2	-0.2	0.6	0.2	0.1	0.3
7/17/2009	12	14	0	22	2.5	-0.1	0.3	-0.7	0.2	-0.2	-0.1	-0.3
7/18/2009	21	6	3	17	1.0	0.5	2.1	-0.2	9.6	1.1	0.6	1.4
7/19/2009	23	0	7	18	0.7	0.0	0.1	-0.1	0.2	0.1	0.0	0.1
7/20/2009	2	15	6	24	4.2	-0.5	0.1	-0.5	-0.4	-0.9	-0.5	-1.2
7/21/2009	16	0	6	11	0.6	0.0	0.1	0.0	0.1	0.1	0.0	0.1

Final Report
Site OK3A
Pork Production Facility
for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
Site OK3A
Pork Production Facility

for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on location (relative to climate and typical practice), method of manure collection, method of manure storage, and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3) and hydrogen sulfide (H_2S) emissions from the waste lagoon open source at the western hog finisher facility. Within that objective, this report will:

- Describe the farm and the lagoon/basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the lagoon were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Lagoon emissions were measured for up to 21 days (d) each season over two years. The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the lagoon were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using

two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc, Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*Windtrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the lagoon pH, oxidation-reduction potential, and temperature at 0.3 m depth were also measured from a float located at least 30 m from the lagoon inlet (Table 1-2). Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the lagoon berm (Table 1-2).

Table 1-1: Critical measurements.

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder2™	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind speed	3D Sonic anemometer/ RM Young 81000	0-60 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/16 Hz averaging	30 min & 24 h
Wind direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/16 Hz averaging	30 min & 24 h
3D turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/16 Hz averaging	30 min
Temperature variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01^{o}C	160 Hz sampling/16 Hz averaging	30 min
GSS sample flow rate	GSS/S-OS	10 L min^{-1}	0.1 L min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/SOP-S	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to RPM Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the lagoon (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation, lagoon pH, lagoon oxidation-reduction potential, lagoon temperature, and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure, flow, temperature, and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer and downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Additional information concerning farm operations and the United States Department of Agriculture National Resource Conservation Service (USDA NRCS)-required analysis of wastewater used to irrigate nearby fields were routinely collected from the producers.

Table 1-2: Non-critical measurements.

Measurement	Method/Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
Ambient temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50°C	0.1°C	5 min	30 min, 24 h
Relative humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min & 24 h
Solar radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 Wm^{-2}	10 Wm^{-2}	5 min	30 min & 24 h
Lagoon solids depth	Sludge level detector/ SludgeGun 10HD, Markland Specialty Eng.	0-10 m	0.05 m	1/ measurement period	1 time
Lagoon/ basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	0-14 units	0.2 unit	5 min	30 min & 24 h
Lagoon/ basin oxidation-reduction potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	-800 - +1100 mV	20 mV	5 min	30 min & 24 h
Lagoon/ basin temperature	Thermistor/ Campbell Scientific Inc 107-L	-35 - +50°C	0.5°C	5 min	30 min & 24 h

1.3 Farm description and operation

The western finisher facility was located in Oklahoma. The elevation at the farm was 927 m. The farm consisted of three barns (Fig. 1-1). The facility had a maximum capacity of 3,024 finishing pigs. Construction was completed in 1997.

Manure from the barns was transferred three times a week to the lagoon by a pull plug system with lagoon water recharge. Waste water from all three units combined into one inlet. The waste lagoon was rectangular and was located to the west of the barns (separated by a drainage swale). The clay-lined lagoon was 59 m wide and 210 m long, and was oriented north-south. The lagoon

bank was clay, with a berm slope of 3.8:1. At maximum capacity, the liquid depth 6 m with a surface area of 22,500 m^2 and a volume of 28,700 m^3. Liquid was removed approximately every six months. Sludge from the lagoon had not been removed since construction (20-yr sludge removal cycle). Since the gaseous lagoon emissions emanate from manure and effluent residing in the lagoon for multiple months, it was assumed that the number of animals contributing to the lagoon was the maximum capacity of the farm.

Figure 1-1: Configuration of the OK3A farm.

1.4 Operational events and changes

A number of feed changes occurred at this location during the study period (Table 1-3).

Table 1-3: Operational changes during the study.

Period	Events during period
2: 8/29 - 9/19/2007	8/30/2007 feed change: Paylean 4.5g 9/13/2007 feed change: Paylean 6.5g
4: 5/7 - 5/29/2008	5/7/2008 feed change: Paylean 4.5g all 3 barns. 5/20/2008 feed change: Paylean 6.5g north barn 5/22/2008 feed change: Paylean 6.5g middle and south barns.

1.5 Measurement layout

The NH_3 emissions from the basin were monitored for 8 to 20 d each quarter of the year for two years using scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path

instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*) and backward Lagrangian Stochastic (bLS) emissions models. The H_2S emissions from the lagoon were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments (TDLAS/scanner) were mounted at 1-m height above the lagoon berm (abl) at the northwest and southeast corners (Figure 1-2). Towers for mounting retro-reflectors were located off the northeast and southwest corners of the lagoon (Figure 1-2). A description of the position and path length of the optical paths along each side of the lagoon follows:

- North side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 21 m and 42 m from the northwest TDLAS/scanner. Three retro-reflectors were mounted on the northeast tower 63 m from the TDLAS/scanner at heights of 0.85 m, 6.65 m, and 14.1 m abl.
- East side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 69 m and 138 m from the southeast TDLAS/scanner. Three retro-reflectors were mounted on the northeast tower 215.5 m from the TDLAS/scanner at heights of 0.85 m, 6.65 m, and 14.1 m abl.
- South side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 20 m and 40 m from the southeast TDLAS/scanner. Three retro-reflectors were mounted on the southwest tower 68 m from the TDLAS/scanner at heights of 1.1 m, 6.8 m, and 14.2 m abl.
- West side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 70 m and 144 m from the northwest TDLAS/scanner. Three retro-reflectors were mounted on the southwest tower 219.5 m from the TDLAS/scanner at heights of 1.1 m, 6.8 m, and 14.2 m abl.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1-m abl. A 50-m long S-OPS path was parallel to and 5 m north of the north berm and began at the northwest berm corner and extended east (Figure 1-2). The second 50-m long S-OPS was parallel to and 5 m south of the south lagoon berm and began at the southeast corner of south berm and extended west (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Meteorological measurements (barometric pressure, air temperature and relative humidity, solar radiation, and surface wetness) were made 10 m south of the northwest berm corner (Fig. 1-2). The 3D sonic anemometers were located on the meteorological tower at 2.5 m abl and on the southwest corner tower (Fig. 1-2) at 4.6 m and 16.3 m abl.

The barns located 10 m to the west of the lagoon berm have an approximate ridge height of 5.8 m agl, which resulted in a fetch ratio of 6:10 to the east side of the lagoon. Fetch in all other directions was better than 1:100, with upwind interference from center-pivot irrigated crops (Fig. 1-1). Due to the proximity of the barns, emissions from wind directions of 90 ^{o} to 135° were excluded from analysis. The aerodynamic roughness of the barns (5.8 m high) contributed to non-homogeneous surface roughness. All fans exhausted on the East side of the barns and therefore did not influence the lagoon PIC measurements except under easterly winds (which were not the prevailing winds at any time of the year).

Lagoon measurements (pH, oxidation-reduction potential, and temperature) were made from a float located in the northwest corner of the lagoon.

Figure 1-2: Locations of instrumentation around the lagoon under measurement. Retro-reflectors are indicated according to side (north, south, east, and west) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The locations of the two S-OPS are indicated by the solid yellow lines. The instrumentation trailer was located on the east side of the lagoon.

2 Monitoring activities

2.1 Measurement periods

This location was measured for approximately 20 d each season in rotation with three other farms. The equipment was on site a total of 161 d over eight measurement periods (Table 2.1-1). Setup calibrations and site takedowns reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 155 d and H_2S emissions were measured 120 d.

Table 2.1-1: Days on site

Measurement period	Start date	End date	# days
2	8/30/2007	9/18/2007	19
3	1/24/2008	2/19/2008	26
4	5/7/2008	5/29/2008	22
5	5/29/2008	6/10/2008	12
6	11/5/2008	12/2/2008	27
7	12/2/2008	12/16/2008	14
8	4/23/2009	5/14/2009	21
9	7/15/2009	8/4/2009	20

2.2 Site visits

The field operation team visited this farm 33 d (Table 2.2.1). Visits to set up the site instrumentation and conduct calibration verification checks of instruments typically lasted 3 d, while visits for calibration verifications and take-down of the equipment on site typically lasted 2 d.

Table2.2-1 Dates of site visits

Year	Spring	Summer	Fall	Winter
2007		Aug 30,31	Sep 18,19	Jan 24,25 Feb 5,6,19
2008	May 6,7,8 19,28,29	Jun 10,	Nov 5,6,7,17	Dec 2,3,16,17
2009	Apr 21,22,23 May 6,14	Jul 14,15,16 Aug 4		

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21 d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder2™ NH_3 TDLAS serial number (s/n) 1026, 1027, 1028, 1029, 1031 and 1032 (Section 6.1)
- TEC 450i H_2S Analyzer s/n 0733825128 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1920, 1921, 1927, 1928, 1932, 1936 and 1938 (Section 6.3)
- lagoon pH probes s/n 002, 0008, and 009 (Section 6.4)
- lagoon ORP probe s/n 020, 030 and 050 (Section 6.5)
- GSS/ S-OPS s/n 4-0017 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multi-point calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers (Section 6.3) with three unused 'standard' anemometers. A further QA check was made by inter-comparing TDLAS units: on May 28, 2009 two TDLAS units were inter-compared on site (s/n 1026 and 1032).

2.4 Audits

Three internal audits were conducted at this location: 1) on May 28, 2008, with particular attention to the TDLAS calibration verification and the lagoon probe calibrations, 2) on December 2, 2008, with particular attention to the H_2S Analyzer and TDLAS calibration verification and the checks on the meteorological sensors, and 3) on April 23, 2009, with particular attention to the sonic anemometer inter-comparison and the lagoon probe calibrations. The TDLAS units on location (s/n 1026 and 1032) were inter-compared on May 28, 2008.

2.5 Repair trips

Four repair trips were made to this location: February 5-6, 2008, May 19, 2008, November 17, 2008, and May 6, 2009.

2.6 Remote site checks

Over the course of measurements, there were 55 remote checks made from PAML through the computer for instruments operating at this location.

2.7 Measurement data acquisition

Data from the TDLAS units (Model GasFinder2™ NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather and lagoon data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *LoggerNet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored

on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *LoggerNet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA) were downloaded in real-time through a serial cable to the trailer computer using the *iPort* (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built *Visual Basic* software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every 6 h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory “FTP” and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory “Data”. The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the “FTP” directory.

3 Data Processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDL. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files were still present in the "FTP" directory, and in some cases these empty files were useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes needed to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site, data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer causing the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period,

unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one minute off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the lagoon and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream

may depend on one or more of the preceding streams, but not on following data streams. For each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment failures, calibration failures, and calibration checks in progress. Periods of invalidated measurements associated with the calibration check failures are documented in the calibration reports in Section 6. Significant data exclusions of greater than one-day duration are indicated below by instrument with all time references in Coordinated Universal Time (UTC:

TDLAS measurement exclusions: Excluded measurements are summarized in Table 3.2-1.

Table 3.2-1: TDLAS measurement exclusions

Begin		End		Reason
9/9/2007	15:00	9/11/2007	18:53	TDLAS 1 Has no data, unknown cause
9/10/2007	20:02	9/18/2007	13:00	TDLAS 2 Shutter failed
2/7/2008	06:30	2/19/2008	00:00	TDLAS 1 Scanner failed
5/9/2008	00:40	5/28/2008	12:00	TDLAS 1 Scanner failed
11/7/2008	14:41	11/17/2008	15:55	TDLAS 2 Power supply unstable
11/27/2008	05:20	12/2/2008	22:00	TDLAS 2 Laptop Locked up
4/22/2009	23:58	5/2/2009	09:30	TDLAS 1 Centerline Duty Cycle failure
4/23/2009	22:27	5/6/2009	23:30	TDLAS 2 Missing Data (TDLAS Failure)
5/8/2009	15:00	5/14/2009	15:00	TDLAS 1 Scanner failed: Pan-tilt error
7/27/2009	05:10	7/30/2009	19:32	TDLAS 1 Power failed from storm
8/1/2009	02:00	8/3/2009	15:25	TDLAS 1 Power failed from storm

TEC 450i measurement exclusions: Excluded measurements are summarized in Table 3.2-2.

Table 3.2-2: TEC 450i measurement exclusions

Begin		End		Reason
2/2/2008	07:00	2/4/2008	15:30	Data not retrieved on time
2/7/2008	06:30	2/7/2008	21:30	Data not retrieved on time

Air temperature and relative humidity measurement exclusions: There was often no communications between meteorological data logger and trailer. However measurements were stored on the internal data storage module. Excluded measurements are summarized in Table 3.2-3.

Table 3.2-3: Air temperature and relative humidity measurement exclusions

Begin		End		Reason
9/9/2007	08:10	9/10/2007	17:30	Power failed at farm
5/6/2008	22:15	5/8/2008	14:45	FOS on site; data logger unplugged
5/15/2008	02:45	5/19/2008	21:30	Power failure at meteorological station
7/27/2009	05:10	7/30/2009	19:32	Power failure at meteorological station
8/1/2009	02:00	8/3/2009	15:25	Power failure at meteorological station

Solar radiation measurement exclusions: There was often no communications between meteorological data logger and trailer. However measurements were stored on the internal data storage module. Excluded measurements are summarized in Table 3.2-4.

Table 3.2-4: Solar radiation measurement exclusions

Begin		End		Reason
9/9/2007	08:10	9/10/2007	17:30	Power failed at farm
5/6/2008	22:15	5/8/2008	14:45	FOS on site; data logger unplugged
5/15/2008	02:45	5/19/2008	21:30	Power failure at meteorological station
7/27/2009	05:10	7/30/2009	19:32	Power failure at meteorological station
8/1/2009	02:00	8/3/2009	15:25	Power failure at meteorological station

Wetness measurement exclusions: There was often no communications between meteorological data logger and trailer. However measurements were stored on the internal data storage module. Excluded measurements are summarized in Table 3.2-5.

Table 3.2-5: Wetness measurement exclusions

Begin		End		Reason
9/9/2007	08:10	9/10/2007	17:30	Power failed at farm
5/6/2008	22:15	5/8/2008	14:45	FOS on site; data logger unplugged
7/27/2009	05:10	7/30/2009	19:32	Power failure at meteorological station
8/1/2009	02:00	8/3/2009	15:25	Power failure at meteorological station

Barometric Pressure measurement exclusions: There was often no communications between meteorological data logger and trailer. However measurements were stored on the internal data storage module. Excluded measurements are summarized in Table 3.2-6.

Table 3.2-6: Barometric Pressure measurement exclusions

Begin		End		Reason
9/9/2007	08:10	9/10/2007	17:30	Power failed at farm
5/6/2008	22:15	5/8/2008	14:45	FOS on site; data logger unplugged
5/15/2008	02:45	5/19/2008	21:30	Power failure at meteorological station
7/27/2009	05:10	7/30/2009	19:32	Power failure at meteorological station
8/1/2009	02:00	8/3/2009	15:25	Power failure at meteorological station

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-7.

Table 3.2-7: Sonic anemometer measurement exclusions

Begin		End		Reason
9/9/2007	08:10	9/10/2007	17:30	Sonic 1 Power failed
9/5/2007	20:30	9/6/2007	18:25	Sonic 2 No Data Sent
1/28/2008	18:50	1/31/2008	15:30	All Sonic anemometers fail, Program Failure?
2/5/2008	07:50	2/6/2008	18:25	All Sonic anemometers fail due to ice storm
2/10/2008	15:50	2/11/2008	16:09	All Sonic anemometers fail due to ice on sonic anemometers
5/15/2008	02:45	5/19/2008	21:30	Sonic 1 Power failure at met station
12/8/2008	18:10	12/10/2008	19:15	All Sonic anemometers program error
12/12/2008	15:15	12/16/2008	16:30	All Sonic anemometers program error
7/27/2009	05:10	7/30/2009	19:32	Sonic 1 Power failed from storm
8/1/2009	02:00	8/3/2009	15:25	Sonic 1 Power failed from storm

Lagoon temperature, pH, and ORP measurement exclusions: There was often no communications between meteorological data logger and trailer. However measurements were stored on the internal data storage module. Lagoon measurements stopped during winter due to expected lagoon freezing before next 20 day visit. Excluded measurements are summarized in Table 3.2-8.

Table 3.2-8: Lagoon temperature, pH, and ORP measurement exclusions

Begin		End		Reason
Lagoon temperature exclusion times				
1/24/2008	21:00	2/19/2008	21:15	No probes for this period, lagoon frozen
5/6/2008	22:15	5/8/2008	14:45	FOS on site; data logger unplugged
5/15/2008	02:45	5/19/2008	21:30	Power failure at meteorological station
7/27/2009	05:10	7/30/2009	19:32	Power failure at meteorological station

8/1/2009	02:00	8/3/2009	15:25	Power failure at meteorological station
Begin		**End**		**Reason**
Lagoon pH exclusion times				
7/15/2009	16:20	8/4/2009	18:30	Probe did not pass calibration at beginning or end of period
1/24/2008	21:00	2/19/2008	21:15	No probes for this period, lagoon frozen
5/6/2008	22:15	5/8/2008	14:45	FOS on site; data logger unplugged
5/15/2008	02:45	5/19/2008	21:30	Power failure at meteorological station
7/27/2009	05:10	7/30/2009	19:32	Power failure at meteorological station
8/1/2009	02:00	8/3/2009	15:25	Power failure at meteorological station
Begin		**End**		**Reason**
Lagoon ORP exclusion times				
1/24/2008	21:00	2/19/2008	21:15	No probes for this period, lagoon frozen
5/6/2008	22:15	5/8/2008	14:45	FOS on site; data logger unplugged
5/15/2008	02:45	5/19/2008	21:30	Power failure at meteorological station
7/27/2009	05:10	7/30/2009	19:32	Power failure at meteorological station
8/1/2009	02:00	8/3/2009	15:25	Power failure at meteorological station

GSS/S-OPS measurement exclusions: Rodents chewed through south S-OPS; measurements excluded from 6/8/2008 06:00 through 6/10/2008 21:30.

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20°C (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in super-saturated “holes” in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a super-saturated condition in which the light levels appear valid, but in

reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maximized light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably super-saturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-second value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be super-saturated were flagged as super-saturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not super-saturated. To determine which points truly were super-saturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest path integrated concentrations corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be super-saturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as super-saturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the corresponding r^2. Data points with PIC values greater than the threshold were considered to be supersaturated and excluded.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-minute intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the S-OPS changed from one line to the other line. This array was later used when separating the H_2S data according to which SOPS line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic anemometer software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic temperature variance of greater than 2.5 K^2, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic temperature variance had to be less than 2.5 K^2. To be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and more efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be *RPM* processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-

minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *Windtrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beamlines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference

was significant. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-minute intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3} \frac{34.0818\left(\left[H_2S\right]_{downwind} - \left[H_2S\right]_{upwind}\right)}{17030.4\left[NH_3\right]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and tells the model to run depending on whether or not the u_* and L values are acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths. All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the lagoon include transfer of waste from barns into the lagoon (Table 4.1-1) and lagoon pump-outs for irrigation. Lagoon was pumped-down in June 2009. No other pump-outs occurred during the study. Animal inventories for the calculation of lagoon loading rates are indicated in Table 4.1-1.

Table 4.1-1: Producer activities

Period	Activity	Animal inventory
2: 8/30 – 9/18/2007	No events	2267
9/25/2007	All 3 Barns Emptied	
9/27 and 10/4/2007	New Group of Pigs Restocked	
3: 1/24 - 2/19/2008	1/29/2008 North Barn emptied 1/30/2008 Middle Barn emptied 1/31/2008 South Barn emptied 2/11/2008 North & Middle restocked 2/14/2008 South Barn restocked	2660
4: 5/7 - 5/29/2008	No events	2747
5: 5/29 - 6/10/2008	5/28-6-11/2008 Pig Shipments: Total of 2079 was shipped out during this period.	2747
6: 11/4 -12/3/2008	No events	2909
7: 12/3 - 12/16/2008	No events	2880
8: 4/21 - 5/14/2009	No events	2882
9: 7/14 - 8/4/2009	No events	2845

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for midlatitude climates (Table 4.2-1). Twenty-nine percent of the days had extra-tropical frontal systems overhead while 71% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Measurement period	# days	# Warm front passages	# Cold front passages	# days stationary front	# days tropical storm
2	19	0	2	1	0
3	26	0	7	0	0
4	22	2	4	2	0
5	12	0	3	1	0
6	27	0	6	1	0
7	14	0	3	0	0
8	21	2	4	2	0
9	20	0	3	3	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from -13.4^{o} C to 34.5^{o} C, while the barometric pressure varied from 88.78 kPa to 92.27 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ hr solar irradiance of 1170Wm^{-2} to overcast conditions with maximum ½ hr solar irradiance of 62 Wm^{-2} (Section 6.10).

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared to the monthly climatology is indicated in Figure 4.2-1. Temperatures were generally within the climatological normal conditions throughout the study measurement periods at this location.

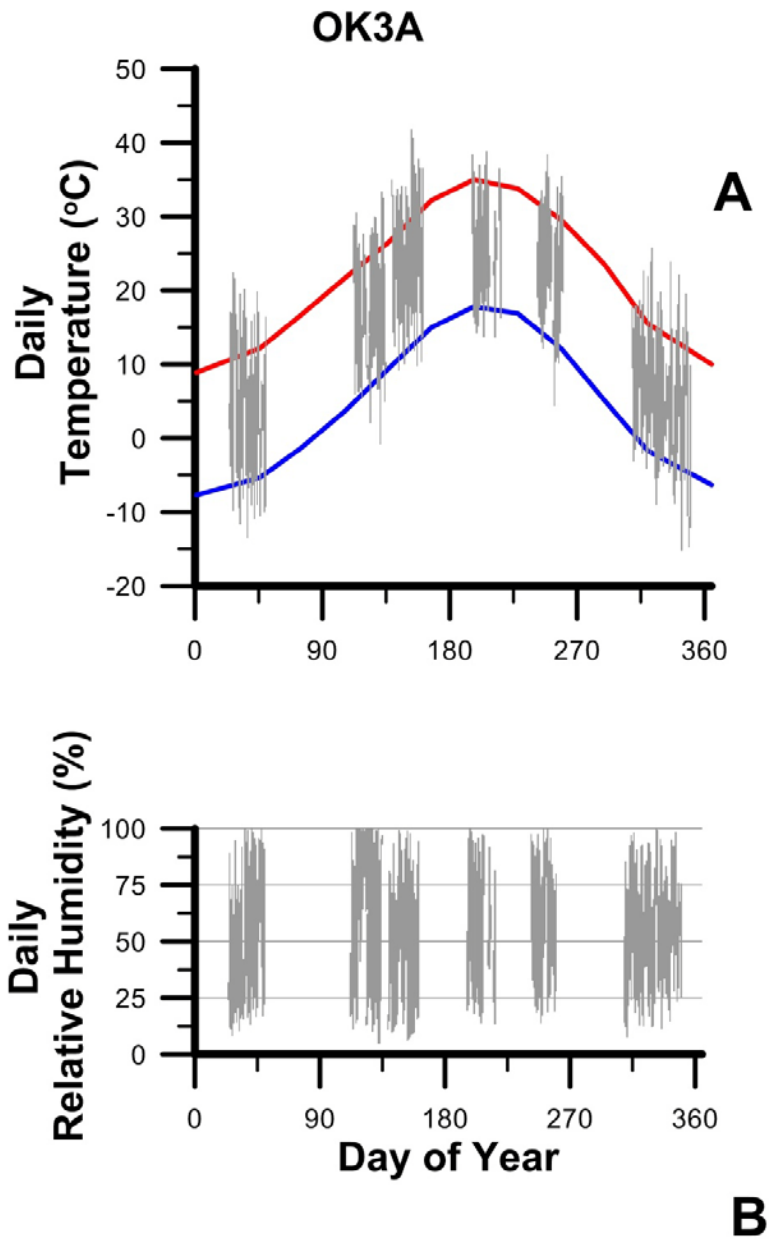

Figure 4.2-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line) temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidity for measurement days is indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figure 4.2-2 through 4.2-5. Emission calculation exclusion regions due to surrounding sources (wind directions of 90° through 135°) are indicated as a grayed region in the figure. Winds were generally from the north

during periods 3 (Winter), 4 (Spring), and 6 (Fall) and from the south or southwest during periods 2 (Fall), 5 (Summer), 9 (Summer). Wind directions were highly variable during periods 6 (Fall), 7 (Winter), and 8 (Spring). Winds speeds were commonly greater than 5 ms^{-1}.

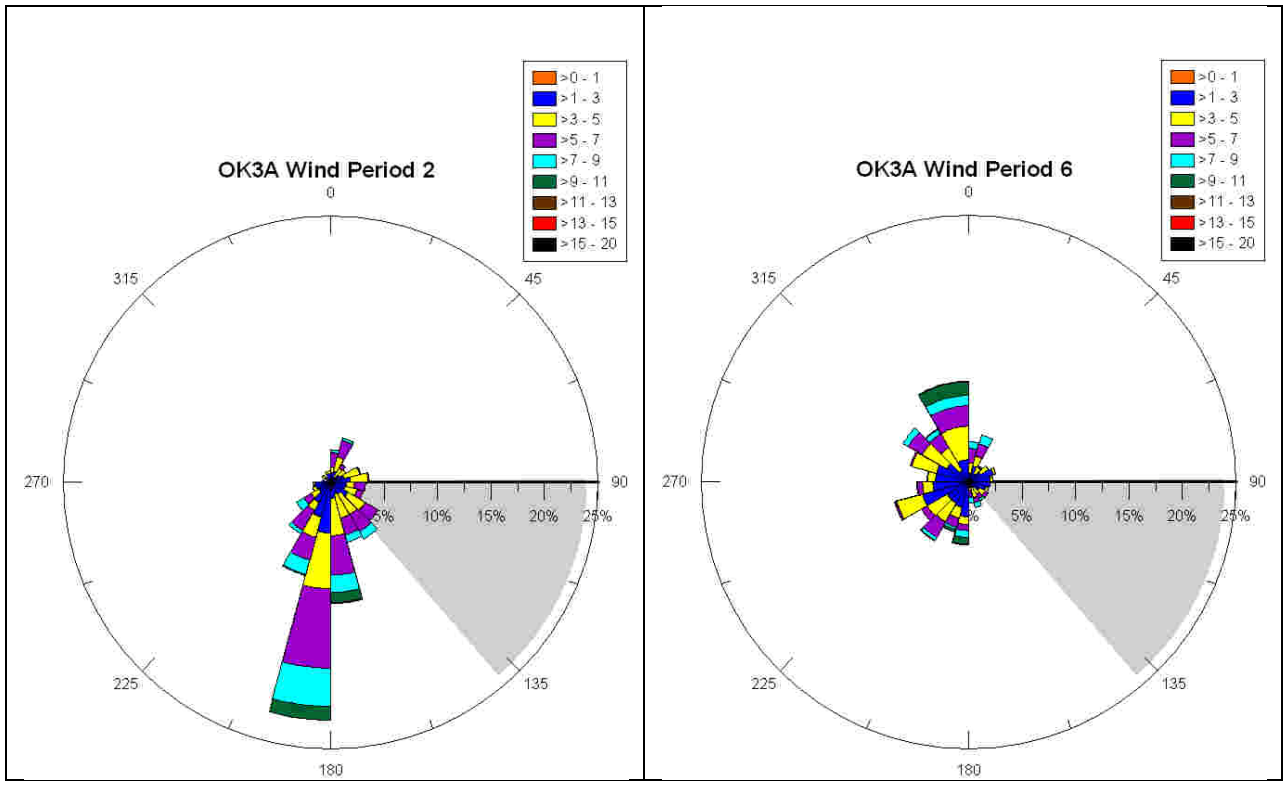

Figure 4.2-2: Wind roses for ½ hourly wind measurements during the Fall measurement periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m/s) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

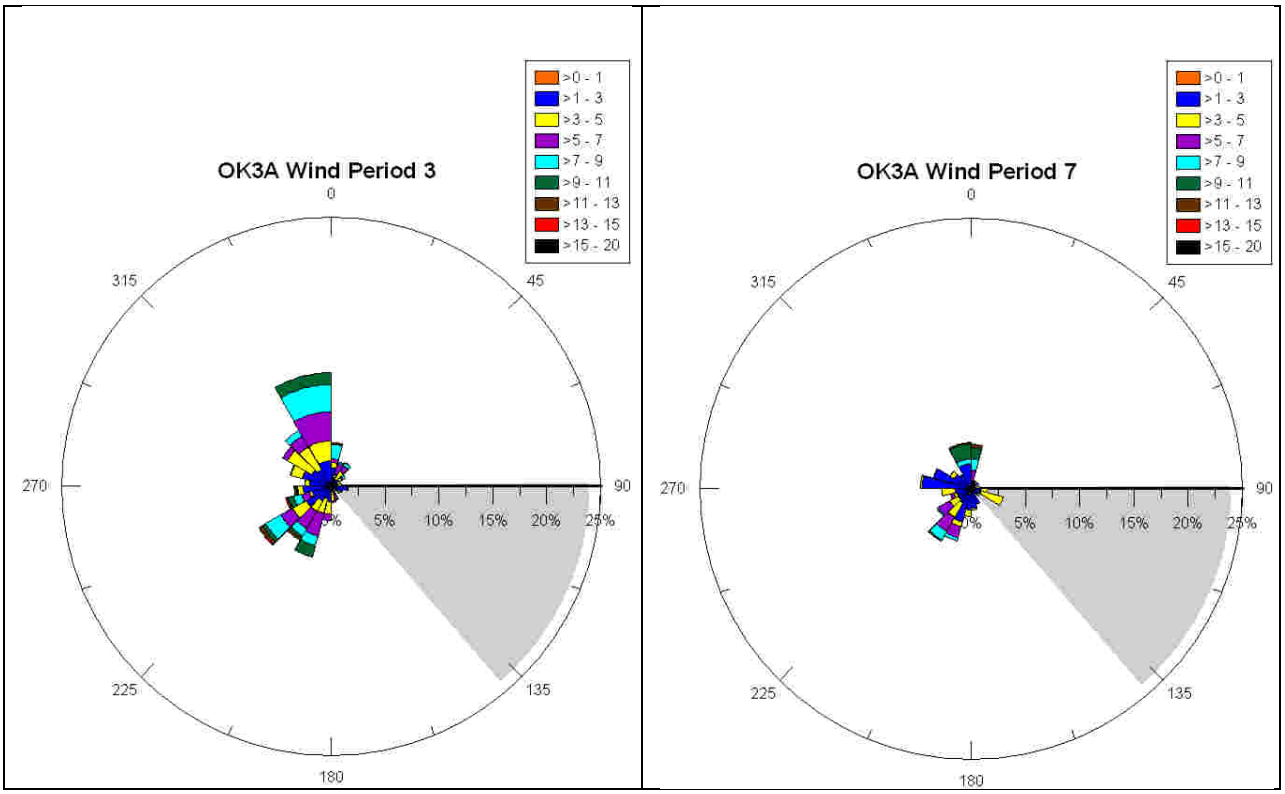

Figure 4.2-3: Wind roses for ½ hourly wind measurements during the Winter measurement periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m/s) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

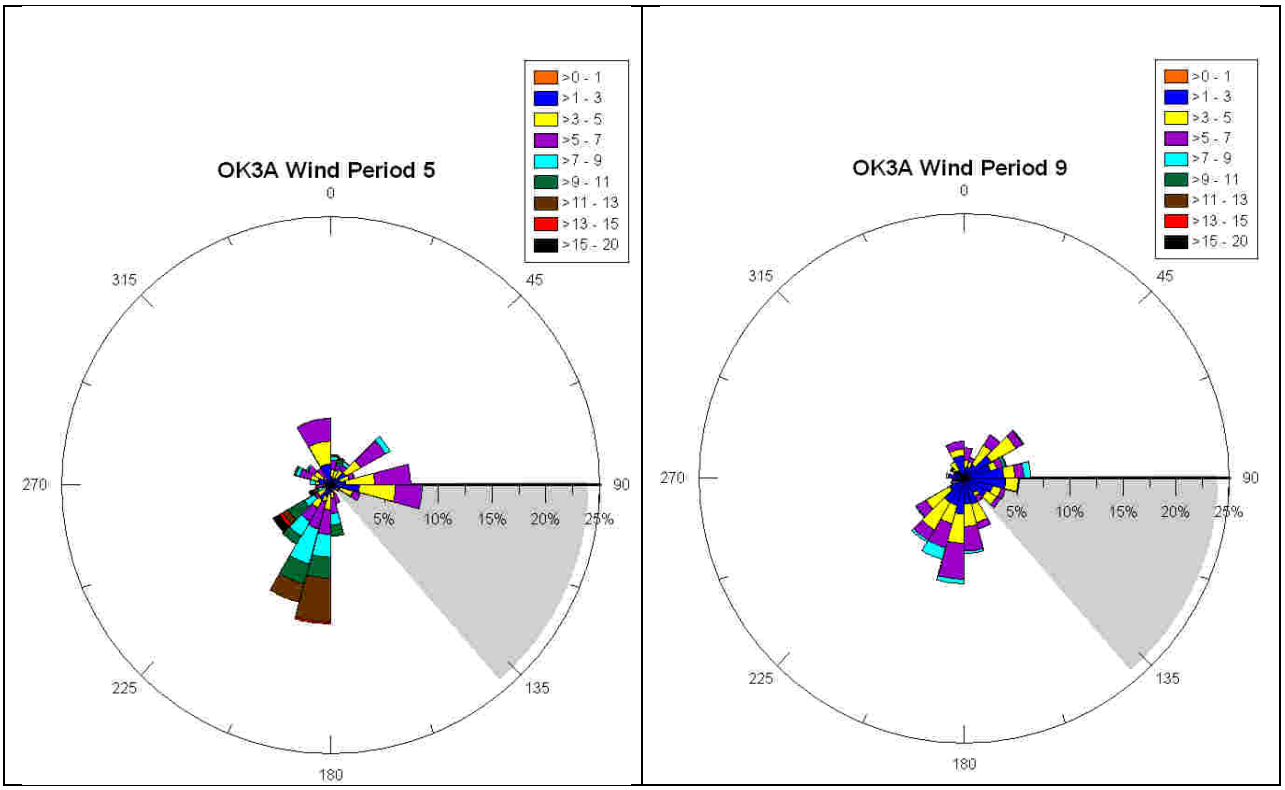

Figure 4.2-4: Wind roses for ½ hourly wind measurements during the Summer measurement periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m/s) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

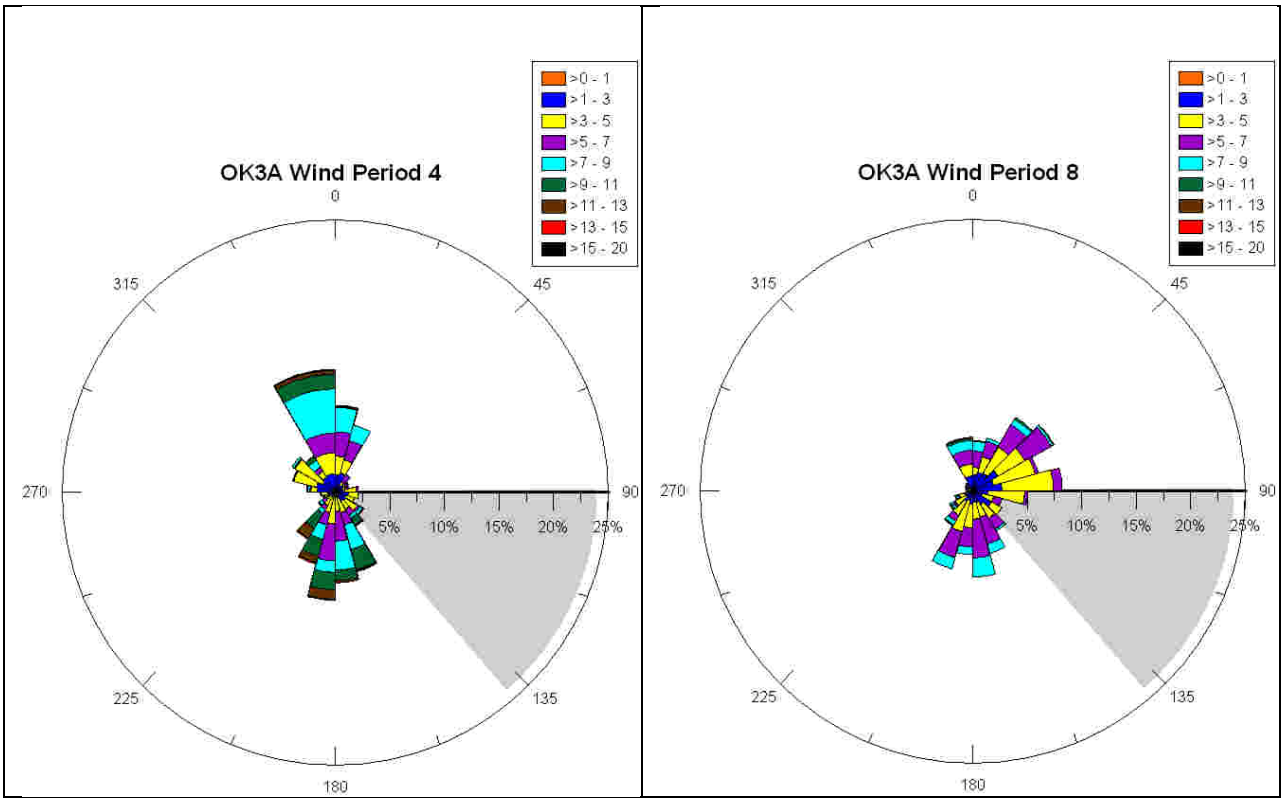

Figure 4.2-5: Wind roses for ½ hourly wind measurements during the Spring measurement periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m/s) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

4.3 Lagoon conditions

4.3.1 Lagoon appearance, liquid depth and sludge depth

The appearance of the lagoon was recorded on almost every site visit (Table 4.3-1). The lagoon generally appeared brown with surface characteristics ranging from frozen during the winter to free of crust during the remainder of the year.

Table 4.3-1: Lagoon physical characteristics

OK3A	Date, appearance (color/crust)	Liquid depth	Sludge depth	Source of meas.
Period		(m)	(m)	
2: 8/29 - 9/19/2007	8/30/2007 brown/red/foamy 8/31/2007 brown/red/ no crust 9/18/2007 brown/red/ no crust 9/19/2007 brown/red/ 20% crust	5.26	N/A	Producer
3: 1/24 - 2/19/2008	1/24/2008 brown/ 100% frozen 1/25/2008 brown/ 100% frozen 2/5/2008 brown/ no crust 2/6/2008 brown/ no crust 2/19/2008 brown/red/ 5% crust	5.54	N/A	Producer
4: 5/07 - 5/29/2008	5/6/2008 brown/ no crust 5/7/2008 brown/ no crust 5/8/2008 brown/ no crust/100% film 5/19/2008 brown/ 15% scum 5/28/2008 brown/ 15% crust 5/29 /2008 brown/ no crust	5.69	N/A	Producer
5: 5/29 - 6/10/2008	5/29/2008 brown/ no crust 6/10/2008 brown/ no crust	5.71	N/A	Producer
6: 11/04 - 12/3/2008	11/5/2008 brown/ no crust 11/6/2008 brown/red/ 5% scum 11/7/2008 brown/red/ no crust 11/17/2008 brown/ no crust 12/2/2008 brown/red/ no crust 12/3/2008 brown/ no crust	5.41	N/A	Producer
7: 12/03 - 12/16/2008	12/3/2008 brown/ no crust 12/16/2008 brown/red/ 50% frozen	1/5/2009 5.56	N/A	Producer
8: 4/21 - 5/14/2009	4/21/2009 Black/ 40% scum 4/22/2009 brown/ 30% scum 4/23/2009 brown/ 50% scum 5/6/2009 brown/ 20% scum 5/14/2009 brown/ 10% scum	4/14/2009 5.49	N/A	Producer
9: 7/14 - 8/4/2009	7/14/2009 brown/ no crust 7/15/2009 brown/ no crust 7/16/2009 brown/black/ no crust 8/4/2009 Black/ no crust	N/A	N/A	

4.3.2 Temperature, pH and oxidation-reduction potential

The measured lagoon liquid temperature varied from 0.9^{o}C to 27.9^{o}C with the lowest temperatures just prior to when the sensors were removed in anticipation of the lagoon freezing during the winter (Section 6.11). The measured lagoon pH varied from 7.4 to 8.2 (Section 6.11) while the oxidation-reduction potentials varied from -201 mV to -591 mV over the entire study period (Section 6.11).

4.3.3 Lagoon Chemistry

Lagoon water chemical analyses were not conducted by the project but analyses required by the NRCS at the time of water removal for field application were available for applications during the overall project period (Table 4.3-3).

Table 4.3-3: Record of lagoon chemistry

				Percent (wet weight basis)		
Date	**n**	**pH (SU)**	**Nitrogen**	**Solids**	**Ammonia**	**Sulfur**
11/28/2007	1	8.36	0.68	0.55	0.55	0.03
11/19/2008	1	8.26	0.46	0.43	0.45	0.03
7/17/2009	1	7.90	0.57	0.40	0.49	0.02

4.4 Emissions measurements

Emissions data were calculated on a ½ hour basis since this was the interval over which the S-OPS system sampled both sides of the lagoon and since this interval is in the range over which turbulence statistics are often calculated. To account for the longer term manure storage of the lagoon, emissions reported on a head basis were scaled by the animal population for which the facility was designed and not the animal population at the time of measurements. Emissions reported on an animal unit (AU) basis (1 AU = 500 kg) assumed the typical animal weight values reported by the producer. Emissions reported on an area basis are based on the surface area of the lagoon.

Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison was based on 1414 half-hour measurement periods over the entire measurement time at this location. Results show that the bLS emissions did not have a significantly difference precision (F=0.68, critical F 1.0) but had a significant bias over the *RPM* emissions (t=-9.92, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 1.06 (Table 4.4.1-1). Consequently the ½ hour bLS emissions measurements are biased low by 17% compared to the *RPM* measurements.

Table 4.4.1-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	**bLS**	**bLS-RPM**
Mean emission (g/s)	0.94	0.80	-0.013
Standard Deviation (g/s)	0.747	0.614	
Variance of the mean (g/s)	0.558	0.377	

4.4.1 NH3 Emissions

4.4.1.1 Mean daily NH_3 emissions

An annual trend in the daily NH_3 emissions based on the *RPM* model was indicated (Figure 4.4.1-1) with an early fall maximum emission of approximately 60 g $NH_3 d^{-1} hd^{-1}$. The spring and

summer lagoon emissions were similar at between 20 g $NH_3d^{-1}hd^{-1}$ and 40 g $NH_3d^{-1}hd^{-1}$. The daily emissions during the winter decreased to approximately 5 g $NH_3d^{-1}hd^{-1}$. The measurements with potential for atmospheric moisture interference could be low by 40% (Figure 4.4.1-1: green circles). There were only a small number of measurements with more than 75% of the day's emissions measured. The wide variability during the spring and fall in combination with the few 'complete' days of measurements limits confidence in the magnitude of the emissions. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

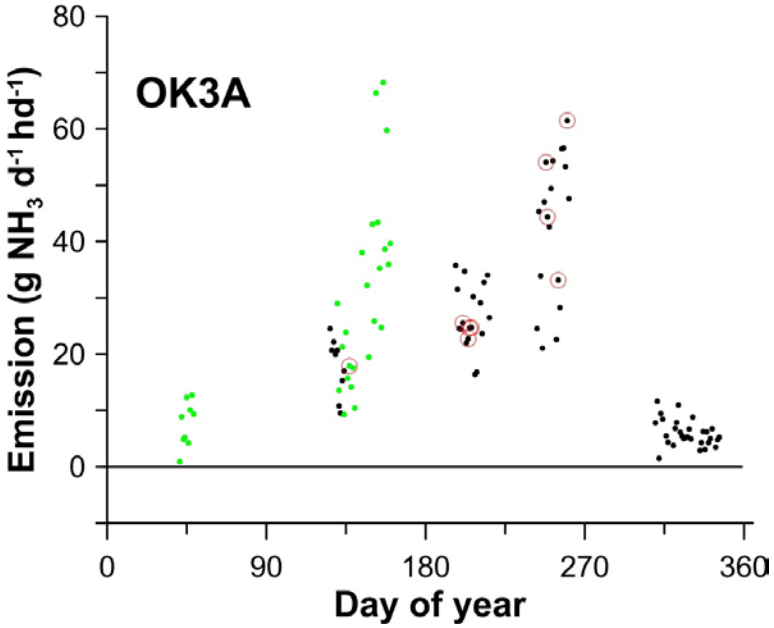

Figure 4.4.1-1: Annual variation in RPM-computed daily NH_3 emissions. The green solid circles indicate moisture interference with the NH_3 concentration measurement. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

An annual trend in the daily NH_3 emissions based on the bLS model was indicated (Figure 4.4.1-2); again with an early fall maximum emission of approximately 60 g $NH_3d^{-1}hd^{-1}$. The spring and summer lagoon emissions were similar at between 15 g $NH_3d^{-1}hd^{-1}$ and 35 g $NH_3d^{-1}hd^{-1}$. The measurements with potential for atmospheric moisture interference could be low by 40% although comparisons between these measurements and those without interference suggest negligible effect of moisture on the NH_3 emissions at this relatively dry location (Figure 4.4.1-2: green circles). Measurements with more than 75% of the day's emissions measured include days in summer, fall, and winter providing a good confidence that the emission measurements are representative. There was however still a relatively wide range in emissions from day to day. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

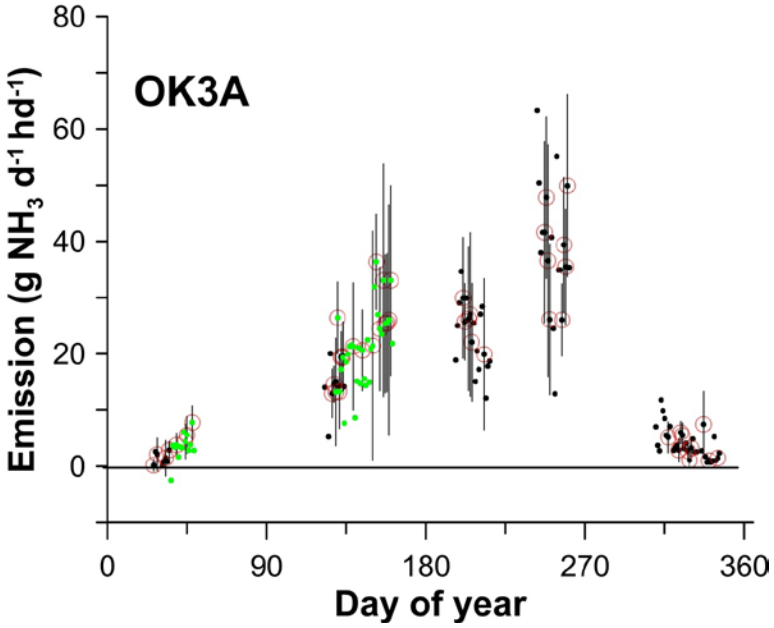

Figure 4.4.1-2: Annual variation in bLS-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

The bLS model is influenced by the calculated background concentrations. Results indicate that the background concentration of NH_3 was generally less than 0.2 ppm (Figure 4.4.1-3). Given that the typical path length around the lagoon was 100 m and the typical background concentration is less than 0.2 ppm, this corresponds to a background concentration for a given PIC of less than 20 ppm-m. This is approximately ten times the MDL for the TDLAS instruments of 2 ppm-m (Section 8.1) and therefore represents a real background for this location. This may be expected given the relatively high density of swine production units in the vicinity of this farm.

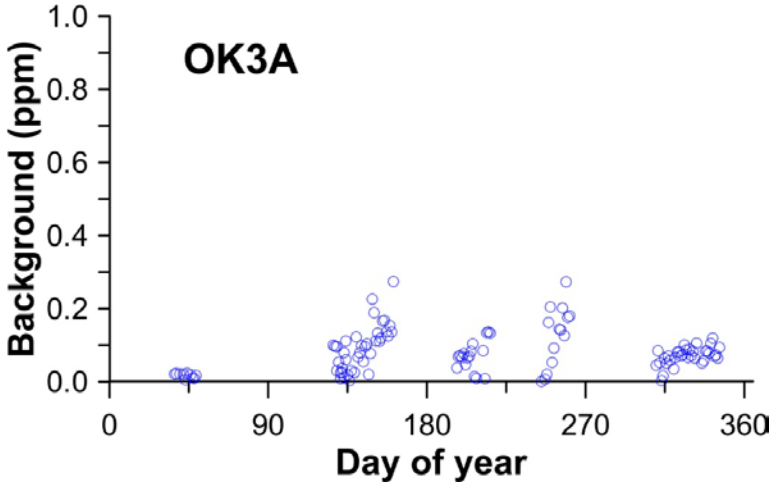

Figure 4.4.1-3: Annual variation in bLS-computed mean daily background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

In general, there was not a strong diurnal pattern to the NH_3 emissions. A diurnal pattern in the emissions was evident during only three of the eight measurement periods (Figure 4.4.1-4). This lack of diurnal pattern was likely due to the generally high winds at the location.

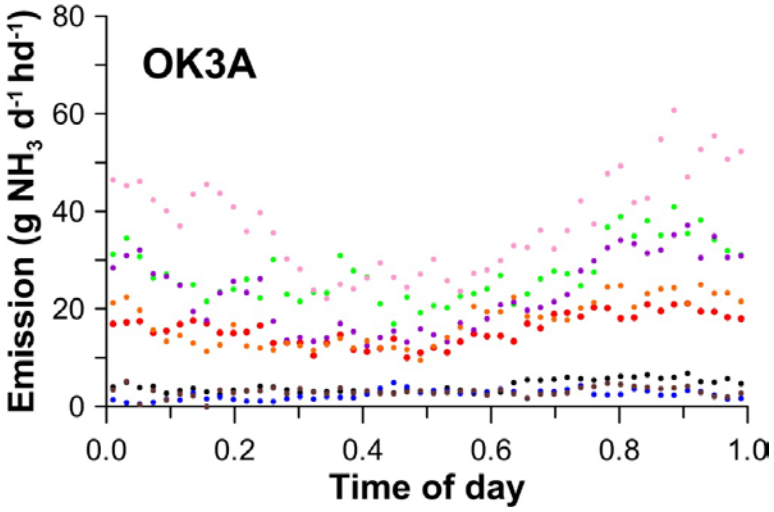

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 2-Fall (pink), Period 3- Winter (brown), Period 4- Spring (orange), Period 5-Summer (green), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ hour intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ hour periods (corresponding to 75% completeness on a daily basis) is given. Because of the requirement of 5 to 10 valid TDLAS measurements before an *RPM* emission measurement is possible, the number of valid ½ hour periods with *RPM* emissions was greatly limited. The wind conditions and wind direction exclusion region did not greatly reduce the yield of valid bLS emission measurements. The completeness statistics by measurement period are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH3 emissions measurements

	Measurement period								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
NH3 RPM model									
Valid 1/2 hour measurements (d)	8.2	0.9	4.5	2.8	7.0	3.0	3.1	8.0	**37.5**
Measurements excluded due to wind direction (d)	0.7	0.0	0.0	0.5	0.5	0.4	0.9	1.0	**4.0**
Measurements excluded because at least one downwind path is missing or invalid (d)	6.8	15.7	13.4	6.4	11.4	1.3	16.0	8.9	**79.8**
Number of days with ≥ 36 valid 1/2 hour periods	4	0	1	0	0	0	0	4	**9**
NH3 bLS model									
Valid 1/2 hour measurements (d)	11.6	13.0	11.9	9.5	12.1	4.8	6.1	11.3	**80.5**
Measurements excluded due to wind direction (d)	1.4	0.2	0.2	1.3	1.0	0.6	0.9	1.3	**7.0**
Measurements excluded because touchdown fraction < 0.1 (d)	0.4	0.5	2.2	0.0	4.2	0.0	3.1	1.3	**11.7**
Measurements excluded because u* < 0.15 m/s or |L| < 2 m (d)	3.4	4.6	2.4	0.8	4.3	2.0	1.8	4.5	**23.6**
Number of days with ≥ 36 valid 1/2 hour periods	8	8	6	8	7	3	4	6	**50**

In total, 37 d of valid NH_3 emissions were determined from the 161 measurement days using the *RPM* model, with 30 d having at least 36 valid ½ hour NH_3 emissions. The absence or invalidation of at least one downwind path led to 80 d for which emissions could not be calculated.

Eighty days of valid NH_3 emissions were determined from the 161 measurement days using the bLS model, with 50 d having at least 36 valid ½ hour NH_3 emissions. The exclusion wind directions due to the location of the barns relative to the lagoon resulted in the loss of only 7 d of measurements. Invalid turbulence statistics ($u_* < 0.15$ m/s or $|L| < 2$ m) led to 23 d for which emissions could not be calculated. A touchdown fraction of less than 0.1 led to the exclusion of

11.7 d of data. Low touchdown fractions indicated that little, if any, downwind data was available. This corresponded to either when the downwind TDLAS was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ hour interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ hour mean wind speed and direction, in contrast to the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times that the *RPM* model produces a valid emission that the bLS model does not. However, these times are overwhelmed by the times that the *RPM* model is missing concentration data for one or more paths, while the bLS model is able to run.

4.4.2 H2S Emissions

4.4.2.1 Mean daily H_2S emissions

Emissions of H_2S calculated using the Ratiometric model were highest in the spring and decreased throughout the rest of the year (Figure 4.4.2-1). Peak emissions were approximately 10 g H_2S d^{-1} hd^{-1}. There was however wide variability in H_2S emissions from day to day during the spring and summer (Figure 4.4.2-1). Since only one day had more the 75% of the ½ periods with valid emissions measurements, there is no confidence that the emissions pattern illustrated is representative of conditions on the farm. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

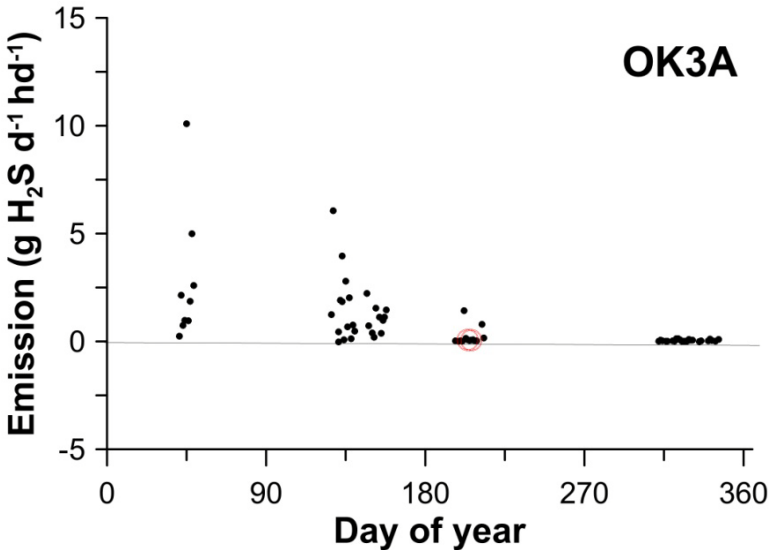

Figure 4.4.2-1: Annual variation in Radiometric-computed daily H_2S emissions. The green solid circles indicate moisture interference with the NH_3 concentration measurement. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

Emissions of H_2S determined using the bLS model suggested that emissions during the winter and spring are highest at approximately 5 g H_2S d^{-1} hd^{-1} with the emissions decreasing throughout the rest of the year (Figure 4.4.2-2). Peak emissions were approximately 10 g H_2S d^{-1} hd^{-1} with wide variability in H_2S emissions from day to day during the winter and spring (Figure 4.4.2-2). A near-zero emission during the summer, fall and early winter is strongly indicated. The relatively large number of days with at least 75% of the ½ hour emissions measurements valid confirms the emission tendencies for this location. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

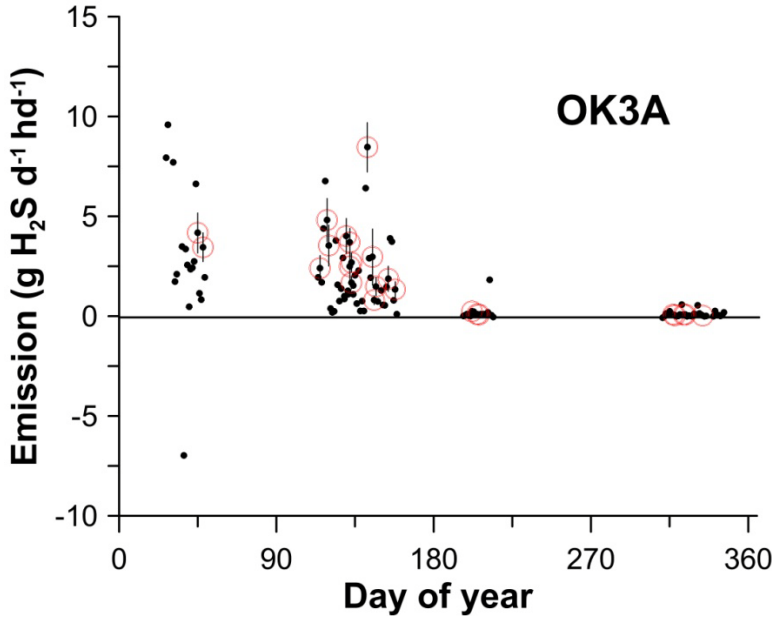

Figure 4.4.2-2: Annual variation in bLS-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS emission model depends on a good estimate of the background H_2S concentration. Results indicate that the background concentration was generally less than ± 2.5 ppb (Figure 4.4.2-3).

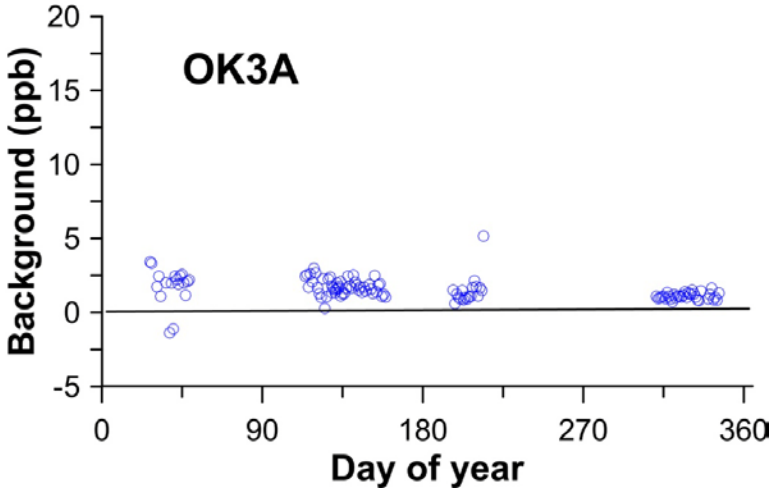

Figure 4.4.3-3: Annual variation in mean bLS-computed daily background concentration of H_2S.

4.4.2.2 Diurnal variation in H_2S emissions

The H_2S emissions calculated using the bLS model generally showed a diurnal trend when emissions were greater than approximately 0.5 g H_2S d^{-1} hd^{-1} (Figure 4.4.2-4). Highest emissions occurred during the day.

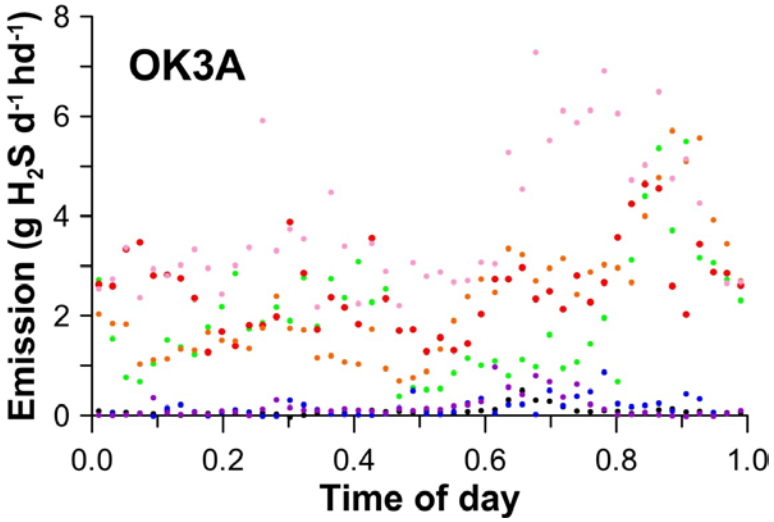

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 3- Winter (pink), Period 4- Spring (orange), Period 5- Summer (green), Period 6- Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.2.3 H_2S emissions data completeness

H_2S Measurements were begun in Period 3. Consequently there were no measurements possible for fall 2007. As described for the NH_3 emissions, emissions completeness and failure totals are

given in number of days corresponding to the total number of ½ hour intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics by measurement period are summarized in Table 4.4.2-1.

Because there were few valid ½ measurements of the NH_3 emissions based on the *RPM* model (Table 4.4.1-2), the number of valid ½ periods of valid Ratiometric emissions measurements of H_2S is small. The majority of bLS emissions measurements were invalidated due to wind conditions. In total, 27 d of valid H_2S emissions were determined using the Ratiometric emission method, with 17 d having at least 36 valid ½ hour H_2S emissions. Forty-five days of valid H_2S emissions were determined using the bLS model, with 24 d having at least 36 valid ½ hour H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ m/s or $|L| < 2$ m) and excluded wind directions contributed equally to the invalidation of measurements.

Table 4.4.2-1: Completeness statistics for H2S emissions measurements

	Measurement period								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
H2S Ratiometric model									
Valid 1/2 hour measurements (d)		0.5	3.2	0.7	4.8	1.1	1.6	5.6	**17.6**
Number of days (d) with ≥ 36 valid 1/2 hour periods		0	0	0	0	0	0	2	**2**
H2S bLS model									
Valid 1/2 hour measurements (d)		8.3	13.8	5.0	13.5	1.6	12.5	8.3	**62.9**
Measurements excluded due to wind direction (d)		0.2	1.1	1.1	1.0	0.0	2.0	1.8	**7.2**
Measurements excluded because angle of attack < 60° (d)		2.0	1.6	2.3	5.1	0.8	3.8	2.0	**17.5**
Measurements excluded because u* < 0.15 m/s or |L| < 2 m (d)		3.5	2.5	0.6	4.3	1.3	1.7	4.3	**18.2**
Number of days (d) with ≥ 36 valid 1/2 hour periods		2	7	2	5	0	5	3	**24**

4.4.3 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of TDLAS serial numbers 1026, 1027, and 1028 prior to July 21, 2008. TDLAS 1026 was used at OK3A from 1/24/2008 to 2/19/2008 (Measurement period 3), 5/7/2008 to 5/29/2008 (Measurement period 4), and 5/29/2008 to 6/10/2008 (Measurement period 5). Under the calibration verification checks, the allowed TDLAS error of all units was 10% accuracy. Howe ver due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and units without apparent interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from dewpoint temperatures of -2°C to 20°C. A conservative estimate of the bias of all of the above TDLAS units with evident moisture interference was -40%.

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions, underestimated by 13% under unstable conditions, and overestimated by 38% under stable

conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%. Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was -14% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -54% for TDLAS NH_3 measurements made by units with moisture interference and a bias of-14% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the Ratiometric measurement of H_2S emissions was ± 18%.

5 References

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6 Appendices

6.1 TDLAS NH3 calibrations

Six TDLAS units (Model GasFinder2^{TM} NH3OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used for measurements at this location: TDLAS 1026, TDLAS 1027, TDLAS 1028, TDLAS 1029, TDLAS 1031 and TDLAS 1032.

TDLAS 1026 was multipoint calibrated seven times during the study (Figure 6.1-1). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 1/17/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3,$$

where X was the instrument response. The response of the sensor was influenced by humidity until July, 21 2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration resulted in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and were well within the precision DQI. The accuracy DQI was ± 10% of

the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and 11/10/2009 exceeding biases were followed the same or next day with a passing verification and were deemed to be a result of operator error. The negative bias over the period 4/2/2008 through 7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used) and was only intermittently evident during operations because two different multipoint calibration were applied to the calibration verification measurements. Repeated calibrations within 24 h often showed biases differing by more than 10 ppm-m, suggesting operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period are considered valid and the error is assumed to be due to the calibration verification operator.

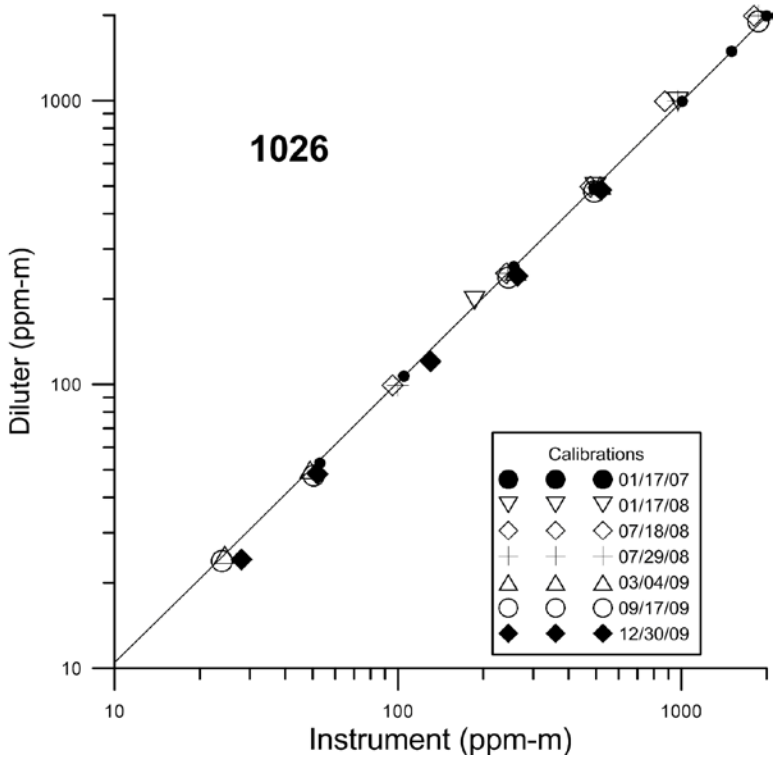


Figure 6.1-1: Multipoint calibrations of the GasFinder2 ™ s/n NH3OP-1026. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

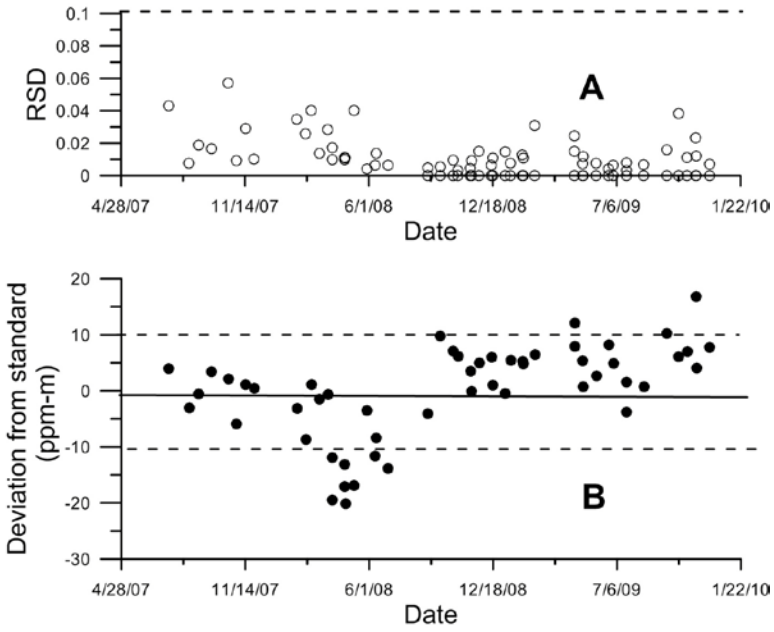


Figure 6.1-2: Control charts of the GasFinder2 ™ s/n NH3OP-1026

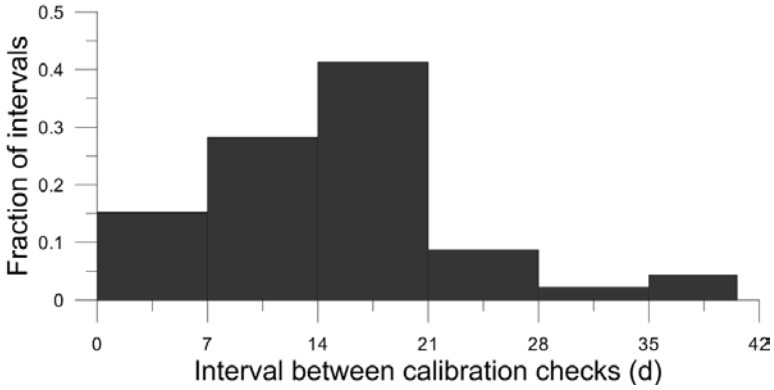


Figure 6.1-3: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1026

TDLAS 1027 was multipoint calibrated eight times during the study (Figure 6.1-4). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 6/18/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 2.24 + 0.9936 * X - 3.59E\text{-}5 * X^2 + 6.230E\text{-}8 * X^3,$$

where X was the instrument response. The response of the sensor was influenced by humidity until July, 21 2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration resulted in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.13 ppm-m prior to the July 2008 modification and 1.83 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 5.36 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 9/26/2008 and 9/24/2009 (Figure 6.1-5). No negative biases exceeding the DQI occurred. Since both positive exceeding biases were followed by a DQI compliant verification on the subsequent calibration verification without intervention, it is assumed that operator error was the cause for the non-compliance.

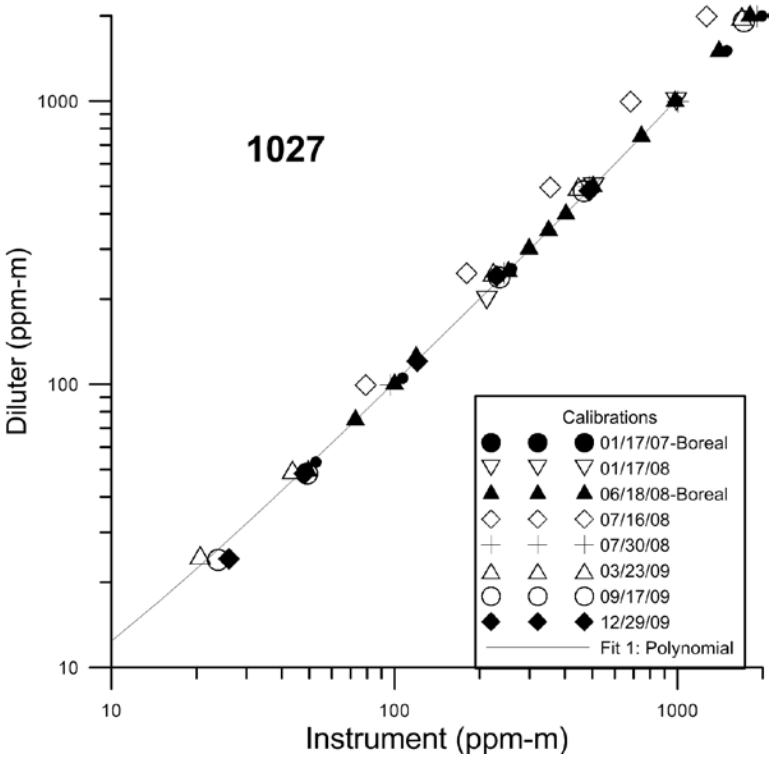


Figure 6.1-4: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1027. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

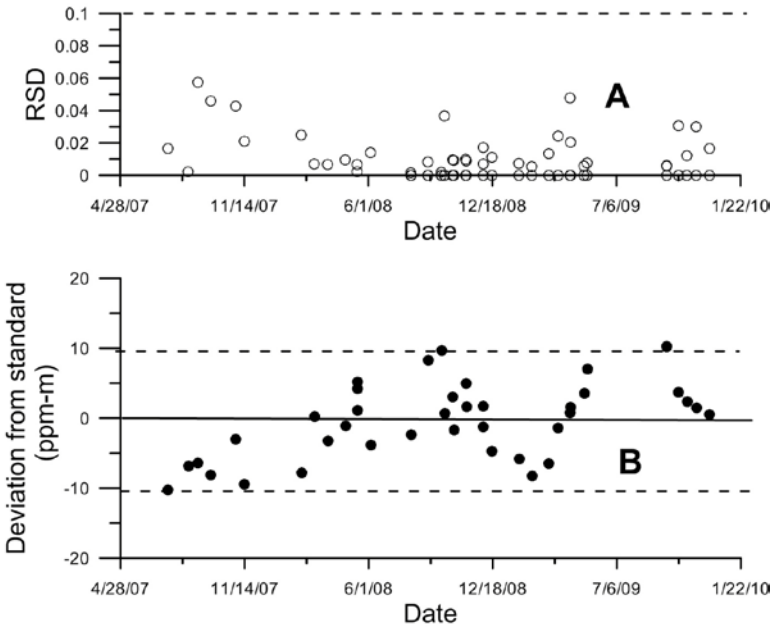


Figure 6.1-5: Control charts of the GasFinder2 [TM] s/n NH3OP-1027

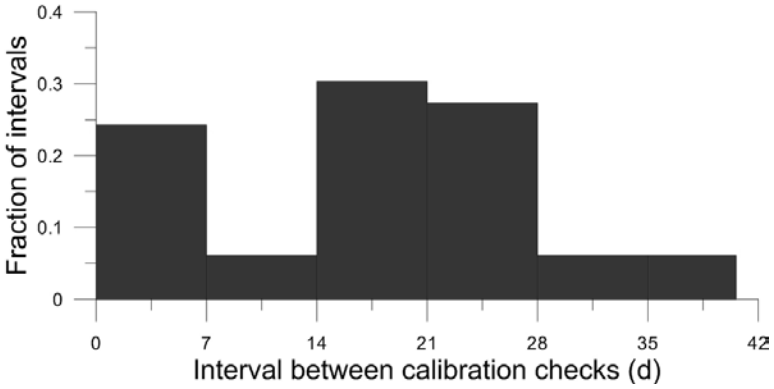


Figure 6.1-6: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1027

TDLAS 1028 was multipoint calibrated six times during the study (Figure 6.1-7). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 5/23/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$ppm\text{-}m = 1.46 + 0.985 * X + 8.465E\text{-}6 * X^2 + 3.879E\text{-}8 * X^3$,

where X was the instrument response. The response of the sensor was influenced by humidity until July, 21 2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r2 reached by the instrument when in the field for long path lengths and high humidity.
A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d was the result of calibration checks made at

the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-8) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 6.1-8). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceeding biases and it is concluded that operator error resulted in the exceeding biases rather than instrument failure.

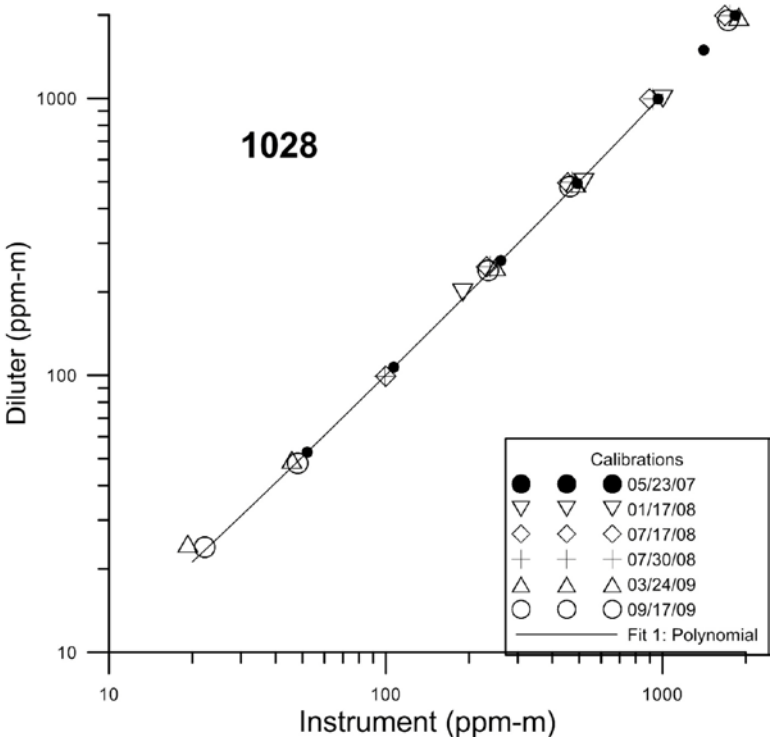


Figure 6.1-7: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1028. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

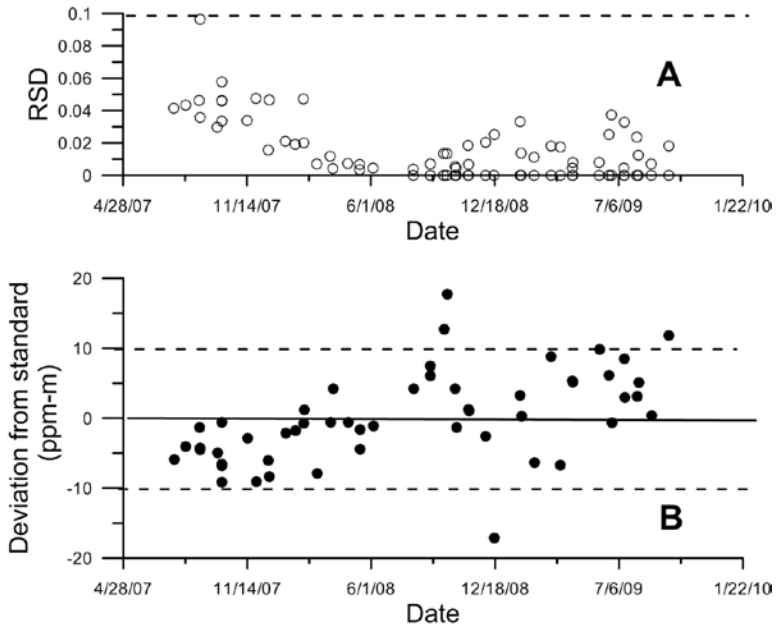


Figure 6.1-8: Control charts of the GasFinder2 ™ s/n NH3OP-1028

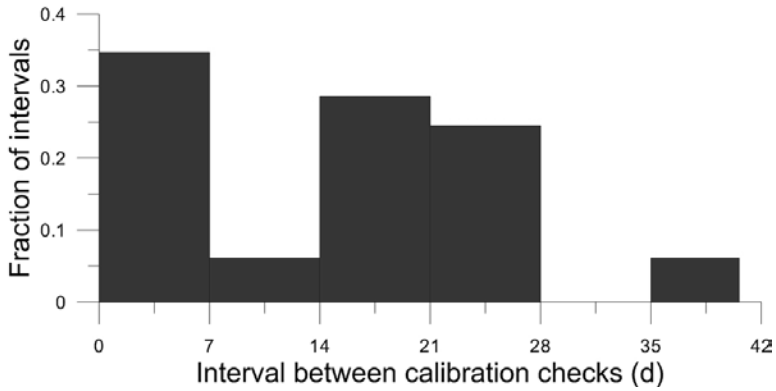


Figure 6.1-9: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1028

TDLAS 1029 was multipoint calibrated seven times during the study (Figure 6.1-10). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-1 indicated the multi-point calibrations used during different periods in the study.

Table 1- Multi-point calibration application

Period of applicability (MM/DD/YYYY)		
Begin	**End**	**Multipoint calibration**
6/24/2007	3/1/2008	5/24/2007
3/24/2008	7/15/2008	3/24/2008
7/31/2008	8/3/2009	3/4/2009
8/4/2009	12/2/2009	12/29/2009

The offsets of the calibration equations were determined from a least squares fit of the appropriate period (Table 1) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

5/24/2007: ppm-m = -1.48 + 0.967 * X + 4.842E-005 * X^2 - 7.312-009 * X^3

3/24/2008: ppm-m = -2.58 + 0.998 * X - 1.611E-004 * X^2 + 7.449E-008 * X^3

3/4/2009: ppm-m = 4.36 + 1.069 * X + 1.128-004 * X^2 - 1.206E-007 * X^3

12/29/2009: ppm-m = 5.48+ 1.268 * X - 6.072E-005 * X^2

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.74 ppm-m prior to the July 2008 modification and 1.66 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL prior to the July 2008 modification was greater than the offset in the calibration regression equations but less than the offset in the calibration equations after the modification. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-12). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equations was 4.65, 4.15, 5.23, and 4.27 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-11) and well within the precision DQI.

The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI threshold occurred on two dates (Figure 6.1-11). No positive bias exceeding the DQI threshold occurred. In all cases subsequent calibration verifications did not indicate the same exceeding bias and it is concluded that operator error resulted in the exceeding biases rather than instrument failure.

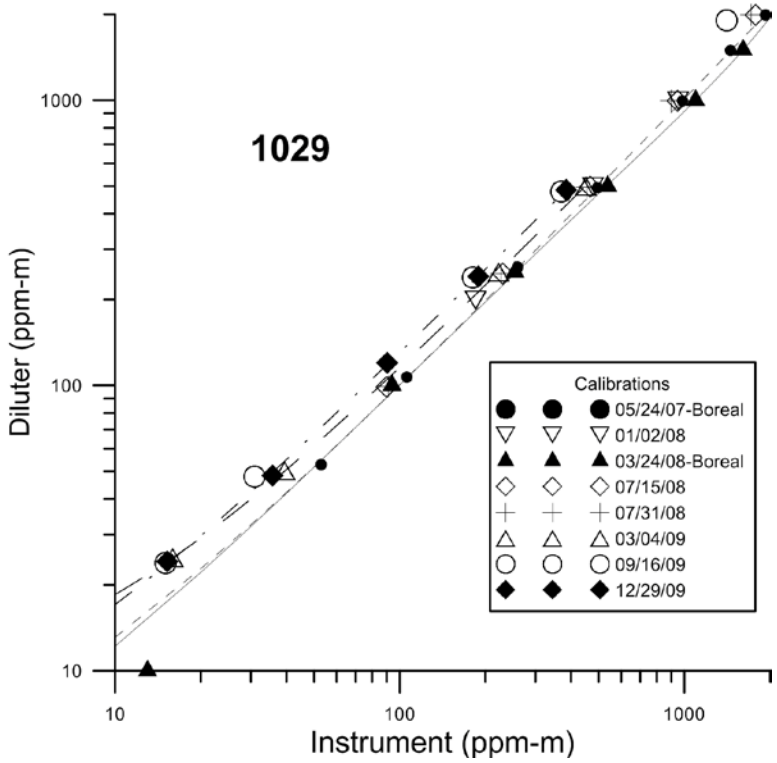


Figure 6.1-10: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1029. The solid (5/24/2007), dotted (3/24/2008), dashed (3/4/2009) and dash-dot (12/29/2009) lines are the 3rd order polynomial regression for the chosen multipoint calibration.

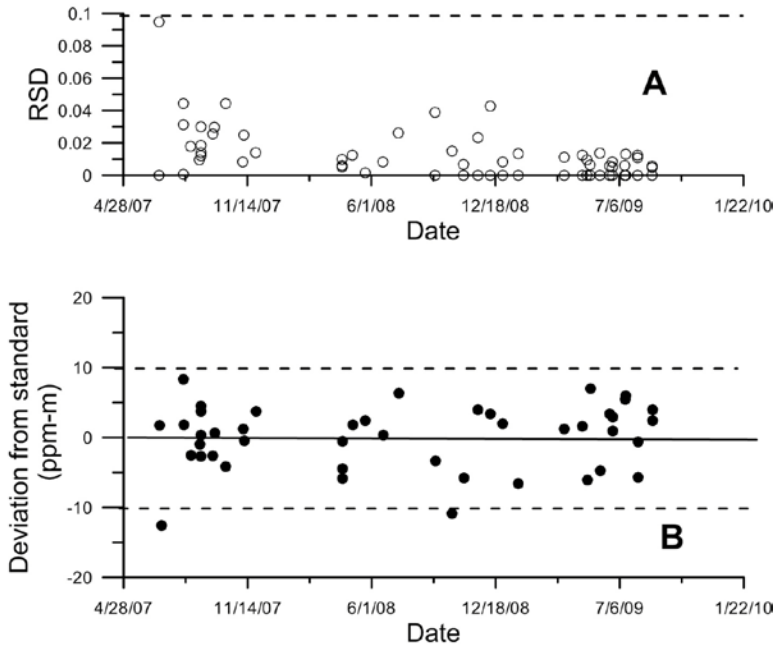


Figure 6.1-11: Control charts of the GasFinder2 ™ s/n NH3OP-1029

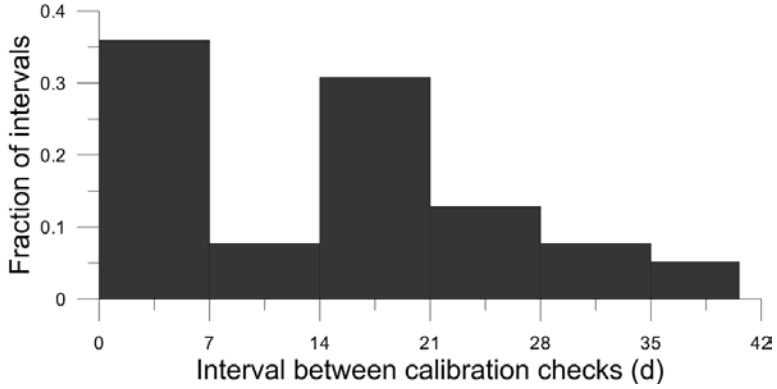


Figure 6.1-12: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1029

TDLAS 1031 was multipoint calibrated six times during the study (Figure 6.1-13). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multi-point calibration on 5/30/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$ppm\text{-}m = -4.43 + 1.0120 * X - 5.7496E\text{-}005 * X^2 + 6.0196E\text{-}008 * X^3,$

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 5.70 ppm-m prior to the July 2008 modification and 1.92 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The average MDL was approximately equal to the offset indicated in the calibration regression. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-14) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-15). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 15.60 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-14) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI occurred in the calibration verifications between 8/2/2007 and 9/18/2007 (Figure 6.1-14). Positive DQI exceeding biases occurred on 6/28/2007, 9/11/2008, 4/8/2009 and 8/12/2009. Verification failures in the 6/28/2007 to 9/18/2007 interval were a result of un-anticipated optical noise in the calibration procedure which was later corrected. The 4/8/2009 exceeding bias was preceded and followed by DQI-compliant verifications and the 8/12/2009 verification was preceded by a compliant verification and followed by a multi-point indicating no problem with instrument performance. The instrument was taken out of service between 9/11/2008 and 12/31/2008.

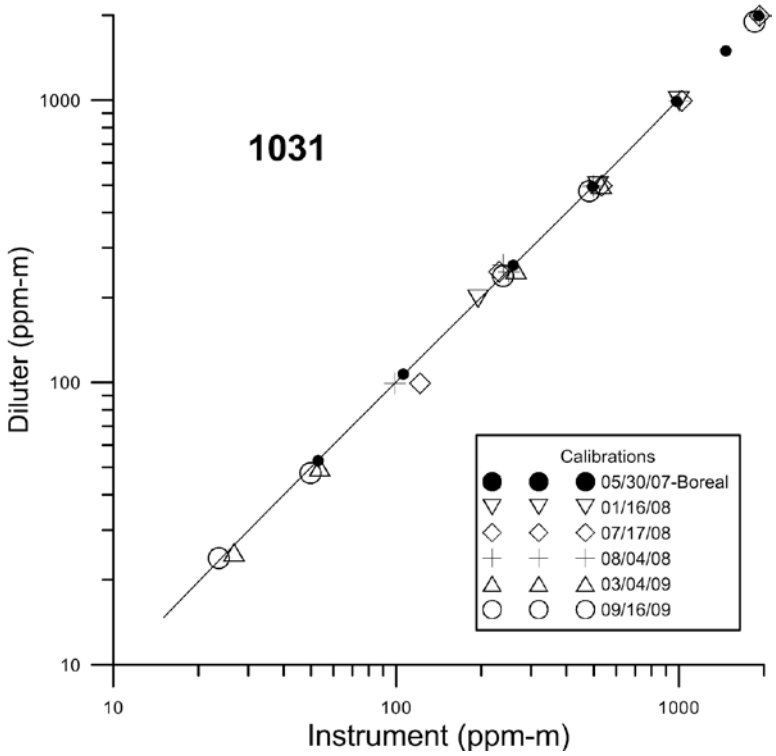


Figure 6.1-13: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1031. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

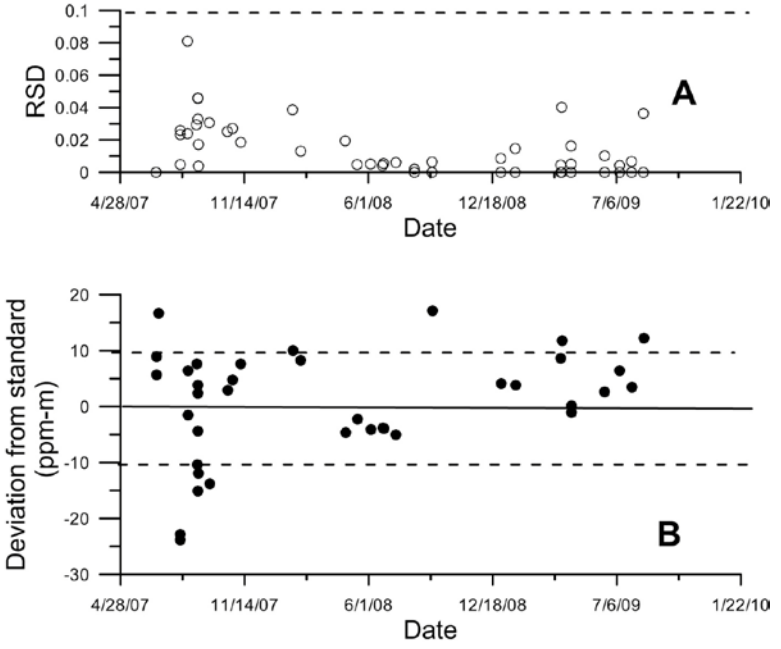


Figure 6.1-14: Control charts of the GasFinder2 [TM] s/n NH3OP-1031

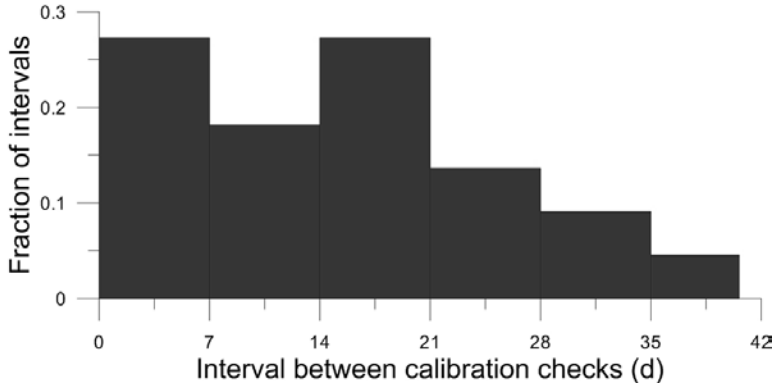


Figure 6.1-15: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1031

TDLAS 1032 was multipoint calibrated six times during the study (Figure 6.1-16). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-2 indicated the multi-point calibrations used during different periods in the study.

Table 6.1-2: Multi-point calibration application

Period of applicability (MM/DD/YYYY)		
Begin	**End**	**Multipoint calibration**
9/21/2007	8/1/2008	9/12/2007
8/27/2008	8/18/2009	3/4/2009

The offset of the calibration equation was determined from a least squares fit of the appropriate period (Table 6.1-2) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

9/12/2007: ppm-m = -4.35 + 1.005 * X + 3.563 E-005 * X^2 - 2.618 E-008 * X^3

3/4/2009: ppm-m = -0.69 + 0.995 * X - 2.3298 E-004 * X^2 + 2.891 E-007 * X^3

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments). The laser was found on 7/21/2008 to not be internally grounded properly, resulting is the inclusion of responses at very low light levels. The no-return light levels were above the minimum light level threshold considered for a valid instrument measurement.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The

MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.60 ppm-m prior to the July 2008 modification and 1.36 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL was greater than the offset in the calibration equation for measurements prior to July 2008 and less than that after July 2008. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-17) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-18). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.13 and 5.61 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-17) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias exceeding the DQI occurred on 3/26/2008 and 9/10/2008 (Figure 6.1-17). These exceeding biases were preceded and followed by valid calibration verifications and it was assumed that since no modifications of the instrument were made that the exceeding biases were due to operator error. A negative bias exceeding the DQI was indicated in the calibration verifications on 5/6/2008 (Figure 6.1-17). The grounding problem found on 7/21/2008 (described above) may have been the cause for the period of consistently negative verifications after 4/21/2008 when the background light levels exceeded the minimum acceptable light level. However since the 5/6/2008 exceeding bias was followed by compliant verifications (although low) without correction of the grounding problem it is assumed that the measurements were valid throughout the period of the grounding problem.

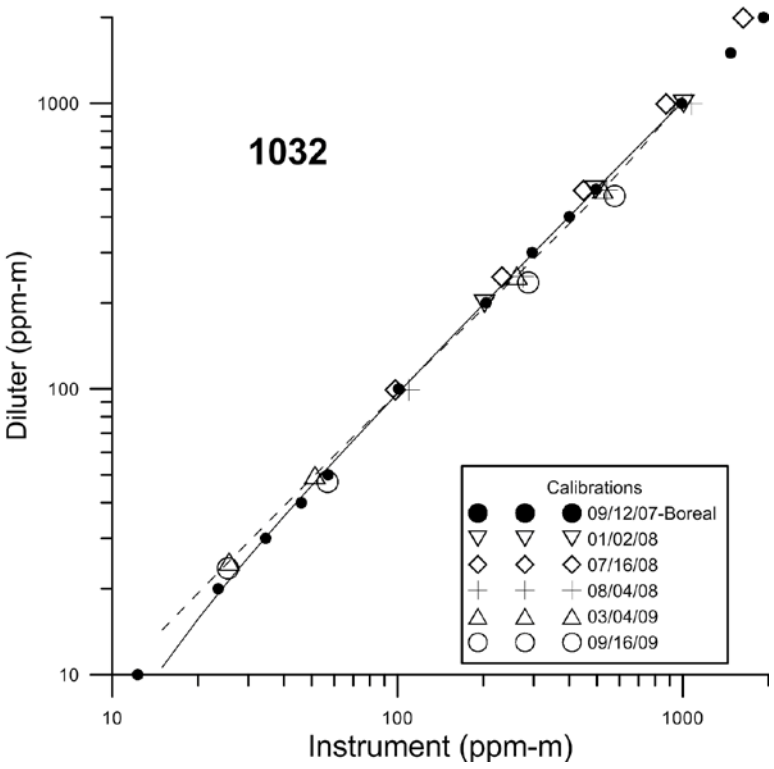


Figure 6.1-16: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1032. The solid (9/12/2007) and dashed (3/4/2009) lines are the 3rd order polynomial regressions for the chosen multipoint calibration.

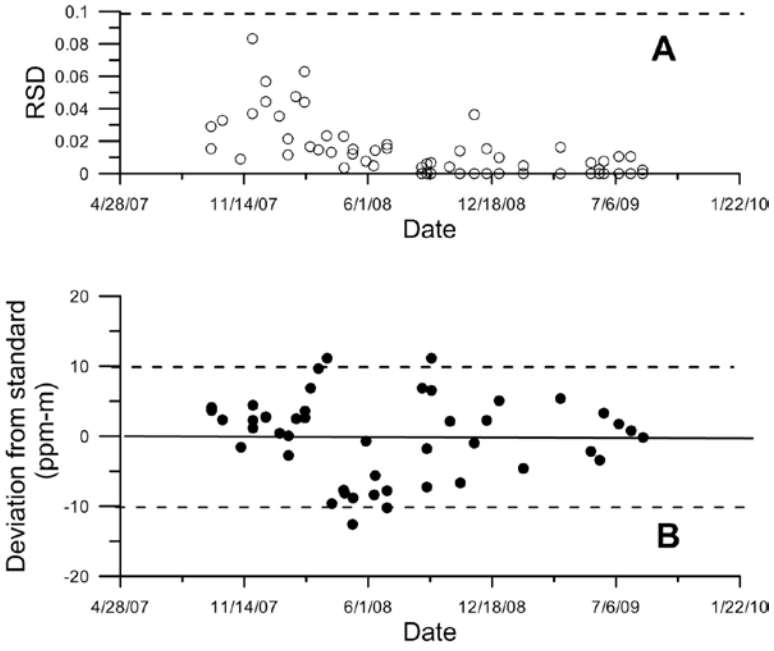


Figure 6.1-17: Control charts of the GasFinder2 [TM] s/n NH3OP-1032

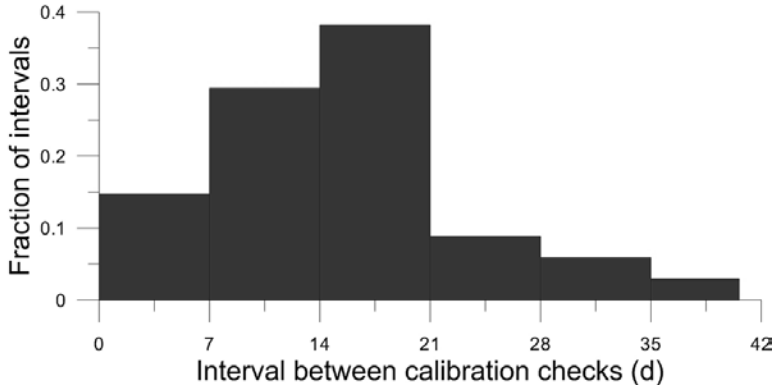


Figure 6.1-18: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1032

6.2 TEC 450i analyzer H_2S calibrations

The H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA) with serial number 0733825128 was multipoint calibrated eight times during the study (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.73 to 1.38 (Table 6.2-1). Part of the variation in slope was a result of the H_2S calibration cylinders used. The initial multipoint calibration was conducted prior to the complete burn-in of the converter and consequently differs greatly from the other calibrations.

Table 1- Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r2
12/12/2007	1.38	-0.0220	0.999
7/11/2008	0.99	0.0034	0.999
8/13/2008	1.18	-0.0045	0.999
9/4/2008	1.22	0.0065	0.999
3/25/2009	0.73	0.0068	0.999
6/19/2009	1.14	-0.0037	0.999
6/24/2009	0.75	0.0075	0.999
9/9/2009	1.14	-0.0052	0.999

The standard deviation of instrument response with CEM zero air measured over a one hour period was 0.83 ppb (10/19/2009). The instrument MDL, defined as 3σ, was 2.5 ppb and is indicated in Figure 6.2-2A with dashed lines. This value was much less than the mean absolute multipoint calibration intercept concentration of 7.5 ppb.

Instrument performance calibration checks (Figure 6.2-2, 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.2-4). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.788. The mean zero concentration was +1.7 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). Three major periods of instrument bias that exceeded the ± 10% of FS are evident (Figure 6.2-2). The first period extended from the beginning of the measurements until 9/5/2008. Based on the correlation of instrument performance and the calibration cylinder used, it was determined that the concentration of H_2S in the SGAL053 cylinder, which could not be independently verified, was significantly below the indicated specification. This resulted in unusually high ratios of diluter concentration versus instrument response (1.01 to 1.18) up until the cylinder was replaced. The second period was from 11/4/2008 to 12/16/2008 when the calibration checks were inconsistent. Checks conducted on 11/04 and 12/16 at the end of measurement periods failed while checks made two days later at the set up of the next site passed. Since no

modifications/repairs of the instruments were done in the interim between these calibrations, it was assumed that the FOS must have erred in his or her procedures.

The third period of calibration check failures occurred after April 2009. High zero checks (Figure 6.2-2A) and low reference checks (Figure 6.2-2B) occurred throughout this time. The instrument response time was found to be unusually long (11 min versus typical 5 min) when specifically checked in July 2009. After the prescribed 10 minute interval, as was specified in the SOP, the response was only 59% of the span value when the long time constant was discovered. Given the SOP reference value of 0.5 ppm, the 59% response after 10 min corresponds to approximately 0.2 ppm less than the stabilized reference value. The control chart of the calibration checks (Figure 6.2-2) showed a shift in response of approximately -0.2 ppm, which occurred in May 2009 and continued through July 2009 but appeared to return to normal operation in August 2009. This change in time response occurred during dusty conditions when the equipment was at WA5A. The change in response resulted in two multipoint calibrations in the field (Table 6.1-1).

The instrument measurement precision DQI was 10% of FS. Precision DQI exceeding biases (Figure 6.2-3) occurred on 9/5/2008, 6/4/2009 and 8/4/2009. The failure on 9/5/2008 was associated with a change in calibration cylinder (from SGAL053 to FF27944). As previously discussed, it is believed that the certified concentration in SGAL053 was low, resulting in a significant shift in the measured diluter concentration when the new cylinder began use. The failures on 6/4/2009 and 8/4/2009 were probably associated with the variable response of the instrument during the period that the shift in response time of the instrument occurred.

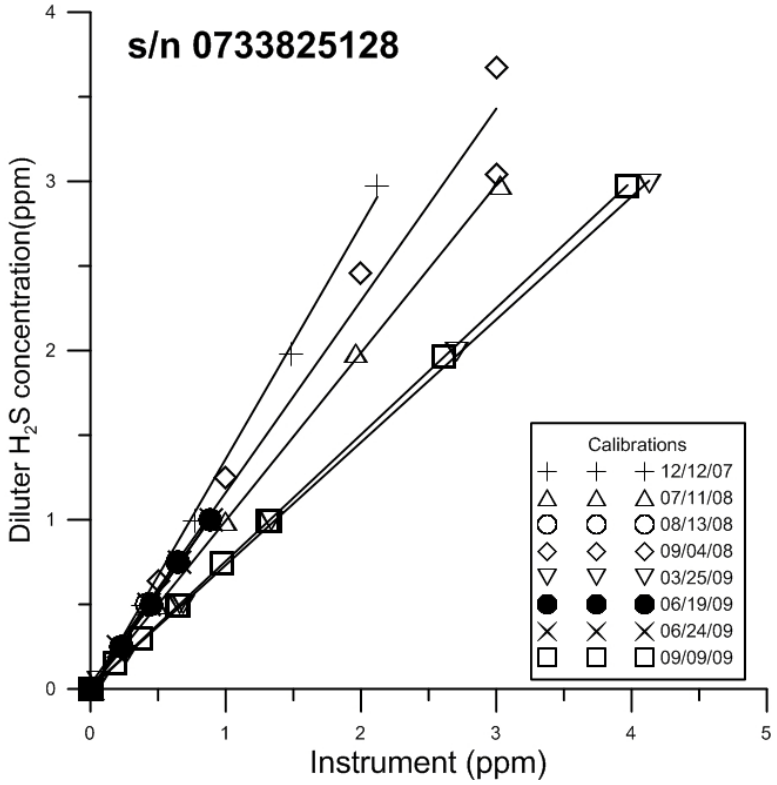


Figure 6.2-1: Multipoint calibrations of the 450i SO2/H2S Analyzer

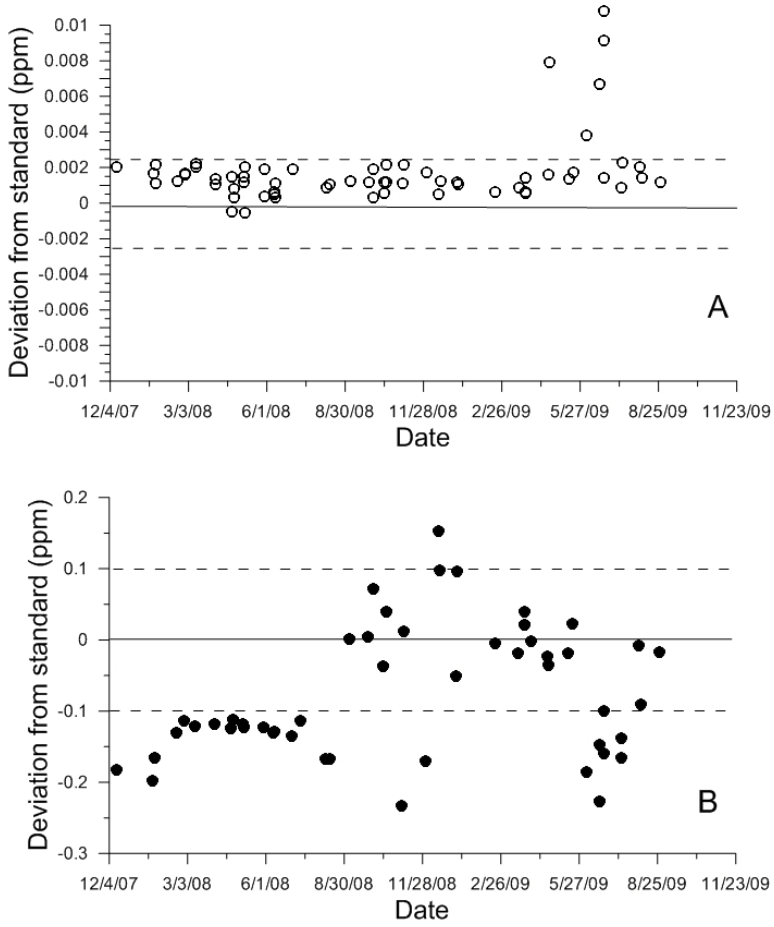


Figure 6.2-2: Instrument Control Charts.
The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

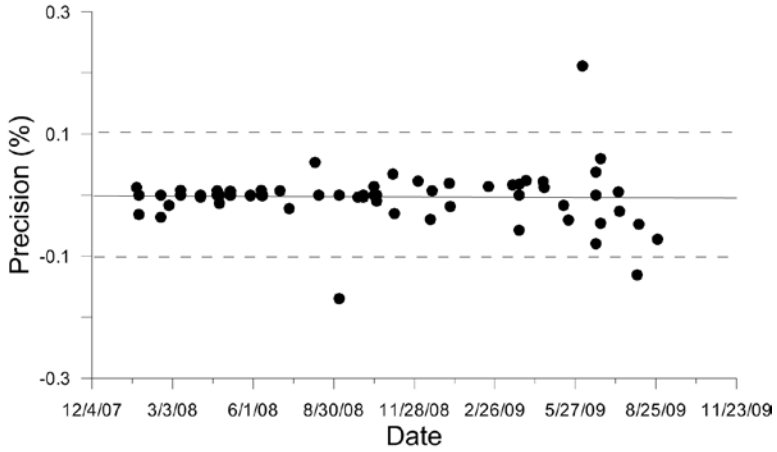


Figure 6.2-3: Instrument Precision
The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

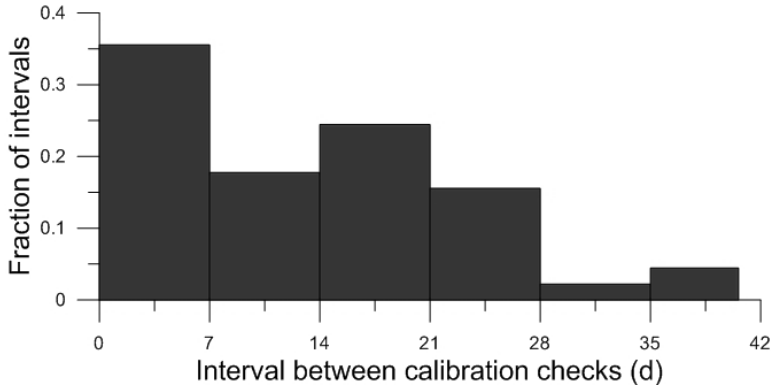


Figure 6.2-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Six sonic anemometers (Model 81000, RM Young Inc, Traverse City, MI) were used at this location: serial numbers 1920, 1921, 1927, 1928, 1932, and 1936.

Sonic anemometer 1927 was inter-compared with three standard anemometers of identical design, five times (Table 6.3-1). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check on all checks except 9/23-25/2008 when it was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back to use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-1: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.025	-0.043
1/21/2008	1/23/2008	-0.051	-0.033
7/16-17/2008	7/17-18/2008	+0.042	+0.029
3/23-25/2009	3/25-27/2009	-0.050	-0.028
9/1-2/2009	9/2-3/2009	-0.035	-0.023

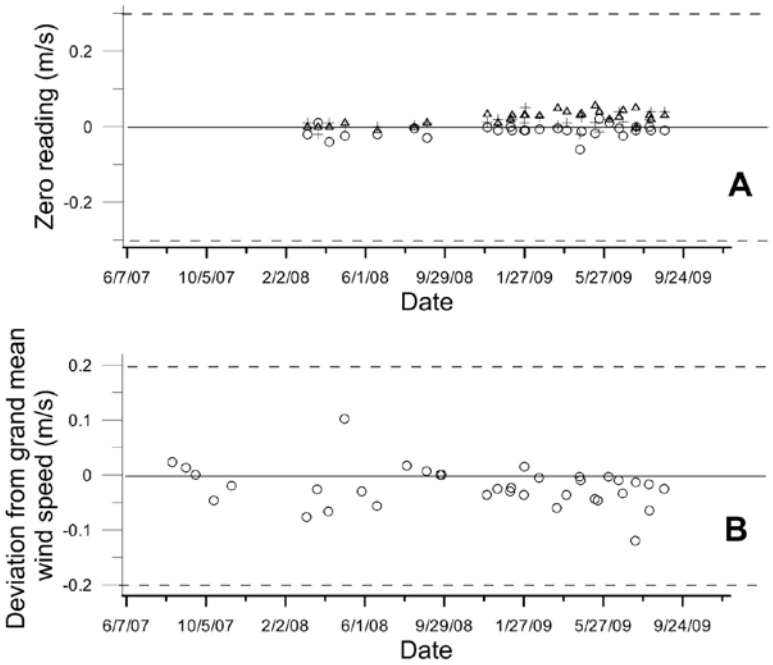


Figure 6.3-1: On-site quality assurance of s/n 1927. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

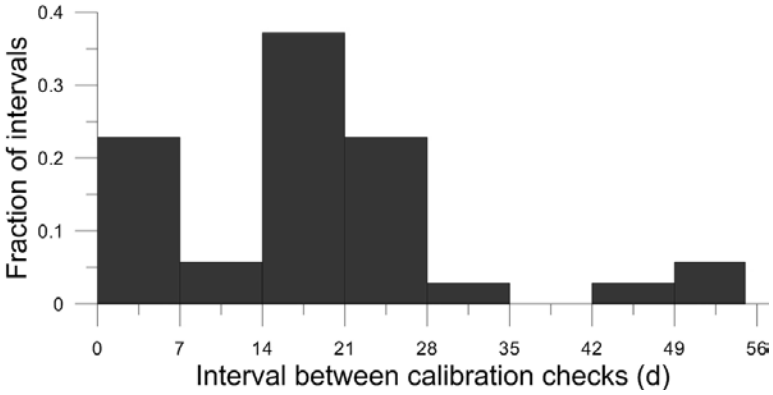


Figure 6.3-2: Inter-comparison check intervals for s/n 1927.

Sonic anemometer 1920 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-2). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 51 times (Figure 6.3-3). The majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-3B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair on 10/10/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-3A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-2: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29/2007-7/2/2007	+0.001	+0.002
1/17-19/2008	1/20-21/2008	+0.045	+0.003
7/18-21/2008	7/21-22/2008	+0.017	-0.006
3/23-25/2009	3/25-27/2009	-0.036	-0.033
9/1-2/2009	9/2-3/2009	-0.046	-0.025

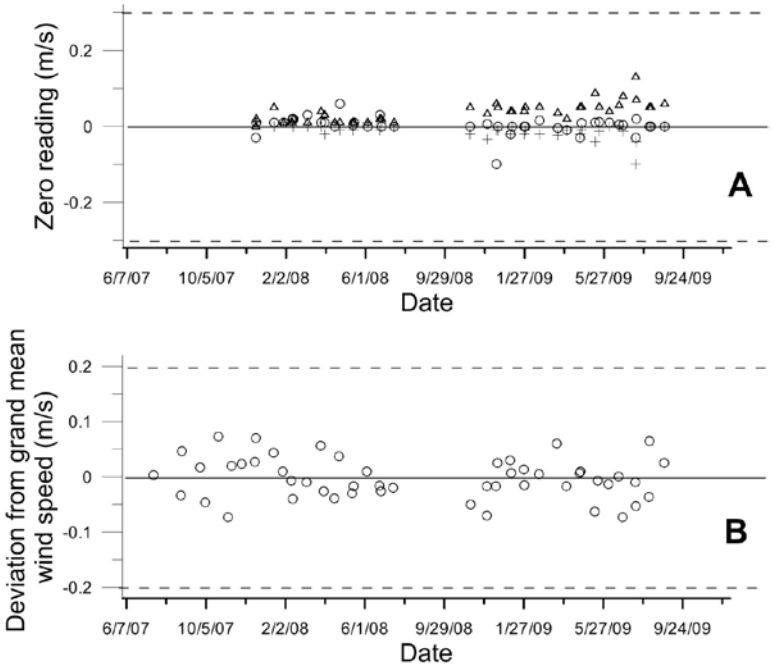


Figure 6.3-3: On-site quality assurance of s/n 1920. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

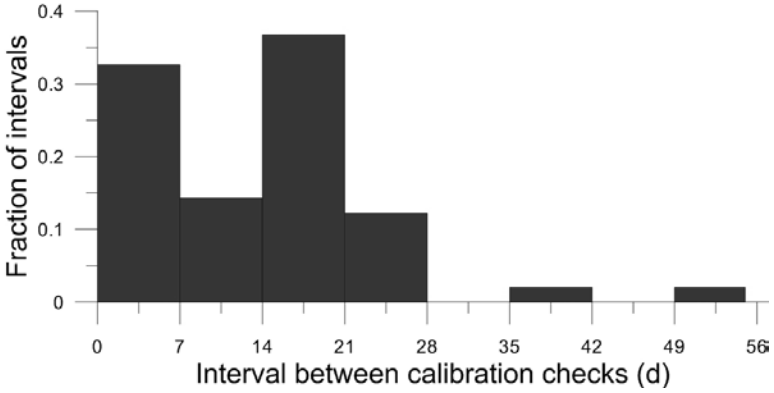


Figure 6.3-4: Inter-comparison check intervals for s/n 1920.

Sonic anemometer 1928 was inter-compared with three standard sonic anemometers of identical design six times (Table 6.3-3). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 48 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-5B). This instrument passed this check all but one time. On this one date, the inter-comparison was rerun and the instrument passed the check.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-3: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.004	+0.019
12/27-28/2007	12/29-31/2007	+0.003	-0.005
7/10-11/2008	7/11-14/2008	+0.022	+0.007
3/3-4/2009	3/5-6/2009	+0.070	-0.027
9/16-17/2009	9/17-18/2009	+0.056	+0.022
12/18-19/2009	12/21-23/2009	+0.094	-0.077

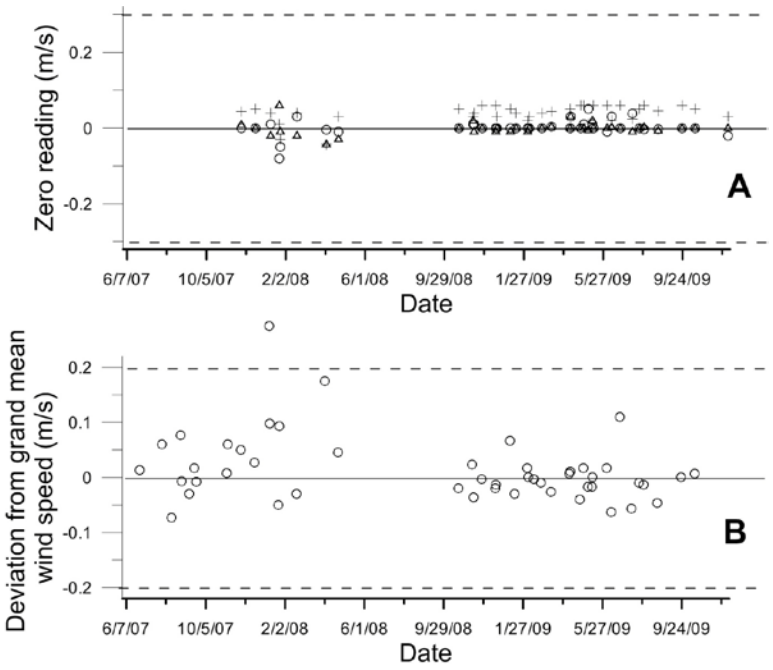


Figure 6.3-5: On-site quality assurance of s/n 1928. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

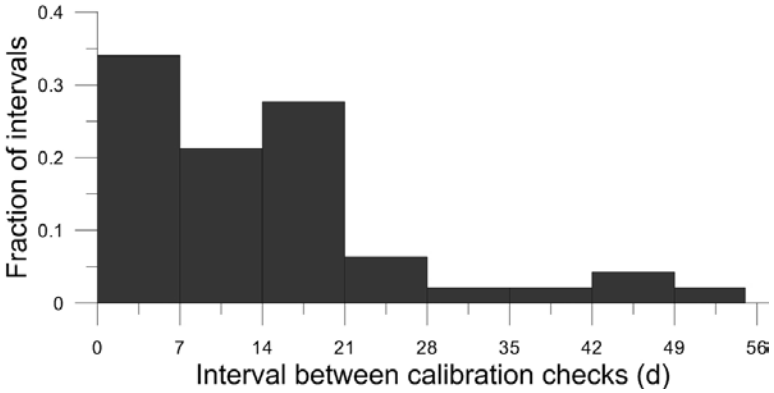


Figure 6.3-6: Inter-comparison check intervals for s/n 1928.

Sonic anemometer 1921 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-4). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 43 times (Figure 6.3-7). The majority of calibration checks were made within 21 d (Figure 6.3-8). The large fraction of checks made within 7 d were the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-7B). This instrument passed this check at all times. However, this instrument developed intermittent problems during operation and was sent to the factory for repair on 12/9/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-7A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-4: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.008	-0.003
12/27-28/2007	12/29-31/2007	-0.034	+0.001
7/10-11/2008	7/11-14/2008	+0.029	-0.022
3/23-25/2009	3/25-27/2009	-0.021	-0.040
9/8-14/2009	9/15-16/2009	+0.028	+0.038
12/18-19/2009	12/21-23/2009	+0.078	+0.002

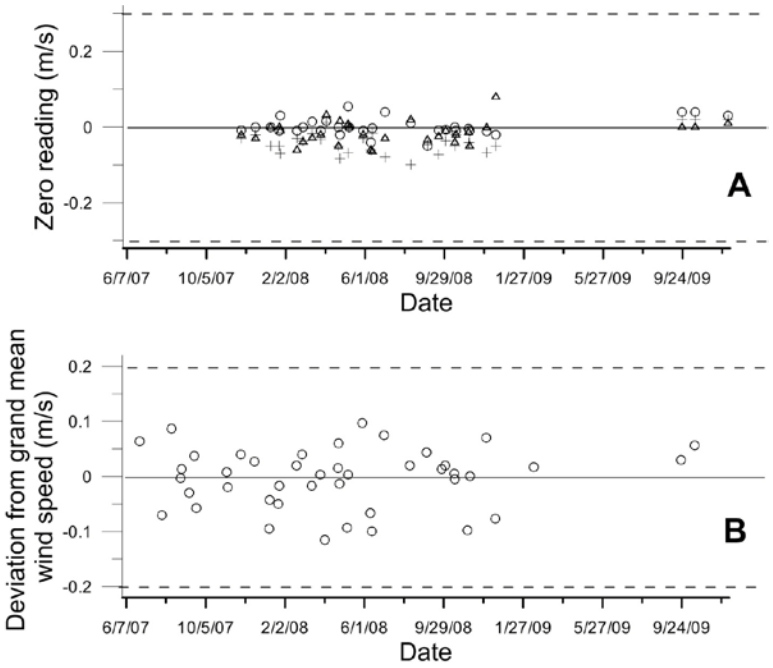


Figure 6.3-7: On-site quality assurance of s/n 1921. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

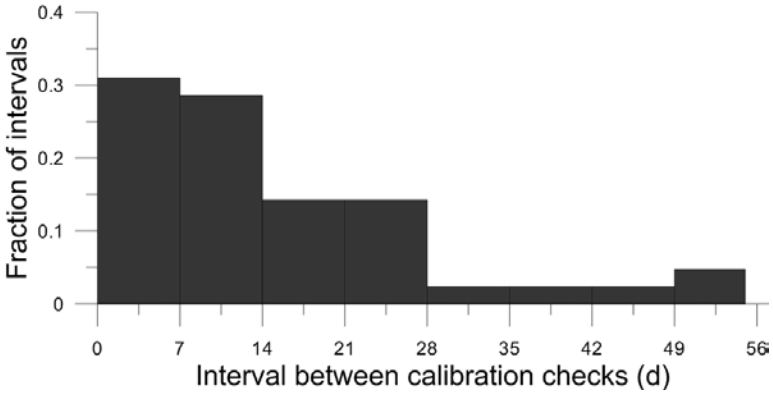


Figure 6.3-8: Inter-comparison check intervals for s/n 1921.

Sonic anemometer 1932 was inter-compared with three standard sonic anemometers of identical design six times during the study (Table 6.3-5). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 55 times (Figure 6.3-9). The majority of calibration checks were made within 21 d (Figure 6.3-10). The large fraction of checks made within 7 d was

the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-9B). This instrument passed this check on all checks except 10/15-16/2008 when it was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back to use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-9B). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-5: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-17/2007	6/18-19/2007	+0.004	+0.160
12/27-28/2007	12/29-31/2007	+0.014	-0.009
7/10-11/2008	7/11-14/2008	+0.008	+0.031
3/3-5/2009	3/5-6/2009	-0.024	-0.005
9/8-14/2009	9/15-16/2009	-0.025	-0.044
1/7-9/2010	1/23-24/2010	+0.020	-0.016

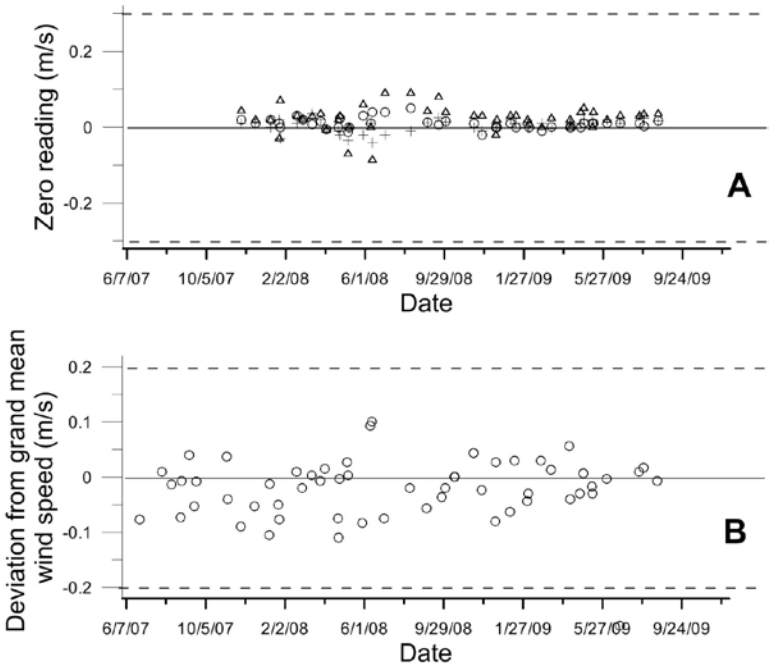


Figure 6.3-9: On-site quality assurance of s/n 1932. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

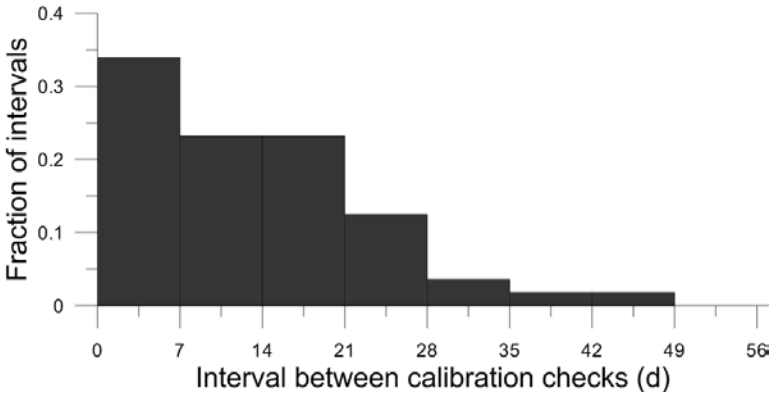


Figure 6.3-10 Inter-comparison check intervals for s/n 1932.

Sonic anemometer 1936 was inter-compared with three standard sonic anemometers of identical design five times during the study (Table 6.3-6). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 41 times (Figure 6.3-11). The majority of calibration checks were made within 21 d (Figure 6.3-12). The large fraction of checks made within 7 d was

the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-11B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-11A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-5: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.011	-0.036
12/27-28/2007	12/29-31/2007	-0.022	-0.009
7/10-11/2008	7/11-14/2008	+0.021	-0.019
3/23-25/2009	3/25-27/2009	+0.018	+0.047
9/1-2/2009	9/2-3/2009	-0.029	-0.016

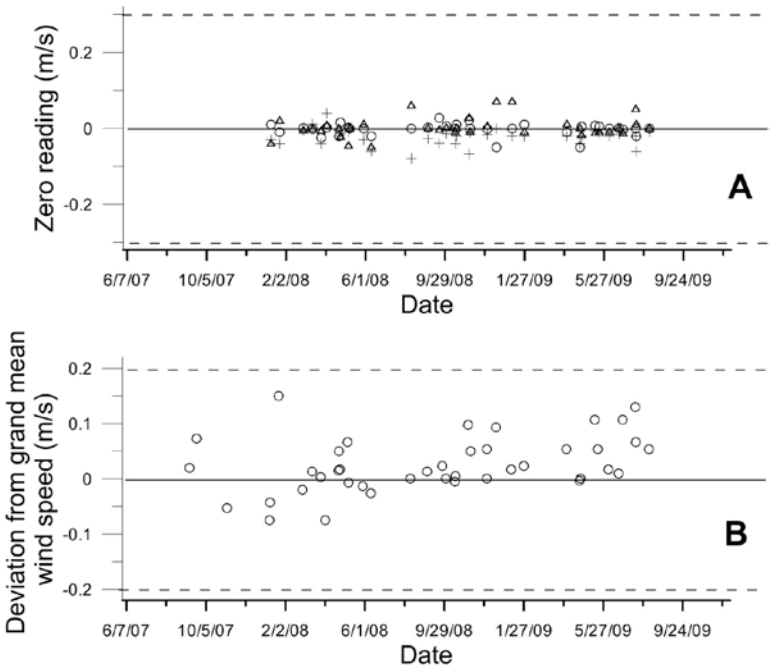


Figure 6.3-11: On-site quality assurance of s/n 1936. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

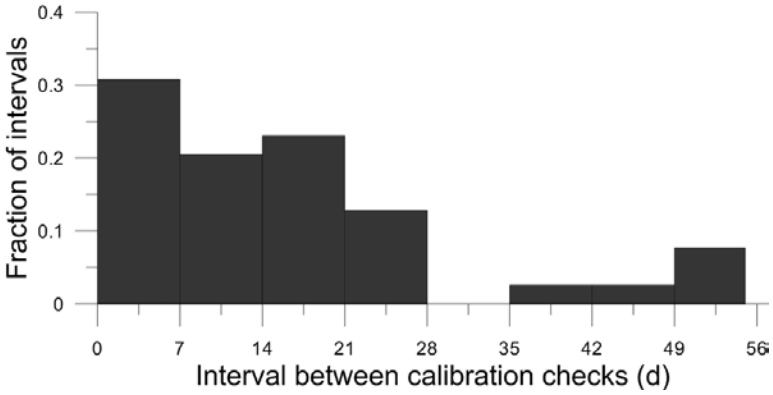


Figure 6.3-12: Inter-comparison check intervals for s/n 1936.

6.4 pH probe calibrations

Three pH probes (Model CSIMM-ph, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 002, 008, and 009.

Probe 002 was first used 6/27/2007 and last used 10/2/2008. The probe was calibrated 16 times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-1A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The accuracy check exceeded the DQI on 4/24/2008, 5/6/2008, and 10/2/2008. The DQI exceedances on 4/24/2008 and 5/6/2008 were followed with a valid accuracy check without sensor modification or repair so it is assumed that the checks failed due to inadequate probe cleaning. The accuracy check failure on 10/2/2008 was a result of probe failure. The stability check failed on 11/28/2007, 12/19/2007, 6/10/2008, and 10/2/2008. The failed stability checks on 11/28/2007 and 12/19/2007 did not correspond with accuracy check failures and were assumed to be operator error. The stability check on 6/10/2008 was indicative of the probe failure noted in the following accuracy check.

Probe 008 was first used 9/4/2008 and last used 4/21/2009. The probe was calibrated eight times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-2A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The accuracy check did not meet the DQI on 4/21/2009 and 9/17/2009. The stability check did not meet requirements 11/15/2008, 12/3/2008, 12/16/2008 and 9/17/2009.

Probe 009 was first used 4/23/2009 and last used 8/4/2009. The probe was calibrated seven times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-3A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-3B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the stability check but failed the accuracy DQI for pH 7 and pH 10 four times: 7/14/2009, 7/15/2009, 8/4/2009 and 9/17/2009. These accuracy failures were likely due to operator error.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since lagoon pH measurements were not made at several locations the interval between calibrations can be large when locations that did not have lagoon pH measurements were visited between locations where the measurements were made. Since freezing conditions damage the probe, the probes were not used during the winter at many locations.

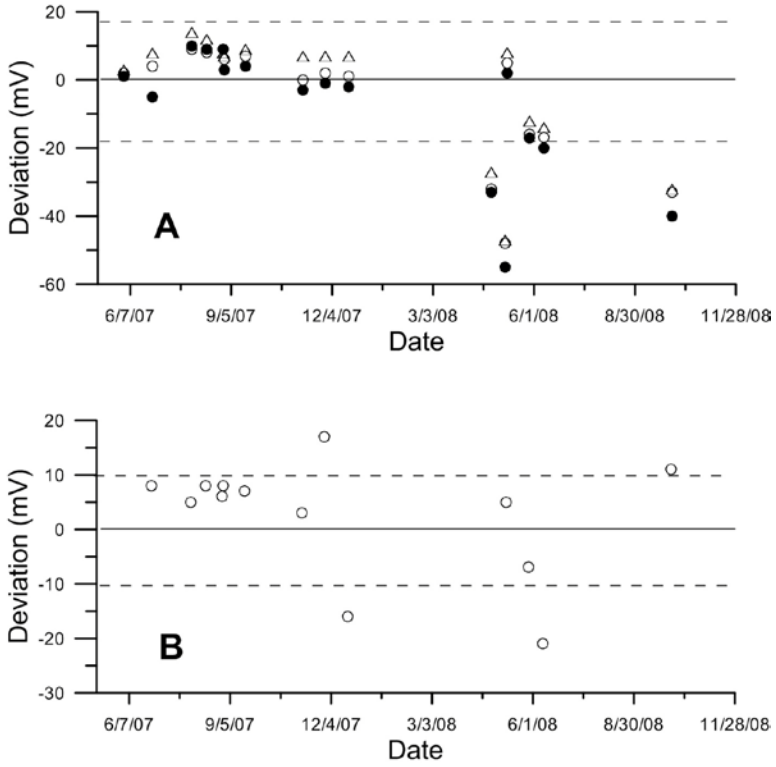


Figure 6.4-1: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 002. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

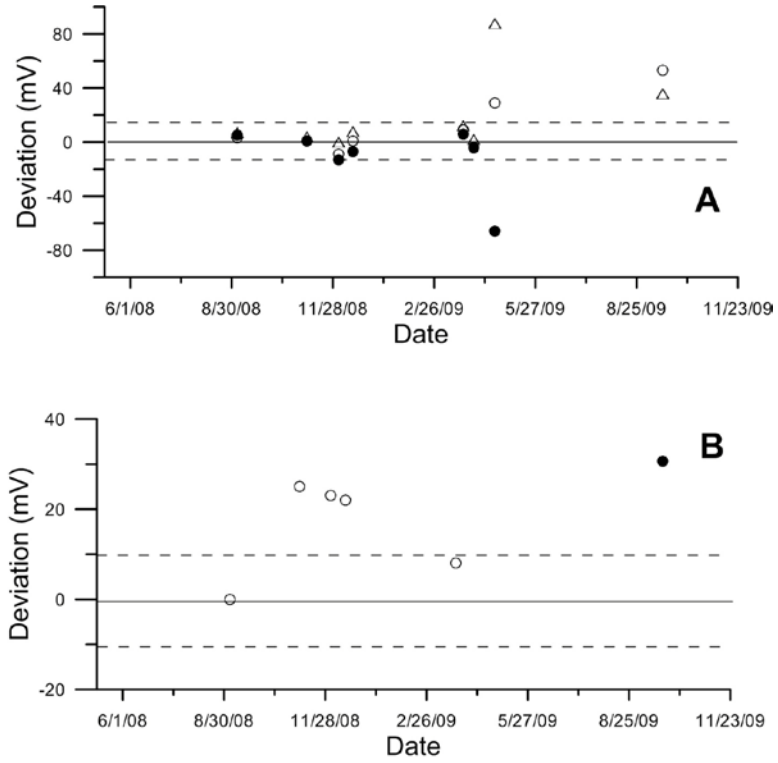


Figure 6.4-2: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 008. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

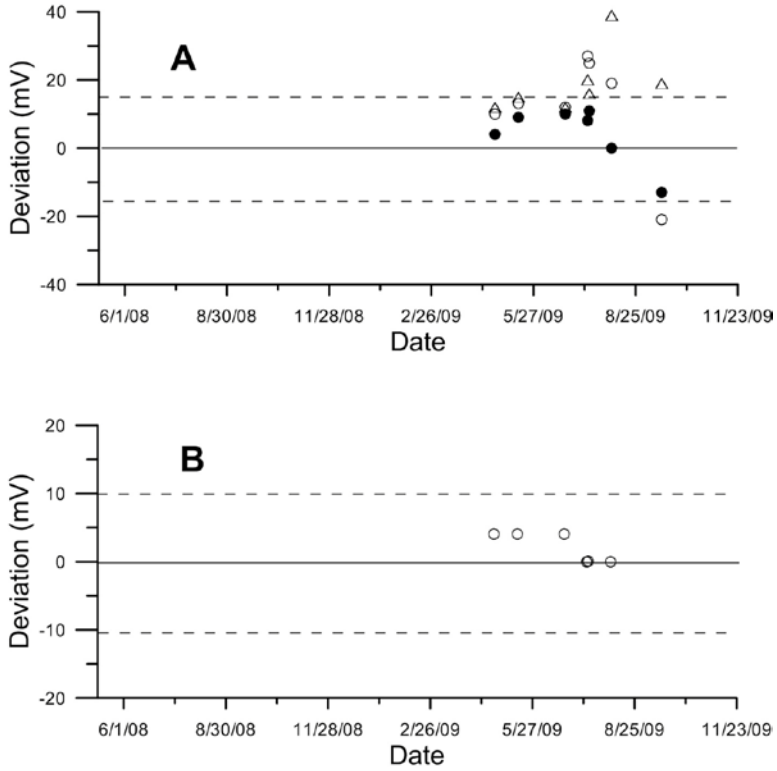


Figure 6.4-3: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 009. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds on the stability.

6.5 ORP probe calibrations

Two oxidation-reduction potential (ORP) probes (Model CSIM11-ORP, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 030 and 050.

Probe 030 was first used 6/27/2007 and last used 6/24/2009. The probe was calibrated 19 times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-1A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The stability checks indicated variability in the response but the accuracy check passed the DQI except for the first check (6/27/2007) which was assumed to fail due to operator error since the probe passed the subsequent accuracy check without modification.

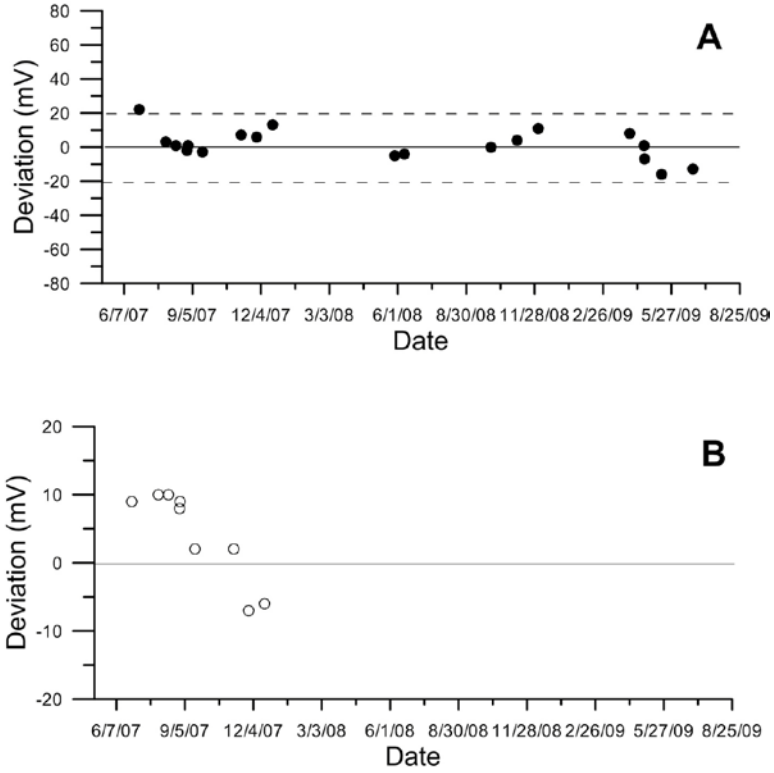


Figure 6.5-1: Accuracy and stability calibration checks of CSIM11 ORP probe, s/n 030. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

Probe 050 was first used 4/24/2008 and last used 2/23/2009. The probe was calibrated 11 times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-2A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV

of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the accuracy DQI although showed wide response variation to the stability check. The cause of this instability is unknown.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since lagoon ORP measurements were not made at several locations the interval between calibrations can be large when locations that did not have lagoon ORP measurements were visited between locations where the measurements were made. Since freezing conditions damage the probe, the probes were not used during the winter at many locations.

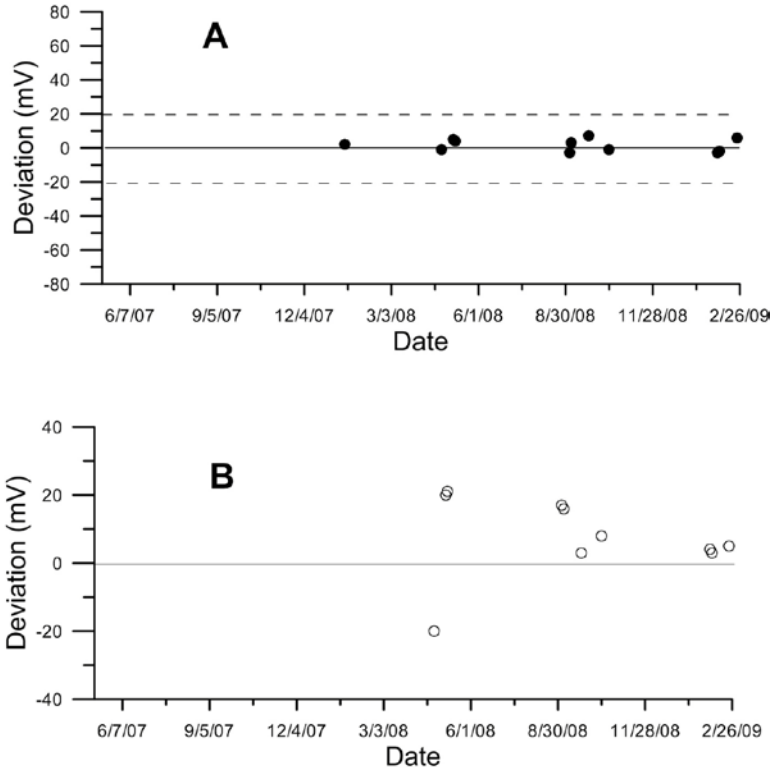


Figure 6.5-2: Accuracy and stability calibration checks of CSIM11 ORP probe, s/n 050. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

6.6 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n B and E) and the Gas Sampling System (GSS s/n 4-0017) used at this location were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results for the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 6.6-1. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Leaks in the GSS rarely occurred, however leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 9/3/2008, 10/2/2008, 12/6/2008, 5/14/2009, 8/4/2009, 10/29/2009 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on the subsequent visit.
- GSS leak check failure on 1/6/2009 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only in height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 6.6-1).

Table 6.6-1 - Record of leak checks for GSS and GSS/S-OPS

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
3/13/2008	WA5A	2	0.08	-41.29	Pass	8	0.56	-41.19	Pass
		3	0.01	-41.46	Pass	10.1	0.43	-39.25	Pass
4/3/2008	TX5A	2	0.00	-37.94	Pass	9.3	0.46	-40.07	Pass
		3	-0.01	-40.41	Pass	9.7	0.34	-40.19	Pass
4/22/2008	TX5A	2	0.09	-31.84	Pass	9.2	0.50	-32.48	Pass
		3	0.04	-40.85	Pass	9.6	0.36	-39.59	Pass
4/24/2008	OK4A	2	0.07	-30.69	Pass	8.4	0.44	-31.03	Pass
		3	0.01	-28.52	Pass	9.7	0.63	-28.7	Pass
5/6/2008	OK4A	2	0.14	-24.42	Pass	8.5	0.65	-26.2	Pass
		3	0.17	-24.74	Fail	9.8	0.66	-23.07	Pass
5/8/2008	OK3A	2	-0.14	-32.28	Pass	9.7	0.11	-30.99	Pass
		3	-0.14	-31.16	Pass	9.2	0.51	-30.83	Pass
5/29/2008	OK3A	2	0.15	-30.98	Fail	9.8	0.31	-32.07	Pass
		3	0.27	-30.89	Fail	9.2	0.58	-32.37	Pass
6/10/2008	OK3A	2	0.07	-39.64	Pass	9.7	0.37	-38.89	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
		3	0.06	-40.66	Pass	N/A	N/A	N/A	N/A
6/11/2008	TX5A	2	0.19	-39.52	Fail	9.4	0.19	-38.31	Pass
		3	0.00	-38.50	Pass	9.5	0.77	-38.43	Pass
7/1/2008	TX5A	2	0.15	-31.62	Fail	9.3	0.28	-31.17	Pass
		3	0.15	-31.69	Fail	9.3	1.00	-32.02	Pass
8/10/2008	WA5A	2	0.09	-40.90	Pass	7.5	0.44	-40.5	Pass
		3	0.07	-40.35	Pass	10.5	0.75	-38.31	Pass
9/3/2008	WA5A	2	0.27	-32.88	Fail	8	6.86	-23.56	Fail
		3	0.30	-32.92	Fail	10.5	0.53	-34.62	Pass
9/3/2008	WA5A	2	0.20	-32.22	Fail	8	0.43	-32.51	Pass
		3	0.30	-32.36	Fail	10.5	0.52	-32.73	Pass
9/26/2008	WA5A	2	0.53	-38.99	Fail	8.1	0.33	-40.01	Pass
		3	0.19	-37.03	Fail	10.5	0.41	-39.44	Pass
10/2/2008	OK4A	2	0.23	-40.69	Fail	9.6	0.95	-0.43	Pass
		3	0.23	-39.56	Fail	8.6	0.87	-0.04	Fail
10/15/2008	OK4A	2	0.17	-41.03	Fail	9.8	0.32	-38.14	Pass
		3	0.18	-38.71	Fail	8.5	0.32	-38.9	Pass
10/16/2008	TX5A	2	0.20	-39.65	Fail	9.7	0.28	-39.72	Pass
		3	0.23	-40.98	Fail	9.5	0.59	-39.55	Pass
11/4/2008	TX5A	2	0.33	-41.59	Fail	9.4	0.31	-39.62	Pass
		3	0.32	-41.56	Fail	9.3	0.50	-40.62	Pass
11/6/2008	OK3A	2	0.33	-39.79	Fail	8.7	0.73	-42.34	Pass
		3	0.32	-38.77	Fail	9.3	0.47	-39.46	Pass
12/3/2008	OK3A	2	0.79	-40.32	Fail	8.4	0.65	-39.24	Pass
		3	0.83	-39.05	Fail	9.2	0.43	-40.53	Pass
12/16/2008	OK3A	2	0.72	-37.70	Fail	8.6	1.05	-40.13	Fail
		3	0.79	-36.81	Fail	9.5	0.91	-40.65	Pass
12/18/2008	TX5A	2	1.98	-38.41	Fail	9.4	0.92	-37.74	Pass
		3	2.09	-38.03	Fail	9.4	0.90	-37.46	Pass
1/6/2009	TX5A	2	0.12	-40.60	Pass	9.1	2.09	-37.63	Fail
		3	0.13	-40.35	Pass	8.9	2.12	-37.72	Fail
1/8/2009	OK4A	2	0.11	-38.95	Pass	9.8	0.41	-39.67	Pass
		3	0.11	-37.59	Pass	7.2	0.30	-41.91	Pass
1/27/2009	OK4A	2	0.09	-38.64	Pass	9.4	0.36	-40.34	Pass
		3	0.09	-38.15	Pass	8.3	0.20	-41.46	Pass
1/29/2009	TX5A	2	0.05	-37.73	Pass	9.8	0.37	-38.37	Pass
		3	0.17	-38.46	Fail	9.6	0.24	-37.24	Pass
2/19/2009	TX5A	2	0.19	-36.64	Fail	9.9	0.92	-39.35	Pass
		3	0.04	-36.77	Pass	9.7	0.64	-38.72	Pass
3/18/2009	TX5A	2	0.15	-38.19	Fail	9.3	0.65	-37.14	Pass
		3	0.07	-39.28	Pass	9.8	0.45	-37.54	Pass
4/21/2009	OK4A	2	0.15	0.06	Fail	10.2	0.55	-40.07	Pass
		3	0.01	-39.72	Pass	9	0.24	-37.98	Pass
4/22/2009	OK3A	2	0.14	-40.11	Pass	9.7	0.30	-38.44	Pass
		3	0.05	-38.69	Pass	8.8	0.77	-27.92	Pass
5/14/2009	OK3A	2	0.20	-39.22	Fail	9.7	0.26	-38.46	Pass
		3	0.09	-39.13	Pass	8.6	0.88	-38.07	Fail
5/21/2009	WA5A	2	0.17	-37.70	Fail	7.9	0.18	-39.69	Pass
		3	0.02	-39.60	Pass	10.5	0.96	-39.37	Pass
6/4/2009	WA5A	2	0.18	-40.86	Fail	8.6	0.24	-40.49	Pass
		3	0.04	-38.48	Pass	10.5	0.97	-38.07	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
6/19/2009	WA5A	2	0.33	-39.50	Fail	8.7	0.25	-38.74	Pass
		3	0.14	-39.60	Pass	10.5	0.95	-37.89	Pass
6/23/2009	OK4A	2	0.07	-39.89	Pass	9.7	0.37	-39.37	Pass
		3	0.04	-38.56	Pass	8.8	0.60	-40.96	Pass
7/14/2009	OK4A	2	0.25	-39.85	Fail	8.5	0.14	-40.79	Pass
		3	0.08	-38.49	Pass	9.7	0.13	-39.51	Pass
7/15/2009	OK3A	2	0.02	-38.14	Pass	8.7	0.63	-38.59	Pass
		3	0.04	-36.71	Pass	9.9	0.08	-39.75	Pass
8/4/2009	OK3A	2	0.06	-38.09	Pass	8.5	2.25	-37.22	Fail
		3	0.11	-34.41	Pass	9.7	0.09	-39.78	Pass
8/6/2009	TX5A	2	0.05	-38.30	Pass	9.8	0.75	-39.4	Pass
		3	0.00	-40.36	Pass	9.9	0.14	-38.93	Pass
8/27/2009	TX5A	2	0.02	-39.89	Pass	9.7	0.65	-37.52	Pass
		3	0.05	-40.26	Pass	9.5	0.11	-38.95	Pass
9/23/2009	NC3A	2	0.06	-40.15	Pass	10.1	0.34	-39.61	Pass
		3	0.07	-38.33	Pass	0	-0.60	-0.05	Pass
10/13/2009	NC3A	2	0.17	-39.38	Fail	9.6	0.41	-39.03	Pass
		3	0.04	-37.77	Pass	10	0.20	-41.33	Pass
10/27/2009	NC3A	2	0.08	-41.29	Pass	10	0.26	-39.3	Pass
		3	0.01	-41.46	Pass	9.3	1.45	0.11	Fail
10/27/2009	NC3A	2	0.00	-37.94	Pass	10	0.26	-39.3	Pass
		3	-0.01	-40.41	Pass	9.3	0.51	-40.26	Pass
11/11/2009	NC3A	2	0.04	-39.92	Pass	10	0.79	-40.71	Pass
		3	0.04	-39.74	Pass	9.6	0.27	-40.26	Pass

The inlet flow balance checks are summarized in sequence in Tables 6.6-2A and 6.6-2B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A: Record of flow balancing-Side 1 (s/n B)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	-0.20	-0.21	-0.06	-0.14	-0.20	-0.24	-0.21	-0.04	-0.20	-0.23	**Fail**
4/3/2008	4/22/2008	TX5A	-0.08	-0.07	-0.08	-0.09	-0.07	-0.09	-0.13	-0.09	-0.12	-0.14	**Pass**
4/24/2008	5/6/2008	OK4A	-0.02	-0.04	-0.01	-0.14	-0.02	-0.03	-0.09	-0.10	-0.07	-0.12	**Fail**
5/8/2008	5/29/2008	OK3A	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.03	0.01	0.04	**Pass**
5/29/2008	6/10/2008	OK3A	M	M	M	M	M	M	M	M	M	M	**M**
6/11/2008	7/1/2008	TX5A	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	**Pass**
7/1/2008	8/10/2008	TX5A	0.35	0.38	0.11	0.39	0.27	0.31	0.30	0.18	0.34	0.31	**Pass**
8/10/2008	9/3/2008	WA5A	0.00	-0.10	0.11	-0.20	0.00	0.00	-0.10	0.00	-0.10	0.00	**Fail**
9/3/2008	9/26/2008	WA5A	0.00	-0.10	-0.10	0.10	0.00	-0.20	-0.10	0.10	0.00	0.00	**Fail**
10/2/2008	10/15/2008	OK4A	0.02	-0.02	0.01	0.01	-0.03	0.06	0.06	0.05	0.04	0.02	**Fail**
10/16/2008	11/4/2008	TX5A	0.02	0.00	0.00	-0.01	-0.02	-0.05	-0.05	0.00	0.01	0.03	**Pass**
11/6/2008	12/3/2008	OK3A	0.03	0.00	0.00	0.01	-0.02	0.03	0.04	0.05	0.05	0.05	**Pass**
12/3/2008	12/16/2008	OK3A	-0.02	-0.01	-0.01	0.00	0.04	-0.06	0.04	-0.04	-0.03	-0.03	**Pass**
12/18/2008	1/6/2009	TX5A	-0.02	-0.06	-0.03	0.00	-0.04	-0.02	-0.02	0.00	0.01	-0.01	**Fail**
1/8/2009	1/27/2009	OK4A	-0.02	-0.04	-0.04	0.00	-0.05	-0.01	0.00	0.00	0.00	0.01	**Pass**
1/29/2009	2/19/2009	TX5A	-0.04	-0.02	0.00	0.06	0.00	-0.06	0.00	-0.02	-0.02	0.00	**Pass**
2/19/2009	3/18/2009	TX5A	0.01	-0.02	0.01	0.01	0.01	-0.02	0.00	0.00	0.00	-0.01	**Fail**
3/18/2009	4/2/2009	TX5A	0.06	0.06	0.05	0.06	0.04	0.08	0.06	0.10	0.05	0.11	**Pass**
4/2/2009	4/21/2009	OK4A	0.02	0.05	0.04	0.04	-0.03	0.01	0.02	0.01	-0.01	-0.01	**Pass**
4/22/2009	5/14/2009	OK4A	-0.03	-0.04	-0.02	-0.03	-0.02	-0.14	-0.02	-0.01	-0.02	-0.03	**Pass**
5/14/2009	5/21/2009	OK4A	0.23	0.24	0.27	0.28	0.17	0.28	0.23	0.26	0.17	0.29	**Pass**
5/21/2009	6/4/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/23/2009	7/14/2009	OK4A	0.00	-0.02	-0.03	-0.01	-0.04	0.01	0.01	0.00	-0.01	-0.04	**Pass**
7/15/2009	8/4/2009	OK3A	0.05	0.04	0.13	0.09	0.13	0.20	0.16	0.14	0.14	0.18	**Pass**
8/6/2009	8/27/2009	TX5A	0.05	0.05	0.01	0.00	0.01	0.03	0.02	0.03	0.06	0.04	**Pass**
8/27/2009	9/24/2009	TX5A	-0.10	-0.06	-0.05	-0.06	-0.08	-0.01	-0.04	-0.05	-0.14	-0.01	**Pass**
9/24/2009	10/13/2009	NC3A	0.00	-0.03	0.00	-0.05	-0.03	-0.08	87.39	-0.11	-0.12	0.06	**Pass**
10/13/2009	10/27/2009	NC3A	-0.02	-0.05	-0.04	-0.03	-0.04	-0.04	-0.03	-0.03	-0.05	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.00	-0.02	-0.01	-0.01	-0.01	0.00	-0.02	0.00	-0.04	0.02	**Pass**
11/11/2009	12/2/2009	NC3A	0.02	0.04	-0.11	-0.01	0.01	0.00	-0.03	-0.08	0.37	0.03	**Fail**

M: missing measurements.

Table 6.6-2B: Record of flow balancing- Side 2 (s/n E)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	0.19	0.18	0.11	0.19	0.14	0.14	0.15	0.17	0.15	0.21	**Fail**
4/3/2008	4/22/2008	TX5A	-0.03	-0.03	0.01	-0.04	-0.09	-0.06	0.00	0.01	0.00	0.00	**Pass**
4/24/2008	5/6/2008	OK4A	0.00	0.00	0.00	-0.03	-0.02	-0.05	0.06	-0.01	-0.03	0.06	**Fail**
5/8/2008	5/29/2008	OK3A	0.02	0.01	0.04	0.00	0.05	0.02	0.01	0.04	0.02	0.02	**Pass**
5/29/2008	6/10/2008	OK3A	-0.01	-0.01	-0.02	0.00	0.00	-0.02	0.01	-0.04	-0.02	0.00	**Pass**
6/11/2008	7/1/2008	TX5A	0.01	0.00	0.00	0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.03	**Pass**
7/1/2008	7/29/2008	TX5A	-0.03	-0.09	0.00	-0.05	-0.03	-0.06	0.02	-0.03	-0.02	0.00	**Pass**
8/10/2008	9/3/2008	WA5A	0.05	0.14	0.09	0.10	0.16	0.14	0.12	0.15	0.18	0.15	**Pass**
9/3/2008	9/26/2008	WA5A	-0.04	-0.06	-0.02	-0.01	0.00	0.00	0.02	-0.04	0.02	0.00	**Pass**
10/2/2008	10/15/2008	OK4A	0.00	0.01	-0.02	0.00	-0.01	0.01	0.03	0.03	0.11	0.00	**Pass**
10/16/2008	11/4/2008	TX5A	-0.02	-0.05	-0.03	-0.04	0.00	0.00	-0.04	-0.04	-0.01	-0.02	**Pass**
11/6/2008	12/3/2008	OK3A	-0.01	0.01	0.00	-0.02	0.14	-0.07	0.01	0.02	0.02	0.02	**Fail**
12/3/2008	12/16/2008	OK3A	0.01	-0.02	-0.01	-0.02	-0.01	0.02	0.00	0.00	-0.02	-0.01	**Pass**
12/18/2008	1/6/2009	TX5A	-0.03	-0.08	-0.05	-0.05	-0.06	-0.05	-0.06	-0.04	-0.07	-0.02	**Pass**
1/8/2009	1/27/2009	OK4A	-0.04	-0.03	-0.03	-0.04	-0.04	-0.02	-0.03	-0.02	-0.02	-0.01	**Pass**
1/29/2009	2/19/2009	TX5A	0.00	-0.05	0.00	0.01	-0.02	-0.05	0.02	0.02	0.12	-0.01	**Pass**
2/19/2009	3/18/2009	TX5A	0.03	0.03	0.04	0.03	0.02	0.04	0.01	0.02	0.03	0.01	**Fail**
3/18/2009	4/2/2009	TX5A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.16	-0.14	-0.12	-0.15	-0.14	**Pass**
4/2/2009	4/21/2009	OK4A	0.00	0.05	0.05	0.04	0.04	0.07	0.05	0.03	0.01	0.02	**Pass**
4/22/2009	5/14/2009	OK3A	-0.06	0.00	0.00	-0.01	0.01	0.02	0.01	0.03	0.03	0.00	**Pass**
5/14/2009	5/21/2009	OK3A	-0.07	-0.11	-0.13	-0.11	-0.21	-0.10	-0.19	-0.16	-0.17	-0.18	**Pass**
5/21/2009	6/4/2009	WA5A	0.01	0.00	0.00	0.01	0.07	-0.03	0.05	0.02	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.01	0.01	-0.04	-0.03	-0.03	-0.03	-0.02	-0.01	-0.02	0.00	**Pass**
6/23/2009	7/14/2009	OK3A	-0.02	-0.02	0.00	-0.02	-0.02	0.03	-0.03	-0.02	-0.02	0.01	**Pass**
7/15/2009	8/4/2009	OK3A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
8/4/2009	8/6/2009	OK3A	0.00	-0.01	0.01	0.01	-0.01	0.01	-0.01	0.02	0.01	0.00	**Pass**
8/6/2009	8/27/2009	TX5A	0.00	-0.03	-0.05	-0.04	-0.02	-0.02	-0.01	0.01	0.01	0.03	**Pass**
8/27/2009	9/23/2009	TX5A	0.05	0.05	0.08	0.11	0.22	0.22	0.21	0.25	0.22	0.21	**Fail**
9/24/2009	10/13/2009	NC3A	0.02	0.03	0.00	0.02	0.00	0.00	0.00	-0.03	0.00	0.16	**Fail**
10/13/2009	10/27/2009	NC3A	0.00	-0.01	0.12	-0.05	-0.02	-0.12	-0.04	-0.05	-0.06	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.15	0.06	0.18	0.10	-0.05	0.25	0.25	0.05	0.21	-0.60	**Fail**

The nominal planned interval between S-OPS checks was 20 d (three weeks). S-OPS checks were conducted at this long-term measurement location a relatively few times with the period of time between checks varying from one to three weeks (Figure 6.6-1). Shorter intervals between checks occurred due to work on the systems.

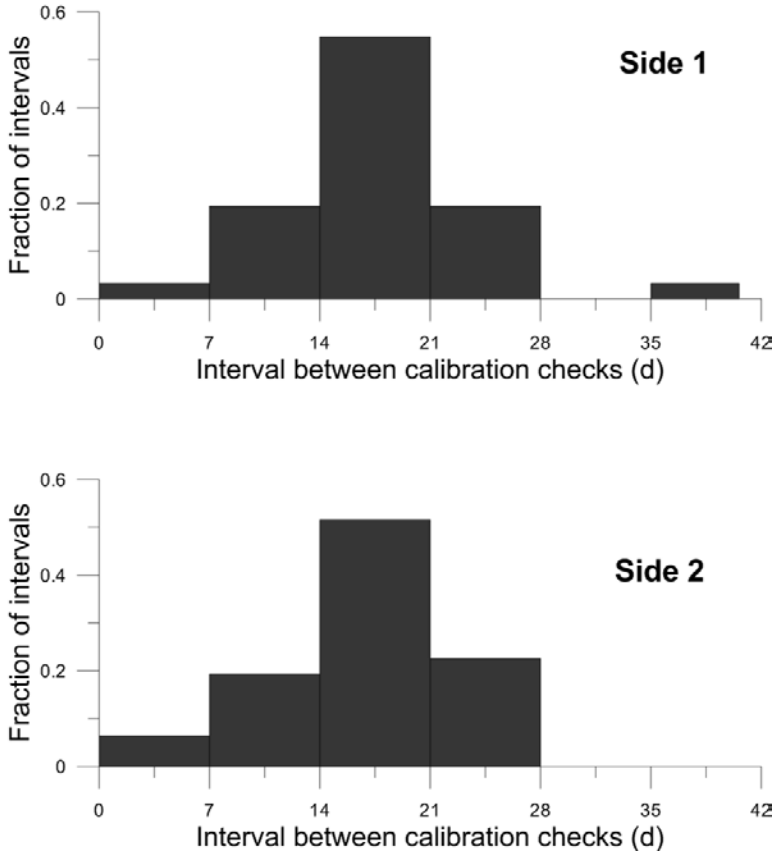


Figure 6.6-1 – Intervals between checks

6.7 Miscellaneous meteorological and lagoon calibrations

6.7.1 Air temperature/ humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n: 4410015

Relative humidity (RH)					
Calibration date	**Expected RH (%)**	**Measured RH (%)**	**Difference from expected RH (%)**	**Average difference RH (%)**	**Action**
2/17/2010	21	19	2		
	50	48	2		
	98	94	4		
				2.7	Accept
9/18/2009	11	20	-9		
	50	50	0		
	98	85	13		
				7.3	Adjust
	11	11	0		
	98	95	3		
	50	37	13		
	11	11	0		
	50	42	8		
				4.8	Accept
3/26/2009	23	20	3	3	Accept

Temperature (T)				
Calibration date	**Expected T (°C)**	**Measured T (°C)**	**Difference from expected T (°C)**	**Action**
2/17/2010	24.3	24.5	-0.2	Accept
9/18/2009	26.5	26.9	-0.4	Accept
3/26/2009	24.9	24.9	0.0	Accept

6.7.2 Barometric Pressure

An aneroid barometer (Model 278, Setra Inc., Boxborough, MA) was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial

calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278, s/n: 3033740

Calibration date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
2/11-12/2010	998.6-992.5	5	1.5	Pass
9/16-17/2009	997.5-1000.1	6	0.9	Pass
3/24-25/2009	986.0-992.0	6	1.4	Pass
7/9-11/2008	993.1-996.8	6	1.5	Pass
1/3-4/2008	1018.4-1001.7	6	2.5	Pass

6.7.3 Solar radiation

A pyranometer (Model 200SB, LiCOR Inc., Lincoln, NE) was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-3.

Table 6.7-3: Calibration record of LiCOR Pyranometer, s/n: PY55449

Calibration date	Mean difference from reference (Wm^{-2})	Mean difference from reference (%)	Action
3/5/2010	4.84	0.91	Retry
3/6/2010	1.4	0.37	Pass
8/30/2006			Pass - Factory Cal.

6.7.4 Lagoon water temperature

A thermistor (Model 107-L, Campbell Scientific Inc., Logan, UT) was used to measure lagoon temperature. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. Three thermistor probes (s/n 0020, 0040, and I) were used at this location. The record of calibration checks are documented in Table 6.7-4.

Table 6.7-4: Calibration record of Thermistor CSI 107-L

Calibration date	Expected value (°C)	Difference from expected (°C)	Action
Thermistor CSI 107-L, s/n 0020 (8888)			
6/18/2007	25	0.3	Accept
6/18/2007	24.5	0.4	Accept
6/18/2007	24	0.6	Accept
Thermistor CSI 107-L, s/n 0040			
6/18/2007	25	0.5	Accept
6/18/2007	24.5	0.7	Accept
6/18/2007	24	0.6	Accept
Thermistor CSI 107-L, s/n I			
2/15/2010	1.1	1.2	Accept
2/15/2010	35.7	2.9	Accept
9/14/2009	0.1	0.0	Accept
3/27/2009	- 0.1	-0.0	Accept

6.7.5 Sludge Gun

A sludge gun (Model 10, Marklin Specialty Engineering, Toronto, Ontario, Canada) with serial number 20176 was used to measure sludge depth in the lagoon. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-5.

Table 6.7-5: Calibration record of Marklin Sludge Gun, s/n 20176C

Calibration date	Mean (mm)	Standard Deviation (mm)	Accuracy (mm)	Action
2/26/2010	69.7	0.51	1.7	Accept
3/24/2009	78.11	1.05	-0.11	Accept
7/23/2008	75.38	0.51	1.1	Accept
1/4/2008	39.67	2.06	0.67	Accept
3/23/2007	81.56	0.73	1.56	Accept

6.7.6 CR1000 Data logger

The CR1000 data logger (Campbell Scientific Inc., Logan, UT) was used to log all lagoon measurements (pH, oxidation-reduction potential, and temperature) and air temperature, relative humidity, barometric pressure, and wetness. Calibration checks of this unit were conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-6.

Table 6.7-6: Calibration record of Campbell Scientific CR1000 data logger, s/n 7677

Factory calibration						
Calibration date: 1/18/2007			Single-ended		Differential	
Channel	**Input (mV)**	**Tolerance (mV)**	**Measured mV**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
13	5000	± 3	5000.48	-0.48	5001.02	-1.02
13	-5000	± 3	-5001.56	-1.56	-5001.02	-1.02
13	2500	± 1.5			2500.34	-0.34
13	250	± 0.15			250.042	-0.042
13	25	± 0.015			25.004	-0.004
13	7.5	± 0.0045			7.49724	0.00276
13	2.5	± 0.0015			2.49923	0.00077
13	-2.5	± 0.0015			-2.49906	0.00094
13	5000	± 6	4999.31	1.31	4998.64	2.64
13	5000	± 6	5000.58	-0.58	5001.02	-1.02
13	5000	± 6				
13	5000	± 6				

PAML calibration						
Calibration date: 2/5/2007			Single ended		Differential	
SE Channel	**Input (mV)**	**Tolerance SE|DE (mV)**	**Measured mV Mean Value**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	4950	± 6.96| 4.97	4951.7	-1.7		
2	4950	± 6.96| 4.97	4951.7	-1.7		
3	4950	± 6.96| 4.97	4951.7	-1.7		
4	4950	± 6.96| 4.97	4951.7	-1.7		
5	4950	± 6.96| 4.97	4951.7	-1.7		
6	4950	± 6.96| 4.97	4951.7	-1.7		
7	4950	± 6.96| 4.97	4951.7	-1.7		
8	4950	± 6.96| 4.97	4951.7	-1.7		
9	4950	± 6.96| 4.97	4951.7	-1.7		
10	4950	±6.96| 4.97	4951.7	-1.7		
12	4950	± 6.96| 4.97	4951.7	-1.7		
13	4950	± 6.96| 4.97	4951.7	-1.7		
14	4950	± 6.96| 4.97	4951.7	-1.7		
15	4950	± 6.96| 4.97	4951.7	-1.7		
16	4950	± 6.96| 4.97	4951.7	-1.7		
Calibration date: 3/10/2010			Single-ended		Differential	

PAML calibration						
Calibration date: 2/5/2007			Single ended		Differential	
SE	**Input**	**Tolerance**	**Measured**	**Error**	**Measured**	**Error**
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.06 | 1.06	99.37	0.63		
2	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
3	100	±2.06 | 1.06	99.37	0.63		
4	100	± 2.06 | 1.06	99.37	0.63		
5	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
6	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
7	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
8	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
9	100	± 2.06 | 1.06	99.37	0.63		
10	100	± 2.06 | 1.06	99.37	0.63		
11	100	± 2.06 | 1.06	99.37	0.63		
12	100	± 2.06 | 1.06	99.37	0.63		
13	100	± 2.06 | 1.06	99.37	0.63		
14	100	± 2.06 | 1.06	99.37	0.63		
15	100	± 2.06 | 1.06	99.37	0.63		
16	100	± 2.06 | 1.06	99.37	0.63		
Calibration date: 3/10/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.06 | 1.06	0	0		
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0		
4	0	± 2.06 | 1.06	0	0		
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0		
10	0	± 2.06 | 1.06	0	0		
11	0	± 2.06 | 1.06	0	0		
12	0	± 2.06 | 1.06	0	0		
13	0	± 2.06 | 1.06	0	0		
14	0	± 2.06 | 1.06	0	0		
15	0	± 2.06 | 1.06	0	0		
16	0	± 2.06 | 1.06	0	0		

6.7.7 CR800 Data logger

The CR800 data logger (Campbell Scientific Inc., Logan UT) was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration check

of this unit was conducted only at end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-7.

Table 6.7-7: Calibration record of Campbell Scientific CR800 data logger, s/n 3698

Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	0	2.061	99.23	0.77
2	0	2.061	99.23	0.77
3	0	2.061	99.23	0.77
4	0	2.061	99.23	0.77
5	0	2.061	99.23	0.77
6	0	2.061	99.23	0.77
Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**
1	0	2.061	0	0
2	0	2.061	0	0
3	0	2.061	0	0
4	0	2.061	0	0
5	0	2.061	0	0
6	0	2.061	0	0

6.8 Site Activity

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
	8/30/2007	Setup	When setting up retro-reflectors, noticed that a tripod was broken when extending the legs. Another tripod was bent at the leg.
	8/30/2007	Setup	TDLAS 1031 has lower light values than 1029 when placed in exactly same position. Changed to Port B.
	8/30/2007	Setup	Noticed C must have a leak in diluter because flow of air is so high relative to A and B.
	8/30/2007	Setup	TDLAS 1031 was not giving steady values during calibration while TDLAS 1029 was giving accurate and stable values when using Port B.
	8/30/2007	Setup	During sonic anemometer inter-comparison, there was a trip in power outlet, so data stopped temporarily in calibration data file.
	8/30/2007	Setup	pH sensor: calibration done; acceptance and QA accepted.
	8/30/2007	Setup	ORP sensor: acceptance and calibration done.
15:40-16:40	8/30/2007	Setup	Sonic inter-comparison: Sonic 1: 1.89 Sonic 2: 1.91 Sonic 3: 1.91
18:11	8/30/2007	Setup	Zero calibration performed on sonic anemometers; all pass.
21:26-00:15	8/30/2007	Setup	TDLAS 1031 calibration failed. Notes: R-squared values were above 0.84 for 4 times during first background calibration; values varied significantly and were too high. Values also too high during second calibration. Switched from Port A to Port C. Lots of pressure released when removed from Port A when using Port C, use of gas is ~2-3 times the amount using Port A. Values still jumpy so restarted TDLAS power. Wiped off lenses. Changed to Port B.
23:47-23:53	8/30/2007	Setup	Calibrated TDLAS 1029: Mean: 25.8 - SD: 2.3 - Accuracy: 3.6 - Notes: Accuracy was too low but very stable on first calibration. Calibration chamber was bumped on second calibration, so values decreased significantly (R^2 was too low during end of period). Used port B.
	8/31/2007	Setup	Wetness sensor giving values (not INF), but sunny day; had bird droppings on it. Used Port B.
	8/31/2007	Setup	Tried sludge gun measurements (have pictures), but wind was too strong, would give inaccurate readings, so it was put on hold.
	8/31/2007	Setup	After aligning scanner 1 (TDLAS 1031), gave back values of 0.28 for R^2 for every path. Then gave R^2 reading of 0.60 for every path. This was a result of forgetting to turn on scanning, not aligning made. Power-cycled.
	8/31/2007	Setup	Retro and berm heights taken.

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
14:19-14:24	8/31/2007	Setup	Calibrated TDLAS 1031: Mean: 97.9 - SD: 2.3 - Notes: Left TDLAS 1031 running overnight while emptying chamber and TDL was reading ~60-80 ppm in the morning. Tank may not have been shut off completely. Redid background. Retested from tank directly (496 ppm) for calibration test 1. Standard deviation is very low. For actual test, ran 200 ppm thru diluter.
	9/18/2007	Takedown	Too windy for sludge depth measurements today (~15 mph winds with gusts to 25 mph)
	9/18/2007	Takedown	Wetness sensor had bird droppings on it, but it did not affect measurements. Cleaned wetness sensor off between metal grid.
	9/18/2007	Takedown	Calibrated TDLAS measurements at 100 ppm since that is what we were measuring in the field.
	9/18/2007	Takedown	Could not find pen to use during TDLAS calibrations, so wrote with pencil at beginning of TDLAS 1029 calibrations and traced over with pen.
	9/18/2007	Takedown	Repaired TDLAS 1029. Disassemble, inspect, replace shutter mechanism with new part (OEM). Reassemble, verify, calibration.
	9/18/2007	Takedown	pH sensor: calibration done; acceptance and QA accepted.
	9/18/2007	Takedown	ORP sensor: acceptance and calibration done.
18:40-19:40	9/18/2007	Takedown	Sonic Inter-comparison: Sonic 1: 4.20 - Sonic 2: 4.29 - Sonic: 4.22
20:18-20:33	9/18/2007	Takedown	Zero calibration performed on sonic anemometers; all pass.
21:28-21:33	9/18/2007	Takedown	Calibration TDLAS 1031− Mean: 98.36 - SD: 4.1% - Notes: Saved log file in wrong location. Had to close log file after trial 1 and move to correct directory. Reopened correct data file in correct directory for rest of calibrations. Appended log file.
22:47-22:52	9/18/2007	Takedown	Calibrated TDLAS 1029− Mean: 92.67 - SD: 2.4% - Notes: Calibrated at 100 ppm because these were/are values that were seen in the field.
	9/19/2007	Takedown	Collected data and packed trailer to move to TX5A. See inspection checklist.
	9/19/2007	Takedown	Data for this period (weather data) ended at 9:30 a.m. EST, even though data extends beyond this on data CD's and memory card.
	9/19/2007	Takedown	Still too windy to take sludge depth measurements.
	9/19/2007	Takedown	When switching out memory card for data logger, plug was unplugged from outlet; plugged met station back into charge memory card; waited 2 min for light to turn green, but stayed orange-red color; switched out memory card (light turned yellow-orange)-may have lost data on memory card but have it recorded on CD.
	1/24/2008	Setup	Frozen lagoon so no pH, ORP, or temp. probes

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
	1/24/2008	Setup	Could not calibration TDLAS 1029 at 50 ppm (25 ppm), but it would not stabilize for 50 min. Tried again straight from calibration gas (NH3) cylinder at 502 ppm. Stabilized well at 502 ppm--tried again at 25 ppm/50 ppm. Would not stabilize at 25 ppm/50 ppm. Tried again at 502 ppm.
	1/25/2008	Setup	Lagoon is frozen; no pH, ORP, or temp. probes TDLAS aimed.
	1/25/2008	Setup	S-OPS acceptance; S-OPS placement form made.
	2/5/2008	Calibration	Everything was covered in 0.25-inch of ice upon arrival (TDLAS, retro-reflectors, sonic anemometers, etc.). Both TDLs were getting zero light values because of ice.
	2/5/2008	Calibration	Calibrated TDL's 1026, 1029, and 1032. 1029 would not calibrate at 50 ppm so had to calibrate at 500 ppm. Will take 1029 back to PAML and replace with 1026.
	2/5/2008	Calibration	Scanner in NW corner was way off target (by about 45 degrees), and scanner in SW corner was off by about 100-200 steps. Unable to realign because of 0.25-inch of ice on retro-reflectors. Will warm up tomorrow, so will come back out to align scanners.
	2/5/2008	Calibration	Cleared ice off retro-reflectors and aimed scanners. NW scanner was off by about 45 degrees to the right. SE scanner was off by about 500 steps to the right. Changed optimization settings on NW scanner because it was optimizing too much.
	2/6/2008	Calibration	H_2S analyzer had motherboard failure. Looked inside 450i and could not find anything wrong. Performed H_2S calibration on 450i by running gas straight from H_2S tank. Calibration results in open site notes.
	2/7/2008	Remote	Checked site status. NW scanner was not aligned. Forced data to send to office. H_2S analyzer stopped at same time as scanner (~midnight 2/6-7/2008). Had to stop sonic anemometers and start *iPort*.
	2/11/2008	Remote	Checked sonic anemometer status. Inhomogeneous turbulence (w) flagged (starting at 406.67; 2/10/2008 1605 UTC). At beginning of flagged data, noticed wetness and RH values showed some type of precipitation. Also saw freezing fog observations in Guymon on NWS website starting at 9am (CST) on 2/10/2008. Vertical wind speeds increased dramatically during this time too, and temps have not reached above freezing since time of flagged values.
	2/19/2008	Takedown	Scanner 6 (NW corner) off by 180 degrees. Will let run overnight on 2 retro-reflectors on ground after sending high power command.
	2/19/2008	Takedown	S-OPS acceptance
	2/19/2008	Takedown	TFC 450i Reference Precision Check/Calibration check.
	2/19/2008	Takedown	S-OPS Inlet flow verification: pass (Solenoids 2 and 3)

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
17:35-18:35	2/19/2008	Takedown	Sonic Inter-comparison: Sonic 1: 3.13 Sonic 2: 3.14 Sonic 3: 3.18. All pass.
20:22	2/19/2008	Takedown	Zero calibration performed on sonic anemometers; all pass.
21:10	2/19/2008	Takedown	Barometer audit: pass
21:10-21:12	2/19/2008	Takedown	Wetness sensor calibration: accepted
22:23-22:28	2/19/2008	Takedown	Calibrated TDLAS 1026: Mean: 26.6 - SD: 0.69 - RSD: 0 Bias: 0
23:22-23:23	2/19/2008	Takedown	Calibrated TDLAS 1032: Mean: 24.9 - SD: 1.1 - RSD:4.4 Bias: 0
	5/6/2008	Setup	Chance of rain tonight. Could be difficult to pull on muddy road. Pulled in trailer; leveled and tied down.
	5/7/2008	Setup	Hooked up power to trailer, so calibrations could be performed inside of trailer (raining outside).
	5/7/2008	Setup	Changed all S-OPS filters and put Teflon tape on filter holder threads.
	5/7/2008	Setup	Changed settings on TDL's 1032 and 1026 to 200 sample/Ref scans (had been 20).
	5/7/2008	Setup	Too windy to perform sludge depth measurements.
	5/7/2008	Setup	Burned new TX5A period 4 data disc. Checked on computer and both discs 1-2 work properly. Burned discs for OK4A period 4. Both work properly on LAN.
17:15	5/7/2008	Setup	Calibrated TDLAS 1026: Mean: 51.4 - SD: 2.1 - RSD: 4.0% - Bias: 3.1%
17:50	5/7/2008	Setup	Calibrated TDLAS 1032: Mean: 51.2 - SD: 0.77 - RSD: 1.5% - Bias: 2.8% - Notes: Lost communication even though directly connected to Panasonic. Did not zero but R-squared values low enough (< 84).
18:27	5/7/2008	Setup	TEC 450i reference precision check.
18:35	5/7/2008	Setup	TEC 450i instrument operating parameters.
18:37	5/7/2008	Setup	TEC 450i calibration verification check.
19:40-20:40	5/7/2008	Setup	Sonic inter-comparison: pass.
	5/7/2008	Setup	Sonic inter-comparison performed (no bias)-pass.
	5/8/2008	Setup	Could not perform sonic anemometer bias. Sonic anemometers were giving all zeros for readings. May have water leakage.
	5/8/2008	Setup	Changed pH reference solution. Calibration passed.
	5/8/2008	Setup	Troubleshot NW scanner. See notes for details.
	5/8/2008	Setup	Changed filters in S-OPS inlets.
	5/8/2008	Setup	Power box #5 had burning smell and was very hot.
	5/8/2008	Setup	TDL 1026 had centerline duty problems at OK4A.
	5/8/2008	Setup	Lagoon site layout made.
	5/8/2008	Setup	Getting motherboard failure on H2S analyzer, but still seems to be working properly.
	5/8/2008	Setup	GSS leak test: pass
	5/8/2008	Setup	GSS no flow test
	5/8/2008	Setup	GSS max flow test

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
	5/8/2008	Setup	S-OPS/GSS leak test: Pass
	5/8/2008	Setup	pH calibration: pass
13:48	5/8/2008	Setup	Could not perform sonic anemometer bias. Sonic anemometers were giving all zeros for readings. May have water leakage. Will set up sonic anemometers and run for measurement period. Will redo bias test at takedown.
14:24	5/8/2008	Setup	Barometer audit: pass
18:26	5/8/2008	Setup	Wetness sensor calibration: accepted
14:32	5/9/2008	Remote	Daily Status Check from PAML. Notes: Most periods over past day have >160 spike counts for sonic anemometer 3. TDL 1 not present due to poor power supply failure failures. Communication with CR1000 not working. TDL 2 paths 2 and 9 have low light levels—re-aim successfully.
12:33	5/12/2008	Remote	Daily Status Check from PAML. Notes: Sonic 1 flagged briefly at 715 UTC. As of 2015 UTC (497) H2S values no longer normal. H2S analyzer lost connection; last update on 1916 UTC on 5/11/2008. Filled starting at 1915 UTC 5/11/2008. CR1000 communication problems with LAN. Motherboard status – fail on 450i.
13:00	5/13/2008	Remote	Daily Status Check from PAML. Notes: A flags on GSS/H2S/Innova QC yesterday but occurred before correction yesterday; currently working properly.
13:14	5/14/2008	Remote	Daily Status Check from PAML. Notes: H2S Motherboard status – fail. Can only temporarily connect to CR1000 to check time synch.
14:32	5/15/2008	Remote	Daily Status Check from PAML. Notes: Zero unflagged on sonic anemometer 1 during previous day; zero flagged (seems odd); will monitor. Limited communication with CR1000. No data sent from sonic anemometer 1 as of 0241 UTC on 5/15/2008. Will keep eye on data and see if it updates. Also no communications with CR1000 (same power outlet), but have been having problems with communications throughout period.
18:02	5/16/2008	Remote	Daily Status Check from PAML – Notes: Sonic 1 has not received valid data since 0250 Z on 5/15/2008. All data is coming in as zero values for sonic anemometer 1. Sonic 1 data is not incrementing.
	5/19/2008	Repair	Sonic 1, met tower without power. GFCI tripped and could not be reset. No tripped breakers in power box. Shut off all power to rewire new GFCI outlet (new outlet works fine). Found large spiders/dead bugs inside power outlet.
	5/19/2008	Repair	Pumping lagoon.
	5/19/2008	Repair	Tried aligning paths with new power supply box (NW corner-TDL 1 (1032)) using scanner test box. Powered scanner and TDLAS successfully, but could not

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			communicate with either instrument. Aligned NW scanner/TDLAS with modem from wall.
	5/19/2008	Repair	Sonic 1 now running, incrementing same amount of data as sonic anemometers 2 and 3. CR1000 now capable to communicate with LAN (even though temporarily).
	5/19/2008	Repair	Took out cubes in retro-reflectors 1, 2, 6, and 7 NW scanner (TDL 1). #1--1 cube remaining; #2--3 cubes; #6--1 cube; #7--3 cubes.
	5/19/2008	Repair	Put 1/4-inch plastic in 1, 6 paths on SE scanner (TDL 2). Put 1/8-inch in 2, 7 paths on SE corner (TDL 2)
	5/19/2008	Repair	Communication with TDL 1032 (1--NW) is in and out but still working majority of time.
	5/19/2008	Repair	Having same voltage issues with power supply box-works temporarily then only uses 6 VOC. Tried new and old cables but still have issues. Removing box and bringing back to PAML. Leaving rest of instrumentation setup.
12:59	5/19/2008	Remote	Daily Status Check from PAML – Notes: Sonic 1 seems to be not working since 5/15/2008 as last data received was at 250 UTC on 5/15/2008 CR1000 seems not to be connected.
19:20	5/21/2008	Remote	Daily Status Check from PAML – Notes: TDL1 not present (bad scanner); no connection to TDL laptops. Poor communication with CR1000. Values look ok on numeric display for CR1000. Back-up error related to sonic anemometer program/*iPort*/Innova program.
12:35	5/22/2008	Remote	Daily Status Check from PAML – Notes: Graphs of u,v, and w look different for sonic anemometer 1. Data not incrementing for TDLAS since 5/20/2008. Communication problems with CR1000; can only connect for 1-2 min, and hence data cannot be transferred. Back-up error related to sonic anemometer/*iPort*/Innova programs. Not able to connect to TDLAS laptops.
14:45	5/27/2008	Remote	Daily Status Check from PAML – Notes: Lamp voltage has dropped from about 950 at start of period to about 935 now. No TDLAS data since 5/19/2008. Poor communication with CR1000 prevents download. Looked at data directly, and they seem reasonable. Unable to access TDL laptops.
	5/28/2008	Calibration	TDLAS 1032 zero calibration went smoothly. Could not get span gas to reach 50 ppm (100 ppmm). Tried spanning 200 ppmm (100 ppm) but could not get values above 89 ppm. Removed TDLAS from calibration and started calibration 1026.
	5/28/2008	Calibration	UPS output power has been stored to Load Segment 2 (probably when shut power down when changing GFCI outlet)…5/19/2008 21:33:10. UPS switched to battery power…5/25/2008 21:54:08. AC restored message sent to registered clients connected to Load Segment

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			2...5/25/2008 21:54:12.
	5/28/2008	Calibration	Performed pH/ORP calibrations. pH gave values about -17 mV to -12 mV deviated from expected. Will launch lagoon and perform calibration after measurement period.
	5/28/2008	Calibration	Performed TDLAS inter-comparison (1026/1032). 1026 gave lower concentrations than 1032 and did not have good R^2 values (0.20). Installed new power supply with new scanner on NW corner.
	5/28/2008	Calibration	pH calibration: pH gave values about -17 mV to -12 mV deviated from expected. Will launch lagoon and perform calibration after measurement period.
	5/28/2008	Calibration	ORP calibration: pass
14:42	5/28/2008	Calibration	Calibrated TDLAS 1026 – Mean: 45.3 - SD: 0.18 - RSD: 0.4% - Bias: -9.0%
15:08	5/28/2008	Calibration	Calibrated TDLAS 1032 – Mean: 47.76 - SD: 0.37 - RSD: 0.8% - Bias: -3.9% - Notes: Could not get span gas to reach 50 ppm (100 ppmm). Tried spanning 200 ppmm (100 ppm) but could not get values above 89 ppm. Removed TDLAS from calibration and started calibration 1026. During first background, got values of 0.0 R-squared and 0.0 ppm. Second background gave values of 40-50 R^2 and 5-6 ppm.
	5/29/2008	Calibration	Too windy today and yesterday to perform sludge depth measurements. No film on lagoon today because of such windy conditions (lagoon producing waves).
	5/29/2008	Calibration	Painted scanners white and put Vaseline/petroleum jelly on screws to prevent streaking.
	5/29/2008	Calibration	Used new zero gas cylinder for 450i calibration.
	5/29/2008	Calibration	*iPort* was not logging any H2S data since yesterday 17:19 UTC. Was giving an error due to data collection and has logged any data since error. Closed *iPort* and reopened a few times, loading data from 17:19 UTC yesterday in fillOK3A450I0529081727.dat. Calibrations from today were in this "fill" file; calibration times are entered on control chart. 450i motherboard still failing, but parameters/measurements seem valid.
	5/29/2008	Calibration	Sonic anemometers did not pass during first inter-comparison--very high winds. Sonic anemometers 1 and 3 barely out of spec.
	5/29/2008	Calibration	Updated *rsync* program and restarted all computers.
	5/29/2008	Calibration	Removed plastics and cubes from TDL 2 (1026-SE) paths 1, 2, 6, and 7. 1 and 6 have one cube remaining. 2 and 7 have three cubes computers.
	5/29/2008	Calibration	Yesterday, switched scanners to low hold and reg move.
	5/29/2008	Calibration	Could not connect to CR1000 long enough to download data. Used laptop and downloaded from 5/1/2008--present and transferred to LAN. C:\NAEMS\Data\OK3A\Period4\CR1000 …and

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			Period5\CR1000.
	5/29/2008	Calibration	Lagoon site layout made.
	5/29/2008	Calibration	GSS leak test: pass
	5/29/2008	Calibration	GSS no flow test
	5/29/2008	Calibration	GSS max flow test
	5/29/2008	Calibration	S-OPS/GSS leak test: Pass
15:50-16:50	5/29/2008	Calibration	Sonic inter-comparison: pass. Notes: Did not pass during first inter-comparison, very high winds. Sonic anemometers 1 and 3 barely out of spec.
16:20	5/29/2008	Calibration	TEC 450i reference precision check.
16:57	5/29/2008	Calibration	Barometer audit: pass
16:54	5/29/2008	Calibration	TEC 450i calibration verification check.
17:05	5/29/2008	Calibration	TEC 450i instrument operating parameters.
18:21	5/29/2008	Calibration	Sonic zero calibration: pass.
21:58	5/29/2008	Calibration	Wetness sensor calibration: accepted
12:54	6/2/2008	Remote	Daily Status Check from PAML – Notes: CR1000 data was downloaded and stored on laptop then LAN on 5/29/2008 (day 515). Communications with CR1000 are limited which is why data has not been updated since manual data upload. Could not perform back up because there was not enough space. Changed settings to only keep last backup (not last 3). Deleted 2 previous backups and kept/saved last backup. Now Directory (NAEMS_West) has 28.8GB. Paths 1 and 2 were off on TDL 1. Realigned and now running properly. Could temporarily connect to CR1000-checked current values and all parameters looked valid.
12:15	6/3/2008	Remote	Daily Status Check from PAML Notes: Limited communication with CR 1000. Was able to temporarily connect to CR1000 but could not collect data. Values seem to be valid.
12:15	6/4/2008	Remote	Daily Status Check from PAML – Notes: Flagging on each sonic anemometer at approx. the same time (~520.9); currently none are flagging. Paths on TDL 2 that seemed to be not aligned were actually aligned--after entering aim menu, left scanner stationary on unaligned path and light level gradually increased to valid levels.
12:30	6/5/2008	Remote	Daily Status Check from PAML– Notes: Not sure how to sync times; will check later. Internet connect is very slow; TDL time sync check may not be correct.
12:30	6/6/2008	Remote	Daily Status Check from PAML – Notes: Not enough space to perform backup. CR1000 has not updated since day 515.
	6/10/2008	Takedown	Too windy to perform sludge depth measurements.
	6/10/2008	Takedown	pH probe gave values that were too low for each solution; will return to PAML for more analysis.
	6/10/2008	Takedown	Sonic anemometers did not pass during first inter-

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			comparison. Sonic 1, deviations were greater than 0.3 m/s. Noticed bird droppings on sonic anemometer 1.
	6/10/2008	Takedown	TDLAS 1032 second background did not give zero. Gave one with R^2 over 0.84. Power-cycled and redid background--passed.
	6/10/2008	Takedown	Tubing for S-3 on south end had holes where rodent chewed through. Could not perform max-flow/leak/inlet tests for S-OPS. Repaired and will perform leak test when setting up at TX5A.
	6/10/2008	Takedown	Farm manager said lagoon overturned about two weeks ago, and place had strong odor.
	6/10/2008	Takedown	pH sensor: calibration, acceptance, QA done. Probe did not pass acceptance, but probe is finished for 6-month calibration. Will inspect at PAML.
	6/10/2008	Takedown	ORP sensor: calibration done. Acceptance passes.
	6/10/2008	Takedown	GSS leak test: pass
	6/10/2008	Takedown	GSS no flow test
	6/10/2008	Takedown	GSS max flow test
	6/10/2008	Takedown	S-OPS/GSS leak test: Pass
16:59	6/10/2008	Takedown	TEC 450i reference precision check.
17:05	6/10/2008	Takedown	TEC 450i calibration verification check.
17:05	6/10/2008	Takedown	TEC 450i instrument operating parameters.
17:40	6/10/2008	Takedown	Calibrated TDLAS 1032 – Mean: 50.82 - SD: 0.23 - RSD: 0.5% - Bias: 2.5% - Note: Second background test did not pass; had one value ~1 R^2 >84. Power-cycled and redid background.
18:33	6/10/2008	Takedown	Calibrated TDLAS 1026 – Mean: 47.12 - SD: 0.30 - RSD: 0.6% - Bias: -4.2%
19:55-20:55	6/10/2008	Takedown	Sonic inter-comparison: pass
21:25	6/10/2008	Takedown	Sonic zero calibration: pass.
22:02	6/10/2008	Takedown	Wetness sensor calibration: accepted
22:58	6/10/2008	Takedown	Barometer audit: pass
	11/5/2008	Setup	Tied down trailer and hooked up power
	11/5/2008	Setup	Calibrated all instruments except weather station and S-OPS/GSS (sonic anemometer bias were done tomorrow)
	11/5/2008	Setup	Fixed lagoon probe wire
	11/5/2008	Setup	pH sensor: calibration done; acceptance and QA accepted.
	11/5/2008	Setup	ORP sensor: calibration done. Acceptance passes.
21:15-22:15	11/5/2008	Setup	Sonic inter-comparison: all pass
22:26	11/5/2008	Setup	Calibrated TDLAS 1028
22:56	11/5/2008	Setup	Calibrated TDLAS 1027
00:03	11/6/2008	Setup	Barometer audit: pass
00:03	11/6/2008	Setup	Wetness sensor calibration: accepted
	11/6/2008	Setup	Used N2 cylinder #CC8383; used zero air cylinder #CC183079 (changed on H_2S control chart)
	11/6/2008	Setup	Outlets in SE corner (scanner outlet/TDL 2) and retro 6/TDL 2 without power. Ran extension cords from retro

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			7 outlet to scanner and retro 6.
	11/6/2008	Setup	Towers have 1/8 plastics; short sides have 1 and 3 cubes with 1/4 plastics; long sides have 1 and 3 cubes with 1/8 plastics.
	11/6/2008	Setup	New scanner/power supply SE corner (24 V)
	11/6/2008	Setup	Lagoon site layout made.
	11/6/2008	Setup	Maintenance list completed.
16:25	11/6/2008	Setup	Zero calibration performed on sonic anemometers; all pass.
20:52	11/6/2008	Setup	Launched lagoon float
16:00	11/7/2008	Remote	Daily Status Check from PAML − Notes: It appears that TDL 2/scanner 2 has lost power. Last TDL record at 14:44 GMT on 11/7/2008. West team mentioned power issues in open site notes. Sonic 3 has a lot of spikes (up to 400). Pump diaphragm changed on H_2S analyzer.
16:56-16:58	11/7/2008	Setup	TEC 450i leak test. Flow went to ~0 LPM; pressure ~317.1 mmHg (above 250 mmHg). According to manual, pump may need to be rebuilt. Changed inlet filter (was clean previously but still changed). No obstruction in capillary but blew dust remover air through just in case. Tightened all metal fittings inside 450i. Checked capillary to see if loose on 11/5/2008 but was tight; tightened again and reapplied tape to secure. Flow ~0.77 LPM.
16:00	11/10/2008	Remote	Daily Status Check from PAML − Notes: Currently no power to TDL 2 (SE corner). Bad GFCI outlet was replaced by Hitch but extension cord may not have been plugged back in. Call Ken Smith and left voicemail to check to see if cord was plugged in. Sonic QC did not run today. Poor communications between CR 1000 and LAN. Last CR 1000 data point around 21:00 GMT on 10/30/2008).
13:30	11/11/2008	Remote	Daily Status Check from PAML − Notes: The following happened yesterday: Had Ken Smith from Hitch go to site to check power at outlets on south side of lagoon (TDL 2); all outlets have power. Ken opened power supply box to check if modem lights were on--they were not. Checked power from pins from cord running from outlets to power box--has power. Plugged back in and checked voltage to modems and spontaneously started working; went back to align paths ~5-10 min later and system had no power. The following today: sonic anemometer 1 is 7-8C greater than sonic anemometers 2 and 3. Ken Smith checked if metal post mounting power supply was touching and heat sink black where they made contact; no power/voltage from power supply to modems; power coming from outlet to 3-pin cord; power supply most likely shorted out (burned up) and needs to be

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			replaced...repair trip. Sonic program QC not running daily. H_2S chamber pressure gradually decreasing but may be due to weather. Cannot see CR 1000 data to test hypothesis due to poor communication with CR 1000. Will continue to monitor.
13:45	11/12/2008	Remote	Daily Status Check from PAML− Notes: TDL 2/scanner not working. Repair trip next week. Runtime error in QC program. H_2S conc. Range ~0-12.5 ppb with outlier 22.8 ppb. Limited communications between LAN-CR1000; no QC files.
13:30	11/13/2008	Remote	Daily Status Check from PAML − Notes: Bad power supply for TDL 2/SE scanner. Repair trip next week. Runtime errors in QC program. Limited LAN-CR 1000 communications.
14:00	11/14/2008	Remote	Daily Status Check from PAML − Notes: Bad power supply for TDL 2/SE scanner. Repair trip next week. Runtime errors in QC program. Limited LAN-CR 1000 communications.
	11/17/2008	Repair	Changed 24V power supply on the modem/power box for TDL 2. TDLAS and scanner are working fine now. Re-aimed few paths and saved new settings in the Gas View setup file.
13:30	11/17/2008	Remote	Daily Status Check from PAML − Notes: Last H2S modification occurrence at 23:04 11/16/2008 (yesterday evening). Filled data: FillOK3A450I1117081330.dat. Restarted sonic anemometer program. QC program runtime error. Limited LAN-CR 1000 communications.
13:30	11/18/2008	Remote	Daily Status Check from PAML − Notes: H_2S analyzer running properly and collecting data. QC program may only be accepting data for data file referenced in QC parameter files; new files started yesterday when program failed (fill and current real-time files). Will check then change to first file/last file if needed (was needed and changed). Flagging on all sonic anemometers. See notes for details. H_2S values are zero due to *iPort* failure. New power supply for TDL 2/SE scanner during repair trip yesterday. Not much data collected since then. Limited LAN-CR 1000 communications.
15:40	11/19/2008	Remote	Daily Status Check from PAML − Notes: No CR 1000 data in QC file due to communication problems.
14:15	11/20/2008	Remote	Daily Status Check from PAML − Notes: All 3 sonic anemometers have irregular number of total data points (occasionally). Sonic 1 about 8C higher than the other two sonic anemometers. Flag 4 is frequent in H_2S data (value does not vary more than 2 ppb over 1 hour). No communication with CR 1000.
13:30	11/21/2008	Remote	Daily Status Check from PAML − Notes: Sonic 1 had some flagging but majority not flagged. Sonic 1 temp is

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			7-8C greater than sonic anemometers 2 and 3. Sonic 2 w is less than zero (0.1-0.2 m/s). Sonic 3 has had spike counts greater than 160 in the past but not during previous day. No communication with CR 1000.
13:30	11/24/2008	Remote	Daily Status Check from PAML − Notes: Sonic 1 had some flagging but majority not flagged. Sonic 1 temp is 7-8C greater than sonic anemometers 2 and 3. Sonic 2 w is less than zero (0.1-0.2 m/s). Sonic 3 has had spike counts greater than 160 but majority is less than 160. No communication with CR 1000.
13:56	11/25/2008	Remote	Daily Status Check from PAML − Notes: Sonic 1 had some flagging but majority not flagged. Sonic 1 temp is 7-8C greater than sonic anemometers 2 and 3. Sonic anemometers 1 and 2, average w as less than zero (0.2-0.5 m/s). Sonic 3 has had spike counts greater than 160 but majority is less than 160. No communication with CR 1000.
13:15	11/26/2008	Remote	Daily Status Check from PAML − Notes: Sonic 1 had some flagging but majority not flagged. Sonic 1 temp is 7-8C greater than sonic anemometers 2 and 3. Sonic anemometers 1 and 2, average w is less than zero (0.2-0.5 m/s). Sonic 3 has excessive spike counts greater than 160; occur daily around 23:30 GMT. No communication with CR 1000.
14:15	12/1/2008	Remote	Daily Status Check from PAML − Notes: Sonic program crashed. Restarted sonic anemometer program at 15:53. See notes for details. TDL 2 laptop appears to have frozen up on 11/26 at 13:17. Last data in file on 11/26/2008 at 15:10. Still able to connect but no response on screen. TDL 1 path 1 has low LL. Re-aimed and LL are now good. Sonic 3 has a lot of spikes on days 698 and 699. No communication with CR 1000.
	12/2/2008	Calibration	Tied in old NH3 cylinder (FF15402--500 ppm) with new cylinder (FF57856--469 ppm) using TDLAS 1027.
	12/2/2008	Calibration	Parser message; value creation failed at line 599.
	12/2/2008	Calibration	New NH3 cylinder started at 1750 psi.
	12/2/2008	Calibration	Power failures recorded on 11/20/2008 and 11/29/2008. See open site notes for details.
	12/2/2008	Calibration	Performed two sonic anemometer inter-comparisons; one with old sonic anemometer (1921) and one with new (1927).
	12/2/2008	Calibration	TEC 450i flow less than 0.9 LPM; performed leak test after calibration (0.017 LPM).
	12/2/2008	Calibration	New steel gear scanner in NW corner; shipping old scanner in that corner back to DP. Old brass scanner: PTU #5, s/n: 50705255001207, Purdue #: 1043282; New steel scanner: PTU #4, s/n: ...1206, Purdue #: 1043284.
	12/2/2008	Calibration	Too windy to perform sludge depth measurements.

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
	12/2/2008	Calibration	Restarted all computers and installed updates.
	12/2/2008	Calibration	S-OPS installation report completed.
17:51	12/2/2008	Calibration	Barometer audit: pass
17:51	12/2/2008	Calibration	Wetness sensor calibration: accepted
18:09-19:09	12/2/2008	Calibration	Sonic inter-comparison: all pass
18:43	12/2/2008	Calibration	Calibrated TDLAS 1028
19:14	12/2/2008	Calibration	Calibrated TDLAS 1027
20:08	12/2/2008	Calibration	Sonic zero/bias check. Notes: sensor 4 was sensor 1 in program. Replaced old sensor 1 (1921) with new sensor 1 (1927) and performed bias at different times.
20:27	12/2/2008	Calibration	SO2 calibration
20:35	12/2/2008	Calibration	TEC 450i calibration verification check.
20:35	12/2/2008	Calibration	TEC 450i instrument operating parameters.
20:43	12/2/2008	Calibration	H2S check
21:20-22:20	12/2/2008	Calibration	Sonic inter-comparison: all pass
	12/3/2008	Calibration	Very windy today; foam from lagoon blowing off top layer towards south retro-reflectors and S-OPS path. Too windy to perform sludge depth measurements.
	12/3/2008	Calibration	Restarted LAN (sonic anemometer program error? C++ runtime error with visual basic program). Sonic anemometers were still running after error.
	12/3/2008	Calibration	Tubing length for S-OPS: North--124 m; South--231 m
	12/3/2008	Calibration	Distances not entered into TDL 1--NW--1028
	12/3/2008	Calibration	*rsync* took a few hours to ship previous data and could not wait for completion. Had to go to Praxair and UPS before they closed. Will check back later remotely to complete *rsync* process.
	12/3/2008	Calibration	Lagoon site layout made.
	12/3/2008	Calibration	Maintenance list completed.
	12/3/2008	Calibration	ORP sensor: calibration done. Acceptance passes.
	12/3/2008	Calibration	S-OPS balance: South
	12/3/2008	Calibration	S-OPS balance: North
	12/3/2008	Calibration	S-OPS/GSS leak test: Pass
	12/3/2008	Calibration	S-OPS max flow test
	12/3/2008	Calibration	GSS max flow test
	12/3/2008	Calibration	GSS no flow test
	12/3/2008	Calibration	GSS leak test: pass
18:40	12/3/2008	Calibration	Removed lagoon float.
19:00	12/3/2008	Calibration	pH sensor: QA completed; acceptance done; inspection done.
19:35	12/3/2008	Calibration	Rewired lagoon float.
19:00	12/10/2008	Remote	Daily Status Check from PAML − Notes: Sonic error at son_100s_time. Increased 2nd dimension of son_100s_time (and _u, _v, _w, _T) from 4000 to 8000. Restarted sonic anemometer program and it works fine. There are about 20 sonic anemometer flags continuously

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			for all three sonic anemometers. In H2S data, there are two 30-minute periods with flag 1. No communication with CR 1000.
13:15	12/11/2008	Remote	Daily Status Check from PAML – Notes: No CR 1000 data in QC file due to communication problems.
14:00	12/12/2008	Remote	Daily Status Check from PAML – Notes: No CR 1000 data in QC file due to communication problems. Some data lost due to sonic anemometer flagging on sonic anemometer 3, but not significant. TDL 1 path 8 not aligned; re-aimed successfully.
	12/16/2008	Takedown	Started GSS/SOPS calibration at 18:45 GMT (end H2S/GSS data collection).
	12/16/2008	Takedown	Lagoon frozen where probes/float is inserted. Cut ropes when trying to pull out probes. Had to throw rocks at float to break loose.
	12/16/2008	Takedown	12/8/2008 02:33:51: AC restored message sent to registered clients connected to load segment 2. 12/14/2008 13:23:32: UPS switched to battery power; UPS bypass unavailable. 12/14/2008 13:23:37: AC restored message sent to registered clients connected to load segment 2.
	12/16/2008	Takedown	Too windy to perform sludge depth measurements.
	12/16/2008	Takedown	Pumping into lagoon producing strong odor.
	12/16/2008	Takedown	NH3 tank/regulator threads stripped after calibration. Turned a few times then stopped moving and could not move without using a sledge hammer. Will return NH3 cylinder tomorrow and bring regulator to PAML. Cannot perform TDL calibrations in TX5A--TDL's passed today. Will perform calibration at end of the period in TX (assuming new NH3 tank will arrives on time).
	12/16/2008	Takedown	Maintenance list completed.
	12/16/2008	Takedown	pH sensor: QA completed; acceptance done; inspection done.
	12/16/2008	Takedown	ORP sensor: calibration done. Acceptance passes.
17:45	12/16/2008	Takedown	Barometer audit: pass
17:48	12/16/2008	Takedown	Wetness sensor calibration: accepted
18:15-19:10	12/16/2008	Takedown	Sonic inter-comparison; all pass.
20:10	12/16/2008	Takedown	Zero calibration performed on sonic anemometers; all pass.
22:31	12/16/2008	Takedown	Calibrated TDLAS 1027 – See site notes for details.
	12/17/2008	Takedown	Unhooked the trailer, weather station, and power and will move to TX5A.
	4/21/2009	Setup	Reached site at 6:30 PM local time. Found a flat tire on trailer; replaced tire with new one.
	4/22/2009	Setup	Lagoon 20-30% crusted.
18:24	4/22/2009	Setup	Calibrated TDLAS 1027
18:50	4/22/2009	Setup	Calibrated TDLAS 1028

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
16:40-17:17	4/22/2009	Setup	TEC 450i Single Point calibration
17:00	4/22/2009	Setup	GSS/S-OPS calibrations
	4/23/2009	Setup	UPS history: 4/22/2009: 15:15:49: Communication with UPS restored. 4/22/2009 15:13:17: UPS output power has been restored to Load Segment 1. 4/22/2009 15:13:17: UPS output power has been restored to Load Segment 2. Most likely happened when power was hooked up.
	4/23/2009	Setup	Apparent problem with TDL 1028 shutter; disassembled device, it appeared ok, so it was put back into service.
	4/23/2009	Setup	Failed pH probe (008) replaced with new one (009); will take broken probe to PAML for analysis.
	4/23/2009	Setup	Maintenance list completed.
	4/23/2009	Setup	Lagoon site layout made.
	4/23/2009	Setup	ORP sensor: calibration done.
14:50-15:50	4/23/2009	Setup	Sonic inter-comparison; all pass.
15:00	4/23/2009	Setup	pH sensor (009): QA, calibration, and maintenance and inspection completed. Note: Think pH buffer is bad; will replace on next trip.
16:08	4/23/2009	Setup	Zero calibration performed on sonic anemometers; all pass.
20:12	4/23/2009	Setup	Wetness sensor calibration: accepted
20:12	4/23/2009	Setup	Barometer audit: pass
13:30	4/27/2009	Remote	Daily Status Check from PAML − Notes: Not enough space to perform backup. Deleted previous backups to make room for new backups. TDL 1 only aligned on path 9. Optimization was not enrolled; enabled optimization after finding the lost paths. Saved new backup running setup files. TDL 1 path 8 was very difficult to find with high enough light levels; running optimization on path to see if program can find path. Will check later. Sonic 3 always has excessive spike counts at OK3A. Poor communication with CR 1000; files have not updated since yesterday.
12:30	4/28/2009	Remote	Daily Status Check from PAML − Notes: Unable to access site remotely. QC files not up to date. No data beyond 848.9. Cannot force shipment of data. Sonic 3 always has excessive spike counts at OK3A.
12:30	5/4/2009	Remote	Daily Status Check from PAML − Notes: Not able to remotely access site. Sonic 3 always has excessive spike counts at OK3A. Centerline duty cycle up to 255 when no paths were aligned. CDC is 156 currently when there are two paths aligned. QC files are update through yesterday.
	5/6/2009	Repair	Found red checkmark on DnyDNS. Forced update and powercycled modem and routers but no change. Internet is working but still red checkmark. Forced another

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			update and green checkmark appeared.
	5/6/2009	Repair	TDL 1 only had two paths aligned upon arrival. All paths needed to be moved ten steps up and five steps left. Retro seven was knocked out of place due to soft ground; secured in a more solid area. Used modem from wall to align TDL 2 (1029/NW corner/scanner 1205).
	5/6/2009	Repair	Restarted LAN and Panasonic anemometers.
	5/6/2009	Repair	Deleted previous backups to make room for new backups.
	5/6/2009	Repair	Forced data shipment.
	5/6/2009	Repair	UPS history: 5/2/2009 9:20:11: AC Restored Message sent to registered clients connected to Load Segment 2 5/4/2009 16:02:51: UPS switched to battery power. 5/4/2009 16:02:52: AC Restored Message sent to registered clients connected to Load Segment 2
22:00	5/6/2009	Repair	Calibrated TDLAS 1029
14:30	5/8/2009	Remote	Daily Status Check from PAML – Notes: No QC update. Microsoft Visual C++ runtime error. No CR 1000 update since 5/6/2009. TDL 1 paths 2, 3, 7, and 8 were off. Could not re-aim path 3 due to slow internet. Started showing pan/tilt errors for all paths; unsuccessfully tried to fix but could not. Will talk to Dr. Grant.
	5/14/2009	Takedown	Found pan/tilt error on SE scanner. Power supply/modem box was not mounted on tripod correctly (wind may have moved it) and antenna was not vertical (wind?). Power-cycled scanner and it now works properly.
	5/14/2009	Takedown	Yellow wire pulled out of CR 1000 when disconnecting lagoon sensors; reattached for calibration (from barometer); also, the wetness sensor wires were disconnected but reattached for calibration.
	5/14/2009	Takedown	Maintenance list completed.
	5/14/2009	Takedown	ORP sensor: calibration and acceptance performed; all pass.
16:00-18:00	5/14/2009	Takedown	S-OPS/GSS calibrations Note: S3 failed GSS leak test; will check again at WA5A.
16:55-17:55	5/14/2009	Takedown	Sonic inter-comparison; all pass.
18:09	5/14/2009	Takedown	Zero calibration performed on sonic anemometers; all pass.
19:15	5/14/2009	Takedown	Pulled out lagoon float.
19:30	5/14/2009	Takedown	pH sensor: QA and inspection completed.
20:25-21:04	5/14/2009	Takedown	TEC 450i single point calibration Note: Had to redo H2S calibration because initial calibration was performed at about 1 ppm and not at 0.5 ppm.
20:48	5/14/2009	Takedown	Wetness sensor calibration: accepted
20:52	5/14/2009	Takedown	Barometer audit: pass
22:35-22:52	5/14/2009	Takedown	Calibrated TDLAS 1027
23:02-23:22	5/14/2009	Takedown	Calibrated TDLAS 1029

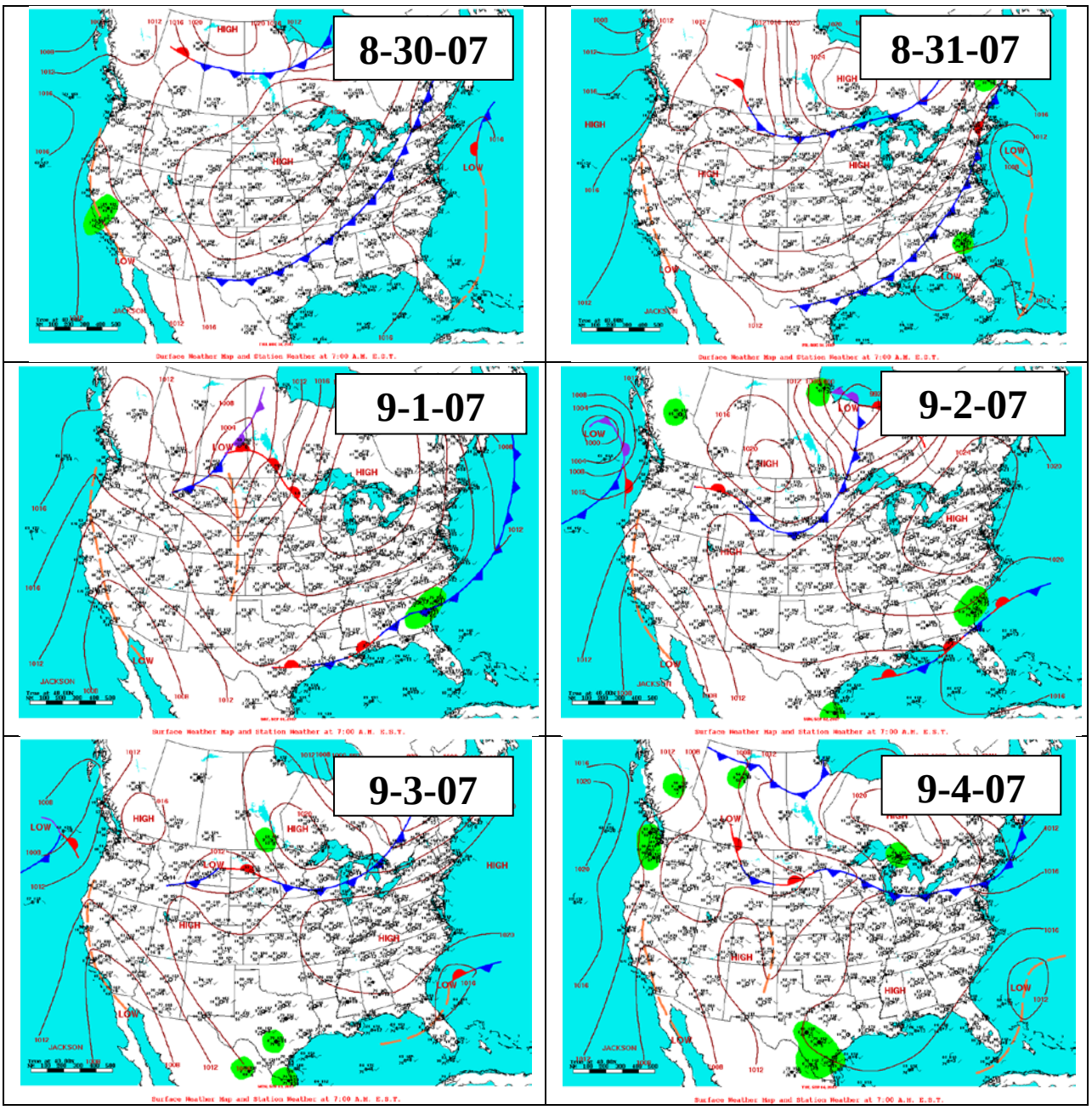
Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
	7/14/2009	Setup	Leveled trailer and started to tie down and hook up power to the trailer. However, a storm arrived with heavy rain and lightning forced us to leave for the day. Will continue tomorrow.
	7/15/2009	Setup	Too windy to perform sludge depth measurements.
	7/15/2009	Setup	TDLAS 1029 failed calibration at low light levels. Managed to increase the light levels, and it passed barely with a bias of -9.53%.
	7/15/2009	Setup	Sonic anemometers failed calibration (sonic anemometer 3 specifically; it was giving high values). Sonic anemometers passed on the second calibration.
	7/15/2009	Setup	SO2 and zero gas PSI values have decreased by a lot; checked for leaks but couldn't find any.
	7/15/2009	Setup	pH probe failed calibration again. Will use it anyway as it is passing at buffer 4 and 10. Will discuss, and if needed will disregard data collected during this period (OK3A Period 9).
	7/15/2009	Setup	UPS history: 7/15/2009: 15:39:50: Load Segment 2 has been turned off. 7/15/2009 15:43:19: UPS output power has been restored to Load Segment 1. 7/15/2009 15:43:19: UPS output power has been restored to Load Segment 2.
	7/15/2009	Setup	Maintenance list completed.
	7/15/2009	Setup	Lagoon site layout made.
	7/15/2009	Setup	ORP sensor: calibration and acceptance performed; all pass.
16:40	7/15/2009	Setup	Sonic inter-comparison; all pass.
17:40-18:00	7/15/2009	Setup	Calibrated TDLAS 1028
18:43-19:03	7/15/2009	Setup	Calibrated TDLAS 1029
19:30-20:33	7/15/2009	Setup	S-OPS/GSS calibrations
19:32-20:04	7/15/2009	Setup	TEC 450i single point calibration
20:21	7/15/2009	Setup	Zero calibration performed on sonic anemometers; all pass.
22:15	7/15/2009	Setup	pH sensor: QA, inspection, and maintenance done. Notes: pH probe failed calibration again. Will use it anyway as it is passing at buffer 4 and 10. Will discuss, and if needed will disregard data collected during this period (OK3A Period 9).
	7/16/2009	Setup	Had many aiming problems with TDL 1028. Telescope is not aimed properly. Could not get good light level values for path 9 without removing plastic.
	7/16/2009	Setup	Took out plastic in retro 4 of TDL 1 because of insufficient light not achieved.
14:58	7/16/2009	Setup	Wetness sensor calibration: accepted
14:58	7/16/2009	Setup	Barometer audit: pass

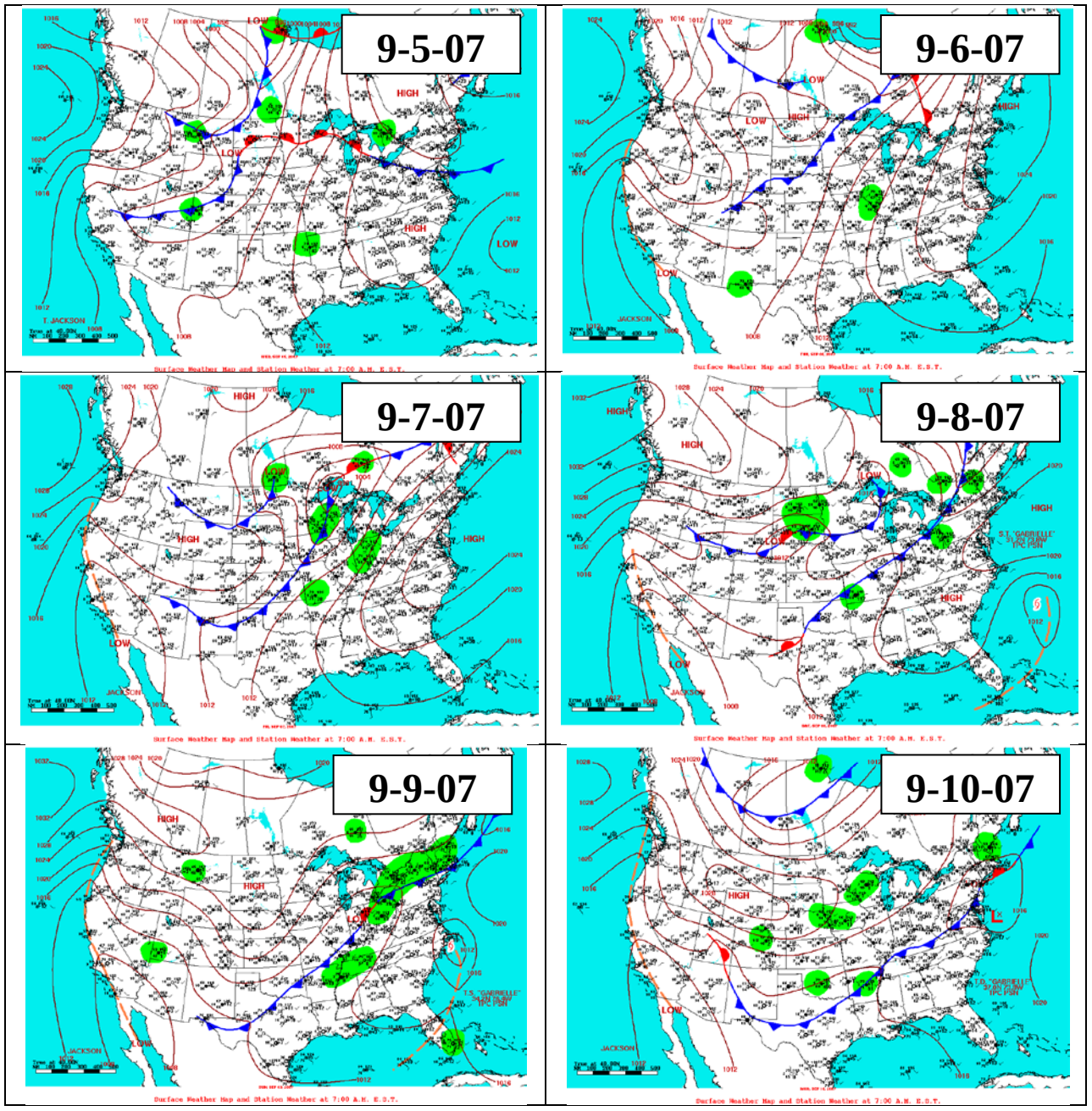
Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
16:45	7/16/2009	Setup	Launched lagoon float
12:30	7/17/2009	Remote	Daily Status Check from PAML − Notes: Sonic anemometers had some flagging during big storm (especially sonic anemometer 2). Sonic 3 has up to 350 spikes. Many TDL paths were not aligned. TDL 1 path 1 was being skipped; changed dwell time from 0 s to 15 s. Changed dist on TDL 1 path 1 from 15 s to one minute. CR 1000 data file contained a bunch of old data, and no data from current site. Did a custom collection to download data for current site and then placed this data in the appropriate file. Data are now collected.
12:15	7/20/2009	Remote	Daily Status Check from PAML − Notes: Not enough space to perform backup. Deleted previous backups to make room for new backups. TDL 1 paths 4 and 5 are way off their saved setup values. Saved setup to get original paths back to normal; paths had been changed without setup being saved.
13:00	7/21/2009	Remote	Daily Status Check from PAML − Notes: Sonic 3 always has periods of excessive flagging at OK3A. Strong storms in area last night; they may have knocked TDL 2 path 9 out of alignment. On both TDL's CDC temperature dropped to 133, now back to normal.
12:15	7/22/2009	Remote	Daily Status Check from PAML − Notes: Sonic 3 always has periods of excessive flagging at OK3A.
13:06	7/24/2009	Remote	Daily Status Check from PAML
12:30	7/27/2009	Remote	Daily Status Check from PAML − Notes: Upon login, found runtime error: "Program: C:\Program Files\Genie-Soft\GBMPro7\GBM7.exe has requisitioned the runtime to terminate it in an unusual way. Please contact the applications support team for more info." Click ok. TDL 1 lost connection during optimization. Could not aim TDL 2 path 7. Overall, sonic anemometer 3 w is not that far off the line, but it has four recent points that are way above zero. Sonic 2 w has three negative points and one positive point. H2S graphs showed that chamber pressure, sample flow, voltage, and lamp intensity briefly went to zero. Remote check showed H2S analyzer was working fine thought. No communication with CR 1000.
12:30	7/29/2009	Remote	Daily Status Check from PAML − Notes: *iPort* encountered a problem and needed to close. TEC 450i is sending back zeros for H2S data. Sonic 1 not recording data since 7/27/2009. No CR 1000 data since 7/27/2009. No TDL 1 info since 7/27/2009. TDL 1 had pan/tilt error. Unable to aim TDL 1 paths 1 and 7.
13:00	7/30/2009	Remote	Daily Status Check from PAML − Notes: TEC 450i is sending back zeros for H2S data. Sonic 1 not recording data since 7/27/2009. No CR 1000 data since 7/27/2009. No TDL 1 info since 7/27/2009. Unable to aim TDL 1

Time (GMT)	Date (MM/DD/YYYY)	Activity (setup, takedown, calibration, repair, remote)	Event
			path 1. MJB talked to Thomas Sowell at site. Found two tripped GFCI outlets on NW corner area. Found one plug unplugged on SW tower. Found TDL 2 path 1 knocked over and unplugged. Found TDL 1 path 7 leaning. Sonic anemometers are now working. After talking to Thomas, site was running except for low light levels on TDL 2 path 2.
13:00	7/31/2009	Remote	Daily Status Check from PAML − Notes: Unsuccessfully tried to re-aim TDL 2 path 7. Could only get light levels around 200. A couple of outlying values for v, w for sonic anemometer 2. Several points with very large w and low temperature for sonic anemometer 3.
13:00	8/3/2009	Remote	Daily Status Check from PAML − Notes: No data from sonic anemometer 1; data stop at 1:55 UTC. No connection to CR 1000. Appears like power has been lost again to NW corner. Appears that a thunderstorm passed through the site around 02:00 UTC on 8/1/2009. Thomas Sowell fixed outlets again.
	8/4/2009	Takedown	TEC 450i failed calibration. Will take to next site (TX5A), and if it fails again will perform multipoint calibration.
	8/4/2009	Takedown	SO2 cylinder only has 75 PSI left. It is still leaking but cannot locate leak.
	8/4/2009	Takedown	S-OPS side B (south side) failed leak test. Will check again at TX5A.
	8/4/2009	Takedown	TDLAS 1029 failed calibration with a bias of -13.5%.
	8/4/2009	Takedown	Too windy to perform sludge depth measurements.
	8/4/2009	Takedown	See open site notes for UPS history.
	8/4/2009	Takedown	Maintenance list completed.
	8/4/2009	Takedown	ORP probe: calibration and acceptance pass.
	8/4/2009	Takedown	pH sensor: QA fails.
15:00	8/4/2009	Takedown	Barometer audit: pass
15:04	8/4/2009	Takedown	Wetness sensor calibration: accepted
16:25-17:24	8/4/2009	Takedown	Sonic inter-comparison; all pass.
16:38-17:03	8/4/2009	Takedown	Calibrated TDLAS 1028
17:17-17:38	8/4/2009	Takedown	Calibrated TDLAS 1029 − Notes: Failed calibration with a bias of -13.5%.
18:03	8/4/2009	Takedown	Zero calibration performed on sonic anemometers; all pass.
19:45-21:00	8/4/2009	Takedown	S-OPS/GSS calibrations Notes: Side B (south side) failed leak test. Will check again at TX5A.
20:15-20:49	8/4/2009	Takedown	TEC 450i single point calibration: failed. Notes: Will take to next site (TX5A), and if it fails again will perform multipoint calibration.

6.9 Site Weather

Period 2

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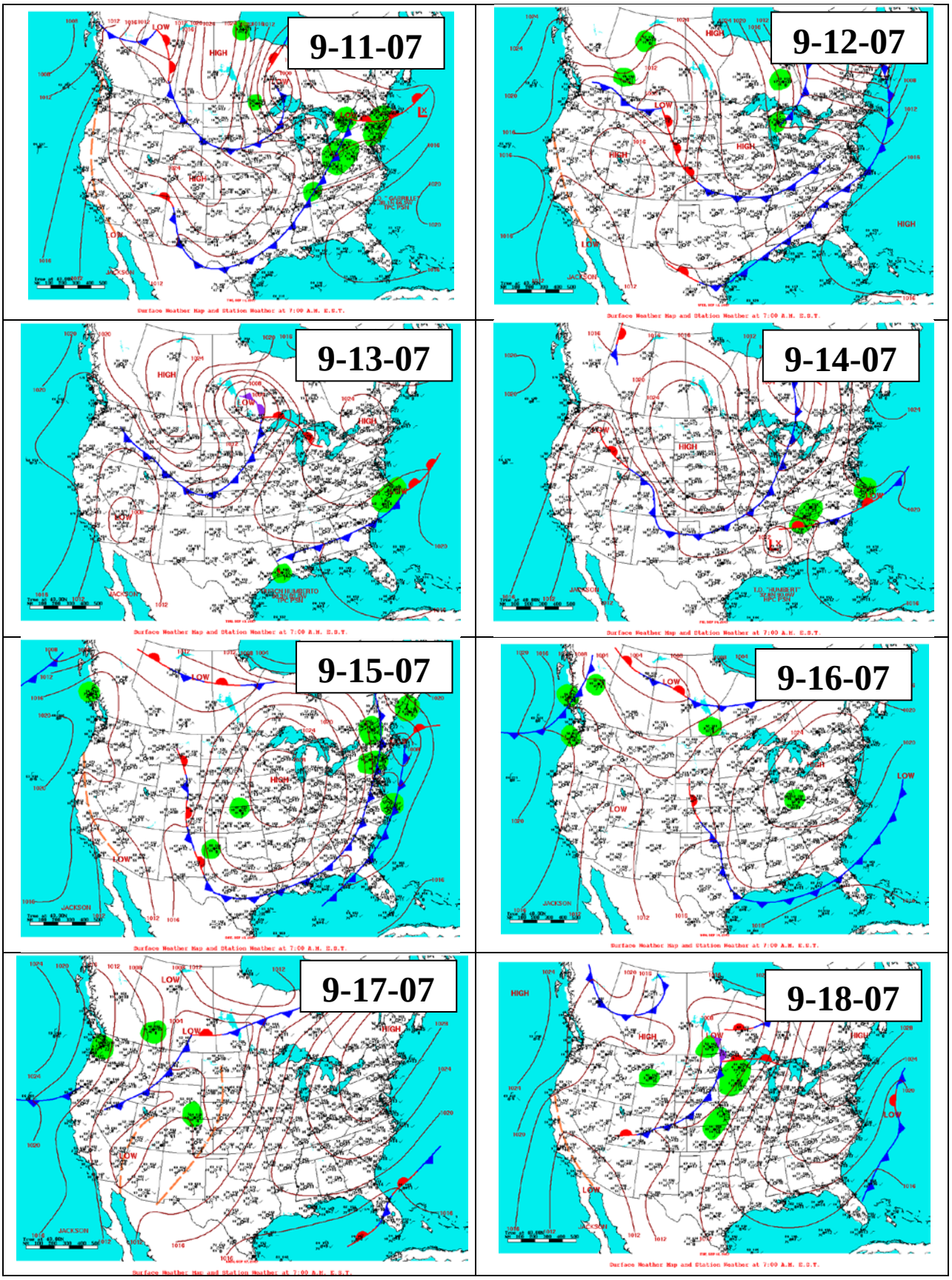
9-10-07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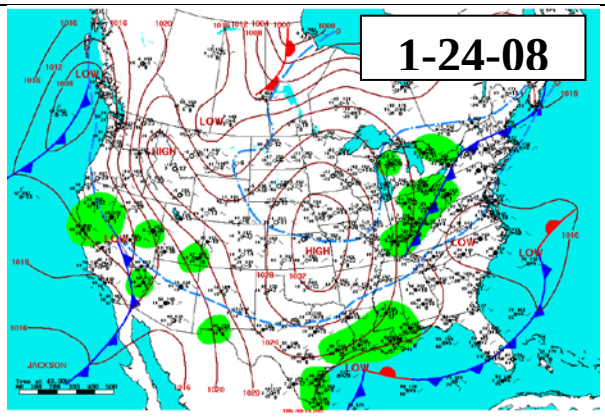
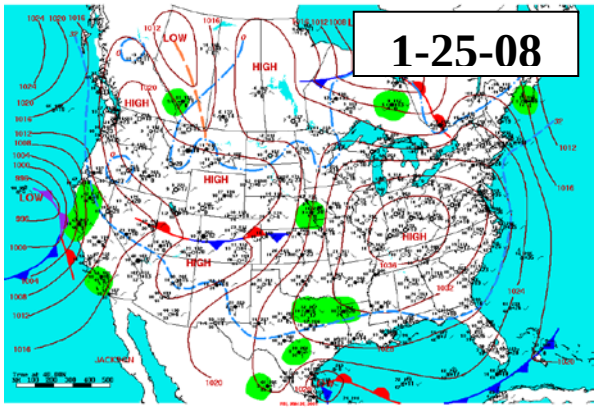
9-18-07

Period 3


1-24-08
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


1-25-08
LOW
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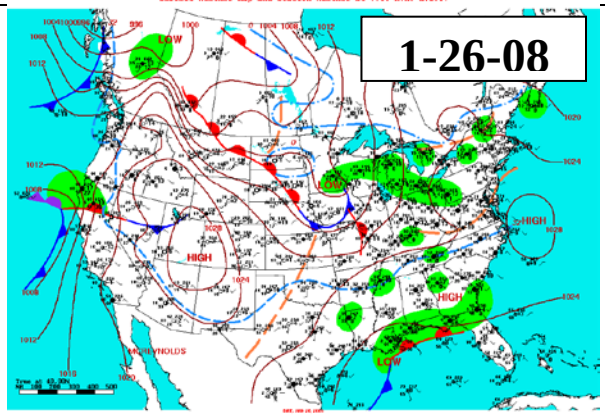
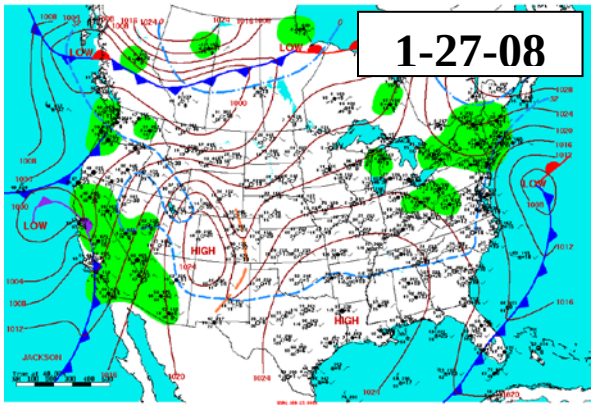
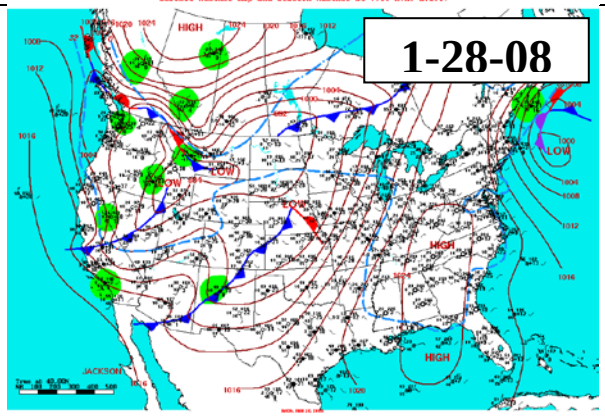
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


1-26-08
LOW
HIGH
REYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


1-27-08
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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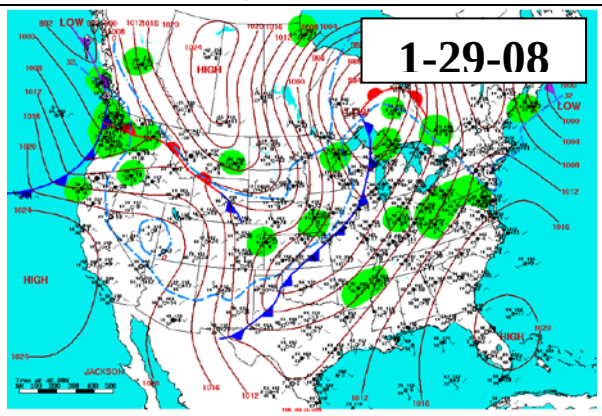
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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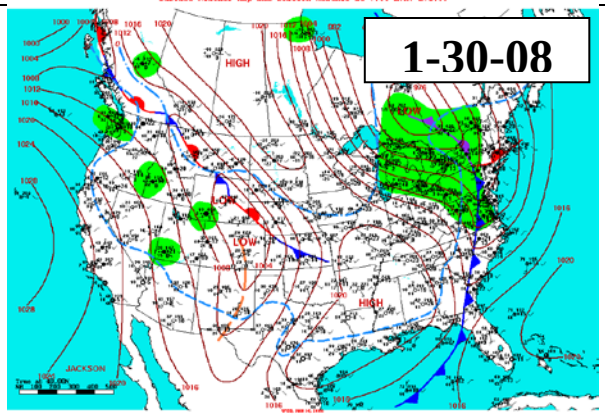
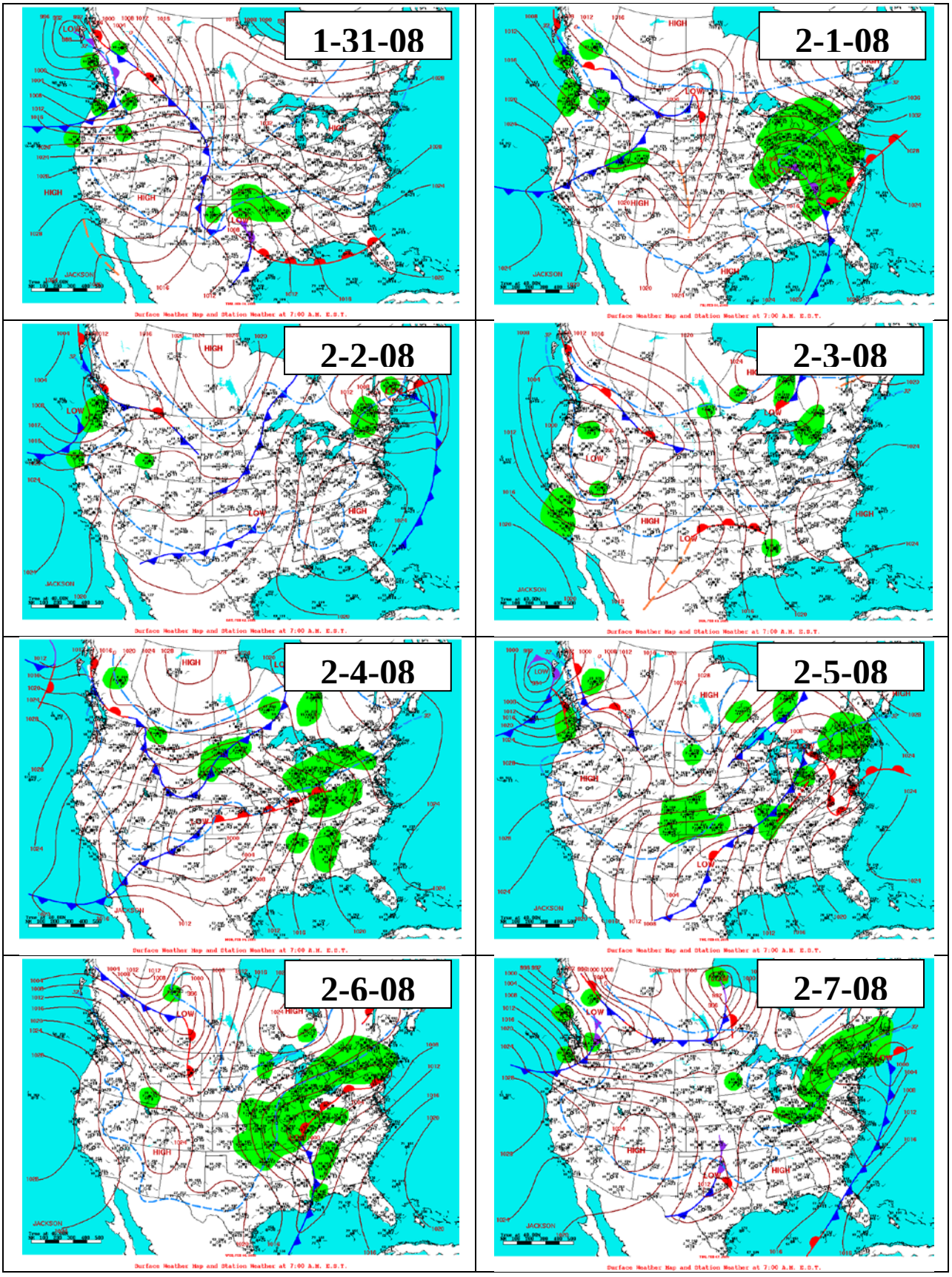
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


1-30-08
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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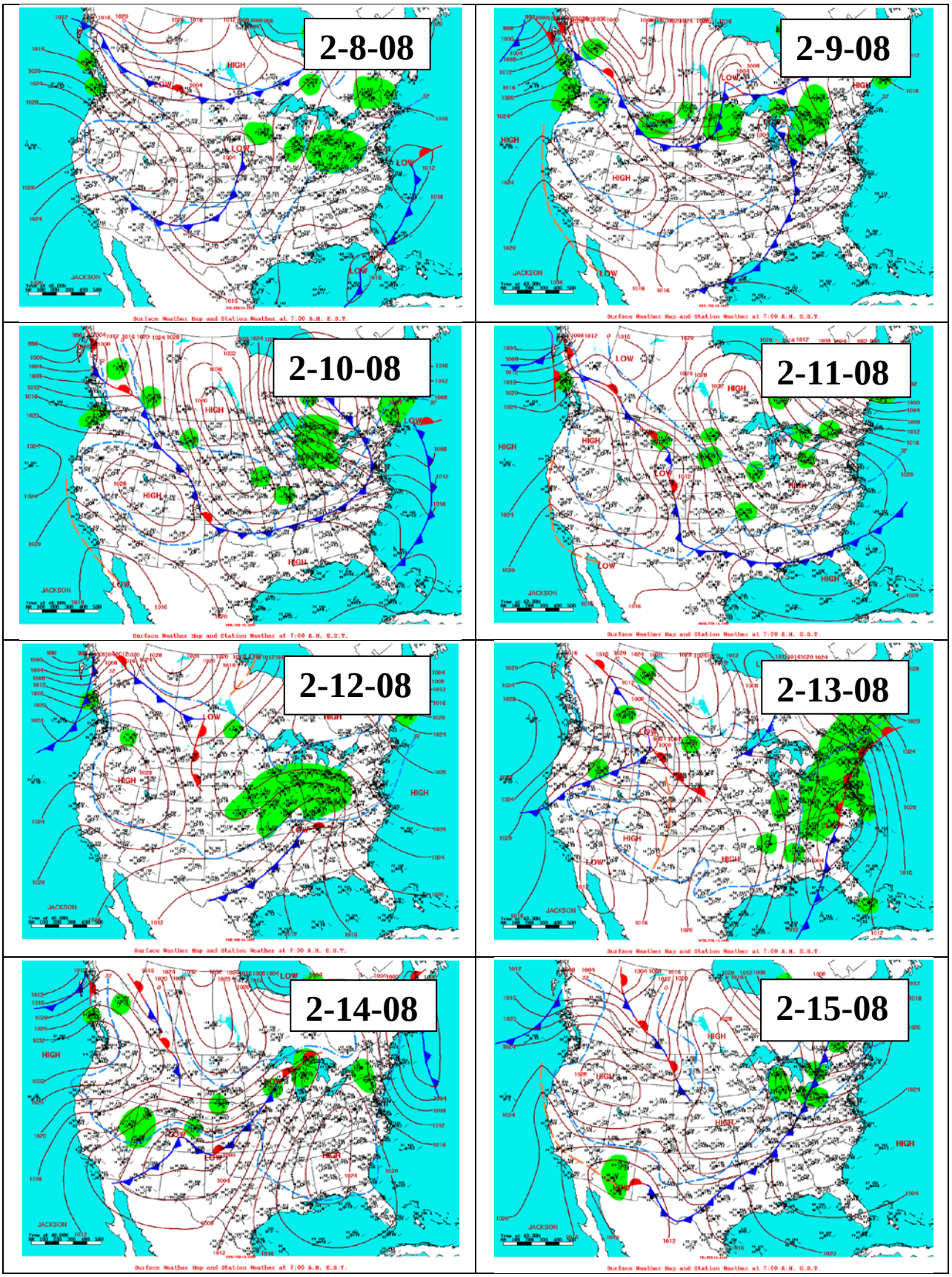
2-7-08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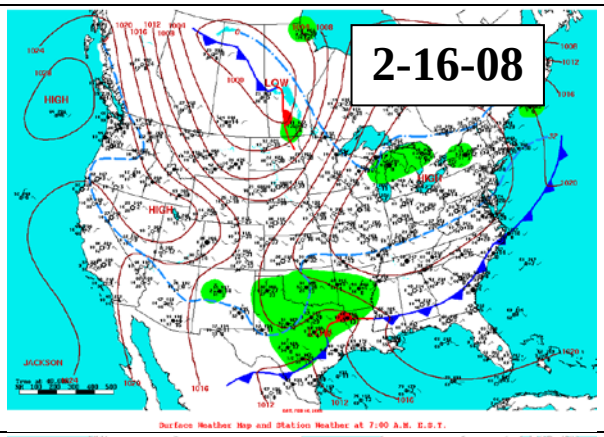
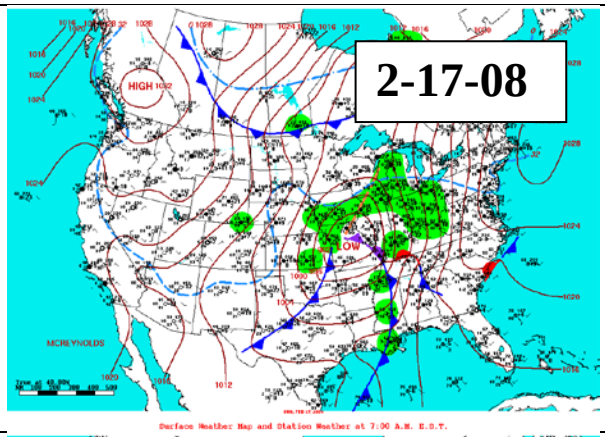
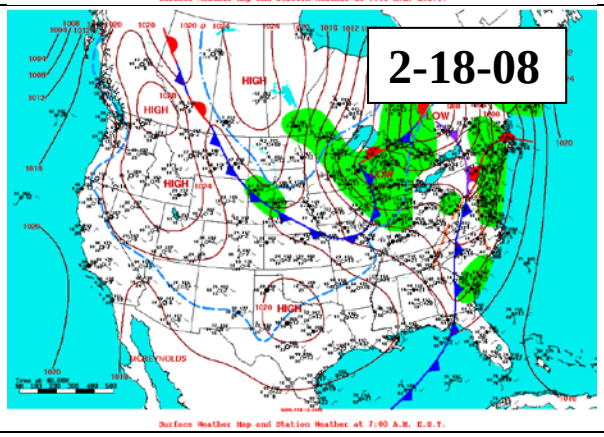
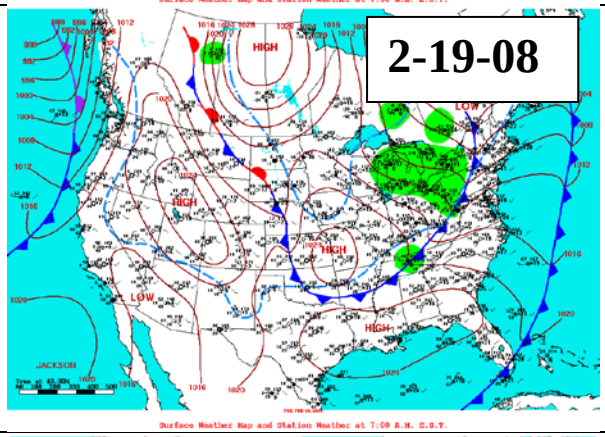
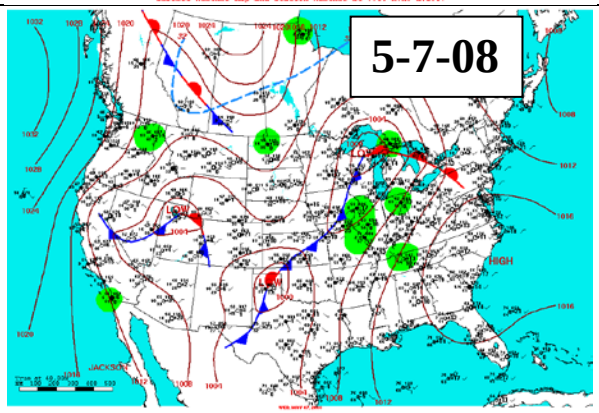


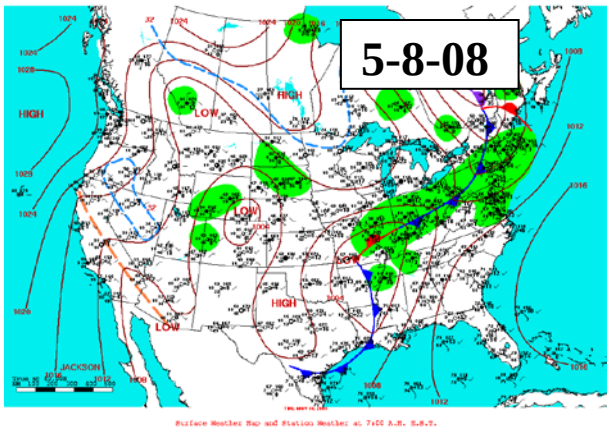


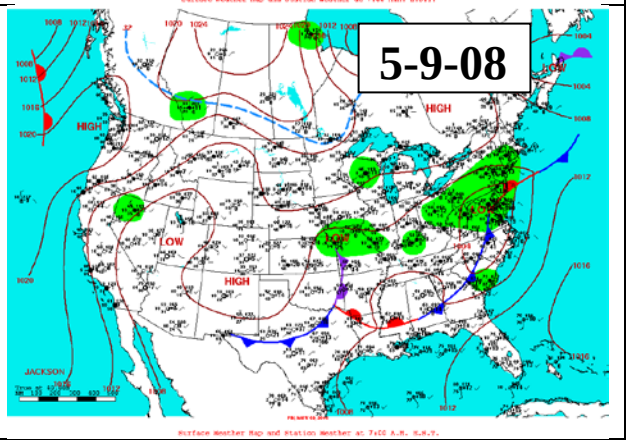


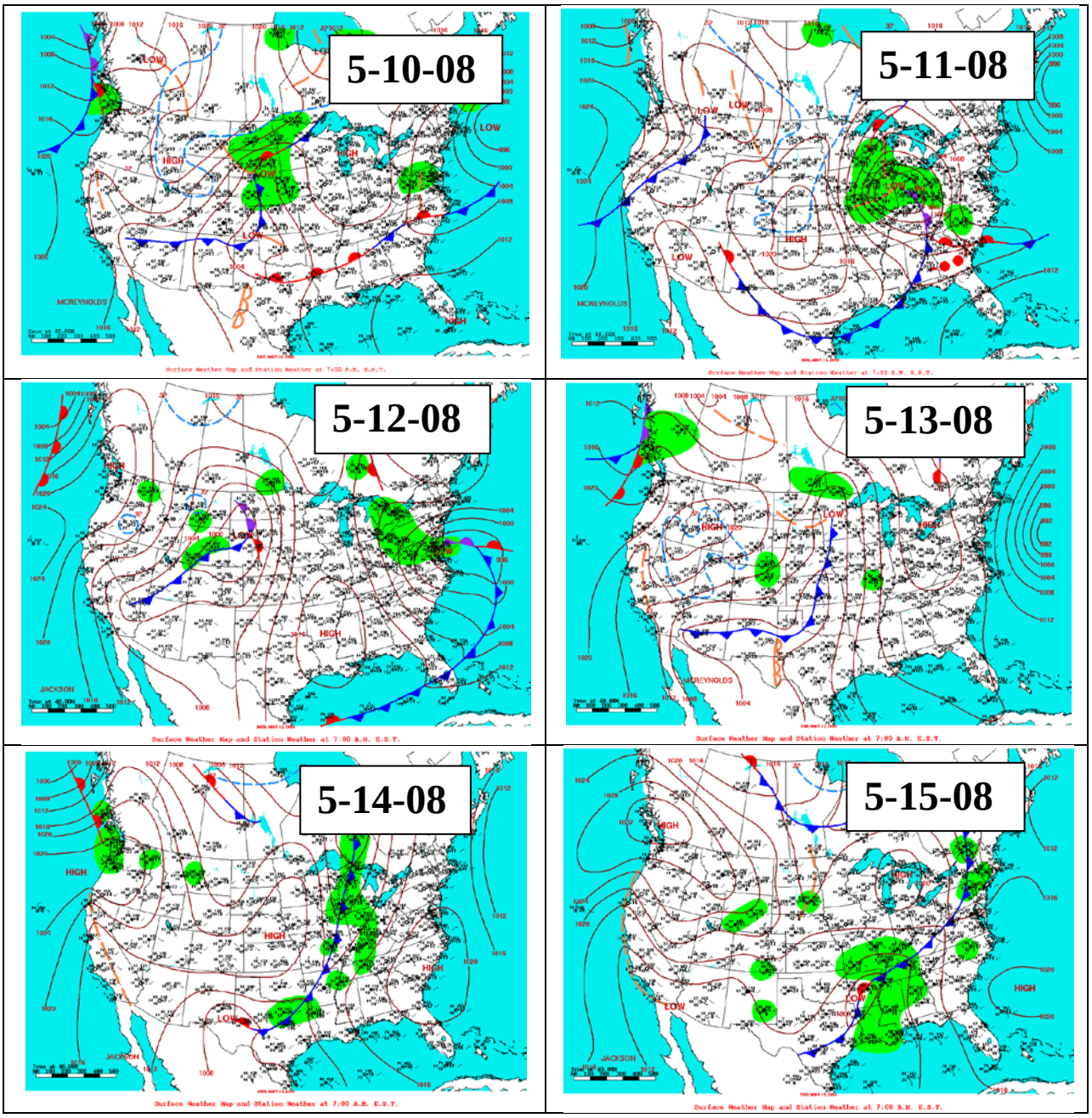


Period 4





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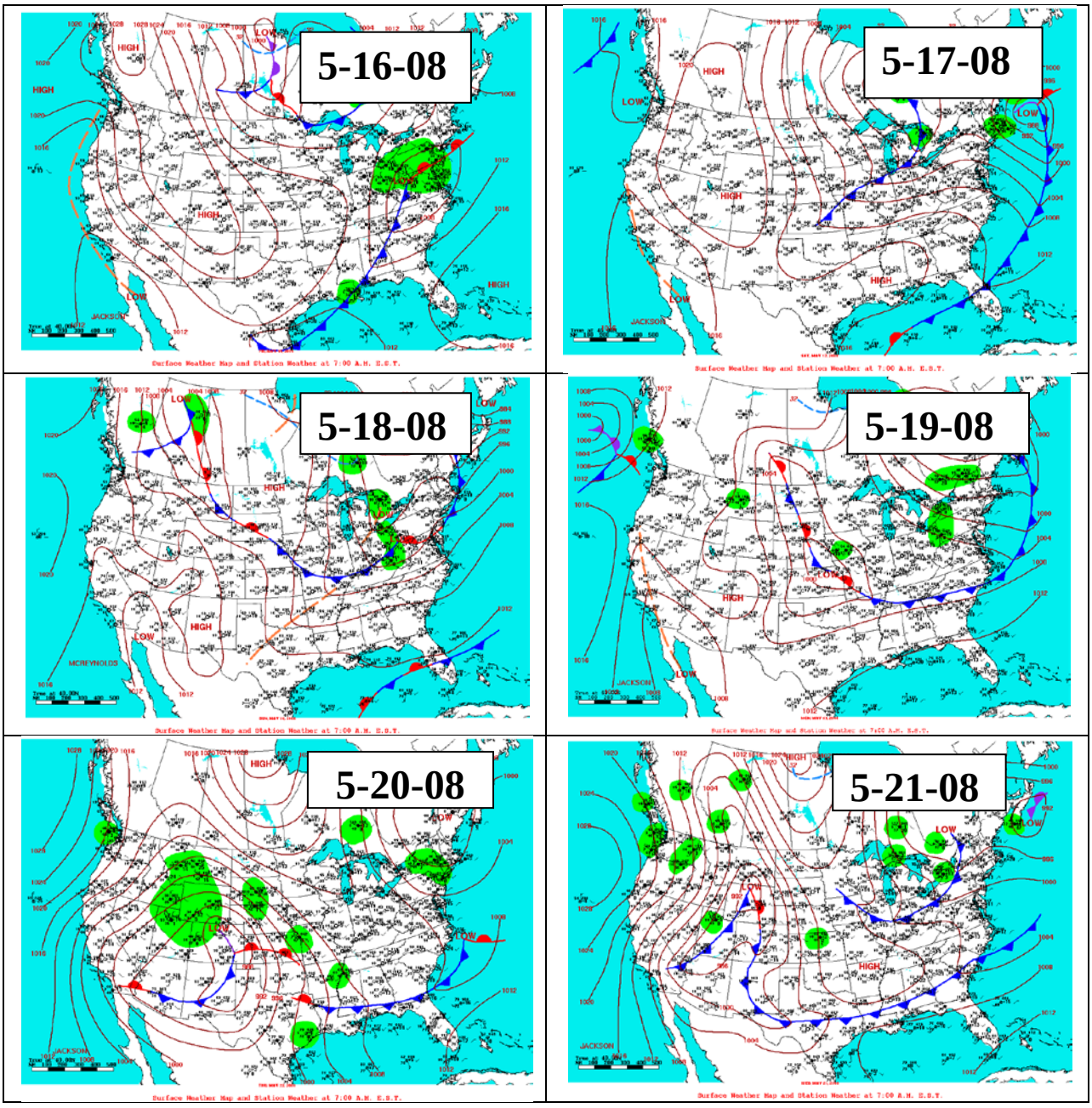
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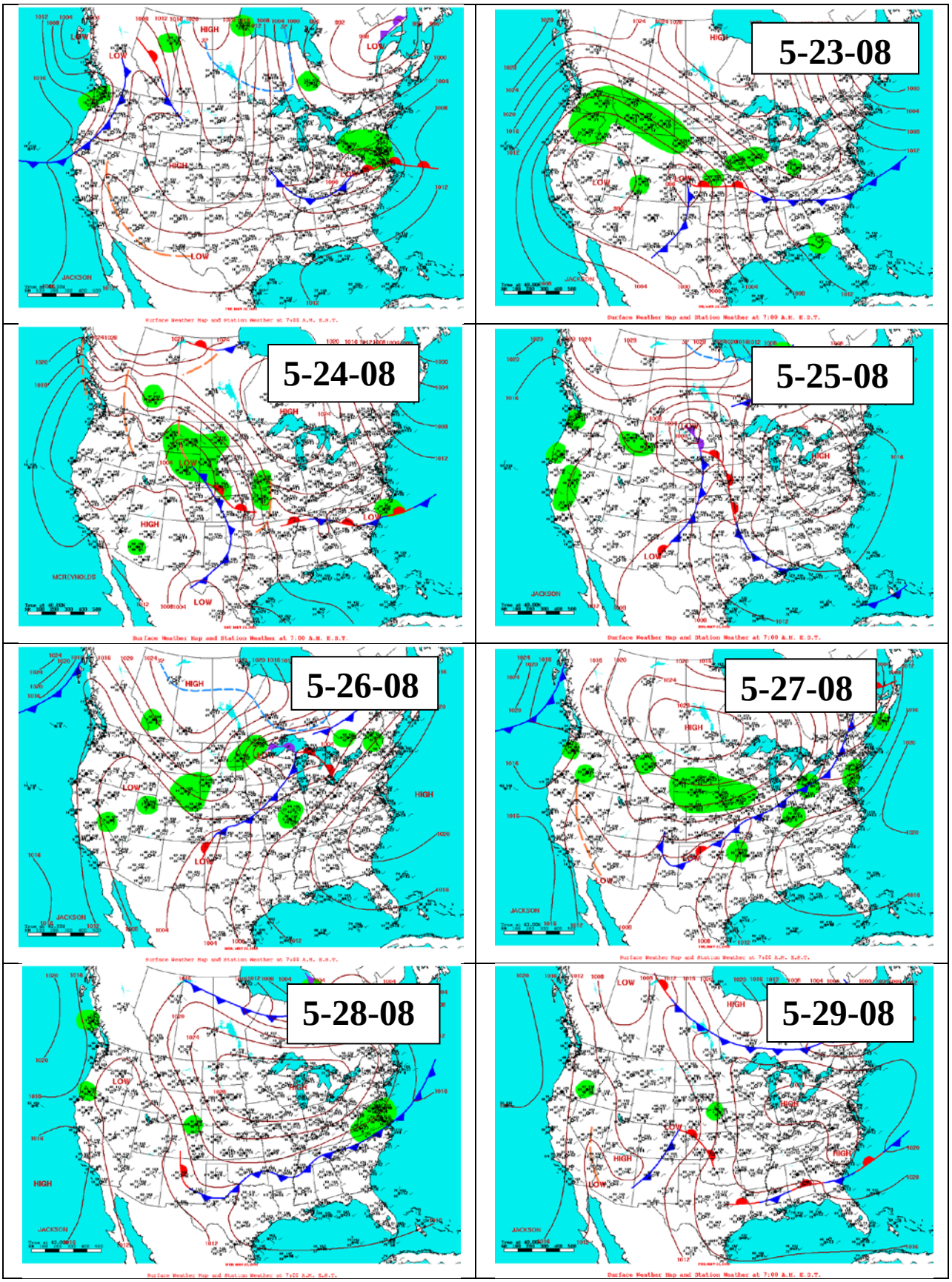
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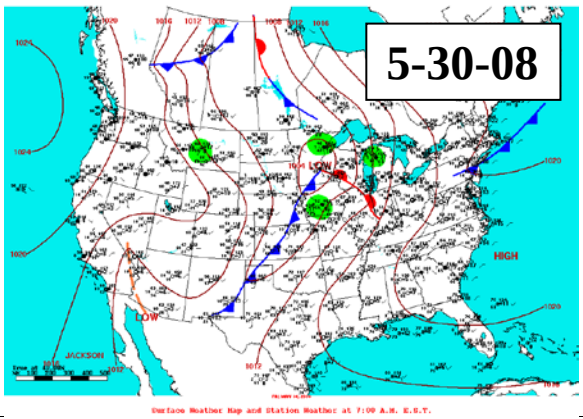
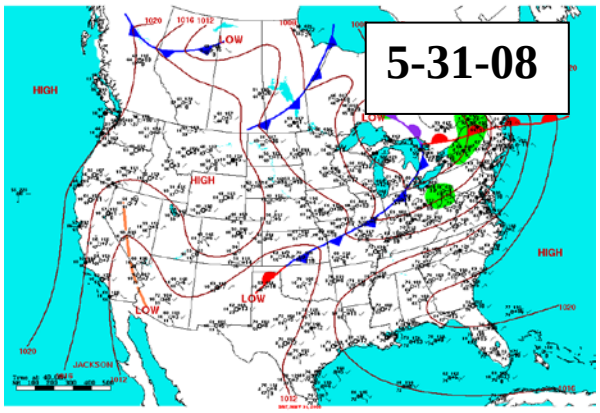
Period 5


5-30-08
HIGH
LOW
JACKSON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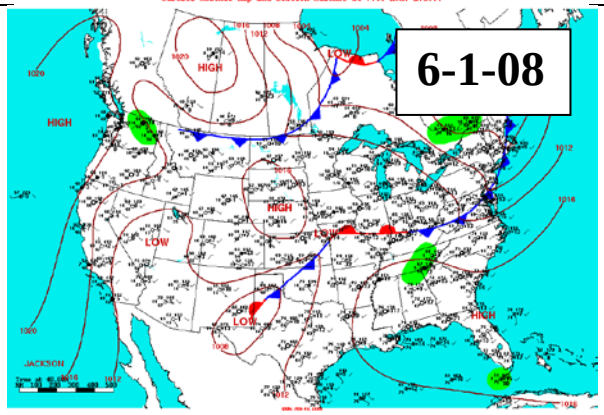
HIGH
LOW
JACKSON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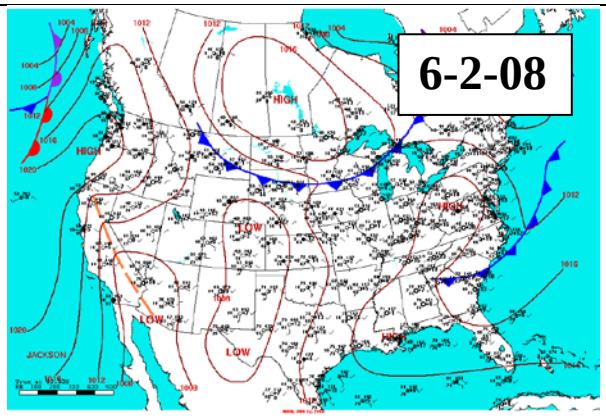
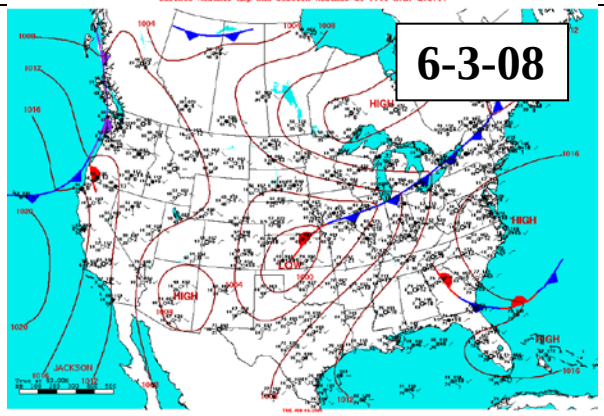
HIGH
LOW
JACKSON


6-2-08
HIGH
LOW
JACKSON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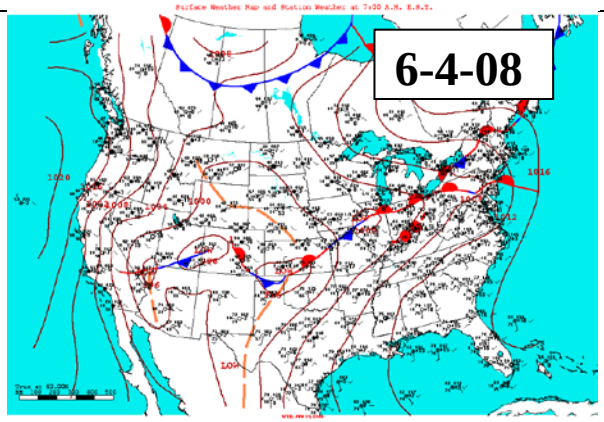
HIGH
LOW
JACKSON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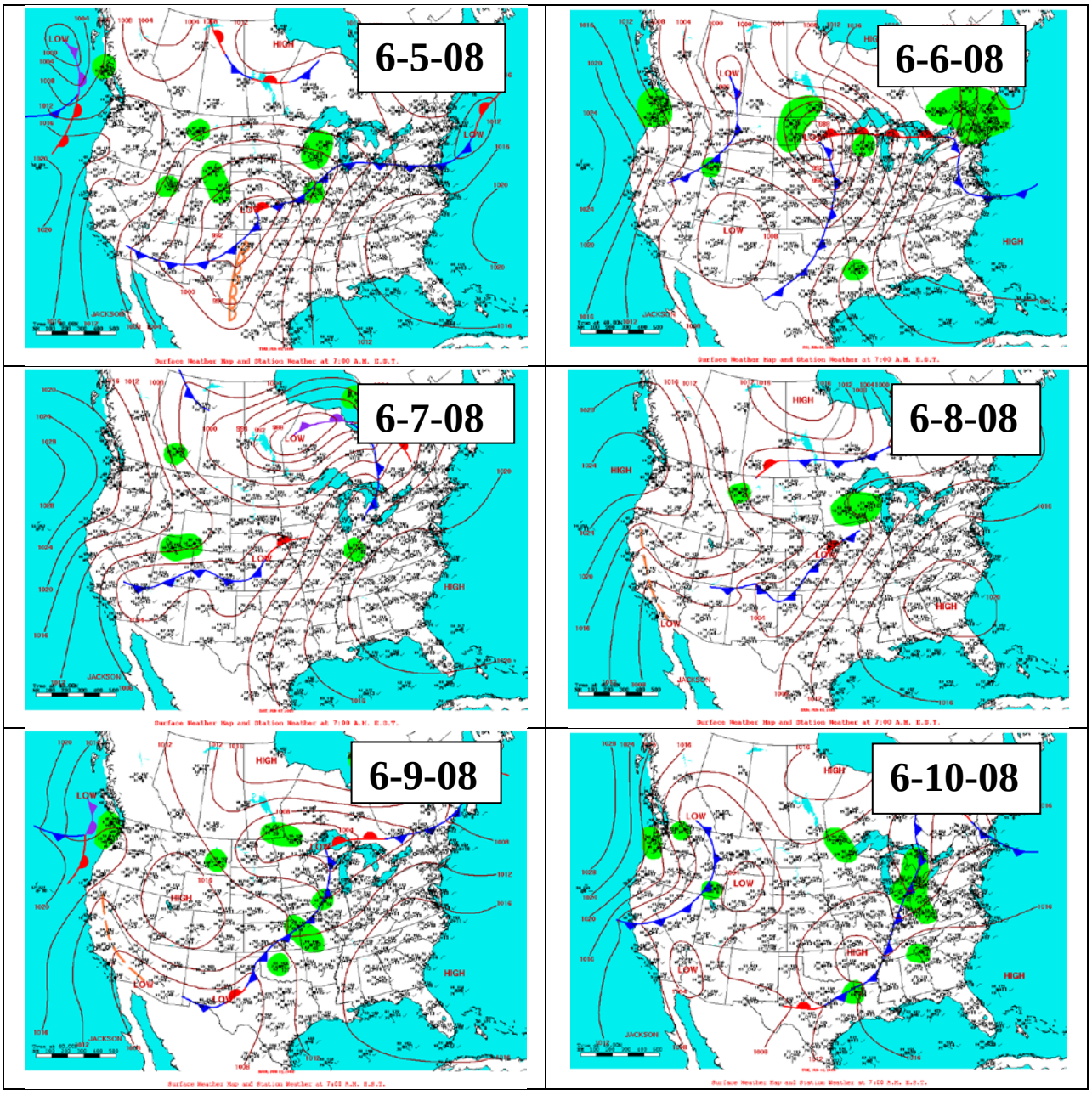
LOW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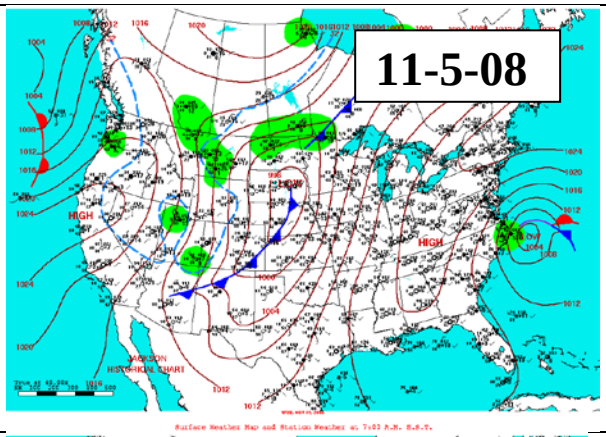
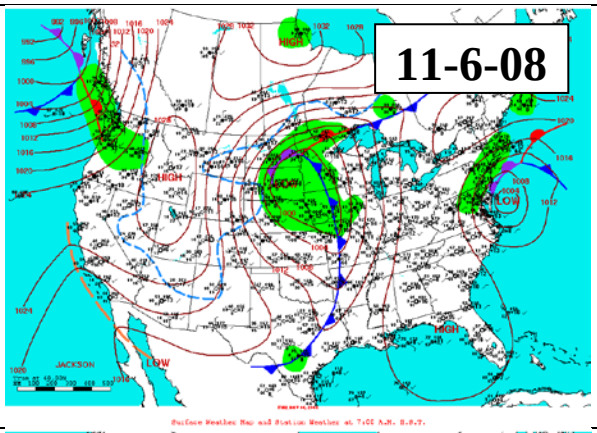
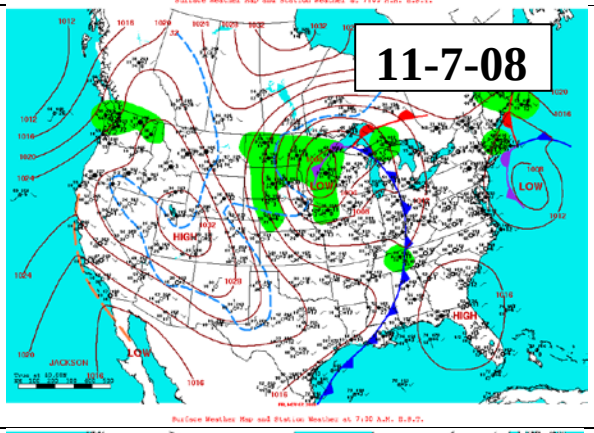
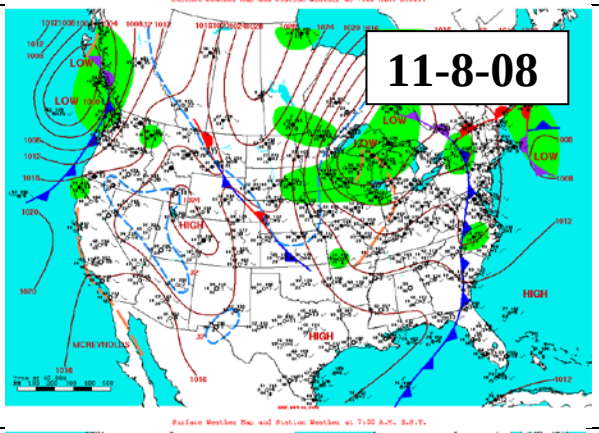
6-10-08

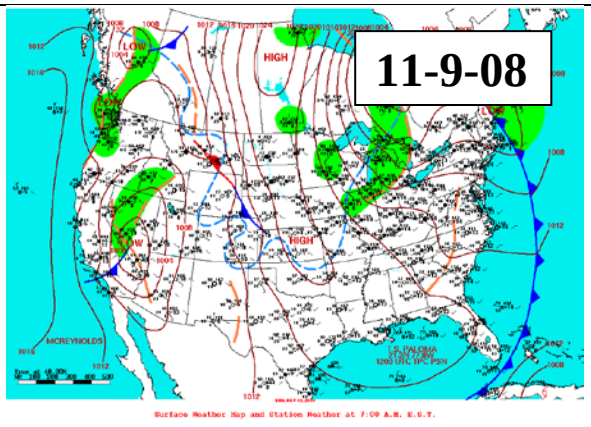
Period 6

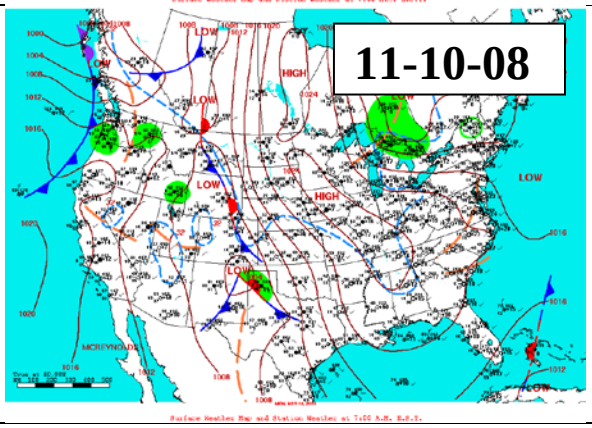


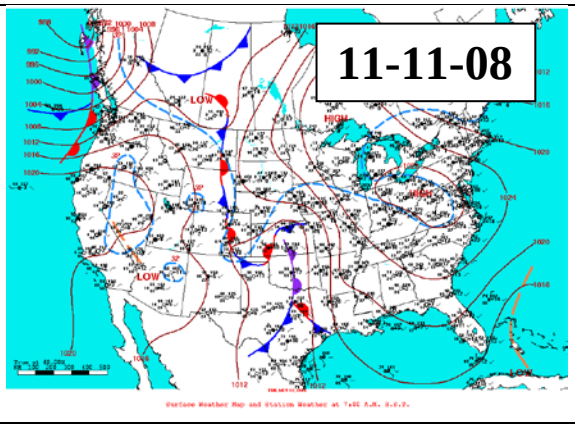


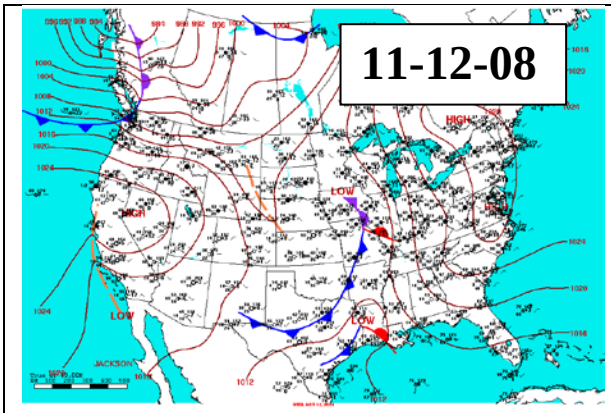








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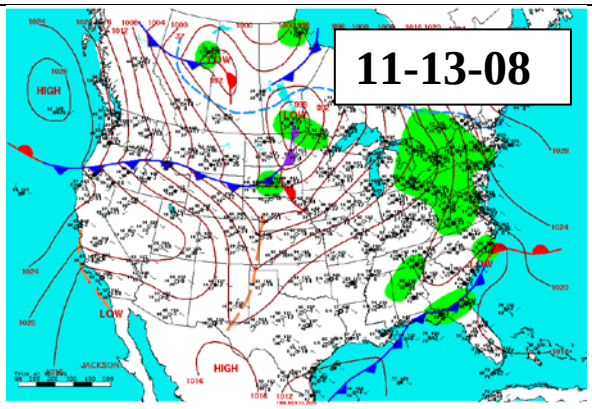
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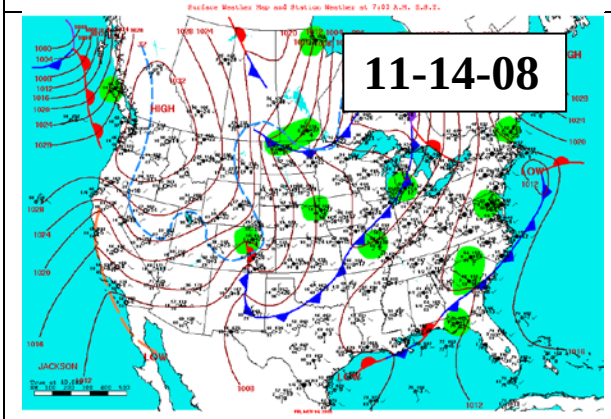
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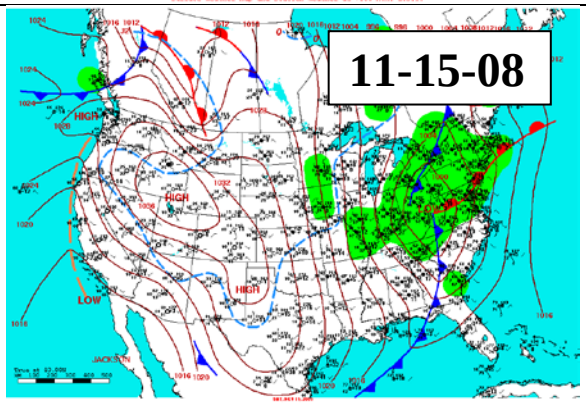
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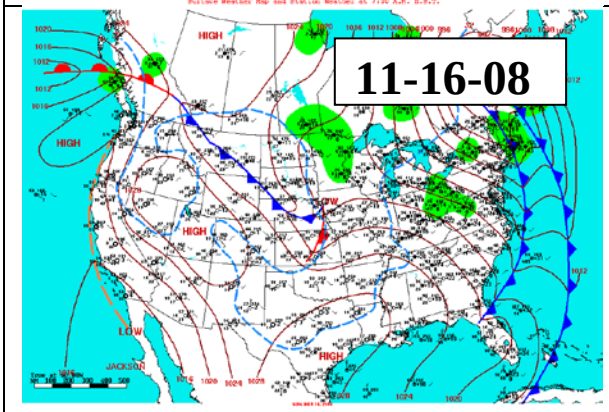
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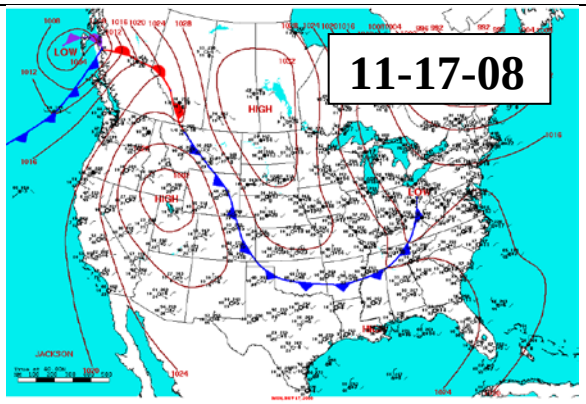
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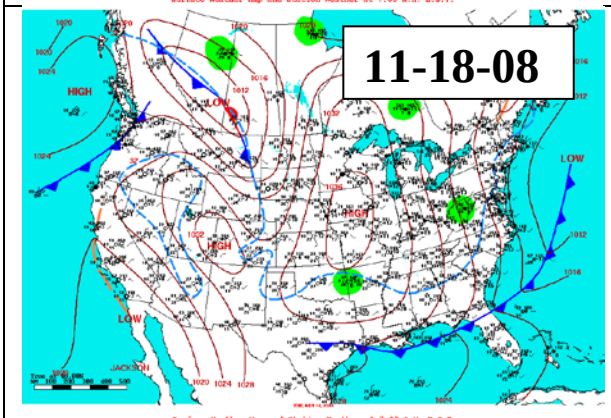
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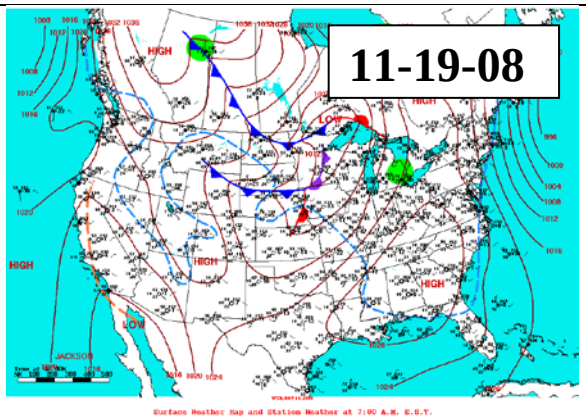
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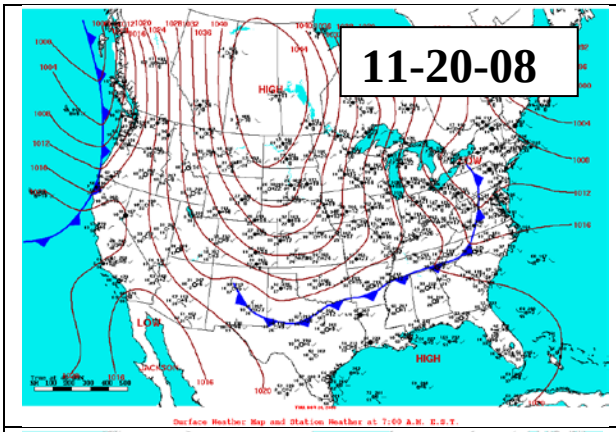
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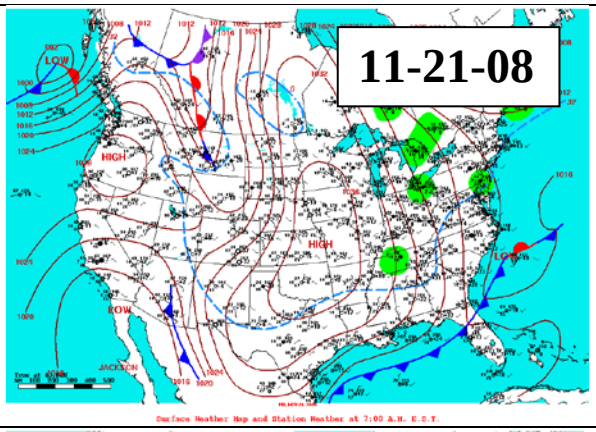
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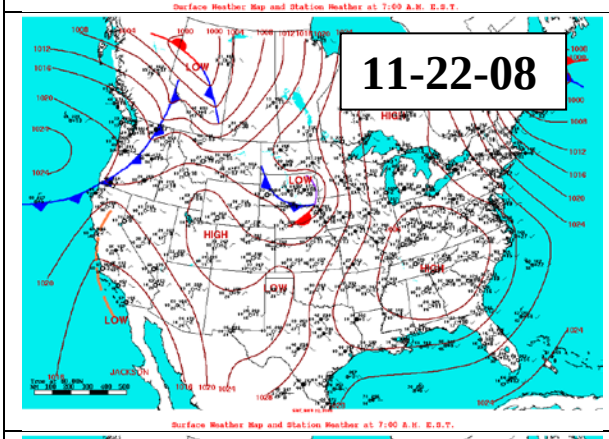
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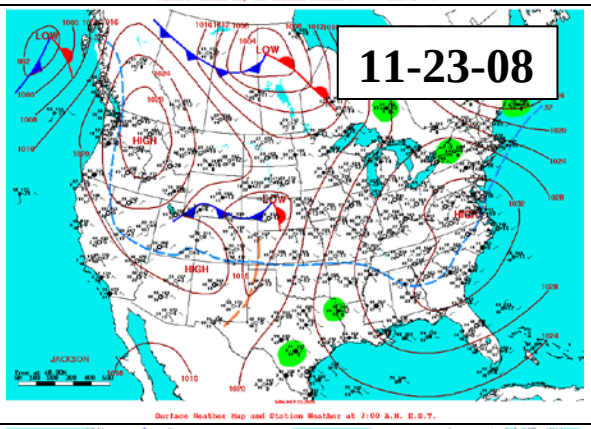
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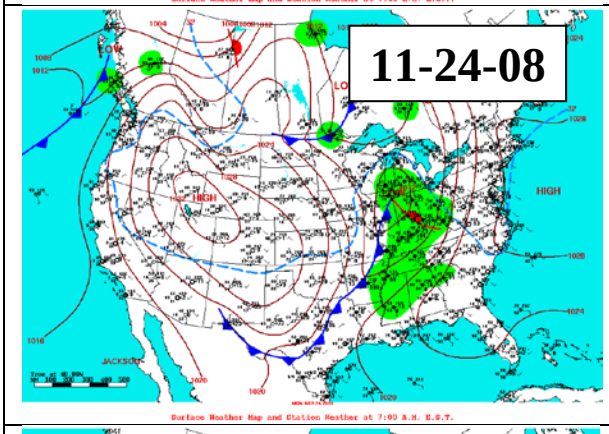
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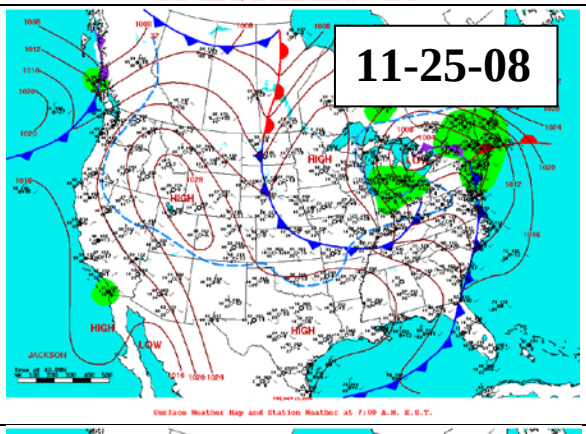
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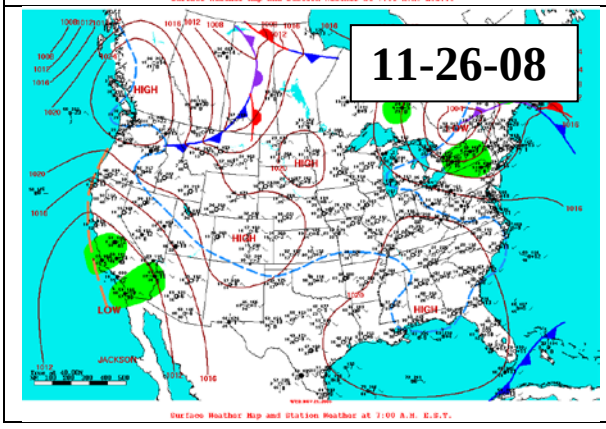
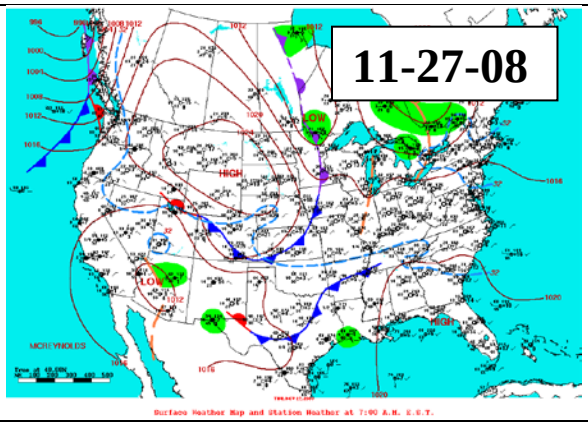

11-26-08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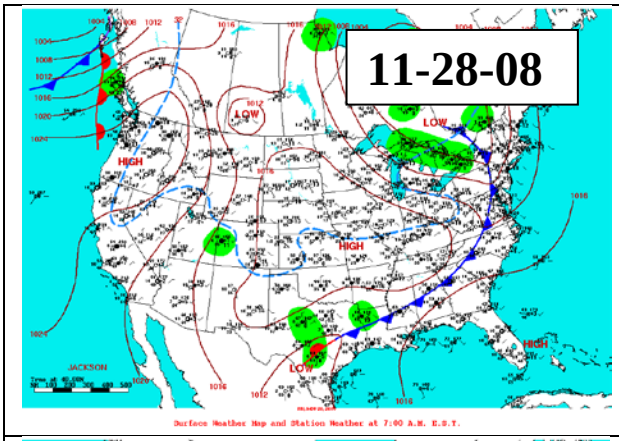
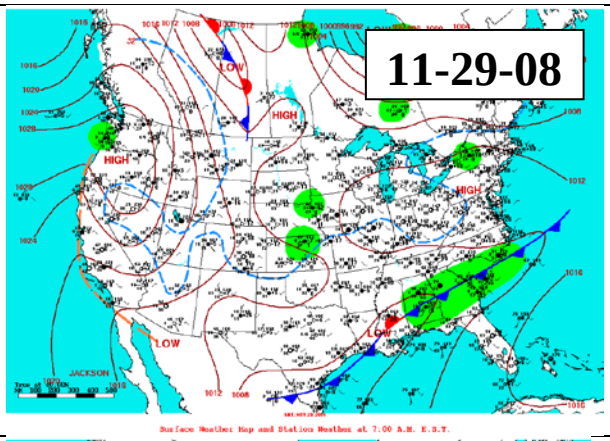
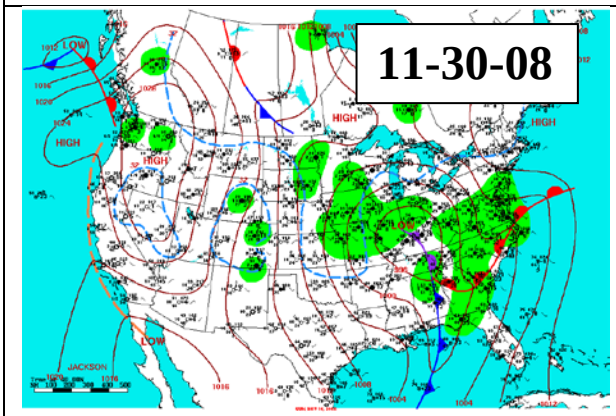
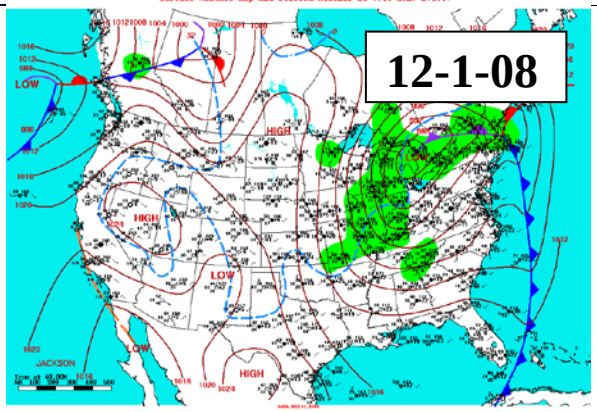
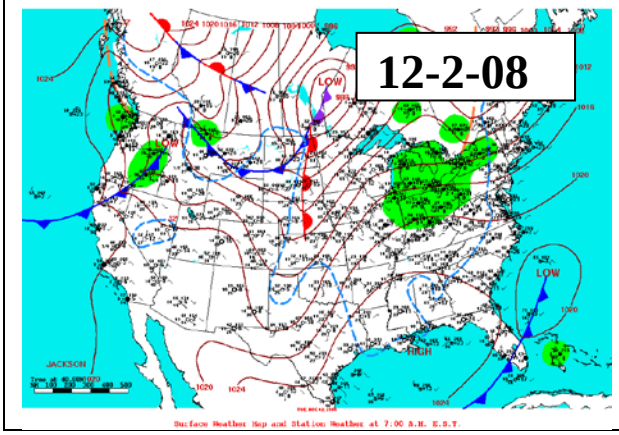


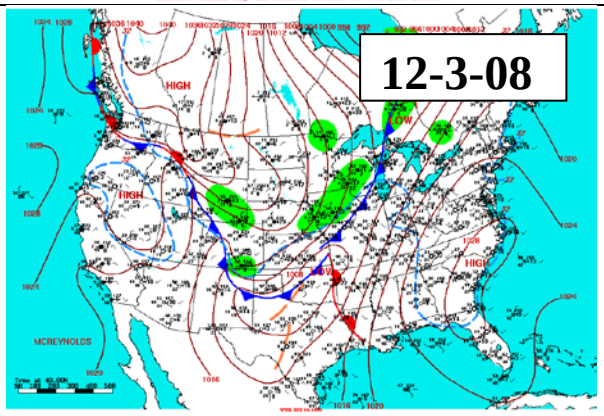


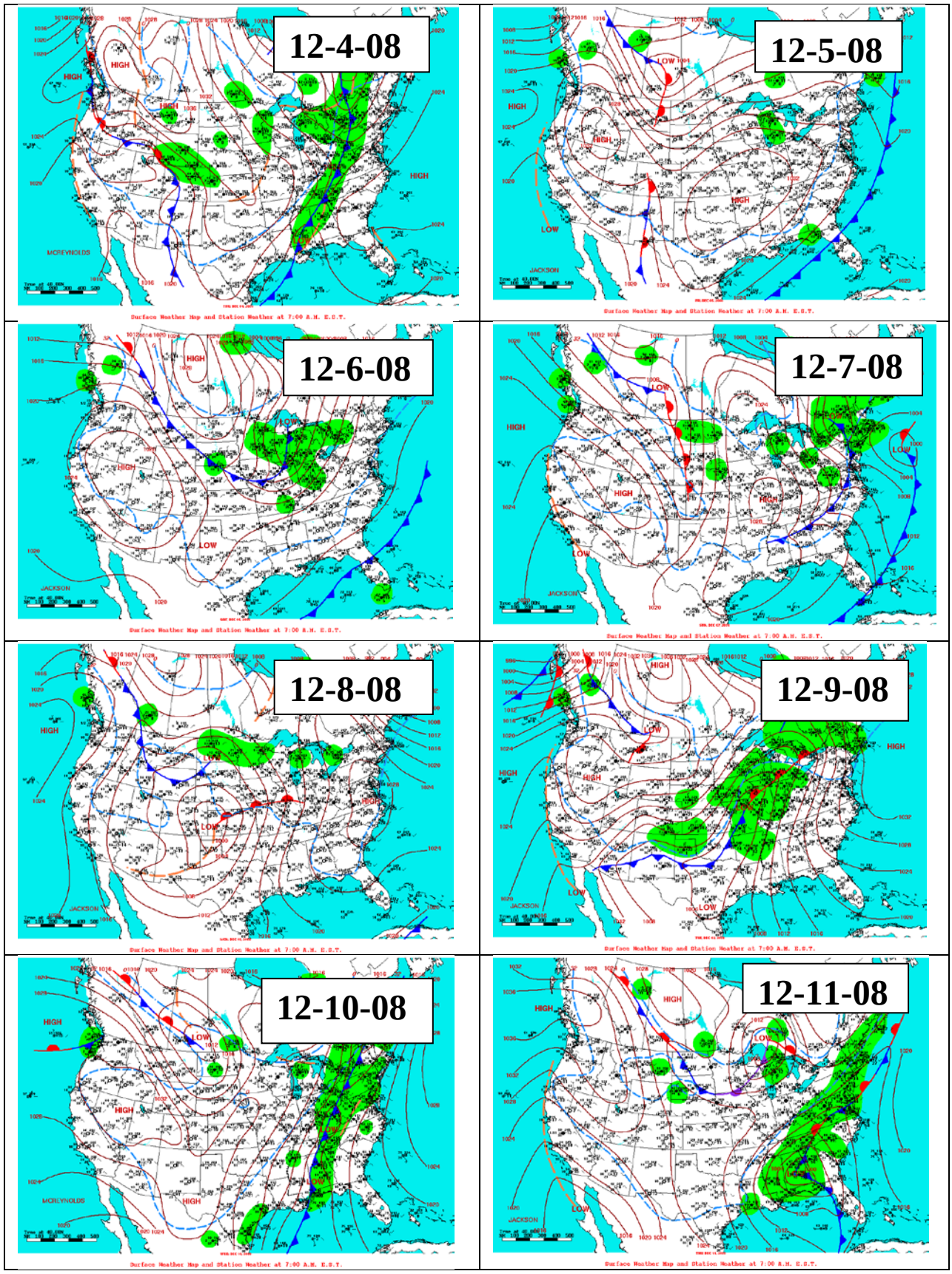




Period 7



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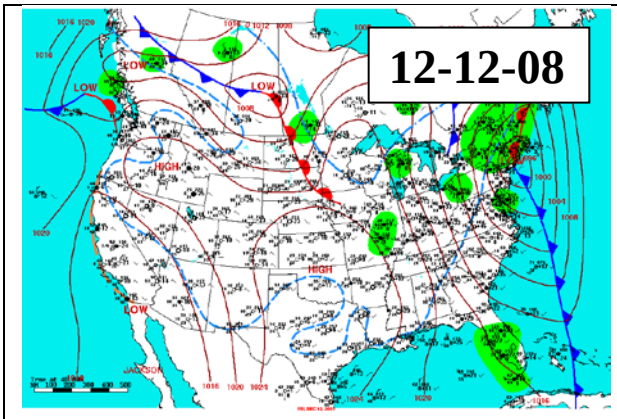
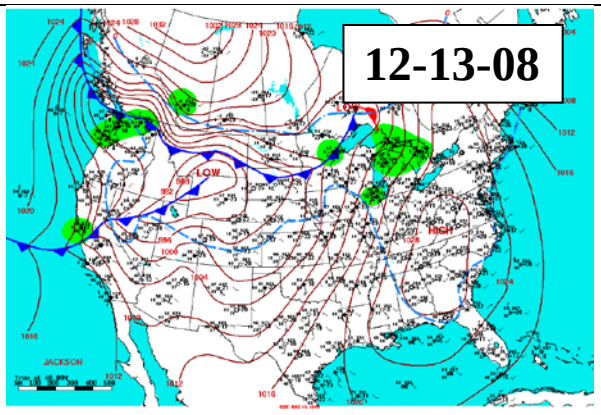
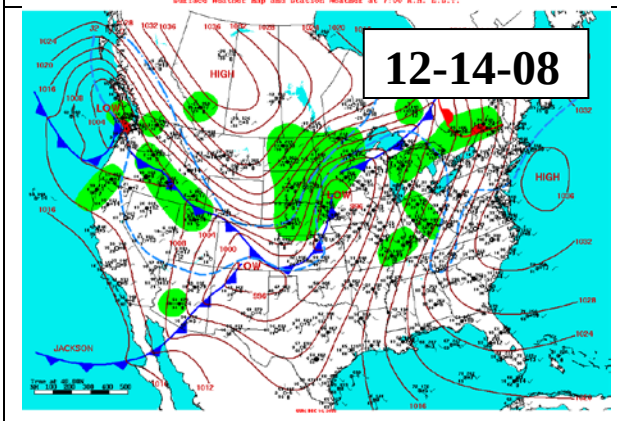
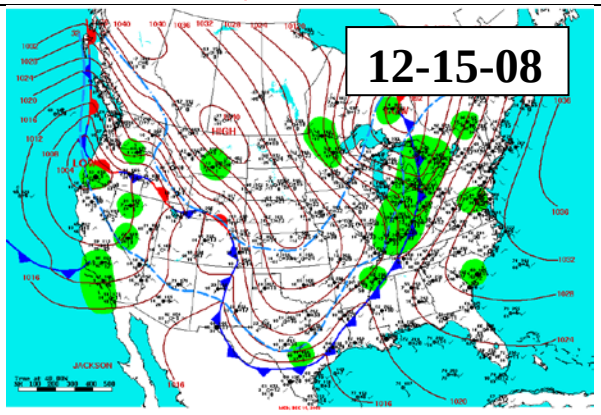
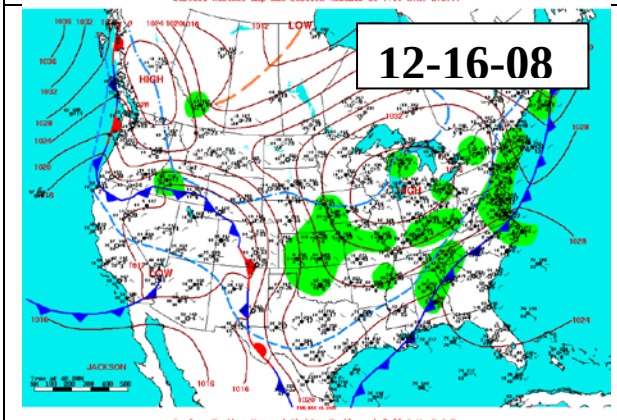
12-10-08
12-11-08



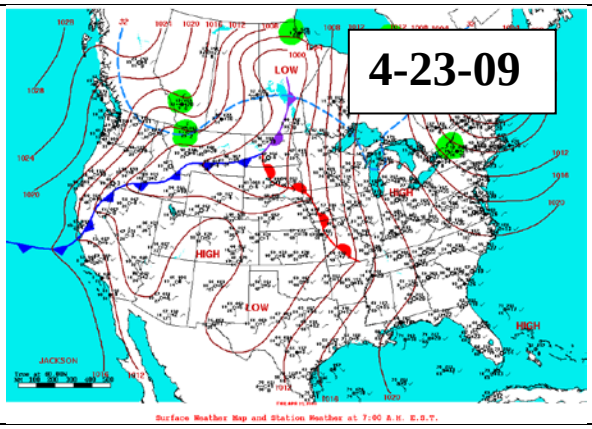


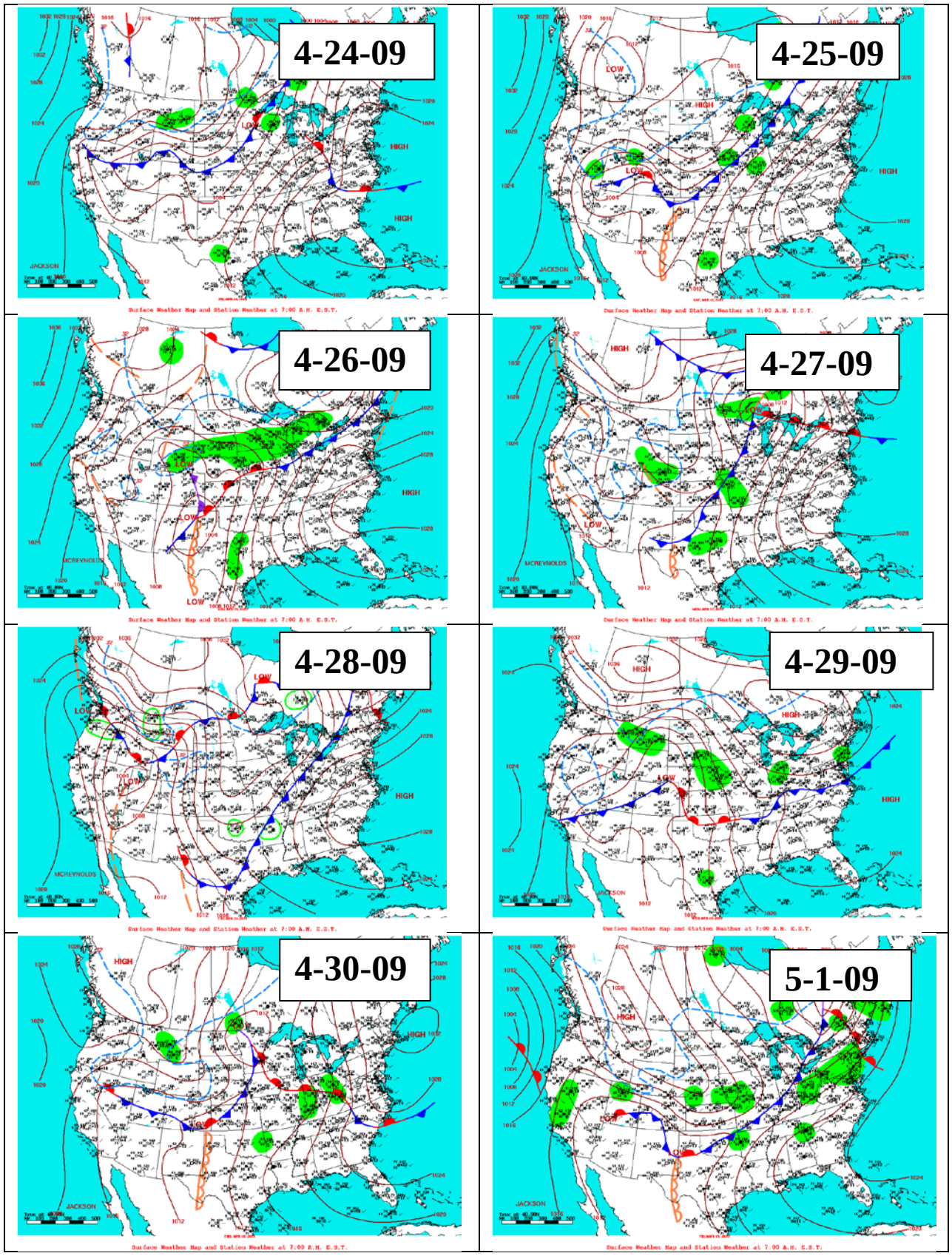






Period 8

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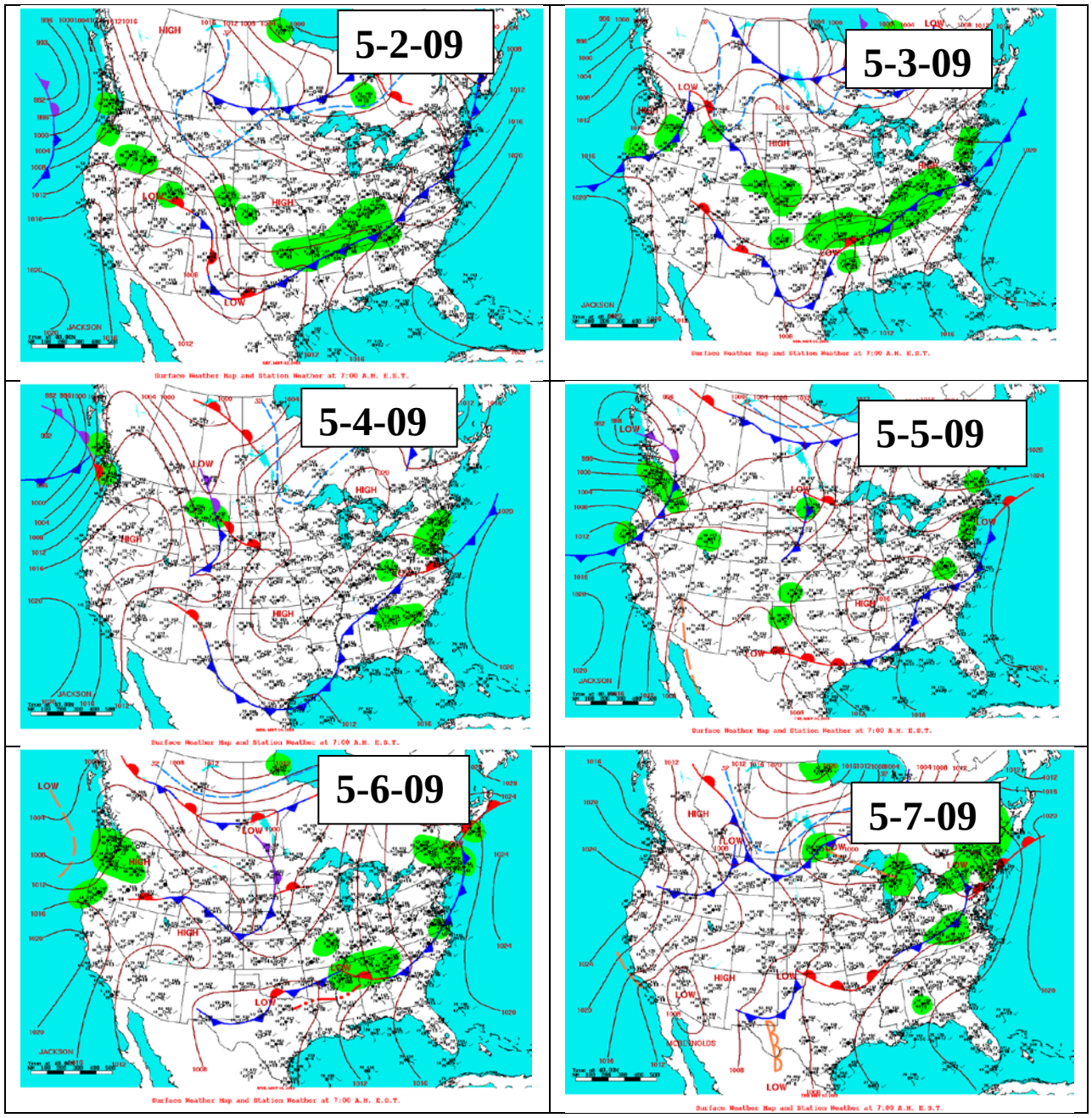
4-29-09
4-30-09
5-1-09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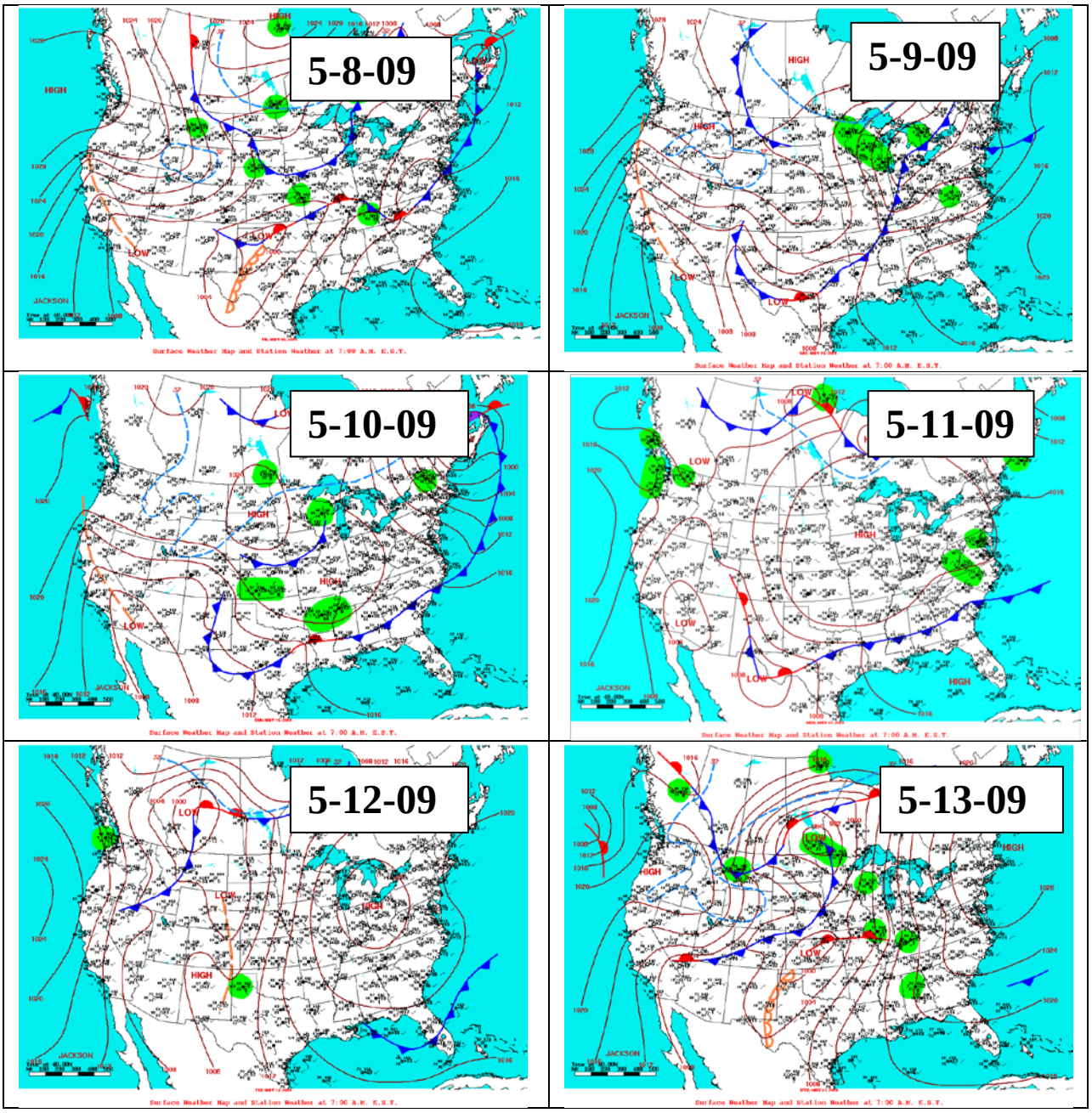
5-5-09
5-6-09
5-7-09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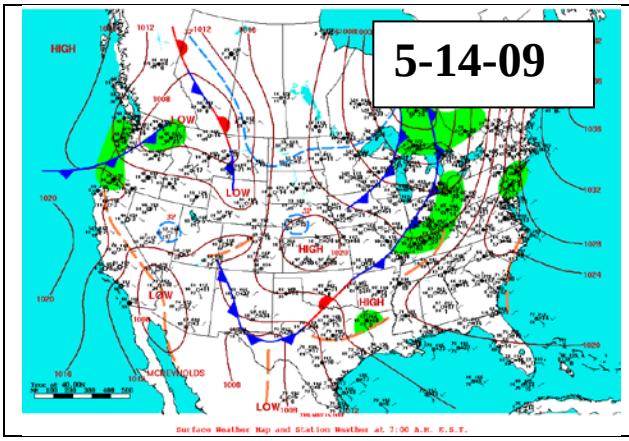
5-12-09
5-13-09



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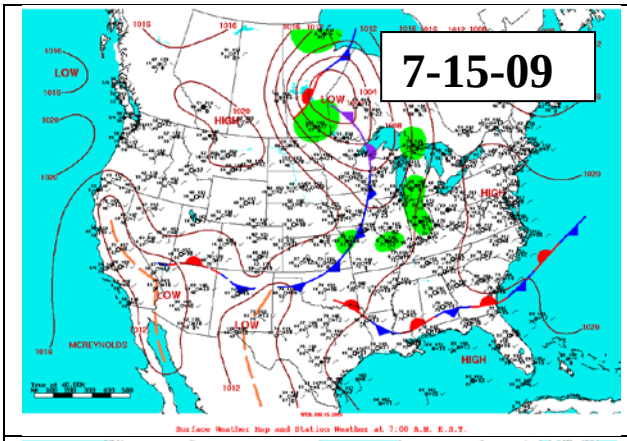

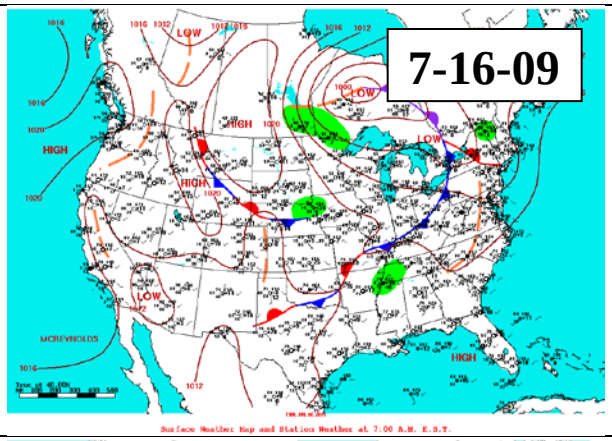

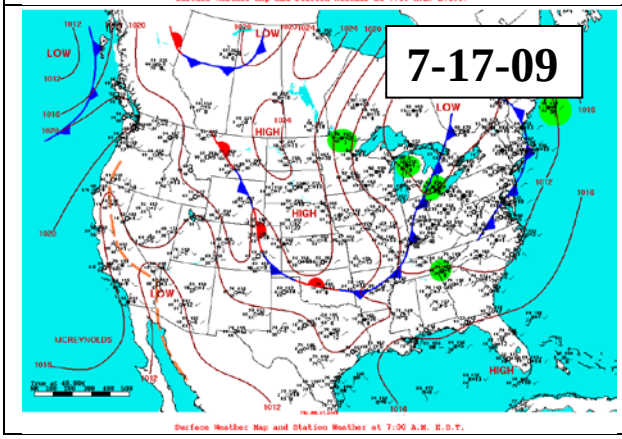

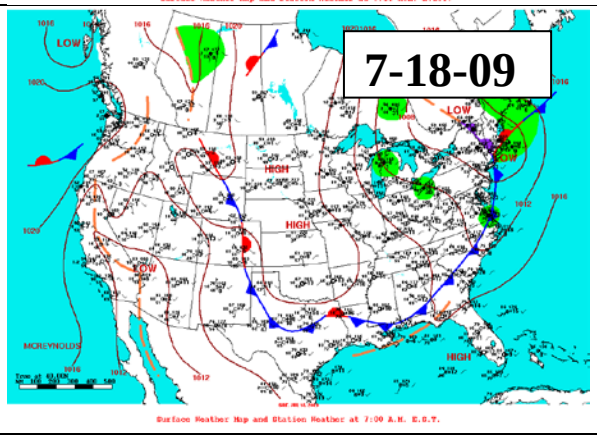

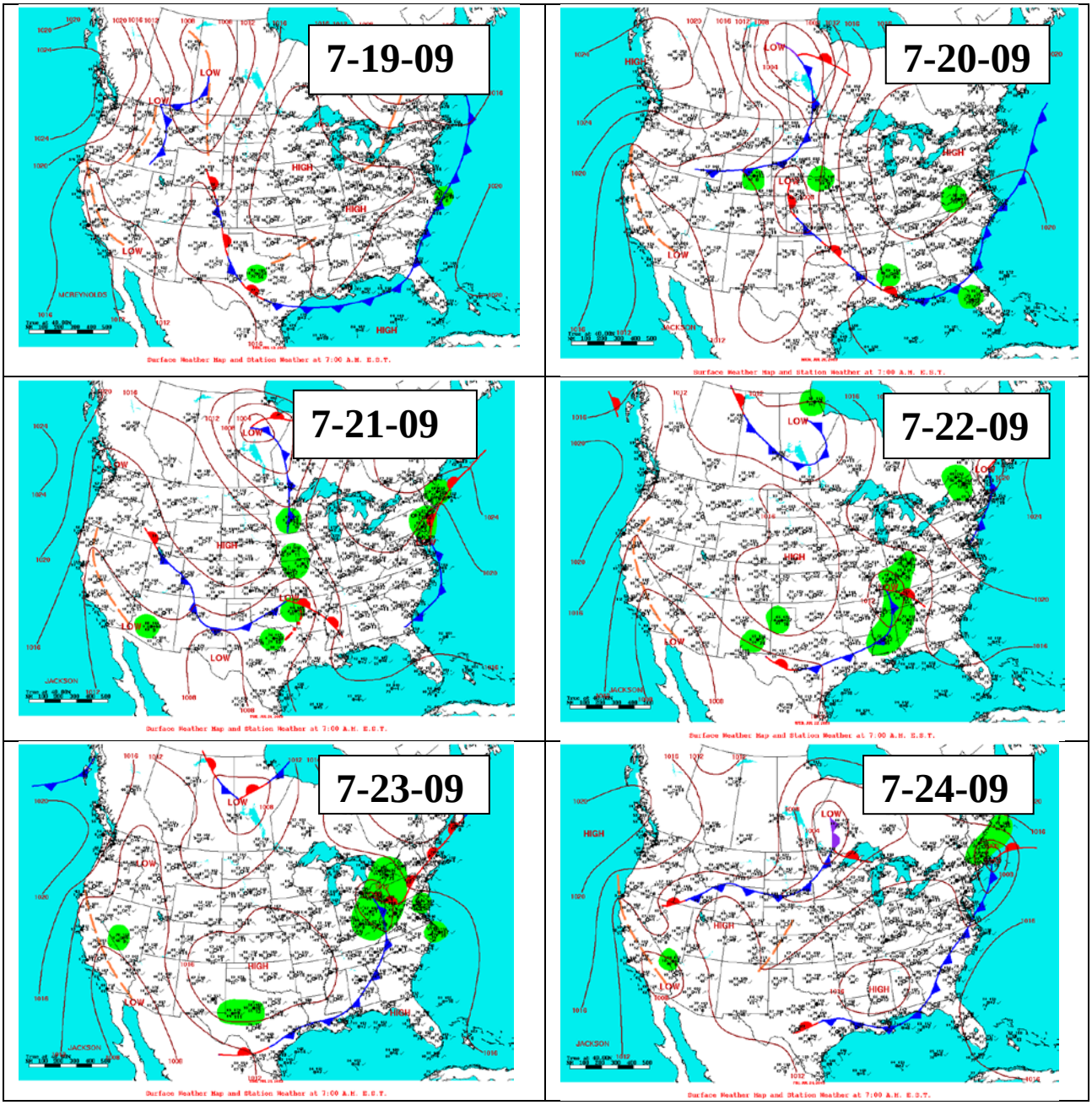
7-19-09
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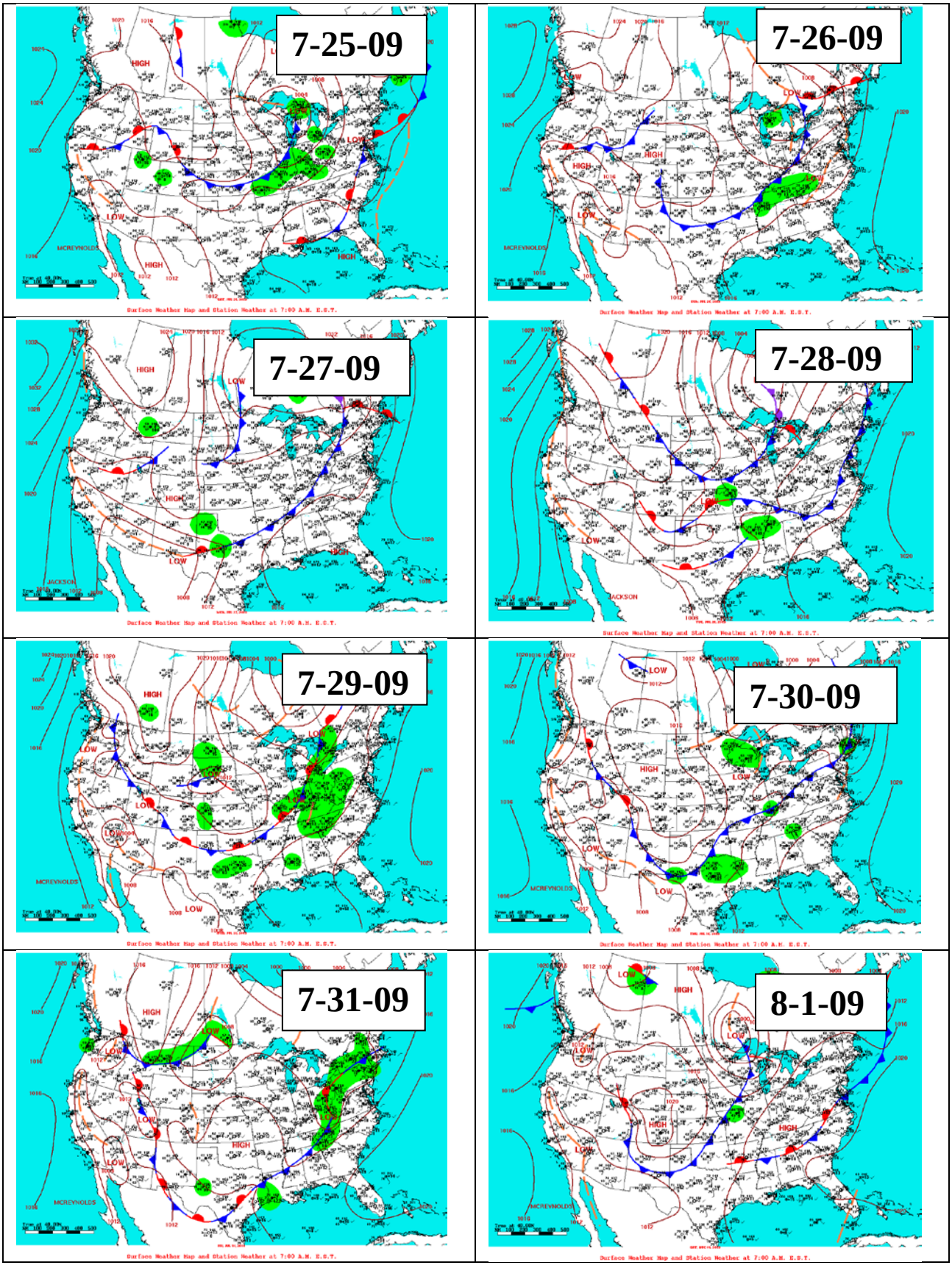
7-21-09
7-22-09
7-23-09
7-24-09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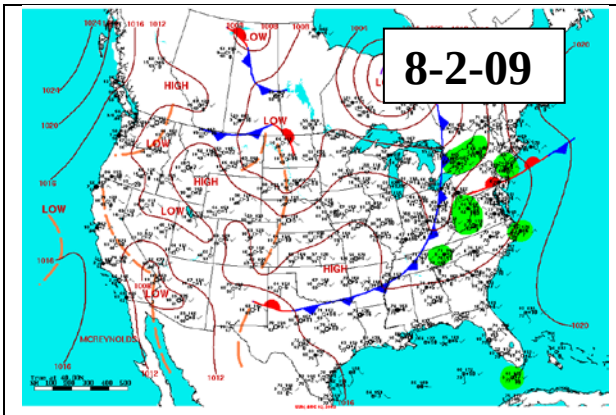
8-1-09


8-2-09
HIGH
LOW
LOW
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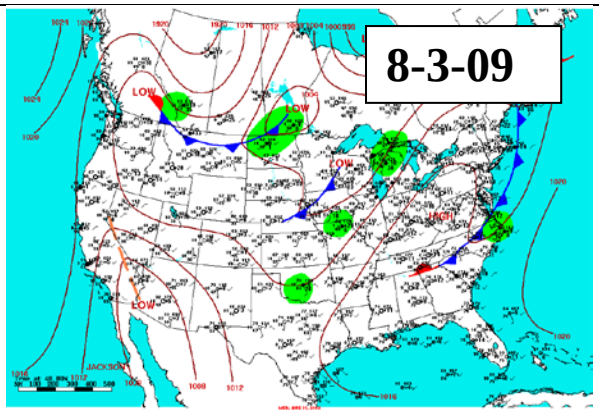
LOW
MCHENRY/OLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-3-09
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HIGH
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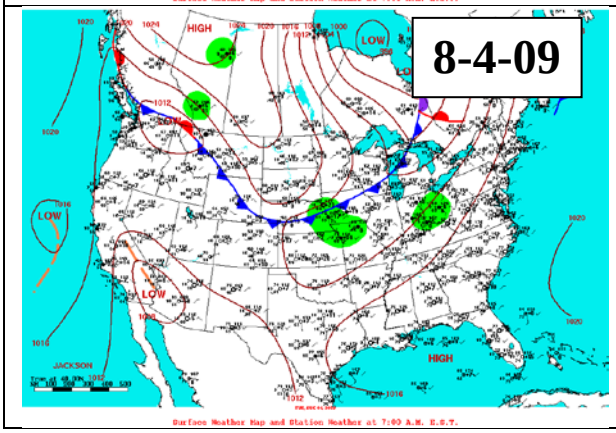
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


8-4-09
HIGH
LOW
LOW
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

6.10 Daily Weather conditions

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 2				
8/30/2007	91.80	958	0%	23.1
8/31/2007	91.57	973	9%	23.0
9/1/2007	91.40	977	42%	23.5
9/2/2007	91.37	898	71%	24.0
9/3/2007	91.40	897	64%	23.2
9/4/2007	90.99	951	61%	24.3
9/5/2007	90.46	855	74%	25.6
9/6/2007	90.30	1010	61%	28.6
9/7/2007	90.82	446	69%	25.7
9/8/2007	91.04	1020	64%	23.4
9/9/2007	91.13	76	43%	23.7
9/10/2007	91.78	285	40%	14.9
9/11/2007	91.75	843	43%	15.2
9/12/2007	91.21	832	0%	18.9
9/13/2007	90.85	822	15%	22.1
9/14/2007	91.46	672	0%	17.1
9/15/2007	91.57	808	0%	20.0
9/16/2007	91.00	844	0%	27.0
9/17/2007	90.66	851	0%	25.2
Period 3				
1/24/2008	91.30	242	0%	2.9
1/25/2008	91.07	607	33%	3.6
1/26/2008	91.35	613	1%	3.5
1/27/2008	91.12	610	6%	4.4
1/28/2008	89.69	609	4%	16.3
1/29/2008	89.88	630	14%	4.1
1/30/2008	89.95	755	0%	3.1
1/31/2008	90.68	633	6%	-2.4
2/1/2008	90.43	710	0%	0.9
2/2/2008	90.65	642	16%	2.7
2/3/2008	90.26	686	40%	3.2
2/4/2008	89.52	646	0%	12.2
2/5/2008	90.39	256	92%	-1.1
2/6/2008	90.75	658	87%	-4.1
2/7/2008	90.67	674	17%	0.8
2/8/2008	90.28	673	6%	3.0
2/9/2008	91.02	694	24%	1.6
2/10/2008	91.67	186	46%	-1.9
2/11/2008	90.89	837	68%	-1.5
2/12/2008	91.06	807	43%	3.4
2/13/2008	90.74	685	28%	3.1
2/14/2008	90.00	454	0%	6.9
2/15/2008	91.62	472	40%	-4.3

2/16/2008	90.85	312	52%	0.4
2/17/2008	90.12	868	53%	4.1
2/18/2008	91.13	768	15%	-0.6
2/19/2008	91.18	610	12%	0.5
Period 4				
5/3/2008	91.45	972	0%	16.0
5/4/2008	91.27	978	0%	12.8
5/5/2008	91.15	1035	3%	19.1
5/6/2008	90.77	1009	48%	18.6
5/7/2008	N/A	N/A	100%	N/A
5/8/2008	89.77	979	13%	23.9
5/9/2008	90.38	1073	56%	15.5
5/10/2008	90.12	1077	7%	18.0
5/11/2008	91.26	991	30%	10.7
5/12/2008	90.03	1063	0%	19.9
5/13/2008	90.10	970	9%	17.7
5/14/2008	91.04	971	66%	10.8
5/15/2008	91.00	62	100%	10.0
5/16/2008	N/A	N/A	100%	N/A
5/17/2008	N/A	N/A	100%	N/A
5/18/2008	N/A	N/A	100%	N/A
5/19/2008	90.09	763	0%	33.8
5/20/2008	90.67	972	4%	21.9
5/21/2008	89.96	1074	0%	21.0
5/22/2008	88.78	1018	0%	26.0
5/23/2008	89.39	1071	37%	24.4
5/24/2008	90.28	1001	0%	19.9
5/25/2008	90.41	1018	0%	23.8
5/26/2008	90.15	942	3%	23.5
5/27/2008	90.62	953	46%	17.2
5/28/2008	91.49	949	54%	14.2
5/29/2008	90.98	944	18%	23.1
Period 5				
5/30/2008	90.48	997	0%	25.3
5/31/2008	90.71	1117	18%	22.8
6/1/2008	90.80	1158	35%	23.4
6/2/2008	90.32	1073	39%	26.9
6/3/2008	89.80	996	5%	27.6
6/4/2008	89.34	1010	39%	21.8
6/5/2008	88.95	1135	1%	25.9
6/6/2008	90.11	988	6%	21.1
6/7/2008	90.04	977	0%	28.7
6/8/2008	90.11	1012	0%	26.4
6/9/2008	90.75	986	5%	20.4
6/10/2008	90.61	964	24%	22.6
Period 6				
11/5/2008	89.93	106	0%	12.7
11/6/2008	90.69	635	0%	6.5

11/7/2008	91.23	644	0%	6.5
11/8/2008	91.16	613	0%	7.9
11/9/2008	90.79	603	49%	6.3
11/10/2008	90.16	634	23%	10.5
11/11/2008	90.49	545	45%	6.1
11/12/2008	90.80	696	57%	5.8
11/13/2008	90.26	543	11%	9.9
11/14/2008	90.68	581	25%	7.6
11/15/2008	92.15	556	0%	2.1
11/16/2008	91.63	545	0%	7.0
11/17/2008	91.81	534	10%	6.1
11/18/2008	92.10	531	50%	7.4
11/19/2008	91.27	536	0%	13.6
11/20/2008	92.23	297	1%	3.8
11/21/2008	92.27	515	4%	-0.4
11/22/2008	91.45	526	26%	2.4
11/23/2008	90.99	555	24%	5.4
11/24/2008	91.91	528	16%	5.1
11/25/2008	91.35	544	0%	6.6
11/26/2008	91.15	553	0%	5.9
11/27/2008	91.15	494	9%	2.7
11/28/2008	91.02	159	100%	1.7
11/29/2008	90.56	625	42%	3.8
11/30/2008	90.50	468	0%	5.5
12/1/2008	91.10	518	11%	2.1
12/2/2008	90.49	537	21%	6.3
12/3/2008	90.32	519	0%	7.1
Period 7				
12/4/2008	92.06	193	0%	-2.9
12/5/2008	91.89	502	0%	-1.6
12/6/2008	91.22	504	0%	1.8
12/7/2008	90.98	489	0%	6.8
12/8/2008	89.56	525	0%	10.1
12/9/2008	90.60	483	58%	0.3
12/10/2008	91.74	516	55%	-6.3
12/11/2008	91.42	497	61%	3.6
12/12/2008	91.47	505	63%	1.9
12/13/2008	89.53	541	0%	10.7
12/14/2008	89.57	431	0%	2.8
12/15/2008	91.89	349	0%	-13.4
12/16/2008	91.22	505	23%	-8.3
Period 8				
4/22/2009	90.42	543	0%	25.6
4/23/2009	90.31	1077	34%	17.6
4/24/2009	90.06	1036	4%	19.8
4/25/2009	90.33	1020	25%	14.0
4/26/2009	90.04	1028	75%	14.0
4/27/2009	90.75	1000	69%	11.4

4/28/2009	91.53	515	100%	8.6
4/29/2009	90.77	1022	73%	18.2
4/30/2009	90.54	1076	68%	18.3
5/1/2009	90.97	420	86%	12.8
5/2/2009	91.08	556	98%	9.0
5/3/2009	90.83	1097	76%	9.4
5/4/2009	90.88	1107	72%	10.2
5/5/2009	90.59	940	70%	12.9
5/6/2009	90.52	934	56%	17.6
5/7/2009	90.35	949	34%	20.9
5/8/2009	90.16	942	67%	20.6
5/9/2009	91.27	1068	69%	14.2
5/10/2009	91.34	252	96%	10.4
5/11/2009	91.49	953	100%	10.1
5/12/2009	90.46	985	84%	17.9
5/13/2009	89.85	973	71%	22.1
5/14/2009	91.11	1018	21%	15.6
Period 9				
7/15/2009	91.04	957	0%	34.5
7/16/2009	91.10	1002	55%	24.4
7/17/2009	91.47	1038	53%	21.2
7/18/2009	91.62	1170	56%	20.6
7/19/2009	91.43	948	43%	24.1
7/20/2009	90.70	942	13%	27.7
7/21/2009	90.97	1048	36%	24.6
7/22/2009	91.29	1091	12%	23.7
7/23/2009	91.18	948	31%	24.0
7/24/2009	90.93	950	57%	27.4
7/25/2009	90.84	958	38%	29.0
7/26/2009	91.25	1077	62%	25.0
7/27/2009	91.07	73	99%	23.1
7/28/2009	N/A	N/A	N/A	N/A
7/29/2009	N/A	N/A	N/A	N/A
7/30/2009	91.23	892	0%	23.3
7/31/2009	91.19	1049	40%	21.1
8/1/2009	90.76	128	0%	27.1
8/2/2009	N/A	N/A	N/A	N/A
8/3/2009	90.71	934	0%	34.4
8/4/2009	90.87	921	1%	24.9

6.11 Daily lagoon conditions

Lagoon temperature, pH, and oxidation-reduction potential

Date	Lagoon temp (°C)	Lagoon pH	Lagoon ORP (mV)
Period 2			

Date	Lagoon temp (°C)	Lagoon pH	Lagoon ORP (mV)
8/30/2007	N/A	N/A	N/A
8/31/2007	27.9	7.71	-353
9/1/2007	25.6	7.71	-445
9/2/2007	25.5	7.72	-440
9/3/2007	24.8	7.74	-446
9/4/2007	24.5	7.75	-449
9/5/2007	24.2	7.76	-439
9/6/2007	24.7	7.77	-445
9/7/2007	24.1	7.76	-495
9/8/2007	23.4	7.70	-530
9/9/2007	23.9	7.71	-521
9/10/2007	22.1	7.68	-532
9/11/2007	21.2	7.71	-521
9/12/2007	21.1	7.71	-514
9/13/2007	21.5	7.72	-523
9/14/2007	21.1	7.69	-539
9/15/2007	20.0	7.72	-496
9/16/2007	20.9	7.73	-514
9/17/2007	21.0	7.73	-453
Period 3			
1/24/2008	N/A	N/A	N/A
1/25/2008	N/A	N/A	N/A
1/26/2008	N/A	N/A	N/A
1/27/2008	N/A	N/A	N/A
1/28/2008	N/A	N/A	N/A
1/29/2008	N/A	N/A	N/A
1/30/2008	N/A	N/A	N/A
1/31/2008	N/A	N/A	N/A
2/1/2008	N/A	N/A	N/A
2/2/2008	N/A	N/A	N/A
2/3/2008	N/A	N/A	N/A
2/4/2008	N/A	N/A	N/A
2/5/2008	N/A	N/A	N/A
2/6/2008	N/A	N/A	N/A
2/7/2008	N/A	N/A	N/A
2/8/2008	N/A	N/A	N/A
2/9/2008	N/A	N/A	N/A
2/10/2008	N/A	N/A	N/A
2/11/2008	N/A	N/A	N/A
2/12/2008	N/A	N/A	N/A
2/13/2008	N/A	N/A	N/A
2/14/2008	N/A	N/A	N/A
2/15/2008	N/A	N/A	N/A
2/16/2008	N/A	N/A	N/A
2/17/2008	N/A	N/A	N/A

Date	Lagoon temp (°C)	Lagoon pH	Lagoon ORP (mV)
2/18/2008	N/A	N/A	N/A
2/19/2008	N/A	N/A	N/A
Period 4			
5/3/2008	N/A	N/A	N/A
5/4/2008	N/A	N/A	N/A
5/5/2008	N/A	N/A	N/A
5/6/2008	N/A	N/A	N/A
5/7/2008	N/A	N/A	N/A
5/8/2008	18.7	7.57	-391
5/9/2008	18.0	7.66	-485
5/10/2008	17.9	7.71	-491
5/11/2008	17.4	7.78	-516
5/12/2008	17.1	7.82	-481
5/13/2008	17.0	7.86	-503
5/14/2008	17.3	7.88	-504
5/15/2008	17.3	7.88	-509
5/16/2008	N/A	N/A	N/A
5/17/2008	N/A	N/A	N/A
5/18/2008	N/A	N/A	N/A
5/19/2008	20.1	7.79	-540
5/20/2008	20.5	7.81	-506
5/21/2008	20.8	7.81	-522
5/22/2008	21.0	7.87	-460
5/23/2008	21.0	7.90	-492
5/24/2008	21.1	7.89	-514
5/25/2008	21.2	7.90	-472
5/26/2008	21.0	7.97	-460
5/27/2008	21.0	7.96	-501
5/28/2008	20.2	7.96	-460
5/29/2008	20.4	7.92	-444
Period 5			
5/30/2008	21.6	7.97	-444
5/31/2008	22.3	7.96	-498
6/1/2008	23.7	7.95	-475
6/2/2008	23.9	7.95	-534
6/3/2008	23.2	7.99	-514
6/4/2008	23.5	8.00	-514
6/5/2008	22.9	8.04	-504
6/6/2008	21.8	8.10	-495
6/7/2008	22.1	8.12	-409
6/8/2008	22.5	8.17	-427
6/9/2008	22.6	8.17	-540
6/10/2008	22.7	8.19	-525
Period 6			
11/5/2008	N/A	N/A	N/A

Date	Lagoon temp (°C)	Lagoon pH	Lagoon ORP (mV)
11/6/2008	12.1	7.74	-201
11/7/2008	11.3	7.97	-246
11/8/2008	11.1	8.00	-279
11/9/2008	10.9	8.01	-288
11/10/2008	10.4	8.04	-263
11/11/2008	10.3	8.04	-513
11/12/2008	10.4	8.02	-529
11/13/2008	10.1	8.03	-531
11/14/2008	9.8	8.03	-472
11/15/2008	8.2	8.08	-507
11/16/2008	8.0	8.09	-530
11/17/2008	8.1	8.09	-523
11/18/2008	8.0	8.08	-478
11/19/2008	8.3	8.05	-543
11/20/2008	8.1	8.06	-541
11/21/2008	6.6	8.09	-323
11/22/2008	6.1	8.10	-418
11/23/2008	6.0	8.11	-530
11/24/2008	6.0	8.10	-531
11/25/2008	6.0	8.06	-525
11/26/2008	5.6	8.06	-539
11/27/2008	5.8	8.06	-539
11/28/2008	5.3	8.07	-519
11/29/2008	5.0	8.07	-537
11/30/2008	4.9	8.09	-456
12/1/2008	4.1	8.11	-481
12/2/2008	4.5	8.06	-480
12/3/2008	5.2	8.02	-448
Period 7			
12/4/2008	4.1	8.10	-411
12/5/2008	3.3	8.12	-336
12/6/2008	3.5	8.11	-494
12/7/2008	3.8	8.11	-459
12/8/2008	4.0	8.09	-517
12/9/2008	4.3	8.10	-393
12/10/2008	3.4	8.09	-501
12/11/2008	3.2	8.08	-538
12/12/2008	3.5	8.08	-470
12/13/2008	4.1	8.10	-315
12/14/2008	4.8	8.11	-489
12/15/2008	2.7	8.14	-481
12/16/2008	0.9	8.14	-449
Period 8			
4/22/2009	N/A	N/A	N/A
4/23/2009	18.1	7.47	-431

Date	Lagoon temp (°C)	Lagoon pH	Lagoon ORP (mV)
4/24/2009	17.7	7.48	-451
4/25/2009	17.8	7.48	-455
4/26/2009	17.5	7.48	-466
4/27/2009	17.2	7.49	-510
4/28/2009	16.2	7.51	-528
4/29/2009	16.1	7.47	-530
4/30/2009	17.1	7.42	-533
5/1/2009	17.9	7.47	-540
5/2/2009	16.7	7.49	-546
5/3/2009	16.3	7.47	-547
5/4/2009	15.9	7.48	-542
5/5/2009	16.1	7.47	-549
5/6/2009	17.2	7.44	-550
5/7/2009	18.6	7.44	-547
5/8/2009	19.4	7.45	-538
5/9/2009	19.3	7.46	-540
5/10/2009	18.8	7.45	-543
5/11/2009	18.0	7.45	-553
5/12/2009	18.0	7.47	-537
5/13/2009	18.8	7.48	-539
5/14/2009	18.9	7.47	-539
Period 9			
7/15/2009	N/A	N/A	N/A
7/16/2009	27.4	N/A	-390
7/17/2009	26.0	N/A	-384
7/18/2009	25.6	N/A	-416
7/19/2009	25.7	N/A	-410
7/20/2009	26.0	N/A	-482
7/21/2009	25.9	N/A	-531
7/22/2009	26.2	N/A	-534
7/23/2009	26.0	N/A	-527
7/24/2009	26.7	N/A	-541
7/25/2009	27.2	N/A	-551
7/26/2009	25.8	N/A	-556
7/27/2009	26.7	N/A	-591
7/28/2009	N/A	N/A	N/A
7/29/2009	N/A	N/A	N/A
7/30/2009	23.9	N/A	-559
7/31/2009	23.8	N/A	-560
8/1/2009	24.3	N/A	-549
8/2/2009	N/A	N/A	N/A
8/3/2009	27.3	N/A	-543
8/4/2009	25.7	N/A	-563

6.12 Daily Site Emissions and Data completeness

6.12.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid values: Number of ½ hour periods with valid emissions data
Direction Limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction
Missing Downwind NH3: Number of ½ hour periods invalidated because at least 1 TDL path was either missing or else had invalid concentration values
Emission Average (µg m^{-2} s^{-1}): Daily average emission calculated from the valid ½ hour periods
Emissions SD (µg m^{-2} s^{-1}): Daily emission standard deviation of the valid ½ hour periods
Emission Minimum (µg m^{-2} s^{-1}): Daily minimum emission of the valid ½ hour periods
Emission Maximum (µg m^{-2} s^{-1}): Daily maximum emission of the valid ½ hour periods
Emission Average (kg d^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area
Emission Average (g d^{-1} hd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis
Emission Average (g d^{-1} AU^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing Down-wind NH3	Average ($\mu g m^{-2} s^{-1}$)	SD ($\mu g m^{-2} s^{-1}$)	Minimum ($\mu g m^{-2} s^{-1}$)	Maximum ($\mu g m^{-2} s^{-1}$)	Average ($kg d^{-1}$)	Average ($g d^{-1} hd^{-1}$)	Average ($g d^{-1} AU^{-1}$)
Period 2										
8/31/2007	2	3	6	85.0	11.3	77.0	93.0	73.4	24.5	160.0
9/1/2007	22	2	15	157.3	39.7	78.0	238.0	135.9	45.3	296.1
9/2/2007	12	0	36	117.6	36.8	59.0	191.0	101.6	33.9	221.3
9/3/2007	2	0	46	73.0	17.0	61.0	85.0	63.1	21.0	137.4
9/4/2007	21	0	27	163.3	26.0	114.0	214.0	141.1	47.0	307.4
9/5/2007	37	0	8	187.6	63.3	109.0	444.0	162.1	54.0	353.1
9/6/2007	39	0	0	154.0	99.5	49.0	487.0	133.1	44.4	289.9
9/7/2007	26	1	0	148.1	83.4	27.0	348.0	128.0	42.7	278.8
9/8/2007	13	12	13	171.6	74.5	26.0	301.0	148.3	49.4	323.0
9/9/2007	14	6	13	188.5	148.1	-74.0	373.0	162.9	54.3	354.8
9/10/2007	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/11/2007	3	3	39	78.3	50.0	33.0	132.0	67.7	22.6	147.5
9/12/2007	39	3	1	115.1	48.2	43.0	296.0	99.4	33.1	216.6
9/13/2007	32	0	12	98.2	37.8	42.0	221.0	84.8	28.3	184.8
9/14/2007	10	1	25	196.2	73.0	68.0	261.0	169.5	56.5	369.3
9/15/2007	33	3	0	196.5	75.6	71.0	319.0	169.8	56.6	369.9

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing Down-wind NH3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
9/16/2007	24	0	24	185.0	35.8	125.0	254.0	159.8	53.3	348.2
9/17/2007	48	0	0	213.5	79.3	109.0	395.0	184.4	61.5	401.8
9/18/2007	15	0	14	165.4	68.4	82.0	321.0	142.9	47.6	311.3
Period 3										
1/25/2008	0	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/26/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/28/2008	0	0	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/29/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/30/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2008	0	0	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/2/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/3/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/4/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2008	0	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2008	0	0	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/8/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/9/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2008	1	0	35	3.0	N/A	3.0	3.0	2.6	0.9	5.6
2/11/2008	3	0	7	30.7	16.9	19.0	50.0	26.5	8.8	57.7
2/12/2008	5	0	9	16.8	6.1	8.0	24.0	14.5	4.8	31.6
2/13/2008	2	0	28	18.0	7.1	13.0	23.0	15.6	5.2	33.9
2/14/2008	4	0	40	42.8	9.6	36.0	57.0	36.9	12.3	80.5
2/15/2008	2	0	23	14.5	0.7	14.0	15.0	12.5	4.2	27.3
2/16/2008	6	0	28	35.0	13.3	16.0	53.0	30.2	10.1	65.9
2/17/2008	11	0	15	44.0	15.6	17.0	59.0	38.0	12.7	82.8
2/18/2008	10	0	17	32.4	15.4	15.0	60.0	28.0	9.3	61.0
2/19/2008	0	0	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4										
5/8/2008	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/9/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2008	2	0	42	100.5	4.9	97.0	104.0	86.8	28.9	189.2
5/11/2008	13	0	30	46.8	14.7	26.0	67.0	40.5	13.5	88.2
5/12/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/13/2008	15	0	17	73.8	28.1	30.0	135.0	63.8	21.3	138.9
5/14/2008	10	0	26	32.1	12.0	14.0	50.0	27.7	9.2	60.4
5/15/2008	23	0	21	82.9	22.4	35.0	109.0	71.6	23.9	156.0
5/16/2008	24	0	14	54.5	23.2	18.0	101.0	47.1	15.7	102.7
5/17/2008	39	0	2	62.1	23.4	13.0	119.0	53.6	17.9	116.9
5/18/2008	28	0	9	49.1	22.6	6.0	101.0	42.4	14.1	92.4
5/19/2008	24	0	20	60.9	23.4	25.0	119.0	52.6	17.5	114.7

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing Down-wind NH3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
5/20/2008	4	0	41	36.0	3.7	31.0	40.0	31.1	10.4	67.8
5/21/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	10	0	37	132.1	52.1	53.0	204.0	114.1	38.0	248.7
5/25/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2008	19	0	26	111.6	26.6	23.0	138.0	96.4	32.1	210.1
5/28/2008	6	0	19	67.5	8.4	56.0	76.0	58.3	19.4	127.1
Period 5										
5/29/2008	0	0	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2008	3	3	31	149.3	74.3	88.0	232.0	129.0	43.0	281.1
5/31/2008	10	2	11	89.8	63.3	37.0	238.0	77.6	25.9	169.0
6/1/2008	8	7	13	230.4	72.6	128.0	358.0	199.0	66.3	433.6
6/2/2008	9	3	31	150.7	39.1	122.0	251.0	130.2	43.4	283.6
6/3/2008	18	1	22	122.3	37.2	67.0	200.0	105.7	35.2	230.3
6/4/2008	12	2	24	85.7	51.0	13.0	174.0	74.0	24.7	161.3
6/5/2008	16	0	30	236.9	105.4	79.0	404.0	204.7	68.2	445.9
6/6/2008	17	0	24	134.1	43.3	88.0	234.0	115.9	38.6	252.5
6/7/2008	2	0	45	207.5	43.1	177.0	238.0	179.3	59.8	390.6
6/8/2008	18	0	22	124.7	59.3	43.0	279.0	107.7	35.9	234.7
6/9/2008	21	4	17	137.6	93.7	26.0	345.0	118.9	39.6	259.0
6/10/2008	0	0	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6										
11/6/2008	2	0	3	27.0	1.4	26.0	28.0	23.3	7.8	50.8
11/7/2008	24	0	19	40.4	7.8	16.0	54.0	34.9	11.6	76.0
11/8/2008	1	2	40	5.0	N/A	5.0	5.0	4.3	1.4	9.4
11/9/2008	23	15	0	32.8	13.1	13.0	61.0	28.4	9.5	61.8
11/10/2008	6	0	8	29.2	10.0	12.0	39.0	25.2	8.4	54.9
11/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/12/2008	9	1	31	19.0	9.9	5.0	32.0	16.4	5.5	35.8
11/13/2008	2	0	42	15.0	2.8	13.0	17.0	13.0	4.3	28.2
11/14/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/15/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/16/2008	2	0	42	13.0	5.7	9.0	17.0	11.2	3.7	24.5
11/17/2008	4	0	35	23.8	12.3	14.0	41.0	20.5	6.8	44.7
11/18/2008	33	1	3	27.1	16.7	9.0	66.0	23.4	7.8	51.1
11/19/2008	19	0	1	38.2	18.1	10.0	71.0	33.0	11.0	71.8
11/20/2008	31	0	3	21.3	7.7	9.0	41.0	18.4	6.1	40.1
11/21/2008	31	1	2	18.9	7.5	6.0	33.0	16.4	5.5	35.6
11/22/2008	20	3	1	17.3	7.2	5.0	28.0	14.9	5.0	32.6
11/23/2008	35	0	1	17.7	7.8	4.0	31.0	15.3	5.1	33.2
11/24/2008	19	0	3	18.4	7.4	7.0	34.0	15.9	5.3	34.6

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing Down-wind NH3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
11/25/2008	27	0	0	23.1	13.0	5.0	50.0	20.0	6.7	43.6
11/26/2008	23	0	0	17.0	8.7	3.0	39.0	14.7	4.9	32.1
11/27/2008	8	3	36	30.5	11.6	9.0	44.0	26.4	8.8	57.4
11/28/2008	0	0	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/29/2008	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/30/2008	0	0	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2008	1	0	16	10.0	N/A	10.0	10.0	8.6	2.9	18.8
12/2/2008	15	0	19	14.8	11.9	7.0	52.0	12.8	4.3	27.9
Period 7										
12/3/2008	18	0	15	21.7	5.4	11.0	30.0	18.7	6.2	40.8
12/4/2008	16	18	0	10.6	5.5	4.0	19.0	9.2	3.1	20.0
12/5/2008	6	2	12	21.5	15.0	11.0	51.0	18.6	6.2	40.5
12/6/2008	19	0	12	14.9	10.1	2.0	43.0	12.9	4.3	28.0
12/7/2008	19	1	9	17.3	16.2	-6.0	59.0	14.9	5.0	32.5
12/8/2008	15	0	7	23.5	18.1	-7.0	63.0	20.3	6.8	44.3
12/9/2008	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2008	7	0	1	12.0	6.0	4.0	18.0	10.4	3.5	22.6
12/11/2008	23	0	1	16.6	4.8	8.0	27.0	14.3	4.8	31.3
12/12/2008	19	0	3	18.1	7.4	5.0	34.0	15.6	5.2	34.1
12/13/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/14/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/16/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8										
4/22/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/23/2009	0	0	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/24/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/26/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/27/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/28/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/4/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/5/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/6/2009	1	0	47	85.0	N/A	85.0	85.0	73.4	24.5	160.0
5/7/2009	22	5	9	71.9	29.6	26.0	110.0	62.1	20.7	135.3
5/8/2009	25	4	18	76.8	28.9	25.0	145.0	66.3	22.1	144.5
5/9/2009	10	10	28	69.2	6.9	59.0	82.0	59.8	19.9	130.3
5/10/2009	25	16	5	71.8	10.4	46.0	86.0	62.0	20.7	135.1

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing Down-wind NH3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
5/11/2009	25	4	10	37.5	15.2	19.0	77.0	32.4	10.8	70.6
5/12/2009	26	0	10	33.1	8.4	22.0	60.0	28.6	9.5	62.3
5/13/2009	15	0	30	53.1	17.2	34.0	93.0	45.8	15.3	99.9
5/14/2009	2	2	28	59.0	17.0	47.0	71.0	51.0	17.0	111.1
Period 9										
7/15/2009	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/16/2009	2	0	46	124.0	49.5	89.0	159.0	107.1	35.7	233.4
7/17/2009	2	1	45	109.5	26.2	91.0	128.0	94.6	31.5	206.1
7/18/2009	20	6	12	85.0	39.9	48.0	179.0	73.4	24.5	160.0
7/19/2009	32	3	6	84.7	26.1	37.0	151.0	73.2	24.4	159.5
7/20/2009	40	0	6	88.6	37.2	42.0	172.0	76.6	25.5	166.8
7/21/2009	11	2	34	120.5	22.7	76.0	164.0	104.2	34.7	226.9
7/22/2009	28	8	5	76.3	26.5	26.0	118.0	65.9	22.0	143.7
7/23/2009	43	0	2	78.8	27.5	23.0	126.0	68.1	22.7	148.4
7/24/2009	41	0	0	85.4	31.0	33.0	147.0	73.8	24.6	160.8
7/25/2009	39	6	1	85.8	36.5	29.0	169.0	74.1	24.7	161.4
7/26/2009	27	12	5	104.8	52.6	8.0	204.0	90.5	30.2	197.2
7/27/2009	8	6	31	57.0	32.2	33.0	131.0	49.2	16.4	107.3
7/28/2009	4	0	44	58.3	9.4	45.0	67.0	50.3	16.8	109.6
7/29/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/30/2009	1	0	14	101.0	N/A	101.0	101.0	87.3	29.1	190.1
7/31/2009	32	5	5	82.0	31.5	37.0	168.0	70.8	23.6	154.3
8/1/2009	14	0	33	113.7	36.2	61.0	203.0	98.2	32.7	214.1
8/2/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/3/2009	18	0	30	118.1	38.4	57.0	183.0	102.0	34.0	222.3
8/4/2009	21	0	9	91.9	35.3	40.0	183.0	79.4	26.5	173.0

6.12.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ hour periods with valid emissions data
Direction Limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction
Touchdown Limited: Number of ½ hour periods invalidated because fraction of source area surface covered by particle touchdowns was less than 0.1
Turbulence Limited: Number of ½ hour periods that the bLS model was not run because either u* < 0.15 m/s or |L| < 2 m
Background (ppm): bLS model calculated daily average background concentration (ppm); average is over the ½ hour periods included in the valid column
Emission Average (µg m^{-2} s^{-1}): Daily average emission calculated from the valid ½ hour periods
Emissions SD (µg m^{-2} s^{-1}): Daily emission standard deviation of the valid ½ hour periods
Emission Minimum (µg m^{-2} s^{-1}): Daily minimum emission of the valid ½ hour periods
Emission Maximum (µg m^{-2} s^{-1}): Daily maximum emission of the valid ½ hour periods
Emission Average (kg d^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area
Emission Average (g d^{-1} hd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis
Emission Average (g d^{-1} AU^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Background (ppm)	Emission Average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission Minimum ($\mu g m^{-2} s^{-1}$)	Emission Maximum ($\mu g m^{-2} s^{-1}$)	Emission Average ($kg d^{-1}$)	Emission Average ($g d^{-1} hd^{-1}$)	Emission Average ($g d^{-1} AU^{-1}$)
Period 2												
8/31/2007	4	7	1	0	-0.10	209.1	18.5	181.8	222.0	189.8	63.3	413.4
9/1/2007	28	9	0	10	-0.03	166.6	52.5	63.4	277.5	151.2	50.4	329.4
9/2/2007	28	9	0	10	0.00	125.6	54.3	32.2	243.0	113.9	38.0	248.2
9/3/2007	34	2	0	11	-0.01	137.6	38.1	46.2	243.6	124.9	41.6	272.1
9/4/2007	37	0	0	11	0.01	137.6	53.3	40.5	247.7	124.9	41.6	272.1
9/5/2007	48	0	0	0	0.02	158.0	47.5	79.1	265.2	143.3	47.8	312.3
9/6/2007	41	0	0	7	0.16	121.0	68.2	11.3	260.9	109.7	36.6	239.1
9/7/2007	36	9	0	3	0.20	86.2	44.2	20.5	183.6	78.3	26.1	170.5
9/8/2007	12	7	0	28	0.05	134.6	61.5	43.4	224.0	122.1	40.7	266.1
9/9/2007	28	6	7	3	0.09	81.0	39.7	23.5	180.9	73.5	24.5	160.2
9/10/2007	6	0	3	17	-0.02	42.6	25.3	3.7	65.8	38.6	12.9	84.2
9/11/2007	4	5	7	20	-0.30	182.4	195.4	25.6	448.5	165.5	55.2	360.6
9/12/2007	27	3	0	16	0.14	115.4	46.5	37.7	212.2	104.7	34.9	228.2
9/13/2007	35	0	0	13	0.14	115.4	39.9	21.3	209.0	104.7	34.9	228.0

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Background (ppm)	Emission Average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission Minimum ($\mu gm^{-2}s^{-1}$)	Emission Maximum ($\mu gm^{-2}s^{-1}$)	Emission Average (kgd^{-1})	Emission Average ($gd^{-1}hd^{-1}$)	Emission Average ($gd^{-1}AU^{-1}$)
9/14/2007	38	1	1	8	0.20	86.1	21.3	19.4	139.4	78.1	26.0	170.2
9/15/2007	38	10	0	0	0.13	130.1	39.8	80.2	237.2	118.1	39.4	257.2
9/16/2007	48	0	0	0	0.27	117.3	34.1	76.3	185.7	106.4	35.5	231.8
9/17/2007	48	0	0	0	0.18	165.1	53.7	110.6	276.4	149.8	49.9	326.3
9/18/2007	18	1	1	6	0.18	117.0	49.2	25.0	249.2	106.1	35.4	231.2
Period 3												
1/25/2008	0	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/26/2008	36	0	0	12	-0.02	0.6	3.5	-5.2	8.2	0.6	0.2	1.2
1/27/2008	27	0	0	20	-0.04	8.7	8.2	0.4	31.4	7.9	2.6	17.2
1/28/2008	38	0	0	0	-0.02	6.9	9.8	-27.8	27.2	6.3	2.1	13.6
1/29/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/30/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2008	16	0	0	1	-0.01	0.3	3.7	-4.7	10.5	0.3	0.1	0.6
2/1/2008	28	0	0	18	-0.01	3.0	4.0	-8.9	11.1	2.7	0.9	5.9
2/2/2008	41	4	0	2	-0.04	4.7	10.5	-25.0	46.0	4.3	1.4	9.3
2/3/2008	23	1	4	16	-0.03	2.7	6.5	-9.2	13.8	2.4	0.8	5.3
2/4/2008	47	0	0	1	-0.04	9.4	5.2	-0.3	18.2	8.6	2.9	18.7
2/5/2008	16	0	0	0	-0.02	-8.2	33.2	-116.0	30.3	-7.4	-2.5	-16.2
2/6/2008	8	0	1	1	0.02	12.3	8.7	-4.9	21.1	11.1	3.7	24.3
2/7/2008	20	2	0	5	0.02	11.1	7.1	2.3	33.9	10.0	3.3	21.9
2/8/2008	36	0	3	9	0.00	12.4	7.0	4.2	31.9	11.3	3.8	24.6
2/9/2008	21	0	0	21	0.02	5.5	4.5	0.3	18.1	5.0	1.7	10.9
2/10/2008	9	1	8	11	-0.01	11.3	2.7	6.0	15.0	10.2	3.4	22.3
2/11/2008	17	0	1	0	0.02	10.8	11.3	-13.8	26.6	9.8	3.3	21.3
2/12/2008	33	0	1	14	0.01	20.0	6.3	0.7	30.0	18.1	6.0	39.5
2/13/2008	42	0	0	6	0.02	14.6	10.2	-3.6	34.1	13.2	4.4	28.8
2/14/2008	48	0	0	0	0.00	18.4	10.9	-7.5	36.2	16.7	5.6	36.4
2/15/2008	28	0	4	15	0.02	9.2	13.4	-14.5	55.2	8.4	2.8	18.3
2/16/2008	22	1	0	20	0.01	12.7	5.2	0.4	21.5	11.5	3.8	25.1
2/17/2008	38	0	0	7	0.01	25.8	10.0	7.6	48.1	23.4	7.8	51.0
2/18/2008	32	0	1	14	0.02	9.2	6.2	-14.0	19.3	8.4	2.8	18.2
2/19/2008	0	0	0	26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4												
5/8/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/9/2008	37	4	2	0	0.03	43.7	31.7	-28.8	142.1	39.6	13.2	86.3
5/10/2008	37	0	3	0	-0.02	87.3	21.2	52.9	136.4	79.2	26.4	172.6
5/11/2008	39	0	2	7	0.01	44.0	21.8	4.4	97.0	39.9	13.3	86.9
5/12/2008	30	0	12	0	0.02	56.9	26.2	8.0	97.7	51.6	17.2	112.5
5/13/2008	40	0	7	0	0.01	63.9	19.5	4.6	106.1	58.0	19.3	126.3
5/14/2008	17	1	10	17	0.06	25.4	18.8	-14.7	53.6	23.0	7.7	50.2
5/15/2008	25	0	2	18	0.02	61.3	21.8	12.8	97.4	55.6	18.5	121.2
5/16/2008	33	0	0	15	0.00	65.8	27.6	16.2	116.0	59.7	19.9	130.0
5/17/2008	31	0	0	14	0.03	70.4	24.0	28.0	104.1	63.9	21.3	139.2
5/18/2008	24	2	2	16	-0.04	71.4	53.9	24.3	253.4	64.8	21.6	141.1

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Background (ppm)	Emission Average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission Minimum ($\mu gm^{-2}s^{-1}$)	Emission Maximum ($\mu gm^{-2}s^{-1}$)	Emission Average (kgd^{-1})	Emission Average ($gd^{-1}hd^{-1}$)	Emission Average ($gd^{-1}AU^{-1}$)
5/19/2008	38	0	0	8	0.02	70.4	37.5	17.6	154.7	63.9	21.3	139.1
5/20/2008	10	0	20	11	0.12	28.5	5.8	19.3	36.5	25.8	8.6	56.3
5/21/2008	14	0	10	2	0.07	50.0	18.7	17.8	82.3	45.4	15.1	98.9
5/22/2008	19	0	4	0	0.08	69.6	26.3	19.5	109.0	63.2	21.1	137.6
5/23/2008	25	1	7	2	0.10	48.5	26.2	-9.4	90.5	44.0	14.7	95.8
5/24/2008	39	1	2	2	0.05	68.2	23.8	-1.1	97.8	61.9	20.6	134.8
5/25/2008	33	0	8	1	0.10	51.4	21.5	-0.4	81.5	46.6	15.5	101.5
5/26/2008	35	0	6	0	0.10	47.4	23.1	-27.6	79.1	43.0	14.3	93.6
5/27/2008	28	1	5	0	0.02	74.3	36.0	-6.3	146.0	67.5	22.5	147.0
5/28/2008	19	0	2	0	0.08	49.3	17.4	13.3	84.2	44.7	14.9	97.4
Period 5												
5/29/2008	8	0	0	0	0.23	69.0	66.8	-40.7	137.4	62.6	20.9	136.3
5/30/2008	40	6	0	0	0.19	70.8	67.5	-59.2	255.6	64.3	21.4	140.0
5/31/2008	26	15	0	7	0.11	105.5	43.8	30.0	165.2	95.7	31.9	208.6
6/1/2008	36	12	0	0	0.13	120.3	28.2	71.6	182.1	109.1	36.4	237.8
6/2/2008	25	12	2	9	0.11	89.2	22.8	26.8	122.8	80.9	27.0	176.3
6/3/2008	46	2	0	0	0.12	80.7	36.4	27.0	219.1	73.3	24.4	159.6
6/4/2008	32	8	0	6	0.17	77.6	51.0	4.1	172.6	70.4	23.5	153.5
6/5/2008	46	0	0	2	0.17	109.3	68.4	-17.2	272.1	99.2	33.1	216.1
6/6/2008	44	0	0	4	0.14	83.8	40.6	8.5	188.0	76.0	25.3	165.6
6/7/2008	48	0	0	0	0.12	84.4	40.7	-22.8	145.9	76.6	25.5	166.9
6/8/2008	48	0	0	0	0.15	86.0	67.8	-35.7	271.5	78.0	26.0	169.9
6/9/2008	37	4	0	6	0.14	109.2	55.9	10.9	204.7	99.1	33.0	215.9
6/10/2008	22	1	0	3	0.27	72.2	36.3	8.6	149.9	65.5	21.8	142.8
Period 6												
11/6/2008	3	0	2	0	0.04	23.2	6.2	16.9	29.4	21.0	7.0	45.8
11/7/2008	24	0	14	5	0.08	12.2	7.0	7.1	33.5	11.1	3.7	24.2
11/8/2008	11	4	21	9	0.05	9.1	9.0	0.9	29.1	8.3	2.8	18.0
11/9/2008	24	16	0	8	0.00	39.1	11.3	18.8	55.0	35.5	11.8	77.3
11/10/2008	30	16	1	1	0.02	32.4	11.2	5.6	51.4	29.4	9.8	64.0
11/11/2008	1	0	27	2	0.06	28.1	N/A	28.1	28.1	25.5	8.5	55.6
11/12/2008	20	0	3	22	0.05	18.2	6.9	4.2	31.4	16.5	5.5	36.0
11/13/2008	36	0	3	8	0.07	17.0	9.1	3.8	42.3	15.4	5.1	33.6
11/14/2008	5	0	3	2	0.06	23.3	10.0	8.5	32.7	21.1	7.0	46.0
11/15/2008	0	0	21	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/16/2008	11	0	27	8	0.04	9.2	6.4	0.4	18.6	8.3	2.8	18.2
11/17/2008	22	0	12	9	0.07	10.9	8.3	-18.8	23.5	9.9	3.3	21.5
11/18/2008	30	0	0	17	0.08	12.4	3.5	7.0	22.6	11.3	3.8	24.6
11/19/2008	46	0	0	2	0.08	9.4	7.0	0.1	25.9	8.5	2.8	18.6
11/20/2008	45	0	0	3	0.07	19.8	6.6	8.6	34.9	18.0	6.0	39.2
11/21/2008	36	3	0	9	0.07	18.0	7.6	3.8	34.2	16.4	5.5	35.7
11/22/2008	27	7	0	12	0.10	10.4	6.3	0.1	23.4	9.4	3.1	20.6
11/23/2008	33	0	0	13	0.09	13.4	10.8	2.0	34.8	12.2	4.1	26.6
11/24/2008	46	0	0	2	0.07	9.0	5.5	0.6	18.6	8.2	2.7	17.8

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Background (ppm)	Emission Average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission Minimum ($\mu gm^{-2}s^{-1}$)	Emission Maximum ($\mu gm^{-2}s^{-1}$)	Emission Average (kgd^{-1})	Emission Average ($gd^{-1}hd^{-1}$)	Emission Average ($gd^{-1}AU^{-1}$)
11/25/2008	40	0	0	6	0.09	3.5	4.5	-2.1	22.7	3.1	1.0	6.8
11/26/2008	38	0	0	10	0.07	10.7	5.2	2.2	30.3	9.7	3.2	21.1
11/27/2008	15	0	12	15	0.08	16.0	8.3	0.4	27.5	14.5	4.8	31.6
11/28/2008	29	3	1	15	0.06	8.3	4.0	1.8	20.2	7.5	2.5	16.4
11/29/2008	1	1	18	13	0.11	8.3	N/A	8.3	8.3	7.6	2.5	16.5
11/30/2008	0	0	12	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2008	0	0	11	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/2/2008	8	0	14	12	0.05	9.0	1.8	5.4	11.4	8.2	2.7	17.9
Period 7												
12/3/2008	47	0	0	0	0.06	24.7	19.5	-1.3	68.7	22.4	7.5	48.7
12/4/2008	6	19	0	23	0.08	5.7	1.1	3.9	7.3	5.1	1.7	11.2
12/5/2008	31	12	0	3	0.08	2.2	4.6	-6.2	9.6	2.0	0.7	4.4
12/6/2008	36	0	0	11	0.08	3.2	2.2	0.0	9.4	2.9	1.0	6.4
12/7/2008	35	0	0	13	0.10	2.3	3.3	-3.1	10.2	2.1	0.7	4.6
12/8/2008	15	0	0	11	0.12	3.2	1.3	1.5	6.0	2.9	1.0	6.2
12/9/2008	7	0	0	0	0.07	17.2	2.8	13.3	21.6	15.6	5.2	34.1
12/10/2008	4	0	0	5	0.07	3.2	1.5	2.1	5.5	2.9	1.0	6.4
12/11/2008	40	0	0	8	0.06	4.8	2.2	0.9	8.9	4.3	1.4	9.4
12/12/2008	9	0	0	20	0.09	7.8	6.0	1.7	20.7	7.1	2.4	15.4
12/13/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/14/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8												
4/22/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/23/2009	0	0	6	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/24/2009	0	0	1	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2009	0	0	6	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/26/2009	0	0	12	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/27/2009	0	0	12	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/28/2009	0	0	5	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2009	0	0	8	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2009	0	0	20	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2009	0	0	28	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2009	13	0	27	3	-0.02	46.5	25.3	17.7	100.0	42.2	14.1	91.8
5/4/2009	0	0	4	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/5/2009	1	0	0	5	-0.02	17.2	N/A	17.2	17.2	15.6	5.2	34.1
5/6/2009	14	1	11	2	-0.01	66.2	26.6	40.9	148.7	60.0	20.0	130.8
5/7/2009	39	7	0	2	0.10	42.9	14.4	16.7	74.3	38.9	13.0	84.8
5/8/2009	44	4	0	0	0.10	48.3	10.6	26.2	72.5	43.8	14.6	95.5
5/9/2009	29	10	1	8	0.10	49.8	10.5	26.7	70.0	45.2	15.1	98.4
5/10/2009	23	16	0	9	0.05	46.9	8.3	31.8	65.1	42.6	14.2	92.8
5/11/2009	29	4	0	14	0.02	47.2	24.9	7.0	87.3	42.8	14.3	93.2

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Background (ppm)	Emission Average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission Minimum ($\mu gm^{-2}s^{-1}$)	Emission Maximum ($\mu gm^{-2}s^{-1}$)	Emission Average (kgd^{-1})	Emission Average ($gd^{-1}hd^{-1}$)	Emission Average ($gd^{-1}AU^{-1}$)
5/12/2009	46	0	0	0	0.04	64.0	15.1	38.6	98.1	58.1	19.4	126.6
5/13/2009	42	0	5	0	0.08	64.7	20.4	10.9	108.1	58.7	19.6	127.9
5/14/2009	15	2	2	10	0.11	46.8	9.6	33.6	69.4	42.5	14.2	92.5
Period 9												
7/15/2009	0	0	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/16/2009	19	0	6	14	0.04	62.5	39.2	5.9	145.2	56.7	18.9	123.5
7/17/2009	7	16	5	19	0.07	82.7	38.0	6.4	117.1	75.0	25.0	163.4
7/18/2009	25	6	0	17	0.07	95.9	29.5	17.8	140.7	87.0	29.0	189.6
7/19/2009	27	1	0	19	0.07	114.5	33.8	29.1	174.3	103.9	34.6	226.3
7/20/2009	38	0	0	10	0.08	99.0	35.6	35.4	190.4	89.9	30.0	195.8
7/21/2009	42	0	0	5	0.05	85.0	22.6	38.3	140.2	77.1	25.7	167.9
7/22/2009	28	9	0	11	0.07	98.9	38.5	42.4	179.5	89.7	29.9	195.5
7/23/2009	37	0	0	11	0.07	86.7	42.3	21.3	163.0	78.7	26.2	171.4
7/24/2009	45	0	0	3	0.08	89.3	48.2	39.4	207.7	81.0	27.0	176.6
7/25/2009	38	6	0	4	0.10	72.9	34.7	36.0	180.8	66.2	22.1	144.2
7/26/2009	26	11	0	10	0.01	84.2	51.7	5.3	215.8	76.4	25.5	166.3
7/27/2009	21	10	5	10	0.01	49.9	32.2	-12.0	109.3	45.2	15.1	98.6
7/28/2009	31	1	6	8	-0.03	67.8	39.5	11.7	166.7	61.5	20.5	134.0
7/29/2009	8	0	28	10	-0.11	56.8	23.2	3.1	74.5	51.6	17.2	112.4
7/30/2009	13	0	1	0	0.00	89.3	26.2	37.3	136.0	81.1	27.0	176.6
7/31/2009	25	1	0	22	0.08	93.8	37.7	34.8	172.9	85.1	28.4	185.5
8/1/2009	39	0	2	5	0.01	65.9	44.5	-21.1	210.2	59.8	19.9	130.3
8/2/2009	24	0	1	21	0.13	40.1	23.1	-3.0	70.6	36.4	12.1	79.2
8/3/2009	35	0	9	3	0.14	58.9	40.2	-2.8	178.3	53.4	17.8	116.4
8/4/2009	13	0	0	14	0.13	61.7	30.3	19.8	119.4	56.0	18.7	122.0

6.12.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ hour periods with valid emissions data
Emission Average (µg m^{-2} s^{-1}): Daily average emission calculated from the valid ½ hour periods
Emissions SD (µg m^{-2} s^{-1}): Daily emission standard deviation of the valid ½ hour periods
Emission Minimum (µg m^{-2} s^{-1}): Daily minimum emission of the valid ½ hour periods
Emission Maximum (µg m^{-2} s^{-1}): Daily maximum emission of the valid ½ hour periods
Emission Average (kg d^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area
Emission Average (g d^{-1} hd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis
Emission Average (g d^{-1} AU^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average (µg$m^{-2}s^{-1}$)	Emission SD (µg$m^{-2}s^{-1}$)	Emission minimum (µg$m^{-2}s^{-1}$)	Emission maximum (µg$m^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average (g$d^{-1}hd^{-1}$)	Emission average (g$d^{-1}AU^{-1}$)
Period 3								
1/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/10/2008	1	0.8	0.0	0.8	0.8	0.7	0.2	1.6
2/11/2008	1	7.4	0.0	7.4	7.4	6.4	2.1	14.0
2/12/2008	2	2.6	22.8	1.3	3.9	2.2	0.7	4.9
2/13/2008	1	3.4	0.0	3.4	3.4	2.9	1.0	6.3
2/14/2008	4	35.0	69.0	0.0	71.9	30.3	10.1	65.9
2/15/2008	2	3.3	25.7	3.1	3.6	2.9	1.0	6.3
2/16/2008	1	6.4	0.0	6.4	6.4	5.6	1.9	12.1
2/17/2008	9	17.3	40.3	8.9	32.5	15.0	5.0	32.6
2/18/2008	3	9.0	35.2	5.8	14.9	7.8	2.6	16.9
2/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4								

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/11/2008	2	-0.1	0.0	-0.2	0.0	-0.1	0.0	-0.1
5/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/13/2008	14	6.4	25.4	1.6	12.1	5.5	1.8	12.1
5/14/2008	7	0.3	5.4	-0.3	0.5	0.2	0.1	0.5
5/15/2008	18	9.7	30.5	4.0	17.5	8.4	2.8	18.2
5/16/2008	23	2.4	15.6	-0.5	11.8	2.0	0.7	4.4
5/17/2008	27	7.0	26.1	-0.5	14.4	6.1	2.0	13.2
5/18/2008	20	0.4	6.7	-0.2	3.3	0.4	0.1	0.8
5/19/2008	15	2.6	16.6	0.3	9.6	2.3	0.8	5.0
5/20/2008	4	1.6	14.7	1.0	2.6	1.4	0.5	3.1
5/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/27/2008	18	7.7	27.5	1.9	21.9	6.7	2.2	14.5
5/28/2008	6	2.5	17.2	1.2	3.9	2.2	0.7	4.8
Period 5								
5/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2008	1	1.3	0.0	1.3	1.3	1.2	0.4	2.5
5/31/2008	7	0.7	8.9	0.1	1.5	0.6	0.2	1.3
6/1/2008	1	5.3	0.0	5.3	5.3	4.6	1.5	10.0
6/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/3/2008	10	3.9	20.4	0.3	9.7	3.4	1.1	7.3
6/4/2008	6	1.3	12.4	-0.1	3.9	1.1	0.4	2.4
6/5/2008	4	3.4	21.0	1.8	5.0	2.9	1.0	6.4
6/6/2008	2	3.9	28.1	1.4	6.3	3.4	1.1	7.3
6/7/2008	2	5.1	31.4	5.0	5.1	4.4	1.5	9.5
6/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6								
11/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/8/2008	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11/9/2008	16	0.2	4.7	-0.2	1.0	0.2	0.1	0.4
11/10/2008	6	0.1	3.2	-0.2	0.3	0.1	0.0	0.2
11/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/12/2008	6	0.0	2.1	-0.1	0.2	0.0	0.0	0.1
11/13/2008	2	0.1	3.2	0.0	0.1	0.0	0.0	0.1
11/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
11/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/16/2008	2	0.1	4.0	0.0	0.1	0.1	0.0	0.1
11/17/2008	2	0.0	1.5	0.0	0.1	0.0	0.0	0.0
11/18/2008	32	0.5	6.9	-0.2	4.7	0.4	0.1	0.9
11/19/2008	11	0.5	7.1	0.1	1.3	0.4	0.1	0.9
11/20/2008	29	0.3	5.1	-0.3	0.9	0.2	0.1	0.5
11/21/2008	29	0.0	2.2	-0.2	0.6	0.0	0.0	0.1
11/22/2008	11	0.0	0.5	-0.2	0.3	0.0	0.0	0.0
11/23/2008	28	0.0	1.4	-0.6	0.5	0.0	0.0	0.0
11/24/2008	6	0.0	2.4	-0.3	0.5	0.0	0.0	0.1
11/25/2008	15	0.3	5.9	-0.2	1.2	0.3	0.1	0.6
11/26/2008	10	0.2	4.5	-1.0	0.7	0.2	0.1	0.3
11/27/2008	7	0.2	5.0	0.0	0.4	0.2	0.1	0.4
11/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2008	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12/2/2008	15	0.1	2.6	0.0	0.2	0.1	0.0	0.1
Period 7								
12/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/6/2008	6	0.1	3.1	0.0	0.2	0.1	0.0	0.1
12/7/2008	19	0.3	6.0	-0.1	1.8	0.3	0.1	0.7
12/8/2008	11	0.1	3.9	-0.1	0.6	0.1	0.0	0.3
12/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2008	6	0.0	2.2	-0.1	0.1	0.0	0.0	0.1
12/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/12/2008	11	0.3	6.0	-0.1	1.7	0.3	0.1	0.6
12/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8								
4/22/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/23/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/3/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/4/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/7/2009	14	4.3	21.1	1.6	9.2	3.7	1.2	8.1
5/8/2009	16	21.0	43.5	3.5	73.0	18.2	6.1	39.6
5/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/11/2009	8	1.6	13.5	-0.1	6.4	1.3	0.4	2.9
5/12/2009	26	6.6	25.4	1.9	14.3	5.7	1.9	12.5
5/13/2009	15	13.7	35.7	3.0	30.3	11.9	4.0	25.8
5/14/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 9								
7/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/16/2009	1	0.1	0.0	0.1	0.1	0.1	0.0	0.1
7/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/18/2009	10	0.0	1.7	-0.1	0.3	0.0	0.0	0.1
7/19/2009	23	0.1	2.8	-0.3	0.3	0.1	0.0	0.1
7/20/2009	35	0.0	1.4	-0.5	0.6	0.0	0.0	0.0
7/21/2009	5	5.0	24.3	-0.2	23.0	4.3	1.4	9.4
7/22/2009	22	0.5	7.3	-0.2	2.8	0.4	0.1	1.0
7/23/2009	36	0.2	4.9	-0.2	1.3	0.2	0.1	0.4
7/24/2009	34	0.2	4.1	-0.4	1.4	0.1	0.0	0.3
7/25/2009	37	0.2	4.3	-0.9	1.3	0.2	0.1	0.3
7/26/2009	17	0.3	5.4	-0.6	1.5	0.2	0.1	0.5
7/27/2009	6	0.1	2.7	0.0	0.2	0.1	0.0	0.1
7/28/2009	3	0.1	3.4	-0.1	0.4	0.1	0.0	0.1
7/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/31/2009	30	2.8	16.7	-0.2	16.3	2.4	0.8	5.2
8/1/2009	12	0.5	7.7	-0.4	2.3	0.5	0.2	1.0
8/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/3/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/4/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ hour periods with valid emissions data
Direction Limited: Number of ½ hour periods invalidated because wind was from an excluded wind direction
Angle Limited: Number of ½ hour periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence Limited: Number of ½ hour periods that the bLS model was not run because either u* < 0.15 m/s or |L| < 2 m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ hour periods included in the valid column
Emission Average (µg m^{-2} s^{-1}): Daily average emission calculated from the valid ½ hour periods
Emissions SD (µg m^{-2} s^{-1}): Daily emission standard deviation of the valid ½ hour periods
Emission Minimum (µg m^{-2} s^{-1}): Daily minimum emission of the valid ½ hour periods
Emission Maximum (µg m^{-2} s^{-1}): Daily maximum emission of the valid ½ hour periods
Emission Average (kg d^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area
Emission Average (g d^{-1} hd^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per head basis
Emission Average (g d^{-1} AU^{-1}): Daily average emission calculated from the valid ½ hour periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} hd^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
Period 3												
1/27/2008	26	0	1	17	3.4	28.2	33.3	-0.6	84.1	23.8	7.9	51.8
1/28/2008	33	0	5	0	3.3	34.1	23.7	13.5	123.1	28.7	9.6	62.6
1/29/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/30/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/31/2008	14	0	0	1	1.7	27.4	21.0	5.1	69.1	23.1	7.7	50.4
2/1/2008	14	0	12	20	2.4	6.1	7.7	0.5	24.4	5.2	1.7	11.3
2/2/2008	11	0	0	1	1.1	7.5	2.7	2.2	12.3	6.3	2.1	13.7
2/3/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/4/2008	0	0	16	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2/5/2008	15	0	0	0	2.0	12.4	4.5	6.6	23.9	10.4	3.5	22.8
2/6/2008	11	0	0	1	245.4	-24.8	122.6	-394.2	16.7	-20.9	-7.0	-45.6
2/7/2008	10	2	0	5	-1.4	11.9	12.1	4.2	45.3	10.1	3.4	22.0
2/8/2008	33	0	4	9	2.0	9.1	5.6	1.7	23.7	7.7	2.6	16.7
2/9/2008	10	0	11	23	-1.1	1.6	0.9	0.4	2.9	1.4	0.5	3.0
2/10/2008	7	2	8	12	2.4	8.4	3.9	3.2	13.9	7.1	2.4	15.4
2/11/2008	12	0	4	0	2.2	8.6	4.0	-0.1	16.3	7.3	2.4	15.8
2/12/2008	29	0	3	14	1.9	9.8	3.6	3.0	17.6	8.2	2.7	17.9
2/13/2008	29	0	11	6	2.5	23.5	20.1	3.8	68.0	19.9	6.6	43.2
2/14/2008	47	0	1	0	2.5	14.8	7.9	0.0	52.3	12.5	4.2	27.2

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} h d^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
2/15/2008	26	3	2	15	2.0	4.1	2.0	0.0	8.2	3.4	1.1	7.5
2/16/2008	16	1	5	20	1.2	3.0	2.2	0.0	7.2	2.5	0.8	5.4
2/17/2008	36	2	0	7	2.1	12.3	6.8	2.9	30.2	10.4	3.5	22.6
2/18/2008	21	0	12	14	2.2	6.9	3.5	2.2	14.5	5.8	1.9	12.7
Period 4												
5/9/2008	26	4	6	0	1.8	3.1	4.1	-1.6	11.3	2.6	0.9	5.7
5/10/2008	46	0	2	0	1.7	14.3	11.1	4.1	50.8	12.1	4.0	26.3
5/11/2008	29	0	12	7	1.3	3.9	3.2	-0.1	11.8	3.3	1.1	7.1
5/12/2008	48	0	0	0	1.6	8.9	7.5	2.0	37.0	7.5	2.5	16.3
5/13/2008	47	0	1	0	1.6	6.0	3.0	1.5	13.9	5.1	1.7	11.0
5/14/2008	20	3	7	17	2.1	5.5	8.6	-0.9	27.9	4.6	1.5	10.0
5/15/2008	21	4	5	18	1.3	7.3	3.4	1.0	13.5	6.2	2.1	13.4
5/16/2008	31	0	0	15	1.3	2.3	2.3	-0.3	8.1	1.9	0.6	4.1
5/17/2008	27	0	4	17	1.6	8.1	4.6	0.2	16.5	6.8	2.3	14.9
5/18/2008	24	3	2	19	2.4	0.9	1.8	-3.2	5.0	0.8	0.3	1.7
5/19/2008	30	0	3	7	1.8	2.7	2.5	-1.5	9.7	2.2	0.7	4.9
5/20/2008	7	10	17	12	1.7	0.9	0.2	0.5	1.1	0.8	0.3	1.7
5/21/2008	34	10	0	2	2.5	22.8	15.9	2.1	64.0	19.2	6.4	41.8
5/22/2008	42	5	0	0	2.0	30.1	16.7	8.1	75.5	25.4	8.5	55.3
5/23/2008	35	9	0	2	1.9	10.3	11.8	0.1	49.8	8.7	2.9	19.0
5/24/2008	29	1	12	2	1.5	6.9	8.6	-1.2	29.2	5.8	1.9	12.6
5/25/2008	45	0	0	2	1.7	10.5	11.7	0.7	60.3	8.9	3.0	19.4
5/26/2008	47	0	0	0	1.4	2.8	2.0	0.4	8.7	2.4	0.8	5.2
5/27/2008	43	1	3	0	1.7	5.3	4.2	-0.3	18.4	4.5	1.5	9.7
5/28/2008	30	2	3	0	1.5	2.6	1.3	0.2	5.6	2.2	0.7	4.9
Period 5												
5/30/2008	35	6	5	0	1.9	4.6	4.2	-3.2	19.3	3.9	1.3	8.4
5/31/2008	13	13	13	7	1.6	2.0	1.5	0.2	4.3	1.7	0.6	3.6
6/1/2008	7	10	29	0	1.3	1.9	1.2	0.4	3.7	1.6	0.5	3.5
6/2/2008	5	13	19	9	2.5	5.2	4.9	0.0	10.7	4.4	1.5	9.5
6/3/2008	36	2	10	0	1.4	6.7	5.8	0.1	26.1	5.6	1.9	12.3
6/4/2008	21	8	11	6	1.9	13.9	18.2	-0.1	71.8	11.7	3.9	25.5
6/5/2008	34	0	12	2	1.9	13.3	14.1	0.2	56.8	11.2	3.7	24.4
6/6/2008	31	0	13	4	1.1	2.8	2.7	-0.4	9.8	2.4	0.8	5.1
6/7/2008	48	0	0	0	1.2	4.8	3.2	0.4	16.3	4.0	1.3	8.8
6/8/2008	11	0	0	0	1.0	0.3	0.3	-0.2	0.7	0.3	0.1	0.6
Period 6												
11/7/2008	5	0	27	1	1.1	-0.3	0.4	-0.7	0.2	-0.2	-0.1	-0.5
11/8/2008	11	4	22	9	0.9	0.0	0.1	-0.3	0.1	0.0	0.0	0.0
11/9/2008	19	16	5	8	1.0	0.5	0.6	-0.2	2.0	0.4	0.1	0.9
11/10/2008	30	16	1	1	1.1	0.6	0.7	-0.6	2.2	0.5	0.2	1.0
11/11/2008	27	0	16	3	1.1	0.9	2.9	-0.7	14.6	0.7	0.2	1.6
11/12/2008	19	0	3	23	0.9	0.3	0.4	-0.5	1.3	0.3	0.1	0.6
11/13/2008	36	0	3	8	1.3	0.3	0.6	-1.4	1.3	0.2	0.1	0.5
11/14/2008	43	0	1	2	1.1	0.2	0.4	-0.7	1.3	0.2	0.1	0.3
11/15/2008	31	0	14	1	0.9	0.0	0.3	-0.6	0.6	0.0	0.0	0.0

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} hd^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
11/16/2008	5	0	31	10	0.7	0.1	0.2	-0.3	0.3	0.0	0.0	0.1
11/17/2008	23	0	16	9	1.2	0.3	0.4	-1.1	0.8	0.3	0.1	0.6
11/18/2008	29	0	0	17	1.0	2.1	3.0	-0.1	10.3	1.7	0.6	3.8
11/19/2008	36	0	8	2	1.1	0.3	0.4	-0.8	1.4	0.2	0.1	0.5
11/20/2008	43	0	2	3	1.1	0.3	0.3	-0.3	1.1	0.2	0.1	0.5
11/21/2008	34	3	2	9	1.0	0.0	0.2	-0.6	0.4	0.0	0.0	-0.1
11/22/2008	18	6	9	12	1.2	0.1	0.2	-0.2	0.7	0.1	0.0	0.1
11/23/2008	28	0	4	13	1.4	0.0	0.3	-0.6	0.7	0.0	0.0	0.1
11/24/2008	27	0	17	2	1.0	0.0	0.2	-0.4	0.4	0.0	0.0	0.0
11/25/2008	27	0	13	6	1.3	0.4	0.7	-0.7	2.3	0.4	0.1	0.8
11/26/2008	27	0	11	10	1.2	0.3	0.4	-0.8	1.1	0.2	0.1	0.5
11/27/2008	24	0	6	17	1.5	1.9	1.2	0.0	4.5	1.6	0.5	3.6
11/28/2008	17	3	13	15	1.3	0.5	0.4	0.0	1.2	0.4	0.1	0.8
11/29/2008	30	1	4	13	1.0	0.3	0.4	-0.5	1.0	0.2	0.1	0.5
11/30/2008	38	0	2	0	0.8	0.1	0.4	-0.9	0.8	0.1	0.0	0.2
12/1/2008	12	0	2	2	0.8	0.0	0.3	-0.5	0.4	0.0	0.0	-0.1
12/2/2008	8	0	13	12	1.5	0.1	0.1	0.0	0.2	0.0	0.0	0.1
Period 7												
12/6/2008	2	0	2	5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12/7/2008	33	0	2	13	1.2	0.9	1.0	-0.8	3.4	0.8	0.3	1.6
12/8/2008	9	0	5	12	1.6	0.1	0.2	-0.2	0.3	0.1	0.0	0.3
12/9/2008	7	0	0	0	0.9	0.2	0.4	-0.4	0.7	0.2	0.1	0.3
12/10/2008	4	0	0	5	1.0	0.0	0.2	-0.1	0.3	0.0	0.0	0.0
12/11/2008	15	0	25	8	0.8	0.2	0.3	-0.2	0.8	0.2	0.1	0.4
12/12/2008	7	0	2	21	1.3	0.7	0.5	0.1	1.4	0.6	0.2	1.2
Period 8												
4/24/2009	31	0	2	4	2.4	6.9	10.2	-4.6	44.1	5.8	1.9	12.7
4/25/2009	43	0	5	0	2.5	8.5	6.5	1.3	27.8	7.2	2.4	15.7
4/26/2009	29	0	17	2	1.7	6.0	9.9	-0.2	46.7	5.1	1.7	11.0
4/27/2009	34	0	5	6	2.6	15.6	23.2	-3.5	112.1	13.2	4.4	28.7
4/28/2009	11	16	18	3	2.1	24.0	33.3	3.0	107.7	20.3	6.8	44.2
4/29/2009	48	0	0	0	3.0	17.1	9.0	1.3	39.5	14.4	4.8	31.5
4/30/2009	43	1	4	0	2.6	12.6	9.3	0.6	35.6	10.6	3.5	23.1
5/1/2009	34	2	10	0	1.7	1.4	1.0	-0.3	3.6	1.2	0.4	2.5
5/2/2009	20	11	15	0	1.3	0.7	0.6	-0.5	1.7	0.6	0.2	1.3
5/3/2009	19	2	22	3	1.0	0.8	0.9	0.1	2.7	0.7	0.2	1.5
5/4/2009	27	4	3	14	2.3	13.5	10.7	0.0	44.5	11.4	3.8	24.8
5/5/2009	31	11	1	5	0.3	5.6	12.6	0.1	71.6	4.7	1.6	10.3
5/6/2009	24	9	12	2	1.1	2.7	2.9	-0.1	12.2	2.2	0.7	4.9
5/7/2009	28	7	10	2	2.3	4.9	4.0	-1.4	15.8	4.1	1.4	8.9
5/8/2009	34	4	9	0	2.4	10.4	11.9	1.1	63.6	8.7	2.9	19.0
5/9/2009	20	10	10	8	1.3	3.5	2.7	0.2	7.3	3.0	1.0	6.5
5/10/2009	0	15	23	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/11/2009	17	4	12	15	1.5	4.5	4.5	0.0	12.5	3.8	1.3	8.3
5/12/2009	46	0	0	0	2.0	13.1	10.1	1.5	53.6	11.1	3.7	24.1
5/13/2009	43	0	5	0	1.7	9.6	7.1	0.2	27.9	8.1	2.7	17.6

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/14/2009	16	0	0	8	1.1	3.9	2.8	0.3	9.6	3.3	1.1	7.2
Period 9												
7/16/2009	26	2	4	16	1.5	0.0	0.4	-1.0	0.8	0.0	0.0	0.1
7/17/2009	3	17	8	19	0.6	0.1	0.3	-0.1	0.4	0.1	0.0	0.2
7/18/2009	8	6	15	17	1.2	0.4	0.7	-0.2	2.1	0.3	0.1	0.7
7/19/2009	20	1	4	20	1.0	0.1	0.2	-0.5	0.5	0.1	0.0	0.2
7/20/2009	33	0	4	10	0.9	0.1	0.2	-0.3	0.7	0.0	0.0	0.1
7/21/2009	37	0	5	6	1.5	0.8	3.2	-0.6	19.2	0.7	0.2	1.5
7/22/2009	26	9	2	11	0.9	0.8	1.2	-0.3	4.2	0.6	0.2	1.4
7/23/2009	32	0	4	11	1.0	0.3	0.6	-0.5	1.8	0.2	0.1	0.5
7/24/2009	39	0	3	3	0.9	0.3	0.5	-0.6	1.8	0.3	0.1	0.6
7/25/2009	37	6	0	4	1.1	0.3	0.5	-1.3	1.8	0.2	0.1	0.5
7/26/2009	15	11	11	11	1.1	0.4	0.7	-0.4	2.5	0.3	0.1	0.7
7/27/2009	16	13	5	10	1.7	0.4	1.0	-0.1	3.9	0.3	0.1	0.7
7/28/2009	25	3	10	8	2.1	0.3	0.4	-0.1	1.7	0.3	0.1	0.6
7/29/2009	10	17	11	10	1.7	0.2	0.4	-0.3	0.9	0.2	0.1	0.4
7/30/2009	12	0	2	0	1.1	0.7	1.9	-0.2	6.6	0.5	0.2	1.2
7/31/2009	25	1	0	22	1.7	6.5	10.1	-0.2	37.2	5.5	1.8	11.9
8/1/2009	31	2	6	6	1.5	0.2	0.5	-0.6	1.2	0.1	0.0	0.3
8/2/2009	1	0	0	23	5.2	-0.2	N/A	-0.2	-0.2	-0.2	-0.1	-0.3

Final Report
Site OK4A
Pork Production Facility
for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
Site OK4A
Pork Production Facility

for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on location (relative to climate and typical practice), method of manure collection, method of manure storage, and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3) and hydrogen sulfide (H_2S) emissions from the waste lagoon open source at the western hog finisher facility. Within that objective, this report will:

- Describe the farm and the lagoon/basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the lagoon were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Lagoon emissions were measured for up to 21 days (d) each season over two years. The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the lagoon were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using

two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc, Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*Windtrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the lagoon pH, oxidation-reduction potential, and temperature at 0.3 m depth were also measured from a float located at least 30 m from the lagoon inlet (Table 1-2). Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the lagoon berm (Table 1-2).

Table 1-1: Critical measurements.

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder2™	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind speed	3D Sonic anemometer/ RM Young 81000	0-60 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/16 Hz averaging	30 min & 24 h
Wind direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/16 Hz averaging	30 min & 24 h
3D turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/16 Hz averaging	30 min
Temperature variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01^{o}C	160 Hz sampling/16 Hz averaging	30 min
GSS sample flow rate	GSS/S-OS	10 L min^{-1}	0.1 L min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/SOP-S	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to RPM Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the lagoon (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation, lagoon pH, lagoon oxidation-reduction potential, lagoon temperature, and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure, flow, temperature, and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer and downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Additional information concerning farm operations and the United States Department of Agriculture National Resource Conservation Service (USDA NRCS)-required analysis of wastewater used to irrigate nearby fields were routinely collected from the producers.

Table 1-2: Non-critical measurements.

Measurement	Method/Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
Ambient temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50°C	0.1°C	5 min	30 min, 24 h
Relative humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min & 24 h
Solar radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 Wm^{-2}	10 Wm^{-2}	5 min	30 min & 24 h
Lagoon solids depth	Sludge level detector/ SludgeGun 10HD, Markland Specialty Eng.	0-10 m	0.05 m	1/ measurement period	1 time
Lagoon/ basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	0-14 units	0.2 unit	5 min	30 min & 24 h
Lagoon/ basin oxidation-reduction potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	-800 - +1100 mV	20 mV	5 min	30 min & 24 h
Lagoon/ basin temperature	Thermistor/ Campbell Scientific Inc 107-L	-35 - +50°C	0.5°C	5 min	30 min & 24 h

1.3 Farm description and operation

The facility measured was a sow lagoon located in Oklahoma. The elevation at the farm was 905 m. The sow farm consists of three barns and one office (Fig. 1-1). The facility has a capacity of 1225 breeding and gestation sows in each of two breeding and gestation units, and 384 farrowing sows in one farrowing unit. Construction of the sow farm was completed in 1994.

Manure from the barns was transferred weekly from the two gestation units and every 2.5 weeks from the farrowing unit to the lagoon by pull plug and lagoon water recharge. Waste water from the two gestation units combined into one inlet (the southerly inlet in Fig. 1-1), while wastewater

from the farrowing unit entered the lagoon from the northerly inlet (Fig. 1-1). The rectangular waste lagoon was located to the east and was separated by a drainage swale from the barns. The clay-lined lagoon was 119 m wide and 193 m long, and was oriented north-south. The lagoon bank was rocky with a berm slope of 4:1. Liquid depth was approximately 5.5 m, with an inner berm-to-water distance of 1.2 to 3 m. The lagoon volume was approximately 72,800 m^3. Sludge from the lagoon has not been removed since construction (20-yr sludge removal cycle).

Lagoon liquid analysis was contracted by the producer every year for all nitrogen components. Lagoon liquid was applied through center-pivot irrigation when liquid levels reached maximum lagoon capacity (minimum freeboard). Additional liquid analyses for all nitrogen compounds occurred at the time of field applications (0-2 times annually based on rainfall).

Figure 1-1: Configuration of the OK4A farm.

1.4 Operational events and changes

The producer modified the feed ratio during the study (Table 1-3).

Table 1-3: Operational changes during the study.

Period	Events during period
1: 6/27 - 8/29/2007	N/A
2: 11/6-28/2007	11/6 Gestation ration changed from milo to corn.
3: 11/28 - 12/19/2007	12/17 Gestation ration changed from corn to milo.
4: 4/22 - 5/6/2008	N/A
6: 9/30 - 10/15/2008	N/A
7: 1/7-27/2009	N/A
8: 4/1-21/2009	N/A
9: 6/22 - 7/14/2009	N/A

1.5 Measurement layout

The NH_3 emissions from the basin were monitored for 8 to 20 days each quarter of the year for two years using scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*) and backward Lagrangian Stochastic (bLS) emissions models. The H_2S emissions from the lagoon were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments (TDLAS/scanner) were mounted at 1-m height above the lagoon berm (abl) at the northeast and southwest corners (Figure 1-2). Towers for mounting retro-reflectors were located off the northwest and southeast corners of the lagoon (Figure 1-2). A description of the position and path length of the optical paths along each side of the lagoon follows:

- North side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 44 m and 80 m from the northeast TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 125 m from the TDLAS/scanner at heights of 1 m, 7.3 m, and 14.7 m abl.
- East side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 66 m and 132 m from the northeast TDLAS/scanner. Three retro-reflectors were mounted on the southeast tower 209 m from the TDLAS/scanner at heights of 0.7 m, 7.8 m, and 13.5 m abl.
- South side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 54 m and 82 m from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the southeast tower 131 m from the TDLAS/scanner at heights of 0.7 m, 7.8 m, and 13.5 m abl.

- West side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 66 m and 132 m from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 210 m from the TDLAS/scanner at heights of 1 m, 7.3 m, and 14.7 m abl.

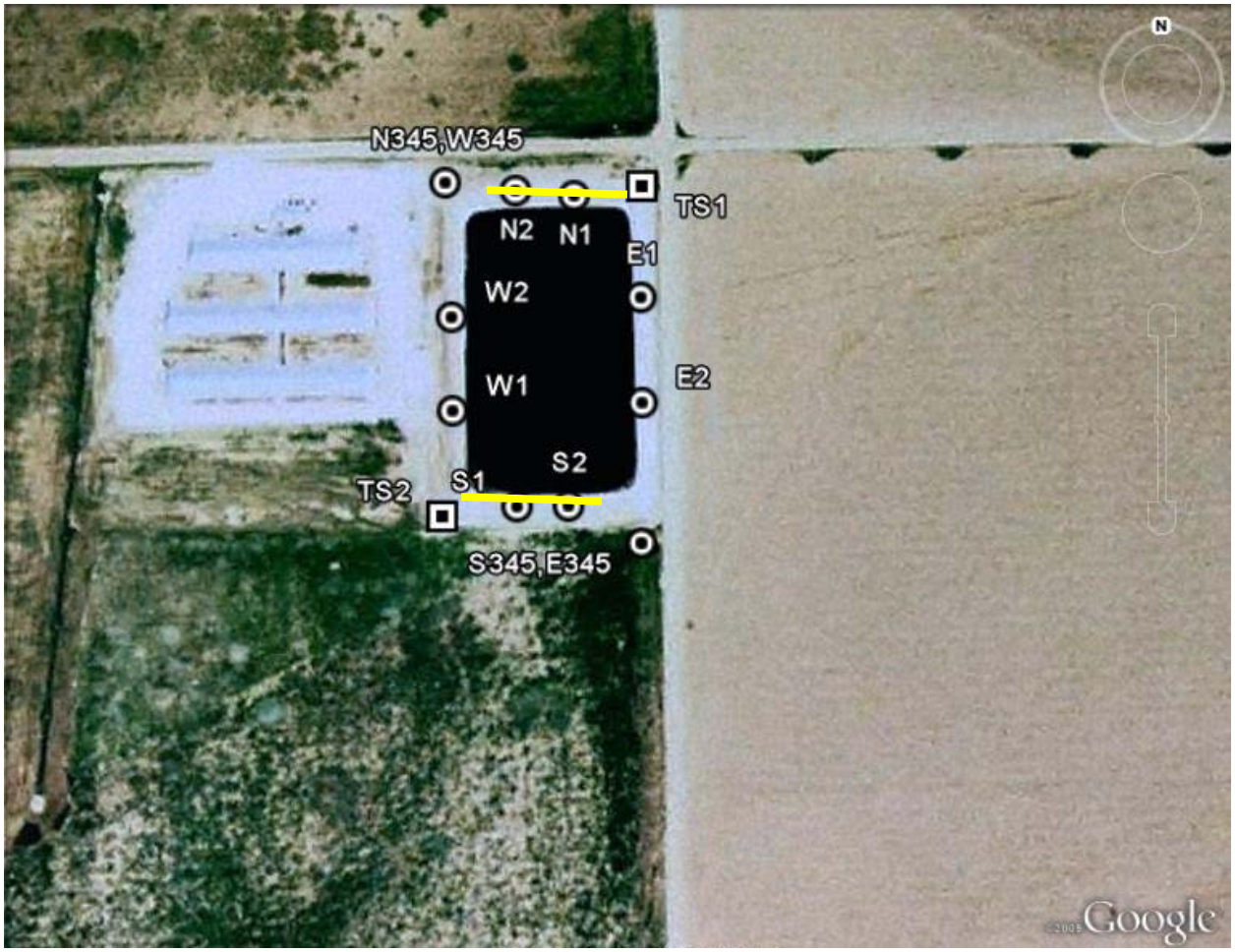

Figure 1-2: Locations of instrumentation around the lagoon under measurement.

Retro-reflectors are indicated according to side (north, south, east, and west) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The location of the two S-OPS is indicated by the solid yellow lines. The instrumentation trailer was located on the east side of the lagoon.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1-m abl. A 50-m length S-OPS path at 1 m abl. began at the northeast berm corner and extended west parallel to the north berm (Figure 1-2). The second 50-m long S-OPS was parallel to and 5 m south of the south lagoon berm and began at the southwest berm corner and extended to the east along the south berm (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through

and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Meteorological measurement sensors, including barometric pressure, air temperature and relative humidity, solar radiation, and surface wetness were located 5 m west of the NE berm corner, on the berm (Fig. 1-2). The data from these meteorological measurements were ~~collected by and also~~ telemetered to the on-site instrumentation trailer. The 3D sonic anemometers were located on the meteorological tower at 2.5 m heights and on the SE corner tower (Fig. 1-2) at 4.2 m and 15 m heights abl (Fig. 1-2).

The barns located 53 m to the west of and 1.2 m above the lagoon berm had a ridge height of 5.8 m agl. Therefore, the nearest building obstruction is 7 m above the berm, resulting in a fetch ratio to the west of 8:100. Fetch in all other directions is better than 1:100 (Fig. 1-2). Due to the proximity of the barns, emissions from wind direction of 225° to 315° were excluded from analysis.

Lagoon measurements (pH, oxidation-reduction potential, and temperature) were made from a float located in the NE corner of the lagoon.

2 Monitoring activities

2.1 Measurement periods

This location was measured as part of an approximately 20 d rotation between three other farms. The equipment was on site a total of 188 d over eight measurement periods (Table 2.1-1). Setup calibrations and site takedowns reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 181 d and H_2S emissions were measured 72 d.

Table 2.1-1: Period of measurements

Period	Start date	End date	# days
1	6/27/2007	8/29/2007	63
2	11/7/2007	11/27/2007	20
3	11/28/2007	12/18/2007	20
4	4/23/2008	5/6/2008	13
6	10/1/2008	10/15/2008	14
7	1/8/2009	1/27/2009	19
8	4/1/2009	4/21/2009	20
9	6/25/2009	7/14/2009	19

2.2 Site visits

The Field operation team visited this farm 38 d (Table 2.2-1). Visits to set up the site instrumentation and conduct calibration verification checks of instruments typically lasted 3 d, while visits for calibration verifications and take-down of the equipment on site typically lasted ~~needed~~ 2 d.

Table 2.2-1: Dates of site visits

OK4A	Spring	Summer	Fall	Winter
2007		Jun 27,28 Jul 9,18,19,30,31 Aug 1,2,3,4,15,16,28,29	Nov 7,8,27,28	Dec 18,19
2008	Apr 23,24 May 6		Oct 1,2,14,15,	Jan 7,8,27
2009	Apr 1,2,21	Jun 23,24,25, Jul 14		

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21 d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder2™ NH3 TDLAS serial number (s/n) 1026, 1027, 1028, 1029, 1031 and 1032 (Section 6.1)
- TEC 450i H_2S Analyzer s/n 0733825128 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1920, 1921, 1927, 1928, 1932, 1936 and 1938 (Section 6.3)
- lagoon pH probes s/n 002, 0008, and 009 (Section 6.4)
- lagoon ORP probe s/n 020, 030 and 050 (Section 6.5)
- GSS/ S-OPS s/n 4-0017 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multipoint calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers (Section 6.3) with three unused 'standard' anemometers.

2.4 Audits

One internal audit was conducted at this location on 11/27/2007 with particular attention to documentation and sonic anemometer inter-comparison. There was an USEPA Technical Systems Audit on 6/25/2009 at this location.

2.5 Repair trips

Two repair trips were made to this location: 7/9/2007 and 7/18/2007.

2.6 Remote site checks

Over the course of measurements, there were 50 remote checks made through the computer for instruments operating at this location.

2.7 Measurement data acquisition

Data from the TDLAS units (Model GasFinder2™ NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather and lagoon data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *Loggernet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *Loggernet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA) were downloaded in real-time through a serial cable to the trailer computer using the *iPort* (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built *Visual Basic* software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic anemometer temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory "FTP" and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory "Data". The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the "FTP" directory.

3 Data Processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic anemometer parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDL. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes needed to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site , data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software that was used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer and caused the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period, unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one minute off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the lagoon and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream may depend on one or more of the preceding streams, but not on following data streams. For

each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment and calibration failures, and because calibration checks were in progress. Periods of invalidated measurements associated with the calibration check failures are documented in the calibration reports in Section 6. Significant data exclusions of greater than one-day duration are indicated below by instrument with all time references in Coordinated Universal Time (UTC):

TDLAS measurement exclusions: Exclusions include problems with the TDLAS units and the scanners. Exclusions are summarized in Table 3.2-1.

Table 3.2-1: TDLAS measurement exclusions

Begin		End		Reason
8/1/2007	15:10	8/2/2007	17:00	TDLAS 1 Calibration Check
8/1/2007	15:05	8/2/2007	20:30	TDLAS 2 Calibration Check
8/3/2007	17:59	8/4/2007	06:00	Program glitch, data not saved TDLAS1
8/4/2007	17:59	8/5/2007	18:00	Program glitch, data not saved TDLAS1
8/6/2007	05:59	8/7/2007	06:01	Program glitch, data not saved TDLAS1
8/7/2007	17:59	8/8/2007	18:01	Program glitch, data not saved TDLAS1
8/10/2007	17:59	8/11/2007	18:00	Program glitch, data not saved TDLAS1
11/18/2007	23:58	11/22/2007	00:02	TDLAS 1 Concentration data shows a shutter problem
11/23/2007	23:59	11/27/2007	16:00	TDLAS 1 Concentration data shows a shutter problem
12/8/2007	21:00	12/18/2007	15:30	TDLAS 2 Scanner misaligned by 45 degrees
4/24/2008	21:00	5/6/2008	14:00	Scanner malfunction entire period for TDLAS2
1/8/2009	21:00	1/27/2009	17:00	Scanner malfunction entire period for TDLAS2

Air temperature and relative humidity measurement exclusions: Exclusions are summarized in Table 3.2-2

Table 3.2-2: Air temperature and relative humidity measurement exclusions

Begin		End		Reason
8/14/2007	13:10	8/15/2007	17:20	Calibration check
7/11/2009	17:25	7/14/2009	16:35	No power at meteorological station when FOS arrived

Solar radiation exclusions: Exclusions are summarized in Table 3.2-3

Table 3.2-3: Solar radiation measurement exclusions

Begin		End		Reason
8/14/2007	13:10	8/15/2007	17:20	Calibration check
7/11/2009	17:25	7/14/2009	16:35	No power at meteorological station when FOS arrived

Wetness measurement exclusions: The only exclusion was between 7/11/2009 at 17:25 and 7/14/2009 at 16:35 due to loss of power on site.

Pressure measurement exclusions: Exclusions are summarized in Table 3.2-4

Table 3.2-4: Pressure measurement exclusions

Begin		End		Reason for exclusion
11/7/2007	19:00	11/28/2007	15:50	Barometer was sent back for repairs. Not on site.
11/28/2007	15:55	12/19/2007	18:35	Barometer was sent back for repairs. Not on site.
7/11/2009	17:25	7/14/2009	16:35	No power at meteorological station when FOS arrived

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-5.

Table 3.2-5: Sonic anemometer measurement exclusions

Begin		End		Reason
8/14/2007	15:05	8/15/2007	14:05	Calibration check
7/24/2007	12:45	7/31/2007	19:55	All Sonic anemometers have no data for unknown reason
7/31/2007	21:20	8/1/2007	13:40	Calibration check
8/1/2007	14:25	8/3/2007	13:55	Zero check sonic anemometers not started until FOS left site 8/3
12/7/2007	22:30	12/10/2007	17:20	All Sonic anemometers entirely flagged; icing?
12/11/2007	13:45	12/12/2007	06:25	All Sonic anemometers entirely flagged; icing?
12/13/2007	09:05	12/13/2007	15:35	All Sonic anemometers entirely flagged; icing?
12/14/2007	15:25	12/15/2007	06:20	All Sonic anemometers entirely flagged; icing?
10/4/2008	18:00	10/15/2008	06:00	Sonic anemometer 1 has several episodes of extensive flagging
7/11/2009	17:25	7/14/2009	16:35	Power failure at farm stopped operation

Lagoon temperature, pH, and ORP measurement exclusions: Lagoon measurements were not made during the winter due to expected lagoon freezing before next 20 d visit. Rocks along the berm damaged the probe cables in 11-12/2007: all probes (pH, oxidation-reduction, T) were replaced. Excluded measurements are summarized in Table 3.2-6.

Table 3.2-6: Lagoon temperature, pH, and ORP measurement exclusions

Begin		End		Reason
Lagoon temperature exclusion times				
8/1/2007	15:45	8/3/2007	14:10	Wiring was switched for probes
8/14/2007	12:55	8/15/2007	17:20	Calibration check
11/28/2007	15:55	12/19/2007	18:35	Probes failed. Tried to repair on site, but this did not work. Float was taken out entire period.
10/8/2008	02:20	10/15/2008	16:25	Probes stopped working
1/8/2009	15:45	1/27/2009	22:05	Did not install for winter
7/11/2009	17:25	7/14/2009	16:35	No power at meteorological station when FOS arrived
Lagoon pH exclusion times				
8/1/2007	15:45	8/3/2007	14:10	Wiring was switched for probes
8/14/2007	12:55	8/15/2007	17:20	Calibration check
11/28/2007	15:55	12/19/2007	18:35	Probes failed. Tried to repair on site, but this did not work. Float was taken out entire period.
4/25/2008	00:45	5/6/2008	20:50	Did not pass calibration
10/2/2008	17:20	10/15/2008	16:25	Did not pass calibration
1/8/2009	15:45	1/27/2009	22:05	Did not install for winter
7/11/2009	17:25	7/14/2009	16:35	No power at meteorological station when FOS arrived
Lagoon ORP exclusion times				
8/1/2007	15:45	8/3/2007	14:10	Wiring was switched for probes
8/14/2007	12:55	8/15/2007	17:20	Calibration check
11/28/2007	15:55	12/19/2007	18:35	Probes failed. Tried to repair on site, but this did not work. Float was taken out entire period.
10/8/2008	02:20	10/15/2008	16:25	Probes stopped working
1/8/2009	15:45	1/27/2009	22:05	Did not install for winter
7/11/2009	17:25	7/14/2009	16:35	No power at meteorological station when FOS arrived
8/1/2007	15:45	8/3/2007	14:10	Wiring was switched for probes

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20°C (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in super-saturated “holes” in the retro-

reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a super-saturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maximized light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably super-saturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-s value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be super-saturated were flagged as super-saturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not super-saturated. To determine which points truly were super-saturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest PIC corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be super-saturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as super-saturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the S-OPS changed from one line to the other line. This array was later used when separating the H_2S data according to which S-OPS line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic anemometer software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic anemometer temperature variance of greater than 2.5 K^2, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic temperature variance had to be less than 2.5 K^2. To be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH_3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM*

data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be *RPM* processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH_3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigned values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *WindTrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly

greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3}\frac{34.0818\left(\left[H_2S\right]_{downwind} - \left[H_2S\right]_{upwind}\right)}{17030.4\left[NH_3\right]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H_2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigned values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths. All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the lagoon include transfer of waste from barns into the lagoon (Table 5.1-1) and lagoon pump-outs for irrigation. Once every 2 weeks, usually on Wednesday, pit draining of the breeding or gestation barns starts around mid morning and lasts for 1.5 h with draining alternating weekly between gestation and breeding barns. There are 16 rooms in the farrowing barn with five or six cleaned every week when pigs are weaned (usually 2 rooms on Monday, 1 on Tuesday, 1 on Thursday, and 1 or 2 on Friday). Pits under the farrowing barn rooms start to drain around 8 A.M. local time and take up to 2 h. Before noon the pits are back filled with recycle water from the lagoon.

The lagoon was not pumped-out during the study periods. Animal inventories for the calculation of lagoon loading rates are indicated in Table 4.1-1.

Table 4.1-1 Producer activities

Period	Activity	Animal inventory
1: 6/27 - 8/29/2007	No events	2748
2: 11/6-28/2007	11/6 Gestation ration changed from milo to corn	2712
3: 11/28 - 12/19/2007	12/17 Gestation ration changed from corn to milo	2712
4: 4/22 - 5/6/2008	No events	2777
6: 9/30 - 10/15/2008	No events	2720
7: 1/7-27/2009	No events	2731
8: 4/1-21/2009	No events	2762
9: 6/22 - 7/14/2009	No events	2777

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for midlatitude climates (Table 4.2-1). Twenty-three percent of the days had extra-tropical frontal systems overhead while 77% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Measurement period	# days	# warm front passages	# cold front passages	# days stationary front	# days tropical storm
1	63	3	4	3	0
2	20	0	2	1	0
3	20	1	2	1	0
4	13	0	2	1	0
6	14	1	6	0	0
7	19	1	3	0	0
8	20	1	4	2	0
9	19	1	3	3	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from -11.7 ^{o}C to 37.1 ^{o}C while the barometric pressure varied from 89.38 kPa to 92.66 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ hr solar irradiance of 1191 Wm^{-2} to overcast conditions with maximum ½ hr solar irradiance of 55 Wm^{-2} (Section 6.10). The wetness sensor failed frequently due to corrosion issues.

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared to the monthly climatology is indicated in Figure 4.2-1. Temperatures were generally within the climatological normal conditions throughout the study measurement periods at this location.

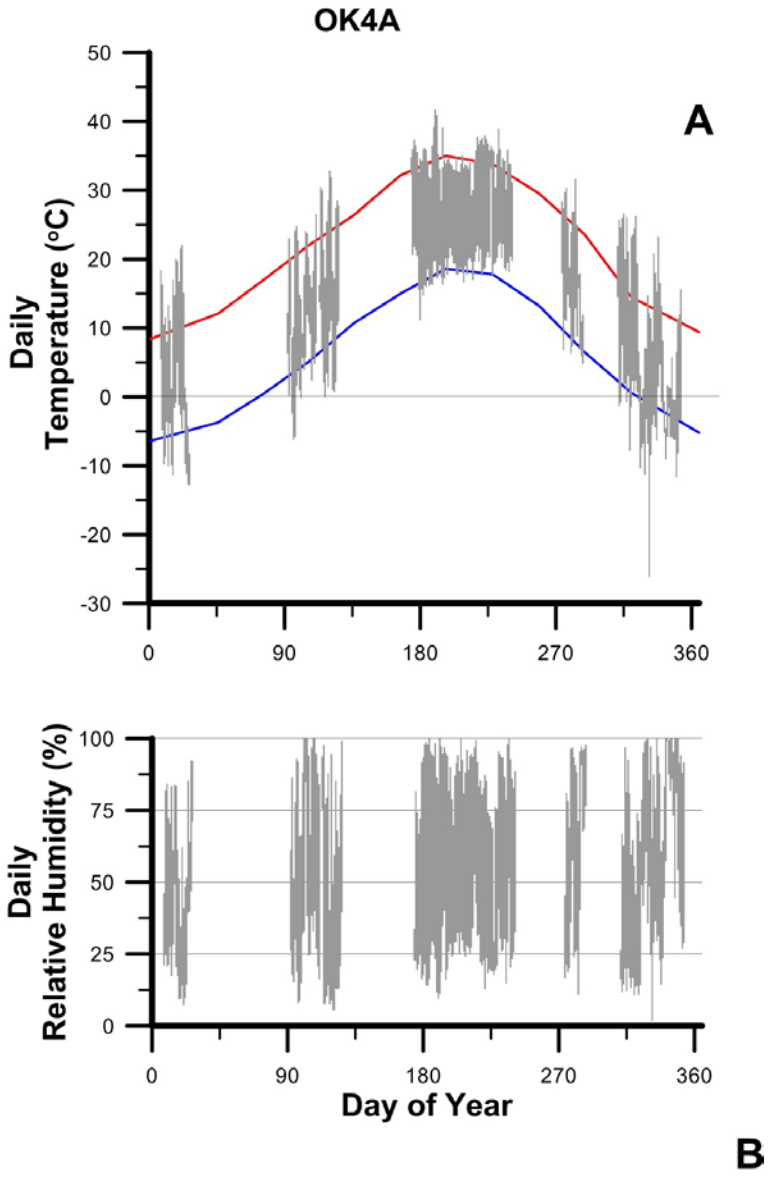

Figure 4.2-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line) temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidities for measurement days are indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figure 4.2-2 through 4.2-5. Emission calculation exclusion regions due to surrounding sources (wind directions of 225° through 315°) are indicated as a grayed region in the figure. Winds were generally from the north during periods 2 (Fall), 3 (Winter), 4 (Spring), 7 (Winter), and 8 (Spring) and from the

south or southwest during periods 1 (Summer) and 6 (Fall). Winds speeds were commonly greater than 5 ms^{-1}.

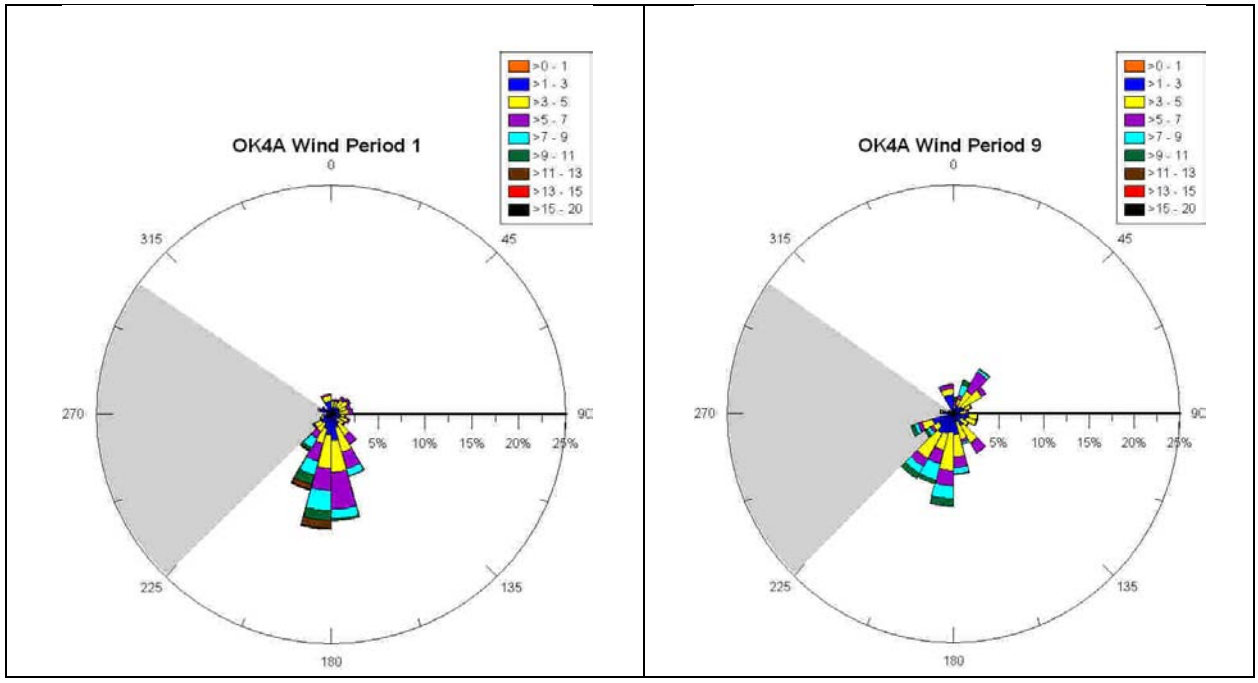

Figure 4.2-2: Wind roses for ½ hourly wind measurements during the Summer Measurement Periods. The periods which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

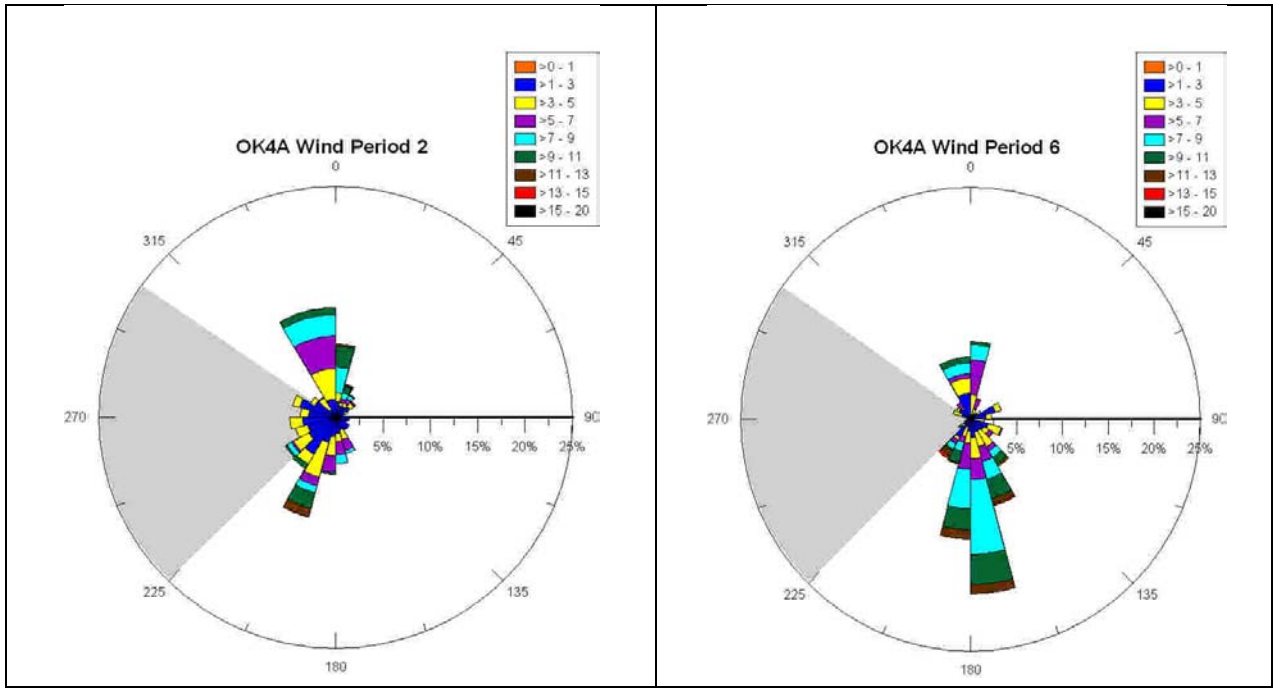

Figure 4.2-3: Wind roses for ½ hourly wind measurements during the Fall Measurement Periods. The periods which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

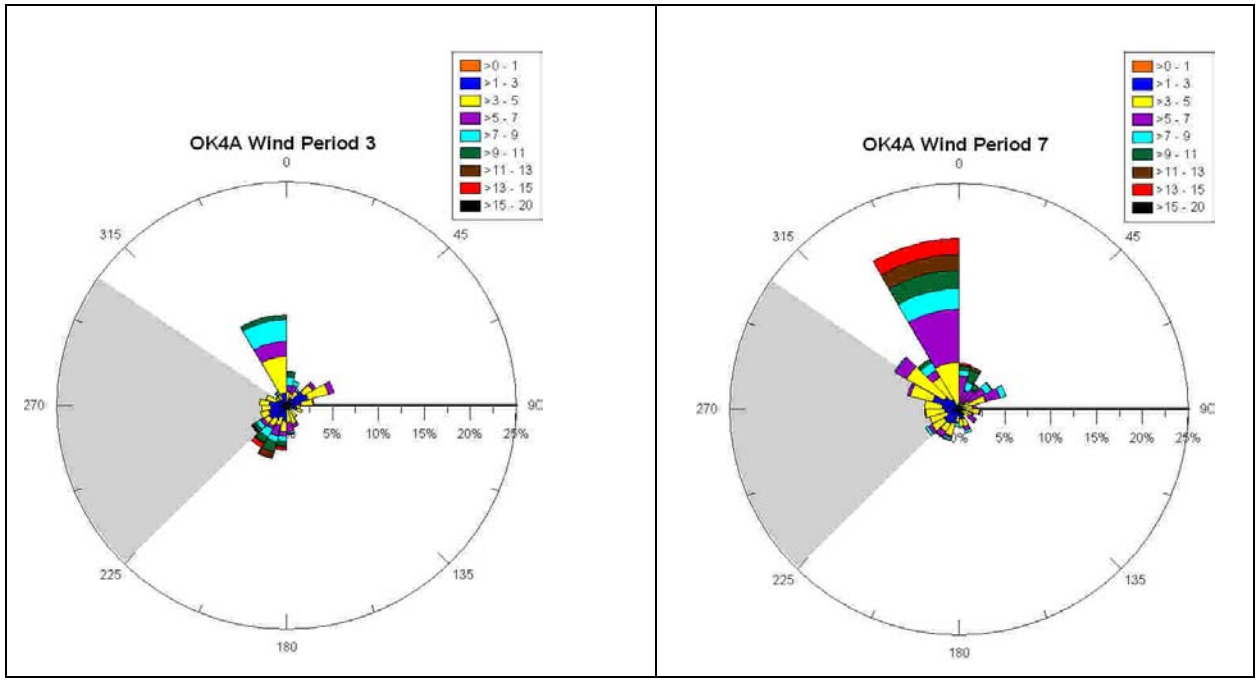

Figure 4.2-4: Wind roses for ½ hourly wind measurements during the Winter Measurement Periods. The periods which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

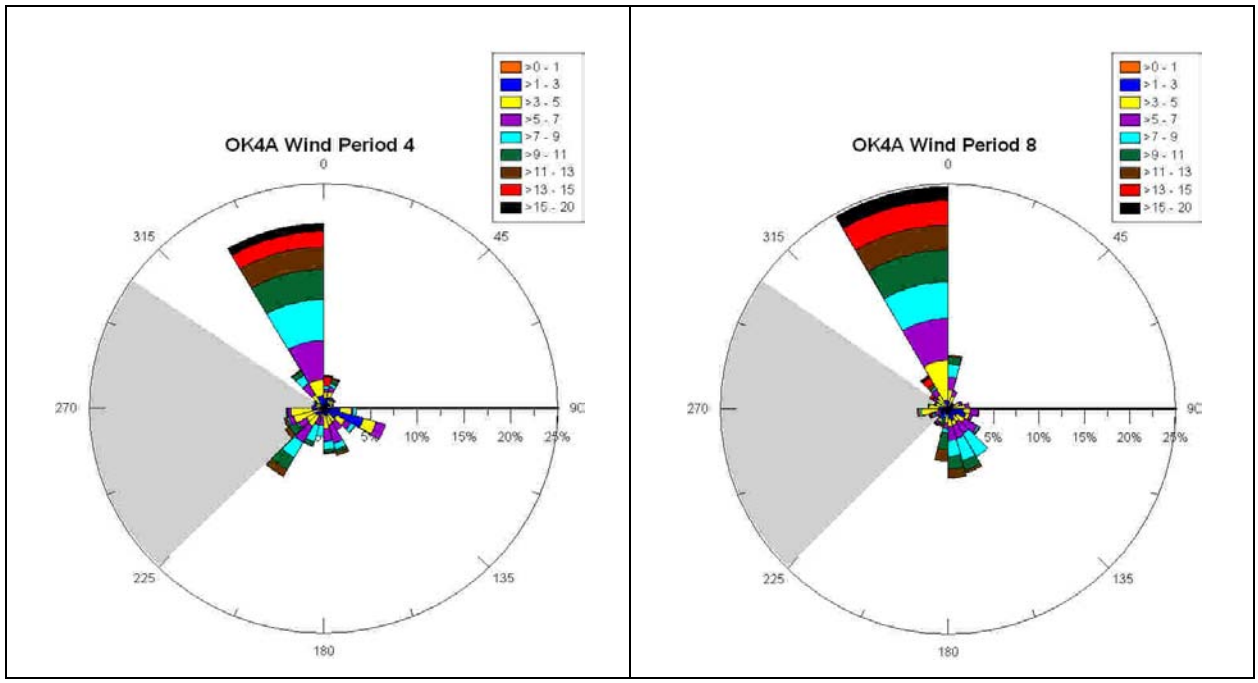

Figure 4.2-5: Wind roses for ½ hourly wind measurements during the Spring Measurement Periods. The four periods which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the wind directions excluded due to upwind influence of the barns.

4.3 Lagoon conditions

4.3.1 Lagoon appearance, liquid depth and sludge depth

The appearance of the lagoon was recorded on almost every site visit (Table 4.3-1). The lagoon generally appeared brown with surface characteristics ranging from frozen during the winter to free of crust during the remainder of the year.

Table 4.3-1: Lagoon physical characteristics

Period	Appearance color/crust	Liquid depth (m)	Sludge depth (m)	Source of meas.*
1: 6/27 - 8/29/2007	6/27 brown/ no crust 6/28 brown/ no crust 7/9 brown/ no crust 7/18 brown/ no crust 7/19 brown/ no crust 7/30 brown/ 5% Crust 7/31 brown/ 5% crust 8/1 brown/ 5% crust 8/2 brown/ no crust 8/3 brown 20% crust 8/4 brown/ 5% crust 8/18 brown/ 5% crust 8/16 brown/red/ no crust 8/28 brown/red/ no crust 8/29 brown/dark red/ no crust	Lagoon level below gauge	N/A	Producer
2: 11/06 - 11/28/2007	11/7 brown/red/ 2% crust 11/8 brown/red/ 1% crust 11/27 brown/red/ no crust 11/28 brown/red/ no crust	11/8 2.98	11/8 0.44	Sludge Gun
3: 11/28 - 12/19/2007	11/28 brown/red/ no crust 12/18 brown/red/ no crust 12/19 brown/red/purple/ no crust	Lagoon level below gauge	N/A	Producer
4: 4/22 - 5/6/2008	4/23 brown/no crust 4/24 brown/ no crust 5/6 brown/no crust	Lagoon level below gauge	N/A	Producer
6: 9/30 -10/15/2008	10/1 brown/no crust 10/2 brown/no crust 10/14 brown/ no crust 10/15 brown/no crust	Lagoon level below gauge	N/A	Producer
7: 1/7 - 1/27/2009	1/7 black/ no crust 1/8 brown/ no crust 1/27 snow covered/frozen	Lagoon level below gauge	N/A	Producer
8: 4/1 - 4/21/2009	4/1 brown/ 10% ice 4/2 brown/ no crust 4/21 brown/ no crust	Lagoon level below gauge	N/A	Producer
9: 6/22 - 7/14/2009	6/23 brown/ no crust 6/24 brown/ no crust 6/25 brown/ no crust 7/14 brown/ no crust	Lagoon level below gauge	N/A	Producer

4.3.2 Temperature, pH and oxidation-reduction potential

The measured lagoon liquid temperature varied from 3.3 ^{o}C to 28.8 ^{o}C with the lowest temperatures just prior to when the sensors were removed in anticipation of the lagoon freezing during the winter (Section 6.11). The measured lagoon pH varied from 6.5 to 8.4 (Section 6.11) while the oxidation-reduction potentials varied from -249 mV to -545 mV over the entire study period (Section 6.11).

4.3.3 Lagoon Chemistry

Lagoon water chemical analyses were not conducted by the project but analyses required by the NRCS at the time of water removal for field application were available for applications during the overall project period. Due to the drought conditions present at the site, water was only removed once (Table 4.3-3).

Table 4.3-3: Record of lagoon chemistry

			Percent (wet weight basis)			
Date	**n**	**pH (SU)**	**Nitrogen**	**Solids**	**Ammonia**	**Sulfur**
11/1/2008	1	8.28	0.44	0.20	0.33	0.03

4.4 Emissions measurements

Emissions data were calculated on a ½ hour basis since this was the interval over which the S-OPS system sampled both sides of the lagoon and since this interval is in the range over which turbulence statistics are often calculated. To account for the longer term manure storage of the lagoon, emissions reported on a head basis were scaled by the animal population for which the facility was designed and not the animal population at the time of measurements. Emissions reported on an animal unit (AU) basis (1 AU = 500 kg) assumed the typical animal weight values reported by the producer. Emissions reported on an area basis are based on the surface area of the lagoon.

Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison was based on 1760 ½ h measurement periods over the entire measurement time at this location. Results show that the bLS emissions had a significantly different precision (F=1.33, critical F=1.0) and a significant bias over the *RPM* emissions (t=11.43, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 1.10 (Table 4.4-1). Consequently, the ½ h bLS emissions measurements were biased high by 9% compared with the *RPM* measurements.

Table 4.4-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	**bLS**	**bLS-RPM**
Mean emission (gs^{-1})	2.15	2.36	0.21
Standard deviation (gs^{-1})	1.16	1.33	
Variance of the mean (gs^{-1})	1.34	1.78	

4.4.1 NH_3 Emissions

4.4.1.1 Mean daily NH_3 emissions

An annual trend in the daily NH_3 emissions based on the *RPM* model was indicated (Figure 4.4.1-1) with a summer emission of approximately 100 g NH_3 $d^{-1}hd^{-1}$. The daily emissions during the winter decreased to approximately 10 g NH_3 $d^{-1}hd^{-1}$. In contrast to the large number of measurements with more than 75% of the day's emissions measured during the spring and

summer, there were no days during the winter in which at least 75% of the daily emissions were measured for any given day. This was largely due to low concentrations resulting in failures to compute the emissions using the *RPM* model. There was a relatively wide range in emissions from day to day. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

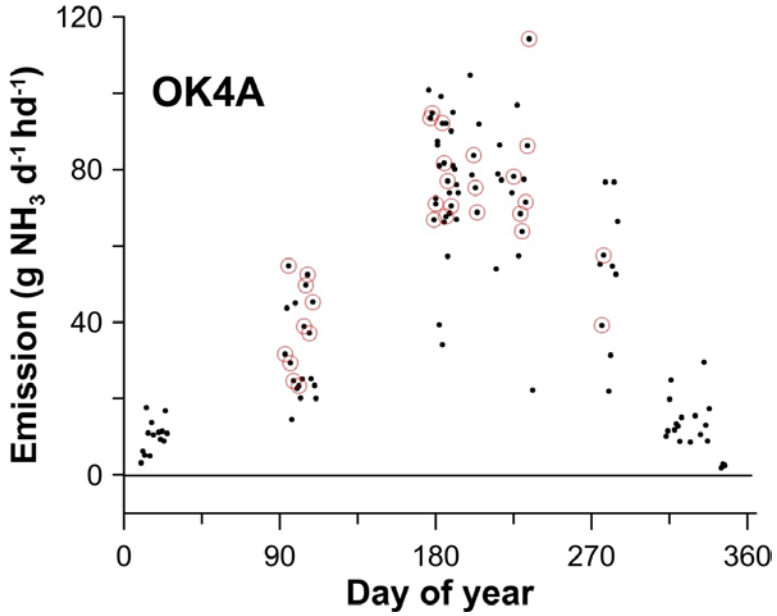

Figure 4.4.1-1: Annual variation in RPM-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

An annual trend in the daily NH_3 emissions based on the bLS model was also evident (Figure 4.4.1-2) with a summer emission of approximately 120 g NH_3 $d^{-1}hd^{-1}$. The daily emissions during the winter decreased to near zero. Winter emissions of approximately 5 g NH_3 $d^{-1}hd^{-1}$ are likely a result of barn effluent entering the lagoon on top of the frozen surface. Measurements with more than 75% of the day's emissions measured include days in summer, fall, and winter, providing good confidence that the emission measurements are representative. There was, however, still a relatively wide range in emissions from day to day. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

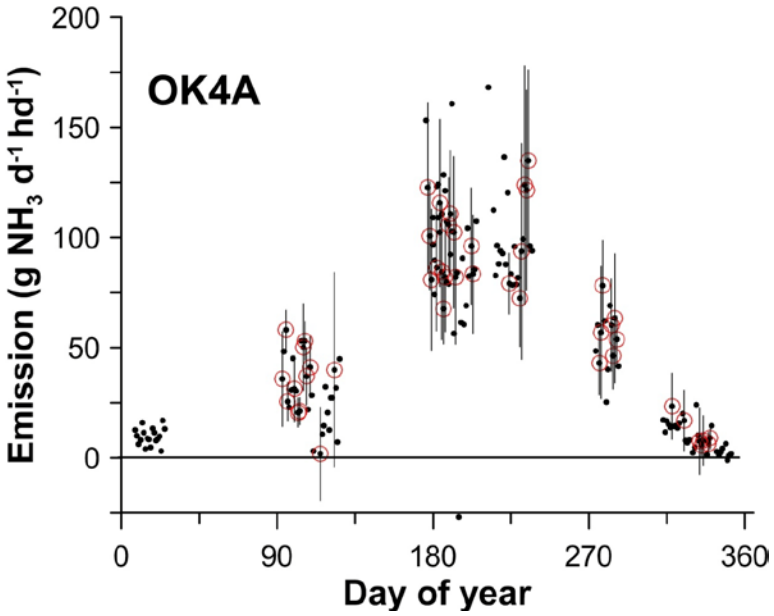

Figure 4.4.1-2: Annual variation in bLS-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS model was influenced by the calculated background concentrations. Results indicated that the background concentration of NH_3 was generally less than 0.05 ppm (Figure 4.4.1-3). Given that the typical path length around the lagoon was 100 m and the typical background concentration is less than 0.05 ppm, this corresponds to a background PIC of less than 5 ppm-m. This is approximately the MDL for the TDLAS instruments of 2 ppm-m (Section 6.1) and therefore represents essentially no background concentration. The greatest background concentrations occurred around day of year 200 to 230. The high background values correspond to high measured emissions (Figure 4.4.1-2). Since higher background values will tend to reduce emissions, the emissions measured during the summer may be underestimates of the true emissions. These measurements were made at the very beginning of the study and the cause for the high background is not known.

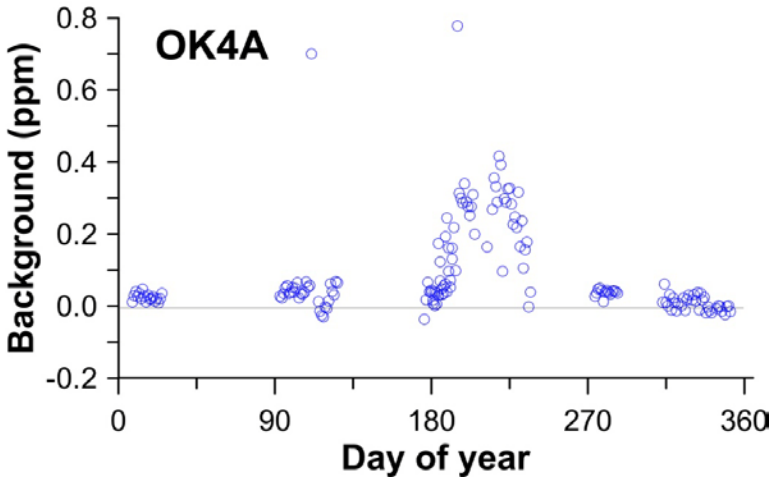

Figure 4.4.1-3: Annual variation in bLS-computed mean daily background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

In general, there was not a strong diurnal pattern to the NH_3 emissions. A diurnal pattern in the emissions was evident for only two of the eight measurement periods (Figure 4.4.1-4). This was likely due to the generally high winds at the location.

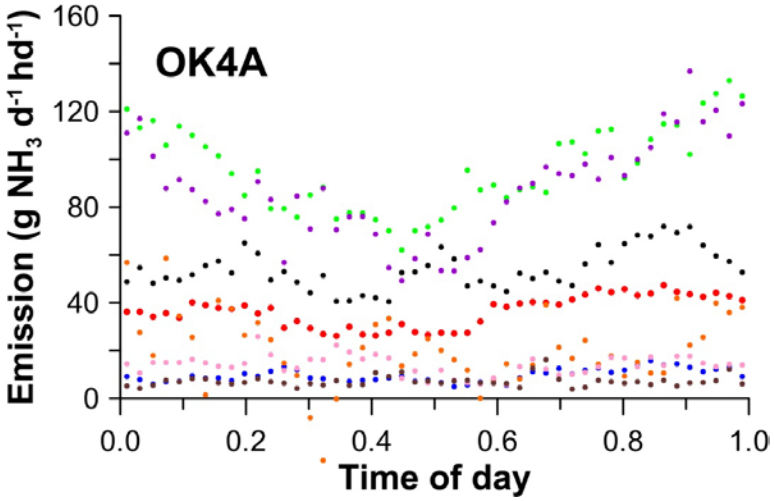

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on UTC. The mean emission for each half-hour of the day within a given measurement period (Period 1-Summer (green), Period 2-Fall (pink), Period 3-Winter (brown), Period 4-Spring (orange), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was

true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ h periods (corresponding to 75% completeness on a daily basis) is given. The completeness statistics by measurement period are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

	Period								
Model / Parameter	**1**	**2**	**3**	**4**	**6**	**7**	**8**	**9**	**Total**
RPM Model									
Valid 1/2 hour measurements (d)	14.6	1.5	0.6	0.0	5.6	1.8	12.3	11.8	**48.2**
Measurements excluded due to wind direction (d)	0.6	2.0	1.1	0.0	0.6	3.0	1.6	1.1	**10.1**
Measurements excluded because at least one downwind path is missing or invalid (d)	30.7	14.5	11.8	11.6	6.3	13.3	3.6	2.1	**94.0**
Number of days with ≥ 36 valid 1/2 h periods (d)	9	0	0	0	2	0	10	9	**30**
bLS Model									
Valid 1/2 h measurements (d)	26.4	8.1	7.9	5.8	8.2	5.9	14.0	11.1	**87.4**
Measurements excluded due to wind direction (d)	2.3	2.3	1.9	1.8	0.6	3.9	1.8	1.9	**16.4**
Measurements excluded because touchdown fraction < 0.1 (d)	3.2	0.4	0.5	1.2	0.6	1.6	0.0	0.0	**7.5**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| <$ 2 m (d)	8.1	6.0	3.7	1.5	1.9	2.9	2.4	2.7	**29.2**
Number of days with ≥ 36 valid 1/2 h periods (d)	12	2	5	2	7	0	10	8	**46**

In total, 48 d of valid NH_3 emissions were determined from the 188 measurement days using the *RPM* model, with 30 d having at least 36 valid ½ h NH_3 emissions. The absence or invalidation of at least one downwind path led to 94 days for which emissions could not be calculated.

Eighty seven days of valid NH_3 emissions were determined from the 188 measurement days using the bLS model, with 73 d having at least 36 valid ½ h NH_3 emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) led to 29 d for which emissions could not be calculated. A touchdown fraction of less than 0.1 led to the exclusion of 7.5 d of data. Low touchdown fractions indicated that little, if any, downwind data was available. This corresponded to either when the downwind TDLAS was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ h interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ h mean wind speed and direction, in contrast to the bLS

model that requires extensive turbulence statistics over this same period. As a result, there are times that the *RPM* model produces a valid emissions estimate that the bLS model does not. However, these times are overwhelmed by the times that the *RPM* model is missing concentration data for one or more paths, while the bLS model is able to run.

4.4.2 H_2S Emissions

4.4.2.1 Mean daily H_2S emissions

Emissions of H_2S calculated using the Ratiometric model were highest in the spring and decreased throughout the rest of the year (Figure 4.4.2-1). Peak emissions were approximately 14 g H_2S d^{-1} hd^{-1}. There was however wide variability in H_2S emissions from day to day during the spring and summer (Figure 4.4.2-1). The trend for high spring emissions followed by continual decrease through the rest of the year is also evident considering only those days in which 75% of the day had valid emission measurements. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

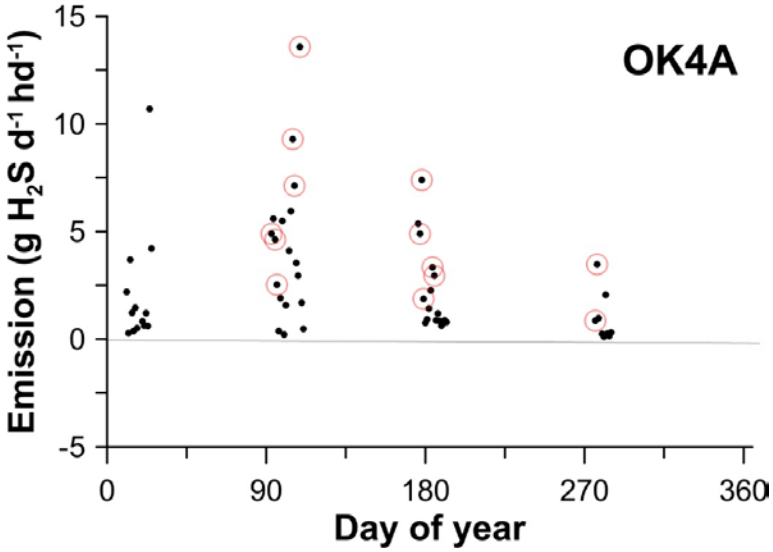

Figure 4.4.2-1: Annual variation in Radiometric-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

Emissions of H_2S determined using the bLS model suggest that emissions during the winter and spring are high with emissions decreasing throughout the rest of the year (Figure 4.4.2-2). Peak emissions were approximately 10 g H_2S d^{-1} hd^{-1} with wide variability in H_2S emissions from day to day during the spring and summer (Figure 4.4.2-2). A near-zero emission during the fall is strongly indicated. The winter, spring and summer emissions are similar in magnitude and variability when considering only those days in which 75% of the day had valid emission measurements. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

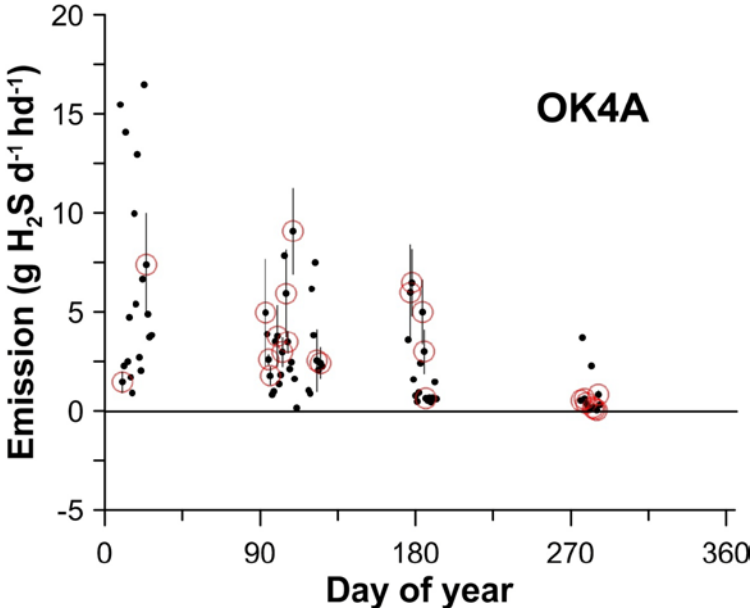

Figure 4.4.2-2: Annual variation in bLS-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ hr values when at least 75% of the day had valid measurements.

The bLS emission model depends on a good estimate of the background H_2S concentration. Results indicate that the background concentration was generally less than ± 2.5 ppb (Figure 4.4.2-3). This background is consistent with an equivalent zero value since the instrument MDL was 3.4 ppb (Section 6.2).

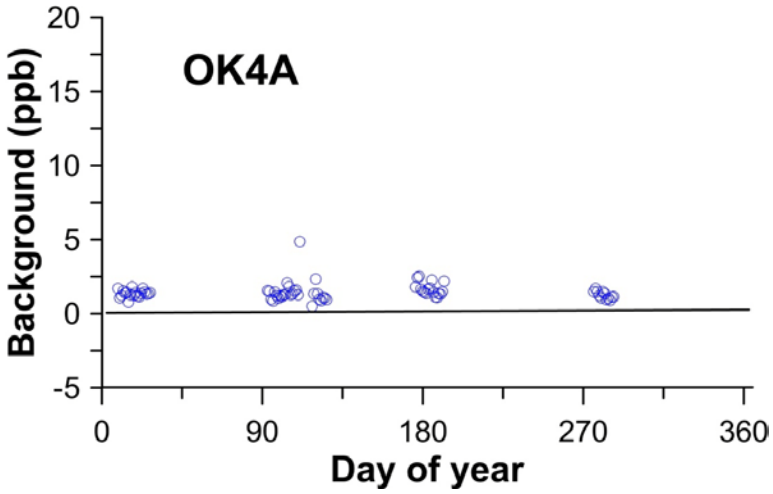

Figure 4.4.3-3: Annual variation in bLS-computed mean daily background concentration of H_2S.

4.4.2.2 Diurnal variation in H_2S emissions

The H_2S emissions calculated using the bLS model generally showed no diurnal trend (Figure 4.4.2-4). The one period indicating a strong diurnal trend was period 7 with the highest emissions occurring during the day.

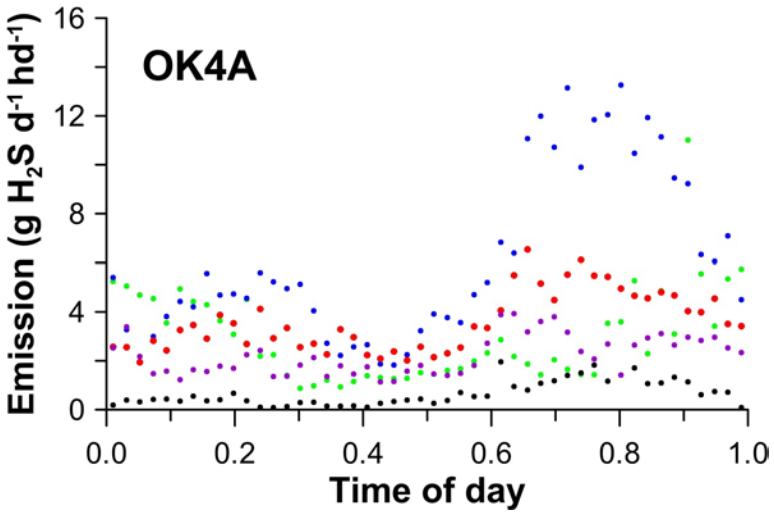

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period [Period 4-Spring (green), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)] are indicated.

4.4.2.3 H_2S emissions data completeness

H_2S Measurements were begun in Period 4. Consequently there were no measurements possible until Spring 2008. As described for the NH_3 emissions, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics by measurement period are summarized in Table 4.4.2-1.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

	Period								
Model / Parameter	**1**	**2**	**3**	**4**	**6**	**7**	**8**	**9**	**Total**
H_2S Ratiometric									
Valid 1/2 h measurements (d)				0.0	4.8	1.8	10.5	10.2	**27.3**
Number of days with ≥ 36 valid 1/2 h periods				0	2	0	6	5	**13**
H_2S bLS									
Valid 1/2 h measurements (d)				4.9	8.8	9.5	12.5	9.8	**45.6**
Measurements excluded due to wind direction (d)				1.6	0.6	3.8	1.6	1.8	**9.5**
Measurements excluded because angle of attack < 60° (d)				0.6	0.6	1.8	1.3	1.2	**5.4**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| < 2$ m (d)				1.1	1.5	2.9	2.4	2.9	**10.8**
Number of days with ≥ 36 valid 1/2 h periods				2	7	2	8	5	**24**

In total, 27 d of valid H_2S emissions were determined using the Ratiometric emission method, with 13 d having at least 36 valid ½ h H_2S emissions. Forty-five d of valid H_2S emissions were determined using the bLS model, with 24 d having at least 36 valid ½ h H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) and excluded wind directions contributed equally to the invalidation of measurements.

4.4.3 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of the TDLAS serial numbers 1026, 1027, and 1028 prior to 7/21/2008. TDLAS 1026 was used at OK4A from 4/23/2008 to 5/6/2008 (Measurement period 4). Under the calibration verification checks, the TDLAS error of all units was 10% accuracy. However due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and units without apparent interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from dew point temperatures of -2 ^{o}C to 20 ^{o}C. A conservative estimate of the bias of all of the above TDLAS units with evident moisture interference was -40%.

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly 2 h periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions,

underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%. Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was +10% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -30% for TDLAS NH_3 measurements made by units with moisture interference and a bias of +10% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no effect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the Ratiometric measurement of H_2S emissions was ± 18%.

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6 Appendices

6.1 TDLAS NH_3 calibrations

Six TDLAS units (Model GasFinder2^{TM} NH3OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used for measurements at this location: TDLAS 1026, TDLAS 1027, TDLAS 1028, TDLAS 1029, TDLAS 1031 and TDLAS 1032.

TDLAS 1026 was multipoint calibrated seven times during the study (Figure 6.1-1). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 1/17/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$\text{ppm-m} = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3$$

where X is the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and

11/10/2009 bias exceedences were followed the same or next day with a passing verification and was deemed to be a result of operator error. The negative bias over the period 4/2/2008 through 7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used). During operations the bias was only intermittently evident because to different multipoint calibration was applied to the calibration verification measurements during the progress of the study than finally applied during the analysis. Repeated calibrations within 24 h often showed biases differing by more than 10 ppm-m suggesting operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period are considered valid and the error assumed to be due to the calibration verification operator.

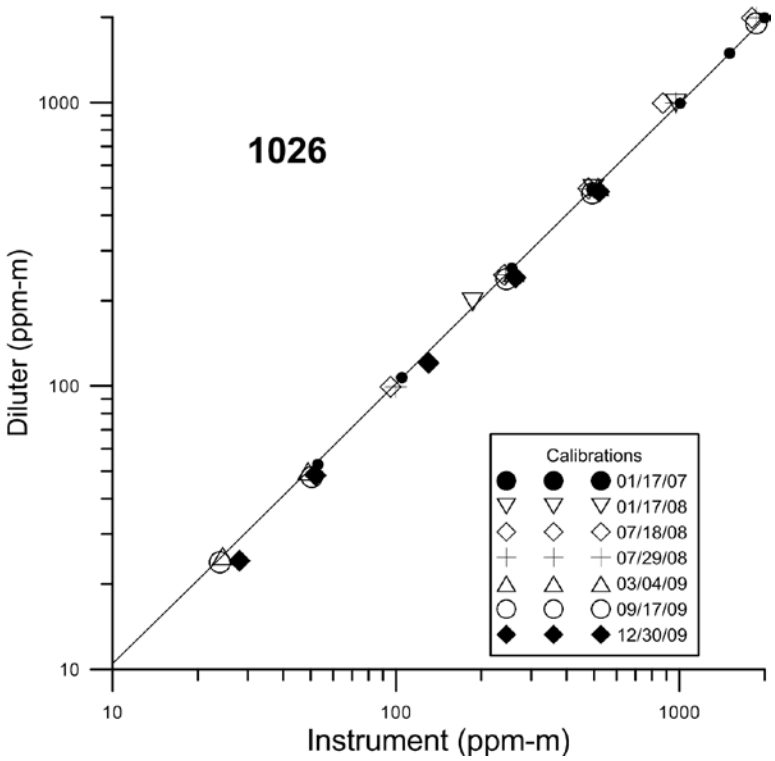


Figure 6.1-1: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1026. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

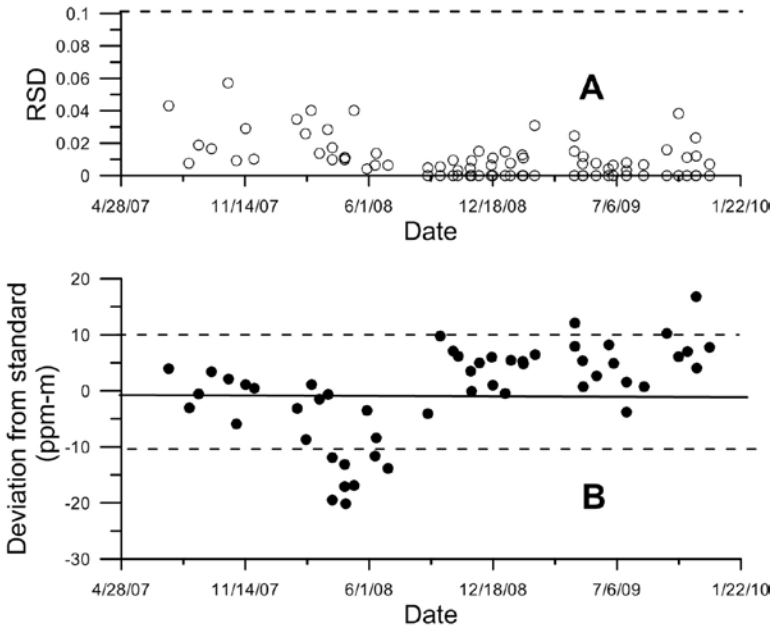


Figure 6.1-2: Control charts of the GasFinder2 ™ s/n NH3OP-1026

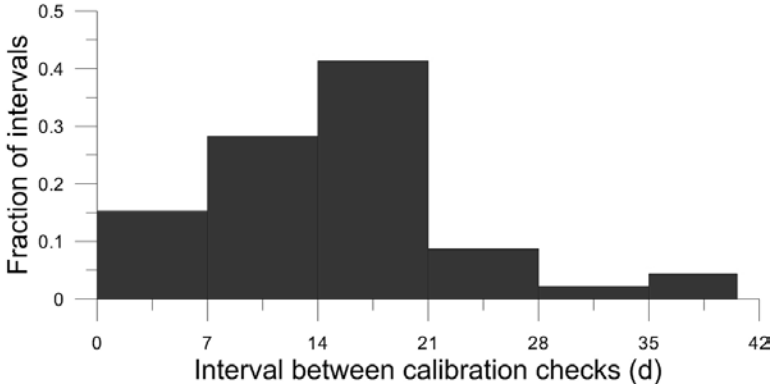


Figure 6.1-3: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1026

TDLAS 1027 was multipoint calibrated eight times during the study (Figure 6.1-4). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 6/18/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$ppm\text{-}m = 2.24 + 0.9936 * X - 3.59E\text{-}5 * X^2 + 6.230E\text{-}8 * X^3$

where X is the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.13 ppm-m prior to the July 2008 modification and 1.83 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 5.36 ppm-m. The precision DQI was ± 0% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 9/26/2008 and 9/24/2009 (Figure 6.1-4). No negative biases exceeding the DQI occurred. Since both positive bias exceedences were followed by a DQI compliant verification on the subsequent calibration verification without intervention, it is assumed that operator error was the cause for the non-compliance.

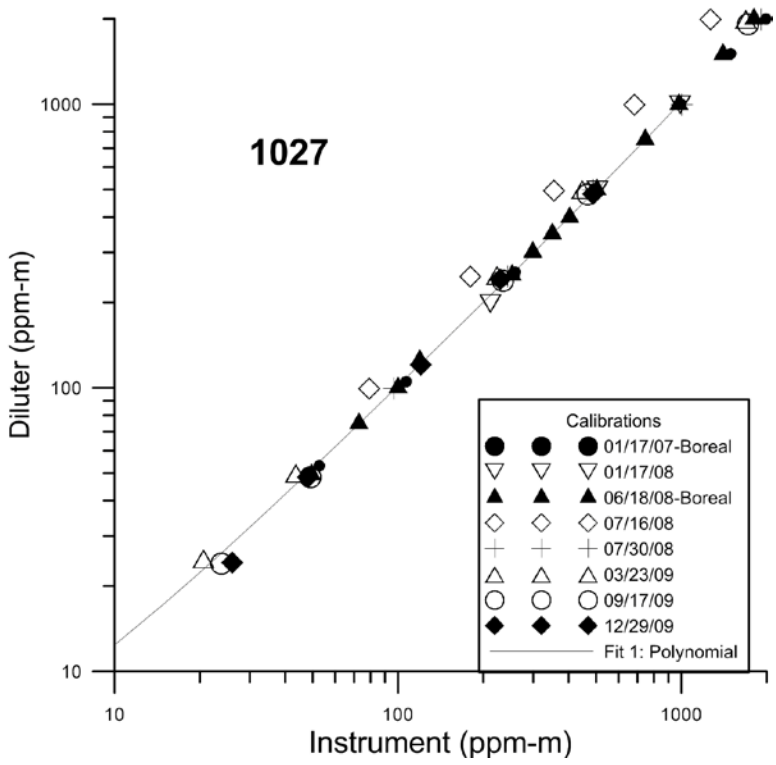


Figure 6.1-4: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1027. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

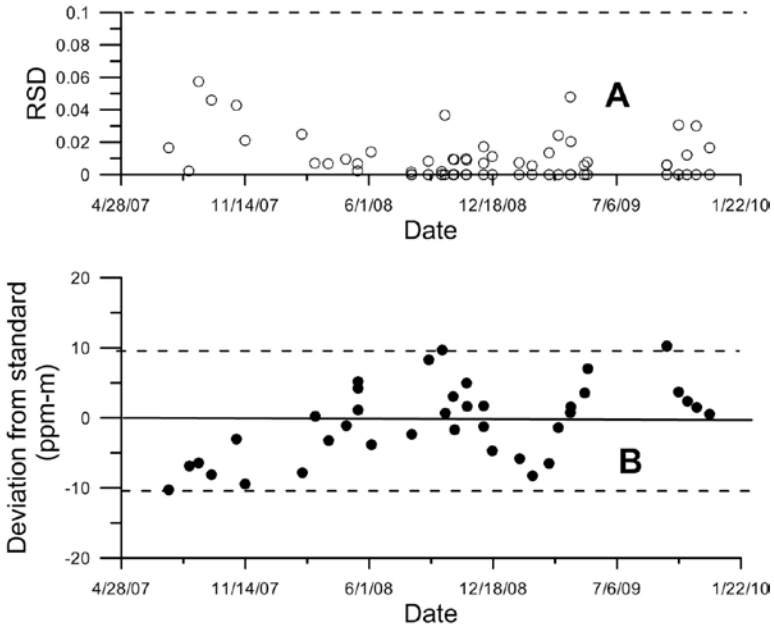


Figure 6.1-5: Control charts of the GasFinder2 ™ s/n NH3OP-1027

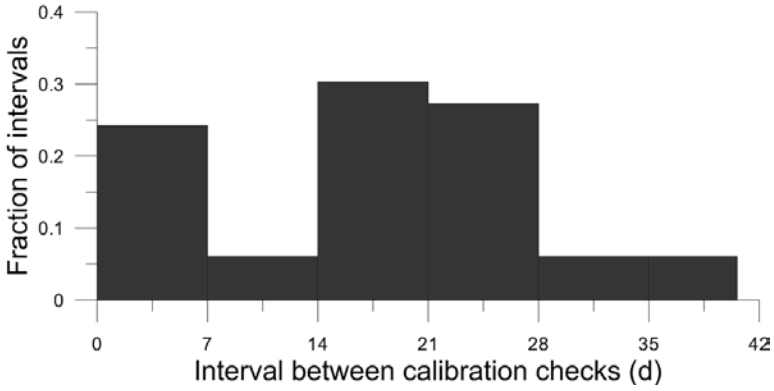


Figure 6.1-6: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1027

TDLAS 1028 was multipoint calibrated six times during the study (Figure 6.1-7). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/23/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$ppm\text{-}m = 1.46 + 0.985 * X + 8.465E\text{-}6 * X^2 + 3.879E\text{-}8 * X^3$

where X is the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-8) and well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 6.1-8). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceedence bias and it is concluded that operator error resulted in the exceedences rather than instrument failure.

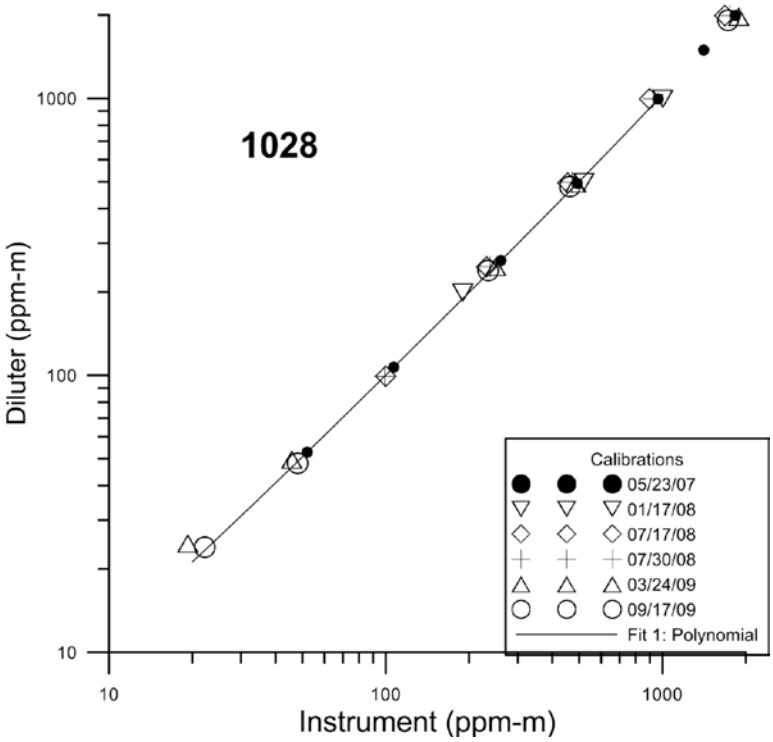


Figure 6.1-7-Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1028. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

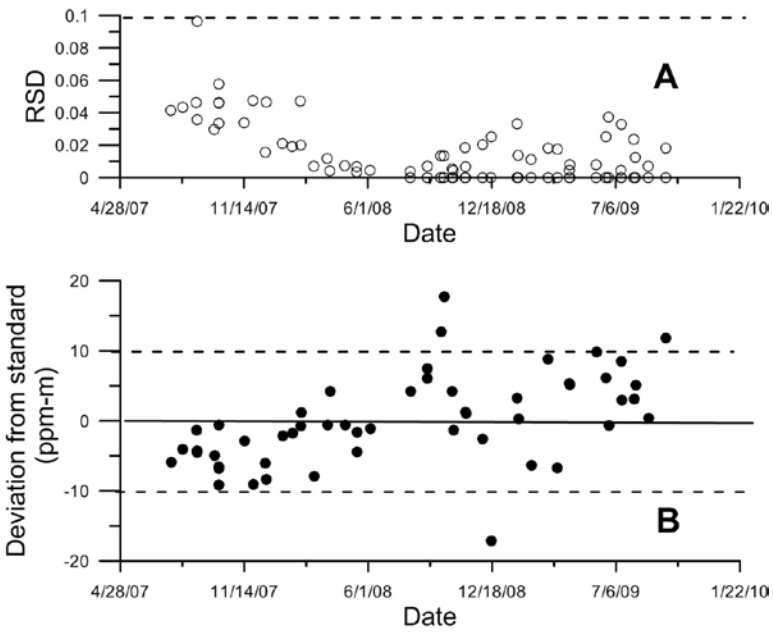


Figure 6.1-8 – Control charts of the GasFinder2 [TM] s/n NH3OP-1028

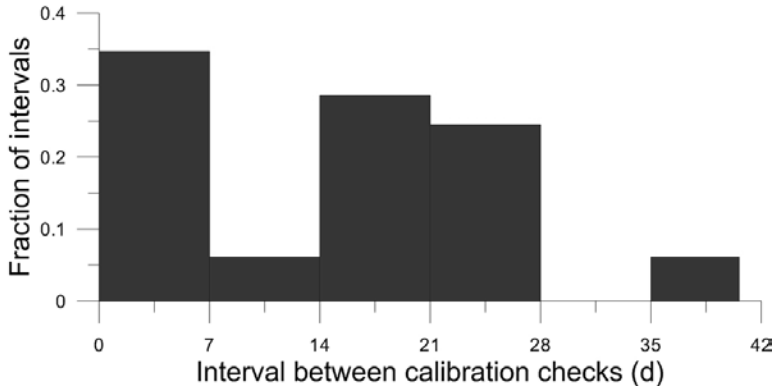


Figure 6.1-9- Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1028

TDLAS 1029 was multipoint calibrated seven times during the study (Figure 6.1-10). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-1 indicated the multipoint calibrations used during different periods in the study.

Table 6.1-1- Multipoint calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
6/24/2007	3/1/2008	5/24/2007
3/24/2008	7/15/2008	3/24/2008
7/31/2008	8/3/2009	3/4/2009
8/4/2009	12/2/2009	12/29/2009

The offsets of the calibration equations were determined from a least squares fit of the appropriate period (Table 6.1-1) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

5/24/2007: ppm-m = -1.48 + 0.967 * X + 4.842E-005 * X^2 - 7.312-009 * X^3

3/24/2008: ppm-m = -2.58 + 0.998 * X - 1.611E-004 * X^2 + 7.449E-008 * X^3

3/4/2009: ppm-m = 4.36 + 1.069 * X + 1.128-004 * X^2 - 1.206E-007 * X^3

12/29/2009: ppm-m = 5.48+ 1.268 * X - 6.072E-005 * X^2

where X is the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.74 ppm-m prior to the July 2008 modification and 1.66 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL prior to the July 2008 modification was greater than the offset in the calibration regression equations but less than the offset in the calibration equations after the modification. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-12). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equations was 4.65, 4.15, 5.23, and 4.27 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-11) and well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI threshold occurred on two dates (Figure 6.1-11). No positive bias exceeding the DQI threshold occurred. In all cases subsequent calibration verifications did not indicate the same exceedence bias and it is concluded that operator error resulted in the exceedences rather than instrument failure.

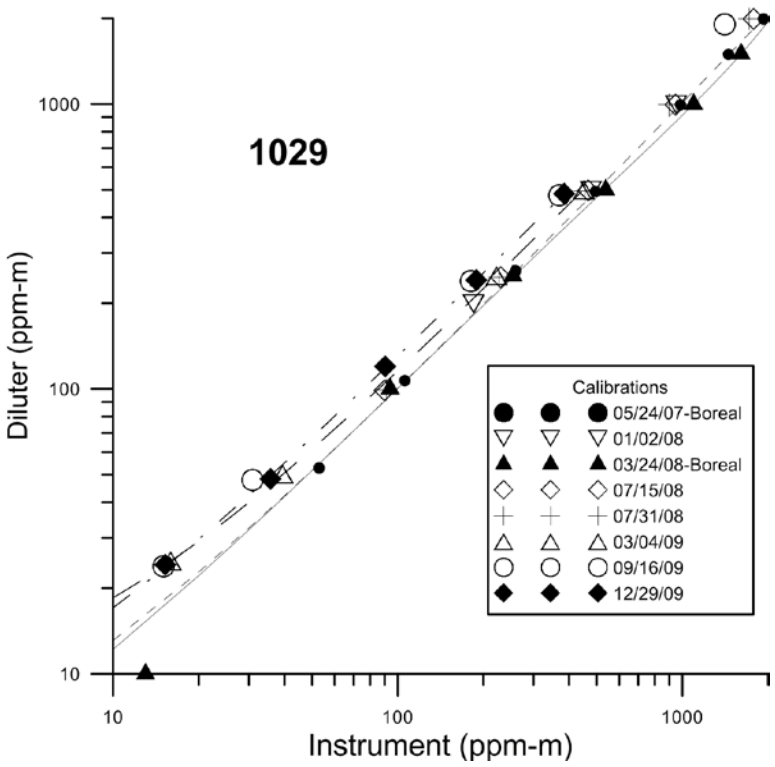


Figure 6.1-10: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1029. The solid (5/24/2007), dotted (3/24/2008), dashed (3/4/2009) and dash-dot (12/29/2009) lines are the 3rd order polynomial regression for the chosen multipoint calibration.

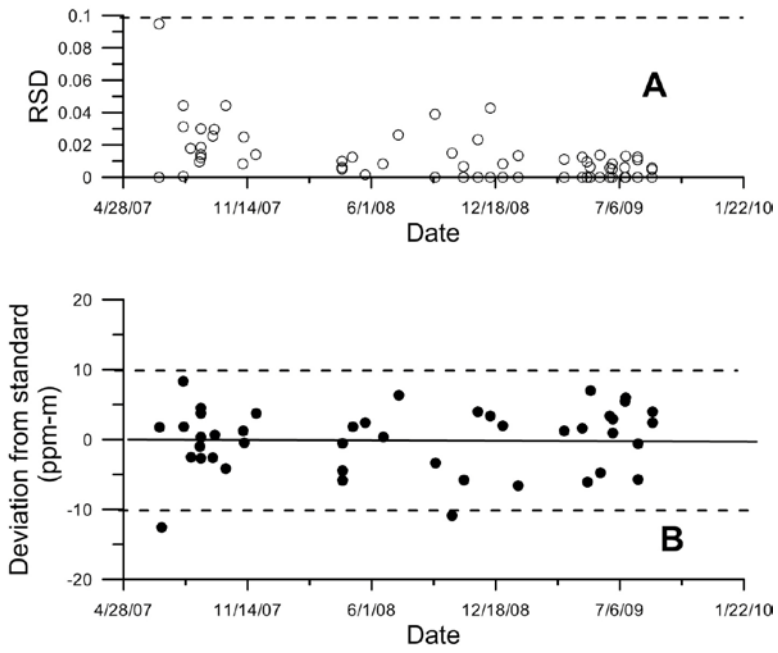


Figure 6.1-11: Control charts of the GasFinder2 ™ s/n NH3OP-1029

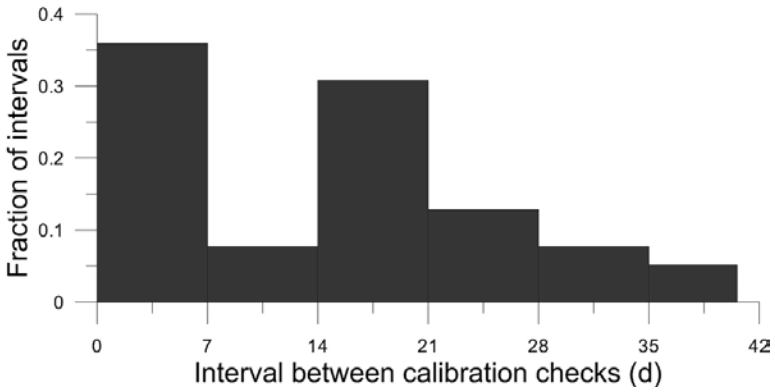


Figure 6.1-12: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1029

TDLAS 1031 was multipoint calibrated six times during the study (Figure 6.1-13). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/30/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -4.43 + 1.0120 * X - 5.7496E\text{-}005 * X^2 + 6.0196E\text{-}008 * X^3$$

where X is the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 5.70 ppm-m prior to the July 2008 modification and 1.92 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The average MDL was approximately equal to the offset indicated in the calibration regression. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-14) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-15). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 15.60 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-14) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI occurred in the calibration verifications between 8/2/2007 and 9/18/2007 (Figure 6.1-14). Positive DQI bias exceedences occurred on 6/28/2007, 9/11/2008, 4/8/2009 and 8/12/2009. Verification failures in the 6/28/2007 to 9/18/2007 interval were a result of un-anticipated optical noise in the calibration procedure which was later corrected. The 4/8/2009 exceedence was preceded and followed by DQI-compliant verifications and the 8/12/2009 verification was preceded by a compliant verification and followed by a multi-point indicating no problem with instrument performance. The instrument was taken out of service between 9/11/2008 and 12/31/2008.

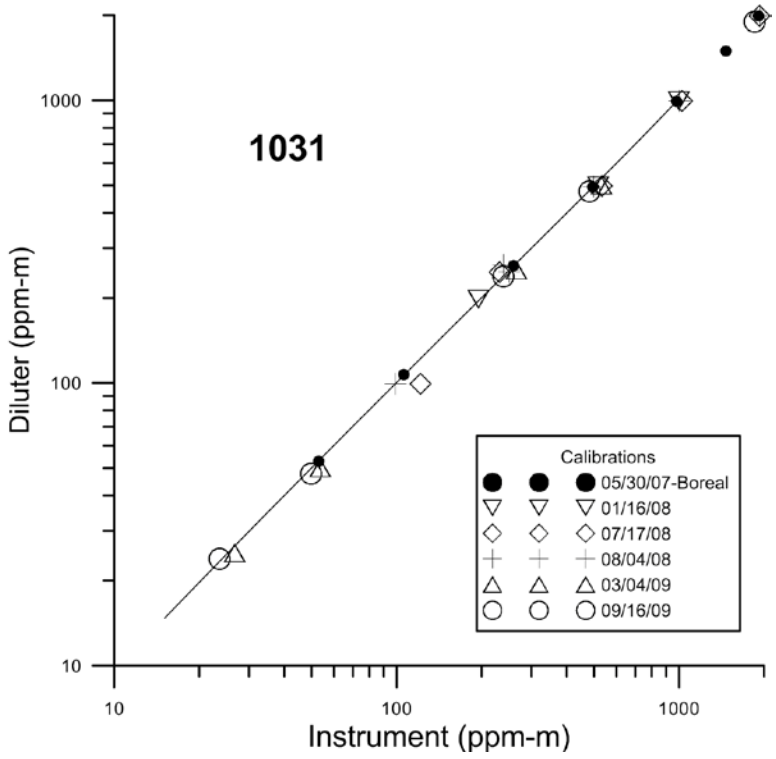


Figure 6.1-13: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1031. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

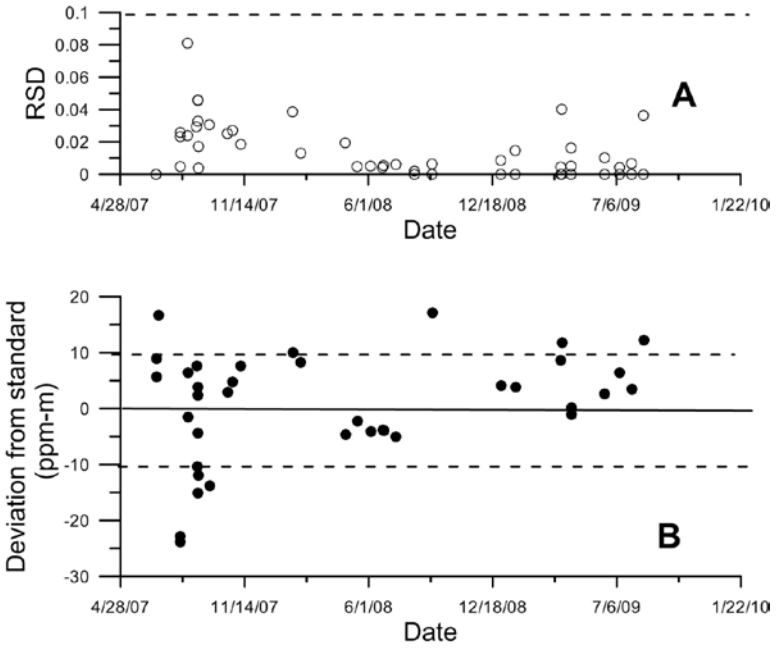


Figure 6.1-14: Control charts of the GasFinder2 [TM] s/n NH3OP-1031

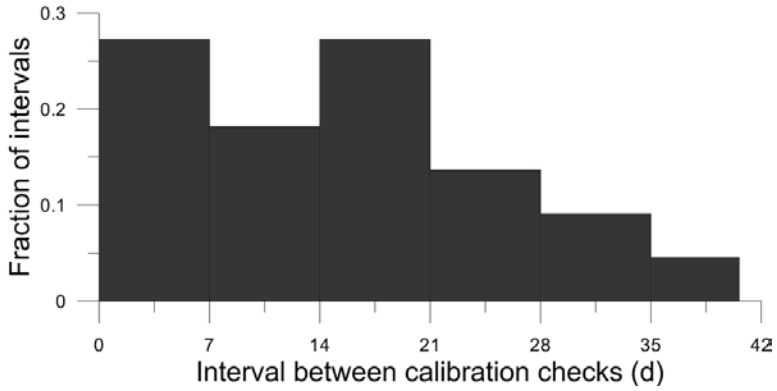


Figure 6.1-15: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1031

TDLAS1032 was multipoint calibrated six times during the study (Figure 6.1-16). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-2 indicates the multi-point calibrations used during different periods in the study.

Table 6.1-2- Multi-point calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
9/21/2007	8/1/2008	9/12/2007
8/27/2008	8/18/2009	3/4/2009

The offset of the calibration equation was determined from a least squares fit of the appropriate period (Table 1) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

9/12/2007: ppm-m = -4.35 + 1.005 * X + 3.563 E-005 * X^2 - 2.618 E-008 * X^3

3/4/2009: ppm-m = -0.69 + 0.995 * X - 2.3298 E-004 * X^2 + 2.891 E-007 * X^3

where X is the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments). The laser was found on 7/21/2008 to not be internally grounded properly, resulting is the inclusion of responses at very low light levels. The no-return light levels were above the minimum light level threshold considered for a valid instrument measurement.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 times the standard deviation) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.60 ppm-m prior to the July 2008 modification and 1.36 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL was greater than the offset in the calibration equation for measurements prior to July 2008 and less than that after July 2008. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-17) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-18). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.13 and 5.61 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-17) and well within the precision DQI. The accuracy DQI was ±10% of the 1000 ppm-m range of the measurements. A positive bias exceeding the DQI occurred on 3/26/2008 and 9/10/2008 (Figure 6.1-17). These exceedences were preceeded and followed by valid calibration verifications and it is assumed that since no modifications of the instrument were made that the exceedences are due to operator error. A negative bias exceeding the DQI was indicated in the calibration verifications on 5/6/2008 (Figure 6.1-17). The grounding problem found on 7/21/2008 (described above) may have been the cause for the period of consistently negative verifications after 4/21/2008 when the background light levels exceeded the minimum acceptable light level. However since the 5/6/2008 exceedence was followed by compliant verifications (although low) without correction of the grounding problem it is assumed that the measurements are valid throughout the period of the grounding problem.

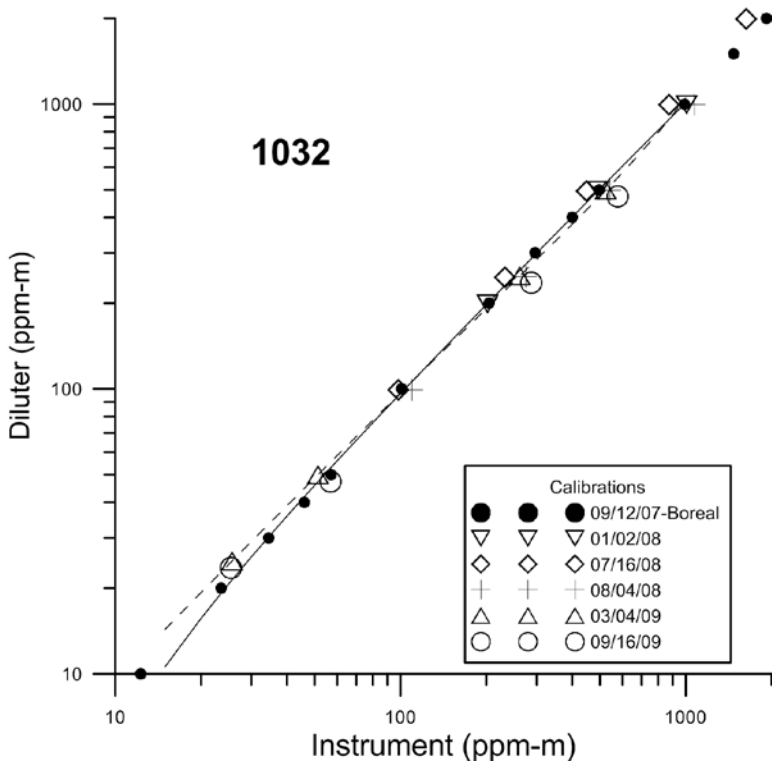


Figure 6.1-16: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1032. The solid (9/12/2007) and dashed (3/4/2009) lines are the 3rd order polynomial regressions for the chosen multipoint calibration.

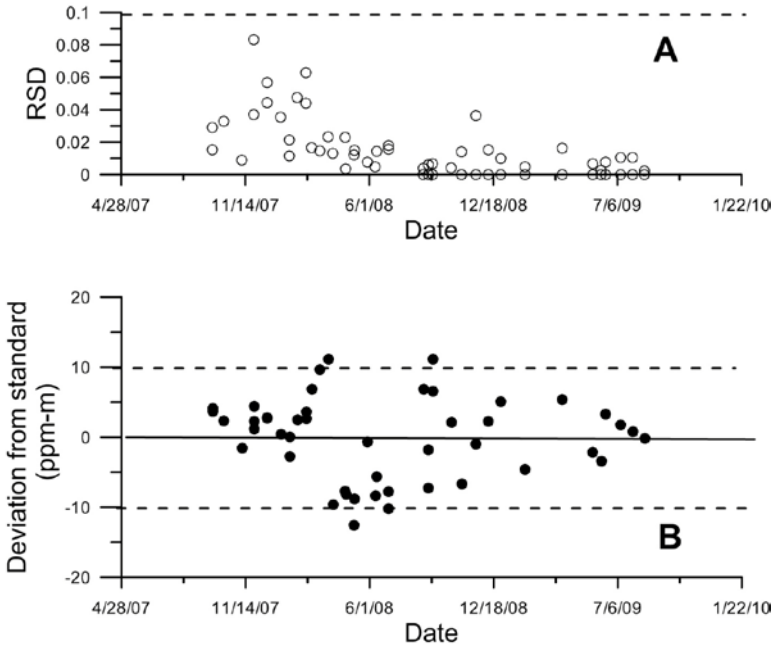


Figure 6.1-17: Control charts of the GasFinder2 [TM] s/n NH3OP-1032

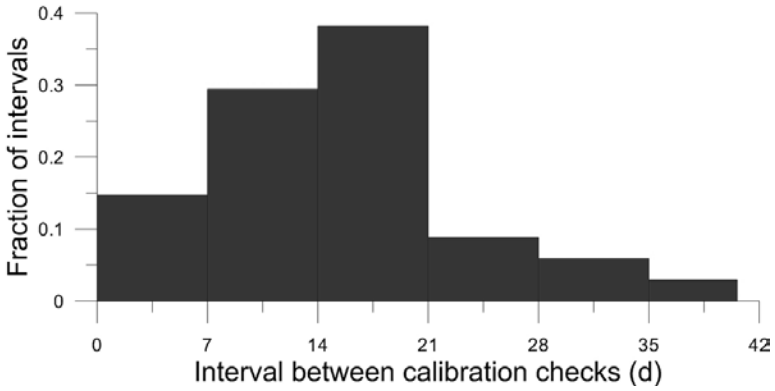


Figure 6.1-18: Calibration check intervals of the GasFinder2 [TM] s/n NH3OP-1032

6.2 TEC 450i analyzer H_2S calibrations

The H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA) with serial number 0733825128 was multipoint calibrated eight times during the study (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.73 to 1.38 (Table 6.2-1). Part of the variation in slope was a result of the H_2S calibration cylinders used. The initial multipoint calibration was conducted prior to the complete burn-in of the converter and consequently differs greatly from the other calibrations.

Table 6.2-1: Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
12/12/2007	1.38	0.0220	0.999
7/11/2008	0.99	0.0034	0.999
8/13/2008	1.18	-0.0045	0.999
9/4/2008	1.22	0.0065	0.999
3/25/2009	0.73	0.0068	0.999
6/19/2009	1.14	-0.0037	0.999
6/24/2009	0.75	0.0075	0.999
9/9/2009	1.14	-0.0052	0.999

The standard deviation of instrument response with CEM zero air measured over a one hour period was 0.83 ppb (10/19/2009). The instrument MDL, defined as 3σ was 2.5 ppb and is indicated in Figure 2A with dashed lines. This is much less than the mean absolute multipoint calibration intercept concentration of 7.5 ppb.

Instrument performance calibration checks (Figure 6.2-2, 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.2-4). The large fraction of checks made within 7 days is the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.788. The mean zero concentration was +1.7 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). Three major periods of instrument bias that exceeded the ± 10% of FS are evident (Figure 6.2-2). The first period extends from the beginning of the measurements until 9/5/2008. Based on the correlation of instrument performance and the calibration cylinder used, it was determined that the concentration of H_2S in the SGAL053 cylinder, which could not be independently verified, was significantly below indicated specification. This resulted in unusually high ratios of diluter concentration versus instrument response (1.01 to 1.18) up until when the cylinder was replaced. The second period was from 11/4/2008 to 12/16/2008 when the calibration checks were inconsistent. Checks conducted on 11/04 and 12/16 at the end of measurement periods failed while checks made two days later at the set up of the next site passed. Since no

modifications/repairs of the instruments were done in the interim between these calibrations, we assume that the FOS must have erred in their procedures.

The third period of calibration check failures occurred after April 2009. High zero checks (Figure 6.2-2A) and low reference checks (Figure 6.2-2B) occurred throughout this time. The instrument response time was found to be unusually long (11 min versus typical 5 min) when specifically checked in July 2009. After the prescribed 10 min interval specified in the S-OPS the response was only 59% of the span value when the long time constant was discovered. Given the S-OPS reference value of 0.5 ppm, the 59% response after 10 min corresponds to approximately 0.2 ppm less than the stabilized reference value. The control chart of the calibration checks (Figure 6.2-2) show a shift in response of approximately -0.2 ppm occurring in May 2009 and continuing through July 2009 but appeared to return to normal operation in August 2009. This change in time response occurred during dusty conditions when the equipment was at WA5A. The change in response resulted in two multipoint calibrations in the field (Table 6.2-1).

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedences (Figure 6.2-3) occurred on 9/5/2008, 6/4/2009 and 8/4/2009. The failure on 9/5/2008 was associated with a change in calibration cylinder (from SGAL053 to FF27944). As previously discussed, it is believed that the certified concentration in SGAL053 was low, resulting a significant shift in the measured diluter concentration when the new cylinder was begun to be used. The failure on 6/4/2009 and 8/4/2009 are probably associated with variable response the instrument during the period of the shift in response time of the instrument.

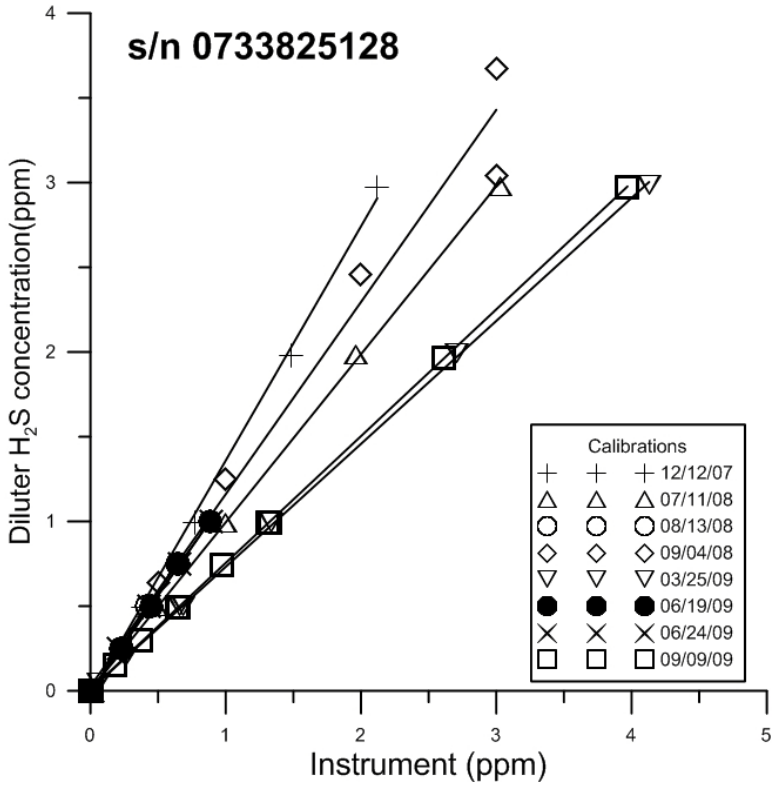


Figure 6.2-1: Multipoint calibrations of the 450i SO_2/H_2S Analyzer

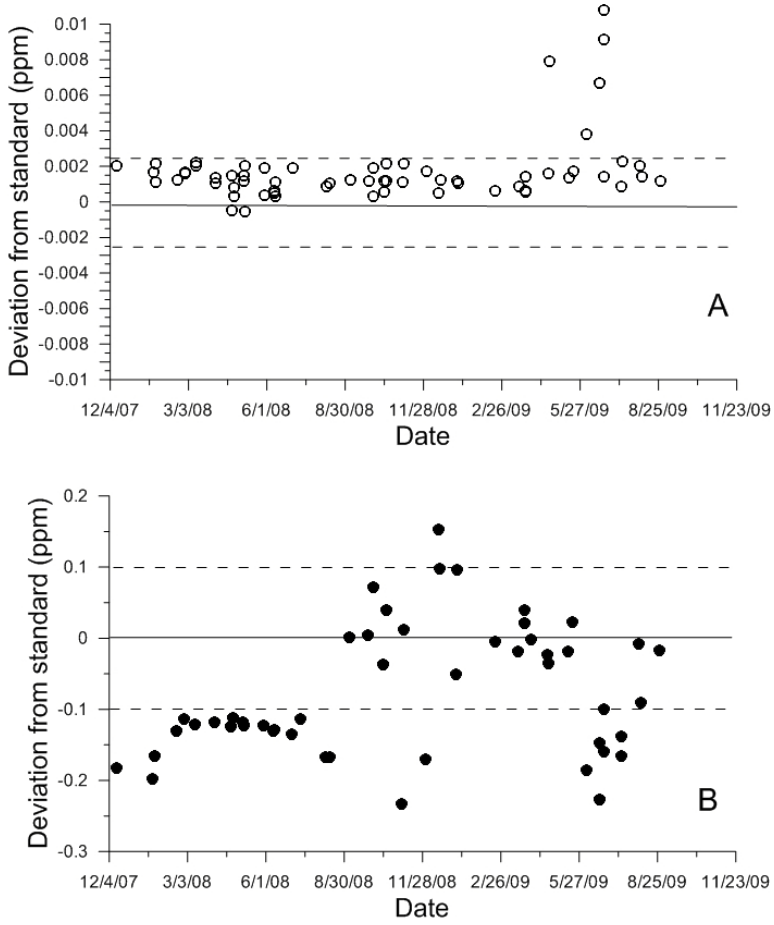


Figure 6.2-2: Instrument Control Charts.

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

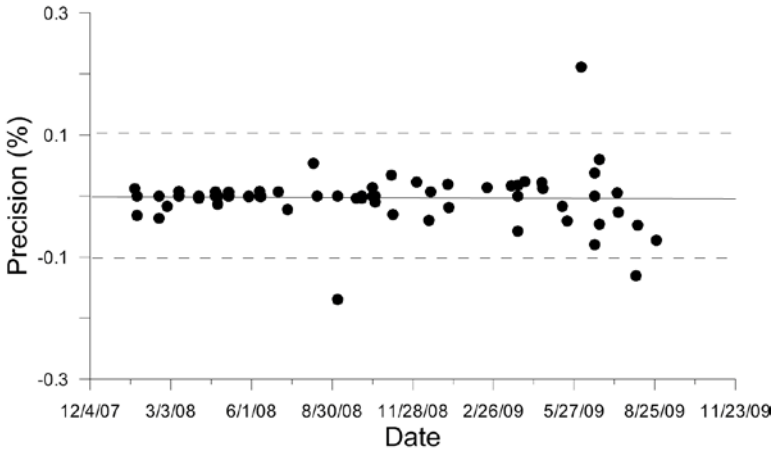


Figure 6.2-3: Instrument Precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

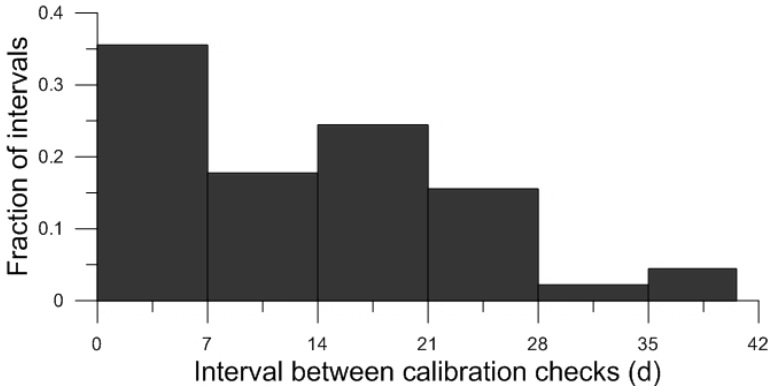


Figure 6.2-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Six sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were used at this location: serial numbers 1920, 1921, 1927, 1928, 1932, and 1936.

Sonic anemometer 1927 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-1). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check on all checks except 9/23-25/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back in use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-1: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (ms^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.025	-0.043
1/21/2008	1/23/2008	-0.051	-0.033
7/16-17/2008	7/17-18/2008	+0.042	+0.029
3/23-25/2009	3/25-27/2009	-0.050	-0.028
9/1-2/2009	9/2-3/2009	-0.035	-0.023

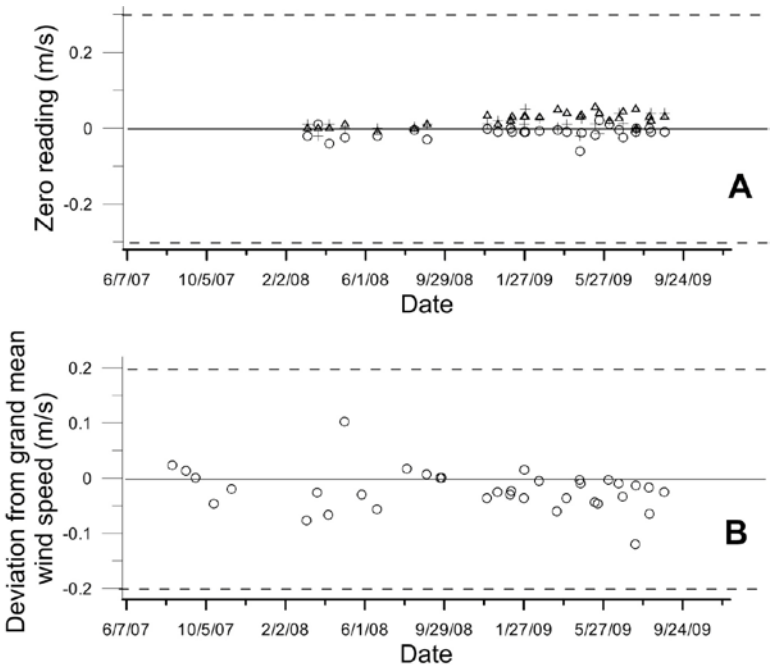


Figure 6.3-1: On-site quality assurance, s/n 1927. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

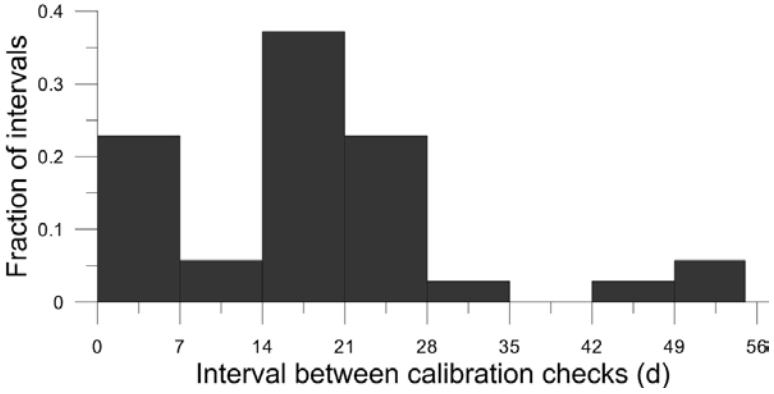


Figure 6.3-2: Inter-comparison check intervals, s/n 1927

Sonic anemometer 1920 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-2). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 51 times (Figure 6.3-3). The majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of

checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-3B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 10/10/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-3A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-2: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29 - 7/2/2007	+0.001	+0.002
1/17-19/2008	1/20-21/2008	+0.045	+0.003
7/18-21/2008	7/21-22/2008	+0.017	-0.006
3/23-25/2009	3/25-27/2009	-0.036	-0.033
9/1-2/2009	9/2-3/2009	-0.046	-0.025

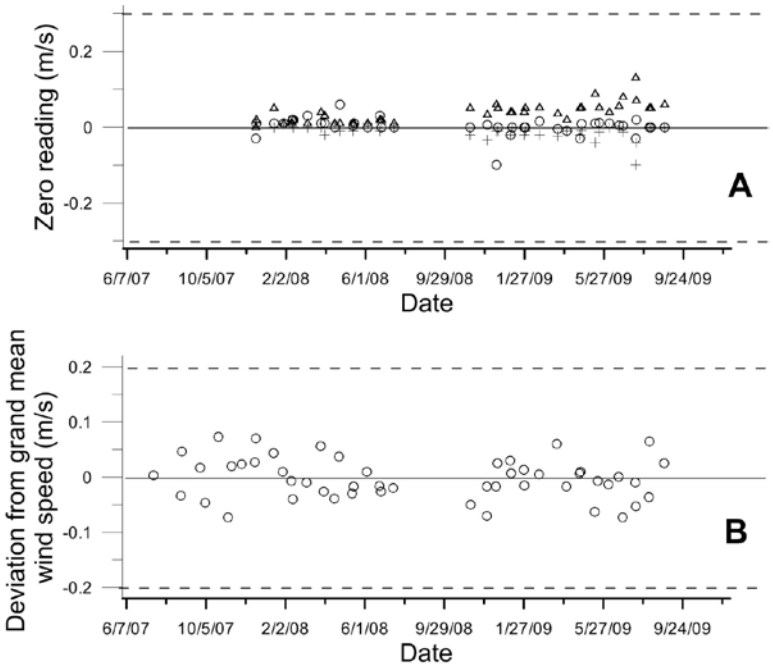


Figure 6.3-3: On-site quality assurance, s/n 1920. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

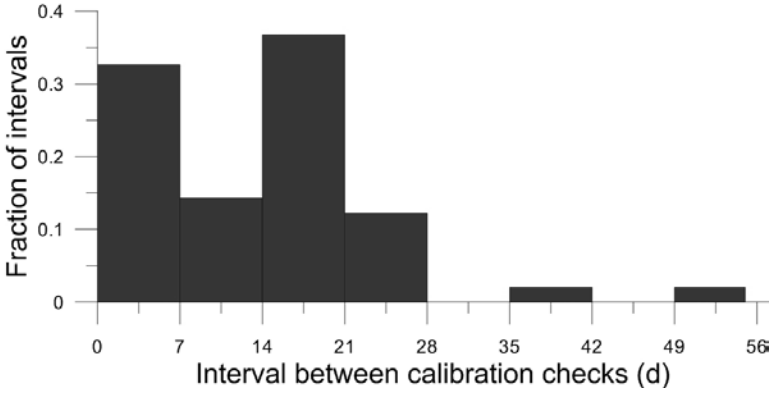


Figure 6.3-4: Inter-comparison check intervals, s/n 1920

Sonic anemometer 1928 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-3). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 48 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of

checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments(Figure 6.3-5B). This instrument passed this check all but one time. On this one date, the inter-comparison was rerun and the instrument passed the check.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-3: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.004	+0.019
12/27-28/2007	12/29-31/2007	+0.003	-0.005
7/10-11/2008	7/11-14/2008	+0.022	+0.007
3/3-4/2009	3/5-6/2009	+0.070	-0.027
9/16-17/2009	9/17-18/2009	+0.056	+0.022
12/18-19/2009	12/21-23/2009	+0.094	-0.077

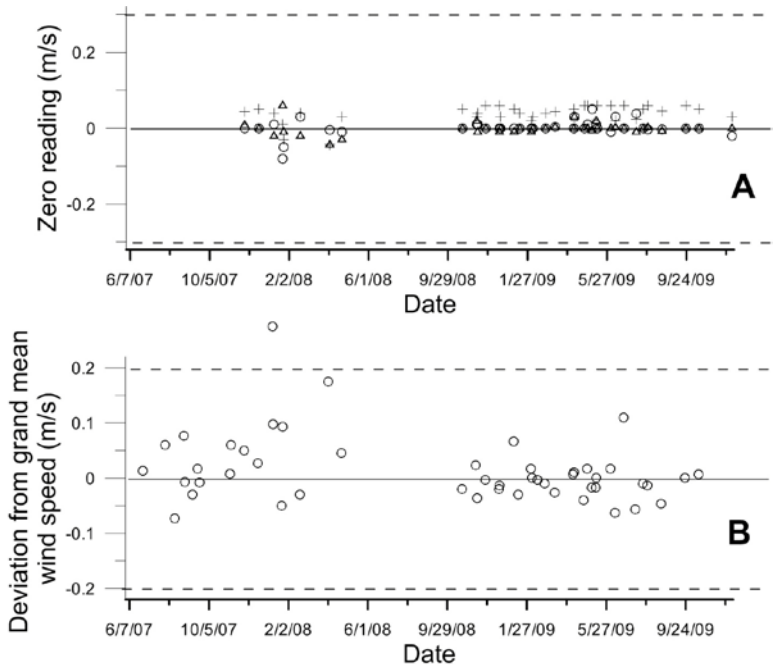


Figure 6.3-5: On-site quality assurance, s/n 1928. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

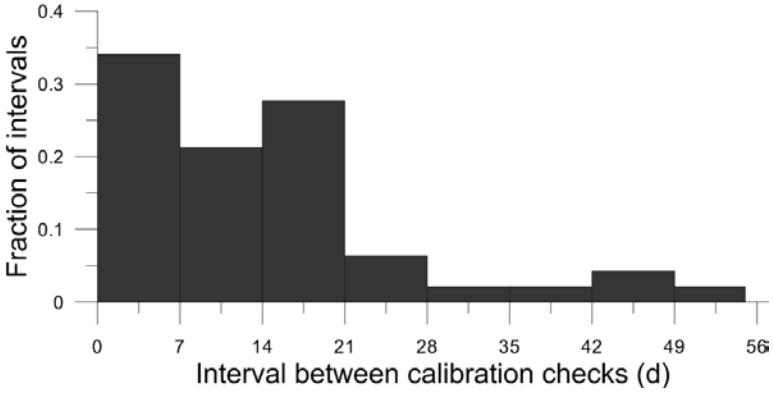


Figure 6.3-6: Inter-comparison check intervals, s/n 1928.

Sonic anemometer 1921 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-4). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 43 times (Figure 6.3-7). The majority of calibration checks were made within 21 d (Figure 6.3-8). The large fraction of

checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-7B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 12/9/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-7A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-4: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.008	-0.003
12/27-28/2007	12/29-31/2007	-0.034	+0.001
7/10-11/2008	7/11-14/2008	+0.029	-0.022
3/23-25/2009	3/25-27/2009	-0.021	-0.040
9/8-14/2009	9/15-16/2009	+0.028	+0.038
12/18-19/2009	12/21-23/2009	+0.078	+0.002

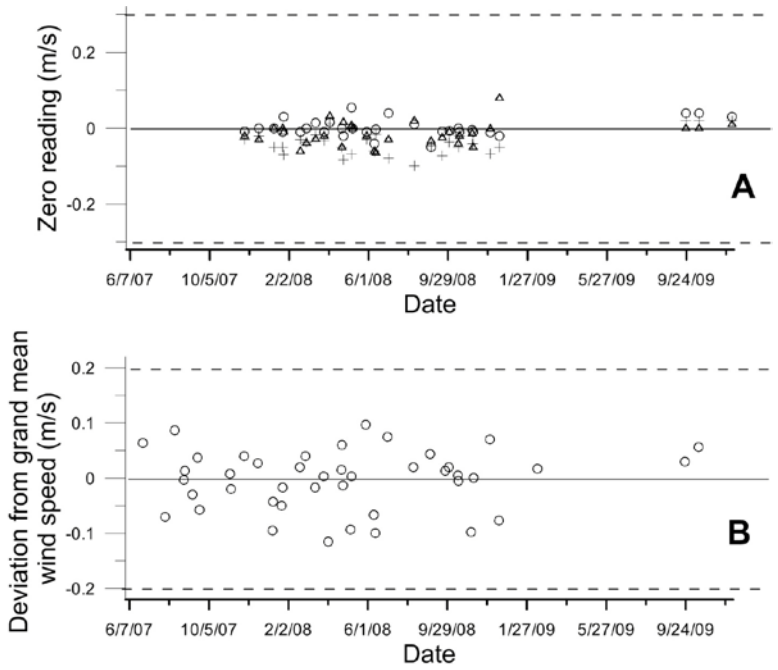


Figure 6.3-7: On-site quality assurance, s/n 1921. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

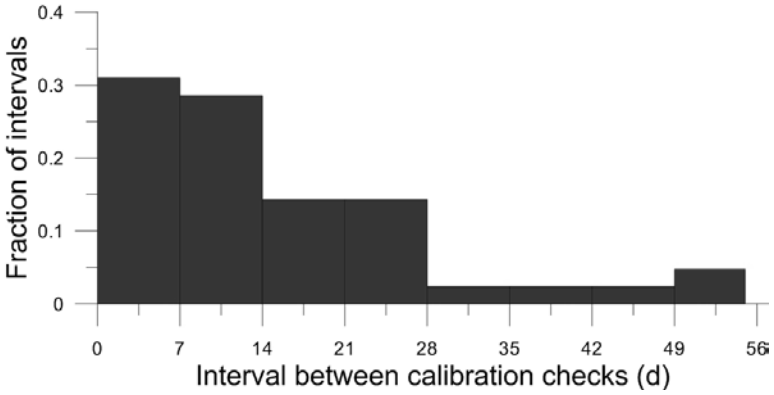


Figure 6.3-8: Inter-comparison check intervals, s/n 1921

Sonic anemometer 1932 was inter-compared with three standard anemometers of identical design six times during the study (Table 6.3-5). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 55 times (Figure 6.3-9). The

majority of calibration checks were made within 21 d (Figure 6.3-10). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-9B). This instrument passed this check on all checks except 10/15-16/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back in use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-9B). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-5: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-17/2007	6/18-19/2007	+0.004	+0.160
12/27-28/2007	12/29-31/2007	+0.014	-0.009
7/10-11/2008	7/11-14/2008	+0.008	+0.031
3/3-5/2009	3/5-6/2009	-0.024	-0.005
9/8-14/2009	9/15-16/2009	-0.025	-0.044
1/7-9/2010	1/23-24/2010	+0.020	-0.016

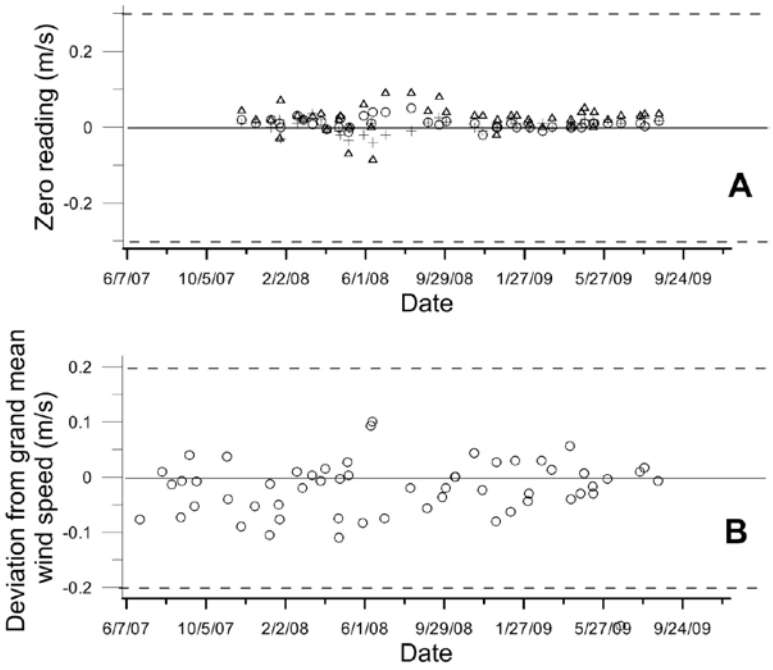


Figure 6.3-9: On-site quality assurance, s/n 1932. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

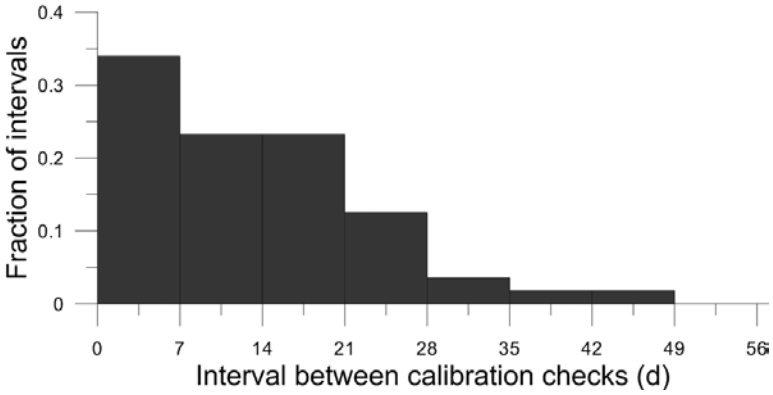


Figure 6.3-10: Inter-comparison check intervals, s/n 1932

Sonic anemometer 1936 was inter-compared with three standard anemometers of identical design five times during the study (Table 6.3-5). No absolute turbulence calibration is possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 41 times (Figure 6.3-11). The

majority of calibration checks were made within 21 d (Figure 6.3-12). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-11B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-11A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-6: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.011	-0.036
12/27-28/2007	12/29-31/2007	-0.022	-0.009
7/10-11/2008	7/11-14/2008	+0.021	-0.019
3/23-25/2009	3/25-27/2009	+0.018	+0.047
9/1-2/2009	9/2-3/2009	-0.029	-0.016

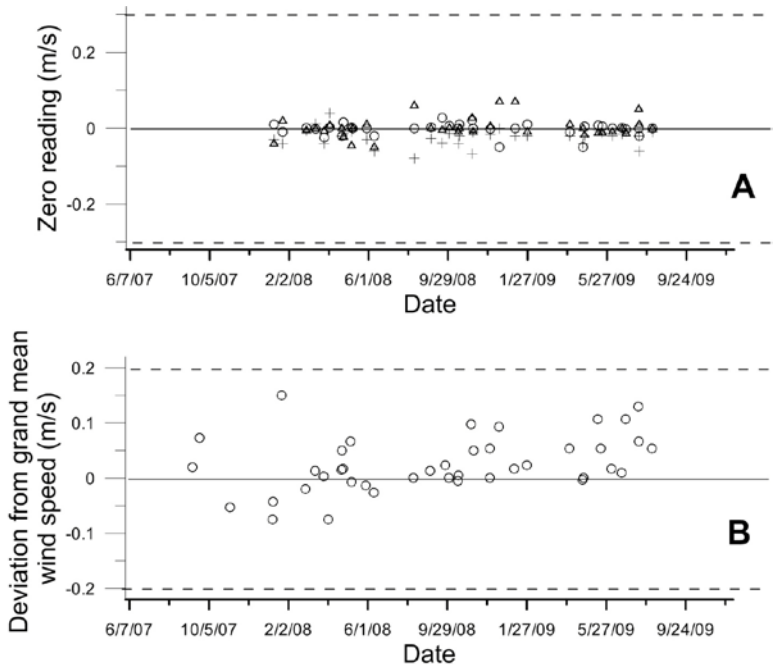


Figure 6.3-11: On-site quality assurance, s/n 1936. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

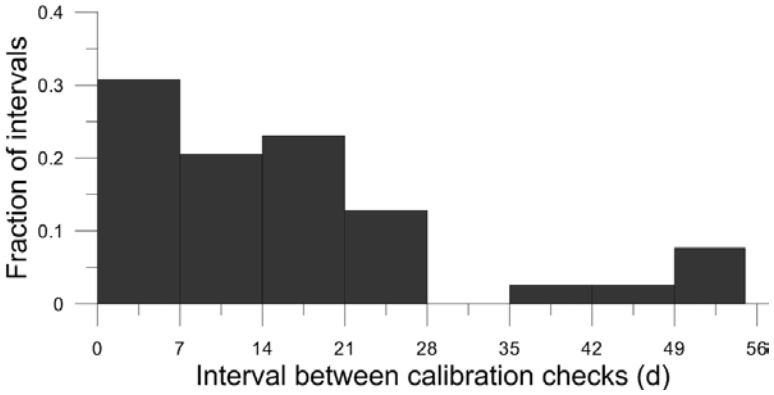


Figure 6.3-12: Inter-comparison check intervals, s/n 1936

6.4 pH probe calibrations

Three pH probes (Model CSIMM-ph, Innovative Sensors, Inc., Anaheim, California) were used at this location: serial numbers 002, 008 and 009.

Probe 002 was first used 6/27/2007 and last used 10/2/2008. The probe was calibrated 16 times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-1A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The accuracy check exceeded the DQI on 4/24/2008, 5/6/2008, and 10/2/2008. The DQI exceedences on 4/24/2008 and 5/6/2008 were followed with a valid accuracy check without sensor modification or repair so it is assumed that the checks failed due to inadequate probe cleaning. The accuracy check failure on 10/2/2008 was a result of probe failure. The stability check failed on 11/28/2007, 12/19/2007, 6/10/2008, and 10/2/2008. The failed stability checks on 11/28/2007 and 12/19/2007 did not correspond with accuracy check failures and were assumed to be operator error. The stability check on 6/10/2008 was indicative of the probe failure noted in the following accuracy check.

Probe 003 was first used 7/24/2007 and last used 11/15/2007. The probe was calibrated seven times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-2A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed both the accuracy DQI and the stability checks.

Probe 009 was first used 4/23/2009 and last used 8/4/2009. The probe was calibrated seven times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-3A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-3B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the stability check but failed the accuracy DQI for pH 7 and pH 10 four times: 7/14/2009, 7/15/2009, 8/4/2009 and 9/17/2009. These accuracy failures were likely due to operator error.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since lagoon pH measurements were not made at several locations the interval between calibrations can be large when locations that did not have lagoon pH measurements were visited

between locations where the measurements were made. Since freezing conditions damage the probe, the probes were not used during the winter at many locations

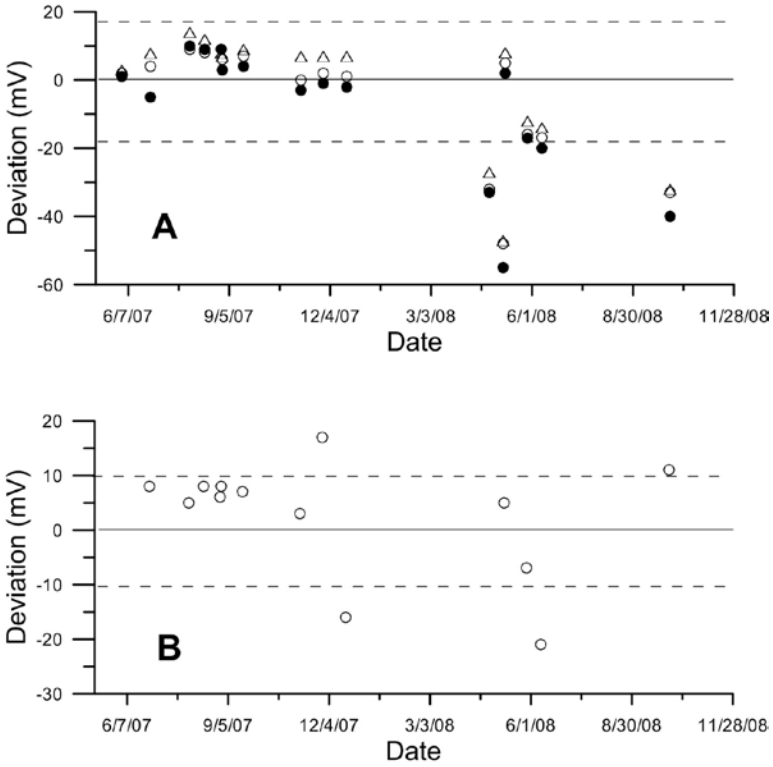


Figure 6.4-1: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 002. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

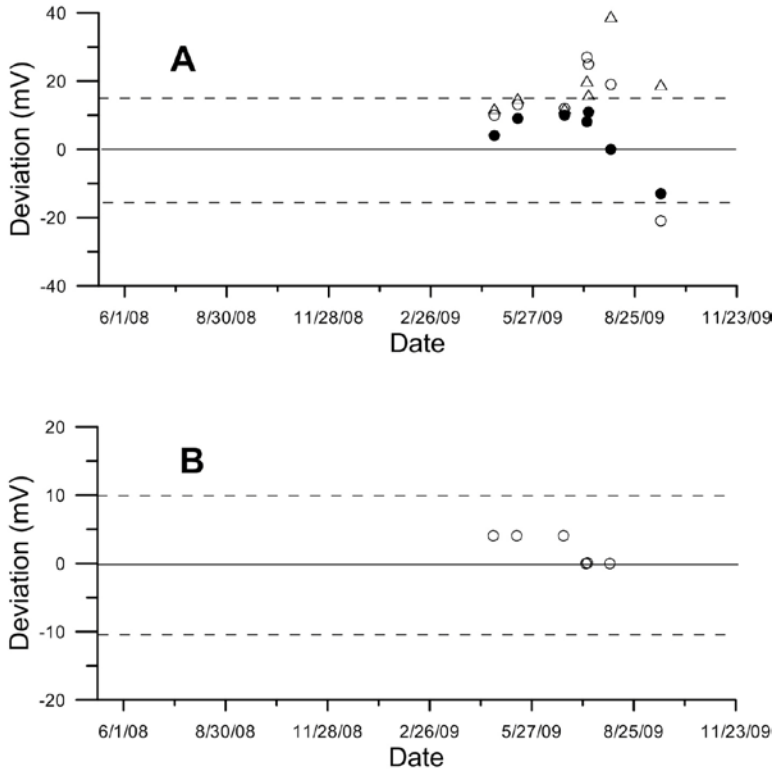


Figure 6.4-2: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 009. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

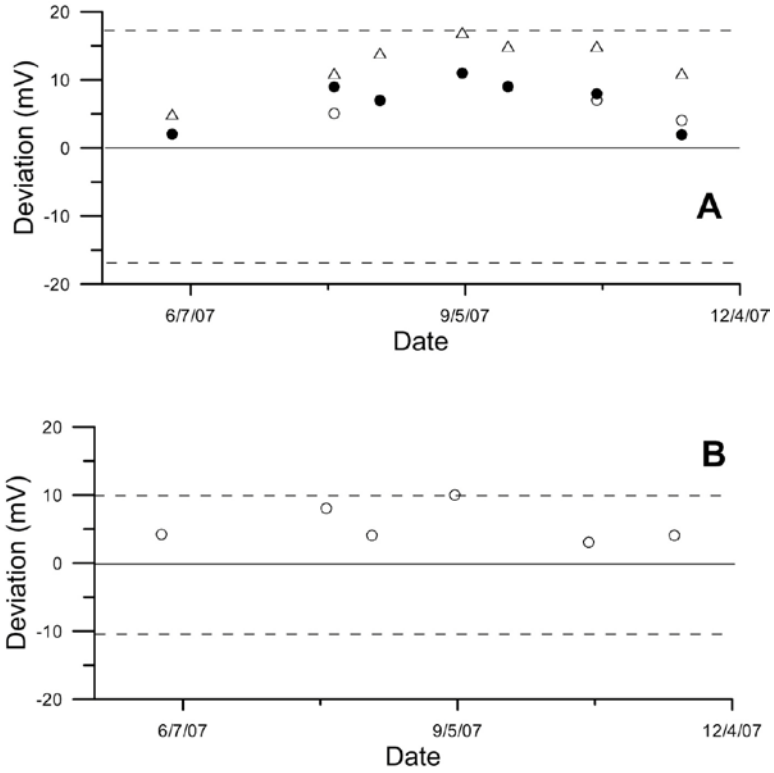


Figure 6.4-3: Accuracy and stability calibration checks of CSIM11 pH probe, s/n 003. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and ph 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

6.5 ORP probe calibrations

Three oxidation-reduction potential (ORP) probes (Model CSIM11-ORP, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 020, 030 and 050.

Probe 020 was first used 7/18/2007 and last used 9/3/2008. The probe was calibrated 16 times. The ORP probe DQI specified an accuracy of ±20 mV (Figure 6.5-1A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe passed the accuracy check DQI on all but 3/27/2008, 4/2/2008, and 8/14/2008. Subsequent accuracy check however met the accuracy DQI without probe modification so the prior failures were assumed to be due to operator error. The stability deviated significantly from the normal range on 4/2/2008 and 8/14/2008 indicating a possible partially-plugged probe.

Probe 030 was first used 6/27/2007 and last used 6/24/2009. The probe was calibrated 19 times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-2A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The stability checks indicated variability in the response but the accuracy check passed the DQI except for the first check (6/27/2007) which was assumed to fail due to operator error since the probe passed the accuracy check subsequent to the first check without modification.

Probe 050 was first used 4/24/2008 and last used 2/23/2009. The probe was calibrated 11 times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-3A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-3B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the accuracy DQI although showed wide response variation to the stability check. The cause of this instability is unknown.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since lagoon ORP measurements were not made at several locations the interval between calibrations can be large when locations that did not have lagoon ORP measurements were visited between locations where the measurements were made. Since freezing conditions damage the probe, the probes were not used during the winter at many locations.

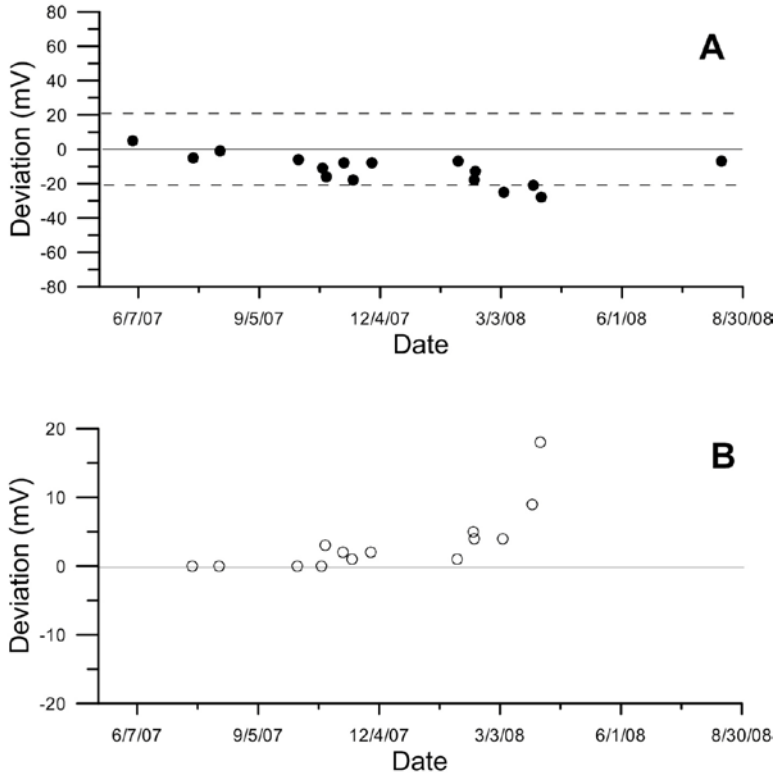


Figure 6.5-1- Accuracy and stability calibration checks of CSIM11 ORP probe, s/n 020. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

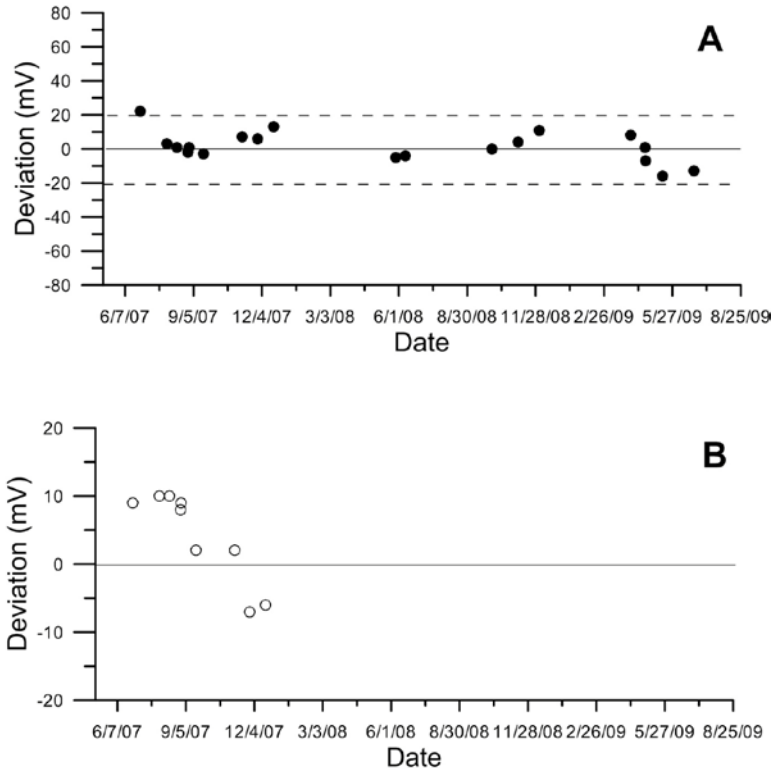


Figure 6.5-2: Accuracy and stability calibration checks of CSIM11 ORP probe, s/n 030. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

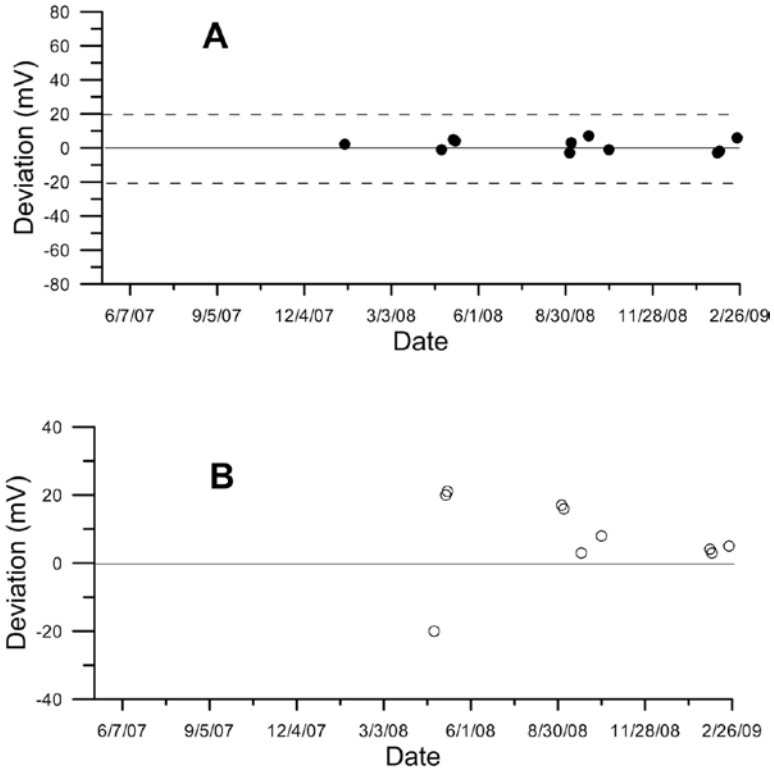


Figure 6.5-3: Accuracy and stability calibration checks of CSIM11 ORP probe, s/n 050. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A

6.6 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n B and E) and the Gas Sampling System (GSS s/n 4-0017) were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results of the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 6.6-1. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Leaks in the GSS rarely occurred, however leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 9/3/2008, 10/2/2008, 12/6/2008, 5/14/2009, 8/4/2009, 10/29/2009 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on the subsequent visit.
- GSS leak check failure on 1/6/2009 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 6.6-1).

Table 6.6-1: Record of leak checks for GSS and GSS/S-OPS

Date (mm/dd/yyyy)	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
3/13/2008	WA5A	2	0.08	-41.29	Pass	8.0	0.56	-41.19	Pass
		3	0.01	-41.46	Pass	10.1	0.43	-39.25	Pass
4/3/2008	TX5A	2	0.00	-37.94	Pass	9.3	0.46	-40.07	Pass
		3	-0.01	-40.41	Pass	9.7	0.34	-40.19	Pass
4/22/2008	TX5A	2	0.09	-31.84	Pass	9.2	0.50	-32.48	Pass
		3	0.04	-40.85	Pass	9.6	0.36	-39.59	Pass
4/24/2008	OK4A	2	0.07	-30.69	Pass	8.4	0.44	-31.03	Pass
		3	0.01	-28.52	Pass	9.7	0.63	-28.70	Pass
5/6/2008	OK4A	2	0.14	-24.42	Pass	8.5	0.65	-26.20	Pass
		3	0.17	-24.74	Fail	9.8	0.66	-23.07	Pass
5/8/2008	OK3A	2	-0.14	-32.28	Pass	9.7	0.11	-30.99	Pass
		3	-0.14	-31.16	Pass	9.2	0.51	-30.83	Pass
5/29/2008	OK3A	2	0.15	-30.98	Fail	9.8	0.31	-32.07	Pass
		3	0.27	-30.89	Fail	9.2	0.58	-32.37	Pass
6/10/2008	OK3A	2	0.07	-39.64	Pass	9.7	0.37	-38.89	Pass
		3	0.06	-40.66	Pass	N/A	N/A	N/A	N/A
6/11/2008	TX5A	2	0.19	-39.52	Fail	9.4	0.19	-38.31	Pass
		3	0.00	-38.50	Pass	9.5	0.77	-38.43	Pass
7/1/2008	TX5A	2	0.15	-31.62	Fail	9.3	0.28	-31.17	Pass
		3	0.15	-31.69	Fail	9.3	1.00	-32.02	Pass

Date (mm/dd/yyyy)	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
8/10/2008	WA5A	2	0.09	-40.90	Pass	7.5	0.44	-40.50	Pass
		3	0.07	-40.35	Pass	10.5	0.75	-38.31	Pass
9/3/2008	WA5A	2	0.27	-32.88	Fail	8.0	6.86	-23.56	Fail
		3	0.30	-32.92	Fail	10.5	0.53	-34.62	Pass
9/3/2008	WA5A	2	0.20	-32.22	Fail	8.0	0.43	-32.51	Pass
		3	0.30	-32.36	Fail	10.5	0.52	-32.73	Pass
9/26/2008	WA5A	2	0.53	-38.99	Fail	8.1	0.33	-40.01	Pass
		3	0.19	-37.03	Fail	10.5	0.41	-39.44	Pass
10/2/2008	OK4A	2	0.23	-40.69	Fail	9.6	0.95	-0.43	Pass
		3	0.23	-39.56	Fail	8.6	0.87	-0.04	Fail
10/15/2008	OK4A	2	0.17	-41.03	Fail	9.8	0.32	-38.14	Pass
		3	0.18	-38.71	Fail	8.5	0.32	-38.90	Pass
10/16/2008	TX5A	2	0.20	-39.65	Fail	9.7	0.28	-39.72	Pass
		3	0.23	-40.98	Fail	9.5	0.59	-39.55	Pass
11/4/2008	TX5A	2	0.33	-41.59	Fail	9.4	0.31	-39.62	Pass
		3	0.32	-41.56	Fail	9.3	0.50	-40.62	Pass
11/6/2008	OK3A	2	0.33	-39.79	Fail	8.7	0.73	-42.34	Pass
		3	0.32	-38.77	Fail	9.3	0.47	-39.46	Pass
12/3/2008	OK3A	2	0.79	-40.32	Fail	8.4	0.65	-39.24	Pass
		3	0.83	-39.05	Fail	9.2	0.43	-40.53	Pass
12/16/2008	OK3A	2	0.72	-37.70	Fail	8.6	1.05	-40.13	Fail
		3	0.79	-36.81	Fail	9.5	0.91	-40.65	Pass
12/18/2008	TX5A	2	1.98	-38.41	Fail	9.4	0.92	-37.74	Pass
		3	2.09	-38.03	Fail	9.4	0.90	-37.46	Pass
1/6/2009	TX5A	2	0.12	-40.60	Pass	9.1	2.09	-37.63	Fail
		3	0.13	-40.35	Pass	8.9	2.12	-37.72	Fail
1/8/2009	OK4A	2	0.11	-38.95	Pass	9.8	0.41	-39.67	Pass
		3	0.11	-37.59	Pass	7.2	0.30	-41.91	Pass
1/27/2009	OK4A	2	0.09	-38.64	Pass	9.4	0.36	-40.34	Pass
		3	0.09	-38.15	Pass	8.3	0.20	-41.46	Pass
1/29/2009	TX5A	2	0.05	-37.73	Pass	9.8	0.37	-38.37	Pass
		3	0.17	-38.46	Fail	9.6	0.24	-37.24	Pass
2/19/2009	TX5A	2	0.19	-36.64	Fail	9.9	0.92	-39.35	Pass
		3	0.04	-36.77	Pass	9.7	0.64	-38.72	Pass
3/18/2009	TX5A	2	0.15	-38.19	Fail	9.3	0.65	-37.14	Pass
		3	0.07	-39.28	Pass	9.8	0.45	-37.54	Pass
4/21/2009	OK4A	2	0.15	0.06	Fail	10.2	0.55	-40.07	Pass
		3	0.01	-39.72	Pass	9.0	0.24	-37.98	Pass
4/22/2009	OK3A	2	0.14	-40.11	Pass	9.7	0.30	-38.44	Pass
		3	0.05	-38.69	Pass	8.8	0.77	-27.92	Pass
5/14/2009	OK3A	2	0.20	-39.22	Fail	9.7	0.26	-38.46	Pass
		3	0.09	-39.13	Pass	8.6	0.88	-38.07	Fail
5/21/2009	WA5A	2	0.17	-37.70	Fail	7.9	0.18	-39.69	Pass
		3	0.02	-39.60	Pass	10.5	0.96	-39.37	Pass
6/4/2009	WA5A	2	0.18	-40.86	Fail	8.6	0.24	-40.49	Pass
		3	0.04	-38.48	Pass	10.5	0.97	-38.07	Pass
6/19/2009	WA5A	2	0.33	-39.50	Fail	8.7	0.25	-38.74	Pass
		3	0.14	-39.60	Pass	10.5	0.95	-37.89	Pass
6/23/2009	OK4A	2	0.07	-39.89	Pass	9.7	0.37	-39.37	Pass
		3	0.04	-38.56	Pass	8.8	0.60	-40.96	Pass
7/14/2009	OK4A	2	0.25	-39.85	Fail	8.5	0.14	-40.79	Pass
		3	0.08	-38.49	Pass	9.7	0.13	-39.51	Pass

Date (mm/dd/yyyy)	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
7/15/2009	OK3A	2	0.02	-38.14	Pass	8.7	0.63	-38.59	Pass
		3	0.04	-36.71	Pass	9.9	0.08	-39.75	Pass
8/4/2009	OK3A	2	0.06	-38.09	Pass	8.5	2.25	-37.22	Fail
		3	0.11	-34.41	Pass	9.7	0.09	-39.78	Pass
8/6/2009	TX5A	2	0.05	-38.30	Pass	9.8	0.75	-39.40	Pass
		3	0.00	-40.36	Pass	9.9	0.14	-38.93	Pass
8/27/2009	TX5A	2	0.02	-39.89	Pass	9.7	0.65	-37.52	Pass
		3	0.05	-40.26	Pass	9.5	0.11	-38.95	Pass
9/23/2009	NC3A	2	0.06	-40.15	Pass	10.1	0.34	-39.61	Pass
		3	0.07	-38.33	Pass	0.0	-0.60	-0.05	Pass
10/13/2009	NC3A	2	0.17	-39.38	Fail	9.6	0.41	-39.03	Pass
		3	0.04	-37.77	Pass	10.0	0.20	-41.33	Pass
10/27/2009	NC3A	2	0.08	-41.29	Pass	10.0	0.26	-39.30	Pass
		3	0.01	-41.46	Pass	9.3	1.45	0.11	Fail
10/27/2009	NC3A	2	0.00	-37.94	Pass	10.0	0.26	-39.30	Pass
		3	-0.01	-40.41	Pass	9.3	0.51	-40.26	Pass
11/11/2009	NC3A	2	0.04	-39.92	Pass	10.0	0.79	-40.71	Pass
		3	0.04	-39.74	Pass	9.6	0.27	-40.26	Pass

The inlet flow balance checks are summarized in sequence in Tables 6.6-2A and 6.6-2B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A: Record of flow balancing- side 1 (s/n B)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	-0.20	-0.21	-0.06	-0.14	-0.20	-0.24	-0.21	-0.04	-0.20	-0.23	**Fail**
4/3/2008	4/22/2008	TX5A	-0.08	-0.07	-0.08	-0.09	-0.07	-0.09	-0.13	-0.09	-0.12	-0.14	**Pass**
4/24/2008	5/6/2008	OK4A	-0.02	-0.04	-0.01	-0.14	-0.02	-0.03	-0.09	-0.10	-0.07	-0.12	**Fail**
5/8/2008	5/29/2008	OK3A	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.03	0.01	0.04	**Pass**
5/29/2008	6/10/2008	OK3A	M	M	M	M	M	M	M	M	M	M	**M**
6/11/2008	7/1/2008	TX5A	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	**Pass**
7/1/2008	8/10/2008	TX5A	0.35	0.38	0.11	0.39	0.27	0.31	0.30	0.18	0.34	0.31	**Pass**
8/10/2008	9/3/2008	WA5A	0.00	-0.10	0.11	-0.20	0.00	0.00	-0.10	0.00	-0.10	0.00	**Fail**
9/3/2008	9/26/2008	WA5A	0.00	-0.10	-0.10	0.10	0.00	-0.20	-0.10	0.10	0.00	0.00	**Fail**
10/2/2008	10/15/2008	OK4A	0.02	-0.02	0.01	0.01	-0.03	0.06	0.06	0.05	0.04	0.02	**Fail**
10/16/2008	11/4/2008	TX5A	0.02	0.00	0.00	-0.01	-0.02	-0.05	-0.05	0.00	0.01	0.03	**Pass**
11/6/2008	12/3/2008	OK3A	0.03	0.00	0.00	0.01	-0.02	0.03	0.04	0.05	0.05	0.05	**Pass**
12/3/2008	12/16/2008	OK3A	-0.02	-0.01	-0.01	0.00	0.04	-0.06	0.04	-0.04	-0.03	-0.03	**Pass**
12/18/2008	1/6/2009	TX5A	-0.02	-0.06	-0.03	0.00	-0.04	-0.02	-0.02	0.00	0.01	-0.01	**Fail**
1/8/2009	1/27/2009	OK4A	-0.02	-0.04	-0.04	0.00	-0.05	-0.01	0.00	0.00	0.00	0.01	**Pass**
1/29/2009	2/19/2009	TX5A	-0.04	-0.02	0.00	0.06	0.00	-0.06	0.00	-0.02	-0.02	0.00	**Pass**
2/19/2009	3/18/2009	TX5A	0.01	-0.02	0.01	0.01	0.01	-0.02	0.00	0.00	0.00	-0.01	**Fail**
3/18/2009	4/2/2009	TX5A	0.06	0.06	0.05	0.06	0.04	0.08	0.06	0.10	0.05	0.11	**Pass**
4/2/2009	4/21/2009	OK4A	0.02	0.05	0.04	0.04	-0.03	0.01	0.02	0.01	-0.01	-0.01	**Pass**
4/22/2009	5/14/2009	OK4A	-0.03	-0.04	-0.02	-0.03	-0.02	-0.14	-0.02	-0.01	-0.02	-0.03	**Pass**
5/14/2009	5/21/2009	OK4A	0.23	0.24	0.27	0.28	0.17	0.28	0.23	0.26	0.17	0.29	**Pass**
5/21/2009	6/4/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/23/2009	7/14/2009	OK4A	0.00	-0.02	-0.03	-0.01	-0.04	0.01	0.01	0.00	-0.01	-0.04	**Pass**
7/15/2009	8/4/2009	OK3A	0.05	0.04	0.13	0.09	0.13	0.20	0.16	0.14	0.14	0.18	**Pass**
8/6/2009	8/27/2009	TX5A	0.05	0.05	0.01	0.00	0.01	0.03	0.02	0.03	0.06	0.04	**Pass**
8/27/2009	9/24/2009	TX5A	-0.10	-0.06	-0.05	-0.06	-0.08	-0.01	-0.04	-0.05	-0.14	-0.01	**Pass**
9/24/2009	10/13/2009	NC3A	0.00	-0.03	0.00	-0.05	-0.03	-0.08	87.39	-0.11	-0.12	0.06	**Pass**
10/13/2009	10/27/2009	NC3A	-0.02	-0.05	-0.04	-0.03	-0.04	-0.04	-0.03	-0.03	-0.05	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.00	-0.02	-0.01	-0.01	-0.01	0.00	-0.02	0.00	-0.04	0.02	**Pass**
11/11/2009	12/2/2009	NC3A	0.02	0.04	-0.11	-0.01	0.01	0.00	-0.03	-0.08	0.37	0.03	**Fail**

M: missing measurements.

Table 6.6-2B: Record of flow balancing- side 2 (s/n E)

			Delta inlet flow (beginning-end) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	0.19	0.18	0.11	0.19	0.14	0.14	0.15	0.17	0.15	0.21	**Fail**
4/3/2008	4/22/2008	TX5A	-0.03	-0.03	0.01	-0.04	-0.09	-0.06	0.00	0.01	0.00	0.00	**Pass**
4/24/2008	5/6/2008	OK4A	0.00	0.00	0.00	-0.03	-0.02	-0.05	0.06	-0.01	-0.03	0.06	**Fail**
5/8/2008	5/29/2008	OK3A	0.02	0.01	0.04	0.00	0.05	0.02	0.01	0.04	0.02	0.02	**Pass**
5/29/2008	6/10/2008	OK3A	-0.01	-0.01	-0.02	0.00	0.00	-0.02	0.01	-0.04	-0.02	0.00	**Pass**
6/11/2008	7/1/2008	TX5A	0.01	0.00	0.00	0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.03	**Pass**
7/1/2008	7/29/2008	TX5A	-0.03	-0.09	0.00	-0.05	-0.03	-0.06	0.02	-0.03	-0.02	0.00	**Pass**
8/10/2008	9/3/2008	WA5A	0.05	0.14	0.09	0.10	0.16	0.14	0.12	0.15	0.18	0.15	**Pass**
9/3/2008	9/26/2008	WA5A	-0.04	-0.06	-0.02	-0.01	0.00	0.00	0.02	-0.04	0.02	0.00	**Pass**
10/2/2008	10/15/2008	OK4A	0.00	0.01	-0.02	0.00	-0.01	0.01	0.03	0.03	0.11	0.00	**Pass**
10/16/2008	11/4/2008	TX5A	-0.02	-0.05	-0.03	-0.04	0.00	0.00	-0.04	-0.04	-0.01	-0.02	**Pass**
11/6/2008	12/3/2008	OK3A	-0.01	0.01	0.00	-0.02	0.14	-0.07	0.01	0.02	0.02	0.02	**Fail**
12/3/2008	12/16/2008	OK3A	0.01	-0.02	-0.01	-0.02	-0.01	0.02	0.00	0.00	-0.02	-0.01	**Pass**
12/18/2008	1/6/2009	TX5A	-0.03	-0.08	-0.05	-0.05	-0.06	-0.05	-0.06	-0.04	-0.07	-0.02	**Pass**
1/8/2009	1/27/2009	OK4A	-0.04	-0.03	-0.03	-0.04	-0.04	-0.02	-0.03	-0.02	-0.02	-0.01	**Pass**
1/29/2009	2/19/2009	TX5A	0.00	-0.05	0.00	0.01	-0.02	-0.05	0.02	0.02	0.12	-0.01	**Pass**
2/19/2009	3/18/2009	TX5A	0.03	0.03	0.04	0.03	0.02	0.04	0.01	0.02	0.03	0.01	**Fail**
3/18/2009	4/2/2009	TX5A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.16	-0.14	-0.12	-0.15	-0.14	**Pass**
4/2/2009	4/21/2009	OK4A	0.00	0.05	0.05	0.04	0.04	0.07	0.05	0.03	0.01	0.02	**Pass**
4/22/2009	5/14/2009	OK3A	-0.06	0.00	0.00	-0.01	0.01	0.02	0.01	0.03	0.03	0.00	**Pass**
5/14/2009	5/21/2009	OK3A	-0.07	-0.11	-0.13	-0.11	-0.21	-0.10	-0.19	-0.16	-0.17	-0.18	**Pass**
5/21/2009	6/4/2009	WA5A	0.01	0.00	0.00	0.01	0.07	-0.03	0.05	0.02	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.01	0.01	-0.04	-0.03	-0.03	-0.03	-0.02	-0.01	-0.02	0.00	**Pass**
6/23/2009	7/14/2009	OK3A	-0.02	-0.02	0.00	-0.02	-0.02	0.03	-0.03	-0.02	-0.02	0.01	**Pass**
7/15/2009	8/4/2009	OK3A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
8/4/2009	8/6/2009	OK3A	0.00	-0.01	0.01	0.01	-0.01	0.01	-0.01	0.02	0.01	0.00	**Pass**
8/6/2009	8/27/2009	TX5A	0.00	-0.03	-0.05	-0.04	-0.02	-0.02	-0.01	0.01	0.01	0.03	**Pass**
8/27/2009	9/23/2009	TX5A	0.05	0.05	0.08	0.11	0.22	0.22	0.21	0.25	0.22	0.21	**Fail**
9/24/2009	10/13/2009	NC3A	0.02	0.03	0.00	0.02	0.00	0.00	0.00	-0.03	0.00	0.16	**Fail**
10/13/2009	10/27/2009	NC3A	0.00	-0.01	0.12	-0.05	-0.02	-0.12	-0.04	-0.05	-0.06	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.15	0.06	0.18	0.10	-0.05	0.25	0.25	0.05	0.21	-0.60	**Fail**

The nominal planned interval between S-OPS checks was 20 d (three weeks). S-OPS checks were conducted at this long-term measurement location a relatively few times with the period of time between checks varying from one to three weeks (Figure 6.6-1). Shorter intervals between checks occurred due to work on the systems.

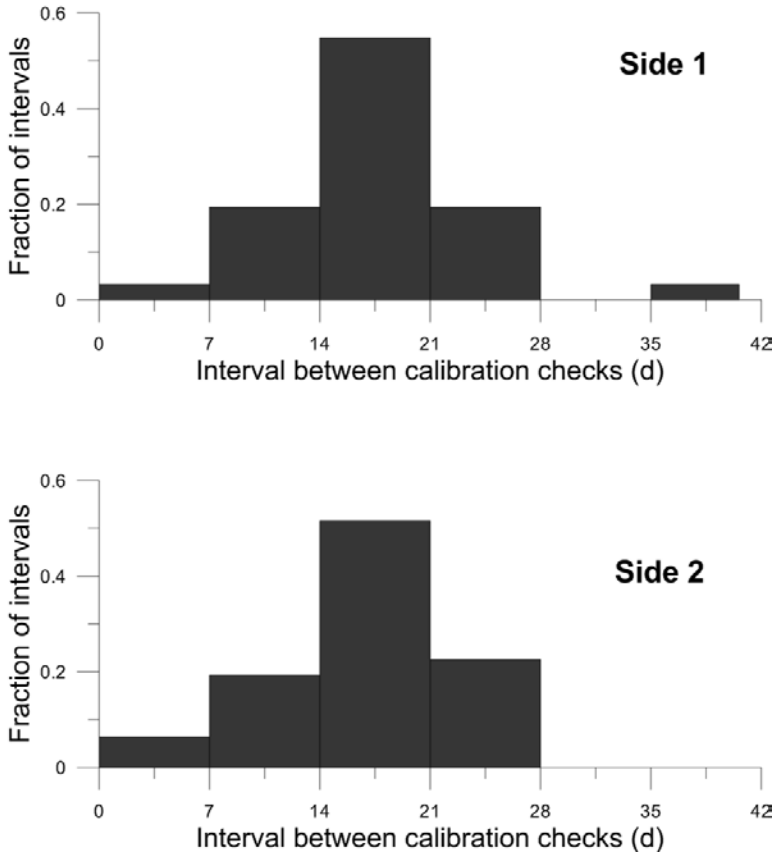


Figure 6.6-1: Intervals between checks

6.7 Miscellaneous meteorological and lagoon calibrations

6.7.1 Air temperature/ humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n 4410015

Relative humidity (RH)					
Calibration date	**Expected RH (%)**	**Measured RH (%)**	**Deviation from expected RH (%)**	**Average deviation RH (%)**	**Action**
2/17/2010	21	19	2		
	50	48	2		
	98	94	4		
				3	Accept
9/18/2009	11	20	-9		
	50	50	0		
	98	85	13		
				7	Adjust
	11	11	0		
	98	95	3		
	50	37	13		
	11	11	0		
	50	42	8		
				5	Accept
3/26/2009	23	20	3	3	Pass

Temperature (T)					
Calibration date	**Expected T (°C)**	**Measured T (°C)**	**Deviation from expected T (°C)**		**Action**
2/17/2010	24.3	24.5	-0.1		Pass
9/18/2009	26.5	26.9	-0.4		Pass
3/26/2009	24.9	24.9	0.0		Pass

6.7.2 Barometric pressure

An aneroid barometer (Model 278, Setra Inc., Boxborough, MA) with serial number 3033740 was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278, s/n 3033740

Calibration date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
2/11-12/2010	998.6-992.5	5	1.5	Pass
9/16-17/2009	997.5-1000.1	6	0.9	Pass
3/24-25/2009	986.0-992.0	6	1.4	Pass
7/9-11/2008	993.1-996.8	6	1.5	Pass
1/3-4/2008	1018.4-1001.7	6	2.5	Pass

6.7.3 Solar radiation

A pyranometer (Model 200SB, LiCOR Inc., Lincoln, NE) was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-3.

Table 6.7-3: Calibration record of LyCOR 200SB Pyranometer, s/n PY55449

Calibration date	Mean difference from reference (Wm^{-1})	Mean difference from reference (%)	Action
3/5/2010	4.84	0.91	Retry
3/6/2010	1.40	0.37	Pass
8/30/2006			Factory calibration

6.7.4 Lagoon water temperature

A thermistor (Model 107-L Campbell Scientific Inc., Logan, UT) was used to measure lagoon temperature. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. Three thermistor probes were used at this location. The record of calibration checks are documented in Table 6.7-4.

Table 6.7-4: Calibration record of thermistor CSI 107-L

Calibration date	Expected value (°C)	Difference from expected (°C)	Action
Thermistor CSI 107-L, s/n 0020 (8888)			
6/18/2007	25.0	0.3	Accept
6/18/2007	24.5	0.4	Accept
6/18/2007	24.0	0.6	Accept
Thermistor CSI 107-L, s/n 0040			
6/18/2007	25.0	0.5	Accept
6/18/2007	24.5	0.7	Accept
6/18/2007	24.0	0.6	Accept
Thermistor CSI 107-L, s/n I			
2/15/2010	1.1	1.2	Accept
2/15/2010	35.7	2.9	Accept
9/14/2009	0.1	0.0	Pass
3/27/2009	-0.1	0.0	Pass

6.7.5 Sludge gun

The Marklin 20176 Sludge gun was used to measure sludge depth in the lagoon. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-5.

Table 6.7-5: Calibration record of Marklin sludge un s/n 20176C

Calibration date	Mean (mm)	Standard deviation (mm)	Accuracy (mm)	Action
2/26/2010	69.70	0.51	1.70	Action
3/24/2009	78.11	1.05	-0.11	Action
7/23/2008	75.38	0.51	1.10	Action
1/4/2008	39.67	2.06	0.67	Action
3/23/2007	81.56	0.73	1.56	Action

6.7.6 CR1000 data logger

The CR1000 data logger (Campbell Scientific Inc., Logan, UT) was used to log all lagoon measurements (pH, oxidation-reduction potential, and temperature) and air temperature, relative humidity, barometric pressure, and wetness. Calibration check of this unit was conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-6.

Table 6.7-6: Calibration record of Campbell Scientific CR1000 data logger s/n 7677

Factory calibration						
Calibration date: 1/18/2007			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance (mV)**	**Measured mV**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
13	5000	± 3	5000.48	-0.48	5001.02	-1.02
13	-5000	± 3	-5001.56	-1.56	-5001.02	-1.02
13	2500	± 1.5	—	—	2500.34	-0.34
13	250	± 0.15	—	—	250.042	-0.042
13	25	± 0.015	—	—	25.004	-0.004
13	7.5	± 0.0045	—	—	7.49724	0.00276
13	2.5	± 0.0015	—	—	2.49923	0.00077
13	-2.5	± 0.0015	—	—	-2.49906	0.00094
13	5000	± 6	4999.31	1.31	4998.64	2.64
13	5000	± 6	5000.58	-0.58	5001.02	-1.02
13	5000	± 6	—	—	—	—
13	5000	± 6	—	—	—	—

PAML calibration						
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
SE Channel	**Input (mV)**	**Tolerance SE|DE (mV)**	**Measured mV mean value**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	4950	±6.96| 4.97	4951.7	-1.7	—	—
2	4950	±6.96| 4.97	4951.7	-1.7	—	—
3	4950	±6.96| 4.97	4951.7	-1.7	—	—
4	4950	±6.96| 4.97	4951.7	-1.7	—	—
5	4950	±6.96| 4.97	4951.7	-1.7	—	—
6	4950	±6.96| 4.97	4951.7	-1.7	—	—
7	4950	±6.96| 4.97	4951.7	-1.7	—	—
8	4950	±6.96| 4.97	4951.7	-1.7	—	—
9	4950	±6.96| 4.97	4951.7	-1.7	—	—
10	4950	±6.96| 4.97	4951.7	-1.7	—	—
12	4950	±6.96| 4.97	4951.7	-1.7	—	—
13	4950	±6.96| 4.97	4951.7	-1.7	—	—

PAML calibration						
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
SE Channel	**Input (mV)**	**Tolerance SE|DE (mV)**	**Measured mV mean value**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
14	4950	±6.96| 4.97	4951.7	-1.7	—	—
15	4950	±6.96| 4.97	4951.7	-1.7	—	—
16	4950	±6.96| 4.97	4951.7	-1.7	—	—

Calibration date: 3/10/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.06 | 1.06	99.37	0.63	—	—
2	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
3	100	± 2.06 | 1.06	99.37	0.63	—	—
4	100	± 2.06 | 1.06	99.37	0.63	—	—
5	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
6	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
7	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
8	100	± 2.06 | 1.06	99.37	0.63	99.71	0.29
9	100	± 2.06 | 1.06	99.37	0.63	—	—
10	100	± 2.06 | 1.06	99.37	0.63	—	—
11	100	± 2.06 | 1.06	99.37	0.63	—	—
12	100	± 2.06 | 1.06	99.37	0.63	—	—
13	100	± 2.06 | 1.06	99.37	0.63	—	—
14	100	± 2.06 | 1.06	99.37	0.63	—	—
15	100	± 2.06 | 1.06	99.37	0.63	—	—
16	100	± 2.06 | 1.06	99.37	0.63	—	—
Calibration date: 3/10/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.06 | 1.06	0	0	—	
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0	—	—
4	0	± 2.06 | 1.06	0	0	—	—
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0	—	—

Calibration date: 3/10/2010			**Single-ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
10	0	± 2.06 | 1.06	0	0	—	—
11	0	± 2.06 | 1.06	0	0	—	—
12	0	± 2.06 | 1.06	0	0	—	—
13	0	± 2.06 | 1.06	0	0	—	—
14	0	± 2.06 | 1.06	0	0	—	—
15	0	± 2.06 | 1.06	0	0	—	—
16	0	± 2.06 | 1.06	0	0	—	—

6.7.7 CR800 data logger

The CR800 data logger (Campbell Scientific Inc., Logan, UT) was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). A calibration check of this unit was conducted only at end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-7.

Table 6.7-7: Calibration record of Campbell Scientific CR800 data logger s/n 3698

Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.061	99.23	0.77
2	100	± 2.061	99.23	0.77
3	100	± 2.061	99.23	0.77
4	100	± 2.061	99.23	0.77
5	100	± 2.061	99.23	0.77
6	100	± 2.061	99.23	0.77
Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.061	0	0
2	0	± 2.061	0	0
3	0	± 2.061	0	0
4	0	± 2.061	0	0
5	0	± 2.061	0	0
6	0	± 2.061	0	0

6.8 Site Activity

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
6/24/2007	22:18-22:57	Calibration	Calibration verification of TDLAS 1029; instrument passes, 1031 fails with RSD 8.5%; still working on proper procedure
6/27/2007		Setup	Retro-reflectors mounted and prepped with plastic, holes, and back plates. Sonic anemometers tested and mounted. Electrical finished (except for missing outlet on met trailer).
6/27/2007		Setup	No DSL internet communication established (No means to remotely check operations)
6/27/2007	23:00-23:10; 21:40-22:40	Setup	Zero and Inter-comparison Sonic Anemometers, instruments pass
6/27/2007	22:27	Setup	Calibrate Barometer, instrument passes
6/27/2007	1:48	Setup	Calibrate ORP Sensor, instrument passes
6/27/2007	0:29	Setup	Calibrate pH sensor, instrument passes
6/27/2007		Setup	Lagoon temperature Check
6/28/2007		Setup	Tower height measurements taken. ORP and pH probe caps empty when placed into lagoon for measurements (no KCL solution)
6/28/2007	15:50; 15:38	Setup	Calibration verification of TDLAS 1029, 1031; instruments fail; still working on proper procedure
7/9/2007		Repair	Calibrate TDLAS 1031
7/9/2007		Repair	TDLAS's have light values below 2000 for retro-reflectors 1-2 & 4-8/TDLAS 1031. 1-4 & 6-10/ TDLAS 1029. Retro-reflectors 3, 9-10/ TDLAS 1031 and 5/ TDLAS 1029 have Light levels just above 2000.
7/9/2007		Repair	Checked all retro-reflectors; all seemed to be in good shape/not damaged except 1/1029 where condensation was found inside retro-reflector box. Opened up retro-reflector box to dry out and lined up and ran again.
7/9/2007		Repair	Meteorological data was not logged between 7/2/2007 and 7/9/2007. Power outlet used for met. tower is same as output used for retro-reflector 1 of TDLAS 1029. Thought power outlet was bad, but power is running though outlet. *Loggernet* program, running meteorological/lagoon measurements, was closed on LAN computer. Restarted program and data started to flow again.
7/18/2007		Repair	Installed DSL internet modem (dynamic dns) Reset optimization to every 6 h. Scanner not responding each time when sending pan/tilt commands from *GasView MP* program to realign scanner with retro-reflectors. Tried stopping scan, closing then reopening pan-tilt unit in *GasView MP* program. Now scanner will not respond at all, gives "Pan-Tilt Error" message. Called Boreal Laser. Viewed pan-tilt data in *GasView MP* program (none was showing when sending pan-tilt commands). Tried unplugging scanner and plugging it back in; started correctly but still giving "pan-tilt"

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
			error. Checked to see if optimization changes affected scanner, but when resetting to original optimization time, still gave same error.
7/18/2007		Repair	Scanners still reading "Pan-Tilt" error this morning. Turned off scanner modem inside trailer, closed pan-tilt unit in *GasView MP* program, turned modem back on, and opened pan-tilt unit in *GasView MP* program. This worked successfully.
7/19/2007		Repair	Retro-reflectors with condensation include: TDLAS 1031 retro-reflector 1 & 5, and TDLAS 1029 retro-reflector 1 & 6. Dried condensation in retro-reflectors and sealed with duct seal around windows. When opened retro-reflector doors, water poured out. Assumed most likely a leak where rain was able to drain in.
7/30/2007		Repair	Sealed retro-reflector windows (on ground) with silicone seal/caulk. Retro-reflectors with water on previous trip have no water after using duct electronic seal Lagoon is starting to crust over-- may indicate dry weather recently.
7/30/2007		Repair	No functioning internet DSL communications. Communications lost when Purdue changed parameters (from dynamic dns to fixed dns) with DSL provider without asking us. Automatic updating of DSL modem by provider did not happen due to trailer location being outside provider's service range (roving).
7/31/2007	20:15-21:15	Setup	Sonic anemometer inter-comparison, instruments pass
7/31/2007		Setup	Sludge depth measurements made but affected by wind.
8/1/2007	14:02-14:17	Setup	Sonic anemometer zero check, instrument passes
8/1/2007	17:07	Setup	ORP Calibration, instrument passes
8/1/2007	16:54	Setup	pH Calibration, instrument passes
8/2/2007	19:03	Setup	Calibration verification of TDLAS 1031: Measurements were too high for zero and calibration verification gas on first trial. Second background also too high, but third gave valid measurements. Second calibration verification gas was not very steady and gave large (invalid) accuracy. Assumed diluter was working improperly, so flowed calibration gas directly into calibration chamber instead of indirectly and thru diluter--gave valid measurements for third trial. Still noticed when fan was running and door was open, concentrations increased and were unstable.
8/1/2007	19:38	Setup	Calibration verification of TDLAS 1029: first background was valid, but calibration verification gas gave an invalid accuracy value. Second background trial was done without diluter and calibration gas flowed directly thru calibration chamber. Gave valid accuracy and calibration values. Port C of TEC 146i diluter gave the invalid readings; port A used and gave valid readings, but still found that if fan was turned on, concentrations would increase and be unstable
8/3/2007		Setup	pH and ORP values did not seem valid. Wiring was switched for both probes; rewired and fixed problem.
8/3/2007		Setup	Installed new *GasView MP* software version

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
8/3/2007		Setup	Drove to Colorado to upgrade internet radio. Worked on laptop in Colorado but not when brought back to site. Need to bring back to Lafayette for upgrade with correct area code.
8/14/2007		Inspection	DSL modem re-installed, operational
8/14/2007	19:25-20:25	Inspection	Sonic anemometer inter-comparisons, instruments fail. Anemometer calibration inter-comparison had to be redone because values were slightly off the first time. Anemometers' boxes switched 1-1928 2-1921 3-1932, instruments pass.
8/14/2007	21:43-21:54	Inspection	Sonic anemometer zero check, instruments pass.
8/14/2007		Inspection	pH Calibration, instrument passes
8/14/2007		Inspection	ORP Calibration, instrument passes
8/14/2007	20:36	Inspection	Calibrate TDLAS 1031: TDLAS calibrations went smoothly; redid calibration gas for 1031 because values took a while to stabilize, instrument passes
8/14/2007	21:17	Inspection	Calibrate TDLAS 1029, instrument passes
8/15/2007		Inspection	Anemometers are mounted and working well.
8/15/2007		Inspection	Scanner 5 retro-reflector 3 distance changed from 1 to 125m
8/15/2007		Inspection	Noted that putting window of sliver tape around nearest retro-reflectors helped with light values.
8/15/2007		Inspection	Connection on failed UPS was loose; made connection improvement and UPS works.
8/15/2007		Inspection	Spiders found in meteorological power box. Added duct/electrical putty to wire inlet to prevent in future.
8/16/2007		Inspection	Sludge depth measurements taken, not calculated; possibly affected by wind
8/28/2007		Takedown	Did TDLAS and sonic anemometer calibrations/acceptance. Sonic anemometers 1 and 3 were giving values greater than 1 ms^{-1} for bias check. Chris closed boxes more tightly which gave values accepting numbers.
8/28/2007	18:20	Takedown	Sonic anemometer inter-comparison, instrument passes
8/28/2007	19:18	Takedown	Calibration verification of TDLAS 1029, instrument passes
8/28/2007	20:29	Takedown	Calibration verification of TDLAS 1031, instrument fails accuracy measurements
8/28/2007	21:15	Takedown	Zero Check Sonic anemometers, instrument passes
8/29/2007		Takedown	Loaded up trailer and got ready to move to OK3A. pH/ORP acceptance passed
8/29/2007		Takedown	Calibrate pH probe, instrument passes
8/29/2007		Takedown	Calibrate ORP probe, instrument passes
8/30/2007		Takedown	Calibrate pH probe
11/7/2007		Setup	Could not perform barometer audit because it was sent to manufacturer for repair and has not been installed.
11/7/2007		Setup	Too windy to perform sludge depth measurements.
11/7/2007		Setup	Measured chemicals for QCCS and KCl solutions.
11/7/2007		Setup	Mounted retro-reflectors and installed anemometers. Could not install anemometer 2 because threads were not working properly. Need to take to hardware store to fix.
11/7/2007		Setup	Calibrate Wetness Sensor

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
11/8/2007		Setup	Too windy to perform sludge depth measurements in morning. Measurements done in afternoon.
11/8/2007		Setup	Broken head on tripod.
11/8/2007		Setup	Fixed bolt on SE tower.
11/8/2007		Setup	Mounted sonic anemometer 2 and swapped antennas on units 5 and 6 due to orientation.
11/8/2007		Setup	Calibrate pH probe
11/8/2007		Setup	Calibrate ORP probes
11/8/2007		Setup	Take sludge depth measurements
11/9/2007	16:40	Remote	Check out sonic anemometer program after call from Chris indicating it had crashed. Logged onto LAN
11/9/2007	16:40	Remote	Check out sonic anemometer program. Crashed at second line in initial summing routine (subscript out of range). Counter=4001. Crashed around 1540Z. Messed up time stamps in 300-s data around this time
11/12/2007		Remote	Re-aim one path on TDLAS and change parameters. Logged onto LAN, TDLAS 1 (1029), and TDLAS 2 (1031)
11/12/2007		Remote	TDLAS 2 (192.168.0.102). TDLAS (1032) path 8 not aligned. Changed obstruction level from 500 to 100. Both TDLAS's now working.
11/16/2007		Remote	Check status and modify *GasView MP* parameters
11/16/2007		Remote	Changed timeout from 3600 s to 900 s on both TDLAS's. At 1445Z, observed "xxxx" on TDLAS 2 (1032) while on path 2 (during optimization). It eventually corrected itself.
11/27/2007		Calibration	Blew off (with dust remover spray) the temp/RH filter. It's still dirty and needs to be cleaned.
11/27/2007		Calibration	Another bolt on SE tower loose. Will fix tomorrow.
11/27/2007		Calibration	Could not get stable measurements for TDLAS 1032 tests 1 and 2.
11/27/2007		Calibration	Could not check barometer; sent back to manufacturer for repair.
11/27/2007	16:55-17:55	Calibration	Inter-comparison calibration for sonic anemometers
11/27/2007	18:43	Calibration	Zero calibrate sonic anemometers
11/27/2007	20:41	Calibration	Calibrate TDLAS 1029
11/27/2007	21:19	Calibration	Calibrate TDLAS 1032
11/27/2007	21:19	Calibration	Could not get stable measurements for calibration gas tests #1 and 2.
11/28/2007		Calibration	Calibrate pH
11/28/2007		Calibration	Calibrate radiation (noted on open site notes but no record found)
11/28/2007		Calibration	Calibrate ORP probe
11/28/2007		Calibration	Calibrate wetness sensor
11/28/2007		Calibration	Tightened bolt on SE tower that was loose
11/28/2007		Calibration	Installed probe float. pH and ORP were reading valid measurements; temp probe was reading between 20C and 83C. Removed probe float and unwired temp. pH probe and temp probe started reading "NAN" in *Loggernet* at same time. Checked pH probe with pH 7 solution. Read 5mV (7.08 pH units). Reinstalled/wired pH probe; still NAN in *Loggernet* in

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
			lagoon. Checked temp probe resistance at room temp. Read about 1000 olms. Returning temp. probe to office. Noticed nicks in temp proble cables. Worsened on sharp rocks in lagoon berm bank when installed probe float in lagoon. Temp probe was working properly before launched. Other probes (pH/ORP) have small nicks but nothing through the casing. pH and ORP wire casings have a heavier rubber.
11/28/2007		Calibration	Status LED light on CRM100 showing orange. Tried to restart data logger and remove/reinstall memory card to no success. Looked at CFM100 manual to find meaning for orange status LED light. Manual said it only signified an error. Overall removed lagoon probe float 3 times for testing/difficulties.
11/28/2007		Calibration	Calibrate wetness sensor
12/18/2007		Takedown	Too windy to perform sludge depth measurements.
12/18/2007		Takedown	Tightened bolts on NW tower.
12/18/2007		Takedown	Communications with data logger were not working properly. Tried adjusting position of NEMA box and antenna--still not working. Memory card contained no data. Will bring met tower closer to trailer tomorrow to establish communication (West laptop no longer has *Loggernet* to download from data logger).
12/18/2007	18:05-19:05	Takedown	Sonic anemometer inter-comparison
12/18/2007	19:31	Takedown	Zero Calibrate Sonic anemometers
12/18/2007	20:40	Takedown	Calibrate TDLAS 1032
12/18/2007	20:40	Takedown	TDLAS 2 was not aligned-was aimed 45 degrees to the right
12/19/2007		Takedown	Calibrate pH probe
12/19/2007		Takedown	Calibrate ORP probes
12/19/2007		Takedown	Calibrate wetness sensor
12/19/2007		Takedown	1. Too windy to perform sludge depth measurements. 2. Moved met. Tower near trailer to download data on LAN. Data from met station is on CD. Could not append data file. 3. Packed trailer. 4. Truck oil change, topped fluids. 5. Made new Zobells. 5. Used distilled water in pH and ORP caps--will change solution in lab.
4/23/2008		Setup	While performing 2nd background calibration on TDLAS 1032, TDLAS kept losing connection to Panasonic; checked wire connections but still showed communication problems.
4/23/2008		Setup	Tied down trailer; powered up trailer, and started sonic anemometer inter-comparison before storms hit.
4/23/2008		Setup	Inter-comparison was performed during storm with mean wind speeds greater than 11.5 ms^{-1}. Inter-comparison did not pass (most likely due to high wind speeds). Will run sonic anemometer program overnight and calculate inter-comparison in the morning.
4/23/2008		Setup	Calibrated TDLAS 1032 – Mean: 50.83 - SD: 0.18 - RSD: 0.4% - Bias: 2.1% - Notes: Could not get it to completely zero, but r^2 values were below 84% (~40-55). Directly hooked up, lost connection during second background calibration.

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
4/23/2008	20:41-20:46	Setup	Calibrated TDLAS 1026 − Mean: 52.76 - SD: 0.57 - RSD: 1.0% - Bias -1.2%
4/23/2008	20:45-21:45	Setup	Sonic anemometer inter-comparison: All pass. Notes: Storm was approaching and sonic anemometer 2 stopped working (gave values of zero) before an hour of measurements were taken. Water may have gotten into the sonic anemometer; will still mount sonic anemometer for measurement period (values for half hour of inter-comparison passed); saw this problem before and it usually dries within a day approx. Will perform full inter-comparison at takedown.
4/24/2008		Setup	Too windy to perform sludge depth measurements.
4/24/2008		Setup	Checked sonic anemometer values to perform inter-comparison after running overnight. Sonic anemometer 2 was giving zero values (could be from rain). Storm was approaching and sonic anemometer 2 stopped working (gave values of zero) before an hour of measurements were taken. Water may have gotten into the sonic anemometer; will still mount sonic anemometer for measurement period (values for half hour of inter-comparison passed); saw this problem before and it usually dries within a day approx. Will perform full inter-comparison at takedown.
4/24/2008		Setup	Made KCl, Zoebell's, and QCCS solutions. pH and ORP probes calibrations and acceptance had invalid values. Changed reference solution, cleaned probes with soap and water, shook probes about 10 times. Will install probes into lagoon and check readings at end of period.
4/24/2008		Setup	Motherboard on 450i no longer failing.
4/24/2008		Setup	Pulling scanner in SW corner. Grinding/not moving properly. Sent high-power command--still not working. Power-cycled (2x)--worked temporarily, then started grinding/shaking again.
4/24/2008		Setup	Checked battery on CR800 with mulitmeter voltage--read the same values.
4/24/2008		Setup	Site setup map included with site notes.
4/24/2008		Setup	Wetness sensor calibration: accepted.
4/24/2008		Setup	ORP Calibration: pass
4/24/2008		Setup	pH Calibration: pass
4/24/2008		Setup	S-OPS Installation map made.
4/24/2008	14:13	Setup	Zero sonic anemometer calibration: all pass. Note: Sonic anemometer 2 started working when taken down from inter-comparison mount.
4/24/2008	14:35-15:35	Setup	Sonic anemometer inter-comparison: All pass. Notes: Second trial after sonic anemometer 2 stopped giving zero values--successful.
4/24/2008	16:04	Setup	Barometer audit: accepted.
4/25/2008	14:00	Remote	Daily Status Check from PAML− Notes: Seeing some sonic anemometer flagged points in all three sonic anemometers. pH is about 8.7. Closed log file for TDLAS 2 since unit is not present (bad scanner). Updated *rsync* for new site and transferred data.

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
4/25/2008	14:00	Remote	Daily Status Check from PAML − Notes: No H_2S motherboard failures. There were failures before takedown at TX5A but not during setup at OK4A.
4/29/2008	13:47	Remote	Daily Status Check from PAML − Notes: Lagoon temperature jumped about 5°C but is currently back to where it was previously. Will monitor temperature carefully
4/30/2008	12:30	Remote	Daily Status Check from PAML − Notes: Lagoon temperature jumped around the same time it did previous day. Currently the temperature is back to normal.
5/1/2008	12:23	Remote	Daily Status Check from PAML − Notes: TDLAS 2 not present due to scanner issues.
5/2/2008	14:00	Remote	Daily Status Check from PAML − Notes: Temp/ORP spikes at same time but return to normal.
5/2/2008	12:30	Remote	Daily Status Check from PAML − Notes: pH around 9. Firewall turned off. More than a week since last backup. Not enough space to perform backup. Enabled Windows Firewall for all network connections.
5/5/2008	12:30	Remote	Daily Status Check from PAML. Notes: pH around 9.0. Issues with alignment on retro-reflectors 3 and 4 on TDLAS 1. Minor issues intermittently with TDLAS1 calibration worksheet graphs. Reference r^2 sometimes drops; CDC sometimes drops. TDLAS 2 not present due to scanner failure. Firewall turned off. More than a week since last backup. Not enough space to perform backup. Enabled Windows firewall for all network connections.
5/6/2008		Takedown	Too windy to perform sludge depth measurements.
5/6/2008		Takedown	UPS switched to battery power at 1:13:43 and AC restored message was sent at 1:13:48.
5/6/2008		Takedown	Only calibrated TDLAS 1032 because 1026 was not used this measurement period.
5/6/2008		Takedown	Checked retro-reflectors for TDLAS 1032; looked clean and facing at good angle.
5/6/2008		Takedown	Performed pH/ORP calibrations. ORP values were reasonable. pH values not acceptable but will replace current 1M KCl solution with 3.5 M KCl solution before installing in OK3A.
5/6/2008		Takedown	Packed up trailer and moved to OK3A.
5/6/2008		Takedown	GSS Leak Test: pass
5/6/2008		Takedown	S-OPS inlet flow verification: Fail
5/6/2008		Takedown	ORP Calibration: pass
5/6/2008		Takedown	pH calibration: Fail Note: Will make new KCl solution.
5/6/2008	17:45-18:45	Takedown	Sonic anemometer inter-comparison: Pass
5/6/2008	18:31	Takedown	Calibrated TDLAS 1032 − Mean: 53.4 - SD: 0.64 - RSD: 1.2% - Bias: 7.1% - Notes: During first background, distance was set to 66 meters, but values were zero during background period. Changed path distance to 1 meter by multiplying concentration column by 66 to achieve PIC during background.
5/6/2008	18:45	Takedown	Barometer audit: accepted.
5/6/2008	18:59	Takedown	Wetness sensor calibration: accepted.

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
5/6/2008	19:09-19:29	Takedown	TEC 450i Instrument Operating Parameters
5/6/2008	19:09-19:29	Takedown	TEC 450i Calibration Verification Check
5/6/2008	19:36	Takedown	Sonic anemometer zero calibration: Pass
10/1/2008		Setup	Made QCCS, KCl, and Zobells solutions
10/1/2008		Setup	Barometer reading high when manually taking voltage reading, but values in *Loggernet* program seem accurate (~9.84 kPa); will keep in field/
10/1/2008		Setup	Could not do lagoon probe calibrations due to faulty battery in multimeter (24 V supply shows ~29.5 V on multimeter). Will purchase 9V battery to perform calibrations tomorrow.
10/1/2008		Setup	Zero gas pressure too low to perform H_2S calibration. Had regulator turned off (zero off), but gas must have leaked out (tank pressure now 0.0 psi).
10/1/2008		Setup	Lagoon site layout made
10/1/2008	14:50-15:50	Setup	Sonic anemometer inter-comparison: all pass.
10/1/2008	15:40	Setup	Wetness sensor calibration: accepted.
10/1/2008	16:28	Setup	Zero sonic anemometer calibration
10/1/2008	18:42	Setup	Calibrated TDLAS 1028
10/1/2008	19:20	Setup	Calibrated TDLAS 1027
10/2/2008		Setup	There are only two calibration files for the H_2S /SO_2 calibration. They are both saved in the H_2S control chart.
10/2/2008		Setup	Had to restart sonic anemometer program in order to start *iPort*.
10/2/2008		Setup	pH probe was not replaced during six months calibrations. Current probe is stable but reading ~30-40 mV lower than expected. Still launched probe but need to bring new probe during next visit.
10/2/2008		Setup	Refrigerator does not seem to be working so Zobell's solution may not be good during next visit.
10/2/2008		Setup	Maintenance list completed.
10/2/2008		Setup	pH sensor acceptance and stability Notes: Did not bring new probe; passed stability but not acceptance; will still launch probe but will bring new one during next visit.
10/2/2008		Setup	TEC 450i Calibration Verification Check − See Control Chart for details.
10/2/2008		Setup	GSS Leak Test: pass
10/2/2008		Setup	GSS No Flow Test
10/2/2008		Setup	GSS Max Flow Test
10/2/2008		Setup	S-OPS Max Flow Test
10/2/2008		Setup	S-OPS/GSS Leak Test: Fail
10/2/2008	14:26	Setup	Barometer audit: accepted.
10/2/2008	14:45	Setup	ORP Calibration: pass
10/2/2008	14:53	Setup	TEC 450i Instrument Operating Parameters
10/2/2008	14:55	Setup	pH quality assurance. Notes: Did not bring new probes and did not pass; will still launch (passed stability), but will bring new probe next time.
10/2/2008	15:11	Setup	TEC 450i Reference Precision Check

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
10/2/2008	16:21	Setup	SO_2 calibration
10/2/2008	17:15	Setup	Launched lagoon probes.
10/2/2008	19:30	Setup	Started GSS.
10/3/2008	12:50	Remote	Daily Status Check from PAML − Notes: Five "backup" files were present in GSS data. Merged all these into the file CR800_OK4A_20081001.dat and deleted to neaten up directory. CR 1000 file contained all data from preceding period (WA5A P6). Saved a backup of this file and removed this data. Sonic anemometer 1 had up to 370 flagged points around 641.81. All three sonic anemometers had 1 point at 642.017 with about 9500 data points (missed a time; made up for low values during previous two periods). H_2S sample flow is 0.96 LPM.
10/6/2008	12:07	Remote	Daily Status Check from PAML − Notes: Lots of flagged data on sonic anemometer 1 on day 644. TDLAS QC program has crashed. Innova flag 16. Rain and fog has caused loss of many paths on both TDLAS's.
10/7/2008	12:30	Remote	Daily Status Check from PAML - Notes: TDLAS 1 and 2 had retro-reflectors that were not aligned, most likely due to high winds. Was able to find all paths, but when running TDLAS 1 scanner could not find paths 6, 7, and 8. Tried re-aiming multiple times and paths were still not found while program was running (when aiming, scanner was only off about one step from finding valid light level). Will let program run awhile and will check on again later today. Missing data for sonic anemometer one between 643.7 and 645.2; w values not averaging zero. Sonic anemometers 2 and 3 have same w trend but not as severe. Sonic anemometer 3 spiked about 646.1 but not back to normal with 160 spike points. Innova flag 16.
10/8/2008	12:30	Remote	Daily Status Check from PAML − Notes: TDLAS 1 paths 6 and 7 are still not staying aligned. pH values have increased (jumped up but not a drastic amount. Innova flag 16.
10/14/2008		Takedown	TDLAS 1 *GasView MP* program was frozen and had a pan/tilt error. Scanner did not appear to be moving. TDLAS 2 did not really have any path aligned due to heavy rain. Many of the tripod legs on the ground retro-reflectors were sinking several inches into the ground causing the retro-reflector to tilt a bit (no grass on the berm).
10/14/2008		Takedown	When taking lagoon float, all three lagoon probe wires (pH, ORP, and temperature) were cut in several places by the sharp rocks along the edge of the lagoon. One of the ropes holding the lagoon in place. Cause must have been high winds and large waves on the lagoon pulling the wires back and forth over the sharp rocks.
10/14/2008		Takedown	TEC 450i Calibration Verification Check − See Control Chart for details.
10/14/2008	16:22	Takedown	Barometer audit: accepted.
10/14/2008	16:23	Takedown	Wetness sensor calibration: accepted.
10/14/2008	17:36	Takedown	Calibrated TDLAS 1027

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
10/14/2008	18:15	Takedown	Calibrated TDLAS 1028
10/14/2008	22:33	Takedown	TEC 450i Reference Precision Check
10/14/2008	22:44	Takedown	TEC 450i Instrument Operating Parameters
10/14/2008	23:04	Takedown	SO_2 calibration
10/15/2008		Takedown	Road very muddy last evening. Rain stopped in late evening. Road a little better this morning but still poor in places.
10/15/2008		Takedown	Maintenance list completed.
10/15/2008		Takedown	GSS Leak Test: pass
10/15/2008		Takedown	GSS No Flow Test
10/15/2008		Takedown	GSS Max Flow Test
10/15/2008		Takedown	S-OPS Max Flow Test
10/15/2008		Takedown	S-OPS/GSS Leak Test: Pass
10/15/2008	12:00-13:00	Takedown	Sonic anemometer inter-comparison Notes: Sonic anemometer 2 (1932) is passing values of all 0's with flag 2. May be due to wet weather yesterday.
10/15/2008	16:26	Takedown	Zero sonic anemometer calibration − Notes: Sonic anemometer 2 (1932) not working. Passing all 0's with flag 2.
1/7/2009		Setup	Reached site at 1:15 pm local time. Hooked up trailer with power and tied down.
1/7/2009		Setup	Hooked up trailer with power and tied down.
1/7/2009		Setup	Set up all ground retro-reflectors.
1/7/2009		Setup	There was no NH_3 gas cylinder, so TDLAS calibration could not be done.
1/7/2009		Setup	Too windy to perform sludge depth measurements.
1/7/2009		Setup	Leak in 590 (CGA) zero gas regulator; will take back to PAML.
1/8/2009		Setup	Too windy to perform sludge depth measurements.
1/8/2009		Setup	Not installing lagoon sensors due to possibility of lagoon freezing during measurement period.
1/8/2009		Setup	Could not replace desiccant in NEMA box because airport security found it to be explosive and threw them out; will replace next time.
1/8/2009		Setup	Had PTU/TDLAS system aligned in SW corner (TDLAS 1027, PTU 1315/unit 6, TDLAS 2) and working properly.
1/8/2009		Setup	Tried aligning TDLAS 1028, PTU 1206/unit 5, TDLAS 1, but could not get scanner to move; tried restarting scanner by unplugging to outlet. Plugged back in but no power to modems (performed no initialization).
1/8/2009		Setup	Switched power cords used on SW and NE corners; system on SW still working, but NE corner still without power.
1/8/2009		Setup	Switched power supply/modem boxes (6 now on NE corner). There is power to both modems, but the scanner not moving when sending commands. "Pan-Tilt Link" not sending any data to Panasonic when commands sent. Found heat sink was touching metal post and was brownish/black where contact was made (indicating short in past). Found small post loose inside box touching metal plate (not sure but could cause problems?).
1/8/2009		Setup	Placed scanner from SW corner (1315) on NE corner with box

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
			#6. System working properly.
1/8/2009		Setup	Will bring scanner, power supply, and modem box to PAML for further investigation.
1/8/2009		Setup	Lagoon site layout made
1/8/2009		Setup	Maintenance list completed.
1/8/2009	15:45-16:45	Setup	Sonic anemometer inter-comparison; all pass.
1/8/2009	15:46	Setup	Wetness sensor calibration: accepted.
1/8/2009	17:08	Setup	Zero sonic anemometer calibration; all pass.
1/8/2009	18:30	Setup	Started collecting H_2S data.
1/9/2009	19:10	Remote	Daily Status Check from PAML − Notes: Changed dwell from 0 sec to 15 sec for TDLAS 1 paths 2, 4, 5, 7 and re-aimed slightly. This was causing 0 light level values for these paths. No lagoon probes. (Note: Paper copy is missing. DWS: 2/26/2009)
1/12/2009	14:10	Remote	Daily Status Check from PAML − Notes: TDLAS 2 is not running at site. H_2S sample flow low at 0.8 LPM; steady at this rate. (Note: Paper copy is missing. DWS: 2/26/2009)
1/13/2009	13:40	Remote	Daily Status Check from PAML − Notes: TDLAS 2 is not running at site. H_2S sample flow low at 0.8 LPM; steady at this rate. QC files stop at 20:45 UTC on 1/12/2009 for GSS/ H_2S data. (Note: Paper copy is missing. DWS: 2/26/2009)
1/14/2009	14:00	Remote	Daily Status Check from PAML − Notes: TDLAS 2 is not running at site. H_2S sample flow low at 0.8 LPM; steady at this rate. Difficult to check time synch because of slow internet connection. (Note: Paper copy is missing. DWS: 2/26/2009)
1/15/2009	13:55	Remote	Daily Status Check from PAML − Notes: TDLAS 2 is not running at site. H_2S sample flow low at 0.8 LPM; steady at this rate. (Note: Paper copy is missing. DWS: 2/26/2009)
1/16/2009	14:26	Remote	Daily Status Check from PAML − Notes: H_2S sample flow steady at about 0.8 LPM. No TDLAS 2 at this site.
1/20/2009	14:15	Remote	Daily Status Check from PAML
1/21/2009	13:00	Remote	Daily Status Check from PAML− Notes: TDLAS 2 not present due to scanner issues.
1/22/2009	13:40	Remote	Daily Status Check from PAML - Notes: TDLAS 2 not present due to scanner issues. Approximately 50% of the time, 9 paths are aligned on TDLAS 1 (~96% of the time, 9-10 paths aligned). No lagoon measurements.
1/23/2009	13:20	Remote	Daily Status Check from PAML − Notes: No QC file update. TDLAS 2 is not present due to scanner problems.
1/26/2009	16:15	Remote	Daily Status Check from PAML − Notes: *iPort* error. Stopped sonic anemometer program to restart *iPort* program. Connected to H_2S analyzer. Filled data starting at 15:08 on 1/24/2009. All H_2S QC data is fine through that time. Second data fill starting at 11:19 on 1/26/2009. Had to create a couple new files. Restarted sonic anemometer program. TDLAS 2 is not present due to power supply/scanner issue. No lagoon probes.
1/27/2009		Takedown	Luggage lost which contained the zero gas regulator; cannot perform H_2S 450i calibration. The tank concentration is too high

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
			for 450i to read (i.e. cannot do zero or span calibrations).
1/27/2009		Takedown	UPS giving year as 1970 in records. See open site notes for details.
1/27/2009		Takedown	Special form made showing OK4A period 7 S-OPS tubing extension layout.
1/27/2009		Takedown	Maintenance list completed.
1/27/2009	19:10	Takedown	Sonic anemometer inter-comparison; all pass.
1/27/2009	19:20	Takedown	Calibrated TDLAS 1028
1/27/2009		Takedown	Zero sonic anemometer calibration; all pass.
1/27/2009	20:39	Takedown	Barometer audit: accepted.
1/27/2009	20:40	Takedown	Wetness sensor calibration: accepted.
4/1/2009		Setup	Set up all ground retro-reflectors, tower retro-reflectors, met station (not plugged in), scanners/scanner tripods, and scanner power supply boxes.
4/1/2009	21:25-:21:45	Setup	Sonic anemometer inter-comparison; all pass.
4/1/2009	23:00	Setup	Zero sonic anemometer calibration; all pass.
4/2/2009		Setup	SO_2 regulator still not working properly. It's showing zero (0.0) for tank pressure.
4/2/2009		Setup	Outlet on SW corner not working. Replaced with new outlet.
4/2/2009		Setup	UPS History: 4/2/2009: 10:23:22: UPS switched to battery power. 10:23:22: UPS bypass unavailable. 10:23:26: AC restored message sent to registered clients connected to Load Segment 2.
4/2/2009		Setup	Too windy to perform sludge depth measurements.
4/2/2009		Setup	Maintenance list completed.
4/2/2009		Setup	Lagoon site layout made
4/2/2009		Setup	ORP sensor: calibration and acceptance pass
4/2/2009	15:45	Setup	Calibrated TDLAS 1028
4/2/2009	16:14	Setup	Calibrated TDLAS 1027
4/2/2009	16:15	Setup	Wetness sensor calibration: accepted.
4/2/2009	16:15	Setup	Barometer audit: accepted.
4/2/2009	17:00-17:44	Setup	TEC 450i single point calibrations: pass
4/2/2009	17:15-22:40	Setup	S-OPS/GSS calibrations: all pass
4/2/2009	21:22	Setup	pH sensor: acceptance, calibration, and inspection: all pass
4/3/2009	16:45	Remote	Daily Status Check from PAML − Notes: CR 1000 file was not present. Forced a "collect now" and it caught up.
4/6/2009	13:30	Remote	Daily Status Check from PAML − Notes: Not enough space to perform backup. Deleted all previous backups to make room for new backups. *Microsoft Visual C++* runtime error (program: C:\ProgramFiles\Genie-Soft\GBMPro7\GBM7.exe). Not sure why there was a runtime error. Will check to see if there is a runtime error again tomorrow. Had to realign TDLAS 1 paths 5, 7, and 8. Could not get path 7 realigned. Light level instantly dropped around 14:30 UTC on 4/4/2009. Texas A&M engineering group were on site Wednesday and will check with them to see if retro-reflector got knocked down to the ground or

Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
			if something is blocking it. Also realigned TDLAS 2 paths 7, 9, and 10. See attached TDLAS pan/tilt log sheet. All sonic anemometers w are below zero around same time' shows that perhaps readings are accurate.
4/7/2009	13:00	Remote	Daily Status Check from PAML – Notes: Not enough space to perform backup. Forgot to delete old backups yesterday; deleting today. TDLAS 1 path 7 still not aligned. Texas A&M engineering group were on site Wednesday and will check with them to see status of retro-reflector. TDLAS 1 path 1 was not aligned. When aligning/aiming, path was aligned but moved 3 steps up and 1 step right to achieve better light levels.
4/8/2009	13:30	Remote	Daily Status Check from PAML – Notes: *Microsoft Visual C++* runtime error (program: C:\ProgramFiles\Genie-Soft\GBMPro7\GBM7.exe). "This application has requested the Runtime to terminate it in an unusual way. Please contact the applications support team for more information." In back up summary says that backup completed successfully (despite runtime error). "Backup Started: 4/7/2009 18:10:30" "Backup Ended: 4/8/2009 01:27:06" No hard errors. TDLAS 1 path 7 still not found. Al from TX A&M was on site today and tomorrow and will contact us about retro-reflector status. Later: Al called and said retro-reflector tripod looked as if it had been knocked a little out of whack (wind? vehicle?); the ratchet strap was loose as well. Al moved tripod upright and tightened strap. Al said one leg looked like it had been moved--the other two looked stationary. Sonic anemometer u,v, w, and T graphs did not look normal around 829.3715972 (sonic anemometer 1), 829.371856 (sonic anemometer 2), and 829.3715972 (sonic anemometer 3). Temperatures were not in agreement (Sonic anemometer 1: 277.24735K; sonic anemometer 2: 280.94117K; sonic anemometer 3: 284.95057K). Will monitor.
4/9/2009	13:00	Remote	Daily Status Check from PAML – Notes: Not enough space to perform backup. Deleted all previous backups to make room for new backups. Changed pan/tilt options specs for minimum acceptable light levels from 1000 to 2000 to see if it will improve fraction of time with all ten paths aligned; saved new setups (backup and running). Flag 4 in H_2S data.
4/10/2009	17:00	Remote	Daily Status Check from PAML– Notes: Realigned TDLAS 1 paths 7 and 8. See report for details. Changed TDLAS minimum acceptable light levels from 2000 to 1000 to prevent excessive optimization. Data file not up to date, so after remote login, forced data shipment. Very windy conditions, this period will lead to loss of *RPM* data.
4/13/2009	13:40	Remote	Daily Status Check from PAML – Notes: Re-aimed path 2 on TDLAS 2. Tried to re-aim path 7 on TDLAS 1 but could not find it. Average w on sonic anemometers 1 and 3 is -0.2 ms^{-1}. Some flagging on sonic anemometer 3 on day 833.
4/14/2009	13:20	Remote	Daily Status Check from PAML– Notes: Cannot remotely

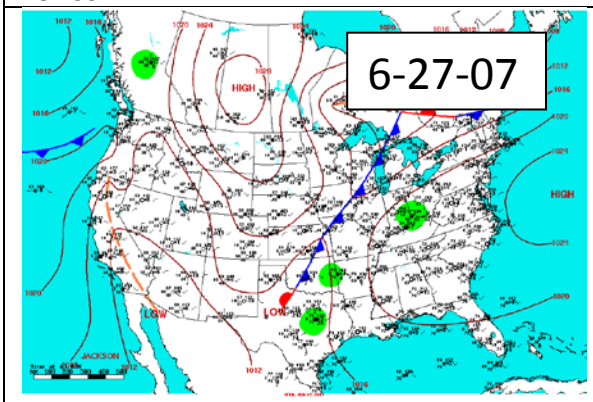
Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
			connect to site. No QC data since 4/13/2009.
4/17/2009	12:30	Remote	Daily Status Check from PAML − Notes: TDLAS 1 paths 7 and 9 were off. Path 9 needed to be moved up 10 steps and 10 steps to the right. Cannot get path 7 aligned; may be on the ground or knocked way out of place. We're heading to this site on 4/21/2009; engineering group will not be on the site to fix it. TDLAS 2 path 1 not aligned; moved 15 steps right and 15 steps down to re-aim.
4/20/2009	12:25	Remote	Daily Status Check from PAML − Notes: Re-aimed path 1 on TDLAS 1; all paths are now aligned. H_2S sample flow is low but steady at 0.85 LPM.
4/21/2009		Takedown	On arrival found the lagoon water level to be low; the probe float was almost submerged beneath the sludge.
4/21/2009		Takedown	When calibrating pH and ORP probes found small rocks were stuck inside near the glass bulb. The bulb seems to be broken. pH failed calibration; changed the reference solution, but it still failed.
4/21/2009		Takedown	Maintenance list completed.
4/21/2009		Takedown	ORP sensor: calibration and acceptance pass
4/21/2009	17:15-18:15	Takedown	Sonic anemometer inter-comparison; all pass.
4/21/2009	17:40	Takedown	pH sensor: acceptance, calibration, and inspection: Calibration fails.
4/21/2009	19:15	Takedown	S-OPS/GSS calibrations: all pass
4/21/2009	20:40	Takedown	Calibrated TDLAS 1028
4/21/2009	21:00-21:43	Takedown	TEC 450i single point calibrations: pass
4/21/2009	21:18	Takedown	Zero sonic anemometer calibrations; all pass.
6/23/2009		Setup	Set up all outside equipment except putting sonic anemometers on tower and aligning the TDLAS units.
6/23/2009		Setup	Cannot find the 900 Mhz; Dr. Grant will bring new one on Thursday. Will calibrate sonic anemometers on Thursday (6/25/2009).
6/23/2009		Setup	Did not finish S-OPS/GSS leak test on north side of lagoon. Changed all inlet filters. Found a leak but did not have enough time to find its location. Will continue tomorrow.
6/23/2009		Setup	Too windy to perform sludge depth measurements.
6/23/2009	20:45-16:15 (6/24/2009)	Setup	GSS/S-OPS calibrations − Notes: Could not completely plug a leak. S-OPS extension-to-inlet connection was cut through at connector. Inlet #10 holder threads were stripped. Changed the filter holder, but kept the old filter (clean enough) to keep the inlets balanced.
6/24/2009		Setup	Finished S-OPS/GSS calibration. Connection at S-OPS/extension tubing was clamped off at the connector. Inlet #10 holder stripped, replaced with new holder. Kept same filter so inlets would be balanced.
6/24/2009		Setup	Burned missing/corrupted data from OK3A period 8 onto a new disc.
6/24/2009		Setup	Changed pump on TEC 450i pump bladder after performing a

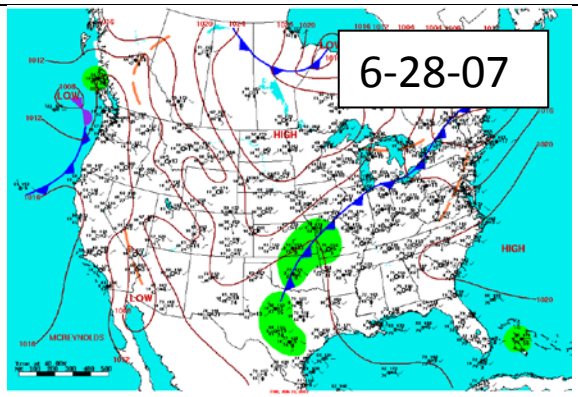
Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
			leak test that failed. Flow increased to ~0.956 LPM. Performed new calibration and multipoint calibration.
6/24/2009		Setup	Performed NH_3 inter-comparison with TDLAS 1029 – OLD: bias= -3.64% - NEW: bias=-3.98%
6/24/2009		Setup	UPS history: 6/23/2009 16:18:25: Communication with UPS restored. 16:21:49: UPS output power has been restored to Load Segment 1. 16:21:53: UPS output power has been restored to Load Segment 2.
6/24/2009		Setup	Too windy to perform sludge depth measurements.
6/24/2009		Setup	Maintenance list completed.
6/24/2009		Setup	Lagoon site layout made
6/24/2009		Setup	ORP sensor: calibration and acceptance pass
6/24/2009	15:00	Setup	pH probe: QA, calibration, and inspection completed.
6/24/2009	16:06-16:52	Setup	TEC 450i leak test: failed. Changed pump bladder; will perform new calibration.
6/24/2009	16:31	Setup	Wetness sensor calibration: accepted.
6/24/2009	16:35	Setup	Barometer audit: accepted.
6/24/2009	18:26-19:09	Setup	Performed TEC 450i single point calibrations: pass. Notes: Actual single point calibration performed during multipoint calibration. New leak test performed: Passed.
6/24/2009	18:36-19:40	Setup	TEC 450i multipoint calibration
6/24/2009	20:20-20:51	Setup	Calibrated TDLAS 1029
6/24/2009	21:01-21:18	Setup	Calibrated TDLAS 1028
6/25/2009		Setup	EPA officials audited the site today.
6/25/2009		Setup	Changed AC filter. Noticed old filter was not dirty at all because it was the wrong size.
6/25/2009		Setup	Too windy to perform sludge depth measurements.
6/29/2009	13:30	Remote	Daily Status Check from PAML – Notes: Error message upon login: "Not enough space to perform backup." No TDLAS QC because the data did not ship due to AutoCopy not being edited correctly; will try again tomorrow. No Innova at site.
6/30/2009	12:30	Remote	Daily Status Check from PAML – Notes: TDLAS 1 paths 1, 3, and 9 were not aligned; moved each path about up ten steps and to the right ten steps to get all the paths aligned. Cannot aligned TDLAS 2 path 7. Had problems with path 7 last time at this site as well. Ground under retro-reflector is very unstable, and strong winds and rain were detected at this site last night. Technician from TX A&M were on site Friday to check the status of this retro-reflector. Will still continue to monitor path and occasionally attempt to re-aim the path. No Innova at site. TDLAS 2 CDC occasionally drops about 40 points then comes back to normal levels.
7/1/2009	12:30	Remote	Daily Status Check from PAML – Notes: Error message upon login: "Not enough space to perform backup." Deleted previous

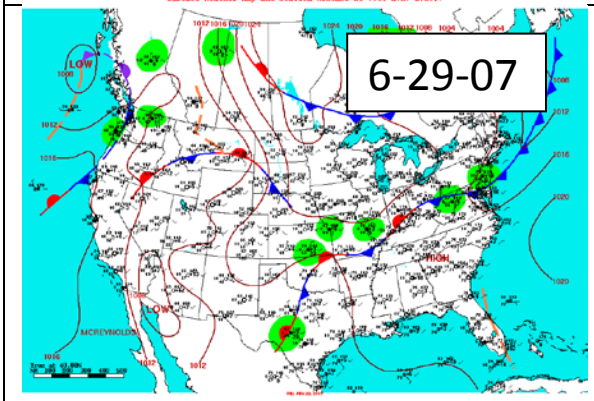
Date (mm/dd/yyyy)	Time (HH:MM)	Activity (setup, takedown, calibration, repair, remote)	Event
			backups to make room for a new backup. TDLAS 2 path 7 is still not aligned. Barn technician from TX A&M will check retro-reflector for us on Friday (7/3/2009) to if it is on the ground or dismounted/moved.
7/6/2009	12:56	Remote	Daily Status Check from PAML − Notes: Not enough space to perform backups. Deleted all necessary files.
7/7/2009	12:15	Remote	Daily Status Check from PAML − Notes: "*iPort* has encountered an error and needs to close…." Stopped sonic anemometer program, filled missing data, started new data file, and restarted the sonic anemometer program. Last H_2S data point was at 13:49 UTC 7/6/2009; filled missing data from 13:30 UTC to present. File name: FillOK4A450I0707091229.dat. TDLAS 1 paths 1, 2, 3, and 8 were not aligned. Could not get valid light levels; all are near the ground, and dew/fog could be causing low light levels. Will check later. TDLAS 2 is optimizing a lot too, probably from the same causes.
7/8/2009	12:15	Remote	Daily Status Check from PAML − Notes: Not enough space to perform backups. Deleted all necessary files.
7/9/2009	12:50	Remote	Daily Status Check from PAML − Notes: Both TDLAS's CDC dropped to 133 temporarily but now back to normal.
7/10/2009	12:20	Remote	Daily Status Check from PAML − Notes: Lagoon pH around 6.5
7/13/2009	12:50	Remote	Daily Status Check from PAML − Notes: Stopped and restarted sonic anemometer program twice, but there is still no data. Data stopped collecting at 923.729 (7/11/2009 17:30 UTC). Last CR 1000 data at 7/11/2009 17:30 UTC
7/14/2009		Takedown	Too windy to perform sludge depth measurements.
7/14/2009		Takedown	Sonic anemometer values were not as close as normal; probably caused by high winds.
7/14/2009		Takedown	No power at met station for CR 1000 and sonic anemometer 1 data collection or calibrations. Ran extension cord to NE corner outlet.
7/14/2009		Takedown	Several UPS history entries recorded on Open Site Notes.
7/14/2009		Takedown	pH/ORP probes were in sludge and probe heads were filled with sludge. pH probe failed in two buffers (10 and 7). Changed the reference solution. Will use at next site as it did not fail badly.
7/14/2009		Takedown	ORP sensor: calibration and acceptance pass
7/14/2009		Takedown	pH sensor: QA fails. Notes: pH probe failed in two buffers (10 and 7). Changed the reference solution, but instrument still fails.
7/14/2009		Takedown	Maintenance list completed.
7/14/2009	16:45-17:40	Takedown	Sonic anemometer inter-comparison: Pass
7/14/2009	17:28-17:48	Takedown	Calibrated TDLAS 1029
7/14/2009	17:59-18:19	Takedown	Calibrated TDLAS 1028
7/14/2009	18:30	Takedown	S-OPS/GSS calibrations: all pass
7/14/2009	18:35-19:03	Takedown	TEC 450i single point calibrations: pass
7/14/2009	18:40	Takedown	Bias/zero sonic anemometer calibration Notes: too windy
7/14/2009	20:57	Takedown	Wetness sensor calibration: accepted.
7/14/2009	20:57	Takedown	Barometer audit: accepted.

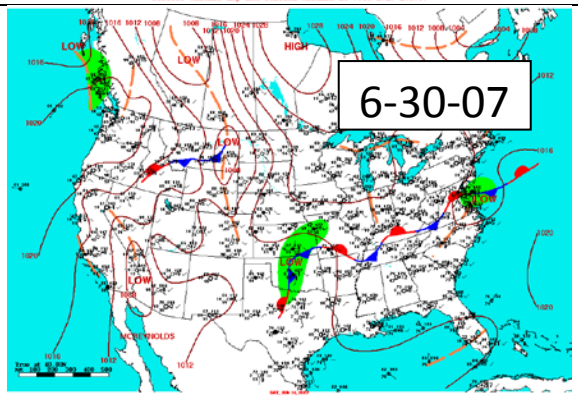
6.9 Site weather

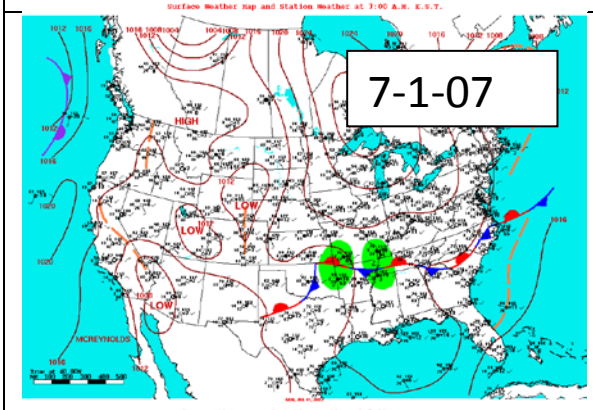
Period 1

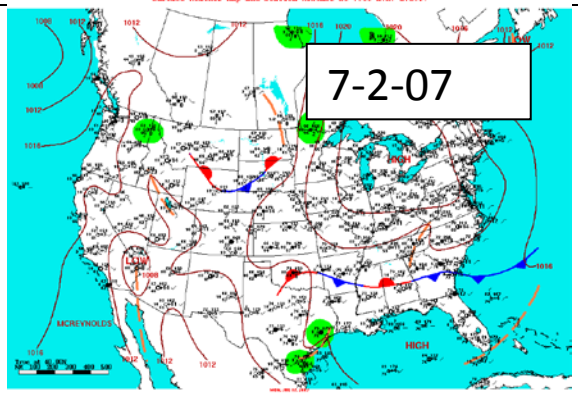


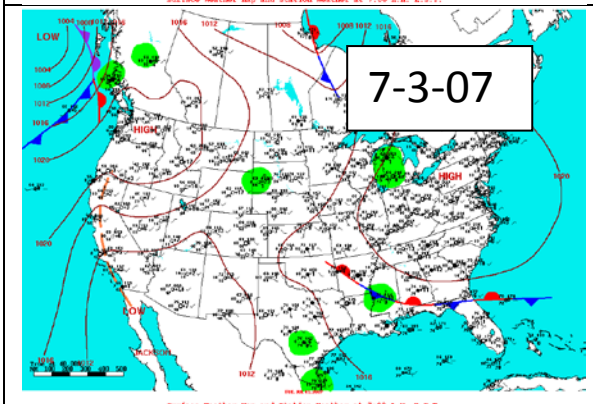


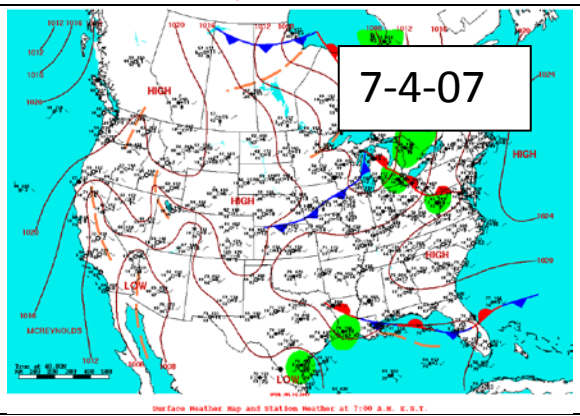


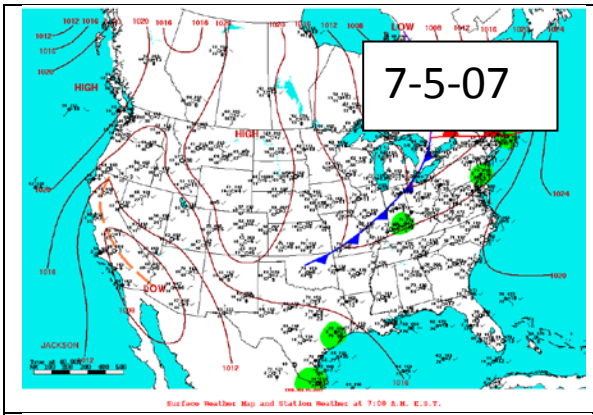








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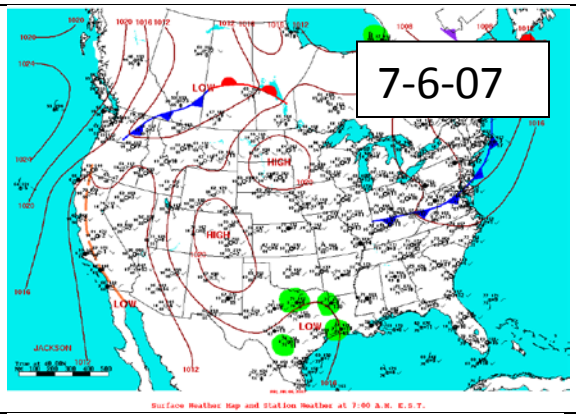
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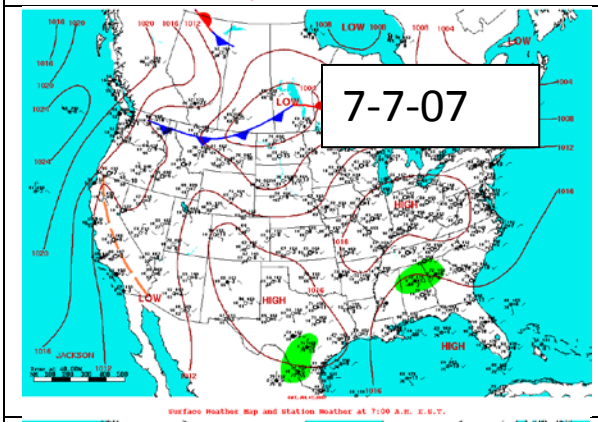
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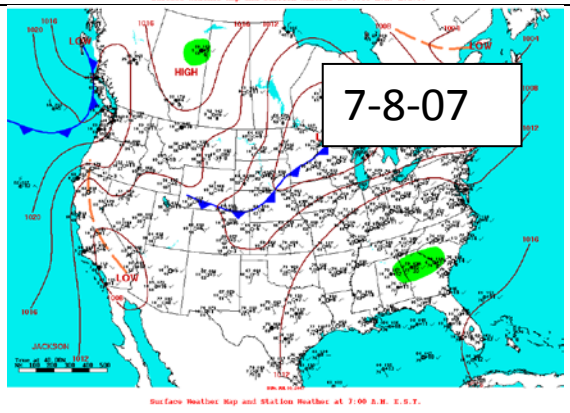
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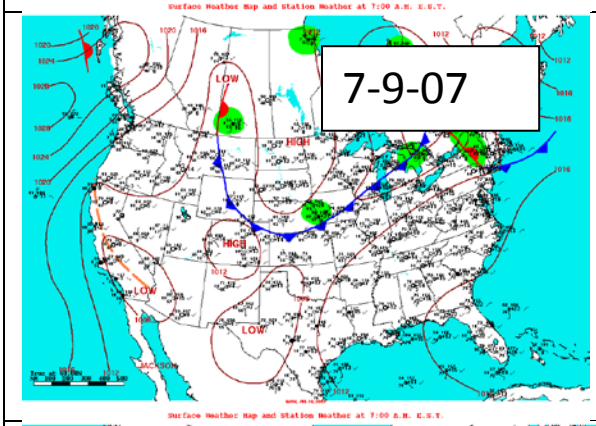
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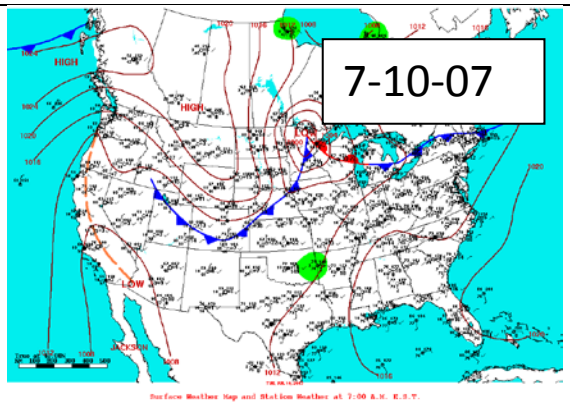
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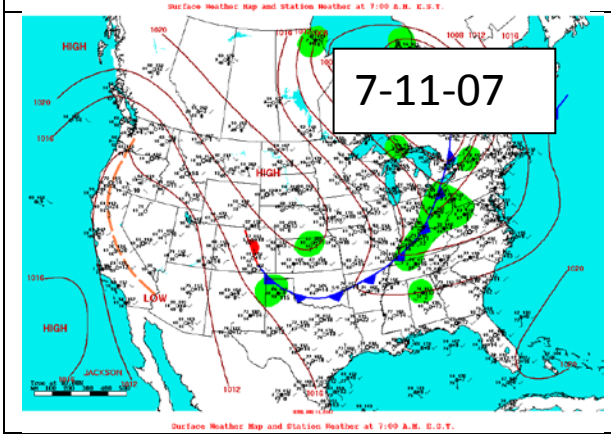
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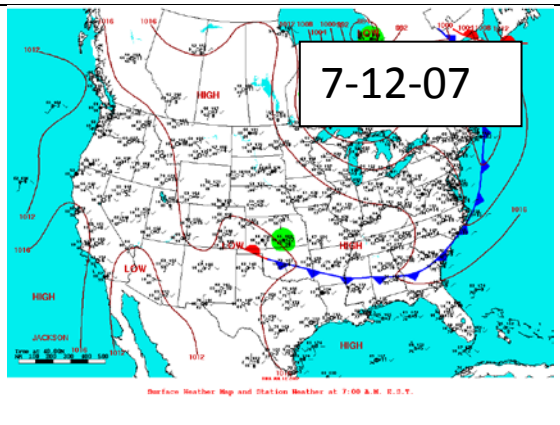
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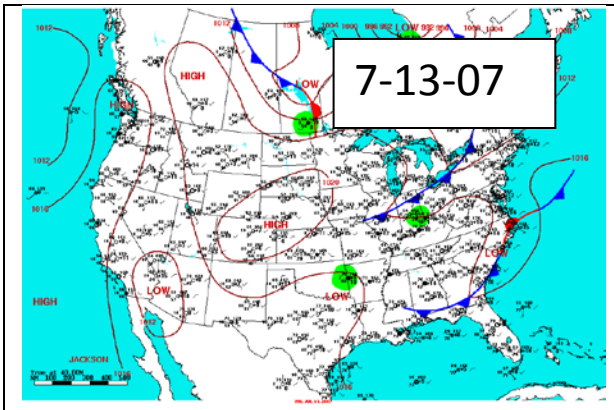
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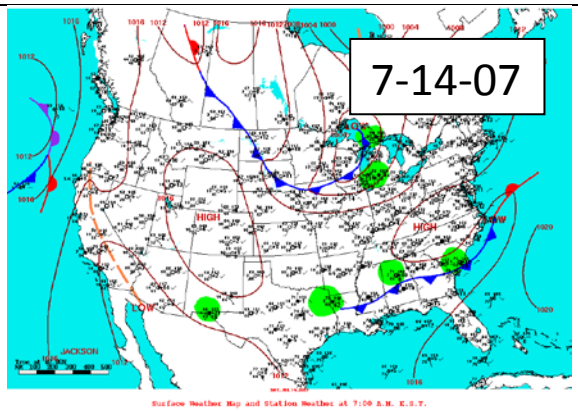
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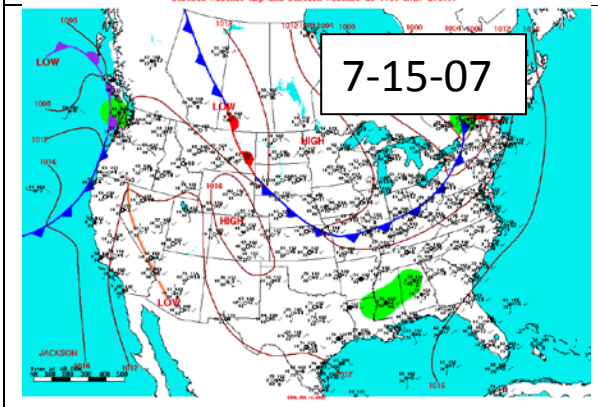
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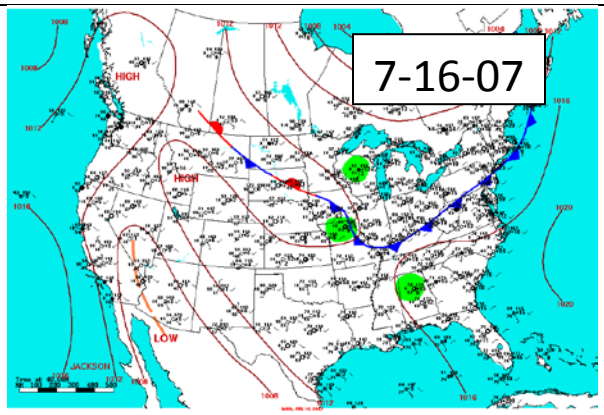
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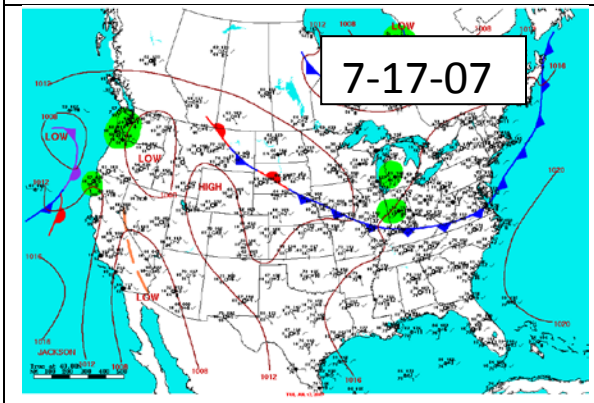
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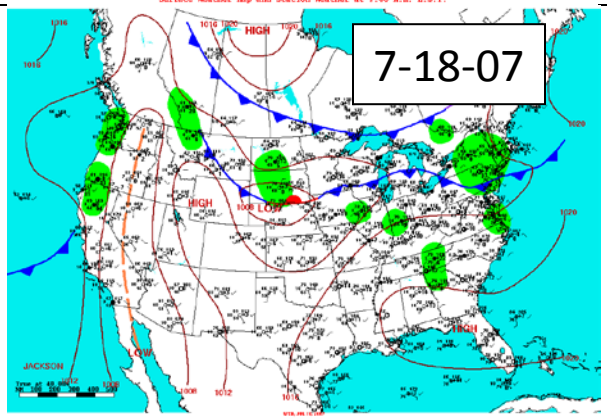
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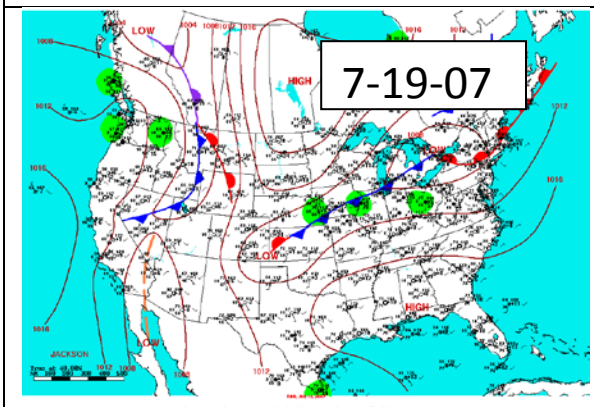
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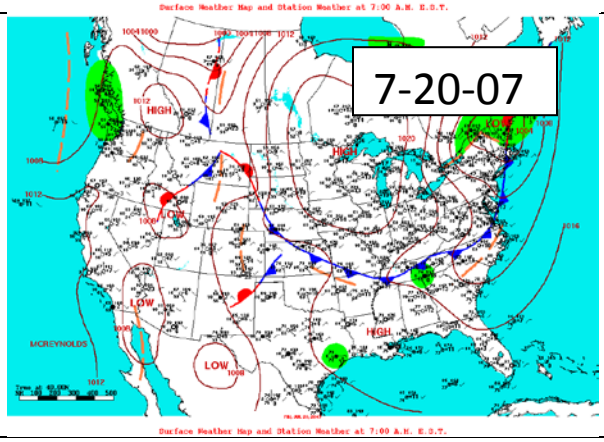
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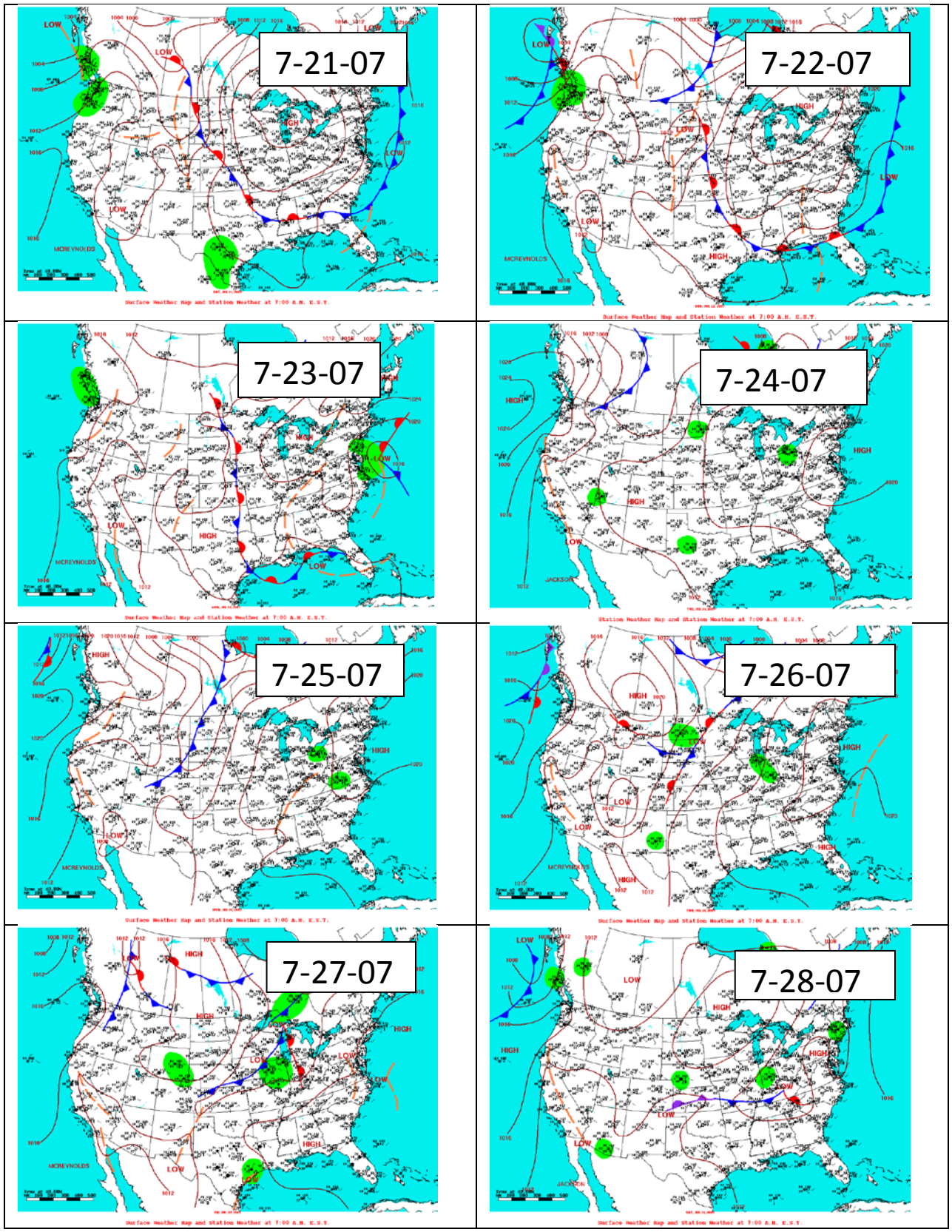
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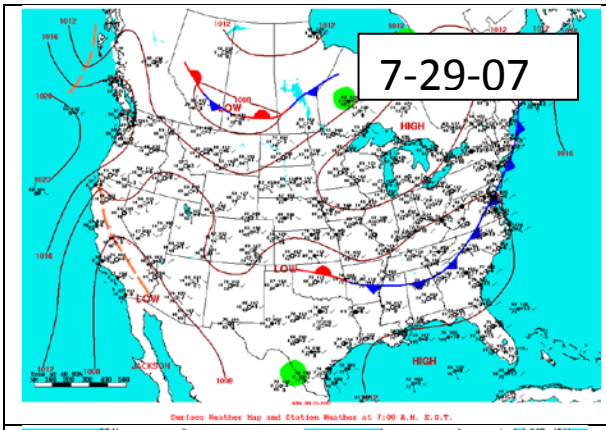
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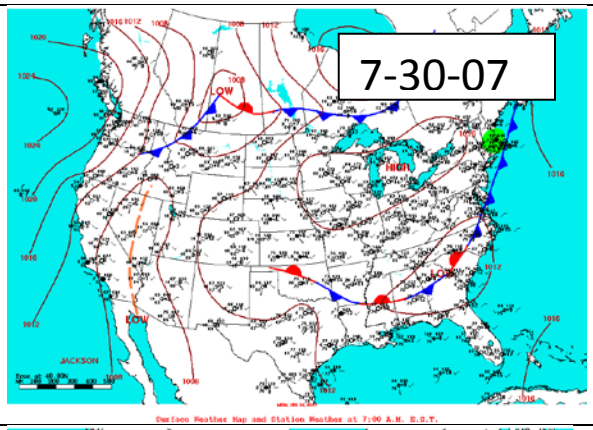
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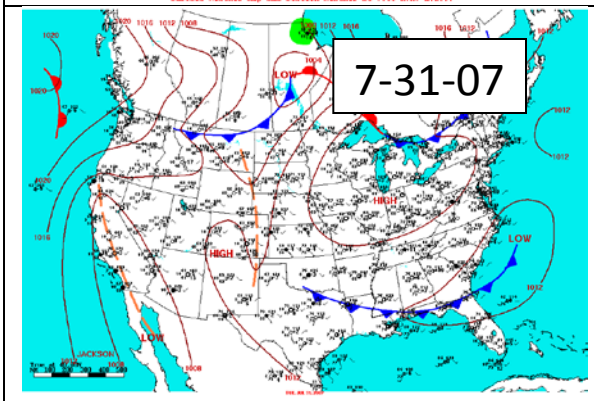
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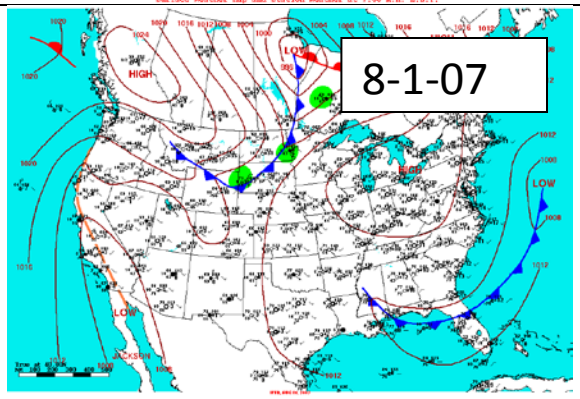
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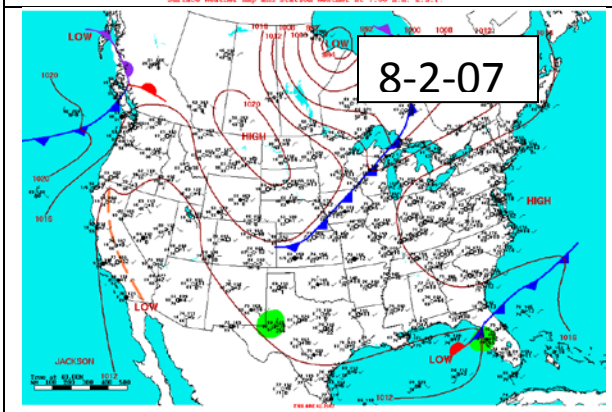
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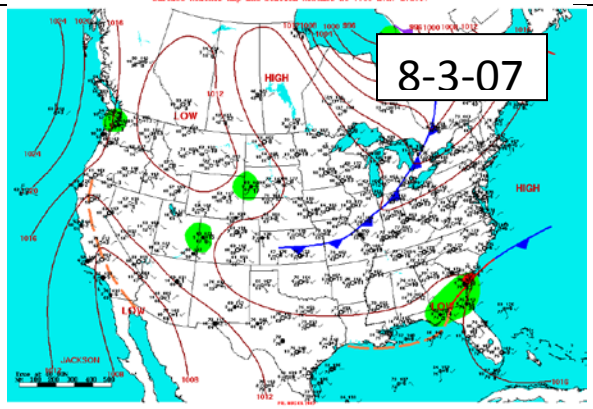
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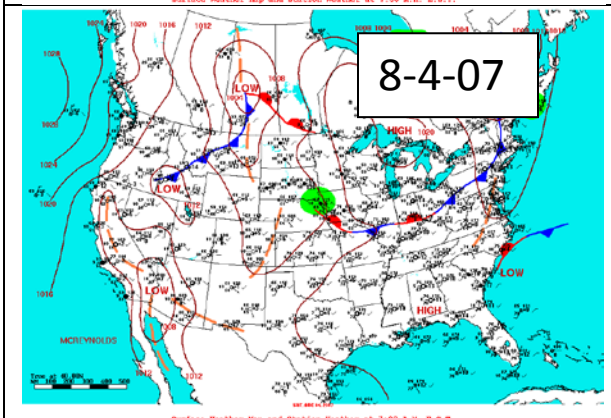
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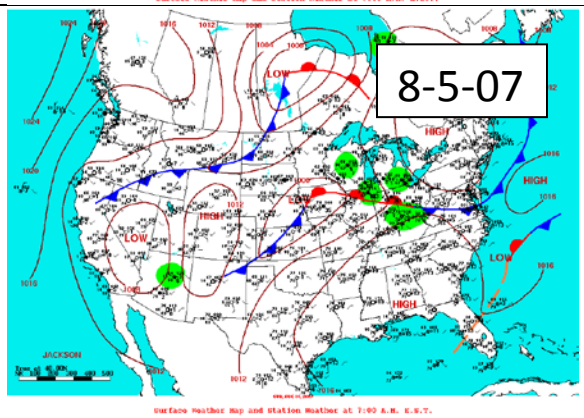
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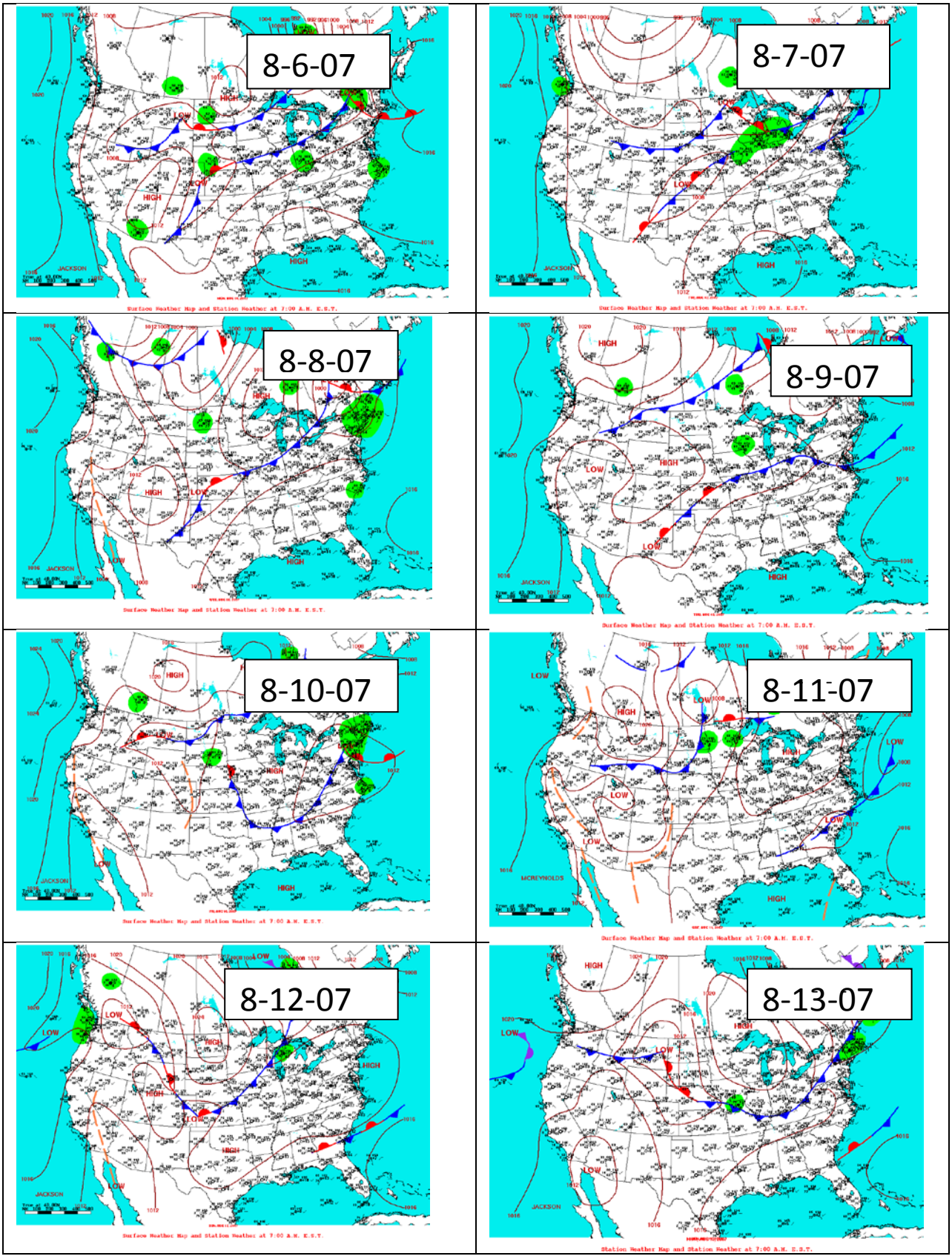
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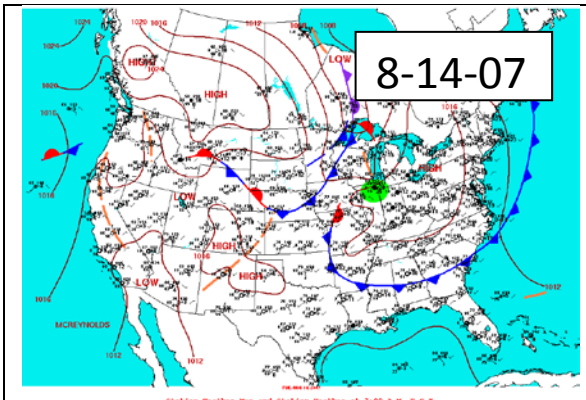
8-13-07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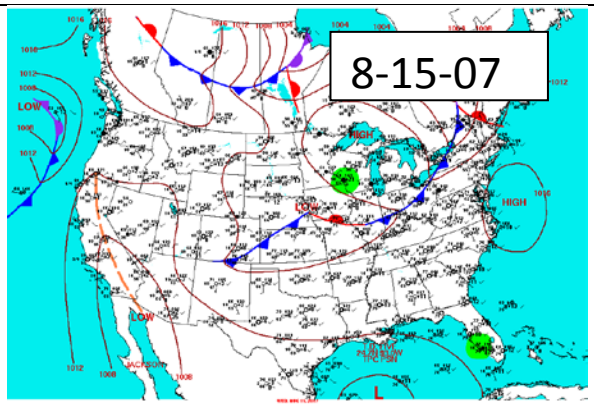
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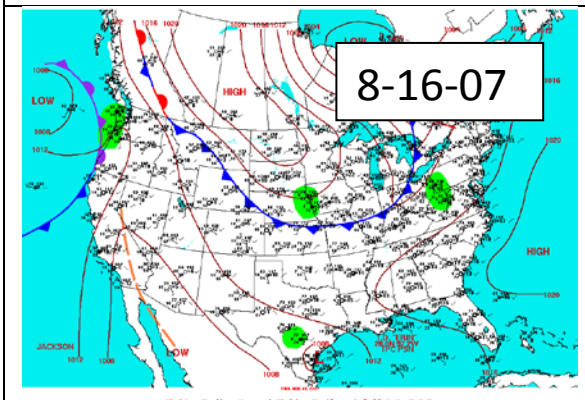
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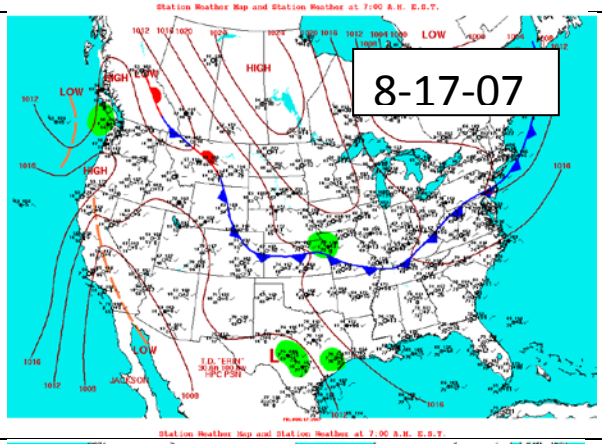
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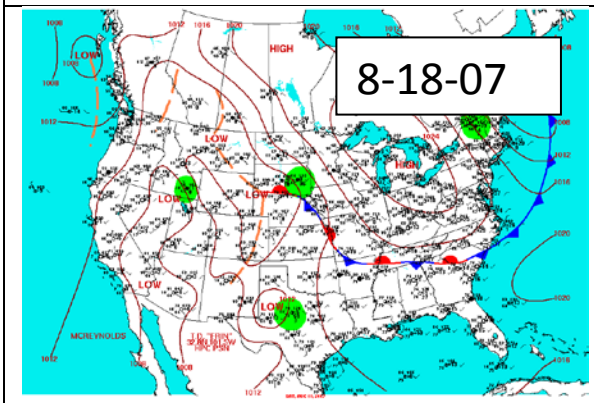
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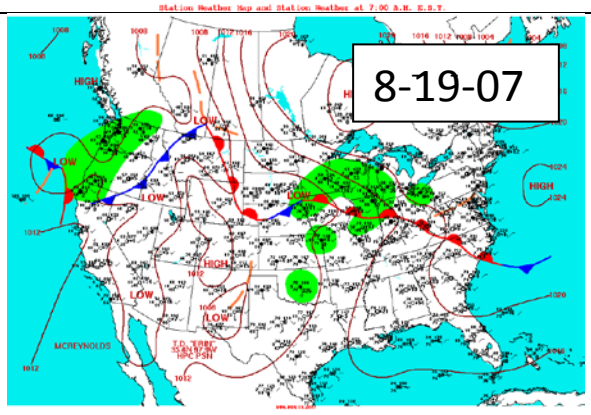
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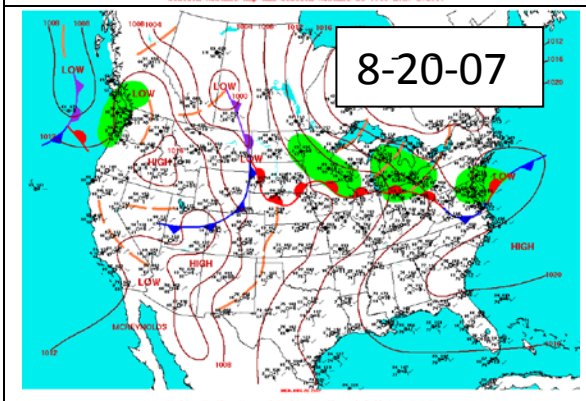
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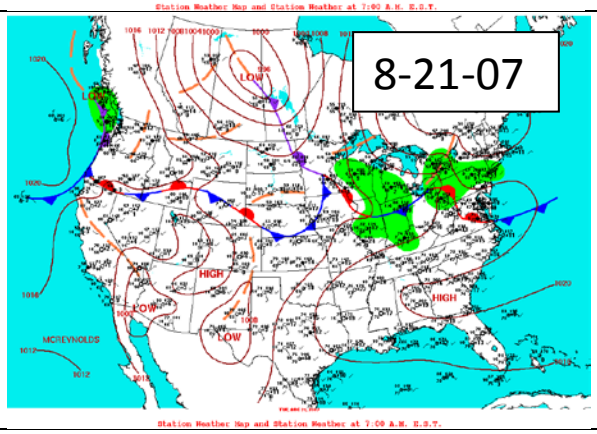
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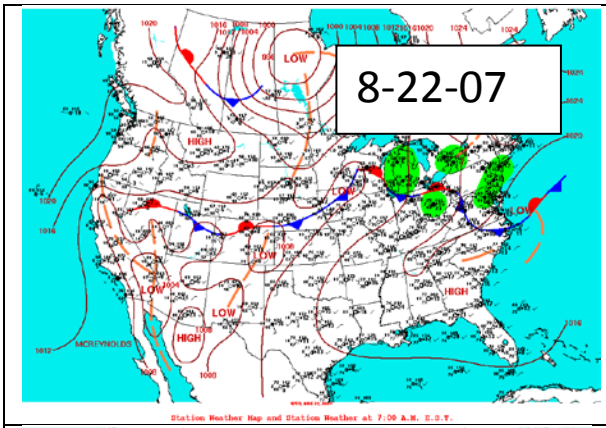
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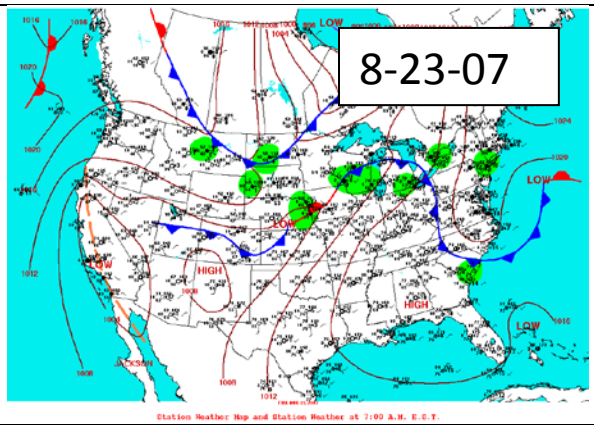
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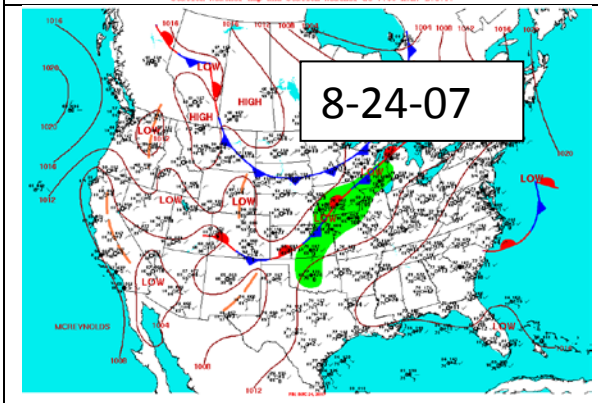
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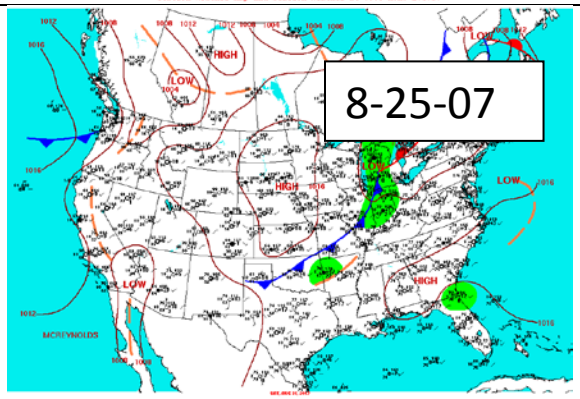
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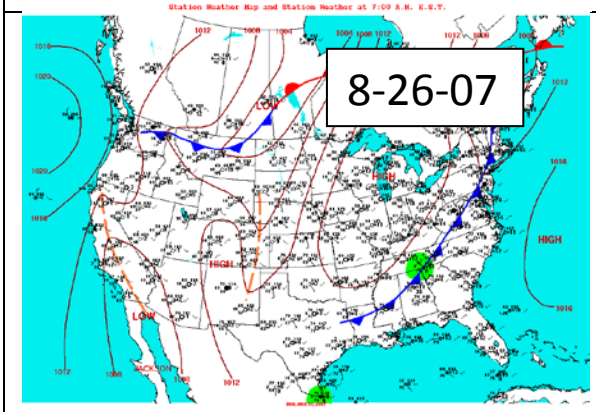
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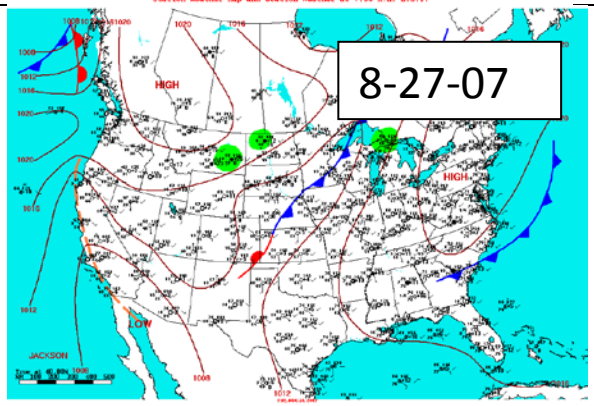
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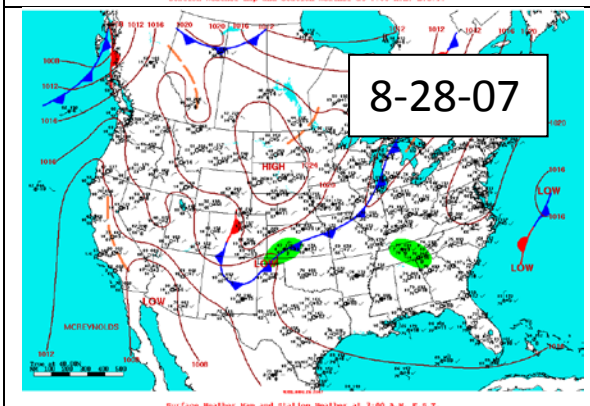
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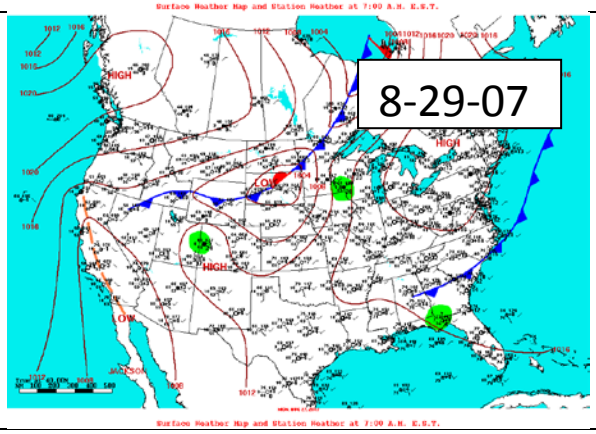
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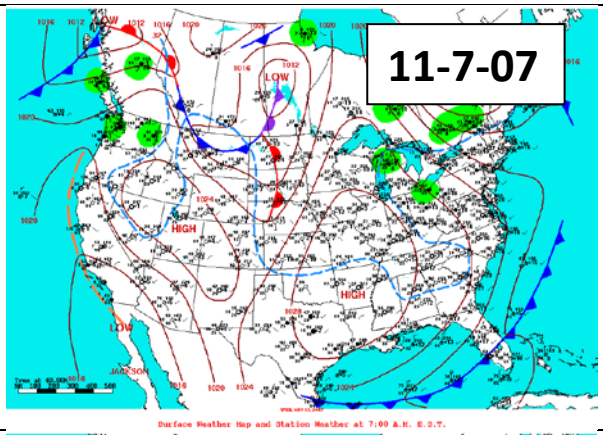
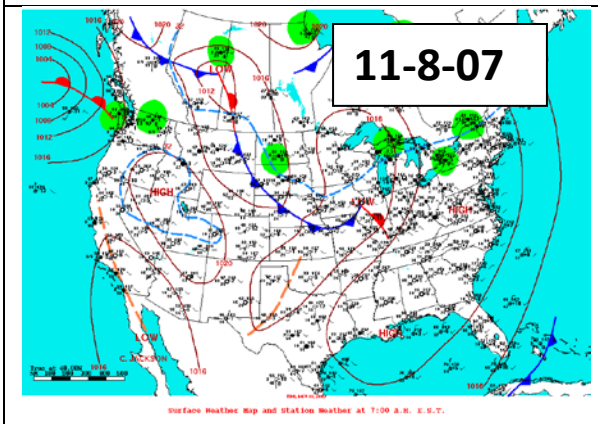
Period 2


11-7-07
LOW
HIGH
JACKSON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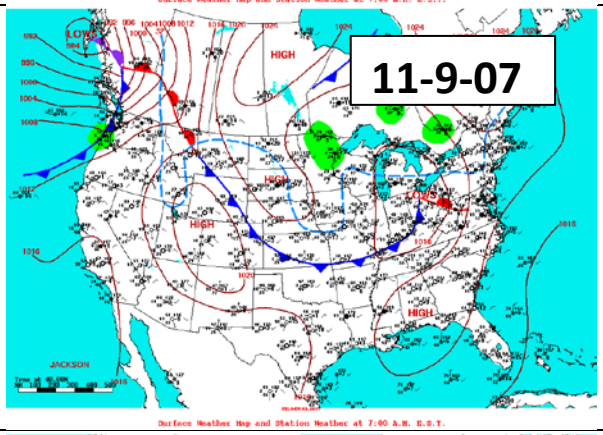
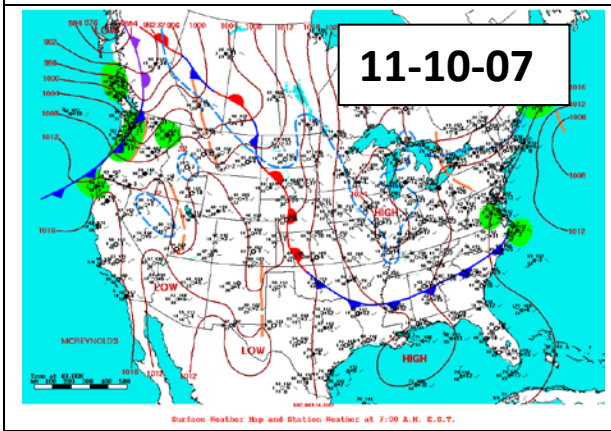
LOW


11-9-07
HIGH
LOW
JACKSON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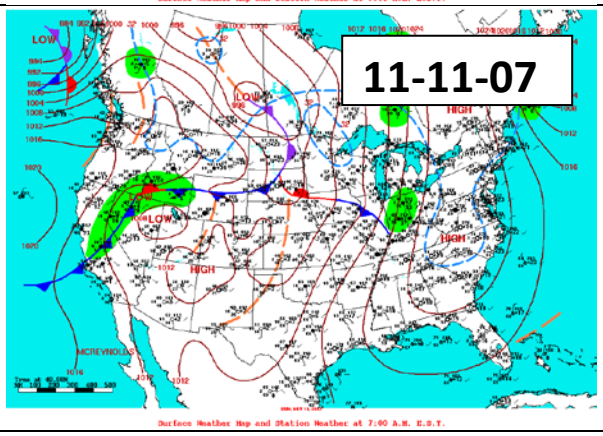
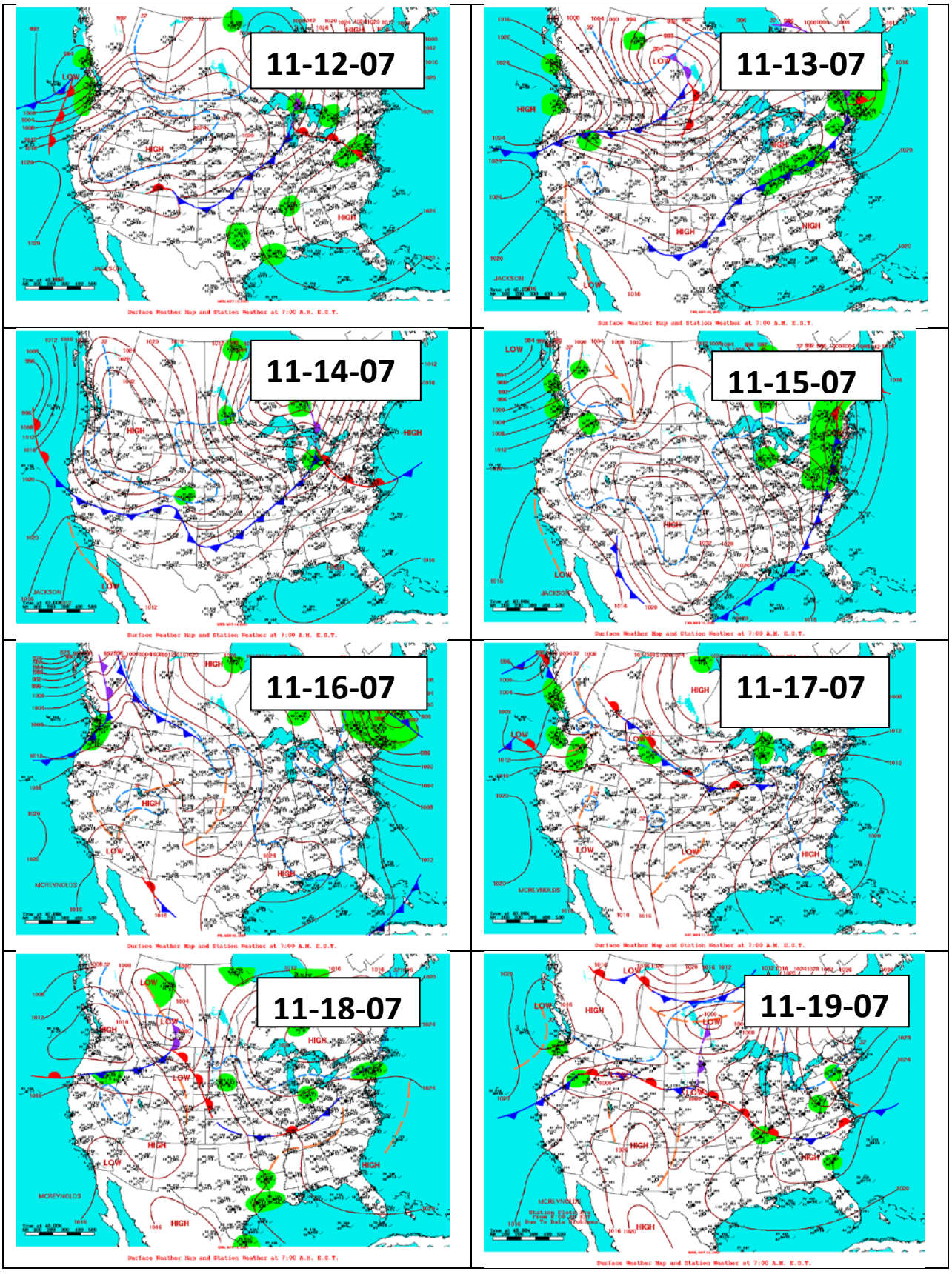
LOW
MCREYNOLDS


11-11-07
HIGH
LOW
MCREYNOLDS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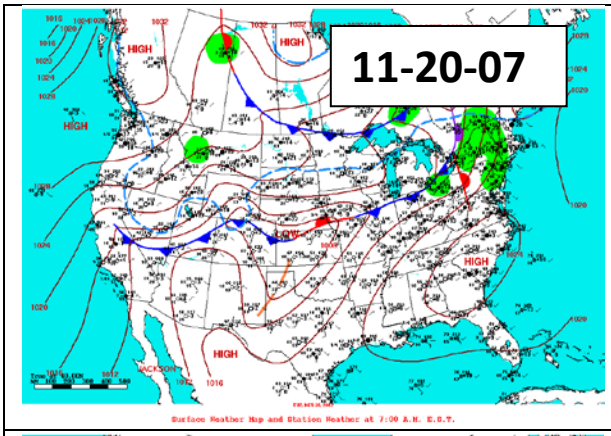
11-19-07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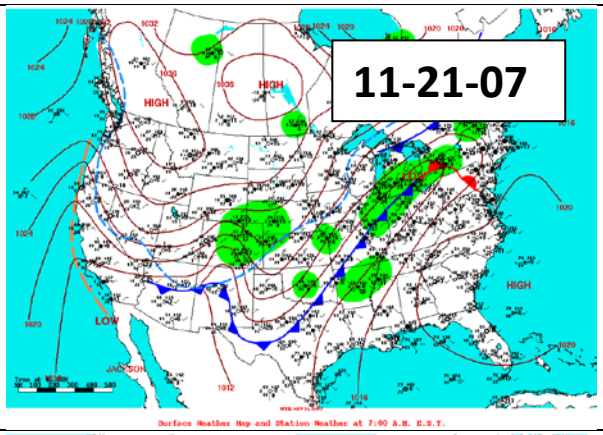
HIGH
HIGH
HIGH
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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HIGH
HIGH
LOW
JACKSON
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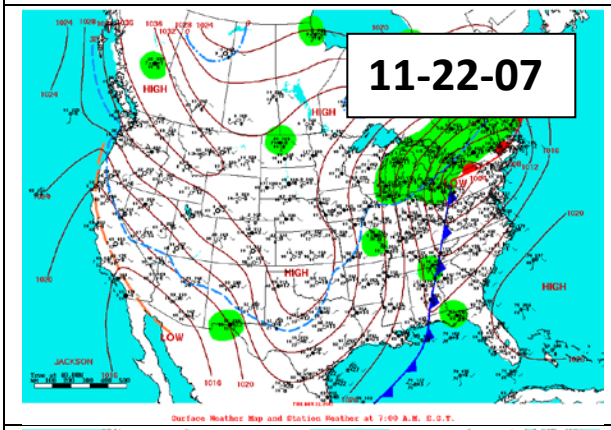
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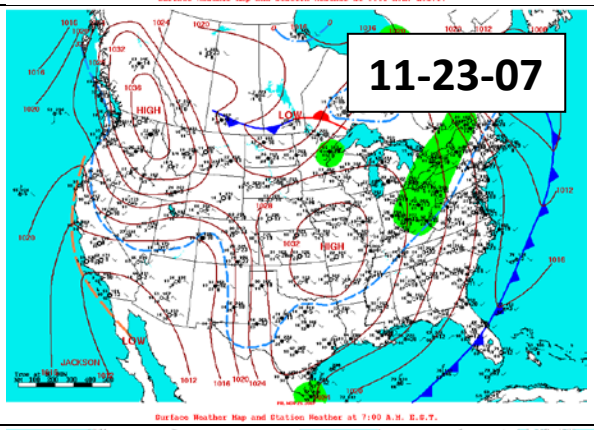
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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HIGH
LOW
JACKSON
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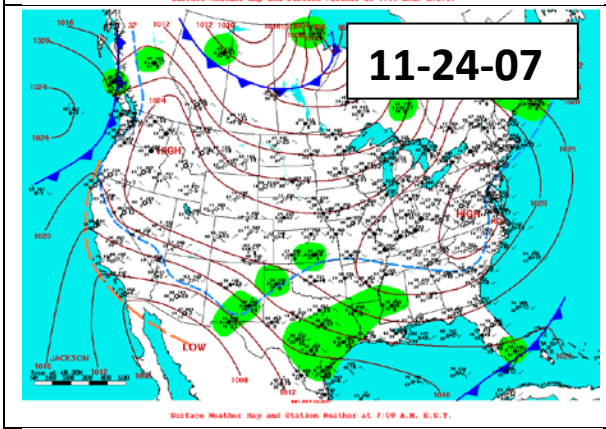
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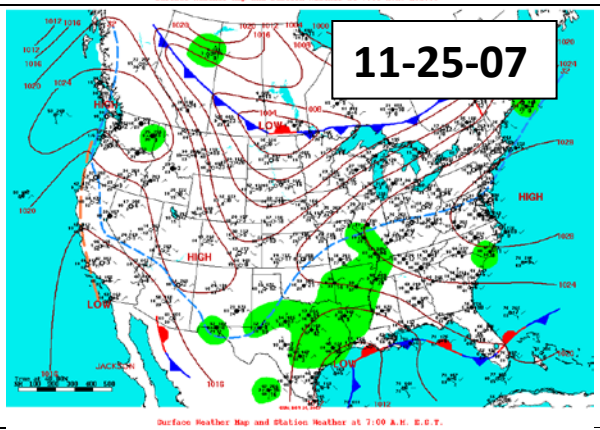
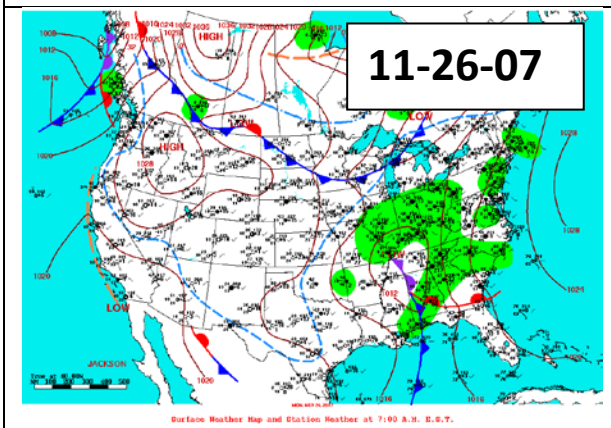
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


11-25-07
HIGH
LOW
HIGH
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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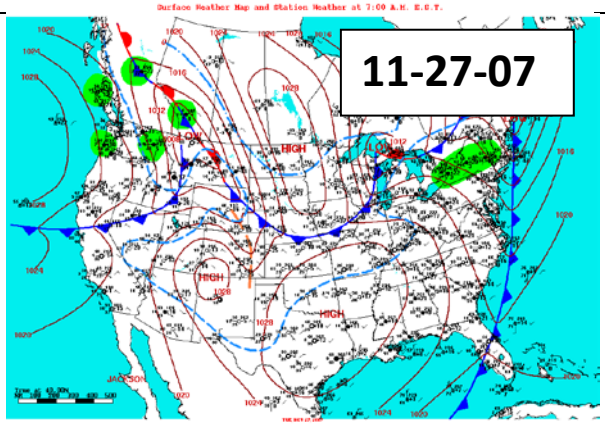
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


11-27-07
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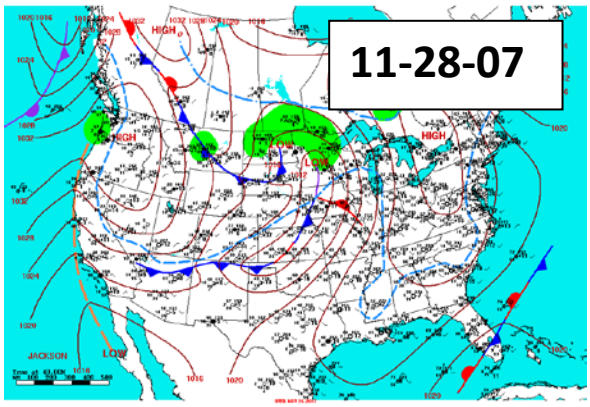
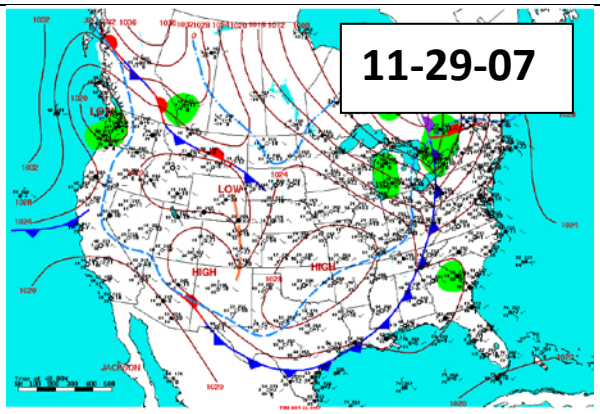
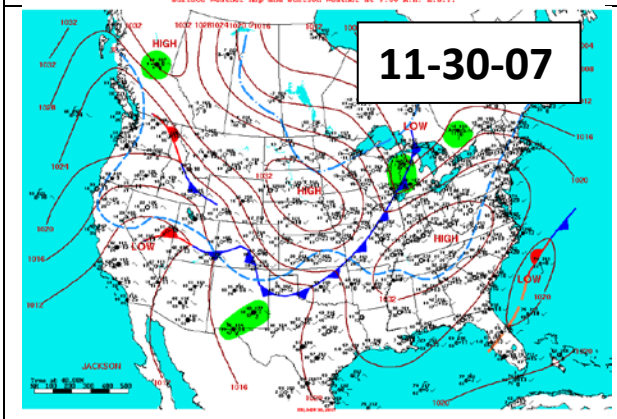
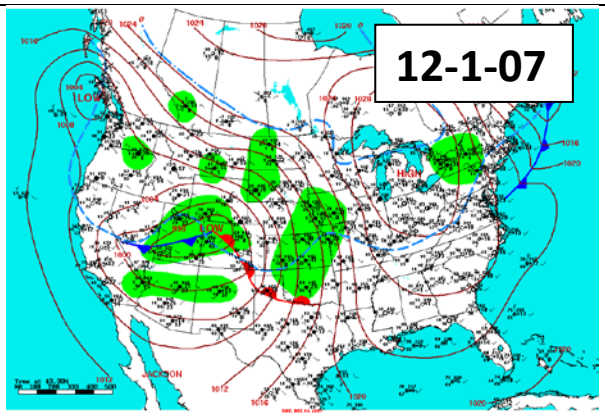
HIGH
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

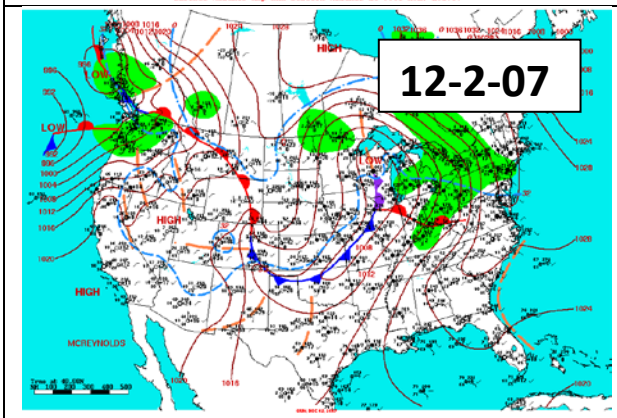
Period 3

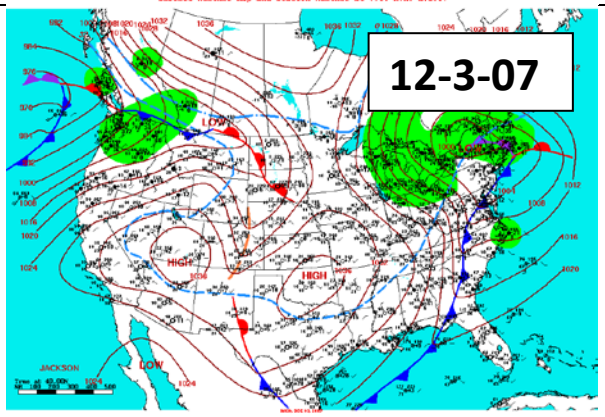


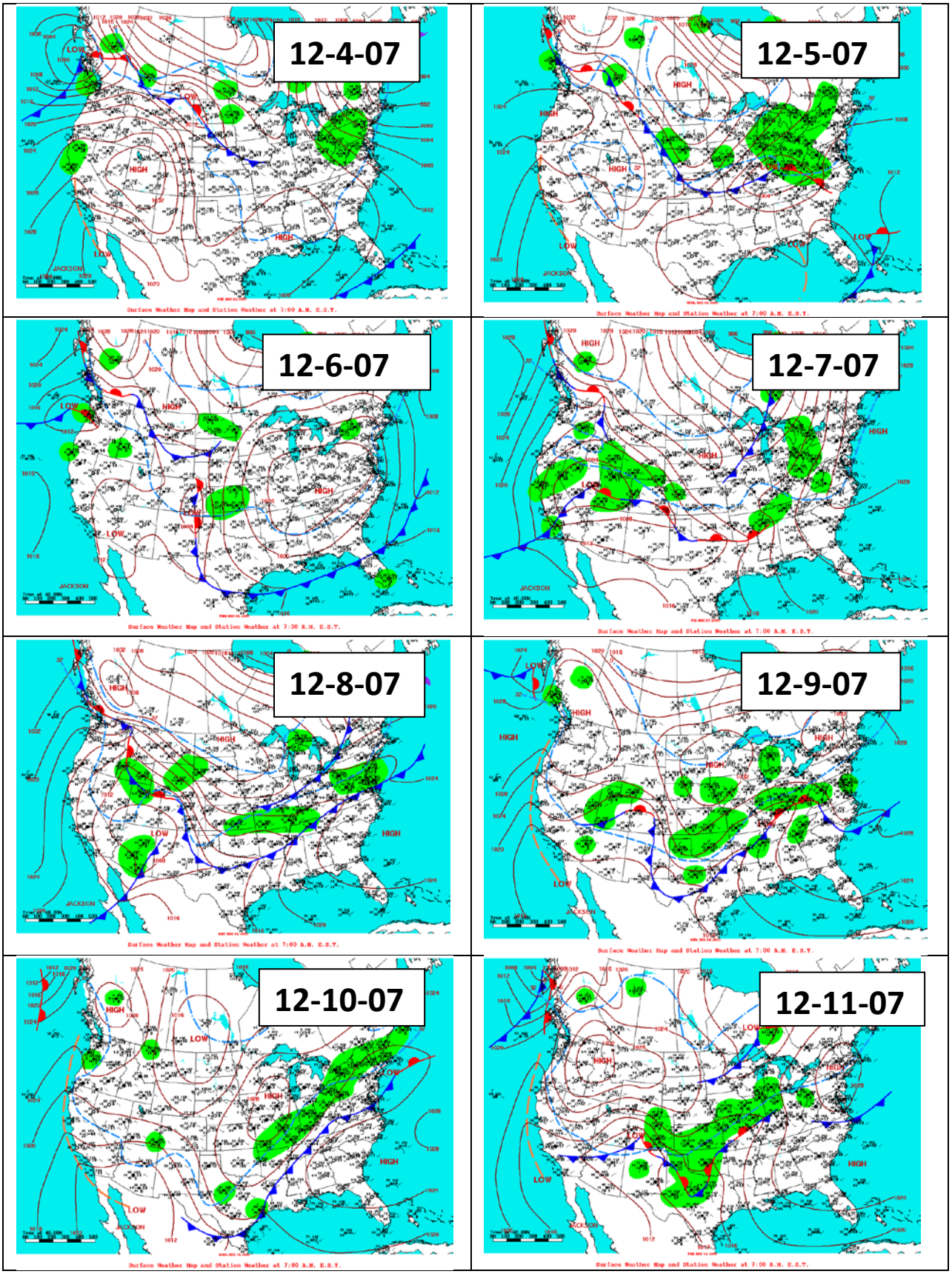








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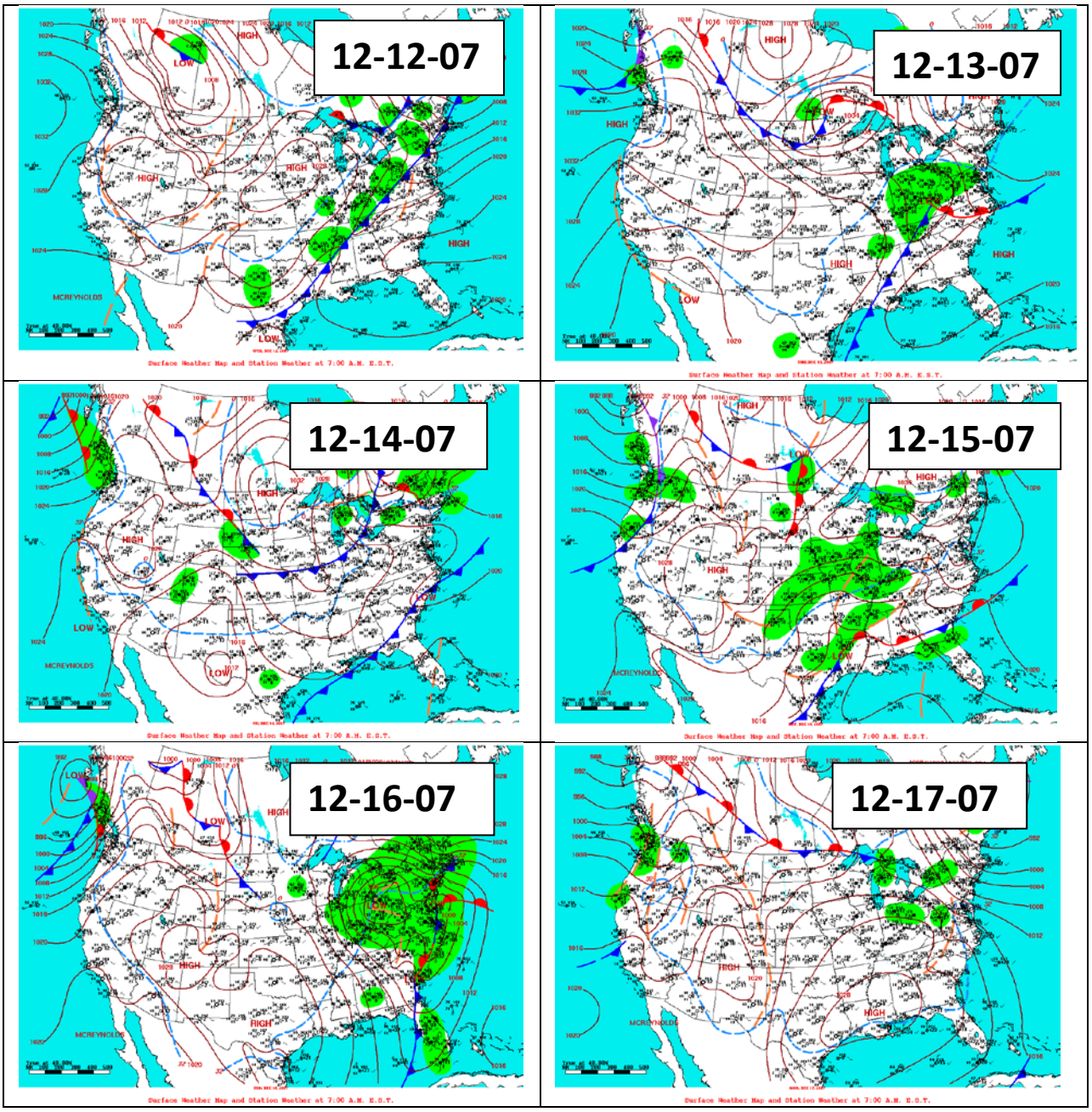
12-11-07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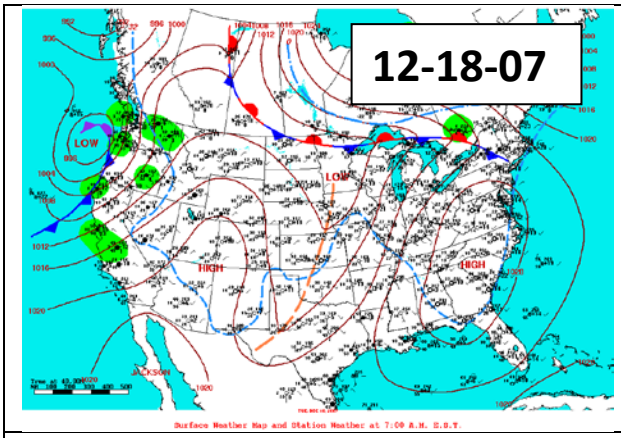
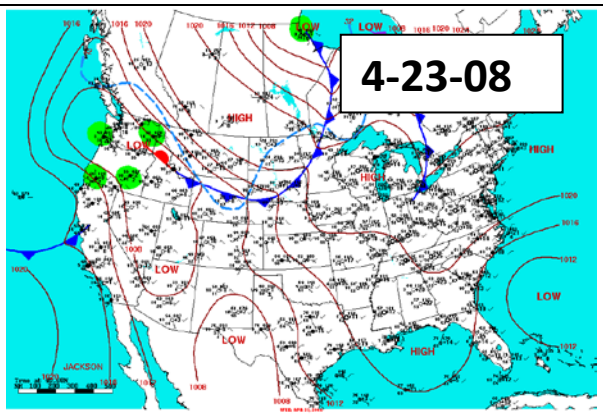
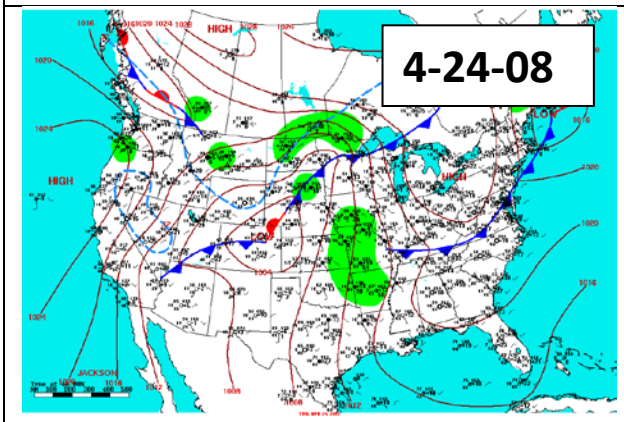
12-17-07


12-18-07
LOW
HIGH
JACKSON

Period 4


4-23-08
LOW
HIGH
JACKSON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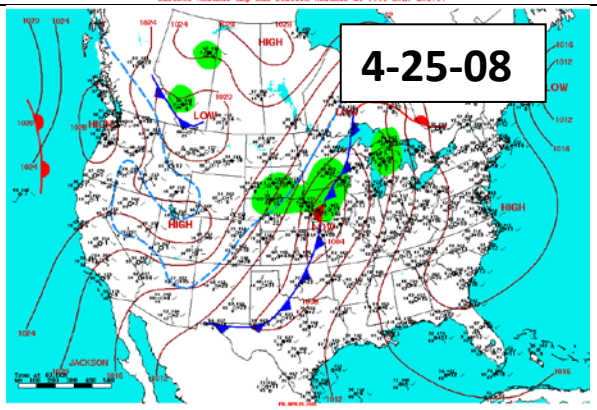
LOW
JACKSON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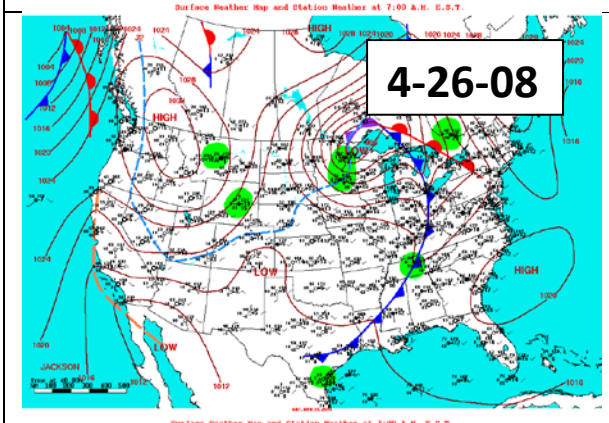
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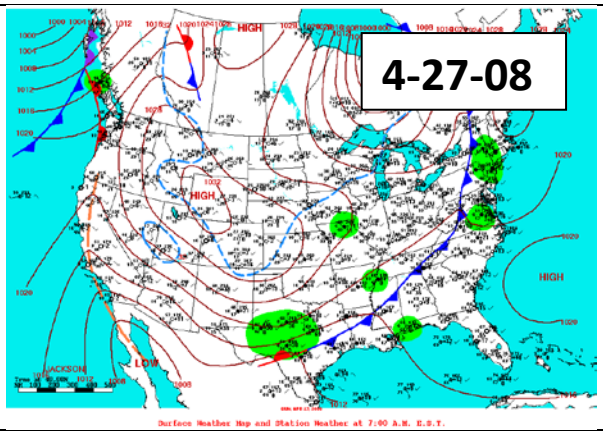
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LOW
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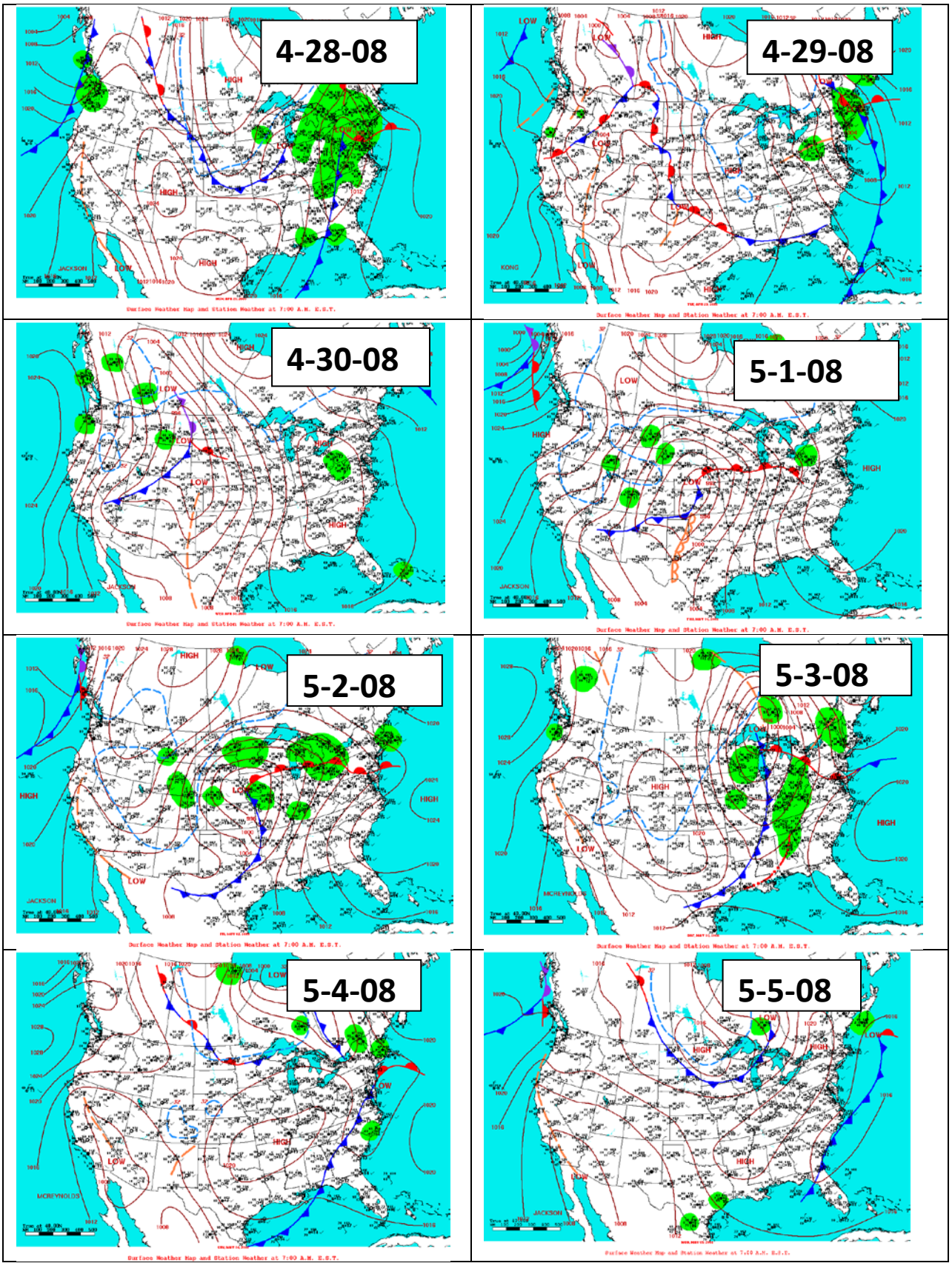
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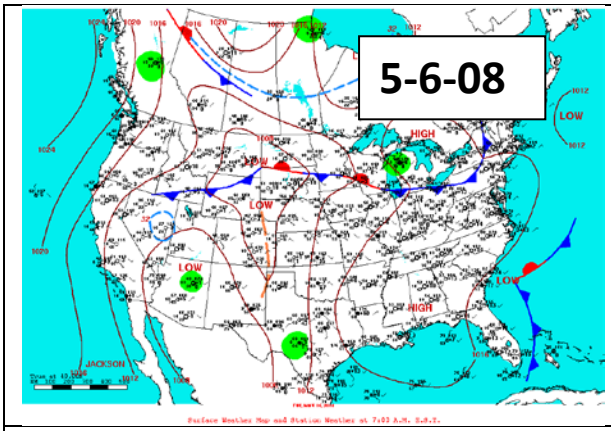
5-2-08
5-3-08
5-4-08
5-5-08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LOW
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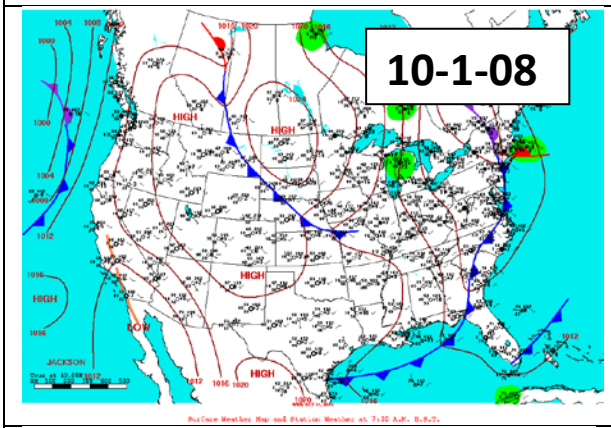
HIGH
JACKSON

Period 6


10-1-08
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HIGH
HIGH
HIGH
LOW
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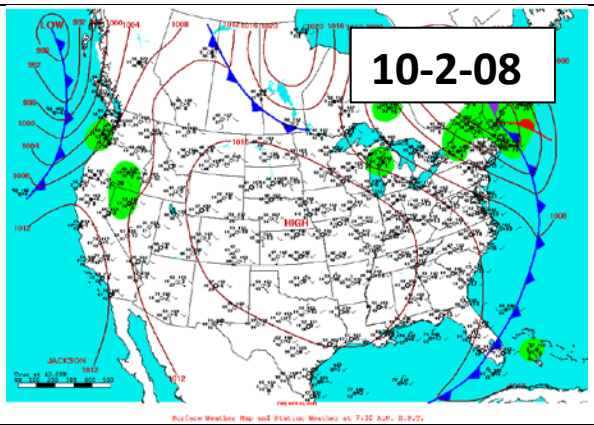
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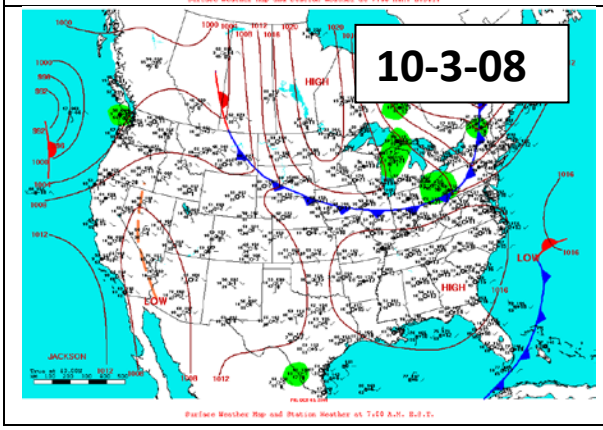
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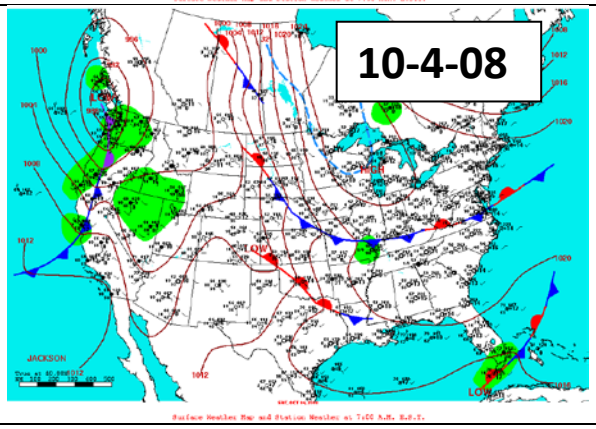
LOW
LOW
HIGH
JACKSON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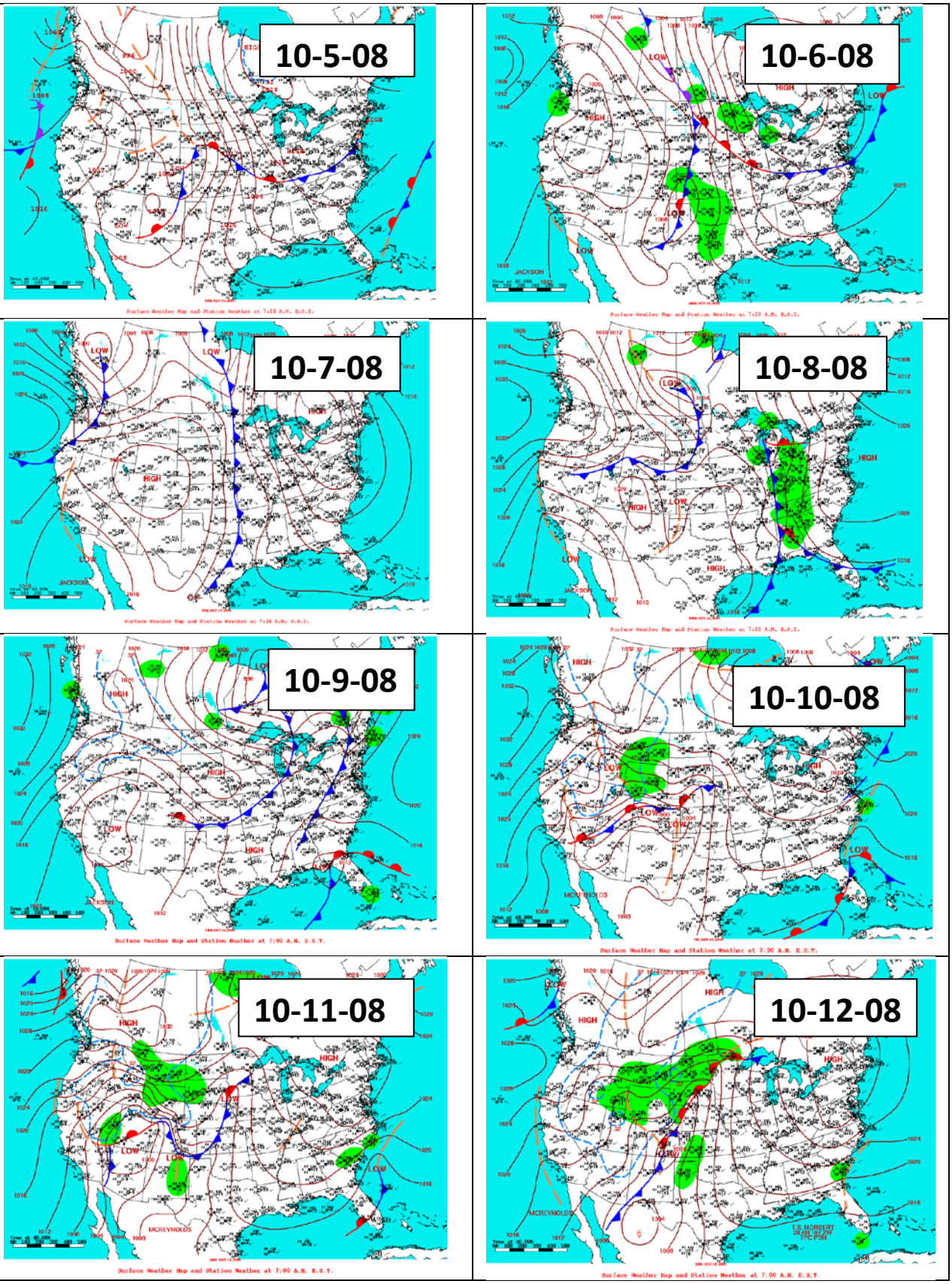
LOW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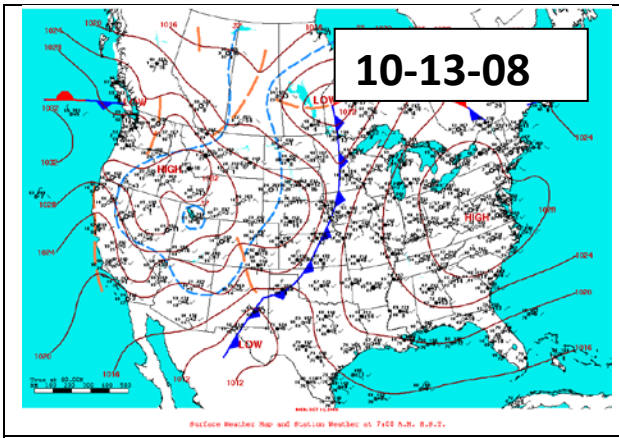
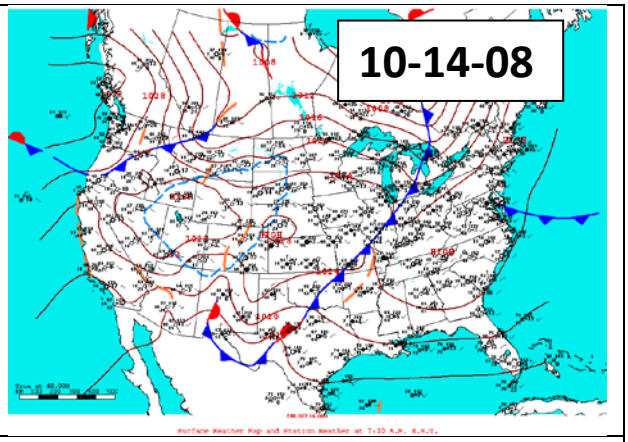
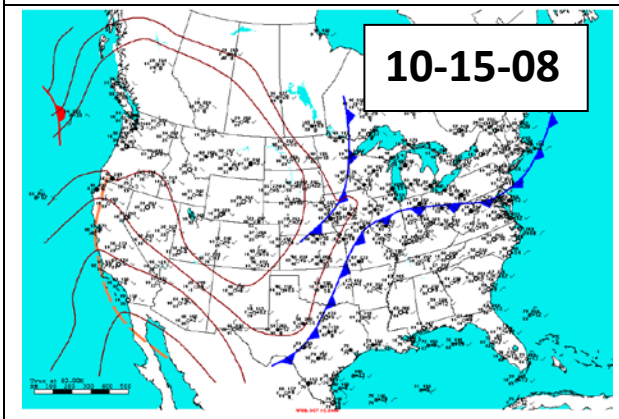
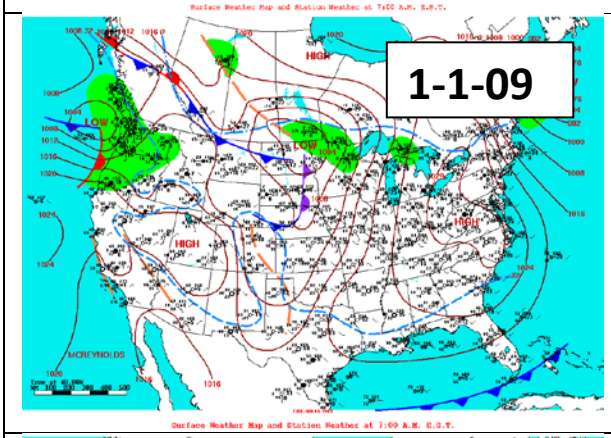
10-12-08

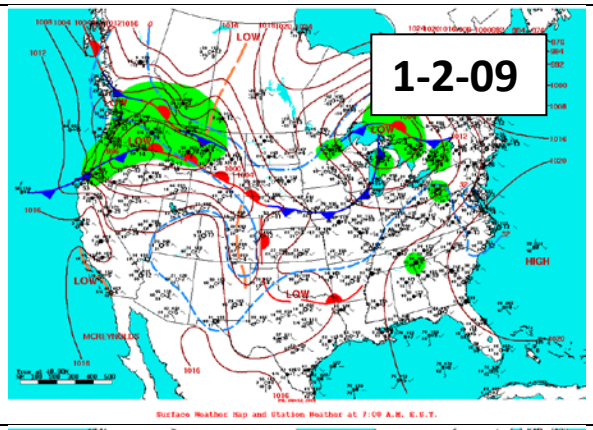


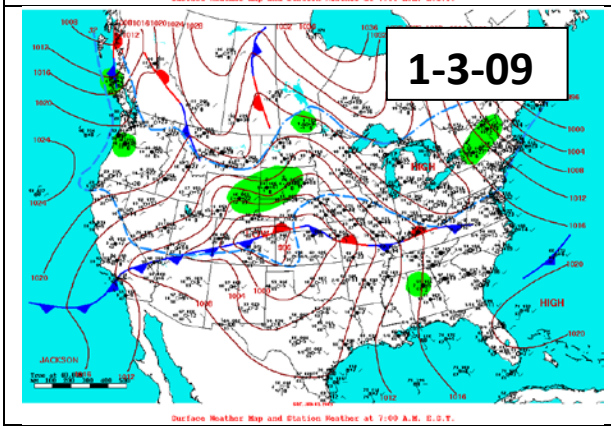


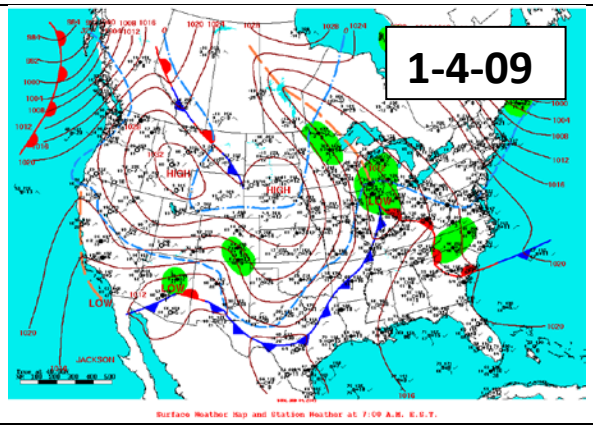


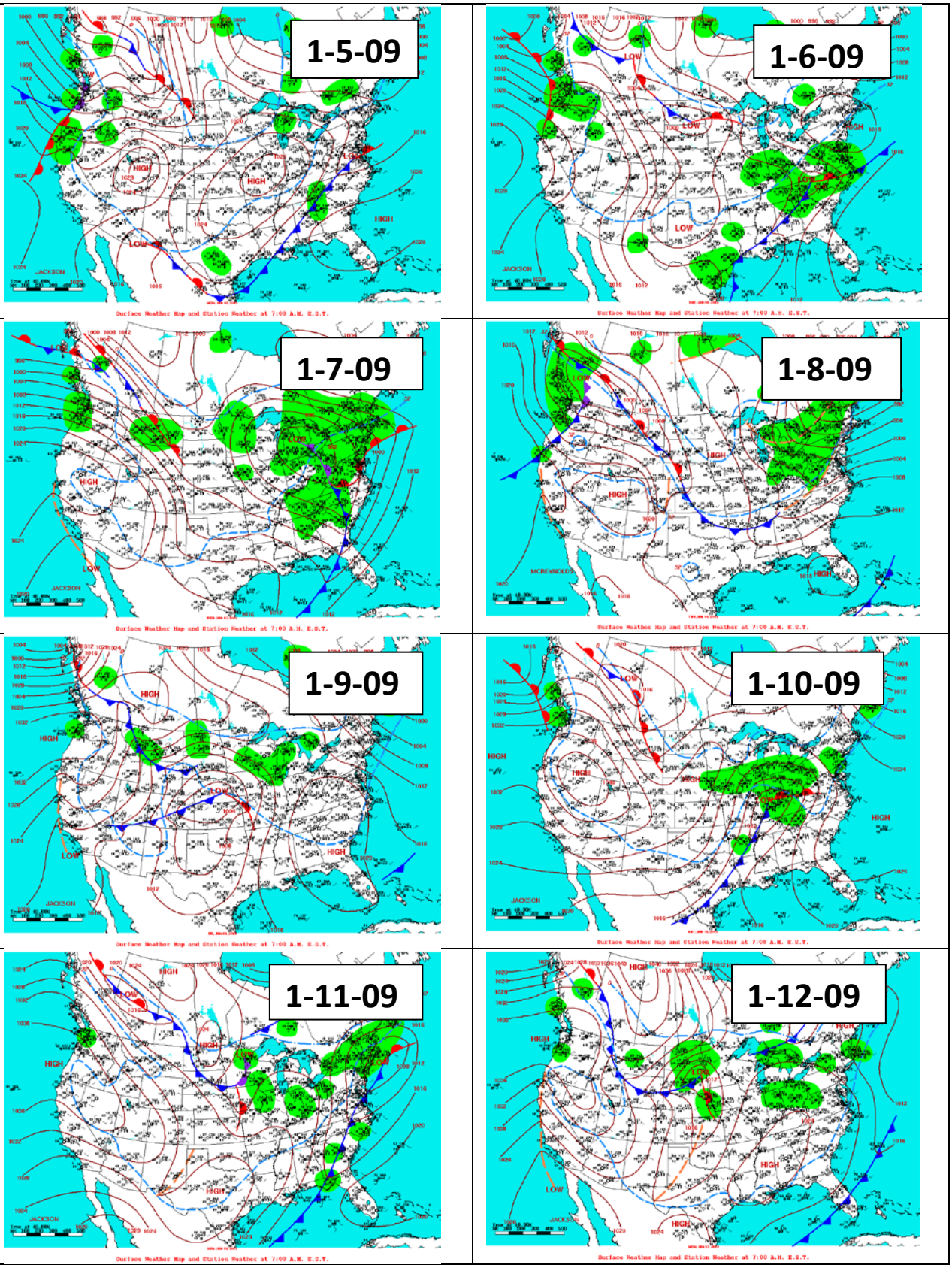
Period 7







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1-6-09
1-7-09
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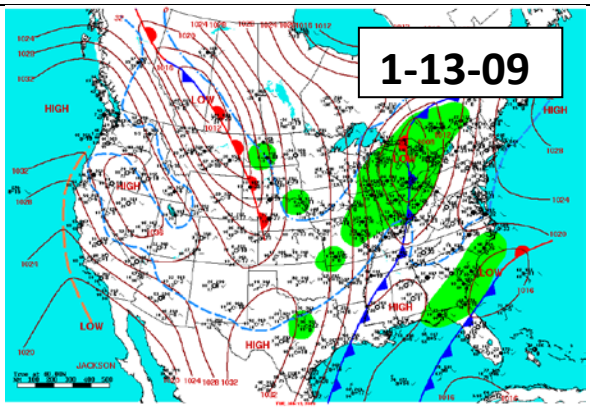
1-10-09
1-11-09
1-12-09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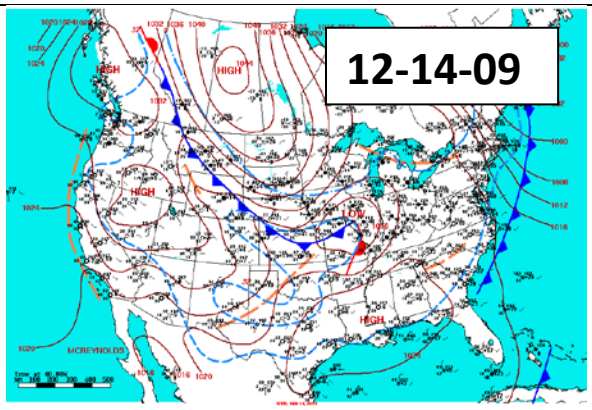
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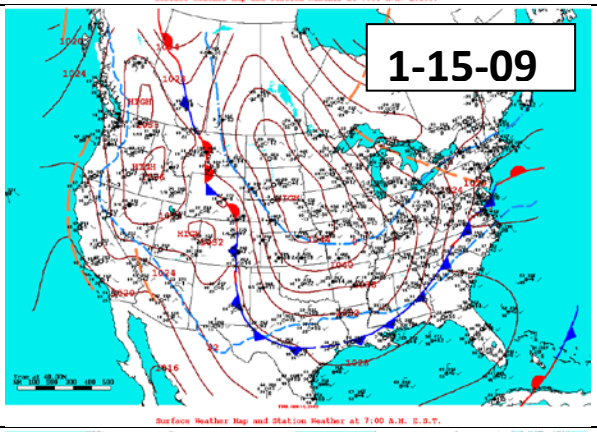
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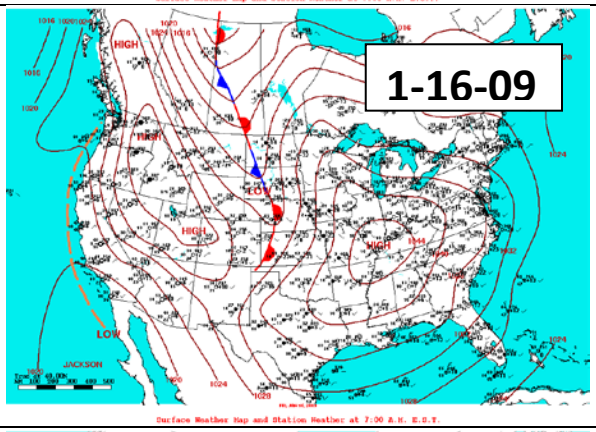
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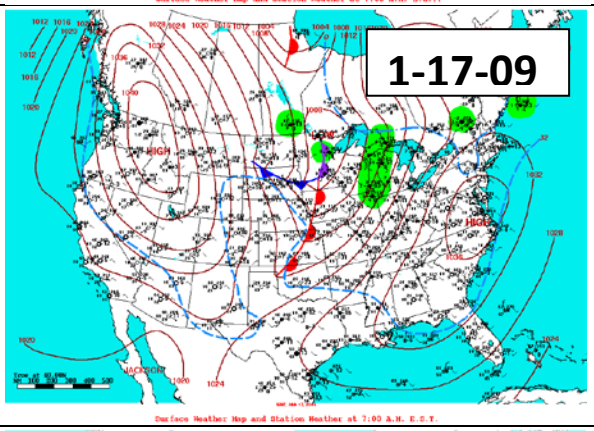
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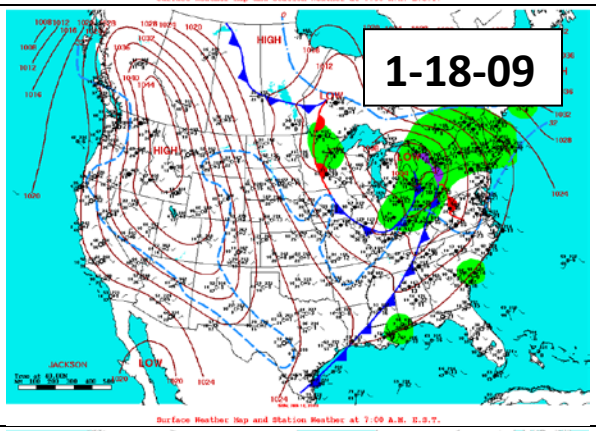
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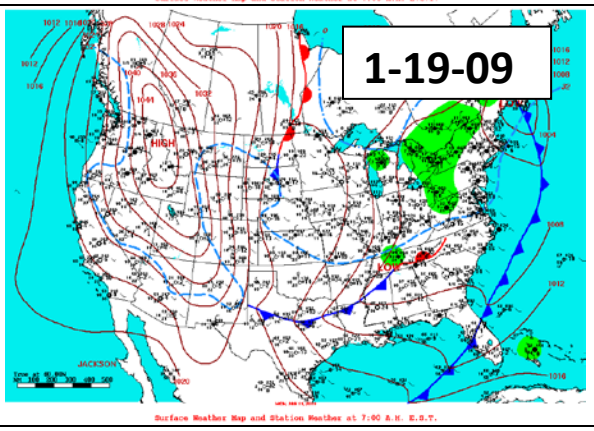
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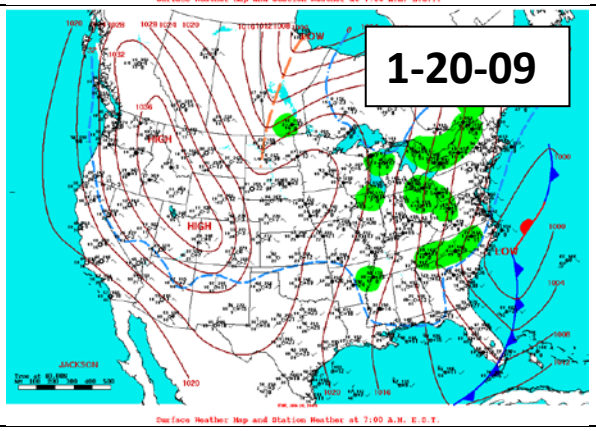
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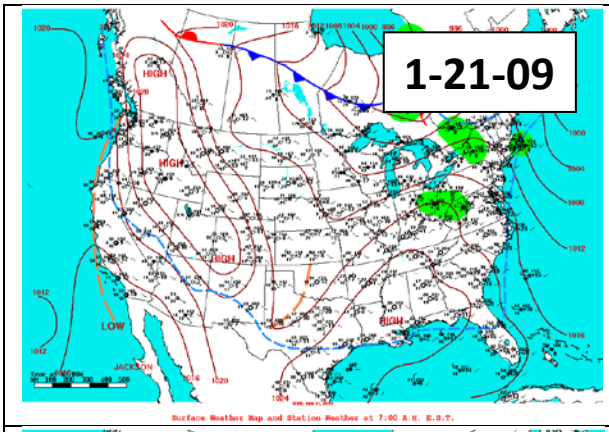
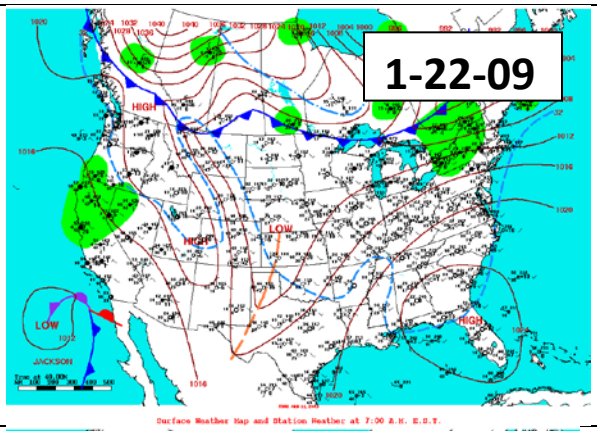

1-21-09
HIGH
HIGH
HIGH
LOW
HIGH
JACKSON


1-22-09
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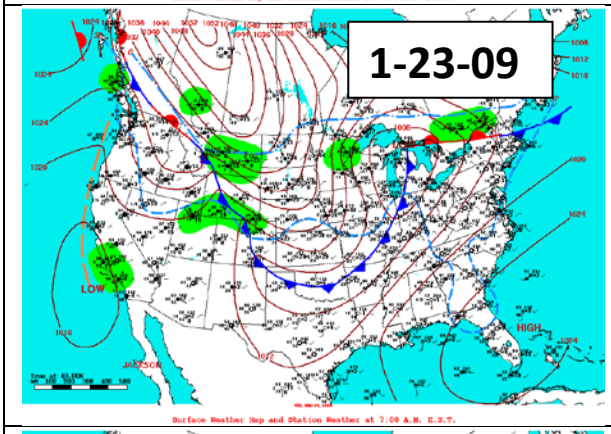
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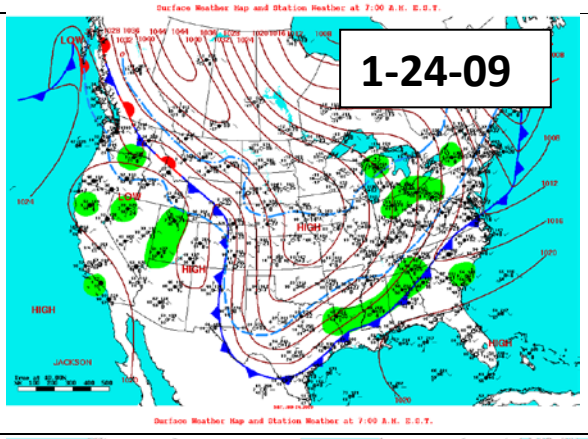
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HIGH
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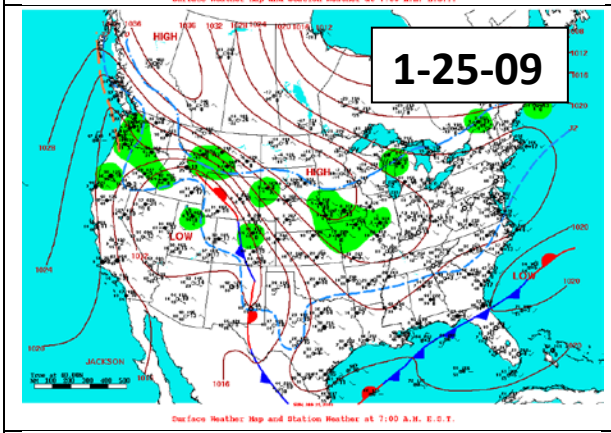
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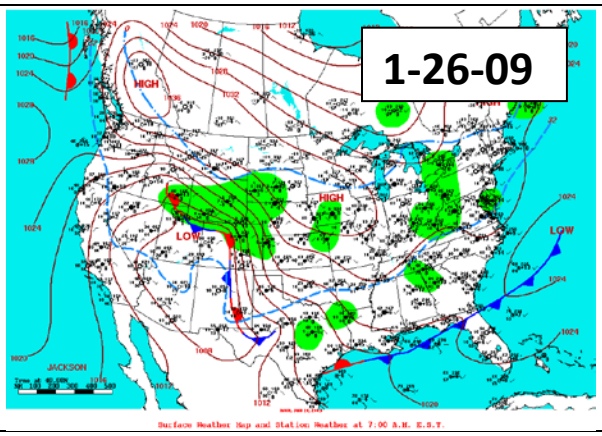
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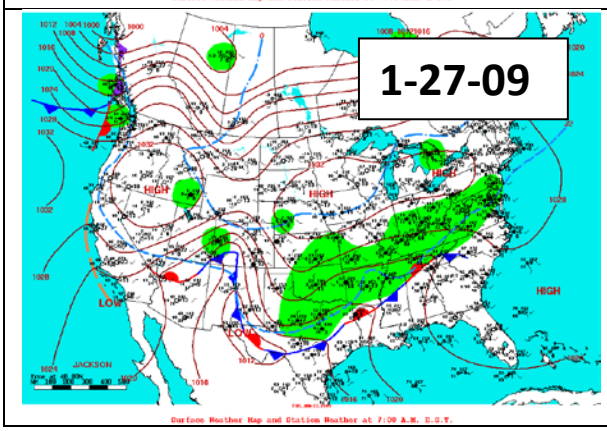
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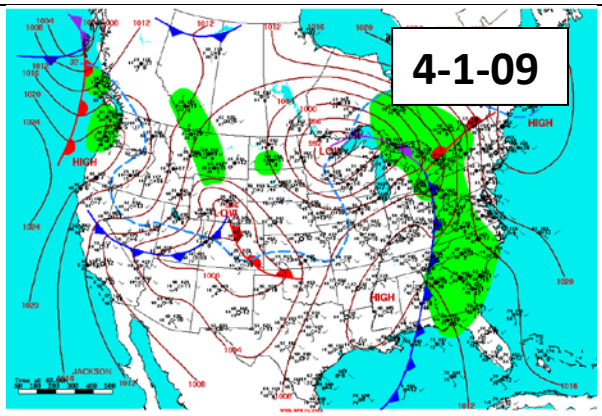
HIGH
LOW
HIGH
JACKSON

Period 8


4-1-09
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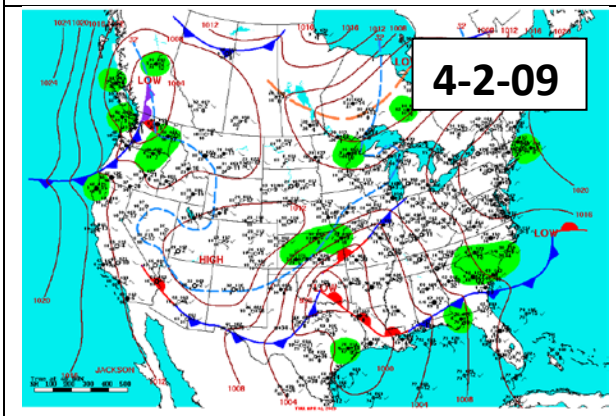
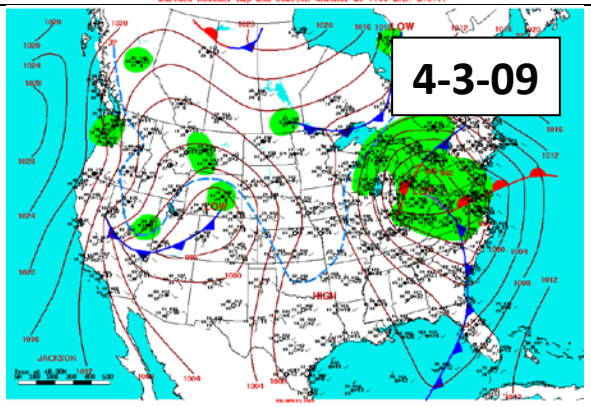
LOW
HIGH
LOW
HIGH
JACKSON


4-2-09
LOW
LOW
HIGH
LOW
JACKSON


4-3-09
LOW
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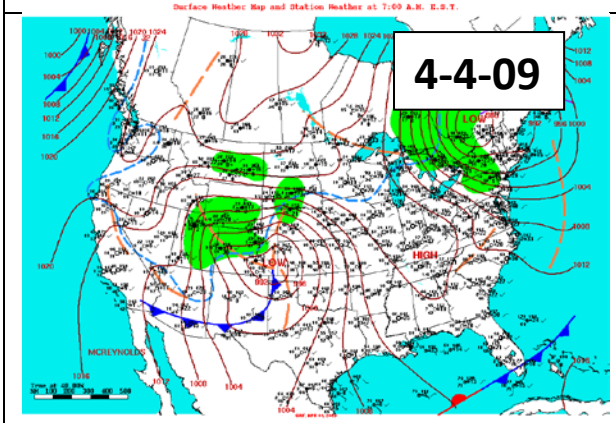
JACKSON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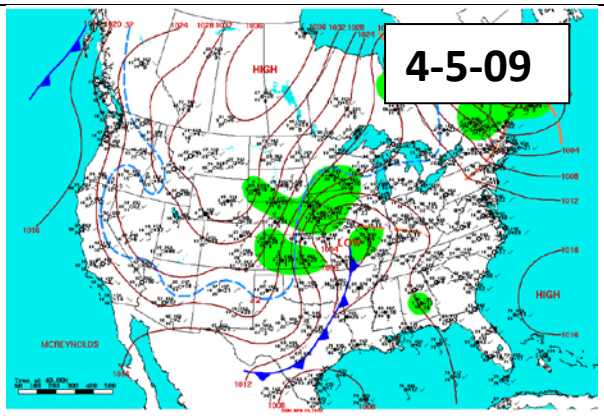
LOW
HIGH
LOW
MCREYNOLDS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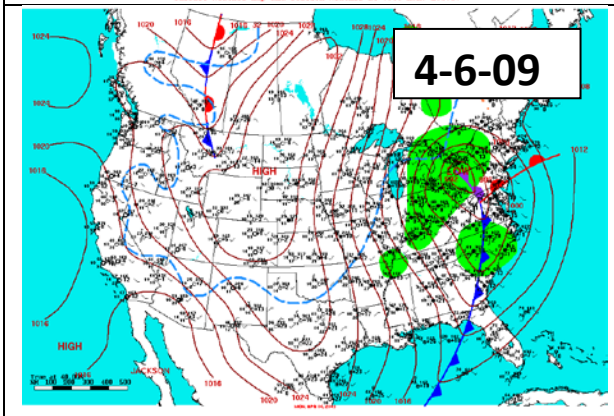
HIGH
MCREYNOLDS


4-6-09
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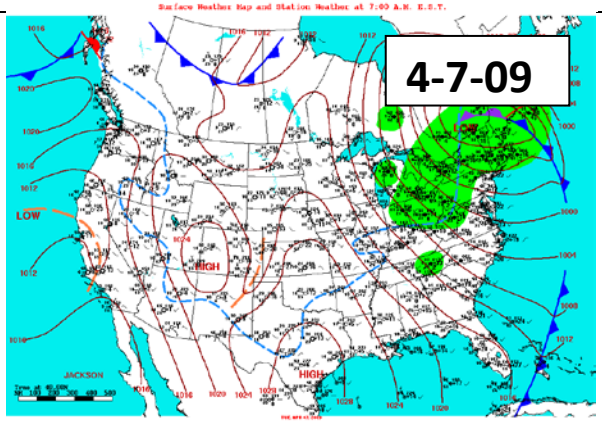
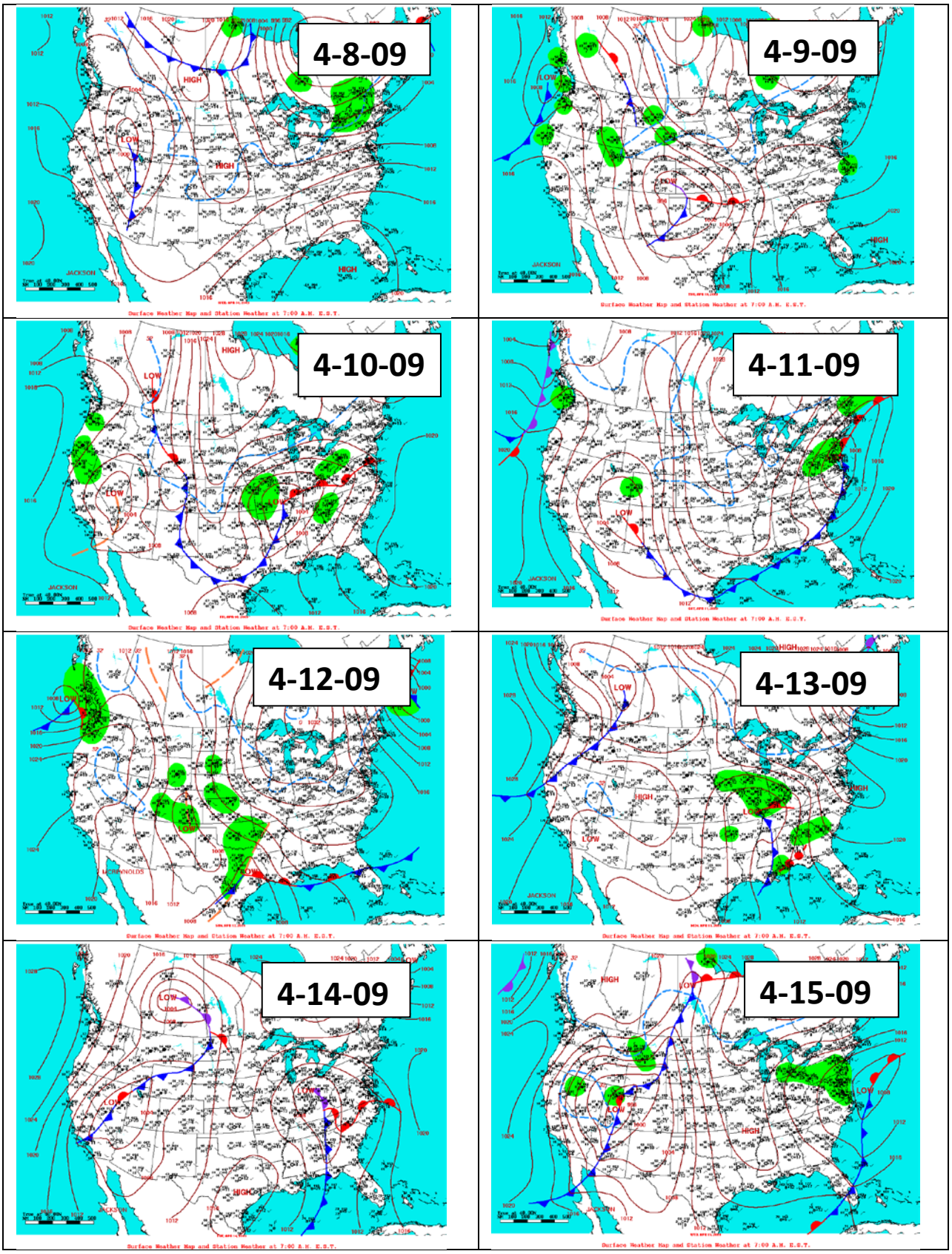
HIGH
JACKSON


4-7-09
LOW
HIGH
HIGH
JACKSON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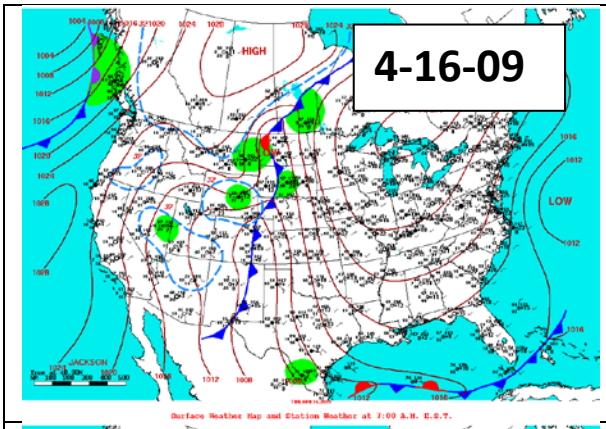
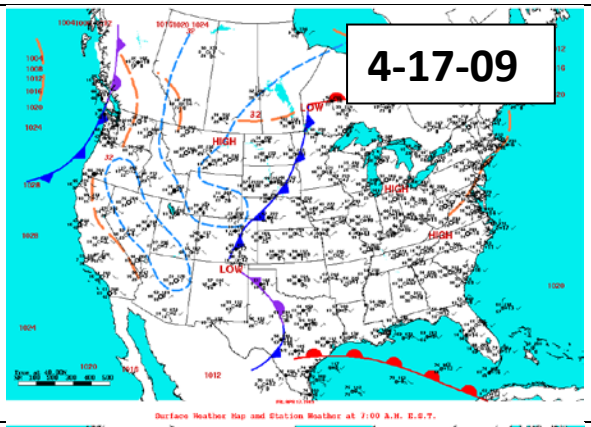
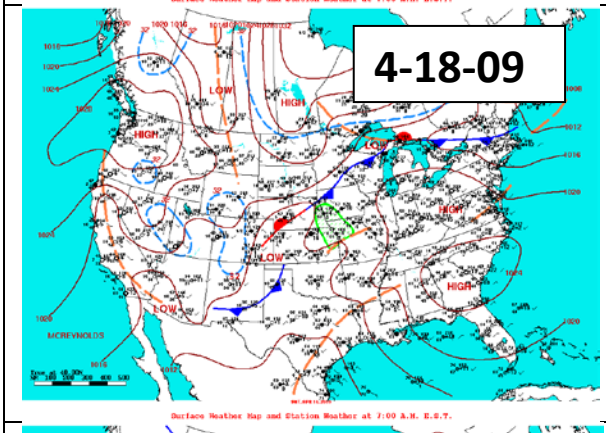
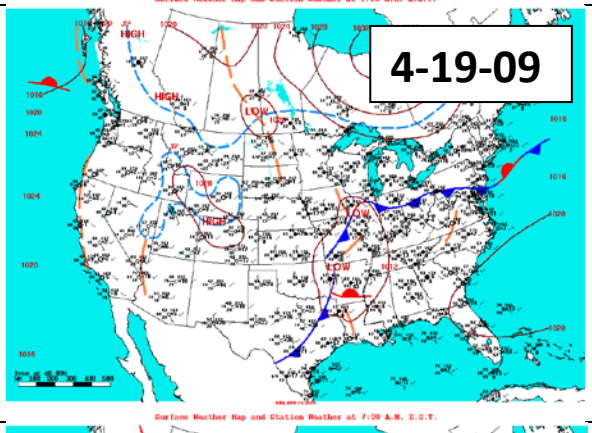
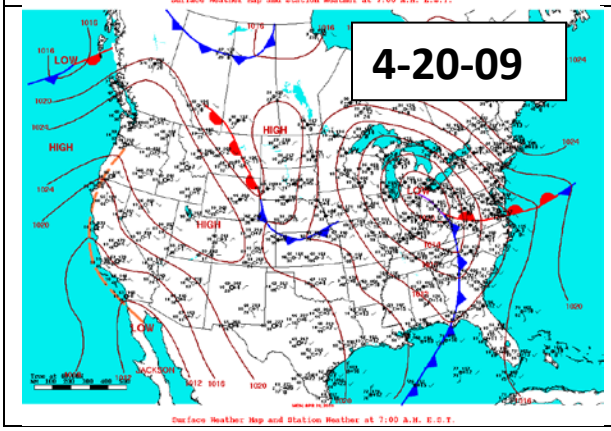
4-12-09
4-13-09
4-14-09
4-15-09

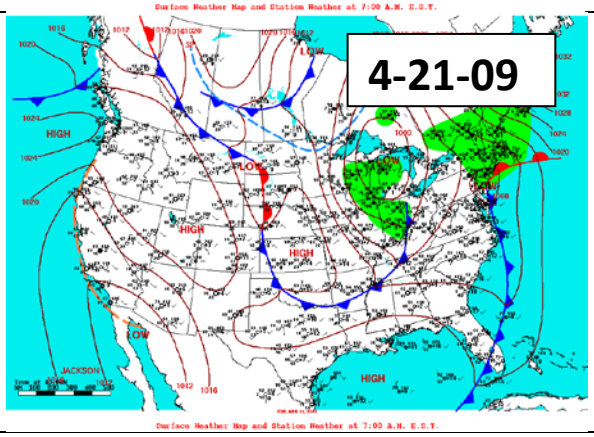




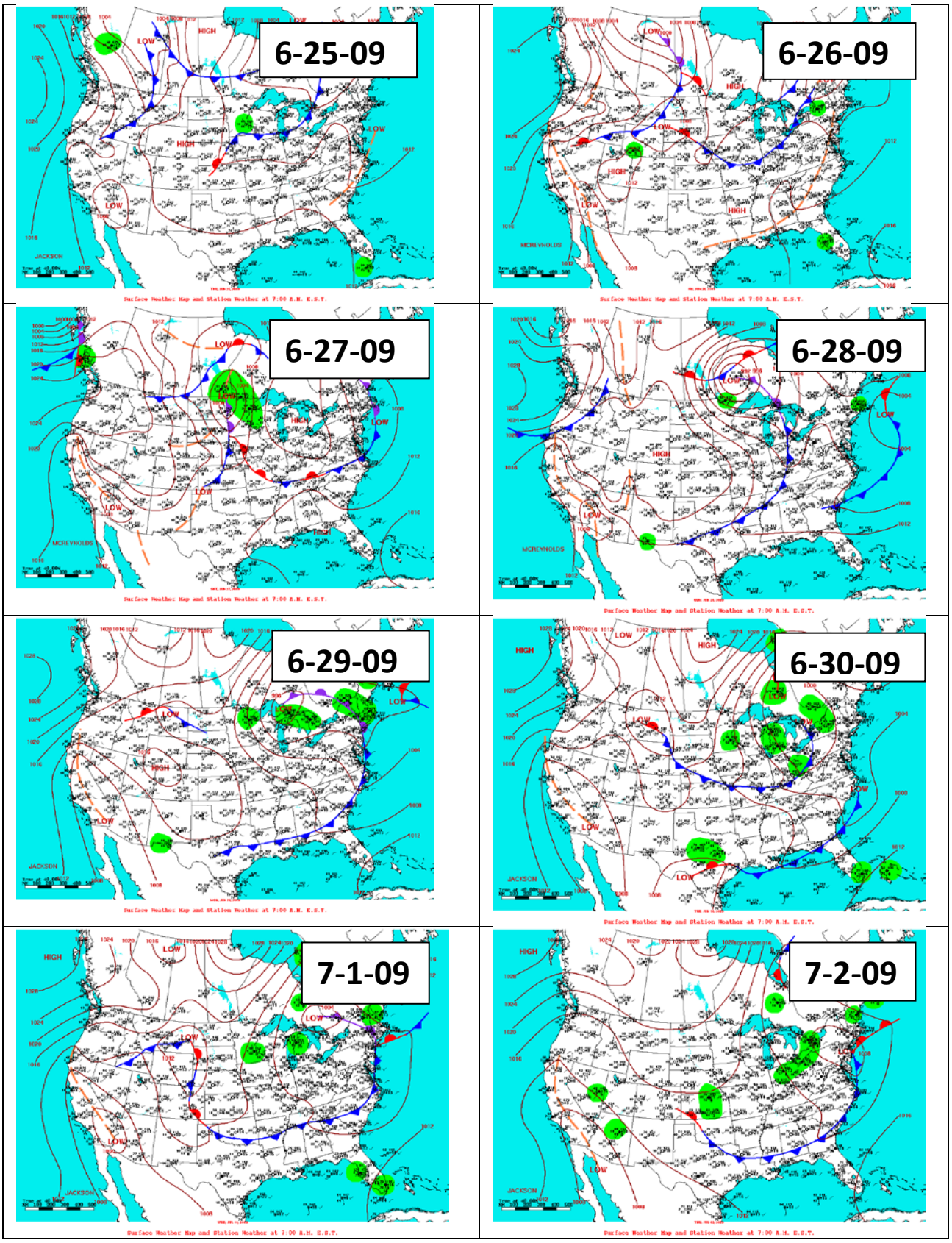


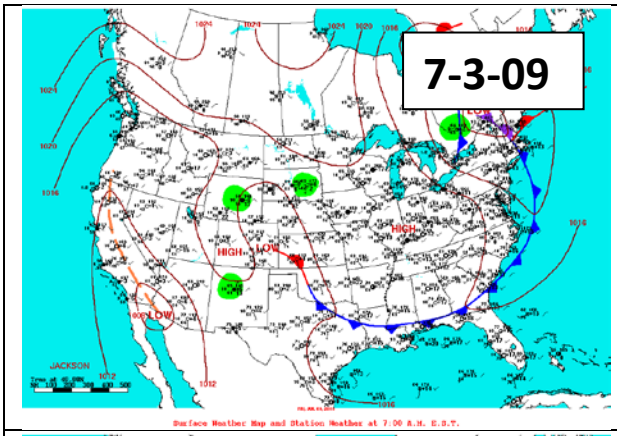


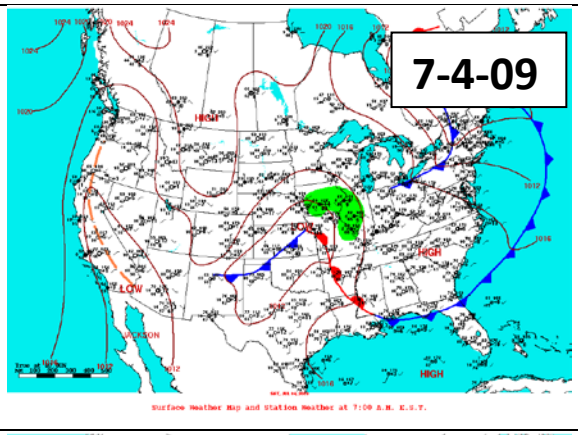


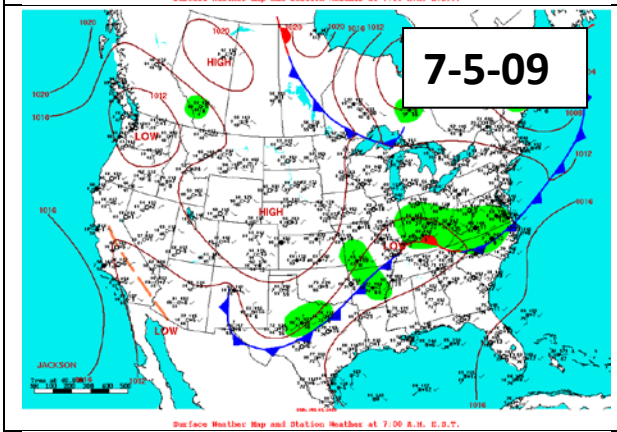


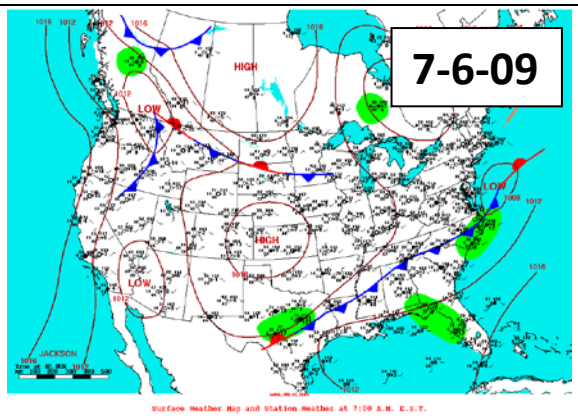
Period 9	


6-25-09
6-26-09
6-27-09
6-28-09
6-29-09
6-30-09
7-1-09
7-2-09


7-3-09
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-4-09
HIGH
LOW
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-5-09
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-6-09
HIGH
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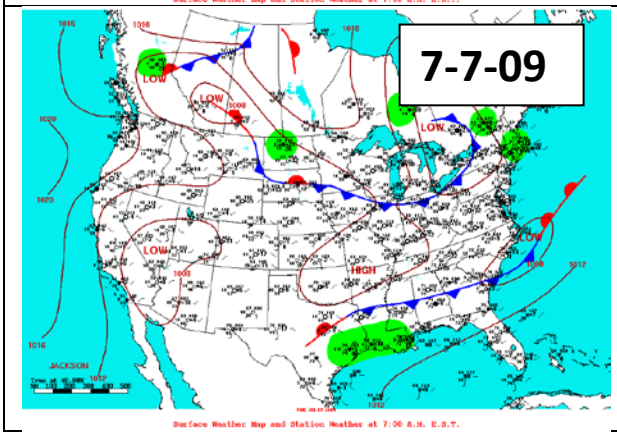
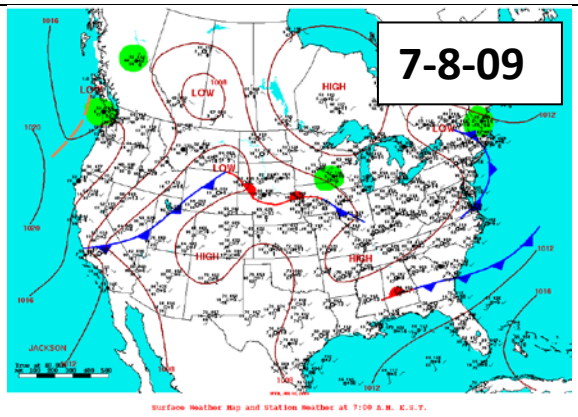
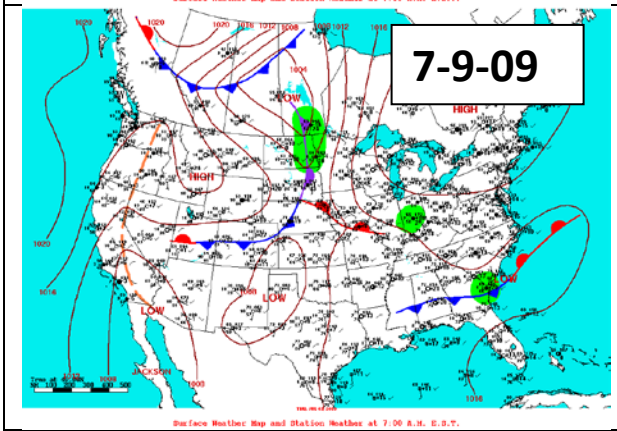
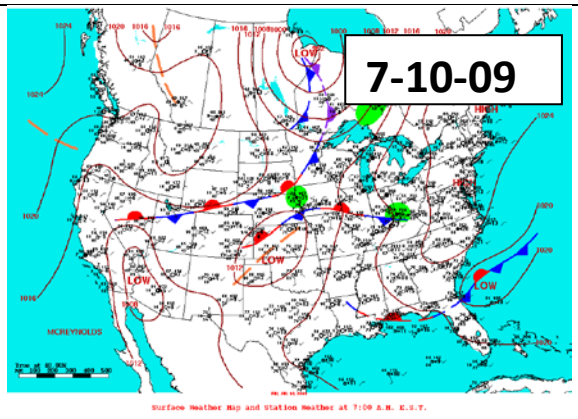
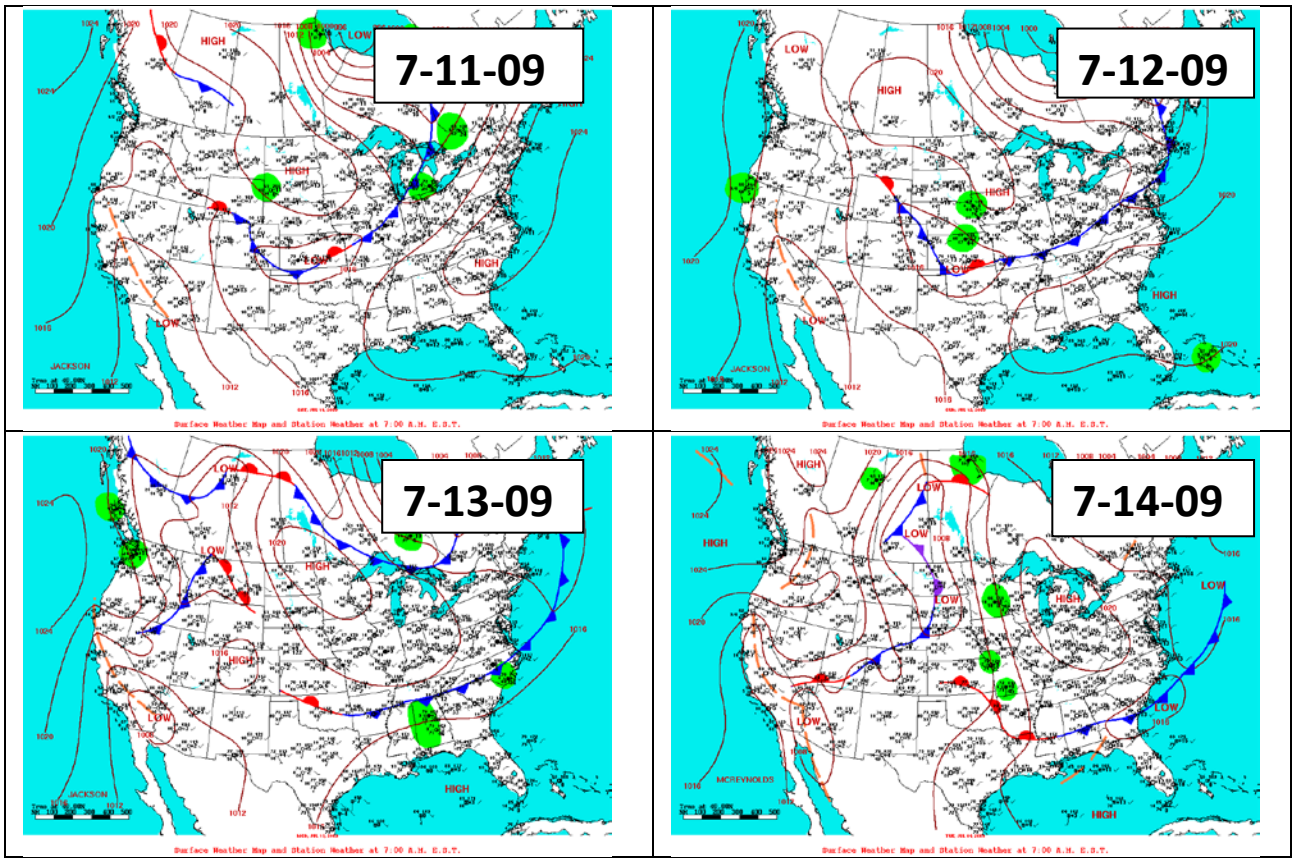
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-7-09
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-8-09
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-9-09
HIGH
LOW
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-10-09
HIGH
LOW
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-11-09
7-12-09
7-13-09
7-14-09

6.10 Daily weather conditions

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 1				
6/28/2007	91.50	438	0%	25.5
6/29/2007	91.59	995	52%	19.6
6/30/2007	91.43	1171	64%	21.6
7/1/2007	91.47	990	62%	21.3
7/2/2007	91.55	1189	59%	22.5
7/3/2007	91.44	966	93%	23.4
7/4/2007	91.50	955	61%	26.2
7/5/2007	91.71	897	56%	23.1
7/6/2007	91.85	976	51%	23.9
7/7/2007	91.44	1029	42%	25.3
7/8/2007	90.76	955	20%	27.5
7/9/2007	90.80	930	19%	25.9
7/10/2007	91.11	912	37%	24.8
7/11/2007	91.66	998	31%	23.1
7/12/2007	91.37	1018	51%	25.0
7/13/2007	91.64	1156	34%	21.3
7/14/2007	91.39	1065	0%	24.5
7/15/2007	91.24	972	6%	25.4
7/16/2007	91.13	953	0%	26.8
7/17/2007	91.18	949	0%	26.1
7/18/2007	91.11	948	0%	27.4
7/19/2007	90.97	982	0%	27.3
7/20/2007	91.19	1107	0%	26.9
7/21/2007	91.41	1057	69%	26.4
7/22/2007	91.57	1098	63%	26.1
7/23/2007	91.43	1058	46%	27.2
7/24/2007	91.25	1027	49%	25.6
7/25/2007	91.14	1063	44%	26.1
7/26/2007	91.12	941	18%	26.2
7/27/2007	91.19	946	28%	26.5
7/28/2007	91.10	1058	32%	25.8
7/29/2007	91.05	1050	27%	26.5
7/30/2007	91.12	1073	29%	26.7
7/31/2007	91.14	1091	28%	26.4
8/1/2007	91.07	1037	41%	25.6
8/2/2007	91.40	1074	62%	23.2
8/3/2007	91.55	1084	36%	23.3
8/4/2007	91.19	937	20%	26.6

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
8/5/2007	90.94	979	22%	28.5
8/6/2007	90.74	979	71%	29.9
8/7/2007	90.70	997	54%	29.5
8/8/2007	90.72	923	64%	28.9
8/9/2007	91.06	938	52%	28.6
8/10/2007	91.25	922	56%	28.1
8/11/2007	91.14	923	38%	29.1
8/12/2007	91.49	943	38%	29.7
8/13/2007	91.56	919	34%	29.9
8/14/2007	91.38	244	25%	25.8
8/15/2007	91.11	933	0%	35.2
8/16/2007	91.23	913	0%	27.4
8/17/2007	91.42	933	0%	27.3
8/18/2007	91.27	1007	38%	24.6
8/19/2007	90.95	892	41%	25.6
8/20/2007	90.65	885	26%	29.6
8/21/2007	90.94	886	5%	28.2
8/22/2007	90.98	885	0%	26.9
8/23/2007	90.61	1109	0%	28.1
8/24/2007	90.94	620	50%	21.3
8/25/2007	91.33	874	49%	22.2
8/26/2007	91.13	897	0%	26.9
8/27/2007	91.12	908	0%	27.2
8/28/2007	91.12	997	0%	27.1
8/29/2007	91.53	750	0%	23.9
Period 2				
11/7/2007	N/A	628	0%	19.8
11/8/2007	N/A	631	0%	11.6
11/9/2007	N/A	614	0%	12.2
11/10/2007	N/A	638	37%	14.6
11/11/2007	N/A	602	0%	14.8
11/12/2007	N/A	435	2%	10.2
11/13/2007	N/A	579	0%	9.5
11/14/2007	N/A	697	0%	9.5
11/15/2007	N/A	583	0%	1.8
11/16/2007	N/A	593	0%	9.2
11/17/2007	N/A	594	0%	12.2
11/18/2007	N/A	560	0%	12.4
11/19/2007	N/A	574	0%	13.5
11/20/2007	N/A	575	0%	10.6
11/21/2007	N/A	594	0%	2.3
11/22/2007	N/A	568	23%	-4.2

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
11/23/2007	N/A	291	46%	-4.3
11/24/2007	N/A	661	64%	-3.0
11/25/2007	N/A	568	70%	-4.0
11/26/2007	N/A	623	1%	1.4
11/27/2007	N/A	551	57%	1.8
11/28/2007	N/A	166	0%	8.9
Period 3				
11/29/2007	N/A	518	0%	-0.4
11/30/2007	N/A	338	0%	-0.9
12/1/2007	N/A	477	33%	6.2
12/2/2007	N/A	534	0%	6.5
12/3/2007	N/A	539	0%	2.3
12/4/2007	N/A	529	0%	10.1
12/5/2007	N/A	562	0%	8.8
12/6/2007	N/A	434	2%	3.9
12/7/2007	N/A	94	63%	0.5
12/8/2007	N/A	109	100%	-2.2
12/9/2007	N/A	513	99%	-6.8
12/10/2007	N/A	331	95%	-3.1
12/11/2007	N/A	214	100%	0.0
12/12/2007	N/A	545	78%	-2.5
12/13/2007	N/A	583	52%	-1.0
12/14/2007	N/A	55	55%	-3.9
12/15/2007	N/A	532	77%	-4.0
12/16/2007	N/A	527	0%	-5.0
12/17/2007	N/A	543	0%	-0.3
12/18/2007	N/A	523	0%	3.9
12/19/2007	N/A	506	0%	1.8
Period 4				
4/23/2008	90.65	383	29%	15.5
4/24/2008	90.32	832	71%	17.0
4/25/2008	90.80	968	0%	15.4
4/26/2008	91.25	917	0%	11.1
4/27/2008	92.16	966	8%	8.1
4/28/2008	91.59	1041	0%	13.7
4/29/2008	90.91	1038	26%	14.1
4/30/2008	89.75	1054	0%	20.3
5/1/2008	89.38	994	0%	19.8
5/2/2008	90.29	1096	0%	9.9
5/3/2008	91.60	984	0%	7.8
5/4/2008	91.27	978	0%	12.8

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
5/5/2008	91.15	1035	3%	19.1
5/6/2008	90.78	1009	49%	18.5
Period 6				
10/1/2008	91.64	787	0%	25.4
10/2/2008	91.37	775	13%	16.4
10/3/2008	90.83	794	60%	19.6
10/4/2008	90.69	769	52%	20.5
10/5/2008	90.62	125	80%	18.1
10/6/2008	90.67	703	73%	14.7
10/7/2008	91.76	782	53%	13.8
10/8/2008	91.31	779	25%	15.1
10/9/2008	90.93	760	22%	17.9
10/10/2008	90.39	766	0%	21.0
10/11/2008	90.87	144	38%	16.8
10/12/2008	90.77	96	100%	16.7
10/13/2008	91.56	356	54%	11.2
10/14/2008	92.03	104	52%	8.0
10/15/2008	91.82	587	90%	6.7
Period 7				
1/8/2009	90.84	478	0%	15.2
1/9/2009	90.39	479	37%	6.1
1/10/2009	92.01	499	61%	0.0
1/11/2009	92.04	497	9%	0.9
1/12/2009	91.57	442	2%	2.3
1/13/2009	92.01	499	43%	-0.8
1/14/2009	91.62	516	0%	3.2
1/15/2009	92.66	436	35%	-7.2
1/16/2009	92.39	508	56%	-1.8
1/17/2009	91.78	521	0%	6.7
1/18/2009	91.99	597	0%	7.0
1/19/2009	91.57	526	0%	11.5
1/20/2009	91.99	530	0%	6.9
1/21/2009	91.45	553	0%	8.3
1/22/2009	90.84	667	0%	8.0
1/23/2009	91.17	611	0%	6.3
1/24/2009	92.33	523	31%	-5.8
1/25/2009	91.29	558	0%	-6.4
1/26/2009	91.49	186	44%	-9.9
1/27/2009	91.80	503	94%	-11.7
Period 8				
4/2/2009	90.58	905	0%	10.1
4/3/2009	90.05	891	45%	8.7

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
4/4/2009	89.38	904	0%	14.2
4/5/2009	91.46	902	0%	1.9
4/6/2009	92.43	973	24%	1.8
4/7/2009	91.67	937	13%	7.0
4/8/2009	90.73	940	0%	13.6
4/9/2009	89.56	840	0%	13.1
4/10/2009	91.19	973	42%	6.6
4/11/2009	91.46	851	51%	5.7
4/12/2009	90.72	405	98%	6.5
4/13/2009	91.00	1073	61%	8.3
4/14/2009	90.85	991	36%	13.4
4/15/2009	90.60	1050	0%	16.4
4/16/2009	90.77	764	42%	13.2
4/17/2009	91.01	1123	71%	12.0
4/18/2009	90.99	1112	43%	8.4
4/19/2009	91.68	1006	54%	10.7
4/20/2009	91.67	956	5%	13.2
4/21/2009	91.42	967	1%	15.3
Period 9				
6/23/2009	90.97	1055	0%	33.8
6/24/2009	91.15	1080	16%	28.5
6/25/2009	91.17	973	1%	29.1
6/26/2009	90.96	977	0%	29.1
6/27/2009	90.94	1190	0%	27.4
6/28/2009	91.58	1009	31%	24.1
6/29/2009	91.15	987	0%	26.0
6/30/2009	91.00	995	49%	25.5
7/1/2009	91.08	979	28%	25.9
7/2/2009	91.17	970	62%	28.0
7/3/2009	91.21	1100	68%	28.9
7/4/2009	91.12	1105	57%	26.8
7/5/2009	91.51	1191	19%	23.0
7/6/2009	91.36	1121	17%	23.0
7/7/2009	90.90	965	46%	24.7
7/8/2009	90.61	970	27%	28.3
7/9/2009	90.65	987	7%	31.1
7/10/2009	90.97	1061	0%	32.9
7/11/2009	91.44	884	7%	26.8
7/12/2009	N/A	N/A	N/A	N/A
7/13/2009	N/A	N/A	N/A	N/A
7/14/2009	90.75	997	0%	37.1

6.11 Daily lagoon conditions

Date	Air temperature (°C)	Lagoon temperature (°C)	Lagoon pH	ORP (mV)
Period 1				
6/28/2007	25.5	25.7	7.9	-468
6/29/2007	19.6	25.0	7.9	-478
6/30/2007	21.6	25.2	7.9	-500
7/1/2007	21.3	25.3	7.9	-504
7/2/2007	22.5	26.4	7.9	-498
7/3/2007	23.4	27.7	7.9	-486
7/4/2007	26.2	27.5	7.9	-505
7/5/2007	23.1	26.3	7.8	-517
7/6/2007	23.9	27.1	7.8	-506
7/7/2007	25.3	27.4	7.8	-494
7/8/2007	27.5	26.3	7.8	-456
7/9/2007	25.9	26.0	7.8	-507
7/10/2007	24.8	26.5	7.8	-518
7/11/2007	23.1	26.5	7.8	-507
7/12/2007	25.0	27.2	7.8	-495
7/13/2007	21.3	26.7	7.9	-492
7/14/2007	24.5	28.4	7.8	-510
7/15/2007	25.4	28.1	7.8	-505
7/16/2007	26.8	27.4	7.8	-467
7/17/2007	26.1	26.4	7.8	-492
7/18/2007	27.4	26.2	7.8	-489
7/19/2007	27.3	25.9	7.8	-488
7/20/2007	26.9	27.2	7.8	-506
7/21/2007	26.4	27.6	7.8	-510
7/22/2007	26.1	27.5	7.8	-510
7/23/2007	27.2	28.3	7.8	-513
7/24/2007	25.6	28.3	7.8	-527
7/25/2007	26.1	28.0	7.8	-511
7/26/2007	26.2	26.8	7.8	-503
7/27/2007	26.5	26.9	7.8	-520
7/28/2007	25.8	28.0	7.8	-525
7/29/2007	26.5	28.8	7.8	-518
7/30/2007	26.7	28.2	7.8	-515
7/31/2007	26.4	27.5	7.8	-514
8/1/2007	25.6	26.6	7.8	-518
8/2/2007	23.2	N/A	N/A	N/A
8/3/2007	23.3	28.1	7.8	-435
8/4/2007	26.6	26.8	7.8	-413
8/5/2007	28.5	27.0	7.8	-438

Date	Air temperature (°C)	Lagoon temperature (°C)	Lagoon pH	ORP (mV)
8/6/2007	29.9	27.5	7.8	-454
8/7/2007	29.5	28.1	7.8	-453
8/8/2007	28.9	27.3	7.8	-510
8/9/2007	28.6	27.4	7.8	-536
8/10/2007	28.1	27.7	7.8	-499
8/11/2007	29.1	26.8	7.8	-491
8/12/2007	29.7	27.1	7.8	-504
8/13/2007	29.9	27.3	7.8	-501
8/14/2007	25.8	26.6	7.8	-526
8/15/2007	35.2	27.4	7.8	-334
8/16/2007	27.4	26.7	7.9	-446
8/17/2007	27.3	27.3	7.9	-444
8/18/2007	24.6	26.3	7.9	-454
8/19/2007	25.6	27.0	7.9	-484
8/20/2007	29.6	28.8	7.9	-458
8/21/2007	28.2	27.2	7.9	-478
8/22/2007	26.9	26.5	7.9	-435
8/23/2007	28.1	25.4	7.9	-360
8/24/2007	21.3	25.0	7.9	-517
8/25/2007	22.2	25.6	7.9	-518
8/26/2007	26.9	26.0	7.9	-491
8/27/2007	27.2	24.8	7.9	-498
8/28/2007	27.1	24.7	7.9	-513
8/29/2007	23.9	24.5	7.9	-525
Period 2				
11/7/2007	19.8	N/A	N/A	N/A
11/8/2007	11.6	10.4	8.2	-345
11/9/2007	12.2	9.6	8.2	-397
11/10/2007	14.6	9.8	8.2	-402
11/11/2007	14.8	10.6	8.2	-433
11/12/2007	10.2	10.6	8.2	-459
11/13/2007	9.5	9.5	8.2	-416
11/14/2007	9.5	9.4	8.2	-466
11/15/2007	1.8	8.2	8.2	-431
11/16/2007	9.2	7.4	8.3	-467
11/17/2007	12.2	7.8	8.3	-494
11/18/2007	12.4	8.2	8.3	-475
11/19/2007	13.5	9.1	8.3	-456
11/20/2007	10.6	8.3	8.2	-510
11/21/2007	2.3	7.7	8.3	-468
11/22/2007	-4.2	6.3	8.3	-489

Date	Air temperature (°C)	Lagoon temperature (°C)	Lagoon pH	ORP (mV)
11/23/2007	-4.3	5.2	8.3	-469
11/24/2007	-3.0	3.8	8.3	-428
11/25/2007	-4.0	3.6	8.3	-464
11/26/2007	1.4	3.4	8.3	-504
11/27/2007	1.8	3.3	8.3	-408
11/28/2007	8.9	4.0	8.3	-249
Period 3				
11/29/2007	-0.4	N/A	N/A	N/A
11/30/2007	-0.9	N/A	N/A	N/A
12/1/2007	6.2	N/A	N/A	N/A
12/2/2007	6.5	N/A	N/A	N/A
12/3/2007	2.3	N/A	N/A	N/A
12/4/2007	10.1	N/A	N/A	N/A
12/5/2007	8.8	N/A	N/A	N/A
12/6/2007	3.9	N/A	N/A	N/A
12/7/2007	0.5	N/A	N/A	N/A
12/8/2007	-2.2	N/A	N/A	N/A
12/9/2007	-6.8	N/A	N/A	N/A
12/10/2007	-3.1	N/A	N/A	N/A
12/11/2007	0.0	N/A	N/A	N/A
12/12/2007	-2.5	N/A	N/A	N/A
12/13/2007	-1.0	N/A	N/A	N/A
12/14/2007	-3.9	N/A	N/A	N/A
12/15/2007	-4.0	N/A	N/A	N/A
12/16/2007	-5.0	N/A	N/A	N/A
12/17/2007	-0.3	N/A	N/A	N/A
12/18/2007	3.9	N/A	N/A	N/A
12/19/2007	1.8	N/A	N/A	N/A
Period 4				
4/23/2008	15.5	N/A	N/A	N/A
4/24/2008	17.0	N/A	N/A	N/A
4/25/2008	15.4	15.7	N/A	-428
4/26/2008	11.1	15.3	N/A	-474
4/27/2008	8.1	14.1	N/A	-485
4/28/2008	13.7	14.6	N/A	-466
4/29/2008	14.1	14.9	N/A	-513
4/30/2008	20.3	15.0	N/A	-442
5/1/2008	19.8	15.6	N/A	-435
5/2/2008	9.9	14.3	N/A	-459
5/3/2008	7.8	12.7	N/A	-478
5/4/2008	12.8	13.8	N/A	-460
5/5/2008	19.1	14.8	N/A	-452

Date	Air temperature (°C)	Lagoon temperature (°C)	Lagoon pH	ORP (mV)
5/6/2008	18.5	16.1	N/A	-455
Period 6				
10/1/2008	25.4	N/A	N/A	N/A
10/2/2008	16.4	19.5	N/A	-416
10/3/2008	19.6	19.2	N/A	-475
10/4/2008	20.5	19.0	N/A	-456
10/5/2008	18.1	18.1	N/A	-330
10/6/2008	14.7	17.2	N/A	-477
10/7/2008	13.8	17.0	N/A	-525
10/8/2008	15.1	18.6	N/A	-528
10/9/2008	17.9	N/A	N/A	N/A
10/10/2008	21.0	N/A	N/A	N/A
10/11/2008	16.8	N/A	N/A	N/A
10/12/2008	16.7	N/A	N/A	N/A
10/13/2008	11.2	N/A	N/A	N/A
10/14/2008	8.0	N/A	N/A	N/A
10/15/2008	6.7	N/A	N/A	N/A
Period 7				
1/8/2009	15.2	N/A	N/A	N/A
1/9/2009	6.1	N/A	N/A	N/A
1/10/2009	0.0	N/A	N/A	N/A
1/11/2009	0.9	N/A	N/A	N/A
1/12/2009	2.3	N/A	N/A	N/A
1/13/2009	-0.8	N/A	N/A	N/A
1/14/2009	3.2	N/A	N/A	N/A
1/15/2009	-7.2	N/A	N/A	N/A
1/16/2009	-1.8	N/A	N/A	N/A
1/17/2009	6.7	N/A	N/A	N/A
1/18/2009	7.0	N/A	N/A	N/A
1/19/2009	11.5	N/A	N/A	N/A
1/20/2009	6.9	N/A	N/A	N/A
1/21/2009	8.3	N/A	N/A	N/A
1/22/2009	8.0	N/A	N/A	N/A
1/23/2009	6.3	N/A	N/A	N/A
1/24/2009	-5.8	N/A	N/A	N/A
1/25/2009	-6.4	N/A	N/A	N/A
1/26/2009	-9.9	N/A	N/A	N/A
1/27/2009	-11.7	N/A	N/A	N/A
Period 8				
4/2/2009	10.1	7.2	8.4	-433
4/3/2009	8.7	7.4	8.2	-515

Date	Air temperature (°C)	Lagoon temperature (°C)	Lagoon pH	ORP (mV)
4/4/2009	14.2	8.3	7.9	-520
4/5/2009	1.9	7.7	7.9	-520
4/6/2009	1.8	6.7	7.9	-537
4/7/2009	7.0	6.6	7.8	-531
4/8/2009	13.6	7.6	7.7	-464
4/9/2009	13.1	8.7	7.6	-453
4/10/2009	6.6	8.8	7.7	-458
4/11/2009	5.7	9.6	7.6	-483
4/12/2009	6.5	9.2	7.6	-513
4/13/2009	8.3	8.8	7.7	-533
4/14/2009	13.4	9.3	7.8	-535
4/15/2009	16.4	10.8	7.6	-513
4/16/2009	13.2	11.5	7.7	-514
4/17/2009	12.0	11.6	7.8	-499
4/18/2009	8.4	11.9	7.6	-527
4/19/2009	10.7	11.5	7.5	-538
4/20/2009	13.2	11.6	7.5	-536
4/21/2009	15.3	12.6	7.2	-544
Period 9				
6/23/2009	33.8	N/A	N/A	N/A
6/24/2009	28.5	27.2	7.9	-400
6/25/2009	29.1	26.6	7.7	-448
6/26/2009	29.1	26.1	7.4	-502
6/27/2009	27.4	25.1	7.2	-521
6/28/2009	24.1	24.5	6.9	-536
6/29/2009	26.0	25.0	6.8	-538
6/30/2009	25.5	25.4	6.7	-542
7/1/2009	25.9	25.3	6.6	-545
7/2/2009	28.0	25.8	6.6	-545
7/3/2009	28.9	25.1	6.7	-541
7/4/2009	26.8	24.7	6.9	-477
7/5/2009	23.0	24.6	6.7	-496
7/6/2009	23.0	24.6	6.6	-520
7/7/2009	24.7	24.8	6.6	-521
7/8/2009	28.3	25.7	6.5	-525
7/9/2009	31.1	26.3	6.5	-529
7/10/2009	32.9	26.1	6.7	-514
7/11/2009	26.8	25.3	6.6	-452
7/12/2009	N/A	N/A	N/A	N/A
7/13/2009	N/A	N/A	N/A	N/A
7/14/2009	37.1	25.8	6.6	-540

6.12 Daily site emissions and data completeness

6.12.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either u_* < 0.15 ms^{-1} or |L| < 2 m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
Period 1										
6/29/2007	5	0	15	124.1	10.8	112.8	138.8	201.7	72.4	164.3
6/30/2007	10	0	34	149.7	84.9	44.1	285.6	243.2	87.4	198.1
7/1/2007	2	0	45	67.6	2.3	66.0	69.1	109.7	39.4	89.4
7/2/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/3/2007	3	0	43	58.5	6.8	51.1	64.4	95.0	34.1	77.4
7/4/2007	8	0	40	113.5	26.3	54.8	139.4	184.4	66.2	150.2
7/5/2007	20	0	28	157.8	32.3	77.1	219.7	256.4	92.1	208.8
7/6/2007	2	0	46	98.1	25.2	80.3	116.0	159.4	57.3	129.8
7/7/2007	13	0	34	117.4	32.4	60.1	155.9	190.7	68.5	155.4
7/8/2007	35	0	13	154.3	24.9	110.6	211.2	250.7	90.1	204.2
7/9/2007	13	0	35	138.7	35.4	77.1	183.5	225.4	81.0	183.6
7/10/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/11/2007	10	0	38	130.3	62.1	13.3	199.5	211.7	76.0	172.4
7/12/2007	1	0	47	126.6	N/A	126.6	126.6	205.6	73.9	167.5
7/13/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
7/14/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/15/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/16/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/17/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/18/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/19/2007	7	0	41	179.6	42.2	84.0	201.1	291.7	104.8	237.6
7/20/2007	31	8	7	134.6	68.0	26.1	259.6	218.7	78.6	178.1
7/21/2007	43	0	5	143.5	47.1	89.4	351.1	233.1	83.7	189.9
7/22/2007	36	0	12	128.9	37.7	79.8	270.2	209.4	75.2	170.6
7/23/2007	37	3	8	117.9	48.8	29.8	283.5	191.4	68.8	155.9
7/24/2007	7	0	19	157.6	149.8	47.3	386.7	256.0	92.0	208.5
7/25/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/26/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/27/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/28/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/29/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/30/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/31/2007	2	0	2	393.6	108.3	317.0	470.2	639.4	229.7	520.8
8/1/2007	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/2/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/3/2007	3	0	18	92.4	24.0	66.5	113.8	150.0	53.9	122.2
8/4/2007	22	0	26	135.1	19.3	110.1	186.2	219.4	78.8	178.7
8/5/2007	12	0	36	148.0	41.8	64.4	197.9	240.5	86.4	195.9
8/6/2007	12	0	36	132.4	26.1	58.5	159.0	215.1	77.3	175.2
8/7/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/8/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/9/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/10/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2007	15	0	33	126.5	28.9	76.1	162.8	205.5	73.8	167.4
8/13/2007	37	0	11	134.1	23.1	71.8	178.2	217.8	78.2	177.4
8/14/2007	0	0	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/15/2007	18	2	0	166.0	51.4	78.7	240.4	269.7	96.9	219.7
8/16/2007	20	12	12	98.3	49.7	11.7	187.2	159.6	57.3	130.0
8/17/2007	40	2	3	117.3	49.4	39.4	266.5	190.5	68.4	155.2
8/18/2007	46	0	2	109.4	31.4	26.1	192.6	177.6	63.8	144.7
8/19/2007	22	0	23	132.7	92.9	11.7	294.7	215.5	77.4	175.5
8/20/2007	47	0	1	122.5	48.0	62.2	269.1	198.9	71.4	162.0
8/21/2007	36	0	12	147.8	35.8	99.5	249.5	240.1	86.2	195.5
8/22/2007	48	0	0	195.7	71.8	85.6	334.6	317.9	114.2	259.0
8/23/2007	33	0	15	209.3	79.1	103.7	383.5	339.9	122.1	276.8
8/24/2007	3	0	45	38.1	7.5	29.8	44.1	61.9	22.2	50.4
8/25/2007	0	0	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
8/26/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/27/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/28/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 2										
11/8/2007	0	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/9/2007	5	8	27	17.4	4.2	11.7	21.3	28.3	10.2	23.1
11/10/2007	21	0	25	19.7	5.7	5.9	27.7	32.0	11.5	26.1
11/11/2007	10	25	10	34.0	13.2	16.0	65.4	55.2	19.8	45.0
11/12/2007	1	0	46	42.6	N/A	42.6	42.6	69.1	24.8	56.3
11/13/2007	0	8	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/14/2007	1	1	45	20.2	N/A	20.2	20.2	32.8	11.8	26.7
11/15/2007	7	8	32	22.9	3.4	18.1	27.7	37.2	13.3	30.3
11/16/2007	8	12	27	21.9	5.8	16.0	31.4	35.5	12.8	28.9
11/17/2007	3	7	38	15.1	11.4	7.4	28.2	24.5	8.8	19.9
11/18/2007	6	16	25	25.8	13.7	12.2	50.5	41.9	15.1	34.1
11/19/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/20/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/21/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/22/2007	0	13	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/23/2007	7	0	32	14.7	3.8	10.1	21.8	23.9	8.6	19.5
11/24/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/25/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/26/2007	1	0	45	26.6	N/A	26.6	26.6	43.2	15.5	35.2
11/27/2007	0	0	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/28/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 3										
11/29/2007	8	6	18	18.2	5.8	9.6	26.6	29.6	10.6	24.1
11/30/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2007	4	1	34	50.5	25.2	19.7	81.4	82.1	29.5	66.9
12/2/2007	5	1	32	22.2	7.4	13.3	30.9	36.1	13.0	29.4
12/3/2007	5	8	20	15.2	2.4	13.3	19.1	24.7	8.9	20.1
12/4/2007	2	26	16	29.8	4.5	26.6	33.0	48.4	17.4	39.4
12/5/2007	0	5	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/6/2007	0	2	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/7/2007	0	0	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/8/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/9/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2007	0	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/11/2007	1	0	25	3.2	N/A	3.2	3.2	5.2	1.9	4.2
12/12/2007	1	3	21	4.8	N/A	4.8	4.8	7.8	2.8	6.3
12/13/2007	1	1	30	4.3	N/A	4.3	4.3	6.9	2.5	5.6
12/14/2007	0	0	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2007	0	1	36	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
12/16/2007	0	1	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/17/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/18/2007	0	0	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4										
4/24/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/26/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/27/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/28/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2008	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/4/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/5/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/6/2008	0	0	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6										
10/1/2008	0	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/2/2008	22	0	22	94.7	21.4	52.7	139.4	153.9	55.3	125.3
10/3/2008	43	4	0	67.2	25.4	20.7	120.2	109.2	39.2	89.0
10/4/2008	47	0	1	98.7	40.8	8.0	190.4	160.3	57.6	130.6
10/5/2008	35	0	13	131.4	23.6	76.6	183.5	213.5	76.7	173.9
10/6/2008	0	4	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2008	10	10	25	37.6	13.3	18.1	55.9	61.0	21.9	49.7
10/8/2008	22	7	19	53.7	20.1	26.1	89.9	87.3	31.3	71.1
10/9/2008	31	0	17	93.7	47.0	25.5	168.6	152.1	54.7	123.9
10/10/2008	21	2	25	131.4	42.4	70.7	213.8	213.4	76.7	173.9
10/11/2008	31	2	15	90.1	29.1	9.0	169.7	146.4	52.6	119.2
10/12/2008	9	0	39	113.8	22.8	64.9	137.2	184.9	66.4	150.6
10/13/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/14/2008	0	0	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7										
1/8/2009	0	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/9/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/10/2009	1	2	43	5.3	N/A	5.3	5.3	8.6	3.1	7.0
1/11/2009	7	19	20	10.8	5.0	4.8	17.6	17.5	6.3	14.3
1/12/2009	6	11	28	8.8	3.3	6.4	13.8	14.3	5.1	11.6
1/13/2009	14	16	12	30.2	9.9	17.6	54.8	49.1	17.6	40.0
1/14/2009	2	15	30	18.9	1.9	17.6	20.2	30.7	11.0	25.0
1/15/2009	3	0	45	8.5	1.9	6.4	10.1	13.8	5.0	11.3
1/16/2009	19	6	21	23.6	12.3	8.5	42.0	38.4	13.8	31.3
1/17/2009	3	16	27	18.1	12.0	8.0	31.4	29.4	10.6	23.9

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
1/18/2009	0	19	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/19/2009	0	1	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/20/2009	1	3	42	19.1	N/A	19.1	19.1	31.1	11.2	25.3
1/21/2009	4	18	21	16.0	3.6	11.7	19.1	25.9	9.3	21.1
1/22/2009	9	11	21	19.6	9.1	9.0	35.6	31.8	11.4	25.9
1/23/2009	9	9	30	15.2	8.4	6.9	32.4	24.8	8.9	20.2
1/24/2009	9	0	39	28.8	5.2	17.0	34.6	46.8	16.8	38.1
1/25/2009	1	0	47	18.6	N/A	18.6	18.6	30.2	10.9	24.6
1/26/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2009	0	0	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8										
4/2/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2009	45	0	0	54.2	33.3	4.8	128.2	88.0	31.6	71.7
4/4/2009	25	6	17	74.9	16.7	51.1	112.8	121.7	43.7	99.1
4/5/2009	47	0	1	93.8	15.4	60.6	122.3	152.4	54.7	124.1
4/6/2009	39	0	9	50.2	13.7	23.4	77.1	81.6	29.3	66.4
4/7/2009	16	0	31	25.0	8.4	12.8	44.7	40.6	14.6	33.1
4/8/2009	37	0	3	42.2	27.0	6.9	108.5	68.6	24.6	55.8
4/9/2009	21	16	9	77.1	51.6	12.8	210.1	125.2	45.0	101.9
4/10/2009	10	0	29	38.9	15.1	23.4	70.7	63.2	22.7	51.5
4/11/2009	42	0	5	40.0	14.0	14.9	68.1	65.0	23.3	52.9
4/12/2009	25	0	17	34.5	12.4	21.8	77.7	56.0	20.1	45.6
4/13/2009	10	0	36	42.9	12.4	22.3	56.4	69.7	25.0	56.8
4/14/2009	36	2	6	66.7	34.2	12.2	126.1	108.3	38.9	88.2
4/15/2009	47	0	1	85.2	37.4	33.0	155.9	138.3	49.7	112.7
4/16/2009	46	0	1	89.9	28.6	29.8	138.8	146.1	52.5	119.0
4/17/2009	39	0	9	63.6	18.2	35.6	101.1	103.3	37.1	84.2
4/18/2009	35	11	1	43.1	14.7	20.2	69.1	70.1	25.2	57.1
4/19/2009	47	0	0	77.6	22.0	40.4	127.7	126.1	45.3	102.7
4/20/2009	20	25	0	40.1	16.6	18.1	86.2	65.1	23.4	53.0
4/21/2009	2	16	0	34.3	32.7	11.2	57.4	55.7	20.0	45.4
Period 9										
6/24/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/25/2009	10	0	0	172.8	68.8	49.5	275.0	280.7	100.8	228.6
6/26/2009	48	0	0	160.3	53.1	76.1	295.2	260.3	93.5	212.0
6/27/2009	39	6	0	162.4	34.5	93.6	250.0	263.8	94.8	214.9
6/28/2009	47	0	0	114.6	38.1	21.8	203.2	186.1	66.9	151.6
6/29/2009	37	7	1	121.7	38.3	32.4	215.4	197.6	71.0	161.0
6/30/2009	21	0	22	148.2	67.5	68.6	342.6	240.6	86.4	196.0
7/1/2009	33	0	11	138.8	52.5	36.2	317.0	225.4	81.0	183.6
7/2/2009	24	0	22	169.9	37.7	80.9	236.7	276.0	99.1	224.8
7/3/2009	43	0	3	157.9	41.0	83.0	246.8	256.5	92.1	208.9
7/4/2009	43	4	0	140.0	42.9	33.0	268.6	227.4	81.7	185.2

	Valid values	Cause for invalid values		Emission						
Date		Direction limited	Missing downwind NH_3	Average ($\mu gm^{-2}s^{-1}$)	SD ($\mu gm^{-2}s^{-1}$)	Minimum ($\mu gm^{-2}s^{-1}$)	Maximum ($\mu gm^{-2}s^{-1}$)	Average (kgd^{-1})	Average ($gd^{-1}hd^{-1}$)	Average ($gd^{-1}AU^{-1}$)
7/5/2009	40	0	0	116.0	30.7	55.3	176.1	188.5	67.7	153.5
7/6/2009	47	0	0	131.9	40.7	51.1	213.8	214.3	77.0	174.6
7/7/2009	27	8	10	126.6	55.3	31.9	227.7	205.6	73.9	167.5
7/8/2009	38	0	7	120.7	43.2	20.7	195.2	196.1	70.4	159.7
7/9/2009	30	7	7	162.7	95.8	55.9	475.5	264.3	94.9	215.3
7/10/2009	21	9	16	137.3	23.8	86.2	184.0	223.0	80.1	181.7
7/11/2009	20	12	0	114.8	43.8	33.5	182.4	186.5	67.0	151.9
7/12/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/14/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Touchdown limited: Number of ½ h periods invalidated because fraction of source area surface covered by particle touchdowns was less than 0.1
Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m
Background (ppm): bLS model calculated daily average background concentration (ppm); average is over the ½ h periods included in the valid column
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission Average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 1												
6/29/2007	20	0	0	0	0.04	186.4	34.3	124.2	246.4	303.7	109.1	247.4
6/30/2007	22	0	6	16	0.01	126.7	94.8	8.8	456.5	206.4	74.1	168.1
7/1/2007	24	1	4	16	0.00	210.4	67.0	90.5	300.9	342.8	123.1	279.2
7/2/2007	26	0	2	18	0.01	211.9	71.0	105.1	461.4	345.3	124.0	281.2
7/3/2007	24	1	2	21	0.17	174.8	50.7	101.1	308.4	284.9	102.3	232.0
7/4/2007	25	3	3	8	0.12	189.1	44.3	94.2	300.6	308.1	110.7	250.9
7/5/2007	34	0	3	9	0.03	2 19.4	74.6	102.4	519.8	357.4	128.4	291.1
7/6/2007	19	2	12	14	0.06	207.3	99.1	4.9	360.2	337.7	121.3	275.1
7/7/2007	25	10	0	12	0.19	183.2	52.4	92.3	276.5	298.4	107.2	243.1
7/8/2007	45	0	0	0	0.24	180.4	36.8	115.2	271.3	294.0	105.6	239.4
7/9/2007	37	4	2	1	0.16	189.2	49.0	103.8	314.3	308.3	110.8	251.1
7/10/2007	16	0	11	18	0.05	274.8	127.2	142.9	632.2	447.8	160.8	364.7
7/11/2007	41	0	2	2	0.13	175.0	58.9	31.6	274.3	285.1	102.4	232.2
7/12/2007	42	1	1	2	0.22	139.9	51.9	9.7	256.2	228.0	81.9	185.7
7/13/2007	31	5	3	6	0.10	144.0	74.9	-0.4	323.8	234.6	84.3	191.1
7/14/2007	9	9	8	20	0.78	-45.9	204.4	-531.5	114.9	-74.8	-26.9	-60.9
7/15/2007	8	4	8	24	0.31	105.1	97.1	-5.7	253.3	171.2	61.5	139.4
7/16/2007	25	0	5	5	0.30	154.6	40.1	79.7	229.5	251.9	90.5	205.2
7/17/2007	14	0	5	8	0.29	103.3	19.4	81.3	151.4	168.3	60.5	137.1
7/18/2007	20	0	11	2	0.34	118.0	18.7	70.2	149.6	192.2	69.0	156.6

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/19/2007	10	0	0	0	0.29	178.0	35.7	118.9	232.2	290.1	104.2	236.3
7/20/2007	33	7	0	6	0.28	140.8	52.0	4.2	242.0	229.3	82.4	186.8
7/21/2007	40	0	0	3	0.25	164.2	45.2	77.8	267.0	267.5	96.1	217.9
7/22/2007	37	0	0	7	0.28	142.4	45.9	73.7	254.2	232.1	83.4	189.0
7/23/2007	26	3	2	14	0.31	146.1	59.1	-3.2	273.6	238.1	85.5	193.9
7/24/2007	11	0	0	13	0.20	183.5	75.6	113.8	332.9	299.0	107.4	243.5
7/25/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/26/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/27/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/28/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/29/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/30/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/31/2007	3	0	0	0	0.16	287.3	146.3	118.4	376.0	468.1	168.1	381.3
8/1/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/2/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/3/2007	10	0	6	0	0.27	192.1	107.7	92.9	377.1	313.0	112.4	254.9
8/4/2007	24	0	3	3	0.36	141.2	34.6	91.8	215.0	230.1	82.6	187.4
8/5/2007	13	0	2	3	0.33	164.7	23.1	123.1	204.8	268.3	96.4	218.5
8/6/2007	12	0	5	1	0.29	150.4	19.9	125.1	181.7	245.0	88.0	199.5
8/7/2007	14	11	9	3	0.42	160.4	91.0	-5.4	337.7	261.3	93.9	212.8
8/8/2007	11	9	6	7	0.39	158.5	71.4	56.4	253.1	258.2	92.8	210.3
8/9/2007	32	1	2	13	0.10	233.2	72.0	102.2	360.8	380.0	136.5	309.5
8/10/2007	10	0	10	21	0.30	150.1	72.7	92.3	340.9	244.5	87.8	199.2
8/11/2007	13	0	16	6	0.29	205.6	67.2	98.4	343.6	335.1	120.4	272.9
8/12/2007	36	0	0	10	0.33	135.1	23.6	76.3	179.4	220.1	79.1	179.3
8/13/2007	35	2	0	10	0.33	142.7	21.3	90.9	174.6	232.5	83.5	189.4
8/14/2007	21	7	0	2	0.28	133.9	23.1	92.1	179.2	218.2	78.4	177.7
8/15/2007	18	2	0	0	0.23	163.8	32.5	126.7	249.6	266.8	95.8	217.3
8/16/2007	18	18	0	9	0.25	134.5	63.2	0.0	278.9	219.1	78.7	178.5
8/17/2007	32	0	0	15	0.22	139.7	51.4	61.0	318.6	227.7	81.8	185.5
8/18/2007	38	1	0	9	0.32	123.9	37.7	50.5	208.4	201.9	72.5	164.5
8/19/2007	37	6	0	5	0.17	160.2	83.8	3.0	416.9	261.0	93.8	212.6
8/20/2007	35	0	0	12	0.24	169.7	63.5	87.8	332.0	276.6	99.3	225.3
8/21/2007	47	0	0	0	0.11	211.6	92.5	118.4	702.6	344.8	123.8	280.8
8/22/2007	48	0	0	0	0.16	207.6	77.6	89.0	382.1	338.3	121.5	275.6
8/23/2007	48	0	0	0	0.18	230.4	70.6	115.6	447.6	375.4	134.9	305.8
8/24/2007	35	2	3	6	0.00	164.1	61.1	37.6	324.1	267.3	96.0	217.7
8/25/2007	14	0	1	8	0.04	160.6	26.9	106.9	198.9	261.6	94.0	213.1
8/26/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/27/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/28/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 2												
11/8/2007	0	0	0	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/9/2007	17	8	0	20	0.01	29.1	12.9	0.6	48.9	47.5	17.0	38.7
11/10/2007	24	1	0	22	0.06	19.8	8.6	5.1	40.3	32.2	11.6	26.2
11/11/2007	18	26	0	3	0.01	28.3	17.3	7.3	63.6	46.1	16.5	37.5

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
11/12/2007	30	5	0	12	0.00	26.0	17.6	-9.9	57.2	42.3	15.2	34.4
11/13/2007	11	13	0	23	0.03	23.4	8.0	13.4	35.6	38.1	13.7	31.0
11/14/2007	39	0	0	7	-0.01	39.9	25.7	-3.6	103.1	65.1	23.4	53.0
11/15/2007	23	18	0	7	0.02	24.4	14.0	1.2	52.5	39.7	14.3	32.4
11/16/2007	20	9	0	19	0.01	24.8	8.8	9.7	41.9	40.5	14.5	33.0
11/17/2007	28	1	0	17	-0.01	22.9	17.1	5.0	71.0	37.4	13.4	30.4
11/18/2007	12	10	0	22	0.01	26.8	22.8	-1.6	66.1	43.6	15.7	35.5
11/19/2007	0	0	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/20/2007	16	0	1	15	0.00	34.2	16.8	1.3	54.4	55.7	20.0	45.4
11/21/2007	48	0	0	0	0.02	28.9	23.6	-21.6	58.6	47.1	16.9	38.3
11/22/2007	17	12	0	17	-0.01	13.5	12.3	-0.2	37.7	22.0	7.9	17.9
11/23/2007	24	0	0	22	0.02	11.7	3.3	4.3	18.4	19.0	6.8	15.5
11/24/2007	25	3	8	7	0.03	13.6	19.9	-20.2	54.1	22.1	7.9	18.0
11/25/2007	0	0	8	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/26/2007	34	3	3	8	0.02	3.9	15.3	-23.5	37.9	6.3	2.3	5.1
11/27/2007	2	0	1	23	0.03	8.0	3.2	5.8	10.3	13.1	4.7	10.7
Period 3												
11/28/2007	4	0	1	0	0.01	41.3	36.5	8.3	75.1	67.3	24.2	54.8
11/29/2007	19	1	0	23	0.04	17.3	10.5	-8.0	31.6	28.2	10.1	23.0
11/30/2007	46	0	0	2	-0.01	13.0	25.9	-2.0	156.8	21.2	7.6	17.3
12/1/2007	37	3	0	0	0.04	9.7	8.1	-8.1	28.5	15.9	5.7	12.9
12/2/2007	37	10	0	1	0.02	13.3	19.4	-13.8	74.4	21.6	7.8	17.6
12/3/2007	26	4	0	15	0.02	13.3	6.5	0.5	26.8	21.7	7.8	17.7
12/4/2007	8	29	0	10	-0.02	2.2	5.2	-4.2	11.1	3.6	1.3	2.9
12/5/2007	37	5	0	6	0.00	10.8	9.1	-26.9	30.2	17.6	6.3	14.4
12/6/2007	39	4	3	2	-0.01	15.6	8.5	-9.2	28.8	25.3	9.1	20.6
12/7/2007	29	0	0	14	-0.02	24.7	10.7	7.2	47.5	40.2	14.4	32.7
12/8/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/9/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2007	14	0	0	0	-0.01	4.7	2.5	-1.2	8.3	7.7	2.8	6.3
12/11/2007	17	0	4	2	0.00	2.2	2.0	-1.8	5.6	3.7	1.3	3.0
12/12/2007	10	1	0	14	0.00	4.3	2.2	0.5	7.8	7.0	2.5	5.7
12/13/2007	7	0	5	12	-0.01	7.2	2.6	4.1	11.9	11.8	4.2	9.6
12/14/2007	0	0	1	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2007	28	0	6	2	-0.02	10.9	2.2	5.5	17.0	17.8	6.4	14.5
12/16/2007	1	19	2	24	0.00	-1.9	N/A	-1.9	-1.9	-3.1	-1.1	-2.5
12/17/2007	13	2	0	32	0.00	1.6	5.0	-3.1	12.1	2.6	0.9	2.1
12/18/2007	6	14	0	9	-0.01	3.0	2.3	1.9	7.7	4.8	1.7	3.9
Period 4												
4/24/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2008	37	6	3	0	0.01	3.0	36.3	-76.2	96.1	4.8	1.7	4.0
4/26/2008	16	1	5	18	-0.01	18.4	34.0	-23.3	81.6	29.9	10.7	24.4
4/27/2008	29	0	1	2	-0.03	24.8	26.0	-11.3	99.8	40.3	14.5	32.8
4/28/2008	14	26	2	5	-0.03	55.1	84.6	-6.2	326.9	89.9	32.3	73.2
4/29/2008	11	1	8	12	0.00	34.9	49.0	-17.5	113.7	56.8	20.4	46.3
4/30/2008	18	14	4	11	-0.01	21.5	28.4	-12.3	94.5	35.0	12.6	28.5

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
5/1/2008	35	13	0	0	0.01	46.4	57.9	-30.4	190.8	75.7	27.2	61.6
5/2/2008	26	22	0	0	0.06	46.5	96.5	-152.3	244.7	75.7	27.2	61.7
5/3/2008	38	3	7	0	0.04	68.2	75.6	-143.3	189.8	111.2	39.9	90.6
5/4/2008	21	1	2	21	0.03	54.1	26.2	14.7	98.8	88.2	31.7	71.8
5/5/2008	27	0	16	4	0.07	12.1	28.3	-32.7	73.2	19.7	7.1	16.0
5/6/2008	8	0	10	0	0.06	76.7	77.9	-64.6	221.6	125.0	44.9	101.8
Period 6												
10/1/2008	3	0	0	0	0.03	82.9	9.0	72.5	88.3	135.1	48.5	110.1
10/2/2008	17	0	0	25	0.04	102.7	22.1	52.5	131.3	167.3	60.1	136.3
10/3/2008	40	4	0	2	0.05	73.4	24.7	41.1	136.6	119.5	42.9	97.4
10/4/2008	39	0	0	9	0.05	97.2	51.3	37.2	203.5	158.4	56.9	129.0
10/5/2008	36	0	5	0	0.04	133.7	34.9	67.9	236.0	217.9	78.3	177.5
10/6/2008	17	3	2	5	0.01	106.2	30.5	53.1	172.8	173.1	62.2	141.0
10/7/2008	25	15	0	6	0.04	43.2	10.2	26.3	65.4	70.3	25.3	57.3
10/8/2008	22	6	0	19	0.04	68.5	21.2	37.6	109.6	111.7	40.1	91.0
10/9/2008	24	0	0	24	0.04	117.9	53.0	34.0	186.7	192.1	69.0	156.5
10/10/2008	46	2	0	0	0.03	102.9	35.8	55.1	192.5	167.7	60.2	136.6
10/11/2008	44	1	0	1	0.04	79.0	25.7	23.6	131.2	128.8	46.2	104.9
10/12/2008	36	0	8	0	0.04	108.1	50.1	-74.8	186.9	176.2	63.3	143.5
10/13/2008	45	0	3	0	0.04	91.8	18.3	52.9	137.9	149.7	53.8	121.9
10/14/2008	1	0	9	0	0.04	71.2	N/A	71.2	71.2	115.9	41.6	94.4
Period 7												
1/8/2009	1	0	0	1	0.01	21.4	N/A	21.4	21.4	34.8	12.5	28.4
1/9/2009	17	8	10	11	0.03	16.9	4.8	8.1	29.3	27.5	9.9	22.4
1/10/2009	26	5	6	2	0.04	10.6	4.5	-0.1	19.1	17.2	6.2	14.0
1/11/2009	15	2	3	23	0.03	13.7	7.8	3.0	25.2	22.3	8.0	18.2
1/12/2009	20	18	2	8	0.04	27.4	11.5	7.3	48.3	44.6	16.0	36.3
1/13/2009	22	16	0	10	0.02	19.4	12.0	4.4	47.9	31.6	11.4	25.7
1/14/2009	11	12	1	8	0.05	7.0	3.0	2.5	11.3	11.3	4.1	9.2
1/15/2009	10	0	13	2	0.03	14.9	4.5	9.4	23.8	24.3	8.7	19.8
1/16/2009	17	12	1	15	0.01	14.2	5.3	3.5	19.4	23.1	8.3	18.8
1/17/2009	14	13	12	9	0.03	8.0	3.9	-3.6	12.6	13.1	4.7	10.7
1/18/2009	16	27	0	3	0.02	22.6	6.6	12.2	35.9	36.9	13.2	30.0
1/19/2009	31	13	4	0	0.02	19.6	9.7	5.9	35.8	32.0	11.5	26.1
1/20/2009	22	18	3	3	0.03	13.2	3.8	2.8	19.1	21.5	7.7	17.5
1/21/2009	10	30	0	8	0.01	14.5	3.4	10.2	22.3	23.6	8.5	19.2
1/22/2009	18	12	2	14	0.02	16.6	6.4	2.1	27.1	27.1	9.7	22.1
1/23/2009	3	1	1	19	0.01	5.2	1.5	3.6	6.6	8.4	3.0	6.9
1/24/2009	16	0	3	0	0.02	28.9	7.5	17.7	39.6	47.1	16.9	38.4
1/25/2009	16	0	13	0	0.04	22.3	2.6	17.6	25.7	36.4	13.1	29.7
1/26/2009	0	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2009	0	0	4	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8												
4/2/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2009	39	0	0	9	0.03	61.1	36.9	16.4	125.3	99.5	35.7	81.1
4/4/2009	31	17	0	0	0.02	82.6	14.9	54.8	117.7	134.5	48.3	109.6

Date	Valid	Direction limited	Touch-down limited	Turbulence limited	Back-ground (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
4/5/2009	48	0	0	0	0.03	99.3	15.2	71.2	133.2	161.8	58.1	131.8
4/6/2009	43	5	0	0	0.05	43.6	14.8	14.3	72.9	71.0	25.5	57.9
4/7/2009	14	13	0	20	0.06	39.1	12.2	20.4	60.5	63.7	22.9	51.8
4/8/2009	29	0	0	14	0.03	52.4	26.8	13.0	92.0	85.4	30.7	69.5
4/9/2009	32	15	0	1	0.04	77.0	41.1	2.2	164.0	125.4	45.0	102.1
4/10/2009	48	0	0	0	0.05	53.5	25.7	8.9	119.1	87.1	31.3	71.0
4/11/2009	27	0	0	21	0.04	51.8	19.6	20.0	85.0	84.4	30.3	68.8
4/12/2009	48	0	0	0	0.05	35.1	11.3	7.0	74.7	57.1	20.5	46.5
4/13/2009	48	0	0	0	0.07	36.1	10.5	15.9	53.8	58.8	21.1	47.9
4/14/2009	28	1	0	18	0.02	90.6	33.2	23.0	137.6	147.7	53.1	120.3
4/15/2009	47	0	0	1	0.03	85.9	33.7	32.1	162.0	139.9	50.3	114.0
4/16/2009	48	0	0	0	0.03	90.6	14.9	53.4	119.1	147.6	53.0	120.3
4/17/2009	48	0	0	0	0.04	63.0	22.1	0.5	92.7	102.7	36.9	83.7
4/18/2009	24	11	0	10	0.07	37.6	13.3	1.6	65.8	61.3	22.0	49.9
4/19/2009	47	1	0	0	0.05	70.3	23.7	31.6	127.9	114.6	41.2	93.3
4/20/2009	20	18	0	10	0.06	48.6	8.9	33.9	62.8	79.2	28.4	64.5
4/21/2009	1	3	0	13	0.70	5.2	N/A	5.2	5.2	8.4	3.0	6.9
Period 9												
6/24/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/25/2009	11	0	0	0	-0.04	261.4	127.4	105.1	480.2	426.0	153.0	347.0
6/26/2009	38	0	0	7	0.02	209.5	66.0	91.8	330.7	341.4	122.6	278.1
6/27/2009	36	5	0	7	0.07	172.2	41.7	82.9	284.2	280.6	100.8	228.5
6/28/2009	36	0	0	12	0.04	137.9	54.9	45.1	305.6	224.7	80.7	183.0
6/29/2009	24	3	0	21	0.04	165.4	66.4	25.3	322.1	269.5	96.8	219.5
6/30/2009	30	5	0	12	0.02	153.4	59.3	41.7	280.9	249.9	89.8	203.5
7/1/2009	38	3	0	6	0.04	147.4	49.0	74.6	285.1	240.1	86.3	195.6
7/2/2009	28	16	1	2	0.04	186.1	54.2	107.3	302.6	303.3	108.9	247.0
7/3/2009	41	0	0	6	0.03	197.6	64.9	89.0	381.8	322.0	115.7	262.3
7/4/2009	40	4	0	3	0.07	144.0	52.4	21.6	312.0	234.7	84.3	191.1
7/5/2009	44	0	0	4	0.05	115.4	27.1	59.8	187.4	188.0	67.5	153.1
7/6/2009	37	0	0	11	0.03	140.1	42.4	71.6	252.3	228.3	82.0	186.0
7/7/2009	31	6	0	11	0.06	135.8	56.2	-6.0	217.7	221.3	79.5	180.3
7/8/2009	33	2	0	12	0.04	134.9	50.5	16.2	239.1	219.7	78.9	179.0
7/9/2009	29	10	0	7	0.10	157.8	59.9	40.5	284.5	257.2	92.4	209.5
7/10/2009	18	22	0	6	0.07	175.6	60.9	101.5	271.4	286.1	102.8	233.1
7/11/2009	17	13	0	4	0.16	96.4	40.7	34.3	156.3	157.1	56.4	127.9
7/12/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/14/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 4								
4/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6								
10/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/3/2008	39	1.5	8.8	-4.5	8.4	2.4	0.9	1.9
10/4/2008	37	5.9	17.0	0.1	24.8	9.7	3.5	7.9
10/5/2008	35	1.7	9.4	-0.3	7.1	2.7	1.0	2.2
10/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/7/2008	10	0.4	5.0	0.1	1.1	0.7	0.2	0.6
10/8/2008	17	0.2	3.3	-0.1	0.8	0.3	0.1	0.3
10/9/2008	30	3.5	13.5	-0.2	19.3	5.8	2.1	4.7
10/10/2008	21	0.5	5.0	-0.3	1.6	0.7	0.3	0.6
10/11/2008	31	0.2	3.6	-2.8	4.9	0.4	0.1	0.3
10/12/2008	9	0.5	5.7	-0.4	1.8	0.9	0.3	0.7

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7								
1/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/9/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/11/2009	6	3.8	14.9	0.3	6.9	6.1	2.2	5.0
1/12/2009	6	0.5	5.5	0.0	1.0	0.8	0.3	0.6
1/13/2009	14	6.3	17.9	2.0	14.8	10.3	3.7	8.4
1/14/2009	2	2.1	14.8	1.9	2.3	3.4	1.2	2.8
1/15/2009	3	0.7	7.2	0.5	0.9	1.1	0.4	0.9
1/16/2009	19	2.5	11.6	0.5	5.2	4.1	1.5	3.3
1/17/2009	3	0.9	8.4	0.1	2.4	1.4	0.5	1.1
1/18/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/19/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/20/2009	1	1.4	0.0	1.4	1.4	2.3	0.8	1.9
1/21/2009	4	1.1	8.6	0.7	1.5	1.7	0.6	1.4
1/22/2009	9	2.1	10.9	0.1	5.1	3.4	1.2	2.8
1/23/2009	9	1.0	7.9	0.0	2.5	1.7	0.6	1.4
1/24/2009	9	18.3	27.8	2.8	27.1	29.8	10.7	24.3
1/25/2009	1	7.2	0.0	7.2	7.2	11.7	4.2	9.5
1/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8								
4/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2009	41	8.4	19.8	0.0	36.9	13.6	4.9	11.1
4/4/2009	24	9.6	20.9	1.2	17.5	15.6	5.6	12.7
4/5/2009	46	7.9	19.2	-0.6	26.5	12.9	4.6	10.5
4/6/2009	37	4.3	14.8	0.6	9.9	7.0	2.5	5.7
4/7/2009	16	0.6	6.0	0.1	3.0	1.1	0.4	0.9
4/8/2009	33	3.3	13.0	-0.6	9.7	5.3	1.9	4.3
4/9/2009	21	9.4	21.3	0.1	49.9	15.3	5.5	12.4
4/10/2009	4	0.4	5.1	-1.0	2.2	0.6	0.2	0.5
4/11/2009	22	2.7	12.0	-0.3	12.5	4.4	1.6	3.6
4/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/13/2009	10	7.0	19.0	1.6	15.2	11.4	4.1	9.3
4/14/2009	32	10.2	21.6	0.0	22.6	16.5	5.9	13.5
4/15/2009	47	15.9	24.7	0.5	54.7	25.9	9.3	21.1
4/16/2009	46	12.2	22.7	2.5	27.1	19.8	7.1	16.2
4/17/2009	25	6.1	17.4	0.2	15.0	9.9	3.5	8.0
4/18/2009	33	5.0	16.2	0.2	26.7	8.2	2.9	6.7
4/19/2009	47	23.3	26.8	7.1	65.5	37.8	13.6	30.8
4/20/2009	20	2.9	12.4	0.1	7.1	4.7	1.7	3.8
4/21/2009	2	0.8	9.3	0.4	1.2	1.3	0.5	1.1
Period 9								

Date	Valid	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} hd^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
6/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/25/2009	8	9.2	21.9	0.0	21.6	14.9	5.4	12.2
6/26/2009	48	8.4	19.7	0.6	25.4	13.6	4.9	11.1
6/27/2009	39	12.7	23.0	-0.1	27.1	20.6	7.4	16.7
6/28/2009	36	3.2	12.8	0.1	10.8	5.2	1.9	4.2
6/29/2009	31	1.3	8.4	0.0	5.7	2.1	0.8	1.7
6/30/2009	10	1.6	9.5	0.1	6.0	2.6	0.9	2.1
7/1/2009	25	2.4	11.4	-0.1	9.9	4.0	1.4	3.2
7/2/2009	24	3.9	14.3	1.0	9.5	6.3	2.3	5.1
7/3/2009	43	5.7	16.7	1.9	15.6	9.3	3.3	7.6
7/4/2009	43	5.0	15.8	0.1	22.3	8.2	2.9	6.7
7/5/2009	35	1.5	8.9	-0.2	4.0	2.4	0.9	2.0
7/6/2009	30	2.0	10.4	-0.3	7.0	3.3	1.2	2.7
7/7/2009	25	1.4	8.8	-0.6	4.7	2.3	0.8	1.9
7/8/2009	27	1.1	7.6	-1.6	4.6	1.7	0.6	1.4
7/9/2009	25	1.3	8.3	-0.2	3.9	2.1	0.7	1.7
7/10/2009	21	1.5	9.0	0.4	4.5	2.4	0.9	2.0
7/11/2009	20	1.4	8.6	-1.9	4.2	2.2	0.8	1.8
7/12/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/14/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Angle limited	Turbulence limited	Back-ground (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 4												
4/28/2008	13	26	1	1	0.5	1.8	0.9	0.2	3.1	2.9	1.0	2.3
4/29/2008	21	1	13	12	1.3	1.5	0.8	-0.2	2.9	2.4	0.9	2.0
4/30/2008	18	14	3	11	2.4	10.5	8.9	-0.7	29.5	17.1	6.2	13.9
5/1/2008	35	13	0	0	1.3	6.5	4.8	0.0	19.4	10.6	3.8	8.7
5/2/2008	26	21	0	0	1.0	12.8	8.4	3.1	34.9	20.8	7.5	17.0
5/3/2008	43	3	2	0	0.9	4.3	4.7	-0.1	16.5	7.1	2.5	5.8
5/4/2008	23	1	0	23	1.1	3.5	2.6	0.0	9.0	5.8	2.1	4.7
5/5/2008	43	0	0	5	1.1	4.1	3.0	0.4	11.0	6.7	2.4	5.5
5/6/2008	13	0	10	0	0.9	3.9	2.4	1.2	7.9	6.3	2.3	5.1
Period 6												
10/3/2008	37	4	2	3	1.5	0.9	0.8	-0.4	2.7	1.5	0.5	1.2
10/4/2008	31	0	6	9	1.7	6.3	5.5	0.0	18.5	10.2	3.7	8.3
10/5/2008	47	0	0	0	1.5	1.1	1.7	-0.2	6.6	1.7	0.6	1.4
10/6/2008	37	2	1	5	1.2	0.7	1.1	-0.3	5.0	1.1	0.4	0.9
10/7/2008	25	15	0	8	1.1	0.4	0.4	0.0	1.3	0.7	0.2	0.6
10/8/2008	13	5	9	20	1.5	0.1	0.2	-0.2	0.6	0.2	0.1	0.2
10/9/2008	20	0	3	24	1.4	3.9	3.9	0.1	12.7	6.3	2.3	5.1
10/10/2008	46	2	0	0	0.9	0.3	0.4	-0.2	1.4	0.5	0.2	0.4
10/11/2008	41	1	3	1	1.0	0.2	0.5	-1.0	1.9	0.3	0.1	0.2

Date	Valid	Direction limited	Angle limited	Turbulence limited	Back-ground (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
10/12/2008	45	0	3	0	0.9	0.1	0.4	-1.0	0.9	0.1	0.0	0.1
10/13/2008	46	0	0	0	1.1	1.4	3.7	-0.3	24.5	2.3	0.8	1.9
10/14/2008	35	0	0	0	1.1	0.5	0.4	0.0	1.7	0.8	0.3	0.7
Period 7												
1/9/2009	29	8	0	11	1.7	26.4	30.0	0.3	100.7	43.0	15.5	35.1
1/10/2009	40	5	0	2	1.1	2.5	1.9	-0.1	7.7	4.0	1.4	3.3
1/11/2009	16	2	5	24	1.2	3.9	1.7	1.1	7.4	6.4	2.3	5.2
1/12/2009	22	18	0	8	1.5	24.1	21.2	0.0	84.0	39.2	14.1	31.9
1/13/2009	22	16	0	10	1.4	4.3	4.8	0.7	17.4	7.0	2.5	5.7
1/14/2009	24	10	3	8	1.4	8.1	5.3	0.3	25.7	13.2	4.7	10.7
1/15/2009	15	0	28	3	0.8	2.9	2.8	0.5	11.0	4.7	1.7	3.9
1/16/2009	17	12	2	15	1.3	1.5	0.7	0.1	2.7	2.5	0.9	2.1
1/17/2009	24	13	0	9	1.8	17.1	9.9	0.0	36.0	27.8	10.0	22.6
1/18/2009	16	27	0	5	1.2	9.2	8.3	2.5	33.6	15.0	5.4	12.2
1/19/2009	35	13	0	0	1.4	22.1	18.9	1.9	65.3	36.1	13.0	29.4
1/20/2009	27	18	0	3	1.2	4.6	3.3	0.3	15.1	7.6	2.7	6.2
1/21/2009	9	29	0	8	1.1	3.5	2.3	0.7	8.4	5.7	2.0	4.6
1/22/2009	20	12	0	14	1.4	11.4	6.8	0.0	23.1	18.6	6.7	15.1
1/23/2009	27	1	0	19	1.7	28.2	17.4	0.0	59.6	45.9	16.5	37.4
1/24/2009	43	0	5	0	1.5	12.6	10.1	1.5	38.7	20.5	7.4	16.7
1/25/2009	28	0	18	0	1.3	8.4	4.1	2.7	15.0	13.6	4.9	11.1
1/26/2009	19	0	27	1	1.3	6.4	4.2	2.5	19.6	10.4	3.7	8.4
1/27/2009	23	0	0	0	1.4	6.5	5.2	0.1	14.6	10.6	3.8	8.7
Period 8												
4/3/2009	38	0	0	3	1.6	8.5	8.6	0.1	28.8	13.8	5.0	11.2
4/4/2009	30	17	0	0	1.5	6.6	3.4	0.7	13.6	10.8	3.9	8.8
4/5/2009	47	0	0	0	1.0	4.4	3.5	-0.4	17.0	7.2	2.6	5.9
4/6/2009	41	5	0	0	0.9	3.0	1.7	0.5	8.2	4.9	1.8	4.0
4/7/2009	15	12	0	20	1.5	1.4	1.4	0.1	5.5	2.2	0.8	1.8
4/8/2009	27	0	2	17	1.2	1.7	1.4	-0.5	5.1	2.7	1.0	2.2
4/9/2009	32	13	0	1	1.0	6.0	7.8	0.0	30.7	9.7	3.5	7.9
4/10/2009	42	0	6	0	1.2	6.5	5.6	-0.6	24.1	10.5	3.8	8.6
4/11/2009	21	0	6	21	1.1	2.3	2.2	-0.2	8.1	3.7	1.3	3.1
4/12/2009	16	0	30	0	1.3	3.1	2.1	0.4	6.0	5.1	1.8	4.2
4/13/2009	48	0	0	0	1.3	5.1	3.0	1.1	13.2	8.2	3.0	6.7
4/14/2009	28	1	0	18	2.1	13.4	7.1	0.3	25.4	21.8	7.8	17.7
4/15/2009	47	0	0	1	1.8	10.1	9.1	0.9	39.0	16.5	5.9	13.4
4/16/2009	48	0	0	0	1.3	5.9	2.4	1.4	13.7	9.7	3.5	7.9
4/17/2009	30	0	16	0	1.3	3.6	2.7	0.1	11.6	5.9	2.1	4.8
4/18/2009	23	11	1	10	1.5	4.2	4.3	0.3	15.7	6.8	2.5	5.6
4/19/2009	47	1	0	0	1.6	15.5	11.3	2.3	44.9	25.3	9.1	20.6
4/20/2009	20	18	0	10	1.3	2.7	1.7	0.0	6.1	4.5	1.6	3.6
4/21/2009	1	1	0	14	4.9	0.2	N/A	0.2	0.2	0.4	0.1	0.3
Period 9												
6/25/2009	10	0	0	0	1.8	6.1	4.1	0.0	12.1	10.0	3.6	8.1
6/26/2009	38	0	0	8	2.4	10.2	8.0	1.3	24.1	16.6	6.0	13.5

Date	Valid	Direction limited	Angle limited	Turbulence limited	Back-ground (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/27/2009	36	5	0	7	2.5	11.1	5.4	0.3	23.0	18.0	6.5	14.7
6/28/2009	26	0	10	12	1.7	2.7	2.4	0.2	9.9	4.4	1.6	3.6
6/29/2009	24	3	0	21	1.5	1.3	1.8	-0.1	6.1	2.1	0.8	1.7
6/30/2009	18	5	11	12	1.4	0.8	1.1	0.1	4.7	1.3	0.5	1.1
7/1/2009	29	3	8	6	1.4	1.6	1.9	-0.1	6.9	2.6	0.9	2.1
7/2/2009	29	16	0	3	1.7	4.1	3.2	0.7	11.9	6.7	2.4	5.5
7/3/2009	41	0	0	7	1.7	8.5	6.1	1.6	27.7	13.9	5.0	11.3
7/4/2009	40	4	0	4	2.3	5.1	5.6	0.0	26.1	8.3	3.0	6.8
7/5/2009	40	0	4	4	1.4	1.1	0.9	-0.3	2.8	1.8	0.6	1.4
7/6/2009	24	0	12	11	1.1	0.9	0.6	-0.2	2.8	1.5	0.5	1.2
7/7/2009	29	6	2	11	1.1	1.1	1.4	-0.1	5.2	1.8	0.7	1.5
7/8/2009	26	2	7	12	1.3	0.8	1.1	-0.5	3.8	1.2	0.4	1.0
7/9/2009	27	10	2	8	1.3	1.1	1.3	-0.3	3.9	1.8	0.6	1.5
7/10/2009	18	22	0	8	1.5	2.5	1.9	0.3	7.3	4.0	1.4	3.3
7/11/2009	17	11	0	5	2.2	1.0	1.0	-0.5	3.3	1.7	0.6	1.3

Final Report
Site WA5A
Milk Production Facility
for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
Site WA5A
Milk Production Facility

for the

NATIONAL AIR EMISSIONS MONITORING STUDY

to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on the location (relative to climate and typical practice), method of manure collection, manure storage and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3), hydrogen sulfide (H_2S) emissions from a basin open source at the western dairy facility. Within that objective, this report will:

- Describe the farm and the basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the basin were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Basin emissions were measured for up to 21 d each season over two years. The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the basin were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc,

Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*WindTrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the basin berm (Table 1-2).

Table 1-1: Critical measurements

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder 2.0 ™	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind speed	3D Sonic anemometer/ RM Young 81000	0-60 m s^{-1}	0.01 m s^{-1}	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
Wind direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
3D turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 m s^{-1}	0.01 m s^{-1}	160 Hz sampling/ 16 Hz averaging	30 min
Temperature variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01°C	160 Hz sampling/ 16 Hz averaging	30 min
GSS sample flow rate	GSS/SOP-S	10 **L** min^{-1}	0.1 **L** min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/SOP-S	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to RPM Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the basin (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with

associated pressure, flow, temperature and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer that was downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Additional information concerning farm operations was routinely collected from the producer.

Table 1-2: Non-critical measurements.

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
Ambient temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50 ^{o} C	0.1 ^{o} C	5 min	30 min, 24 h
Relative humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min & 24 h
Solar radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 W m^{-2}	10 W m^{-2}	5 min	30 min & 24 h

1.3 Farm description and operation

The western freestall dairy facility was located in Washington. The elevation at the farm was approximately 244 m. The farm consisted of six barns, a milking parlor, and an office (Fig. 1). The facility had a capacity of 4400 milking cows and 1200 dry cows in three units. Construction of the dairy was completed in 2002.

The farm had freestall style barns, with automated flushing that occurred four times daily. Manure was transferred to the upper basins from a sand separation pit. The two earthen-lined settling basins were located to the south of the barns, and were used in alternate years. Liquids were skimmed, separated, and returned as flush to the barns. While one basin was actively filled while the other was drying or sludge being entirely removed. The settled solids (sludge) were completely removed within a year by front end loader. These removed solids were then strained through Agpro screens and centrifugal/screw presses with the liquid transferred to large serpentine concrete basins for secondary settling. These settled solids were then dried for bedding. Removed water from the settled solids was stored in a large clarified water storage basin for dilution of barn flush water from the basins. Sludge from the settling basins prior to complete removal was periodically applied on surrounding land utilizing underground pressurized pipes and a no-till soil injector. Wastewater entered the measured basin from the northwest corner.

Gaseous emissions occur both during basin filling and during sludge removal. The east basin was rectangular with dimensions of 183 m by 72 m. The west basin was five-sided with dimensions of approximately 183 m long and 83 m wide with the southwest corner of the basin cut off. The berm on the west side dropped from 2 m high to 4 m high from south to north, flat along the south side, and dropping 15 m or more to the north toward the serpentine basins. The berm on

the east side dropped about 1 to 2 m, then rises approximately 2 m to fields to the east. The east basin was measured for gaseous emissions. This basin had a surface area of 13,099 m^2 and a volume of 56,796 m^3.

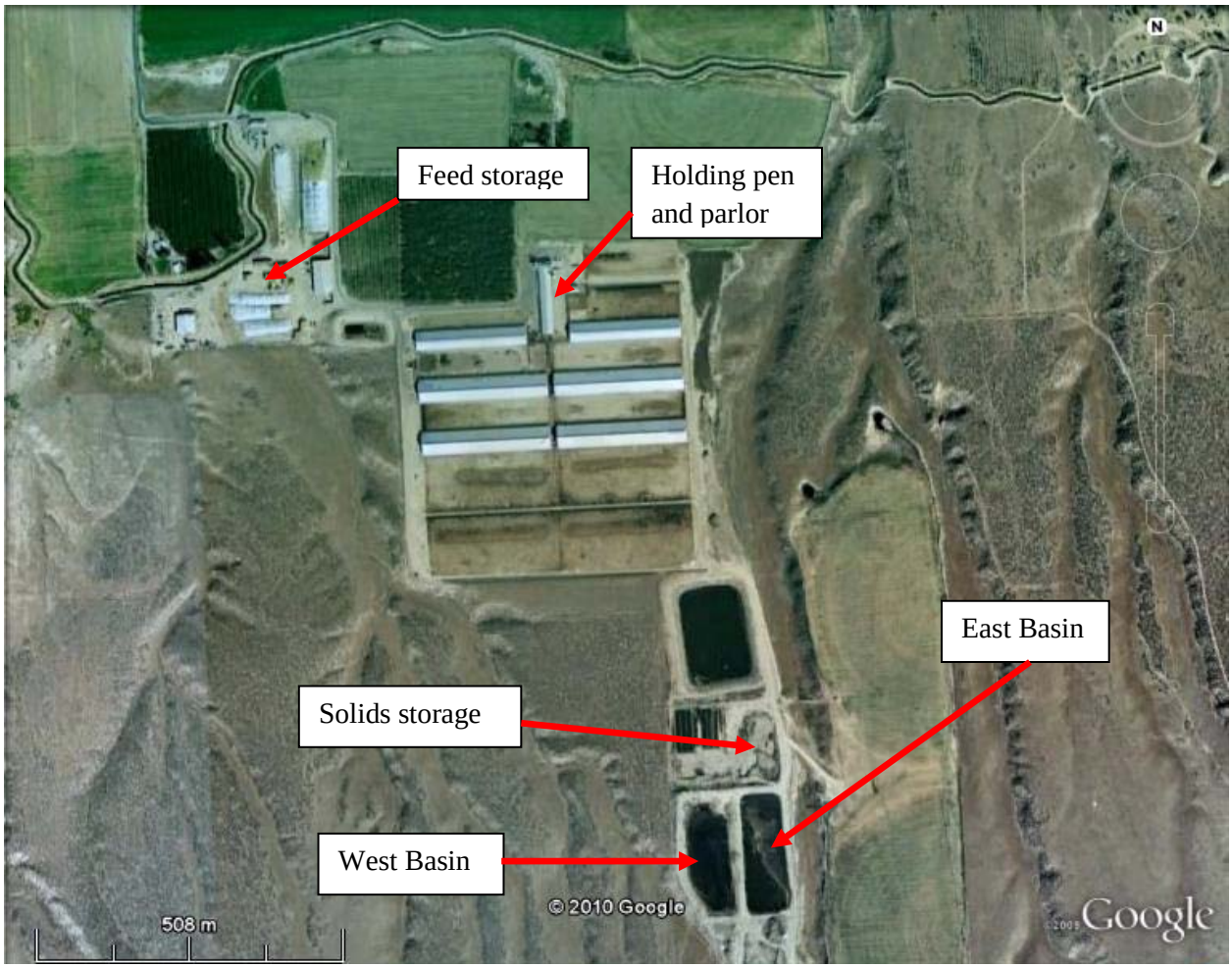

Figure 1-1: Configuration of the WA5A farm.

1.4 Changes in farm operation

Calf hutches were added to the south of the basins between measurements periods 4 and 5.

1.5 Measurement layout

The NH_3 emissions from the two upper lagoons/settling basins were monitored for 8 to 20 d each quarter of the year for two years, using scanning TDLAS open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*). H_2S emissions from the same lagoons/settling basins over the same periods of time were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM*

emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments (TDLAS/scanner) were mounted at 1-m height above the basin berm (abl) at the northwest and southeast corners of the east basin (Figure 1-2). Towers for mounting retro-reflectors were located off the northeast and southwest corners of the east basin (Figure 1-2). A description of the position and path length of the optical paths along each side of the basin follows:

- West side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 70 m and 140 m from the northwest TDLAS/scanner. Three retro-reflectors were mounted on the southwest tower 221 m from northwest TDLAS scanner at heights of 1.2 m, 6.9 m and 14.9 m abl.
- North side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 26 m and 50 m along berm from northwest TDLAS/scanner. Three retro-reflectors were mounted on the northeast tower 84 m from the TDLAS/scanner at heights of 1.2 m, 7 m and 15 m abl.
- East side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 71 m and 135 m from southeast TDLAS/scanner. Three retro-reflectors were mounted on the northeast tower 215 m from the southeast TDLAS/scanner at heights of 1.2 m, 7 m and 15 m abl.
- South side: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 32.5 and 63.5 m from southeast TDLAS/scanner. Three retro-reflectors were mounted on the southwest tower 94.5 m from the TDLAS scanner at heights of 1.2 m, 6.9 m and 14.9 m abl.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1-m abl. A 50 m long S-OPS path ran east parallel to the north berm and 10 m north of the north berm beginning at the northwest berm corner (Figure 1-2). The second 50-m long S-OPS path ran west parallel to and 2 m south of south berm beginning at the southeast berm corner (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Figure 1-2: Locations of instrumentation around the basin under measurement. Retro-reflectors are indicated according to side (north, south, east, and west) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The locations of the two S-OPS are indicated by the solid yellow lines. The instrumentation trailer was located in the northeast corner of the basin.

Meteorological measurements (barometric pressure, air temperature, relative humidity, solar radiation, and surface wetness) were located on the meteorological tower located on the dividing berm between the east and west basins 23 m north of the southwest corner of the east basin. The 3D sonic anemometers were located on the meteorological tower at 2.5 m abl and on the southwest tower (Figure 1-2) at 4 m and 17 m abl.

2 Monitoring activities

2.1 Measurement periods

This location was measured as part of an approximate 20-d rotation between three other farms. The equipment was on site a total of 112 d over six measurement periods (Table 2.1-1). Setup calibrations and site takedowns reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 101.9 d and H_2S emissions were measured 80.7 d.

Table 2.1-1: Measurement Periods

Period	Start date	End date	# days
3	2/25/2008	3/12/2008	13
4	3/12/2008	3/26/2008	14
5	8/8/2008	9/3/2008	26
6	9/3/2008	9/26/2008	23
8	5/18/2009	6/4/2009	16
9	6/4/2009	6/20/2009	15

2.2 Site visits

The field operation team involved in the set-up, take-down, and on-site calibration checks visited this farm 21 d (Table 2.2-1). Visits to set up the site instrumentation and conduct calibration verification checks of instruments typically lasted 3 d while visits for calibration verifications and take-down of the equipment on site typically needed 2 d.

Table 2.2-1 Dates of site visits

Year	Spring	Summer	Fall	Winter
2007				Feb 25,26,27,28,29
2008	Mar 12,13,26	Aug 8,9,10,11,12,13	Sep 4,26	
2009	May 19,20,21,	Jun 4,19		

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21-d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder 2.0™ NH_3 TDLAS serial number (s/n) 1026, 1027, 1028, 1029 and 1032 (Section 6.1)
- TEC 450i H_2S Analyzer s/n 0733825128 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1920, 1921, 1927, 1928, 1932 and 1936 (Section 6.3)
- GSS/ S-OPS s/n 4-0017 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multipoint calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers

(Section 6.3) with three unused 'reference' anemometers. A further QA check was made by inter-comparing TDLAS units: on May 21, 2009 two TDLAS units were inter-compared on site (s/n 1028 and 1029).

2.4 Audits

Two internal audits were conducted at this location: 1) on 12 March 2008 with particular attention to the TDLAS calibration verification, and 2) on 21 May 2009 with particular attention to the operation documentation. The TDLAS units on location (s/n 1027 and 1029) were inter-compared on 21 May 2008.

2.5 Remote site checks

Over the course of measurements, there were 50 remote checks made through the computer for instruments operating at this location.

2.6 Measurement data acquisition

Data from the TDLAS units (Model GasFinder 2.0^{TM} NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *LoggerNet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *LoggerNet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA)were downloaded in real-time through a serial cable to the trailer computer using the *iPort*® (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built Visual Basic software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic anemometer temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory "FTP" and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory "Data". The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the "FTP" directory.

3 Data processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic anemometer parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDL. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes need to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site, data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer causing the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period, unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one min off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the basin and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream may depend on one or more of the preceding streams, but not on following data streams. For each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment failures, calibration failures, and because calibration checks were in progress. Periods of invalidated measurements associated with the calibration check failures are documented in the calibration reports in Section 8. Significant data exclusions of greater than one-day duration are indicated below by instrument. All time references are in Universal Coordinate Time (UTC):

TDLAS measurement exclusions: Examples of events resulting in measurement exclusions include the following issues. Specific events are described in Table 3.2-1.

Table 3.2-1: TDLAS exclusion events

Exclusion		Exclusion		Reason
3/2/2008	09:47:00	3/12/2008	20:58:50	northwest scanner and TDL 1; power issues
8/23/2008	19:24:08	8/27/2008	20:21:25	TDLAS 1 power failure
5/27/2009	03:50:22	5/31/2009	00:14:37	TDLAS 2 unknown failure; no data
5/21/2009	23:40:48	6/4/2009	21:48:07	TDLAS 1 (1027) failed

Air temperature and relative humidity measurement exclusions: The air temperature and relative humidity sensor experienced four exclusion events that are described in Table 3.2-2.

Table 3.2-2: Air temperature and relative humidity sensor measurement exclusion events

Begin		End		Reason
Air temperature				
2/3/2008	03:20:00	3/5/2008	16:05:00	Power lost on northwest side of basin
3/9/2008	21:55:00	3/11/2008	17:05:00	Power lost on northwest side of basin
8/14/2008	00:15:00	8/15/2008	00:05:00	Power lost on northwest side of basin
6/4/2009	21:20:00	6/9/2009	16:30:00	No power at met station
Relative humidity				
3/2/2008	03:20:00	3/5/2008	16:05:00	Power lost on northwest side of basin
3/9/2008	21:55:00	3/11/2008	17:05:00	Power lost on northwest side of basin
8/14/2008	00:15:00	8/15/2008	00:05:00	Power lost on northwest side of basin
6/4/2009	21:20:00	6/9/2009	16:30:00	No power at met station

Wetness measurement exclusions: There were four instances of wetness measurement exclusions, which are described in Table 3.2-3.

Table 3.2-3: Wetness sensor exclusion events

Begin		End		Reason
3/2/2008	03:20:00	3/5/2008	16:05:00	Power lost on northwest side of basin
3/9/2008	21:55:00	3/11/2008	17:05:00	Power lost on northwest side of basin
8/14/2008	00:15:00	8/15/2008	00:05:00	Power lost on northwest side of basin
6/4/2009	21:20:00	6/9/2009	16:30:00	No power at met station

Pressure measurement exclusions: The barometer used at this location experienced 4 exclusion events as described in Table 3.2-4.

Table 3.2-4: Barometric pressure measurement exclusion events

Begin		End		Reason
3/2/2008	03:20:00	3/5/2008	16:05:00	Power lost on northwest side of basin
3/9/2008	21:55:00	3/11/2008	17:05:00	Power lost on northwest side of basin
8/14/2008	00:15:00	8/15/2008	00:05:00	Power lost on northwest side of basin
6/4/2009	21:20:00	6/9/2009	16:30:00	No power at meteorological station

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-4.

Table 3.2-1: Sonic anemometer measurement exclusions

Begin		End		Reason
3/2/2008	03:20:00	3/5/2008	16:05:00	Sonic anemometer 1 due to power loss on northwest side of basin
3/4/2008	20:30:00	3/6/2008	13:55:00	All 3 sonic anemometers; sonic anemometer program failure
3/15/2008	20:05:00	3/17/2008	12:50:00	All 3 sonic anemometers; sonic anemometer program failure
8/15/2008	21:35:00	8/18/2008	12:05:00	All 3 sonic anemometers; sonic anemometer program failure
8/30/2008	14:10:00	9/3/2008	16:30:00	Sonic anemometer 2 no data collected
6/4/2009	21:20:00	6/9/2009	16:30:00	All 3 sonic anemometers power failure

GSS/S-OPS measurement exclusions: Excluded measurements are summarized in Table 3.2-3.

Table 3.2-3: GSS/S-OPS measurement exclusions

Begin		End		Reason
GSS				
3/12/2008	00:15:00	4/3/2008	19:45:00	Pump turned off; H_2S Analyzer sent to manufacturer for repair
9/6/2008	19:15:00	9/9/2008	07:15:00	GSS solenoids not switching
9/14/2008	16:45:00	9/17/2008	15:45:00	GSS solenoids not switching
9/23/2008	16:15:00	9/26/2008	23:15:00	GSS solenoids not switching
S-OPS				
3/12/2008	00:15	4/3/2008	19:45	Opening in line, repaired

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20 ^oC (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in supersaturated "holes" in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a supersaturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maxed-out light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably supersaturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 s on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-s value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be super-saturated were flagged as supersaturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not super-saturated. To determine which points truly were super-saturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest path integrated concentrations corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be super-saturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as super-saturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the

GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the SOPs changed from one line to the other line. This array was later used when separating the H_2S data according to which SOPs line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic anemometer software imported the 300-s sonic anemometer data files and produced the final sonic anemometer QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic anemometer data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic anemometer temperature variance of greater than 2.5 K^2, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic anemometer temperature variance had to be less than 2.5 K^2 to be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH_3 emissions by RPM

The *RPM* model was used to estimate the NH_3 emission rates based on the TDLAS and sonic anemometer data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and efficient, the sonic anemometer and TDLAS data processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be

RPM processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH_3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro-reflectors. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the basin or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *Windtrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant.. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3}\frac{34.0818\left(\left[H_2S\right]_{downwind} - \left[H_2S\right]_{upwind}\right)}{17030.4\left[NH_3\right]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H_2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic anemometer, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and tells the model to run depending on whether or not the u_* and L values are acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the basin or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths. All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the basin emissions include transfer of waste from barns into the basin, irrigation with wastewater (Table 4.1-1) and sludge removal from the basin. Animal inventories for the calculation of basin loading rates are indicated in Table 4.1-1.

Table 4.1-1 Producer activities

Period	Activity	Animal inventory
3: 2/25-3/12/2008	No events, West basin full and drying, East basin filling	4430
4: 3/12-3/26/2008	No events, West basin full and drying, East basin filling	4430
5: 8/8 - 9/3/2008	West basin sludge being removed, East basin filling 8/10 Spread manure East of dairy 8/16 Spread manure East of dairy 9/2 Spread manure East of Dairy.	4398
6: 9/3 - 9/26/2008	West basin filling, East basin filling 9/8-9/18 started liquid manure soil injection 9/23 Spread manure East of dairy.	4398
8: 5/18 - 6/4/2009	West basin filling, East basin filling and drying	4328
9: 6/4 - 6/20/2009	West basin filling, East basin filling and drying	4328

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied widely as expected for dry Steppe climates (Table 4.2-1). Sixteen percent of the days had extra-tropical frontal systems overhead while 84% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Measurement period	# days	# warm front passages	# cold front passages	# days stationary front	# days tropical storm
3	13	0	3	1	0
4	14	0	1	0	0
5	26	0	4	0	0
6	23	0	2	0	0
8	16	0	2	0	0
9	15	0	0	4	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from 4.1^{o}C to 31.7^{o}C while the barometric pressure varied from 97.26 kPa to 100.19 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ h solar irradiance of 1159 W m^{-2} to overcast conditions with maximum ½ h solar irradiance of 86 W m^{-2} (Section 6.10).

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared with the monthly climatology is indicated in Figure 4-1. Temperatures were generally within the climatological normal conditions throughout the study measurement periods at this location.

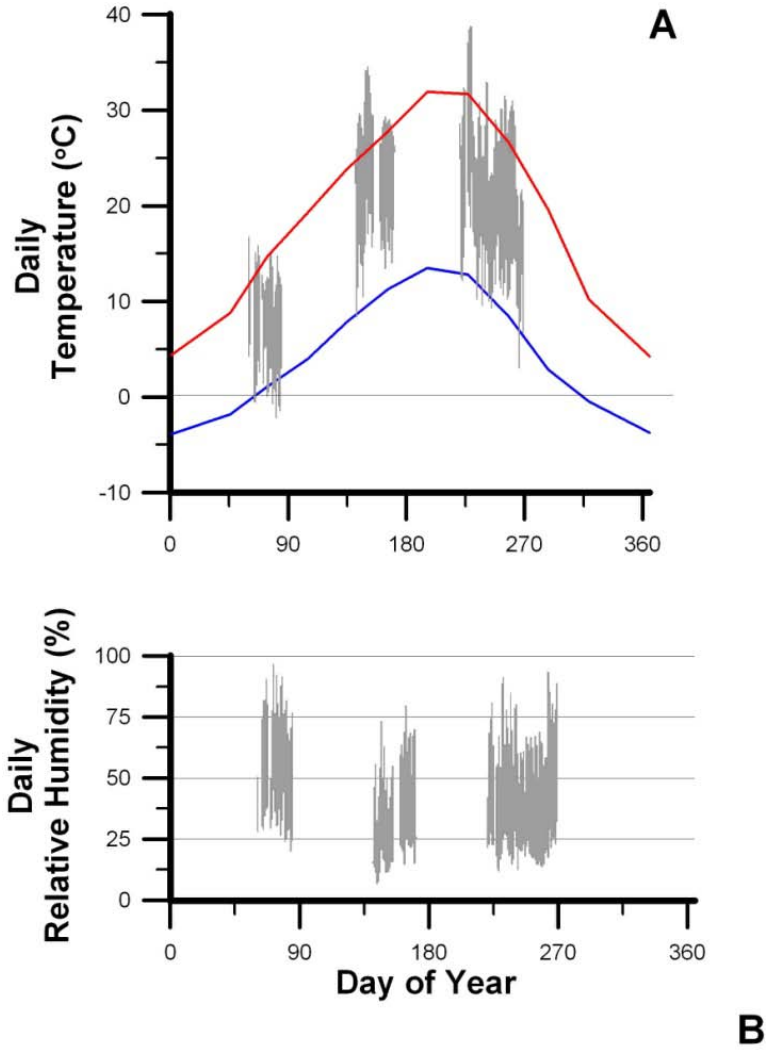

Figure 4-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line) temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidity for measurement days is indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figures 4.2-1 through 4.2-3. The bLS emission calculation exclusion regions due to surrounding sources (wind directions of 225°

through 360°) are indicated as a grayed region in the figures. No wind direction exclusions were needed for the *RPM* emissions calculations.

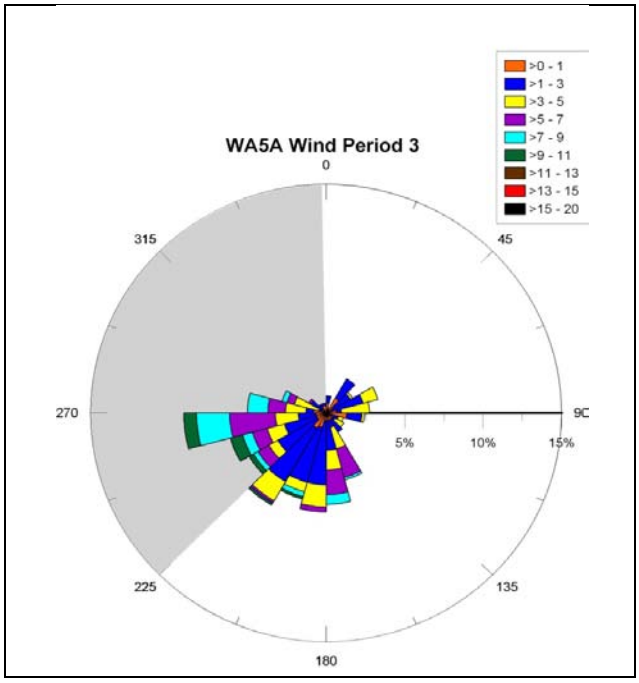

Figure 4.2-1: Wind rose for ½ hourly wind measurements during the winter measurement period. The period in which measurements were made is indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m s^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

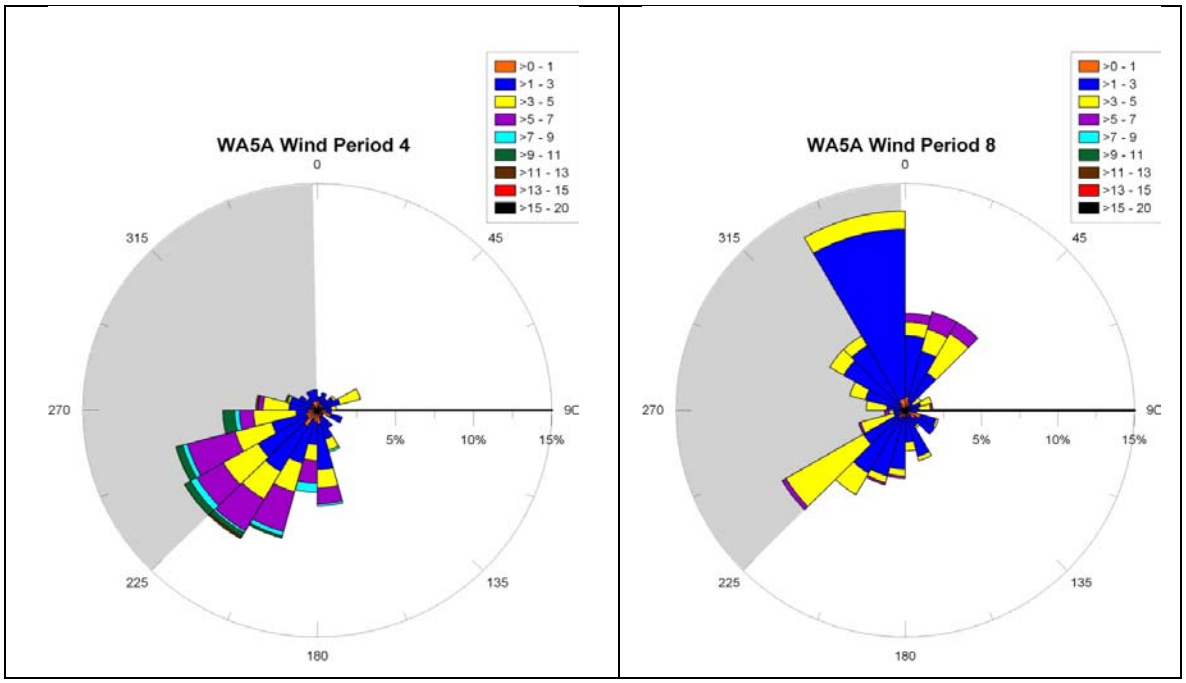

Figure 4.2-2: Wind roses for ½ hourly wind measurements during the spring measurement periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m s^{-1}) is indicated by colors within each triangle. The shaded regions define the excluded wind directions.

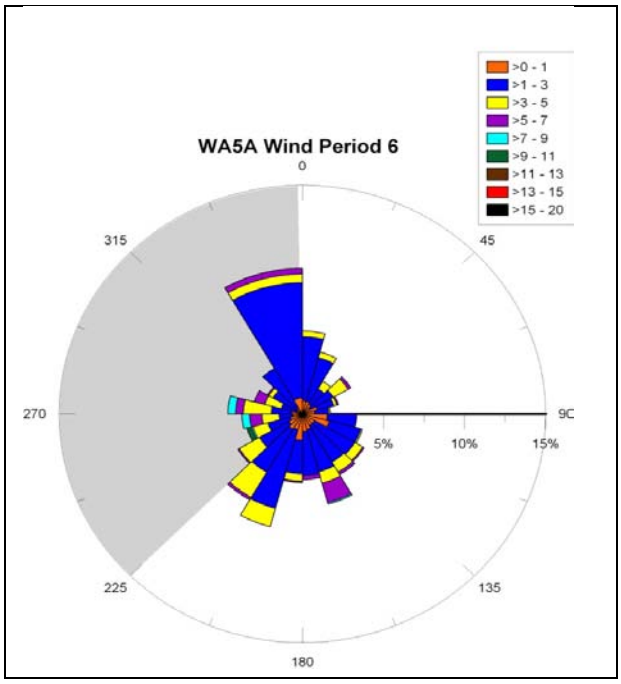

Figure 4.2-3: Wind rose for ½ hourly wind measurements during the fall measurement period. The period in which measurements were made is indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m s^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

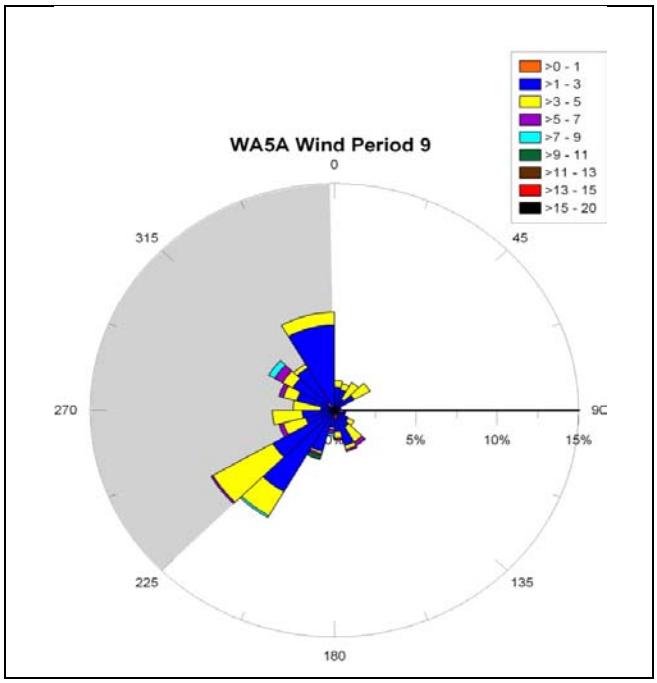

Figure 4.2-4: Wind rose for ½ hourly wind measurements during the summer measurement period. The period in which measurements were made is indicated. The relative portion of time in which the wind is from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of m s^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

4.3 Basin conditions

4.3.1 Basin appearance, liquid depth and sludge depth

The appearance of the basin was recorded on almost every site visit (Table 4.3-1). The basin generally appeared brown and entirely crusted.

Table 4.3-1: Basin physical characteristics

Period	Date, appearance (color/crust)
3:2/25-3/12/2008	2/25/08 - brown/ no crust 2/26/08 - brown/ no crust 2/27/08 - brown/ no crust 2/28/08 - brown/ no crust 2/29/08 - brown/ no crust
4: 3/12-3/26/2008	3/12/08 - brown/1% crust 3/13/08 - brown w/yellow film/1% crust 3/26/08 - brown/5% crust
5: 8/8 - 9/3/2008	8/8/08 - brown/100% crust 8/9/08 - brown/100% crust 8/10/08 - brown/100% crust 8/11/08 - brown/100% crust 8/12/08 - brown/100% crust 8/13/08 - brown/100% crust

Period	Date, appearance (color/crust)
6: 9/3 - 9/26/2008	9/4/08 - brown/100% crust 9/26/08 - brown/100% crust
8: 5/18 - 6/4/2009	5/19/09 - brown/100% crust 5/20/09 - brown/100% crust 5/21/09 - brown/100% crust
9: 6/4 - 6/20/2009	6/4/09 - brown/100% crust 6/19/09 - brown/100% crust

4.4 Emissions

Emissions data were calculated on a ½ h basis since this was the interval over which the S-OPS system sampled both sides of the basin and since this interval is in the range over which turbulence statistics are often calculated. Emissions reported on a head basis were scaled by the design animal population and not the animal population at the time of measurements to account for the longer term manure storage of the basin. Emissions reported on an animal unit (AU) basis assumed an animal weight of 500 lb equals 1 AU and the typical animal weight values reported by the producer. Piglets and calves were not included in the populations or AU determinations. Emissions reported on an area basis are based on the surface area of the basin.

Due to the rotation in use of the basins described in Section 1.3, the time axis is in sequential days. The NAEMS day refers to the days after measurements began for the entire project (not this location).

Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison based on 233 ½ h measurement periods over the entire measurement time at this location. Results showed that the bLS emissions had a significantly different precision (F=1.16, critical F 1.0) and a significant bias over the *RPM* emissions (t=-1.47, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 0.93 (Table 4.4.1-1). Consequently the ½ h bLS emissions measurements were biased low by 7% compared with the *RPM* measurements.

Table 4.4.1-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	bLS	bLS-RPM
Mean emission (g s^{-1})	0.524	0.491	-0.033
Standard Deviation (g s^{-1})	0.311	0.335	
Variance of the mean (g s^{-1})	0.098	0.112	

4.4.1 NH_3 emissions

4.4.1.1 Mean daily NH_3 emissions

There was no distinct temporal pattern evident in the emissions based on the *RPM* model (Figure 4.4.1-1). Emissions were generally between 5 g to 15g $NH_3 d^{-1} hd^{-1}$. The daily emissions during the beginning of measurements was generally less than measurements later however these emissions measurements may be underestimated by up to 40% due to the interference of atmospheric moisture. The only daily emissions measurements estimated with more than 75% of

the day's emissions are around September 2008. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

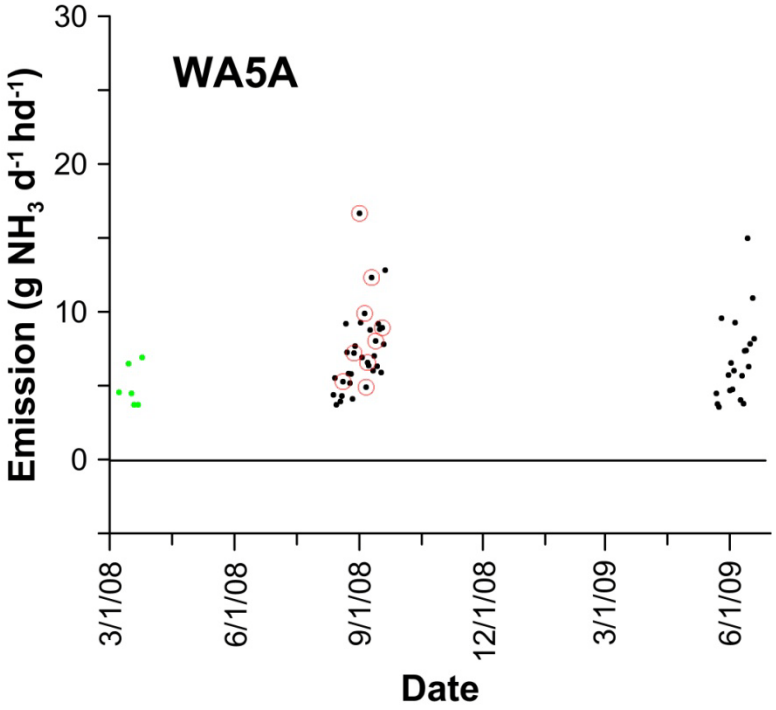

Figure 4.4.1-1: Annual variation in RPM-determined daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

There was a distinct temporal pattern evident in the emissions based on the bLS model (Figure 4.4.1-2). Emissions were initially between 0 and 18g $NH_3d^{-1}hd^{-1}$ diminishing gradually to approximately 5 g $NH_3d^{-1}hd^{-1}$. The daily emissions during the beginning of measurements may be underestimated by 40% due to the interference of atmospheric moisture however the dryness of the environment probably resulted in less of an underestimate than 40%. Only one day's estimated daily emissions was based on more than 75% of the day's emissions. This consequently limits the confidence in the calculated emissions. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

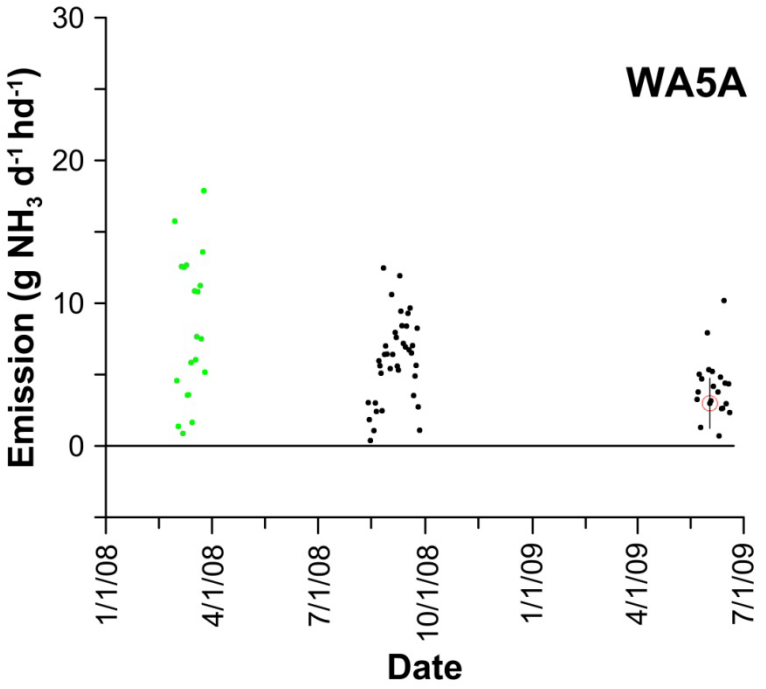

Figure 4.4.1-2: Annual variation in bLS-determined daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH_3 concentration measurement. The bars represent the standard deviation of emissions based on individual ½ h values when at least 75% of the day had valid measurements.

The bLS model was influenced by the calculated background concentrations. Results indicated that the background concentration of NH_3 was generally less than 0.1 ppm (Figure 4.4.1-3). Given that the typical path length around the basin was 200 m and the typical background concentration is less than 0.3 ppm, this corresponds to a background concentration for a given PIC of approximately 60 ppm-m. This is approximately 30 times the MDL for the TDLAS instruments of 2 ppm-m (Section 6.1) and therefore represents a real background for this location. Negative background concentrations occur when the winds are variable resulting in no distinct upwind or downwind S-OPS.

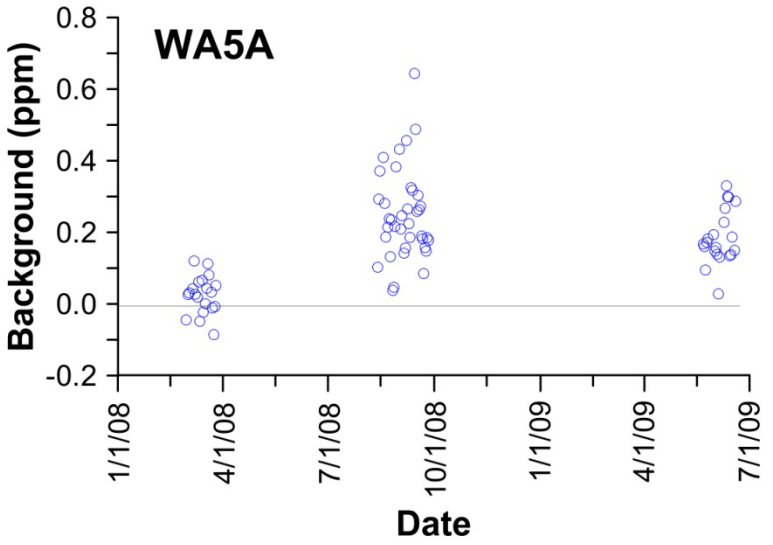

Figure 4.4.1-3: Annual variation in bLS-determined mean daily background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

In general, there was a weak diurnal pattern to the NH_3 emissions with the likelihood for high emissions greater during the day than at night (Figure 4.4.1-4).

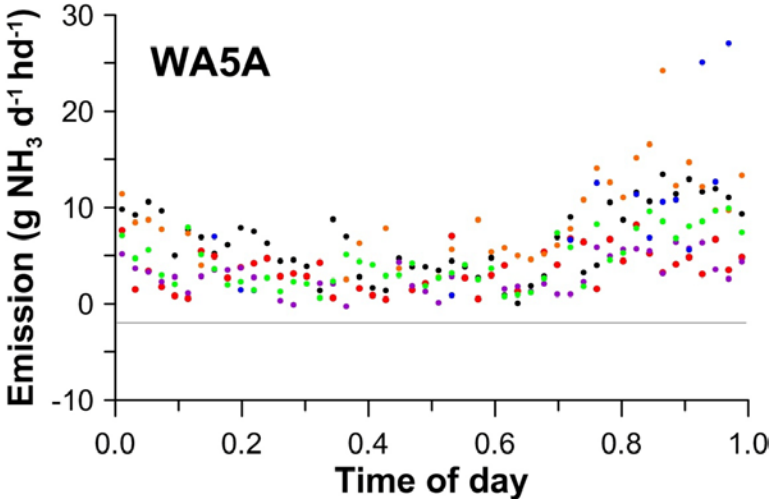

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 2-Fall (pink), Period3-Winter (brown), Period 4-Spring (orange), Period 5-Summer (green), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. Therefore, an additional value giving the total number of days with at least 36 valid ½ h periods (corresponding to 75% completeness on a daily basis) is given. Because of the requirement of 5 to 10 valid TDLAS measurements before an *RPM* emission measurement is possible, the number of valid ½ h periods with *RPM* emissions was greatly limited. The wind conditions and wind direction exclusion region did not greatly reduce the yield of valid bLS emission measurements. The completeness statistics are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

	Measurement period						
	3	**4**	**5**	**6**	**8**	**9**	**Total**
NH_3 RPM model							
Valid 1/2 h measurements (d)	0.0	0.2	11.2	10.6	2.0	4.6	**28.8**
Measurements excluded due to wind direction (d)	1.9	2.0	0.5	1.3	0.3	1.0	**7.0**
Measurements excluded because at least one downwind path is missing or invalid (d)	7.1	7.7	6.8	5.7	11.0	2.6	**40.9**
Number of days (d) with ≥36 valid 1/2 h periods	0.0	0.0	5.0	6.0	0.0	1.0	**12.0**
NH_3 bLS model							
Valid 1/2 h measurements (d)	0.5	1.5	3.7	5.3	2.4	2.3	**15.6**
Measurements excluded due to wind direction (d)	4.1	5.6	9.6	8.6	3.0	5.6	**36.5**
Measurements excluded because touchdown fraction < 0.1 (d)	1.0	0.0	1.8	0.2	3.0	0.0	**5.9**
Measurements excluded because $u_* < 0.15$ m s^{-1} or $\|L\| < 2$ m (d)	3.8	3.6	3.4	5.4	2.8	2.0	**21.1**
Number of days (d) with ≥36 valid 1/2 h periods	0.0	0.0	0.0	0.0	1.0	0.0	**1.0**

In total 28.8 d of valid NH_3 emissions were determined using the *RPM* model from the 101.9 d of measurements. Of these days, only 12 d had at least 36 valid ½ h NH_3 emissions. The absence or invalidation of at least one downwind path led to 40.9 d for which emissions could not be calculated.

In total 15 d of valid NH_3 emissions were determined from the 101.9 d of measurement using the bLS model, with only one day having at least 36 valid ½ h NH_3 emissions. The exclusion wind directions due to the location of the adjacent manure storage basin relative to the basin studied resulted in the loss of 36 d of measurements. Invalid turbulence statistics ($u_* < 0.15$ m s^{-1} or $|L| <$ 2 m) led to 21 d for which emissions could not be calculated. A touchdown fraction of less than 0.1 led to the exclusion of 6 d of data. Low touchdown fractions indicated that little, if any,

downwind data was available. This corresponded to either when the downwind TDL was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ h interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ h mean wind speed and direction, in contrast to the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times when the *RPM* model produces a valid emission while the bLS model does not. However there are times when the wind direction invalidated the bLS emissions measurement due to lack of upwind TDL measurement but the *RPM* emissions measurement was valid.

4.4.2 H_2S emissions

4.4.2.1 Mean daily H_2S emissions

There was an apparent decline in emissions evident in the emissions based on the Ratiometric model (Figure 4.4.2-1). Emissions were generally 2 g H_2S $d^{-1}hd^{-1}$ or less. Only one day of emissions measurements during the beginning of the study was possible due to instrument problems. There were no days in which more than 75% of the day's emissions were available for calculating the daily emission rate. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

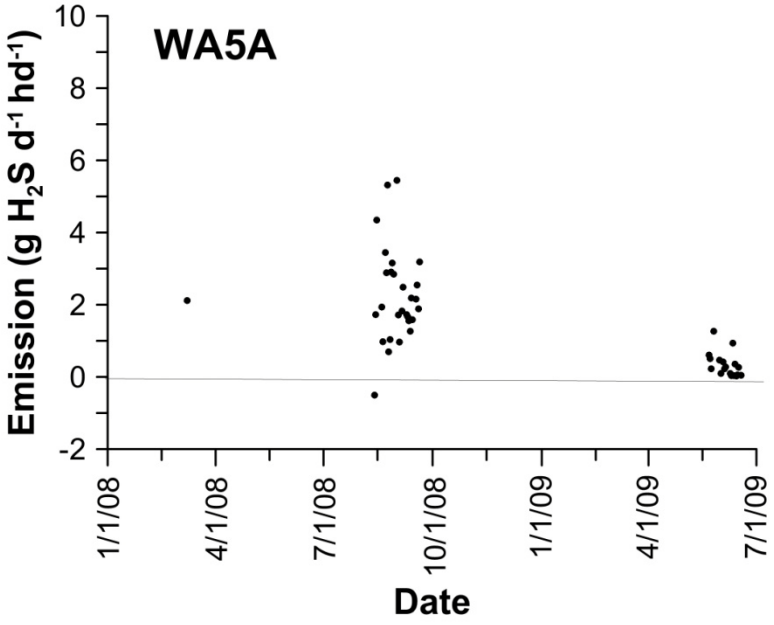

Figure 4.4.2-1: Annual variation in Ratiometric-determined daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

There was an apparent decline in emissions evident in the emissions based on the bLS model (Figure 4.4.2-1). Emissions were generally 4 g H_2S $d^{-1}hd^{-1}$ or less. There were no days in which

more than 75% of the day's emissions were available for calculating the daily emission rate. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

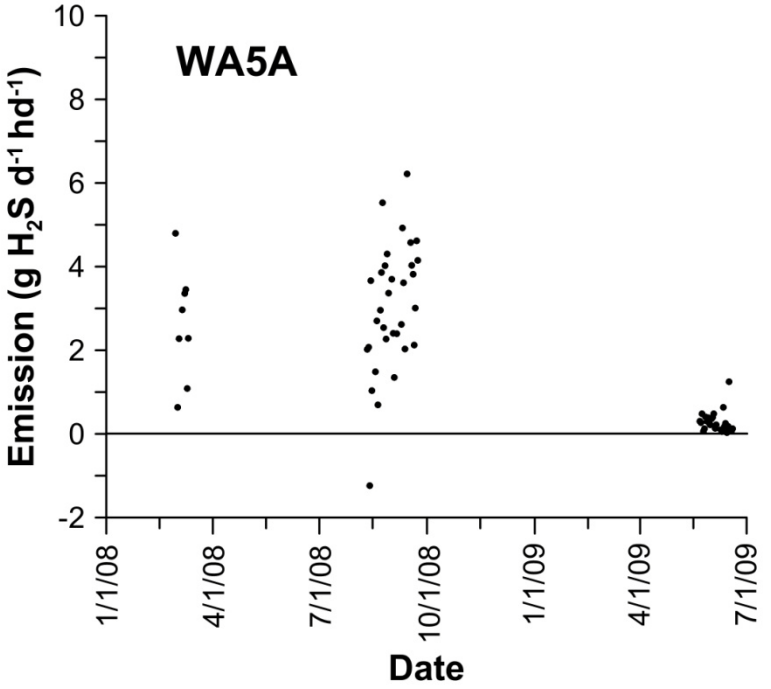

Figure 4.4.2-2: Annual variation in bLS-determined daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ h values when at least 75% of the day had valid measurements. The green solid circles indicate moisture interference with the NH_3 concentration measurement.

The bLS emission model depends on a good estimate of the background H_2S concentration. Results indicate that the background concentration was generally less than ± 5 ppb but had a significant number of higher concentrations (Figure 4.4.3-3). Two values are above the top of the y-axis at 180 g H_2S $d^{-1}hd^{-1}$ (8/18/2008) and 305 g H_2S $d^{-1}hd^{-1}$ (8/20/2008). The high background concentrations indicate nearby sources of H_2S.

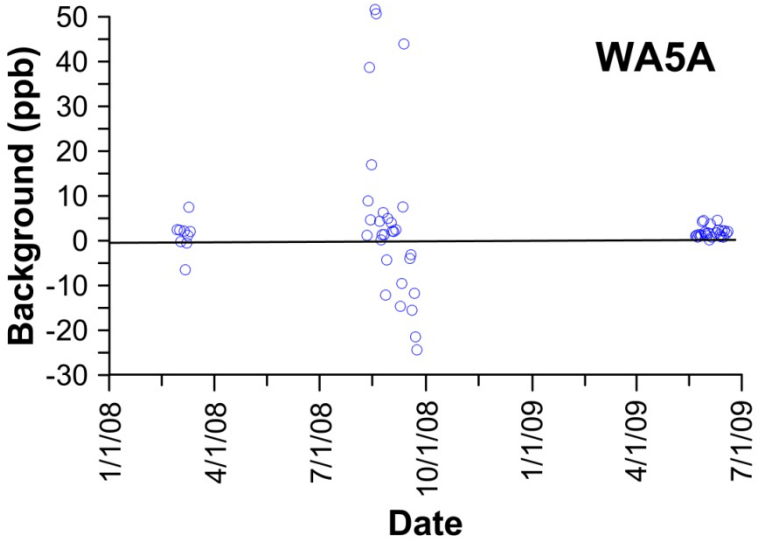

Figure 4.4.3-3: Annual variation in bLS-determined mean daily background concentration of H_2S.

4.4.2.2 Diurnal variation in H_2S emissions

There was no distinct diurnal periodicity in the H_2S emissions measurements (Figure 4.4.2-4).

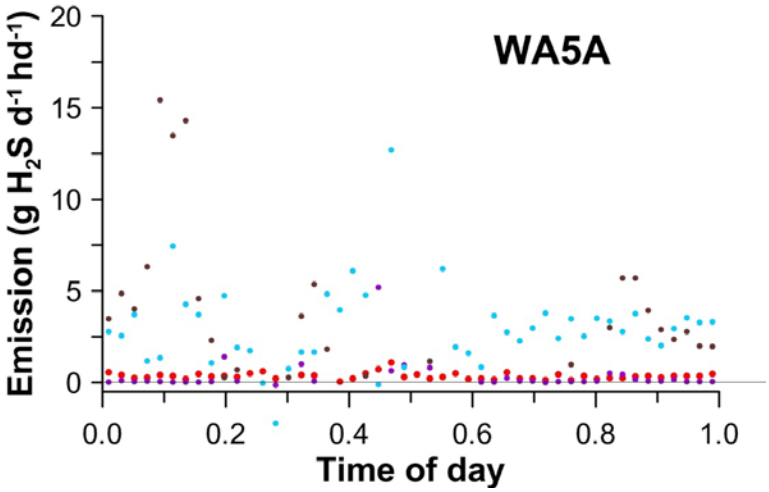

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 3-Winter (brown), Period 4-Spring (green), Period 5-Summer (light blue), Period 6-Fall (black), Period 7-Winter (blue), Period 8-Spring (red), and Period 9-Summer (purple)) are indicated.

4.4.2.3 H_2S emissions data completeness

H_2S Measurements were begun in Period 3. Consequently there were no measurements possible for autumn 2007. As described for the NH_3 emissions, emissions completeness and failure totals

are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics are summarized in Table 4.4.2-1.

The H_2S emissions were measured a total of 80.7 d at this location. The majority of measurements were invalidated as a result wind direction (Figure 1-2). Because there were few valid ½ measurements of the NH_3 emissions based on the *RPM* model (Table 4.4.1-2), the number of valid ½ periods of valid Ratiometric emissions measurements of H_2S is small. The majority of bLS emissions measurements were invalidated due to wind conditions. In total, 6 d of valid H_2S emissions were determined using the Ratiometric emission method, with no days having at least 36 valid ½ h H_2S emissions. Valid H_2S emissions for 12 d were determined using the bLS model, with no days having at least 36 valid ½ h H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ m s^{-1} or $|L| < 2$ m) excluded 15 d, largely due to low wind speeds. Wind direction exclusions invalidated 33 d of measurements.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

	Measurement period						
	3	**4**	**5**	**6**	**8**	**9**	**Total**
H_2S Ratiometric model							
Valid 1/2 h measurements (d)	0.0	0.0	2.3	2.4	0.6	0.8	**6.1**
Number of days (d) with ≥ 36 valid 1/2 h periods	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
H_2S bLS model							
Valid 1/2 h measurements (d)	1.2	0.0	3.5	2.2	3.3	2.1	**12.2**
Measurements excluded due to wind direction (d)	3.5	0.0	11.6	6.3	6.2	5.5	**33.0**
Measurements excluded because angle of attack > 60 degrees (d)	0.5	0.0	1.0	0.5	0.6	0.1	**2.7**
Measurements excluded because $u_* < 0.15$ m s^{-1} or $\|L\| < 2$ m (d)	3.6	0.0	3.2	3.2	2.9	2.1	**15.0**
Number of days (d) with ≥ 36 valid 1/2 h periods	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**

4.4.3 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of the TDLAS serial numbers 1026, 1027, and 1028 prior to July 21, 2008. TDLAS 1026 was used at WA5A from 2/28/2008 to 3/26/2008 (Measurement periods 3 and 4). Under the calibration verification checks, the TDLAS error of all units was 10% accuracy. However due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and units without apparent interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from dewpoint temperatures of -2°C to 20°C. A conservative estimate of the bias of all of the above TDLAS units with evident moisture interference was estimated at -40%.

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions, underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%.

Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was -6% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -46% for TDLAS NH_3 measurements made by units with moisture interference and a bias of -6% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the ratiometric measurement of H_2S emissions was ± 18%.

5 References

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6 Appendices

6.1 TDLAS NH_3 calibrations

Five TDLAS units (Model GasFinder2^{TM} NH3OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used at this location: serial numbers 1026, 1027, 1028, 1029, and 1032.

TDLAS 1026, was multipoint calibrated seven times (Figure 6.1-1). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 1/17/07 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$\text{ppm-m} = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until July, 21 2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-3). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and 11/10/2009 bias exceedances were followed the same or next day with a passing verification and were deemed to be a result of operator error. The negative bias over the period 4/2/2008 through

7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used). During operations the bias was only intermittently evident because to different multipoint calibration was applied to the calibration verification measurements during the progress of the study than finally applied during the analysis. Repeated calibrations within 24 h often showed biases differing by more than 10 ppm-m suggesting operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period are considered valid and the error assumed to be due to the calibration verification operator.

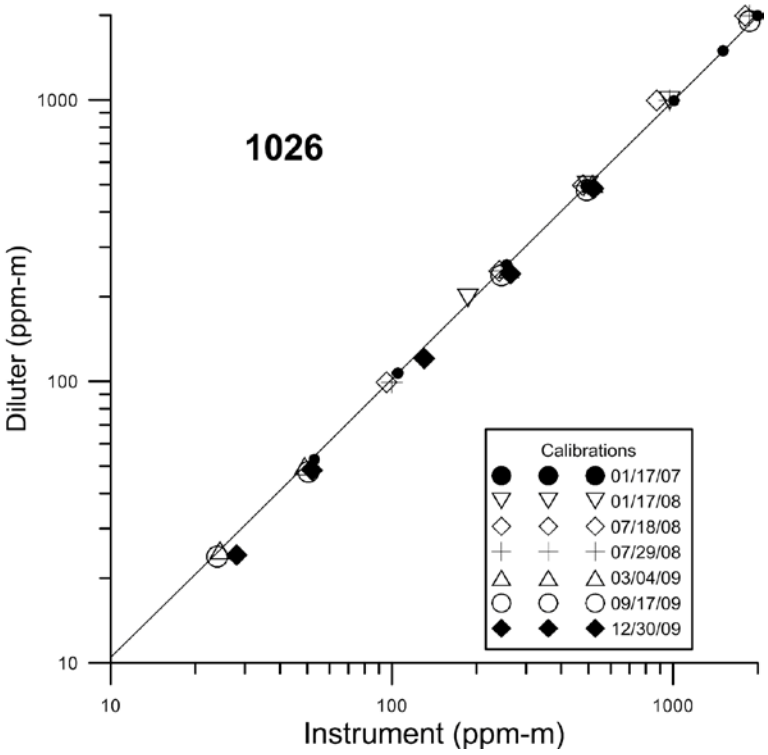


Figure 6.1-1: Multipoint calibrations of TDLAS 1026. The solid line is the 3rd order polynomial regressions for the chosen multipoint calibrations.

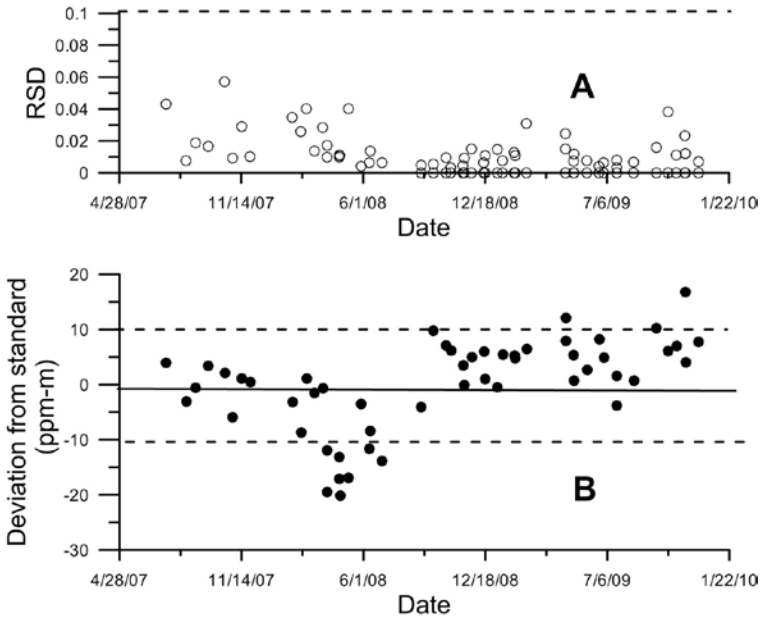


Figure 6.1-2: Control charts of TDLAS 1026

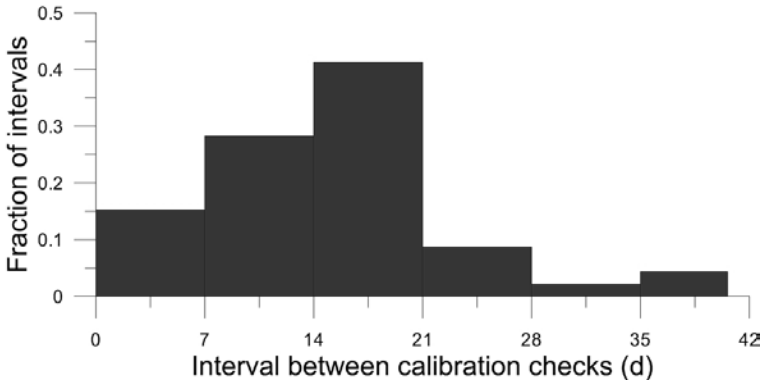


Figure 6.1-3: Calibration check intervals of TDLAS 1026

TDLAS 1027 was multipoint calibrated eight times during the study (Figure 6.1-4). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 6/18/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$ppm\text{-}m = 2.24 + 0.9936 * X - 3.59E\text{-}5 * X^2 + 6.230E\text{-}8 * X^3$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.13 ppm-m prior to the July 2008 modification and 1.83 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-6). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 5.36 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 9/26/2008 and 9/24/2009 (Figure 6.1-4). No negative biases exceeding the DQI occurred. Since both positive bias exceedances were followed by a DQI compliant verification on the subsequent calibration verification without intervention, it is assumed that operator error was the cause for the non-compliance.

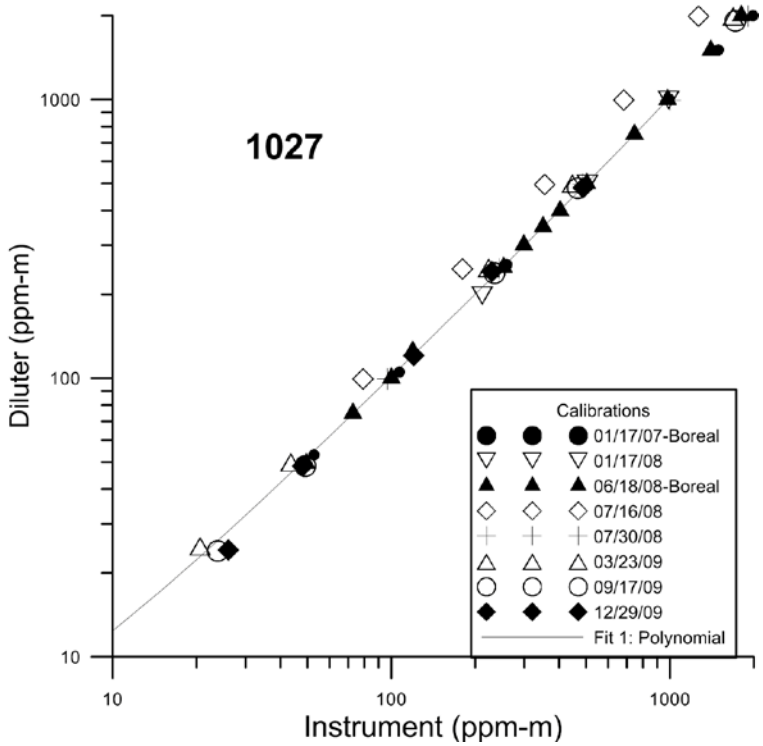


Figure 6.1-4: Multipoint calibrations of TDLAS 1027. The solid line is the 3rd order polynomial regressions for the chosen multipoint calibrations.

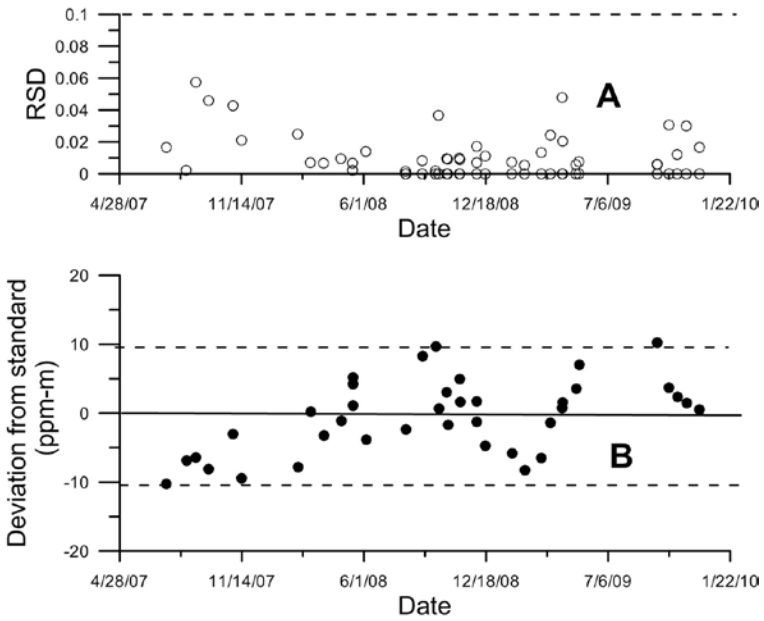


Figure 6.1-5: Control charts of TDLAS 1027

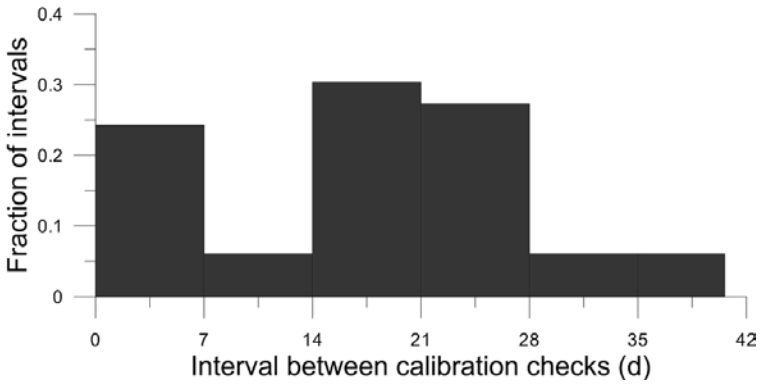


Figure 6.1-6: Calibration check intervals of TDLAS 1027

TDLAS 1028 was multipoint calibrated six times during the study (Figure 6.1-7). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/23/2007 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 1.46 + 0.985 * X + 8.465E\text{-}6 * X^2 + 3.879E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-9). The large fraction of checks made within 7 d is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-8) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 6.1-8). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

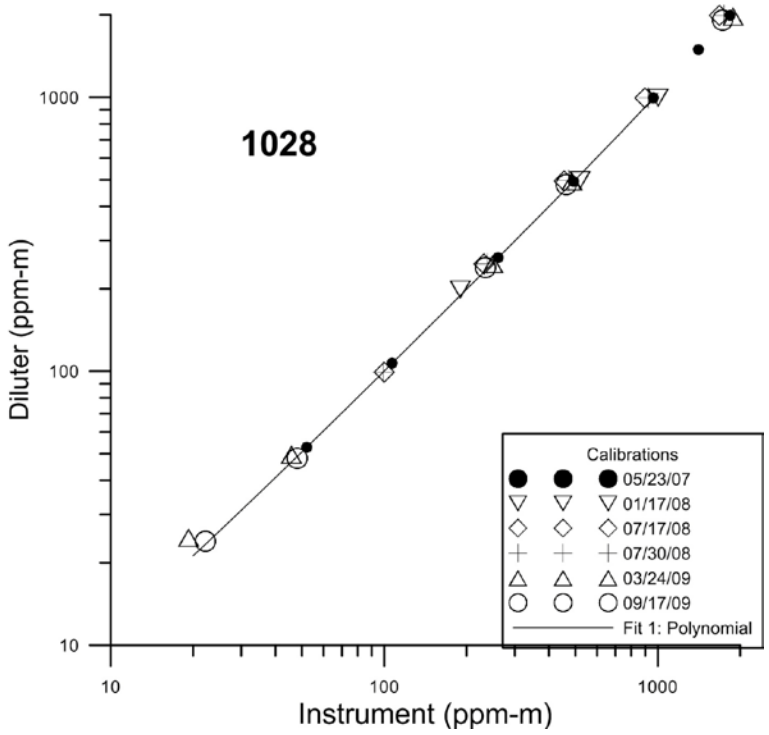


Figure 6.1-7: Multipoint calibrations of TDLAS 1028. The solid line is the 3rd order polynomial regressions for the chosen multipoint calibrations.

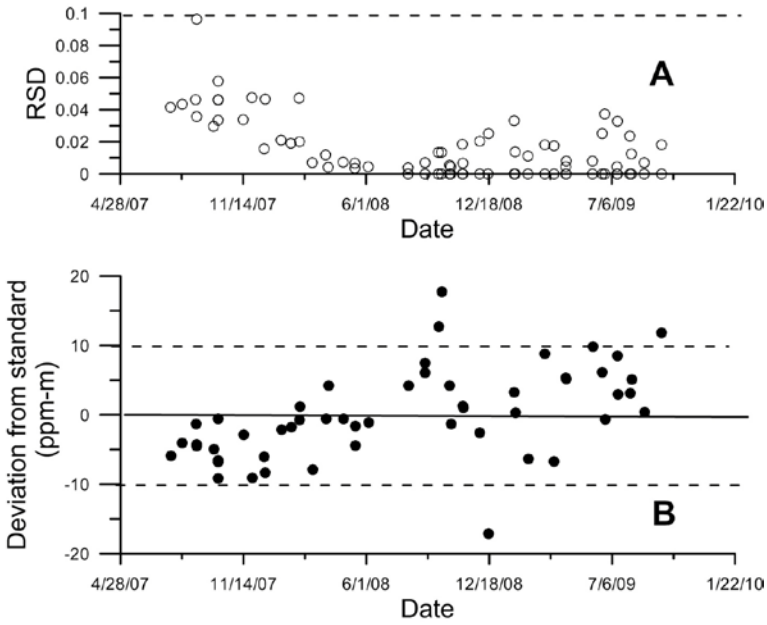


Figure 6.1-8: Control charts of TDLAS 1028

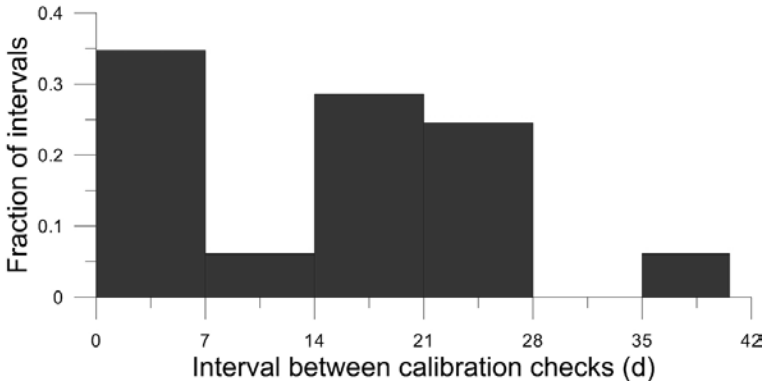


Figure 6.1-9: Calibration check intervals of TDLAS 1028

TDLAS 1029 was multipoint calibrated seven times during the study (Figure 6.1-10). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-1 indicated the multipoint calibrations used during different periods in the study.

Table 6.1-1: Multipoint calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
6/24/2007	03/01/2008	05/24/2007
3/24/2008	07/15/2008	03/24/2008
7/31/2008	08/03/2009	03/04/2009
8/4/2009	12/2/2009	12/29/2009

The offsets of the calibration equations were determined from a least squares fit of the appropriate period (Table 6.1-1) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

05/24/07: ppm-m = -1.48 + 0.967 * X + 4.842E-005 * X^2 - 7.312-009 * X

03/24/08: ppm-m = -2.58 + 0.998 * X - 1.611E-004 * X^2 + 7.449E-008 * X^3

03/04/09: ppm-m = 4.36 + 1.069 * X + 1.128-004 * X^2 - 1.206E-007 * X^3

12/29/09: ppm-m = 5.48+ 1.268 * X - 6.072E-005 * X^2

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.74 ppm-m prior to the July 2008 modification and 1.66 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL prior to the July 2008 modification was greater than the offset in the calibration regression equations but less than the offset in the calibration equations after the modification. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-12). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equations was 4.65, 4.15, 5.23, and 4.27 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-11) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A negative bias

exceeding the DQI threshold occurred on two dates (Figure 6.1-11). No positive bias exceeding the DQI threshold occurred. In all cases subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

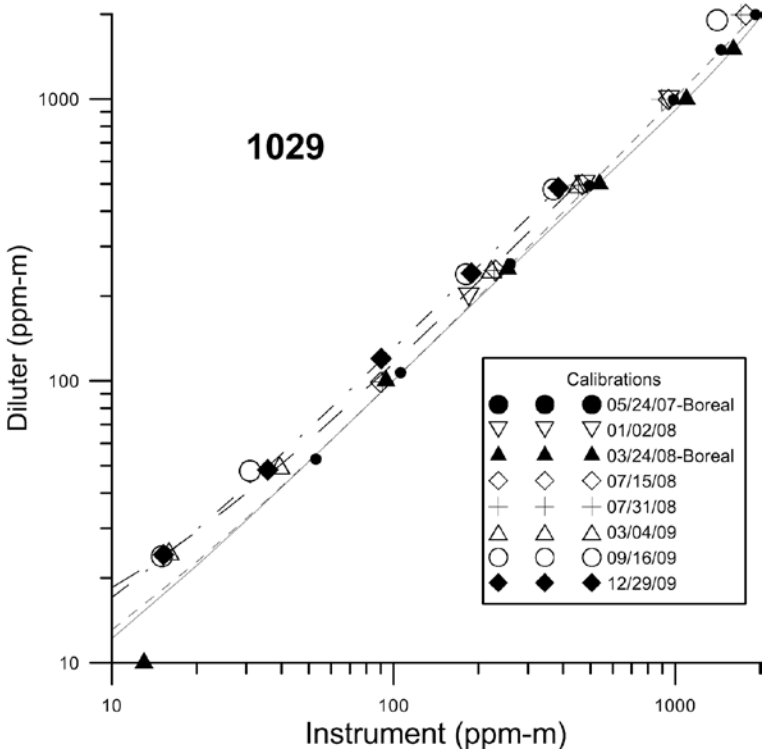


Figure 6.1-10: Multipoint calibrations of TDLAS 1029. The solid (5/24/07), dotted (3/24/08), dashed (3/4/09) and dash-dot (12/29/09) lines are the 3rd order polynomial regressions for the chosen multipoint calibrations.

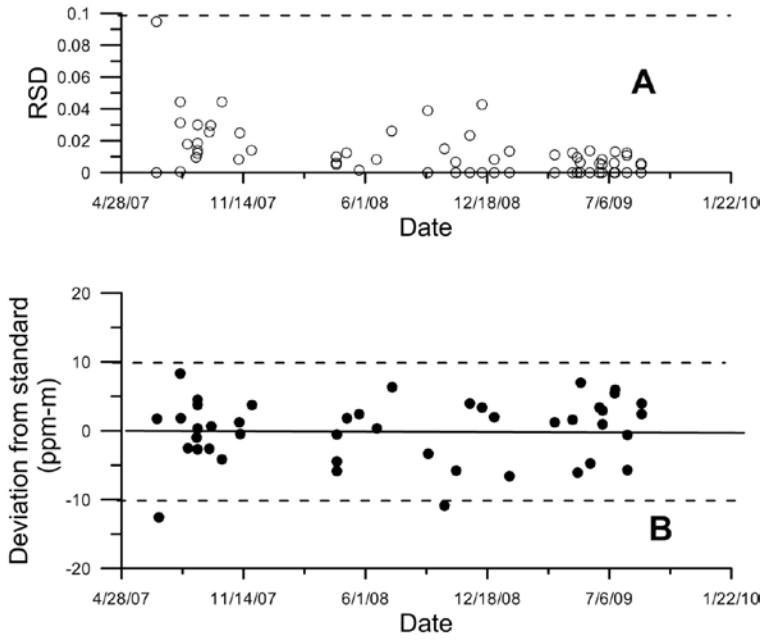


Figure 6.1-11: Control charts of TDLAS 1029

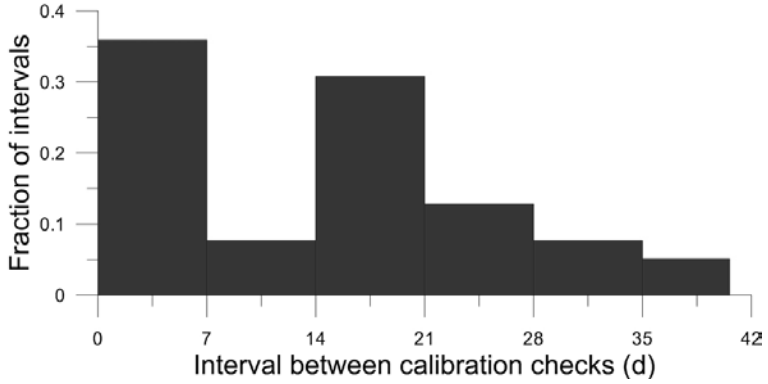


Figure 6.1-12: Calibration check intervals of TDLAS 1029

TDLAS 1032, was multipoint calibrated six times (Figure 6.1-13). The response is non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. Table 6.1-2 indicated the multipoint calibrations used during different periods in the study.

Table 1- Multipoint calibration application

Period of applicability (mm/dd/yyyy)		
Begin	**End**	**Multipoint calibration**
9/21/2007	8/1/2008	9/12/2007
8/27/2008	8/18/2009	3/4/2009

The offset of the calibration equation was determined from a least squares fit of the appropriate period (Table 6.1-2) of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibrations. The regression equations were:

9/12/07: ppm-m = -4.35 + 1.005 * X + 3.563 E-005 * X^2 - 2.618 E-008 * X^3

3/4/09: ppm-m = -0.69 + 0.995 * X - 2.3298 E-004 * X^2 + 2.891 E-007 * X^3

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments). The laser was found on 7/21/2008 to not be internally grounded properly, resulting is the inclusion of responses at very low light levels. The no-return light levels were above the minimum light level threshold considered for a valid instrument measurement.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3 σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.60 ppm-m prior to the July 2008 modification and 1.36 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The MDL was greater than the offset in the calibration equation for measurements prior to July 2008 and less than that after July 2008. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-14) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.1-15). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.13 and 5.61 ppm-m respectively. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-14) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias exceeding the DQI occurred on 3/26/2008 and 9/10/2008 (Figure 6.1-14). These exceedances were preceeded and followed by valid calibration verifications and it is assumed that since no modifications of the instrument were made that the exceedances are due to operator error. A negative bias exceeding the DQI was indicated in the calibration verifications on 5/6/2008

(Figure 6.1-14). The grounding problem found on 7/21/2008 (described above) may have been the cause for the period of consistently negative verifications after 4/21/08 when the background light levels exceeded the minimum acceptable light level. However since the 5/6/2008 exceedance was followed by compliant verifications (although low) without correction of the grounding problem it is assumed that the measurements are valid throughout the period of the grounding problem.

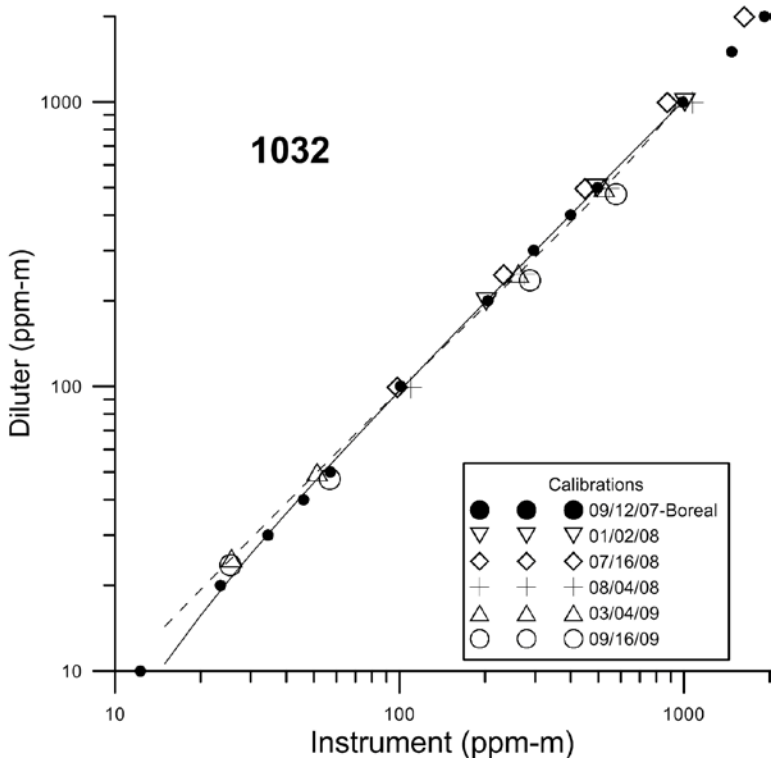


Figure 6.1-13: Multipoint calibrations of TDLAS 1032. The solid (9/12/07) and dashed (3/4/09) lines are the 3rd order polynomial regressions for the chosen multipoint calibrations.

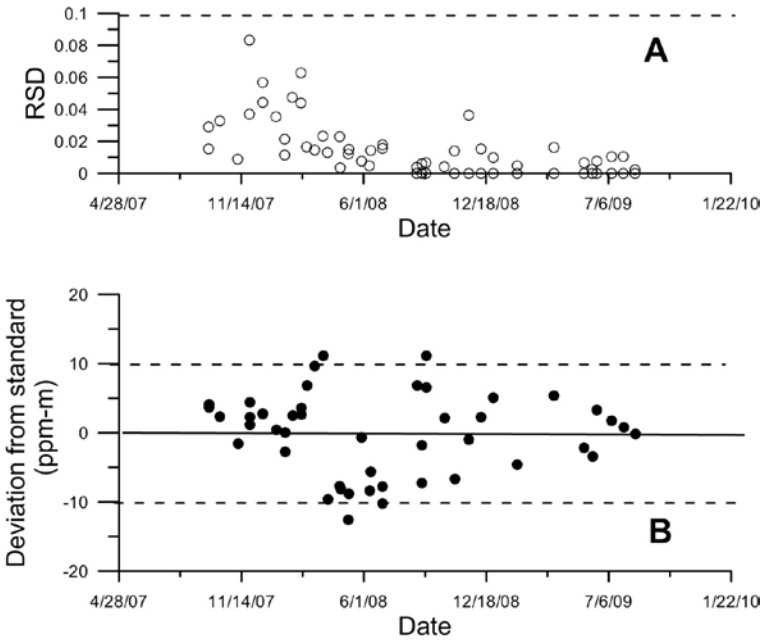


Figure 6.1-14: Control charts of TDLAS 1032

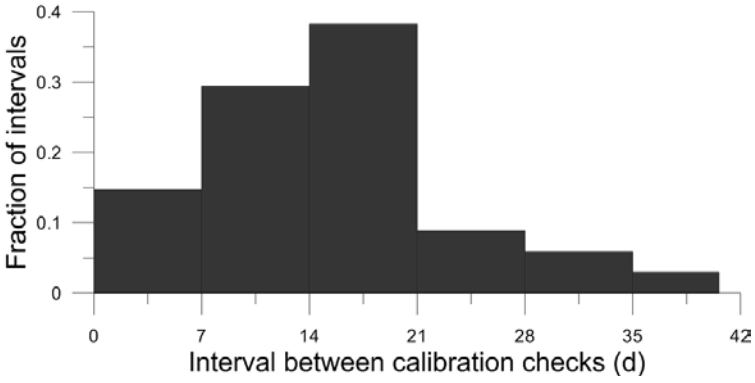


Figure 6.1-15: Calibration check intervals of TDLAS 1032

6.2 TEC 450i analyzer H_2S calibrations

The H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA), serial number 0733825128, was multipoint calibrated eight times (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.73 to 1.38 (Table 6.2-1). Part of the variation in slope was a result of the H_2S calibration cylinders used. The initial multipoint calibration was conducted prior to the complete burn-in of the converter and consequently differs greatly from the other calibrations.

Table 6.2-1: Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
12/12/2007	1.38	-0.0220	0.999
7/11/2008	0.99	0.0034	0.999
8/13/2008	1.18	-0.0045	0.999
9/4/2008	1.22	0.0065	0.999
3/25/2009	0.73	0.0068	0.999
6/19/2009	1.14	-0.0037	0.999
6/24/2009	0.75	0.0075	0.999
09/09/2009	1.14	-0.0052	0.999

The standard deviation of instrument response with CEM zero air measured over a one hour period was 0.83 ppb (10/19/2009). The instrument MDL, defined as 3σ was 2.5 ppb and is indicated in Figure 6.2-2A with dashed lines. This is much less than the mean absolute multipoint calibration intercept concentration of 7.5 ppb.

Instrument performance calibration checks (Figures 6.2-2 and 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 d (Figure 6.2-4). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.788. The mean zero concentration was +1.7 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). Three major periods of instrument bias that exceeded the ± 10% of FS are evident (Figure 6.2-2). The first period extended from the beginning of the measurements until 9/5/2008. Based on the correlation of instrument performance and the calibration cylinder used, it was determined that the concentration of H_2S in the SGAL053 cylinder, which could not be independently verified, was significantly below indicated specification. This resulted in unusually high ratios of diluter concentration versus instrument response (1.01 to 1.18) up until when the cylinder was replaced. The second period was from 11/4/2008 to 12/16/2008 when the calibration checks were inconsistent. Checks conducted on 11/4 and 12/16 at the end of measurement periods failed while checks made two days later at the set up of the next site passed. Since no modifications/repairs of the instruments were done in the interim between these calibrations, we assume that the FOS must have erred in their procedures.

The third period of calibration check failures occurred after April 2009. High zero checks (Figure 6.2-2A) and low reference checks (Figure 6.2-2B) occurred throughout this time. The instrument response time was observed to be unusually long (11 min versus typical 5 min) when specifically checked in July 2009. After the prescribed 10 min interval, which is specified in the SOP, the response was only 59% of the span value when the long time constant was discovered. Given the SOP reference value of 0.5 ppm, the 59% response after 10 min corresponds to approximately 0.2 ppm less than the stabilized reference value. The control chart of the calibration checks (Figure 6.2-2) showed a shift in response of approximately -0.2 ppm that occurred in May 2009 and continued through July 2009 but then appeared to return to normal operation in August 2009. This change in time response occurred during dusty conditions when the equipment was at WA5A. The change in response resulted in two multipoint calibrations in the field (Table 6.2-1).

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedances (Figure 6.2-3) occurred on 9/5/2008, 6/4/2009 and 8/4/2009. The failure on 9/5/2008 was associated with a change in calibration cylinder (from SGAL053 to FF27944). As previously discussed, it is believed that the certified concentration in SGAL053 was low, resulting a significant shift in the measured diluter concentration when the new cylinder began use. The failure on 6/4/2009 and 8/4/2009 were probably associated with variable response the instrument during the period of the shift in response time of the instrument.

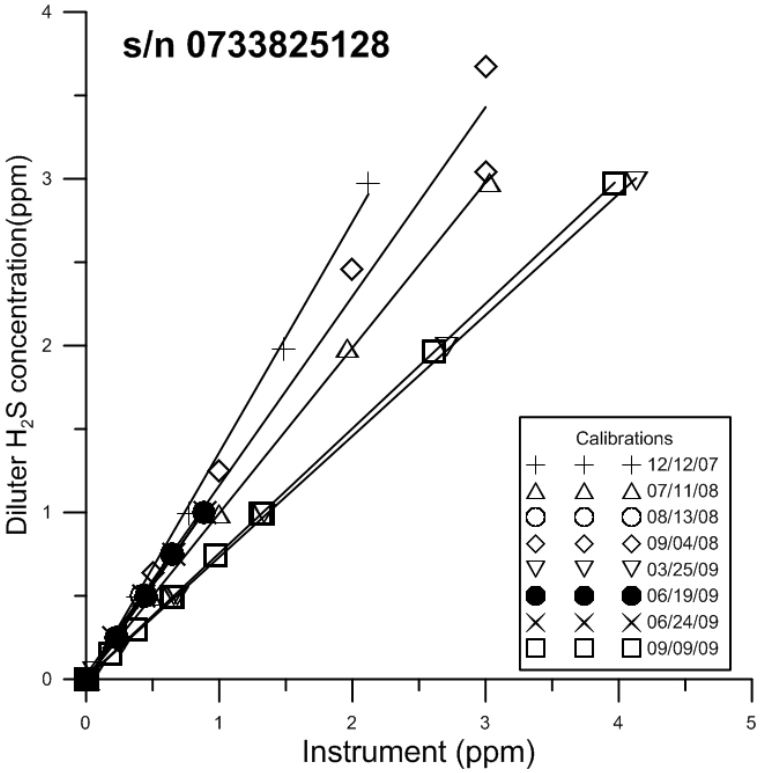


Figure 6.2-1: Multipoint calibrations of the 450i SO2/ H_2S Analyzer

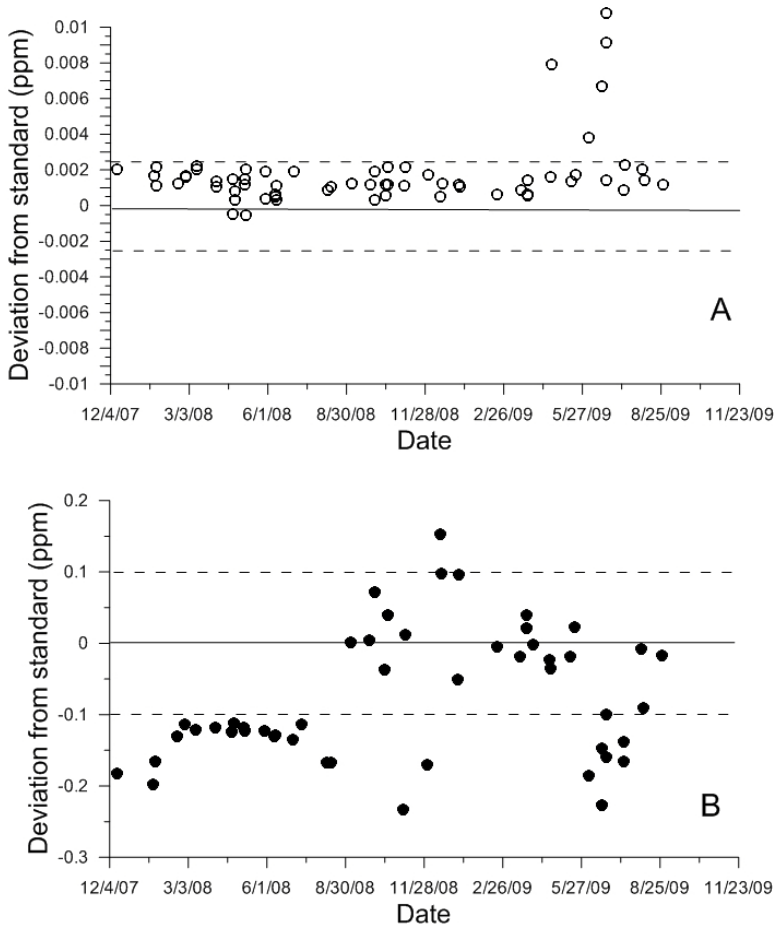


Figure 6.2-2: Instrument Control Charts.

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

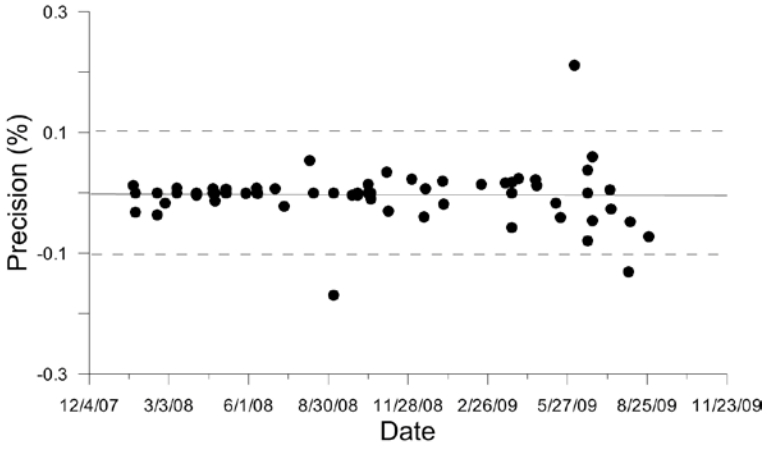


Figure 6.2-3: Instrument Precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

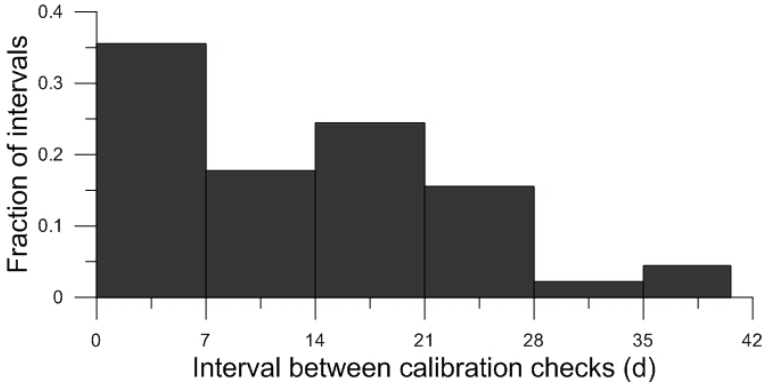


Figure 6.2-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Five sonic anemometers (Model 81000, RM Young Inc, Traverse City, MI) were used at this location: serial numbers 1927, 1920, 1921, 1932, and 1936.

The sonic anemometer 1927 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.3-1). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-1). The majority of calibration checks were made within 21 d (Figure 6.3-2). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check on all checks except 9/23-25/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back to use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-1: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (m s^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/8-12/2007	6/12-14/2007	-0.025	-0.043
1/21/2008	1/23/2008	-0.051	-0.033
7/16-17/2008	7/17-18/2008	+0.042	+0.029
3/23-25/2009	3/25-27/2009	-0.050	-0.028
9/1-2/2009	9/2-3/2009	-0.035	-0.023

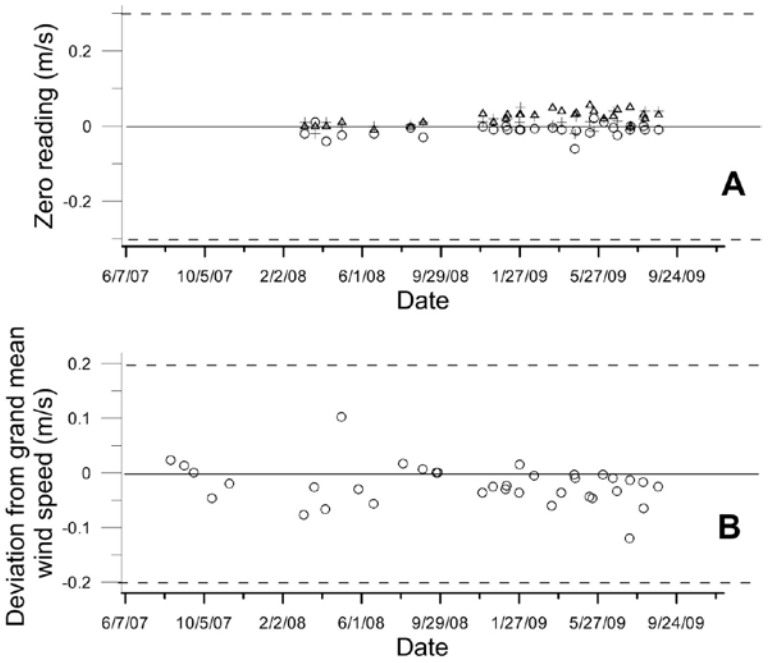


Figure 6.3-1: On-site quality assurance of sonic anemometer 1927. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

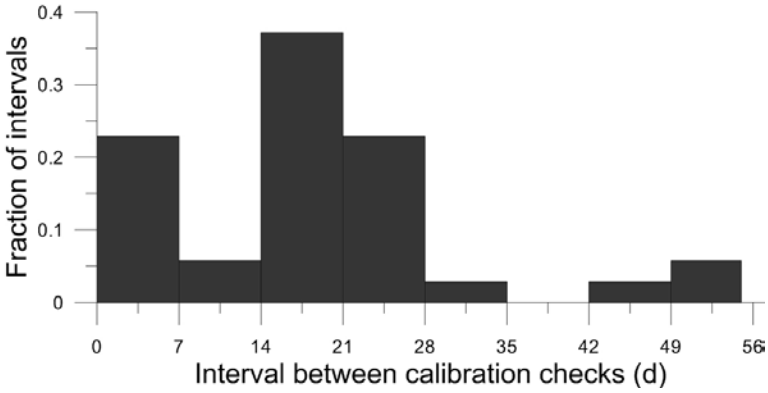


Figure 6.3-2: Inter-comparison check intervals for sonic anemometer 1927

The sonic anemometer 1920 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.2-2). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 51 times (Figure 6.3-3). The majority of calibration checks were made within 21 d (Figure 6.3-4). The large fraction of checks made within 7 d was

the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-3B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 10/10/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-3A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-2: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (m s^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/2007	6/29-7/2/2007	+0.001	+0.002
1/17-19/2008	1/20-21/2008	+0.045	+0.003
7/18-21/2008	7/21-22/2008	+0.017	-0.006
3/23-25/2009	3/25-27/2009	-0.036	-0.033
9/1-2/2009	9/2-3/2009	-0.046	-0.025

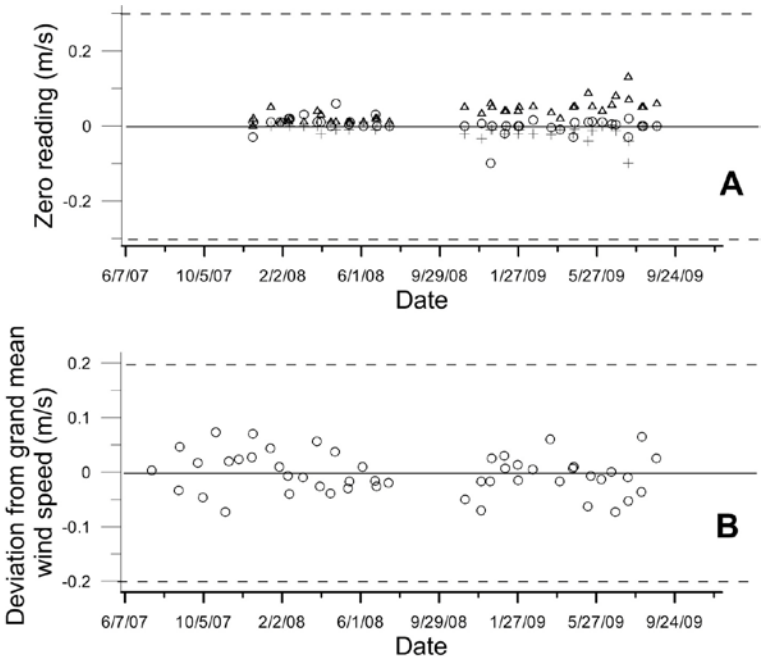


Figure 6.3-3: On-site quality assurance of sonic anemometer 1920. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

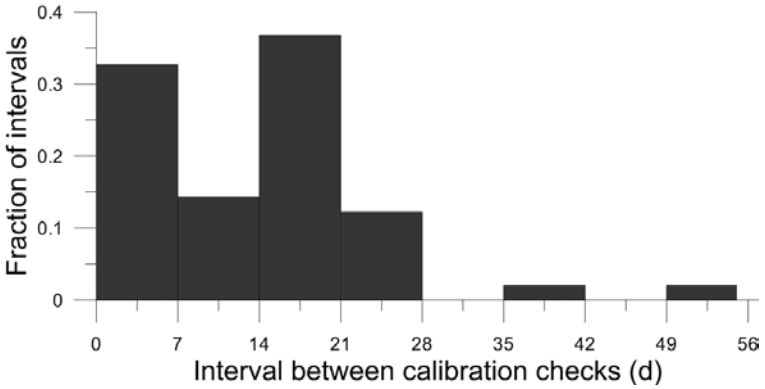


Figure 6.3-2: Inter-comparison check intervals for sonic anemometer 1920.

The sonic anemometer 1921 was inter-compared with three reference anemometers of identical design six times during the study (Table 6.3-3). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 43 times (Figure 6.3-5). The majority of calibration checks were made within 21 d (Figure 6.3-6). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-5B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 12/9/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-3: Standards inter-comparisons

Calibration date		**Mean difference from reference anemometers (m s^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.008	-0.003
12/27-28/2007	12/29-31/2007	-0.034	+0.001
7/10-11/2008	7/11-14/2008	+0.029	-0.022
3/23-25/2009	3/25-27/2009	-0.021	-0.040
9/8-14/2009	9/15-16/2009	+0.028	+0.038
12/18-19/2009	12/21-23/2009	+0.078	+0.002

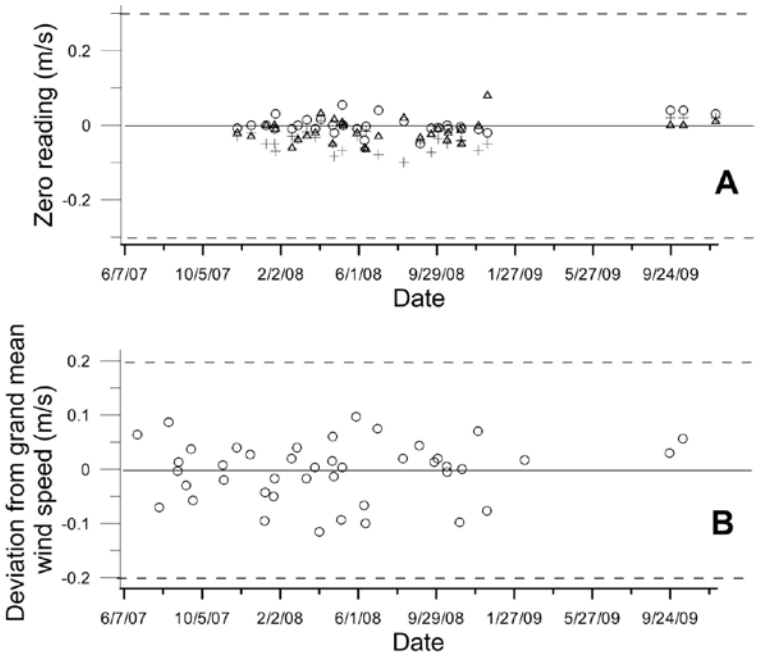


Figure 6.3-5: On-site quality assurance of sonic anemometer 1921. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

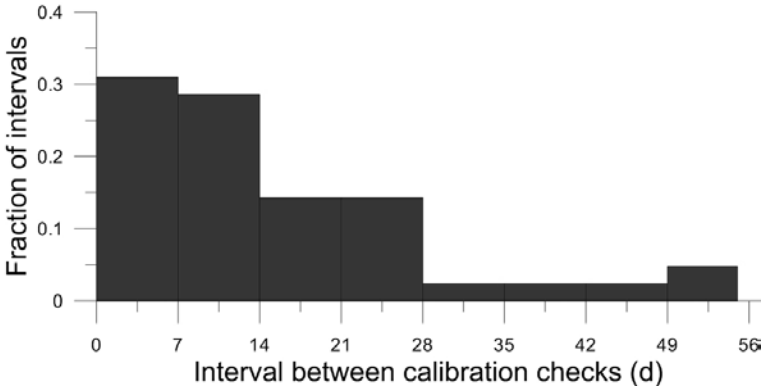


Figure 6.3-6: Inter-comparison check intervals for sonic anemometer 1921.

The sonic anemometer 1932 was inter-compared with three reference anemometers of identical design six times during the study (Table 6.3-4). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 55 times (Figure 6.3-7). The majority of calibration

checks were made within 21 d (Figure 6.3-8). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-7B). This instrument passed this check on all checks except 10/15-16/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back in use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-7B). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-4: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (m s^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-17/2007	6/18-19/2007	+0.004	+0.160
12/27-28/2007	12/29-31/2007	+0.014	-0.009
7/10-11/2008	7/11-14/2008	+0.008	+0.031
3/3-5/2009	3/5-6/2009	-0.024	-0.005
9/8-14/2009	9/15-16/2009	-0.025	-0.044
1/7-9/2010	1/23-24/2010	+0.020	-0.016

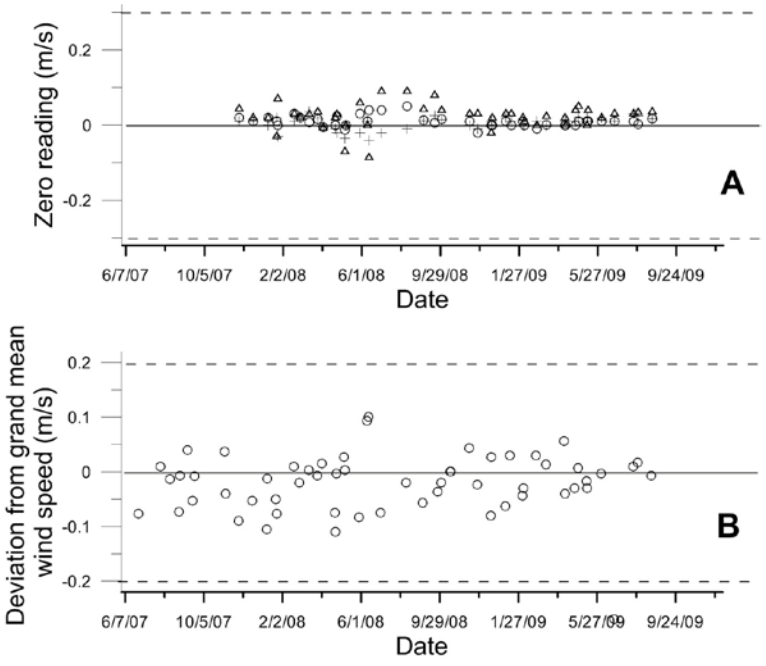


Figure 6.3-7: On-site quality assurance of sonic anemometer 1932. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

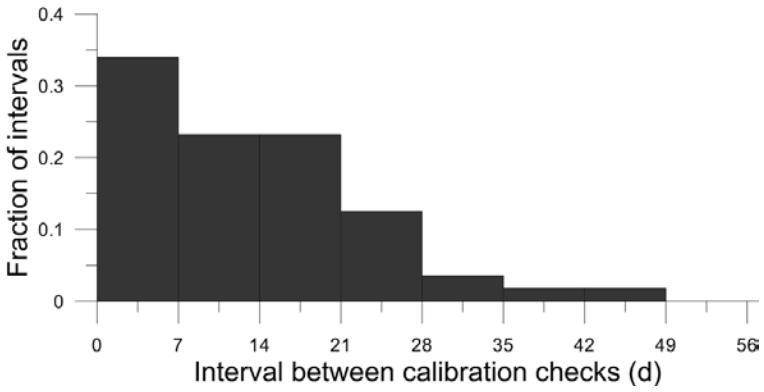


Figure 6.3-8: Inter-comparison check intervals for sonic anemometer 1932.

The sonic anemometer 1936 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.3-5). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 41 times (Figure 6.3-9). The majority of calibration checks were made within 21 d (Figure 6.3-10). The large fraction of checks made within 7 d was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 m s^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-9B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 m s^{-1} of zero (Figure 6.3-9A). Records of the zero checks made before 12/2007 were recorded as pass/fail- not indicating the actual measurements. The instrument always passed this DQI.

Table 6.3-5: Standards inter-comparisons

Calibration date		Mean difference from reference anemometers (m s^{-1})	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18/2007	6/18-19/2007	+0.011	-0.036
12/27-28/2007	12/29-31/2007	-0.022	-0.009
7/10-11/2008	7/11-14/2008	+0.021	-0.019
3/23-25/2009	3/25-27/2009	+0.018	+0.047
9/1-2/2009	9/2-3/2009	-0.029	-0.016

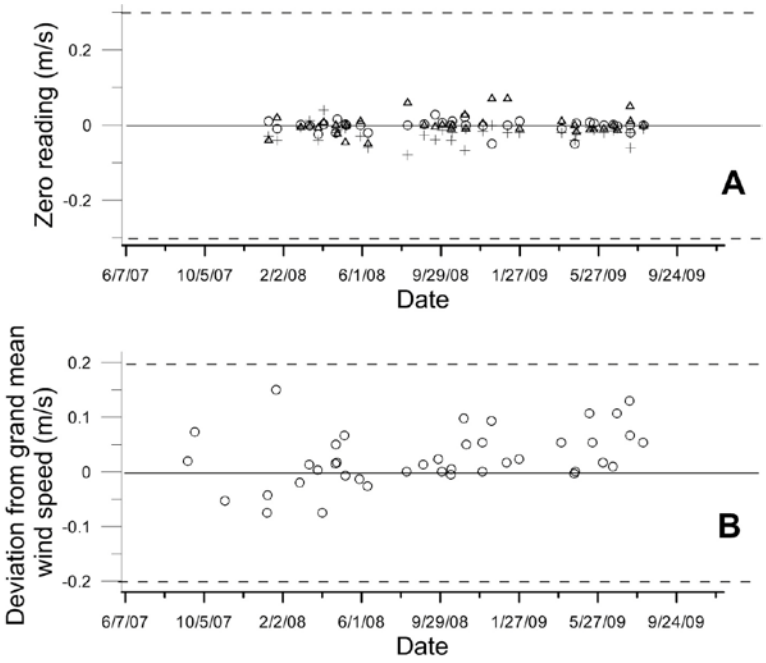


Figure 6.3-9: On-site quality assurance of sonic anemometer 1936. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

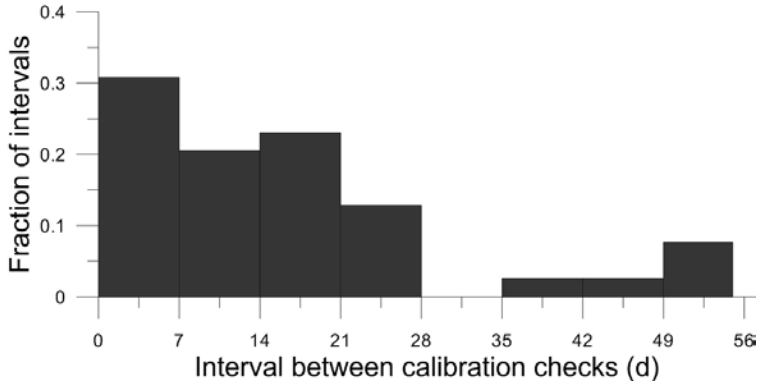


Figure 6.3-10: Inter-comparison check intervals for sonic anemometer 1936.

6.4 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n B and E) and the Gas Sampling System (GSS s/n 4-0017) were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results of the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 1. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Leaks in the GSS rarely occurred, however leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 9/3/2008, 10/2/2008, 12/6/2008, 5/14/2009, 8/4/2009, 10/29/2009 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on the subsequent visit.
- GSS leak check failure on 1/6/2009 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 1).

Table 6.6-1: Record of leak checks for GSS and GSS/S-OPS

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
3/13/2008	WA5A	2	0.08	-41.29	Pass	8	0.56	-41.19	Pass
		3	0.01	-41.46	Pass	10.1	0.43	-39.25	Pass
4/3/2008	TX5A	2	0.00	-37.94	Pass	9.3	0.46	-40.07	Pass
		3	-0.01	-40.41	Pass	9.7	0.34	-40.19	Pass
4/22/2008	TX5A	2	0.09	-31.84	Pass	9.2	0.50	-32.48	Pass
		3	0.04	-40.85	Pass	9.6	0.36	-39.59	Pass
4/24/2008	OK4A	2	0.07	-30.69	Pass	8.4	0.44	-31.03	Pass
		3	0.01	-28.52	Pass	9.7	0.63	-28.7	Pass
5/6/2008	OK4A	2	0.14	-24.42	Pass	8.5	0.65	-26.2	Pass
		3	0.17	-24.74	Fail	9.8	0.66	-23.07	Pass
5/8/2008	OK3A	2	-0.14	-32.28	Pass	9.7	0.11	-30.99	Pass
		3	-0.14	-31.16	Pass	9.2	0.51	-30.83	Pass
5/29/2008	OK3A	2	0.15	-30.98	Fail	9.8	0.31	-32.07	Pass
		3	0.27	-30.89	Fail	9.2	0.58	-32.37	Pass
6/10/2008	OK3A	2	0.07	-39.64	Pass	9.7	0.37	-38.89	Pass
		3	0.06	-40.66	Pass	N/A	N/A	N/A	N/A
6/11/2008	TX5A	2	0.19	-39.52	Fail	9.4	0.19	-38.31	Pass
		3	0.00	-38.5	Pass	9.5	0.77	-38.43	Pass
7/1/2008	TX5A	2	0.15	-31.62	Fail	9.3	0.28	-31.17	Pass
		3	0.15	-31.69	Fail	9.3	1.00	-32.02	Pass
8/10/2008	WA5A	2	0.09	-40.9	Pass	7.5	0.44	-40.5	Pass

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
		3	0.07	-40.35	Pass	10.5	0.75	-38.31	Pass
9/3/2008	WA5A	2	0.27	-32.88	Fail	8	6.86	-23.56	Fail
		3	0.30	-32.92	Fail	10.5	0.53	-34.62	Pass
9/3/2008	WA5A	2	0.20	-32.22	Fail	8	0.43	-32.51	Pass
		3	0.30	-32.36	Fail	10.5	0.52	-32.73	Pass
9/26/2008	WA5A	2	0.53	-38.99	Fail	8.1	0.33	-40.01	Pass
		3	0.19	-37.03	Fail	10.5	0.41	-39.44	Pass
10/2/2008	OK4A	2	0.23	-40.69	Fail	9.6	0.95	-0.43	Pass
		3	0.23	-39.56	Fail	8.6	0.87	-0.04	Fail
10/15/2008	OK4A	2	0.17	-41.03	Fail	9.8	0.32	-38.14	Pass
		3	0.18	-38.71	Fail	8.5	0.32	-38.9	Pass
10/16/2008	TX5A	2	0.20	-39.65	Fail	9.7	0.28	-39.72	Pass
		3	0.23	-40.98	Fail	9.5	0.59	-39.55	Pass
11/4/2008	TX5A	2	0.33	-41.59	Fail	9.4	0.31	-39.62	Pass
		3	0.32	-41.56	Fail	9.3	0.50	-40.62	Pass
11/6/2008	OK3A	2	0.33	-39.79	Fail	8.7	0.73	-42.34	Pass
		3	0.32	-38.77	Fail	9.3	0.47	-39.46	Pass
12/3/2008	OK3A	2	0.79	-40.32	Fail	8.4	0.65	-39.24	Pass
		3	0.83	-39.05	Fail	9.2	0.43	-40.53	Pass
12/16/2008	OK3A	2	0.72	-37.7	Fail	8.6	1.05	-40.13	Fail
		3	0.79	-36.81	Fail	9.5	0.91	-40.65	Pass
12/18/2008	TX5A	2	1.98	-38.41	Fail	9.4	0.92	-37.74	Pass
		3	2.09	-38.03	Fail	9.4	0.90	-37.46	Pass
1/6/2009	TX5A	2	0.12	-40.6	Pass	9.1	2.09	-37.63	Fail
		3	0.13	-40.35	Pass	8.9	2.12	-37.72	Fail
1/8/2009	OK4A	2	0.11	-38.95	Pass	9.8	0.41	-39.67	Pass
		3	0.11	-37.59	Pass	7.2	0.30	-41.91	Pass
1/27/2009	OK4A	2	0.09	-38.64	Pass	9.4	0.36	-40.34	Pass
		3	0.09	-38.15	Pass	8.3	0.20	-41.46	Pass
1/29/2009	TX5A	2	0.05	-37.73	Pass	9.8	0.37	-38.37	Pass
		3	0.17	-38.46	Fail	9.6	0.24	-37.24	Pass
2/19/2009	TX5A	2	0.19	-36.64	Fail	9.9	0.92	-39.35	Pass
		3	0.04	-36.77	Pass	9.7	0.64	-38.72	Pass
3/18/2009	TX5A	2	0.15	-38.19	Fail	9.3	0.65	-37.14	Pass
		3	0.07	-39.28	Pass	9.8	0.45	-37.54	Pass
4/21/2009	OK4A	2	0.15	0.06	Fail	10.2	0.55	-40.07	Pass
		3	0.01	-39.72	Pass	9	0.24	-37.98	Pass
4/22/2009	OK3A	2	0.14	-40.11	Pass	9.7	0.30	-38.44	Pass
		3	0.05	-38.69	Pass	8.8	0.77	-27.92	Pass
5/14/2009	OK3A	2	0.20	-39.22	Fail	9.7	0.26	-38.46	Pass
		3	0.09	-39.13	Pass	8.6	0.88	-38.07	Fail
5/21/2009	WA5A	2	0.17	-37.7	Fail	7.9	0.18	-39.69	Pass
		3	0.02	-39.6	Pass	10.5	0.96	-39.37	Pass
6/4/2009	WA5A	2	0.18	-40.86	Fail	8.6	0.24	-40.49	Pass
		3	0.04	-38.48	Pass	10.5	0.97	-38.07	Pass
6/19/2009	WA5A	2	0.33	-39.5	Fail	8.7	0.25	-38.74	Pass
		3	0.14	-39.6	Pass	10.5	0.95	-37.89	Pass
6/23/2009	OK4A	2	0.07	-39.89	Pass	9.7	0.37	-39.37	Pass
		3	0.04	-38.56	Pass	8.8	0.60	-40.96	Pass
7/14/2009	OK4A	2	0.25	-39.85	Fail	8.5	0.14	-40.79	Pass
		3	0.08	-38.49	Pass	9.7	0.13	-39.51	Pass
7/15/2009	OK3A	2	0.02	-38.14	Pass	8.7	0.63	-38.59	Pass
		3	0.04	-36.71	Pass	9.9	0.08	-39.75	Pass
8/4/2009	OK3A	2	0.06	-38.09	Pass	8.5	2.25	-37.22	Fail

Date	Site	GSS solenoid	GSS mass flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
		3	0.11	-34.41	Pass	9.7	0.09	-39.78	Pass
8/6/2009	TX5A	2	0.05	-38.3	Pass	9.8	0.75	-39.4	Pass
		3	0.00	-40.36	Pass	9.9	0.14	-38.93	Pass
8/27/2009	TX5A	2	0.02	-39.89	Pass	9.7	0.65	-37.52	Pass
		3	0.05	-40.26	Pass	9.5	0.11	-38.95	Pass
9/23/2009	NC3A	2	0.06	-40.15	Pass	10.1	0.34	-39.61	Pass
		3	0.07	-38.33	Pass	0	-0.60	-0.05	Pass
10/13/2009	NC3A	2	0.17	-39.38	Fail	9.6	0.41	-39.03	Pass
		3	0.04	-37.77	Pass	10	0.20	-41.33	Pass
10/27/2009	NC3A	2	0.08	-41.29	Pass	10	0.26	-39.3	Pass
		3	0.01	-41.46	Pass	9.3	1.45	0.11	Fail
10/27/2009	NC3A	2	0.00	-37.94	Pass	10	0.26	-39.3	Pass
		3	-0.01	-40.41	Pass	9.3	0.51	-40.26	Pass
11/11/2009	NC3A	2	0.04	-39.92	Pass	10	0.79	-40.71	Pass
		3	0.04	-39.74	Pass	9.6	0.27	-40.26	Pass

The inlet flow balance checks are summarized in sequence in Tables 2A and 2B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A: Record of flow balancing- Side 1 (s/n B)

			Delta inlet flow (Beginning-End) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	-0.20	-0.21	-0.06	-0.14	-0.20	-0.24	-0.21	-0.04	-0.20	-0.23	**Fail**
4/3/2008	4/22/2008	TX5A	-0.08	-0.07	-0.08	-0.09	-0.07	-0.09	-0.13	-0.09	-0.12	-0.14	**Pass**
4/24/2008	5/6/2008	OK4A	-0.02	-0.04	-0.01	-0.14	-0.02	-0.03	-0.09	-0.10	-0.07	-0.12	**Fail**
5/8/2008	5/29/2008	OK3A	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.03	0.01	0.04	**Pass**
5/29/2008	6/10/2008	OK3A	M	M	M	M	M	M	M	M	M	M	**M**
6/11/2008	7/1/2008	TX5A	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	**Pass**
7/1/2008	8/10/2008	TX5A	0.35	0.38	0.11	0.39	0.27	0.31	0.30	0.18	0.34	0.31	**Pass**
8/10/2008	9/3/2008	WA5A	0.00	-0.10	0.11	-0.20	0.00	0.00	-0.10	0.00	-0.10	0.00	**Fail**
9/3/2008	9/26/2008	WA5A	0.00	-0.10	-0.10	0.10	0.00	-0.20	-0.10	0.10	0.00	0.00	**Fail**
10/2/2008	10/15/2008	OK4A	0.02	-0.02	0.01	0.01	-0.03	0.06	0.06	0.05	0.04	0.02	**Fail**
10/16/2008	11/4/2008	TX5A	0.02	0.00	0.00	-0.01	-0.02	-0.05	-0.05	0.00	0.01	0.03	**Pass**
11/6/2008	12/3/2008	OK3A	0.03	0.00	0.00	0.01	-0.02	0.03	0.04	0.05	0.05	0.05	**Pass**
12/3/2008	12/16/2008	OK3A	-0.02	-0.01	-0.01	0.00	0.04	-0.06	0.04	-0.04	-0.03	-0.03	**Pass**
12/18/2008	1/6/2009	TX5A	-0.02	-0.06	-0.03	0.00	-0.04	-0.02	-0.02	0.00	0.01	-0.01	**Fail**
1/8/2009	1/27/2009	OK4A	-0.02	-0.04	-0.04	0.00	-0.05	-0.01	0.00	0.00	0.00	0.01	**Pass**
1/29/2009	02/19/2009	TX5A	-0.04	-0.02	0.00	0.06	0.00	-0.06	0.00	-0.02	-0.02	0.00	**Pass**
2/19/2009	3/18/2009	TX5A	0.01	-0.02	0.01	0.01	0.01	-0.02	0.00	0.00	0.00	-0.01	**Fail**
3/18/2009	4/2/2009	TX5A	0.06	0.06	0.05	0.06	0.04	0.08	0.06	0.10	0.05	0.11	**Pass**
4/02/2009	4/21/2009	OK4A	0.02	0.05	0.04	0.04	-0.03	0.01	0.02	0.01	-0.01	-0.01	**Pass**
4/22/2009	5/14/2009	OK4A	-0.03	-0.04	-0.02	-0.03	-0.02	-0.14	-0.02	-0.01	-0.02	-0.03	**Pass**
5/14/2009	5/21/2009	OK4A	0.23	0.24	0.27	0.28	0.17	0.28	0.23	0.26	0.17	0.29	**Pass**
5/21/2009	6/4/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
6/23/2009	7/14/2009	OK4A	0.00	-0.02	-0.03	-0.01	-0.04	0.01	0.01	0.00	-0.01	-0.04	**Pass**
7/15/2009	8/4/2009	OK3A	0.05	0.04	0.13	0.09	0.13	0.20	0.16	0.14	0.14	0.18	**Pass**
8/6/2009	8/27/2009	TX5A	0.05	0.05	0.01	0.00	0.01	0.03	0.02	0.03	0.06	0.04	**Pass**
8/27/2009	9/24/2009	TX5A	-0.10	-0.06	-0.05	-0.06	-0.08	-0.01	-0.04	-0.05	-0.14	-0.01	**Pass**
9/24/2009	10/13/2009	NC3A	0.00	-0.03	0.00	-0.05	-0.03	-0.08	87.39	-0.11	-0.12	0.06	**Pass**
10/13/2009	10/27/2009	NC3A	-0.02	-0.05	-0.04	-0.03	-0.04	-0.04	-0.03	-0.03	-0.05	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.00	-0.02	-0.01	-0.01	-0.01	0.00	-0.02	0.00	-0.04	0.02	**Pass**
11/11/2009	12/2/2009	NC3A	0.02	0.04	-0.11	-0.01	0.01	0.00	-0.03	-0.08	0.37	0.03	**Fail**

M: missing measurements.

Table 6.6-2B: Record of flow balancing- Side 2 (s/n E)

			Delta inlet flow (Beginning-End) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/13/2008	4/3/2008	WA5A	0.19	0.18	0.11	0.19	0.14	0.14	0.15	0.17	0.15	0.21	**Fail**
4/3/2008	4/22/2008	TX5A	-0.03	-0.03	0.01	-0.04	-0.09	-0.06	0.00	0.01	0.00	0.00	**Pass**
4/24/2008	5/6/2008	OK4A	0.00	0.00	0.00	-0.03	-0.02	-0.05	0.06	-0.01	-0.03	0.06	**Fail**
5/08/2008	5/29/2008	OK3A	0.02	0.01	0.04	0.00	0.05	0.02	0.01	0.04	0.02	0.02	**Pass**
5/29/2008	6/10/2008	OK3A	-0.01	-0.01	-0.02	0.00	0.00	-0.02	0.01	-0.04	-0.02	0.00	**Pass**
6/11/2008	7/1/2008	TX5A	0.01	0.00	0.00	0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.03	**Pass**
7/1/2008	7/29/2008	TX5A	-0.03	-0.09	0.00	-0.05	-0.03	-0.06	0.02	-0.03	-0.02	0.00	**Pass**
8/10/2008	9/3/2008	WA5A	0.05	0.14	0.09	0.10	0.16	0.14	0.12	0.15	0.18	0.15	**Pass**
9/3/2008	9/26/2008	WA5A	-0.04	-0.06	-0.02	-0.01	0.00	0.00	0.02	-0.04	0.02	0.00	**Pass**
10/2/2008	10/15/2008	OK4A	0.00	0.01	-0.02	0.00	-0.01	0.01	0.03	0.03	0.11	0.00	**Pass**
10/16/2008	11/4/2008	TX5A	-0.02	-0.05	-0.03	-0.04	0.00	0.00	-0.04	-0.04	-0.01	-0.02	**Pass**
11/6/2008	12/3/2008	OK3A	-0.01	0.01	0.00	-0.02	0.14	-0.07	0.01	0.02	0.02	0.02	**Fail**
12/3/2008	12/16/2008	OK3A	0.01	-0.02	-0.01	-0.02	-0.01	0.02	0.00	0.00	-0.02	-0.01	**Pass**
12/18/2008	1/6/2009	TX5A	-0.03	-0.08	-0.05	-0.05	-0.06	-0.05	-0.06	-0.04	-0.07	-0.02	**Pass**
1/8/2009	1/27/2009	OK4A	-0.04	-0.03	-0.03	-0.04	-0.04	-0.02	-0.03	-0.02	-0.02	-0.01	**Pass**
1/29/2009	2/19/2009	TX5A	0.00	-0.05	0.00	0.01	-0.02	-0.05	0.02	0.02	0.12	-0.01	**Pass**
2/19/2009	3/18/2009	TX5A	0.03	0.03	0.04	0.03	0.02	0.04	0.01	0.02	0.03	0.01	**Fail**
3/18/2009	4/2/2009	TX5A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.16	-0.14	-0.12	-0.15	-0.14	**Pass**
4/02/2009	4/21/2009	OK4A	0.00	0.05	0.05	0.04	0.04	0.07	0.05	0.03	0.01	0.02	**Pass**
4/22/2009	5/14/2009	OK3A	-0.06	0.00	0.00	-0.01	0.01	0.02	0.01	0.03	0.03	0.00	**Pass**
5/14/2009	5/21/2009	OK3A	-0.07	-0.11	-0.13	-0.11	-0.21	-0.10	-0.19	-0.16	-0.17	-0.18	**Pass**
5/21/2009	6/4/2009	WA5A	0.01	0.00	0.00	0.01	0.07	-0.03	0.05	0.02	0.00	0.00	**Pass**
6/4/2009	6/19/2009	WA5A	0.01	0.01	-0.04	-0.03	-0.03	-0.03	-0.02	-0.01	-0.02	0.00	**Pass**
6/23/2009	7/14/2009	OK3A	-0.02	-0.02	0.00	-0.02	-0.02	0.03	-0.03	-0.02	-0.02	0.01	**Pass**
7/15/2009	8/4/2009	OK3A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Pass**
8/4/2009	8/6/2009	OK3A	0.00	-0.01	0.01	0.01	-0.01	0.01	-0.01	0.02	0.01	0.00	**Pass**
8/6/2009	8/27/2009	TX5A	0.00	-0.03	-0.05	-0.04	-0.02	-0.02	-0.01	0.01	0.01	0.03	**Pass**
8/27/2009	9/23/2009	TX5A	0.05	0.05	0.08	0.11	0.22	0.22	0.21	0.25	0.22	0.21	**Fail**
9/24/2009	10/13/2009	NC3A	0.02	0.03	0.00	0.02	0.00	0.00	0.00	-0.03	0.00	0.16	**Fail**
10/13/2009	10/27/2009	NC3A	0.00	-0.01	0.12	-0.05	-0.02	-0.12	-0.04	-0.05	-0.06	0.00	**Pass**
10/27/2009	11/11/2009	NC3A	0.15	0.06	0.18	0.10	-0.05	0.25	0.25	0.05	0.21	-0.60	**Fail**

The nominal planned interval between S-OPS checks was 20 d (three weeks). S-OPS checks were conducted at this long-term measurement location a relatively few times with the period of time between checks varying from one to three weeks (Figure 1). Shorter intervals between checks occurred due to work on the systems.

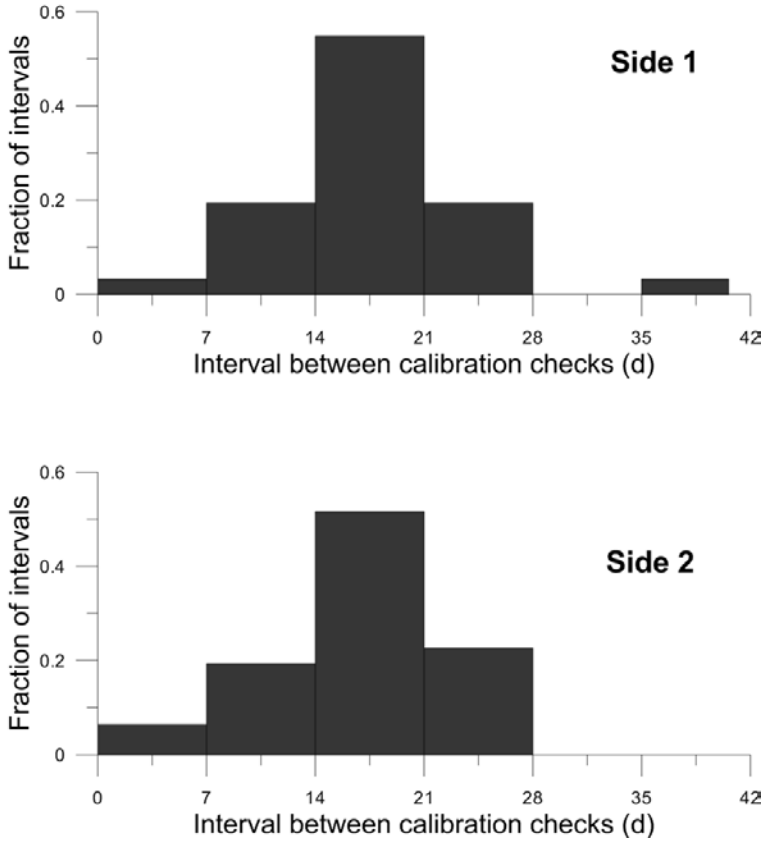


Figure 6.6-1: Intervals between checks

6.5 Miscellaneous meteorological and basin calibrations

6.5.1 Air temperature/humidity

A hygrothermometer (Model HMP45C, Vaisala Inc., Helsinki, Finland) measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n 4410015

Relative humidity (RH)					
Calibration date	**Expected RH (%)**	**Measured RH (%)**	**Deviation from expected RH (%)**	**Average deviation RH (%)**	**Action**
2/17/2010	21	18.8	2.2		
	50	48.2	1.9		
	98	94.3	3.7		
				2.6	Accept
9/18/2009	11	19.9	-8.9		
	50	50.4	-0.4		
	98	85.4	12.6		
				7.3	Adjust
	11	10.7	0.2		
	98	95.2	2.8		
	50	36.7	13.3		
	11	11.2	-0.2		
	50	42.1	7.9		
				4.9	Accept
3/26/2009	23	20.3	2.7	2.7	Accept
Temperature (T)					
Calibration date	**Expected T (°C)**	**Measured T (°C)**	**Deviation from expected T (°C)**		**Action**
2/17/2010	24.3	24.5	-0.2		Accept
9/18/2009	26.5	26.9	-0.4		Accept
3/26/2009	24.9	24.9	0.0		Accept

6.5.2 Barometric Pressure

An aneroid barometer (Model 278, Setra Inc, Boxborough, MA.) with serial number 3033740 was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278 s/n 3033740

Calibration Date	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
2/11-12/2010	998.6-992.5	5	1.5	Pass
9/16-17/2009	997.5-1000.1	6	0.9	Pass
3/24-25/2009	986.0-992.0	6	1.4	Pass
7/9-11/2008	993.1-996.8	6	1.5	Pass
1/3-4/2008	1018.4-1001.7	6	2.5	Pass

6.5.3 Solar radiation

The LiCOR was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-3.

Table 6.7-3: Calibration record of LiCOR 200SB Pyranometer, s/n PY554449

Calibration Date	Mean difference from reference	Mean deviation from standard (%)	Action
3/5/2010	4.84	0.91	Retry
3/6/2010	1.40	0.37	Pass
8/30/2006	—	—	Pass, Factory Calibration

6.5.4 CR1000 data logger

The CR1000 data logger was used to log all air temperature, relative humidity, barometric pressure, and wetness. Calibration checks of this unit were conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-4.

Table 6.7-4: Calibration record of Campbell Scientific CR1000 data logger, s/n 7888 (7677)

SE channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV	Error (mV)	Measured mV	Error (mV)
FACTORY CALIBRATION						
Calibration date: 1/18/2007			**Single-ended**		**Differential**	
13	5000	± 3	5000.48	0.096	5001.02	0.02
13	-5000	± 3	-5001.56	0.31	-5001.02	0.02
13	2500	± 1.5	—	—	2500.34	0.34
13	250	± 0.15	—	—	250.042	0.042
13	25	± 0.015	—	—	25.004	0.004
13	7.5	± 0.0045	—	—	7.49724	0.00037
13	2.5	± 0.0015	—	—	2.49923	0.00062
13	-2.5	± 0.0015	—	—	-2.49906	0.00024
13	5000	± 6	4999.31	0.31	4998.64	1.6
13	5000	± 6	5000.58	0.58	5001.02	0.02
13	5000	± 6	—	—	—	—
13	5000	± 6	—	—	—	—
PAML CALIBRATIONS						
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
1	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
2	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
3	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
4	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
5	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
6	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
7	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
8	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
9	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
10	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
12	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
13	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
14	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
15	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
16	4950	± 0.19 | 0.06	4951.7	-1.7	—	—
Calibration date: 3/10/2010			**Single-ended**		**Differential**	
1	100	± 0.19 | 0.06	99.37	0.006	—	—

SE channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV	Error (mV)	Measured mV	Error (mV)
2	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
3	100	± 0.19 | 0.06	99.37	0.006	—	—
4	100	± 0.19 | 0.06	99.37	0.006	—	—
5	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
6	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
7	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
8	100	± 0.19 | 0.06	99.37	0.006	99.71	0.003
9	100	± 0.19 | 0.06	99.37	0.006	—	—
10	100	± 0.19 | 0.06	99.37	0.006	—	—
11	100	± 0.19 | 0.06	99.37	0.006	—	—
12	100	± 0.19 | 0.06	99.37	0.006	—	—
13	100	± 0.19 | 0.06	99.37	0.006	—	—
14	100	± 0.19 | 0.06	99.37	0.006	—	—
15	100	± 0.19 | 0.06	99.37	0.006	—	—
16	100	± 0.19 | 0.06	99.37	0.006	—	—
Calibration date: 3/10/2010			**Single-ended**		**Differential**	
1	0	± 0.19 | 0.06	0	0	—	—
2	0	± 0.19 | 0.06	0	0	0	0
3	0	± 0.19 | 0.06	0	0	—	—
4	0	± 0.19 | 0.06	0	0	—	—
5	0	± 0.19 | 0.06	0	0	0	0
6	0	± 0.19 | 0.06	0	0	0	0
7	0	± 0.19 | 0.06	0	0	0	0
8	0	± 0.19 | 0.06	0	0	0	0
9	0	± 0.19 | 0.06	0	0	—	—
10	0	± 0.19 | 0.06	0	0	—	—
11	0	± 0.19 | 0.06	0	0	—	—
12	0	± 0.19 | 0.06	0	0	—	—
13	0	± 0.19 | 0.06	0	0	—	—
14	0	± 0.19 | 0.06	0	0	—	—
15	0	± 0.19 | 0.06	0	0	—	—
16	0	± 0.19 | 0.06	0	0	—	—

6.5.5 CR800 data logger

The CR800 data logger was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration checks of this unit were conducted only at end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-5.

Table 6.7-5: Calibration record of Campbell Scientific CR800 data logger, s/n 3698

Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured mV**	**Error (%)**
1	0	± 0.19 | 0.06	99.2	0.01
2	0	± 0.19 | 0.06	99.2	0.01
3	0	± 0.19 | 0.06	99.2	0.01
4	0	± 0.19 | 0.06	99.2	0.01
5	0	± 0.19 | 0.06	99.2	0.01
6	0	± 0.19 | 0.06	99.2	0.01
Calibration date: 3/10/2010			**Single-ended**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured mV**	**Error (%)**
1	0	± 0.19 | 0.06	0	0
2	0	± 0.19 | 0.06	0	0
3	0	± 0.19 | 0.06	0	0
4	0	± 0.19 | 0.06	0	0
5	0	± 0.19 | 0.06	0	0
6	0	± 0.19 | 0.06	0	0

6.6 Site activity

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	2/25/2008	Setup	Leveled ground for trailer. Tied down trailer. Mounted antennas.
	2/25/2008	Setup	Mounted retro-reflectors on towers. Shopped for bolt for met tower, ground rods.
	2/26/2008	Setup	Stu started trenches (~0.25 east basin); Scott finished trenching, excluding across roads.
	2/26/2008	Setup	Wired towers and trailers. Pounded ground rod at trailer. Started pounding ground rod at southwest corner of west basin but sledgehammer broke.
	2/26/2008	Setup	Electrician showed up in afternoon and started laying wire.
	2/27/2008	Setup	Set up ground retro-reflectors and sonic anemometers on met tower for inter-comparison. Scanner tripod (southeast) with tripods.
	2/27/2008	Setup	Finished trenching. Electrician continued to lay wire and wire boxes; ran out of wire. It will be delivered tomorrow morning to finish electrical work.
	2/27/2008	Setup	Installed underground tubing for S-OPS lines to run under roads.
	2/27/2008	Setup	All ground rods pounded except for southeast tower; will use generator from electrician.
	2/27/2008	Setup	All towers finished wiring (to bottom outlet and plugs).
	2/27/2008	Setup	Pounded S-OPS posts and installed inlets with tubing. Used 1000 ft along west side. Connected with plastic union.
	2/27/2008	Setup	Taped underground tubing pipe around tubing to minimize dirt entering pipes.
	2/28/2008	Setup	Power hooked up to trailer in the afternoon.
	2/28/2008	Setup	Motherboard for H_2S analyzer switched out with new motherboard. Display light comes on, but no characters are shown on display. Put back old motherboard (old motherboard currently in use). Noticed prong on new motherboard for display was bent.
	2/28/2008	Setup	Changed plastic union on west side tubing with metal union.
	2/28/2008	Setup	Cut tubing near trailer so tubing can permanently stay in underground pipe under road (near trailer (two tubes are hard to pass through tubing)). Metal connectors on both ends.
	2/28/2008	Setup	UPS at northwest corner dead; plugged scanner directly into alignment and will charge UPS overnight.
	2/28/2008	Setup	Aligned TDLAS at southeast corner using power from generator.
	2/28/2008	Setup	Scanner at northwest corner did not originally start up; unplugged scanner from power supply; jiggled cords, plugged back in; scanner initiated and TDLAS turned on.
	2/28/2008	Setup	Forgot to check pressures from gas cylinders.
	2/28/2008	Setup	H_2S calibration was closer to 0.5 ppm than baseline done in lab.
	2/28/2008	Setup	GSS acceptance
	2/28/2008	Setup	S-OPS acceptance
20:05-21:05	2/28/2008	Setup	Sonic anemometer inter-comparison: Sensor 1: 1.68 Sensor 2: 1.74 Sensor 3: 1.74
20:44-20:49	2/28/2008	Setup	Calibrated TDLAS 1026: Mean: 24.1 SD: 0.97 RSD: 4.0% Bias: -3.5%

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
21:16-21:21	2/28/2008	Setup	Calibrated TDLAS 1032: Mean: 24.8 SD: 0.41 RSD: 1.77% Bias: -0.6%
21:48	2/28/2008	Setup	Zero sonic anemometer calibration. All pass.
23:25	2/28/2008	Setup	450i Calibration Verification Check
23:40	2/28/2008	Setup	450i Reference Precision Check
23:50	2/28/2008	Setup	450i Calibration Verification Check
	2/29/2008	Setup	Aligned both TDLAS units. Scanner 1 is TDL 1032, 1-5 on west side, 6-10 on north side. Scanner 2 is 1026, 1-5 on south side, 6-10 on east side.
	2/29/2008	Setup	Checked power, logging of CR800, CR1000, H_2S, and TDLAS 1 and 2.
	2/29/2008	Setup	Started met, sonic anemometers, TDLAS/scanners, and H_2S.
	2/29/2008	Setup	Measured coordinated of S-OPS.
	3/4/2008	Remote	Met tower, sonic anemometer 1 (on met tower), and TDL/scanner 1032 do not have power.
	3/6/2008	Remote	Check if power has been corrected.
21:42	3/12/2008	Calibration	450i Reference Precision Check
	3/13/2008	Calibration	S-OPS Inlet Flow Verification (south): Fail
	3/13/2008	Calibration	S-OPS Inlet Flow Verification (north): Fail
	3/13/2008	Calibration	GSS Max Flow Test conducted (solenoids 2 and 3)
	3/13/2008	Calibration	GSS No Flow Test conducted (solenoids 2 and 3)
	3/13/2008	Calibration	S-OPS Max Flow Test conducted (solenoids 2 and 3)
	3/13/2008	Calibration	S-OPS/GSS Leak Test: Pass (solenoids 2 and 3)
15:05-16:05	3/13/2008	Calibration	Sonic anemometer inter-comparison. All pass
16:23	3/13/2008	Calibration	Zero sonic calibration. All pass.
	3/17/2008	Remote	Check status.
14:55	3/20/2008	Remote	Daily Status Check from PAML Notes: No H_2S analyzer in west trailer. No communications with CR1000
13:55	3/21/2008	Remote	Daily Status Checks from PAML Notes: CR1000 not communicating with trailer. No H_2s analyzer present. No Innova present.
13:15	3/24/2008	Remote	Daily Status Check from PAML Notes: No H_2S analyzer; no Innova. Keep eye on TDL 1 calibration worksheet "Centerline Duty Cycle"; seems to increase (not drastically). Limited communication with CR 1000; no data available for viewing. "Append Filename to Logged Lived" was checked in Log File Operations (TDL 1). Unchecked box and renamed new log file to "TDL1_WA5A_YYY_MM_HHMMSS.gvl" Will go back and change filenames currently named "TDL1_WA5A_ ____.gvl" to correct format. Need to change strings in filename to correct format.
15:30	3/25/2008	Remote	Daily Status Check from PAML - Notes: H_2S analyzer out for repair. Filenames for TDLAS 2 were corrected yesterday. Backup monitor not enough space to perform backup.
	3/26/2008	Takedown	Strong odor at basin
	3/26/2008	Takedown	Inlet pumping.
	3/26/2008	Takedown	TDLASs aligned upon arrival.
	3/26/2008	Takedown	No H_2S analyzer to calibrate. GSS has not been running; no acceptance performed.
	3/26/2008	Takedown	Evidence of power failure on 3/24/2008 (at 14:52:26, UPS

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			switched to battery power). At 17:52:30, AC restored message sent to registered clients to Load Segment 2.
17:25-17:30	3/26/2008	Takedown	Calibrated TDLAS 1032: Mean: 46.3 SD: 1.07 RSD: 2.3% Bias: -7.4%
17:35-18:35	3/26/2008	Takedown	Sonic inter-comparison: Sensor 1: 5.03 Sensor 2: 5.04 Sensor 3: 5.03 Action: pass
17:59-18:04	3/26/2008	Takedown	Calibrated TDLAS 1026: Mean: 47.7 SD: 1.36 RSD: 2.8% Bias: -4.3%
19:15	3/26/2008	Takedown	Barometer audit: pass.
19:36	3/26/2008	Takedown	Zero sonic calibration. All pass.
00:17	3/27/2008	Takedown	Wetness sensor calibration: accepted.
	8/8/2008	Setup	Setup and level trailer; hooked up power to trailers.
	8/8/2008	Setup	Setup ground retro-reflectors and TDLAS/scanner units.
20:43	8/8/2008	Setup	Calibrated TDLAS 1028 Mean: 48.94 SD: 0.18 RSD: 0.4% Bias: -9.8%
21:39	8/8/2008	Setup	Calibrated TDLAS 1027 Mean: 51.50 SD: 0.08 RSD: 0.2% Bias: -5.7%
	8/9/2008	Setup	Center power circuit between basins will not work. Tried many different fixes but could not get it to work. Also, southeast circuit was not working since an outlet was run over and crushed. Replaced outlet and it is now working.
	8/9/2008	Setup	Tried to aim southeast scanner. Had to re-aim it three times to get it to hold paths. When running *GasView MP* program, scanner worked only for a short time before losing paths again.
	8/9/2008	Setup	Found broken connected on scanner in northwest corner (s/n: 1205). Must have broken during shipping back from Directed Perception.
19:40-20:40	8/9/2008	Setup	Sonic inter-comparison. All pass
21:31	8/9/2008	Setup	Zero sonic calibration. All pass.
21:29	8/9/2008	Setup	Barometer audit: pass.
21:31	8/9/2008	Setup	Wetness sensor calibration: accepted.
	8/10/2008	Setup	Used extension cord run from northwest tower to power the northwest scanner. Moved met station to beside the south tower and plugged into the tower power. Found a cut in the wire on center circuit. Will try to splice together tomorrow.
	8/10/2008	Setup	When northwest scanner was powered up, it made a really bad grinding noise while moving on the pan axis. Tried to aim it many times, but it would not hold paths. Tried to send new command string to scanners, but they would not accept it. Scanners would read "initializing pan/tilt unit, but then they would just freeze up that way. When we tried to move the scanner it would just shake and not go anywhere.
	8/10/2008	Setup	Everything is now working on the site except for the TDLAS/scanners.
	8/10/2008	Setup	S-OPS balance: North
	8/10/2008	Setup	S-OPS balance: South
	8/11/2008	Setup	Worked on scanners to try and get them working properly, but had not success. Communicated with Boreal Laser, and they will talk to Directed Perception to try to solve the problem. Old scanners to be shipped overnight to get here Wed morning.

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	8/11/2008	Setup	Performed SO_2 calibration on TEC 450i.
	8/13/2008	Setup	Maintenance list completed
	8/14/2008	Setup	Innova single point calibration.
	8/15/2008	Remote	Fixed minor issues in computer setup. In *rsync* program, the GSS files were not being shipped…corrected. In data logger, the Table 1 data were set to collect "Most Recently Logged Records." Should be "Data Logged Since Last Collection." Major issues collecting data from CR1000. Added "WA5A" to beginning of all 450i filenames.
14:00	8/15/2008	Remote	Daily Status Check from PAML Notes: Every other data point is missing in CR1000 data due to incorrect setting in *Loggernet*. Gap in data from 592.1 to 593.03. Innova flag 16. Reference cell quatily stuck at 10,000; reference r^2 often below 99.
13:38	8/18/2008	Remote	Daily Status Check from PAML Notes: Sonic error happened on 8/15/2008 at 21:37. Very irregular time stamp in data led to problem. See 100 and 300 s data for this time. Restarted program at 12:00. Sonic program stopped again at 14:26 (runtime error 9); restarted program at 14:40 today. Flag 16 in Innova data. Cannot connect to CR 1000.
12:43	8/19/2008	Remote	Daily Status Check from PAML Notes: Lost connection to both TDLAS 1 and 2 laptops (must have performed an automatic windows update). Computers restarted themselves, and all paths were still on. Checked time on TDL 1 just before shutdown, and the clocks were within 10 s; after restart time was off by almost 4 min. About 2 min later the clocks on the TDLAS laptops updated, and both clocks were very close to LAN time. Later, the laptops kept losing time compared to the LAN. Not sure if it is because of a slow internet connection. When the TDLAS screen is minimized and reopened, the time is up to date. Must be due to slow connection. The sonic program stopped again at 19:39 UTC. I restarted the program right away. Innova flag 16. Cannot connect to CR 1000.
13:09	8/20/2008	Remote	Daily Status Check from PAML Notes: H_2S file is updating fine, but does not show connection on *iPort*. Innova flag 16. Cannot connect to CR 1000.
13:50	8/21/2008	Remote	Daily Status Check from PAML Notes: Stopped sonic and Innova program. Still unable to see H_2S screen although data still updating. Found second *iPort* window in the process and shut down. Restarted *iPort* and data file. Restarted sonic and Innova programs. Innova flag 16 (pump test failure). No CR 1000 data since day 593.
12:20	8/22/2008	Remote	Daily Status Check from PAML Notes: No communication with CR1000. Sonic 1 flagging from about 8/21 11:00 to 8/21 15:00.
12:42	8/25/2008	Remote	Daily Status Check from PAML Notes: TDLAS 1 has lost power. Will call the farm manager to reset the GFCI on the southeast circuit. Cannot connect to the CR 1000. Innova flag 16.
12:50	8/26/2008	Remote	Daily Status Check from PAML Notes: TDLAS 1 still has no power. Re-aimed path 6 on TDLAS 2. Had to move TDLAS down 5 steps; later, moved TDLAS down 5 steps because the light level was maximized. Innova flag 16. Cannot connect to CR 1000.

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
14:21	8/27/2008	Remote	Daily Status Check from PAML Notes: No power to TDLAS 1. Were communicating with Hung Soo from the Engineering Group today to try to get the power working on TDLAS 1. An obstruction is blocking path 1 on TDLAS 2. Innova flag 16. Cannot connect to CR 1000.
12:11	8/28/2008	Remote	Daily Status Check from PAML Notes: On 8/27/2008, was able to get power working on TDLAS 1 with help from Hung Soo from the engineering NAEMS team. The H_2S file is missing data points sporadically. It works well for awhile and then misses points. Cannot connect to CR 1000.
12:48	8/29/2008	Remote	Daily Status Check from PAML Notes: i*Port* had stopped working at about 00:30 UTC on 8/29/2008. Had to stop the sonic and Innova programs in order to start the *iPort* back up again. Restarted the sonic and Innova programs. Made a fill data file for the H_2S for the time that the *iPort* was shut down. Very slow connection on TDLAS 1, and it is difficult to tell time synchronization. Innova flag 16. Cannot connect to CR 1000.
	9/2/2008	Calibration	Electronic data chain of custody form completed.
	9/3/2008	Calibration	S-OPS balance: North
	9/3/2008	Calibration	S-OPS balance: South
	9/3/2008	Calibration	Basin site layout made.
17:20-18:20	9/3/2008	Calibration	Sonic inter-comparison. All pass
19:13	9/3/2008	Calibration	Zero sonic calibration. All pass.
20:55 and 22:25	9/3-4/2008	Calibration	Calibrated TDLAS 1027 Mean: 41.32 SD: 0.35 RSD: 0.8% Bias: -8.6% Notes: During calibration, could not reach value greater than 43 ppm-m. Stopped TDLAS calibration--continued next day after diluter MFC calibration. Accidentally stepped in front of beam during calibration gas run; removed this part during calculations (~22:13).
	9/4/2008	Calibration	Performed TEC 450i, Zero MFC, and Gas MFC calibrations according to directions given from PAAQL--see scanned documents
	9/4/2008	Calibration	Restarted LAN and both Panasonics; updated software on all computers.
	9/4/2008	Calibration	Burned CD's/DVD's
	9/4/2008	Calibration	Current measuring basin (East side) is 100% crusted. Yesterday inlets in both basins were pumping but more pumping into west basin than west one. Today, no pumping into east basin. Switching to west basin, but continuing measurements on east basin.
	9/4/2008	Calibration	Strong H_2S odor upon arrival.
	9/4/2008	Calibration	Yesterday, TDLAS 1 was not running upon FOS arrival.
	9/4/2008	Calibration	CR 1000 still not connecting to LAN long enough to download data. Used laptop yesterday to download and transfer to LAN.
	9/4/2008	Calibration	Check GSS inlet filter solenoid 2 (north side) at takedown. Could be plugged due to open tubing at inlet 4 T. Still have sufficient flow but less it was at start of period. S-OPS max flow test (< 1 LPM).
	9/4/2008	Calibration	Orange light given when switching out CR 1000 memory card.
	9/4/2008	Calibration	Tied old and new NH_3 cylinders with TDLAS 1028--both

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			cylinders seemed low. 3% error on 400 ppm tank--120 ppm. 3% error on 500 ppm tank--15 ppm.
	9/4/2008	Calibration	Performed Innova multipoint calibration (800 ppm, 200, 100, and 10 with 800 ppm tank). Single point calibration with 10 ppm tank.
	9/4/2008	Calibration	H_2S reading high using new (29.6 ppm) tank (~0.635 ppm). Performed multipoint on H_2S.
	9/4/2008	Calibration	Innova calibration verification: CH_4 and NH_3; CH_4 15% high. Multipoint CH_4 800 ppm tank.
	9/4/2008	Calibration	H_2S calibration verification: high for 0.5 ppm. Multipoint calibration done.
	9/4/2008	Calibration	Retro heights and plastics determined and mapped.
	9/4/2008	Calibration	Maintenance list completed
16:34	9/4/2008	Calibration	Barometer audit: pass.
16:55	9/4/2008	Calibration	Wetness sensor calibration: accepted.
20:04-21:41	9/4/2008	Calibration	Calibrated TDLAS 1028 See calibration sheet for details. Notes: Tied in old/new tanks. 3% of 500 ppm (errors of tanks) ~15 ppm. 3% of 4000 ppm (used during multipoint for cal curves) ~120 ppm. Need to account for tank accuracies/errors.
22:30-00:34	9/4/2008	Calibration	Innova multipoint calibration.
14:00	9/5/2008	Remote	Daily Status Check from PAML Notes: Path 10 on TDLAS 2 has had low light levels on the past 2 scans. After a few min path 10 is back on. Perhaps an obstruction of some type? Flags in H_2S data from 614.09-614.17 (calibration). Innova flag 25; too early in period to tell. GSS Mass Flow 1 (blue) follows 2 from 613.42-613.80 (not switching during this time). Found that TDL 1 data were being saved to period 5. Logged onto TDL 1 PC and corrected. No communication with CR 1000.
13:00	9/8/2008	Remote	Daily Status Check from PAML Notes: H_2S analyzer lost communication with computer so values as of 615.4 were zero--will restart remotely. Had to stop sonic and Innova programs to restart H_2S program in *iPort*. Filled data starting at 9:15 UTC 9/6/2008. Restarted sonic and Innova programs. Sonic 3 had missing data due to flagging and spike counts over 160 overnight. Majority of spike counts was under 160. GSS solenoids not switching as of 615.8 (9/6/2008). No communication with CR 1000.
16:30	9/9/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 had afternoon flagging. Sonic 2 had spike counts over 160 points, but the majority was under 160. H_2S analyzer data had flag 1 because the program stopped due to communications. Innova flag 16 (pump failure). GSS mass flow was normal again at day 618.3. Limited communications with CR 1000.
12:05	9/10/2008	Remote	Daily Status Check from PAML Notes: Sonic 2 had some flagging but not much. Sonic 3 had flagging during the afternoon. Innova flag failure (pump failure). Limited communication with CR 1000.
13:00	9/11/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 had flagging and spike counts over 160 yesterday. Innova flag 16 (pump failure). Communication problems with CR 1000.
12:45	9/12/2008	Remote	Sonic 3 had flagging during the afternoon. No Innova

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			concentrations since day 620.9; program may have failed--will check when logged in remotely. Innova flag 16 (pump failure). Limited communication with CR 1000.
12:30	9/15/2008	Remote	Daily Status Check from PAML Notes: TDL 2 path 6 was not aligned--realigned. Originally (P6906, T283); after alignment (P6904, T284). GSS not switching sides as of yesterday at day 623.7, 12pm PDT; will continue to monitor throughout the day to see if will correct itself (corrected itself yesterday). If no correction, will contact Hung Soo to check GSS connections when he arrives at the site. Sonic anemometers 2 and 3 were flagging. Sonic anemometer 2 had random flagging while sonic 3 had flagging during daytime hours. Limited communications with CR 1000.
12:15	9/16/2008	Remote	Daily Status Check from PAML Notes: H_2S data updating but cannot locate iPort on taskbar; will restart sonic anemometers, Innova, and *iPort* to view *iPort* status. GSS switching back and forth between two paths/solenoids (corrected itself). Sonic 1 had flagging throughout the day yesterday; only 8 values as max. Sonic 3 is flagging everyday during daytime hours. Average w values minorly shift differently from zero for all sonic anemometers, but could be from terrain. Innova flag 16 (pump failure). GSS pressure and mass flow indicate solenoids are not switching. Limited communicated with CR 1000.
12:30	9/17/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 flagging during daytime hours. Innova flag 16 (pump failure). Solenoids no longer getting stuck on solenoid 2; now switching between both solenoids and getting stuck on both. Limited communication with CR 1000.
12:15	9/18/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 flagging during daytime hours. Innova flag 16 (pump failure). As of day 626.7, GSS pressure and flow collecting from correct path; still may switch sides/sounds; have history of doing so throughout measurement period. Limited communication with CR 1000.
12:10	9/19/2008	Remote	Daily Status Check from PAML Notes: Sonic 3 has flagging during daytime hours. As of yesterday's QC check, pressures and flow have been normal on GSS. Innova flag 16 (pump failure). CR 1000 has limited communication with LAN.
12:15	9/24/2008	Remote	Daily Status Check from PAML Notes: Internet very slow, and it keeps kicking me off. Were back on site in two days to check status. Poor CR 1000 communications. Sonic 3 is flagging during daytime hours. As of 632.8, "0" solenoid stuck on "1" on GSS. H_2S values are 0 as of 629.5. *iPort* probably closed; will start.
	9/26/2008	Takedown	Upon arrival, TDL 1 path 10 was not aligned.
	9/26/2008	Takedown	TEC 450i not running so created a "fill" file
	9/26/2008	Takedown	Tower retro-reflectors contained a lot of bird droppings on case and windows.
	9/26/2008	Takedown	northwest (TDL 2) TDLAS window was very dirty (have pictures).
	9/26/2008	Takedown	When performing S-OPS/GSS tests, noticed GSS stuck on solenoid 2 (north path). Moved wires around and working now (but connections are not loose).

Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
	9/26/2008	Takedown	Barometer getting high voltages but seems to be reading correctly in *Loggernet*.
	9/26/2008	Takedown	TDL did not "pass" during calibrations, but suspect diluter is not functioning properly, causing TDL's to be reading low.
	9/26/2008	Takedown	Ran NH_3 through diluter as well; concentrations from Innova reading low for NH_3 but passing for CH$ (straight from tank).
	9/26/2008	Takedown	Maintenance list completed
17:55-18:55	9/26/2008	Takedown	Sonic inter-comparison; all pass.
19:41	9/26/2008	Takedown	Zero sonic calibration. All pass.
20:02	9/26/2008	Takedown	Barometer audit: pass.
20:05	9/26/2008	Takedown	Wetness sensor calibration: accepted.
21:22	9/26/2008	Takedown	Calibrated TDLAS 1028
22:12	9/26/2008	Takedown	Calibrated TDLAS 1027
	9/26/2008	Setup	Started sonic anemometers and will let them run overnight for inter-comparison.
	5/19/2009	Setup	Checked outlets on east basin. All outlets have power except for tripped GFCI on northeast corner (will replace).
20:10-20:27	5/19/2009	Setup	Calibrated TDLAS 1029
20:37-20:53	5/19/2009	Setup	Calibrated TDLAS 1027
21:27-21:58	5/19/2009	Setup	TEC 450i single point calibration
21:45-22:45	5/19/2009	Setup	Sonic inter-comparison; all pass.
	5/20/2009	Setup	Replaced GFCI outlet on northwest corner tower.
	5/20/2009	Setup	Performed TDLAS inter-comparison on TDLs 1027 and 1029. Started at 22:20 UTC and ended on 18:30 UTC 5/21/2009.
17:43	5/20/2009	Setup	Zero sonic calibration. All pass.
17:48	5/20/2009	Setup	Barometer audit: pass.
17:50	5/20/2009	Setup	Wetness sensor calibration: accepted.
	5/21/2009	Setup	Called electricians because the outlets between the basins have low power including the TDL outlet.
	5/21/2009	Setup	TDLAS 1027 ran well overnight, but it froze up after power cycling before alignment. Called Boreal and did a system reset: Put business card under clip on internal battery; switched memory save jumper from "save" to "not save" position; let TDL sit for 30 min. Will take TDL 1027 back to PAML .
	5/21/2009	Setup	Met station location diagramed on Open Site Notes.
	5/21/2009	Setup	Basin site layout made.
	5/21/2009	Setup	S-OPS sensor installation report completed.
	5/21/2009	Setup	Maintenance list completed
20:40	5/21/2009	Setup	S-OPS/GSS calibrations performed.
	5/22/2009	Remote	Daily Status Check from PAML Notes: TDL 1 (1027) is not present. No connection to CR 1000. Last update was on 5/22 at 00:07 UTC; cannot download data. QC parameter files not completed, so no QC check available.
14:15	5/26/2009	Remote	Daily Status Check from PAML Notes: TDLAS QC program not running properly. TDL 2 had a missing path. Tried moving TDL every direction but could not align path. May be blocked by pump or vehicle.
13:15	5/27/2009	Remote	Daily Status Check from PAML Notes: Could not remotely connect in the morning but was successful in afternoon. Power

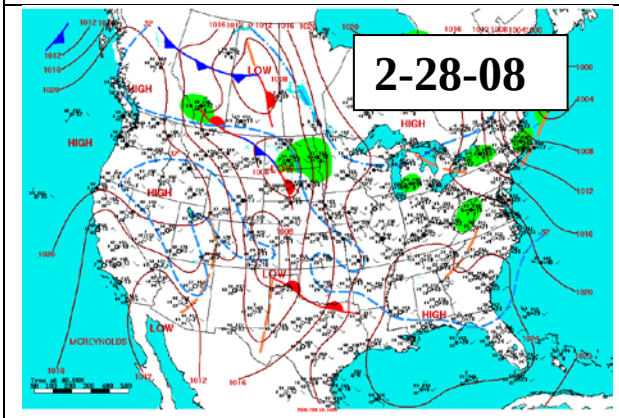
Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			failures at site from 1:25:32-6:04:42 UTC on 5/27/2009. Filled missing H_2S data. TDL laptops were without power for too long and shut down. Will contact technician to restart computer. Restarted sonic anemometers after connecting to *iPort*.
19:15	5/28/2009	Remote	Daily Status Check from PAML Notes: No QC files available today as the modeling computer was turned off. Cannot connect to TDL laptops.
13:00	5/29/2009	Remote	Daily Status Check from PAML Notes: Not enough space to perform backup. Deleted previous backups to make room for a new backup. TDL laptops lost power and need to be restarted.
12:30	6/1/2009	Remote	Daily Status Check from PAML Notes: TDL laptops lost power and need to be restarted. FOS were on site by 6/4/2009. Not enough space to perform backup. Deleted previous backups to make room for a new backup. *iPort* closed at 12:28 UTC on 6/1/2009; stopped sonic anemometers, filled missing data, and restarted sonic anemometers.
13:00	6/2/2009	Remote	Daily Status Check from PAML Notes: Not enough space to perform backup. Deleted previous backups to make room for a new backup. TDL laptops lost power and need to be restarted. FOS were on site by 6/4/2009. TDL 1 not present at site.
13:00	6/3/2009	Remote	Daily Status Check from PAML Notes: TDL laptops lost power and need to be restarted. TDL 1 not present at site.
	6/4/2009	Calibration	TDL laptop for TDLAS 2 was turned on (both TDL laptops were on) upon arrival. However, FOS were unable to connect to TDL 2 computer (M:) from LAN. Restarted all computers and now LAN can connect to both TDL laptops.
	6/4/2009	Calibration	Found basin levels were low (see pictures); looks like farm operators pumped out all the liquid.
	6/4/2009	Calibration	Pumping into "freshwater" basin east of measurement basin.
	6/4/2009	Calibration	New outlet on northwest corner of east basin (TDL 2 corner). Voltage with nothing plugged in was about 120 VAC. When scanner/TDLAS unit is plugged in, outlet voltage is about 44 VAC (scanner/TDLAS does not turn on). Plugged scanner/TDLAS unit back into extension cord for outlet on the north side of the west basin. Scanner/TDLAS system now has power and will turn on.
	6/4/2009	Calibration	Error message: "Not enough space to perform backups." Deleted previous backups to make room for new backups.
	6/4/2009	Calibration	Maintenance list completed
	6/4/2009	Calibration	Basin site layout made. Located with Open Site Notes for 6/4/2009.
19:10-20:09	6/4/2009	Calibration	Sonic inter-comparison; all pass.
19:18-19:43	6/4/2009	Calibration	Calibrated TDLAS 1029
19:30-22:35	6/4/2009	Calibration	S-OPS/GSS calibrations performed. Inlet balance sheet is attached to calibration form.
19:52-20:10	6/4/2009	Calibration	Calibrated TDLAS 1028
19:56	6/4/2009	Calibration	Barometer audit: pass.
19:59	6/4/2009	Calibration	Wetness sensor calibration: accepted.
20:20	6/4/2009	Calibration	Sonic zero/bias check; all pass.
22:04	6/4/2009	Calibration	TEC 450i calibration. Notes: Calibration gas test failed. Will wait

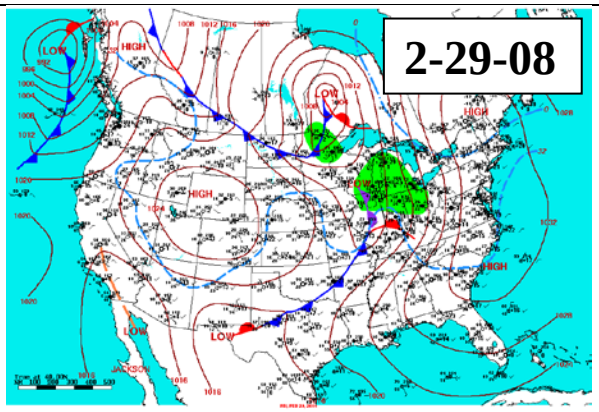
Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			until next visit, and if it fails again, a multipoint calibration were performed.
14:40	6/5/2009	Remote	Daily Status Check from PAML Notes: TDL 1 paths 1, 2, 3, 4, and 6 were off this morning. Unable to find paths 1-4; may be wet from storms last night. They face south and wind was from south. All 3 sonic anemometers have zeros in data starting at 6/5/2009 5:35 UTC. Will check out further remotely.
12:30	6/8/2009	Remote	Daily Status Check from PAML Notes: No power at tower or at weather station; currently there is no sonic data or CR 1000 data. Power was lost on Friday (6/5/2009) night. TDL 2 path 3 not aligned; could not manually align the path. Will let path optimize and check later. Not enough space to perform backup. Deleted previous backups to make room for a new backup.
12:45	6/9/2009	Remote	Daily Status Check from PAML Notes: *Loggernet* no connected to CR 800; restarted *Loggernet* and connected immediately to CR 800. Early in the day, experienced power trouble with sonic anemometers; no sonic anemometers were working. At 17:00 UTC sonic anemometers started working again. Found *iPort* error when started working too. Stopped sonic anemometers to fill missing data. Filled data starting at 15:42 UTC on 6/9/2009. Restarted real-time H_2S data and sonic anemometers. CR 1000 still not working.
12:15	6/10/2009	Remote	Daily Status Check from PAML Notes: Yesterday's GSS/H_2S/Innova QC run showed normal TEC 450i values--now graphs are before yesterday. Today's values are normal. TDL 2 CDC is currently ok, but it had temporarily dropped to 133. Not enough space to perform backup; deleted previous backups to make room for new ones. Technicians were on site today to see what is wrong with TDL 2 retro 3. TDL 2's paths were not aligned; moved about 10 steps left and about 40-50 steps down. Saved new setup.
14:45	6/11/2009	Remote	Daily Status Check from PAML Notes: H_2S chamber pressure increasing at the end of the data returned. CDC in TDL 1 experienced a brief drop a couple of days ago. Yesterday, the water removed from TDL 1 retro 3; this should increase the amount of time all ten paths are aligned. Re-aimed TDL 1 paths 3, 6, and 9; all paths are now aligned.
13:00	6/12/2009	Remote	Daily Status Check from PAML Notes: No basin probes present at site.
12:15	6/15/2009	Remote	Daily Status Check from PAML Notes: TDL 2 path 2 was not aimed; TDLAS QC check shows path 2 was not aligned today and was aligned 1.5% of the time yesterday.
13:15	6/16/2009	Remote	Daily Status Check from PAML Notes: Upon remote login found McShield.exe Application error.
12:00	6/17/2009	Remote	Daily Status Check from PAML
13:40	6/18/2009	Remote	Daily Status Check from PAML
13:07	6/19/2009	Remote	Daily Status Check from PAML
	6/19/2009	Takedown	Upon arrival, TDL 1 path 8 was not aligned.
	6/19/2009	Takedown	UPS activity: 5/27/2009 06:04:42: UPS output power has been restored to Load Segment 2. 6/14/2009 00:51:41: UPS switched to battery power. 00:51:45: AC Restored Message sent

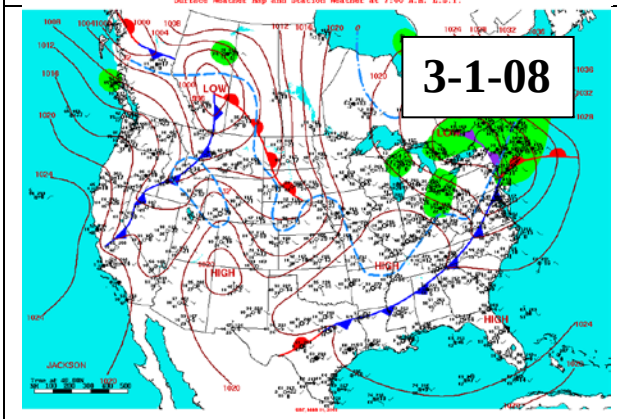
Time HH:MM (UTC)	Date (mm/dd/yyyy)	Activity (setup, takedown, calibration, repair, remote)	Event
			to registered clients connected to Load Segment 2.
	6/19/2009	Takedown	LAN computer message: "Not enough space to perform backup." Deleted previous backups to make room for new backups
	6/19/2009	Takedown	TEC 450i did not pass calibration; performed a new multipoint calibration for a new multipoint curve.
	6/19/2009	Takedown	Maintenance list completed
	6/19/2009	Takedown	S-OPS/GSS calibrations
17:43	6/19/2009	Takedown	Stopped H_2S data collection.
18:20-19:20	6/19/2009	Takedown	Sonic inter-comparison; all pass.
20:03	6/19/2009	Takedown	Zero sonic calibration. All pass.
20:05	6/19/2009	Takedown	Barometer audit: pass.
20:07	6/19/2009	Takedown	Wetness sensor calibration: accepted.
21:29	6/19/2009	Takedown	Performed TEC 450i Single point calibration Notes: Instrument failed calibration; will perform multipoint calibration.
21:43	6/19/2009	Takedown	TEC 450i multipoint calibration
23:16-23:31	6/19/2009	Takedown	Calibrated TDLAS 1029
23:42-23:58	6/19/2009	Takedown	Calibrated TDLAS 1028

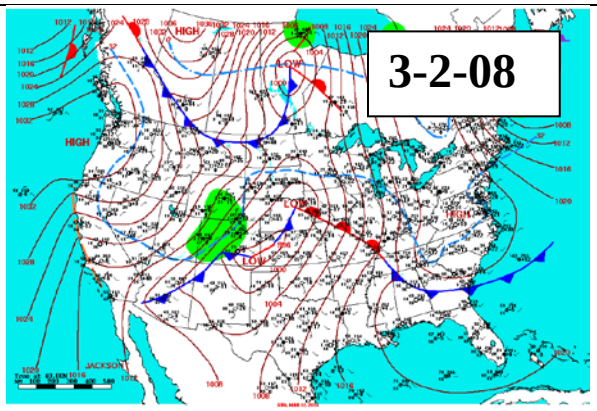
6.7 Site weather

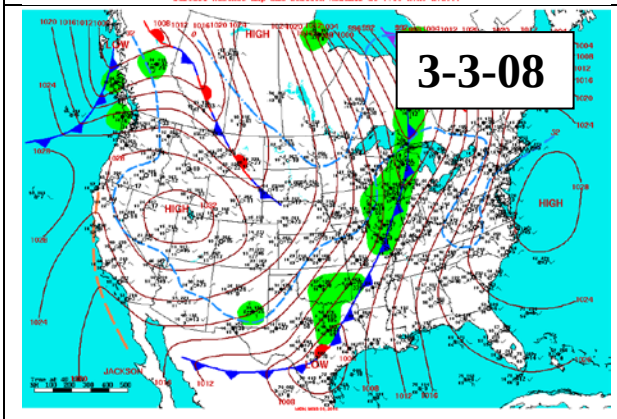
Period 3

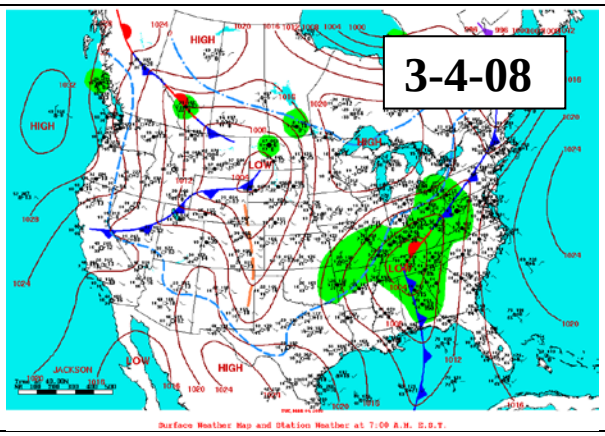


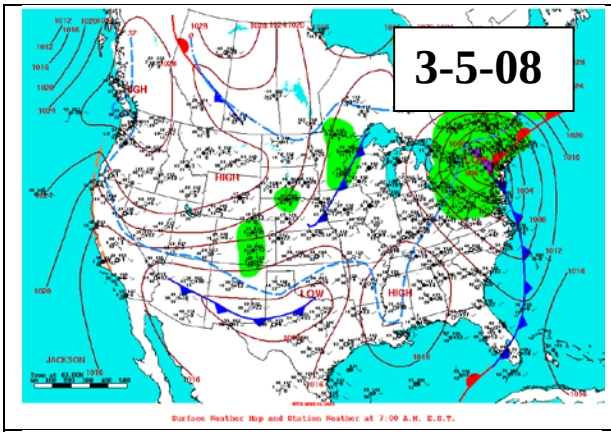


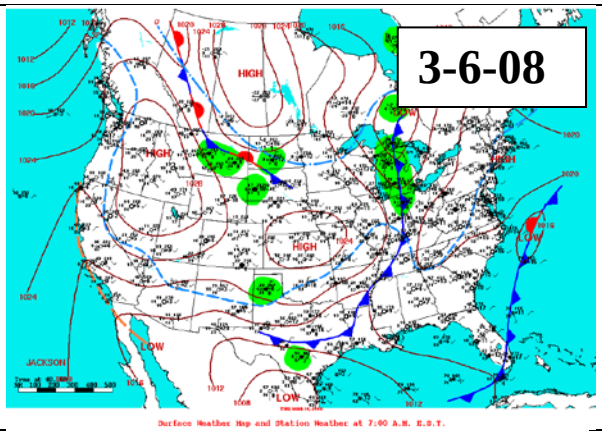


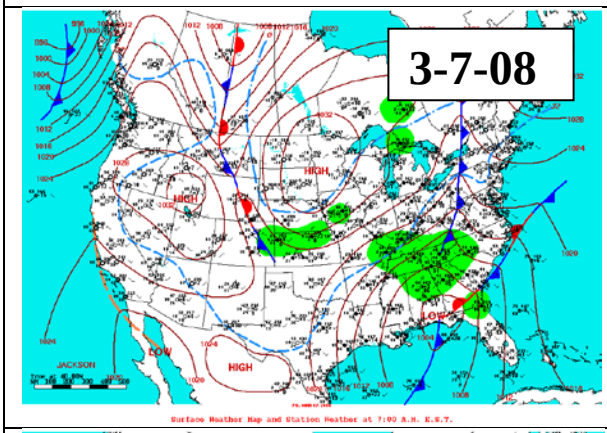


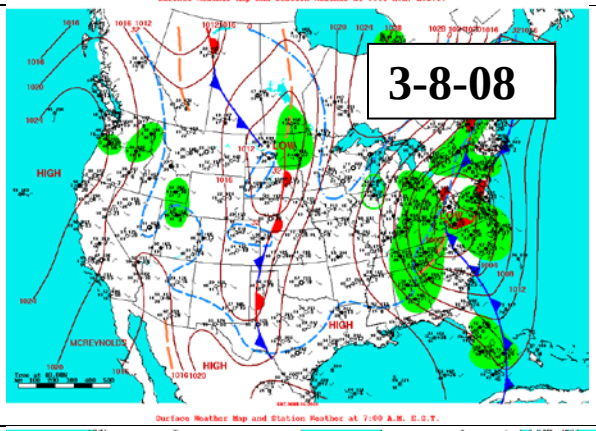


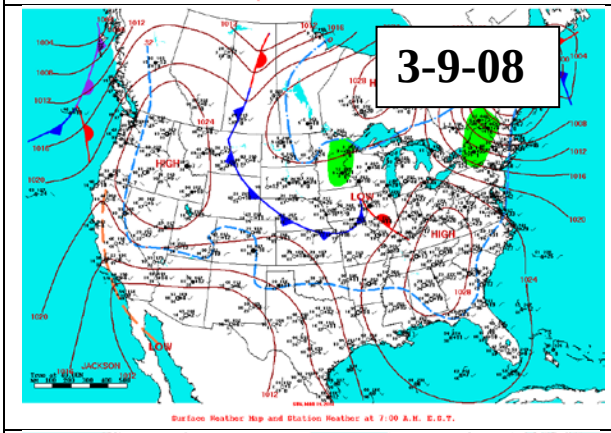


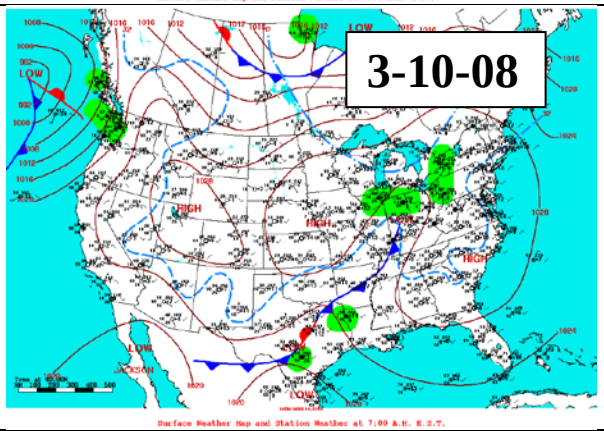


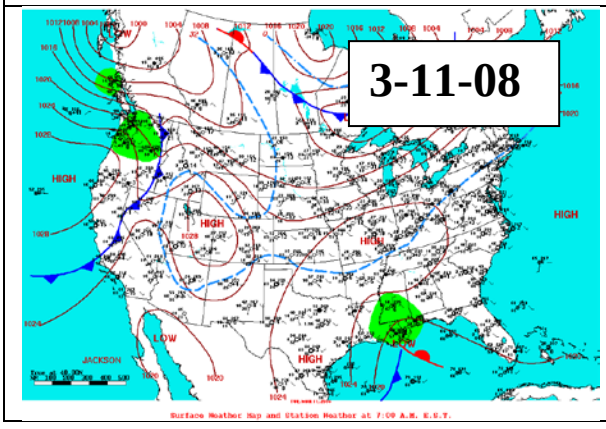




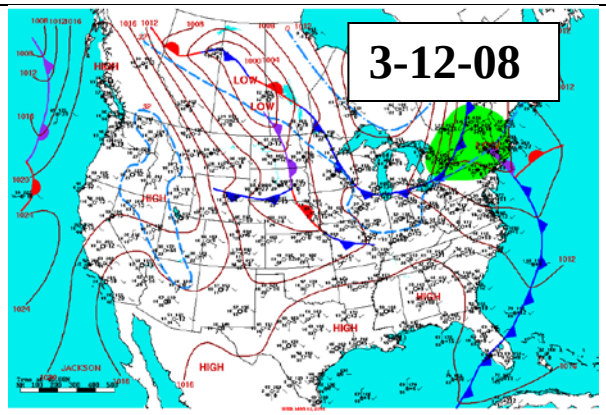








Period 4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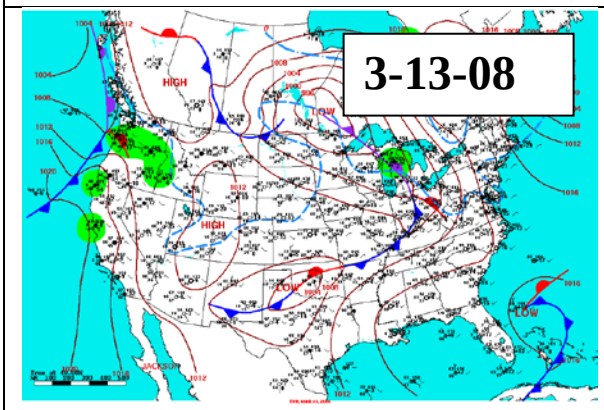
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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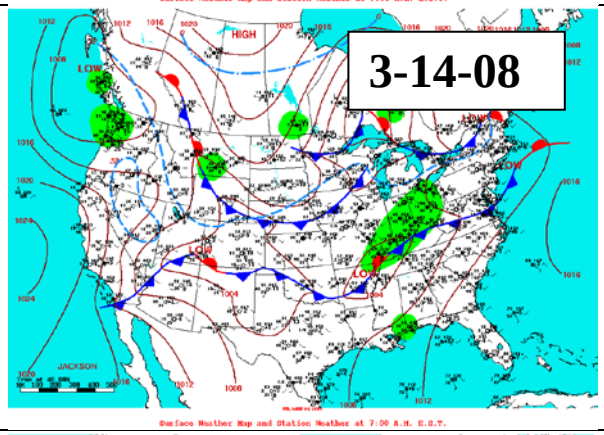
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JACKSON
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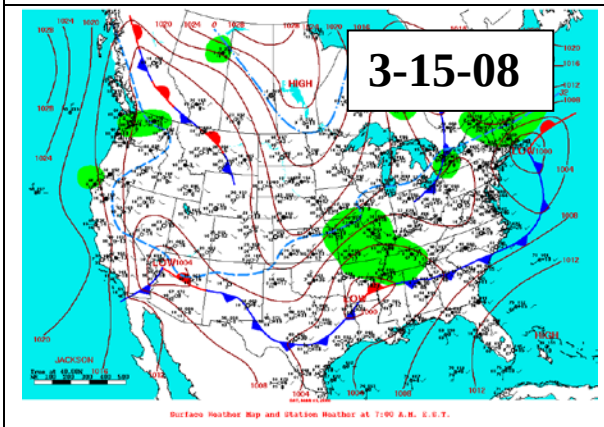
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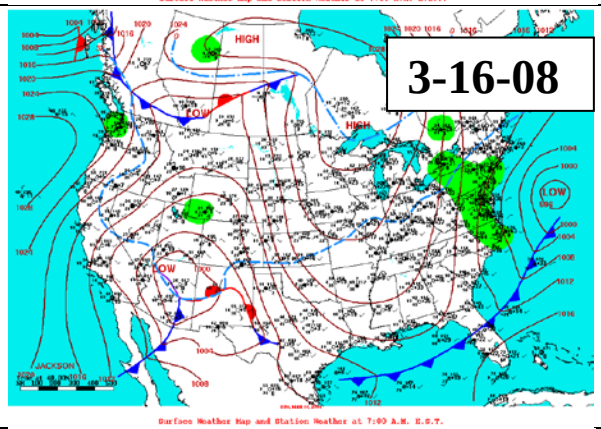
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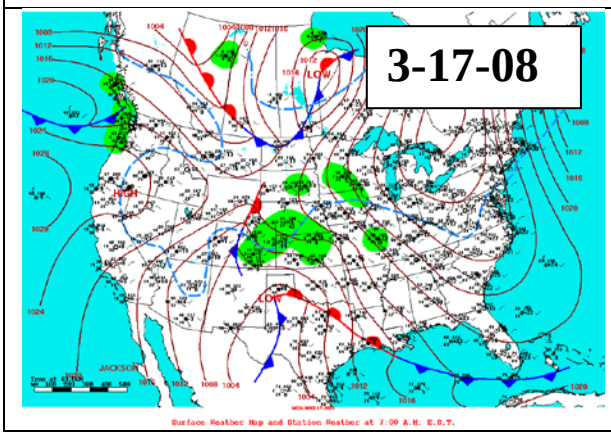
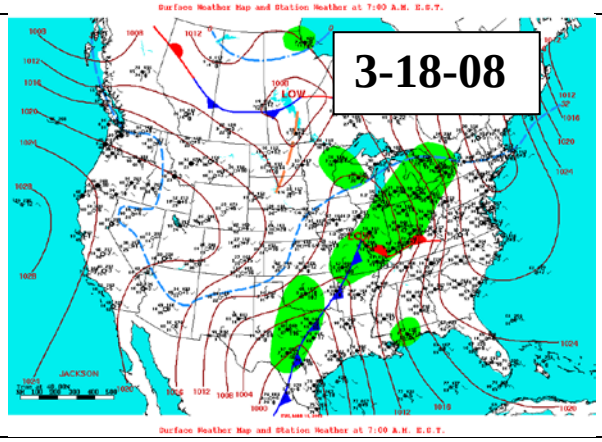
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


3-17-08
LOW
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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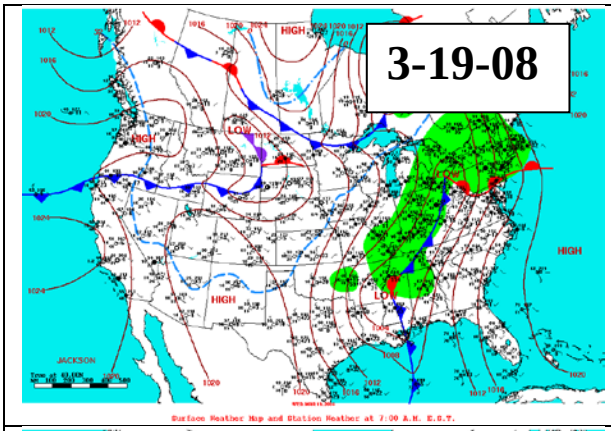
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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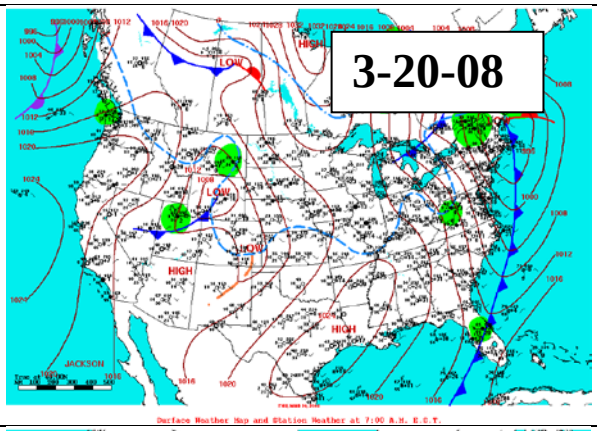
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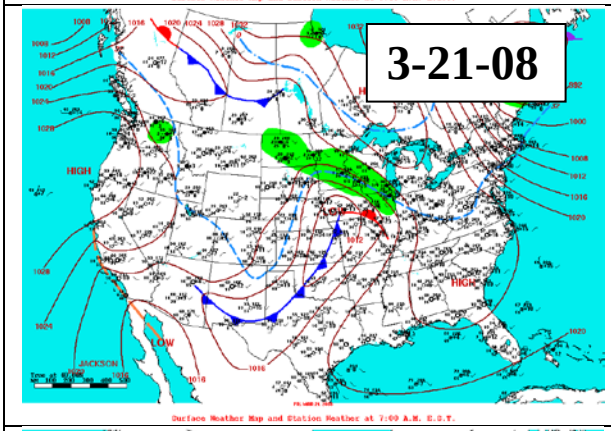
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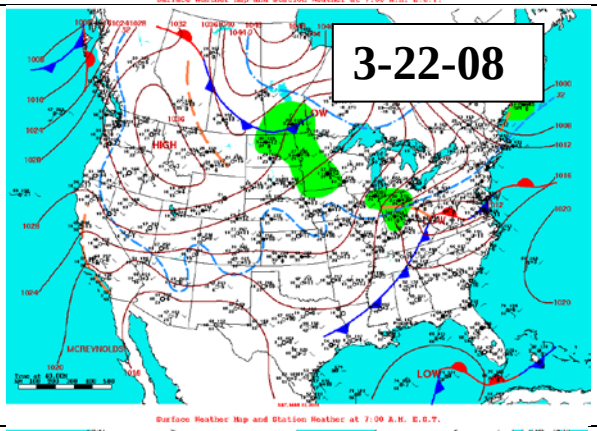
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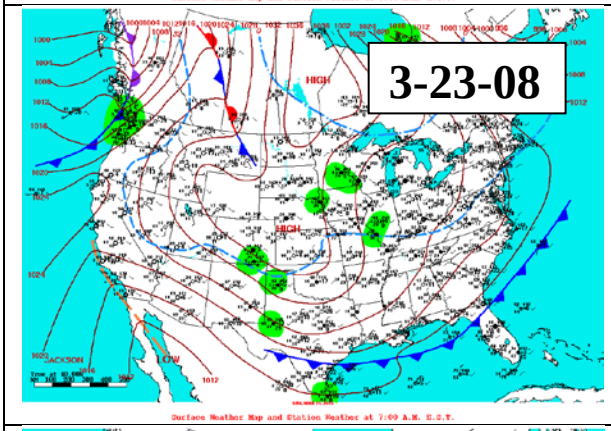
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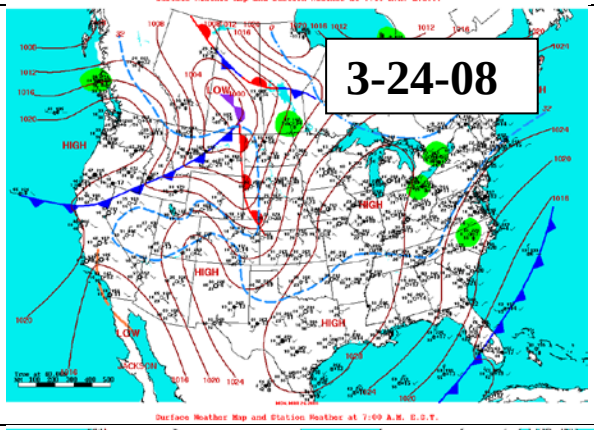
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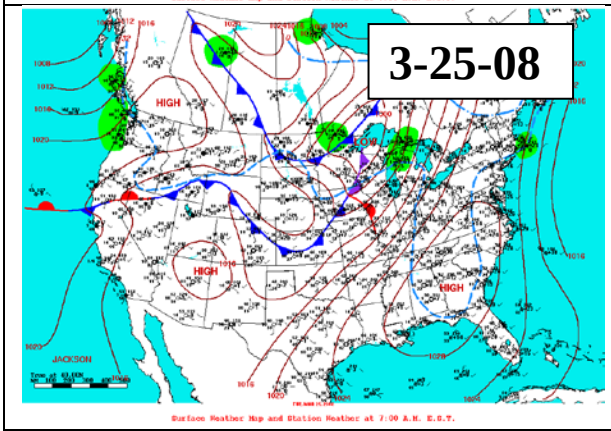
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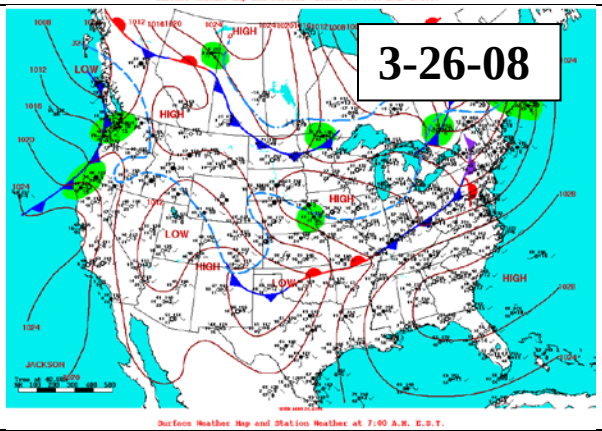
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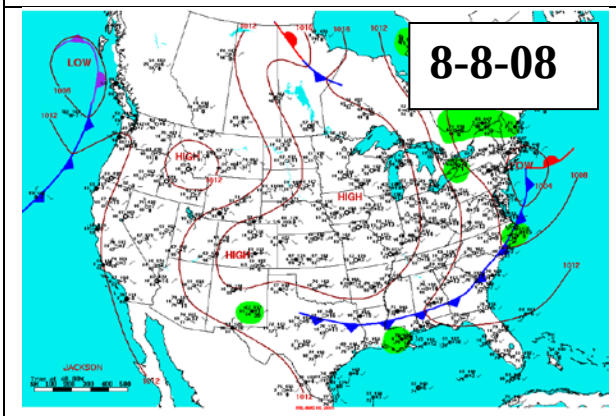
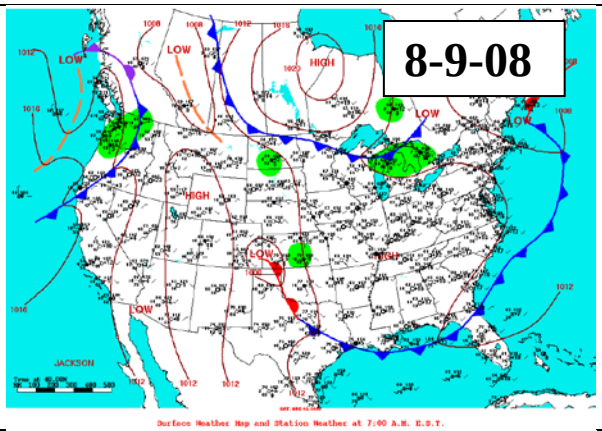
Period 5


8-8-08
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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LOW
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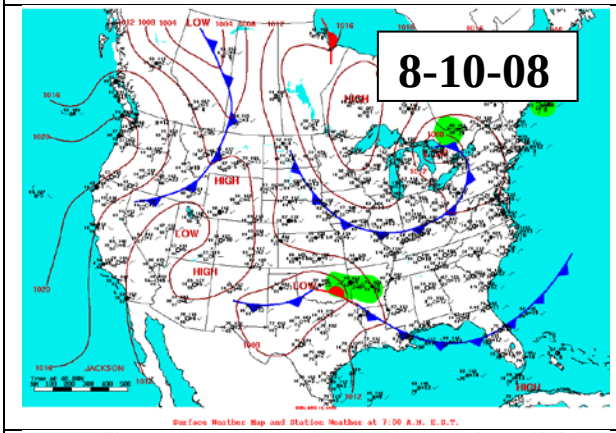
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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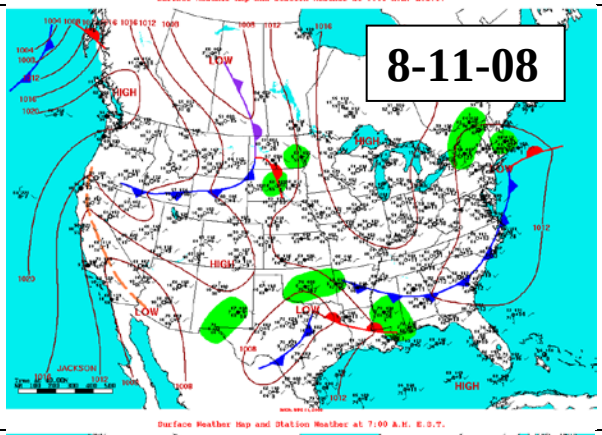
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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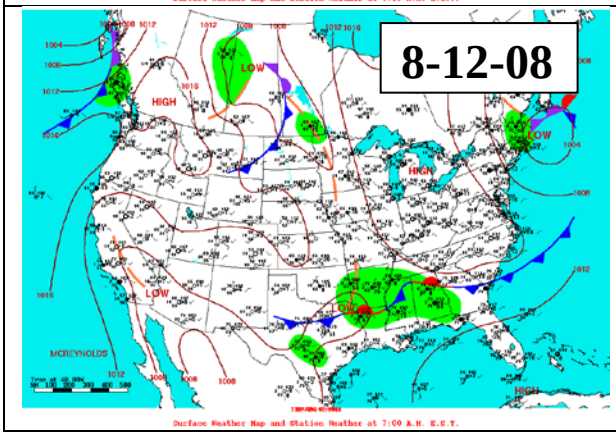
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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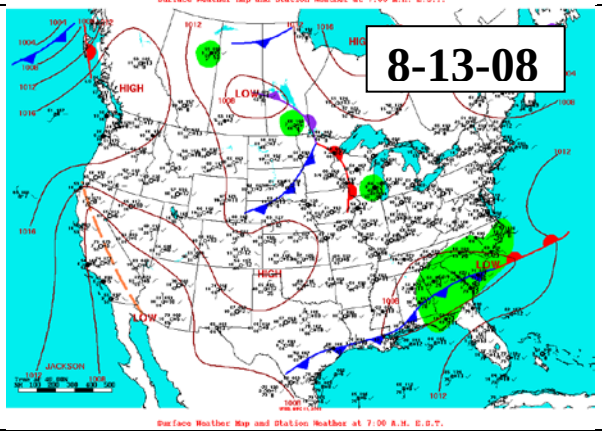
LOW
HIGH
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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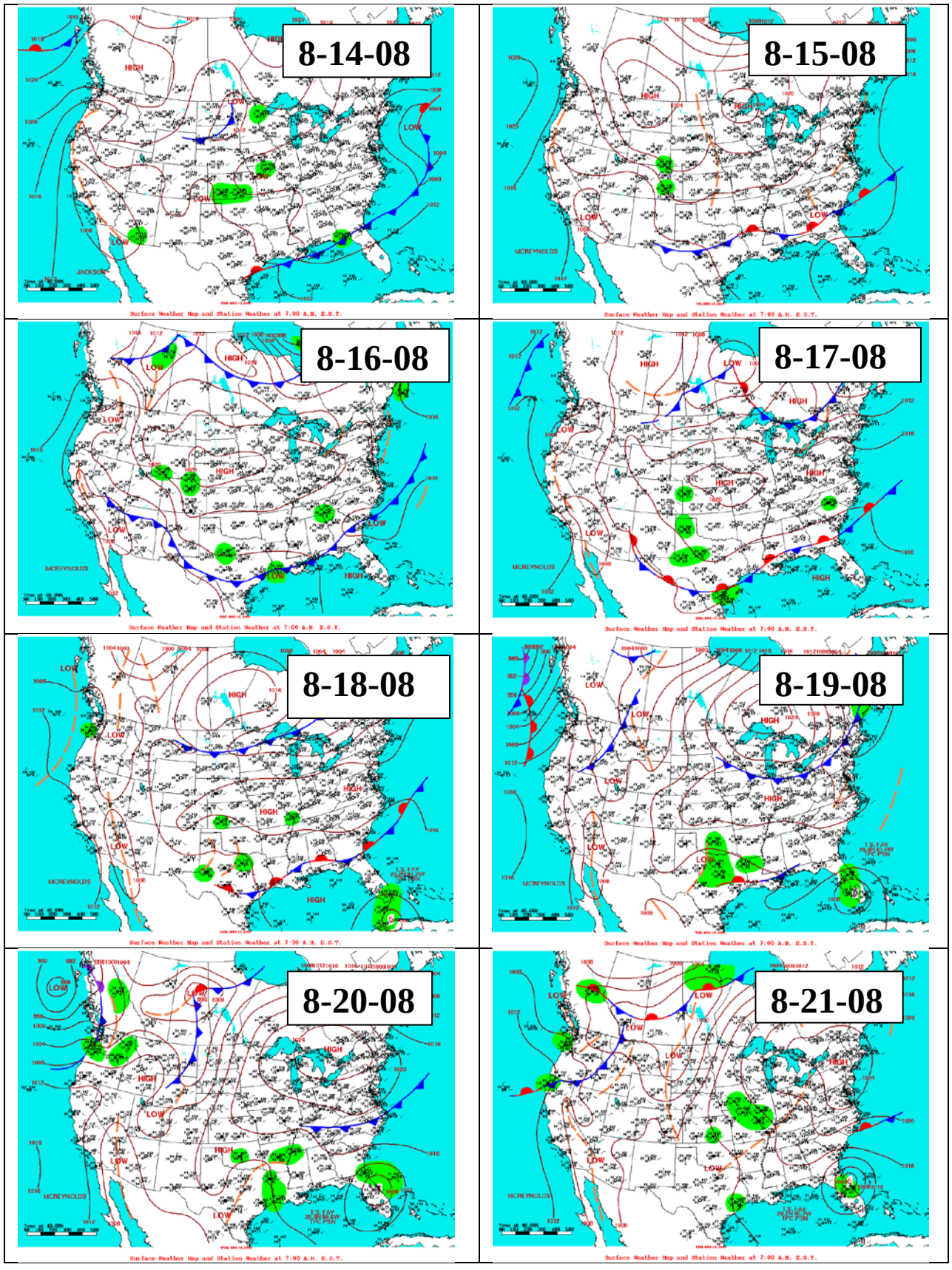
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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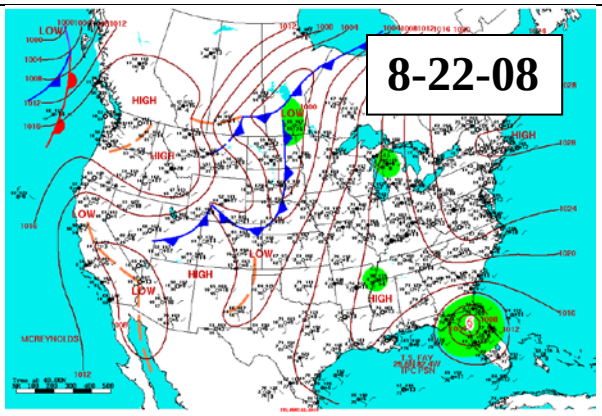
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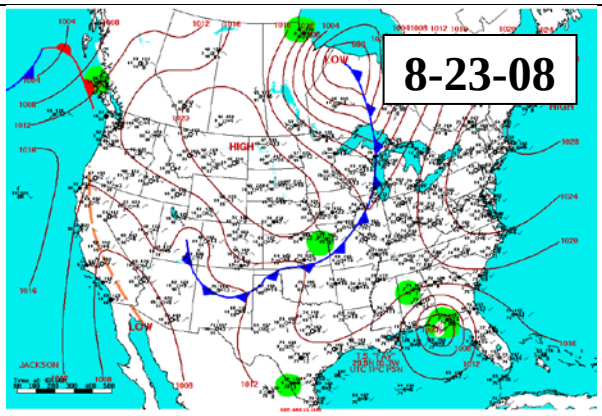
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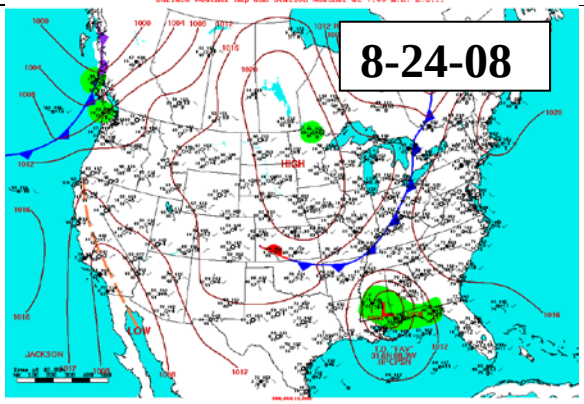
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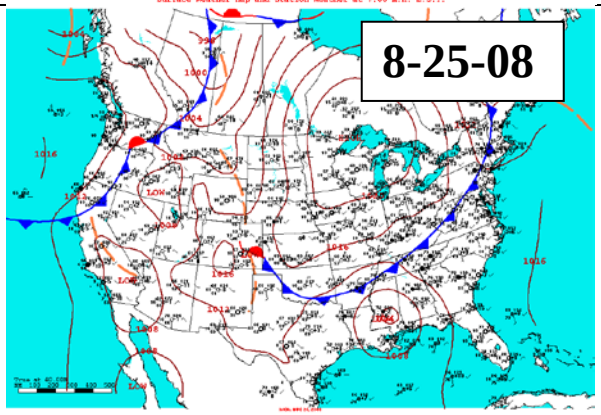
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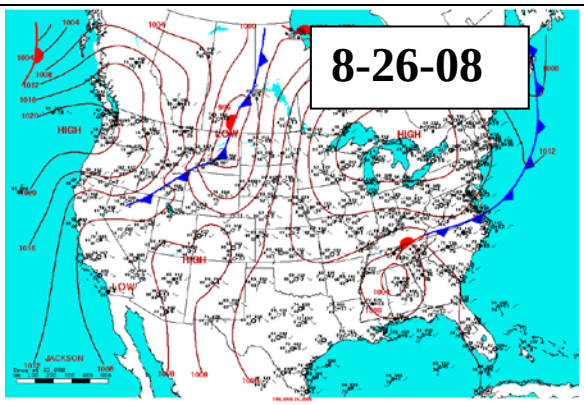
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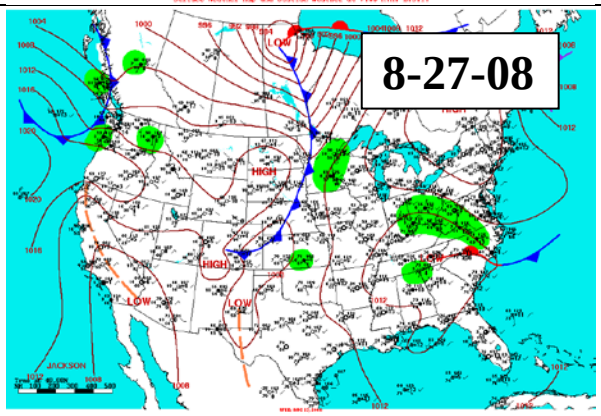
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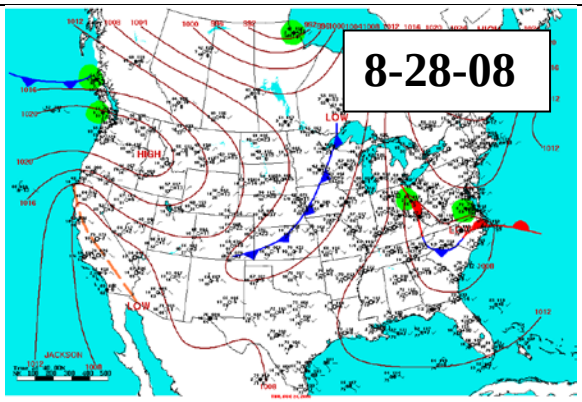
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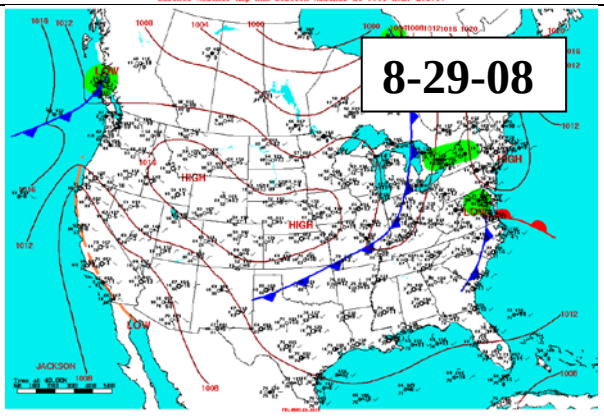
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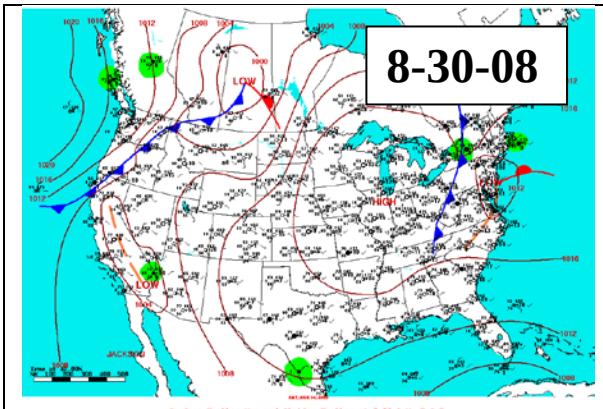
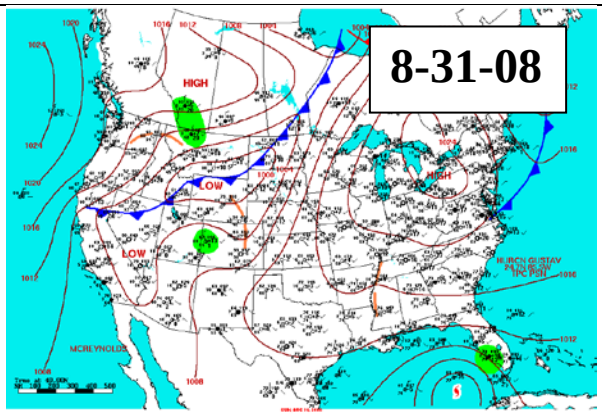
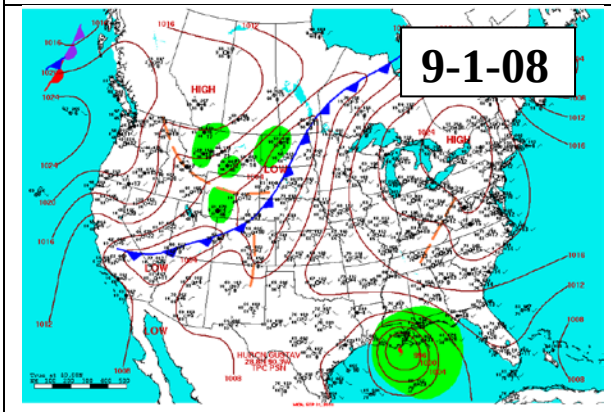
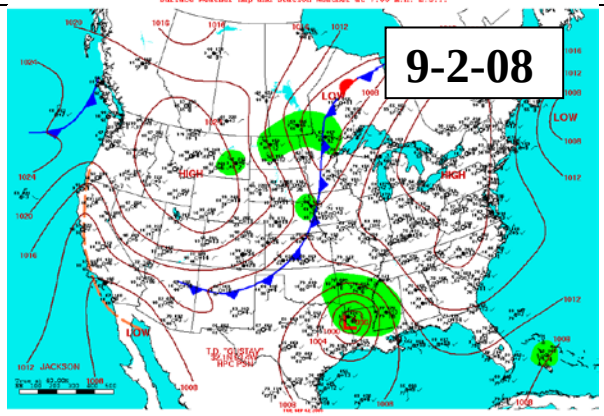
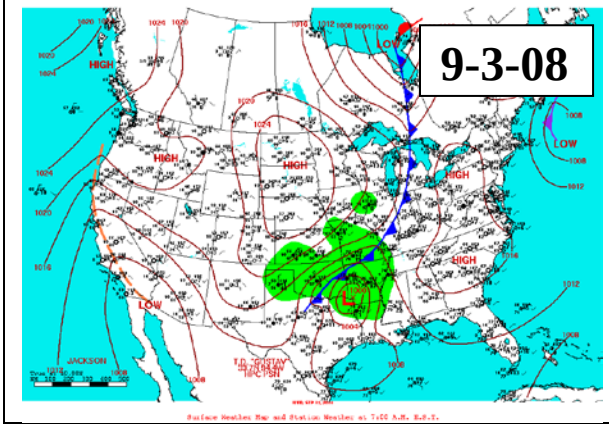


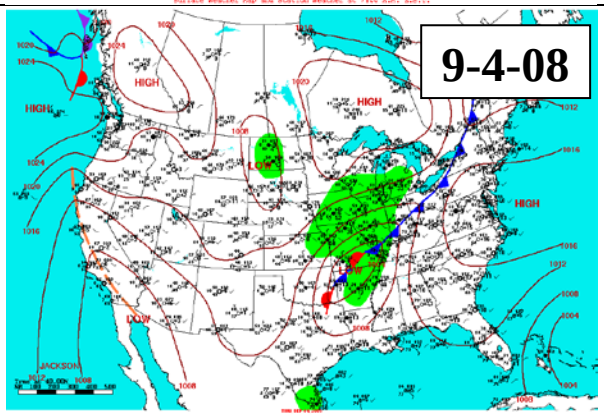


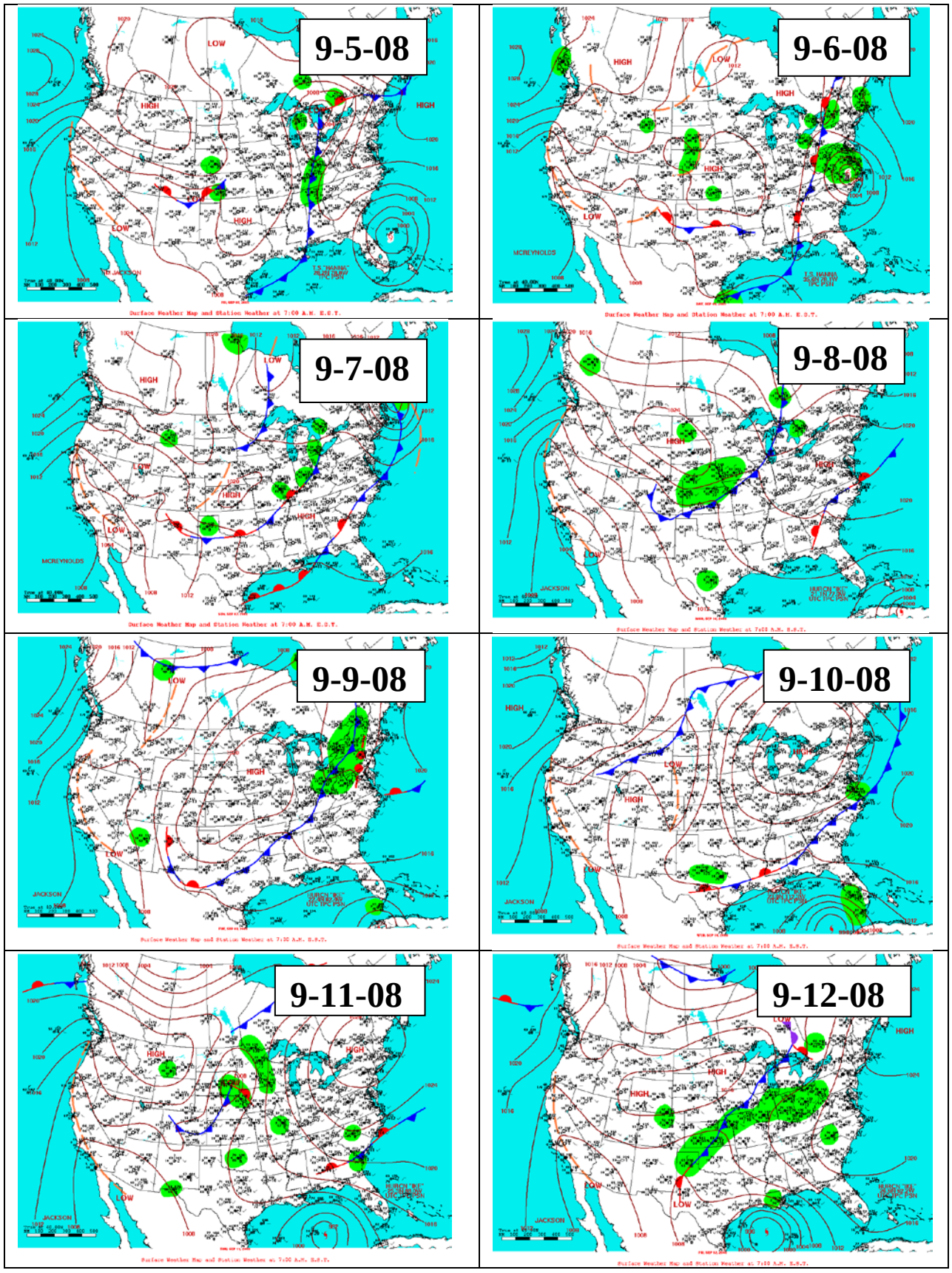




Period 6



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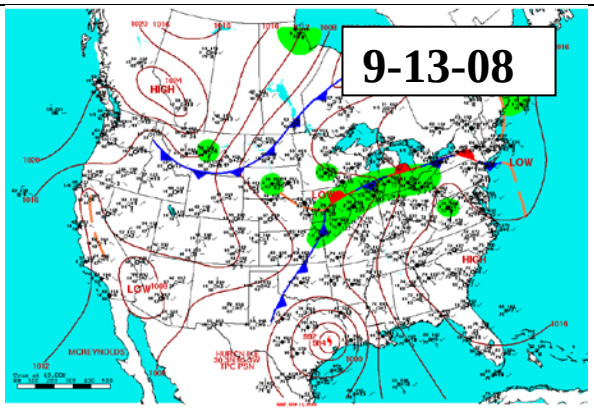
9-12-08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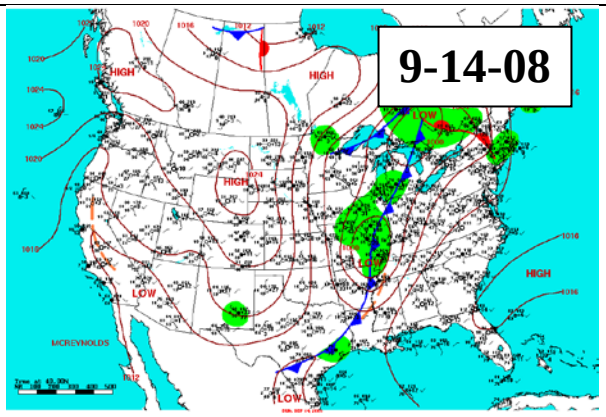
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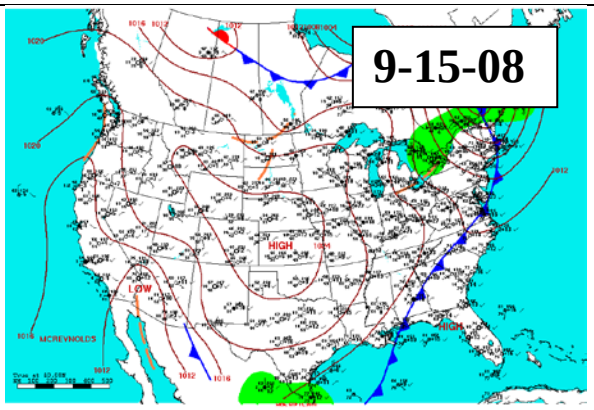
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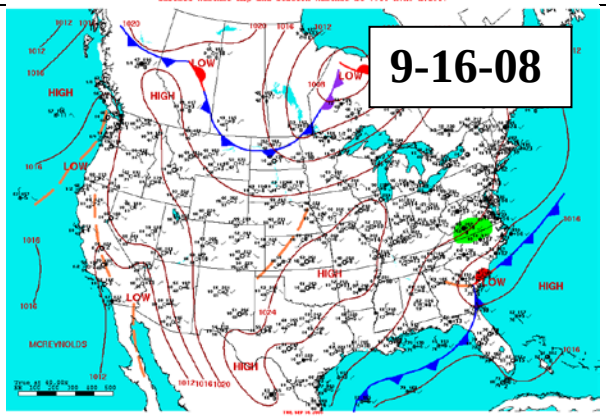
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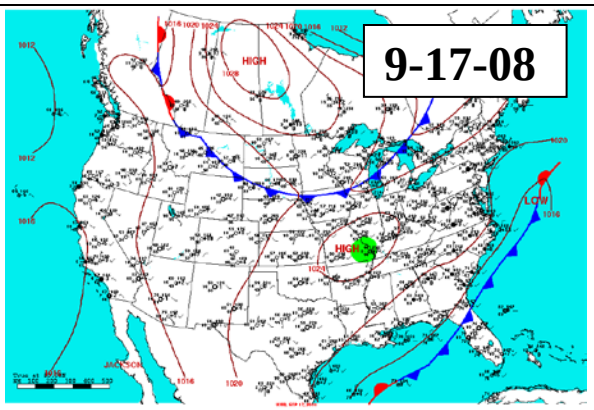
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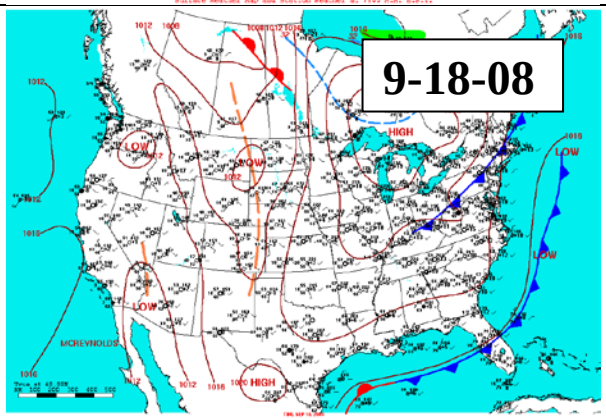
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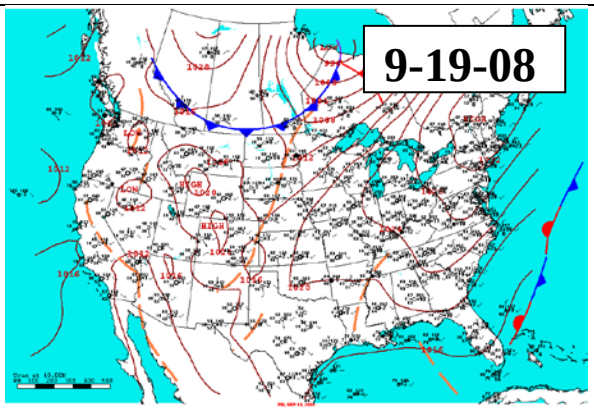
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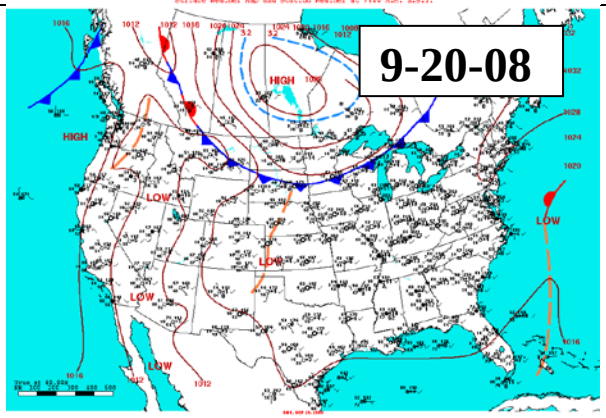
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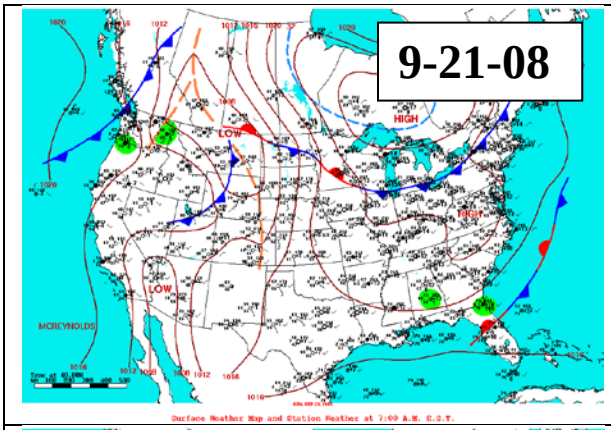
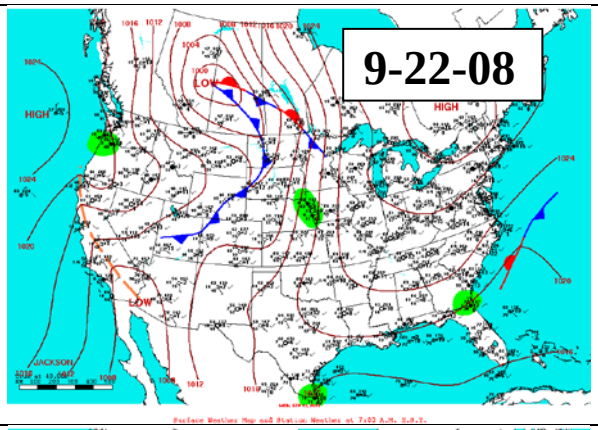
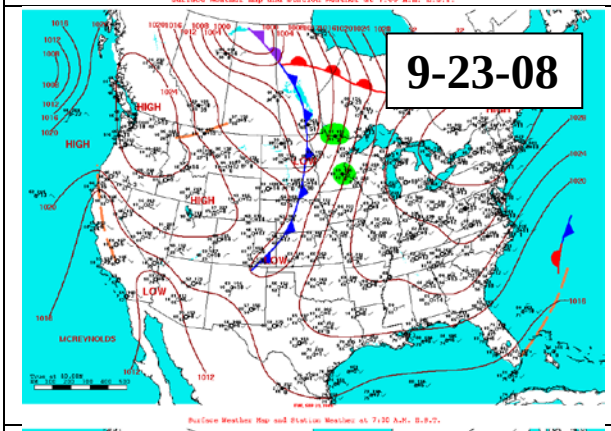
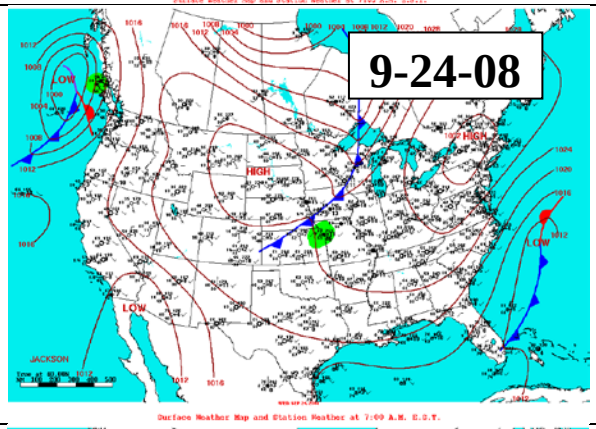
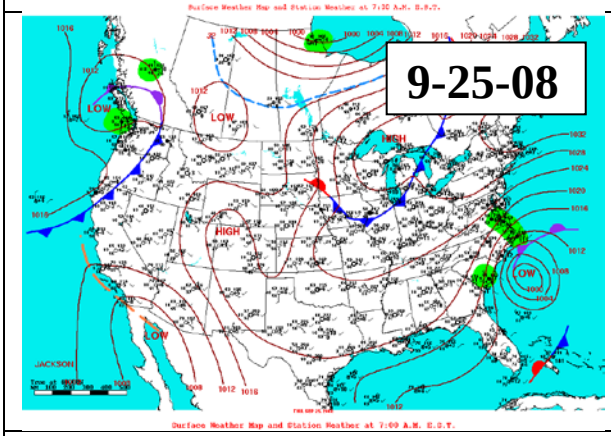
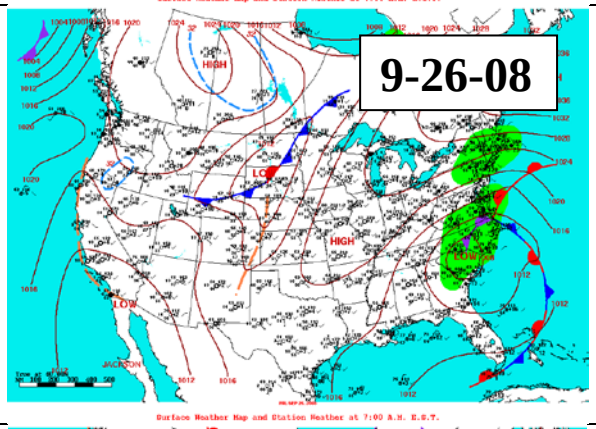




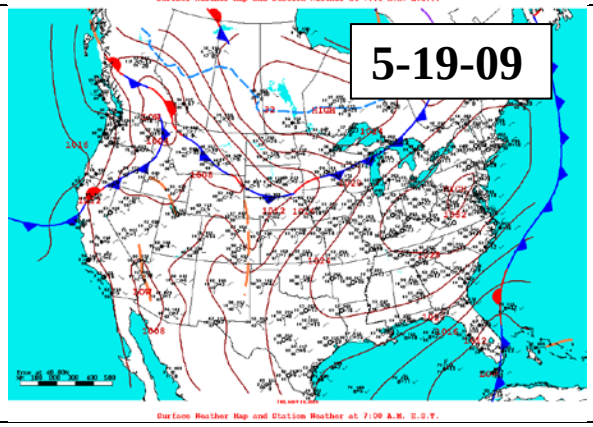


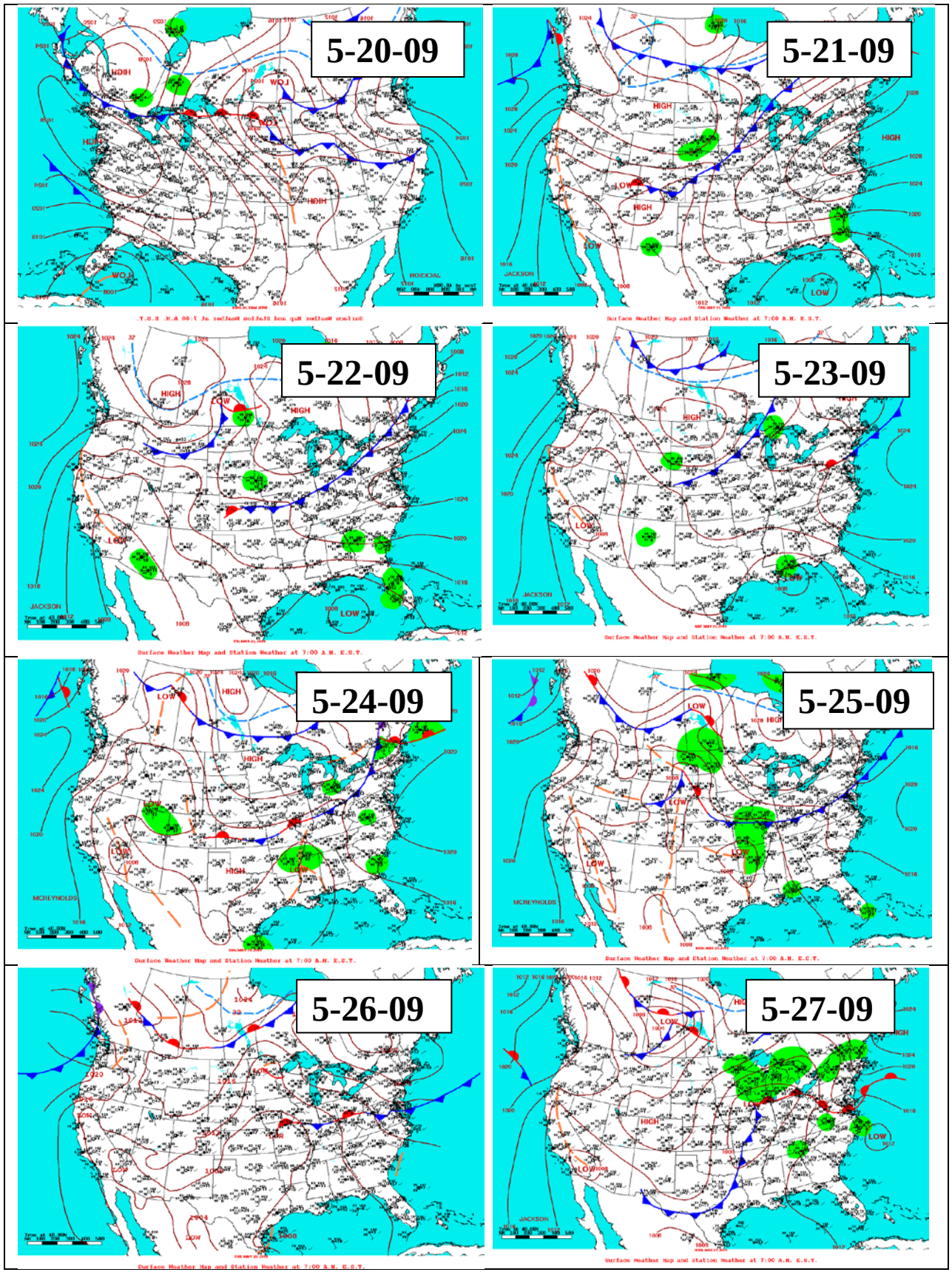






Period 8

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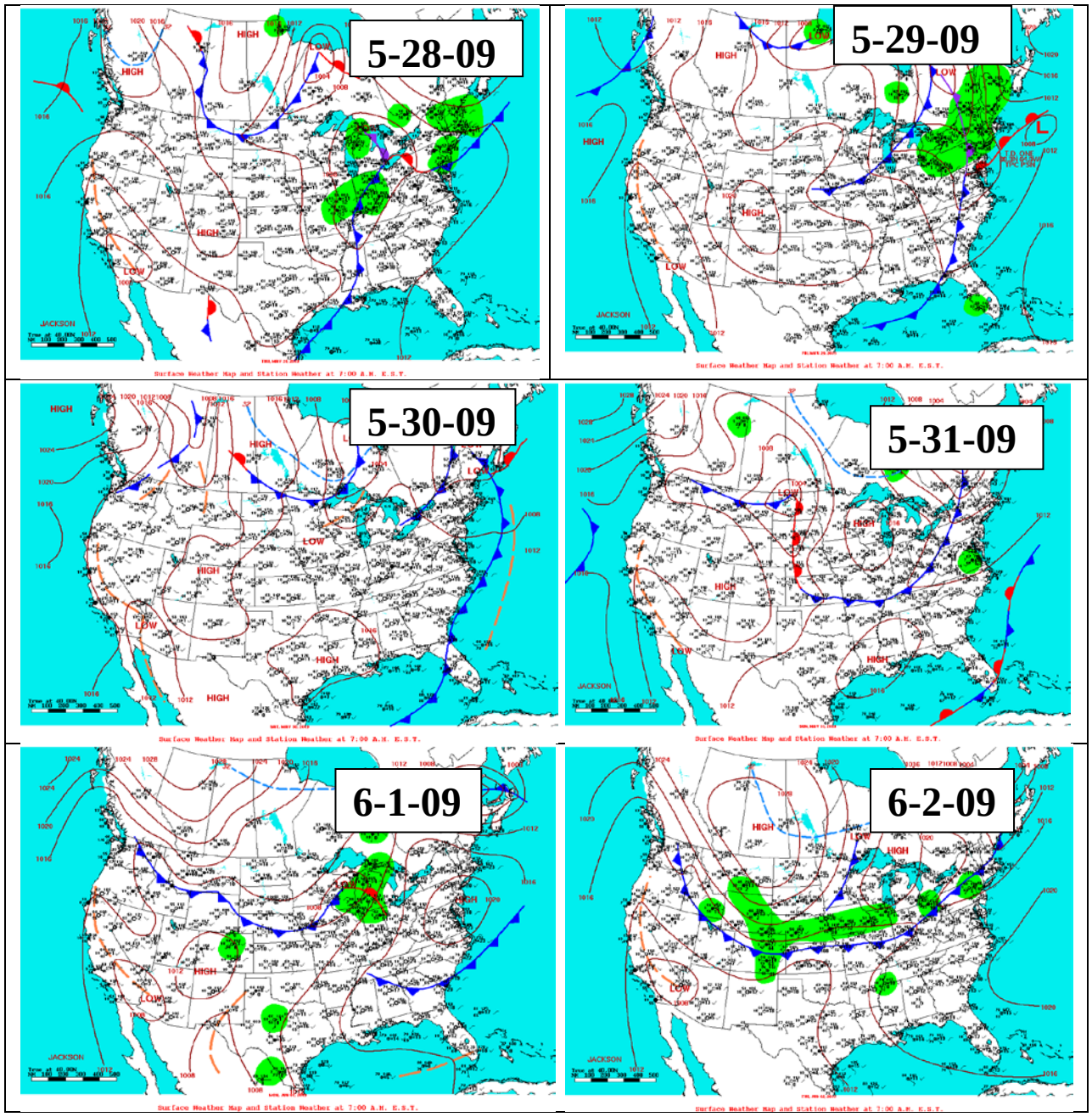
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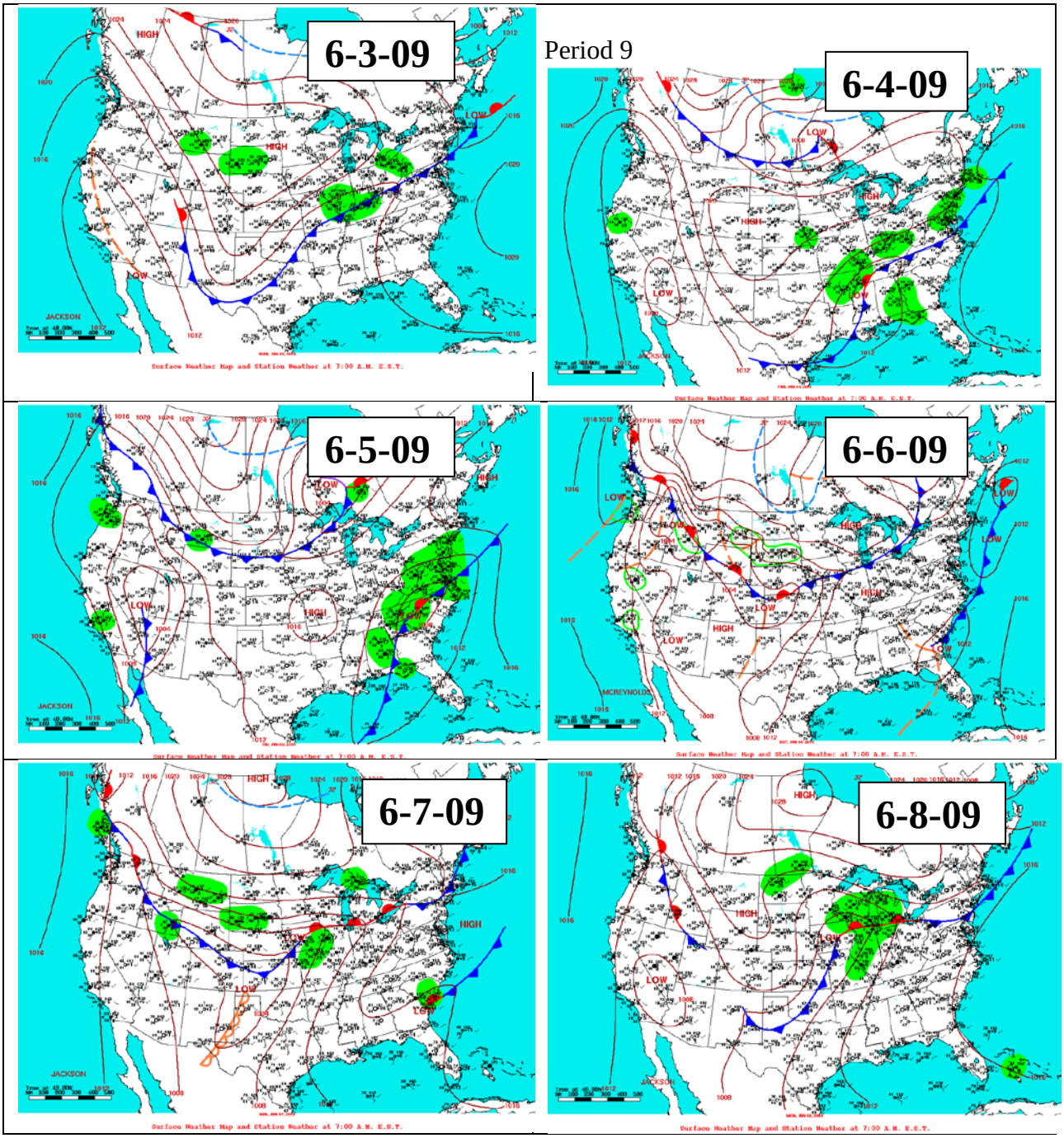
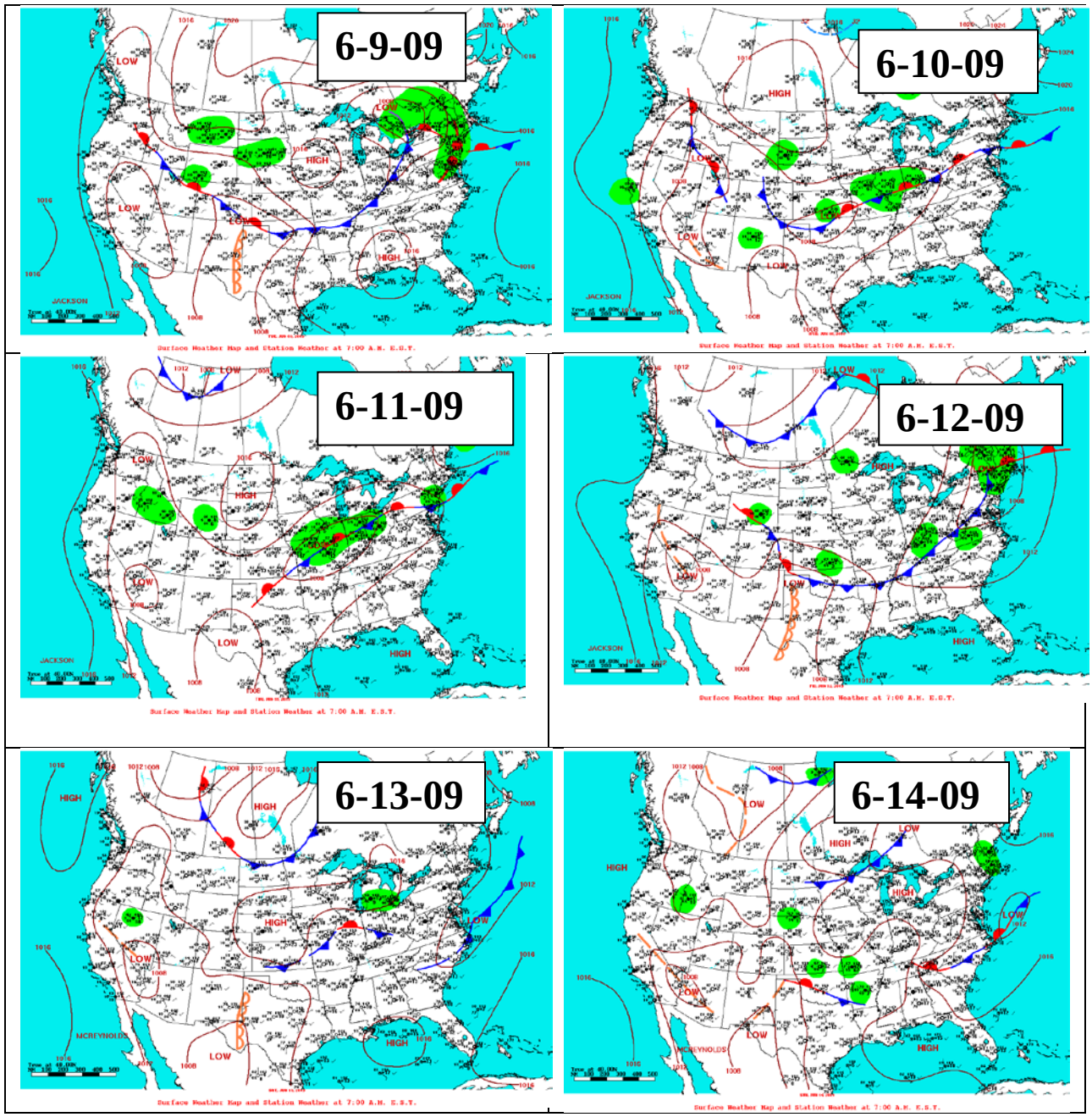
Period 9

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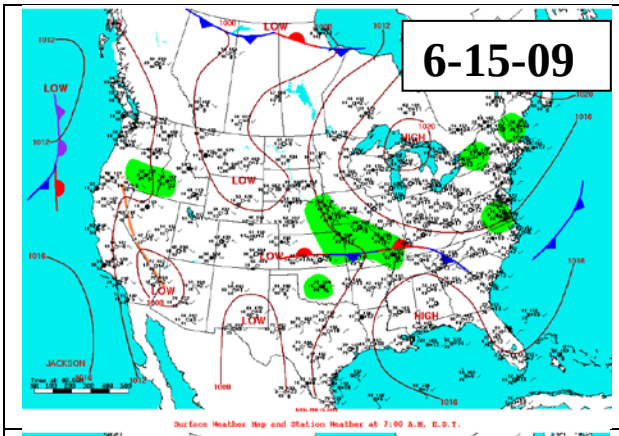
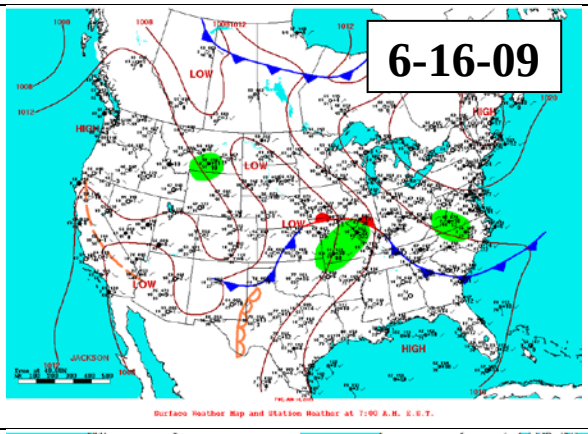
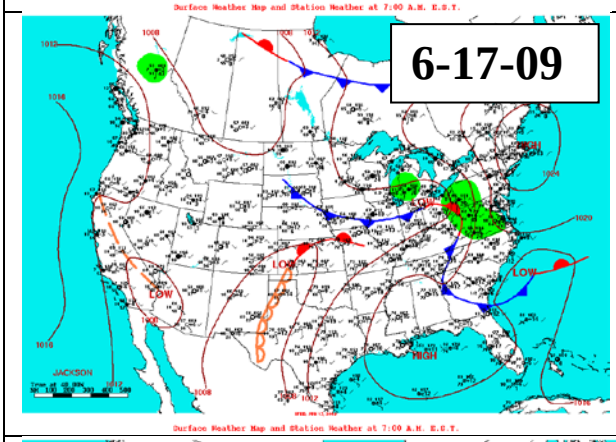
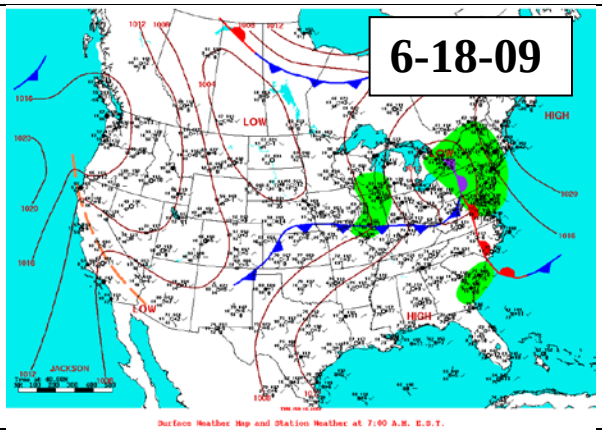
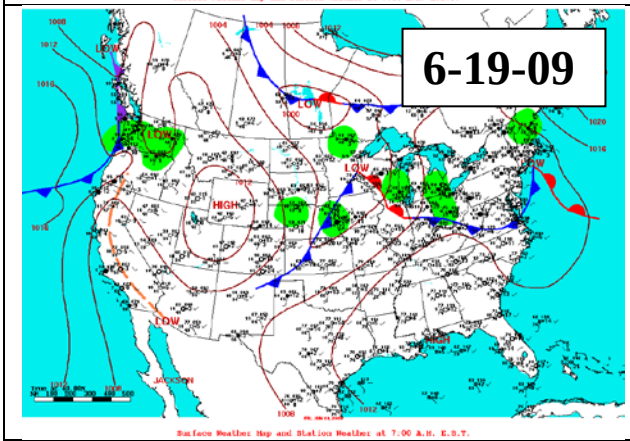

6-15-09
LOW
HIGH
JACKSON


6-16-09
LOW
HIGH
JACKSON


6-17-09
LOW
HIGH
JACKSON


6-18-09
LOW
HIGH
JACKSON


6-19-09
LOW
HIGH

6.8 Daily weather conditions

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 3				
2/29/2008	98.28	N/A	35%	9.1
3/1/2008	98.14	N/A	0%	9.6
3/2/2008	98.98	N/A	0%	8.8
3/3/2008	N/A	N/A	N/A	N/A
3/4/2008	N/A	N/A	N/A	N/A
3/5/2008	99.60	N/A	0%	8.6
3/6/2008	99.41	N/A	4%	6.4
3/7/2008	99.13	N/A	0%	8.4
3/8/2008	98.90	N/A	42%	9.0
3/9/2008	99.18	N/A	0%	7.1
3/10/2008	N/A	N/A	N/A	N/A
3/11/2008	99.29	N/A	0%	11.9
3/12/2008	99.05	N/A	1%	6.4
Period 4				
3/13/2008	97.95	501	55%	7.9
3/14/2008	97.71	599	0%	7.8
3/15/2008	97.87	821	12%	6.2
3/16/2008	98.66	735	4%	6.0
3/17/2008	98.85	861	0%	8.1
3/18/2008	98.49	846	4%	10.0
3/19/2008	98.74	737	5%	5.2
3/20/2008	98.63	597	0%	5.7
3/21/2008	99.37	914	0%	5.8
3/22/2008	100.19	733	10%	4.1
3/23/2008	98.95	372	0%	7.7
3/24/2008	98.86	747	0%	6.0
3/25/2008	98.82	778	0%	4.5
3/26/2008	98.32	642	0%	7.2
Period 5				
8/9/2008	98.10	927	0%	26.8
8/10/2008	98.58	815	0%	18.7
8/11/2008	98.66	857	0%	19.8
8/12/2008	98.21	942	3%	23.9
8/13/2008	98.25	839	0%	25.7
8/14/2008	98.20	528	0%	31.7
8/15/2008	98.30	853	0%	30.1

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
8/16/2008	97.94	908	0%	29.3
8/17/2008	97.53	884	0%	30.2
8/18/2008	97.26	951	0%	30.5
8/19/2008	97.64	913	39%	21.5
8/20/2008	97.43	933	26%	20.8
8/21/2008	97.53	1081	0%	20.0
8/22/2008	98.58	902	0%	17.1
8/23/2008	98.44	838	0%	19.5
8/24/2008	97.97	877	0%	23.2
8/25/2008	97.85	848	14%	20.8
8/26/2008	98.45	831	0%	16.5
8/27/2008	98.16	967	0%	20.6
8/28/2008	98.70	861	0%	19.1
8/29/2008	98.17	801	5%	23.4
8/30/2008	97.69	820	0%	20.6
8/31/2008	97.94	932	0%	15.0
9/1/2008	98.54	804	0%	16.1
9/2/2008	98.93	781	0%	16.1
9/3/2008	98.72	803	0%	16.9
Period 6				
9/4/2008	98.70	789	0%	19.9
9/5/2008	98.58	764	0%	20.3
9/6/2008	98.56	770	0%	21.5
9/7/2008	98.60	774	0%	21.3
9/8/2008	98.47	782	0%	19.3
9/9/2008	97.64	765	0%	20.0
9/10/2008	98.17	769	0%	20.0
9/11/2008	98.59	751	0%	18.8
9/12/2008	98.03	750	0%	20.5
9/13/2008	98.40	754	0%	20.9
9/14/2008	98.77	752	0%	18.5
9/15/2008	98.80	738	0%	19.1
9/16/2008	98.46	722	0%	20.7
9/17/2008	98.18	701	0%	21.7
9/18/2008	97.95	719	0%	22.2
9/19/2008	97.93	707	0%	22.4
9/20/2008	97.87	86	61%	19.2
9/21/2008	98.12	803	11%	15.2

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
9/22/2008	98.48	717	0%	14.6
9/23/2008	99.11	715	0%	10.9
9/24/2008	98.50	879	0%	13.2
9/25/2008	98.19	685	2%	17.5
9/26/2008	98.83	681	19%	12.7
Period 8				
5/21/2009	98.57	492	0%	23.1
5/22/2009	98.56	929	0%	17.1
5/23/2009	98.25	950	0%	20.3
5/24/2009	98.10	941	0%	22.2
5/25/2009	98.21	934	0%	21.5
5/26/2009	98.32	938	0%	21.1
5/27/2009	98.54	941	8%	19.8
5/28/2009	98.39	932	0%	22.6
5/29/2009	98.21	907	0%	24.7
5/30/2009	98.03	940	0%	27.5
5/31/2009	97.92	983	0%	26.2
6/1/2009	97.89	1054	0%	26.4
6/2/2009	98.22	937	0%	24.3
6/3/2009	98.33	938	0%	22.7
6/4/2009	98.03	1040	0%	23.4
Period 9				
6/9/2009	97.81	960	0%	23.7
6/10/2009	97.89	1013	0%	21.2
6/11/2009	97.88	1048	0%	21.9
6/12/2009	97.90	1159	0%	22.4
6/13/2009	97.81	1059	18%	21.1
6/14/2009	97.77	979	1%	22.9
6/15/2009	97.79	950	1%	22.1
6/16/2009	97.95	1002	0%	22.7
6/17/2009	97.87	1040	0%	23.2
6/18/2009	98.12	1063	0%	21.4
6/19/2009	97.66	1027	5%	21.6
6/20/2009	97.50	588	0%	26.0

6.9 Daily site emissions and data completeness

6.9.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either u_* < 0.15 m s^{-1} or |L| < 2 m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 3										
2/29/2008	0	0	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	0	13	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	0	10	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/3/2008	0	14	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	24	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	0	0	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/7/2008	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/8/2008	2	5	35	21.9	30.9	0.0	43.7	25.5	4.6	3.6
3/9/2008	0	2	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	0	18	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2008	0	3	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4										
3/13/2008	0	6	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	5	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	1	6	26	31.1	N/A	31.1	31.1	36.3	6.5	5.1
3/16/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	3	3	17	21.5	28.1	0.0	53.3	25.1	4.5	3.6

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
3/18/2008	0	10	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2008	1	5	36	17.8	N/A	17.8	17.8	20.7	3.7	2.9
3/20/2008	0	7	39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	16	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	1	5	33	17.8	N/A	17.8	17.8	20.7	3.7	2.9
3/23/2008	0	2	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2008	0	19	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2008	4	3	39	33.1	3.5	28.1	36.3	38.7	6.9	5.5
3/26/2008	0	8	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5										
8/10/2008	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2008	4	14	24	20.9	5.3	16.3	27.4	24.4	4.4	3.5
8/14/2008	15	17	0	26.5	23.2	5.2	74.8	30.9	5.5	4.4
8/15/2008	1	23	0	17.8	N/A	17.8	17.8	20.7	3.7	2.9
8/16/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	2	17	0	18.9	1.6	17.8	20.0	22.0	3.9	3.1
8/19/2008	18	18	1	20.7	13.4	-3.7	43.7	24.1	4.3	3.4
8/20/2008	9	33	0	25.3	8.8	10.4	39.3	29.5	5.3	4.2
8/21/2008	0	43	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	11	24	0	44.1	21.4	7.4	64.4	51.4	9.2	7.3
8/23/2008	22	1	5	34.8	20.1	-3.7	65.2	40.6	7.3	5.8
8/24/2008	22	3	14	27.9	14.1	0.0	54.8	32.6	5.8	4.6
8/25/2008	7	1	34	24.8	12.2	6.7	38.5	28.9	5.2	4.1
8/26/2008	6	2	38	27.8	15.9	15.6	58.5	32.4	5.8	4.6
8/27/2008	2	7	36	19.6	3.7	17.0	22.2	22.9	4.1	3.2
8/28/2008	22	20	0	34.5	27.3	0.0	111.1	40.3	7.2	5.7
8/29/2008	14	22	0	36.8	27.2	9.6	88.1	43.0	7.7	6.1
8/30/2008	0	42	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	35	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	1	41	0	80.0	N/A	80.0	80.0	93.3	16.7	13.2
9/2/2008	10	24	5	44.4	18.5	13.3	71.1	51.8	9.3	7.3
9/3/2008	7	2	21	33.1	22.9	-3.7	62.2	38.6	6.9	5.5
Period 6										
9/4/2008	0	2	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	12	27	0	47.5	13.4	19.3	67.4	55.4	9.9	7.8
9/6/2008	6	39	0	23.5	3.9	17.8	29.6	27.4	4.9	3.9
9/7/2008	17	23	0	31.5	24.9	-24.4	80.0	36.7	6.6	5.2
9/8/2008	15	19	0	30.6	16.2	6.7	57.8	35.7	6.4	5.1
9/9/2008	24	11	0	42.1	29.2	1.5	91.9	49.1	8.8	7.0
9/10/2008	4	37	0	59.1	34.6	33.3	107.4	68.9	12.3	9.8
9/11/2008	22	11	1	28.9	22.1	-35.6	71.9	33.7	6.0	4.8
9/12/2008	20	7	0	33.7	15.4	9.6	66.7	39.3	7.0	5.6
9/13/2008	1	43	0	38.5	N/A	38.5	38.5	44.9	8.0	6.4

Date	Valid	Direction limited	Missing downwind NH_3	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/14/2008	12	11	7	30.3	22.2	-13.3	68.9	35.4	6.3	5.0
9/15/2008	17	8	2	44.1	28.5	11.1	95.6	51.5	9.2	7.3
9/16/2008	25	7	0	42.3	23.7	6.7	89.6	49.4	8.8	7.0
9/17/2008	26	7	0	28.3	19.7	0.0	63.0	33.0	5.9	4.7
9/18/2008	31	6	0	42.7	27.6	8.1	103.7	49.9	8.9	7.1
9/19/2008	12	21	0	37.5	36.2	-5.2	98.5	43.7	7.8	6.2
9/20/2008	5	11	31	61.5	19.2	36.3	87.4	71.7	12.8	10.2
9/21/2008	0	7	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/22/2008	0	8	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/23/2008	0	1	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/24/2008	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2008	0	15	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	4	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8										
5/21/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	14	2	27	21.4	9.6	8.9	35.6	25.0	4.5	3.5
5/23/2009	12	2	32	18.0	7.8	8.1	31.9	21.0	3.8	3.0
5/24/2009	2	0	45	17.0	6.3	12.6	21.5	19.9	3.5	2.8
5/25/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2009	1	6	41	45.9	N/A	45.9	45.9	53.6	9.6	7.6
5/27/2009	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2009	7	10	29	27.4	13.5	0.0	40.7	32.0	5.7	4.5
6/1/2009	3	8	37	22.5	19.5	0.0	34.1	26.2	4.7	3.7
6/2/2009	19	0	29	31.3	12.3	0.0	47.4	36.6	6.5	5.2
6/3/2009	15	1	32	22.8	7.5	12.6	36.3	26.6	4.7	3.8
6/4/2009	3	7	21	28.9	9.8	17.8	36.3	33.7	6.0	4.8
Period 9										
6/5/2009	1	4	5	44.4	N/A	44.4	44.4	51.8	9.3	7.3
6/6/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	3	2	10	19.3	5.3	14.8	25.2	22.5	4.0	3.2
6/10/2009	4	2	31	27.2	4.2	23.7	33.3	31.8	5.7	4.5
6/11/2009	4	28	5	18.1	24.1	-7.4	42.2	21.2	3.8	3.0
6/12/2009	10	24	3	35.3	46.4	-13.3	128.9	41.1	7.3	5.8
6/13/2009	14	12	1	35.4	27.1	9.6	104.4	41.3	7.4	5.9
6/14/2009	1	19	28	71.9	N/A	71.9	71.9	83.8	15.0	11.9
6/15/2009	3	31	3	30.1	0.9	29.6	31.1	35.1	6.3	5.0
6/16/2009	3	31	7	37.5	22.5	13.3	57.8	43.8	7.8	6.2
6/17/2009	0	40	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2009	4	12	23	52.4	23.1	22.2	78.5	61.1	10.9	8.7
6/19/2009	4	15	11	39.3	10.1	25.2	48.9	45.8	8.2	6.5

6.9.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either u_* < 0.15 m s^{-1} or |L| < 2 m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average ($\mu g m^{-2} s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu g m^{-2} s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu g m^{-2} s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu g m^{-2} s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average ($kg d^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($g d^{-1} hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($g d^{-1} AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} hd^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
Period 3												
2/29/2008	7	1	0	0	-0.04	77.5	45.1	27.4	136.3	88.2	15.7	12.5
3/1/2008	0	46	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	2	23	3	18	0.03	22.4	5.6	18.5	26.4	25.5	4.6	3.6
3/3/2008	1	28	5	3	0.03	6.8	N/A	6.8	6.8	7.7	1.4	1.1
3/4/2008	0	40	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	1	0	7	9	0.04	61.8	N/A	61.8	61.8	70.4	12.6	10.0
3/7/2008	1	5	4	29	0.12	4.3	N/A	4.3	4.3	4.9	0.9	0.7
3/8/2008	4	2	4	37	0.03	61.6	40.1	14.8	110.5	70.1	12.5	9.9
3/9/2008	0	1	8	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	2	0	12	28	0.02	62.3	30.9	40.4	84.2	70.9	12.7	10.0
3/11/2008	2	38	3	2	0.06	17.4	24.0	0.4	34.4	19.8	3.5	2.8
3/12/2008	2	12	2	22	-0.05	17.7	21.4	2.6	32.8	20.1	3.6	2.8
Period 4												
3/13/2008	0	8	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	2	39	0	4	0.07	28.7	13.9	18.9	38.5	32.7	5.8	4.6
3/15/2008	1	14	0	23	-0.02	8.1	N/A	8.1	8.1	9.2	1.6	1.3
3/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	11	6	0	4	0.00	53.4	29.3	0.6	97.7	60.8	10.9	8.6
3/18/2008	3	42	0	2	0.04	29.7	20.2	6.8	44.6	33.8	6.0	4.8
3/19/2008	9	13	0	24	0.11	37.7	25.0	2.2	72.1	42.9	7.7	6.1
3/20/2008	8	22	0	18	0.08	53.2	10.8	38.1	69.8	60.5	10.8	8.6
3/21/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	9	8	0	27	0.03	55.3	16.9	17.3	80.3	62.9	11.2	8.9
3/23/2008	11	11	0	26	-0.01	36.9	17.4	24.2	85.2	42.0	7.5	6.0
3/24/2008	5	28	0	14	-0.09	66.8	15.8	48.1	84.7	76.0	13.6	10.8
3/25/2008	8	6	0	29	-0.01	88.0	54.3	11.0	198.7	100.1	17.9	14.2
3/26/2008	4	23	0	3	0.05	25.4	8.2	18.0	36.0	28.9	5.2	4.1
Period 5												
8/10/2008	0	0	9	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
8/11/2008	0	0	12	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2008	0	0	18	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2008	4	27	13	3	0.10	15.0	9.3	1.8	22.4	17.0	3.0	2.4
8/14/2008	13	20	0	11	0.29	9.1	11.4	-19.0	30.4	10.3	1.8	1.5
8/15/2008	7	20	0	9	0.37	1.8	2.7	-1.1	6.5	2.1	0.4	0.3
8/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	2	19	0	0	0.41	5.3	17.5	-7.2	17.7	6.0	1.1	0.8
8/19/2008	18	19	0	4	0.28	14.8	11.3	2.5	38.2	16.8	3.0	2.4
8/20/2008	11	33	0	1	0.19	11.9	7.0	2.9	28.9	13.5	2.4	1.9
8/21/2008	0	47	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	11	22	0	12	0.21	29.3	15.2	2.3	51.6	33.3	6.0	4.7
8/23/2008	17	4	1	17	0.24	27.6	16.4	0.1	60.0	31.4	5.6	4.4
8/24/2008	16	5	2	15	0.13	25.1	19.8	4.9	78.9	28.5	5.1	4.0
8/25/2008	14	10	6	2	0.23	12.1	10.2	-5.4	32.4	13.8	2.5	2.0
8/26/2008	11	12	12	1	0.04	61.4	35.3	3.9	97.4	69.8	12.5	9.9
8/27/2008	6	19	10	7	0.05	31.5	13.4	7.1	44.9	35.9	6.4	5.1
8/28/2008	20	16	0	9	0.22	34.4	25.5	5.3	104.9	39.2	7.0	5.6
8/29/2008	11	23	0	9	0.38	31.7	21.1	3.9	86.6	36.1	6.4	5.1
8/30/2008	0	47	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	2	45	0	1	0.43	26.6	29.0	6.1	47.1	30.3	5.4	4.3
9/2/2008	10	25	0	13	0.21	52.1	26.5	7.1	89.8	59.3	10.6	8.4
9/3/2008	3	1	2	6	0.25	31.6	16.5	16.4	49.1	35.9	6.4	5.1
Period 6												
9/4/2008	0	2	2	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	11	20	0	14	0.14	39.2	14.4	7.5	56.4	44.6	8.0	6.3
9/6/2008	5	41	0	2	0.16	37.4	15.9	22.9	64.1	42.5	7.6	6.0
9/7/2008	12	22	0	10	0.46	27.5	24.9	0.4	83.1	31.3	5.6	4.4
9/8/2008	13	20	0	10	0.27	26.2	21.5	2.0	61.2	29.8	5.3	4.2
9/9/2008	13	12	0	15	0.22	58.6	36.7	6.9	97.7	66.7	11.9	9.5
9/10/2008	2	42	0	3	0.19	46.4	35.3	21.5	71.4	52.8	9.4	7.5
9/11/2008	24	8	0	10	0.33	41.4	23.2	3.6	83.9	47.1	8.4	6.7
9/12/2008	16	10	0	17	0.32	35.3	30.2	0.5	99.2	40.2	7.2	5.7
9/13/2008	0	44	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/14/2008	7	10	0	24	0.64	34.1	19.2	12.7	63.1	38.8	6.9	5.5
9/15/2008	16	7	0	17	0.49	41.4	34.8	0.3	98.3	47.1	8.4	6.7
9/16/2008	18	3	0	21	0.26	45.7	24.9	0.4	78.7	52.0	9.3	7.4
9/17/2008	18	9	0	9	0.30	33.1	22.0	3.9	70.7	37.7	6.7	5.3
9/18/2008	22	5	1	11	0.26	47.5	24.0	3.1	83.3	54.0	9.6	7.7
9/19/2008	12	21	0	9	0.27	32.0	27.2	-4.4	65.2	36.4	6.5	5.2
9/20/2008	18	18	0	7	0.19	34.6	25.4	0.4	78.2	39.3	7.0	5.6
9/21/2008	3	33	0	12	0.18	17.4	4.5	12.2	20.5	19.8	3.5	2.8
9/22/2008	4	32	0	12	0.08	24.1	8.1	15.5	35.1	27.4	4.9	3.9
9/23/2008	19	9	0	15	0.16	27.7	18.9	0.6	63.4	31.5	5.6	4.5
9/24/2008	12	7	1	21	0.15	40.6	33.7	-44.5	83.7	46.2	8.3	6.5
9/25/2008	7	29	1	4	0.19	13.4	18.2	-1.9	51.8	15.2	2.7	2.2
9/26/2008	4	9	3	14	0.18	5.4	2.7	2.6	8.0	6.2	1.1	0.9
Period 8												
5/21/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	18	7	3	14	0.17	16.0	13.3	1.5	43.4	18.2	3.2	2.6
5/23/2009	12	15	5	11	0.16	18.6	16.8	3.8	55.6	21.2	3.8	3.0
5/24/2009	4	16	22	3	0.09	24.7	9.3	12.0	32.4	28.1	5.0	4.0
5/25/2009	2	16	25	3	0.17	6.3	6.5	1.8	10.9	7.2	1.3	1.0
5/26/2009	4	24	9	9	0.18	23.0	11.1	14.8	39.0	26.2	4.7	3.7
5/27/2009	0	0	16	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2009	0	0	19	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2009	0	0	18	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2009	0	0	8	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2009	14	14	7	9	0.19	39.0	31.0	6.4	99.4	44.3	7.9	6.3
6/1/2009	7	23	2	10	0.15	26.3	13.9	9.2	49.1	29.9	5.3	4.2
6/2/2009	36	5	1	5	0.16	14.7	8.6	2.2	43.0	16.7	3.0	2.4
6/3/2009	12	17	2	11	0.14	15.5	14.5	2.6	48.1	17.7	3.2	2.5
6/4/2009	4	7	6	17	0.03	25.7	6.5	16.5	31.5	29.2	5.2	4.1
Period 9												
6/5/2009	1	10	0	0	0.13	20.5	N/A	20.5	20.5	23.4	4.2	3.3

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
6/6/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	13	1	0	1	0.23	18.6	9.1	1.1	36.6	21.2	3.8	3.0
6/10/2009	19	14	0	14	0.27	3.4	7.7	-14.2	15.1	3.9	0.7	0.5
6/11/2009	4	25	1	15	0.33	23.7	19.5	0.7	48.2	26.9	4.8	3.8
6/12/2009	18	17	0	9	0.30	12.9	15.6	-9.0	45.9	14.7	2.6	2.1
6/13/2009	17	13	0	15	0.30	12.9	10.3	-1.3	35.9	14.7	2.6	2.1
6/14/2009	11	37	0	0	0.13	50.1	18.2	1.4	66.8	56.9	10.2	8.1
6/15/2009	4	37	0	7	0.14	21.6	9.1	9.0	28.5	24.6	4.4	3.5
6/16/2009	7	33	0	7	0.19	14.5	9.4	1.8	28.1	16.5	3.0	2.3
6/17/2009	0	41	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2009	6	32	0	6	0.15	21.4	21.7	-0.1	57.6	24.3	4.3	3.4
6/19/2009	9	8	0	16	0.29	11.5	9.3	1.2	31.9	13.1	2.3	1.9

6.9.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}h^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 3								
2/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/8/2008	2	10.2	41.4	0.0	20.3	11.8	2.1	1.7
3/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4								
3/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5								

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}h^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
8/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2008	1	-2.4	0.0	-2.4	-2.4	-2.9	-0.5	-0.4
8/14/2008	8	8.3	26.5	0.0	23.5	9.6	1.7	1.4
8/15/2008	1	20.8	0.0	20.8	20.8	24.3	4.3	3.4
8/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/17/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/19/2008	13	9.3	25.9	-0.8	19.5	10.8	1.9	1.5
8/20/2008	5	4.7	21.3	-14.2	18.2	5.4	1.0	0.8
8/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	6	16.5	36.0	0.6	27.8	19.3	3.4	2.7
8/23/2008	14	13.8	30.3	-1.6	34.4	16.1	2.9	2.3
8/24/2008	8	25.5	37.7	8.0	64.7	29.7	5.3	4.2
8/25/2008	3	3.3	18.9	1.3	7.3	3.9	0.7	0.6
8/26/2008	6	5.0	20.6	1.4	7.2	5.8	1.0	0.8
8/27/2008	1	14.0	0.0	14.0	14.0	16.3	2.9	2.3
8/28/2008	17	15.1	31.3	1.9	28.9	17.7	3.2	2.5
8/29/2008	11	13.6	30.1	1.2	32.0	15.9	2.8	2.3
8/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	1	26.2	0.0	26.2	26.2	30.5	5.4	4.3
9/2/2008	10	8.2	24.7	0.8	17.3	9.6	1.7	1.4
9/3/2008	5	4.7	20.7	1.0	10.2	5.4	1.0	0.8
Period 6								
9/4/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	6	8.8	26.7	4.2	11.9	10.2	1.8	1.4
9/6/2008	2	12.0	40.9	10.3	13.6	13.9	2.5	2.0
9/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/9/2008	12	8.3	24.4	1.7	21.8	9.7	1.7	1.4
9/10/2008	3	8.0	29.4	5.7	12.3	9.3	1.7	1.3
9/11/2008	21	7.4	22.9	-0.8	14.9	8.7	1.6	1.2
9/12/2008	13	6.1	21.2	1.0	9.4	7.1	1.3	1.0
9/13/2008	1	10.5	0.0	10.5	10.5	12.2	2.2	1.7
9/14/2008	9	7.6	24.2	-1.5	13.0	8.9	1.6	1.3
9/15/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/16/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2008	14	10.3	26.6	1.3	29.6	12.0	2.2	1.7
9/18/2008	23	12.2	28.2	3.4	21.8	14.3	2.5	2.0
9/19/2008	6	9.0	27.7	-0.3	18.0	10.5	1.9	1.5
9/20/2008	4	15.3	37.2	11.8	23.4	17.8	3.2	2.5
9/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}h^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
9/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8								
5/21/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/22/2009	8	2.9	15.4	0.0	6.0	3.4	0.6	0.5
5/23/2009	7	2.4	14.3	0.0	3.7	2.8	0.5	0.4
5/24/2009	1	1.1	0.0	1.1	1.1	1.2	0.2	0.2
5/25/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/26/2009	1	6.1	0.0	6.1	6.1	7.1	1.3	1.0
5/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/29/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/31/2009	2	2.2	18.1	1.7	2.8	2.6	0.5	0.4
6/1/2009	2	0.5	8.4	0.4	0.6	0.6	0.1	0.1
6/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/3/2009	6	2.0	13.2	0.8	4.7	2.3	0.4	0.3
6/4/2009	2	1.1	12.5	0.7	1.5	1.2	0.2	0.2
Period 9								
6/5/2009	1	1.3	0.0	1.3	1.3	1.6	0.3	0.2
6/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	3	0.4	7.0	-0.2	1.1	0.5	0.1	0.1
6/10/2009	1	0.2	0.0	0.2	0.2	0.2	0.0	0.0
6/11/2009	3	4.5	21.7	0.0	13.5	5.2	0.9	0.7
6/12/2009	9	0.1	3.5	-9.7	10.2	0.2	0.0	0.0
6/13/2009	12	1.7	11.6	-0.2	8.8	2.0	0.4	0.3
6/14/2009	1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
6/15/2009	3	0.3	5.5	0.0	0.6	0.3	0.1	0.0
6/16/2009	3	1.3	11.8	0.9	1.6	1.5	0.3	0.2
6/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2009	3	0.2	5.0	-0.1	0.5	0.3	0.0	0.0
6/19/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.9.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either u_* < 0.15 m s^{-1} or |L| < 2 m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average ($\mu g m^{-2} s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu g m^{-2} s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu g m^{-2} s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu g m^{-2} s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average ($kg d^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($g d^{-1} h d^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($g d^{-1} AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu g m^{-1} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} h d^{-1}$)	Emission average ($g d^{-} AU^{-1}$)
Period 3												
2/29/2008	6	1	0	0	2.4	22.2	8.9	15.0	39.0	26.8	4.8	3.8
3/1/2008	0	46	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/2/2008	5	23	0	18	2.3	3.0	1.7	1.8	6.0	3.6	0.6	0.5
3/3/2008	8	27	0	3	-0.2	10.5	8.3	1.3	24.8	12.7	2.3	1.8
3/4/2008	0	39	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/5/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/6/2008	10	0	0	10	2.1	13.8	7.9	4.5	26.4	16.6	3.0	2.4
3/7/2008	8	5	1	33	-6.5	57.4	46.4	5.3	122.7	69.3	12.4	9.8
3/8/2008	7	2	1	38	-0.5	15.6	13.0	2.6	34.1	18.8	3.4	2.7
3/9/2008	9	1	5	33	1.2	16.0	7.2	3.3	27.2	19.3	3.4	2.7
3/10/2008	1	0	13	33	7.5	5.0	N/A	5.0	5.0	6.1	1.1	0.9
3/11/2008	2	26	4	2	2.1	10.6	15.0	0.0	21.2	12.8	2.3	1.8
Period 5												
8/10/2008	0	1	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/11/2008	9	18	2	15	1.2	9.4	4.0	3.9	16.0	11.3	2.0	1.6
8/12/2008	22	4	4	16	8.9	9.6	12.9	-33.8	27.7	11.6	2.1	1.6
8/13/2008	1	37	4	3	38.7	-5.7	N/A	-5.7	-5.7	-6.9	-1.2	-1.0
8/14/2008	9	20	4	12	4.7	17.0	5.5	9.3	26.5	20.5	3.7	2.9
8/15/2008	6	19	1	9	16.9	4.8	6.2	0.1	16.9	5.8	1.0	0.8
8/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-1}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-}AU^{-1}$)
8/17/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/18/2008	1	19	1	0	51.6	6.9	N/A	6.9	6.9	8.3	1.5	1.2
8/19/2008	13	19	4	4	50.7	12.5	21.2	-40.8	54.0	15.1	2.7	2.1
8/20/2008	7	33	4	1	104.6	3.2	21.6	-37.7	25.9	3.9	0.7	0.5
8/21/2008	0	47	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2008	8	22	2	12	4.3	13.7	6.7	2.8	23.0	16.5	3.0	2.3
8/23/2008	14	5	2	18	0.2	17.9	9.1	0.6	37.9	21.6	3.9	3.1
8/24/2008	11	7	6	16	1.3	25.6	16.2	6.4	53.8	31.0	5.5	4.4
8/25/2008	11	26	3	2	6.2	11.8	9.1	1.8	30.2	14.2	2.5	2.0
8/26/2008	10	33	1	1	1.4	18.6	9.5	4.2	36.8	22.5	4.0	3.2
8/27/2008	3	27	4	7	-12.2	10.5	4.9	6.2	15.9	12.7	2.3	1.8
8/28/2008	17	16	3	9	-4.3	19.9	13.8	5.4	58.8	24.1	4.3	3.4
8/29/2008	9	21	2	9	4.9	15.6	8.4	2.2	24.5	18.9	3.4	2.7
8/30/2008	0	47	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/31/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/1/2008	2	45	0	1	4.0	17.2	14.8	6.7	27.6	20.7	3.7	2.9
9/2/2008	10	25	0	13	2.1	11.1	8.5	1.4	24.1	13.5	2.4	1.9
9/3/2008	3	16	0	6	2.1	6.2	2.6	4.2	9.1	7.5	1.3	1.1
Period 6												
9/4/2008	0	9	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/5/2008	4	19	0	14	2.4	11.1	4.0	5.5	15.0	13.4	2.4	1.9
9/6/2008	0	35	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/7/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/8/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/9/2008	9	8	1	10	-14.6	12.1	8.3	3.1	32.6	14.6	2.6	2.1
9/10/2008	1	42	1	3	-9.6	22.8	N/A	22.8	22.8	27.6	4.9	3.9
9/11/2008	22	8	1	11	7.5	16.7	10.7	-0.1	38.4	20.2	3.6	2.9
9/12/2008	12	10	2	18	43.9	9.4	8.5	-2.8	26.5	11.4	2.0	1.6
9/13/2008	0	43	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/14/2008	3	2	1	21	-84.2	28.8	21.5	15.2	53.7	34.8	6.2	4.9
9/15/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/16/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/17/2008	9	9	2	5	-4.0	21.2	22.1	2.9	66.0	25.6	4.6	3.6
9/18/2008	18	5	4	12	-3.1	18.7	18.8	3.7	57.9	22.6	4.0	3.2
9/19/2008	6	21	6	10	-15.6	17.7	15.9	0.5	41.7	21.4	3.8	3.0
9/20/2008	12	18	4	7	317.8	9.8	25.1	-52.6	42.8	11.9	2.1	1.7
9/21/2008	2	31	1	12	-11.8	13.9	10.5	6.5	21.4	16.8	3.0	2.4
9/22/2008	3	32	1	12	-21.5	21.4	15.2	4.1	32.8	25.8	4.6	3.7
9/23/2008	3	9	1	12	-24.4	19.2	7.0	14.5	27.3	23.2	4.1	3.3
Period 8												
5/22/2009	17	12	0	16	1.0	1.4	1.4	0.0	5.3	1.7	0.3	0.2
5/23/2009	11	22	0	11	1.2	1.2	1.0	0.2	2.7	1.5	0.3	0.2
5/24/2009	4	38	0	3	0.8	2.2	1.2	0.6	3.6	2.7	0.5	0.4
5/25/2009	2	42	0	3	1.4	0.3	0.4	0.0	0.6	0.4	0.1	0.1
5/26/2009	4	34	0	9	1.1	0.6	0.5	0.3	1.4	0.7	0.1	0.1
5/27/2009	14	14	3	11	1.2	1.9	1.2	0.1	4.7	2.3	0.4	0.3

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-1}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-}AU^{-1}$)
5/28/2009	16	12	7	10	4.2	1.4	1.0	0.1	3.1	1.7	0.3	0.2
5/29/2009	18	8	9	12	4.5	1.8	2.0	-0.4	6.7	2.2	0.4	0.3
5/30/2009	12	24	0	11	1.8	1.2	0.7	0.0	2.3	1.5	0.3	0.2
5/31/2009	9	22	3	9	1.5	1.0	1.1	0.1	3.4	1.2	0.2	0.2
6/1/2009	7	30	0	10	1.1	1.7	1.4	0.3	4.0	2.0	0.4	0.3
6/2/2009	27	5	8	5	1.7	1.9	0.7	0.1	3.0	2.2	0.4	0.3
6/3/2009	11	24	1	11	0.2	2.2	2.0	0.7	7.7	2.7	0.5	0.4
6/4/2009	5	9	0	18	3.7	0.6	0.7	0.1	1.3	0.7	0.1	0.1
Period 9												
6/5/2009	1	10	0	0	0.8	1.0	N/A	1.0	1.0	1.2	0.2	0.2
6/6/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/7/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/8/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/9/2009	13	1	0	1	1.7	0.4	0.5	-0.3	2.0	0.5	0.1	0.1
6/10/2009	20	14	0	14	4.6	0.3	0.4	-0.7	0.8	0.3	0.1	0.0
6/11/2009	4	24	0	15	2.4	3.0	5.8	0.0	11.6	3.6	0.6	0.5
6/12/2009	17	17	1	9	1.4	0.8	2.9	-0.3	11.9	1.0	0.2	0.1
6/13/2009	13	13	2	15	0.9	1.2	2.1	-0.3	6.4	1.4	0.2	0.2
6/14/2009	11	33	0	0	2.2	0.1	0.2	-0.1	0.4	0.2	0.0	0.0
6/15/2009	4	37	0	7	0.8	0.8	1.1	0.0	2.5	1.0	0.2	0.1
6/16/2009	7	33	0	8	2.2	5.8	8.4	0.0	24.1	7.0	1.2	1.0
6/17/2009	0	41	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/18/2009	6	32	0	7	1.7	0.3	0.3	-0.1	0.8	0.4	0.1	0.1
6/19/2009	7	8	1	16	2.0	0.6	0.6	0.1	1.9	0.7	0.1	0.1

Final Report
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for the
NATIONAL AIR EMISSIONS MONITORING STUDY

Final Report
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for the

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to

John Thorne, Executive Director
Agricultural Air Research Council
C/O Crowell and Moring, LLP
1001 Pennsylvania Avenue, NW
Washington, DC 20004

and

Bill Schrock, Environmental Engineer
U.S. EPA Office of Air Quality Planning and Standards
Mail Code E143-03, 4930 Page Road
Durham, NC 27703

from

Albert J. Heber, Professor and NAEMS Science Advisor
Agricultural and Biological Engineering, Purdue University
225 S. University St.
West Lafayette, IN 47907

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Contributors:

Jenafer Wolf, Alfred Lawrence, Scott Cortus, Benjamin Evans, Chris Fullerton, Derrick Snyder, Hans Schmitz, and Gianna Hartman

Purdue University, West Lafayette, IN

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1 Overview

1.1 Introduction

The primary goals of the National Air Emissions Monitoring Study (NAEMS) were to: 1) quantify aerial pollutant emissions from dairy, pork, egg, and broiler production facilities, 2) provide reliable data for developing and validating emissions models for livestock and poultry production and for comparison with government regulatory thresholds, and 3) promote a national consensus on methods and procedures for measuring emissions from livestock operations. NAEMS consists of two components: a barn component and an open source component. Open source emissions measurements were conducted at a total of 10 different farms in the continental US. Farms chosen for monitoring were selected based on the location (relative to climate and typical practice), method of manure collection, manure storage and physical configuration of the buildings and lagoons/ basins relative to the surrounding terrain.

The NAEMS was managed by Purdue University, in its role as Independent Research Contractor (IRC) to the Agricultural Air Research Council (AARC). The Purdue Applied Meteorology Laboratory (PAML) maintained and calibrated equipment, collected samples, conducted all other on-site activities, and analyzed the data for all open sources.

The objective of this report is to present the quality-assured measurements of ammonia (NH_3), hydrogen sulfide (H_2S) emissions from two lagoon open sources at the mid-western dairy facility. Within that objective, this report will:

- Describe the farm and the lagoon/basin monitored for the NAEMS
- Describe the monitoring methods and quality assurance
- Present tabulated daily averages of emissions

1.2 Procedures

To meet these objectives, gaseous emissions of NH_3 and H_2S from open sources were measured at a number of farm operations with a range of characteristics. Emissions were measured at a total of 10 farms over the course of two and one-half years.

The emissions from the two lagoons were measured to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Emissions were measured using models that rely on concentration and wind flow measurements. Lagoon emissions were measured for up to 21 d each season over two years. The duration of measurement periods designated ‘up to 21 d’ depends on the weather conditions during the 21-d interval for measurement. The DQO for completeness stipulates a 75% completeness of 10 d per quarter. Setting aside 21 d per quarter to acquire at least 7.5 d of valid data (75% of 10 d) minimized the risk of not meeting this completeness DQO due to instrumentation problems associated with unfavorable weather conditions.

Atmospheric concentrations of NH_3 around the lagoons were measured using narrow-bandwidth open path tunable-diode laser absorption spectroscopy (TDLAS). Atmospheric measurements of H_2S concentrations were made using pulsed fluorescence (PF) technology from air collected from 50 m synthetic open path systems (S-OPS) and sampled from a gas sampling system (GSS) that drew the air through the S-OPS. Emissions of NH_3 were determined from the difference in upwind and downwind concentration measurements from the TDLAS open path systems using two emissions models: a Gaussian plume fit model (Radial Plume Mapping: *RPM*; Arcadis Inc,,

Denver, CO) and a backward Lagrangian Stochastic (bLS) model (*WindTrax*; Thunder Beach Scientific, http://www.thunderbeachscientific.com). Emissions of H_2S were determined using the concentration measurements from the PF analyzer from air sampled by the air inlets of the S-OPS using two emissions models: a Ratiometric model using the ratio of these concentrations to NH_3 concentrations along the same path with the corresponding *RPM* NH_3 emissions measurement, and the bLS model. The critical measurements needed to make the emissions measurements are described in Table 1-1.

Measurements of the lagoon pH, oxidation-reduction potential, and temperature at 0.3 m depth were also measured from a float located at least 30 m from the lagoon inlet (Table 1-2). Measurements of the atmospheric temperature, relative humidity, barometric pressure, solar radiation and wetness were measured and recorded at an automated weather station established on the lagoon berm (Table 1-2).

Table 1-1: Critical measurements

Measurement	Method/ Instrument	Required operating range	MDL	Minimum sample frequency	Final data-aggregation
NH_3	TDLAS/ Boreal Laser, Inc. GasFinder2	1-800 ppb	5 ppm-m	1.2 s dwell	30 min & 24 h
H_2S	PF/Thermo Environmental 450i analyzer	1-800 ppb	2 ppb	60 s averaging	30 min & 24 h
Wind speed	3D Sonic anemometer/ RM Young 81000	0-60 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
Wind direction	3D Sonic anemometer/ RM Young 81000	0° -360°	0.1^o	160 Hz sampling/ 16 Hz averaging	30 min & 24 h
3D turbulence wind components	3D Sonic anemometer/ RM Young 81000	0-40 ms^{-1}	0.01 ms^{-1}	160 Hz sampling/ 16 Hz averaging	30 min
Temperature variability	3D Sonic anemometer/ RM Young 81000	-50 to +50°C	0.01°C	160 Hz sampling/ 16 Hz averaging	30 min
GSS sample flow rate	GSS/SOP-S	10 L min^{-1}	0.1 L min^{-1}	30 s	30 min
GSS sampling manifold pressure	GSS/SOP-S	±60,000 Pa	±500 Pa	30 s	30 min
NH_3 emissions	Radial Plume Mapping Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
NH_3 emissions	Backward Lagrangian Stochastic Model	N/A	N/A	30 min	30 min, 24 h
H_2S emissions	Ratiometric to RPM Model	N/A	N/A	30 min	30 min, 24 h

All measurements from around the lagoon (TDLAS, barometric pressure, air temperature and relative humidity, wetness, solar radiation, lagoon pH, lagoon oxidation-reduction potential, lagoon temperature, and wind) were telemetered to an instrumentation trailer on site via radio communications. The instrumentation trailer also housed the GSS (with associated pressure,

flow, temperature and humidity measurements) and PF analyzer for the measurement of H_2S in the S-OPS collected air and two computers that controlled the two TDLAS scanners and collected measurements made by the two TDLAS units. All measurements were then stored on a computer in the trailer that was downloaded daily by file transfer protocol (FTP) via the internet to a computer located at the PAML.

Additional information concerning farm operations and the United States Department of Agriculture National Resource Conservation Service (USDA NRCS)-required analysis of wastewater used to irrigate nearby fields was routinely collected from the producers.

Table 1-2: Non-critical measurements.

Measurement	Method/ Instrument	Required Operating range	MDL	Minimum sample frequency	Final Data-Aggregation
Ambient temperature	Thermistor/ Campbell Scientific Inc HMP45C (Vaisala)	-40 to 50 ^{o} C	0.1 ^{o} C	5 min	30 min, 24 h
Relative humidity	Hygrometer/ Campbell Scientific Inc HMP45C (Vaisala)	0-100%	5%	5 min	30 min, 24 h
Barometric pressure	Aneroid barometer/ Setra 278	600 to 1100 hPa	600 hPa	5 min	30 min, 24 h
Surface wetness	VAC resistance grid/ Campbell Scientific Inc.	(binary)	(binary)	5 min	30 min, 24 h
Solar radiation	Silicon pyranometer/ LiCOR 190SB	0- 1200 W/m^2	10 W/m^2	5 min	30 min, 24 h
Lagoon solids depth	Sludge level detector/ SludgeGun 10HD, Markland Specialty Eng.	0-10 m	0.05 m	1/ measurement period	1 time
Lagoon/ basin pH	Campbell Scientific Inc CSIM11 (Innovative Sensors, Inc)	0-14 units	0.2 unit	5 min	30 min, 24 h
Lagoon/ basin Oxidation-Reduction Potential potential	Campbell Scientific Inc CSIM11-ORP (Innovative Sensors, Inc)	-800 - +1100 mV	20 mV	5 min	30 min, 24 h
Lagoon/ basin Temperature	Thermistor/ Campbell Scientific Inc 107-L	-35 - +50 ^{o}C	0.5 ^{o}C	5 min	30 min, 24 h

1.3 Farm description and operation

The Midwest freestall dairy facility was located in WI. The elevation at the farm was approximately 332 m. The farm had a total of 6 barns, a milking parlor with holding pen, and a special needs area. The farm had a capacity of 1,700 Holstein cows.

Manure from the freestall barns and the milking parlor complex was removed by flushing three times daily. The manure flushed from the parlor, holding pen, and freestall barns flowed to a solids separator, from which the solids are removed and stacked on a pad until they are spread on fields (the nearest of which is approximately 100 m from the barns) (Figure 1-1). The liquid effluent from the solids separator was pumped back into vertical tanks for reuse to flush the barns. Once a week, enough water was removed from the third stage of the three-stage lagoon and added to the flush tanks to compensate for water lost in the recycled flush system. The

lagoons were pumped out into trucks twice yearly. The first and second stages of the three-stage lagoon system were monitored (Figure 1-1). These lagoons had an outer berm height of 6 m to the west, and between 1 and 6 m to the north. The 1st lagoon at maximum capacity had a surface area of 4,264 m^2 and a volume of 10,563 m^3. The second lagoon at maximum capacity had a surface area of 2,898 m^2 and a volume of 6,420 m^3.

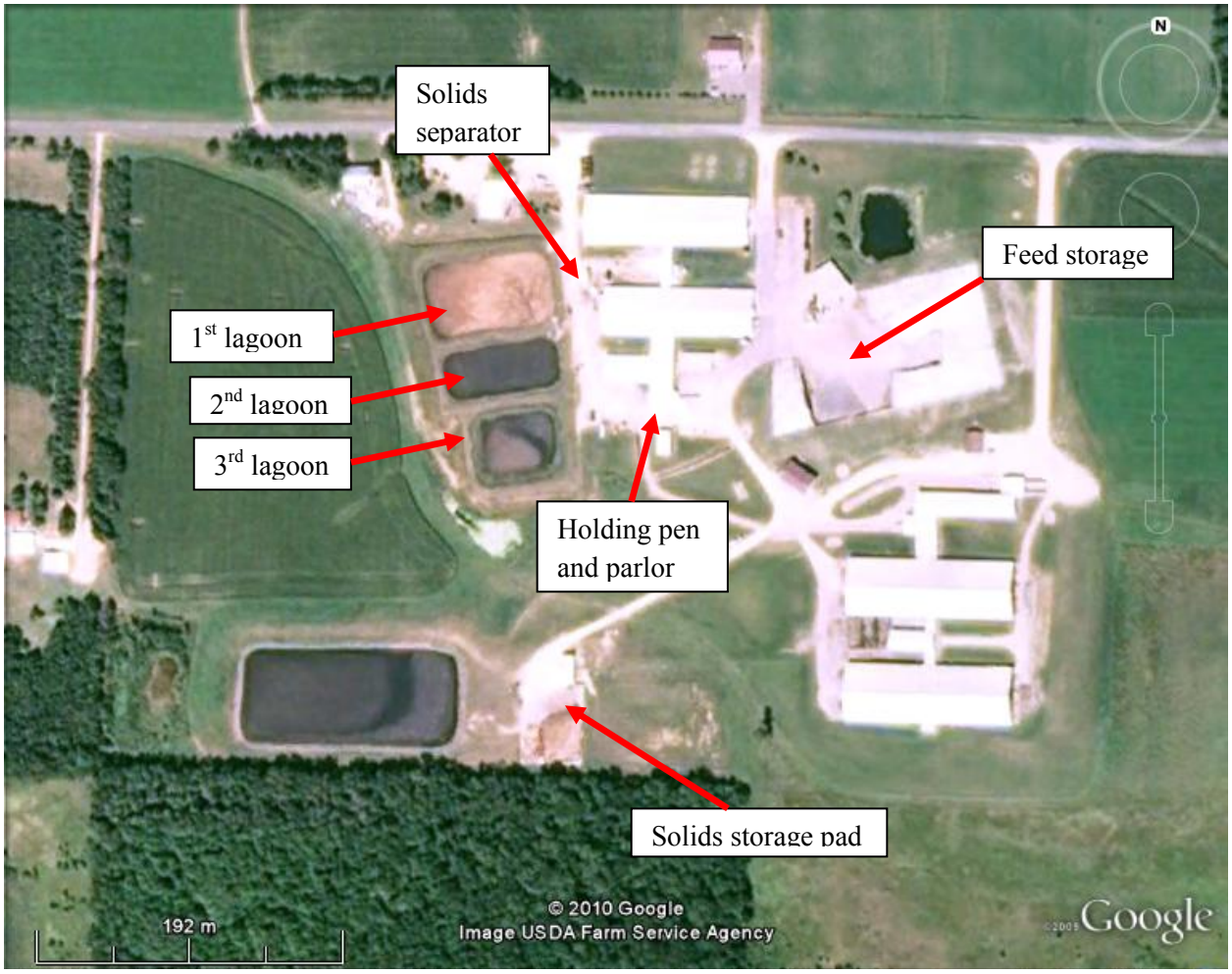

Figure 1-1: Configuration of the WI5A farm.

1.4 Changes in farm operation

The producer modified the bedding and routing of the wastewater several times during the study (Table 1-3).

Table 1-3: Operational changes during the study.

Period	Events during period
1: 7/17-8/28/2007	No events
2: 11/12-11/29/2007	No events
3: 11/29-12/18/2007	No events
4: 4/22-5/13/2008	No events
5: 6/24-7/15/2008	7/15/2008: Modification of wastewater routing: Pumped water from solids separator system to sand separator with excess water from solids separator pumped to lagoon 1
6: 10/20-11/11/2008	10/28/2008: Changed Bedding from Shavings to Recycled Sand 10/30 7:50am (CDT) -10/31/2008 1:00pm: Lagoon 1wastwater emptied into trucks. 11/25/2008: Changed Bedding to Sand
7: 12/17/2008-1/7/2009	Modification of wastewater routing: For entire duration of period water was sucked from parlor flush system and unloaded on top of ice in lagoon 1 (this action required because buried pipe plugged and will continue until permanent fix installed in spring).
8: 3/09-4/7/2009	3/9-3/15/2009: Modification of wastewater routing: Water was sucked from parlor flush system and unloaded on top of ice in lagoon 1. 4/6/2009: Started emptying wastewater from lagoons 1 and 2 into trucks. 3/16/2009: Bedding switched to a mix of sand and recycled sand 3/23/2009: Bedding switched to recycled sand

1.5 Measurement layout

The NH_3 emissions from the basin were monitored for 8 to 20 days each quarter of the year for two years using scanning Tunable Diode Laser Absorption Spectrometer (TDLAS) open-path instruments and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and the radial plume mapping (*RPM*) and backward Lagrangian Stochastic (bLS) emissions models. The H_2S emissions from the lagoon were monitored using pulsed-florescence (PF) of air sampled through a Synthetic Open Path System (S-OPS) and 3-dimensional (3D) sonic anemometers, in conjunction with meteorological measurements and both the bLS emissions model and the *RPM* emissions model in combination with the ratiometric relationships of measured NH_3 and H_2S concentrations.

The path-integrated concentrations (PICs) of NH_3 were measured by TDLAS along optical paths defined by TDLAS/scanner systems and retro-reflectors. The scanning TDLAS instruments were mounted at 1-m heights above berm level (abl) on anchored tripods at the northeast berm corner of the 1st stage lagoon and off the southwest berm corner of the 2nd stage lagoon. Towers for mounting retro-reflectors were located at the southeast corner of the 2nd stage lagoon and at the northwest corners of the 1st stage lagoon (Figure 1-2). A description of the position and path length of the optical paths along each side of the lagoon follows:

- North side of 1st stage lagoon: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 30.5 m and 60 m from the northeast TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 111 m from the TDLAS/scanner at heights of 1.1 m, 7.2 m, and 13.3 m abl.
- East side of lagoons: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 34 m and 73 m from the northeast TDLAS/ scanner. Three retro-reflectors

were mounted on the southeast tower 102 m from the TDLAS/scanner at heights of 1.2 m, 6.3 m, and 13.8 m abl.

- South side of 2nd stage lagoon: Retro-reflectors were located on anchored tripods at 1 m abl at distances of 24.5 m and 54 m from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the southeast tower 83 m from the TDLAS/scanner at heights of 1.2 m, 6.3 m, and 13.8 m abl.
- West side of lagoons: Retro-reflectors were were located on anchored tripods at 1 m abl at distances of 30 m and 60 m from the southwest TDLAS/scanner. Three retro-reflectors were mounted on the northwest tower 108 m from the TDLAS/scanner at heights of 1.1 m, 7.2 m abl, and 13.3 m abl.

Two synthetic PICs of H_2S were measured by PF from air sampled from linear S-OPS positioned at 1-m abl. A 50-m long S-OPS path was parallel to the north berm and began at the northwest berm corner of the 1st lagoon and 2.5 m from the north berm and ran west, parallel to the berm (Figure 1-2). The second 50-m long S-OPS was parallel to the south lagoon berm and began at the southwest berm corner of the 2nd stage lagoon and extended east between the 2nd and 3rd stage lagoons (Figure 1-2). The flow through the S-OPS was maintained and sampled by a gas sampling system (GSS) located in the on-site instrumentation trailer. The temperature and humidity of the air flowing through the GSS, as well as the flow rate through and the suction in the negative-pressure portion of the GSS were measured and recorded on a data logger (Model CR800, Campbell Scientific, Logan, Utah).

Meteorological instruments (barometric pressure, air temperature, relative humidity, solar radiation, and surface wetness) were mounted on the meteorological tower located on the berm between the 1st and 2nd stage lagoons, 20 m to the east of the 2nd lagoon northwest corner (Fig. 1-2). The 3D sonic anemometers were located on the meteorological tower at 2.5 m heights, between the 1st and 2nd stage lagoons (Fig. 1-2), and at 4.1 m and 16.7 m heights above berm level (abl) on the southeast corner tower.

Fetch from the TDLAS beam line along the north berm of the 1st stage lagoon was 1:2.5 (42 m distance, 16 m tree height) (Fig. 1-2). Fetch from the TDLAS beam line south of the south berm of the 2nd stage lagoon was greater than 1:100 while that to the north was 1:8.6. Fetch to east from the TDLAS beam line along the east of the three lagoons is 1:4.6 (7 m high at a distance of 31 m) with the 2nd barn, 1:3.1 (6 m high at a distance of 20 m) with the 1st barn and 1:3.5 (4 m high at a distance of 14 m) with the 3rd barn. Fetch from the S-OPS path along the north berm of the 1st stage lagoon was 1:3 (42 m distance, 16 m tree height) (Fig. 1-2). Fetch from the S-OPS path south of the south berm of the 2nd stage lagoon was greater than 1:100, while that to the north is 1:8.6. Due to poor fetch to the east of the beam lines, measurements were excluded from analysis when winds are from 0° through 180°.

Lagoon measurements (pH, oxidation-reduction potential, and temperature) were made from a float located in the SE corner of the 1st lagoon and when possible the NE corner of 2nd lagoon.

Figure 1-2: Locations of instrumentation around the lagoon under measurement. Retro-reflectors are indicated according to side (N,S,E,W) with 345 indicating the location of a tower. TDLAS/scanner locations are indicated by TS. The location of the two S-OPS are indicated by the solid yellow lines. The instrumentation trailer was located in the northeast corner of the lagoon.

2 Monitoring activities

2.1 Measurement periods

This location was measured as part of an approximate 20-d rotation between three other farms. The equipment was on site 185 d over eight measurement periods (Table 2.1-1). Setup calibrations and site takedowns reduced the number of measurement days from the total number of days on site. NH_3 emissions were measured 176.7 d and H_2S emissions were measured 100 d.

Table 2.1-1: Days on Site

Period	Start date	End date	# days
1	7/18/2007	8/28/2007	41
2	11/13/2007	11/28/2007	15
3	11/28/2007	12/18/2007	20
4	4/23/2008	5/13/2008	20
5	6/25/2008	7/14/2008	19
6	10/21/2008	11/11/2008	21
7	12/17/2008	1/7/2009	21
8	3/10/2009	4/7/2009	28

2.2 Site visits

The field operation team involved in the on-site calibration checks, set-up, and take-down visited this farm 32 d (Table 2.2-1).

Table 2.2-1: Dates of site visits

WI5A	Spring	Summer	Fall	Winter
2007		Jul 17,18,19 Aug 6,7,9,28	Nov 13,14,27,28,29	Dec 17,18
2008	Apr 24, May 12,13,	Jun 24,25 Jul 14,15	Oct 21,22 Nov 11	Dec 17,18 Jan 6,7
2009	Mar 9,10 Apr 6,7			

2.3 Instrumentation QA/QC

Calibration verification checks of the instruments making the critical measurements and some of the non-critical measurements most susceptible to deterioration were generally conducted within 21 d intervals on site. Instruments checked during these visits (with indication of Section documenting the instrument performance and calibration verification check results) included:

- GasFinder2 NH3 TDLAS serial number (s/n) 1026, 1028, 1030 and 1031 (Section 6.1)
- TEC 450i H_2S Analyzer s/n 0733825129 (Section 6.2)
- RM Young 81000 3D sonic anemometers s/n 1920, 1926, 1928, 1932, 1933 and 1945 (Section 6.3)
- lagoon pH probes s/n 001 and 004 (Section 6.4)

- lagoon ORP probe s/n 020 and 040 (Section 6.5)
- GSS/ S-OPS s/n 4-0018 (Section 6.6)

In addition, the instruments making the critical measurements were calibrated at least semi-annually. During the semi-annual calibrations, multipoint calibrations were conducted on the TDLAS (Section 6.1) and TEC 450i (Section 6.2) instruments and an inter-comparison conducted on the sonic anemometers (Section 6.3) with three unused 'reference' anemometers. An inter-comparison of three TDLAS units (s/n 1027, 1028 and 1031) was conducted at this location on April 23, 2008.

2.4 Audits

Two internal audits were conducted at this location: 1) on 23 April 2008 with particular attention to the sonic anemometer inter-comparison and TDLAS calibration verification, and 2) on 28 November 2008 with particular attention to the operation documentation.

2.5 Remote site checks

Over the course of measurements, there were 61 remote checks made through the computer for instruments operating at this location.

2.6 Measurement data acquisition

Data from the TDLAS units (Model GasFinder2 NH3-OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were acquired using the Boreal Laser *GasView MP* software (Boreal Laser Inc., Spruce Grove, Alberta, Canada) program running on laptops dedicated to this purpose (one laptop per TDLAS unit). The TDLAS units sent back data through 2.4 GHz wireless modems about every 1.2 s. This software also controlled the movements of the scanner (Model PTU-D300, Directed Perception Inc., Burlingame, CA) that aimed the TDLAS units.

Weather and lagoon data were saved to the internal memory of the data logger (Model CR1000, Campbell Scientific Inc, Logan, UT) at 5-min intervals. Optimally, these data were transferred to the trailer through 2.4 GHz wireless modem at intervals of 10 min using *Loggernet* software (Campbell Scientific Inc, Logan, UT). However, communications interference at a number of sites significantly impeded this regular data transfer. Thus, it was sometimes necessary to download data directly to a laptop during site visits. The data were then transferred from the laptop to the trailer computer using a USB thumb-drive. As a backup, all data were also stored on a compact flash memory card that was brought back to Purdue and downloaded after each period.

Data from the gas sampling system (GSS) were saved to a data logger (Model CR800, Campbell Scientific Inc, Logan, UT) located in the trailer at intervals of 30 s. These data included the line currently being sampled and the mass flow rate. The data were transferred through a serial cable to the trailer computer every 10 min using *Loggernet*.

Data from the H_2S analyzer (Model 450i, Thermo Fisher Scientific, Franklin, MA)were downloaded in real-time through a serial cable to the trailer computer using the *iPort* (Thermo Fisher Scientific, Franklin, MA) software program. The *iPort* software frequently disconnected from the analyzer, so that during our daily status checks from PAML it was frequently necessary

to reconnect *iPort* to the analyzer, download data back to the time when *iPort* had crashed and stopped collecting data, and restart real-time data collection

Data from the 3D sonic anemometers (Model 81000, RM Young Inc., Traverse City, MI) were downloaded to the data acquisition computer in the trailer using custom built Visual Basic software. Binary data from up to four anemometers were transferred at 16 Hz through 900 MHz wireless modems to a single polling modem connected to the data acquisition computer in the trailer. The software time stamped and stored each 16 Hz data point and calculated 100-s and 300-s averages, variances, and covariances for each component of the wind and the sonic temperature.

Files were transferred from the instrument trailers to the PAML FTP server using the program *rsync* in the *cygwin* environment (open source programs). This transfer took place every six h, as long as the internet connection was available. The program was set up so that only new or modified files were transferred each time, so that only the updated data were transferred. A log of each file transferred was produced by the *rsync* program. The *rsync* program was used to transfer data daily from the PAML FTP server to the PAML data computer. This transfer was performed early each morning before the automated quality control software runs. Two copies of the data were stored on the Data computer. One copy was placed in the directory "FTP" and was never modified. This copy represents the original data as transferred from the trailers. The other copy of the data was placed in the directory "Data". The data processing and quality control programs used this copy of the data, and modifications and corrections were made to this copy of the data as needed to allow the data to be processed. These modifications will be described below. It is important to note that no actual data numbers were changed during these modifications.

In addition to the copies of the data transferred over the internet, a copy of the data for each period was produced on a CD and DVD. To ensure complete and accurate data transfer, a data comparison program was used to compare the data on the CD/DVDs with the data in the "FTP" directory.

3 Data Processing and analysis

Before final data processing, the data files were examined to ensure that they were ready to be processed. Modifications to the files were required due to human error, issues related to changing from one site or period to another, and bugs in the data collection software. None of the actual data were modified in this file preparation, only filenames and/or the file in which the data appeared were changed. A detailed log was kept of each modification.

Deleting empty files: Data files created but not filled with data occurred as a byproduct of the data collection systems. The sonic anemometer data collection program was set up to start automatically when the trailer LAN server computer (hereafter termed LAN) was started. As a result, when the LAN was started at a new location empty files were often created because the sonic anemometers were not yet in place. If the location and/or period were not adjusted in the sonic parameter input file before the computer was shut down at the previous site, these empty files would be present in the directory from this previous location or period. These empty files contain no data and were deleted. Empty files also sometimes occurred for the TDLAS units if the TDLAS laptop was still logging but no data were being transferred from the TDLAS. These empty files were generally deleted, although they were sometimes retained since empty files can be handled by the data analysis and QC software. Even if deleted from the "data" directory, these empty files will still be present in the "FTP" directory, and in some cases these empty files will be useful in determining whether missing TDLAS data are due to problems with the TDLAS unit itself or with the TDLAS data collection laptop computer. Empty files in other data sets were also deleted.

Moving/deleting data from surrounding periods: When moving from one site to another or switching periods during a "back-to-back" site visit, several changes need to be made for the data to be saved in the directories for the new site or period. If these changes were not made when the LAN was first started or before the computer was shut down at the preceding site , data for the new site was often saved in the directory for the preceding site. Data were moved from the file for one site to the file for the correct site. Data to be moved were identified by breaks in the data timestamps corresponding to the period when the equipment was shut down and in transit from one site to the next. Data were most often moved in the files for the CR1000 data logger and GSS (CR800 data logger), as these data files started adding new data immediately when the LAN was turned on, and it was easy to forget to immediately make the directory and file name change in *Loggernet*.

Combining data files: The *iPort* software used to collect data from the H_2S analyzer occasionally lost its connection with the analyzer causing the data collection to stop. These events were noticed during the daily site checks from PAML at which time the missing data were filled from the internal memory on the analyzer and a new data file was started to collect the data in real-time. To allow the quality control software to run most efficiently, these multiple data files were combined into a single file at the conclusion of the period. The files that were included in this single file were placed in a subdirectory of the H_2S data folder named "Pieces". On isolated occasions, the CR1000-logged or CR800-logged data for a period were split into more than one file, and these data files were generally combined into a single file for the period, unless a change was made to the data stream in between the files (e.g. adding temperature and relative humidity probe to the gas sampling system output).

Renaming files: On some occasions, files had to be renamed due to human error in naming the files or, in the early days of the project, because of the lack of a finalized file structure in which the field operations staff had been trained. These changes were primarily to the TDLAS data files, when the files on the TDLAS laptops were not named appropriately or else TDLAS1 and TDLAS2 were reversed. Various files for other instruments also had to be renamed for a variety of reasons.

Data Processing and Quality Control Input Files: The data processing and quality control software programs require inputs that describe the data to be analyzed. The input parameters for a given site and period are in a single *Excel* workbook consisting of a separate worksheet for each component of the data processing software. These parameter files were produced and then independently double-checked for errors.

3.1 QA/QC software procedures

The valid data times were produced by examining the data in a preliminary run through the data and finding in the records the times when the instrument was calibrated and times when the instrument was known to be malfunctioning. The data excluded as being from a calibration or period of instrument malfunction were placed in separate columns in the output files and plotted in a different color on the output graphs.

Because measurements were acquired on various data acquisition systems, time synchronization of the various systems was critical. The time synchronization data were obtained from the remote site visits conducted as part of the daily status checks. Time corrections were only included if the instrument time was more than one minute off from the LAN. In the end, corrections were made only to the TEC 450i H_2S analyzer as this instrument would infrequently be out of sync by several minutes due to issues with its automatic time updates. The time synchronization is especially important for the TEC 450i because it samples from lines located on both sides of the lagoon and the time difference could lead to H_2S concentrations being recorded for the wrong S-OPS line (side of source).

One worksheet in the *Excel* parameter workbook for each site contains a list of the times of valid data for each data stream and one worksheet indicates when an instrument was out of time synchronization with the LAN as well as the time correction required to bring the data stream into time synchronization with the LAN.

Once the data files were prepared for final processing and the input parameter files were produced for each site and period, the data were processed through the custom designed software for this purpose. Through the duration of the project, each data stream was processed through a separate program, but in preparation for the final data processing these individual programs were combined into a single program to allow for more efficient data processing and easier debugging, as processes that were previously done multiple times in the earlier software versions are now done only once.

The order in which the various data streams were processed was determined by the dependencies in the data processing and quality control between the various instruments: a given data stream may depend on one or more of the preceding streams, but not on following data streams. For each data stream, the data were first loaded into arrays and any corrections for time synchronization applied. The flags were then assigned based on the QAPP. After this, the data

exclusion times were applied and the data appropriately broken up into columns. Finally, the data were loaded into *Excel*, plots were produced, and the final data files were saved.

3.2 Data exclusions

Data were excluded from processing due to equipment failures, calibration failures, and because calibration checks were in progress. Periods of invalidated measurements associated with the calibration check failures are documented in the calibration reports in Section 8. Significant data exclusions of greater than one-day duration are indicated below by instrument. All time references are in Coordinated Universal Time (UTC):

TDLAS measurement exclusions: Examples of events resulting in measurement exclusions include the following issues. Specific events are described in Table 3.2-1

Table 3.2-1: TDLAS exclusion events

Begin		End		Reason
8/20/2007	03:40	8/23/2007	15:50	TDLAS 2 Unknown failure
11/14/2007	19:00	12/5/2007	22:30	West side of the lagoon will have no RPM due to TDLAS 2 path 6 being aimed at retro-reflector7
12/6/2007	07:45	12/11/2007	22:45	TDLAS 1 Scanner failure
12/12/2007	07:00	12/17/2007	22:00	TDLAS 1 Scanner failure
12/1/2007	23:45	12/5/2007	20:50	TDLAS 2 Snow/ice storm
3/13/2009	variable	3/16/2009	variable	TDLAS 1 shifted due to snow/icemelt
3/14/2009	variable	3/16/2009	variable	TDLAS 2 shifted due to snow/icemelt
4/28/2008	03:10	5/12/2008	22:00	TDLAS 1 Centerline duty cycle maxed out
3/30/2009	12:00	4/3/2009	18:30	Both TDLAS laptops locked up

Wetness measurement exclusions: Wetness sensor measurements were excluded from 8/4/2007 through 8/28/2001, from 11/14/2007 through 11/27/2007, and from 11/28/2007 through 12/18/2007. These events are described in Table 3.2-2.

Table 3.2-2: Wetness sensor exclusion events

Begin		End		Reason
8/4/2007	00:00:00	8/28/2007	14:20:00	Wetness sensor started showing wetness for entire period after 8/4
11/14/2007	22:30:00	11/27/2007	22:55:00	Sensor malfunction
11/28/2007	20:45:00	12/18/2007	14:15:00	Sensor malfunction

Pressure measurement exclusions: Due to a large spike in the pressure reading, pressure sensor measurements were excluded from 12:55 to 15:15 on 10/28/2008.

Sonic anemometer measurement exclusions: Sonic anemometers experienced communications interference throughout the study. Excluded measurements are summarized in Table 3.2-3.

Table 3.2-3: Sonic anemometer measurement exclusions

Begin		End		Reason
8/7/2007	13:45	8/7/2007	19:00	Calibration check
12/1/2007	23:50	12/5/2007	17:10	All sonic anemometers Icing
12/7/2007	00:35	12/7/2007	17:20	All sonic anemometers Icing
7/8/2008	02:35	7/10/2008	19:55	Sonic anemometer 1 no data transferred (unknown reason)
10/24/2008	07:35	10/27/2008	03:45	Sonic anemometer 3 extensive flagging
12/26/2008	15:24	12/30/2008	19:35	Sonic anemometer 3 extensive flagging
1/3/2009	22:10	1/5/2009	16:00	Sonic anemometer 3 icing
1/3/2009	22:20	1/4/2009	19:25	Sonic anemometers 1 and 2 icing
4/4/2009	13:30	4/6/2009	12:45	All sonic anemometers have no data; program failure?

Lagoon temperature, pH, and ORP measurement exclusions: When possible, lagoon measurements were made on both lagoons. Excluded measurements are summarized in Table 3.2-4.

Table 3.2-4: Lagoon temperature, pH, and ORP measurement exclusions

Begin		End		Reason
Lagoon 1 temperature probe				
7/20/2007	13:55:00	7/20/2007	14:10:00	Removing other probes
8/7/2007	21:25:00	8/7/2007	21:35:00	Adding other probes
8/9/2007	14:50:00	8/9/2007	15:30:00	Removing other probes
11/28/2007	20:45:00	12/18/2007	14:15:00	Probe not in lagoon (frozen)
4/23/2008	15:35:00	5/13/2007	19:10:00	Probe not in lagoon (crusted)
6/26/2008	15:40:00	7/14/2007	20:20:00	Probe not in lagoon (crusted)
10/21/2008	18:25:00	11/11/2008	23:35:00	Probe not in lagoon (empty/dry)
12/18/2008	07:35:00	1/7/2009	18:50:00	Probe not in lagoon (frozen)
3/10/2009	01:40:00	4/7/2009	13:00:00	Probe not in lagoon (frozen)
Lagoon 2 temperature probe				
7/20/2007	13:25:00	7/20/2007	13:55:00	Removing other probes
8/7/2007	21:35:00	8/7/2007	21:50:00	Adding other probes
8/9/2007	14:55:00	8/9/2007	15:05:00	Removing other probes
11/28/2007	20:45:00	12/18/2007	14:15:00	Probe not in lagoon (frozen)
4/23/2008	15:35:00	5/13/2008	19:10:00	Probe not in lagoon (crusted)
6/26/2008	15:40:00	7/14/2008	20:20:00	Probe not in lagoon (crusted)
10/21/2008	18:25:00	11/11/2008	23:35:00	Probe not in lagoon (empty/dry)
12/18/2008	07:35:00	1/7/2009	18:50:00	Probe not in lagoon (frozen)
3/10/2009	01:40:00	4/7/2009	13:00:00	Probe not in lagoon (frozen)
Lagoon 1 pH probe				
7/20/2007	13:25:00	8/7/2007	21:45:00	Only placed in for 1 d
8/9/2007	14:50:00	8/28/2007	14:20:00	Only placed in for 1 d
11/28/2007	20:45:00	12/18/2007	14:15:00	Probe not in lagoon (frozen)
4/23/2008	15:35:00	5/13/2008	19:10:00	Probe not in lagoon (crusted)

Begin		End		Reason
6/26/2008	15:40:00	7/14/2008	20:20:00	Probe not in lagoon (crusted)
10/21/2008	18:25:00	11/11/2008	23:35:00	Probe not in lagoon (empty/dry)
12/18/2008	07:35:00	1/7/2009	18:50:00	Probe not in lagoon (frozen)
3/10/2009	01:40:00	4/7/2009	13:00:00	Probe not in lagoon (frozen)
Lagoon 2 pH probe				
7/20/2007	13:25:00	8/7/2007	21:45:00	Only placed in for 1 d
8/9/2007	14:50:00	8/28/2007	14:20:00	Only placed in for 1 d
11/28/2007	20:45:00	12/18/2007	14:15:00	Probe not in lagoon (frozen)
4/23/2008	15:35:00	5/13/2008	19:10:00	Probe not in lagoon (crusted)
6/26/2008	15:40:00	7/14/2008	20:20:00	Probe not in lagoon (crusted)
10/21/2008	18:25:00	11/11/2008	23:35:00	Probe not in lagoon (empty/dry)
12/18/2008	07:35:00	1/7/2009	18:50:00	Probe not in lagoon (frozen)
3/10/2009	01:40:00	4/7/2009	13:00:00	Probe not in lagoon (frozen)
Lagoon 1 ORP probe				
7/20/2007	13:25:00	8/7/2007	21:45:00	Only placed in for 1 d
8/9/2007	14:50:00	8/28/2007	14:20:00	Only placed in for 1 d
11/28/2007	20:45:00	12/18/2007	14:15:00	Probe not in lagoon (frozen)
4/23/2008	15:35:00	5/13/2008	19:10:00	Probe not in lagoon (crusted)
6/26/2008	15:40:00	7/14/2008	20:20:00	Probe not in lagoon (crusted)
10/21/2008	18:25:00	11/11/2008	23:35:00	Probe not in lagoon (empty/dry)
12/18/2008	07:35:00	1/7/2009	18:50:00	Probe not in lagoon (frozen)
3/10/2009	01:40:00	4/7/2009	13:00:00	Probe not in lagoon (frozen)
Lagoon 2 ORP probe				
7/20/2007	13:20:00	8/7/2007	21:45:00	Only placed in for 1 d
8/9/2007	14:50:00	8/28/2007	14:20:00	Only placed in for 1 d
11/28/2007	20:45:00	12/18/2007	14:15:00	Probe not in lagoon (frozen)
4/23/2008	15:35:00	5/13/2008	19:10:00	Probe not in lagoon (crusted)
6/26/2008	15:40:00	7/14/2008	20:20:00	Probe not in lagoon (crusted)
10/21/2008	18:25:00	11/11/2008	23:35:00	Probe not in lagoon (empty/dry)
12/18/2008	07:35:00	1/7/2009	18:50:00	Probe not in lagoon (frozen)
3/10/2009	01:40:00	4/7/2009	13:00:00	Probe not in lagoon (frozen)

3.3 Data correction procedures

Calibration adjustments based on the multipoint calibrations and calibration verifications were made to the NH_3 and H_2S gas concentration measurements. All concentration measurements were normalized to 101.325 kPa and 20°C (STP) within the instruments. The measured system response corrections used the entire record of calibration verifications and adjusted for a bias associated with the sampling system defined by the EPA Method 301 S-OPS validation by using a correction factor of 0.98. No corrections were required for the sonic anemometer measurements.

3.4 Data validation procedures

3.4.1 NH_3 concentration measurements

Because of the nature of the TDLAS data, the TDLAS routine is the most complicated portion of the data processing and quality control software. It is broken into several subroutines. The first subroutine flags pan/tilt locations that are likely to be in super-saturated "holes" in the retro-reflector array. The TDLAS instrument contains a sensor that detects the intensity of the energy returned from the retro-reflector in arbitrary units. Light levels of between 500 and 12000 are required for data to be considered valid. The light level sensor in the TDLAS instrument has a maximum value of 16368 (arbitrary units). Additional returned energy causes the light level to decrease. This creates a super-saturated condition in which the light levels appear valid, but in reality the returned energy is much greater than the allowable threshold for a valid reading. This leads to erroneous instrument readings, frequently indicated by low r^2 values that are associated with large path integrated concentrations (PICs). The term "hole" refers to a region of light levels that appear valid surrounded by maxed-out light levels. A hole is a region where the instrument will give faulty data, even though the light levels appear valid. The hole-finding algorithm goes through all the data points defined in "optimize" strings output by the instrument each time the scanner moves to a new location and determines data points that either have maximized light levels (16368) on the current day or else are surrounded above and below or to the left and to the right by points that have maximized light levels on the current day. The routine produces a list of locations (pan and tilt) and days that are probably super-saturated.

The next subroutine inputs all the concentration data and calculates averages over each dwell on a retro-reflector array. A scanner moved the TDLAS from one retro-reflector to another, dwelling for about 15 seconds on each retro-reflector array. The *GasView MP* program produced a flag that indicated when the scanner was moving. Once this flag indicated that the scanner had stopped its movement, one additional 1-second value was ignored, and then the remaining points were averaged to produce the dwell averages. The additional ignored value helped reduce the occurrence of data from the preceding path leaking into the current path because of communications delays.

On the next pass, concentration data from pan/tilt locations and days that were determined to be super-saturated were flagged as super-saturated. However, it was found that simply using the light levels as the super-saturation criteria resulted in the removal of much data that was clearly not super-saturated. To determine which points truly were super-saturated and which were not, a threshold curve of PIC as a function of r^2 was produced (for valid data, r^2 generally increases as PIC increases). As part of the determination of this PIC vs. r^2 threshold, a record was kept for each retro-reflector array of the ten largest path integrated concentrations corresponding to each r^2 value from pan/tilt locations that were not determined from the initial hole-finding routine to be super-saturated. Based on this top-ten record, the PIC vs. r^2 threshold was determined by searching for outlying values that might indicate a PIC value that should have been indicated as super-saturated but were not.

Once the PIC vs. r^2 threshold curve was determined, a final pass was made through the data, this time comparing the PIC value for each data point with the threshold value at the current r^2. This resulted in four categories of points depending on whether or not super-saturation was indicated by the hole-finding algorithm and whether or not super-saturation was indicated by the hole-finding routine.

In a final pass through the data, data from the individual dwells was averaged up to the 30-min time intervals required by the *WindTrax* and *RPM* emissions models.

3.4.2 H_2S concentration measurements

The H_2S data processing routine first loaded all the H_2S data into an array. Based on the GSS data array, the data were then sorted by source side and a determination was made whether the GSS had been sampling that side long enough and whether enough time remained until the end of sampling that side for the H_2S data to be considered valid. The data were then sorted and averaged into 30-min intervals for placement into the *WindTrax* input file.

3.4.3 S-OPS sampling

The GSS software routine imported the CR800 data and produced two separate arrays of the data. The time grid for one array was based on when the SOPs changed from one line to the other line. This array was later used when separating the H_2S data according to which SOPs line was being measured and determining whether enough time had elapsed since the previous line-switch and enough time remained before the next line switch to consider the data valid. The other array was based on a regular 30-min grid. This array was used to produce output over the intervals required as input to *WindTrax*. Output from the GSS were also used to ensure that adequate flow was present for the instruments, that condensation was not a problem inside the GSS, and that there were no major issues with the S-OPS lines (leaks, etc.).

3.4.4 Wind component measurements

The sonic software imported the 300-s sonic data files and produced the final sonic QC output file and also arrays of data at 30-min intervals for use by the *WindTrax* and *RPM* emissions models. The *WindTrax* arrays contain the turbulence statistics required as inputs to *WindTrax* and also flags used for characterizing the output from the *WindTrax* or else the reason that sonic data were not suitable for use by *WindTrax* during a particular data interval. The *RPM* arrays contained the wind direction and wind speed averaged over a 30-min interval and interpolated to 10 levels from the surface to 20 m above the surface.

At some sites and during some periods one or more sonic anemometers experienced intermittent communications interference. This interference reduced the number of 16-Hz data points recorded in the trailer and also led to some spurious data points that resulted in some outlying, unphysical data points. These spurious data had little impact on the mean wind speeds, but did impact the variances, sometimes significantly. It was found that the spurious variances were nearly always associated with sonic temperature variance of greater than 2.5 K^2, while realistic variances never exceeded this same value. To be considered a valid 300-s period, at least 90% (4320) of the possible 4800 16-Hz values had to be present and the sonic temperature variance had to be less than 2.5 K^2 To be considered a valid 30-min interval, at least 3 of the 6 possible 300-s intervals were required to be valid. This acceptance scheme caught most, of the unacceptable variances.

3.5 Emission calculations

3.5.1 NH3 emissions by RPM

The *RPM* model was used to estimate the NH3 emission rates based on the TDLAS and sonic data. Running the supplied version of *RPM* was very time consuming and inefficient and produced data at short intervals on the order of several minutes (time for a scan through all the paths). To make *RPM* processing much quicker and efficient, the sonic and TDLAS data

processing programs were used to skip the first two stages of *RPM* data processing by producing data in the proper format and with the proper filenames for level 3 processing by the *RPM*. These files were produced at an interval of 30 min with all the data for a site and period contained in a single *RPM* input file. This allowed an entire period of data to be *RPM* processed with just a few clicks of the mouse, instead of with many clicks just for each individual day. The 30-min time interval was appropriate because the focus of the NAEMS study is on the long-term emissions over the course of the day rather than on the minute-by-minute emissions. In addition, the 30-min interval also allowed for a higher percentage of data capture since not all paths were necessarily required to be present for the entire 30-min interval.

3.5.2 NH3 emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic and TDLAS portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and told the model to run depending on whether or not the u_* and L values were acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the TDLAS units and each of the retro-reflectors. Labeled location markers were then placed at these coordinate locations. . When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.

All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

3.5.3 Validation of bLS emissions model

All ½ hourly emissions calculated using the *WindTrax* bLS emissions model in which there was a corresponding *RPM* emissions measurement were compared by pairs using EPA Method 301. The precision of the bLS method for each pair of bLS and *RPM* measurements of emissions was assessed assuming the *RPM* method was the reference. The F-test was used to determine if the precision of the bLS method was significantly different from that of the *RPM* method under a range of meteorological conditions. The experimental *F*-value was calculated according to

$$F = \frac{S_{bLS}^2}{S_{RPM}^2}$$

where S^2_{bLS} is the variance of the bLS measurement method determined from all PICs, and S^2_{RPM} is the variance of the *RPM* measurement method determined from five to ten PICs (depending on the incidence angle) on a given downwind side (and possibly an upwind side) for the paired 30-min measurement periods. The experimental *F*-value was compared to the critical range of *F* at a 95% confidence level for the appropriate degrees of freedom associated with the number of measurements used in the variance calculations in both the numerator and denominator. If the

experimental *F* was above the critical range, the precision of the bLS method was significantly greater than the *RPM* method. If the experimental *F* was below the critical range, the precision of the bLS method was accepted as equivalent to the *RPM* method.

The bias of the bLS method was determined from the measurement periods and beam lines used in the precision determination. Bias was determined by t-test of the mean differences in emissions calculations for each meteorological condition evaluated for precision. An 80% confidence interval was used (t=1.397). The correction factor was calculated if the difference was significant.. If the correction factor was more than 1.10 or less than 0.90, then the bLS method was considered biased accordingly relative to the *RPM* emissions measurements for the location but not invalidated.

3.5.4 H_2S emissions by Ratiometric

Ratiometric H_2S emissions were determined by first finding 30-min intervals for which all the following conditions were satisfied: the *RPM* calculated a valid emission, one of the S-OPS lines was downwind (angle < 60 degrees) and both S-OPS lines had valid H_2S readings, and the TDLAS path corresponding to the downwind H_2S path had a valid concentration. An upwind TDLAS concentration was not used in the calculations. If the preceding conditions were met, then the H_2S emission was estimated as:

$$Flux_{H2S} = Flux_{RPM-NH3} \frac{34.0818\left(\left[H_2S\right]_{downwind} - \left[H_2S\right]_{upwind}\right)}{17030.4\left[NH_3\right]_{downwind}}$$

The yield for the Ratiometric method for determining H_2S emissions was limited significantly by the generally poor yield for the *RPM* emissions method for NH_3.

3.5.5 H_2S emissions by bLS

Data input into the *WindTrax* model were produced by combining output from the sonic, GSS, and H_2S portions of the data processing software. The *WindTrax* program was run by a portion of the data processing software that assigns values to the concentrations and wind statistics required by the model and tells the model to run depending on whether or not the u_* and L values are acceptable.

GoogleEarth® was used extensively in producing the site maps required by *WindTrax*. By the end of the project, each site had a high-resolution image on *GoogleEarth*® sufficient to see the outline of the source area. A GPS was used to obtain precise latitudes and longitudes for the ends of the S-OPS lines. Labeled location markers were then placed at these coordinate locations. When the locations were obviously wrong (the accuracy indicated by the GPS was generally on the order of 4 m or so), either because the path crossed the lagoon or because it was not correctly placed relative to the corner, the markers were moved slightly to the approximate proper location. The image was then saved and loaded into *WindTrax*, where it was used to define the source areas and measurement paths.All data required for post-processing the *WindTrax* output were placed into the *WindTrax* output file.

4 Results

4.1 Farm activity

Pertinent activities affecting the lagoon include transfer of waste from barns into the lagoon (Table 4.1-1) and lagoon pump-outs for irrigation. Animal inventories for the calculation of lagoon loading rates are indicated in Table 4.1-1.

Table 4.1-1 Producer activities

Period	Activity	Animal Inventory
1: 7/17-8/28/2007	No events	500
11/5/2007	Lagoon 1 emptied	
2: 11/12-11/29/2007	11/22: Stage 1 lowline closed	500
3: 11/29-12/18/2007	12/16: Flow started into stage 3	500
4: 4/22-5/13/2008	No events	500
5: 6/24-7/15/2008	7/15: Pumped water from ISS system to sand separator. Excess water from ISS pumped to lagoon 1	500
6: 10/20-11/11/2008	10/30: Lagoon 1 emptied	556
7: 12/17/2008-1/7/2009	Duration of period: sucked parlor water out of flush system and unloaded on top of ice in lagoon 1.	554
8: 3/09-4/7/2009	3/9-3/15: Sucked parlor water out of flush system and unloaded on top of ice in lagoon 1.	554

4.2 Weather conditions

4.2.1 Synoptic weather events

Weather conditions during the measurement periods varied as expected for upper midlatitude climates (Table 4.2-1). Twenty nine percent of the days had extra-tropical frontal systems overhead while 71% of the days were under the general influence of extra-tropical high pressure. The Daily Weather Maps for the measurement days are found in Section 6.9.

Table 4.2-1: Synoptic weather events during measurements

Measurement Period	# days	# Warm front passages	# Cold front passages	# days stationary front	# days Tropical storms
1	41	1	9	8	0
2	15	0	2	1	0
3	20	0	3	0	0
4	20	1	3	1	0
5	19	3	6	0	0
6	21	1	3	0	0
7	21	1	3	2	0
8	28	1	4	0	0

4.2.2 Variation in barometric pressure, solar radiation, air temperature and wetness

Over the course of the measurement periods, the mean daily air temperature varied from -21.5°C to 26.2°C while the barometric pressure varied from 93.53 kPa to 99.73 kPa (Section 6.10). Sky conditions ranged from clear skies with maximum ½ h solar irradiance of 1287 Wm^{-2} to overcast conditions with maximum ½ h solar irradiance of 85 Wm^{-2} (Section 6.10).

4.2.3 Variation in air temperature and relative humidity

The relationship between the daily mean air temperature and humidity compared with the monthly climatology is indicated in Figure 4-1. Temperatures were generally within the climatological normal conditions throughout the study measurement periods at this location.

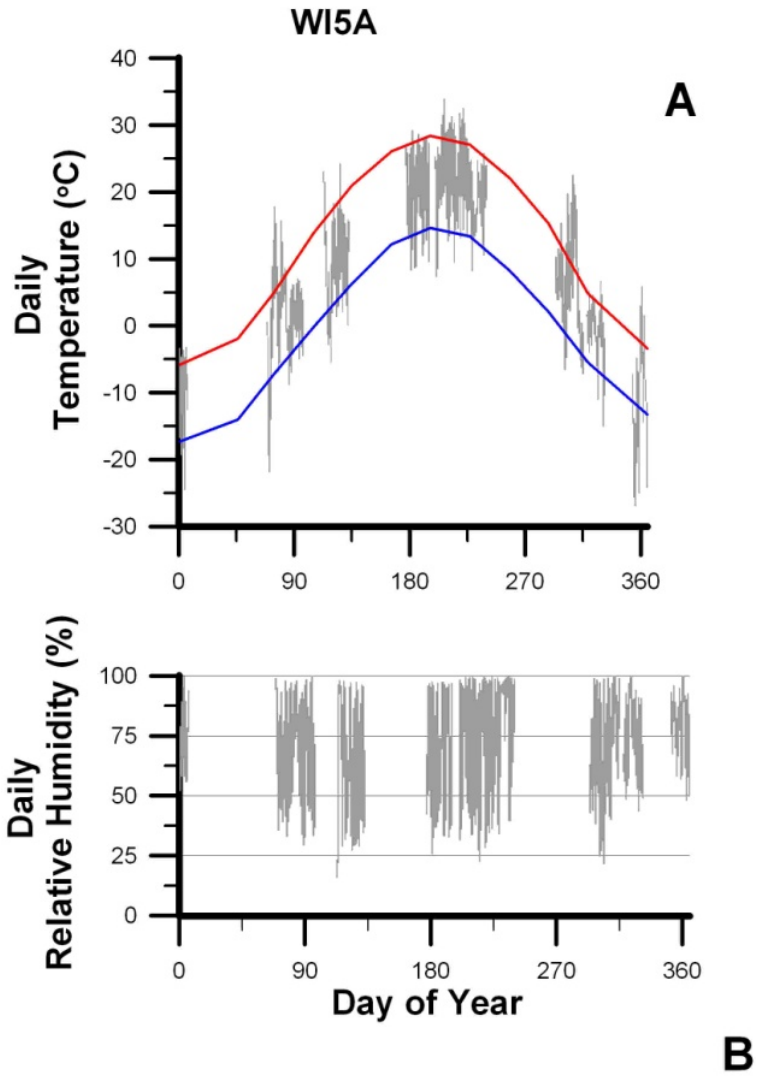

Figure 4-1: Variation in daily temperatures and relative humidity during measurements. The mean monthly climatological maximum (red solid line) and minimum (blue solid line)

temperature are compared against the daily maximum and minimum temperatures for measurement days (grey bars) in panel A. The maximum and minimum relative humidities for measurement days are indicated by the grey bars in panel B.

4.2.4 Wind conditions

Wind conditions for each measurement period are illustrated in Figures 4.2-1 through 4.2-4. Emission calculation exclusion regions due to surrounding sources (wind directions of 0° through 180°) are indicated as a grayed region in the figures.

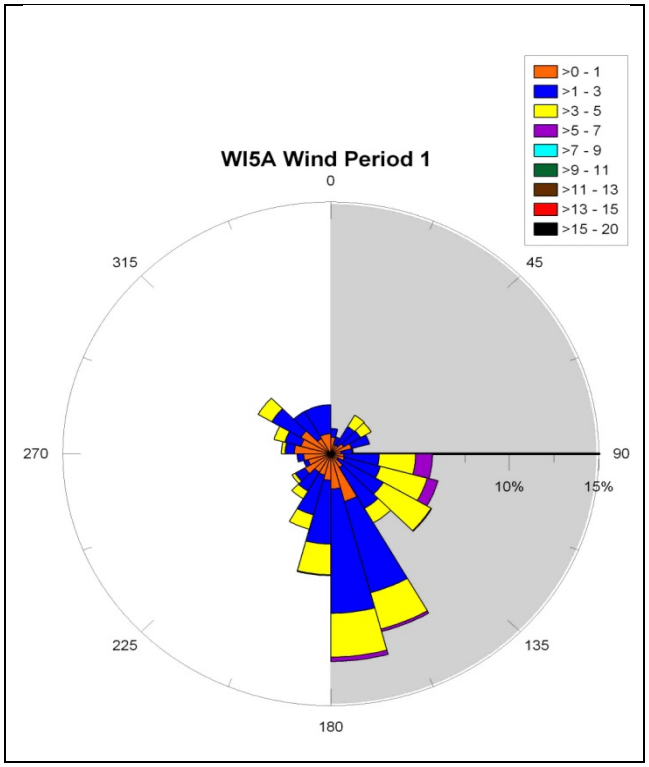

Figure 4.2-1: Wind rose for ½ hourly wind measurements during the Summer Measurement Period. The period in which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

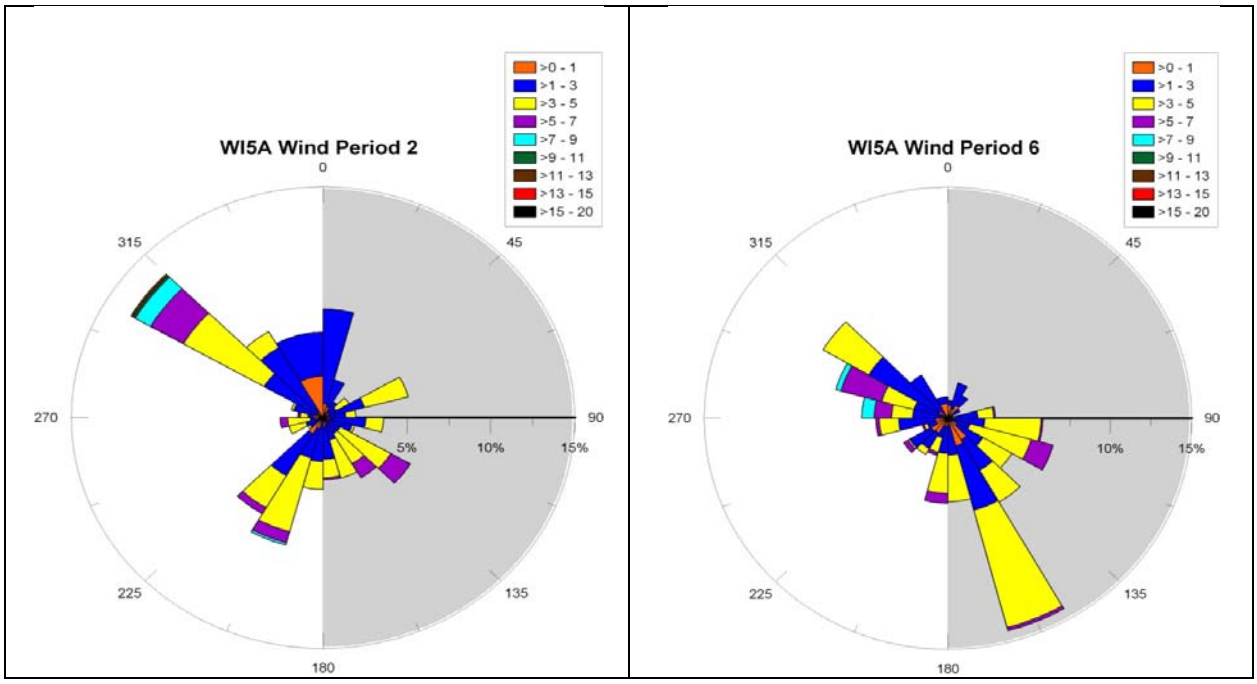

Figure 4.2-2: Wind rose for ½ hourly wind measurements during the Fall Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

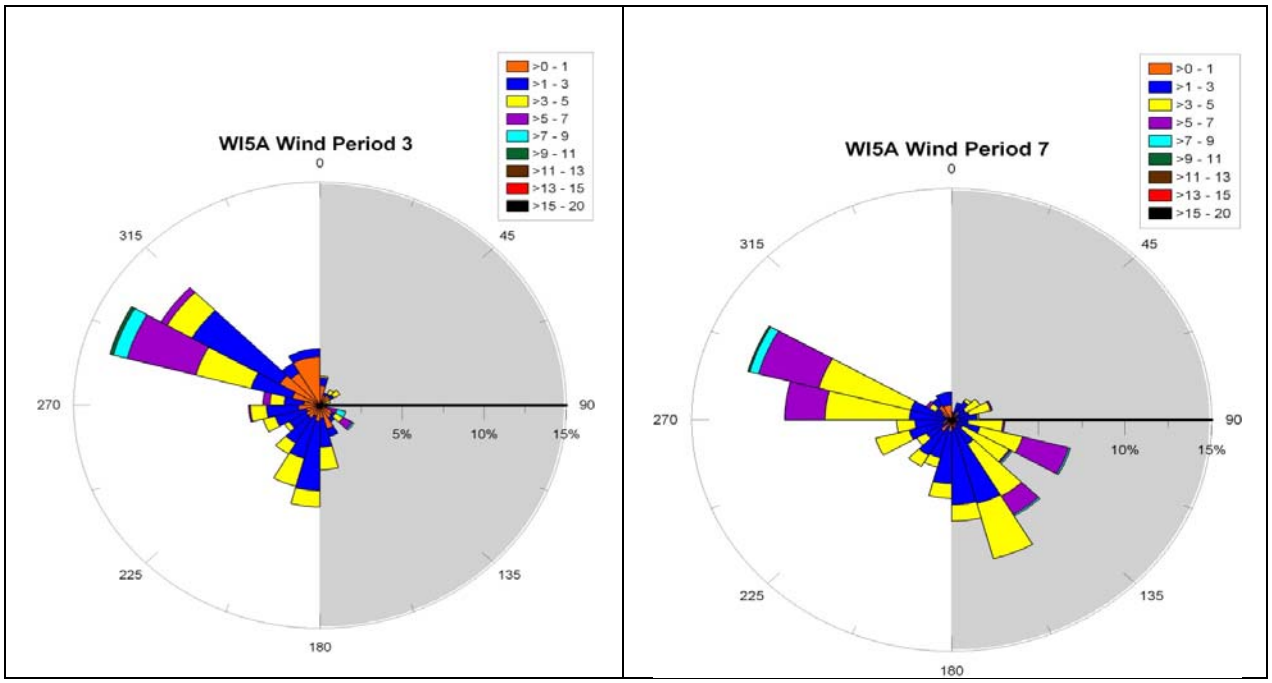

Figure 4.2-3: Wind rose for ½ hourly wind measurements during the Winter Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

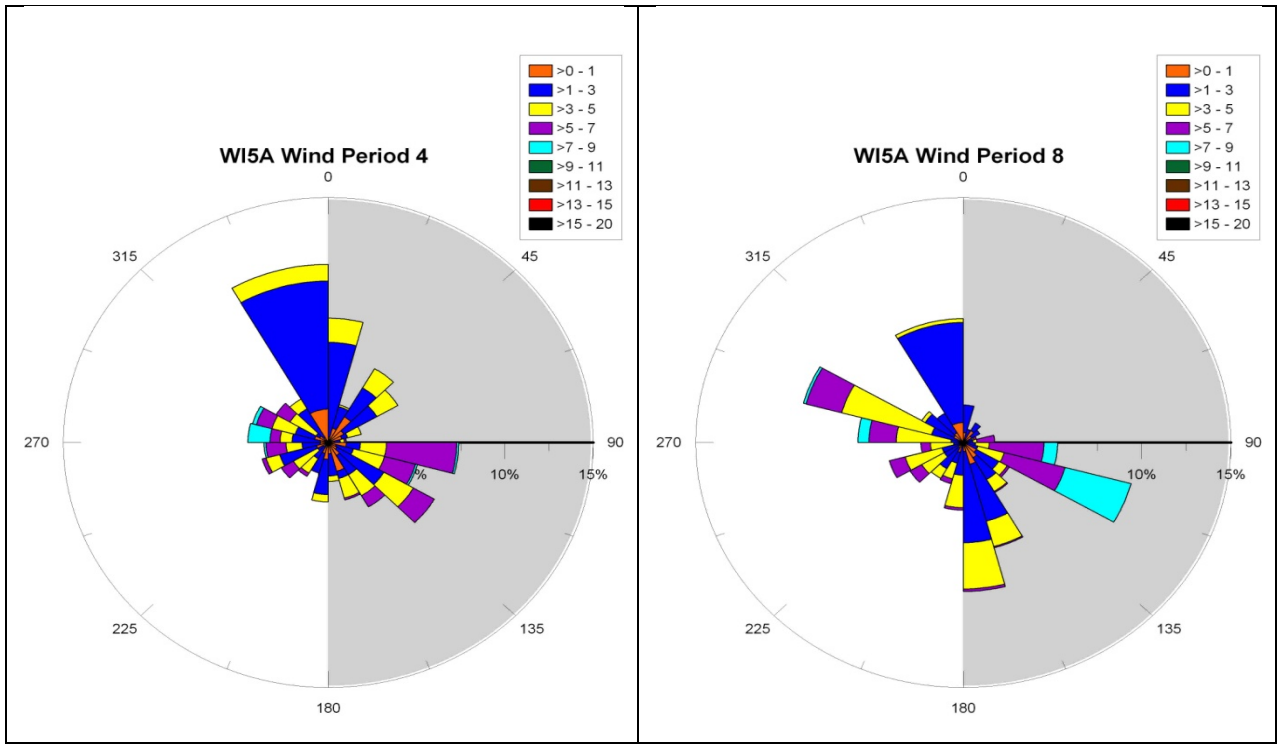

Figure 4.2-4: Wind rose for ½ hourly wind measurements during the Spring Measurement Periods. The periods in which measurements were made are indicated. The relative portion of time in which the wind was from a given direction is indicated by the length of the triangle pointing in that direction. The fraction of time in which the winds were in the binned speed ranges (units of ms^{-1}) is indicated by colors within each triangle. The shaded region defines the excluded wind directions.

4.3 Lagoon conditions

4.3.1 Lagoon appearance, liquid depth and sludge depth

The appearance of the two measurement lagoons was recorded on almost every site visit (Table 4.3-1). The lagoons generally appeared brown/black and crusted.

Table 4.3-1: Lagoon physical characteristics

Period	Date, appearance (Color/Crust)
1: 7/17-8/28/2007	7/17/2007 - Brown/Black/ 75% Crust 7/18/2007 - Brown/Black/ 75% Crust 7/19/2007 - Brown/ 75% Crust 8/6/2007 - Brown/ 90% Crust 8/7/2007 - Brown/Black/ 95% Crust 8/9/2007 - Brown/Black/ 95% Crust 8/28/2007 - Brown/Black/ 100% Crust
2: 11/12-11/29/07	11/13/2007 - Brown/ No crust 11/14/2007 - Brown/ No crust 11/27/2007 - Brown/ Frozen/ 4" Liquid Foam 11/28/2007 - Black/ Frozen
3: 11/29-12/18/07	11/29/2007 - Black/ Frozen 12/17/2007 - Brown/ Frozen 12/18/2007 - White(snow)/ Frozen
4: 4/22-5/13/08	4/24/2008 - Black/ No crust 5/12/2008 - Black/ 85% Crust 5/13/2008 - Black/ 80% Crust
5: 6/24-7/15/08	6/24/2008 - Light brown/ 100% Crust 6/25/2008 - Brown/ 100% Crust 7/14/2008 - Brown/ 100% Crust 7/15/2008 - Brown/ 100% Crust
6: 10/20-11/11/08	10/21/2008 - Black/ Empty 10/22/2008 - Brown/ Empty 11/11/2008 - Black/White/ Frozen
7: 12/17/08-1/7/09	12/17/2008 - White(snow)/ Frozen 12/18/2008 - White(snow)/ Frozen 1/6/2009 - White(snow)/ Frozen 1/7/2009 - White(snow)/ Frozen
8: 3/9-4/7/09	3/9/2009 - White/Brown/ 90% Frozen 3/10/2009 - White/Brown/ 95% Frozen 4/6/2009 - Black/ No crust 4/7/2009 - Black/ No crust

4.3.2 Temperature, pH and Oxidation-Reduction Potential

The conditions of the first two lagoons were measured. The first measured lagoon liquid temperature varied from 4.6°C to 24.7°C with the lowest temperatures just prior to when the sensors were removed in anticipation of the lagoon freezing during the winter (Section 6.11.1). The lagoon pH varied from 6.6 to 7.1 (Section 6.11.1) while the oxidation-reduction potentials varied from -338 mV to -507 mV over the entire study period (Section 6.11.1). The second measured lagoon liquid temperature varied from 1.7°C to 25.0°C with the lowest temperatures just prior to when the sensors were removed in anticipation of the lagoon freezing during the winter (Section 6.11.2). The lagoon pH varied from 6.5 to 7.2 (Section 6.11.2) while the oxidation-reduction potentials varied from -336 mV to -467 mV over the entire study period (Section 6.11.2).

4.4 Emissions measurements

Emissions data were calculated on a ½ h basis since this was the interval over which the S-OPS system sampled both sides of the lagoon and since this interval is in the range over which

turbulence statistics are often calculated. Emissions reported on a head basis were scaled by the design animal population and not the animal population at the time of measurements to account for the longer term manure storage of the lagoon or basin. Emissions reported on an animal unit (AU) basis assumed an animal weight of 500 lb equals 1 AU and the typical animal weight values reported by the producer. Piglets and calves were not included in the populations or AU determinations. Emissions reported on an area basis are based on the surface area of the lagoon.

Comparison of RPM and bLS emissions models

The comparison between the RPM and bLS emissions models was conducted according to the USEPA Method 301 'Field Validation of Pollutant Measurement Method' using NH_3 emissions measurements. The comparison was based on 274 ½ h measurement periods over the entire measurement time at this location. Results showed that the bLS emissions did not have significantly different precision (F=0.47, critical F=1.0) but had a significant bias over the *RPM* emissions (t=-4.39, $t_{0.2}$=1.29) with a corresponding correction factor for the bLS of 0.78 (Table 4.4.1-1). Consequently, the ½ h bLS emissions measurements were biased low by 22% compared with the *RPM* measurements.

Table 4.4.1-1: Comparison of the bLS and RPM NH_3 emissions

	RPM	bLS	bLS-RPM
Mean emission (gs^{-1})	0.427	0.334	-0.094
Standard deviation (gs^{-1})	0.458	0.313	
Variance of the mean (gs^{-1})	0.210	0.098	

4.4.1 NH_3 Emissions

4.4.1.1 Mean daily NH_3 emissions

There was a distinct annual trend in NH_3 emissions based on the *RPM* model (Figure 4.4.1-1). Maximum summertime daily emissions were highly variable, ranging from 20 g to 280 g NH_3 d^{-1} hd^{-1}. These summertime measurements were influenced by the atmospheric moisture interference which the TDLAS instruments had at the time and consequently these emissions may be underestimated by as much as 40%. There were, however, no days in which the daily emission estimate was based on more than 75% of the day's emissions. Consequently there is no confidence that the estimated emission is representative of a daily emission rate. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the *RPM* model are listed in Section 6.12.1.

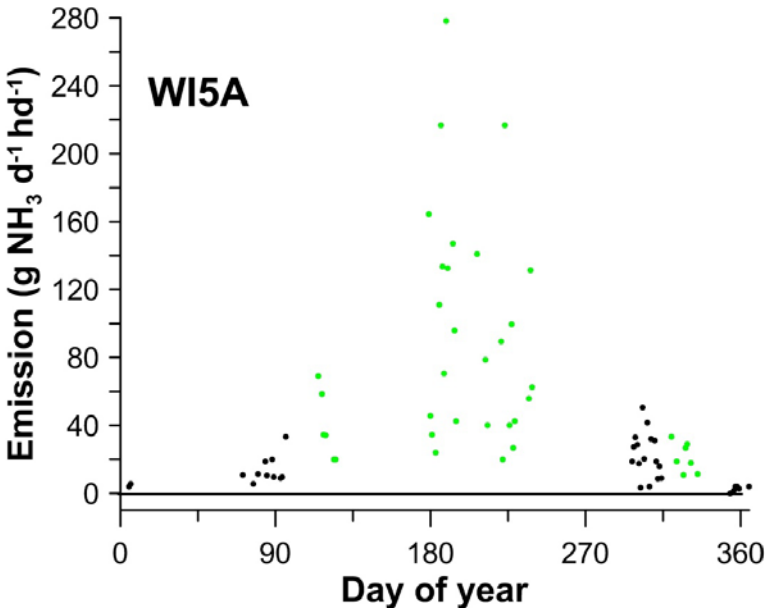

Figure 4.4.1-1: Annual variation in RPM-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH^3 concentration measurement.

There was a distinct annual trend in NH_3 emissions based on the bLS model (Figure 4.4.1-2). Maximum summertime daily emissions were highly variable, ranging from 0 to 180 g NH_3 d^{-1} hd^{-1}. There were however many days in which the daily emission estimate was based on more than 75% of the day's emissions. Considering only those days, the maximum summertime daily emission was approximately 60 g NH_3 d^{-1} hd^{-1}. These summertime measurements were influenced by the atmospheric moisture interference which the TDLAS instruments had at the time and consequently these emissions may be underestimated by as much as 40%. The daily NH_3 emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.2.

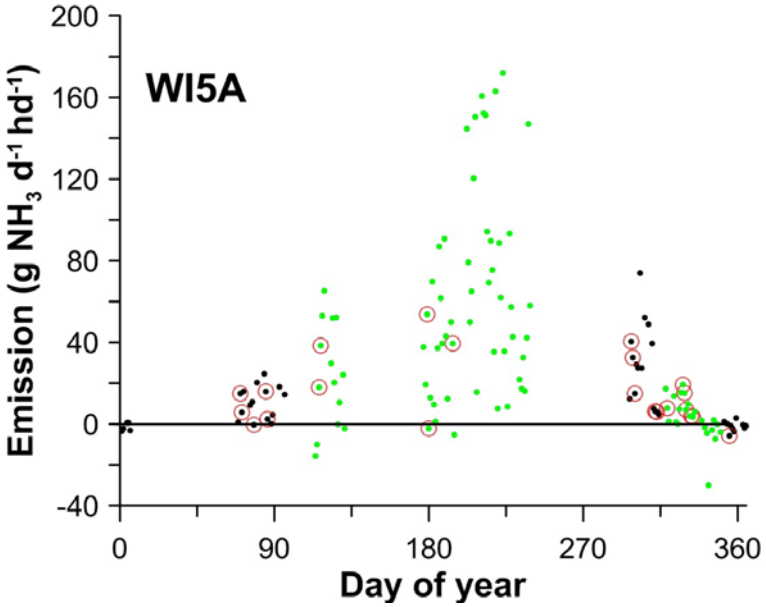

Figure 4.4.1-2: Annual variation in bLS-computed daily NH_3 emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The green solid circles indicate moisture interference with the NH^3 concentration measurement. The bars represent the standard deviation of emissions based on individual ½ h values when at least 75% of the day had valid measurements.

The bLS model was influenced by the calculated background concentrations. Results indicated that the background concentration of NH_3 was generally less than 0.1 ppm except in mid-year (Figure 4.4.1-3). Given that the typical path length around the lagoon was 100 m and the typical background concentration is less than 0.1 ppm, this corresponded to a background concentration for a given PIC of less than 10 ppm-m. This was approximately five times the MDL for the TDLAS instruments of 2 ppm-m (Section 8.1) and therefore represented a real background for this location. Negative background concentrations occurred when the winds were variable resulting in no distinct upwind or downwind S-OPS.

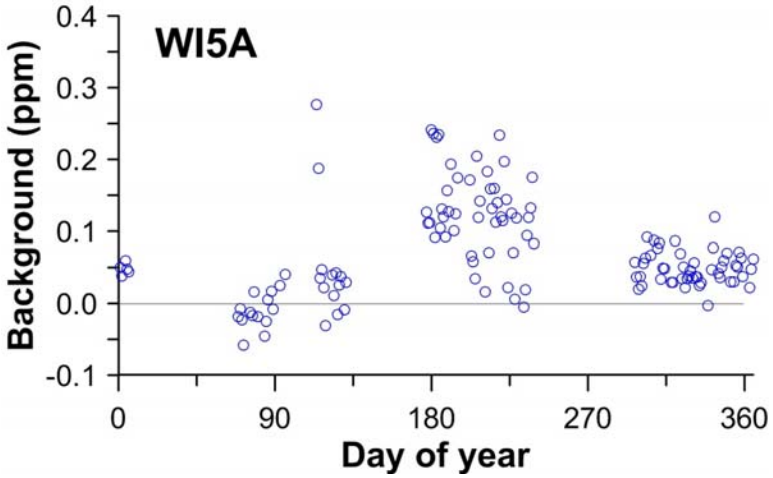

Figure 4.4.1-3: Annual variation in bLS-computed daily background concentration of NH_3.

4.4.1.2 Diurnal variation in NH_3 emissions

In general, there was a strong diurnal pattern to the NH_3 emissions during all but the winter and early spring measurement periods (Figure 4.4.1-4). Negative emission rates are a result of upwind (background) concentrations exceeding the downwind concentrations under variable winds.

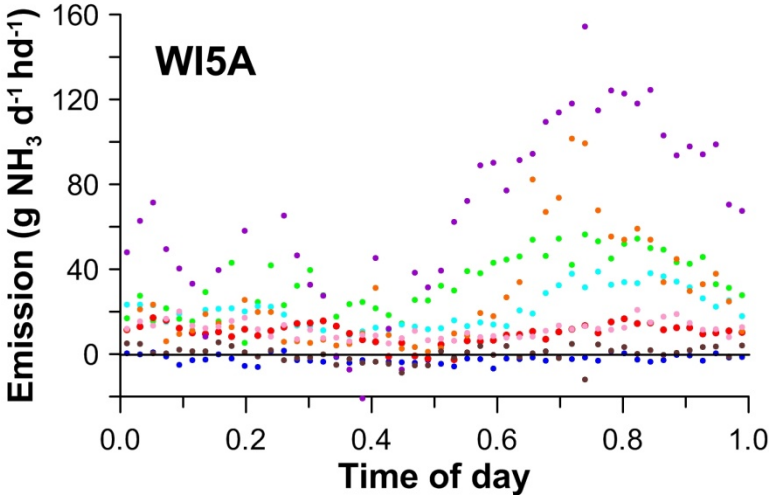

Figure 4.4.1-4: Diurnal variation in bLS-computed NH_3 emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 1-Summer (purple), Period 2-Fall (pink), Period 3-Winter (brown), Period 4-Spring (orange), Period 5-Summer (green), Period 6-Fall (light blue), Period 7-Winter (blue), and Period 8-Spring (red)) are indicated.

4.4.1.3 NH_3 emissions data completeness

Unless otherwise indicated, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day.

Therefore, an additional value giving the total number of days with at least 36 valid ½ h periods (corresponding to 75% completeness on a daily basis) is given. Because of the requirement of 5 to 10 valid TDLAS measurements before an *RPM* emission measurement is possible, the number of valid ½ h periods with *RPM* emissions was greatly limited. The wind conditions and wind direction exclusion region did not greatly reduce the yield of valid bLS emission measurements. The completeness statistics are summarized in Table 4.4.1-2.

Table 4.4.1-2: Completeness statistics for NH_3 emissions measurements

	Measurement period								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
NH_3 RPM model									
Valid 1/2 h measurements (d)	1.0	0.5	0.0	0.4	1.1	3.1	0.3	1.0	**7.4**
Measurements excluded due to wind direction (d)	2.8	0.8	0.1	0.5	1.4	6.9	0.6	0.9	**13.9**
Measurements excluded because at least one downwind path is missing or invalid (d)	31.7	9.3	14.5	16.5	10.3	2.3	9.2	14.0	**107.9**
Number of days with >=36 valid 1/2 h periods (d)	0	0	0	0	0	0	0	0	**0**
NH_3 bLS model									
Valid 1/2 h measurements (d)	7.1	6.5	4.3	5.6	7.8	7.3	5.2	8.0	**51.8**
Measurements excluded due to wind direction (d)	11.6	4.8	1.4	4.2	4.7	8.0	7.1	5.3	**47.1**
Measurements excluded because touchdown fraction < 0.1 (d)	2.4	0.0	1.8	1.9	0.1	0.0	0.6	3.5	**10.4**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| <$ 2 m (d)	12.7	1.5	5.1	3.6	4.1	2.6	2.7	3.9	**36.2**
Number of days with >=36 valid 1/2 h periods (d)	0	4	2	2	3	5	1	5	**22**

In total, 7 d of valid NH_3 emissions were determined from the 176.7 measurement days using the *RPM* model, with no days having at least 36 valid ½ h NH_3 emissions. The absence or invalidation of at least one downwind path led to 108 d for which emissions could not be calculated.

Valid NH_3 emissions for 52 d were determined from the 176.7 measurement days using the bLS model, with 22 d having at least 36 valid ½ h NH_3 emissions. The exclusion wind directions due to the location of the barns relative to the lagoon resulted in the loss of 47 d of measurements. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1}or $|L| < 2$ m) led to 36 d for which emissions could not be calculated. A touchdown fraction of less than 0.1 led to the exclusion of 10 d of data. Low touchdown fractions indicated that little, if any, downwind data was available. This corresponded to either when the downwind TDLAS was not present or else the downwind paths were lost because of invalid light levels.

The *RPM* model requires all 5 or 10 (depending on the wind direction) downwind paths to have valid concentration readings for at least a portion of the ½ h interval. This contrasts with the bLS model which requires only 1 downwind surface path to have valid concentration readings. This difference is largely responsible for the much greater completeness for the bLS model than the *RPM* model. The *RPM* model uses ½ h mean wind speed and direction, in contrast to the bLS model that requires extensive turbulence statistics over this same period. As a result, there are times when the *RPM* model produces a valid emission while the bLS model does not. However, these times are overwhelmed by the times that the *RPM* model is missing concentration data for one or more paths, while the bLS model is able to run.

4.4.2 H_2S Emissions

4.4.2.1 Mean daily H_2S emissions

There was some evidence for an annual pattern of emissions based on the Ratiometric model (Figure 4.4.2-1). Emissions were highest during the summer at approximately 8 g H_2S $d^{-1}hd^{-1}$ or less and decreased to zero during the winter. The summer emissions were however influenced by the moisture interference of the TDLAS instruments and consequently may be 40% low. However since there were no days in which more than 75% of the day's emissions were available for calculating the daily emission rate, the confidence in the daily emission rates using this emissions model is poor. The daily H_2S emissions and the number of valid measurements used in the mean daily emissions estimate calculated using the Ratiometric model are listed in Section 6.12.3.

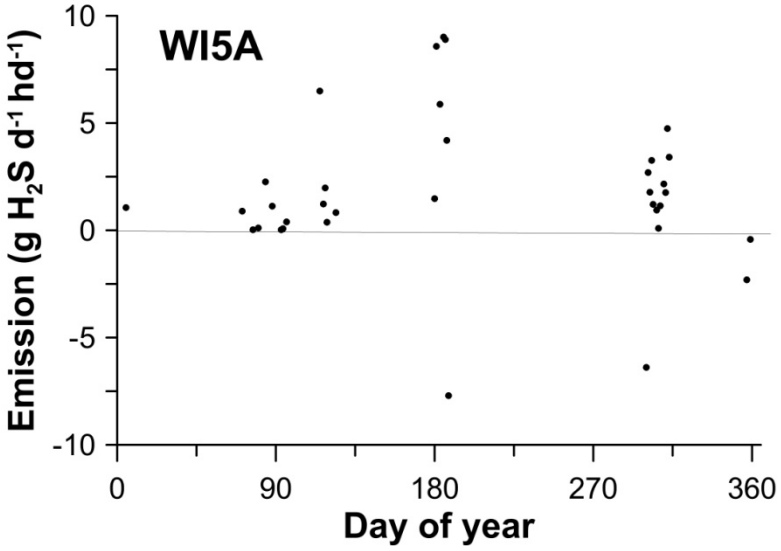

Figure 4.4.2-1: Annual variation in Ratiometric-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day.

There was some evidence for an annual pattern of emissions based on the bLS model (Figure 4.4.2-2). Emissions were highest during the summer at between 2 g and 12 g H_2S $d^{-1}hd^{-1}$ with emissions decreased to zero during the winter. Considering only days in which more than 75% of the day's emissions were available for calculating the daily emission rate, the maximum daily emissions during the summer was 3 g H_2S $d^{-1}hd^{-1}$. The daily H_2S emissions and the number of

valid measurements used in the mean daily emissions estimate calculated using the bLS model are listed in Section 6.12.4.

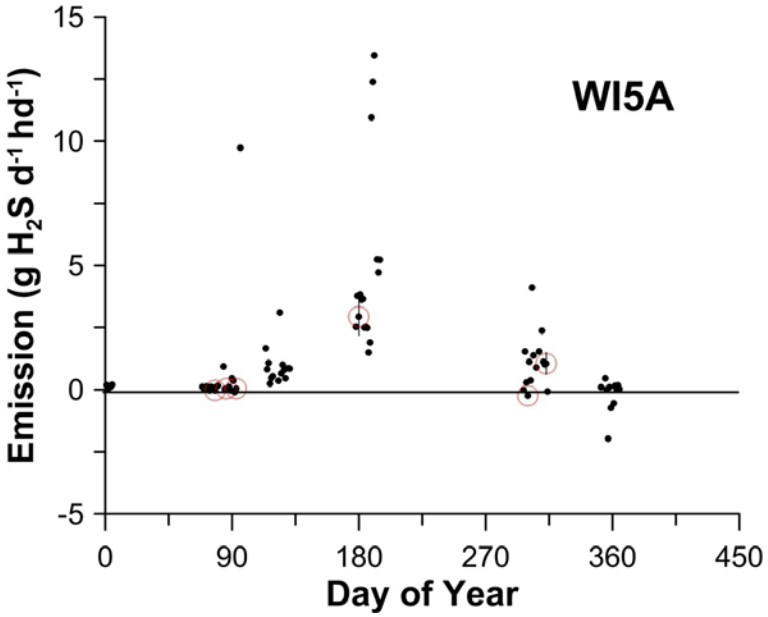

Figure 4.4.2-2: Annual variation in bLS-computed daily H_2S emissions. Days with a red circle indicate there are measurements for greater than 75% of the continuous day. The bars represent the standard deviation of emissions based on individual ½ h values when at least 75% of the day had valid measurements.

The bLS emission model depends on good estimates of the background H_2S concentration. Results indicated that the background concentration was generally less than ± 5 ppb (Figure 4.4.3-3). This background was consistent with an equivalent zero value where the instrument MDL was 3.4 ppb (Section 6.2).

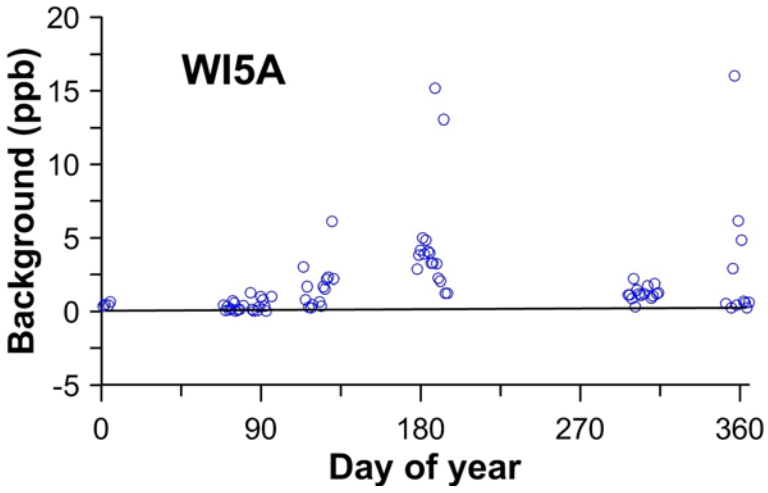

Figure 4.4.3-3: Annual variation in bLS-computed daily background concentration of H_2S.

4.4.2.2 Diurnal variation in H_2S emissions

In general, there was a weak diurnal pattern to the H_2S emissions (Figure 4.4.2-4). Negative emission rates are a result of upwind (background) concentrations exceeding the downwind concentrations under variable winds.

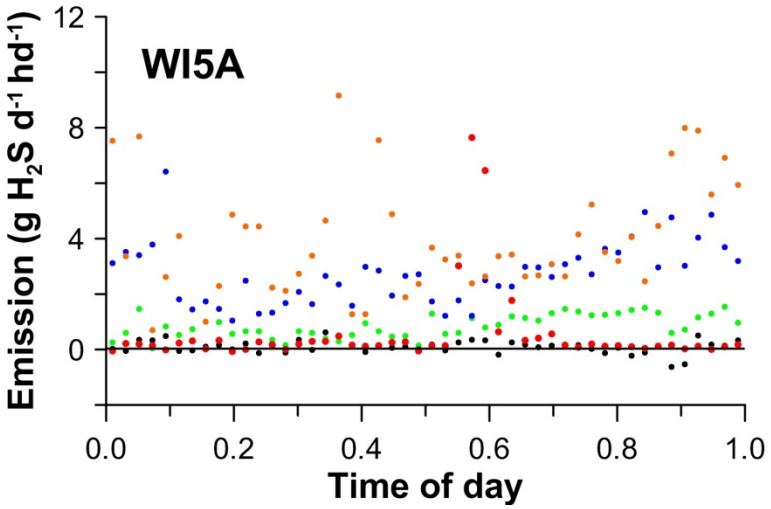

Figure 4.4.2-4: Diurnal variation in bLS-computed H_2S emissions. Time based on Universal Time Coordinates. The mean emission for each half-hour of the day within a given measurement period (Period 6-Fall (red), Period 7-Winter (blue), Period 8-Spring (black), and Period 9-Summer (green)) are indicated.

4.4.2.3 H_2S emissions data completeness

H_2S Measurements were begun in Period 3. Consequently there were no measurements possible for Fall 2007. As described for the NH_3 emissions, emissions completeness and failure totals are given in number of days corresponding to the total number of ½ h intervals for which the indicated condition was true. This number of days does not indicate the data completeness for any individual day. The completeness statistics are summarized in Table 4.4.2-1.

The H_2S emissions were measured a total of 100 d at this location. The majority of measurements were invalidated as a result of wind direction exclusions associated with the proximity of the lagoons to the barns (Figure 1-2). Wind direction exclusions invalidated 36 d of measurements. Because there were few valid ½ measurements of the NH_3 emissions based on the *RPM* model (Table 4.4.1-2), the number of valid ½ periods of valid Ratiometric emissions measurements of H_2S is small. The majority of bLS emissions measurements were invalidated due to wind conditions. In total, only two days of valid H_2S emissions were determined using the Ratiometric emission method, with none having at least 36 valid ½ h H_2S emissions. Valid H_2S emissions for 27 d were determined using the bLS model, with 6 d having at least 36 valid ½ h H_2S emissions. Invalid turbulence statistics ($u_* < 0.15$ ms^{-1} or $|L| < 2$ m) excluded 20 d, due to low wind speeds and turbulence from the local barns and trees.

Table 4.4.2-1: Completeness statistics for H_2S emissions measurements

	Measurement Period								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
H_2S Ratiometric model									
Valid 1/2 h measurements (d)				0.3	0.3	1.3	0.1	0.6	**2.6**
Number of days with >=36 valid 1/2 h periods (d)				0	0	0	0	0	**0**
H_2S bLS model									
Valid 1/2 h measurements (d)				4.4	5.0	5.6	4.5	7.6	**27.2**
Measurements excluded due to wind direction (d)				6.5	4.5	7.9	7.8	9.5	**36.3**
Measurements excluded because angle of attack > 60 degrees (d)				2.1	2.7	1.7	2.7	3.7	**12.9**
Measurements excluded because $u_* < 0.15$ ms^{-1} or $\|L\| <$ 2 m (d)				3.9	5.0	3.5	3.4	4.4	**20.2**
Number of days with >=36 valid 1/2 h periods (d)				0	1	2	0	3	**6**

4.4.3 Estimation of emission measurement errors

Errors in the response of the TDLAS due to atmospheric moisture limited the accuracy of the TDLAS serial numbers 1026, 1028, and 1030 prior to July 21, 2008. TDLAS 1026 was used at WI5A from 11/13/2007 to 12/18/2007 (Measurement period 2 and 3). TDLAS 1028 was used at WI5A from 7/18/2007 to 8/28/2007, 11/13/2007 to 12/18/2007, 4/23/2008 to 5/13/2008, 6/25/2008 to 7/14/2008 (Measurement periods 1, 2, 3, 4 and 5). TDLAS 1030 was used at WI5A from 7/18/2007 to 8/28/2007 (Period 1). Under the calibration verification checks, the TDLAS error of all units was 10% accuracy. However due to the short path length of the calibration verification, these checks did not assess water vapor interferences experienced in the long path lengths around the area sources. Inter-comparisons between various TDLAS units experiencing atmospheric moisture interference and units without apparent interference revealed reduced responses with the moisture-affected units of 28%, 68%, 36% and 31% for atmospheric moisture varying from dew point temperatures of -2°C to 20°C. A conservative estimate of the bias of all of the above TDLAS units with evident moisture interference was estimated at -40%.

4.4.3.1 Error in RPM-measured NH_3 emissions

Tracer releases studies indicated that the RPM emissions measurement has an error in accuracy of approximately ±15% (Hashmonay et al., 2001; Verma et al., 2005; USEPA, 2007). The TDLAS measurement error was 10% (Section 6.1). Combining errors results in an expected error in the RPM-measurement of NH_3 emissions of ± 18%. In addition, the NH_3 measurements made using the TDLAS units with moisture interference had a bias of -40%.

4.4.3.2 Error in bLS-measured NH_3 and H_2S emission

Tracer studies using TDLAS concentration measurements in combination with the bLS emissions model averaged over roughly two hour periods indicated the bLS method error for a given 15-min period varied with stability: overestimated by 12% under near neutral conditions,

underestimated by 13% under unstable conditions, and overestimated by 38% under stable conditions (Flesch et al., 2004). Under conditions when Monin Obukhov similarity theory was valid, the bLS-calculated emission rate was biased 6% high with a standard deviation of 16%. Laubach and Kelliher (2005) evaluated the theoretical errors of the bLS model. The breakdown of their 22% model error included a 12% error for the estimate of the Monin-Obukov Length (L) derived from measurements, a 5% error in turbulence statistics (10% error for the normalized variability statistics in the x and y directions and 5% in the z direction), a 15% error associated with the roughness length (z_o) estimate, and a 10% error due to the stochastic methodology. This was consistent with tracer-estimated errors of the bLS emission calculation method, when constrained by the data quality indicators of the bLS method, of between 5% and 36%.

For this study, we assumed the above theoretical random error of 22% for the bLS emissions measurements. The TDLAS measurement error was 10% (Section 6.1). At this location the daily mean bLS emissions bias from the RPM emissions measurement was -22% (from the RPM/bLS method comparison in Section 4.4). As previously stated, the TDLAS units with moisture interference had a bias of -40%. Combining errors resulted in an expected error in the RPM-measurement of NH_3 emissions of ± 24% with a bias of -62% for TDLAS NH_3 measurements made by units with moisture interference and a bias of -22% for TDLAS NH_3 measurements made by units without moisture interference.

The H_2S PF instrument measurement error was 10% (Section 6.2). Given the expected error in the bLS measurement of emissions of 22%, the H_2S emissions error was estimated as ± 24%

4.4.3.3 Error in Ratiometric-measured H_2S emission

The Ratiometric method of H_2S emissions measurement depends on the RPM measurement of NH_3 emissions. The RPM emissions measurement had an error of approximately ±15%. Since the Ratiometric method ratios the emissions and concentrations of NH_3, there was no affect of the moisture interference in the TDLAS measurement on the H_2S emissions calculation. Given the H_2S PF instrument measurement error of 10% (Section 6.2), the combined error for the Ratiometric measurement of H_2S emissions was ± 18%.

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6 Appendices

6.1 TDLAS NH_3 calibrations

Four TDLAS units (Model GasFinder2^{TM} NH3OP, Boreal Laser Inc., Spruce Grove, Alberta, Canada) were used at this location: serial numbers 1026, 1028, 1030, and 1031.

TDLAS 1026 was multipoint calibrated seven times during the study (Figure 6.1-1). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 1/17/07 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = -0.97 + 1.0197 * X - 4.410E\text{-}5 * X^2 + 1.591E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until July, 21 2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration resulted in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.04 ppm-m prior to the July 2008 modification and 1.77 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-2) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 days (Figure 6.1-3). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 8.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-2) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 4/28/2009 and 11/10/2009 while negative biases exceeding the DQI occurred over the period 4/2/2008 through 7/1/2008 (Figure 6.1-2). The 4/28/2009 and 11/10/2009 bias exceedances were followed the same or next day with a passing verification and were deemed to be a result of operator error. The negative bias over the period 4/2/2008 through

7/1/2008 was not a result of calibration cylinder certification error (three different cylinders were used). During operations the bias was only intermittently evident because to different multipoint calibration was applied to the calibration verification measurements during the progress of the study than finally applied during the analysis. Repeated calibrations within 24 hours often showed biases differing by more than 10 ppm-m suggesting operator errors. Although this instrument had a bias associated with water vapor interference, the instrument was in use in dry climates during this time. The measurements made during this period were considered valid and the error assumed to be due to the calibration verification operator.

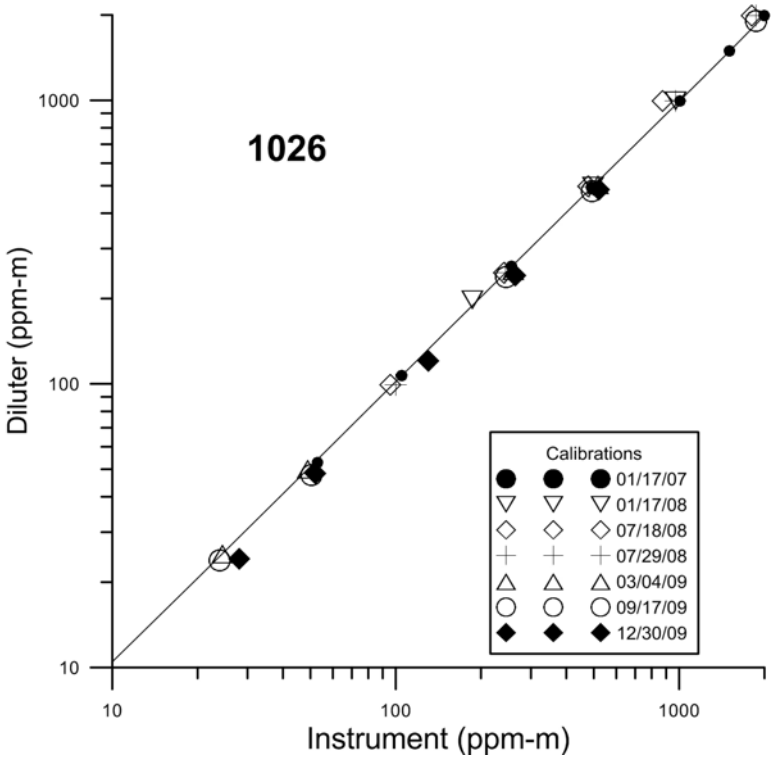


Figure 6.1-1: Multipoint calibrations of the GasFinder2 ^{TM} s/n NH3OP-1026. The solid line is the 3rd order polynomial regressions for the chosen multipoint calibration.

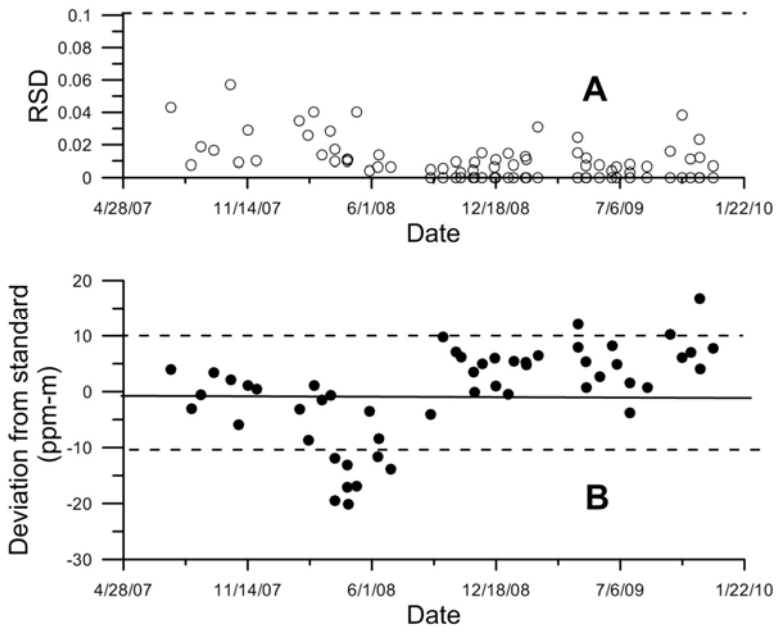


Figure 6.1-2: Control charts of the GasFinder2 ™ s/n NH3OP-1026

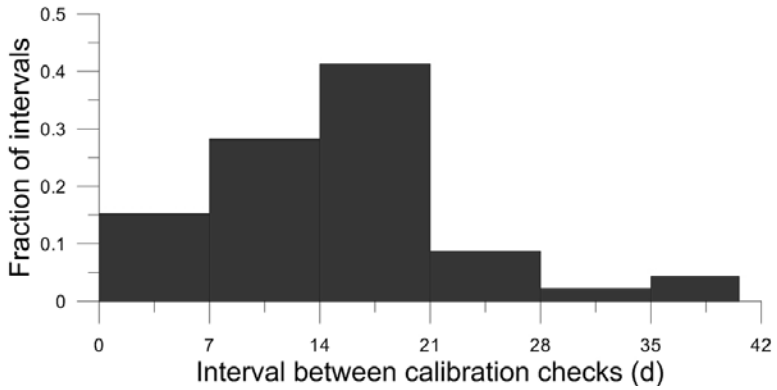


Figure 6.1-3: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1026

TDLAS 1028 was multipoint calibrated six times during the study (Figure 6.1-4). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/23/07 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was:

$$ppm\text{-}m = 1.46 + 0.985 * X + 8.465E\text{-}6 * X^2 + 3.879E\text{-}8 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until July, 21 2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. Adjustments made on the instrument at this time did not appear to affect the calibration conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 2.48 ppm-m prior to the July 2008 modification and 1.91 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-5) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 days (Figure 6.1-6). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 6.46 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-5) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on three dates (9/26/2008, 10/1/20008 and 9/24/2009) while negative biases exceeding the DQI occurred on 12/16/2008 (Figure 6.1-5). In all cases except the short 9/24/2008 through 10/1/2008 period, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

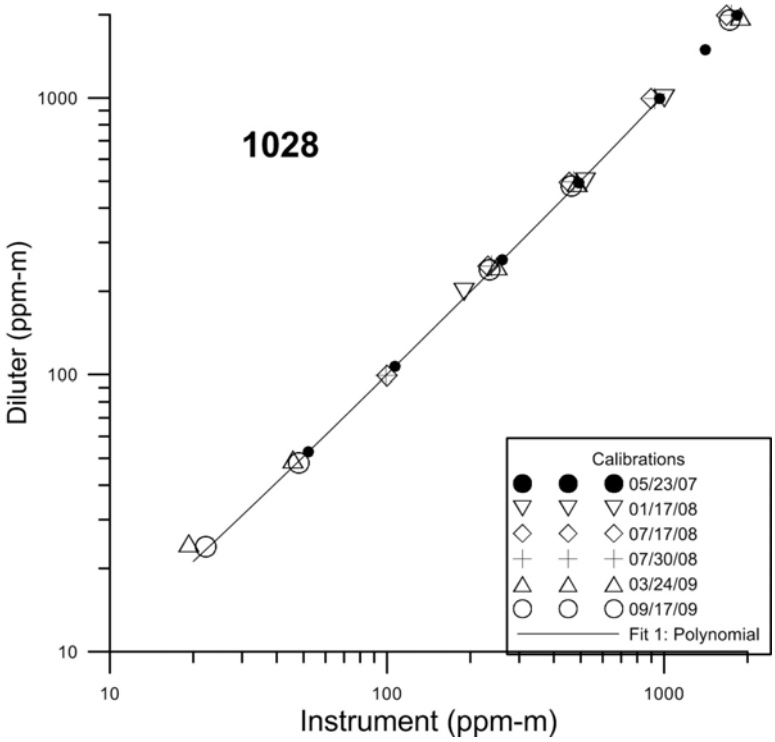


Figure 6.1-4: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1028. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

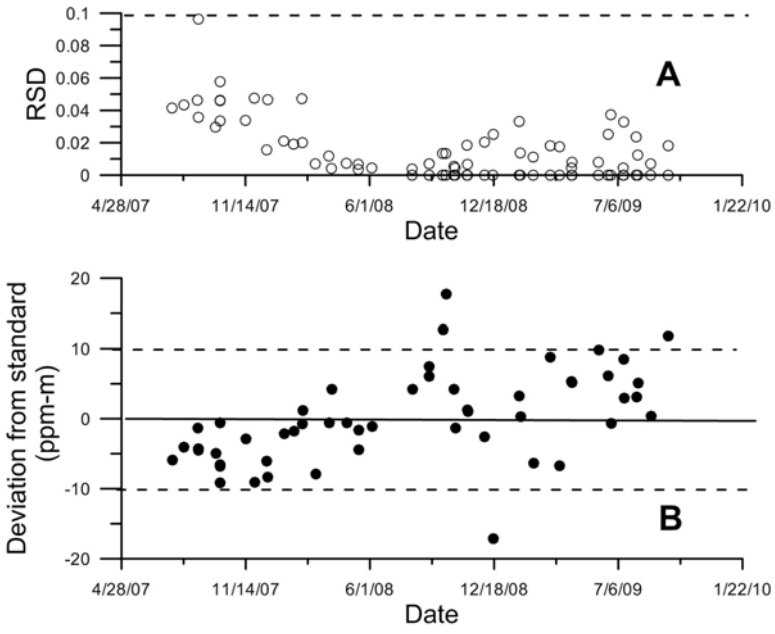


Figure 6.1-5: Control charts of the GasFinder2 [TM] s/n NH3OP-1028

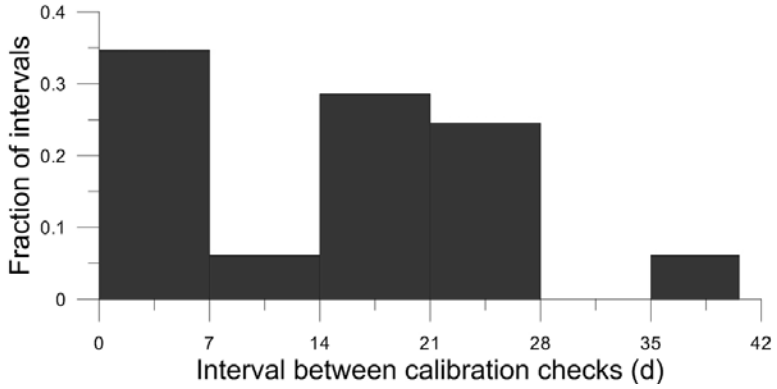


Figure 6.1-6: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1028

TDLAS 1030 was multipoint calibrated eight times during the study (Figure 6.1-7). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 3/26/2008 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was

$$ppm\text{-}m = 0.13 + 0.9974 * X - 2.1056E\text{-}005 * X^2 + 3.050E\text{-}008 * X^3$$

where X was the instrument response. The response of the sensor was influenced by humidity until 7/21/2008 due to an error in the factory settings for the spectral waveband analysis window. At that time, factory personnel corrected the spectral waveband used for analysis. The effect of this error was to 1) reduce the maximum possible linear correlation with the internal reference cell resulting in unusually low r^2 values under conditions in which the concentration of NH_3 was more than three times of the MDL, and 2) reduce the reported concentration. The adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments) but did change the maximum r^2 reached by the instrument when in the field for long path lengths and high humidity.

A zero concentration was not reportable by this instrument because the concentration was based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 3.05 ppm-m prior to the July 2008 modification and 0.685 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-8) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 days (Figure 6.1-9). The large fraction of checks made within 7 days is the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 7.27 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m except on 8/30/2007 (Figure 6.1-8) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A positive bias in the calibration verification exceeding the DQI occurred on 8/14/2008 and 9/23/2008 while negative biases exceeding the DQI occurred on 10/4/2007, 9/23/2008, and 4/28/2009 (Figure 6.1-8). In all cases, subsequent calibration verifications did not indicate the same exceedance bias and it is concluded that operator error resulted in the exceedances rather than instrument failure.

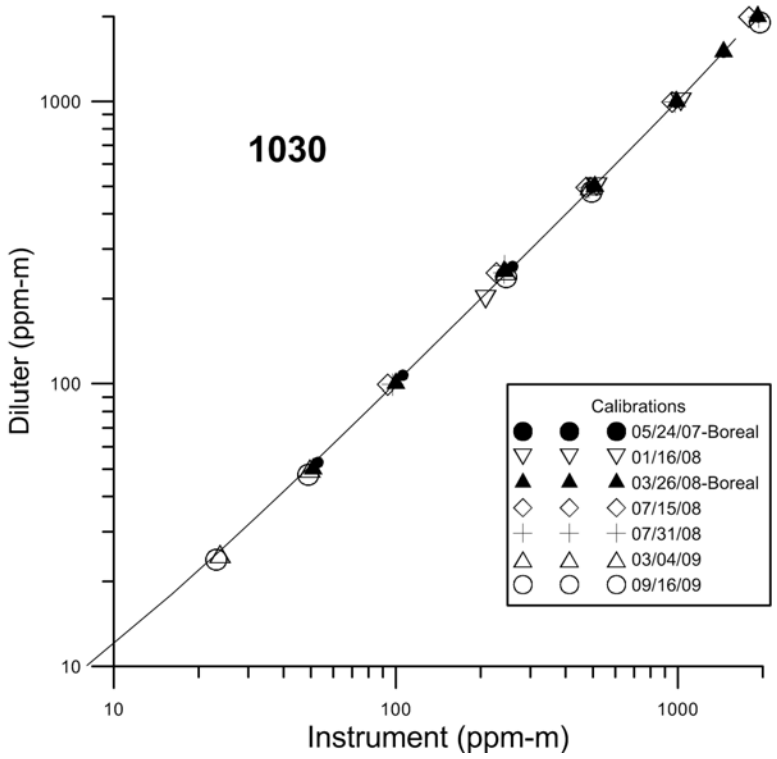


Figure 6.1-7: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1030. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

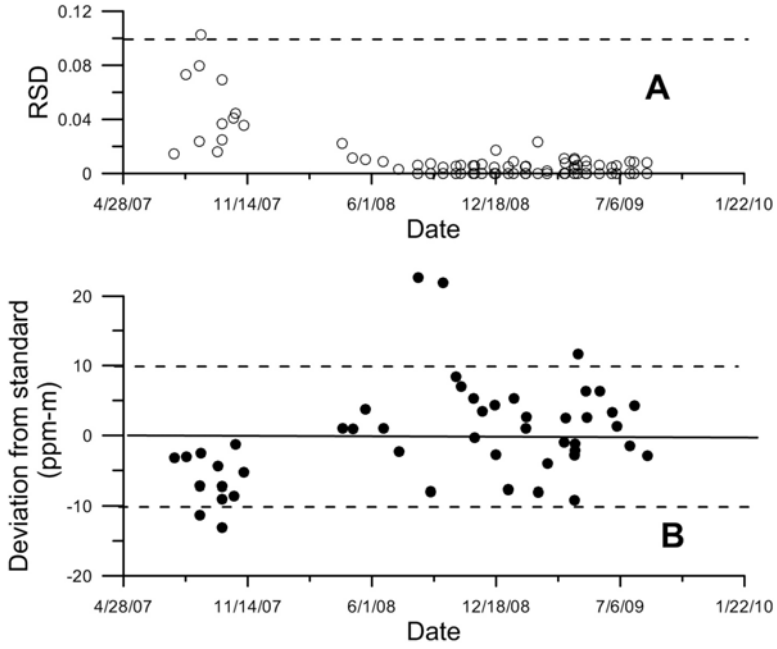


Figure 6.1-8: Control charts of the GasFinder2 ™ s/n NH3OP-1030

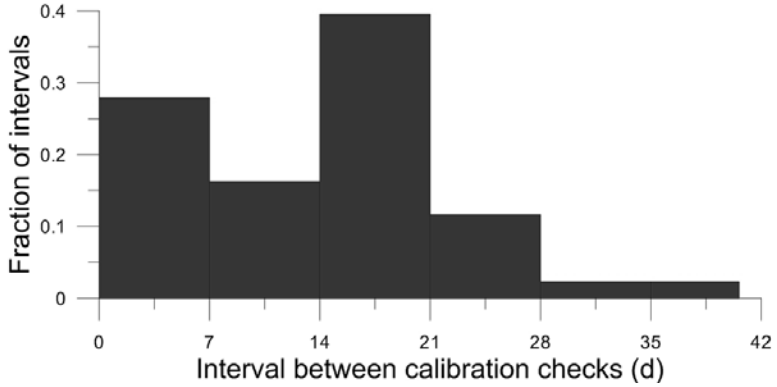


Figure 6.1-9: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1030

TDLAS 1031, was multipoint calibrated six times during the study (Figure 6.1-10). The response was non-linear and consequently a third-order polynomial was used to correct the instrument measurements for the instrument response. The multipoint calibration on 5/30/07 was used for the entire study period. The offset of the equation was determined from a least squares fit of the entire record of calibration verifications made at 50 ppm-m applied to the first, second, and third order terms derived from the multipoint calibration. The regression equation was

$$ppm\text{-}m = -4.43 + 1.0120 * X - 5.7496E\text{-}005 * X^2 + 6.0196E\text{-}008 * X^3$$

where X was the instrument response. In July 2008 factory representatives adjusted the response of this unit. Adjustments made on the instrument at this time did not appear to affect the calibration (conducted before and after adjustments).

A zero concentration is not reportable by this instrument because the concentration is based on the correlation of the measured NH_3 absorption to a reference gas. No measured absorption at zero concentration results in no correlation and consequently no reportable measurement. The MDL of the instrument was determined from the mean of the variability (3σ) experienced at the verification concentration during each calibration verification. Since the calibration verifications were conducted in a very short path length, the water vapor effect on the instrument response was generally not detectable. The MDL was calculated to be 5.70 ppm-m prior to the July 2008 modification and 1.92 ppm-m after the modification. The instrument performance was within the MDL DQI that required the MDL to be less than 10 ppm-m. The average MDL was approximately equal to the offset indicated in the calibration regression. The calibration equation offset was less than the requisite DQI MDL.

Instrument performance calibration checks (Figure 6.1-11) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 21 days (Figure 6.1-12). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods. The standard deviation of the verifications about that predicted by the calibration equation was 15.60 ppm-m. The precision DQI was ±10% RSD at 100 ppm-m. All verifications resulted in less than 10% RSD for 50 ppm-m (Figure 6.1-11) and were well within the precision DQI. The accuracy DQI was ± 10% of the 1000 ppm-m range of the measurements. A negative bias exceeding the DQI occurred in the calibration verifications between 8/2/2007 and 9/18/2007 (Figure 6.1-11). Positive DQI bias exceedances occurred on 6/28/2007, 9/11/2008, 4/8/2009 and 8/12/2009. Verification failures in the 6/28/07 to 9/18/07 interval were a result of un-anticipated optical noise in the calibration procedure which was later corrected. The 4/8/2009 exceedance was preceded and followed by DQI-compliant verifications and the 8/12/2009 verification was preceded by a compliant verification and followed by a multipoint indicating no problem with instrument performance. The instrument was taken out of service between 9/11/2008 and 12/31/2008.

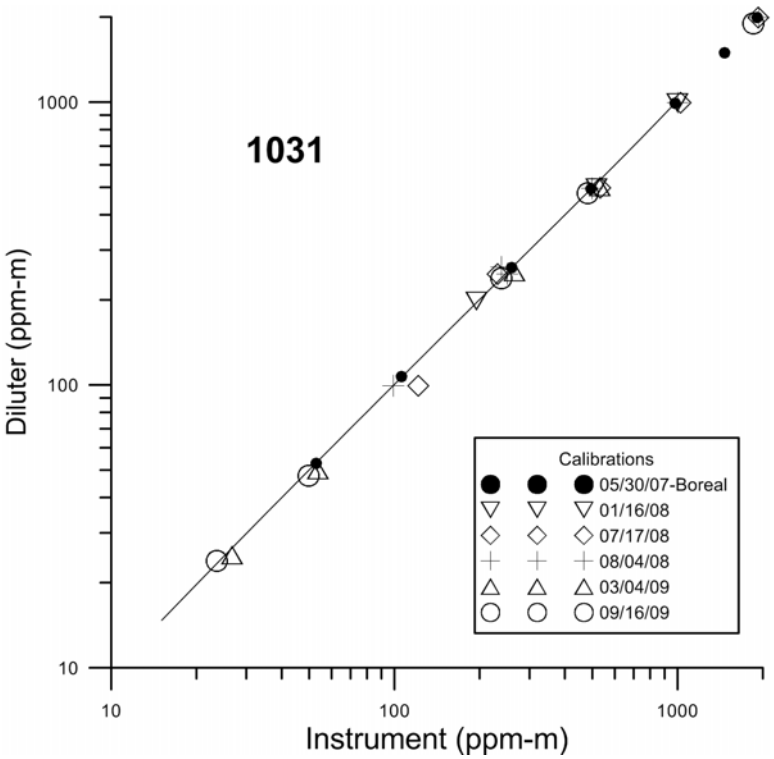


Figure 6.1-10: Multipoint calibrations of the GasFinder2 [TM] s/n NH3OP-1031. The solid line is the 3rd order polynomial regression for the chosen multipoint calibration.

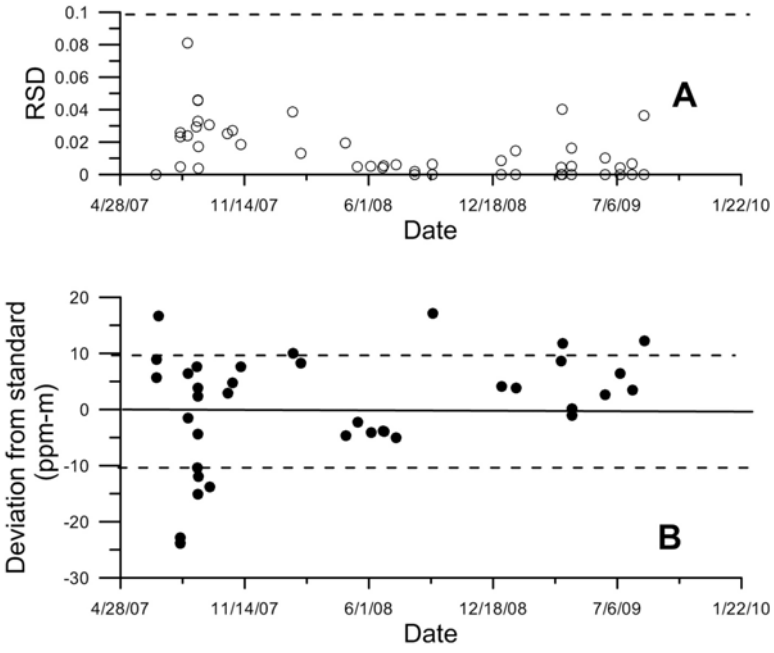


Figure 6.1-11: Control charts of the GasFinder2 [TM] s/n NH3OP-1031

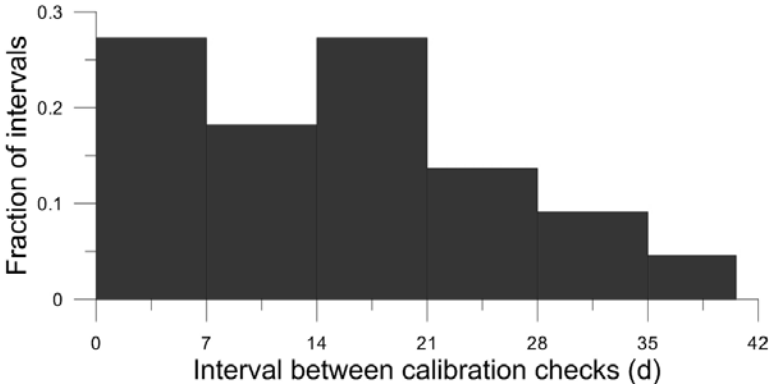


Figure 6.1-12: Calibration check intervals of the GasFinder2 ™ s/n NH3OP-1031

6.2 TEC 450i analyzer H_2S calibrations

The H_2S Analyzer (Model TEC 450i, Thermo Fisher Scientific, Franklin, MA) with serial number 0733825129 was multipoint calibrated seven times during the study (Figure 6.2-1). The coefficient of determination (r^2) for linear fits to the calibration values were never less than 0.999 although the slope of the linear regression equation varied from 0.67 to 0.94 (Table 6.2-1). The initial 12/30/07 multipoint calibration records were lost.

Table 6.2-1: Multipoint H_2S calibrations

Date	Slope (ppb/response)	Intercept (ppb)	r^2
7/21/08	0.67	0.0100	0.999
11/25/08	0.81	0.0070	0.999
3/5/09	0.94	0.0165	0.999
4/23/09	0.73	0.0263	0.999
4/29/09	0.78	0.0206	0.999
9/1/09	0.75	0.0054	0.999
12/29/09	0.81	0.0083	0.999

The standard deviation of instrument response with CEM zero air measured over a one hour period was 0.81 ppb (12/29/2009). The instrument MDL, defined as 3σ was 2.4 ppb and is indicated in Figure 6.2-2A with dashed lines. This is much less than the mean absolute value of the multipoint calibration intercept of 13.4 ppb.

Instrument performance calibration checks (Figures 6.2-2, 6.2-3) were made at the beginning and end of each measurement period. The majority of calibration checks were made within 25 d (Figure 6.2-4). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods. Instrument response was converted into measured concentrations by multiplying the instrument response by the long-term mean ratio of diluted calibration gas by instrument reading. The long-term mean ratio for this instrument was 0.800. The mean zero concentration was +0.3 ppb, less than the MDL.

The instrument measurement accuracy DQI was 10% of full scale (FS; 1 ppm). The initial calibration check (1/15/2008) was conducted prior to the complete burn-in of the converter and consequently differs from the other calibrations and indicated a failed check in the post-study response check (Figure 6.2-2B). Post-study response checks in August and September 2008 also indicated check failures (Figure 6.2-2B), although all of these failures are associated with a non-diluted calibration cylinder where the balance gas was N_2, and the 450i converter was consequently unable to function properly.

The instrument measurement precision DQI was 10% of FS. Precision DQI exceedances (Figure 6.2-3) occurred on 2/12/2008 and 3/5/2009. The 2/2/2008 failure was likely due to the burn-in of the converter and signals changes in the instrument response as the instrument is conditioned. The failure on 3/5/2009 was likely a result of the use of an out-of-certification range calibration cylinder (although within certification period; FF44447). This cylinder was 38% below the mean concentration of nine cylinders inter-compared on 8/28/2009 through 8/31/2009. Calibration certification before and after this date were valid.

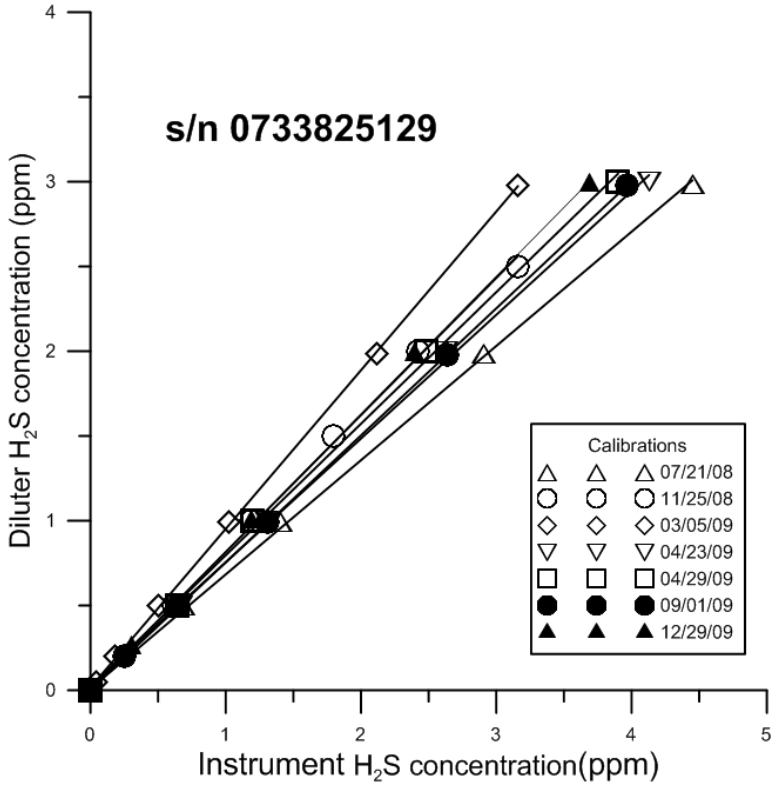


Figure 6.2-1: Multipoint calibrations of the 450i SO_2/H_2S Analyzer

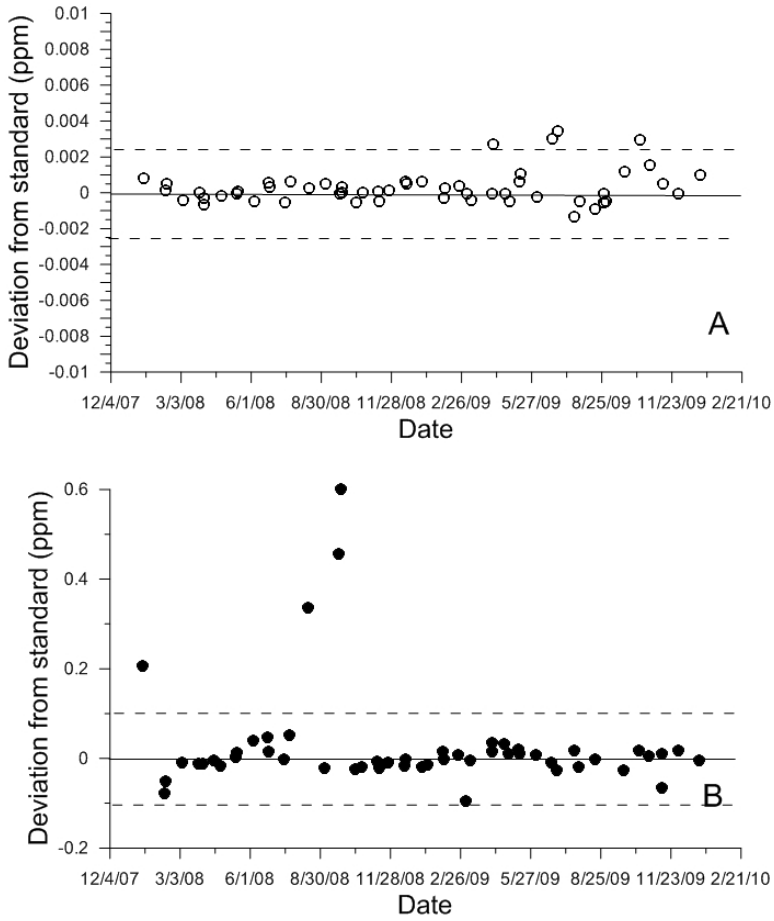


Figure 6.2-2: Instrument Control Charts

The zero check (panel A) and span check (panel B) are indicated. The dashed lines in panel A represent the MDL. The dashed lines in panel B represent 10% of the Full Scale value (1 ppm).

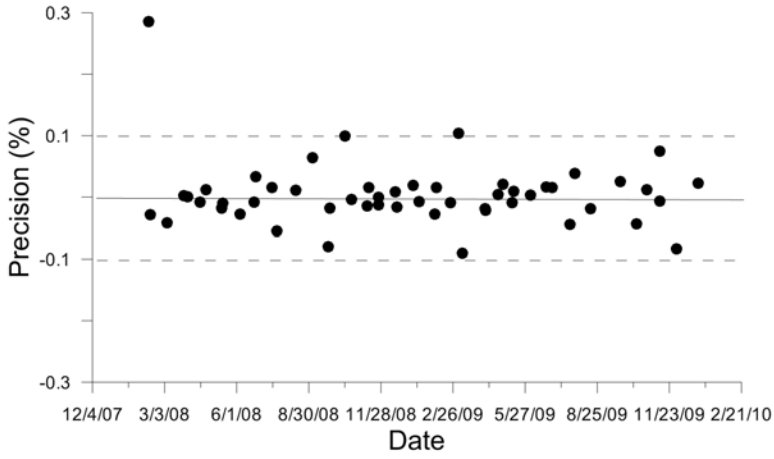


Figure 6.2-3: Instrument Precision

The precision of span checks are indicated. The dashed lines in panel A represent the MDL. The dashed lines represent 10% of the Full Scale value (1 ppm).

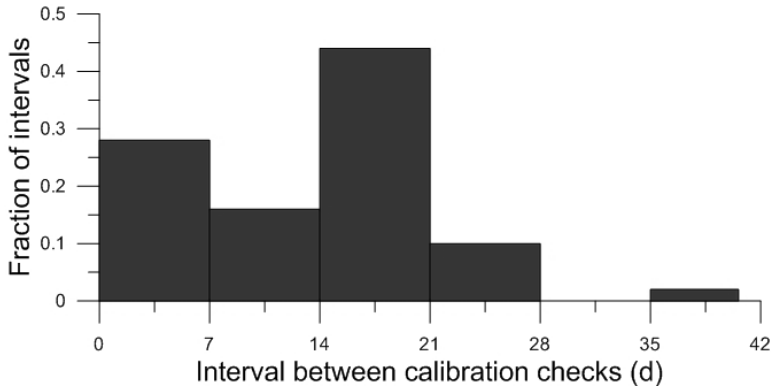


Figure 6.2-4: Calibration check intervals

6.3 Sonic anemometer calibrations

Six sonic anemometers (Model 81000, RM Young Inc, Traverse City, MI) were used at this location: serial numbers 1926, 1933, 1920, 1928, 1945, and 1932.

The sonic 1926 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.3-1). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 35 times (Figure 6.3-1). The majority of calibration checks were made within 21 days (Figure 6.1-2). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-1A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-1 Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/07	6/29-7/2/07	-0.005	-0.033
1/17-18/08	1/20-21/08	-0.013	-0.032
7/16-17/08	7/17-18/08	+0.037	+0.059
3/6-7/09	3/7-9/09	+0.004	+0.048
9/16-17/09	9/17-18/09	+0.059	+0.001

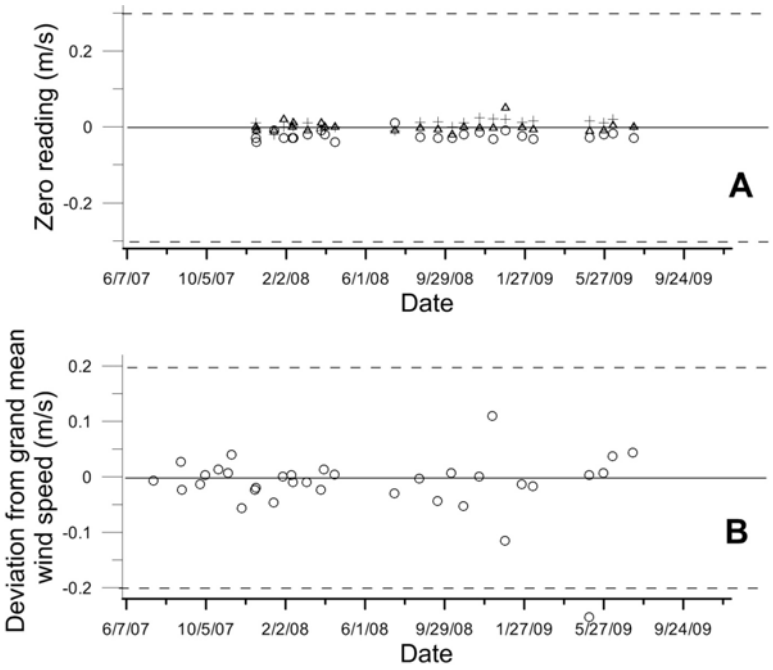


Figure 6.3-1: On-site quality assurance of the 1926 sonic. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

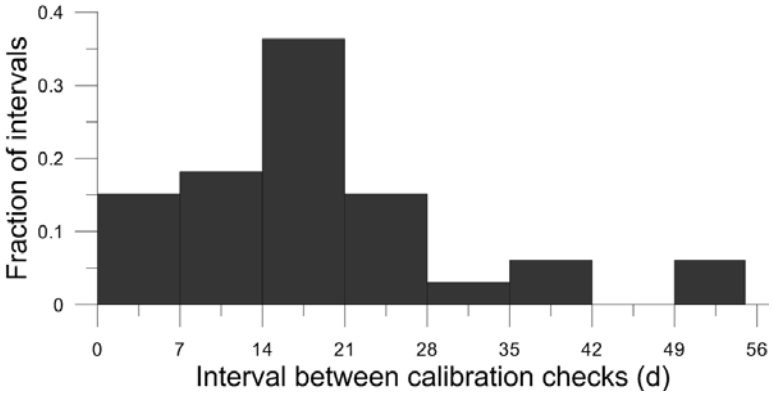


Figure 6.3-2: Inter-comparison check intervals the 1926 sonic.

The sonic 1933 was inter-compared with three reference anemometers of identical design three times during the study (Table 6.3-2). This instrument was used as a reference prior to use in the on-site measurements beginning 4/23/08. No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 23 times (Figure 6.3-3). The majority of calibration

checks were made within 21 days (Figure 6.3-4). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-1B). This instrument passed this check on all checks except 7/21/2009 and was taken out of service. The last standard inter-comparison (1/2010) failed due to loss of communications.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-3A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-2: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
7/18-19/08	7/21-22/08	+0.012	+0.014
3/3-5/09	3/5-6/09	-0.016	-0.004
1/7-9/10	1/23-25/10	-3.733	-3.93

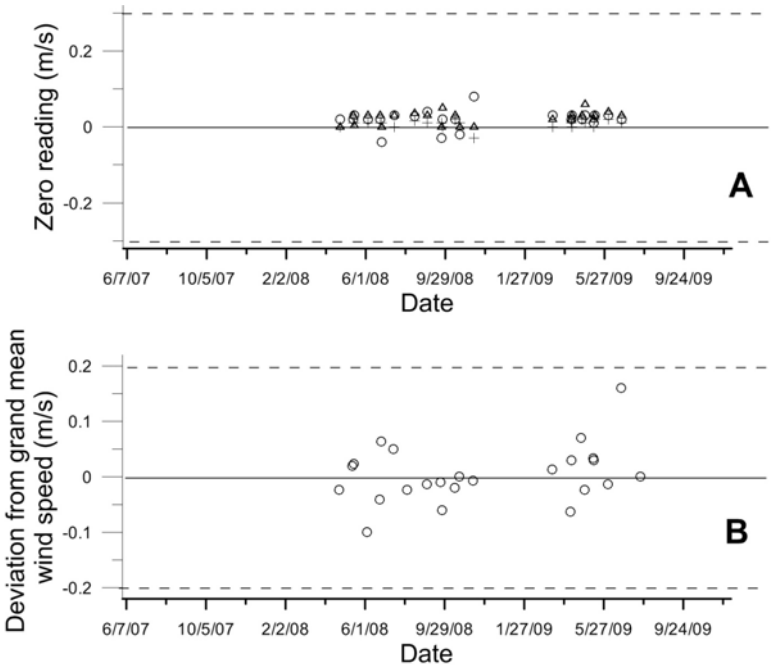


Figure 6.3-3: On-site quality assurance of the 1933 sonic. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

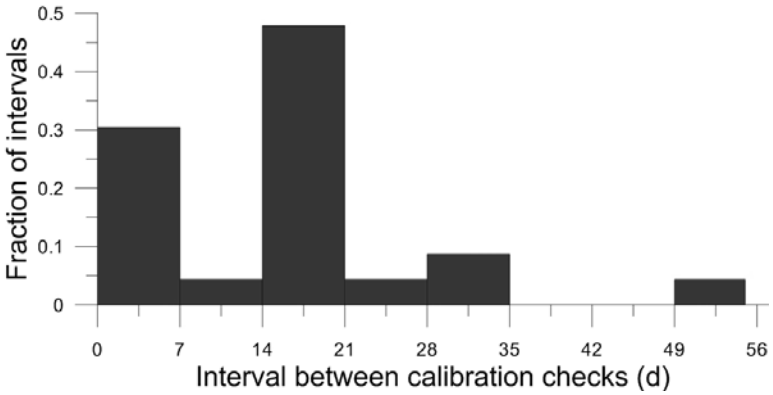


Figure 6.3-4: Inter-comparison check intervals for the 1933 sonic.

The sonic 1920 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.3-3). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 51 times (Figure 6.3-5). The majority of calibration

checks were made within 21 days (Figure 6.3-6). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-5B). This instrument passed this check at all times. However this instrument developed intermittent problems during operation and was sent to the factory for repair 10/10/2008.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-5A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-3: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/07	6/29-7/2/07	+0.001	+0.002
1/17-19/08	1/20-21/08	+0.045	+0.003
7/18-21/08	7/21-22/08	+0.017	-0.006
3/23-25/09	3/25-27/09	-0.036	-0.033
9/1-2/09	9/2-3/09	-0.046	-0.025

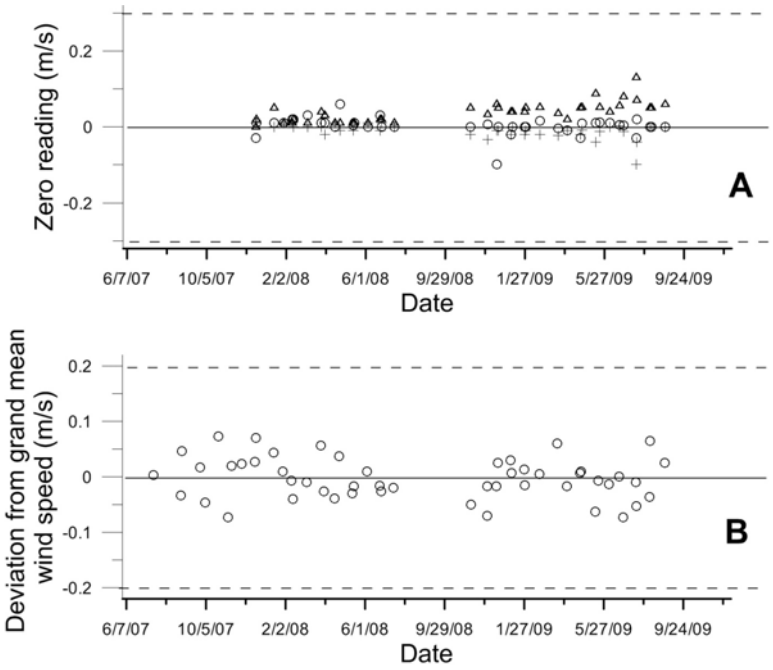


Figure 6.3-5: On-site quality assurance of the 1920 sonic. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

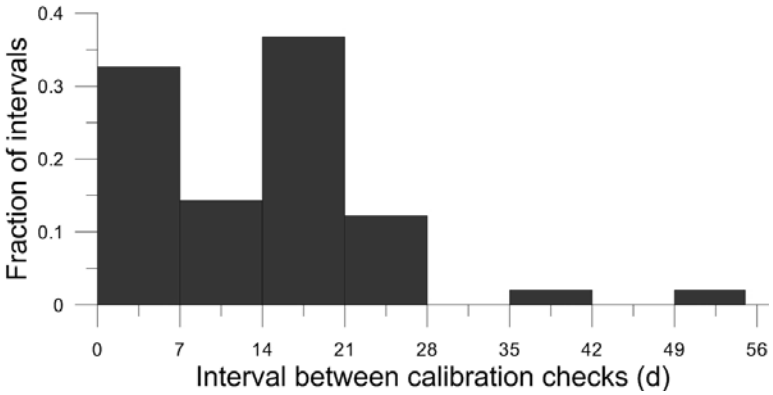


Figure 6.3-6: Inter-comparison check intervals for the 1920 sonic.

The 1928 sonic was inter-compared with three reference anemometers of identical design six times during the study (Table 6.3-4). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 48 times (Figure 6.3-7). The majority of calibration

checks were made within 21 days (Figure 6.3-8). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments(Figure 6.3-7B). This instrument passed this check all but one time. On this one date, the inter-comparison was rerun and the instrument passed the check.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-7A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-4: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-18//07	6/18-19/07	+0.004	+0.019
12/27-28/07	12/29-31/07	+0.003	-0.005
7/10-11/08	7/11-14/08	+0.022	+0.007
3/3-4/09	3/5-6/09	+0.070	-0.027
9/16-17/09	9/17-18/09	+0.056	+0.022
12/18-19/09	12/21-23/09	+0.094	-0.077

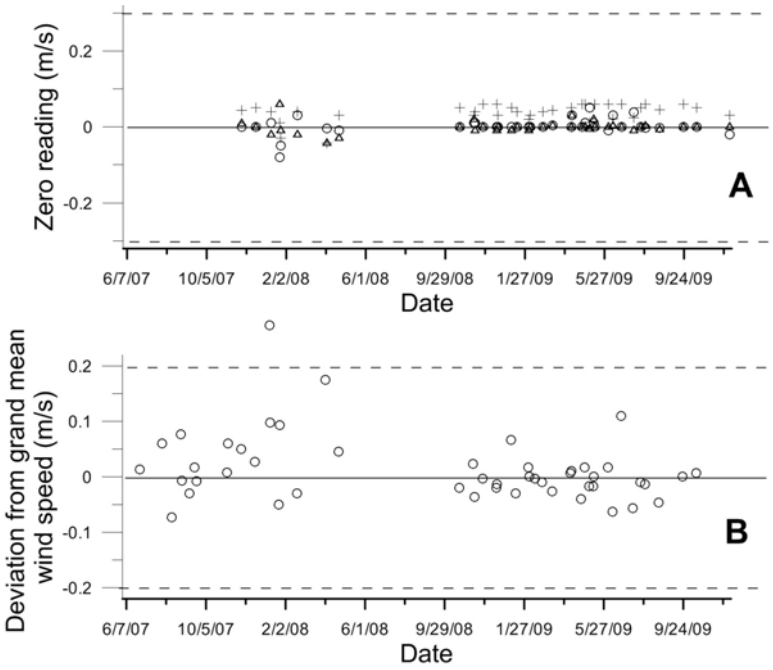


Figure 6.3-7: On-site quality assurance of the 1928 sonic. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

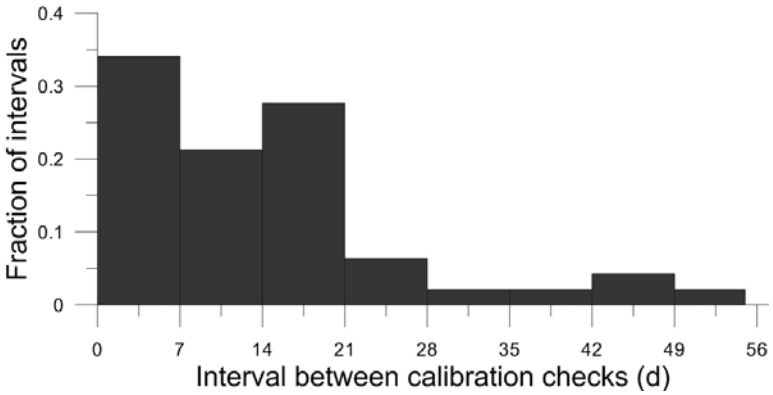


Figure 6.3-8: Inter-comparison check intervals for the 1928 sonic.

The sonic 1945 was inter-compared with three reference anemometers of identical design five times during the study (Table 6.3-5). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 45 times (Figure 6.3-9). The majority of calibration

checks were made within 21 days (Figure 6.3-10). The large fraction of checks made within 7 days is the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-9B). This instrument passed this check at all times.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-9A). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-5: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/19-22/07	6/27-7/2/07	+0.001	-0.051
1/17-19/08	1/20-21/08	-0.023	-0.037
7/18-21/08	7/21-22/08	+0.023	+0.026
3/3-4/09	3/5-6/09	+0.014	+0.171
9/16-17/09	9/17-18/09	+0.028	-0.012

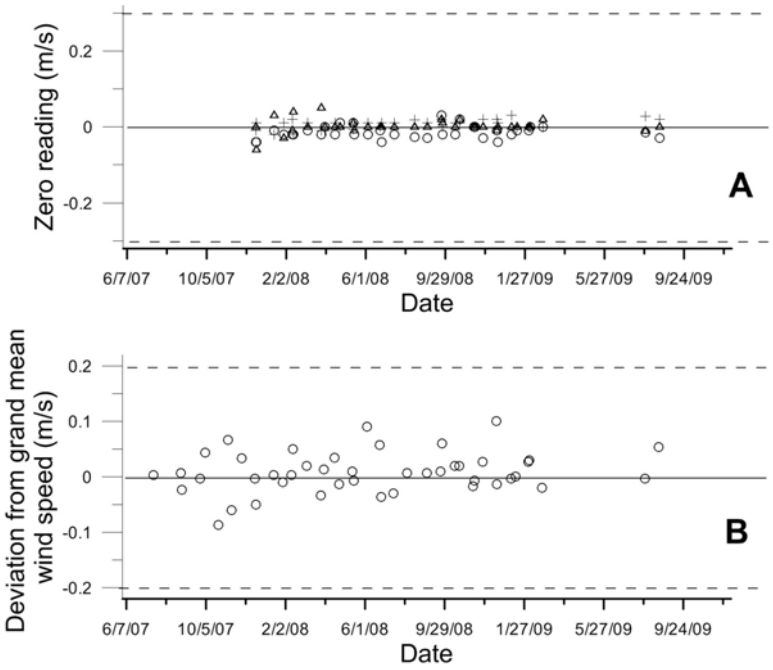


Figure 6.3-9: On-site quality assurance of the 1945 sonic. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

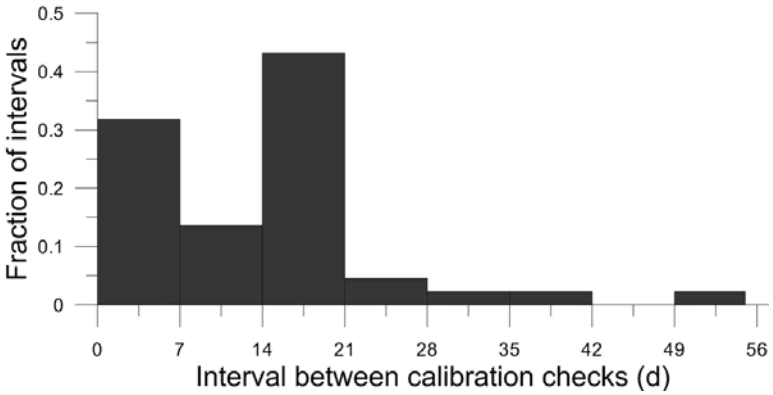


Figure 6.3-10: Inter-comparison check intervals for the 1945 sonic.

The sonic 1932 was inter-compared with three reference anemometers of identical design six times during the study (Table 6.3-6). No absolute turbulence calibration was possible with this instrument. To assure proper performance and comparability in the wind measurements, the anemometer was inter-compared on-site with those used during a given measurement period at the beginning and end of a measurement period. This instrument was inter-compared with the co-located anemometer sensors on site 55 times (Figure 6.3-11). The majority of calibration

checks were made within 21 days (Figure 6.3-12). The large fraction of checks made within 7 days was the result of calibration checks made at the end and beginning of sequential measurement periods.

The accuracy DQI for the on-site inter-comparisons required the individual instruments to have the mean wind speed within 0.2 ms^{-1} of the grand mean value of the three (or four) on-site instruments (Figure 6.3-11B). This instrument passed this check on all checks except 10/15-16/2008 and was taken out of service. Laboratory testing indicated wetness in the sensor. The sensor was dried, tested, and put back to use.

The precision DQI for the on-site inter-comparisons required each wind component (x, y, and z) of the individual instruments to be within 0.3 ms^{-1} of zero (Figure 6.3-11B). Records of the zero checks made before 12/2007 were recorded as pass/fail such that the actual measurements were not indicated. The instrument always passed this DQI.

Table 6.3-6: Standards inter-comparisons

Calibration dates		**Mean difference from reference anemometers (ms^{-1})**	
Alignment 1	**Alignment 2**	**Alignment 1**	**Alignment 2**
6/15-17/07	6/18-19/07	+0.004	+0.160
12/27-28/07	12/29-31/07	+0.014	-0.009
7/10-11/08	7/11-14/08	+0.008	+0.031
3/3-5/09	3/5-6/09	-0.024	-0.005
9/8-14/09	9/15-16/09	-0.025	-0.044
1/7-9/10	1/23-24/10	+0.020	-0.016

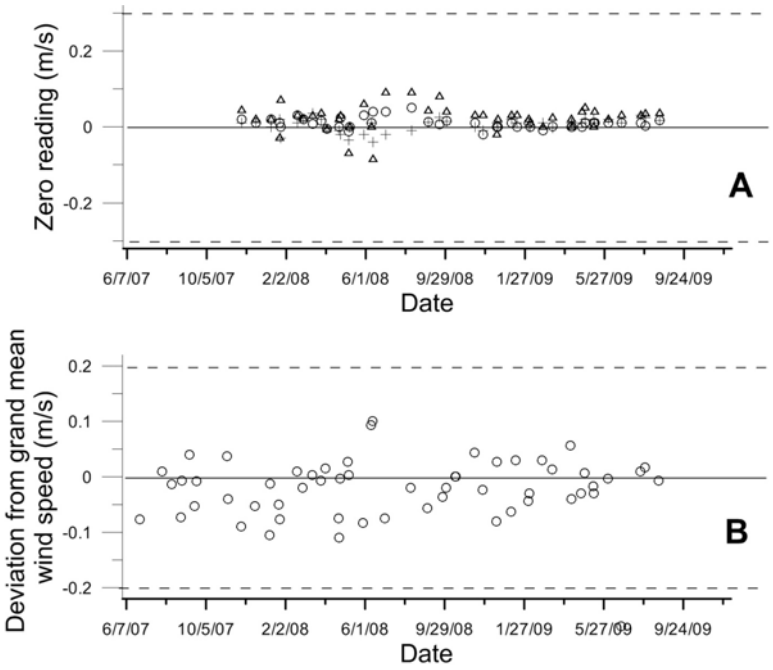


Figure 6.3-11: On-site quality assurance of the 1932 sonic. The DQI for the zero and inter-comparisons are indicated by the dashed lines. The zero check in the x (open circle), y (open triangle) and z (cross) components are indicated in panel A.

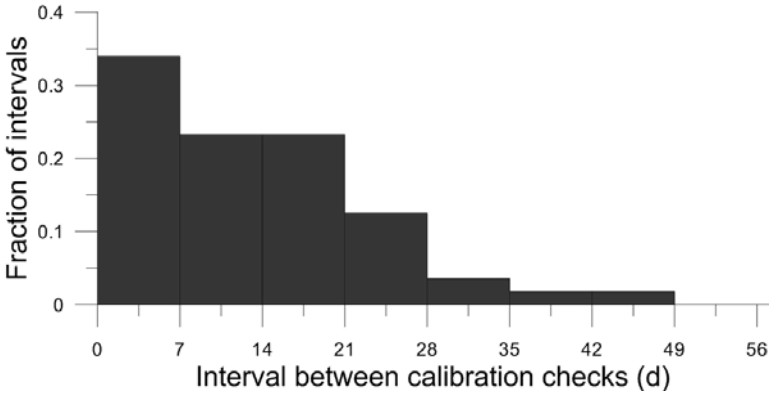


Figure 6.3-12: Inter-comparison check intervals for the 1932 sonic.

6.4 pH probe calibrations

Two pH probes (Model CSIMM-ph, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 002 and 004.

Probe 002, was used between 6/27/2007 and 10/2/2008. The probe was calibrated 16 times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-1A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The accuracy check exceeded the DQI on 4/24/2008, 5/6/2008, and 10/2/2008. The DQI exceedances on 4/24/2008 and 5/6/08 were followed with a valid accuracy check without sensor modification or repair so it is assumed that the checks failed due to inadequate probe cleaning. The accuracy check failure on 10/2/2008 was a result of probe failure. The stability check failed on 11/28/2007, 12/19/2007, 6/10/2008, and 10/2/2008. The failed stability checks on 11/28/2007 and 12/19/2007 did not correspond with accuracy check failures and were assumed to be operator error. The stability check on 6/10/2008 was indicative of the probe failure noted in the following accuracy check.

Probe 004, was used between 7/8/2007 and 2/3/2009. The probe was calibrated 27 times. The pH probe DQI specified an accuracy of ± 0.3 pH units, corresponding to a difference between the calculated and measured pH of 17.7 mV of signal. Figure 6.4-2A illustrates the control chart for the three pH standards used (pH 4, 7, and 10) relative to the mV error. Each sensor was also checked for stability using QCCS solution, with the requirement that the sensor be within 0.05 pH units, or 3 mV. The history of the probe stability check is illustrated in Figure 6.4-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe passed the accuracy DQI on all checks but 2/3/2009 but failed the stability checks 9/23/2008, 9/25/2008, and 2/3/2009. Since the sensor passed checks subsequent to the 9/2008 checks, these failures were likely due to operator error. The last check on 2/3/2009 indicated a faulty sensor.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since freezing conditions damage the probe, the probes were not used during the winter at many locations. Since lagoon pH measurements were not made at several locations the interval between calibrations can be large such that locations that did not have lagoon pH measurements were visited between locations where the measurements were made.

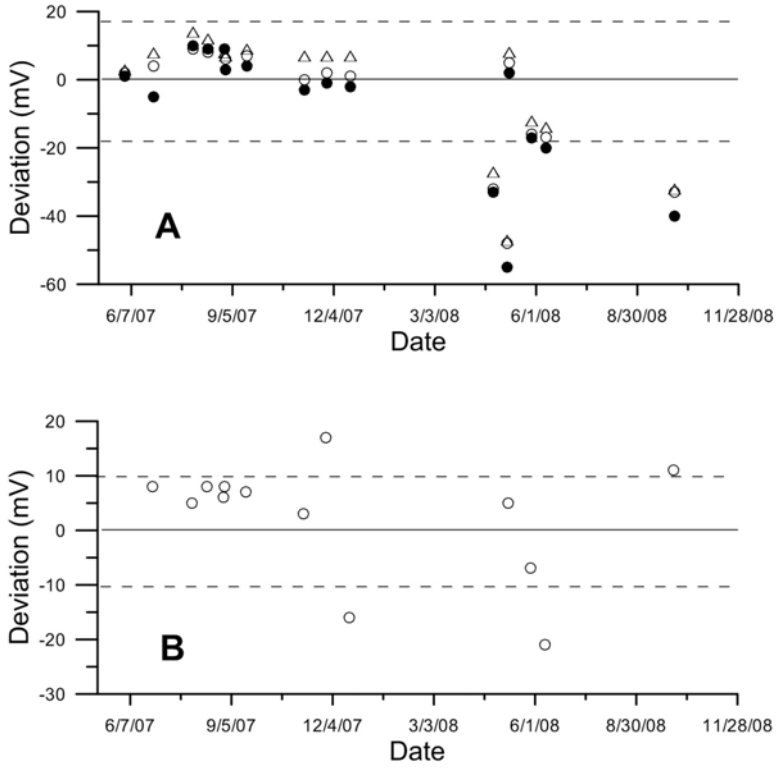


Figure 6.4-1: Accuracy and stability calibration checks of pH probe 002. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and pH 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

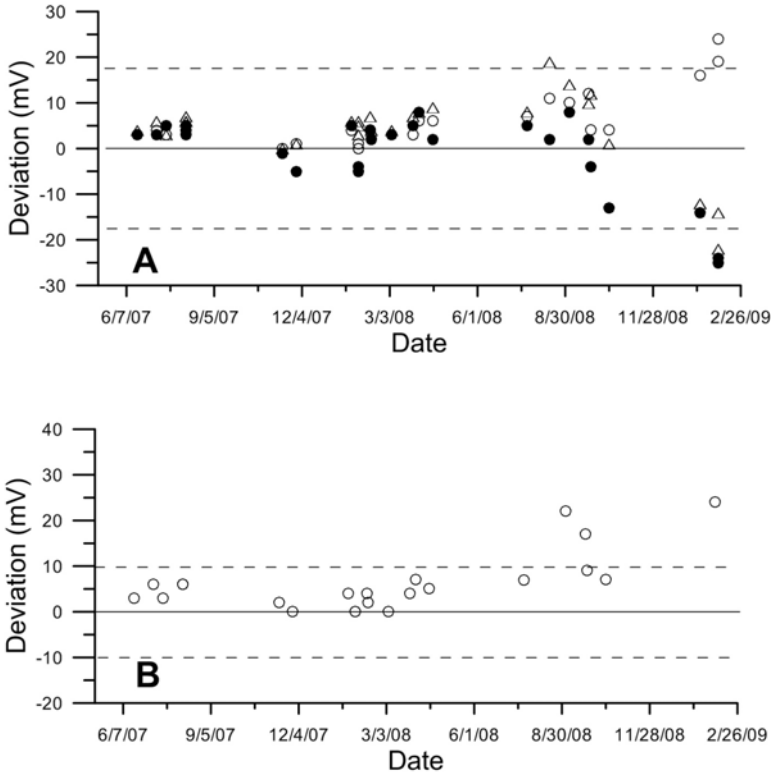


Figure 6.4-2: Accuracy and stability calibration checks of pH probe 004. The absolute deviation in mV of the pH 4 (closed circle), pH 7 (open circle), and pH 10 (solid triangle) tests are indicated in panel A. The dashed lines define the DQI limits. The time history of the absolute stability is indicated in panel B where the dashed lines indicate the desired bounds of the stability.

6.5 ORP probe calibrations

Two oxidation-reduction potential (ORP) probes (Model CSIM11-ORP, Innovative Sensors Inc., Anaheim, California) were used at this location: serial numbers 020 and 040.

Probe 020 was used between 7/18/2007 and 9/3/2008. The probe was calibrated 16 times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-1A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-1B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe passed the accuracy check DQI on all but 3/27/2008, 4/2/2008, and 8/14/2008. Subsequent accuracy check however met the accuracy DQI without probe modification so the prior failures were assumed to be due to operator error. The stability deviated significantly from the normal range on 4/2/2008 and 8/14/2008 indicating a possible partially-plugged probe.

Probe 040 was used between 7/18/2007 and 4/7/2008. The probe was calibrated six times. The ORP probe DQI specified an accuracy of ± 20 mV (Figure 6.5-2A). Each sensor was also checked for stability using a KCl solution, with the requirement that the sensor be within 1 mV of the reference solution. The history of the probe stability check is illustrated in Figure 6.5-2B. Problems with freezing of the electrolyte in the reference electrode during the winter reduced the frequency of these checks. The probe always passed the accuracy check DQI and the stability check indicated excellent probe stability.

In general, the probe calibrations were conducted at the beginning and end of each measurement period. Since freezing conditions damage the probe, the probes were not used during the winter at many locations. Since lagoon ORP measurements were not made at several locations, the interval between calibrations can be large when locations that did not have lagoon ORP measurements were visited between locations where the measurements were made.

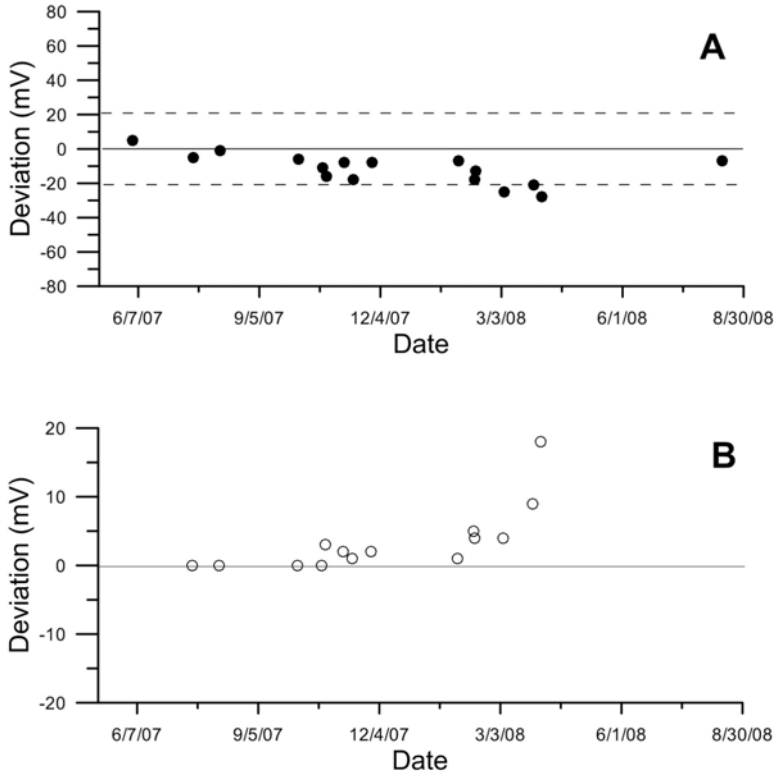


Figure 6.5-1: Accuracy and stability calibration checks of ORP probe 020. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

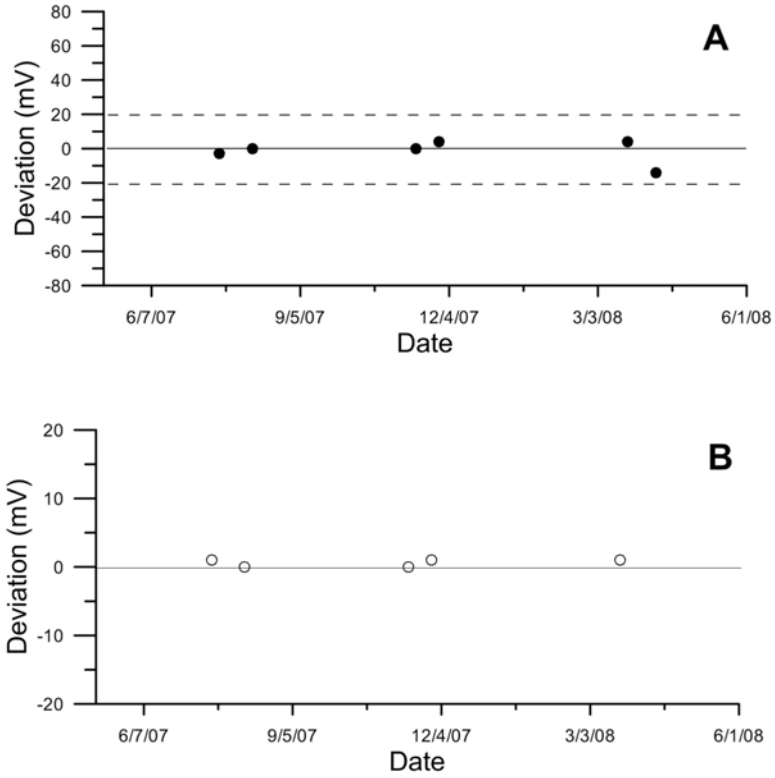


Figure 6.5-2: Accuracy and stability calibration checks of ORP probe 040. The stability check of the probe (Panel B) and the absolute deviation in mV of the probe (panel A) are indicated. The dashed lines define the DQI limits in panel A.

6.6 S-OPS operational checks

The Synthetic Open Path Systems (S-OPS; s/n D and F) and the Gas Sampling System (GSS s/n 4-0018) were checked at the beginning and end of every measurement period. A leak check and maximum flow check were made for both the S-OPS in combination with the GSS and for the GSS alone. In addition, the balance of flow into each inlet in the S-OPS was checked before and after each measurement period.

Results of the leak tests for both the GSS and the Combined GSS/S-OPS are indicated in sequence in Table 6.6-1. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. Often GSS leak check failures corresponded to successful S-OPS leak checks that included the GSS within the system check (Table 6.6-1). Leaks in the GSS generally were a result of pump problems or incorrect zero offset determinations. Leaks in the S-OPS occurred several times in the study. These leaks were apparently a result of vibration within the GSS. The permissible leak in the S-OPS/GSS or GSS alone was 10% of the maximum flow. Details of the leak check failure follow:

- S-OPS leak check failure of single lines on 6/26/2008, 7/15/2008, 12/17/2008, 1/15/2009, 2/3/2009, 2/6/2009, and both lines on 10/22/2008 were not resolved during the site visit due to time constraints. Repairs to the S-OPS were made on subsequent visits.
- GSS leak check failures that paired with S-OPS leak check passes indicated that the GSS leak check test may have been in error.
- GSS leak check failure on 10/14/2008 was a result of pump diaphragm failure.

The impact of leak check failures in the S-OPS lines (with the exception of those at the GSS inlet filters) was minimal as the leaks were at junctions of tubing and tubing/inlet filters and would allow air into the lines that differ only from height above the berm from the air sampled along the inlets themselves. The impact of GSS leak check failures associated with pump diaphragm failures would only influence the volume of flow available to the H_2S analyzer. In all cases flow available to the analyzer greatly exceeded that used by the analyzer (1.5 L min^{-1}) (Table 6.6-1).

Table 6.6-1: Record of leak checks for GSS and GSS/S-OPS

Date	Site	GSS solenoid	GSS mass Flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
4/1/2008	NC4A	2	0.04	-38.42	Pass	9.7	0.49	-35.63	Pass
		3	0.07	-38.12	Pass	9.8	0.62	-37.59	Pass
4/15/2008	NC4A	2	0.04	-36.59	Pass	6.5	0.54	-38.45	Pass
		3	0.04	-36.36	Pass	9.6	0.68	-36.38	Pass
4/24/08	WI5A	2	0.07	-35.13	Pass	8.3	0.62	-35.39	Pass
		3	0.09	-37.54	Pass	8	0.61	-35.54	Pass
5/13/08	WI5A	2	0.08	-34.5	Pass	7.7	0.69	-36.06	Pass
		3	0.07	-37.35	Pass	10	0.65	-37	Pass
5/15/08	IA3A	2	0.01	-37.16	Pass	8.2	0.51	-36.29	Pass
		3	0.04	-36.72	Pass	10	0.65	-35.9	Pass
6/4/2008	IA3A	2	0.08	-38.67	Pass	9.9	0.32	-37.49	Pass
		3	0.07	-23.71	Pass	10	0.47	-20.66	Pass
6/23/2008	IA3A	2	0.01	-35.74	Pass	10	0.38	-36.45	Pass
		3	0.05	-34.5	Pass	10	1.00	-37.66	Pass

Date	Site	GSS solenoid	GSS mass Flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
6/25/2008	WI5A	2	0.05	-35.75	Pass	10	0.31	-34.95	Pass
		3	-0.01	-35.63	Pass	10	1.07	-36.71	Fail
7/15/2008	WI5A	2	0.05	-37.52	Pass	10	0.39	-36.92	Pass
		3	0.08	-34.45	Pass	8	0.90	-34.97	Fail
8/13/2008	NC4A	2	0.11	-36.28	Pass	10.1	0.38	-36.27	Pass
		3	0.08	-35.29	Pass	10	1.03	-36.16	Fail
9/3/2008	NC4A	2	-0.01	-35.49	Pass	9.8	0.46	-35.83	Pass
		3	-0.01	-37.07	Pass	9.5	0.62	-35.51	Pass
9/22/2008	NC4A	2	0.07	-37.58	Pass	10	0.61	-35.03	Pass
		3	0.04	-36.9	Pass	9.8	0.89	-35.95	Pass
9/25/2008	NC3A	2	0.08	-38.32	Pass	10	0.59	-35.9	Pass
		3	0.12	-37.84	Pass	10	0.96	-35.15	Pass
10/14/2008	NC3A	2	0.23	2.01	Fail	9.9	0.85	2.24	Pass
		3	0.24	2.76	Fail	9.8	0.82	3.74	Pass
10/22/2008	WI5A	2	0.03	-37.7	Pass	9.1	1.01	-37.55	Fail
		3	0.05	-36.53	Pass	8.3	0.93	-35.01	Fail
11/11/2008	WI5A	2	0.23	-38.84	Fail	9	0.32	-36.7	Pass
		3	0.09	-40.18	Pass	10	0.18	-39.43	Pass
11/13/2008	IA3A	2	0.14	-35.89	Pass	10	0.31	-33.84	Pass
		3	0.15	-36	Fail	10	0.32	-37.98	Pass
11/25/2008	IA3A	2	0.09	-32.04	Pass	9.9	0.63	-32.86	Pass
		3	0.09	-32.17	Pass	9.8	0.81	-32.56	Pass
12/16/2008	IA3A	2	0.18	-34.49	Fail	10	0.84	-35.46	Pass
		3	0.16	-32.41	Fail	10	0.51	-31.94	Pass
12/17/2009	WI5A	2	0.15	-36.18	Fail	8	0.82	-35.46	Fail
		3	0.18	-37.68	Fail	9.2	0.69	-35.44	Pass
1/6/2009	WI5A	2	0.20	-35.97	Fail	7	0.65	-35.46	Pass
		3	0.24	-23.82	Fail	9.1	0.68	-36.42	Pass
1/15/2009	NC4A	2	-0.05	-44.56	Pass	9.2	0.63	-43.36	Pass
		3	0.12	-43.57	Pass	8.5	1.03	-42.33	Fail
2/3/2009	NC4A	2	-0.03	-32.52	Pass	9	0.66	-31.73	Pass
		3	0.16	-32.07	Fail	8.5	1.07	-30.71	Fail
2/6/2009	NC3A	2	-0.28	-46.68	Pass	9.9	1.43	-33.54	Fail
		3	-0.01	-34.92	Pass	9.7	0.78	-33.01	Pass
2/23/2009	NC3A	2	0.05	-35.36	Pass	9.9	0.85	-35.24	Pass
		3	0.05	-35.51	Pass	9.7	0.43	-36.15	Pass
3/10/2009	WI5A	2	0.00	-36.55	Pass	8.2	0.39	-36.06	Pass
		3	0.03	-34.443	Pass	9.2	0.34	-36.32	Pass
4/7/2009	WI5A	2	0.12	-34.35	Pass	8.3	0.20	-32.15	Pass
		3	0.12	-32.31	Pass	9.4	0.24	-32.25	Pass
4/9/2009	IA3A	2	0.03	-33.32	Pass	10	0.23	-34.89	Pass
		3	0.11	-34.66	Pass	10	0.22	-36.33	Pass
4/23/2009	IA3A	2	0.01	-34.49	Pass	10.01	0.16	-34.9	Pass
		3	0.03	-36.36	Pass	10.01	0.15	-36.06	Pass
4/29/2009	NC4A	2	0.04	-33.83	Pass	9.8	0.14	-33.81	Pass
		3	0.00	-34.77	Pass	9.7	0.15	-34.79	Pass
5/11/2009	NC4A	2	0.03	-34.5	Pass	9.7	0.20	-34.34	Pass
		3	0.04	-32.88	Pass	9.7	0.20	-35.06	Pass
5/13/2009	NC3A	2	0.04	-34.4	Pass	9.3	0.30	-34.94	Pass
		3	0.03	-35.18	Pass	9.7	0.23	-34.04	Pass
6/2/2009	NC3A	2	0.04	-37.94	Pass	9.6	0.14	-37.45	Pass
		3	0.04	-35.54	Pass	9.5	0.22	-35.11	Pass
6/22/2009	NC3A	2	0.01	-35.46	Pass	9.8	0.20	-37.18	Pass
		3	0.03	-35.24	Pass	9.7	0.22	-37.89	Pass

Date	Site	GSS solenoid	GSS mass Flow (L min^{-1})	GSS pressure (kPa)	GSS check result	S-OPS max flow (L min^{-1})	S-OPS mass flow (L min^{-1})	S-OPS pressure (kPa)	S-OPS check result
7/1/2009	NC4A	2	0.03	-35.48	Pass	9.7	0.14	-36.58	Pass
		3	0.01	-34.46	Pass	9.5	0.14	-34.58	Pass
7/21/2009	NC4A	2	0.01	-35.69	Pass	9.8	0.11	-36.99	Pass
		3	0.03	-35.72	Pass	9.6	0.15	-35.37	Pass
7/28/2009	IA3A	2	0.01	-34.9	Pass	10	0.20	-33.94	Pass
		3	0.04	-34.55	Pass	10	0.31	-34.19	Pass
8/17/2009	IA3A	2	0.07	-42.67	Pass	10.05	0.14	-42.19	Pass
		3	0.07	-42.05	Pass	10.05	0.18	-41.85	Pass

The inlet flow balance checks are summarized in sequence in Tables 6.6-2A and 6.6-2B. Consequently records of the checks at a given measurement site are interspersed according to the sequence of measurements for this trailer. While the inlet flow balance was measured at the beginning and end of each measurement period, results showed that the balance throughout the period was not assured if the balance test indicated an adequate balance. Balance across the inlets at any time during a period or at the beginning or end of a period was limited due to wetness of the inlet filters associated with fog, ice, snow, or rain. In addition dust on the inlet filters contributed to an undetermined rate of flow degradation of individual inlets over a period. Spider webs would also restrict flow across the inlet filters. The allowable tolerance in the inlet balance was that the flow through any inlet was within 10% of the expected flow for the inlet.

Condensation or liquid water intrusion into the Teflon tubing of the S-OPS occurred often in the tubing around the area sources. Analysis of the problem revealed that condensation occurred as the air cooled in transit from the inlet to the trailer through tubing under a negative net radiation balance (particularly at night). In addition, water intrusion occurred during the leak testing if any water had accumulated along the junction between the filter/inlet and the S-OPS tubing. The impact of the liquid water in the S-OPS tubing on the measured concentration of H_2S was minimal due to the low solubility of H_2S.

Table 6.6-2A: Record of flow balancing- Side 1 (s/n D)

			Delta inlet flow (Beginning-End) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/26/08	4/1/2008	NC3A	0.00	0.02	0.00	-0.01	0.19	-0.03	-0.01	-0.03	-0.07	-0.09	Fail
4/1/2008	4/15/2008	NC4A	0.03	0.01	0.02	0.09	0.03	0.04	-0.07	0.20	0.28	-0.06	Fail
4/15/2008	4/24/2008	NC4A	-0.13	-0.14	-0.15	-0.12	-0.21	-0.26	-0.32	-0.31	-0.33	-0.36	Fail
4/24/2008	5/13/2008	WI5A	-0.04	-0.03	-0.03	-0.06	-0.03	-0.02	-0.02	-0.02	-0.03	-0.03	Pass
5/15/2008	6/4/2008	IA3A	0.00	-0.05	-0.02	-0.03	-0.01	-0.07	-0.02	-0.03	0.01	0.02	Pass
6/4/2008	6/23/2008	IA3A	0.05	0.02	0.00	0.05	0.00	0.08	0.01	0.01	-0.01	-0.03	Pass
6/25/2008	7/15/2008	WI5A	0.05	0.02	0.07	-0.03	-0.01	-0.05	0.02	-0.03	-0.02	-0.01	Pass
7/15/2008	8/13/2008	WI5A	-0.05	0.10	-0.02	0.03	0.08	-0.09	0.00	0.06	-0.01	0.04	Pass
8/13/2008	9/3/2008	NC4A	-0.27	-0.12	-0.17	-0.13	-0.14	-0.29	-0.20	-0.21	-0.25	-0.22	Pass
9/3/2008	9/22/2008	NC4A	-0.12	-0.13	-0.11	-0.10	-0.15	-0.09	-0.10	-0.06	-0.10	-0.11	Pass
9/25/2008	10/14/2008	NC3A	-0.12	-0.09	-0.11	-0.12	-0.17	-0.16	-0.17	-0.22	-0.17	-0.23	Pass
10/14/2008	10/22/2008	NC3A	-0.32	-0.18	-0.23	-0.31	-0.19	-0.31	-0.29	-0.24	-0.22	-0.13	Pass
10/22/2008	11/11/2008	WI5A	-0.07	-0.10	-0.10	-0.13	-0.10	-0.10	-0.09	-0.13	-0.12	-0.15	Pass
11/13/2008	11/25/2008	IA3A	-0.10	-0.17	-0.18	-0.17	-0.13	-0.06	-0.15	-0.13	-0.15	-0.17	Pass
11/25/2008	12/16/2008	IA3A	-0.22	-0.18	-0.17	-0.18	-0.17	-0.20	-0.20	-0.16	-0.19	-0.16	Pass
12/17/2008	1/6/2009	WI5A	-0.30	-0.41	-0.27	-0.62	-0.15	-0.22	-0.29	-0.15	-0.23	-0.05	Fail
1/6/2009	1/15/2009	WI5A	-0.10	0.17	-0.17	0.34	-0.20	-0.12	-0.02	-0.18	-0.11	-0.17	Fail
1/15/2009	2/3/2009	NC4A	-0.27	-0.32	0.14	-0.07	-0.25	-0.32	-0.13	0.04	-0.40	-0.29	Fail
2/5/2009	2/23/2009	NC3A	-0.11	-0.13	-0.12	-0.12	-0.13	-0.11	-0.13	-0.16	-0.16	-0.09	Pass
2/23/2009	3/10/2009	NC3A	-0.11	-0.07	-0.12	-0.17	-0.15	-0.18	-0.19	-0.03	-0.19	-0.21	Pass
3/10/2009	4/7/2009	WI5A	-0.17	-0.17	-0.16	-0.19	-0.11	-0.08	-0.06	-0.22	-0.07	-0.11	Pass
4/9/2009	4/23/2009	IA3A	-0.15	-0.13	-0.11	-0.14	-0.15	-0.13	-0.13	-0.09	-0.11	-0.10	Pass
4/23/2009	4/29/2009	IA3A	-0.13	-0.11	-0.14	-0.14	-0.14	-0.16	-0.15	-0.20	-0.22	-0.20	Pass
4/29/2009	5/11/2009	NC4A	-0.26	-0.19	-0.16	-0.14	-0.15	-0.13	-0.14	-0.14	-0.11	-0.10	Fail
5/13/2009	6/2/2009	NC3A	-0.14	-0.12	-0.13	-0.12	-0.14	-0.14	-0.14	-0.15	-0.15	-0.14	Pass
6/2/2009	6/22/2009	NC3A	-0.12	-0.10	-0.11	-0.11	-0.11	-0.13	-0.09	-0.14	-0.13	-0.14	Pass
6/22/2009	6/30/2009	NC3A	-0.15	-0.13	-0.13	-0.13	-0.13	-0.11	-0.13	-0.13	-0.12	-0.12	Pass
6/30/2009	7/21/2009	NC4A	-0.09	-0.13	-0.10	-0.11	-0.09	-0.11	-0.11	-0.08	-0.10	-0.10	Pass
7/21/2009	7/28/2009	NC4A	-0.08	-0.06	-0.08	-0.07	-0.06	-0.06	-0.05	-0.06	-0.06	-0.02	Pass
7/28/2009	8/17/2009	IA3A	-0.14	-0.14	-0.15	-0.13	-0.14	-0.15	-0.13	-0.12	-0.11	-0.15	Pass

Table 6.6-2B: Record of flow balancing- Side 2 (s/n F)

			Delta inlet flow (Beginning-End) (L min^{-1})										
Start date	**End date**	**Site**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Check results**
3/26/08	4/1/2008	NC3A	0.09	0.03	0.02	0.04	0.00	0.06	0.06	0.05	0.04	0.02	Pass
4/1/2008	4/15/2008	NC4A	0.05	0.21	0.05	0.04	0.10	0.03	0.27	0.00	0.08	0.13	Fail
4/15/2008	4/24/2008	NC4A	0.09	0.24	0.26	0.26	0.21	0.29	0.22	0.25	0.30	0.22	Fail
4/24/2008	5/13/2008	WI5A	-0.04	-0.03	-0.02	-0.02	0.12	-0.02	-0.04	-0.04	-0.07	0.03	Fail
5/15/2008	6/4/2008	IA3A	-0.09	-0.12	-0.08	-0.10	0.34	-0.02	-0.05	0.88	-0.06	-0.08	Fail
6/4/2008	6/23/2008	IA3A	0.05	0.06	0.04	0.02	0.03	-0.01	0.00	-0.01	0.07	-0.01	Pass
6/26/2008	7/15/2008	WI5A	0.03	0.03	0.02	0.02	-0.02	0.05	0.06	-0.01	0.00	0.01	Pass
7/15/2008	8/13/2008	WI5A	-0.27	-0.25	-0.30	-0.29	-0.23	-0.34	-0.36	-0.17	-0.27	-0.26	Pass
8/13/2008	9/3/2008	NC4A	0.02	0.02	0.06	0.05	0.00	0.09	0.06	-0.07	0.03	0.08	Pass
9/3/2008	9/22/2008	NC4A	0.00	0.02	0.00	-0.01	-0.02	-0.06	-0.02	-0.01	-0.06	-0.03	Pass
9/25/2008	10/14/2008	NC3A	0.00	0.02	0.02	0.00	0.02	-0.01	-0.06	0.03	0.04	0.08	Fail
10/14/2008	10/22/2008	NC3A	0.22	0.16	0.17	0.20	0.23	0.24	0.20	0.19	0.23	0.14	Fail
10/22/2008	11/11/2008	WI5A	-0.02	0.03	0.02	-0.01	0.00	-0.07	-0.09	-0.01	-0.02	0.00	Fail
11/13/2008	11/25/2008	IA3A	-0.23	-0.06	-0.11	-0.09	-0.06	-0.17	-0.16	-0.21	-0.12	-0.10	Pass
11/25/2008	12/16/2008	IA3A	-0.14	-0.23	-0.19	-0.18	-0.21	-0.17	-0.10	-0.07	-0.11	-0.13	Fail
12/17/2008	1/6/2009	WI5A	-0.26	-0.36	-0.28	-0.31	-0.31	-0.33	-0.35	-0.11	-0.26	-0.36	Fail
1/6/2009	1/15/2009	WI5A	0.02	-0.28	0.09	0.12	0.08	0.21	0.24	-0.97	0.20	0.20	Fail
1/16/2009	2/3/2009	NC4A	-0.29	-0.32	-0.20	0.34	-0.42	0.63	0.50	-0.51	0.23	0.23	Fail
2/5/2009	2/23/2009	NC3A	-0.11	-0.11	-0.13	-0.13	-0.15	-0.14	-0.17	-0.16	-0.16	-0.11	Pass
2/23/2009	3/10/2009	NC3A	-0.16	-0.16	-0.18	-0.19	-0.15	-0.19	-0.22	-0.15	-0.17	-0.12	Pass
3/10/2009	4/7/2009	WI5A	-0.21	-0.24	-0.21	-0.21	-0.24	-0.22	-0.23	-0.23	-0.20	-0.32	Pass
4/9/2009	4/23/2009	IA3A	0.00	0.00	0.00	-0.01	-0.03	-0.02	0.00	-0.04	-0.03	-0.05	Pass
4/23/2009	4/29/2009	IA3A	-0.15	-0.16	-0.15	-0.16	-0.16	-0.17	-0.18	-0.18	-0.20	-0.17	Pass
4/29/2009	5/11/2009	NC4A	-0.14	-0.10	-0.14	-0.13	-0.16	-0.11	-0.14	-0.11	-0.09	-0.11	Pass
5/13/2009	6/2/2009	NC3A	-0.12	-0.14	-0.14	-0.14	-0.19	-0.14	-0.22	-0.11	-0.15	-0.21	Pass
6/2/2009	6/22/2009	NC3A	-0.10	-0.77	-0.09	-0.10	-0.04	-0.05	-0.03	-0.04	-0.05	-0.03	Fail
6/22/2009	6/30/2009	NC3A	-0.14	0.53	-0.16	-0.15	-0.22	-0.18	-0.25	-0.20	-0.19	-0.22	Fail
6/30/2009	7/21/2009	NC4A	-0.14	-0.12	-0.11	-0.12	-0.14	-0.10	-0.06	-0.09	-0.10	-0.09	Pass
7/21/2009	7/28/2009	NC4A	-0.08	-0.08	-0.08	-0.10	-0.03	-0.06	-0.06	-0.05	-0.03	-0.03	Fail
7/28/2009	8/17/2009	IA3A	-0.04	-1.01	-0.07	-0.05	-0.04	-0.07	0.01	-0.09	-0.06	-0.05	Fail

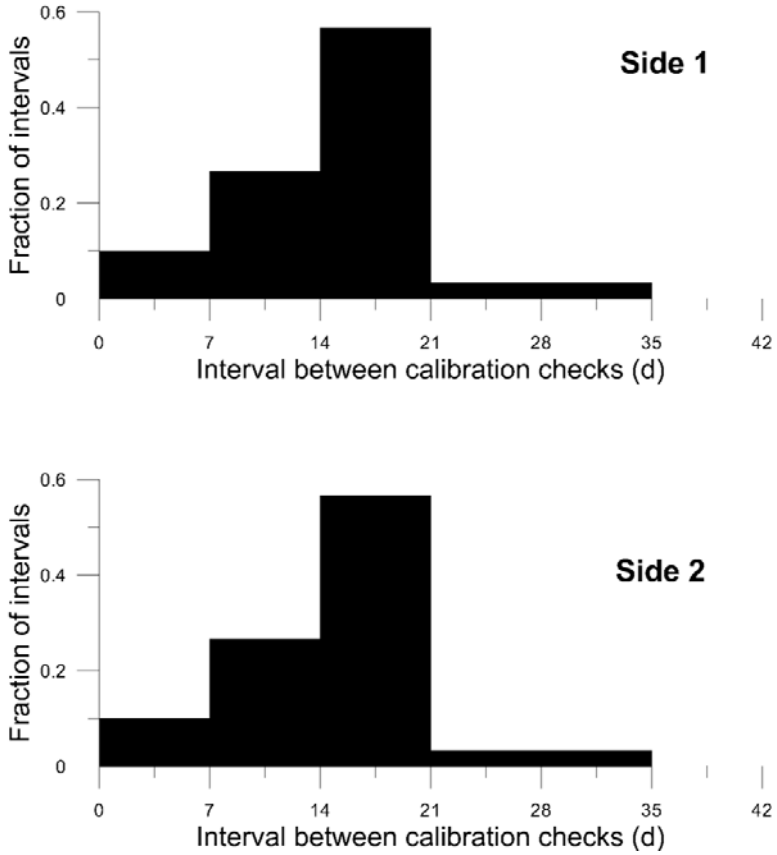


Figure 6.6-1: Intervals between checks

6.7 Miscellaneous meteorological and lagoon calibrations

6.7.1 Air temperature/humidity

The Vaisala HMP45C measured both air temperature and relative humidity. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The calibration checks are documented in Table 6.7-1.

Table 6.7-1: Calibration record of Vaisala HMP45C, s/n 4410027

Relative Humidity (RH)					
Calibration Dates	**Temperature (°C)**	**Expected RH (%)**	**Deviation from expected RH (%)**	**Average deviation RH (%)**	**Action**
3/8/2010	24.7	25	1.9		Accept
3/8/2010	24.7	50	1.4		Accept
3/8/2010	24.7	95	2.3		Accept
3/8/2010				1.9	Accept
3/6/2010	N/A	40	1.2	1.2	Accept
8/1/2008	27.8	11	-0.7		Accept
8/1/2008	27.5	51	2.5		Accept
8/1/2008	27.8	96	8.6		Accept
8/1/2008				3.1	Accept
Temperature (T)					
Calibration Dates	**Expected T (°C)**	**Measured T (°C)**	**Deviation from expected T (°C)**		**Action**
3/8/2010	25.6	24.7	0.9		Accept
3/6/2009	25.3	25.2	0.2		Accept
8/1/2008	27.5	27.3	0.2		Accept

6.7.2 Barometric pressure

An aneroid barometer (Model 278, Setra Inc, Boxborough, MA.) with serial number 3033740 was used to measure barometric pressure. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-2.

Table 6.7-2: Calibration record of Setra 278 s/n 3033740

Calibration dates	Expected value range (hPa)	Number of comparisons	Mean difference from reference (hPa)	Action
2/11-12/2010	998.6-992.5	5	1.5	Pass
9/16-17/2009	997.5-1000.1	6	0.9	Pass
3/24-25/2009	986.0-992.0	6	1.4	Pass
7/9-11/2008	993.1-996.8	6	1.5	Pass
1/3-4/2008	1018.4-1001.7	6	2.5	Pass

6.7.3 Solar radiation

A pyranometer (Model 200SB, LiCOR Inc., Lincoln, NE) was used to measure solar radiation. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-3.

Table 6.7-3: Calibration record of LiCOR 200SB Pyranometer s/n PY554448

Calibration Dates	Mean difference from reference (Wm^{-2})	Mean difference from reference (%)	Action
3/5-3/8 2010	-3.8	0.71	Pass
8/30/2006	—	—	Pass (factory calibration)

6.7.4 Lagoon water temperature

A thermistor (Model 107-L, Campbell Scientific Inc, Logan, Utah) was used to measure lagoon temperature. Calibration of this sensor was conducted at least annually. Initial calibrations were conducted by the factory. Three thermistor probes were used at this location: serial numbers 0030, 005, and 006. The record of calibration checks are documented in Table 6.7-4 and Table 6.7-5.

Table 6.7-4: Calibration record of Thermistor CSI 107-L s/n III

Calibration Date	Expected value (°C)	Difference from expected (°C)	Action
2/15/2010	1.0	18	Replace
9/14/2009	0.0	0.0	Accept
3/6/2009	0.0	0.0	Accept

Table 6.7-5: Calibration record of Thermistor CSI 107-L s/n 0010 (9999)

Calibration Date	Expected value (°C)	Difference from expected (°C)	Action
1/25/2008	0	-0.1	Accept
6/18/2007	25	0.1	Accept
6/18/2007	25	0.2	Accept
6/18/2007	24	0.4	Accept

6.7.5 CR1000 Data logger

The CR1000 data logger (Campbell Scientific Inc., Lagan, UT) was used to log all lagoon measurements (pH, oxidation-reduction potential, and temperature) and air temperature, relative humidity, barometric pressure, and wetness. Calibration checks of this unit were conducted at the beginning and end of the study. Initial calibrations were conducted by the factory. Two different loggers were used. The record of calibration checks are documented in Table 6.7-6 and Table 6.7-7.

Table 6.7-6: Calibration record of Campbell Scientific CR1000 data logger, s/n 7886 (7675)

SE Channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV mean value	Error (mV)	Measured (mV)	Error (mV)
Factory calibration						
Calibration date: 1/18/2007			**Single-ended**		**Differential**	
11	5000	± 3	5001.25	-1.25	5001.35	-1.35
11	-5000	± 3	-5001.48	-1.48	-5001.69	-1.69
11	2500	± 1.5	—	—	2500.3	-0.3
11	250	± 0.15	—	—	249.999	0.001
11	25	± 0.015	—	—	25.0032	-0.0032
11	7.5	± 0.0045	—	—	7.49571	0.00429
11	2.5	± 0.0015	—	—	2.50062	-0.00062
11	-2.5	± 0.0015	—	—	-2.49924	0.00024
11	5000	± 6	4999.45	0.45	4999.32	0.32
11	5000	± 6	5001.96	-1.96	5001.69	-1.69
11	5000	± 6	—	—	—	—
11	5000	± 6	—	—	—	—
PAML calibration						
Calibration date: 2/5/2007			**Single-ended**		**Differential**	
1	4950	± 6.96| 4.97	4950.5	-0.5	—	—
2	4950	± 6.96| 4.97	4950.5	-0.5	—	—
3	4950	± 6.96| 4.97	4950.5	-0.5	—	—
4	4950	± 6.96| 4.97	4950.5	-0.5	—	—
5	4950	± 6.96| 4.97	4950.5	-0.5	—	—
6	4950	± 6.96| 4.97	4950.5	-0.5	—	—
7	4950	± 6.96| 4.97	4950.5	-0.5	—	—
8	4950	± 6.96| 4.97	4950.5	-0.5	—	—
9	4950	± 6.96| 4.97	4950.5	-0.5	—	—
10	4950	± 6.96| 4.97	4950.5	-0.5	—	—
12	4950	± 6.96| 4.97	4950.5	-0.5	—	—
13	4950	± 6.96| 4.97	4950.5	-0.5	—	—
14	4950	± 6.96| 4.97	4950.5	-0.5	—	—

SE Channel	Input (mV)	Tolerance SE|DE (mV)	Measured mV mean value	Error (mV)	Measured (mV)	Error (mV)
15	4950	± 6.96| 4.97	4950.5	-0.5	—	—
16	4950	± 6.96| 4.97	4950.5	-0.5	—	—
Calibration date: 5/28/2010			**Single-ended**		**Differential**	
1	100	± 2.06 | 1.06	99.49	0.51	—	—
2	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
3	100	± 2.06 | 1.06	99.49	0.51	—	—
4	100	± 2.06 | 1.06	99.49	0.51	—	—
5	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
6	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
7	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
8	100	± 2.06 | 1.06	99.49	0.51	99.83	0.17
9	100	± 2.06 | 1.06	99.49	0.51	—	—
10	100	± 2.06 | 1.06	99.49	0.51	—	—
11	100	± 2.06 | 1.06	99.49	0.51	—	—
12	100	± 2.06 | 1.06	99.49	0.51	—	—
13	100	± 2.06 | 1.06	99.49	0.51	—	—
14	100	± 2.06 | 1.06	99.49	0.51	—	—
15	100	± 2.06 | 1.06	99.49	0.51	—	—
16	100	± 2.06 | 1.06	99.49	0.51	—	—
Calibration date: 5/28/2010			**Single-ended**		**Differential**	
1	0	± 2.06 | 1.06	0	0	—	—
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0	—	—
4	0	± 2.06 | 1.06	0	0	—	—
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0	—	—
10	0	± 2.06 | 1.06	0	0	—	—
11	0	± 2.06 | 1.06	0	0	—	—
12	0	± 2.06 | 1.06	0	0	—	—
13	0	± 2.06 | 1.06	0	0	—	—
14	0	± 2.06 | 1.06	0	0	—	—
15	0	± 2.06 | 1.06	0	0	—	—
16	0	± 2.06 | 1.06	0	0	—	—

Table 6.7-7: Calibration record of Campbell Scientific CR1000 data logger, s/n 7752

Calibration Date: 3/1/2010			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.06 | 1.06	99.23	0.77		
2	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
3	100	± 2.06 | 1.06	99.23	0.77		
4	100	± 2.06 | 1.06	99.23	0.77		
5	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
6	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
7	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
8	100	± 2.06 | 1.06	99.23	0.77	99.57	0.43
9	100	± 2.06 | 1.06	99.23	0.77		
10	100	± 2.06 | 1.06	99.23	0.77		
11	100	± 2.06 | 1.06	99.23	0.77		
12	100	± 2.06 | 1.06	99.23	0.77		
13	100	± 2.06 | 1.06	99.23	0.77		
14	100	± 2.06 | 1.06	99.23	0.77		
15	100	± 2.06 | 1.06	99.23	0.77		
16	100	± 2.06 | 1.06	99.23	0.77		
Calibration Date: 3/1/2010			**Single-Ended**		**Differential**	
Channel	**Input (mV)**	**Tolerance SE | DE (mV)**	**Measured (mV)**	**Error (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.06 | 1.06	0	0		
2	0	± 2.06 | 1.06	0	0	0	0
3	0	± 2.06 | 1.06	0	0		
4	0	± 2.06 | 1.06	0	0		
5	0	± 2.06 | 1.06	0	0	0	0
6	0	± 2.06 | 1.06	0	0	0	0
7	0	± 2.06 | 1.06	0	0	0	0
8	0	± 2.06 | 1.06	0	0	0	0
9	0	± 2.06 | 1.06	0	0		
10	0	± 2.06 | 1.06	0	0		
11	0	± 2.06 | 1.06	0	0		
12	0	± 2.06 | 1.06	0	0		
13	0	± 2.06 | 1.06	0	0		
14	0	± 2.06 | 1.06	0	0		
15	0	± 2.06 | 1.06	0	0		
16	0	± 2.06 | 1.06	0	0		

6.7.6 CR800 Data logger

The CR800 data logger (Campbell Scientific Inc., Logan, Utah) was used to log all GSS measurements (air temperature and relative humidity, flow rate, and pressure). Calibration checks of this unit were conducted only at end of the study. Initial calibrations were conducted by the factory. The record of calibration checks are documented in Table 6.7-8.

Table 6.7-8: Calibration record of Campbell Scientific CR800 data logger, s/n 3697

Calibration Date: 3/8/2010			**Single-Ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	100	± 2.061	99.3	0.7
2	100	± 2.061	99.3	0.7
3	100	± 2.061	99.3	0.7
4	100	± 2.061	99.3	0.7
5	100	± 2.061	99.3	0.7
6	100	± 2.061	99.3	0.7
Calibration Date: 3/8/2010			**Single-Ended**	
Channel	**Input (mV)**	**Tolerance SE (mV)**	**Measured (mV)**	**Error (mV)**
1	0	± 2.061	0.0	0
2	0	± 2.061	0.0	0
3	0	± 2.061	0.0	0
4	0	± 2.061	0.0	0
5	0	± 2.061	0.0	0
6	0	± 2.06	0.0	0

6.8 Site activity

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
23:00-23:10	6/27/2007	Calibration	Zero Calibration on sonic anemometers; all pass.
	7/17/2007	Setup	Tower height measurements taken
22:20-23:20	7/17/2007	Setup	Sonic inter-comparison: Sensor 1: 1.32 ms^{-1} Sensor 2: 1.35 ms^{-1} Sensor 3: 1.36 ms^{-1}. Sensors 1 and 3 were reversed from their positions on the tower. They were simply plugged into each others' modem/ power supply box.
	7/18/2007	Setup	pH sensor 001: Calibration and Acceptance done; QA good
	7/18/2007	Setup	pH sensor 004: Calibration and Acceptance done; QA good
	7/18/2007	Setup	ORP sensor 020: Calibration and Acceptance done
	7/18/2007	Setup	ORP sensor 040: Calibration and Acceptance done
13:45-14:21	7/18/2007	Setup	Zero Calibration on sonic anemometers; all pass. Black box used for sensor 1. Plastic bags used for sensors 2 and 3 (on tower). Different time used for sensor 2 since path obstruction was experienced due to the plastic bag of the earlier time.
20:29-21:04	7/18/2007	Setup	Calibrated TDLAS (1028 and 1030); no measurements noted
	7/19/2007	Setup	As 75% of lagoon is crusted we will be doing pH and ORP for 2 days (till we are here), and then we will leave temp probe only for rest of period.
21:04	7/19/2007	Setup	Barometer audit: Accepted
	8/6/2007	Calibration	Rain caused retro-reflectors to fill with water
20:15	8/6/2007	Calibration	CR1000 data collected-all instrument present looks good
20:40	8/6/2007	Calibration	TDLAS 1 (1028) turned off and brought to trailer for calibration (comm. problems). Installed updates on TDLAS 1 PC.
21:45-21:50	8/6/2007	Calibration	Calibrated TDLAS 1028: Mean 48.85 SD: 3.61…all measurements valid
23:01-23:06	8/6/2007	Calibration	Calibrated TDLAS 1030: Mean 49.84 SD: 4.18
	8/7/2007	Calibration	Removed sonic anemometers from tower; tried to put up top sonic, but due to wind, unable to do so. The other two sonic anemometers are working well. Cleaned bird droppings off of wetness sensors with water. Sealed tower retro-reflectors with tube silicon.
	8/7/2007	Calibration	pH sensor 001: Calibration and Acceptance done; QA good
	8/7/2007	Calibration	pH sensor 004: Acceptance and Calibration done; QA good
	8/7/2007	Calibration	ORP sensor 020: Calibration and Acceptance done
	8/7/2007	Calibration	ORP sensor 040: Calibration and Acceptance done
15:15-16:15	8/7/2007	Calibration	Sonic anemometer inter-comparison: Sensor 1: 2.32 Sensor 2: 2.36 Sensor 3: 2.33
16:48	8/7/2007	Calibration	Zero Calibration on sonic anemometers; all pass.
	8/8/2007	Calibration	Wetness sensor not giving valid reading due to bird droppings. Cleaned with distilled water/soap. Still won't give valid reading.
16:22	8/8/2007	Calibration	Barometer audit: Accepted
	8/9/2007	Calibration	Used Emory cloth for cleaning wetness sensor, and then it worked well.

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	8/9/2007	Calibration	Also checked TDLAS, electrical connections and tape, pyronometer level, cables at the towers, scanners, and the UPS. All looked good.
	8/28/2007	Takedown	Took down all sensors from weather station. Took down every ground retro-reflector. Wetness sensor doesn't seem ok; it's in bad condition. Data stored in DVD, CD, thumb drive.
15:40-16:40	8/28/2008	Takedown	Sonic anemometer inter-comparison; all pass.
16:55-17:00	8/28/2007	Takedown	Calibrated TDLAS 1028: Mean 46.85 SD: 2.29
17:16	8/28/2007	Takedown	Zero sonic anemometer calibration; all pass.
18:35-18:40	8/28/2007	Takedown	Calibrated TDLAS 1030: mean 53.72 SD: 5.00. First test failed. Not sure of reason. Door to trailer was opened several times perhaps letting in NH_3 from outside. Perhaps manure from boots in trailer caused problems. Good results for second test came when Alfred held the outlet tubing further out the door.
	10/4/2007	Calibration	pH sensor 001: Calibration and Acceptance done
	10/22/2007	Calibration	pH sensor 001: Calibration and Acceptance done
	10/25/2007	Calibration	pH sensor 001: Calibration and Acceptance done
	11/13/2007	Setup	Installed sonic anemometers and retro-reflectors on towers. Installed ground retro-reflectors and met tower.
	11/13/2007	Setup	No pipe to mount middle sonic anemometer. Will have to purchase it. Also, internet is not working (tried several times).
	11/13/2007	Setup	Sonic anemometer inter-comparison: Sensor 1: 4.42 Sensor 2: 4.44 Sensor 3: 4.52
	11/13/2007	Setup	Zero Calibration on sonic anemometers; all pass.
	11/14/2007	Setup	Launched lagoon probe.
	11/14/2007	Setup	Trailer heater still not working. Will notify manufacturer. Got internet to start working.
	11/14/2007	Setup	pH sensor 001: Calibration and Acceptance done; QA good
	11/14/2007	Setup	pH sensor 004: Calibration and Acceptance done; QA good
	11/14/2007	Setup	ORP sensor 020: Calibration and Acceptance done
	11/14/2007	Setup	ORP sensor 040: Calibration and Acceptance done
	11/14/2007	Setup	Barometer audit: Accepted
	11/14/2007	Setup	Wetness sensor calibration: Accepted
13:52-13:57	11/14/2007	Setup	Calibrated TDLAS 1028: Mean: 24.3 SD: 3.4%
14:36-14:41	11/14/2007	Setup	Calibrated TDLAS 1026: Mean: 24.0 SD: 2.9%
	11/27/2007	Calibration	Top (film) of lagoon was frozen, but electrodes (pH and ORP) and temp probe were immersed inside liquid.
	11/28/2007	Calibration	Internal audit was taken (audited) by Prof. Richard Grant.
	11/28/2007	Calibration	pH sensor 001: Calibration and Acceptance done; QA good
	11/28/2007	Calibration	pH sensor 004: Calibration and Acceptance done; QA good
	11/28/2007	Calibration	ORP sensor 020: Calibration and Acceptance done
	11/28/2007	Calibration	ORP sensor 040: Calibration and Acceptance done
	11/28/2007	Calibration	Barometer audit: Accepted
	11/28/2007	Calibration	Wetness sensor calibration: Accepted
15:45-	11/28/2007	Calibration	Sonic anemometer inter-comparison: Sensor 1: 4.07 Sensor 2:

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
16:-45			3.99 Sensor 3: 3.98
16:40-16:45	11/28/2007	Calibration	Calibrated TDLAS 1028: Mean: 54.06 SD: 2.57/4.7%
17:08	11/28/2007	Calibration	Zero Calibration on sonic anemometers; all pass.
17:24-17:29	11/28/2007	Calibration	Calibrated TDLAS 1026: Mean:47.74 SD: 0.49 RSD: 1.0%
	11/29/2007	Calibration	Evidence of power failure on 11/15/2007
15:30	11/29/2007	Calibration	Reoriented tower sonic anemometers. Middle (4m): was 20 degrees west of north before reorienting. Top was 10 degrees east of north before reorienting.
	12/5/2007	Remote	Get things back on track after snowstorm/ice storm on 12/1/2007. Logged onto LAN, TDLAS 1, TDLAS 2
	12/17/2007	Takedown	Scanner 1 (labeled scanner 4) on NE corner pointing at scanner on SW corner for paths 1-5 and toward barns for paths 6-10.
	12/17/2007	Takedown	Scanner 2 (SW corner) was pointing at retro-reflector7 for both paths 7 and 8. Taken back to Purdue.
23:47-23:52	12/17/2007	Takedown	Calibrated TDLAS 1026: Mean: 50.42 SD: 0.61 RSD: 1.2% Bias: 0.0%
	12/18/2007	Takedown	UPS lost power : 12/1/2007; switched to battery power on 12/5/2007
	12/18/2007	Takedown	Barometer audit: Accepted
	12/18/2007	Takedown	Wetness sensor calibration: Accepted
14:45-15:45	12/18/2007	Takedown	Sonic anemometer inter-comparison: Sensor 1: 1.66 Sensor 2: 1.61 Sensor 3: 1.64…all pass.
16:30	12/18/2007	Takedown	Zero Calibration on sonic anemometers; all pass.
00:37-00:42	12/19/2007	Takedown	Calibrated TDLAS 1028: Mean: 51.53 SD: 0.80 RSD: 1.6% Bias: 2.2%
	4/22/2008	Setup	During morning hours until afternoon, drainage was in progress. At 3:30 pm, loading was started in first sludge lagoon and was then stopped after one hour.
21:05-21:10	4/22/2008	Setup	Calibrated TDLAS 1027: Mean: 46.35 SD: 0.44 RSD: 1.0% Bias: -7.7%
21:48-21:53	4/22/2008	Setup	Calibrated TDLAS 1028: Mean: 47.07 SD: 0.34 RSD: 0.7% Bias: -6.1%
	4/23/2008	Setup	Did inter-comparison of TDLAS. TDLAS 1028 was working well, but TDLAS 1027 was working poorly (very low r^2 values as compared to 1028). Changed to TDLAS TDLAS 1031; have to calibrate 1031.
	4/23/2008	Setup	Still lagoon loading and drainage in process.
	4/23/2008	Setup	Balanced S-OPS "D"
	4/23/2008	Setup	Changed old data logger (CR1000) of weather station to a new one.
14:10-15:05	4/23/2008	Setup	Sonic anemometer inter-comparison; all pass.
15:36	4/23/2008	Setup	Sonic anemometer zero calibration; all pass.
	4/24/2008	Setup	Water leakage from back door of trailer.
	4/24/2008	Setup	Drainage and loading stopped at 10:30 am.
	4/24/2008	Setup	Flagged the tubings properly, leveled the sensors.
	4/24/2008	Setup	GSS max flow test: Fail (solenoids 2 and 3).

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	4/24/2008	Setup	S-OPS/GSS leak test: Pass (solenoids 2 and 3).
	4/24/2008	Setup	GSS No Flow Test conducted (solenoids 2 and 3).
	4/24/2008	Setup	S-OPS Inlet Flow Verification: Pass on second attempt
	4/24/2008	Setup	S-OPS Max Flow Test conducted (solenoids 2 and 3).
14:08-14:13	4/24/2008	Setup	Calibrated TDLAS 1031: Mean: 53.87 SD: 1.05 RSD: 7.4% Bias: 2.0%
18:30	4/24/2008	Setup	TFC 450i Reference Precision Check
20:35	4/24/2008	Setup	Barometer audit: Accepted
20:36	4/24/2008	Setup	Wetness sensor calibration: Accepted
13:00	4/25/2008	Remote	Daily Status Check from PAML Notes: Many periods for sonic anemometer 3 had a few up to 70 sonic anemometer flagged points yesterday. Rainy. A few periods (most is sonic anemometer 3) has >160 spike points.
12:00	4/28/2008	Remote	Daily Status Check from PAML Notes: Sonic anemometer flagging data for 2,3 around day 482.3. *iPort* shut down; restarted this morning. Looked at *iPort* screen to check. Stopped sonic anemometer program. Downloaded missing *iPort* data.
13:17	4/28/2008	Remote	Correct dwell time on TDL2, path 2. Dwell time currently set to 1 s. Change to 15 s.
12:00	4/29/2008	Remote	Daily Status Check from PAML Notes: Lagoon float not present.
12:00	4/29/2008	Remote	Daily Status Check from PAML Notes: Sonic anemometer flagging >160 (sonic anemometer 1--1 point; sonic anemometer 3--3 points)
	4/30/2008	Remote	Correct path lengths in retro-reflector aiming *Excel* workbook for WI5A.
11:40	5/1/2008	Remote	Daily Status Check from PAML Note: Sonic anemometer 3 appears to be having communication issues. Especially during first day and the past 2 days. Total data points have dropped, variance increased, and number of spike data points has increased. Lagoon probe not present.
12:30	5/2/2008	Remote	Daily Status Check from PAML Note: lagoon probe not present
12:15	5/5/2008	Remote	Daily Status Check from PAML Notes: Lagoon probe not present.
12:45	5/6/2008	Remote	Daily Status Check from PAML. Notes: Only one point lost due to sonic anemometer flagging. Lagoon probe not present.
12:50	5/7/2008	Remote	Daily Status Check from PAML Notes: Lagoon probe not present. Innova not present. "XXXX" on TDLAS 2 when first looked at and when looking at paths.
12:00	5/8/2008	Remote	Daily Status Check from PAML. Notes: TDLAS 2 paths 1 and 2 have 0%. Both lost around 2230 UTC on 2008-5-7. Lagoon probes not present. Occasional "xxxx" and red boxes on path 10. Paths 1 and 2 have low light values. Created new .gmp file file and replaced corrupt path 10 values with last good values from mpo string in data file. Uncertain which path values saved for path 10 actually correspond to (likely path 9). Loaded this new setup file. All 10 paths back on.
12:35	5/9/2008	Remote	Daily Status Check from PAML Notes: No lagoon probe. Pan-tilt problems with TDLAS 1 (1028). *iPort* not working;

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
			data was not stored for H_2S since 2008-5-8. Stored data since yester day as a FillWI5A file; checked all the files and saw data was missing from 1220 UTC to 1306 UTC (2008-5-8), so again stored in FillWI5A. Started a new file to save real-time data.
	5/12/2008	Takedown	Reached site at 21:30 UTC. Took down all ground and tower retro-reflectors, and took down sonic anemometers.
	5/12/2008	Remote	Fixed red boxes on TDLAS 2. Red box on path 5.
14:23	5/12/2008	Remote	Daily Status Check from PAML. Notes: Sonic anemometer 1 temp had w values ~0.5 ms^{-1}, but back to normal. No lagoon instruments installed. Path 7 on TDLAS 2 off; moved 10 down for correction.
	5/12/2008	Takedown	80% lagoon crusted
	5/13/2008	Takedown	S-OPS Inlet Flow Verification: Pass on second attempt
	5/13/2008	Takedown	GSS max flow test: Fail (solenoids 2 and 3).
	5/13/2008	Takedown	S-OPS Max Flow Test conducted (solenoids 2 and 3).
	5/13/2008	Takedown	S-OPS/GSS leak test: Pass (solenoids 2 and 3).
	5/13/2008	Takedown	GSS No Flow Test conducted (solenoids 2 and 3).
15:00-16:00	5/13/2008	Takedown	Sonic anemometer inter-comparison: all pass
16:48	5/13/2008	Takedown	Sonic anemometer zero calibration; all pass.
16:53	5/13/2008	Takedown	Calibrated TDLAS 1027 Mean: 53.14 SD: 0.24 RSD: 0.5% Bias: 5.7%
17:27	5/13/2008	Takedown	Calibrated TDLAS 1028 Mean: 47.89 SD: 0.16 RSD: 0.3% Bias: -5.0%
19:53	5/13/2008	Takedown	TFC 450i Reference Precision Check
20:07	5/13/2008	Takedown	TFC 450i Calibration Verification Check
20:08	5/13/2008	Takedown	Barometer audit: Accepted
20:11	5/13/2008	Takedown	Wetness sensor calibration: Accepted
23:30-00:30	5/14/2008	Takedown	Sonic anemometer inter-comparison: Pass Note: Passed on second attempted because sonic anemometers turned perpendicular to the wind before second attempt.
00:48	5/15/2008	Takedown	Sonic anemometer zero calibration; all pass.
	6/24/2008	Setup	Reached WI5A at 5pm local time. Leveled the trailer and made it fixed. Front left jack of the trailer is not working so used wooden blocks.
	6/25/2008	Setup	Lagoon 100% crusted.
	6/25/2008	Setup	S-OPS Inlet Flow Verification: Pass
	6/25/2008	Setup	S-OPS/GSS leak test: Pass (solenoids 2 and 3).
	6/25/2008	Setup	GSS No Flow Test conducted (solenoids 2 and 3).
	6/25/2008	Setup	GSS Leak Test: Pass
15:00-15:55	6/25/2008	Setup	Sonic anemometer inter-comparison: all pass
15:50	6/25/2008	Setup	Calibrated TDLAS 1028 Mean: 48.2 SD: 0.34 RSD: 0.7% Bias: -3.8%
16:39	6/25/2008	Setup	Calibrated TDLAS 1031 Mean: 54.23 SD: 0.29 RSD: 0.5% Bias: 8.2%
16:43	6/25/2008	Setup	Sonic anemometer zero calibration: all pass.
21:24	6/25/2008	Setup	TEC 450i instrument operating parameters calculated
21:24	6/25/2008	Setup	TEC 450i calibration verification check

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
21:45	6/25/2008	Setup	TEC 450i reference precision check
	6/26/2008	Setup	Lagoon site layout completed
	6/26/2008	Setup	While doing S-OPS/GSS leak test, found leak at F-3 (T-section). Used Teflon tape to fix the leak. Changed filter papers of F-7 and F-9, and changed orifices of F-5 and F-9. The leak was about 0.8 LPM, but max flow was 10 LPM, so it passed. Added plastic on all ground retro-reflectors.
	6/26/2008	Setup	S-OPS max flow test: Pass
15:30	6/26/2008	Setup	Barometer audit: Accepted
15:33	6/26/2008	Setup	Wetness sensor calibration: Accepted
15:30	6/27/2008	Setup	Daily Status Check from PAML Notes: QC programs not working. No communication with CR 1000.
12:30	6/30/2008	Remote	Daily Status Check from PAML Notes: Sonic anemometer 2 consistently has non-zero flags, often up to 20 and sometimes 60. TDLAS 2 reference cell quality is usually greater than 12,000. No connection with CR1000.
12:50	7/1/2008	Remote	Daily Status Check from PAML Notes: No connection with CR 1000. No lagoon probe (lagoon is 100% crusted).
11:55	7/2/2008	Remote	Daily Status Check from PAML Notes: No connection with CR 1000. No lagoon probe (lagoon is 100% crusted).
12:10	7/3/2008	Remote	Daily Status Check from PAML Notes: Few excessive periods with over 160 spike counts for sonic anemometer 1. CR 1000 not connected with LAN. No lagoon probe (lagoon is 100% crusted).
12:00	7/7/2008	Remote	Daily Status Check from PAML Notes: Few excessive periods with over 160 spike counts for sonic anemometer anemometers 1 and 2. TDLAS 1 (1028) and TDLAS 2 (1031) were not aimed at all paths. Cause may be due to fog or heavy rain. Checked again at 15:55 UTC, and both TDLAS's were properly aligned with a status code of 1. CR 1000 is not connected with LAN.
15:05	7/8/2008	Remote	Daily Status Check from PAML Notes: TDLAS 1 (1028) is taking too much time for optimizing on path 5. Tried to adjust by to lower light values. TDLAS 1028 path 3 had very low light values (38-52); reaim path for 0.5 hours before finding good light values. Sonic anemometer 1 stop incrementing data at 2:30 UTC. Sonic anemometer 1 had the following error codes: 106, 2, 74, 66, 170, 42, 98, 106, 34, 10, and 6. CR 1000 is not connected to LAN.
12:05	7/9/2008	Remote	Daily Status Check from PAML Notes: Sonic anemometer 1 is not incrementing data. No communication with CR1000.
12:10	7/10/2008	Remote	Daily Status Check from PAML Notes: Sonic anemometer 1 is not incrementing data. Data stopped incrementing on 7/8/2008. Will check today if there is electric problem or not. No communication with CR1000.
16:00	7/11/2008	Remote	Daily Status Check from PAML Notes: Communication problems with CR1000.
12:15	7/14/2008	Remote	Daily Status Check from PAML Notes: No communication with CR1000.
	7/14/2008	Takedown	Reached site at 21:10 UTC. Saw sonic anemometers had stopped incrementing data at 12:36 UTC; probably caused by

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
			someone at PAML starting H_2S analyzer and not restarting sonic anemometer program.
	7/14/2008	Takedown	Evidence of power failure on 7/2/2008 at 14:42:08, on 7/9/2008 at 14:42:36, and on 7/10/2008 at 18:28:11.
21:55-22:49:36	7/14/2008	Takedown	Sonic anemometer inter-comparison: Pass
23:24	7/14/2008	Takedown	Calibrated TDLAS 1028 Mean:46.96 SD: 0.79 RSD: 1.7% Bias: -6.2%
23:26	7/14/2008	Takedown	Calibrated TDLAS 1031 Mean: 54.31 SD: 0.33 RSD: 0.6% Bias: 8.3%
23:26	7/14/2008	Takedown	Wetness sensor calibration: Accepted
23:26	7/14/2008	Takedown	Barometer audit: Accepted
23:28	7/14/2008	Takedown	Zero Calibration on sonic anemometers; all pass.
	7/15/2008	Takedown	UPS boxes contained water and were broken. Saw a lot of bird dropping, especially on met tower.
	7/15/2008	Takedown	GSS Leak Test: Pass
	7/15/2008	Takedown	GSS No Flow Test conducted (solenoids 2 and 3).
	7/15/2008	Takedown	S-OPS Max Flow Test conducted (solenoids 2 and 3).
	7/15/2008	Takedown	S-OPS/GSS leak test: Pass (solenoids 2 and 3).
	7/15/2008	Takedown	S-OPS inlet flow verification: Pass
14:18	7/15/2008	Takedown	TEC 450i instrument operating parameters calculated
14:18	7/15/2008	Takedown	TEC 450i calibration verification check
14:38	7/15/2008	Takedown	TEC 450i reference precision check
	10/21/2008	Setup	Trailer light not working. Tried to fix it but could not.
	10/21/2008	Setup	Lagoons are dried.
	10/21/2008	Setup	Calibrated sonic anemometers and did all ground and tower work.
	10/21/2008	Setup	GFCI outlet at met tower tripped; running extension cord for met tower and sonic anemometer 1 to nearby retro-reflector outlet (SW of met tower).
	10/21/2008	Setup	Using 1/8 plastics in tower retro-reflectors to minimize effects of rain/frost/dew on decreasing light levels.
16:50-17:49:32	10/21/2008	Setup	Sonic anemometer inter-comparison; all pass.
18:17	10/21/2008	Setup	Zero Calibration on sonic anemometers; all pass.
	10/22/2008	Setup	Leak in S-OPS F inlets; tightened connections, T's, and sealed with more Teflon tape. Cleaned inlets and replaced inlet filters.
	10/22/20008	Setup	Ground rod at met tower without a football clamp; secured by twisting/tying ground wire around ground rod.
	10/22/2008	Setup	Lagoon site layout made
	10/22/2008	Setup	Maintenance list completed.
	10/22/2008	Setup	GSS Max Flow test
	10/22/2008	Setup	GSS No Flow Test conducted (solenoids 2 and 3).
	10/22/2008	Setup	GSS Leak Test: Pass
13:15	10/22/2008	Setup	Wetness sensor calibration: Accepted
13:18	10/22/2008	Setup	Barometer audit: Accepted
14:35	10/22/2008	Setup	Calibrated TDLAS 1030
15:36	10/22/2008	Setup	Calibrated TDLAS 1026
16:30	10/22/2008	Setup	TEC 450i instrument operating parameters calculated

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
16:30	10/22/2008	Setup	TEC 450i calibration verification check
16:46	10/22/2008	Setup	TEC 450i reference precision check
17:08	10/22/2008	Setup	SO_2 calibration
12:09	10/23/2008	Remote	Daily Status Check from PAML Notes: Reaimed path 1 on TDLAS 2. Changed pan/tilt settings on TDLAS's; changed minimum light level to 1000 and the optimum light level to 3000. Some flagged data on sonic anemometer 2. Average w value for sonic anemometer 1 is about 0.1 ms^{-1}. Low sample flow on H_2S analyzer. No communication with CR 1000.
14:00	10/24/2008	Remote	Daily Status Check from PAML Notes: Ran time sync on both Panasonics and LAN. Realigned path 1 on TDLAS 2. Sonic anemometer 1 w values are constantly above zero. Sonic anemometer 2 spike counts exceed 160 throughout period, maxing at 250; majority below 160. Sonic anemometer 3 has flagging starting at approx. 663.37. Low flow in H_2S sample flow (0.66 LPM). No communications with CR 1000.
12:50	10/27/2008	Remote	Daily Status Check from PAML Notes: Sonic anemometer 3 appears to be failing. Lots of flagged data and outliers in u, v, w, and T data. Low flow on H_2S sample flow (0.66 LPM). Path 1 on TDLAS 2 is having trouble staying aligned. No communication with CR 1000.
12:00	10/28/2008	Remote	Daily Status Check from PAML Notes: TDLAS 1 path 1 and TDLAS 2 path 6 have low light levels. Tried to reaim paths but could not improve light levels, may be caused by frost as temperature is 28F with dew point of 28F. Later, found TDLAS 1 path 1 with too high light levels. Optimization unable to drop levels below 16368. It appears that super-saturation has been reached. Reaimed path. Sonic anemometer 2 has quite a bit of 5-min periods with up to 20 sonic anemometer flagged points. No communication with CR 1000.
12:35	10/29/2008	Remote	Daily Status Check from PAML Notes: Sonic anemometer 3 has flagging; no flagging on yesterday's status check. Sonic anemometer 3 u, v, w, and T graphs look normal as of yesterday's status check. No communication with CR 1000. No lagoon measurements.
13:00	10/30/2008	Remote	Daily Status Check from PAML Notes: Average w values are greater than zero on sonic anemometer 2. No communications with CR1000. No lagoon measurements.
12:50	10/31/2008	Remote	Daily Status Check from PAML Notes: No communication with CR1000 and LAN. No lagoon measurements.
14:00	11/3/2008	Remote	Daily Status Check from PAML Notes: Reaimed TDLAS 1 path 1 to off of 16368. Fixed invalid data value (red box) in path 3 of TDLAS 2; appeared to have started on 10/31/2008 at 22:53x. No communication with CR 1000. See notes for more details.
13:00	11/4/2008	Remote	Daily Status Check from PAML Notes: TDLAS 1 path 1 has low light level. TDLAS 2 path 6 has low light level. Unable to find valid LL values (dew?). No communication with CR 1000.

Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
13:45	11/5/2008	Remote	Daily Status Check from PAML Notes: No communication with CR 1000.
13:30	11/5/20008	Remote	Daily Status Check from PAML Notes: Sonic anemometer 3 started to get significant flags around 676.27 (heavy rain in area). No communication with CR 1000.
13:30	11/7/2008	Remote	Daily Status Check from PAML Notes: All TDLAS paths good until a few minutes ago. Might be snowing or raining at site. H_2S sample flow at 0.66 LPM. No communication with CR1000.
18:52	11/10/2008	Remote	Daily Status Check from PAML Notes: No communication with CR 1000.
	11/11/2008	Takedown	Arrived on site late on 11/10/2008 and took down sonic anemometers and ground/tower retro-reflectors. Electricity was working well (no evidence of power failure).
	11/11/2008	Takedown	Upon arrival the next morning, found power not to be working in the trailer or on the towers. Could not solve problem; called farm owner but he could not figure out problem either. Called electrician (Richardson), and they will come out to site before Christmas to solve problem. Ran extension cords from barn to trailer for power.
	11/11/20008	Takedown	Unhooked power. Found connecting block. Wiring scheme: white tape--white; red tape--red; yellow tape--black; green tape--ground.
	11/11/2008	Takedown	Lagoon site layout made; see open site notes.
	11/11/2008	Takedown	Maintenance list completed.
	11/11/2008	Takedown	GSS Max flow test
	11/11/2008	Takedown	GSS No Flow Test conducted (solenoids 2 and 3).
	11/11/2008	Takedown	GSS Leak Test: Pass
15:45-16:40	11/11/2008	Takedown	Sonic anemometer inter-comparison; all pass.
15:49	11/11/2008	Takedown	Calibrated TDLAS 1030
17:02	11/11/2008	Takedown	Calibrated TDLAS 1026
17:05	11/11/2008	Takedown	Zero Calibration on sonic anemometers; all pass.
19:13	11/11/2008	Takedown	Wetness sensor calibration: Accepted
19:15	11/11/2008	Takedown	Barometer audit: Accepted
22:51	11/11/2008	Takedown	TEC 450i calibration verification check
22:51	11/11/2008	Takedown	TEC 450i instrument operating parameters calculated
23:06	11/11/2008	Takedown	TEC 450i reference precision check
23:30	11/11/2008	Takedown	SO_2 calibration
	12/17/2008	Setup	We did not do a wetness sensor calibration because it was so cold it would freeze.
	12/17/2008	Setup	Power issue on arrival. Found breakers were loose in farm power supply box.
	12/17/2008	Setup	Lagoon site layout completed
21:00-22:15	12/17/2008	Setup	Sonic anemometer inter-comparison; all pass.
22:30	12/17/2008	Setup	Zero Calibration on sonic anemometers; all pass.
00:58	12/18/2008	Setup	Calibrated TDLAS 1030
01:26	12/18/2008	Setup	Calibrated TDLAS 1026
	12/18/2008	Setup	Lost F5 inlet on S-OPS; replaced.

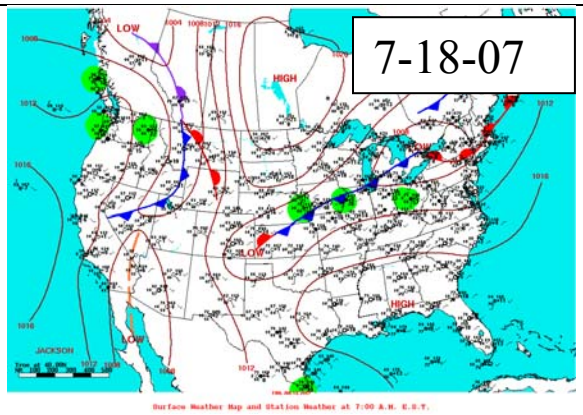
Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	12/18/2008	Setup	Too cold to use electrical tape (it just ripped apart). Also, when using zip ties, had to be very careful or else they would break because of the cold.
	12/18/2008	Setup	Outlet for weather station not working.
	12/18/2008	Setup	Trailer heater not putting out much heat. Can only get temperature in trailer to about 55F.
	12/18/2008	Setup	Maintenance list completed.
19:45	12/18/2008	Setup	Barometer audit: Accepted
16:30	12/22/2008	Remote	Daily Status Check from PAML Notes: Paths 1-5 on TDLAS 2 had low light levels. Successfully reaimed at 21:50 UTC. Sonic anemometer 1 has up to 80 flagged data points. H_2S internal temperature dipped as low as 25C due to chilly trailer. No lagoon probes.
13:15	12/23/2008	Remote	Daily Status Check from PAML Notes: *iPort* had an error and needed to be restarted. Had to stop sonic anemometers to restart *iPort*. Created fill file starting at 12/23/08 at 12:53 (actually had to start 60 records ago). Restarted sonic anemometer program. No lagoon probes.
13:30	12/24/2008	Remote	Daily Status Check from PAML Notes: Flag 1 in H_2S data from 723.53-727.55 (correspond to a fill file). No lagoon probe.
13:29	12/29/2008	Remote	Daily Status Check from PAML Notes: All TDLAS paths out of alignment (Light levels less than 40). Conditions were foggy/drizzly when paths were lost on evening on 12/26. Took about four hours to reaim all the paths. See aiming sheet for new paths. Extensive, but not complete flagging on sonic anemometer three since 726.68. Values for u, v, w, and T have gone crazy for sonic anemometer 3.
13:00	12/30/2008	Remote	Daily Status Check from PAML
14:10	1/5/2009	Remote	Daily Status Check from PAML Notes; Paths 2 and 5 on TDLAS 1 had low light levels. See notes for new paths values. Sonic anemometer 3 flagging all points (malfunctioning). Sonic anemometers 1 and 2 have recovered after flagging yesterday. No lagoon probes.
	1/6/2009	Takedown	All TDLAS paths were aligned upon arrival.
23:42	1/6/2009	Takedown	Calibrated TDLAS 1026
00:03	1/7/2009	Takedown	Calibrated TDLAS 1030
	1/7/2009	Takedown	Performed diluter test with 450i and cylinder from ABE (4.46 ppm H_2S in air). Also diluted our 29.6 ppm H_2S tank in air to 4.46 pmm to compare with direct from ABE tank.
	1/7/2009	Takedown	Maintenance list completed.
15:40-16:40	1/7/2009	Takedown	Sonic anemometer inter-comparison; all pass.
16:55	1/7/2009	Takedown	Zero Calibration on sonic anemometers; all pass.
17:08	1/7/2009	Takedown	Wetness sensor calibration: Accepted
17:11	1/7/2009	Takedown	Barometer audit: Accepted
	3/9/2009	Setup	Performed sonic anemometer calibrations and set up all outside equipment, because it is forecasted to rain/snow tomorrow.
	3/10/2009	Setup	Set up and aligned TDLAS/scanner units.
	3/10/2009	Setup	CR 1000 not connecting to LAN.

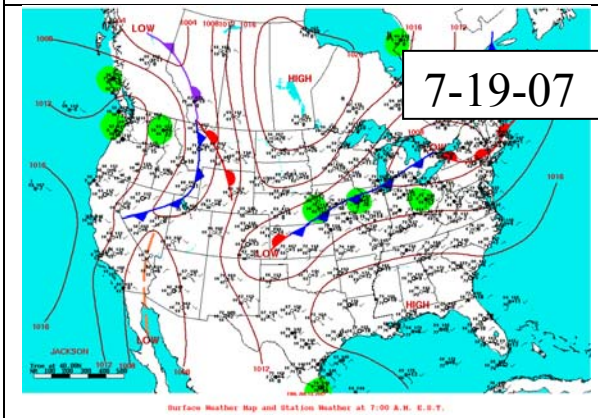
Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
	3/10/2009	Setup	No wetness sensor calibration because of rain.
	3/10/2009	Setup	Maintenance list completed.
	3/10/2009	Setup	Lagoon site layout completed
00:10-01:10	3/10/2009	Setup	Sonic anemometer inter-comparison; all pass.
01:26	3/10/2009	Setup	Zero sonic anemometer calibration; all pass.
14:00-16:00	3/10/2009	Setup	S-OPS/GSS calibrations
16:45	3/10/2009	Setup	Barometer audit: Accepted
17:23	3/10/2009	Setup	Calibrated TDLAS 1031
17:51	3/10/2009	Setup	Calibrated TDLAS 1030
19:45-20:27	3/10/2009	Setup	TEC 450i Single Point calibration
15:40	3/12/2009	Remote	Daily Status Check from PAML Notes: Two points with flag 4 are recurrent in H_2S data. No communication with CR 1000. Lagoon is frozen, so there are no lagoon probes.
12:20	3/13/2009	Remote	Daily Status Check from PAML Notes: TDLAS 1 paths 1-5, and 7-8 currently have low light levels. Likely caused by ice or frost. Will check later after temperatures have warmed to see if they return. At the beginning of day 801, sonic anemometer 3 appears to have no data for several hours.
16:00	3/16/2009	Remote	Daily Status Check from PAML Notes: *iPort* had an error and needed to be restarted. Data stopped collecting at 3/16/2009 at 3:00 UTC. Had to stop sonic anemometers to restart *iPort*. Created fill file starting at 3/16/09 at 2:55. Restarted sonic anemometer program. All paths on TDLAS 1 No lagoon probes.
	3/17/2009	Remote	Daily Status Check from PAML Notes: Reaimed TDLAS 1 (NE corner) with Brian Hetchler's assistance. Scanner tripod had been shifted due to thawing of ground. Paths were off 300+ steps vertically and horizontally. Reaimed paths, and a chart with new coordinates is attached to QC check. Sonic anemometer 3 has a few flagged five-min intervals around 865. Flag 1 on H_2S data from 806.13 to 806.98; missed missing data. No communication with CR 1000.
12:55	3/18/2009	Remote	Daily Status Check from PAML Notes: TDLAS 1 paths 6-10 are lost. Had to reaim twice; see report for details. No lagoon probes.
12:15	3/19/2009	Remote	Daily Status Check from PAML Notes: Changed optimization settings on TDLAS 1. See notes for details. Reaimed paths 7 and 8 on TDLAS 1. No connection with CR 1000.
13:15	3/23/2009	Remote	Daily Status Check from PAML Notes: Average w values for sonic anemometer 1=0.1 ms^{-1}; -0.1 ms^{-1} for sonic anemometer 2; and -0.3 ms^{-1} for sonic anemometer 3. No communication with CR 1000.
13:35	3/24/2009	Remote	Daily Status Check from PAML Notes: Average w values for sonic anemometer 1=0.1 ms^{-1}; -0.1 ms^{-1} for sonic anemometer 2; and -0.3 ms^{-1} for sonic anemometer 3. No communication with CR 1000.
14:30	3/25/2009	Remote	Daily Status Check from PAML Notes: Sonic anemometer 3

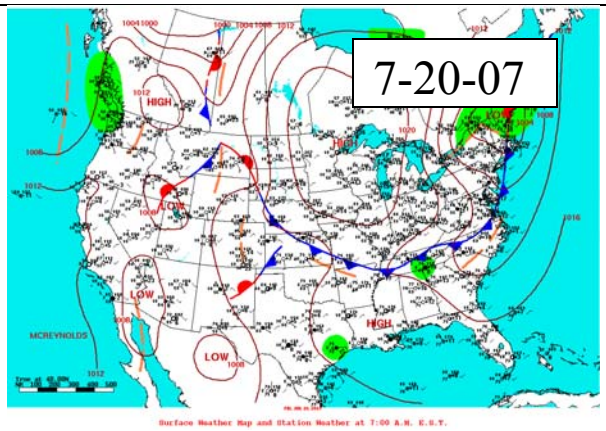
Time HHMM UTC	Date MM/DD/YYYY	Activity (Setup, Takedown, Calibration, Repair, Remote)	Event
			has not sent any data since 11:20 UTC on 3/25/2009. There was also a period from 22:40 UTC on 3/24/2009 to 4:25 UTC on 3/25/2009 where sonic anemometer 3 did not send back any data. Sonic anemometer 1 w is 0.1 ms^{-1}. Sonic anemometer 2 w is 0.15 ms^{-1}. No CR 1000 communication.
15:45	3/26/2009	Remote	Daily Status Check from PAML Notes: There were a few times yesterday that sonic anemometer 3 was sending back no data, but it is working fine now. No CR 1000 connection.
13:20	3/27/2009	Remote	Daily Status Check from PAML Notes: No communication with CR 1000.
15:30	4/2/2009	Remote	Daily Status Check from PAML Notes: TDLAS 1 and 2 appear to have lost connection on 3/30/2009. TDLAS laptop screens are stuck on 3/27/2009. *iPort* program encountered an error. Stopped sonic anemometer program at 16:00 UTC and restarted. Reconnected to TEC 450i and checked time-sync. Filled data starting at 4/2/2009 10:42 UTC. Restarted real-time data collection (0402091605) Restarted sonic anemometers at 16:07 UTC. Sonic anemometer 3 has no data from 821.64 to 821.99.
16:30	4/2/2009	Remote	Daily Status Check from PAML Notes: Called Todd Doornick about resetting the TDLAS laptops. John then helped reset the TDLAS laptops and was able to get everything realigned without too much difficulty. No lagoon probes.
	4/6/2009	Takedown	Used expired NH_3 tank for TDLAS calibrations. Will do inter-comparison with a valid cylinder next time.
	4/6/2009	Takedown	Lagoon is being filled by force (pressurized).
	4/6/2009	Takedown	Lots of work (heavy trucks) is in progress around the lagoon. TDLAS path near the trailer has been blocked by the trucks. Took many photos.
15:14	4/6/2009	Takedown	Barometer audit: Accepted
23:28	4/6/2009	Takedown	Calibrated TDLAS 1030
23:50	4/6/2009	Takedown	Calibrated TDLAS 1031
	4/7/2009	Takedown	S-OPS tubing lengths North: 250 m South: 160 m
	4/7/2009	Takedown	Maintenance list completed.
12:20-13:30	4/7/2009	Takedown	S-OPS/GSS calibrations
13:15-14:10	4/7/2009	Takedown	Sonic anemometer inter-comparison; all pass.
14:53-15:22	4/7/2009	Takedown	TEC 450i Single Point calibration
15:15	4/7/2009	Takedown	Wetness sensor calibration: Accepted
15:16	4/7/2009	Takedown	Zero sonic anemometer calibration; all pass.

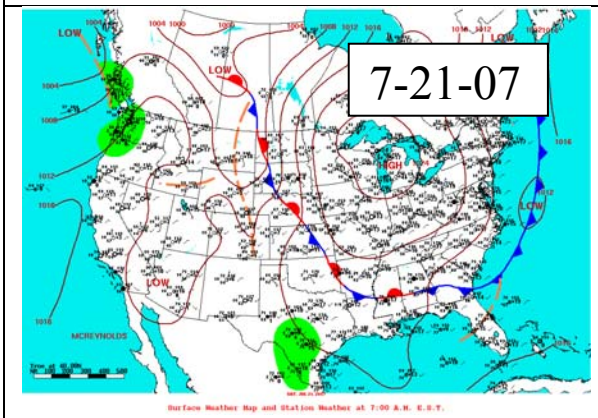
6.9 Site weather

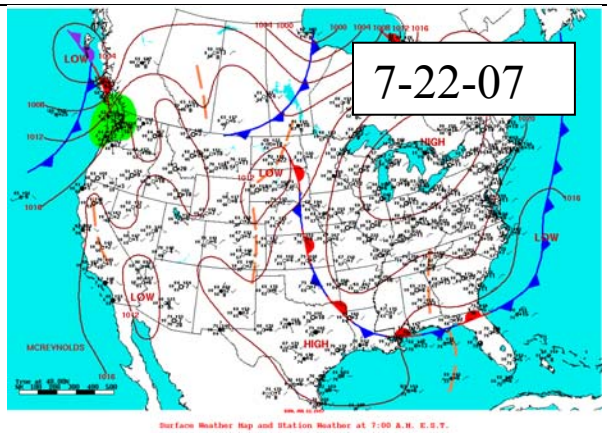
Period 1

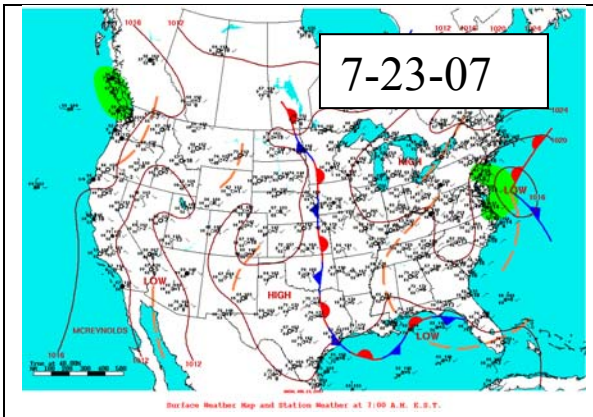








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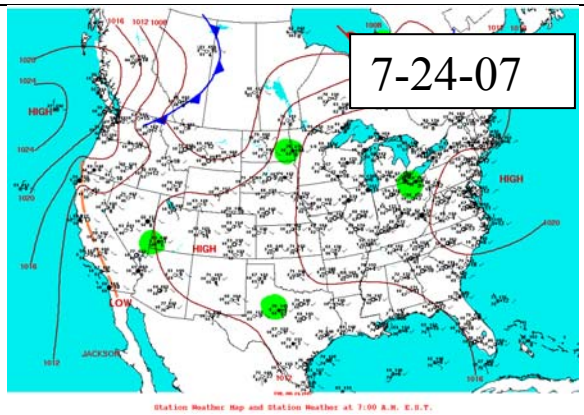
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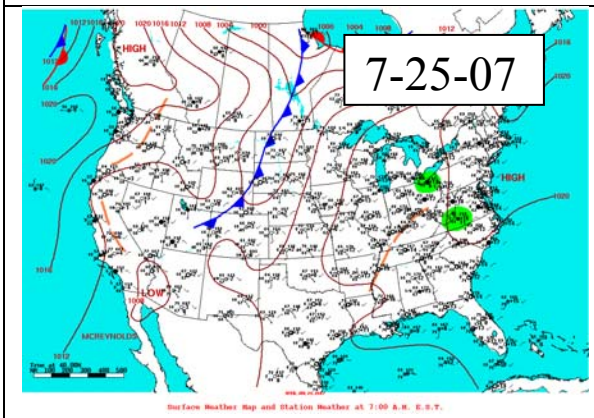
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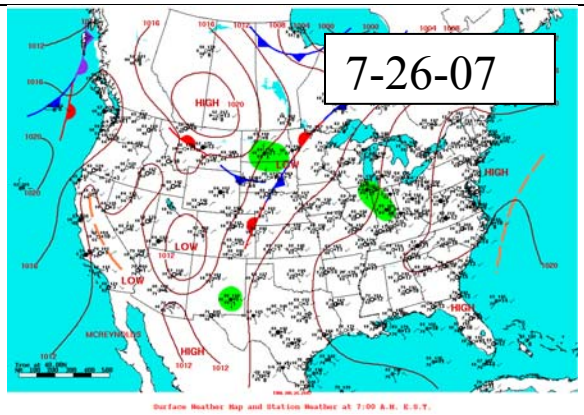
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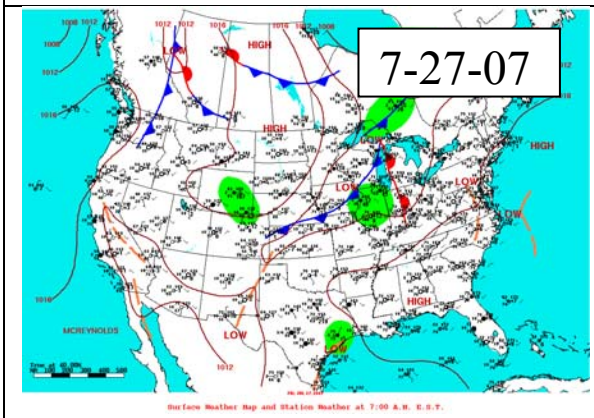
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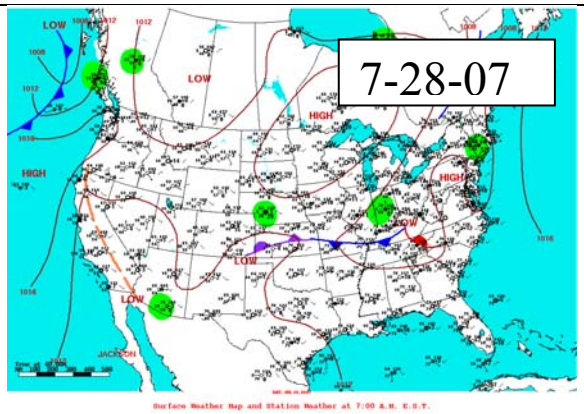
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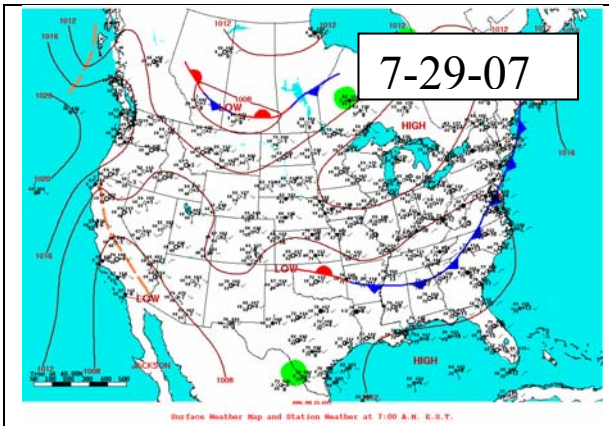
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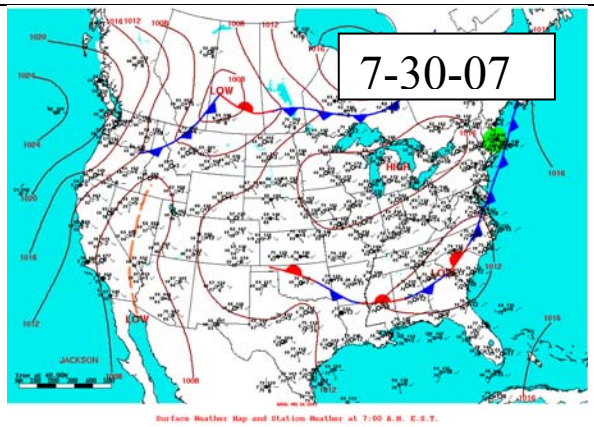
LOW
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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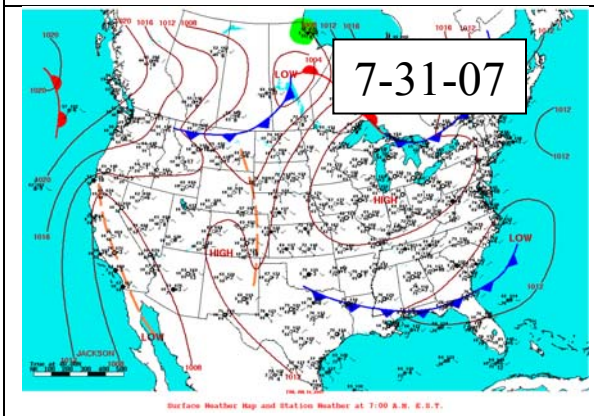
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HIGH
LOW
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JACKSON
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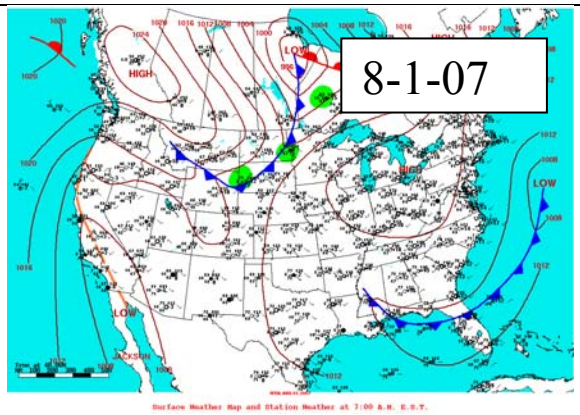
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LOW
LOW
LOW
JACKSON
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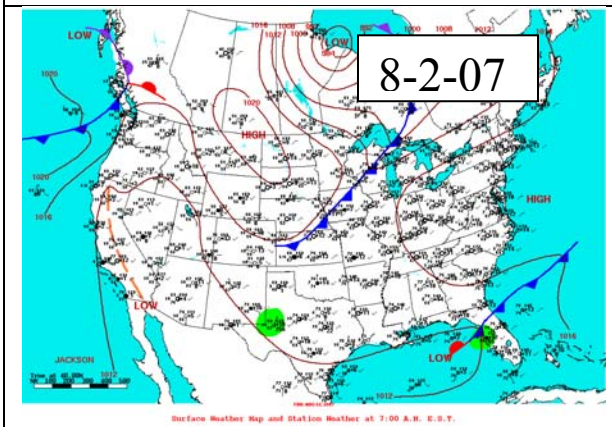
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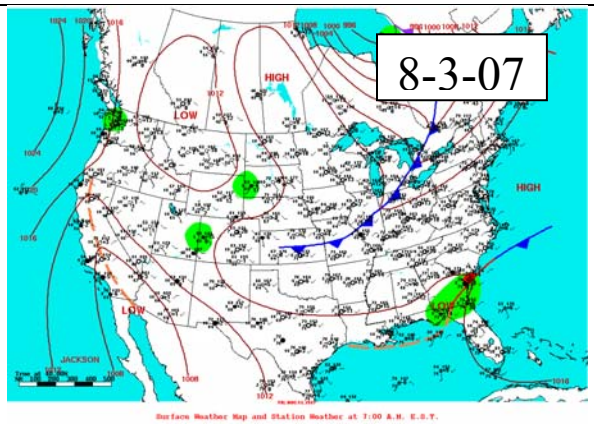
LOW
HIGH
HIGH
LOW
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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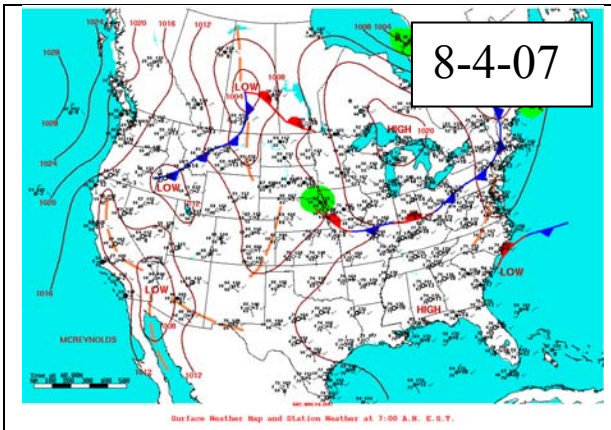
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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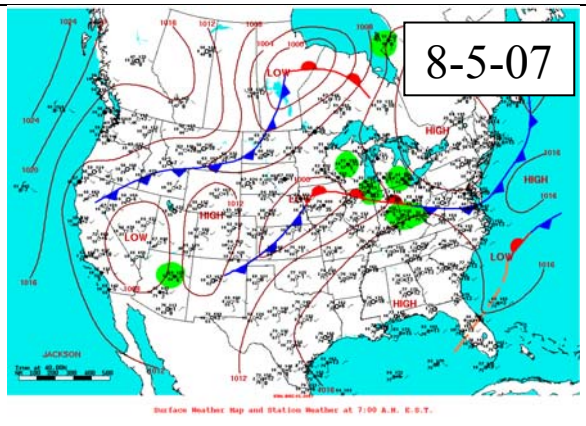
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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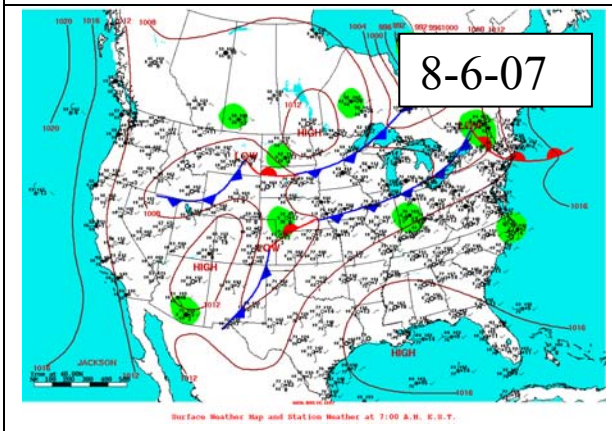
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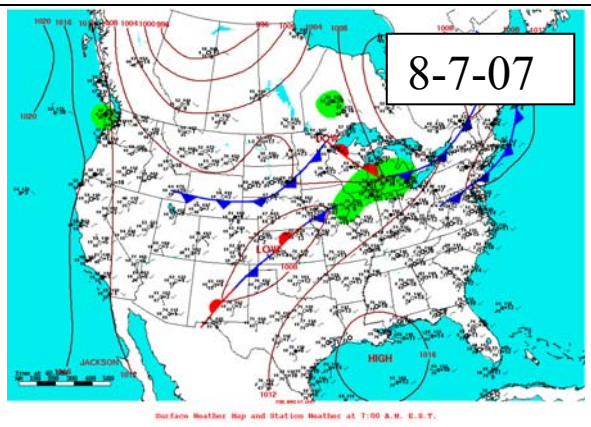
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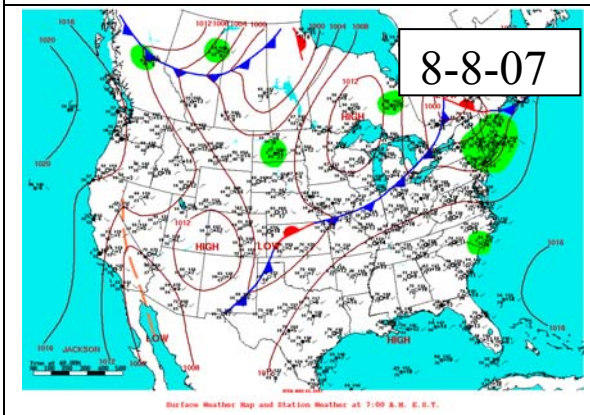
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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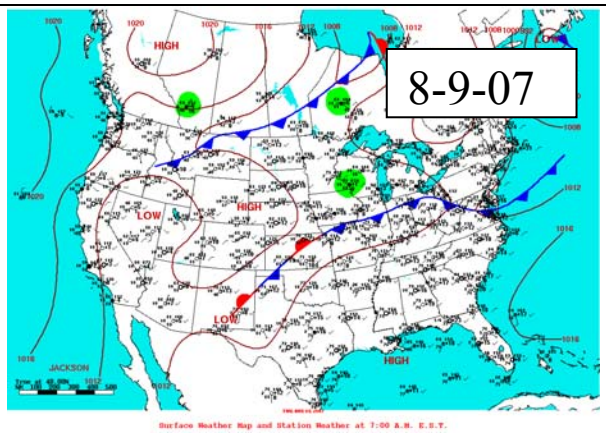
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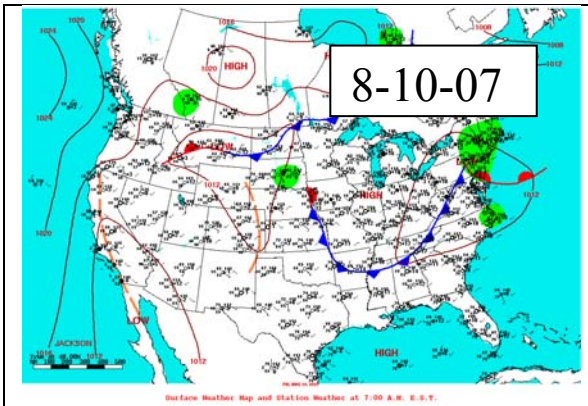
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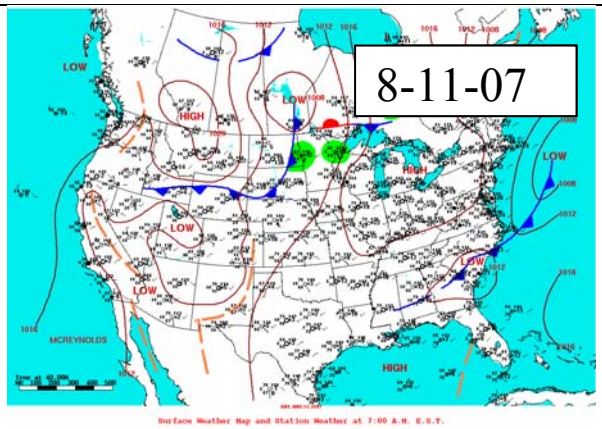
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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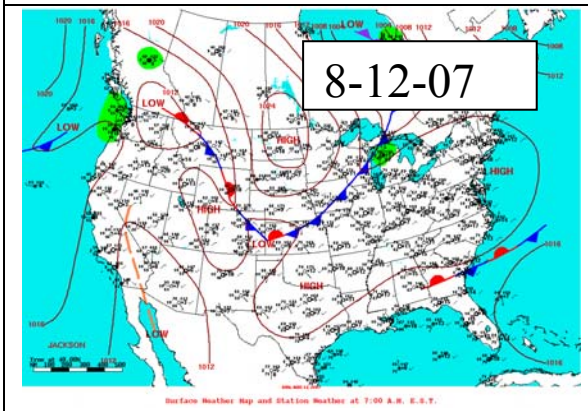
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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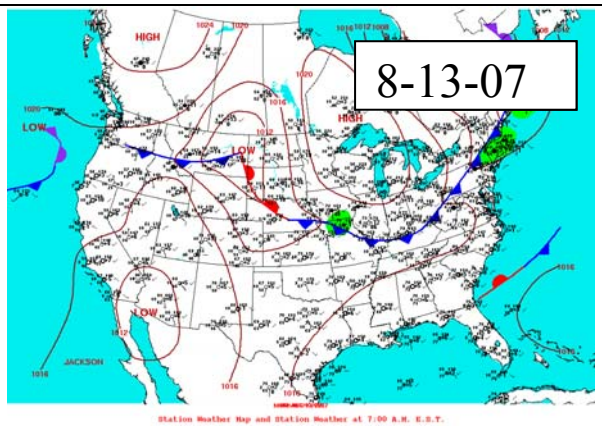
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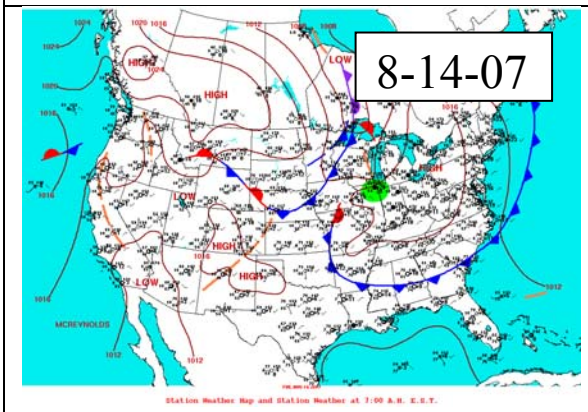
Station Weather Map and Station Weather at 7:00 A.M. E.S.T.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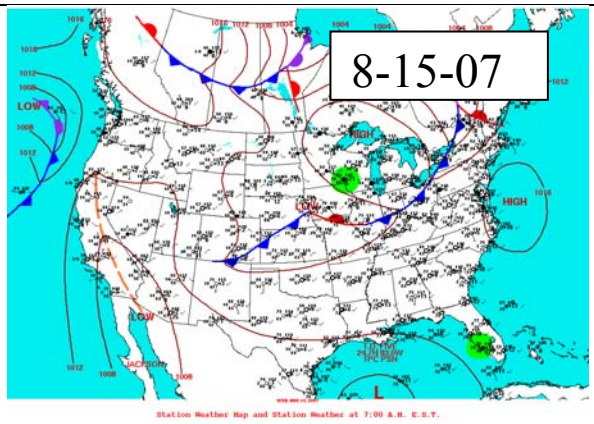
Station Weather Map and Station Weather at 7:00 A.M. E.S.T.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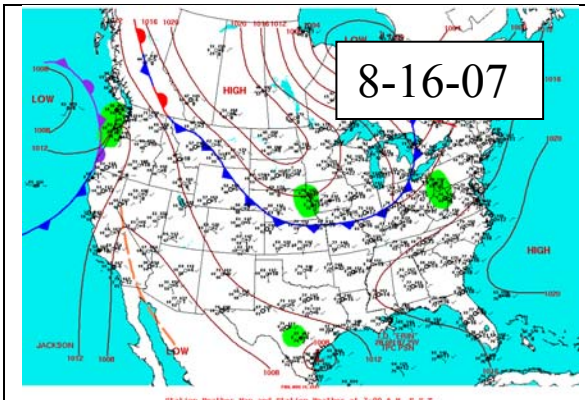
Station Weather Map and Station Weather at 7:00 A.M. E.S.T.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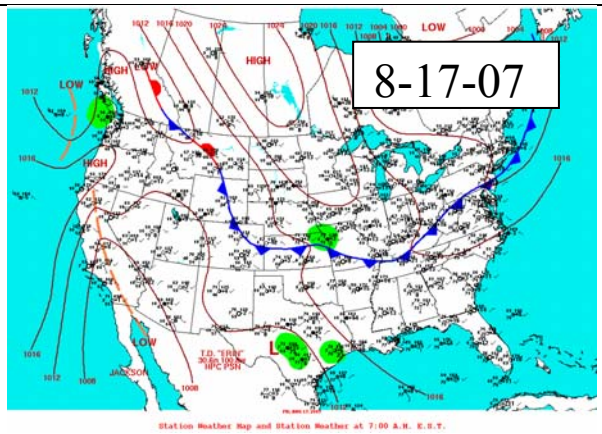
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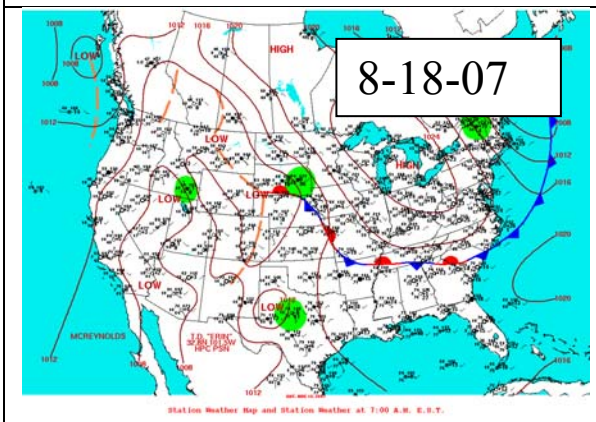
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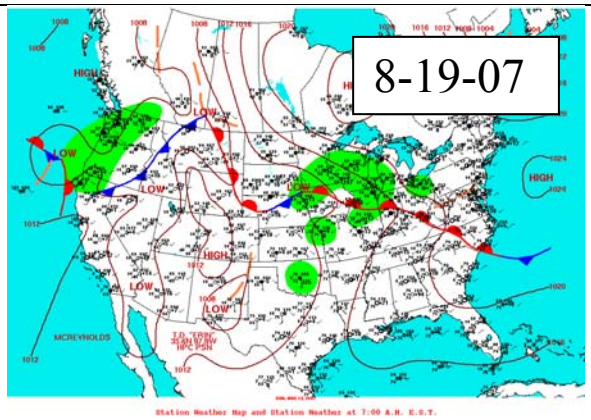
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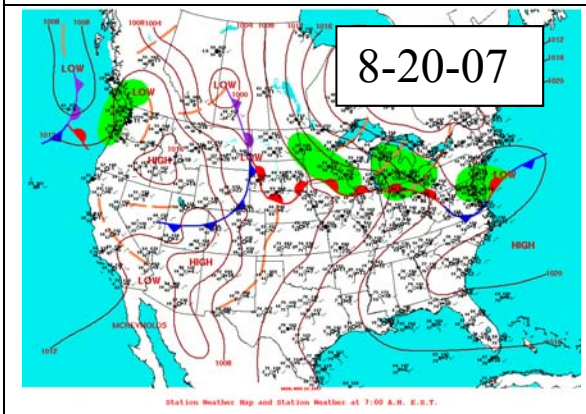
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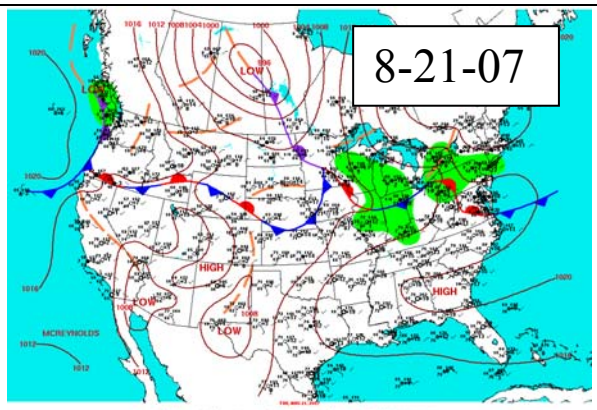
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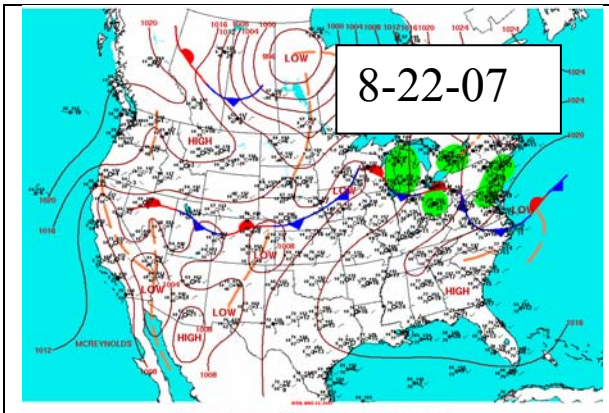
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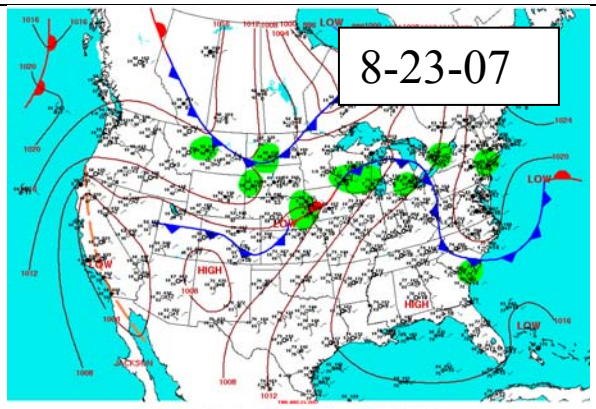
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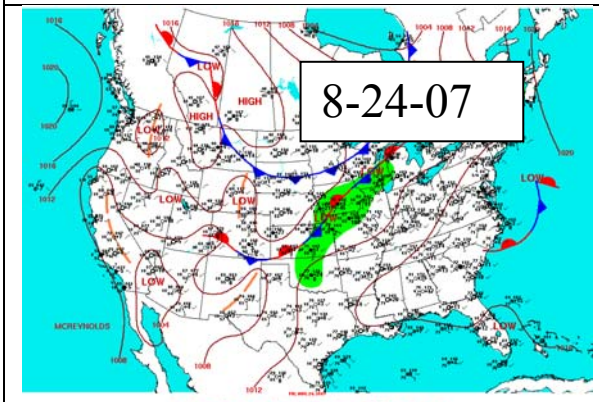
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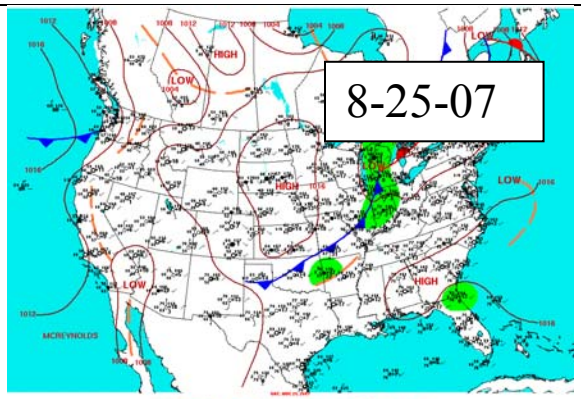
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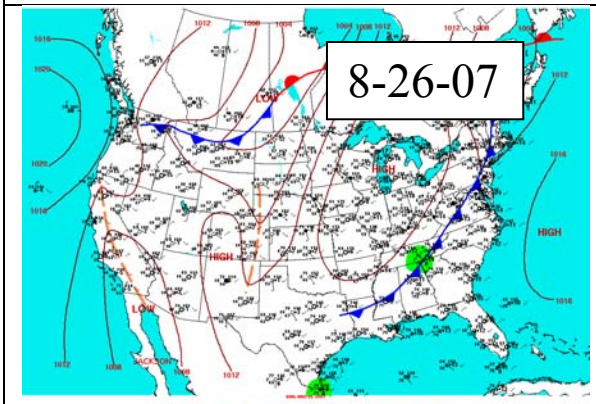
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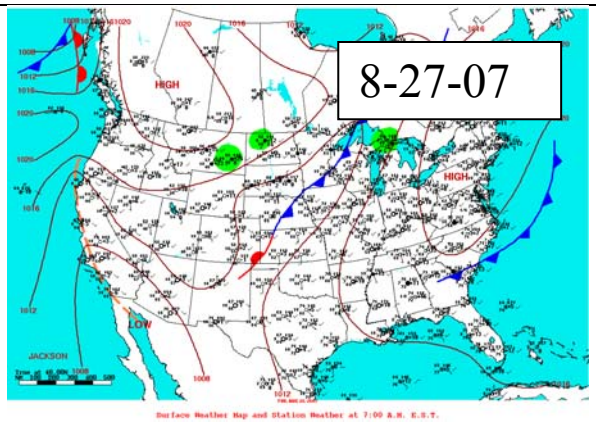
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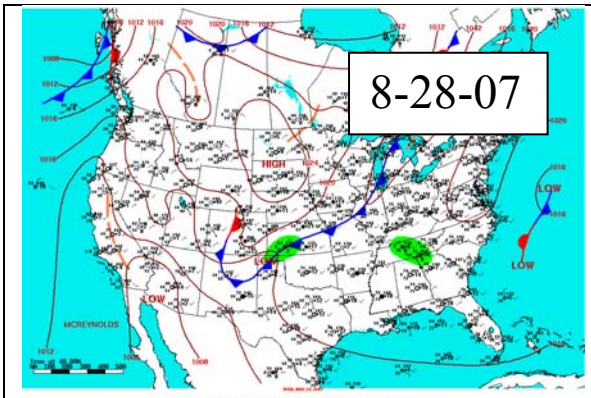
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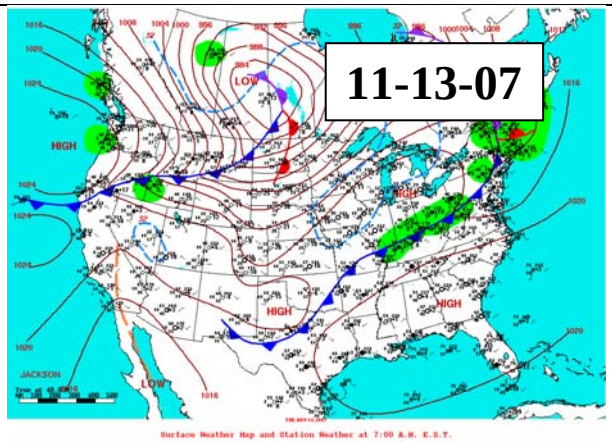
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

Period 2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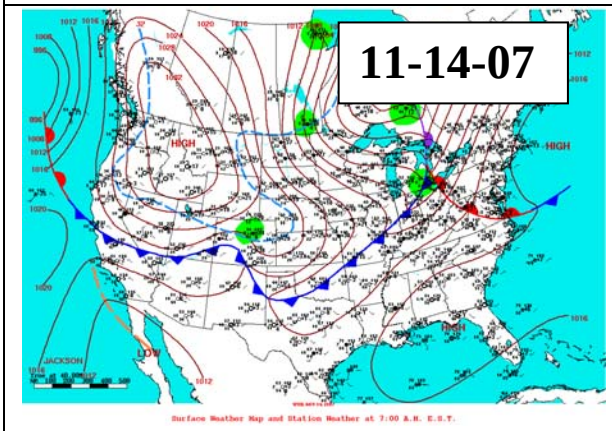
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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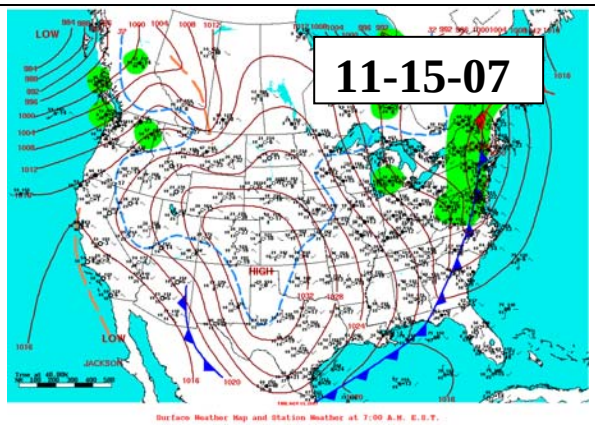
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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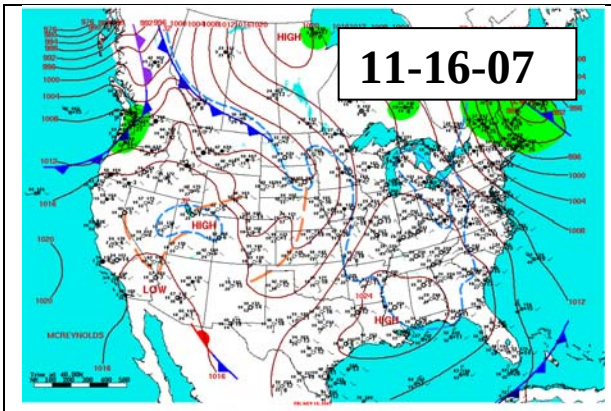
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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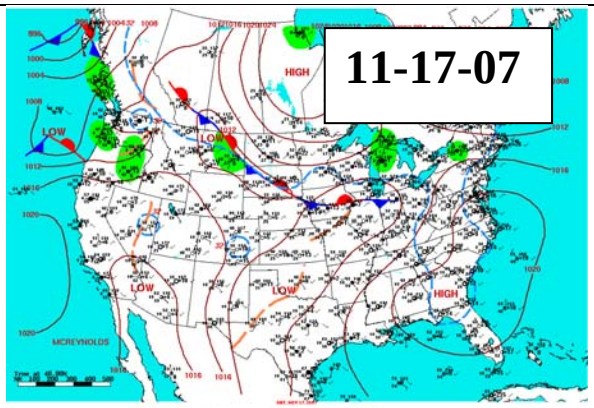
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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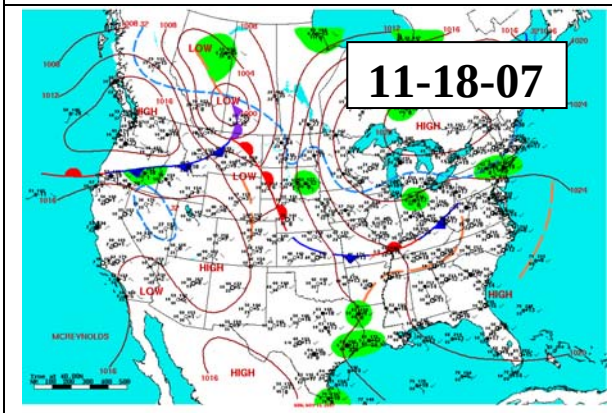
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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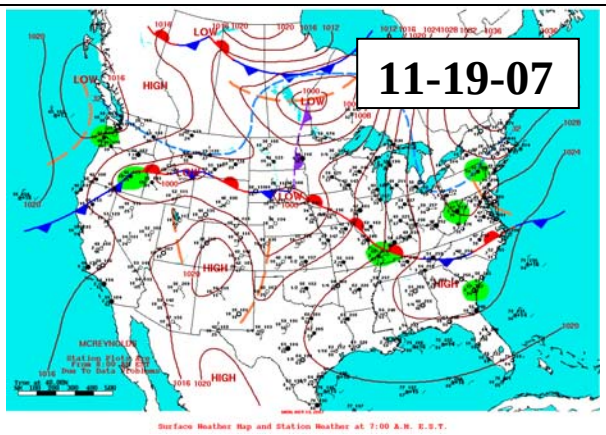
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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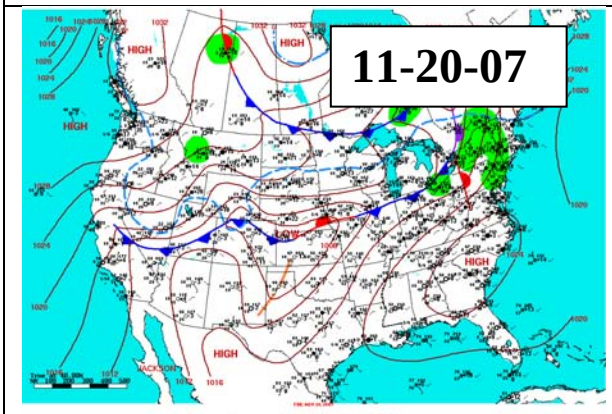
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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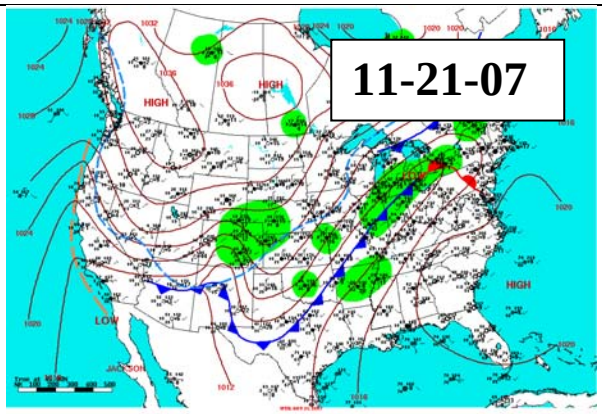
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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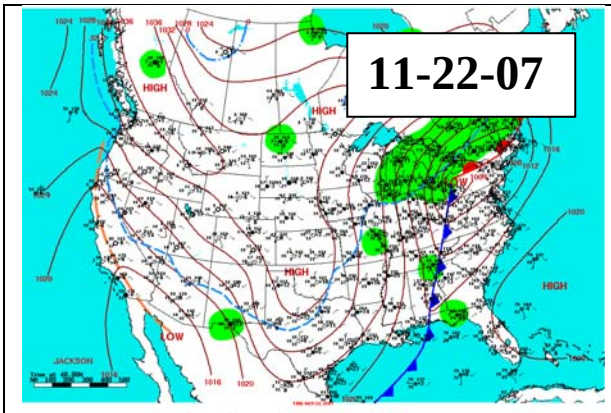
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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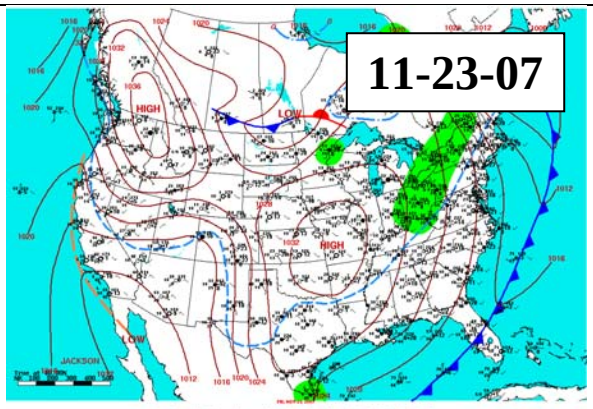
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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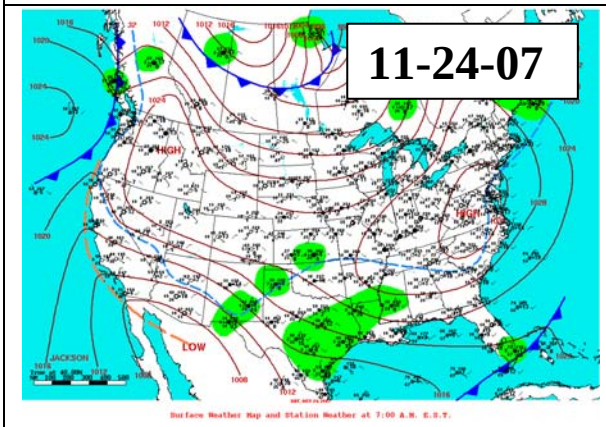
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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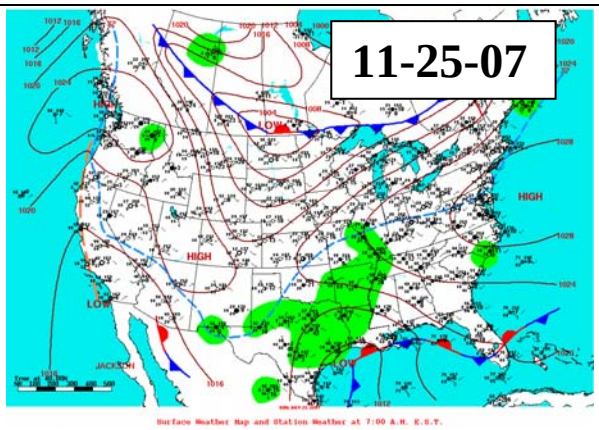
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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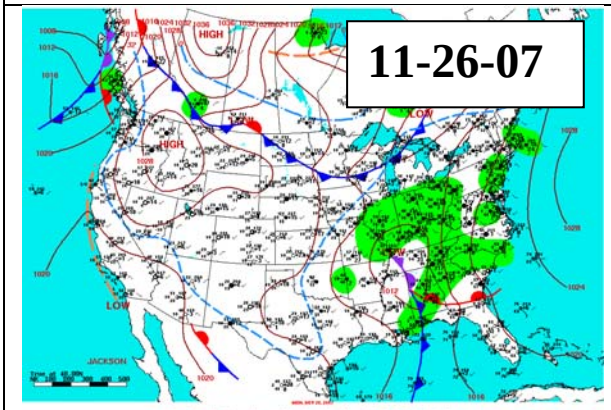
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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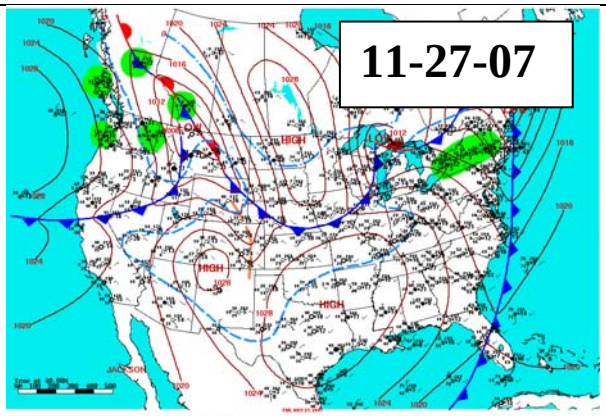
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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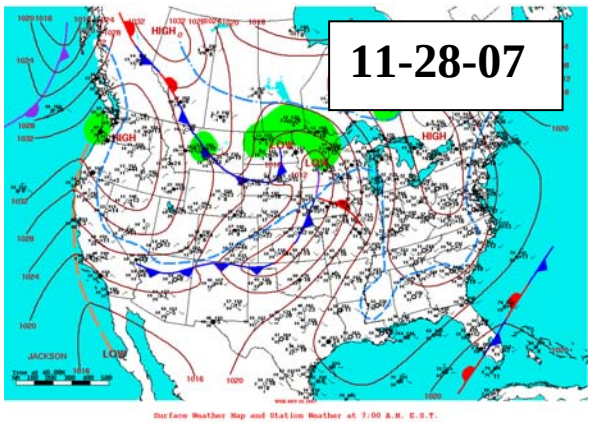
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

Period 3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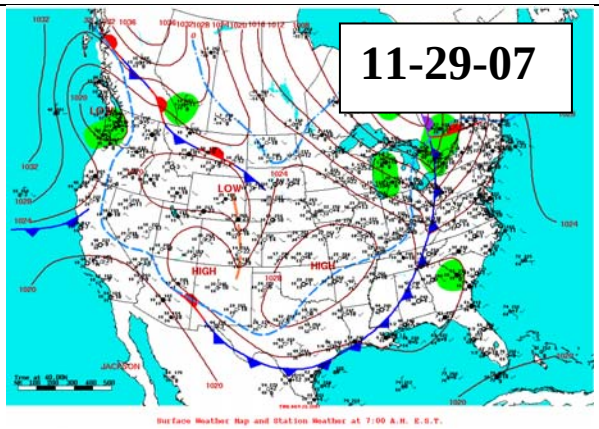
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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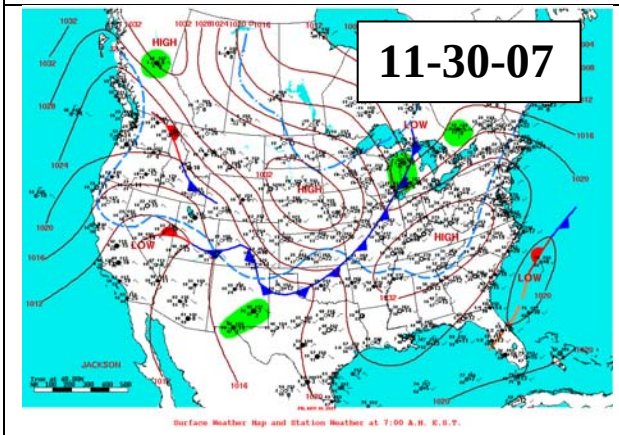
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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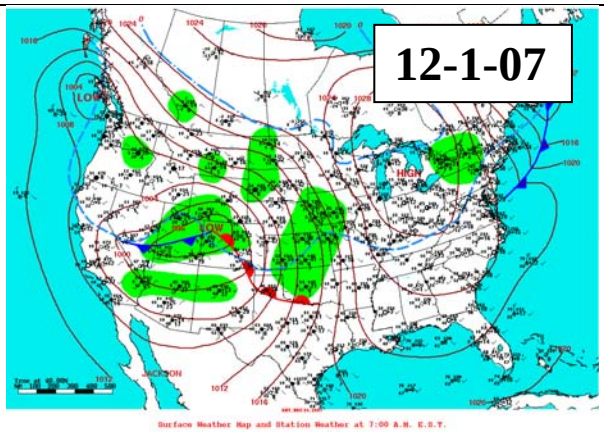
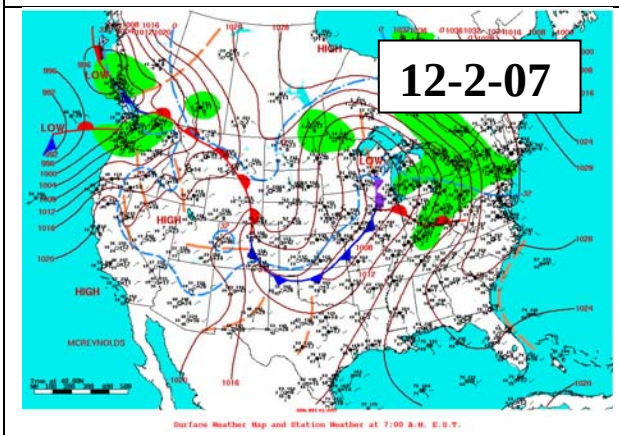
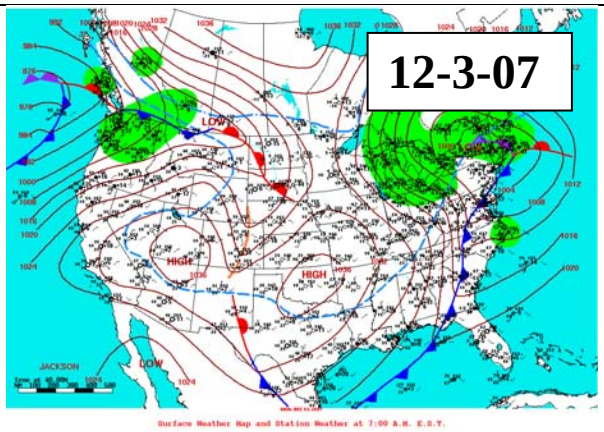
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


12-1-07
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


12-2-07
HIGH
LOW
MCREYNOLDS
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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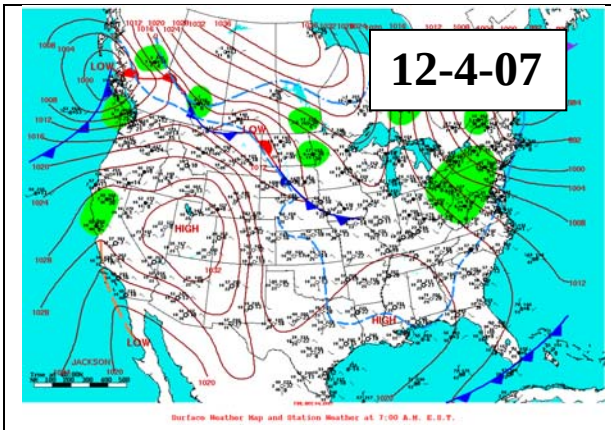
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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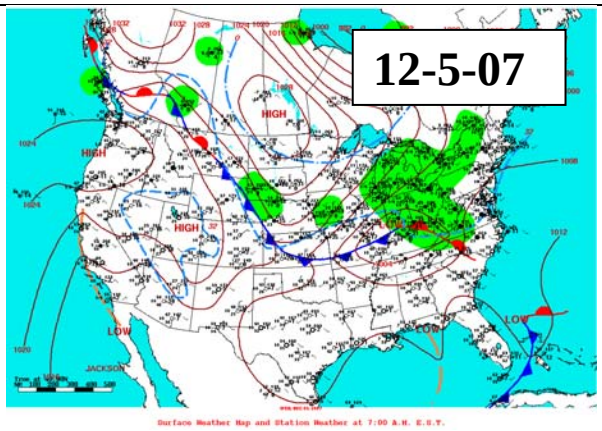
JACKSON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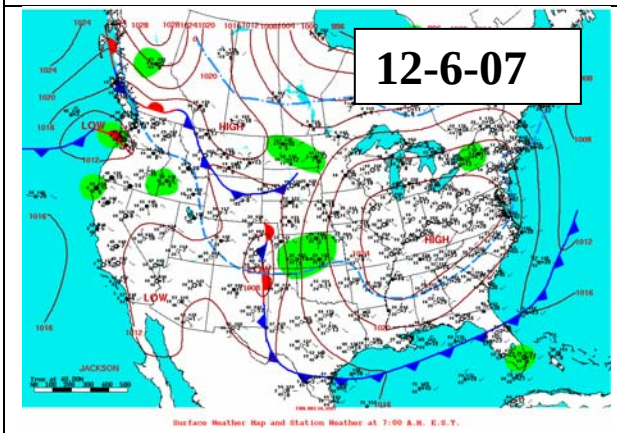
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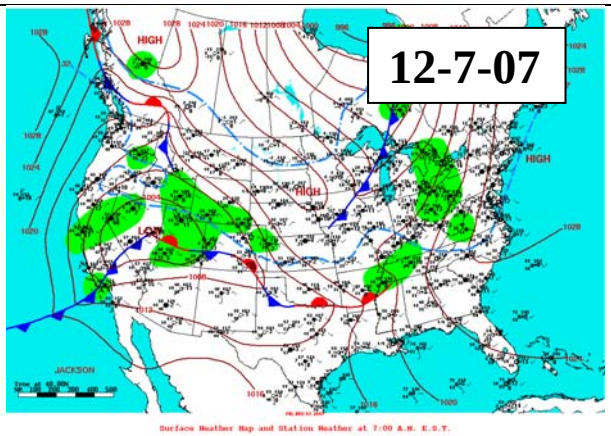
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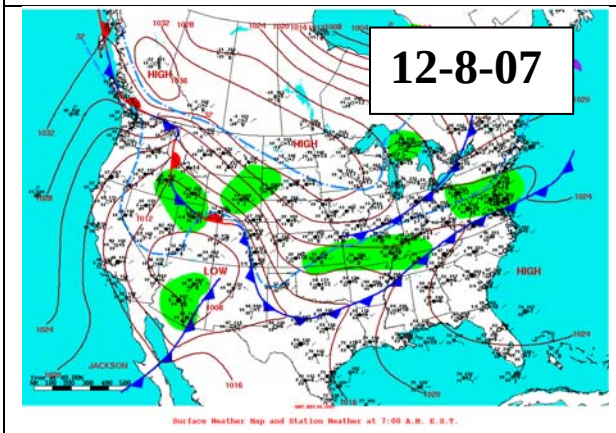
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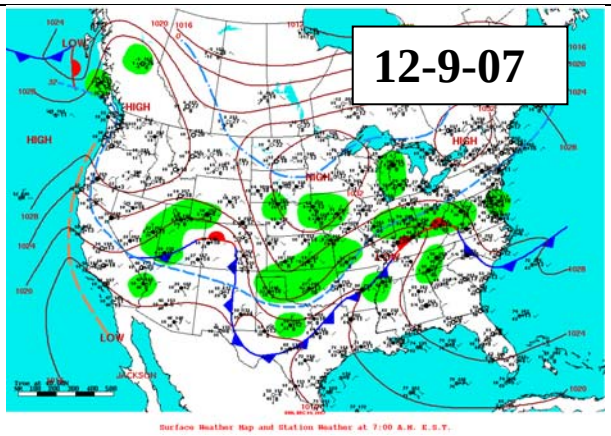
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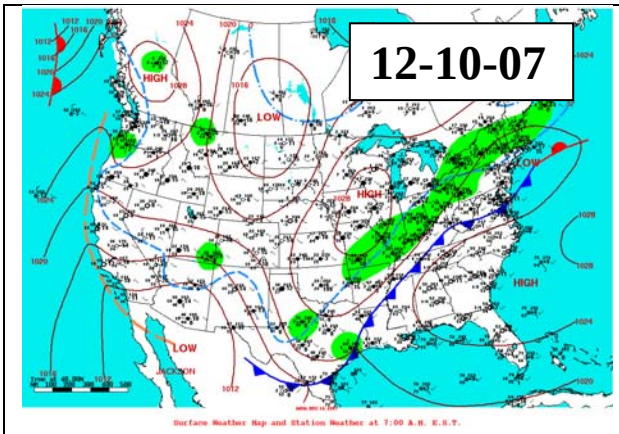
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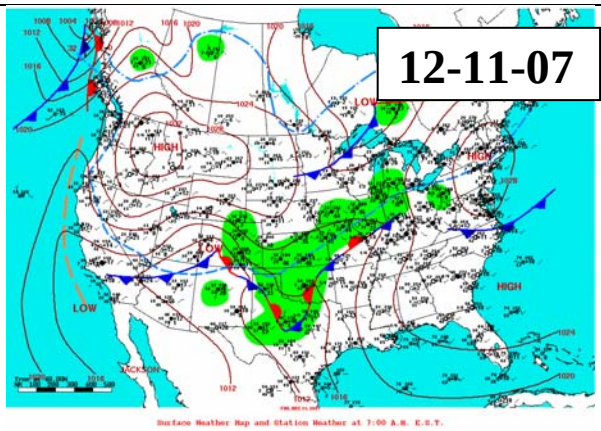
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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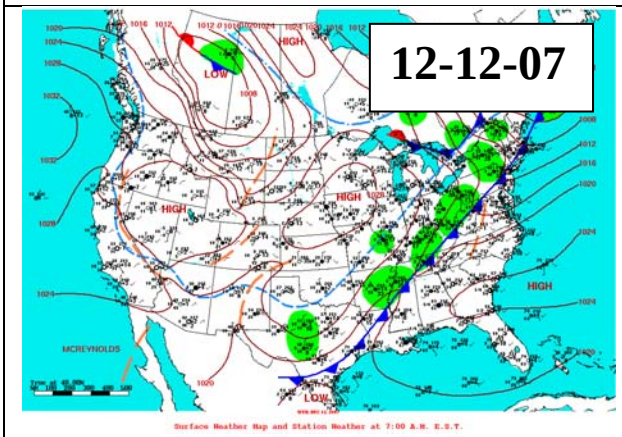
HIGH
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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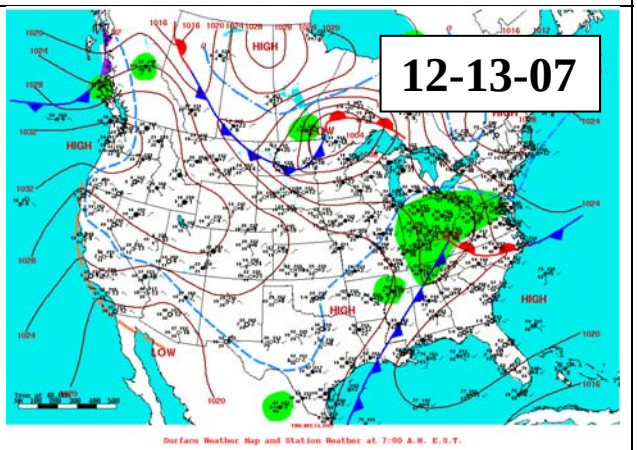
HIGH
HIGH
MCREYNOLDS
LOW
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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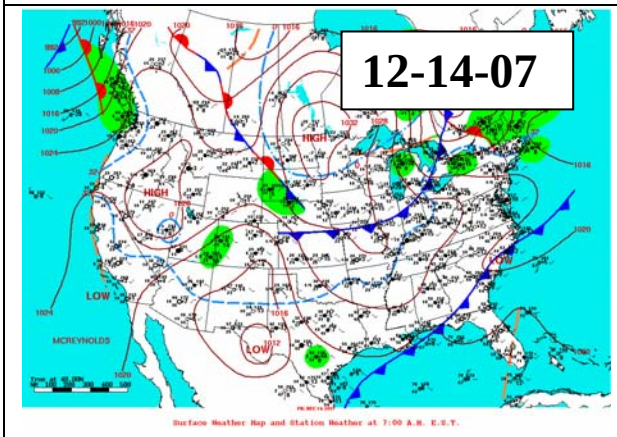
LOW
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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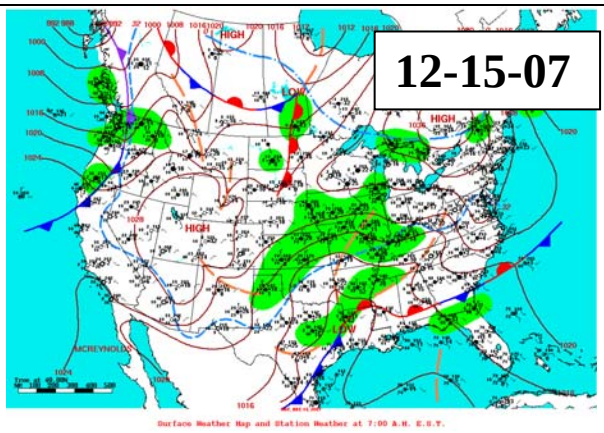
MCREYNOLDS
LOW
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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MCREYNOLDS
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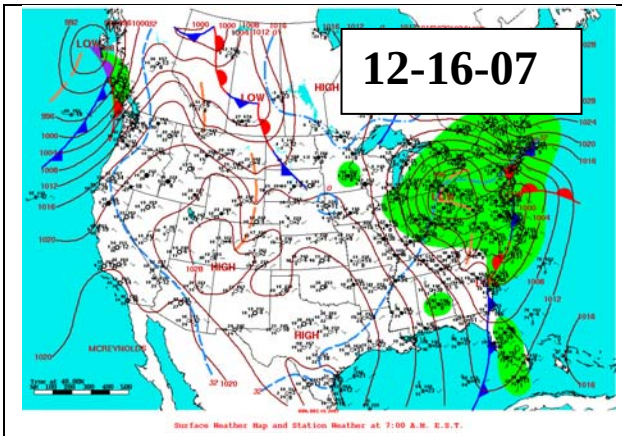
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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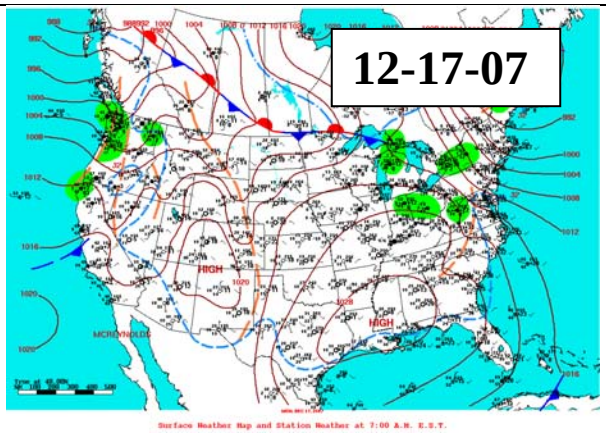
MCREYNOLDS


12-17-07
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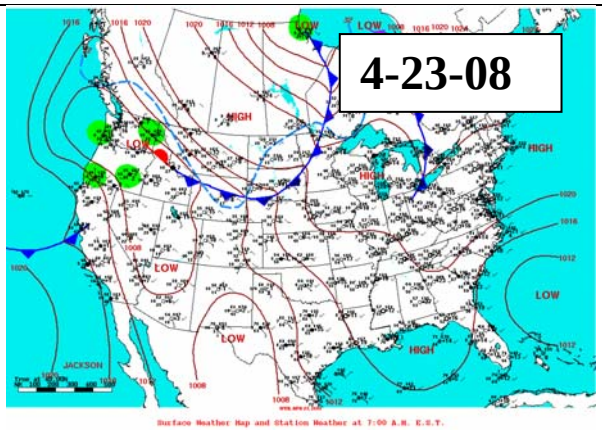
HIGH
MCREYNOLDS

Period 4


4-23-08
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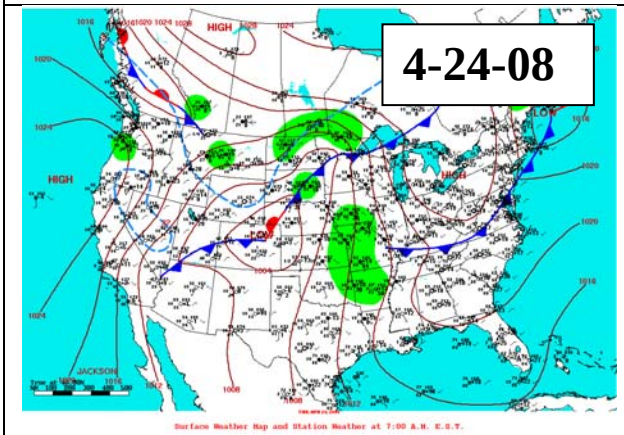
HIGH
HIGH
LOW
LOW
LOW
HIGH
JACKSON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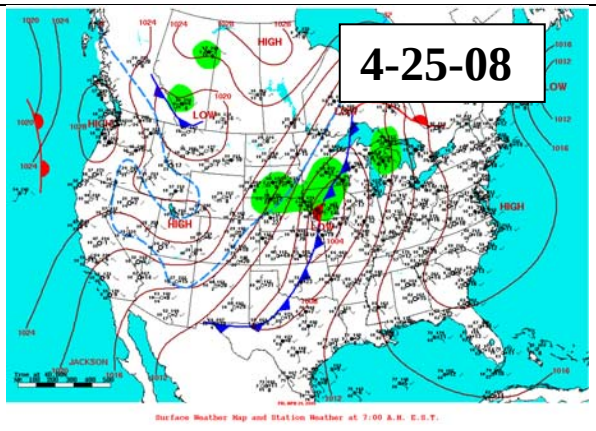
4-25-08
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HIGH
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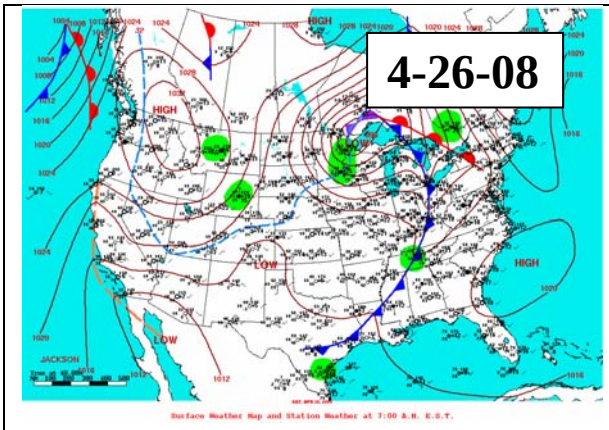
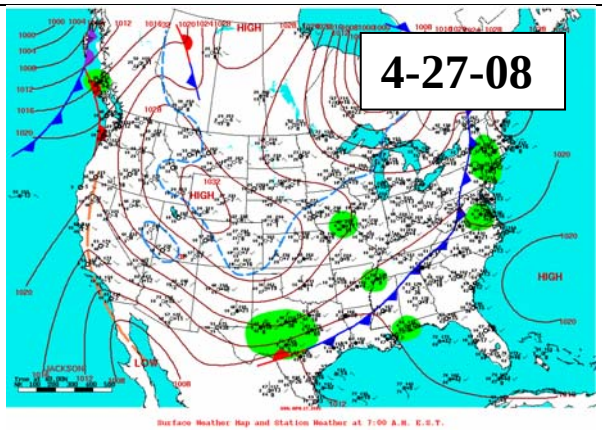

4-26-08
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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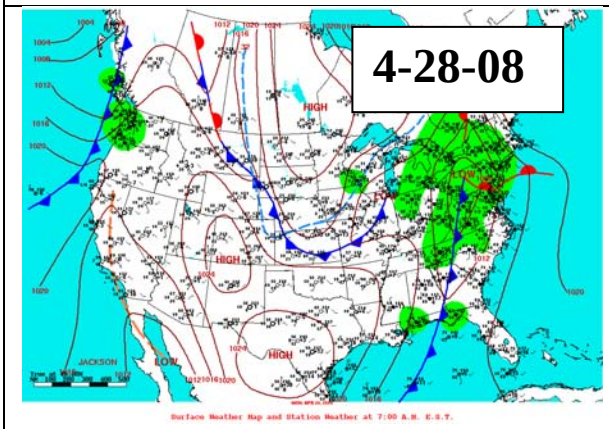
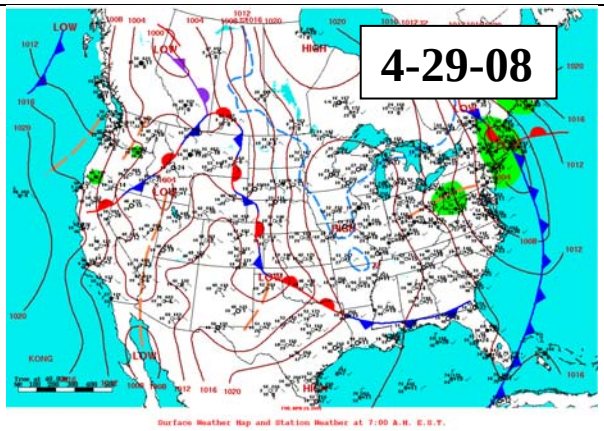
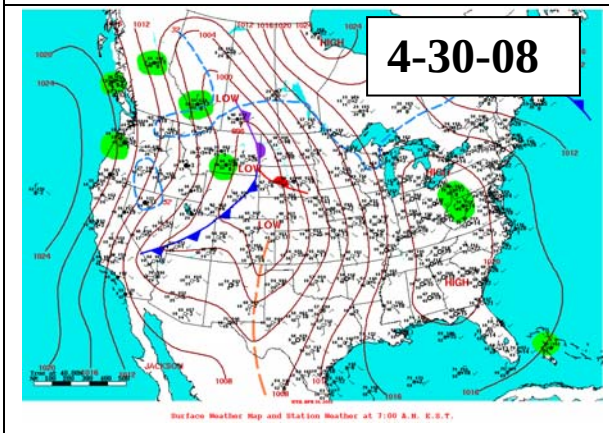
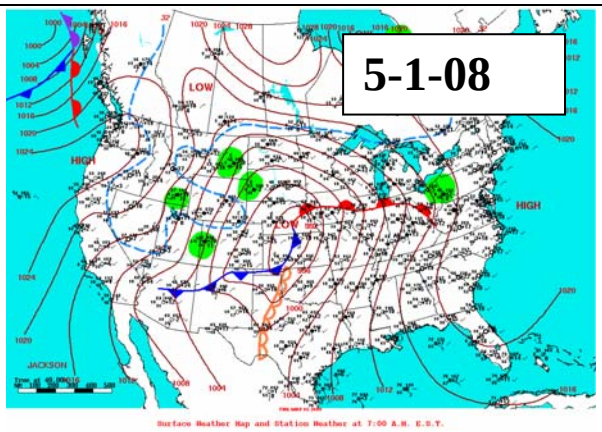
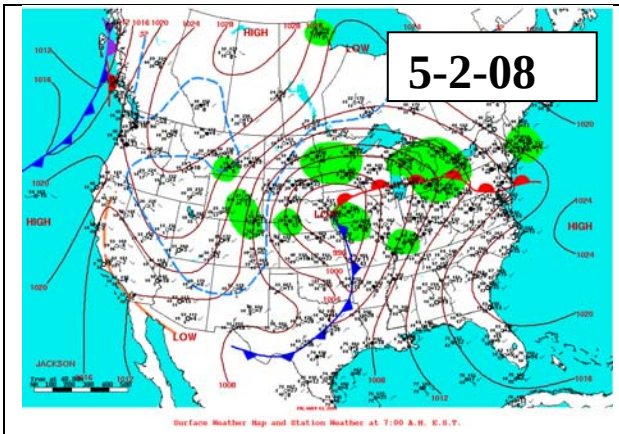
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


4-28-08
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


4-29-08
LOW
HIGH
KONG
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


4-30-08
HIGH
LOW
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


5-1-08
LOW
HIGH
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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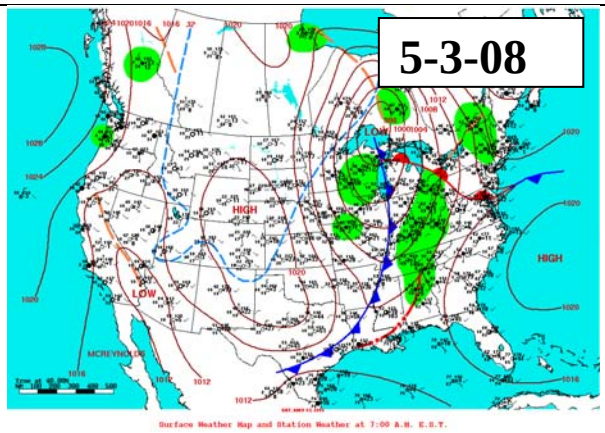
HIGH
LOW
JACKSON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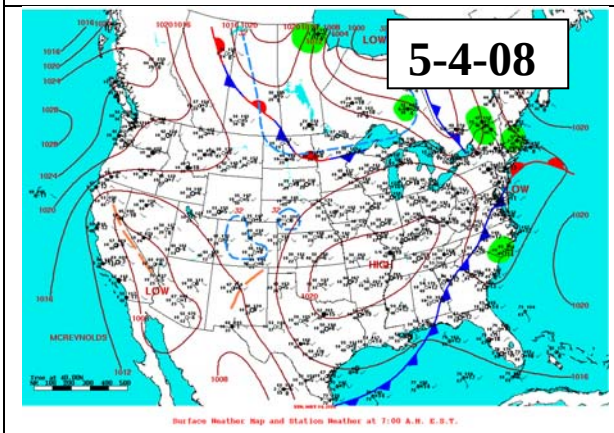
HIGH
MCREYNOLDS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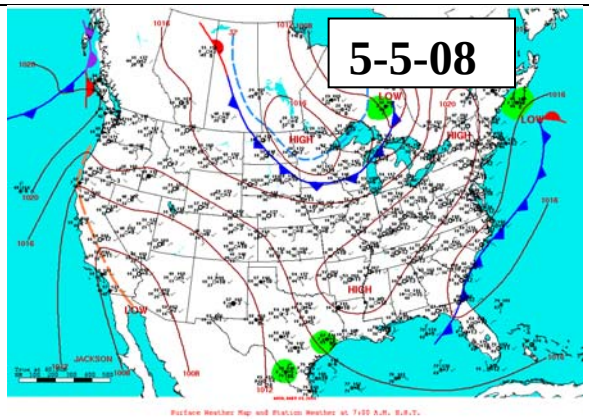
MCREYNOLDS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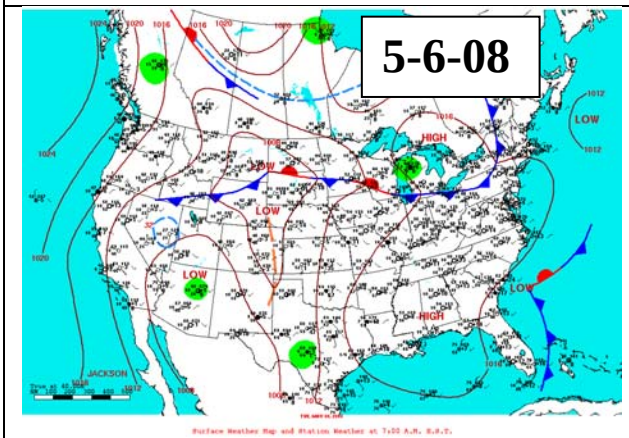
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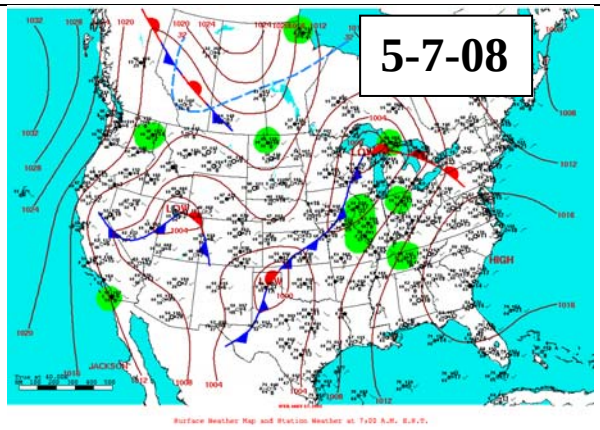
5-7-08
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HIGH
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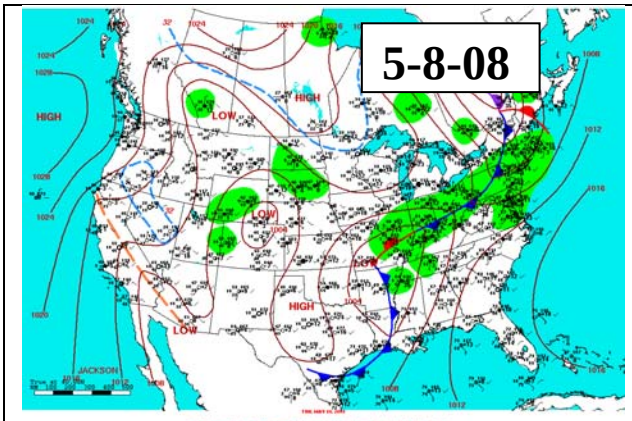
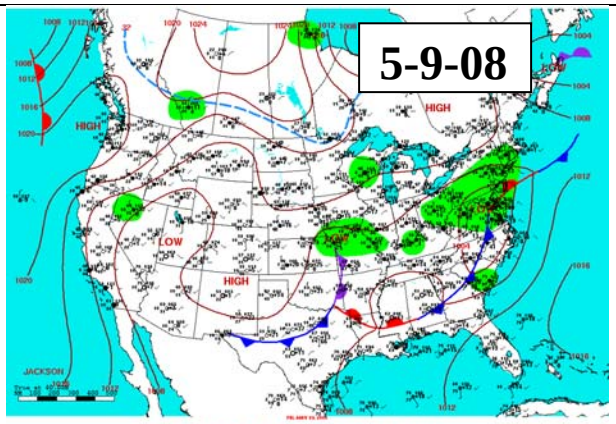
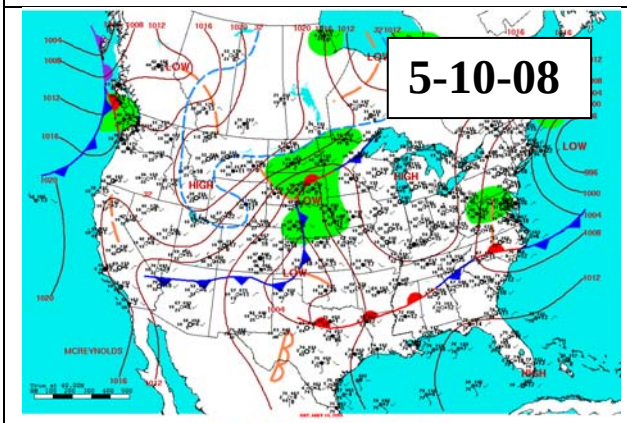
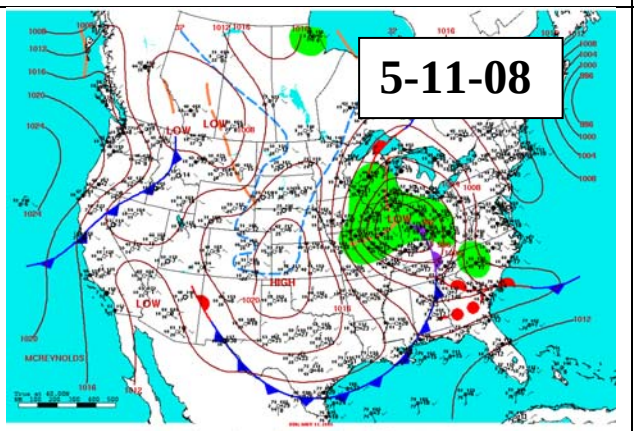
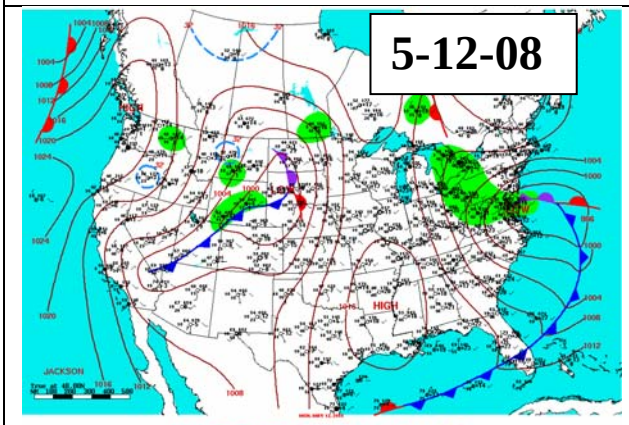
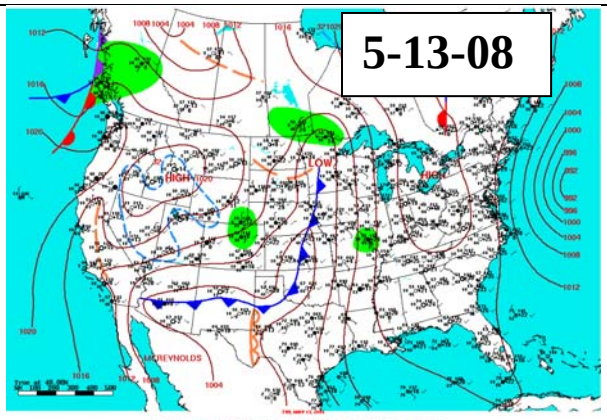




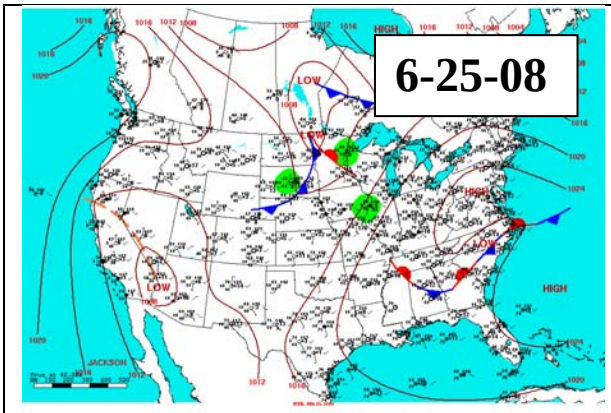








Period 5


6-25-08
HIGH
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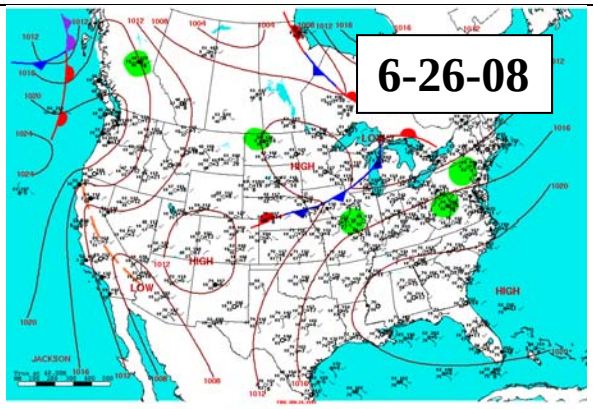
LOW
HIGH
LOW
LOW
HIGH
JACKSON


6-26-08
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HIGH
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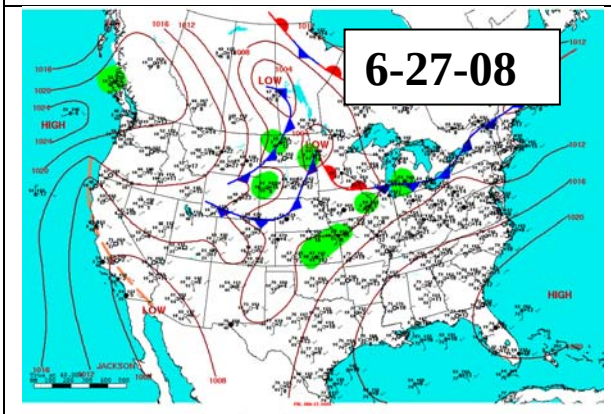
HIGH
JACKSON


6-27-08
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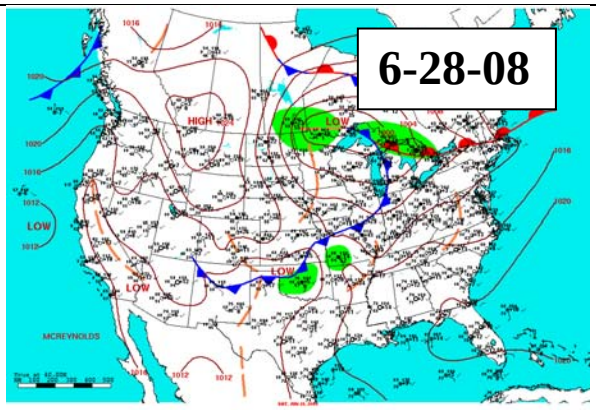
JACKSON


6-28-08
HIGH
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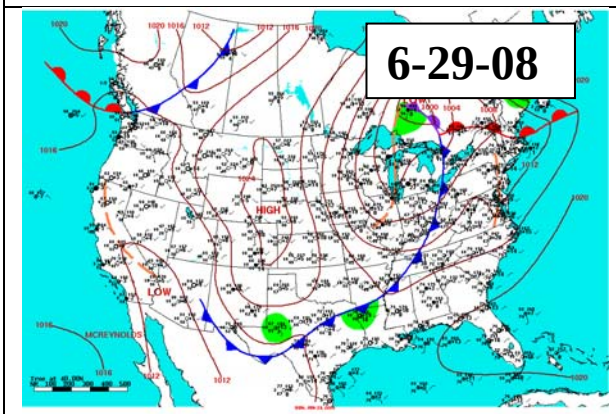
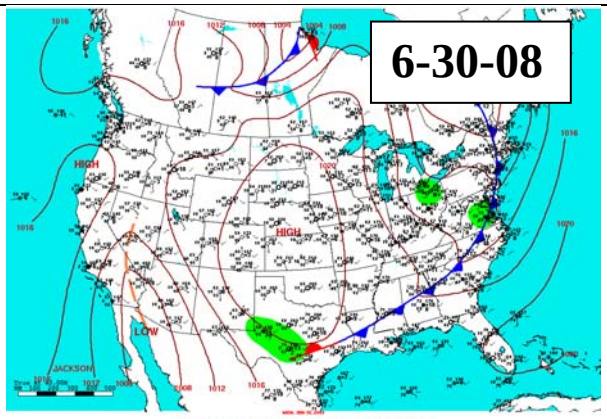
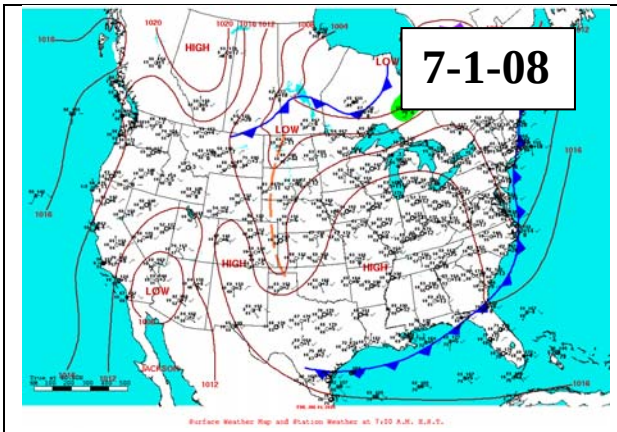
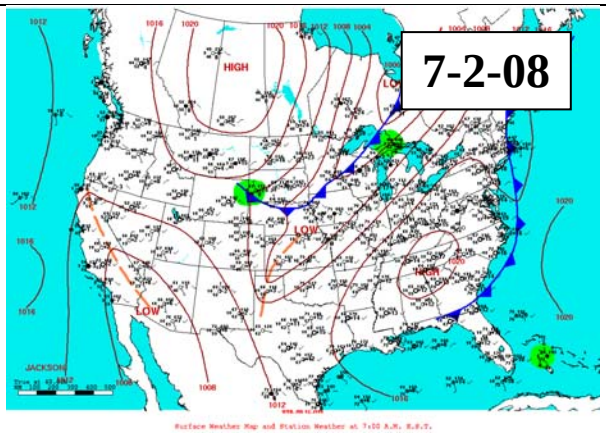
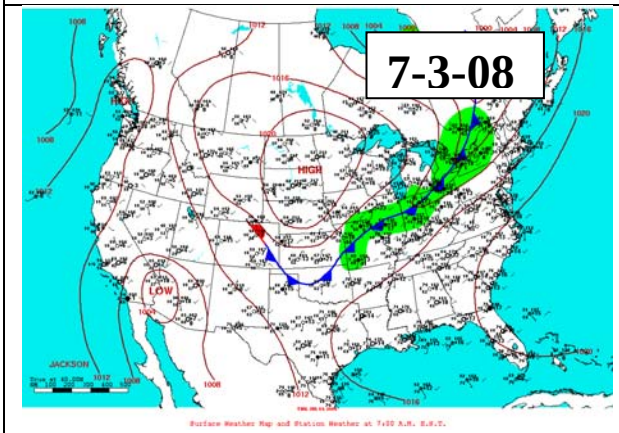
LOW
LOW
LOW
MCREYNOLDS

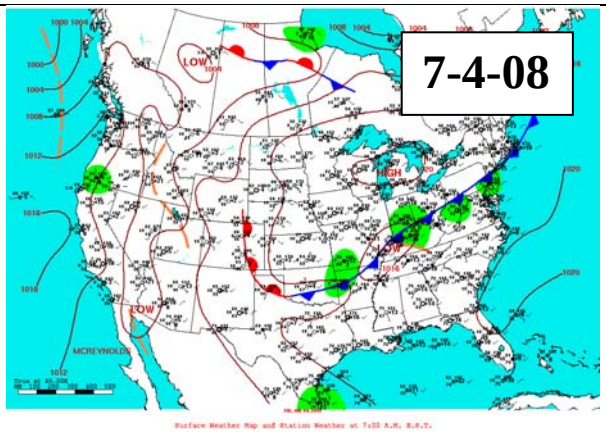

6-29-08
HIGH
LOW
MCREYNOLDS

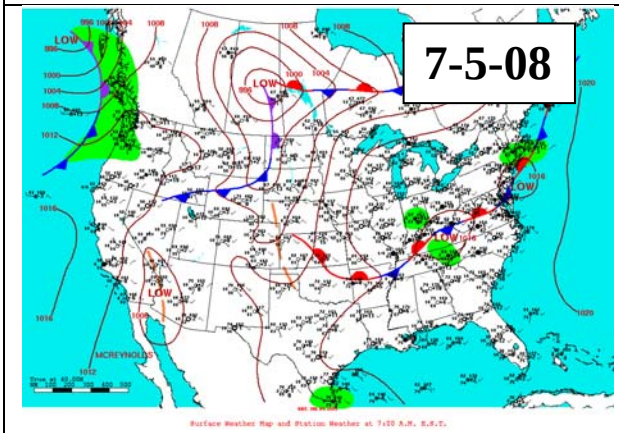

6-30-08
HIGH
HIGH
LOW
JACKSON


7-1-08
HIGH
LOW
LOW
HIGH
HIGH
LOW
JACKSON


7-2-08
HIGH
LOW
LOW
HIGH
JACKSON


7-3-08
HIGH
HIGH
LOW
JACKSON


7-4-08
LOW
HIGH
LOW
LOW
MCREYNOLDS


7-5-08
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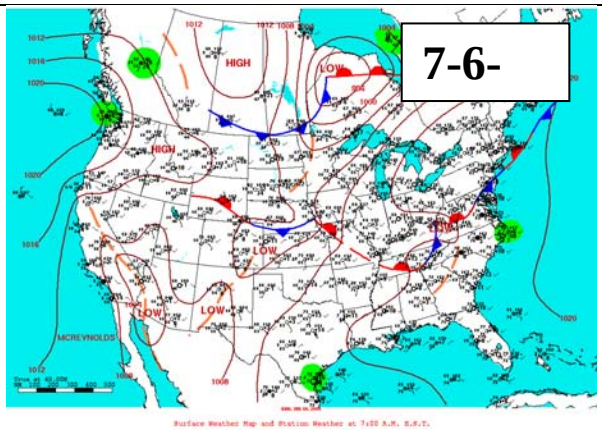
MCREYNOLDS


7-6-
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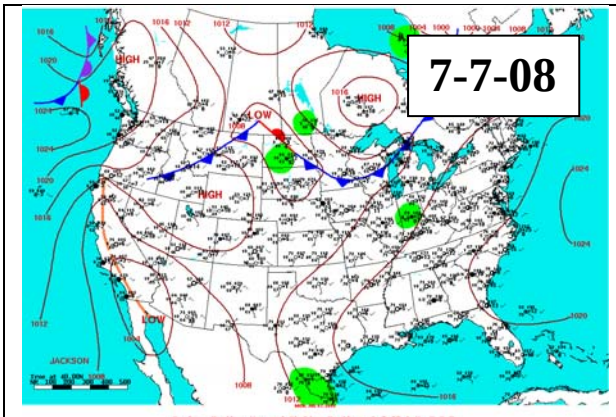
MCREYNOLDS


7-7-08
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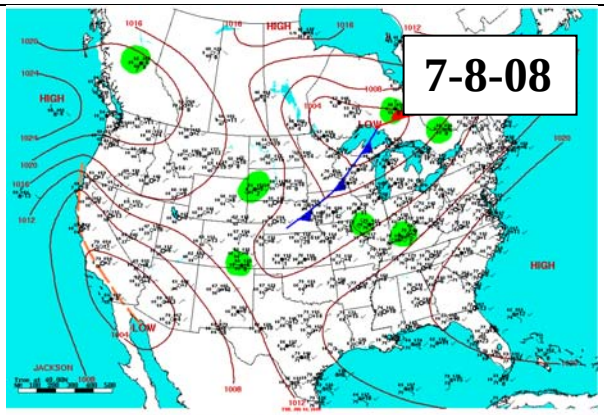
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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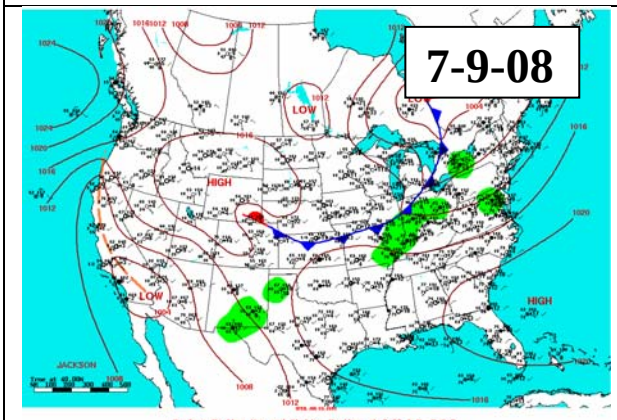
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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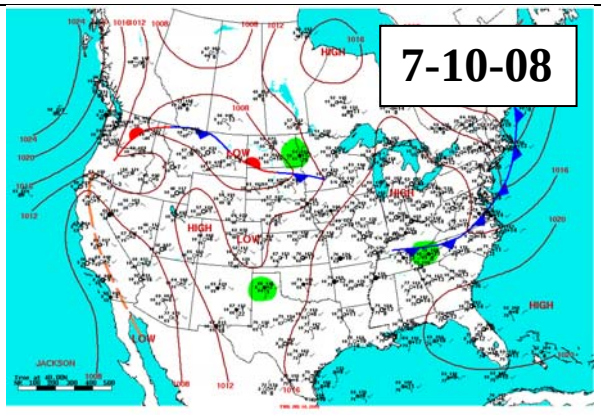
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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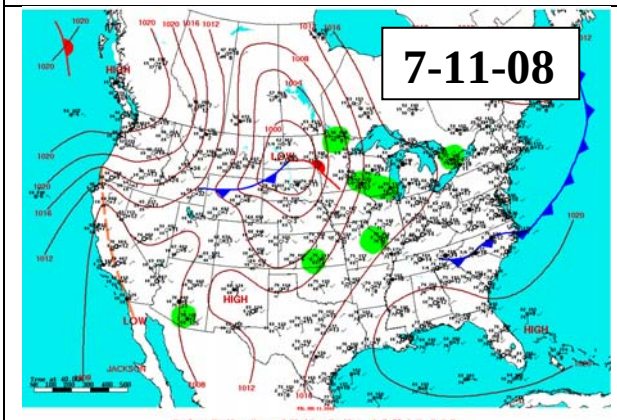
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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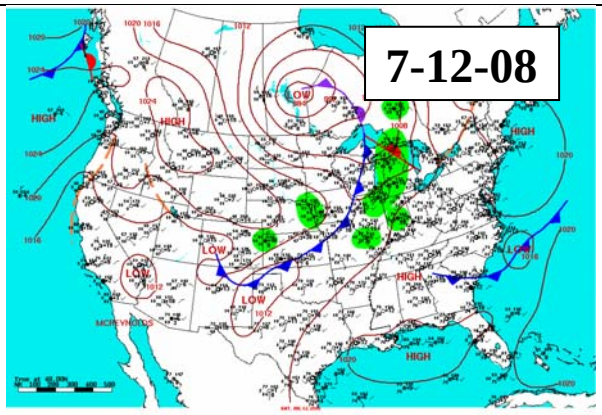
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.


7-12-08
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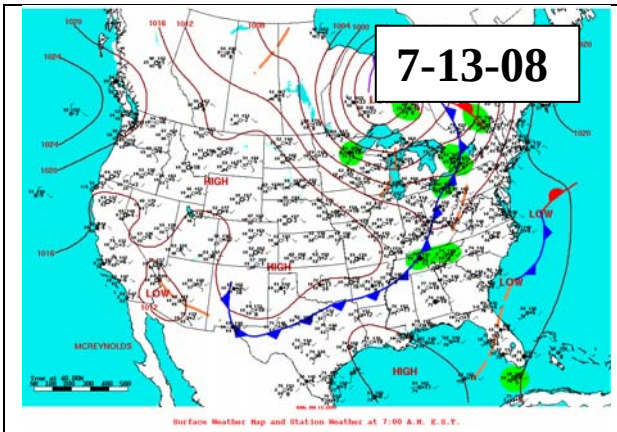
HIGH
MCHENRY
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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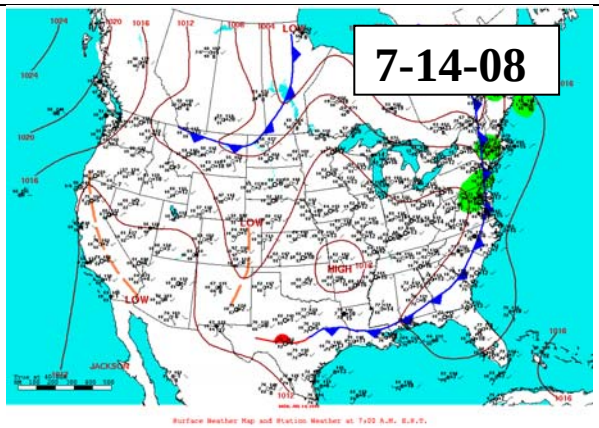
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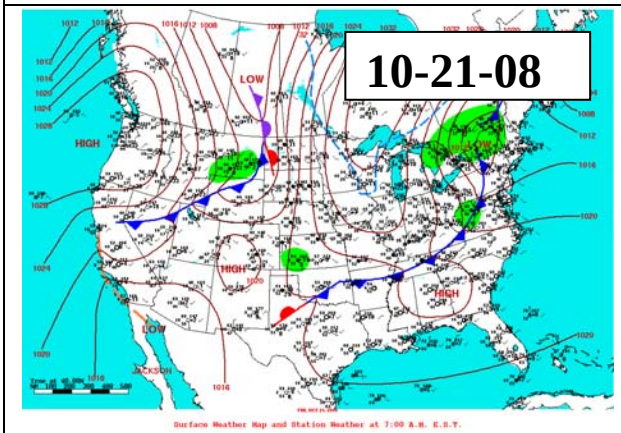
JACKSON

Period 6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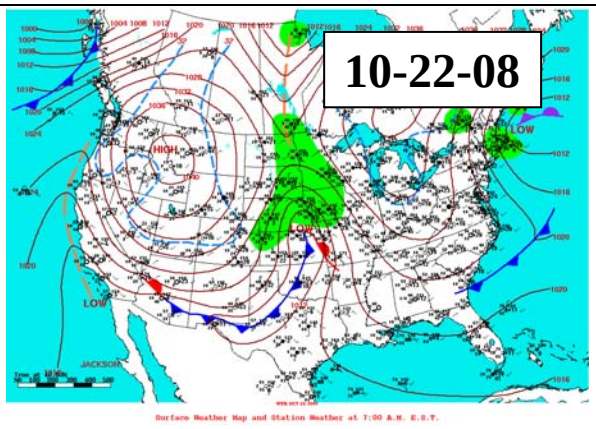
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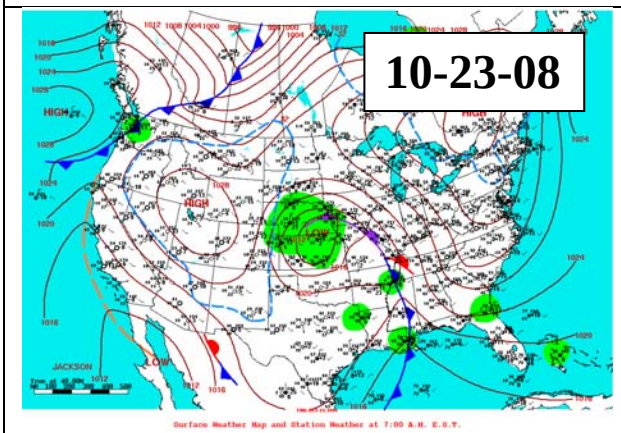
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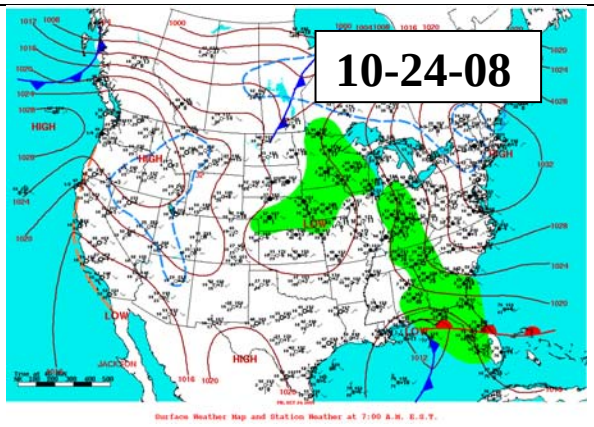
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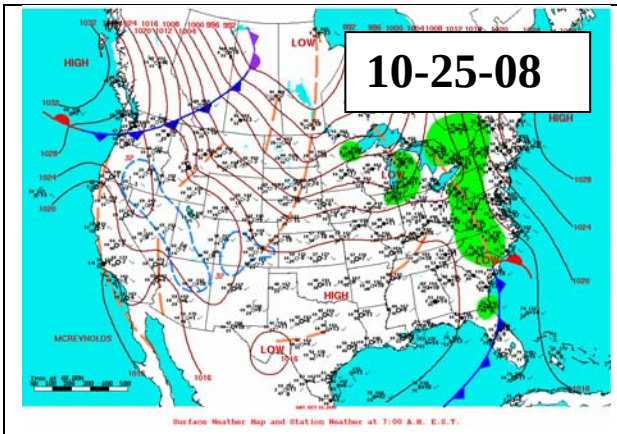
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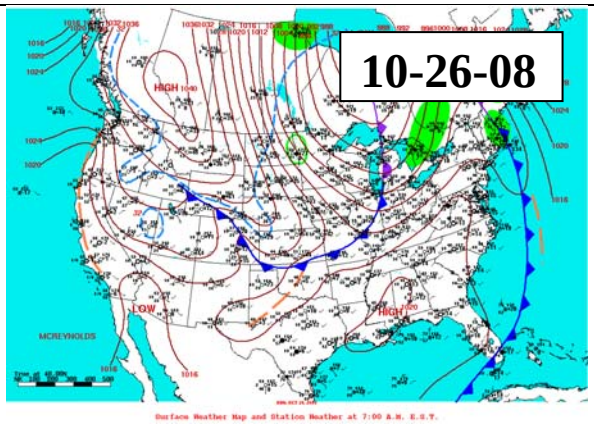
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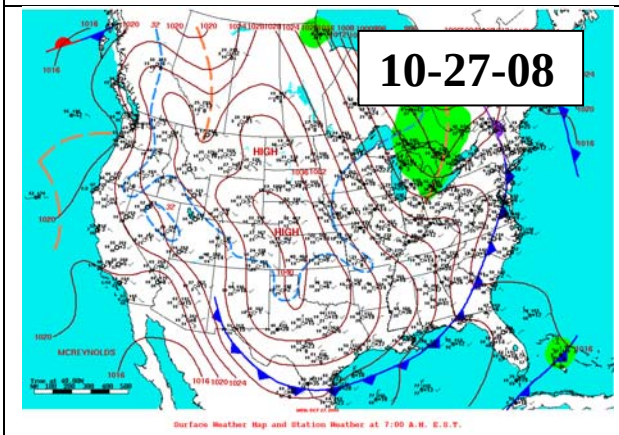
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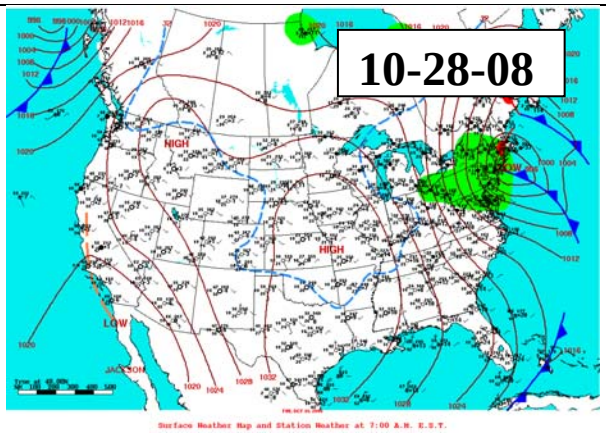
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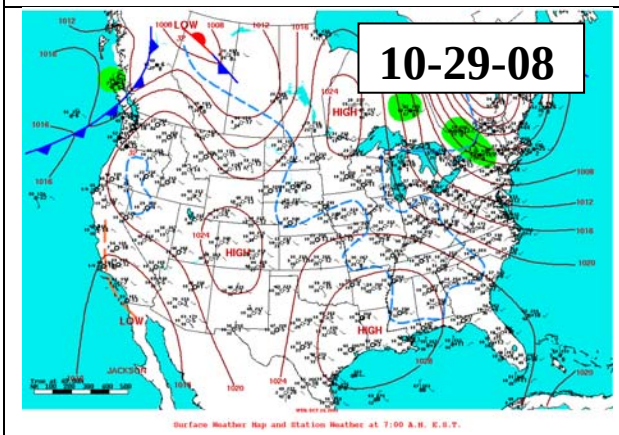
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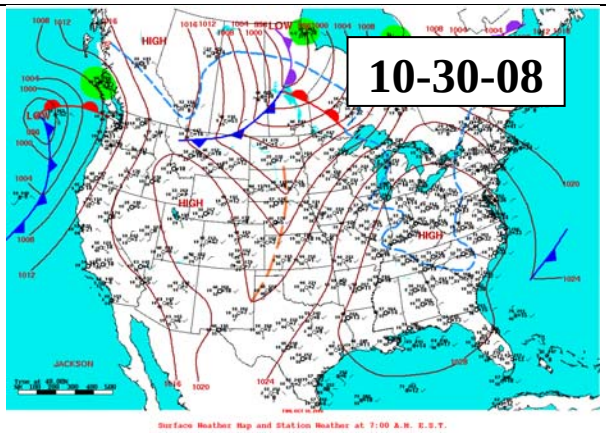
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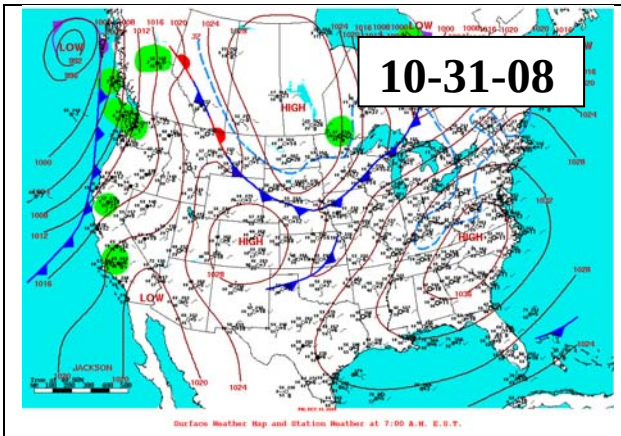
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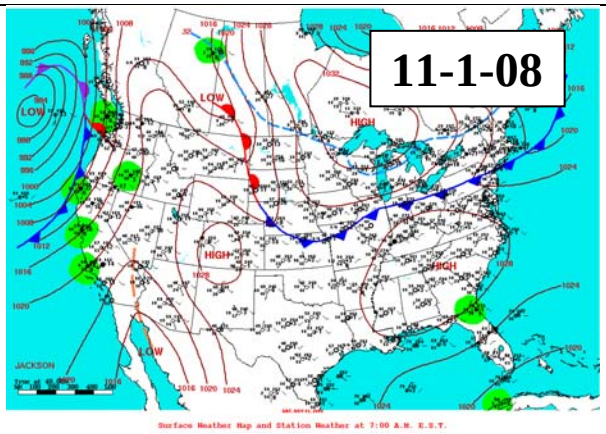
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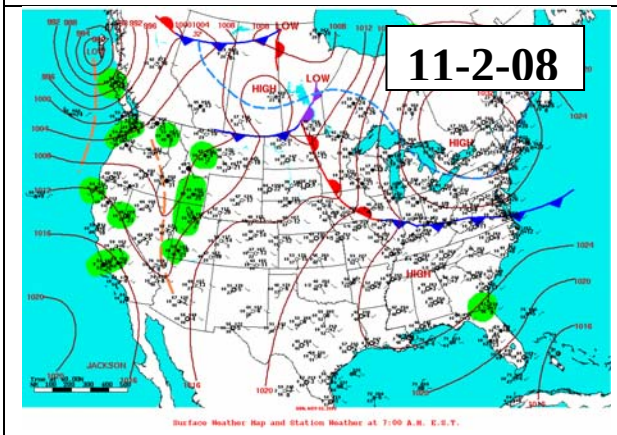
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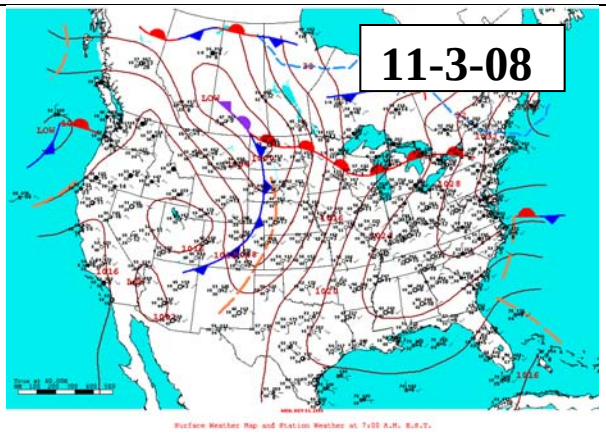
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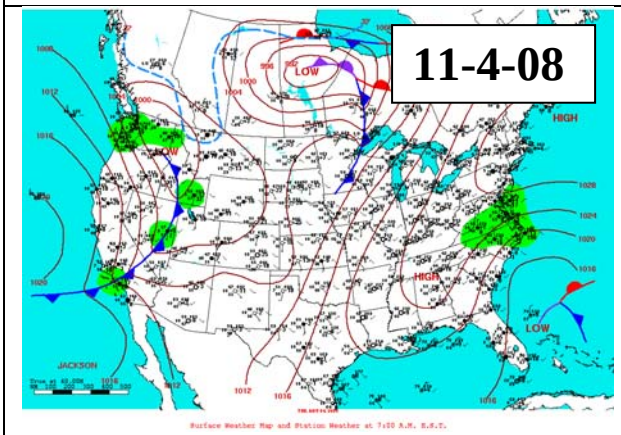
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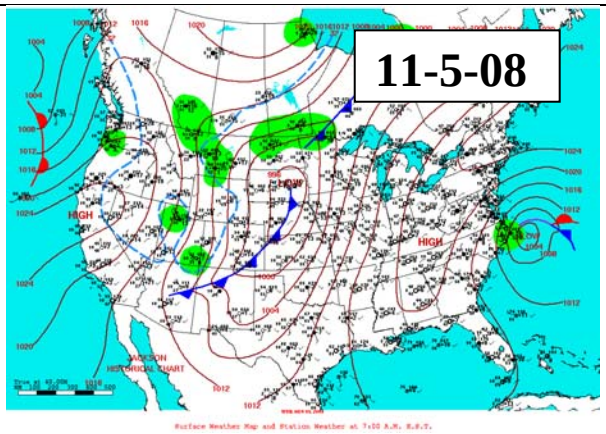
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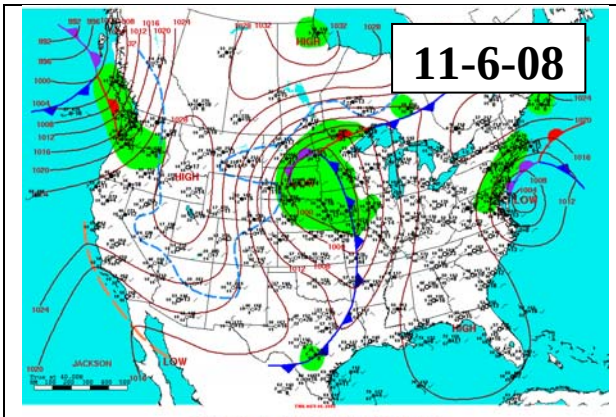
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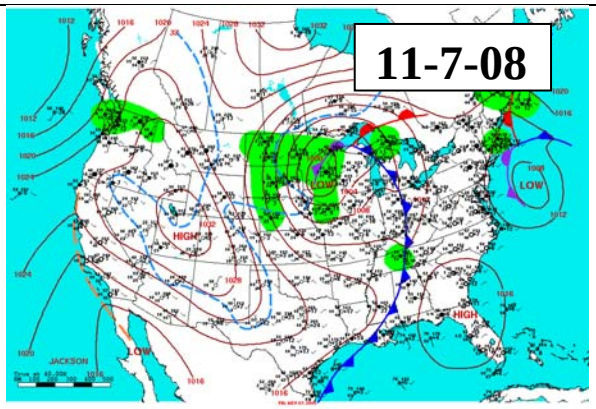
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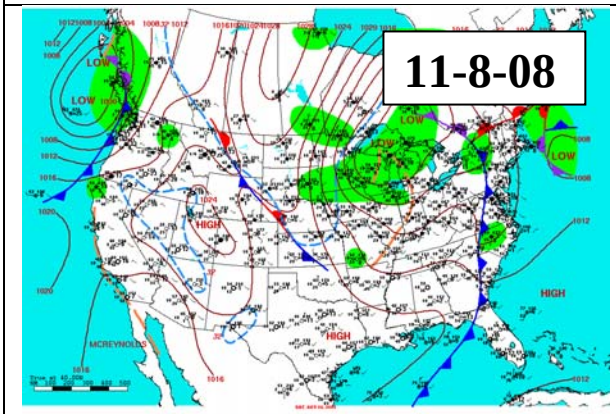
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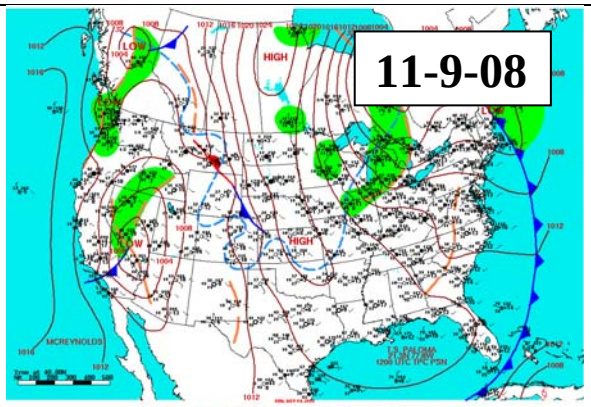
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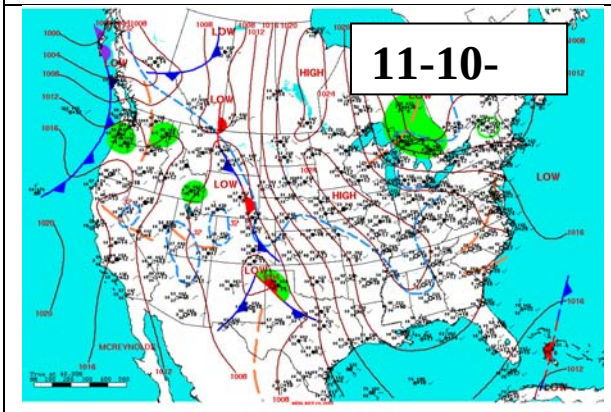
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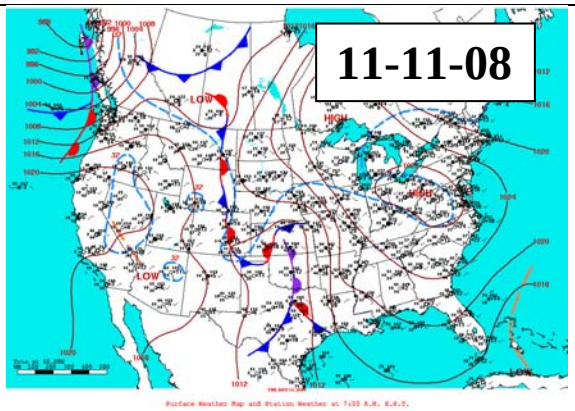
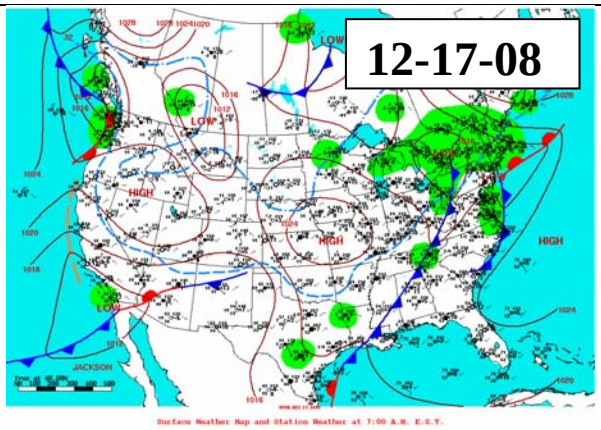

11-11-08

Period 7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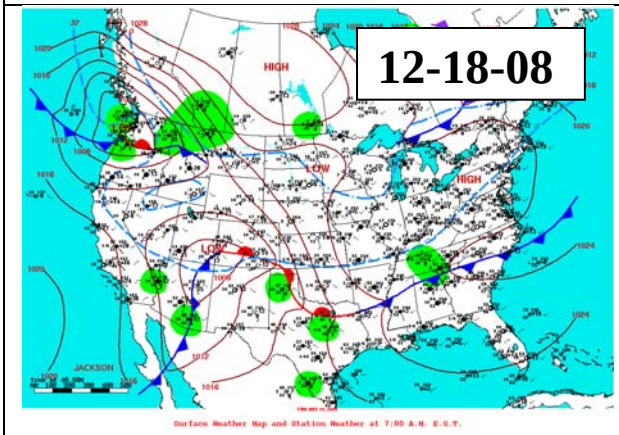
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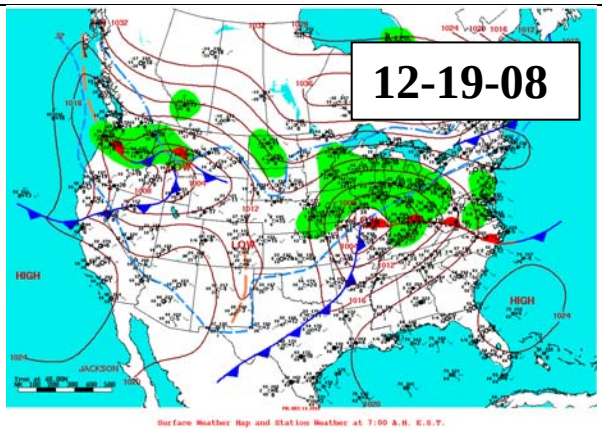
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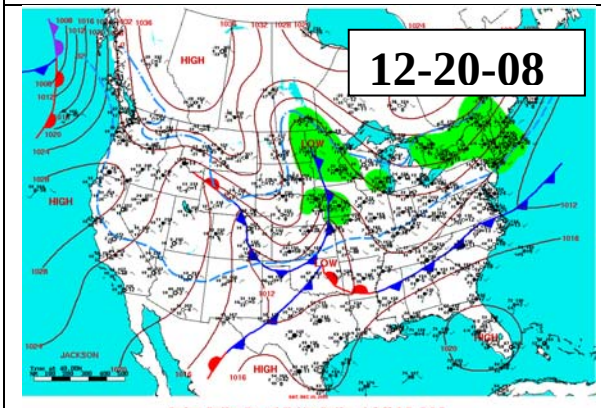
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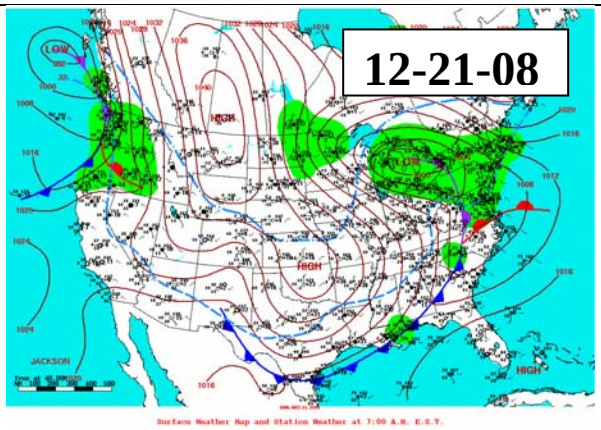
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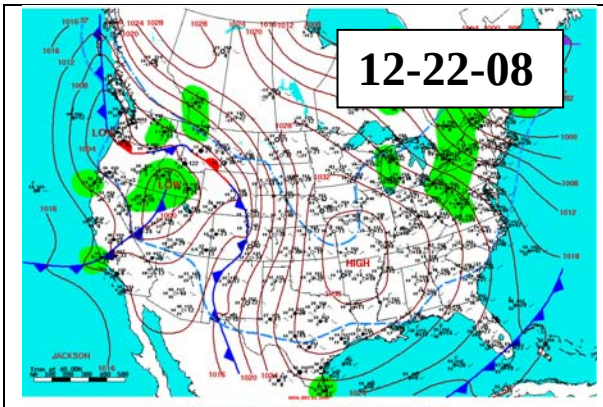
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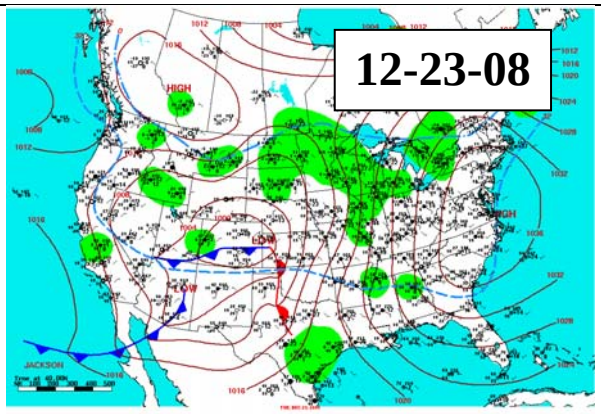
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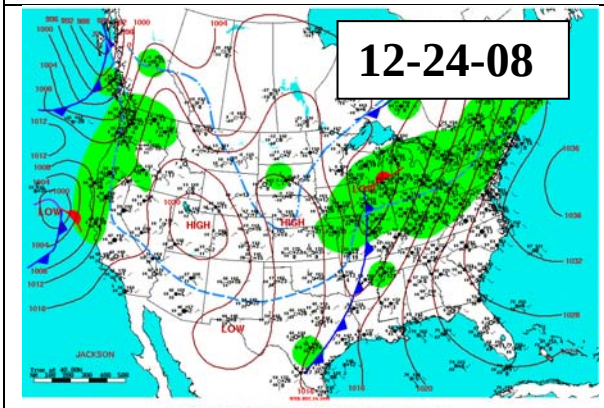
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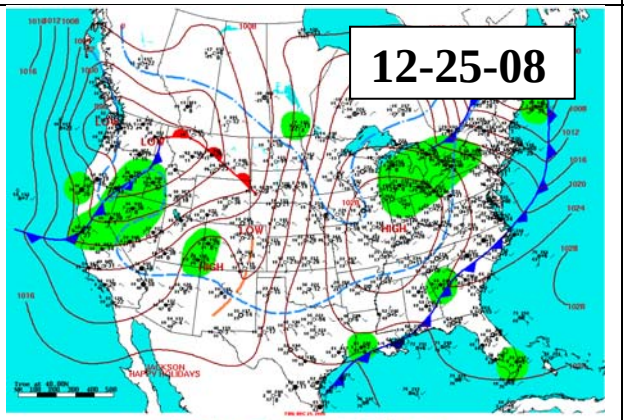
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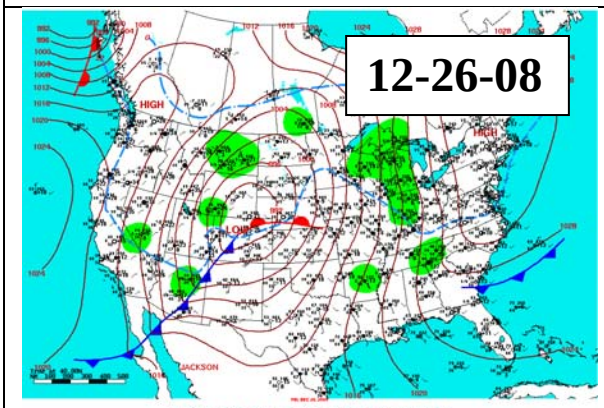
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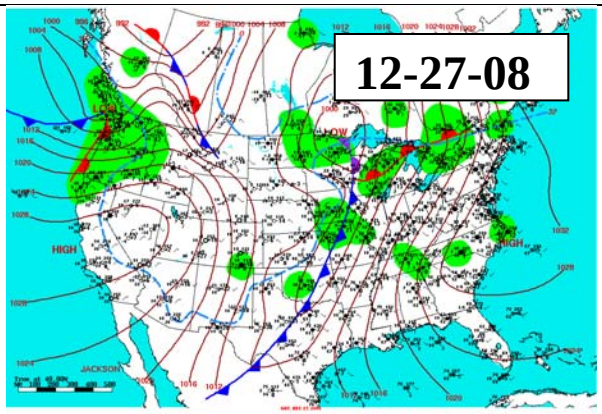
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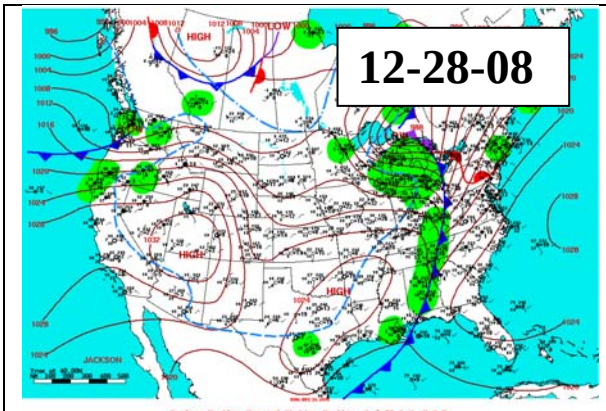
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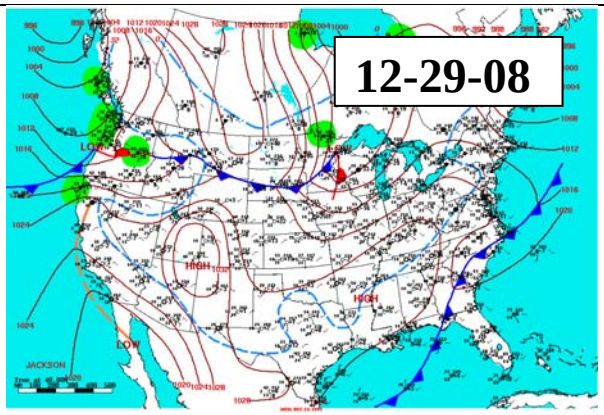
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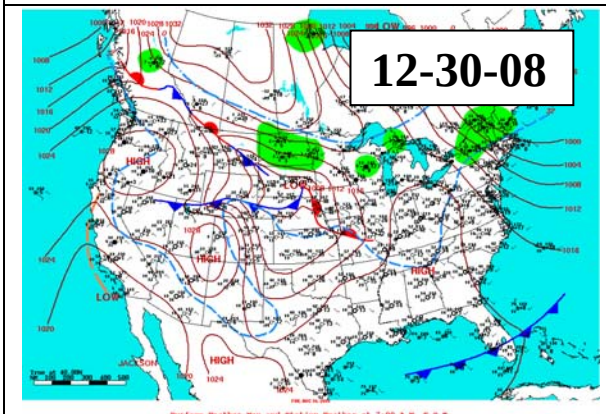
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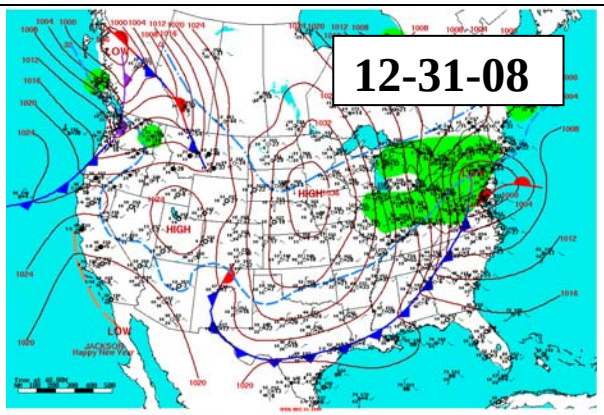
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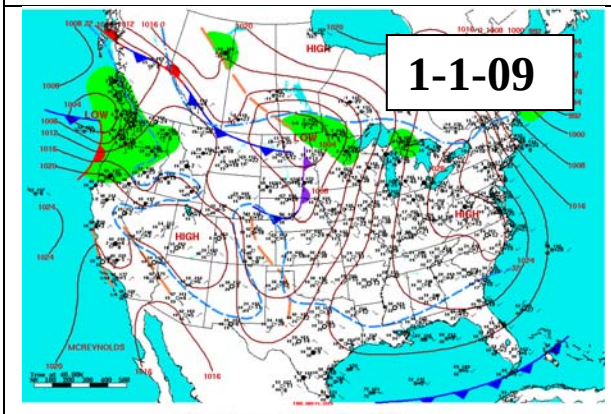
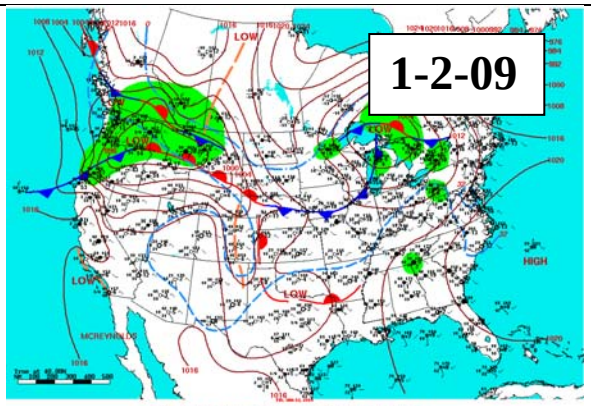

1-1-09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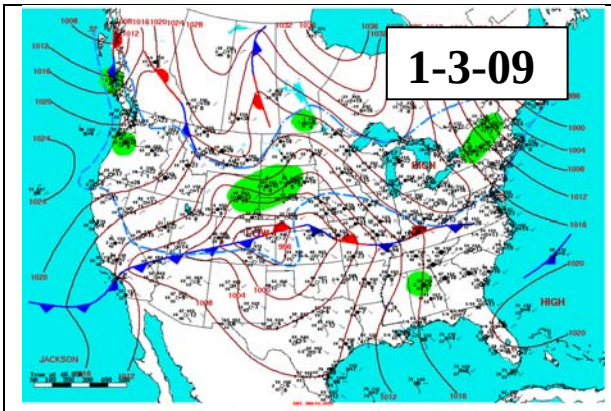
1-3-09
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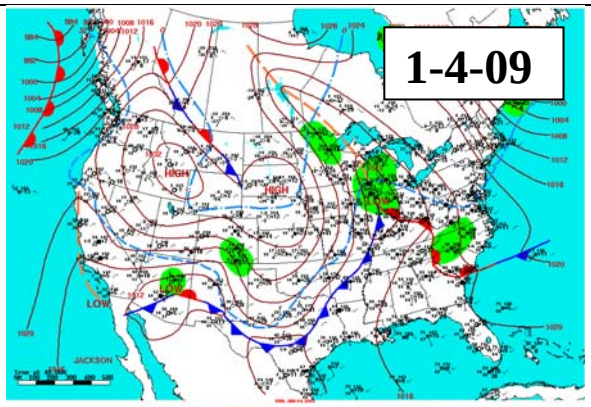
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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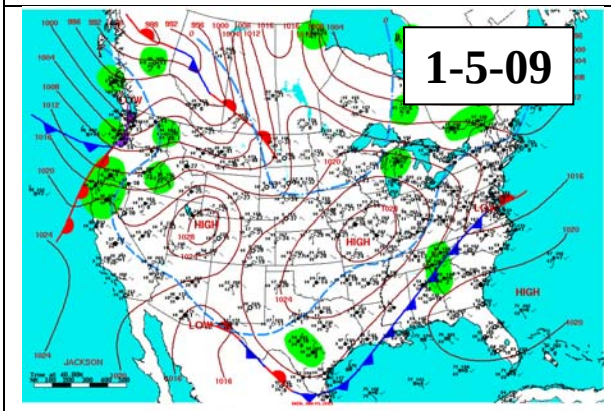
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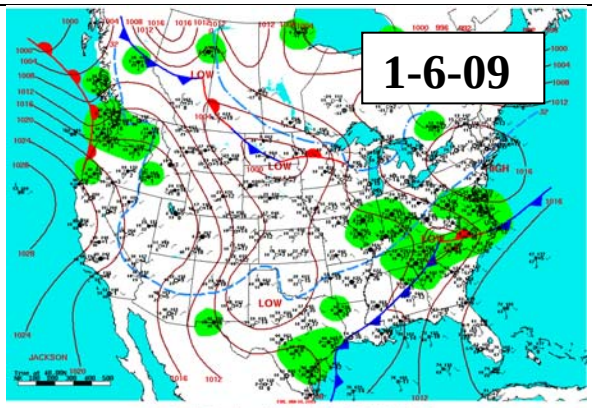
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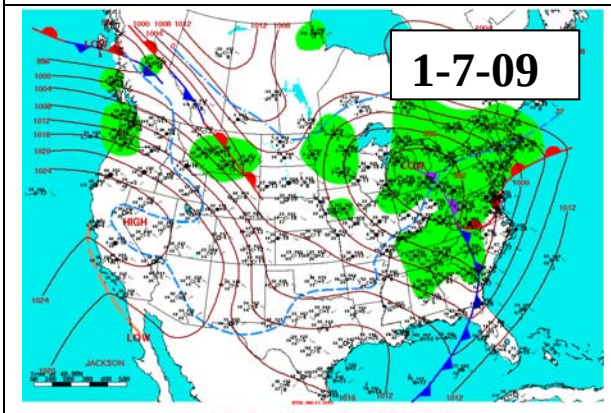
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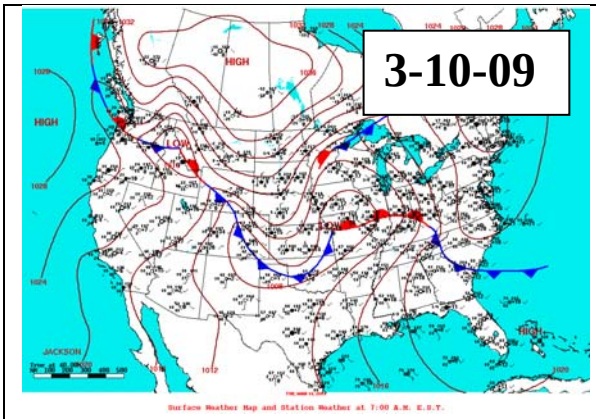
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

Period 8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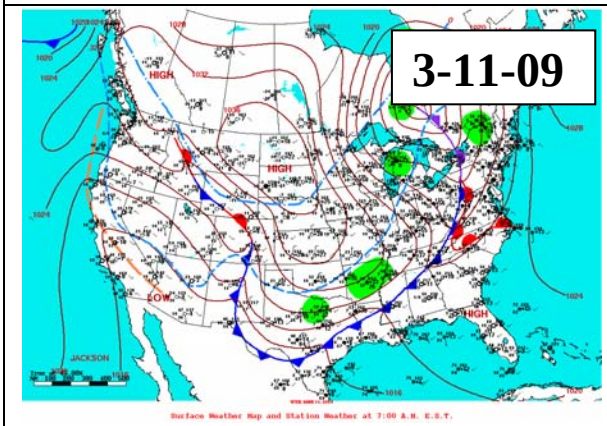
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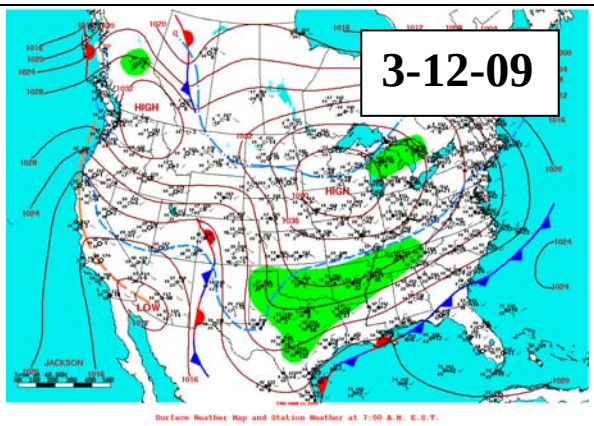
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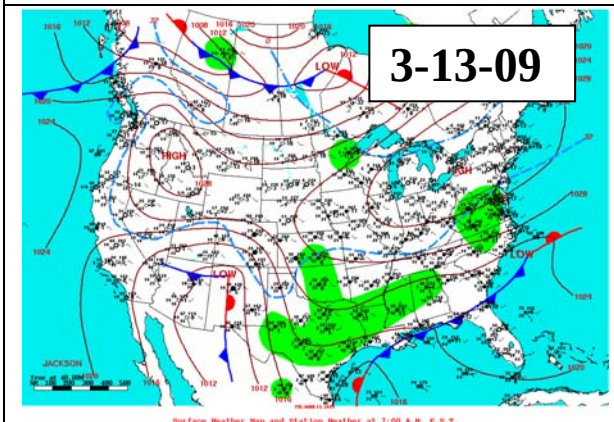
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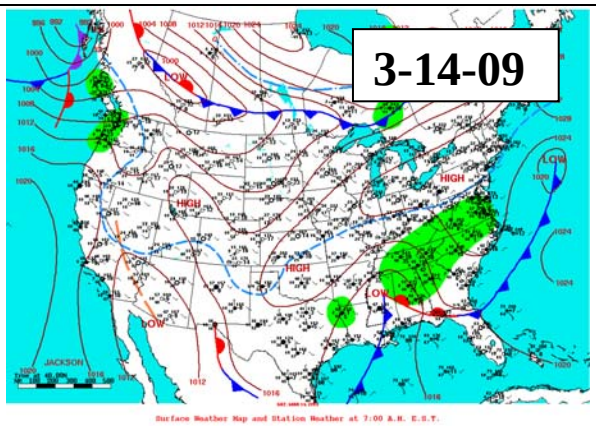
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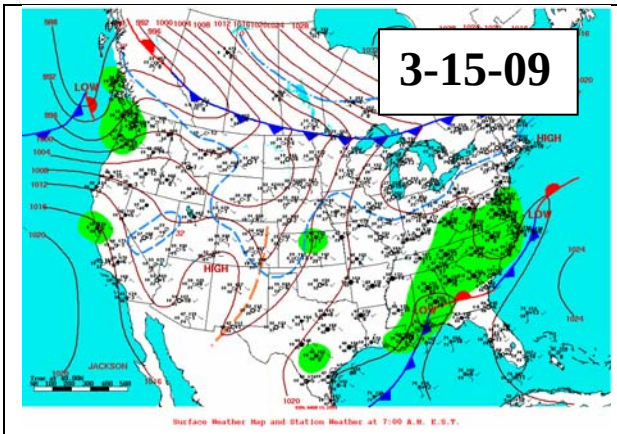
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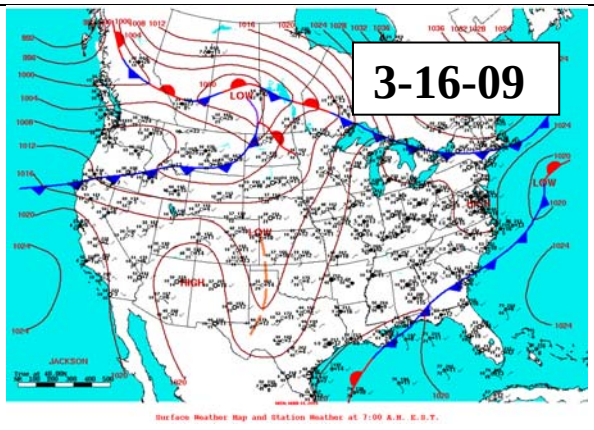
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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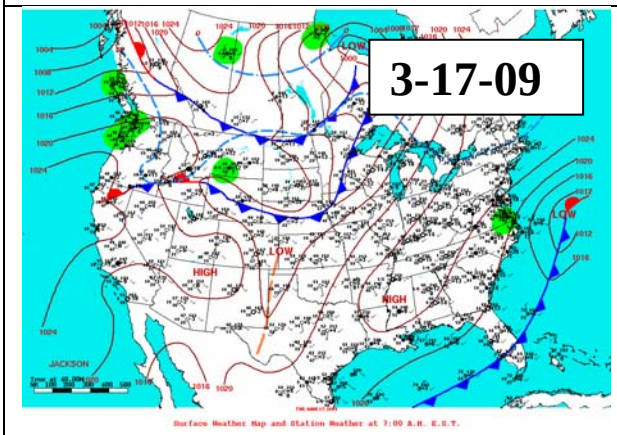
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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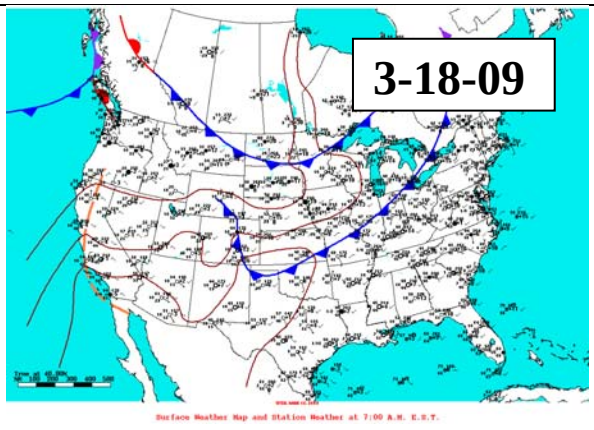
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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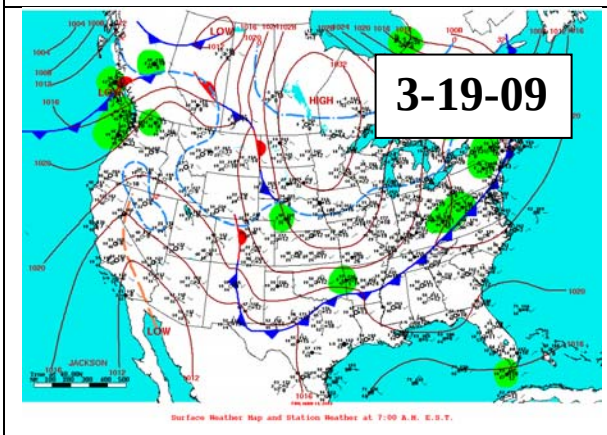
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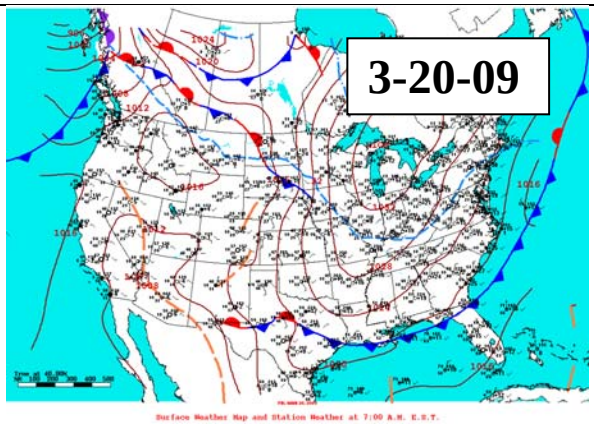
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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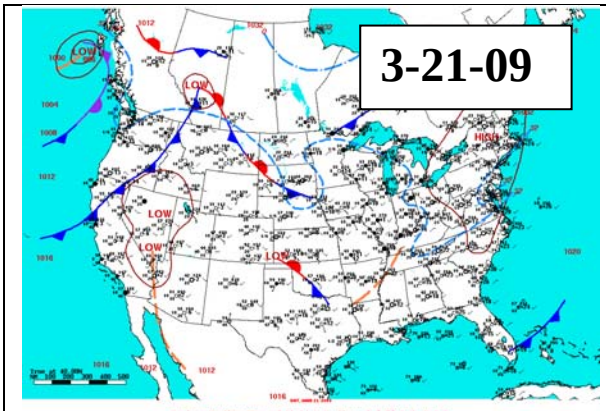
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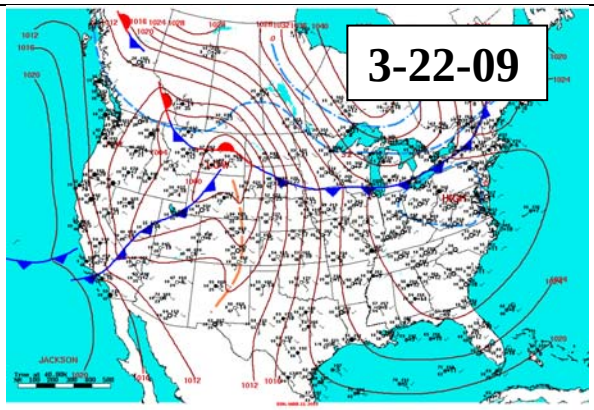
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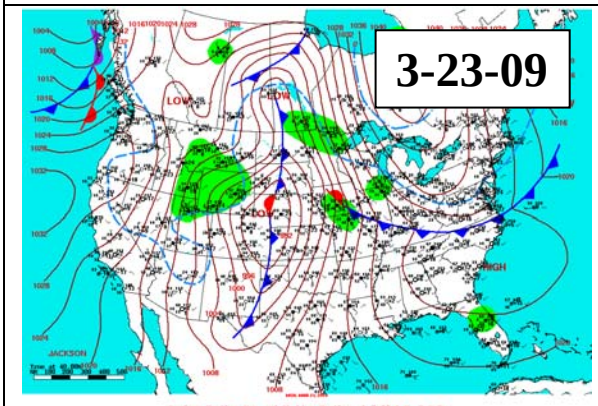
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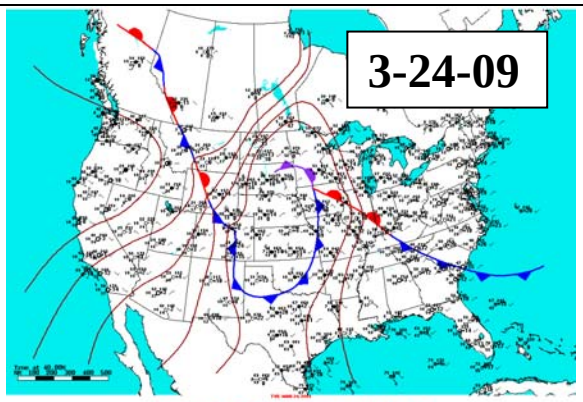
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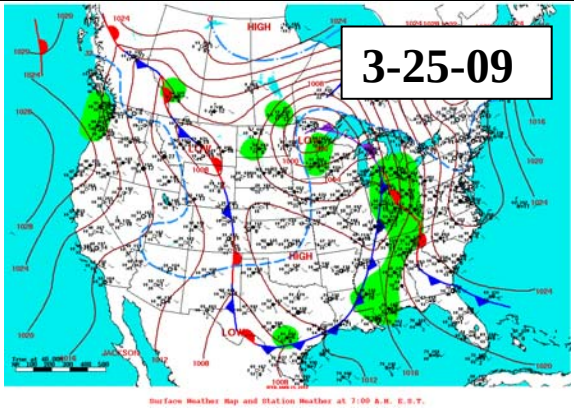
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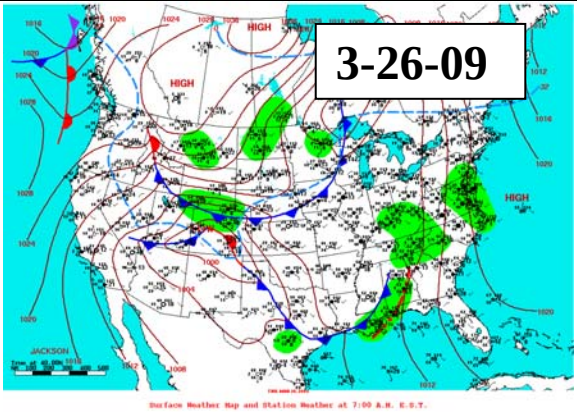
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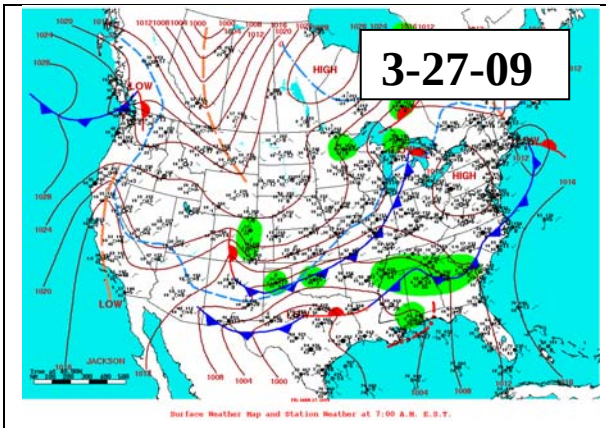
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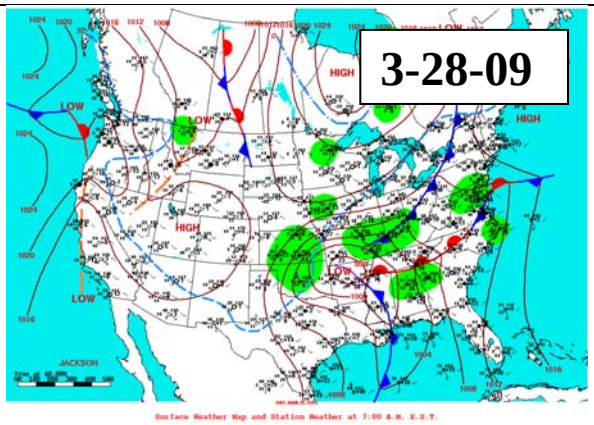
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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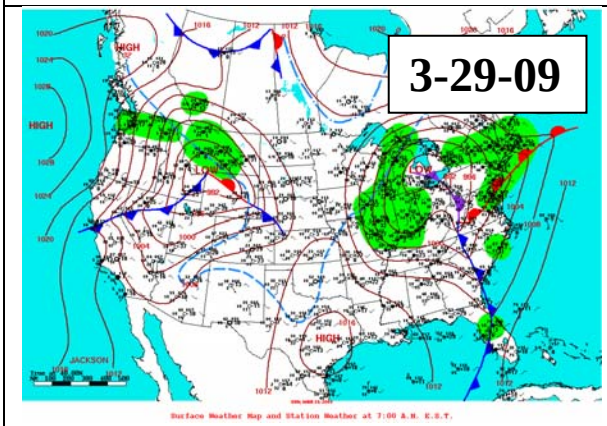
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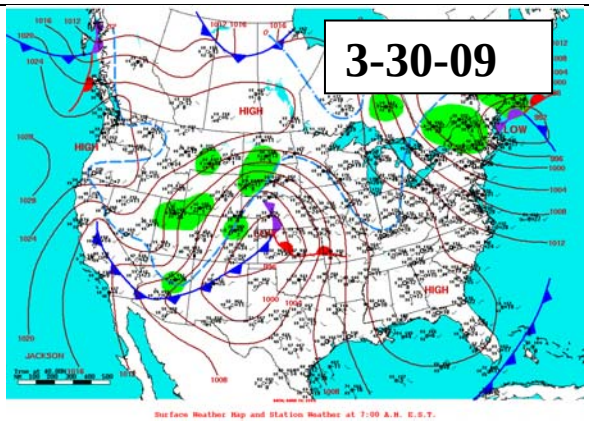
JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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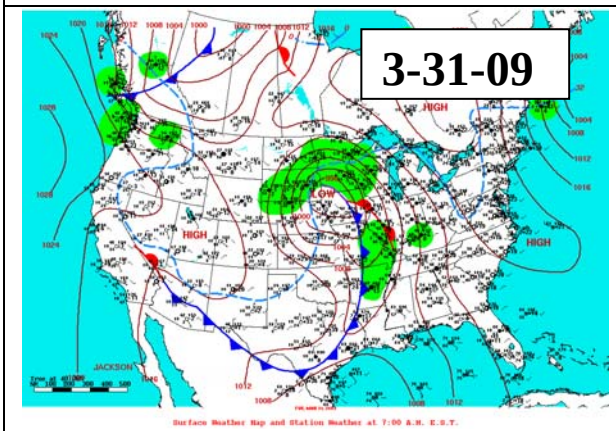
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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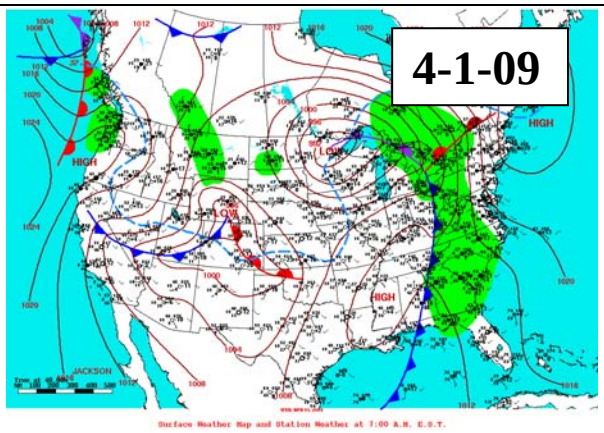
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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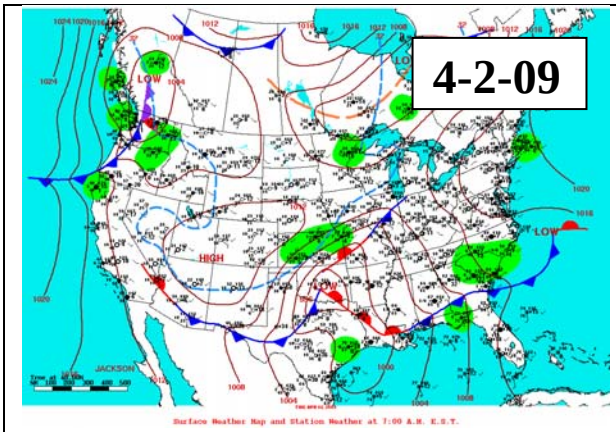
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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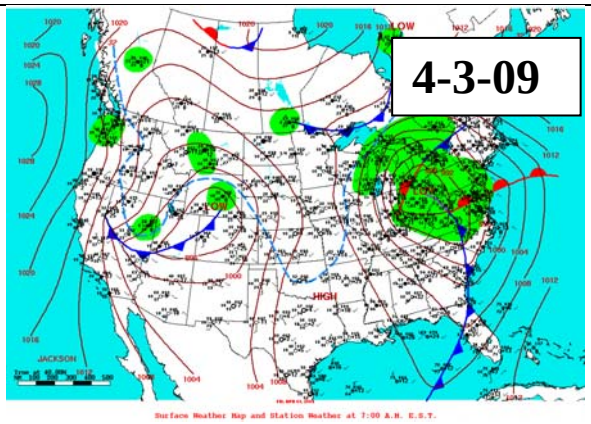
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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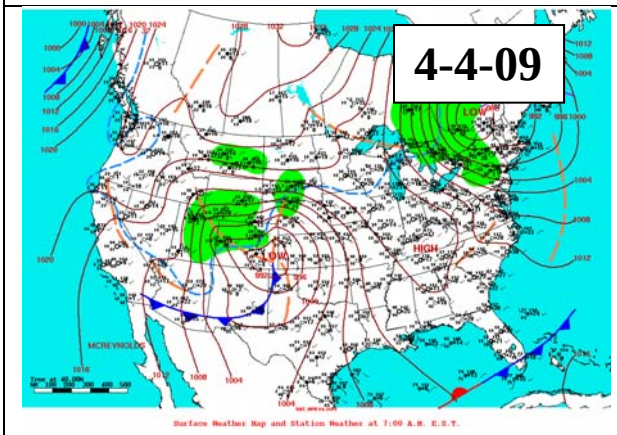
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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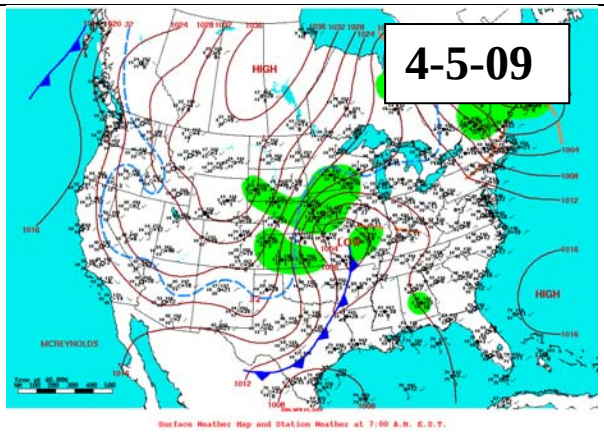
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.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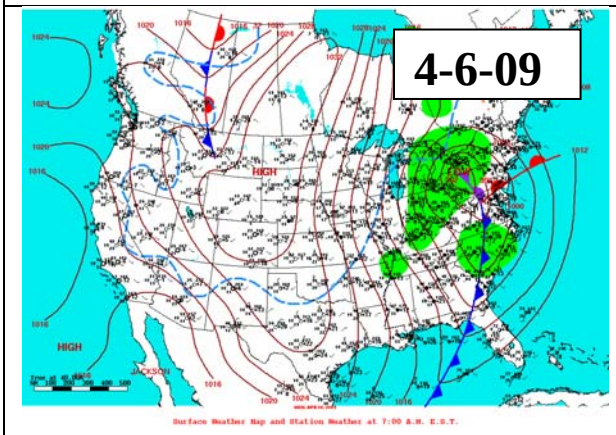
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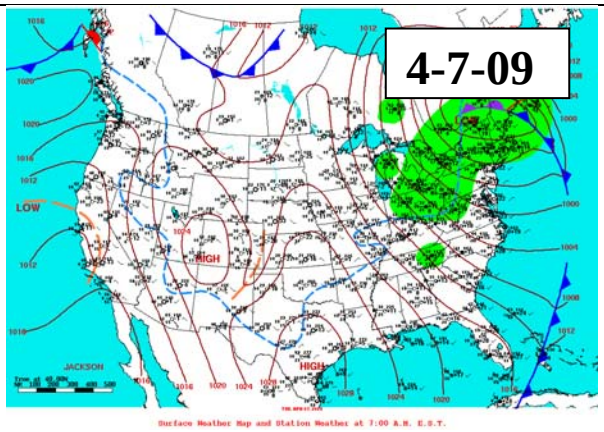
4-7-09
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JACKSON
Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

6.10 Daily weather conditions

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
Period 1				
7/19/2007	97.40	952	4%	24.5
7/20/2007	98.28	944	42%	17.2
7/21/2007	98.32	931	71%	18.2
7/22/2007	98.15	548	92%	19.7
7/23/2007	97.91	643	70%	21.2
7/24/2007	97.73	853	100%	24.0
7/25/2007	97.61	961	83%	25.2
7/26/2007	97.25	941	94%	26.1
7/27/2007	97.28	952	60%	23.8
7/28/2007	97.74	937	23%	22.0
7/29/2007	97.78	939	41%	21.5
7/30/2007	97.86	994	45%	22.2
7/31/2007	97.91	875	42%	24.2
8/1/2007	97.63	986	38%	25.1
8/2/2007	97.63	895	38%	24.3
8/3/2007	97.91	975	34%	20.8
8/4/2007	97.80	457	87%	17.9
8/5/2007	97.13	787	100%	17.6
8/6/2007	97.18	940	100%	20.2
8/7/2007	96.87	878	100%	24.7
8/8/2007	97.20	925	99%	22.1
8/9/2007	97.11	1036	69%	24.9
8/10/2007	97.63	917	36%	23.6
8/11/2007	97.46	926	64%	24.6
8/12/2007	97.95	934	100%	22.3
8/13/2007	98.11	831	100%	21.5
8/14/2007	97.39	768	100%	22.4
8/15/2007	97.39	744	100%	20.0
8/16/2007	97.63	840	100%	20.2
8/17/2007	98.14	879	100%	16.2
8/18/2007	98.15	221	100%	14.3
8/19/2007	97.55	410	100%	14.5
8/20/2007	97.27	261	100%	15.7
8/21/2007	97.21	887	100%	19.0
8/22/2007	97.35	299	100%	20.8
8/23/2007	97.18	257	100%	18.6
8/24/2007	97.22	949	100%	18.6
8/25/2007	97.58	1020	100%	17.6
8/26/2007	97.73	881	100%	17.9
8/27/2007	97.39	782	100%	20.8

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
8/28/2007	97.11	439	100%	21.7
Period 2				
11/14/2007	97.15	N/A	0%	1.7
11/15/2007	97.82	343	0%	2.2
11/16/2007	97.38	392	23%	5.2
11/17/2007	97.46	481	82%	2.4
11/18/2007	98.26	299	100%	3.3
11/19/2007	97.35	86	100%	4.6
11/20/2007	97.61	151	99%	4.3
11/21/2007	98.21	168	97%	1.5
11/22/2007	98.75	207	98%	-1.6
11/23/2007	98.60	425	98%	0.1
11/24/2007	97.79	333	98%	2.3
11/25/2007	97.25	458	98%	6.7
11/26/2007	97.56	454	98%	4.7
11/27/2007	98.22	427	98%	0.5
11/28/2007	97.61	378	98%	-1.8
Period 3				
11/29/2007	N/A	N/A	N/A	N/A
11/30/2007	N/A	N/A	N/A	N/A
12/1/2007	N/A	N/A	N/A	N/A
12/2/2007	N/A	N/A	N/A	N/A
12/3/2007	N/A	N/A	N/A	N/A
12/4/2007	N/A	N/A	N/A	N/A
12/5/2007	N/A	N/A	N/A	N/A
12/6/2007	N/A	N/A	N/A	N/A
12/7/2007	N/A	N/A	N/A	N/A
12/8/2007	N/A	N/A	N/A	N/A
12/9/2007	N/A	N/A	N/A	N/A
12/10/2007	N/A	N/A	N/A	N/A
12/11/2007	N/A	N/A	N/A	N/A
12/12/2007	N/A	N/A	N/A	N/A
12/13/2007	N/A	N/A	N/A	N/A
12/14/2007	N/A	N/A	N/A	N/A
12/15/2007	N/A	N/A	N/A	N/A
12/16/2007	N/A	N/A	N/A	N/A
12/17/2007	N/A	N/A	N/A	N/A
12/18/2007	N/A	N/A	N/A	N/A
Period 4				
4/23/2008	97.92	789	50%	22.5
4/24/2008	97.42	261	100%	14.5
4/25/2008	96.43	208	56%	10.9

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
4/26/2008	96.43	696	4%	0.8
4/27/2008	97.91	1023	57%	1.9
4/28/2008	97.90	532	47%	0.5
4/29/2008	98.03	990	28%	1.4
4/30/2008	97.31	965	68%	7.8
5/1/2008	96.52	948	100%	12.4
5/2/2008	95.91	163	54%	10.2
5/3/2008	96.30	994	0%	5.9
5/4/2008	97.30	1025	11%	10.1
5/5/2008	97.50	970	11%	10.8
5/6/2008	97.18	935	54%	14.8
5/7/2008	96.57	1033	33%	12.7
5/8/2008	97.08	971	13%	10.5
5/9/2008	97.25	1018	45%	11.3
5/10/2008	97.20	753	56%	10.5
5/11/2008	96.94	1178	33%	7.7
5/12/2008	97.30	1027	0%	8.2
5/13/2008	96.96	370	100%	12.7
Period 5				
6/26/2008	97.26	1001	1%	25.0
6/27/2008	96.79	1131	82%	19.5
6/28/2008	96.48	1046	54%	16.7
6/29/2008	97.03	1047	41%	18.4
6/30/2008	97.84	984	44%	18.5
7/1/2008	97.45	1015	80%	20.4
7/2/2008	96.84	989	64%	23.3
7/3/2008	97.88	1287	55%	17.4
7/4/2008	97.93	1086	98%	17.7
7/5/2008	97.52	912	100%	22.0
7/6/2008	97.07	919	100%	23.4
7/7/2008	97.07	621	100%	22.6
7/8/2008	96.92	947	60%	21.4
7/9/2008	97.50	1111	62%	19.1
7/10/2008	97.37	808	93%	18.7
7/12/2008	97.00	733	100%	20.9
7/13/2008	97.05	933	57%	20.0
7/14/2008	96.99	1019	0%	19.4
7/15/2008	97.27	924	44%	18.1
Period 6				
10/21/2008	98.68	525	0%	9.1
10/22/2008	98.60	137	18%	5.6
10/23/2008	98.42	540	0%	7.4

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
10/24/2008	97.59	268	54%	7.7
10/25/2008	96.53	483	54%	7.5
10/26/2008	96.50	253	27%	5.6
10/27/2008	98.32	592	7%	1.9
10/28/2008	98.90	477	41%	-0.7
10/29/2008	98.19	476	4%	2.9
10/30/2008	97.91	468	0%	9.9
10/31/2008	98.35	472	27%	11.5
11/1/2008	98.88	426	0%	6.8
11/2/2008	97.96	488	4%	10.2
11/3/2008	97.46	431	63%	12.6
11/4/2008	97.28	549	19%	17.4
11/5/2008	96.66	318	3%	15.9
11/6/2008	96.23	391	65%	13.2
11/7/2008	96.20	147	70%	2.9
11/8/2008	96.38	98	68%	0.6
11/9/2008	96.41	203	0%	-3.1
11/10/2008	96.33	535	5%	-4.1
11/11/2008	98.24	99	99%	-3.9
Period 7				
12/18/2008	98.21	371	9%	-16.3
12/19/2008	97.88	398	9%	-8.9
12/20/2008	97.66	149	77%	-9.0
12/21/2008	97.48	456	5%	-21.2
12/22/2008	98.60	376	0%	-21.5
12/23/2008	97.39	281	31%	-13.4
12/24/2008	96.84	279	74%	-13.5
12/25/2008	98.01	370	15%	-16.2
12/26/2008	96.70	113	81%	-2.1
12/27/2008	96.16	118	100%	-0.5
12/28/2008	95.62	368	68%	-8.8
12/29/2008	97.27	381	66%	-3.3
12/30/2008	96.73	141	31%	-9.7
12/31/2008	93.53	393	6%	-19.0
1/1/2009	96.65	344	3%	-9.0
1/2/2009	96.96	389	8%	-13.8
1/3/2009	97.29	159	10%	-9.5
1/4/2009	97.72	405	100%	-10.9
1/5/2009	97.80	402	86%	-15.8
1/6/2009	96.34	423	31%	-7.0
1/7/2009	95.63	352	99%	-10.5
Period 8				

Date	Barometric pressure (kPA)	Max solar radiation (Wm^{-2})	Wetness (%)	Air temperature (°C)
3/10/2009	96.22	85	100%	-0.4
3/11/2009	98.18	720	39%	-14.8
3/12/2009	99.73	719	0%	-16.2
3/13/2009	98.74	690	20%	-6.3
3/14/2009	97.83	675	45%	1.6
3/15/2009	97.50	672	0%	5.7
3/16/2009	97.56	667	4%	9.7
3/17/2009	97.31	646	42%	9.3
3/18/2009	98.12	801	20%	3.5
3/19/2009	98.89	727	15%	-2.1
3/20/2009	98.69	616	19%	-1.0
3/21/2009	98.25	711	55%	6.1
3/22/2009	98.37	716	0%	7.6
3/23/2009	97.45	684	38%	5.0
3/24/2009	96.41	380	47%	7.0
3/25/2009	96.03	266	59%	1.7
3/26/2009	97.00	386	0%	-2.0
3/27/2009	97.81	962	7%	-5.2
3/28/2009	97.53	922	35%	-1.9
3/29/2009	96.83	780	31%	-1.6
3/30/2009	97.33	734	28%	0.8
3/31/2009	96.15	349	57%	2.9
4/1/2009	95.59	364	55%	0.7
4/2/2009	96.76	982	19%	1.5
4/3/2009	96.86	865	3%	2.1
4/4/2009	97.65	760	48%	1.1
4/5/2009	97.70	841	70%	1.4
4/6/2009	97.83	819	0%	0.8
4/7/2009	97.62	183	0%	-1.6

6.11 Daily lagoon conditions

6.11.1 Conditions of lagoon 1

Date	Air temperature (°C)	Lagoon temp(°C)	Lagoon pH	Lagoon ORP (mV)
Period 1				
7/19/2007	24.5	24.7	6.58	-407
7/20/2007	17.2	22.8	6.60	-422
7/21/2007	18.2	21.9	N/A	N/A
7/22/2007	19.7	21.5	N/A	N/A
7/23/2007	21.2	21.4	N/A	N/A
7/24/2007	24.0	21.5	N/A	N/A
7/25/2007	25.2	21.8	N/A	N/A
7/26/2007	26.1	22.4	N/A	N/A
7/27/2007	23.8	22.6	N/A	N/A
7/28/2007	22.0	22.6	N/A	N/A
7/29/2007	21.5	22.7	N/A	N/A
7/30/2007	22.2	22.8	N/A	N/A
7/31/2007	24.2	23.2	N/A	N/A
8/1/2007	25.1	23.6	N/A	N/A
8/2/2007	24.3	24.1	N/A	N/A
8/3/2007	20.8	23.8	N/A	N/A
8/4/2007	17.9	23.2	N/A	N/A
8/5/2007	17.6	22.6	N/A	N/A
8/6/2007	20.2	22.3	N/A	N/A
8/7/2007	24.7	22.7	N/A	N/A
8/8/2007	22.1	23.1	N/A	N/A
8/9/2007	24.9	23.3	N/A	N/A
8/10/2007	23.6	23.6	N/A	N/A
8/11/2007	24.6	23.9	N/A	N/A
8/12/2007	22.3	23.9	N/A	N/A
8/13/2007	21.5	23.3	N/A	N/A
8/14/2007	22.4	23.1	N/A	N/A
8/15/2007	20.0	22.6	N/A	N/A
8/16/2007	20.2	22.1	N/A	N/A
8/17/2007	16.2	21.6	N/A	N/A
8/18/2007	14.3	21.1	N/A	N/A
8/19/2007	14.5	20.3	N/A	N/A
8/20/2007	15.7	19.6	N/A	N/A
8/21/2007	19.0	19.8	N/A	N/A
8/22/2007	20.8	20.1	N/A	N/A
8/23/2007	18.6	21.0	N/A	N/A
8/24/2007	18.6	21.7	N/A	N/A
8/25/2007	17.6	22.4	N/A	N/A
8/26/2007	17.9	23.9	N/A	N/A
8/27/2007	20.8	23.4	N/A	N/A

Date	Air temperature (°C)	Lagoon temp(°C)	Lagoon pH	Lagoon ORP (mV)
8/28/2007	21.7	23.8	N/A	N/A
Period 2				
11/14/2007	N/A	N/A	N/A	N/A
11/15/2007	2.2	7.8	7.09	-478
11/16/2007	5.2	7.4	7.05	-505
11/17/2007	2.4	7.1	7.05	-503
11/18/2007	3.3	5.5	7.07	-506
11/19/2007	4.6	5.7	7.04	-503
11/20/2007	4.3	5.5	7.04	-507
11/21/2007	1.5	5.5	7.05	-506
11/22/2007	-1.6	5.3	7.04	-505
11/23/2007	0.1	4.6	7.05	-505
11/24/2007	2.3	4.8	7.03	-506
11/25/2007	6.7	4.7	7.00	-506
11/26/2007	4.7	4.6	7.00	-505
11/27/2007	0.5	4.8	6.98	-506
11/28/2007	-1.8	N/A	N/A	N/A
Period 3				
11/29/2007	N/A	N/A	N/A	N/A
11/30/2007	N/A	N/A	N/A	N/A
12/1/2007	N/A	N/A	N/A	N/A
12/2/2007	N/A	N/A	N/A	N/A
12/3/2007	N/A	N/A	N/A	N/A
12/4/2007	N/A	N/A	N/A	N/A
12/5/2007	N/A	N/A	N/A	N/A
12/6/2007	N/A	N/A	N/A	N/A
12/7/2007	N/A	N/A	N/A	N/A
12/8/2007	N/A	N/A	N/A	N/A
12/9/2007	N/A	N/A	N/A	N/A
12/10/2007	N/A	N/A	N/A	N/A
12/11/2007	N/A	N/A	N/A	N/A
12/12/2007	N/A	N/A	N/A	N/A
12/13/2007	N/A	N/A	N/A	N/A
12/14/2007	N/A	N/A	N/A	N/A
12/15/2007	N/A	N/A	N/A	N/A
12/16/2007	N/A	N/A	N/A	N/A
12/17/2007	N/A	N/A	N/A	N/A
12/18/2007	N/A	N/A	N/A	N/A
Period 4				
4/23/2008	22.5	N/A	N/A	N/A
4/24/2008	14.5	N/A	N/A	N/A
4/25/2008	10.9	N/A	N/A	N/A
4/26/2008	0.8	N/A	N/A	N/A

Date	Air temperature (°C)	Lagoon temp(°C)	Lagoon pH	Lagoon ORP (mV)
4/27/2008	1.9	N/A	N/A	N/A
4/28/2008	0.5	N/A	N/A	N/A
4/29/2008	1.4	N/A	N/A	N/A
4/30/2008	7.8	N/A	N/A	N/A
5/1/2008	12.4	N/A	N/A	N/A
5/2/2008	10.2	N/A	N/A	N/A
5/3/2008	5.9	N/A	N/A	N/A
5/4/2008	10.1	N/A	N/A	N/A
5/5/2008	10.8	N/A	N/A	N/A
5/6/2008	14.8	N/A	N/A	N/A
5/7/2008	12.7	N/A	N/A	N/A
5/8/2008	10.5	N/A	N/A	N/A
5/9/2008	11.3	N/A	N/A	N/A
5/10/2008	10.5	N/A	N/A	N/A
5/11/2008	7.7	N/A	N/A	N/A
5/12/2008	8.2	N/A	N/A	N/A
5/13/2008	12.7	N/A	N/A	N/A
Period 5				
6/26/2008	25.0	N/A	N/A	N/A
6/27/2008	19.5	N/A	N/A	N/A
6/28/2008	16.7	N/A	N/A	N/A
6/29/2008	18.4	N/A	N/A	N/A
6/30/2008	18.5	N/A	N/A	N/A
7/1/2008	20.4	N/A	N/A	N/A
7/2/2008	23.3	N/A	N/A	N/A
7/3/2008	17.4	N/A	N/A	N/A
7/4/2008	17.7	N/A	N/A	N/A
7/5/2008	22.0	N/A	N/A	N/A
7/6/2008	23.4	N/A	N/A	N/A
7/7/2008	22.6	N/A	N/A	N/A
7/8/2008	21.4	N/A	N/A	N/A
7/9/2008	19.1	N/A	N/A	N/A
7/10/2008	18.7	N/A	N/A	N/A
7/12/2008	20.9	N/A	N/A	N/A
7/13/2008	20.0	N/A	N/A	N/A
7/14/2008	19.4	N/A	N/A	N/A
7/15/2008	18.1	N/A	N/A	N/A
Period 6				
10/21/2008	9.1	N/A	N/A	N/A
10/22/2008	5.6	N/A	N/A	N/A
10/23/2008	7.4	N/A	N/A	N/A
10/24/2008	7.7	N/A	N/A	N/A
10/25/2008	7.5	N/A	N/A	N/A

Date	Air temperature (°C)	Lagoon temp(°C)	Lagoon pH	Lagoon ORP (mV)
10/26/2008	5.6	N/A	N/A	N/A
10/27/2008	1.9	N/A	N/A	N/A
10/28/2008	-0.7	N/A	N/A	N/A
10/29/2008	2.9	N/A	N/A	N/A
10/30/2008	9.9	N/A	N/A	N/A
10/31/2008	11.5	N/A	N/A	N/A
11/1/2008	6.8	N/A	N/A	N/A
11/2/2008	10.2	N/A	N/A	N/A
11/3/2008	12.6	N/A	N/A	N/A
11/4/2008	17.4	N/A	N/A	N/A
11/5/2008	15.9	N/A	N/A	N/A
11/6/2008	13.2	N/A	N/A	N/A
11/7/2008	2.9	N/A	N/A	N/A
11/8/2008	0.6	N/A	N/A	N/A
11/9/2008	-3.1	N/A	N/A	N/A
11/10/2008	-4.1	N/A	N/A	N/A
11/11/2008	-3.9	N/A	N/A	N/A
Period 7				
12/18/2008	-16.3	N/A	N/A	N/A
12/19/2008	-8.9	N/A	N/A	N/A
12/20/2008	-9.0	N/A	N/A	N/A
12/21/2008	-21.2	N/A	N/A	N/A
12/22/2008	-21.5	N/A	N/A	N/A
12/23/2008	-13.4	N/A	N/A	N/A
12/24/2008	-13.5	N/A	N/A	N/A
12/25/2008	-16.2	N/A	N/A	N/A
12/26/2008	-2.1	N/A	N/A	N/A
12/27/2008	-0.5	N/A	N/A	N/A
12/28/2008	-8.8	N/A	N/A	N/A
12/29/2008	-3.3	N/A	N/A	N/A
12/30/2008	-9.7	N/A	N/A	N/A
12/31/2008	-19.0	N/A	N/A	N/A
1/1/2009	-9.0	N/A	N/A	N/A
1/2/2009	-13.8	N/A	N/A	N/A
1/3/2009	-9.5	N/A	N/A	N/A
1/4/2009	-10.9	N/A	N/A	N/A
1/5/2009	-15.8	N/A	N/A	N/A
1/6/2009	-7.0	N/A	N/A	N/A
1/7/2009	-10.5	N/A	N/A	N/A
Period 8				
3/10/2009	-0.4	N/A	N/A	N/A
3/11/2009	-14.8	N/A	N/A	N/A
3/12/2009	-16.2	N/A	N/A	N/A

Date	Air temperature (°C)	Lagoon temp(°C)	Lagoon pH	Lagoon ORP (mV)
3/13/2009	-6.3	N/A	N/A	N/A
3/14/2009	1.6	N/A	N/A	N/A
3/15/2009	5.7	N/A	N/A	N/A
3/16/2009	9.7	N/A	N/A	N/A
3/17/2009	9.3	N/A	N/A	N/A
3/18/2009	3.5	N/A	N/A	N/A
3/19/2009	-2.1	N/A	N/A	N/A
3/20/2009	-1.0	N/A	N/A	N/A
3/21/2009	6.1	N/A	N/A	N/A
3/22/2009	7.6	N/A	N/A	N/A
3/23/2009	5.0	N/A	N/A	N/A
3/24/2009	7.0	N/A	N/A	N/A
3/25/2009	1.7	N/A	N/A	N/A
3/26/2009	-2.0	N/A	N/A	N/A
3/27/2009	-5.2	N/A	N/A	N/A
3/28/2009	-1.9	N/A	N/A	N/A
3/29/2009	-1.6	N/A	N/A	N/A
3/30/2009	0.8	N/A	N/A	N/A
3/31/2009	2.9	N/A	N/A	N/A
4/1/2009	0.7	N/A	N/A	N/A
4/2/2009	1.5	N/A	N/A	N/A
4/3/2009	2.1	N/A	N/A	N/A
4/4/2009	1.1	N/A	N/A	N/A
4/5/2009	1.4	N/A	N/A	N/A
4/6/2009	0.8	N/A	N/A	N/A
4/7/2009	-1.6	N/A	N/A	N/A

6.11.2 Conditions of lagoon 2

Date	Air temperature (°C)	Lagoon temp(°C)	Lagoon pH	Lagoon ORP (mV)
Period 1				
7/19/2007	24.5	21.3	6.56	-425
7/20/2007	17.2	20.8	6.61	-457
7/21/2007	18.2	20.3	N/A	N/A
7/22/2007	19.7	20.6	N/A	N/A
7/23/2007	21.2	20.7	N/A	N/A
7/24/2007	24.0	20.7	N/A	N/A
7/25/2007	25.2	21.1	N/A	N/A
7/26/2007	26.1	22.0	N/A	N/A
7/27/2007	23.8	23.8	N/A	N/A
7/28/2007	22.0	23.1	N/A	N/A
7/29/2007	21.5	22.9	N/A	N/A
7/30/2007	22.2	22.7	N/A	N/A
7/31/2007	24.2	22.8	N/A	N/A
8/1/2007	25.1	23.0	N/A	N/A
8/2/2007	24.3	23.4	N/A	N/A
8/3/2007	20.8	22.9	N/A	N/A
8/4/2007	17.9	22.7	N/A	N/A
8/5/2007	17.6	21.5	N/A	N/A
8/6/2007	20.2	21.6	N/A	N/A
8/7/2007	24.7	22.0	6.67	-389
8/8/2007	22.1	21.9	6.80	-428
8/9/2007	24.9	22.1	6.82	-446
8/10/2007	23.6	22.4	N/A	N/A
8/11/2007	24.6	22.3	N/A	N/A
8/12/2007	22.3	22.7	N/A	N/A
8/13/2007	21.5	22.6	N/A	N/A
8/14/2007	22.4	22.2	N/A	N/A
8/15/2007	20.0	22.2	N/A	N/A
8/16/2007	20.2	21.9	N/A	N/A
8/17/2007	16.2	21.8	N/A	N/A
8/18/2007	14.3	20.8	N/A	N/A
8/19/2007	14.5	19.8	N/A	N/A
8/20/2007	15.7	19.0	N/A	N/A
8/21/2007	19.0	18.5	N/A	N/A
8/22/2007	20.8	18.5	N/A	N/A
8/23/2007	18.6	18.9	N/A	N/A
8/24/2007	18.6	19.3	N/A	N/A
8/25/2007	17.6	19.5	N/A	N/A
8/26/2007	17.9	19.7	N/A	N/A
8/27/2007	20.8	19.4	N/A	N/A

Date	Air temperature (°C)	Lagoon temp(°C)	Lagoon pH	Lagoon ORP (mV)
8/28/2007	21.7	19.8	N/A	N/A
Period 2				
11/14/2007	1.5	9.3	7.0	-378
11/15/2007	0.0	8.5	7.1	-429
11/16/2007	-0.2	8.5	7.1	-442
11/17/2007	0.0	5.8	7.1	-438
11/18/2007	-0.6	2.4	7.2	-439
11/19/2007	3.0	4.8	7.2	-435
11/20/2007	1.3	6.0	7.2	-446
11/21/2007	-1.3	6.3	7.1	-449
11/22/2007	-4.0	6.4	7.1	-451
11/23/2007	-6.1	6.3	7.1	-450
11/24/2007	-0.6	6.1	7.0	-445
11/25/2007	0.8	6.1	7.0	-441
11/26/2007	0.1	6.5	7.0	-441
11/27/2007	-8.9	6.9	6.9	-439
11/28/2007	-6.2	N/A	N/A	N/A

6.12 Daily Site Emissions and Data completeness

6.12.1 Daily NH_3 emission using RPM emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid values: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Missing downwind NH_3: Number of ½ h periods invalidated because at least 1 TDL path was either missing or else had invalid concentration values
Emission average ($\mu g m^{-2} s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu g m^{-2} s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu g m^{-2} s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu g m^{-2} s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average ($kg d^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($g d^{-1} hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($g d^{-1} AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Missing Downwind NH_3	Emission average ($\mu g m^{-2} s^{-1}$)	Emission SD ($\mu g m^{-2} s^{-1}$)	Emission minimum ($\mu g m^{-2} s^{-1}$)	Emission maximum ($\mu g m^{-2} s^{-1}$)	Emission average ($kg d^{-1}$)	Emission average ($g d^{-1} hd^{-1}$)	Emission average ($g d^{-1} AU^{-1}$)
Period 1										
7/19/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/20/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/21/2007	0	1	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/22/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/23/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/24/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/25/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/26/2007	1	0	47	189.3	N/A	189.3	189.3	91.6	140.9	111.8
7/27/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/28/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/29/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/30/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/31/2007	1	2	43	105.4	N/A	105.4	105.4	51.0	78.4	62.2
8/1/2007	1	2	43	53.6	N/A	53.6	53.6	25.9	39.9	31.6
8/2/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/3/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/4/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/5/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/6/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/7/2007	0	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/8/2007	0	24	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/9/2007	11	19	17	120.0	58.1	19.6	192.9	58.0	89.3	70.9
8/10/2007	1	2	21	26.8	N/A	26.8	26.8	13.0	19.9	15.8

Date	Valid	Direction limited	Missing Downwind NH_3	Emission average ($\mu g\ m^{-2}\ s^{-1}$)	Emission SD ($\mu g\ m^{-2}\ s^{-1}$)	Emission minimum ($\mu g\ m^{-2}\ s^{-1}$)	Emission maximum ($\mu g\ m^{-2}\ s^{-1}$)	Emission average ($kg\ d^{-1}$)	Emission average ($g\ d^{-1}\ hd^{-1}$)	Emission average ($g\ d^{-1}\ AU^{-1}$)
8/11/2007	1	8	38	291.1	N/A	291.1	291.1	140.8	216.7	172.0
8/12/2007	0	6	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/13/2007	0	10	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/14/2007	1	0	46	53.6	N/A	53.6	53.6	25.9	39.9	31.6
8/15/2007	12	6	23	133.8	54.0	76.8	241.1	64.7	99.6	79.0
8/16/2007	2	0	3	35.7	30.3	14.3	57.1	17.3	26.6	21.1
8/17/2007	4	0	9	57.1	28.8	32.1	98.2	27.6	42.5	33.8
8/18/2007	0	8	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/19/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/20/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/21/2007	0	1	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/22/2007	0	3	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/23/2007	0	3	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/24/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/25/2007	3	4	26	75.0	26.4	57.1	105.4	36.3	55.8	44.3
8/26/2007	11	16	8	176.5	73.9	5.4	282.1	85.4	131.4	104.2
8/27/2007	1	21	11	83.9	N/A	83.9	83.9	40.6	62.5	49.6
Period 2										
11/14/2007	0	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/15/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/16/2007	1	13	23	44.6	N/A	44.6	44.6	21.6	33.2	26.4
11/17/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/18/2007	0	2	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/19/2007	1	10	18	25.0	N/A	25.0	25.0	12.1	18.6	14.8
11/20/2007	0	0	46	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/21/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/22/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/23/2007	3	0	26	14.3	3.6	10.7	17.9	6.9	10.6	8.4
11/24/2007	8	0	2	35.7	11.2	23.2	55.4	17.3	26.6	21.1
11/25/2007	8	0	10	38.6	15.1	19.6	67.9	18.7	28.7	22.8
11/26/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/27/2007	3	3	34	23.8	9.8	12.5	30.4	11.5	17.7	14.1
11/28/2007	0	8	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 3										
11/29/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/30/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/1/2007	2	3	37	15.2	3.8	12.5	17.9	7.3	11.3	9.0
12/2/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/3/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/4/2007	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/5/2007	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/6/2007	0	0	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/7/2007	0	0	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/8/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/9/2007	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/10/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Missing Downwind NH_3	Emission average ($\mu g\ m^{-2}\ s^{-1}$)	Emission SD ($\mu g\ m^{-2}\ s^{-1}$)	Emission minimum ($\mu g\ m^{-2}\ s^{-1}$)	Emission maximum ($\mu g\ m^{-2}\ s^{-1}$)	Emission average ($kg\ d^{-1}$)	Emission average ($g\ d^{-1}\ hd^{-1}$)	Emission average ($g\ d^{-1}\ AU^{-1}$)
12/11/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/12/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/13/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/14/2007	0	0	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/15/2007	0	0	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/16/2007	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/17/2007	0	0	47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4										
4/24/2008	0	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2008	4	11	28	92.9	61.5	3.6	139.3	44.9	69.1	54.9
4/26/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/27/2008	1	1	45	78.6	N/A	78.6	78.6	38.0	58.5	46.4
4/28/2008	1	3	42	46.4	N/A	46.4	46.4	22.5	34.6	27.4
4/29/2008	7	0	29	45.7	20.3	23.2	83.9	22.1	34.0	27.0
4/30/2008	0	7	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/4/2008	7	0	39	26.8	26.7	5.4	78.6	13.0	19.9	15.8
5/5/2008	1	0	47	26.8	N/A	26.8	26.8	13.0	19.9	15.8
5/6/2008	0	2	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/7/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/8/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/9/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/11/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/12/2008	0	0	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5										
6/25/2008	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/26/2008	0	1	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/27/2008	0	8	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/28/2008	18	0	22	220.8	57.7	141.1	308.9	106.8	164.4	130.5
6/29/2008	6	0	39	61.3	84.0	5.4	176.8	29.7	45.6	36.2
6/30/2008	3	3	29	46.4	57.3	10.7	112.5	22.5	34.6	27.4
7/1/2008	0	1	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/2/2008	4	4	29	32.1	39.4	10.7	91.1	15.6	23.9	19.0
7/3/2008	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/4/2008	2	4	11	149.1	46.7	116.1	182.1	72.1	111.0	88.1
7/5/2008	2	20	3	291.1	5.1	287.5	294.6	140.8	216.7	172.0
7/6/2008	2	5	13	179.5	59.3	137.5	221.4	86.8	133.6	106.0
7/7/2008	1	1	28	94.6	N/A	94.6	94.6	45.8	70.4	55.9
7/8/2008	3	3	35	373.8	8.4	364.3	380.4	180.9	278.3	220.8
7/9/2008	3	1	34	178.0	64.8	108.9	237.5	86.1	132.5	105.1
7/10/2008	0	2	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/11/2008	0	12	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/12/2008	7	2	29	197.4	92.1	91.1	335.7	95.5	147.0	116.6

Date	Valid	Direction limited	Missing Downwind NH_3	Emission average ($\mu g\ m^{-2}\ s^{-1}$)	Emission SD ($\mu g\ m^{-2}\ s^{-1}$)	Emission minimum ($\mu g\ m^{-2}\ s^{-1}$)	Emission maximum ($\mu g\ m^{-2}\ s^{-1}$)	Emission average ($kg\ d^{-1}$)	Emission average ($g\ d^{-1}\ hd^{-1}$)	Emission average ($g\ d^{-1}\ AU^{-1}$)
7/13/2008	1	0	44	128.6	N/A	128.6	128.6	62.2	95.7	76.0
7/14/2008	1	0	21	57.1	N/A	57.1	57.1	27.6	42.5	33.8
Period 6										
10/22/2008	0	3	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/23/2008	0	46	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/24/2008	2	23	4	25.0	5.1	21.4	28.6	12.1	18.6	14.8
10/25/2008	11	0	36	36.7	19.2	16.1	71.4	17.8	27.3	21.7
10/26/2008	32	0	3	44.3	16.3	21.4	75.0	21.4	32.9	26.1
10/27/2008	2	0	2	38.4	49.2	3.6	73.2	18.6	28.6	22.7
10/28/2008	23	0	4	23.3	18.2	-8.9	60.7	11.3	17.3	13.8
10/29/2008	7	12	4	4.3	9.2	-7.1	16.1	2.1	3.2	2.6
10/30/2008	14	28	0	67.6	21.9	26.8	98.2	32.7	50.3	39.9
10/31/2008	11	9	4	27.3	12.6	10.7	48.2	13.2	20.3	16.1
11/1/2008	0	25	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/2/2008	9	29	0	55.8	21.3	21.4	80.4	27.0	41.5	32.9
11/3/2008	1	21	17	5.4	N/A	5.4	5.4	2.6	4.0	3.2
11/4/2008	8	30	0	42.9	21.7	23.2	89.3	20.7	31.9	25.3
11/5/2008	0	40	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/6/2008	4	35	2	41.5	6.9	32.1	48.2	20.1	30.9	24.5
11/7/2008	2	31	1	25.0	7.6	19.6	30.4	12.1	18.6	14.8
11/8/2008	10	0	3	11.6	4.1	5.4	19.6	5.6	8.6	6.9
11/9/2008	2	0	14	21.4	5.1	17.9	25.0	10.4	16.0	12.7
11/10/2008	10	0	15	11.8	1.2	10.7	14.3	5.7	8.8	7.0
11/11/2008	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7										
12/18/2008	0	0	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/19/2008	0	1	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/20/2008	1	0	12	0.0	N/A	0.0	0.0	0.0	0.0	0.0
12/21/2008	0	0	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/22/2008	1	2	24	1.8	N/A	1.8	1.8	0.9	1.3	1.1
12/23/2008	1	8	7	5.4	N/A	5.4	5.4	2.6	4.0	3.2
12/24/2008	4	1	12	5.4	4.6	0.0	10.7	2.6	4.0	3.2
12/25/2008	2	3	4	3.6	2.5	1.8	5.4	1.7	2.7	2.1
12/26/2008	0	1	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/27/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/28/2008	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/29/2008	0	0	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/30/2008	0	0	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/31/2008	1	1	16	5.4	N/A	5.4	5.4	2.6	4.0	3.2
1/1/2009	0	3	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/2/2009	0	0	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/3/2009	0	1	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/4/2009	0	0	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/5/2009	2	1	31	5.4	5.1	1.8	8.9	2.6	4.0	3.2
1/6/2009	1	5	12	7.1	N/A	7.1	7.1	3.5	5.3	4.2
Period 8										

Date	Valid	Direction limited	Missing Downwind NH_3	Emission average ($\mu g\ m^{-2}\ s^{-1}$)	Emission SD ($\mu g\ m^{-2}\ s^{-1}$)	Emission minimum ($\mu g\ m^{-2}\ s^{-1}$)	Emission maximum ($\mu g\ m^{-2}\ s^{-1}$)	Emission average ($kg\ d^{-1}$)	Emission average ($g\ d^{-1}\ hd^{-1}$)	Emission average ($g\ d^{-1}\ AU^{-1}$)
3/10/2009	0	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2009	0	0	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2009	1	0	34	14.3	N/A	14.3	14.3	6.9	10.6	8.4
3/13/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2009	0	0	45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/18/2009	2	5	27	7.1	5.1	3.6	10.7	3.5	5.3	4.2
3/19/2009	0	0	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2009	0	11	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2009	7	10	7	15.3	6.0	7.1	25.0	7.4	11.4	9.0
3/22/2009	0	2	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2009	0	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2009	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2009	6	6	6	25.0	12.7	12.5	39.3	12.1	18.6	14.8
3/26/2009	16	0	15	13.7	3.4	7.1	17.9	6.6	10.2	8.1
3/27/2009	0	0	33	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/28/2009	0	1	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/29/2009	1	0	13	26.8	N/A	26.8	26.8	13.0	19.9	15.8
3/30/2009	1	2	24	12.5	N/A	12.5	12.5	6.0	9.3	7.4
3/31/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/1/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2009	0	0	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2009	3	0	38	11.9	1.0	10.7	12.5	5.8	8.9	7.0
4/4/2009	1	5	0	12.5	N/A	12.5	12.5	6.0	9.3	7.4
4/5/2009	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2009	8	0	3	44.6	9.0	33.9	58.9	21.6	33.2	26.4

6.12.2 Daily NH_3 emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Touchdown limited: Number of ½ h periods invalidated because fraction of source area surface covered by particle touchdowns was less than 0.1
Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m
Background (ppm): bLS model calculated daily average background concentration (ppm); average is over the ½ h periods included in the valid column
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 1												
7/19/2007	0	7	13	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/20/2007	0	29	1	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/21/2007	9	14	1	20	0.17	194.3	112.5	110.9	476.7	94.0	144.6	114.8
7/22/2007	4	34	1	7	0.07	106.5	17.6	87.6	129.8	51.5	79.2	62.9
7/23/2007	4	18	10	13	0.06	67.1	13.7	53.3	85.7	32.5	50.0	39.7
7/24/2007	2	4	7	27	0.03	87.3	49.0	52.6	121.9	42.2	64.9	51.5
7/25/2007	9	10	6	22	0.20	161.7	49.5	94.8	262.2	78.2	120.3	95.5
7/26/2007	15	10	5	10	0.12	202.2	93.4	60.8	371.5	97.8	150.5	119.4
7/27/2007	3	2	16	12	0.14	21.2	55.5	-42.8	56.9	10.2	15.8	12.5
7/28/2007	0	1	12	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/29/2007	0	1	12	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/30/2007	17	2	0	23	0.02	215.8	74.8	106.1	373.0	104.4	160.6	127.5
7/31/2007	17	4	0	21	0.18	204.5	60.5	127.1	313.8	98.9	152.2	120.8
8/1/2007	28	4	0	15	0.07	203.4	81.0	87.8	382.7	98.4	151.3	120.1
8/2/2007	32	0	0	11	0.16	126.7	81.4	-9.9	266.6	61.3	94.3	74.9
8/3/2007	22	0	0	17	0.13	93.2	30.9	36.0	155.4	45.1	69.3	55.0
8/4/2007	2	20	0	20	0.16	120.4	22.2	104.7	136.1	58.2	89.6	71.1
8/5/2007	10	23	0	15	0.11	101.3	44.7	22.7	178.6	49.0	75.4	59.9
8/6/2007	1	11	1	31	0.14	47.5	N/A	47.5	47.5	23.0	35.3	28.1

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
8/7/2007	10	0	1	21	0.23	219.1	71.9	48.6	301.5	106.0	163.0	129.4
8/8/2007	1	22	0	21	0.12	10.1	N/A	10.1	10.1	4.9	7.5	6.0
8/9/2007	23	2	0	21	0.12	119.1	69.5	4.9	227.4	57.6	88.6	70.3
8/10/2007	5	16	1	17	0.20	83.1	78.4	0.0	158.7	40.2	61.9	49.1
8/11/2007	13	25	3	3	0.14	231.0	108.1	-53.0	368.4	111.7	171.9	136.4
8/12/2007	11	18	0	11	0.02	47.7	52.1	11.2	189.6	23.0	35.5	28.1
8/13/2007	0	25	4	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/14/2007	26	7	5	3	0.12	11.5	19.8	-41.2	48.3	5.5	8.5	6.8
8/15/2007	13	11	1	19	0.07	125.4	53.3	1.8	206.0	60.7	93.3	74.1
8/16/2007	1	0	0	3	0.01	76.9	N/A	76.9	76.9	37.2	57.2	45.4
8/17/2007	8	0	0	4	0.12	57.4	23.1	30.3	102.8	27.8	42.7	33.9
8/18/2007	0	35	0	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/19/2007	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/20/2007	0	47	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8/21/2007	5	25	6	11	-0.01	29.1	12.2	12.4	44.5	14.1	21.7	17.2
8/22/2007	4	13	4	25	0.02	23.3	10.0	16.5	37.8	11.3	17.3	13.7
8/23/2007	1	6	3	36	0.09	43.6	N/A	43.6	43.6	21.1	32.5	25.8
8/24/2007	15	6	1	19	0.12	21.8	36.2	-45.3	65.7	10.5	16.2	12.9
8/25/2007	19	1	0	24	0.13	56.7	46.2	2.9	210.9	27.4	42.2	33.5
8/26/2007	11	14	0	19	0.18	197.5	48.0	148.8	289.5	95.6	147.0	116.7
8/27/2007	1	42	2	0	0.08	78.0	N/A	78.0	78.0	37.7	58.0	46.1
Period 2												
11/14/2007	6	0	0	0	0.03	23.1	6.0	12.8	28.8	11.2	17.2	13.7
11/15/2007	44	0	0	2	0.03	10.3	6.3	-1.3	24.9	5.0	7.6	6.1
11/16/2007	2	32	0	9	0.09	1.4	2.0	0.0	2.9	0.7	1.1	0.9
11/17/2007	0	47	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/18/2007	0	47	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/19/2007	18	26	0	4	0.07	18.2	14.6	-12.7	40.9	8.8	13.5	10.7
11/20/2007	3	18	0	21	0.03	1.0	1.6	-0.6	2.7	0.5	0.8	0.6
11/21/2007	20	26	0	2	0.05	0.1	1.2	-2.4	2.5	0.0	0.1	0.0
11/22/2007	19	27	0	2	0.02	9.8	8.5	-0.6	23.1	4.8	7.3	5.8
11/23/2007	30	0	0	16	0.03	20.8	8.8	2.2	35.9	10.1	15.5	12.3
11/24/2007	48	0	0	0	0.04	25.8	10.6	6.7	64.6	12.5	19.2	15.3
11/25/2007	48	0	0	0	0.05	20.2	17.7	-13.1	60.9	9.8	15.0	11.9
11/26/2007	40	0	0	7	0.03	9.3	6.5	-0.3	29.8	4.5	6.9	5.5
11/27/2007	35	8	0	5	0.06	13.0	9.5	-6.7	33.5	6.3	9.7	7.7
Period 3												
11/28/2007	9	27	0	1	0.04	5.1	8.3	-5.9	16.2	2.5	3.8	3.0
11/29/2007	47	0	0	1	0.04	5.2	13.7	-21.1	38.9	2.5	3.9	3.1
11/30/2007	47	0	0	1	0.02	4.4	6.6	-7.2	24.4	2.1	3.3	2.6
12/1/2007	10	33	0	4	0.03	8.2	3.1	2.6	13.5	3.9	6.1	4.8
12/2/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/3/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/4/2007	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/5/2007	5	0	3	9	0.00	2.3	2.8	-0.2	6.6	1.1	1.7	1.4
12/6/2007	0	0	8	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
12/7/2007	9	0	0	3	0.05	-2.2	4.9	-12.5	4.8	-1.1	-1.6	-1.3
12/8/2007	8	3	1	30	0.08	-6.0	4.9	-12.3	1.6	-2.9	-4.5	-3.5
12/9/2007	3	0	0	43	0.12	-40.3	68.6	-119.5	-0.3	-19.5	-30.0	-23.8
12/10/2007	0	1	13	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/11/2007	21	0	7	7	0.04	-4.0	8.2	-23.8	5.7	-1.9	-2.9	-2.3
12/12/2007	4	1	5	33	0.04	2.4	1.2	1.3	3.7	1.2	1.8	1.4
12/13/2007	11	2	25	1	0.05	-9.9	11.5	-35.8	4.0	-4.8	-7.3	-5.8
12/14/2007	17	0	0	27	0.06	-0.4	6.3	-10.7	10.6	-0.2	-0.3	-0.2
12/15/2007	0	0	1	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/16/2007	16	2	1	24	0.07	-5.5	4.3	-18.6	0.4	-2.7	-4.1	-3.3
12/17/2007	0	0	22	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 4												
4/24/2008	1	13	0	0	0.28	-21.3	N/A	-21.3	-21.3	-10.3	-15.8	-12.6
4/25/2008	7	23	0	16	0.19	-13.5	12.6	-28.1	1.6	-6.5	-10.0	-8.0
4/26/2008	43	0	4	0	0.04	24.1	24.2	-19.8	77.1	11.7	17.9	14.2
4/27/2008	47	0	0	1	0.05	51.6	54.7	-4.1	223.8	25.0	38.4	30.5
4/28/2008	3	5	22	14	0.02	71.1	46.3	25.1	117.7	34.4	52.9	42.0
4/29/2008	21	1	0	21	-0.03	87.7	50.3	14.5	241.0	42.4	65.3	51.8
4/30/2008	0	39	1	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2008	0	34	12	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2008	0	22	13	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2008	26	0	9	4	0.04	39.8	60.1	-49.6	179.2	19.2	29.6	23.5
5/4/2008	34	6	0	8	0.01	69.7	53.0	-0.3	156.4	33.7	51.9	41.2
5/5/2008	26	3	2	16	0.04	27.4	33.7	-34.3	120.3	13.2	20.4	16.2
5/6/2008	21	11	2	12	-0.02	70.1	48.8	2.1	160.7	33.9	52.2	41.4
5/7/2008	12	11	0	7	0.03	-0.2	8.3	-13.6	17.4	-0.1	-0.1	-0.1
5/8/2008	4	1	6	20	0.04	14.2	32.1	-3.7	62.2	6.8	10.5	8.4
5/9/2008	0	2	11	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2008	8	24	0	7	-0.01	32.3	18.2	8.8	64.1	15.6	24.0	19.1
5/11/2008	14	0	10	8	0.03	-3.0	9.5	-16.3	21.5	-1.5	-2.3	-1.8
5/12/2008	0	6	1	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5												
6/25/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/26/2008	12	5	0	17	0.13	50.5	22.6	21.4	90.8	24.4	37.6	29.8
6/27/2008	7	14	0	21	0.11	25.9	21.5	3.6	59.5	12.5	19.3	15.3
6/28/2008	38	0	1	8	0.11	72.2	34.3	10.3	149.1	34.9	53.7	42.6
6/29/2008	41	0	0	6	0.24	-3.1	13.5	-20.4	54.5	-1.5	-2.3	-1.8
6/30/2008	24	0	0	13	0.24	17.3	15.8	-16.5	59.3	8.3	12.8	10.2
7/1/2008	25	0	0	15	0.09	93.8	25.3	10.3	126.4	45.4	69.8	55.4
7/2/2008	33	12	0	1	0.23	12.7	32.4	-18.4	89.2	6.2	9.5	7.5
7/3/2008	10	19	0	14	0.23	1.4	6.8	-4.8	15.0	0.7	1.0	0.8
7/4/2008	13	9	0	21	0.10	50.0	28.6	11.0	106.8	24.2	37.2	29.5
7/5/2008	10	34	0	3	0.13	116.9	40.3	50.0	171.2	56.6	87.0	69.0
7/6/2008	17	28	0	3	0.12	82.7	28.3	38.1	139.5	40.0	61.5	48.8
7/7/2008	4	24	1	18	0.09	53.0	58.6	5.0	129.2	25.6	39.4	31.3
7/8/2008	24	6	1	10	0.16	121.9	46.8	34.5	233.0	58.9	90.7	72.0

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/9/2008	28	0	0	10	0.13	57.8	47.7	2.1	237.2	27.9	43.0	34.1
7/10/2008	1	29	0	9	0.19	16.6	N/A	16.6	16.6	8.0	12.3	9.8
7/11/2008	0	38	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/12/2008	35	6	0	5	0.10	67.0	40.3	12.3	171.8	32.4	49.8	39.6
7/13/2008	48	0	0	0	0.12	52.8	24.1	-9.6	95.8	25.6	39.3	31.2
7/14/2008	5	0	0	16	0.17	-6.9	10.4	-22.1	2.3	-3.3	-5.2	-4.1
Period 6												
10/22/2008	0	4	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/23/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/24/2008	14	25	0	8	0.06	16.6	9.6	1.2	36.1	8.0	12.4	9.8
10/25/2008	37	0	0	10	0.04	54.4	38.0	8.2	130.6	26.3	40.5	32.1
10/26/2008	47	0	0	1	0.02	43.5	10.9	24.1	64.2	21.1	32.4	25.7
10/27/2008	47	0	0	1	0.04	20.2	10.2	1.9	41.1	9.8	15.0	11.9
10/28/2008	18	0	0	20	0.02	39.2	20.3	10.7	67.6	19.0	29.2	23.2
10/29/2008	1	11	0	25	0.06	36.7	N/A	36.7	36.7	17.7	27.3	21.7
10/30/2008	16	26	0	2	0.06	99.1	27.3	46.2	137.0	47.9	73.8	58.5
10/31/2008	8	21	0	12	0.09	36.7	12.9	15.8	49.3	17.8	27.3	21.7
11/1/2008	0	36	0	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/2/2008	11	30	0	6	0.07	70.0	26.6	14.5	111.1	33.8	52.1	41.3
11/3/2008	0	28	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/4/2008	14	33	0	1	0.09	65.7	23.9	33.5	115.5	31.8	48.9	38.8
11/5/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/6/2008	4	43	0	1	0.08	53.0	9.7	45.3	67.3	25.7	39.5	31.3
11/7/2008	5	29	0	9	0.08	10.2	6.0	3.9	20.2	4.9	7.6	6.0
11/8/2008	44	0	0	2	0.03	8.5	4.3	1.4	20.6	4.1	6.3	5.0
11/9/2008	48	0	0	0	0.05	8.0	7.1	-1.1	27.2	3.9	6.0	4.7
11/10/2008	34	2	0	10	0.05	6.3	6.3	-2.2	27.5	3.1	4.7	3.7
11/11/2008	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7												
12/18/2008	8	2	0	8	0.03	1.7	2.8	-2.6	6.1	0.8	1.2	1.0
12/19/2008	0	34	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/20/2008	1	35	0	7	0.03	0.3	N/A	0.3	0.3	0.1	0.2	0.2
12/21/2008	47	0	0	0	0.05	-7.6	6.9	-29.7	7.2	-3.7	-5.7	-4.5
12/22/2008	29	2	0	17	0.05	-1.3	3.4	-11.5	5.6	-0.7	-1.0	-0.8
12/23/2008	2	44	0	1	0.07	-3.0	1.1	-3.8	-2.3	-1.5	-2.2	-1.8
12/24/2008	21	1	0	14	0.06	-4.9	5.0	-13.9	5.8	-2.4	-3.6	-2.9
12/25/2008	7	26	0	8	0.04	3.8	2.1	1.8	7.9	1.9	2.9	2.3
12/26/2008	0	45	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/27/2008	0	5	5	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/28/2008	0	0	13	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/29/2008	15	0	4	0	0.02	-0.7	4.5	-9.4	7.0	-0.3	-0.5	-0.4
12/30/2008	6	20	6	13	0.05	-2.5	1.8	-5.4	0.0	-1.2	-1.8	-1.5
12/31/2008	23	5	0	19	0.06	-1.1	4.0	-11.2	9.0	-0.6	-0.9	-0.7
1/1/2009	23	24	0	1	0.05	-4.6	4.6	-11.2	4.2	-2.2	-3.4	-2.7
1/2/2009	33	1	0	14	0.04	-2.9	6.3	-17.6	13.8	-1.4	-2.2	-1.7
1/3/2009	0	44	2	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Direction limited	Touchdown limited	Turbulence limited	Background (ppm)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
1/4/2009	16	0	0	3	0.06	0.8	7.7	-9.9	15.8	0.4	0.6	0.5
1/5/2009	17	10	0	11	0.05	0.7	5.0	-7.6	9.0	0.3	0.5	0.4
1/6/2009	2	43	0	0	0.04	-4.3	0.8	-4.9	-3.8	-2.1	-3.2	-2.6
Period 8												
3/10/2009	6	0	0	1	-0.02	1.0	5.7	-6.7	6.9	0.5	0.8	0.6
3/11/2009	48	0	0	0	-0.01	19.8	16.4	-11.4	48.0	9.6	14.8	11.7
3/12/2009	39	0	0	9	-0.02	7.7	8.3	-6.1	24.1	3.7	5.7	4.5
3/13/2009	10	1	15	15	-0.06	21.3	8.8	11.0	42.0	10.3	15.8	12.6
3/14/2009	0	0	22	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2009	0	0	45	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2009	0	9	35	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2009	16	2	19	5	-0.01	12.5	16.1	-7.6	40.9	6.1	9.3	7.4
3/18/2009	21	0	0	22	-0.02	14.4	15.9	-16.5	41.1	7.0	10.7	8.5
3/19/2009	38	8	0	2	0.02	-0.6	11.6	-24.0	18.0	-0.3	-0.4	-0.3
3/20/2009	0	32	0	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2009	14	24	0	9	-0.02	27.1	15.8	6.5	62.6	13.1	20.2	16.0
3/22/2009	0	44	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2009	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2009	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2009	35	9	0	0	-0.05	33.1	7.7	18.0	49.4	16.0	24.6	19.5
3/26/2009	48	0	0	0	-0.03	21.3	8.6	5.6	37.6	10.3	15.8	12.6
3/27/2009	45	1	0	2	0.00	3.1	7.0	-12.4	15.5	1.5	2.3	1.8
3/28/2009	0	19	0	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/29/2009	30	10	0	8	0.02	0.0	14.0	-25.5	26.9	0.0	0.0	0.0
3/30/2009	1	0	4	21	-0.01	5.9	N/A	5.9	5.9	2.9	4.4	3.5
3/31/2009	0	0	11	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/1/2009	0	0	14	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2009	0	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2009	12	0	3	8	0.03	24.6	22.5	-24.5	55.0	11.9	18.3	14.5
4/4/2009	0	0	0	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/5/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2009	19	0	0	0	0.04	19.2	14.7	-5.4	45.2	9.3	14.3	11.3

6.12.3 Daily H_2S emission using Ratiometric emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Emission average ($\mu gm^{-2}s^{-1}$): Daily average emission calculated from the valid ½ h periods
Emissions SD ($\mu gm^{-2}s^{-1}$): Daily emission standard deviation of the valid ½ h periods
Emission minimum ($\mu gm^{-2}s^{-1}$): Daily minimum emission of the valid ½ h periods
Emission maximum ($\mu gm^{-2}s^{-1}$): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average ($gd^{-1}hd^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average ($gd^{-1}AU^{-1}$): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 4								
4/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/25/2008	3	8.7	47.4	6.9	12.1	4.2	6.5	5.1
4/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/27/2008	1	1.6	0.0	1.6	1.6	0.8	1.2	1.0
4/28/2008	1	2.7	0.0	2.7	2.7	1.3	2.0	1.6
4/29/2008	4	0.5	10.9	0.2	0.8	0.2	0.4	0.3
4/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/4/2008	5	1.1	15.8	0.4	3.8	0.5	0.8	0.7
5/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/6/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/7/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 5								
6/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/29/2008	4	2.0	21.6	1.0	3.0	1.0	1.5	1.2
6/30/2008	3	11.5	57.2	1.3	28.0	5.6	8.6	6.8
7/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
7/2/2008	4	7.9	43.6	2.6	17.7	3.8	5.9	4.7
7/3/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/4/2008	1	12.1	0.0	12.1	12.1	5.9	9.0	7.1
7/5/2008	2	11.9	63.6	8.3	15.6	5.8	8.9	7.1
7/6/2008	1	5.6	0.0	5.6	5.6	2.7	4.2	3.3
7/7/2008	1	-10.4	0.0	-10.4	-10.4	-5.0	-7.7	-6.1
7/8/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/9/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/12/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/13/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/14/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 6								
10/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/23/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/25/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/27/2008	2	-8.6	0.0	-16.4	-0.7	-4.2	-6.4	-5.1
10/28/2008	2	3.6	35.9	2.8	4.4	1.8	2.7	2.1
10/29/2008	6	2.4	22.5	-1.6	8.9	1.2	1.8	1.4
10/30/2008	14	4.4	28.7	2.4	7.7	2.1	3.3	2.6
10/31/2008	11	1.6	17.7	0.6	2.8	0.8	1.2	1.0
11/1/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/2/2008	9	1.3	15.9	0.5	1.7	0.6	0.9	0.7
11/3/2008	1	0.1	0.0	0.1	0.1	0.1	0.1	0.1
11/4/2008	8	1.5	17.7	0.7	2.3	0.7	1.1	0.9
11/5/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/6/2008	4	2.9	26.1	2.2	4.5	1.4	2.2	1.7
11/7/2008	2	2.4	28.9	2.2	2.6	1.1	1.8	1.4
11/8/2008	1	6.4	0.0	6.4	6.4	3.1	4.7	3.8
11/9/2008	2	4.6	39.9	1.8	7.3	2.2	3.4	2.7
11/10/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/11/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 7								
12/18/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/19/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/20/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/21/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/22/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/23/2008	1	-3.1	0.0	-3.1	-3.1	-1.5	-2.3	-1.8
12/24/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/25/2008	1	-0.6	0.0	-0.6	-0.6	-0.3	-0.4	-0.3
12/26/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/27/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Date	Valid	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
12/28/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/29/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/30/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/31/2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/3/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/4/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/5/2009	2	1.4	22.5	0.1	2.8	0.7	1.1	0.8
1/6/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Period 8								
3/10/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/11/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/12/2009	1	1.2	0.0	1.2	1.2	0.6	0.9	0.7
3/13/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/14/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/15/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/17/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/18/2009	2	0.0	3.9	0.0	0.1	0.0	0.0	0.0
3/19/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/21/2009	7	0.2	5.6	-0.2	0.6	0.1	0.1	0.1
3/22/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/23/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/25/2009	4	3.0	26.9	0.5	6.2	1.5	2.3	1.8
3/26/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/27/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/28/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/29/2009	1	1.5	0.0	1.5	1.5	0.7	1.1	0.9
3/30/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/31/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/1/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/2/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/3/2009	3	0.0	2.9	0.0	0.1	0.0	0.0	0.0
4/4/2009	1	0.1	0.0	0.1	0.1	0.0	0.1	0.1
4/5/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/6/2009	8	0.5	10.4	0.1	1.7	0.3	0.4	0.3
4/7/2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

6.12.4 Daily H_2S emission using bLS emissions model

Column headings for the following table are:

Date: Month/Day/Year
Valid: Number of ½ h periods with valid emissions data
Direction limited: Number of ½ h periods invalidated because wind was from an excluded wind direction
Angle limited: Number of ½ h periods invalidated because angle of attack to the downwind side was greater than 60 degrees
Turbulence limited: Number of ½ h periods that the bLS model was not run because either $u_* < 0.15$ ms^{-1} or $|L| < 2$ m
Background (ppb): bLS model calculated daily average background concentration (ppb); average is over the ½ h periods included in the valid column
Emission average (μgm^{-2}s^{-1}): Daily average emission calculated from the valid ½ h periods
Emissions SD (μgm^{-2}s^{-1}): Daily emission standard deviation of the valid ½ h periods
Emission minimum (μgm^{-2}s^{-1}): Daily minimum emission of the valid ½ h periods
Emission maximum (μgm^{-2}s^{-1}): Daily maximum emission of the valid ½ h periods
Emission average (kgd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area
Emission average (gd^{-1}hd^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per head basis
Emission average (gd^{-1}AU^{-1}): Daily average emission calculated from the valid ½ h periods; totaled over the source area on a per animal unit basis

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average (μgm^{-2}s^{-1})	Emission SD (μgm^{-2}s^{-1})	Emission minimum (μgm^{-2}s^{-1})	Emission maximum (μgm^{-2}s^{-1})	Emission average (kgd^{-1})	Emission average (gd^{-1}hd^{-1})	Emission average (gd^{-1}AU^{-1})
Period 4												
4/24/2008	1	9	0	0	3.0	2.2	N/A	2.2	2.2	1.1	1.7	1.3
4/25/2008	3	24	4	17	0.8	1.1	1.3	0.1	2.6	0.5	0.8	0.6
4/26/2008	19	0	29	0	1.7	1.4	1.0	-0.3	3.6	0.7	1.1	0.9
4/27/2008	29	0	18	1	0.3	0.3	0.5	-1.0	1.1	0.2	0.2	0.2
4/28/2008	6	26	0	15	0.3	0.6	0.4	0.0	1.2	0.3	0.5	0.4
4/29/2008	10	1	11	26	0.5	0.7	0.3	0.3	1.2	0.3	0.5	0.4
4/30/2008	0	40	0	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/1/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/2/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/3/2008	34	8	0	6	0.7	0.5	0.4	-0.3	1.2	0.2	0.4	0.3
5/4/2008	13	6	21	8	0.4	4.1	5.4	0.1	16.6	2.0	3.1	2.5
5/5/2008	18	3	10	17	1.7	0.9	0.8	-0.2	2.4	0.4	0.7	0.5
5/6/2008	12	13	9	14	1.6	1.3	1.3	-0.3	4.0	0.7	1.0	0.8
5/7/2008	17	21	0	9	2.2	1.1	0.7	0.2	2.7	0.5	0.8	0.6
5/8/2008	11	9	0	27	2.3	0.6	0.6	-0.1	1.7	0.3	0.5	0.4
5/9/2008	0	24	0	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5/10/2008	8	25	0	11	6.1	1.2	1.2	-0.3	3.4	0.6	0.9	0.7
5/11/2008	32	7	0	8	2.2	1.1	0.7	-0.1	3.2	0.6	0.8	0.7
5/12/2008												

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
Period 5	5	12	2	25	2.9	3.4	5.7	0.2	13.5	1.6	2.5	2.0
6/25/2008	8	0	32	8	3.8	5.0	2.8	1.1	9.1	2.4	3.8	3.0
6/26/2008	38	0	3	7	4.1	3.9	2.1	1.2	10.4	1.9	2.9	2.3
6/27/2008	24	0	0	23	5.0	5.1	2.3	1.1	10.2	2.5	3.8	3.0
6/28/2008	24	0	1	23	3.9	4.8	3.0	1.7	16.2	2.4	3.6	2.9
6/29/2008	30	12	3	3	4.8	4.9	2.9	0.0	13.7	2.4	3.7	2.9
6/30/2008	10	19	0	16	4.1	3.3	3.5	0.3	9.3	1.6	2.5	2.0
7/1/2008	11	9	2	24	4.0	3.4	3.3	0.0	10.8	1.6	2.5	2.0
7/2/2008	10	34	0	4	3.3	3.3	1.3	1.7	5.5	1.6	2.5	2.0
7/3/2008	16	28	1	3	3.3	2.0	1.0	0.4	4.5	1.0	1.5	1.2
7/4/2008	5	24	0	19	15.2	2.5	2.2	-0.4	5.4	1.2	1.9	1.5
7/5/2008	8	6	18	15	3.2	14.6	5.8	3.3	22.4	7.1	11.0	8.7
7/6/2008	15	0	13	18	2.2	16.5	14.5	-2.4	44.8	8.0	12.4	9.8
7/7/2008	1	29	0	18	2.1	17.9	N/A	17.9	17.9	8.7	13.4	10.7
7/8/2008	0	38	0	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/9/2008	8	6	29	5	13.1	7.0	7.7	-2.0	21.5	3.4	5.3	4.2
7/10/2008	26	0	22	0	1.3	6.3	2.4	2.6	10.7	3.1	4.7	3.7
7/11/2008	3	0	2	20	1.3	7.0	3.0	3.5	9.1	3.4	5.2	4.1
7/12/2008												
7/13/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/14/2008	10	25	4	9	1.1	0.0	0.2	-0.3	0.3	0.0	0.0	0.0
Period 6	29	0	8	11	1.1	2.0	1.1	0.5	5.1	1.0	1.5	1.2
10/22/2008	11	0	36	1	0.9	0.4	0.8	-0.5	2.0	0.2	0.3	0.2
10/23/2008	47	0	0	1	2.2	-0.3	0.9	-2.6	1.3	-0.2	-0.2	-0.2
10/24/2008	2	0	16	29	0.3	1.5	1.9	0.2	2.8	0.7	1.1	0.9
10/25/2008	1	11	0	32	1.5	0.5	N/A	0.5	0.5	0.2	0.4	0.3
10/26/2008	16	26	0	6	1.2	5.5	1.9	2.7	8.2	2.7	4.1	3.3
10/27/2008	8	21	0	16	1.1	1.8	1.0	0.5	3.6	0.9	1.4	1.1
10/28/2008	0	36	0	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/29/2008	11	30	0	7	1.2	1.2	0.4	0.8	2.1	0.6	0.9	0.7
10/30/2008	0	28	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10/31/2008	14	33	0	1	1.7	2.0	0.7	1.2	3.7	1.0	1.5	1.2
11/1/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/2/2008	4	43	0	1	0.9	3.2	1.1	2.3	4.6	1.5	2.4	1.9
11/3/2008	5	29	0	9	1.1	1.5	0.6	0.4	2.1	0.7	1.1	0.9
11/4/2008	34	0	10	2	1.9	1.4	0.6	0.4	3.4	0.7	1.0	0.8
11/5/2008	48	0	0	0	1.2	1.4	1.0	0.3	4.1	0.7	1.1	0.8
11/6/2008	28	2	6	9	1.3	-0.1	0.3	-0.9	0.2	0.0	-0.1	-0.1
11/7/2008												
11/8/2008	8	2	0	8	0.6	0.1	0.1	0.0	0.4	0.1	0.1	0.1
11/9/2008	0	34	0	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/10/2008	0	35	2	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/11/2008	21	0	27	0	0.3	0.6	1.1	-0.8	3.2	0.3	0.5	0.4
Period 7	21	2	8	17	2.9	0.0	1.0	-1.7	2.1	0.0	0.0	0.0
12/18/2008	2	44	0	1	16.0	-2.6	0.3	-2.9	-2.4	-1.3	-2.0	-1.6
12/19/2008	14	1	7	26	0.4	0.1	0.3	-0.5	0.5	0.1	0.1	0.1

Date	Valid	Direction limited	Angle limited	Turbulence limited	Background (ppb)	Emission average ($\mu gm^{-2}s^{-1}$)	Emission SD ($\mu gm^{-2}s^{-1}$)	Emission minimum ($\mu gm^{-2}s^{-1}$)	Emission maximum ($\mu gm^{-2}s^{-1}$)	Emission average (kgd^{-1})	Emission average ($gd^{-1}hd^{-1}$)	Emission average ($gd^{-1}AU^{-1}$)
12/20/2008	2	26	5	15	6.2	-1.0	1.0	-1.7	-0.3	-0.5	-0.7	-0.6
12/21/2008	0	47	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/22/2008	6	10	32	0	4.9	-0.7	0.3	-1.2	-0.4	-0.4	-0.6	-0.4
12/23/2008	22	10	15	1	0.7	0.2	0.5	-0.4	1.4	0.1	0.2	0.1
12/24/2008	29	15	4	0	0.6	0.0	0.5	-1.0	0.9	0.0	0.0	0.0
12/25/2008	6	26	2	14	0.2	0.2	0.3	-0.1	0.7	0.1	0.2	0.1
12/26/2008	22	5	1	19	0.6	0.0	0.1	-0.2	0.3	0.0	0.0	0.0
12/27/2008	20	24	3	1	0.4	0.2	0.3	-0.6	0.7	0.1	0.2	0.1
12/28/2008	25	1	8	14	0.5	0.0	0.4	-0.9	0.7	0.0	0.0	0.0
12/29/2008	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/30/2008	4	1	12	3	0.5	0.1	0.2	-0.2	0.4	0.1	0.1	0.1
12/31/2008	15	10	2	21	0.7	0.3	0.3	-0.1	0.8	0.1	0.2	0.2
1/1/2009	0	35	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/2/2009												
1/3/2009	3	0	3	0	0.4	0.2	0.4	-0.1	0.6	0.1	0.1	0.1
1/4/2009	15	0	33	0	0.1	0.1	0.6	-1.0	1.4	0.0	0.1	0.0
1/5/2009	26	0	13	9	0.3	0.1	0.3	-0.3	1.0	0.1	0.1	0.1
1/6/2009	10	7	11	20	0.1	0.2	0.3	-0.4	0.7	0.1	0.1	0.1
Period 8	19	13	2	14	0.2	0.1	0.2	-0.4	0.5	0.1	0.1	0.1
3/10/2009	3	45	0	0	0.8	0.0	0.2	-0.3	0.1	0.0	0.0	0.0
3/11/2009	5	39	0	0	0.6	0.2	0.2	0.0	0.3	0.1	0.1	0.1
3/12/2009	18	19	3	8	0.0	0.1	0.4	-0.4	1.0	0.1	0.1	0.1
3/13/2009	19	0	2	27	0.1	0.1	0.4	-0.7	1.0	0.0	0.1	0.1
3/14/2009	38	8	0	2	0.1	0.0	0.3	-1.0	0.4	0.0	0.0	0.0
3/15/2009	0	32	0	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/16/2009	13	24	0	10	0.4	0.2	0.2	0.0	0.5	0.1	0.2	0.1
3/17/2009	0	44	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/18/2009	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/19/2009	0	48	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/20/2009	24	9	15	0	1.3	1.2	0.5	0.3	2.4	0.6	0.9	0.7
3/21/2009	10	0	38	0	0.2	0.0	0.5	-1.2	0.8	0.0	0.0	0.0
3/22/2009	45	1	0	2	0.0	0.1	0.3	-0.9	0.7	0.0	0.0	0.0
3/23/2009	0	19	0	29	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/24/2009	30	10	0	8	0.1	0.1	0.3	-0.2	1.0	0.1	0.1	0.1
3/25/2009	1	23	0	24	0.3	0.0	N/A	0.0	0.0	0.0	0.0	0.0
3/26/2009	2	45	0	1	1.0	0.6	0.1	0.6	0.7	0.3	0.5	0.4
3/27/2009	14	12	22	0	0.8	0.5	0.5	-0.2	1.7	0.2	0.4	0.3
3/28/2009	10	0	37	1	0.4	-0.1	0.4	-1.2	0.3	-0.1	-0.1	-0.1
3/29/2009	39	0	0	9	0.0	0.1	0.2	-0.2	0.5	0.0	0.0	0.0
3/30/2009	0	0	0	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/31/2009	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4/1/2009	21	0	0	0	1.0	13.0	27.7	0.0	99.2	6.3	9.7	7.7
4/2/2009	0	11	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX E

Federal Register Notice

Animal Feeding Operations Consent Agreement and Final Order

Federal Register

Monday,
January 31, 2005

Part IV

Environmental Protection Agency

Animal Feeding Operations Consent Agreement and Final Order; Notice

ENVIRONMENTAL PROTECTION AGENCY

[OAR–2004–0237; FRL–7864–4]

Animal Feeding Operations Consent Agreement and Final Order

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of consent agreement and final order, and request for public comment.

SUMMARY: The EPA is offering animal feeding operations (AFOs) an opportunity to sign a voluntary consent agreement and final order (henceforth referred to as the ''Air Compliance Agreement'' or the ''Agreement''). A copy of the Air Compliance Agreement is attached as an Appendix to this notice. The sign-up period for eligible AFOs to sign the Agreement will run for 90 days from the date of this notice.

AFOs that choose to sign the Air Compliance Agreement will share responsibility for funding an extensive, nationwide emissions monitoring study. The monitoring study will lead to the development of methodologies for estimating emissions from AFOs and will help AFOs to determine and comply with their regulatory responsibilities under the Clean Air Act (CAA); the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); and the Emergency Planning and Community Right-To-Know Act (EPCRA). Once applicable emission estimating methodologies have been published by EPA, the Agreement will also require each participating AFO to certify that it is in compliance with all relevant requirements of the CAA, CERCLA and EPCRA.

EPA is requesting comment on the Air Compliance Agreement, with particular emphasis on implementation of the Agreement. All comments should be submitted within 30 days of the date of this notice.

DATES: Comments must be received on or before March 2, 2005.

ADDRESSES: Submit your comments, identified by Docket ID No. OAR–2004–0237, by one of the following methods:

- Agency Web site: *http://www.epa.gov/edocket.* EDOCKET, EPA's electronic public docket and comment system, is EPA's preferred method for receiving comments. Follow the on-line instructions for submitting comments.
- E-mail: *a-and-r-docket@epa.gov.*
- Fax: (202) 566–1741.
- Mail: Air Docket, Environmental Protection Agency, Mailcode: 6102T, 1200 Pennsylvania Ave., NW., Washington, DC 20460. Please include a total of two copies.
- Hand Delivery: Environmental Protection Agency, 1301 Constitution Avenue, NW., Room B102, Washington, DC 20460. Such deliveries are only accepted during the Docket's normal hours of operation, and special arrangements should be made for deliveries of boxed information.

Instructions: Direct your comments to Docket ID No. OAR–2004–0237. The EPA's policy is that all comments received will be included in the public docket without change and may be made available online at *http://www.epa.gov/edocket,* including any personal information provided, unless the comment includes information claimed to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Do not submit information that you consider to be CBI or otherwise protected through EDOCKET, regulations.gov, or e-mail. The EPA EDOCKET and the Federal regulations.gov Web sites are ''anonymous access'' systems, which means EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an e-mail comment directly to EPA without going through EDOCKET or regulations.gov, your e-mail address will be automatically captured and included as part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD–ROM you submit. If EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses.

Docket: All documents in the docket are listed in the EDOCKET index at *http://www.epa.gov/edocket.* Although listed in the index, some information is not publicly available, *i.e.,* CBI or other information whose disclosure is restricted by statute. Certain other information, such as copyrighted materials, is not placed on the Internet and will be publicly available only in hard copy form. Publicly available docket materials are available either electronically in EDOCKET or in hard copy form at Docket ID No. OAR–2004–0237, EPA/DC, EPA West, Room B102, 1301 Constitution Ave., NW., Washington, DC. The Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566–1744, and the telephone number for the Air Docket is (202) 566–1742.

FOR FURTHER INFORMATION CONTACT: For information on the Air Compliance Agreement, contact Mr. Bruce Fergusson, Special Litigation and Projects Division, Office of Enforcement and Compliance Assurance, U.S. EPA, Ariel Rios Building, Washington, DC 20460, telephone number (202) 564–1261, fax number (202) 564–0010, and electronic mail: *fergusson.bruce@epa.gov.*

For information on the monitoring study, contact Ms. Sharon Nizich, Organic Chemicals Group, Emission Standards Division, Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, NC 27711, telephone number (919) 541–2825, fax number (919) 541–3470, and electronic mail: *nizich.sharon@epa.gov.*

SUPPLEMENTARY INFORMATION:

Overview of the Air Compliance Agreement: By offering AFOs this opportunity to sign an Air Compliance Agreement, the Agency will help participating AFOs pool their resources to lower the cost of measuring emissions and ensure that they comply with all applicable environmental regulations in the shortest amount of time. While EPA has the authority on a case-by-case basis to require AFOs to monitor their emissions and to come into compliance with applicable Federal laws, that process has proven to be difficult and time consuming, partly due to the uncertainty regarding emissions from AFOs, which was reiterated in a recent report by the National Academy of Sciences (NAS).[1] Moreover, even when EPA has reached a successful resolution of an enforcement case, only the facilities that are the subject of the enforcement action were directly affected. Consequently, EPA believes that the Air Compliance Agreement will be the quickest and most effective way to address the current uncertainty regarding emissions from AFOs and to bring all participating AFOs into compliance with all applicable regulatory requirements.

The Air Compliance Agreement will not affect in any way EPA's ability to respond to an imminent and substantial endangerment to public health, welfare or the environment. Nor will participation in the Agreement provide protection for criminal violations of

[1] NAS, ''Air Emissions From Animal Feeding Operations: Current Knowledge, Future Needs,'' National Research Council, 2003.

environmental laws. Finally, the Air Compliance Agreement is not intended to affect compliance by AFOs with any requirements of the Clean Water Act (CWA) and the implementing regulations applicable to concentrated animal feeding operations.

AFOs that choose not to sign an Air Compliance Agreement will be subject to potential enforcement action by the Federal Government for any CAA, CERCLA, or EPCRA violations, as would any AFO that signs the Agreement but later drops out by not complying with the terms of the Agreement.

EPA recognizes that AFOs can have a negative impact on nearby residents, particularly with respect to objectionable odors and other nuisance problems that can affect their quality of life. EPA also recognizes that concerns have been raised recently regarding the possible health impacts from AFO emissions. It is important to note, however, that under existing Federal laws, EPA has an important but limited role in dealing with many of the potential impacts from AFOs. To the extent that certain pollutants from AFOs are regulated under the CAA and are emitted in quantities that exceed regulatory thresholds, EPA can and will require AFOs to comply with all applicable CAA requirements, including limiting those emissions where appropriate. However, many of the negative impacts resulting from AFOs, such as odor, are not currently regulated under Federal laws, but are addressed by State and local laws. EPA supports local and State efforts in those areas and relies on them to enforce their State and local laws for odor and nuisance problems, health code violations, and zoning challenges posed by AFOs. The Air Compliance Agreement will explicitly require participants to comply with final State nuisance orders. In addition, the Agreement will not affect the ability of States or citizens to enforce compliance with nonfederally enforceable State laws, existing or future, that are applicable to AFOs.

Sources may also emit fugitive emissions, but this notice does not address fugitive emissions. Guidance on fugitive emissions will be issued along with other appropriate guidance/and or regulations after the conclusion of the monitoring study.

Relevant Air Pollutants and Applicable Laws: AFOs emit several air pollutants, including ammonia (NH_3), hydrogen sulfide (H_2S), particulate matter (PM), and volatile organic compounds (VOC). NH_3 and H_2S are hazardous substances under CERCLA and EPCRA, and the release of these gases may need to be reported under CERCLA and EPCRA if released in sufficient quantities. H_2S, PM, and VOC are all regulated under the CAA and subject to various requirements under that statute and the implementing Federal and State rules and regulations. Emissions of these pollutants come from many different areas at AFOs, including animal housing structures (*e.g.,* barns, covered feed lots) and manure storage areas (*e.g.,* lagoons, covered manure piles). An important issue that arises under the CAA is whether emissions from different areas at AFOs should be treated as fugitive or nonfugitive. The Agency plans to issue regulations and/or guidance on this issue after the conclusion of the monitoring study.

Applicability: The Air Compliance Agreement is being offered to AFOs in the egg, broiler chicken, turkey, dairy and swine industries that meet the definition of an AFO under the CWA. The Agreement will address emissions coming from buildings or structures that house agricultural livestock, and from lagoons or similar structures that are used for storage and/or treatment of agricultural livestock waste at participating AFOs. The Air Compliance Agreement will not address AFOs that only have open-air feedlots, such as cattle feedlots. Nor will it address emissions from sources other than animal housing structures or agricultural livestock waste storage and treatment units.

Major Terms of the Air Compliance Agreement: The Air Compliance Agreement establishes specific obligations that will apply to all participating AFOs and includes limited, conditional covenants not to sue and liability releases from EPA. AFOs that choose to participate will agree to pay a civil penalty which is based on the size of the AFO. The penalty ranges from $200 to $1,000 per AFO, depending upon the number of animals at the AFO. The threshold ranges depend upon the species of animal. The total penalty is capped and ranges from $10,000 for a participant having 10 or fewer farms to $100,000 for a participant having over 200 farms. Participation in the Air Compliance Agreement and payment of a penalty will not be an admission of liability by an AFO.

In addition, participating AFOs, except for certain contract growers, will be responsible for the payment of approximately $2,500 per farm into a fund to conduct a nationwide emission monitoring study and for making their facilities available for emissions testing under the nationwide monitoring study. In general, the monitoring study, which is described more fully below and in Attachment B to the Air Compliance Agreement (included as an appendix to this notice), will undertake over a 2-year period, emissions monitoring at a representative sample of animal housing structures and manure storage and treatment units across the country. At the end of the monitoring study, EPA will use the data from the monitoring study and any other relevant, available data to develop emissions estimating methodologies. These emissions estimating methodologies will then be used by the AFO industry to estimate their annual emissions.

EPA's publication of the emissions estimating methodologies will trigger the obligation of participating AFOs to determine their emissions and to comply with all applicable CAA requirements, including applying for all required permits, and to make any requisite hazardous release notices under CERCLA and EPCRA. EPA expects to apply these emission estimating methodologies to all AFOs, whether or not they participate in the Air Compliance Agreement.

Please note that the Air Compliance Agreement does not define the scope of the term ''source'' as it relates to animal agriculture and farm activities. The Agency plans to provide guidance on this issue at the conclusion of the monitoring study.

Any AFO that fails to comply with the requirements as described will not receive the limited conditional release and covenant not to sue described later in this notice. Any conditional release and covenant not to sue offered as part of the Air Compliance Agreement will be revoked, and the AFO will remain liable for all past and ongoing violations.

AFOs that choose to participate in the Air Compliance Agreement and meet all its conditions will receive from EPA a limited release and covenant not to sue from liability for certain past and on-going CAA, CERCLA and EPCRA violations. The release and covenant not to sue will cover an AFO's liability for failing to comply with certain provisions of CERCLA, EPCRA, and the CAA up to the time the AFO reports its releases under CERCLA or EPCRA and applies for and receives the requisite CAA permits.

Participating AFOs will also be obligated to comply with all final actions and final orders issued by the State or local authority that address a nuisance arising from air emissions at the AFO. Failure to comply with the final action or order to correct the nuisance will void the conditional release and covenant not to sue offered in the Air Compliance Agreement.

Some very large AFOs will be required to immediately report estimated releases of NH_3, solely for purposes of the Air Compliance Agreement and not for purposes of reporting under CERCLA or EPCRA.

Finally, AFOs that install waste-to-energy systems that convert animal manure into electricity will get an extra 180 days to apply for CAA permits and to make the requisite hazardous release notifications under CERCLA and EPCRA.

Terms Applicable to Contract Growers and Integrators: Many AFOs, particularly in the swine, broiler chicken, and turkey industry, raise livestock for separate corporations that usually own the animals, provide feed and medical services, and that process and market the meat products. In those cases, the AFO that grows the animals is referred to as a ''contract grower,'' and the separate corporation that processes and markets the meat products is referred to as an ''integrator.''

The Air Compliance Agreement includes provisions that will allow both integrators and contract growers to participate. Among other things, a contract grower will not be responsible for the payment of monies into the monitoring fund if an integrator has already agreed to be responsible for the payment of such monies. The contract grower/integrator provisions in the Agreement will also apply to AFOs that produce milk under contract with a cooperative or that supply heifers to dairy herds owned by a separate entity.

Emissions Monitoring Study: The purpose of the monitoring study is to: collect data and aggregate it with appropriate existing emissions data; analyze the monitoring results; and create tools (*e.g.,* tables and/or emission models) that AFOs could use to determine whether they emit pollutants at levels that require them to apply for permits under the CAA or submit notifications under CERCLA or EPCRA. The monitoring study is designed to generate scientifically credible data to provide for the characterization of emissions from all major types of AFOs in all geographic areas where they are located. To provide a framework for the monitoring study and to generate a comprehensive field sampling plan from representative farms in the United States, a protocol (Attachment B to the Air Compliance Agreement, included as part of the Appendix to this notice) was developed through the collaborative efforts of industry experts, university scientists, government scientists, and other stakeholders knowledgeable in the field. Although the protocol development was facilitated by the U.S. EPA and the U.S. Department of Agriculture (USDA), it represents the opinions of the scientists, government experts, and stakeholders involved. In addition, there was extensive internal review and input by representatives from U.S. EPA's Office of Enforcement and Compliance Assurance, Office of Air and Radiation, and Office of Research and Development.

As recommended in the NAS 2003 report, ''Air Emissions From Animal Feeding Operations,'' and paraphrased here, EPA and USDA should for the short term, initiate and conduct a coordinated research program designed to produce a scientifically sound basis for measuring and estimating air emissions from AFOs. Specific recommendations being addressed with the protocol that were discussed in the NAS 2002 Interim Report [2] are related to direct measurements at sample farms by utilizing information on the relationships between air emissions and animal types, nutrient outputs, and manure handling practices; conducting studies to evaluate the extent to which ambient atmospheric concentrations of the various pollutants of interest are consistent with estimated emissions; and using scientifically sound and practical protocols for measuring pollutant concentration emission rates. EPA's longer-term strategy involves additional recommendations from the NAS which entail developing a process-based model that considers the entire animal production process. The data collected in the monitoring study will lay the groundwork for developing these more process-related emission estimates. However, as with any large and complex effort, this work must be conducted over a period of years.

Under the Air Compliance Agreement, the participating AFOs will set up an umbrella nonprofit entity (referred to here as the nonprofit organization or NPO) to handle the funds contributed by the individual participating facilities. The NPO will then subcontract to a Science Advisor and independent monitoring contractor (the ''IMC'') to run the nationwide monitoring study. The IMC will submit a proposed plan for review and approval by EPA that is consistent with the monitoring protocol outlined in Attachment B to the Air Compliance Agreement. The proposed plan would also include a list of recommended candidate facilities to be monitored.

EPA will review and approve or disapprove the proposed plan within 30 days of receiving it from the IMC. If the proposed plan is disapproved, EPA will specifically state why the plan is being disapproved and what changes need to be made. The IMC will then have 30 days to modify the proposed plan to address the changes required by EPA and to submit the modified plan to EPA for review and approval. Once the plan is approved, all participating AFOs, through the NPO, will be obligated to fully fund the nationwide emission monitoring study and to establish a binding contract with the IMC to carry out the approved plan.

Monitoring will be conducted pursuant to EPA protocols and be done by a fleet of mobile labs purchased by the NPO and overseen by the IMC hired to run the study. Emissions at the facilities will be monitored at both buildings and waste lagoons and will include H_2S, VOC, PM and NH_3. Monitoring will occur at facilities across the country to get a representative sample of the facility types in major geographic regions. EPA expects that the monitoring will begin in 2005 and continue for 2 years. Two years of monitoring is the minimum time needed because emissions from AFOs can vary greatly over the course of a year and may vary significantly from year to year. The data generated during the monitoring study will be made fully available to the general public.

Technical experts on emissions monitoring at EPA and from a number of universities believe that monitoring the farms described in the attached protocol will provide sufficient data to get a valid sample that is representative of the vast majority of the participating AFOs. Significantly increasing the number of farms to be monitored would be prohibitively expensive and would not add substantially to the value of the data collected.

Throughout the course of the monitoring study, EPA will review and analyze the data as they are generated. EPA will use the data generated from the monitoring and all other available, relevant data to develop methodologies for estimating annual emissions from swine, dairy, egg laying, broiler chicken, and turkey AFOs. Within 18 months after the conclusion of the nationwide emissions monitoring study, EPA expects that it will publish on its Web site, on a rolling basis as work is completed, the methodologies for estimating emissions for the vast majority of AFOs in the eligible animal groups.

[2] NAS, ''The Scientific Basis For Estimating Air Emissions From Animal Feeding Operations.'' Interim Report, National Research Council, 2002.

Relationship Between the Air Compliance Agreement and Other Actions the Agency May Take To Address AFO Air Emissions

In September 2001, EPA's Office of Air and Radiation (OAR) and the USDA jointly commissioned the NAS to prepare a report recommending approaches for characterizing emission profiles and identifying emission mitigation techniques, including:

- Review industry characterization and use of model farms;
- Evaluate emission factors, measurement methods, and modeling approaches;
- Recommend fate and transport methodologies;
- Identify mitigation technologies and management practices; and
- Identify critical research needs.

The NAS concluded its report in 2003 with a number of key findings, some of which are quoted here from the report:

* * * EPA and USDA should use process-based mathematical models with mass balance constraints for nitrogen-containing compounds, methane, and hydrogen sulfide to identify, estimate, and guide management changes that decrease emissions for regulatory and management programs.

* * * measurement protocols, control strategies and management techniques must be emission and scale specific * * *

* * * There is a general paucity of credible scientific information on the effects of mitigation technologies on concentrations, rates, and fates of air emissions from AFOs. However, the implementation of technically and economically feasible management practices (*e.g.,* manure incorporation into soil) designed to decrease emissions should not be delayed.

* * * scientifically sound and practical protocols for measuring air concentrations, emission rates, and fates are needed for the various elements (nitrogen, carbon, sulfur), compounds (*e.g.,* ammonia [NH_3], CH_4, H_2S) and particulate matter.

The EPA is planning to proceed in a manner that is consistent with the recommendations of the NAS. EPA's plan is focused on the achievement of real environmental benefits to protect public health and the environment while supporting a sustainable agricultural sector. EPA plans to continue to work with USDA and others to:

- Collect data and information related to operations at AFOs;
- Determine emissions from individual AFOs; and
- Identify appropriate regulatory and nonregulatory (*e.g.,* best management practices, environmental management systems, etc.) responses for each farm.

The Air Compliance Agreement with individual AFOs is an integral component of the data collection and emissions determinations of this effort. As discussed earlier in this notice, as part of the Air Compliance Agreement, AFOs will fund a 2-year nationwide emissions monitoring study to gather emissions data and mass balance information from AFOs. It is anticipated that emissions monitoring will be conducted at farms that represent the major animal sectors, types of operations, and different geographic locations.

The information gathered during the emissions monitoring study will be used to more adequately characterize emissions from individual farms. Individual farm emissions estimates will be used, along with other relevant information, to determine appropriate regulatory and nonregulatory responses to address the emissions. As recommended in the NAS report, EPA will then move forward to develop a process-based model which entails considering the entire animal feeding process. Similar to other large and complex efforts, the work must be conducted in stages over a period of years. The monitoring study, and the resulting emission estimating methodology, is a critical first step in this multiyear effort.

Conclusion: EPA believes that the Air Compliance Agreement will be the quickest and most effective way to address the current uncertainties regarding air emissions from AFOs and to bring the entire AFO industry into compliance with the CAA, section 103 of CERCLA, and section 304 of EPCRA. The Air Compliance Agreement's terms, conditions, and protections will be available only to those facilities that are eligible, that elect to participate, and that comply with the terms of the agreement. As appropriate, nonparticipants, and those who sign up but later drop out due to noncompliance with the Air Compliance Agreement, will be subject to enforcement actions in which significant penalties and injunctive relief could be sought for violations of the CAA, section 103 of CERCLA, and section 304 of EPCRA.

This notice describes an Air Compliance Agreement that EPA is offering certain types of AFOs and requests public comment on that Agreement. No new rights or obligations on behalf of EPA or any other party are created beyond what is contained in a fully executed and approved Agreement.

This notice provides a general description of the Air Compliance Agreement. Interested parties are encouraged to carefully read the Air Compliance Agreement and its Attachments (included as an Appendix to this notice) to fully understand what is being offered to AFOs. To the extent that provisions of the Air Compliance Agreement and its Attachments are inconsistent with this notice, the provisions of the Agreement will prevail.

Participation in the Air Compliance Agreement is voluntary. The Agreement is not intended to affect in any way EPA's ability to respond to an imminent and substantial endangerment to public health, welfare or the environment. Participation in the Agreement will not provide protection for criminal violations of environmental laws. In addition, the Agreement is not intended to affect the ability of States or citizens to enforce compliance with nonfederally enforceable State laws applicable to AFOs.

EPA recognizes that State and local agencies are undertaking efforts to improve emissions estimation methodologies for AFOs. EPA supports continued action to improve emissions information for all source categories and will use the best information available as we implement our programs. EPA also supports State and local efforts to demonstrate improved emissions reduction strategies and recognizes the value of State or local control requirements tailored to the needs of specific geographic areas. For these reasons, nothing in the Air Compliance Agreement will be used to delay or otherwise interfere with the implementation and enforcement of existing State statutes that eliminate exemptions to CAA requirements for agricultural sources of air pollution.

Request for Public Comment: As stated above, EPA is requesting comment on the Air Compliance Agreement, with particular emphasis on implementation of the Agreement. All comments should be submitted within 30 days of the date of this notice.

Earlier drafts of the Air Compliance Agreement have been circulated publicly. EPA requested and received comments on those drafts from, among others, representatives of state governments, environmental groups, local citizens' groups, and the AFO industry. Those comments were considered, and, where appropriate, changes were made to the draft agreement. In addition, the emission monitoring protocol for the nationwide emission monitoring program (Attachment B to the Agreement, included in the Appendix to this notice) was developed by a group of 30 leaders in the area of AFO air emissions, including scientists from EPA, the AFO industry, environmental groups, and several colleges and universities.

Sign Up Procedures: To participate in the Air Compliance Agreement, eligible AFOs should sign the Air Compliance Agreement and fill out Attachment A to the Agreement (the Farm and Emission Unit Information Sheets). A copy of the Agreement and all attachments can be downloaded from EPA's Web site at: *http://www.epa.gov.* The signed Agreement should be returned to EPA during the 90-day sign-up period that commences on the date of this notice. EPA will not sign the Agreement and forward it to EPA's Environmental Appeals Board for approval until after the conclusion of the public comment period.

Owners and operators of AFOs who want to sign Air Compliance Agreements with EPA will need to provide all of the following information on the Farm and Emission Unit Information Sheets for each AFO they would like to be covered by the Compliance Agreement:

- The name and address of the Respondent signing the Air Compliance Agreement;
- The name of each facility to be covered by the Agreement;
- The name of the owner and operator of each facility, including whether it is a contract grower facility;
- The location of all the covered facilities;
- The animal type and number of animals at each facility;
- The type of animal housing structure and number of structures at each facility;
- The type of manure handling system and the number of manure storage areas (*e.g.,* manure piles or lagoons) at each facility;
- The capacity and surface area, if applicable, of all manure storage areas at each facility; and,
- A description of any emission control technology or nontraditional manure treatment systems at each facility.

Signed Air Compliance Agreements, including all properly filled out attachments, should be sent to: Special Litigation and Projects Division (2248A), Attn: Air Compliance Agreements, Office of Regulatory Enforcement, Office of Enforcement and Compliance Assurance, U.S. EPA, 1200 Pennsylvania Ave., NW., Washington, DC 20460.

At the end of the sign-up period, EPA will determine whether a sufficient number of AFOs of each species have elected to participate. The determination will be based on whether the number of participants is sufficient to fully fund the monitoring study and whether the number of participants for each type of operation is sufficient to provide a representative sample to monitor. If the total number of participants is insufficient, EPA will not sign any Air Compliance Agreements and will not proceed with the monitoring study. If, however, the total number of participants is sufficient but there are an insufficient number of AFOs with a particular species or type of operation, EPA may decline to sign Air Compliance Agreements with those particular operations and decide not to proceed with the monitoring of that type of operation. No later than 30 days after the end of the sign-up period, EPA will decide whether to proceed with all, part, or none of the monitoring study and will sign the Air Compliance Agreements and forward them to EPA's Environmental Appeals Board (EAB) for final approval.

Additional Sources of General Information: To find out more about compliance with the CAA or section 103 of CERCLA, or EPCRA 304, please access the EPA Web site at

http://www.epa.gov/air/oaq_caa.html/

or

http://www.epa.gov/superfund/action/law/cercla.htm.

Dated: January 21, 2005.

Thomas V. Skinner,

Assistant Administrator for Enforcement.

Jeffrey R. Holmstead,

Assistant Administrator for Air and Radiation.

Appendix 1—Air Compliance Agreement With Attachments A and B; Attachment A—Farm Information Sheet; Attachment B—National Air Emissions Monitoring Study Protocol

Appendix 1

In the Matter of [Participating Company]; Consent Agreement and Final Order; CAA–HQ–2005–XX; CERCLA–HQ–2005–XX; EPCRA–HQ–2005–XX

I. Preliminary Statement

1. The United States Environmental Protection Agency (EPA) and [Participating Company] (Respondent) voluntarily enter into this Consent Agreement and Final Order (Agreement) to address emissions of air pollutants and hazardous substances from certain animal feeding operation(s) that may be subject to requirements of the Clean Air Act, the hazardous substance release notification provisions of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the emergency notification provisions of the Emergency Planning and Community Right-to-Know Act (EPCRA).

2. The purpose of this Agreement is to ensure that [Participating Company] complies with applicable requirements of the Clean Air Act and applicable release notification provisions of CERCLA and EPCRA. To that end, this Agreement requires [Participating Company], among other things, to be responsible for the payment of funds towards a two-year national air emissions monitoring study that will lead to the development of Emissions-Estimating Methodologies that will help animal feeding operations determine and comply with their regulatory responsibilities under the Clean Air Act, CERCLA and EPCRA.

3. This Agreement is issued pursuant to section 113 of the Clean Air Act, 42 U.S.C. 7413 (federal enforcement of the Clean Air Act); sections 103 and 109 of CERCLA, 42 U.S.C. 9603 and 9609 (federal enforcement of notification provisions); section 325 of EPCRA, 42 U.S.C. 11045 (federal enforcement of EPCRA notification provisions); and 40 CFR 22.13(b) and 22.18(b)(2) and (3) (procedural requirements for the quick resolution and settlement of matters before the filing of an administrative complaint). Respondent's participation in this Agreement is not an admission of liability. At this time, Respondent neither admits nor denies that any of its Farms is subject to CERCLA or EPCRA reporting or Clean Air Act permitting requirements, or is in violation of any provision of CERCLA, EPCRA or the Clean Air Act. The execution of this Agreement by Respondent is not an admission that any of its agricultural operations has been operated negligently or improperly, or that any such operation is or was in violation of any federal, state or local law or regulation.

4. As described more specifically in paragraphs 26 and 35 below, this Agreement resolves Respondent's civil liability for certain potential violations of the Clean Air Act, CERCLA and/or EPCRA at [Participating Company's] Farm(s) listed in Attachment A. The release and covenant not to sue found in paragraph 26 resolves only violations identified and quantified by applying the Emissions-Estimating Methodologies developed using data from the national air emissions monitoring study described herein.

5. This Agreement is one of numerous identical agreements between EPA and animal feeding operations across the nation. Through these agreements, EPA and participating animal feeding operations aim to assist in the development of improved Emissions-Estimating Methodologies for air emissions from animal feeding operations and to ensure that all animal feeding operations are in compliance with applicable Clean Air Act, CERCLA and EPCRA requirements. Notwithstanding any other provision, this Agreement shall not delay or interfere with the implementation or enforcement of State statutes that eliminate exemptions to Clean Air Act requirements for agricultural sources of air pollution.

6. EPA may decline to enter into this Agreement with animal feeding operations (and their successors and assigns) that have been notified by EPA or a State that they currently may be subject to a Federal or State Clean Air Act, CERCLA section 103 or EPCRA section 304(a) enforcement action.

II. Definitions

7. Unless otherwise defined herein, terms used in this Agreement shall have the same meaning given to those terms in the Clean

Air Act, 42 U.S.C. 7401 *et seq.*; the Comprehensive Environmental Response, Compensation, and Liability Act, 42 U.S.C. 9601 *et seq.*; the Emergency Planning and Community Right-to-Know Act, 42 U.S.C. 11001 *et seq.,* and the implementing regulations promulgated thereunder. For purposes of this Agreement only, the following terms shall have the following meanings.

8. The term ''Agricultural Waste'' or ''Agricultural Livestock Waste'' means Livestock manure, wastewater, litter including bedding material for the disposition of manure, and egg washing or milking center waste treatment and storage. ''Agricultural Livestock'' or ''Livestock'' include dairy cattle, swine and/or poultry among others.

9. The term ''Contract Grower'' means the owner or operator of a Farm that raises Livestock or produces milk or eggs under a contract with Respondent.

10. The term ''Emissions-Estimating Methodologies'' means those procedures that will be developed by EPA, based on data from the national air emissions monitoring study and any other relevant data and information, to estimate daily and total annual emissions from individual Emission Units and/or Sources. These methodologies will be published on EPA's Web site (*http://www.epa.gov*).

11. The term ''Emission Unit'' means any part of a Farm that emits or may emit Volatile Organic Compounds (VOCs), Hydrogen Sulfide (H_2S), Ammonia (NH_3), or Particulate Matter (TSP, PM10 and PM2.5) and is either: (a) A building, enclosure, or structure that permanently or temporarily houses Agricultural Livestock; or (b) a lagoon or installation that is used for storage and/or treatment of Agricultural Waste.

12. The term ''Environmental Appeals Board'' or ''EAB'' means the permanent body with continuing functions designated by the Administrator of EPA under 40 CFR 1.25(e) whose responsibilities include approving administrative settlements commenced at EPA Headquarters.

13. The term ''Facility'' shall mean ''CERCLA Facility and/or EPCRA Facility.'' The term ''CERCLA Facility'' shall have the meaning given that term under section 101(9) of CERCLA, 42 U.S.C. 9601(9). The term ''EPCRA Facility'' shall have the meaning given that term under section 329(4) of EPCRA, 42 U.S.C. 11049(4).

14. The term ''Farm'' shall mean the production area(s) of an animal feeding operation, adjacent and under common ownership, where animals are confined, including animal lots, houses or barns; and Agricultural Waste handling and storage facilities. ''Farm'' does not include land application sites for Agricultural Waste. This definition is limited exclusively to this Agreement and establishes no precedent for the interpretation of any statute, regulation or guidance.

15. The term ''Nuisance'' is defined according to State and local common law, statutes, regulations, ordinances or usage.

16. The term ''Permitting Authority'' means the local, State or Federal government entity with jurisdiction to require compliance with the permitting requirements of the Clean Air Act.

17. The term ''Independent Monitoring Contractor'' means a person or entity that is not affiliated with Respondent or any other animal feeding operation, that has sufficient experience and expertise to fully implement the national air emissions monitoring study described herein, that meets the qualifications set forth in Attachment B to this Agreement, and that is approved by EPA.

18. The term ''Qualifying Release'' means a release that triggers a reporting requirement under section 103 of CERCLA or section 304 of EPCRA.

19. The term ''Respondent'' means [Participating Company].

20. The term ''Source'' shall have the meaning given to the term ''stationary source'' in the implementing regulations of the Clean Air Act at 40 CFR 52.21(b)(5) through (6), as interpreted by applicable guidance issued by EPA.

21. The term ''State or Local Authority'' means a state or local government entity with jurisdiction over Respondent's Farm(s).

III. Consent Agreement

22. EPA and Respondent have agreed to resolve this matter by executing this Agreement, as further set forth herein.

23. Respondent asserts that it either owns, operates or otherwise controls, or contracts with Contract Growers who own, operate or otherwise control, the Farm(s) listed in Attachment A to this Agreement. Respondent agrees that this Agreement applies only to the Farm(s) that are listed in Attachment A and contain one or more Emission Unit(s) as defined in paragraph 11 and described in Attachment A.

24. For the purpose of this proceeding, Respondent does not contest the jurisdiction of the Environmental Appeals Board.

25. As specified more fully below, Respondent consents to pay a civil penalty, to be responsible for the payment of funds to the national air emissions monitoring study, and to facilitate implementation of the monitoring study, including making certain Farms available for monitoring.

26. In consideration of Respondent's obligations under this Agreement and subject to the limitations and conditions set forth in paragraphs 27–30, 33, 34, 36, 37 and 43, EPA releases and covenants not to sue Respondent, with respect to the listed Emission Units located at the Farm(s) in Attachment A, for:

(A) Civil violations of the permitting requirements contained in Title I, Parts C and D, and Title V of the Clean Air Act, and any other federally enforceable State implementation plan (SIP) requirements for major or minor sources based on quantities, rates, or concentrations of air emissions of pollutants that will be monitored under this Agreement, namely Volatile Organic Compounds (VOCs), Hydrogen Sulfide (H_2S), Particulate Matter (TSP, PM10 and PM2.5), and Ammonia (NH_3); and

(B) civil violations of CERCLA section 103 or EPCRA section 304 from air emissions of Hydrogen Sulfide (H_2S) or Ammonia (NH_3) that are not singular unexpected or accidental releases such as those caused by an explosion, fire or other abnormal occurrence.

27. (a) The releases and covenants not to sue described in paragraphs 26 and 35 extend only to violations of the requirements identified in those paragraphs and apply only to emissions from Agricultural Waste at Emission Units (as defined in paragraph 11). They do not extend to any other requirements including but not limited to: (i) Any possible requirements that relate to emissions generated by other equipment or activities co-located at the Farm, including waste-to-energy systems; (ii) activities at open cattle feedlots for beef production; (iii) Clean Air Act permitting requirements triggered by an expansion of a Farm beyond its design capacity as of the date this Agreement is executed; or (iv) requirements that are not triggered by the quantity, concentration or rate of emission of Volatile Organic Compounds (VOCs), Hydrogen Sulfide (H_2S), Particulate Matter (TSP, PM10 and PM2.5) or Ammonia (NH_3), including work practice requirements and equipment specifications.

(b) The release and covenants not to sue in paragraphs 26 and 35 shall apply to the liability of a Contract Grower with respect to a Farm if and only if the Contract Grower executes an Agreement with EPA covering that Farm.

28. The release and covenant not to sue described in paragraph 26 covers Respondent's liability for violations with respect to an Emission Unit located at a Farm listed in Attachment A if and only if Respondent complies with all applicable requirements of this Agreement and, with respect to that Emission Unit:

(A) Within 120 days after receiving an executed copy of this Agreement, for any Farm that confines more than 10 times the ''large Concentrated Animal Feeding Operation'' threshold of an animal species,[3] the animal feeding operation provides to the National Response Center (NRC) and to the relevant local and state emergency response authorities written notice describing its location and stating substantially as follows:

This operation raises [species] and may generate routine air emissions of Ammonia in excess of the reportable quantity of 100 pounds per 24 hours. A rough estimate of those emissions is [__] pounds per 24 hours, but this estimate could be substantially above or below the actual emission rate, which is being determined through an ongoing monitoring study in cooperation with the U.S. Environmental Protection Agency. When that emission rate has been determined by this study, we will notify you of any reportable releases pursuant to CERCLA section 103 or EPCRA section 304. In the interim, further information can be obtained by contacting [insert contact information for a person in charge of the operation].

[3] This definition is being used in this Agreement solely for the purpose of determining the penalty assessed, and for certain limited reporting purposes. ''Large Concentrated Animal Feeding Operation'' is defined as: (a) 2,500 swine weighing more than 55 pounds; (b) 10,000 swine weighing less than 55 pounds; (c) 82,000 laying hens; (d) 125,000 broilers; (e) 55,000 turkeys; or (f) 700 mature dairy cows or 1000 dairy heifers.

Respondent shall provide to EPA, at the address in paragraph 64, a copy of any written notice given pursuant to this subparagraph. This interim notice shall be provided to satisfy the terms of this Agreement only and is not intended to establish a precedent or standard for reporting under CERCLA or EPCRA.

(B) Where application of the Emissions-Estimating Methodologies establishes that no Clean Air Act requirements or that no CERCLA or EPCRA notifications are required for a Source or Facility, Respondent shall so certify to EPA in writing within 60 days after EPA publishes Emissions-Estimating Methodologies applicable to the Emission Units at the Source or Facility. Any such certification shall identify each Source or Facility covered by the certification and the Emissions-Estimating Methodology used to calculate its emissions. If EPA notifies Respondent that this certification is not correct because application of the Emissions-Estimating Methodologies indicates that the Source or Facility is subject to such requirements, Respondent shall have 90 days from notification by EPA to comply with the provisions in paragraph 28(C) or submit, in writing, clear and convincing proof to EPA that Respondent's certification is correct.

(C) Respondent complies with all of the applicable requirements set forth below:

(i) Within 120 days after EPA has published Emissions-Estimating Methodologies applicable to the Emission Units at Respondent's Source, Respondent submits all Clean Air Act permit applications required by the Permitting Authority for the Source, based on application of those Emissions-Estimating Methodologies.

(a) For a Source whose emissions exceed the major source threshold in Title I, Part C or D, based on the area's attainment status (*e.g.,* in an attainment area, more than 250 tons per year of a regulated pollutant), this requirement includes:

(1) Applying for and ultimately obtaining a permit that contains a federally enforceable limitation or condition that limits the potential to emit of the Source to less than the applicable major source threshold for the area where the Source is located; or,

(2) Installing best available control technology (BACT) in an attainment area, or technology meeting the lowest achievable emission rate (LAER) if the Source is located in a nonattainment area, as determined by and in accordance with the schedule provided by the Permitting Authority for the Source, and obtaining a federally enforceable permit that incorporates an appropriate BACT or LAER limit. For the purposes of this Agreement, compliance with the requirements found in 40 CFR 52.21(k) through (p) is not a condition of the release and covenant not to sue described in paragraph 26. Nothing in this paragraph is intended to limit a state or local government's authority to impose applicable permitting requirements. Emission reductions that result from installing BACT or LAER may not be used in netting calculations to offset emissions from a future modification to the Source.

(b) The annual emissions from a particular Source shall be determined based on Respondent's current operating methods and on the maximum number of animals housed at the Source at any time over the 24 months prior to EPA's publication of the applicable Emissions-Estimating Methodologies.

(c) Respondent promptly and fully responds to any notices of deficiency (or other equivalent notification that the permit application is incomplete or incorrect) issued by the Permitting Authority with respect to the permit application(s).

(d) As described in paragraph 34, below, Farms installing waste-to-energy systems will have an additional 180 days to submit the above-referenced permit applications.

(ii) Within 120 days after EPA has published Emissions-Estimating Methodologies applicable to Emission Units at Respondent's Facility, Respondent reports all Qualifying Releases of Hydrogen Sulfide (H_2S) and Ammonia (NH_3) in accordance with section 103 of CERCLA and section 304 of EPCRA.

(iii) Respondent timely installs all emission control equipment and implements all practices required by this Agreement or contained in the Clean Air Act permits issued in response to the applications submitted in accordance with subparagraph (i) of this paragraph.

(iv) Respondent provides EPA with written certification that it has timely installed all emission control equipment and implemented all practices required by this Agreement or contained in the Clean Air Act permits issued in response to the applications submitted in accordance with subparagraph (i) of this paragraph, within 30 days of meeting those requirements or within 30 days of acknowledgment of compliance by the Permitting Authority if such acknowledgment is required.

(D) Respondent's failure to comply with any of the above requirements in this paragraph at any particular Source shall affect the release and covenant not to sue for the noncompliant Source only and shall not affect the release and covenant not to sue for Respondent's complying Sources. In addition, Respondent's failure to comply with any of the above requirements in this paragraph at any particular Facility shall affect the release and covenant not to sue for the noncompliant Facility only and shall not affect the release and covenant not to sue for Respondent's complying Facilities.

29. For any Farm listed in Attachment A that is owned and operated by a Contract Grower, Respondent is not responsible for complying with paragraphs 28, 30 and 60. However, the release and covenant not to sue described in paragraph 26 covers Respondent's liability for violations with respect to the Emission Units located at such Farm if, and only if, the Contract Grower complies with all the requirements of paragraph 28. The Contract Grower's liability for violations with respect to the Emission Units located at that Farm is not covered by any of the releases and covenants not to sue set forth in this Agreement. However, the Contract Grower may enter its own agreement with EPA (thus becoming a respondent in its own agreement) and obtain similar conditional releases and covenants not to sue with respect to the emission units at its farm.

30. In addition, the release and covenant not to sue described in paragraph 26 covers violations with respect to the Emission Units located at a Farm listed in Attachment A if, and only if, Respondent complies with the following requirements, with respect to that Farm:

(A) During the period in which potential violations at the Farm are covered by the release and covenant not to sue as described in paragraph 26, Respondent complies with all final actions and final orders issued by the State or Local Authority that address a Nuisance arising from air emissions at the Farm and that are:

(i) Issued after Respondent has been given notice and opportunity to be heard (including any available judicial review) as required by applicable state or local law; and,

(ii) Issued during the time period in which potential violations at the Farm are covered by the release and covenant not to sue as described in paragraph 26.

(B) Within 60 days of coming into compliance with the final action or order of the State or Local Authority, Respondent provides EPA with written certification that Respondent has complied with the final action or final order and within the time schedule approved by the State or Local Authority.

31. Respondent agrees that the statute of limitations for all claims covered by the release and covenant not to sue in paragraph 26 will be tolled from the date this Agreement is approved by the EAB and until the earlier of: (a) 120 days after Respondent files the required certifications in accordance with paragraph 28(B) or paragraph 28(C)(iv), or (b) December 31, 2011. This time period can be extended by written agreement of both parties.

32. EPA will publish Emissions-Estimating Methodologies within 18 months of the conclusion of the monitoring period and will publish such Methodologies on a rolling basis as soon as they are developed. If EPA's Science Advisory Board determines that EPA is unable to publish Emissions-Estimating Methodologies applicable to a particular type of Emission Unit in Attachment A within 18 months of the conclusion of the monitoring period because of inadequate data, EPA will attempt to resolve such data problems as soon as possible. EPA's inability to publish an Emissions-Estimating Methodology for a particular type of Emission Unit in Attachment A within 18 months shall have no effect on any other deadline or provision of this Agreement for any other type of Emission Unit listed in Attachment A.

33. As a condition of its participation in this Agreement, Respondent agrees to accept, regardless of any collateral proceeding, the study protocols employed in and the emissions data developed by, the national air emissions monitoring study conducted under the plan described in paragraphs 53 through 63 below. If Respondent challenges the protocols employed or the data developed, the release and covenant not to sue described in paragraph 26 of this Agreement will become null and void and will have no effect on Respondent's past or future liability.

34. Respondent may choose to install and operate one or more systems that process

Agricultural Livestock Waste to produce electricity (a waste-to-energy system). If Respondent selects this option, it will have, with respect to a Farm at which such a system will be installed, an additional 180 days to comply with the requirements of paragraph 28 provided the following requirements are met, with respect to that Farm:

(A) Within 120 days after EPA has published Emissions-Estimating Methodologies applicable to the Emission Units at Respondent's Source, Respondent provides EPA with a written certification that it intends to install a waste-to-energy system, identifies each Farm at which such a system is or will be installed, and describes the type of waste-to-energy system installed and the percentage by volume of Agricultural Waste processed by the system at each Farm.

(B) The waste-to-energy system processes at least 50 percent of the Agricultural Waste by volume produced at the Farm.

(C) Respondent makes each Farm at which a waste-to-energy system is installed available for inspection by EPA.

(D) Respondent agrees to operate the waste-to-energy system for 24 months from the first date of operation or the date EPA publishes Emissions-Estimating Methodologies for the Emission Units at Respondent's Source, whichever is later. If during that 24-month period Respondent has to shut down the waste-to-energy system, the benefits of this paragraph will still be applicable if Respondent has made all reasonable efforts to maintain and operate the system.

(E) Respondent obtains, within applicable time limits, all required federal and state permits needed to construct and operate the waste-to-energy system at the Farm.

35. Subject to paragraphs 27, 37 and 43, if during the pendency of the nationwide monitoring study, Respondent promptly reports and corrects a civil violation of a federally approved SIP or an approved Federal implementation plan (FIP) resulting from emissions of Volatile Organic Compounds (VOCs), Hydrogen Sulfide (H_2S), Ammonia (NH_3), or Particulate Matter (TSP, PM10, and PM2.5) from a Farm listed in Attachment A that causes or contributes to a violation of any provision of the federally approved SIP that requires compliance with an ambient air quality standard at the Farm's property line, EPA releases and covenants not to sue Respondent for the reported and corrected violation if, and only if, the conditions set forth below are met:

(A) Unless Respondent first learned of the violation through a notice from EPA, Respondent provides notice of the violation to EPA and the applicable Permitting Authority within 21 days of Respondent's discovery of the violation or the final order of the EAB approving this Agreement, whichever is later;

(B) Respondent corrects the violation, including making any necessary adjustments to its operations at the Farm to prevent the violation from happening again, within 60 days after notice is given by Respondent or EPA as described in subparagraph (A) above. If the violation cannot reasonably be corrected within 60 days, Respondent must, before the end of the 60-day time period, submit a plan that is ultimately approved by EPA and the applicable Permitting Authority to correct the violation and must comply with the approved plan in accordance with the specified schedule. Within 30 days of correcting the violation, Respondent shall submit a written certification to EPA indicating that it has corrected the violation in accordance with the approved plan; and,

(C) The violation is not a repeated violation that Respondent previously reported to EPA pursuant to this paragraph. Respondent may rectify the loss of the above release and covenant not to sue for the first instance of a repeat violation; however, if it pays a stipulated penalty of $500 a day for each day that the Farm exceeds the ambient air quality standard, and it meets the requirements of subparagraphs (A) and (B), except that the time to correct the violation shall be 30 days instead of 60 days.

36. All certifications that Respondent must submit to comply with this Agreement shall include the following statement:

I certify under penalty of law that the information contained in this submittal to EPA is accurate, true, and complete. I understand that there are significant civil and criminal penalties for making false or misleading statements to the United States government.

The above statement shall be signed by a responsible official for the Respondent (*i.e.,* the owner if Respondent is a sole proprietorship, the managing partner if Respondent is a partnership, or a responsible corporate official if Respondent is an incorporated entity).

37. The releases and covenants not to sue described in paragraphs 26 and 35 do not cover Respondent's liability for any violation with respect to an Emission Unit located at a Farm if Respondent fails to comply with any of the applicable requirements of this Agreement with respect to that Emission Unit, including the limitations and conditions in paragraphs 26–29 and 33–34 above. The releases and covenants not to sue described in paragraphs 26 and 35 cover only violations with respect to the Emission Units located at the Farm that occur before the earlier of: (a) The date Respondent submits the last required certification covering those Emission Units; or (b) 2 years after Respondent submits any permit applications pursuant to paragraph 28(C)(i). This time period can be extended by a period not to exceed 6 months upon written agreement of both parties provided the Respondent's action or inaction is not the cause of any delay in obtaining a permit.

38. EPA will notify Respondent if EPA has determined that it cannot develop Emissions-Estimating Methodologies for any Emission Units listed in Attachment A.

(A) This notice shall identify (individually or by category) Emission Units, Sources and/or Facilities for which Emissions-Estimating Methodologies cannot be developed.

(B) For the Emission Units identified in such a notice:

(i) No certification under paragraph 28 shall be required for those Emission Units and any other related Emission Units that comprise the Source or Facility; and,

(ii) The releases and covenants not to sue described in paragraphs 26 and 35 shall cover potential violations that occur on or before 120 days after the date the notice is mailed, but shall not cover potential violations that occur more than 120 days after that date.

(C) Notice required under this paragraph will be deemed proper if sent via U.S. mail postage prepaid to the address listed in Attachment A.

39. The execution of this Agreement is not an admission of liability by Respondent, and Respondent neither admits nor denies that it has violated any provisions of the Clean Air Act, CERCLA or EPCRA.

40. Respondent waives its right to request an adjudicatory hearing on this Agreement, and its right, created by Clean Air Act section 113(a)(4), to confer with the Administrator before this Agreement takes effect. Respondent further waives its right to seek judicial review of the penalty assessed in paragraph 48.

41. Respondent and EPA represent that they are duly authorized to execute this Agreement, and that the persons signing this Agreement on their behalf are duly authorized to bind Respondent and EPA, respectively, to the terms of this Agreement.

42. Respondent agrees not to claim or attempt to claim a federal income tax deduction or credit covering all or any part of the civil penalty paid to the United States Treasurer. Any payments made in connection with the national air emissions monitoring study do not constitute a fine or penalty and are not paid in settlement of any actual or potential liability for a fine or penalty.

43. This Agreement is without prejudice to all rights of EPA against Respondent with respect to any claims not expressly covered by the releases and covenants not to sue contained in paragraphs 26 and 35. This Agreement does not limit in any way EPA's authority to restrain Respondent or otherwise act in any situations that may present an imminent and substantial endangerment to public health, welfare or the environment. In addition, the releases and covenants not to sue in paragraphs 26 and 35 do not cover any criminal liability.

44. With respect to any claims not expressly released herein, in any subsequent administrative or judicial proceeding initiated by the United States for injunctive relief, penalties, recovery of response costs or other relief relating to a Farm listed in Attachment A, Respondent shall not assert, and may not maintain, any defense or claim based upon the principles of waiver, res judicata, collateral estoppel, issue preclusion, claim-splitting or other defenses based upon any contention that the claims raised by the United States in the subsequent proceeding were or should have been brought in the instant proceeding.

45. Respondent recognizes that EPA may not execute this Agreement if EPA determines that there will be inadequate funding for the national air emissions monitoring study or if EPA determines that there is inadequate representation of eligible animal groups and types of Farms, Facilities or Emission Units.

46. Respondent and EPA stipulate to the issuance of the proposed Final Order below.

[Participating Company], Respondent

By: _____
(Print Name): _____
Title: _____
Dated: _____

U.S. Environmental Protection Agency, Complainant

By: _____
Title: _____
Dated: _____

IV. Final Order

It is hereby ordered and adjudged as follows:

Compliance

47. Respondent shall comply with all terms of this Agreement.

Penalty

48. Respondent is hereby assessed a penalty based on the number and size of the Farms listed in Attachment A as follows:

(A) If Respondent has only one Farm and that Farm is below the ''large Concentrated Animal Feeding Operation'' threshold for that animal species,[4] Respondent is assessed a penalty of $200.

(B) All other Respondents are assessed a penalty of $500 per Farm, unless the Farm contains more than 10 times the total number of animals that defines the ''large Concentrated Animal Feeding Operation'' threshold. For those Farms, Respondent is assessed a penalty of $1,000 per Farm.

(C) The total penalty paid by Respondent shall not exceed:

$10,000 if Attachment A lists 1–10 Farms

$30,000 if Attachment A lists 11–50 Farms

$60,000 if Attachment A lists 51–100 Farms

$80,000 if Attachment A lists 101–150 Farms

$90,000 if Attachment A lists 151–200 Farms

$100,000 if Attachment A lists more than 200 Farms.

49. Respondent shall pay the assessed penalty no later than 30 calendar days from the date an executed copy of this Agreement is received by Respondent (hereinafter referred to as the ''Agreement Date'').

50. All penalty assessment monies under this Agreement shall be paid by certified check or money order, payable to the United States Treasurer, and mailed to: U.S. Environmental Protection Agency (Washington, DC Hearing Clerk), P.O. Box 360277, Pittsburgh, Pennsylvania 15251–6277. A transmittal letter, indicating Respondent's name, complete address, and this case docket number must accompany the payment. Respondent shall file a copy of the check and of the transmittal letter by mailing it to: Headquarters Hearing Clerk, US EPA, 1921 Jefferson Davis Hwy, Crystal Mall #2, Room 104, Arlington, VA 22202.

51. Failure to pay the penalty assessed under this Agreement may subject Respondent to a civil action pursuant to section 113(d)(5) of the Clean Air Act, 42 U.S.C. 7413(d)(5), to collect any unpaid portion of the monies owed, together with interest, handling charges, enforcement expenses, including attorney fees and nonpayment penalties. In any such collection action, the validity, amount or appropriateness of this Order or the penalty assessed hereunder is not subject to review.

52. Pursuant to 42 U.S.C. 7413(d)(5) and 31 U.S.C. 3717, Respondent shall pay the following amounts:

(A) *Interest.* Any unpaid portion of the assessed penalty shall bear interest at the rate established pursuant to 26 U.S.C. 6621(a)(2) from the date an executed copy of this Agreement is received by Respondent; provided, however, that no interest shall be payable on any portion of the assessed penalty that is paid within 30 days of the Agreement Date.

(B) *Attorney Fees, Collection Cost, Nonpayment Penalty.* Should Respondent fail to pay on a timely basis the amount of the assessed penalty, Respondent shall be required to pay, in addition to such penalty and interest, the United States' enforcement expenses, including but not limited to attorney fees and costs incurred by the United States for collection proceedings, and a quarterly nonpayment penalty for each quarter during which such failure to pay persists. Such nonpayment penalty shall be 10 percent of the aggregate amount of Respondent's outstanding penalties and nonpayment penalties accrued from the beginning of such quarter.

(C) *Payment.* Interest, attorney fees, collection costs, and nonpayment penalties related to Respondent's failure to timely pay the assessed penalty shall be made in accordance with subparagraphs (A) and (B) of this paragraph.

Monitoring Fund

53. Respondent has a shared responsibility for funding and implementing the national air emissions monitoring study described in paragraphs 53 through 63.

(A) Respondent individually shall be responsible for paying the lesser of: (a) $2,500 for each Farm listed in Attachment A to this Agreement; or (b) Respondent's pro rata share of the amount needed to fully fund the monitoring study (''Full Funding Level''), including any unfunded balance of the monitoring study, consistent with the provisions of paragraph 62. Respondent's pro rata share shall be based on the number of Farms listed in Attachment A divided by the total number of discrete Farms of the same species that share responsibility for funding the national monitoring study. The Full Funding Level is the amount of money actually needed to fully and adequately fund the monitoring study described in this Agreement. The Full Funding Level shall be initially estimated within 60 days of the Agreement date and shall be included as part of the proposed plan to conduct the monitoring described in paragraph 55. The estimated Full Funding Level shall be used to determine the pro rata share of the monitoring fund payment for which Respondent is initially responsible. Any shortfalls that occur because the estimated Full Funding Level was less than the actual Full Funding Level shall be handled in accordance with this paragraph and paragraph 62.

(B) Respondent shall have no obligation to contribute money to the national monitoring study on behalf of a Farm listed in Attachment A if: (a) That Farm has been listed as a contract farm in another agreement that is identical to this agreement except for the respondent involved, and (b) the respondent to the other Agreement has agreed to be responsible for the payment of monies into the monitoring study for that Farm.

54. Respondent shall have met its shared responsibility for funding and implementing the national air emissions monitoring study, including any individual payments by Respondent under paragraph 53 or 62 if, and only if: (a) A nonprofit entity is established for the purposes set forth below; (b) the monitoring fund obligations to the nonprofit entity are fully satisfied; (c) the nonprofit entity enters into a contract with an Independent Monitoring Contractor (the ''IMC'') that obligates the IMC to fulfill the requirements set forth in paragraphs 55 through 59 and 62 of this Agreement; and, (d) Respondent grants access to Farms listed in Attachment A in accordance with paragraphs 60 and 61. The purposes of the nonprofit entity shall include: collecting and holding Respondent's contributions to the national air emissions monitoring study, purchasing and holding title to research equipment, contracting with an IMC to conduct the monitoring study, and other responsibilities.

55. The contract identified in paragraph 54 shall require the IMC to submit to EPA, within 60 days of the Agreement date, a detailed plan to conduct the nationwide monitoring study set forth in Attachment B. The proposed plan shall:

(A) Identify the IMC and its qualifications, including the qualifications of any subcontracted science advisors, for implementing the national air emissions monitoring study;

(B) Be consistent with, expand the explanation of, and include all of the elements of the monitoring study outline set forth in Attachment B to this Agreement, including the requirements that: (1) All monitoring be completed within 2 years of EPA's approval of the monitoring study; (2) a comprehensive quality assurance program be implemented as part of the study; and (3) the emissions to be monitored will be Particulate Matter (TSP, PM10, and PM2.5), Hydrogen Sulfide (H_2S), Ammonia (NH_3), and Volatile Organic Compounds (VOCs);

(C) Identify the Farms to be monitored and the justification for including those Farms based on the specifications for the monitoring set forth in Attachment B; and,

(D) Require the IMC to submit detailed quarterly reports to EPA and to the entity described in paragraph 54. Those reports shall discuss the IMC's progress in implementing the approved monitoring plan, including what it did during the previous 3 months and what it intends to do during the next three months. The IMC shall submit quarterly reports starting with the end of the first calendar quarter (*i.e.,* March 31, June 30, September 30 or December 31) after the proposed monitoring plan is approved by EPA, unless the plan is approved by EPA with less than 30 days left in the current

[4] Ibid.

calendar quarter. If that occurs, the IMC shall submit the first quarterly report at the end of the next calendar quarter. The quarterly reports shall continue through the end of the calendar quarter during which the national monitoring study is completed.

56. EPA will review and approve or disapprove the proposed plan within 30 days of receiving it from the IMC. If the proposed plan is disapproved, EPA will specifically state why it is being disapproved and what changes need to be made. The IMC shall then have 30 days from the date EPA disapproves the proposed plan to modify it and to submit the modified plan to EPA for review and approval. If the IMC does not submit a plan that is ultimately approved by EPA, the releases and covenants not to sue set forth in paragraphs 26 and 35 of this Agreement shall be null and void.

57. Once the plan is approved, the contract between the nonprofit entity identified in paragraph 54 and the IMC shall require the IMC to fully implement the approved plan in accordance with the approved schedule. Failure of the IMC to implement the approved plan in accordance with the approved schedule, unless specifically excused by EPA in writing, shall nullify the releases and covenants not to sue set forth in paragraphs 26 and 35 of the Agreement. The estimated Full Funding Level monies shall be transferred to the nonprofit entity described in paragraph 54 within 60 days of EPA's approval of the monitoring plan.

58. The contract identified in paragraph 54 shall require the IMC to schedule periodic meetings (either by phone or in person) with EPA, and additional meetings upon request by EPA or the IMC, to discuss progress in implementing the approved plan. The IMC shall be required to promptly inform EPA of any problems in implementing the approved plan that have occurred or are anticipated to occur or of any adjustments that may be needed. No changes may be made to the approved plan without the written consent of EPA.

59. All emissions data generated and all analyses of the data made by the IMC during the nationwide monitoring study shall be provided to EPA as soon as possible in a form and through means acceptable to EPA. The parties agree that all emissions data will be fully available to the public, and that Respondent waives any right to claim any privilege with respect to such data.

60. Respondent agrees to make the Farms listed in Attachment A available for emissions monitoring under the national air emissions monitoring study if the Farm is chosen as a monitoring site under the approved plan. As stated in paragraph 29, if the Farm is owned by a Contract Grower, this requirement does not apply. However, a Contract Grower who enters into its own agreement with EPA (thus becoming a respondent in its own agreement) is subject to this requirement.

61. Respondent also agrees to give EPA or its representative access to those Farms for the purpose of verifying their suitability for monitoring or to observe monitoring conducted under the approved nationwide monitoring plan. EPA agrees that prior to entering a Farm, it will comply with proper biosecurity measures as are normal and customary. Nothing in this Agreement is intended in any way to limit EPA's inspection, monitoring, and information collection authorities under the Clean Air Act, CERCLA or EPCRA.

62. If, prior to completion of the national air emissions monitoring study, it appears that there will be insufficient funds to complete the study, the IMC shall notify EPA of this problem within 30 days of making this determination. The notice shall contain a detailed explanation of why there are insufficient funds, account for all money spent, and identify how much more money is needed to complete the monitoring study. If Respondent is not required under paragraph 53 to contribute or secure the contribution of additional money to the national monitoring study that will be sufficient to complete the monitoring study, the IMC or the nonprofit entity described in paragraph 54 shall make all reasonable efforts to find additional funding to complete the monitoring study. The IMC or the nonprofit entity described in paragraph 54 shall advise EPA of the efforts to locate additional funding and shall not commit to the use of additional funding sources without the prior approval of EPA. If, despite the best efforts of Respondent or its representative, the IMC, or the nonprofit entity described in paragraph 54, the national monitoring study cannot be completed due to lack of funding, then the releases and covenants not to sue set forth in paragraphs 26 and 35 of this Agreement will no longer be in effect. For Farms with animal types for which sufficient funds were provided to fully and adequately fund their portion of the national monitoring study, EPA shall make reasonable efforts to avoid terminating the releases and covenants not to sue set forth in paragraphs 26 and 35.

63. If, after completion of the national monitoring study, there is unspent money in the national monitoring fund, the IMC shall notify EPA within 90 days of completion of the monitoring study. The notice shall contain a detailed explanation of why there are unspent funds, including an accounting of all money spent to implement the national monitoring study and how much is left unspent. The notice shall also include a proposed plan for distribution of the leftover money.

64. All certifications required by this Agreement shall be submitted to: Special Litigation and Projects Division (2248A), Attn: AFO/CAFO certifications, Office of Regulatory Enforcement, 1200 Pennsylvania Ave., NW., Washington, DC 20460.

65. Except for a Farm for which Respondent, or the Contract Grower, is able to certify under paragraph 27(B), this document constitutes an ''enforcement response'' as that term is used in the Clean Air Act Penalty Policy and an ''enforcement action'' as that term is used in the EPCRA/CERCLA Penalty Policy.

66. Each party shall bear its own costs, fees, and disbursements in this action, except where explicitly stated as otherwise in this Agreement.

67. The provisions of this Agreement shall be binding on Respondent, its officers, directors, employees, agents, successors and assigns.

68. This Agreement is not binding and without legal effect unless and until approved by the Environmental Appeals Board.

It is so ordered.

Dated this_____ day of _____, 2005.

_____

Environmental Appeals Judge
Environmental Appeals Board
U.S. Environmental Protection Agency

Attachment A to the Consent Agreement

This Attachment identifies and describes the Farms and Emission Units covered by this Agreement. This Agreement has no effect on any Farm or Emission Unit not specifically listed on this Attachment. The terms used in this Attachment shall have the meaning given to those terms in the Agreement.

The attached Farm Information Sheets and Emission Unit Information Sheets provide information about each Farm and Emission Unit(s) to be covered by this Agreement. A separate form for each Farm and each Emission Unit covered by the Agreement is attached below and as such is an integral part of this Attachment. By identifying a Farm for coverage under the Agreement, Respondent is asserting that the Farm meets the definition of a Farm in the Agreement and contains at least one Emission Unit as defined in the Agreement. Also by identifying an Emission Unit at a Farm for coverage under the Agreement, Respondent is asserting that the Emission Unit meets the definition of an Emission Unit in the Agreement. Unless Respondent identifies a Contract Grower for a Farm, Respondent is also asserting it owns, operates or otherwise controls the Farm.

I certify under penalty of law that the information contained in this submittal to EPA is accurate, true, and complete. I understand that there are significant civil and criminal penalties for making false or misleading statements to the United States Government.

[Signature] _____

[Name] [Title] [Date]
[Participating Company]
[Participating Company's Address]

Farm Information Sheet (Example) (Fill Out One Sheet for Each Farm)

Name of Farm: _____

Is the Farm owned and operated by a Contract Grower or is otherwise a contract farm?

_____yes _____no

Name of Contract Grower (if applicable): ____
Location: _____
(street address, city, county, state)

Animal Type (check all that apply):
_____Poultry (layers)
_____Poultry (broilers)
_____Poultry (turkeys)
_____Dairy Cattle (heifers or milking cattle)
_____Swine (nursery, sow or finisher)
_____Other (please identify)

For all Farms that Respondent owns and/or operates, provide a Farm sketch/diagram that numbers or otherwise identifies all Emission Units listed on this Farm Information Sheet.

Emission Unit Information Sheet (Example) (Fill Out One Sheet for Each Emission Unit)

Name of Farm where Emission Unit is located: _____
Unit name and/or number: _____
Date placed in service: _____
Design capacity (No. of animals or No. of gallons): _____

If the Emission Unit is a manure storage and treatment system in use at the Farm, check all that apply:

_____pull plug/flush/in-ground manure storage basin (if lagoon, specify type)
_____deep pit/in-ground manure storage basin (if lagoon specify type)
_____shallow pit/open manure storage
_____shallow pit/closed manure storage
_____deep pit/open manure storage
_____deep pit/closed manure storage
_____manure belt/closed manure storage
_____manure belt/open manure storage
_____flush/open manure storage
_____flush/closed manure storage
_____scrape/open manure storage
_____scrape/closed manure storage
_____other (briefly describe)

If the Emission Unit is a building, enclosure, or structure that permanently or temporarily houses Agricultural Livestock, check all that apply with respect to the ventilation type:

_____natural
_____mechanical
_____other (please describe)

Emission Control Technology (please list type and briefly describe if applicable):

Attachment B—National Air Emissions Monitoring Study Protocol; Overview & Summary

Executive Summary

This document provides an overview and summary of a monitoring study protocol for collecting air emissions data from the egg, broiler chicken, turkey, dairy and swine industries. This protocol was developed through a collaborative effort of industry experts, university scientists, government scientists, and other stakeholders knowledgeable in the field. Although the effort was facilitated by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA), this product represents the opinions of the scientists, government experts, and stakeholders involved. In addition, there was extensive internal review and input by representatives from U.S. EPA's Office of Enforcement and Compliance Assurance, Office of Air and Radiation, and Office of Research and Development.

This protocol is designed to provide a framework for development of a comprehensive field sampling plan for collecting quality-assured air emission data from representative livestock and poultry farms in the U.S. As recommended in the National Academy of Sciences (NAS) 2003 report,[5] and paraphrased here, * * * EPA and USDA should for the short term, initiate and conduct a coordinated research program designed to produce a scientifically sound basis for measuring and estimating air emissions from AFOs. Specific recommendations being addressed with this protocol are related to direct measurements at sample farms; utilizing information on the relationships between air emissions and animal types, nutrient outputs, manure handling practices, animal numbers, climate, and other factors, conducting these studies to evaluate the extent to which ambient atmospheric concentrations of the various pollutants of interest are consistent with estimated farm emissions; and using scientifically sound and practical protocols for measuring pollutant emission rates. The research program will involve additional recommendations from the NAS, which entails developing a process-based model that considers the entire animal production process. The data collected in the monitoring study will lay the groundwork for developing these more process-related emission estimates. However, as with any large and complex effort, this work must be conducted over a period of years.

In the development of this protocol, several alternate techniques were considered. The Science Advisor, in designing the monitoring study, may choose to use an alternate technique that is deemed most appropriate for a particular study unit. (A listing of alternate techniques can be found later in this protocol.) Thus, this protocol does not exclude use or consideration of any measurement methods or technologies that have been demonstrated to be scientifically sound and/or widely accepted for application to collecting air emissions data from the relevant farm sectors. However, the use of alternate techniques is dependent upon EPA approval of a comprehensive study design and budget.

The benchmark data collected and subsequent analyses and interpretation will allow EPA and livestock and poultry producers to reasonably determine which farms are subject to the regulatory provisions of the Clean Air Act and reporting requirements of CERCLA and EPCRA. Following sound scientific principles and using accepted instrumentation and methods, the monitoring study will collect new data from a number of farms across the country and will also evaluate existing emissions data from other selected studies that may meet EPA quality assurance criteria. Together, they will form a database to which additional studies of air emissions and the effectiveness control technologies can be compared.

EPA will review and approve (as described in the Consent Agreement) a comprehensive study design and plan, including a Quality Assurance Project Plan (QAPP), and a budget for all aspects of the monitoring study. The QAPP will outline appropriate procedures to ensure acceptable accuracy, precision, representativeness, and comparability of the data; and will specify the use of properly maintained and reliable instrumentation, sampling schedules, ready supply of spare parts, approved analytical methodologies and standard operation procedures, description of routine quality control (QC) checks, external validation of data, well-trained analysts, field blanks, electrical backups, audits, documentation and format of data submission, and other procedural requirements. Chain of custody documentation will be used for samples of particulate matter. Wetted materials for gas sampling will be Teflon®, stainless steel or glass. All sampling flow rates will be calibrated.

Monitoring Study Responsibilities

Several groups of management and technical staff will be responsible for success of the study. Their responsibilities are discussed here and graphically illustrated in the following flow chart.

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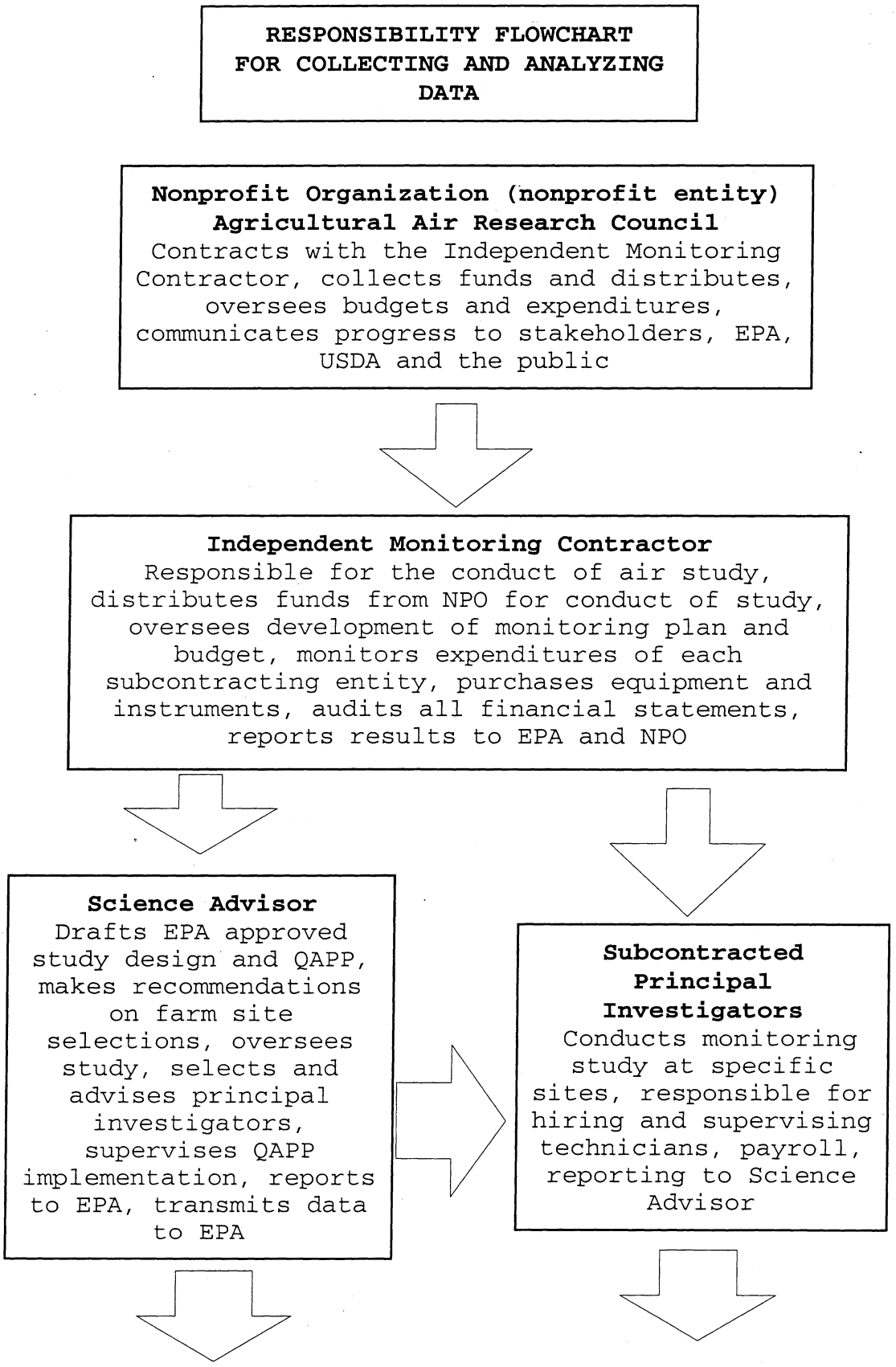
[5] NAS, ''Air Emissions From Animal Feeding Operations: Current Knowledge, Future Needs,'' National Research Council, 2003.



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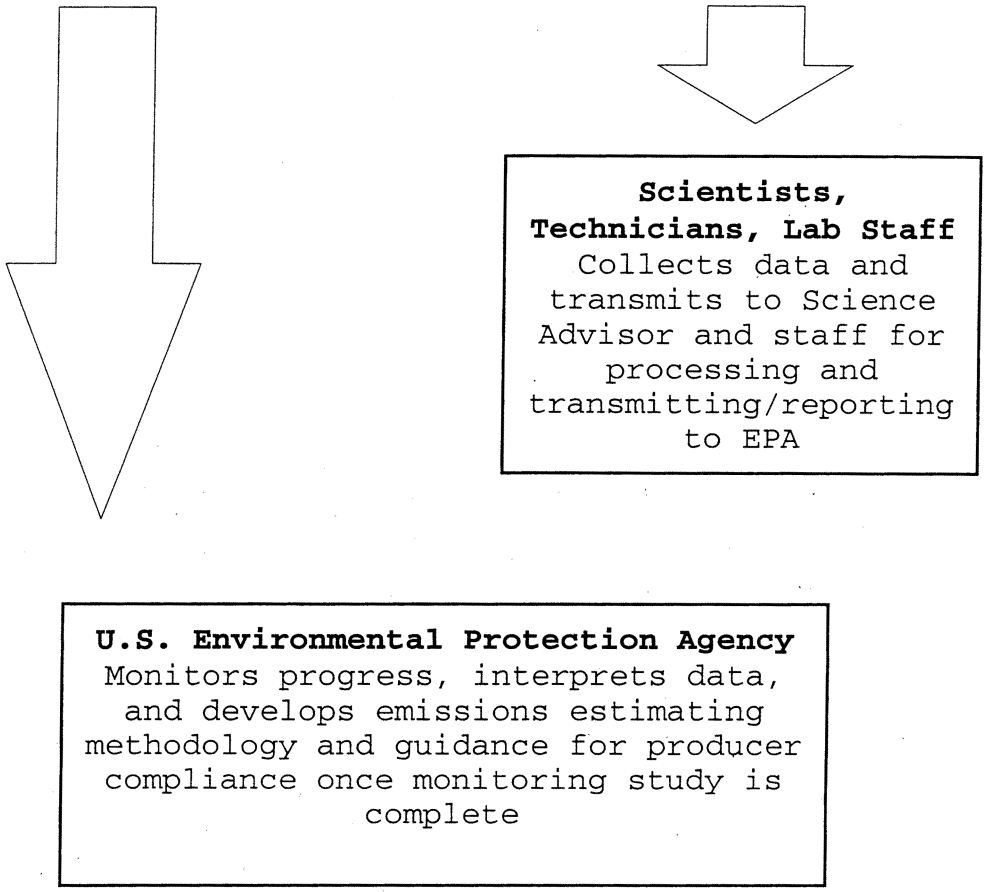
The Nonprofit Organization (NPO)

Industry has established a nonprofit entity (Agricultural Air Research Council, or AARC, and referred to as the nonprofit organization or NPO in the Consent Agreement) to handle the funds contributed by individual participating organizations. The NPO will operate like a company with voting members who elect a board of directors. The board of directors will meet regularly, receive reports on the progress of the study, approve the budget, and review audits of expenditures.



The NPO will be responsible for:

- Selecting the Science Advisor and Independent Monitoring Contractor (IMC);
- Holding and disbursing to the Independent Monitoring Contractor the funds necessary to complete the study according to its approved schedule, protocol and budget; and
- Communicating progress of the study to livestock and poultry producers, the media and other interested parties.

Selection of the IMC and Science Advisor

The NPO will choose an IMC and a Science Advisor based on qualifications, experience and familiarity with all components of the subject matter. The IMC and the Science Advisor must be well staffed with accountants and contract managers who are well versed in fiduciary management. EPA will review the NPO's selection. If EPA believes the qualification criteria have not been met, the NPO will have to select an alternate candidate.

Role of Science Advisor

To be technically qualified, the Science Advisor must have an extensive background in animal agriculture, including expertise in air emissions from animal feeding operations, data processing, and engineering processes. The Science Advisor will be responsible for drafting the comprehensive study design and QAPP and will submit these to EPA for approval. He/She will also coordinate with the IMC to oversee the work of the subcontracted Principal Investigators on the study. The Science Advisor will be employed by the IMC.

Roles of the Independent Monitoring Contractor (IMC)

Technical & Administrative Oversight

The IMC will be contractually responsible for the conduct of the study, and will:

- Be a separate organization from the industry that funds the study;
- Oversee the performance of the Science Advisor;
- Work closely with the Science Advisor in purchasing and assembling equipment and developing contracts for principal investigators; and
- Directly administer all subcontracts, supervise budgets and monitor expenditures, report progress and audit all financial statements.

Reporting on Study Progress

The IMC will:

- Report to EPA and the NPO on financial status of the study;
- Report to EPA and the NPO on the study progress; and
- Create a Web site specifically for the monitoring study and regularly post updates so that the public can follow the study's progress.

Role of the Principal Investigators

Principal investigators will carry out the monitoring at each site. They will report to the Science Advisor and, in turn, to the IMC.

Site Selection

The NPO will be comprised of representatives from the various animal husbandry industries who are knowledgeable of actual farming operations as related to the farm sites proposed for monitoring. They will compile a list of candidate farms from those operations participating in the Consent Agreement and submit the list to the Science

Advisor. The Science Advisor will then facilitate a process to select farms for monitoring based on a set of pertinent factors (*e.g.,* differing regional and climatic conditions, number of animals, different manure handling practices, and types of ventilation (natural vs. forced air)). In addition, logistical issues will be considered to reduce problems associated with egress and convenience; such as, is there a principal investigator located within 3 hours of the site, are there housing accommodations available within 1 hour of the site, is there internet access at the farm, and is 220 V power available? After comprehensive site plans are approved by EPA, the Science Advisor will supervise the set up of equipment at those farms selected, advise the cooperating farmers of their responsibilities, verify utilities, arrange for high speed computer data transmission service, initiate the study and implement the quality assurance project plan. As the study progresses, some investigators may want to alter their approved plans due to interim findings (such as, collecting redundant data or discovering a need to change equipment location). Any changes must be sent to the Science Advisor, with EPA notification and concurrence, for approval or disapproval.

Monitoring Plans by Species

On the following pages, the swine, egg layer, meat bird (broiler and turkey) and dairy air emissions study components are summarized. These were developed over several months by a peer review team of scientists, industry and other stakeholders. While the study scope varies from species to species in line with their data needs, available funding, and industry characteristics, the technologies and measurement methodologies selected by the team are consistent across species.

1. Air Emission Monitoring Plan for Swine

Introduction: Swine production phases include sows (breeding, gestation, and farrowing), nursery pigs, and finishing pigs. The buildings are either naturally ventilated or mechanically ventilated but many buildings have a combination of the two ventilation types. Manure treatment and/or storage generally consists of either basins (earthen, clay or synthetic lined earthen, concrete, glass lined steel) that store manure collected from the barn, or clay/synthetic lined earthen anaerobic treatment lagoons that treat and store manure. Manure collection systems with external manure storage/treatment are generally scrape, flush or pull-plug.

Overall, the U.S. hog inventory is located in three general regions. The five top Midwest swine states, IA, MN, IL, MO, and IN represent about 54 percent of the total inventory in the U.S. In the Southeast, NC, AR, VA, KY, and MS represent about 19 percent, and in the West, OK, NE, KS, SD, and TX represent about 15 percent.

Farm Selection for New Measurements: Swine production farm types are identified by region, production phase, ventilation type, and manure storage/treatment in Table 1. Farms selected will be characterized by criteria such as facility age, size, design and management, local topography and meteorology, swine diet and genetics. The farm should be reasonably isolated from other potential air pollution sources. Producers/farm managers must be willing to attend a training session, make changes as needed to accommodate the project, and maintain and share certain production records to facilitate data analysis and interpretation. Farms to be monitored will be further characterized using farm management data and samples collected for analysis of water, feed and manure. Farms will provide vital management information regarding ventilation controls/management and scheduling of barn activities such as manure management, animal load out, animal treatment, or feeding. At a minimum, water, feed and manure samples will be collected and analyzed for total nitrogen and total sulfur content.

TABLE 1.—FARM SITES IDENTIFIED AND PROPOSED FOR MONITORING

[G = gestation, F = farrowing, FI = finishing, MV = mechanically ventilated]

Production phase	Ventilation type	Number of units	Location of measurements	
			Barns or rooms	Storage/lagoon treatment
SOUTHEAST:				
Sow	MV	4	G & F.	
		Single or double		Lagoon.
Finisher	MV	4	FI.	
		Single or double		Lagoon.
MIDWEST:				
Sow	MV	4	G & F.	
		2		Deep pit.
Finisher	MV	4	FI.	
		1		Basin.
WEST:				
Sow	MV	4	G & F.	
		Single or double		Lagoon.

Methods: The mass balance technique will be used for measuring emissions from mechanically ventilated barns. Micrometeorological techniques will be used for manure storage/treatment systems located outside the barn. Table 2 summarizes the methods and emissions that will be measured from barns and manure storage/treatment systems. A maximum of five farms will be selected for barn measurements and six farms for manure storage/treatment system measurements. If possible, at least one farm will have measurements conducted at both the barns and the manure storage/treatment system.

TABLE 2.—SUMMARY OF EMISSIONS MEASUREMENTS AND METHODOLOGIES

Source units	Methodology	Targeted emissions	Number of farms	Number of units to monitor
Barn	Mass balance	NH_3, PM10, PM2.5 VOC, H_2S, TSP, CO_2.	[1] 5	20
Manure storage/treatment system	Micromet and Water 9	VOC, H_2S, NH_3	[1] 6	6

[1] See Table 1.

Barn Measurements: An on-farm instrumentation shelter (OFIS) will house the equipment for measuring pollutant concentrations at representative air inlets and outlets (primarily by air extraction for gases), barn airflows, operational processes and environmental variables. Sampling will be conducted for 24 months with data logged every 60 seconds. Data will be retrieved with network-connected PCs, formatted, validated, and delivered to EPA for subsequent calculations of emission factors. A multipoint air sampling system in the shelter will draw air sequentially from representative locations (including outdoor air) at the barns and deliver selected streams to a manifold from which on-line gas monitors draw their subsamples. Concentration of constituents of interest will be measured using the following methods:

- Ammonia will be measured using chemiluminescence or photoacoustic ingrared.
- Hydrogen sulfide will be measured with pulsed fluorescence.
- Carbon dioxide will be measured using photoacoustic infrared or equivalent.
- TSP will be measured using an isokinetic multipoint gravimetric method.
- PM2.5 will be measured gravimetrically with a federal reference method for PM2.5 at least for 1 month per site. It will be shared among sites.
- PM10 will be measured in real time using the tapered element oscillating microbalance (TEOM) at representative exhaust locations in the barn and ambient air.
- An initial characterization study of barn volatile organic compounds (VOC) will be conducted on 1 day during the first month at the first site (site 1). While total nonmethane hydrocarbons (NMHC) are continuously monitored using a dual-channel FID analyzer (Method 25A) along with building airflow rate, VOC will be sampled with replication at two barns using Silcosteel canisters, and all-glass impingers (EPA Method 26A). Each sample will be evaluated using concurrent gas chromatography-mass spectrometry (GC–MS) and GC/FID for TO 15 and other FID-responding compounds. VOC mass will be calculated as the sum of individual analytes. The 20 analytes making the greatest contribution to total mass will be identified during the initial characterization study. A sampling method that captures a significant fraction of the VOC mass will be chosen for the remainder of the study.
- The Method 26A sampling train is suitable for collecting samples for analysis of formaldehyde and acetaldehyde using NCASI 94.02, requiring only the addition of spectrophotometry for the detection of formaldehyde. These compounds will be measured during the initial characterization study and, if not found, will not be analyzed during subsequent measurements.
- Total VOC mass may be estimated (scaled) by multiplying the total carbon as determined by Method 25A by the molecular weight/carbon weight ratio derived from GC–MS or GC–FID speciation. This should account for the VOC that are not identified by GC methods due either to sampling bias or the analytical procedures used, although some error is anticipated due to the imprecise response of the Method 25A FID to oxygenated compounds. Acceptance of a scaling factor will depend on whether the Method 25A analyzer response is reasonable based on the manufacturer's stated response factors, bench-scale verification, or judgmental estimation of the mass of unaccounted for VOC.
- By the middle of the second month, the Science Advisor will report results of the initial VOC characterization to EPA with recommendations on the appropriateness and validity of the selected methodologies.
- Quarterly VOC samples using the selected VOC sampling method will occur at all sites, along with continuous Method 25A monitoring at site 1 throughout the study.
- Method 25A measurements will be corrected from an ''as carbon'' basis to a total VOC mass basis by multiplying them by the mean molecular weight per carbon atom established by GC–MS evaluations during applicable intervals of time.

Mechanically ventilated barn airflows will be estimated by continuously measuring fan operational status and building static pressure to calculate fan airflow from field-tested fan performance curves and by directly measuring selected fan airflows using anemometers. Specific processes that directly or indirectly influence barn emissions will be measured including pig activity, manure management/handling, feeding, and lighting. Environmental parameters including heating and cooling operation, floor and manure temperatures, inside and outside air temperatures and humidity, wind speed and direction, and solar radiation will be continuously monitored. Feed and water consumption, manure production and removal, swine mortalities, and animal production will also be monitored. As noted above, samples of feed, water, and manure will be collected and analyzed for total nitrogen and total sulfur. These data will enable the development and validation of process-based emission models in the future.

Table 1 identifies those types of farms where barn measurements will be taken to provide the needed data to complete the objectives of the monitoring study. A total of five farms will be selected as measurement sites. Two farms in the Southeast representing the sow and finishing phases of production with lagoon manure treatment will be selected. Two farms in the Midwest representing a finishing farm using an in-ground manure storage basin and a sow farm with a deep pit gestation barn will be selected. Finally, one farm in the West representing a sow farm with lagoon treatment will be selected. On each of the farms, four barns will have measurements taken simultaneously. Where applicable, the sow farms will have two farrowing rooms and two gestation barn emissions measured and on finishing farms, up to four barns will have emission measurements.

Lagoons: Micrometeorological techniques will be used to estimate emissions of NH_3, H_2S, and a limited number of VOC from lagoons. Fundamentally, this approach will use optical remote sensing (ORS) downwind and upwind of the lagoon coupled with 3-dimensional (3D) wind velocity measurements at heights of 2 and 12 meters (m). The concentrations of NH_3 and the various hydrocarbons will be made using open path Fourier transform infrared spectroscopy (FTIR). Measurements of H_2S (and NH_3) will be made using collocated open path UV differential optical absorption spectroscopy (UV–DOAS) systems. A team of two persons with two scanning FTIR systems, two single-path UV–DOAS systems, and two 3D sonics with supplementary meteorological instruments will move sequentially from farm to farm.

Each of two ORS systems will be oriented parallel to the storage side and approximately 10m from the lagoon edge. Each monostatic FTIR system will scan five retroreflectors; three mounted at 1m height equally dividing the length of the open path along the lagoon side and two mounted on a tower at heights of 6 and 12m located at the corners down the adjacent sides of the lagoon, resulting in scan lines down each of the four sides of the lagoon. Two bistatic single-path UV–DOAS systems will be located at a nominal 2m height within 2m laterally of the FTIR scan lines on the two sides of the lagoon oriented most closely with prevailing winds.

Emissions will be determined from the difference in upwind and downwind concentration measurements using two different methods—a Eulerian Gaussian approach and a Lagrangian Stochastic approach. The Lagrangian approach is based on an inverse dispersion analysis using a backward Lagrangian stochastic method (bLS). This approach will be used to estimate NH_3 emissions from concentration measurements made using the FTIR and UV–DOAS systems and the H_2S emissions from concentration measurements made using the UV–DOAS systems. The emission rate for NH_3 will be the ensemble average of the estimated emissions for each of the five FTIR scans with a corresponding error of the emission estimate. The Eulerian approach is based on a computed tomography (CT) method using Eulerian Gaussian statistics and a fitted wind profile from the two 3D sonics. Measurements of air and lagoon temperatures, wind speed and direction, humidity, atmospheric pressure, and solar radiation will also be conducted.

The bLS and CT emission estimates will be quality assured using tests of instrument response, wind direction and wind speed, stability, turbulence intensity, differences between the lagoon and the surrounding surface temperatures, differences in the mean and turbulent wind components with height, and the temporal variability in emissions. Emission estimates using the CT method will be qualified by the measured fraction of the estimated plume. To estimate VOC emissions from lagoons, samples of the lagoon liquid will be collected and analyzed for VOC, and the EPA model WATER9 will be used to estimate emissions based on measured VOC concentrations, pH, and other factors.

Quality Assurance/Quality Control (QA/QC): QA/QC processes will be established before data collection commences. The QA/QC procedures will be based on EPA guidelines and will include the use of properly maintained and reliable instrumentation, ready supply of spare parts,

approved analytical methodologies and standard operating procedures, external validation of data, well-trained analysts, field blanks, electrical backups, audits, and documentation. Calibration and maintenance logs will be maintained for each instrument.

2. Air Emission Monitoring Plan for Laying Hens

Introduction: Most U.S. layer housing types and manure management schemes fall under one of four categories: (1) High-rise houses with manure stored in the lower level and removed every 1 to 2 years, (2) belt houses with quasi-continuous manure transfer to an external storage/treatment facility, (3) shallow-pit houses with regular manure removal by scraping and temporary storage in uncovered piles, and (4) liquid-manure houses with manure flushed daily into a lagoon. The locations for four sites with specific housing types were recommended for the monitoring study with consideration of these four housing categories along with the potential impact of climatic differences and the geographical density of egg production (Table 3). Final site selections will also depend on site-specific factors including representativeness of facility age, size, design and management, and flock diet and genetics. The facility should be reasonably isolated from other air pollution sources and have potential for testing mitigation strategies. Producers/farm managers must be willing to attend a training session, make changes as needed to accommodate the project, and maintain and share certain production records to facilitate data analysis and interpretation.

TABLE 3.—RECOMMENDED TYPES AND LOCATIONS OF LAYING HEN HOUSES TO BE MONITORED IN THE MONITORING STUDY

Region/location	House 1—type	House 2—type
Midwest	High-rise with inside manure storage (2)	Manure belt (2) with manure storage.
West	Shallow pit with open manure storage	Manure belt with open manure storage.
South	High-rise with inside manure storage	High-rise with inside manure storage.
East	High-rise with inside manure storage	Flushing with anaerobic treatment lagoon

Methods: An on-farm instrument shelter (OFIS) will house the equipment for monitoring pollutant concentrations at representative air inlets and outlets (primarily by air extraction for gases), barn and manure shed airflows, and operational processes and environmental variables. Sampling will be conducted for 24 months with data logged every 60 seconds. Data will be retrieved with network-connected PCs, formatted, validated, and delivered to EPA for subsequent calculations of emission factors. A multipoint air sampling system in the OFIS will draw air sequentially from representative locations (including outdoor air) at the hen houses and manure sheds and deliver selected streams to a manifold from which gas analyzers draw their samples.

Selected pollutants will be evaluated as follows:

- Ammonia will be measured using chemiluminescence or photoacoustic infrared.
- Hydrogen sulfide will be measured with pulsed fluorescence.
- Carbon dioxide will be measured using photoacoustic infrared or equivalent.
- TSP will be measured using an isokinetic multipoint gravimetric method.
- PM2.5 will be measured gravimetrically with a federal reference method for PM2.5 at least for 1 month per site. It will be shared among sites.
- PM10 will be measured in real time using the tapered element oscillating microbalance (TEOM) at representative exhaust locations in the barn, ambient air, and at manure storage exhaust (if manure is disturbed).
- An initial characterization study of barn VOC will be conducted on 1 day during the first month at the first site (site 1). While total nonmethane hydrocarbons (NMHC) are continuously monitored using a dual-channel FID analyzer (Method 25A) along with building airflow rate, VOC will be sampled with replication at two barns using Silcosteel canisters, and all-glass impingers (EPA Method 26A). Each sample will be evaluated using concurrent gas chromatography—mass spectrometry (GC–MS) and GC/FID for TO 15 and other FID-responding compounds. VOC mass will be calculated as the sum of individual analytes. The 20 analytes making the greatest contribution to total mass will be identified during the initial characterization study. A sampling method that captures a significant fraction of the VOC mass will be chosen for the remainder of the study.
- The Method 26A sampling train is suitable for collecting samples for analysis of formaldehyde and acetaldehyde using NCASI 94.02, requiring only the addition of spectrophotometry for the detection of formaldehyde. These compounds will be measured during the initial characterization study and, if not found, will not be analyzed during subsequent measurements.
- Total VOC mass may be estimated (scaled) by multiplying the total carbon as determined by Method 25A by the molecular weight/carbon weight ratio derived from GC–MS or GC–FID speciation. This should account for the VOC that are not identified by GC methods due either to sampling bias or the analytical procedures used, although some error is anticipated due to the imprecise response of the Method 25A FID to oxygenated compounds. Acceptance of a scaling factor will depend on whether the Method 25A analyzer response is reasonable based on the manufacturer's stated response factors, bench-scale verification, or judgmental estimation of unaccounted for VOC mass.
- By the middle of the second month, the Science Advisor will report results of the initial VOC characterization to EPA with recommendations on the appropriateness and validity of the selected methodologies.
- Quarterly VOC samples using the selected VOC sampling method will occur at all sites, along with continuous Method 25A monitoring at site 1 throughout the study.
- Method 25A measurements will be corrected from an ''as carbon'' basis to a total VOC mass basis by multiplying them by the mean molecular weight per carbon atom established by GC–MS evaluations during applicable intervals of time.

Mechanically ventilated barn airflows will be estimated by continuously measuring fan operational status and building static pressure to calculate fan airflow from field-tested fan performance curves and by directly measuring selected fan airflows using anemometers. Specific processes that directly or indirectly influence air emissions will be measured including hen activity, feeding, and lighting. Measured environmental parameters include cooling system status, manure temperatures, inside and outside air temperatures and humidities, wind speed and direction, and solar radiation. Feed and water consumption, egg production, manure production and removal, and bird mortalities will also be monitored with producer assistance. Samples of feed, eggs, water, and manure will be collected and analyzed for total nitrogen and total sulfur. These data will enable the development and validation of process-based emission models in the future.

Quality assurance/quality control (QA/QC): QA/QC processes will be established before data collection commences. The QA/QC procedures will be based on EPA guidelines and will include the use of properly maintained and reliable instrumentation, ready supply of spare parts, approved analytical methodologies and standard operating procedures, external validation of data, well-trained analysts, field blanks, electrical backups, audits, and documentation. Instrument calibration and maintenance logs will be maintained.

3. Air Emission Monitoring Plan for Meat Birds (Broiler Chickens and Turkeys)

Introduction: Meat birds include broilers and turkeys and are raised in confinement barns on dirt or concrete floors covered with litter. Broiler barns are typically mechanically ventilated and turkey barns are typically naturally ventilated. The locations for three sites with specific housing types were recommended for the monitoring study with consideration of the potential impact of climatic differences and the geographical density of poultry meat production (Table 4). The final site selections will depend on site-

specific emission generating factors including representativeness of facility age, size, design and management; and flock diet and genetics. The facility should be reasonably isolated from other air pollution sources and have potential for testing mitigation strategies. Producers/farm managers must be willing to attend a training session, make changes as needed to accommodate the project, and maintain and share certain production records to facilitate data analysis and interpretation.

TABLE 4.—RECOMMENDED TYPES AND LOCATIONS OF MEAT BIRD HOUSES TO BE MONITORED

Region	Type	Ventilation type	Manure handling
Midwest	Turkey	Mechanical	Litter on floor.
West Coast	Broiler	Mechanical	Litter on floor.
Southeast	Broiler	Mechanical	Litter on floor.

Methods: An on-farm instrument shelter (OFIS) will house the equipment for monitoring pollutant concentrations at representative air inlets and outlets (primarily by air extraction for gases), barn airflows, and operational processes and environmental variables. Sampling will be conducted for 24 months with data logged every 60 seconds. Data will be retrieved with network-connected PCs, formatted, validated, and delivered to EPA for subsequent calculations of emission factors. A multipoint air sampling system in the OFIS will draw air sequentially from representative locations (including outdoor air) at the barns and deliver selected streams to a manifold from which gas analyzers draw their subsamples. The pollutants targeted for measurement will be evaluated as follows:

- Ammonia will be measured using chemiluminescence or photoacoustic infrared.
- Hydrogen sulfide will be measured with pulsed fluorescence.
- Carbon dioxide will be measured using photoacoustic infrared or equivalent.
- TSP will be measured using an isokinetic multipoint gravimetric method.
- PM2.5 will be measured gravimetrically with a federal reference method for PM2.5 at least for 1 month per site. It will be shared among sites.
- PM10 will be measured in real time using the tapered element oscillating microbalance (TEOM) at representative exhaust locations in the barn, and ambient air.
- An initial characterization study of barn VOC will be conducted on 1 day during the first month at the first site (site 1). While total nonmethane hydrocarbons (NMHC) are continuously monitored using a dual-channel FID analyzer (Method 25A) along with building airflow rate, VOC will be sampled with replication at two barns using Silcosteel canisters, and all-glass impingers (EPA Method 26A). Each sample will be evaluated using concurrent gas chromatography—mass spectrometry (GC–MS) and GC/FID for TO 15 and other FID-responding compounds. VOC mass will be calculated as the sum of individual analytes. The 20 analytes making the greatest contribution to total mass will be identified during the initial characterization study. A sampling method that captures a significant fraction of the VOC mass will be chosen for the remainder of the study.
- The Method 26A sampling train is suitable for collecting samples for analysis of formaldehyde and acetaldehyde using NCASI 94.02, requiring only the addition of spectrophotometry for the detection of formaldehyde. These compounds will be measured during the initial characterization study and, if not found, will not be analyzed during subsequent measurements.
- Total VOC mass may be estimated (scaled) by multiplying the total carbon as determined by Method 25A by the molecular weight/carbon weight ratio derived from GC–MS or GC–FID speciation. This should account for the VOC that are not identified by GC methods due either to sampling bias or the analytical procedures used, although some error is anticipated due to the imprecise response of the Method 25A FID to oxygenated compounds. Acceptance of a scaling factor will depend on whether the Method 25A analyzer response is reasonable based on the manufacturer's stated response factors, bench-scale verification, or judgmental estimation of the mass of unaccounted for VOC.
- By the middle of the second month, the Science Advisor will report results of the initial VOC characterization to EPA with recommendations on the appropriateness and validity of the selected methodologies.
- Quarterly VOC samples using the selected VOC sampling method will occur at all sites, along with continuous Method 25A monitoring at site 1 throughout the study.
- Method 25A measurements will be corrected from an ''as carbon'' basis to a total VOC mass basis by multiplying them by the mean molecular weight per carbon atom established by GC–MS evaluations during applicable intervals of time.

Mechanically ventilated barn airflows will be estimated by continuously measuring fan operational status and building static pressure to calculate fan airflow from field-tested fan performance curves and by directly measuring selected fan airflows using anemometers. Specific processes that directly or indirectly influence barn emissions will be measured including bird activity, manure handling, feeding, and lighting. Measured environmental parameters include heating and cooling operation, floor and manure temperatures, inside and outside air temperatures and humidity, wind speed and direction, and solar radiation. Feed and water consumption, manure production and removal, bird mortalities and bird production will also be monitored with producer assistance. Samples of feed, water, and manure will be collected and analyzed for total nitrogen and total sulfur. These data will enable the development and validation of process-based emission models in the future.

Quality Assurance/Quality Control (QA/QC): QA/QC processes will be established before data collection commences. The QA/QC procedures will be based on EPA guidelines and will include the use of properly maintained and reliable instrumentation, ready supply of spare parts, approved analytical methodologies and standard operating procedures, external validation of data, well-trained analysts, field blanks, electrical backups, audits, and documentation. Instrument calibration and maintenance logs will be maintained.

Open Manure Piles: Micrometeorological techniques will be used to estimate emissions of NH_3, H_2S, and a limited number of VOC from open manure piles. Fundamentally, this approach will use optical remote sensing (ORS) downwind and upwind of the source coupled with 3-dimensional (3D) wind velocity measurements at heights of 2 and 12m. The concentrations of NH_3 and the various hydrocarbons will be made using open path Fourier transform infrared spectroscopy (FTIR). Measurements of H_2S (and NH_3) will be made using collocated open path UV differential optical absorption spectroscopy (UV–DOAS) systems. A team of two persons with two scanning FTIR systems, two single-path UV–DOAS systems, and two 3D sonics with supplementary meteorological instruments will move sequentially from farm to farm.

Each of two ORS systems will be oriented parallel to the storage side and approximately 10m from the storage edge. Each monostatic FTIR system will scan five retroreflectors; three mounted at 1m height equally dividing the length of the open path along the storage side and two mounted on a tower at heights of 6 and 12m located at the corners down the adjacent sides of the source, resulting in scan lines down each of the four sides of the storage. Two bistatic single-path UV–DOAS systems will be located at a nominal 2m height within 2m laterally of the FTIR scan lines on the two sides of the manure storage area oriented most closely with prevailing winds.

Emissions will be determined from the difference in upwind and downwind concentration measurements using two different methods—an Eulerian Gaussian approach and a Lagrangian Stochastic approach. The Lagrangian approach is based on an inverse dispersion analysis using a backward Lagrangian stochastic method (bLS). This approach will be used to estimate NH_3 emissions from concentration measurements made using the FTIR and UV–DOAS systems and the H_2S emissions from concentration measurements made using the UV–DOAS systems. The emission rate for NH_3 will be the ensemble average of the

estimated emissions for each of the five FTIR scans with a corresponding error of the emissions estimate. The Eulerian approach is based on a computed tomography (CT) method using Eulerian Gaussian statistics and a fitted wind profile from the two-3D sonics. Measurements of air and storage temperatures, wind speed and direction, humidity, atmospheric pressure, and solar radiation will also be conducted.

The bLS and CT emission estimates will be quality assured using tests of instrument response, wind direction and wind speed, stability, turbulence intensity, differences between the storage and the surrounding surface temperatures, differences in the mean and turbulent wind components with height, and the temporal variability in emissions. Emission estimates using the CT method will be qualified by the measured fraction of the estimated plume.

4. Air Emissions Monitoring Plan for Dairy

Introduction: Dairy operations are naturally ventilated buildings with different manure handling systems. Measurement of the emissions from these operations is to be conducted with a series of measurement systems that provide a concentration measurement along a path that would be representative of the emission plume from the building. In order to estimate the emissions rate, it is necessary to couple the concentration with a measurement of the wind flow through the building or facility.

Manure storage sites could be either liquid (lagoons or slurry store) or piles of solid materials. These sites represent a different source area for emissions than buildings and will have to be considered separately in the measurement scheme.

The protocols that are developed for these studies are based on the following assumptions.

- The buildings are naturally ventilated and require a measurement method that captures the entire plume leaving the building. Mechanically ventilated facilities are beginning to enter the industry.
- Manure storage is separate from the building and will have to be measured as a distinct entity as part of the farm emission factor.
- The primary emissions sources are the housing and feeding areas and manure storage.
- There is a large diversity among dairy operations across the U.S., and although there are similar characteristics in general structure, the difference in building design, management, and climate require measurements of facilities that represent these factors.
- Measurements will be conducted at facilities which represent a diversity of systems in three general areas: California and Southern U.S., Northeast U.S., and Upper Midwest.

Milk production facilities include cattle (dry cows, lactating cows, and replacement heifers) and calves. The partially open barns range from those with windows and flaps to fully open free stalls. The buildings are most typically naturally ventilated except for some mechanically ventilated free stall and tie stall houses. The naturally ventilated barns range from partially open barns with windows and flaps to fully open free stalls. External manure storages generally consist of either earthen basins that store undiluted manure collected from the barn, or anaerobic treatment lagoons that treat manure that is diluted by a factor of about 5:1. Manure collection systems generally are either scrape or flush. Four dairy sites that consider climate and types of ventilation, manure collection, and manure storage have been identified by the dairy industry for collecting the comprehensive air emission data required by the monitoring study (Table 5). Final site selections will also depend on site-specific factors including representativeness of facility age, size, design and management; and cow diet and genetics. The facility should be isolated from other potential air pollution sources and have potential for testing mitigation strategies. Producers should be willing to make changes and keep extra records to facilitate a quality study.

TABLE 5.—RECOMMENDED TYPES AND LOCATIONS OF DAIRY FACILITIES TO BE MONITORED IN THIS STUDY

Region	Site type	Ventilation**	Manure collection	Manure storage
Midwest	Free stall	Natural	Flush or scrape	Lagoon.
Northeast	Free stall	Natural	Scrape	Basin.
West	Open* free stall	Natural	Flush	Lagoon.
South	Open free stall	Natural	Scrape	Basin.

*Cattle are free to walk outside in open free stall barns.
**If warranted by current or future use, mechanically ventilated barns may be monitored.

Methods

Naturally Ventilated Buildings: To achieve the most representative measurements of the emissions of the gases, it is recommended that a FTIR system be used to quantify the concentration of NH_3, CO_2, and, at levels above 50 parts per billion (ppb), H_2S in various paths through the atmosphere. A variation of the horizontal gradient method utilizing multiple paths through the airflow from the building, called radial plume mapping, measures the concentrations. The FTIR method is selected because of the extreme turbulence adjacent to the building and the lack of a defined plume in this area of the facility. A scanning system rotates among the paths to provide a serial measurement of the paths utilizing horizontally and vertically located retro-reflectors. A computer calculates the concentration gradients in real time. FTIR measurements are coupled to two sonic anemometers positioned at two locations along the length of the building to provide the wind flow measurements needed to estimate the flux from the measured concentrations.

Particulate load would be sampled using a series of particle samplers located with a sampling height of 5m adjacent to one of the sonic anemometer towers. These units would be designed to collect 2.5μm, 10μm and TSP values.

VOC would be sampled at the same position as the particulate samples for the building emissions. VOC emissions from the manure storage would be sampled with a system located both upwind and downwind of the manure storage system. These units would be positioned at heights of 2 and 12m.

Mechanically Ventilated Buildings: Mechanically ventilated buildings have begun to be used in the dairy industry. If warranted by current or future use, a mechanically ventilated facility will be included in this project. An on-site instrument shelter (OSIS) will house the equipment for monitoring pollutant concentrations at representative air inlets and outlets (primarily by air extraction), barn airflows, and operational processes and environmental variables. Sampling will be conducted for 24 months with data logged every 60 seconds. Data will be retrieved with network-connected PCs, formatted, validated, and delivered to EPA as hourly averages for subsequent calculations of emission factors. A multipoint air sampling system in the OSIS will draw air sequentially from representative locations (including ambient) at the barns and deliver selected streams to a manifold from which on-line gas monitors draw their subsamples. The pollutants targeted for measurement will be evaluated as follows:

- Ammonia will be measured using chemiluminescence or photoacoustic infrared.
- Hydrogen sulfide will be measured with pulsed fluorescence.
- Carbon dioxide will be measured using photoacoustic infrared or equivalent.
- TSP will be measured using an isokinetic multipoint gravimetric method.
- PM2.5 will be measured gravimetrically with a federal reference method for PM2.5 at least for 1 month per site. It will be shared among sites.
- PM10 concentrations will be measured in real time using the tapered element oscillating microbalance (TEOM) at representative exhaust locations in the barn and ambient air.
- An initial characterization study of barn VOC will be conducted on 1 day during the first month at the first site (site 1). While total nonmethane hydrocarbons (NMHC) are

continuously monitored using a dual-channel FID analyzer (Method 25A) along with building airflow rate, VOC will be sampled with replication at two barns using Silcosteel canisters, and all-glass impingers (EPA Method 26A). Each sample will be evaluated using concurrent gas chromatography—mass spectrometry (GC–MS) and GC/FID for TO 15 and other FID-responding compounds. VOC mass will be calculated as the sum of individual analytes. The 20 analytes making the greatest contribution to total mass will be identified during the initial characterization study. A sampling method that captures a significant fraction of the VOC mass will be chosen for the remainder of the study.

• The Method 26A sampling train is suitable for collecting samples for analysis of formaldehyde and acetaldehyde using NCASI 94.02, requiring only the addition of spectrophotometry for the detection of formaldehyde. These compounds will be measured during the initial characterization study and, if not found, will not be analyzed during subsequent measurements.

• Total VOC mass may be estimated (scaled) by multiplying the total carbon as determined by Method 25A by the molecular weight/carbon weight ratio derived from GC–MS or GC–FID speciation. This should account for the VOC that are not identified by GC methods due either to sampling bias or the analytical procedures used, although some error is anticipated due to the imprecise response of Method 25A FID to oxygenated compounds. Acceptance of a scaling factor will depend on whether the Method 25A analyzer response is reasonable based on the manufacturer's stated response factors, bench-scale verification, or judgmental estimation of the mass of unaccounted for VOC.

• By the middle of the second month, the Science Advisor will report results of the initial VOC characterization to EPA with recommendations on the appropriateness and validity of the selected methodologies.

• Quarterly VOC samples using the selected VOC sampling method will occur at all sites, along with continuous Method 25A monitoring at site 1 throughout the study.

• Method 25A measurements will be corrected from an ''as carbon'' basis to a total VOC mass basis by multiplying them by the mean molecular weight per carbon atom established by GC–MS evaluations during applicable intervals of time.

Manure Storage Systems: Micrometeorological techniques will be used to estimate emissions of NH_3, H_2S, and a limited number of VOC from manure storage systems and storages. Fundamentally, this approach will use optical remote sensing (ORS) downwind and upwind of the storage coupled with 3-dimensional (3D) wind velocity measurements at heights of 2 and 12m. The concentrations of NH_3 and the various hydrocarbons will be made using open path Fourier transform infrared spectroscopy (FTIR). Measurements of H_2S (and NH_3) will be made using collocated open path UV differential optical absorption spectroscopy (UV–DOAS) systems. A team of two persons with two scanning FTIR systems, two single-path UV–DOAS systems, and two 3D sonics with supplementary meteorological instruments will move sequentially from farm to farm.

Each of two ORS systems will be oriented parallel to the storage side and approximately 10m from the storage edge. Each monostatic FTIR system will scan five retroreflectors; three mounted at 1m height equally dividing the length of the open path along the storage side and two mounted on a tower at heights of 6 and 12m located at the corners down the adjacent sides of the storage, resulting in scan lines down each of the four sides of the storage. Two bistatic single-path UV–DOAS systems will be located at a nominal 2m height within 2m laterally of the FTIR scan lines on the two sides of the storage oriented most closely with prevailing winds.

Emissions will be determined from the difference in upwind and downwind concentration measurements using two different methods—an Eulerian Gaussian approach and a Lagrangian Stochastic approach. The Lagrangian approach is based on an inverse dispersion analysis using a backward Lagrangian stochastic method (bLS). This approach will be used to estimate NH_3 emissions from concentration measurements made using the FTIR and UV–DOAS systems and the H_2S emissions from concentration measurements made using the UV–DOAS systems. The emission rate for NH_3 will be the ensemble average of the estimated emissions for each of the five FTIR scans with a corresponding error of the emission estimate. The Eulerian approach is based on a computed tomography (CT) method using Eulerian Gaussian statistics and a fitted wind profile from the two 3D sonics. Measurements of air and storage temperatures, wind speed and direction, humidity, atmospheric pressure, and solar radiation will also be conducted.

The bLS and CT emission estimates will be quality assured using tests of instrument response, wind direction and wind speed, stability, turbulence intensity, differences between the storage and the surrounding surface temperatures, differences in the mean and turbulent wind components with height, and the temporal variability in emissions. Emission estimates using the CT method will be qualified by the measured fraction of the estimated plume.

To estimate VOC emissions from lagoons, samples of the lagoon liquid will be collected and analyzed for VOC, and the EPA model WATER9 will be used to estimate emissions based on measured VOC concentrations, pH, and other factors.

Alternate Techniques

1. For the circuit rider system, an instrumental system such as the DustTrak by TSI could be used for continuous particle data for PM2.5 and PM10. These systems provide optical light scattering measurements of the concentration in mg/m3 and cost about $5,000 per point including an environmental shelter.

2. A radial plume mapping approach could be applied to the manure storage systems using a TDL system that has been approved by EPA for use in the aluminum industry in a single path mode. One upwind and three downwind paths provide the same type of data as the FTIR except for a single compound. The single laser is scanned via fiberoptic cables to the individual paths with a complete scan taking 40 seconds. It provides a fast, direct measurement of the flux of ammonia from these manure systems. A single 4-channel system costs $68,000.

3. It is recommended that one short-term (2-week) measurement of each facility be made with a LIDAR system to measure and quantify the plume dynamics of particles, water vapor, and ammonia surrounding the facility. This is recommended because the short-term measurements will be made at different times throughout the year and will be placed at a series of heights based on experience. These associated data of the plume structure will provide evidence of representativeness of the micrometeorological measurements for the emission rates.

4. It is recommended that each building site be instrumented with temperature and associated sensors to provide a continuous measurement record of the microclimate within and adjacent to the building. These systems can be linked with sensors to measure and record animal activity and floor temperature. A similar system would be located to measure the microclimate of the manure storage system and would include air temperature, wind speed, wind direction, surface temperature, and relative humidity of the manure storage system. The continuous record from these manure storage units and buildings would provide a reference for the short-term measurements made with the FTIR systems.

5. A Dynamic Flux Chamber Technique could be used for performing emission measurements from lagoons and/or a manure pile. Ammonia flux is measured over a surface (lagoon and/or soil) using a dynamic flux chamber system interfaced to an environmentally controlled mobile laboratory. This flux chamber system is interfaced to an environmentally controlled mobile laboratory in which two ammonia chemiluminescence analyzers, gas dilution/ titration calibration system, and data logger with lap-top computer are located. The flux calculation of ammonia using the flow-through chamber system is given by the mass balance for ammonia in the chamber.

Typical Factors Used in Determining Farm Selection

Farm Characteristics

1. Did the producer sign up to the Consent Agreement and pay EPA?

2. Does the producer's farm fit the description of any of the farms listed?

3. Is there a principal investigator within 3 hours of the site?

4. Are there housing accommodations available within 1 hour of the site?

5. Does your site have mechanical or natural ventilation for barns? Do the fans blow out directly over the lagoon/ manure storage area?

6. Is the producer/farm manager cooperative to attend a training session and provide needed production information?

7. Is there internet access at the farm? Is 220 V power available?

8. What is the general topography on the farm? Describe the surrounding terrain

(rolling hills, flat, low lying, river bottom, etc.) specifically for areas near the barns and the manure storage/treatment system.

9. Is the farm free from large disturbances such as trees and other buildings?

10. What is the distance from a public road? Is it gravel?

11. Are there other potential air pollutant sources nearby? Explain type (other farms, industrial site, grain elevator/feedmill), distance and direction.

12. Are there other animal species housed on the site, or planned for housing on site?

13. How many barns are located on the site? How many animals in each barn? Please characterize the barns: Barn number/identifier, production phase, rate your barn cleanliness (1–5; 1 being the cleanest), age of barns, and air exchange rate.

14. How far are the land application fields from the lagoons and barns?

15. How often is manure removed from the manure treatment/storage system and land applied?

16. How often is manure removed from the buildings and sent to the outdoor treatment/storage system?

17. Describe (in general terms) the rations fed to the animals.

18. Are the animals hand-fed or is feed delivered through an automatic delivery system?

19. Is fat (vegetable or animal) added to the rations?

20. Are feed rations pelleted or ground?

INFLUENCES ON EMISSIONS

Influences	Producer provided	Collected by study
Climate		X
Air temperature		X
Manure temperature		X
Barn temperature		X
Wind speed		X
Solar radiation		X
Rainfall		X
Relative humidity		X
Wind direction		X
Feed conversion/efficiency		X
Feed analysis (N & P & S)	X	X
Phases		X
Feeding to recommendations	X	
Manure production volume	X	X
Management cycle	X	
Storage duration	X	
Stocking density (actual)		X
Lagoon design	X	X
Swine genetics	X	
Animal inventory	X	
Feed usage	X	
Water usage	X	
Closeouts	X	
Feed analysis	X	X
Water analysis		X
Manure analysis	X	X
Animal/barn activity	X	X

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APPENDIX F

SUPPLEMENTAL FIGURES

DEVELOPMENT OF EMISSIONS-ESTIMATING METHODOLOGIES FOR DAIRY AND SWINE LAGOONS

APPENDIX F – SUPPLEMENTAL FIGURES

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1.0 Supplemental Plots to Support NH_3 EEM Development Decisions

The figures and tables included in this Appendix were used to inform decision on which variables to include in EEMs as predictive parameters and their functional forms. Final decisions are presented in Section 5 of the main document.

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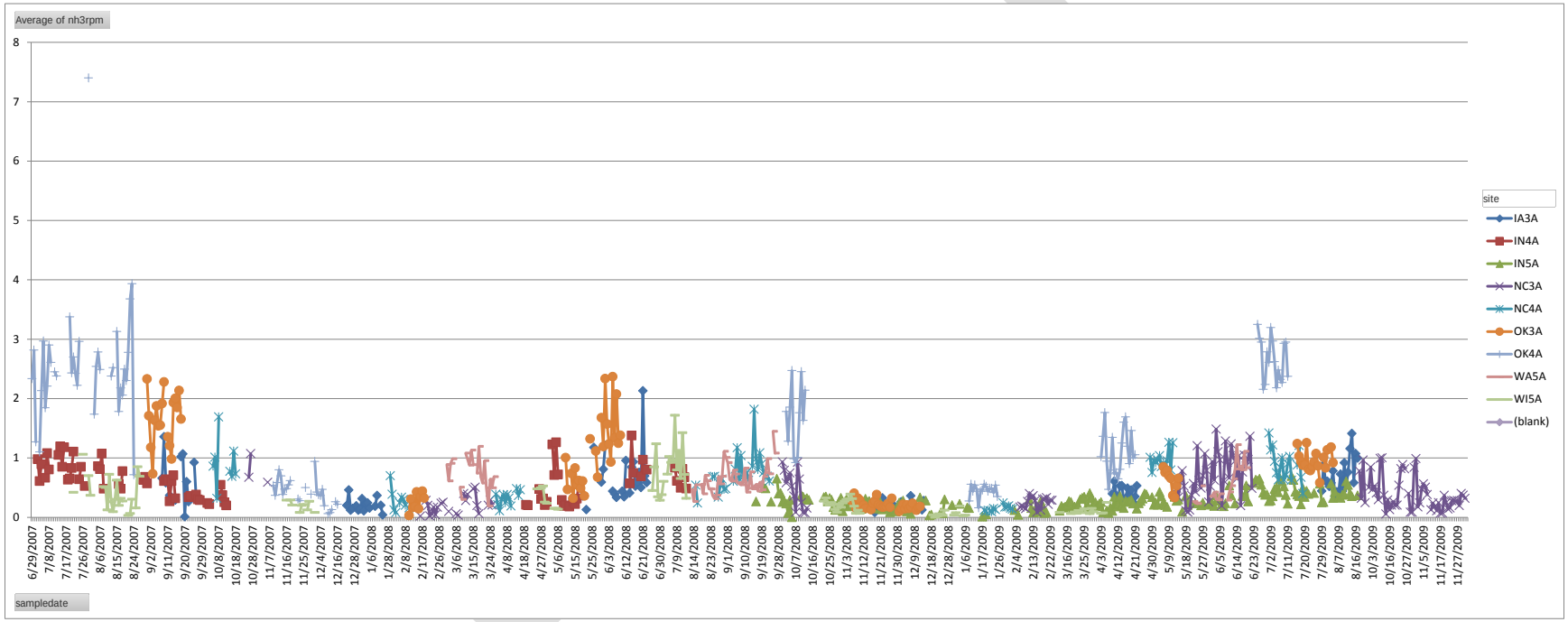
1.1 NH_3 Emissions

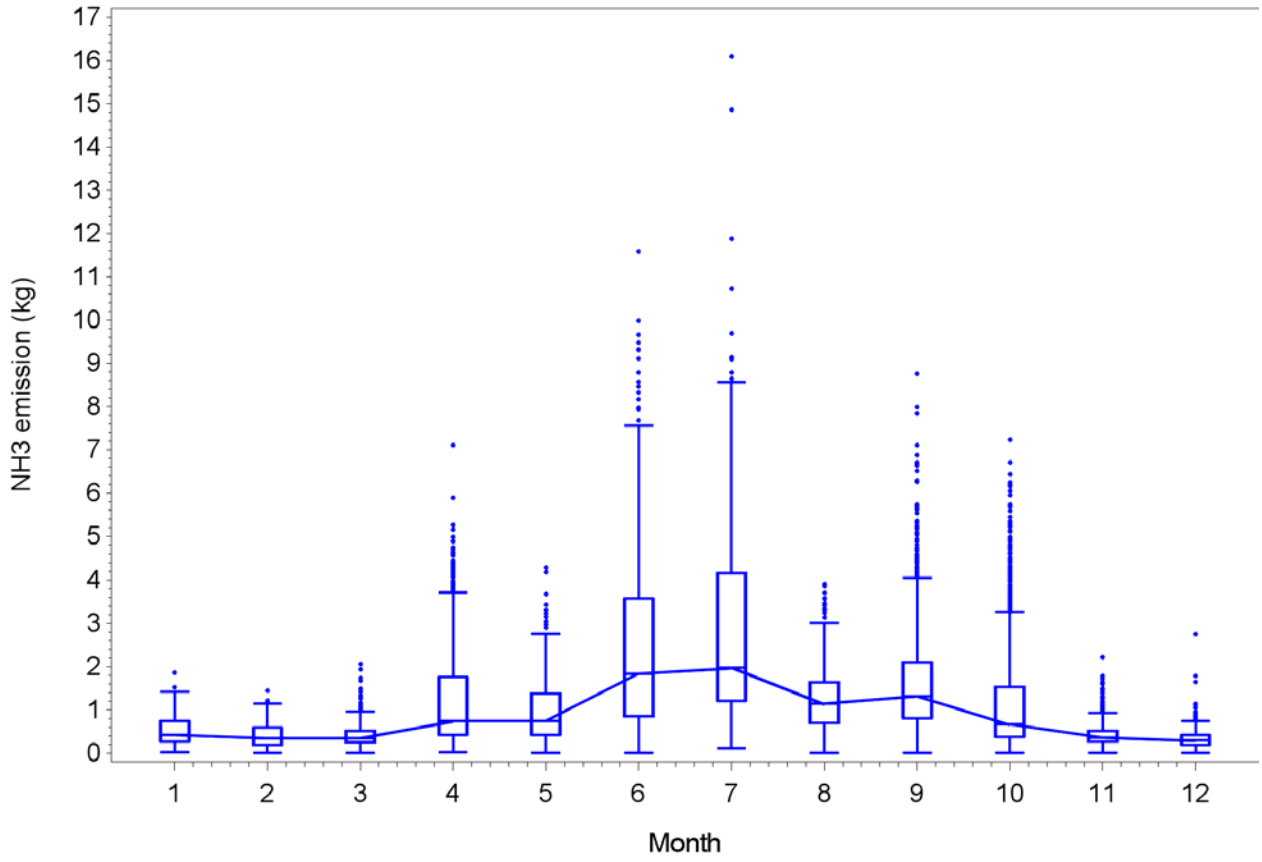
1.1.1 By Calendar date

Plot depicting the daily average NH_3 emissions based on all valid half hour averages over the duration of the NAEMS. This plot does not take into account the 75% completeness data quality objective for daily averages. The purpose of this figure was to allow for a visual representation of the data coverage and comparison of the emission rates from all the sites based on all the available valid half hour data.



1.1.2 By Month

Box plot of the NH_3 emissions by month. The plot shows an increase in emission over the summer months. The accompanying tables provide the counts of valid half hour measurements and the summary statistics for each month, by site.

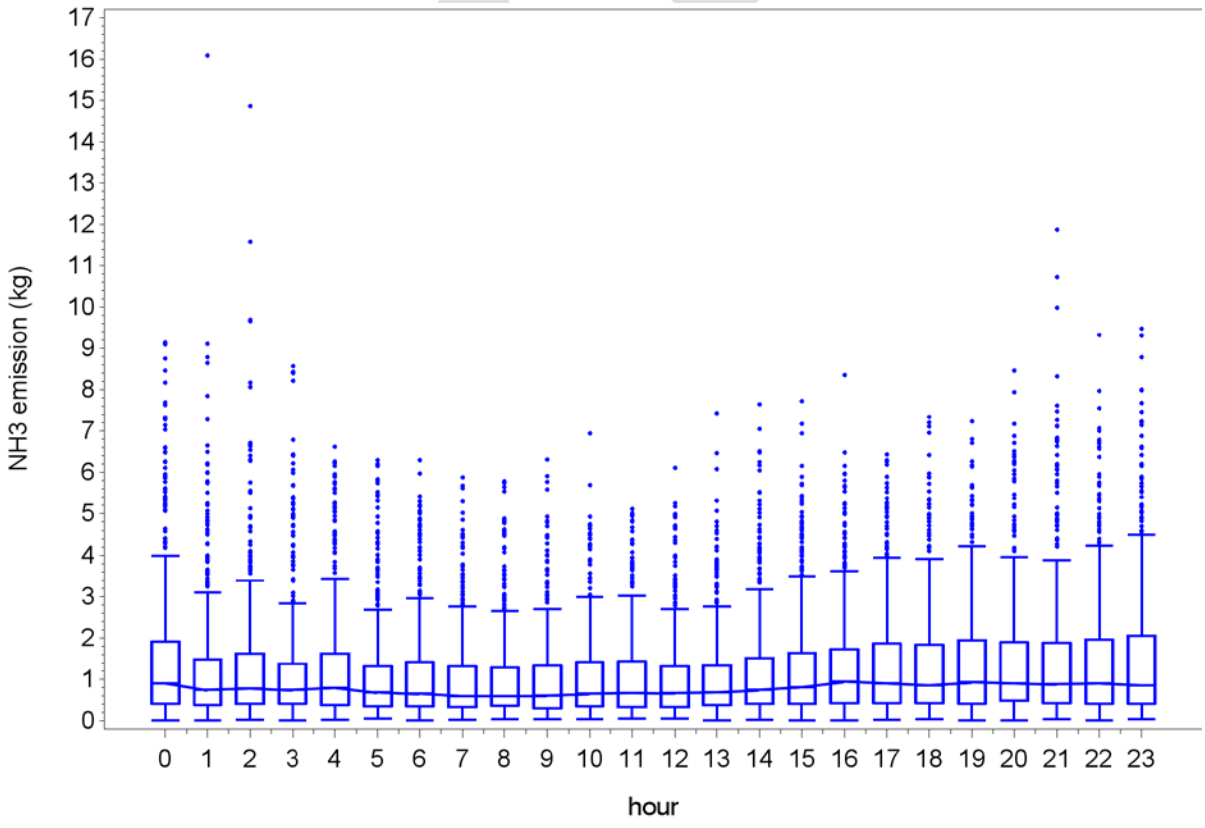


month	_LABEL_	ALL	IA3A	IN5A	NC4A	OK4A	WI5A	NC3A	OK3A	WA5A	IN4A
1	NH3 emission (kg)	182	45	17	27	90	3	.	.	.	.
2	NH3 emission (kg)	563	.	128	83	.	.	308	44	.	.
3	NH3 emission (kg)	625	.	458	.	.	34	121	.	12	.
4	NH3 emission (kg)	1381	115	471	112	569	24	.	.	.	90
5	NH3 emission (kg)	1041	34	260	248	.	8	92	246	35	118
6	NH3 emission (kg)	759	159	.	.	207	27	116	117	84	49
7	NH3 emission (kg)	1440	95	.	268	559	26	.	320	.	172
8	NH3 emission (kg)	643	359	.	51	3	15	.	43	137	35
9	NH3 emission (kg)	1264	85	89	342	.	.	8	355	239	146
10	NH3 emission (kg)	1209	.	452	62	267	97	264	.	.	67
11	NH3 emission (kg)	1284	67	607	.	64	69	158	319	.	.
12	NH3 emission (kg)	393	89	111	.	21	9	7	156	.	.

Analysis Variable : nh3 NH3 emission (kg)										
Month	N	Mean	Std Dev	Skewness	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Quartile Range
1	182	0.524	0.364	0.925	0.0180	0.270	0.414	0.738	1.854	0.468
2	563	0.403	0.274	0.827	0	0.180	0.342	0.576	1.440	0.396
3	625	0.417	0.278	1.821	0	0.234	0.342	0.522	2.052	0.288
4	1381	1.209	1.082	1.450	0.0180	0.432	0.738	1.746	7.110	1.314
5	1041	0.976	0.690	1.083	0	0.432	0.738	1.386	4.284	0.954
6	759	2.437	2.007	1.230	0	0.846	1.836	3.564	11.59	2.718
7	1440	2.717	1.936	1.289	0.108	1.206	1.971	4.167	16.09	2.961
8	643	1.255	0.728	0.882	0	0.684	1.134	1.638	3.906	0.954
9	1264	1.651	1.224	1.719	0	0.810	1.314	2.106	8.766	1.296
10	1209	1.203	1.298	1.875	0	0.378	0.666	1.530	7.236	1.152
11	1284	0.421	0.256	1.654	0	0.252	0.360	0.522	2.214	0.270
12	393	0.333	0.253	3.668	0	0.198	0.288	0.414	2.754	0.216

1.1.3 By Hour

Box plot of the NH_3 emissions by hour of the day. Does not show any strong trend in emissions over the course of the day. Patterns might be masked by the larger number of outliers (dots above the boxes). The accompanying tables provide the counts of valid half hour measurements and the summary statistics for each hour, by site.



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hour	_LABEL_	ALL	IA3A	IN4A	IN5A	NC3A	NC4A	OK3A	OK4A	WA5A	WI5A
0	NH3 emission (kg)	508	44	36	124	28	60	73	94	34	15
1	NH3 emission (kg)	494	45	31	125	22	65	68	86	36	16
2	NH3 emission (kg)	452	40	26	113	20	60	58	88	37	10
3	NH3 emission (kg)	451	43	29	97	28	61	58	80	38	17
4	NH3 emission (kg)	443	48	20	108	23	52	64	88	25	15
5	NH3 emission (kg)	405	39	23	106	29	41	63	71	21	12
6	NH3 emission (kg)	380	41	15	100	23	41	67	67	16	10
7	NH3 emission (kg)	365	37	17	101	27	32	70	59	18	4
8	NH3 emission (kg)	350	37	17	95	21	27	56	72	12	13
9	NH3 emission (kg)	330	30	24	89	21	24	59	59	13	11
10	NH3 emission (kg)	317	25	21	91	16	27	52	65	12	8
11	NH3 emission (kg)	342	23	25	88	21	36	61	64	16	8
12	NH3 emission (kg)	384	35	23	94	32	45	65	66	12	12
13	NH3 emission (kg)	469	38	32	104	66	62	82	67	10	8
14	NH3 emission (kg)	484	43	29	103	86	55	79	72	10	7
15	NH3 emission (kg)	498	47	25	106	84	60	72	75	16	13
16	NH3 emission (kg)	510	56	31	109	85	60	68	71	14	16
17	NH3 emission (kg)	502	56	24	102	92	57	71	73	13	14
18	NH3 emission (kg)	500	55	34	115	75	53	74	65	14	15
19	NH3 emission (kg)	503	59	35	109	71	52	74	67	19	17
20	NH3 emission (kg)	535	54	41	125	58	56	69	76	34	22
21	NH3 emission (kg)	545	61	36	127	62	60	66	81	34	18
22	NH3 emission (kg)	511	48	44	136	45	49	60	83	27	19
23	NH3 emission (kg)	506	44	39	126	39	58	71	91	26	12

Analysis Variable : nh3 NH3 emission (kg)										
hour	N	Mean	Std Dev	Skewness	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Quartile Range
0	508	1.504	1.695	2.105	0	0.414	0.900	1.908	9.144	1.494
1	494	1.327	1.641	3.222	0	0.378	0.738	1.494	16.09	1.116
2	452	1.373	1.706	3.190	0.0180	0.396	0.774	1.629	14.87	1.233
3	451	1.285	1.515	2.452	0	0.414	0.738	1.386	8.568	0.972
4	443	1.317	1.444	1.831	0.0180	0.378	0.792	1.620	6.624	1.242
5	405	1.183	1.309	2.017	0.0540	0.342	0.684	1.296	6.300	0.954
6	380	1.164	1.282	1.797	0	0.342	0.648	1.404	6.300	1.062
7	365	1.044	1.148	1.989	0.0180	0.324	0.594	1.296	5.886	0.972
8	350	1.113	1.216	1.892	0.0360	0.360	0.594	1.278	5.796	0.918
9	330	1.077	1.186	1.984	0.0360	0.306	0.603	1.314	6.318	1.008
10	317	1.129	1.191	1.881	0.0360	0.342	0.648	1.404	6.948	1.062
11	342	1.106	1.134	1.693	0.0540	0.324	0.666	1.422	5.112	1.098
12	384	1.053	1.090	2.000	0.0540	0.324	0.657	1.296	6.120	0.972
13	469	1.065	1.088	2.241	0	0.378	0.684	1.332	7.434	0.954

Analysis Variable : nh3 NH3 emission (kg)										
hour	N	Mean	Std Dev	Skewness	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Quartile Range
14	484	1.242	1.312	2.065	0.0180	0.396	0.738	1.512	7.650	1.116
15	498	1.312	1.352	1.854	31E-19	0.396	0.810	1.638	7.722	1.242
16	510	1.335	1.284	1.814	0	0.432	0.936	1.710	8.352	1.278
17	502	1.377	1.311	1.653	0.0180	0.432	0.900	1.854	6.444	1.422
18	500	1.405	1.425	1.771	0.0360	0.432	0.855	1.827	7.344	1.395
19	503	1.419	1.375	1.651	0	0.414	0.918	1.944	7.236	1.530
20	535	1.430	1.397	1.990	0	0.468	0.900	1.890	8.460	1.422
21	545	1.481	1.663	2.484	0.0360	0.432	0.882	1.872	11.88	1.440
22	511	1.485	1.553	1.874	0	0.414	0.900	1.962	9.324	1.548
23	506	1.555	1.703	2.002	0.0360	0.414	0.855	2.052	9.486	1.638

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1.1.4 By Site

LABEL	ALL	IA3A	IN4A	IN5A	NC3A	NC4A	OK3A	OK4A	WA5A	WI5A
NH3 emission (kg)	10784	1048	677	2593	1074	1193	1600	1780	507	312

Analysis Variable : nh3 NH3 emission (kg)										
site	N	Mean	Std Dev	Skewness	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Quartile Range
IA3A	1048	1.067	0.776	1.119	0.0180	0.459	0.846	1.521	4.554	1.062
IN4A	677	0.934	0.572	1.367	0.108	0.486	0.792	1.206	4.068	0.720
IN5A	2593	0.437	0.239	1.399	0	0.270	0.396	0.558	2.052	0.288
NC3A	1074	0.632	0.585	2.163	0	0.234	0.468	0.846	3.996	0.612
NC4A	1193	1.336	0.623	0.421	0.0360	0.918	1.314	1.692	3.978	0.774
OK3A	1600	1.545	1.329	1.492	0.0360	0.486	1.206	2.214	8.766	1.728
OK4A	1780	3.260	1.969	0.776	0.108	1.638	3.078	4.608	16.09	2.970
WA5A	507	0.839	0.540	1.091	0	0.450	0.720	1.116	3.132	0.666
WI5A	312	0.624	0.766	2.116	0	0.144	0.342	0.702	3.834	0.558

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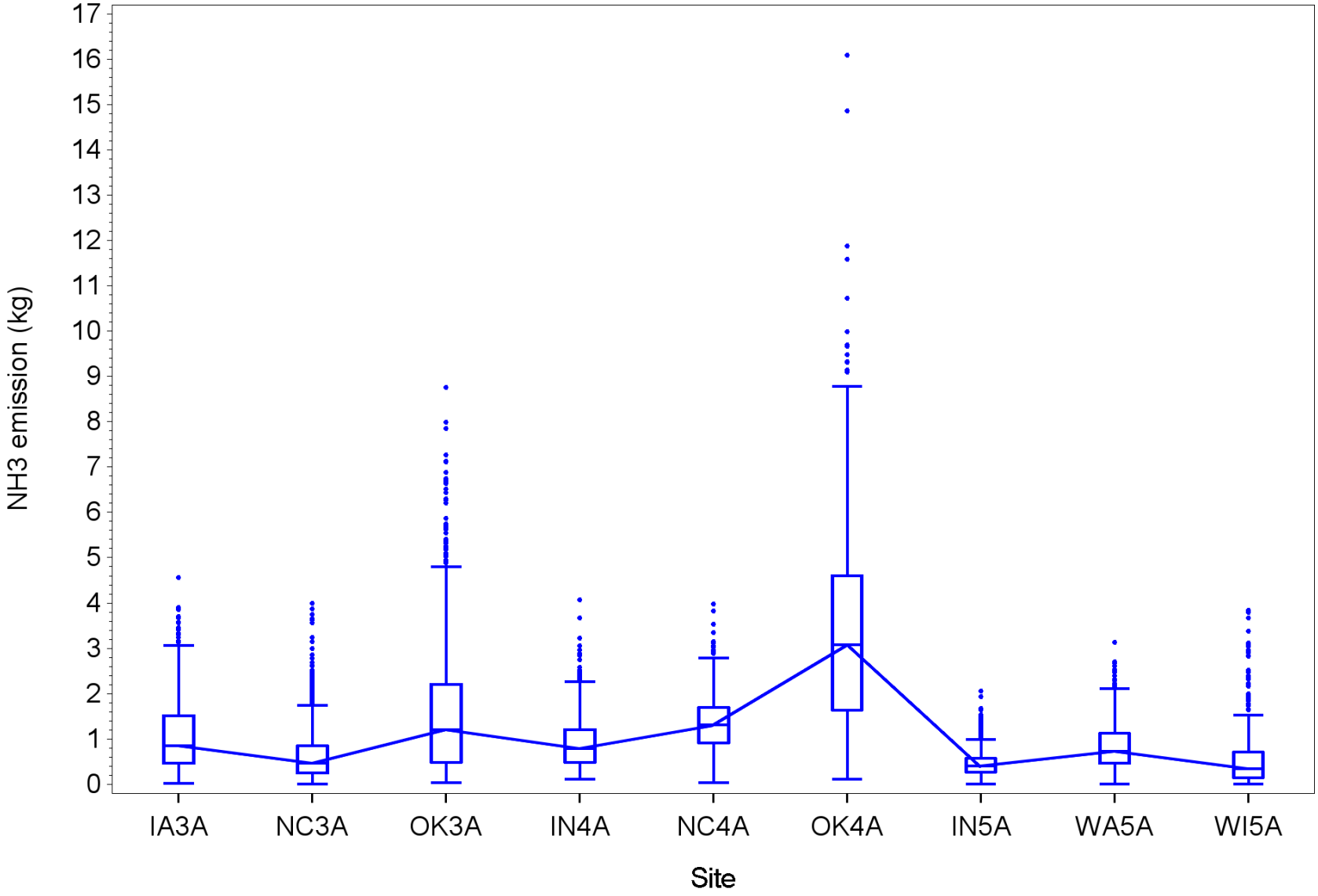
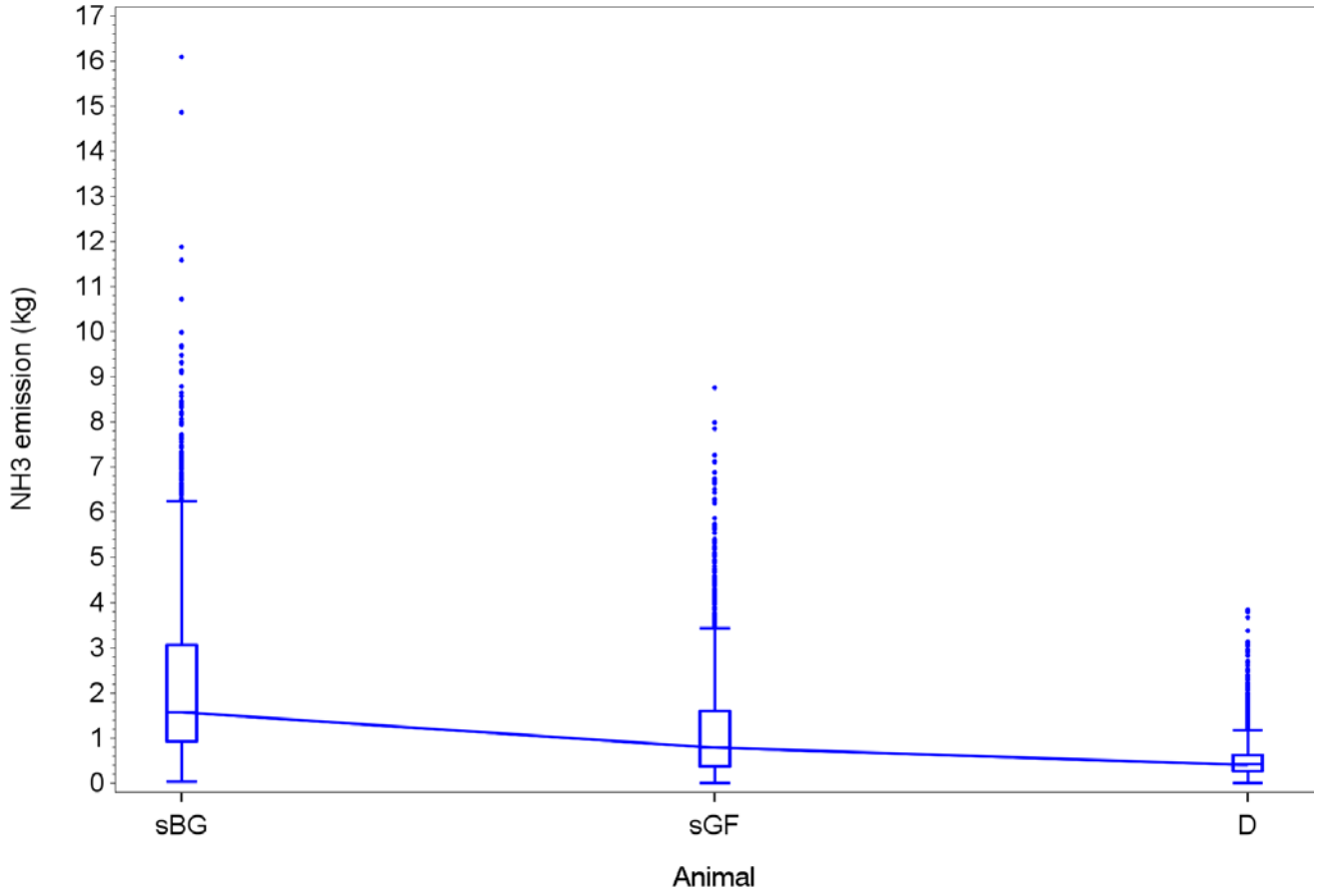
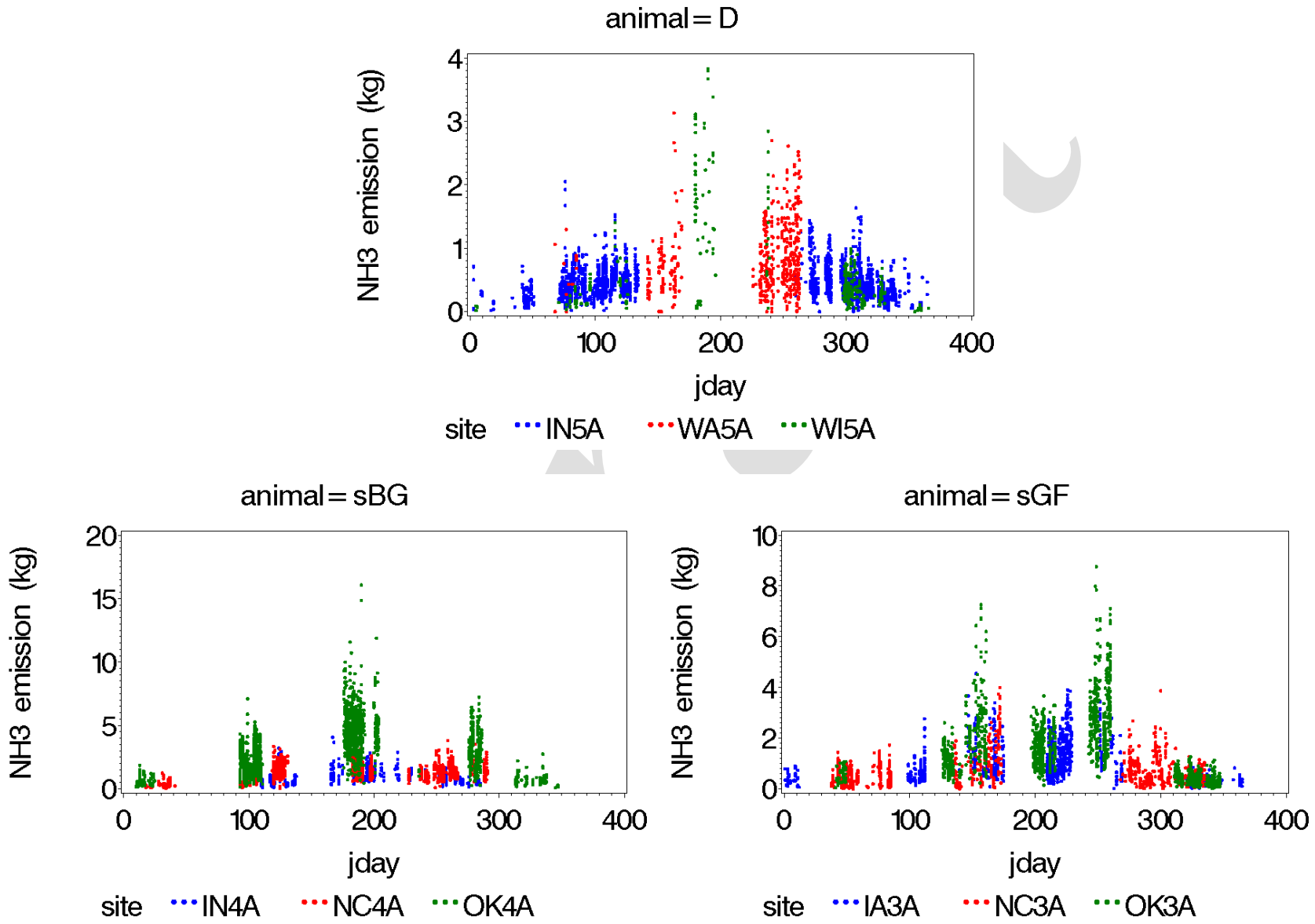

NH3 emission (kg)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
IA3A
NC3A
OK3A
IN4A
NC4A
OK4A
IN5A
WA5A
WI5A
Site

1.1.5 By Animal Type

Analysis Variable : nh3 NH3 emission (kg)										
animal	**N**	**Mean**	**Std Dev**	**Skewness**	**Minimum**	**Lower Quartile**	**Median**	**Upper Quartile**	**Maximum**	**Quartile Range**
D	3412	0.514	0.402	2.787	0	0.270	0.414	0.630	3.834	0.360
sBG	3650	2.200	1.779	1.493	0.0360	0.936	1.566	3.060	16.09	2.124
sGF	3722	1.147	1.083	1.948	0	0.378	0.792	1.602	8.766	1.224



1.1.6 By Julian Day, by Animal Type, color coded by site



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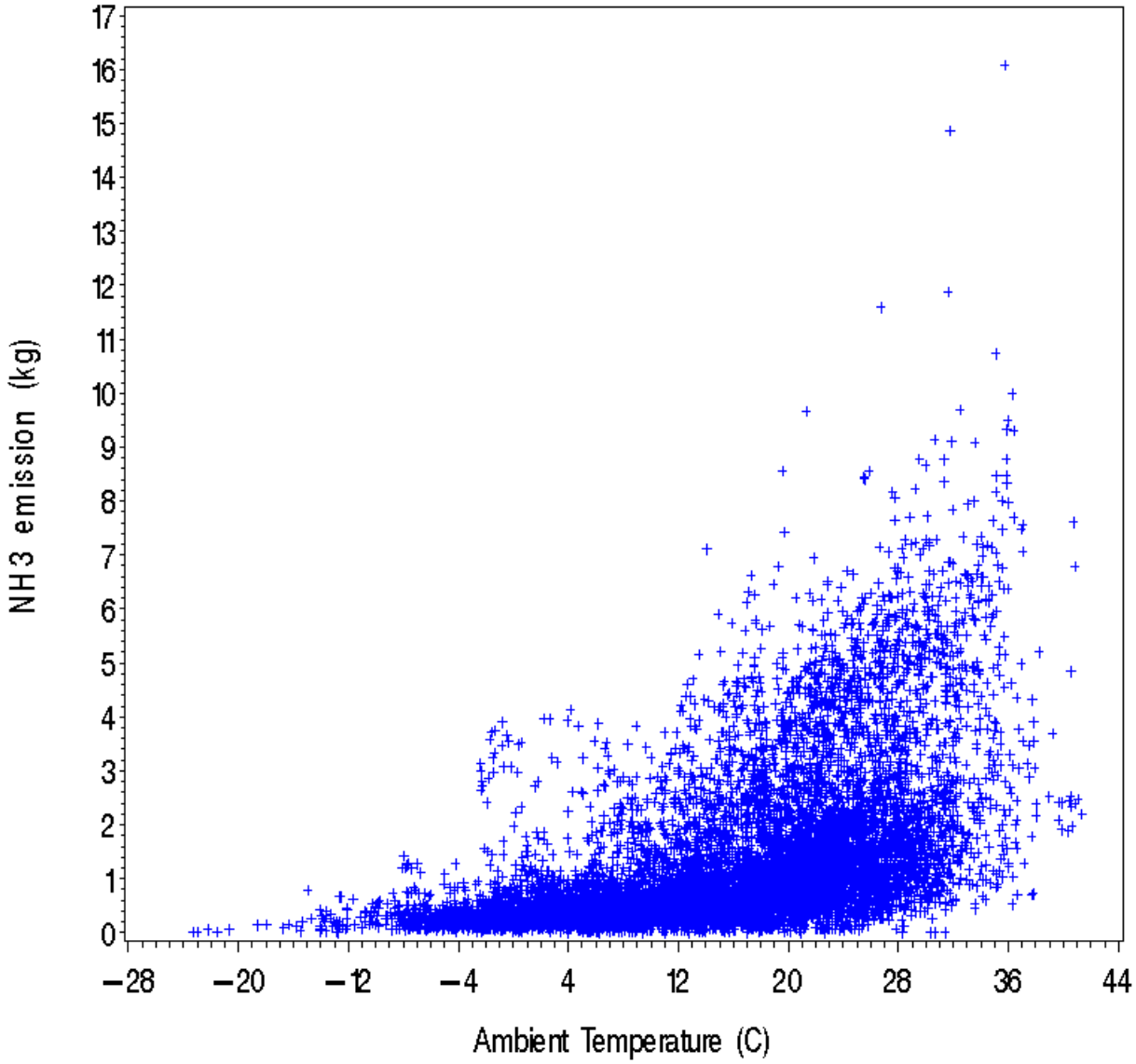
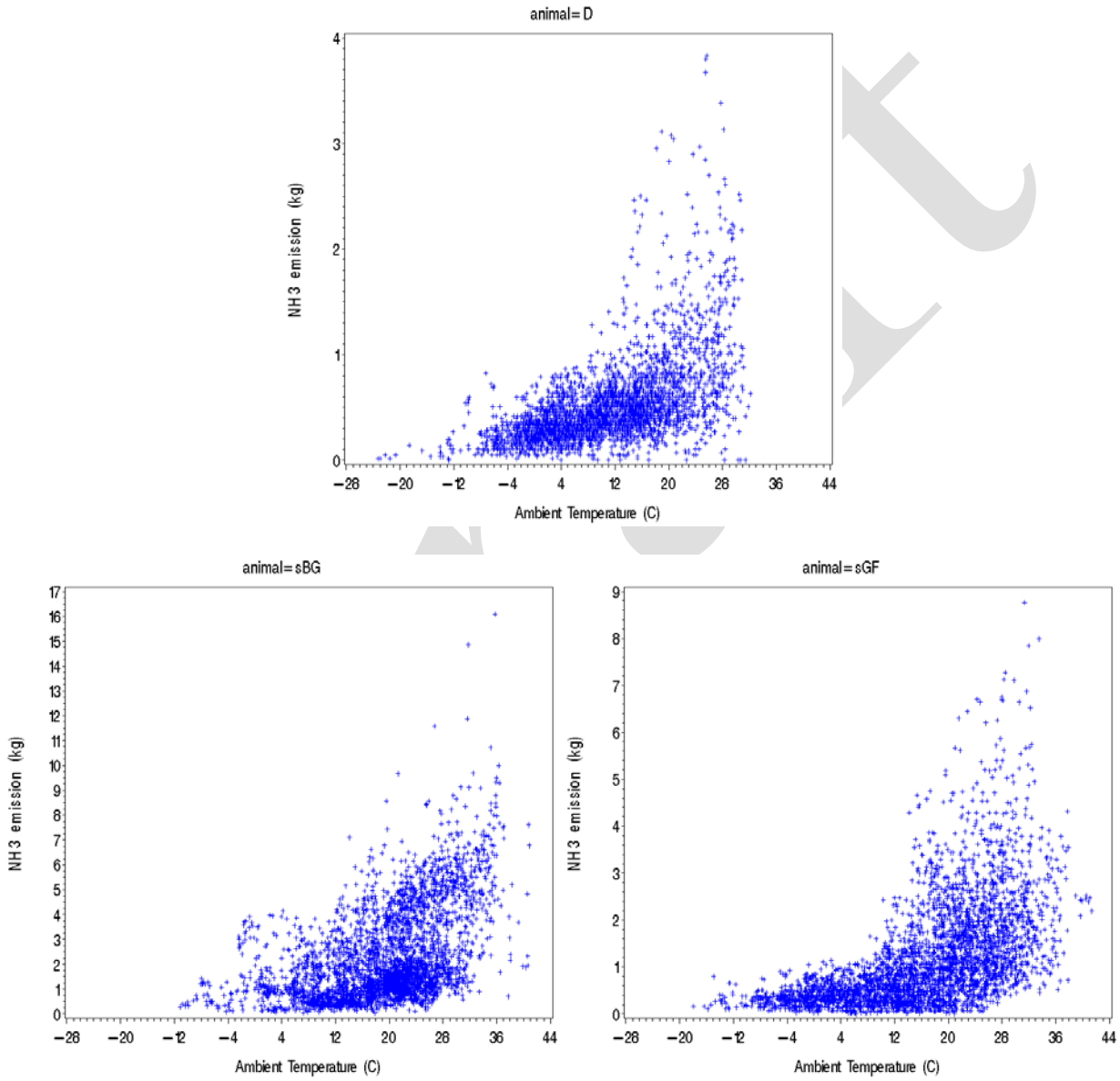
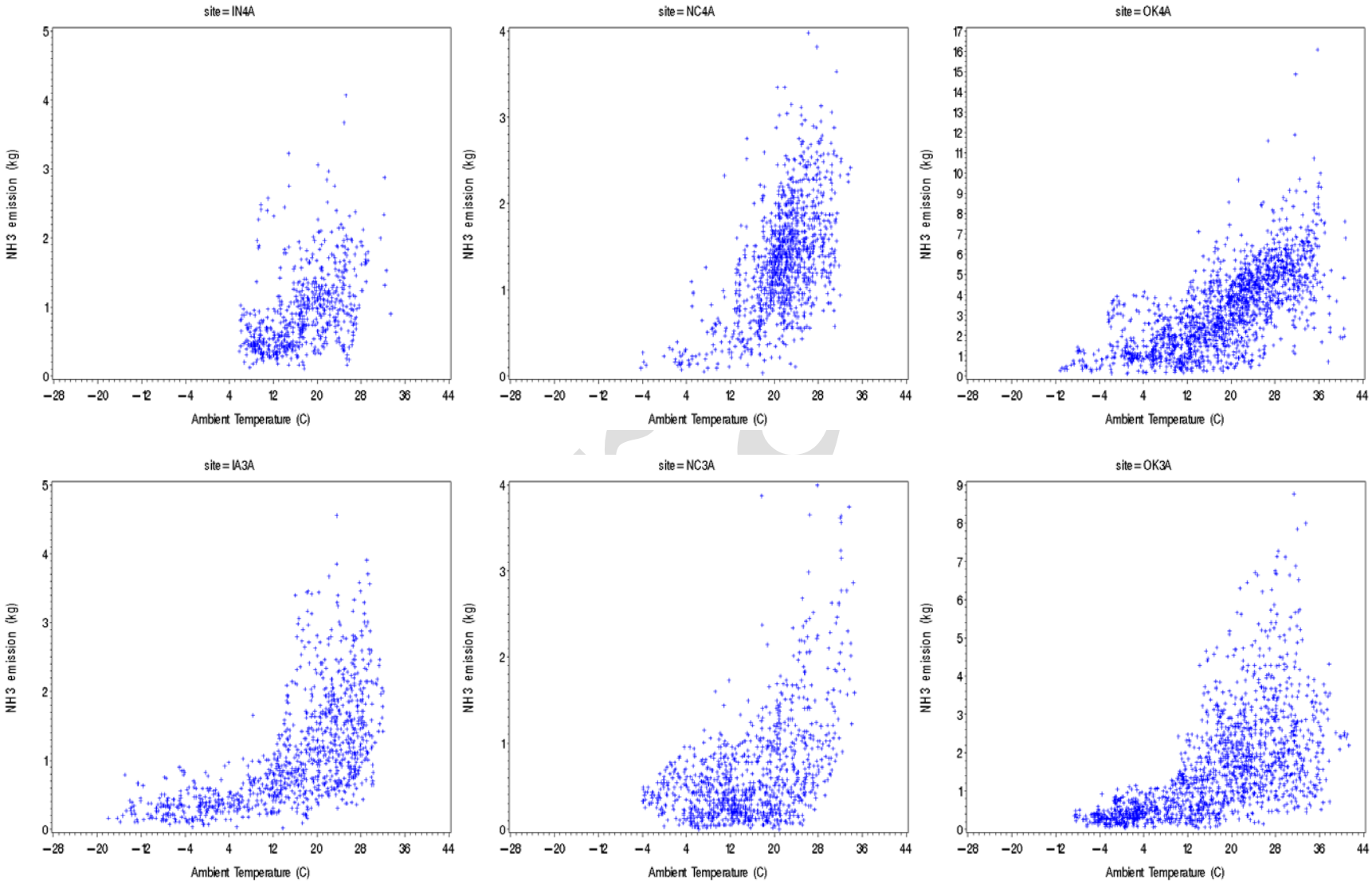
1.2 Ambient Temperature

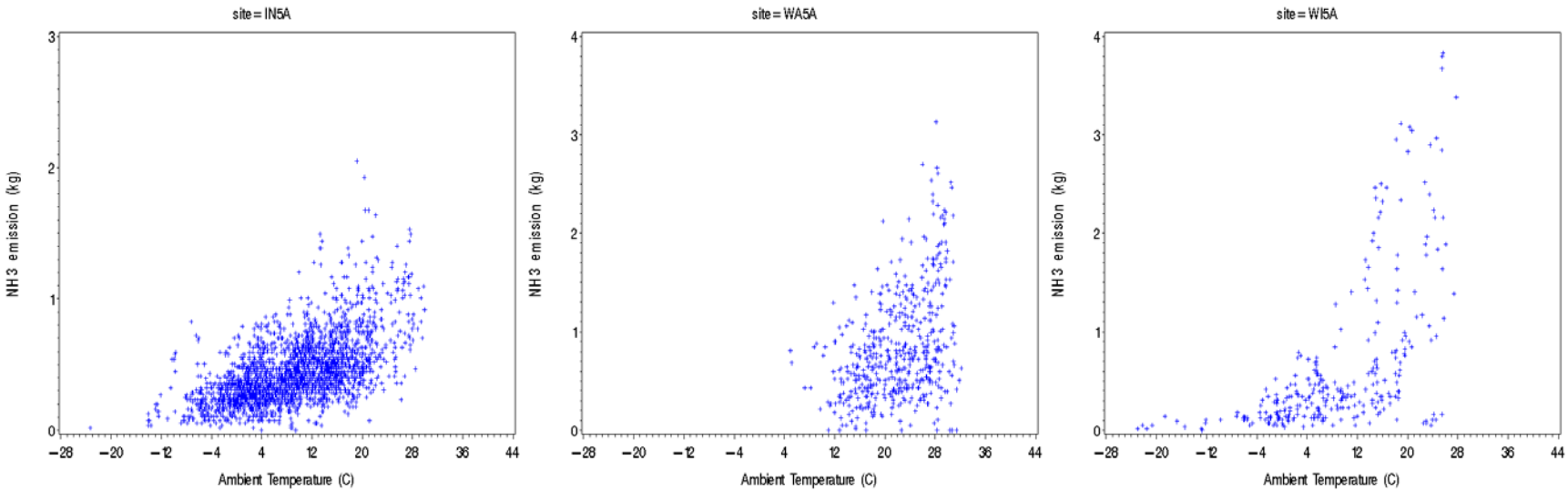


1.2.1 By Animal Type



1.2.2 By Site


site = IN4A
site = NC4A
site = OK4A
site = IA3A
site = NC3A
site = OK3A
NH3 emission (kg)
Ambient Temperature (C)


site = IN5A
site = WA5A
site = WI5A
NH3 emission (kg)
Ambient Temperature (C)
0
1
2
3
4
−28
−20
−12
−4
4
12
20
28
36
44

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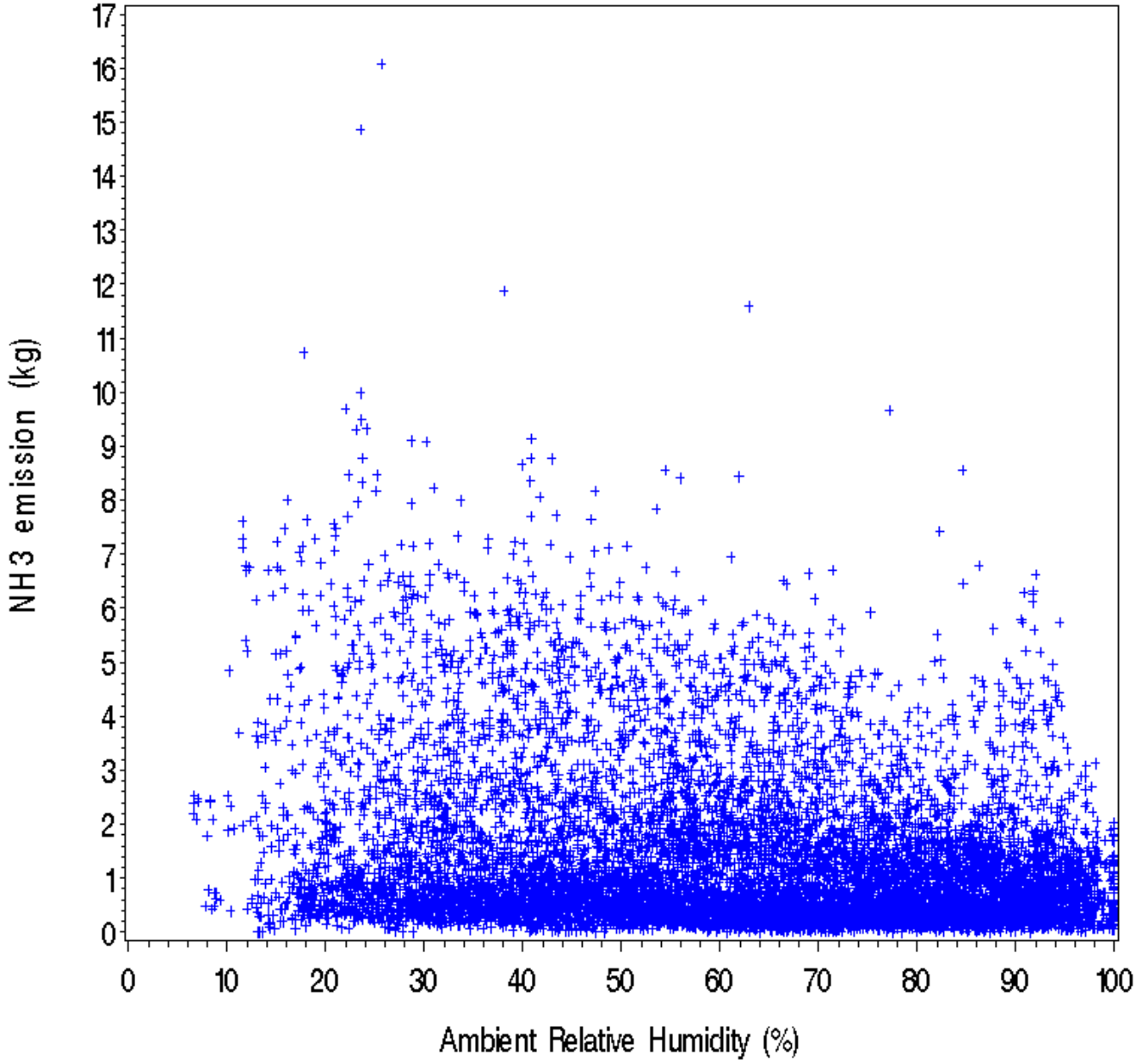
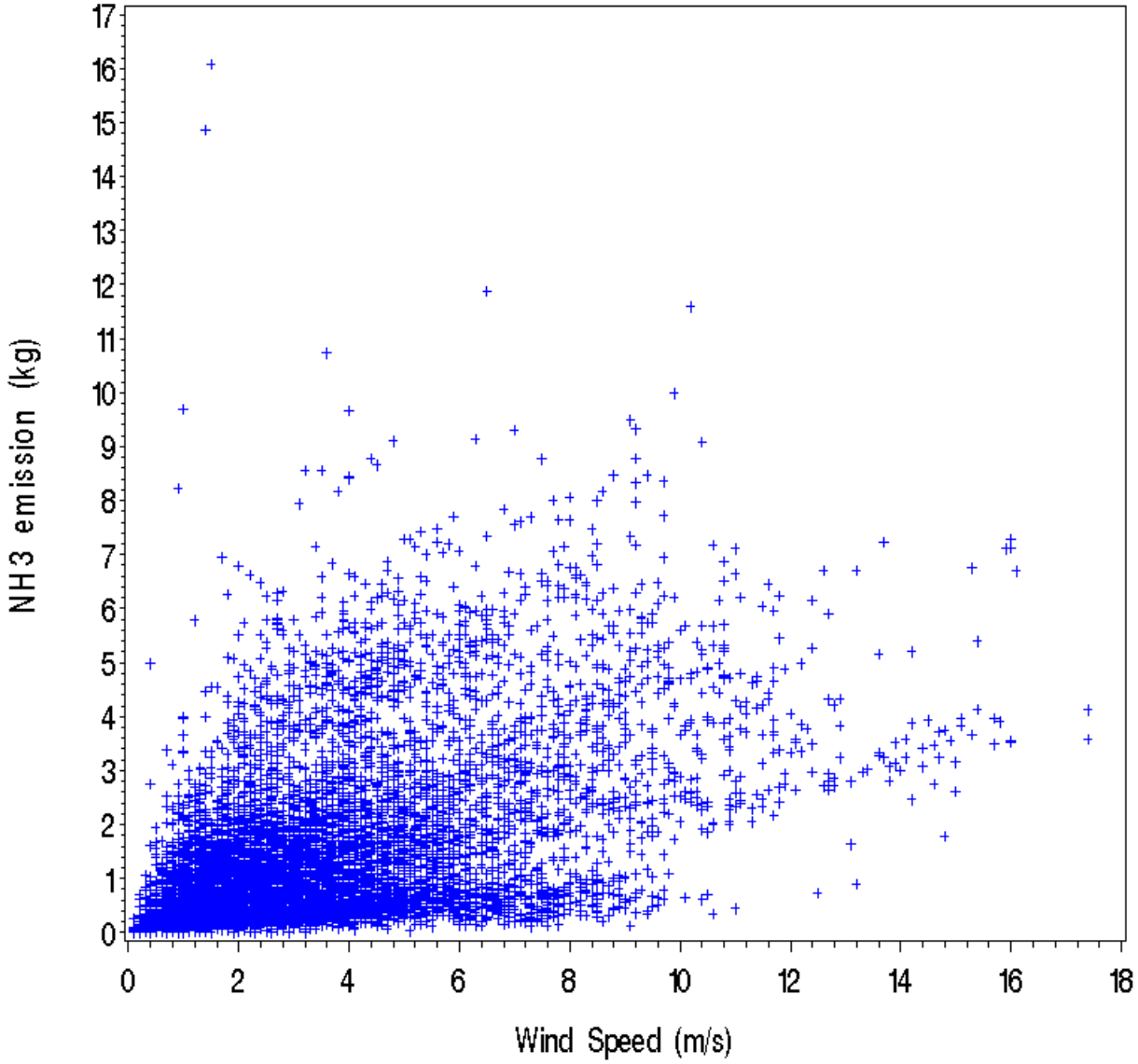
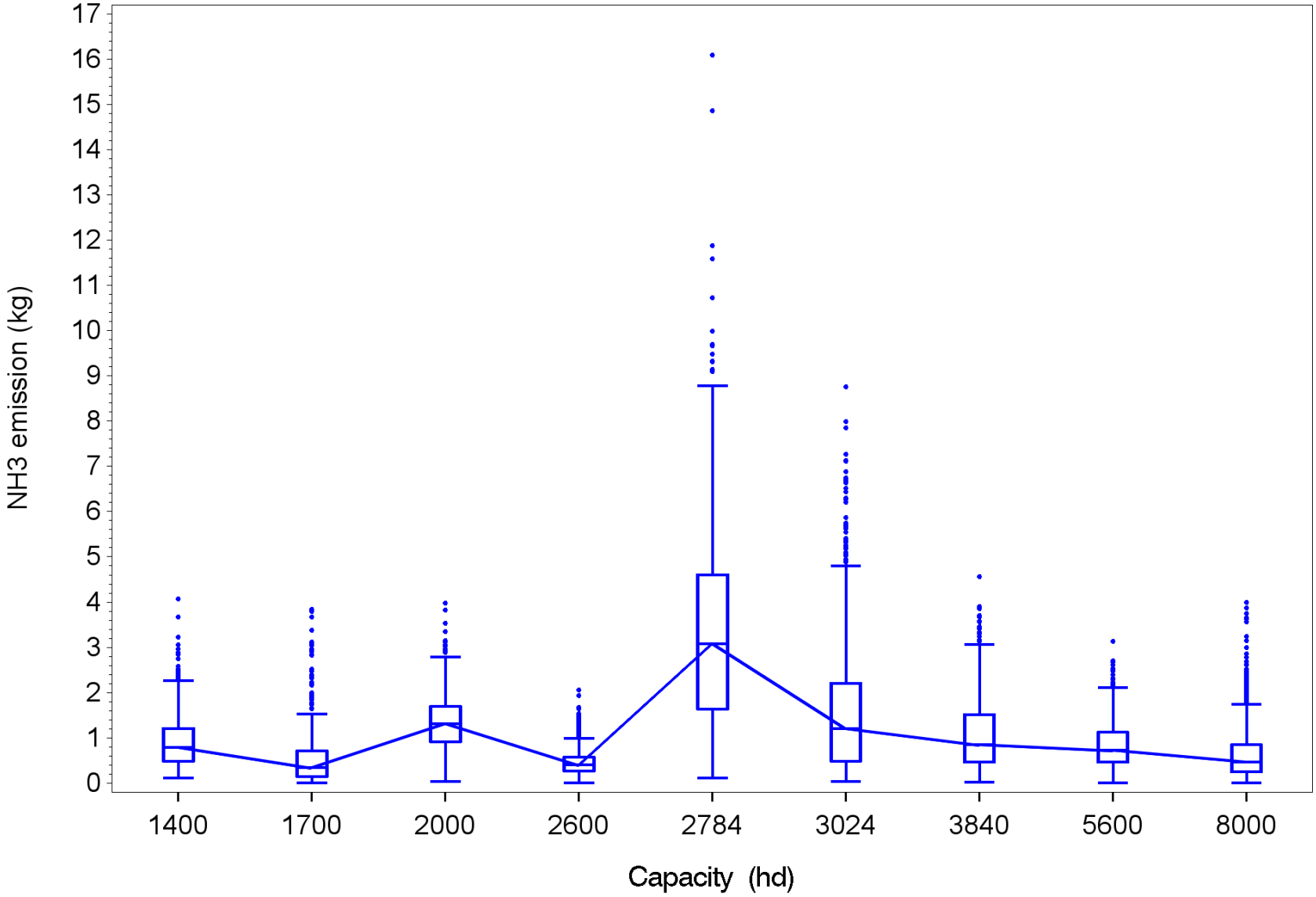
1.3 Relative Humidity

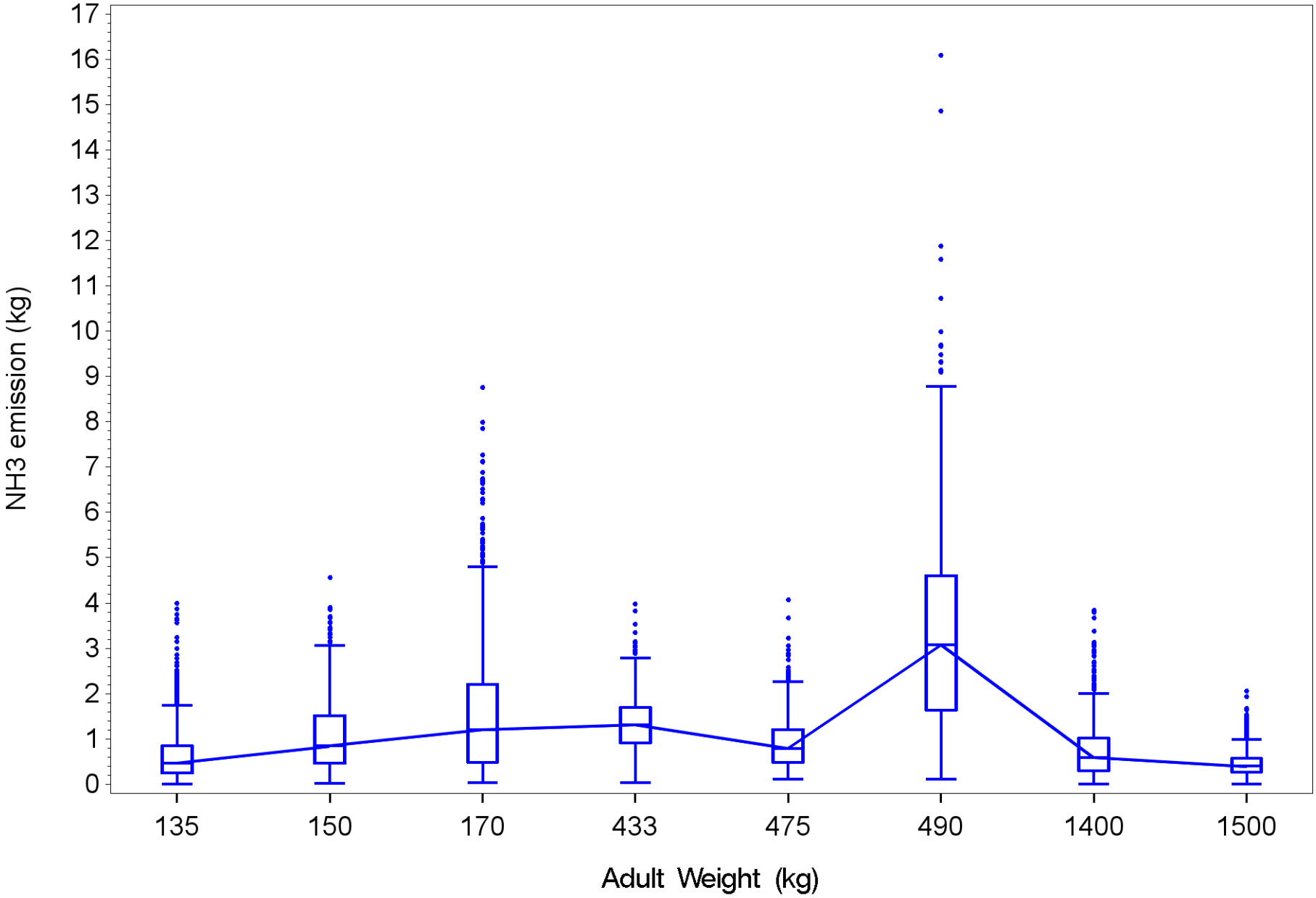


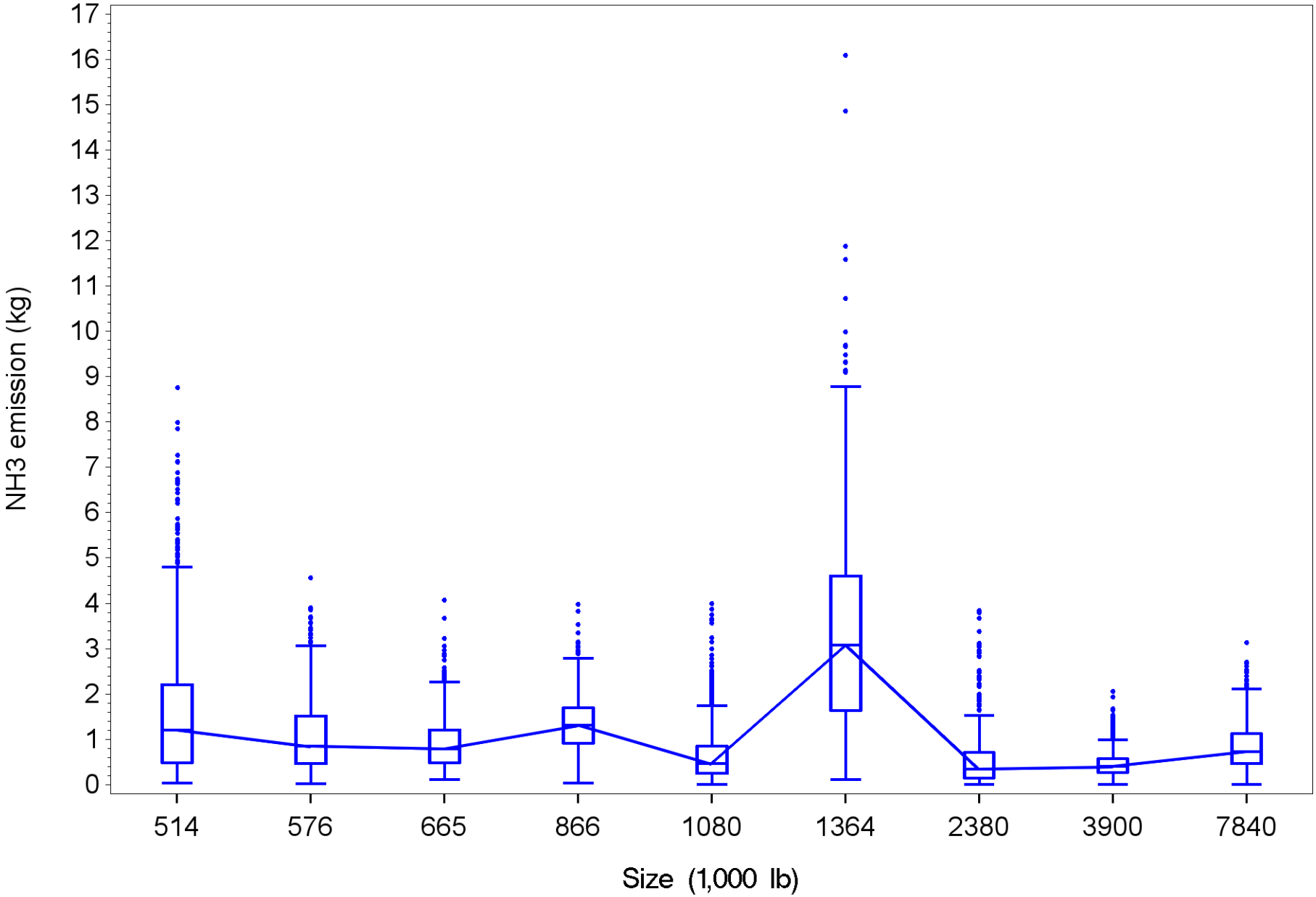
1.4 Wind Speed

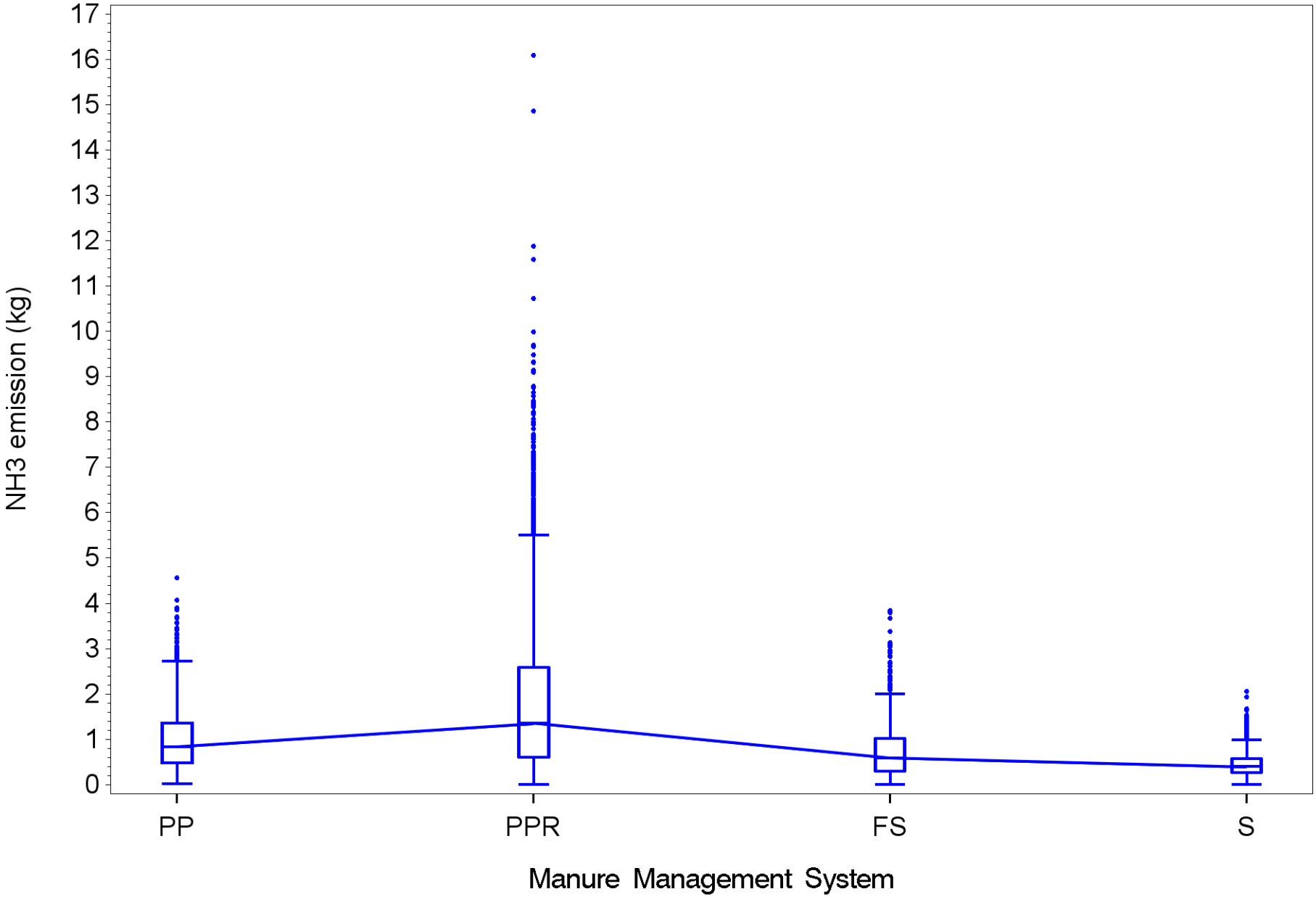


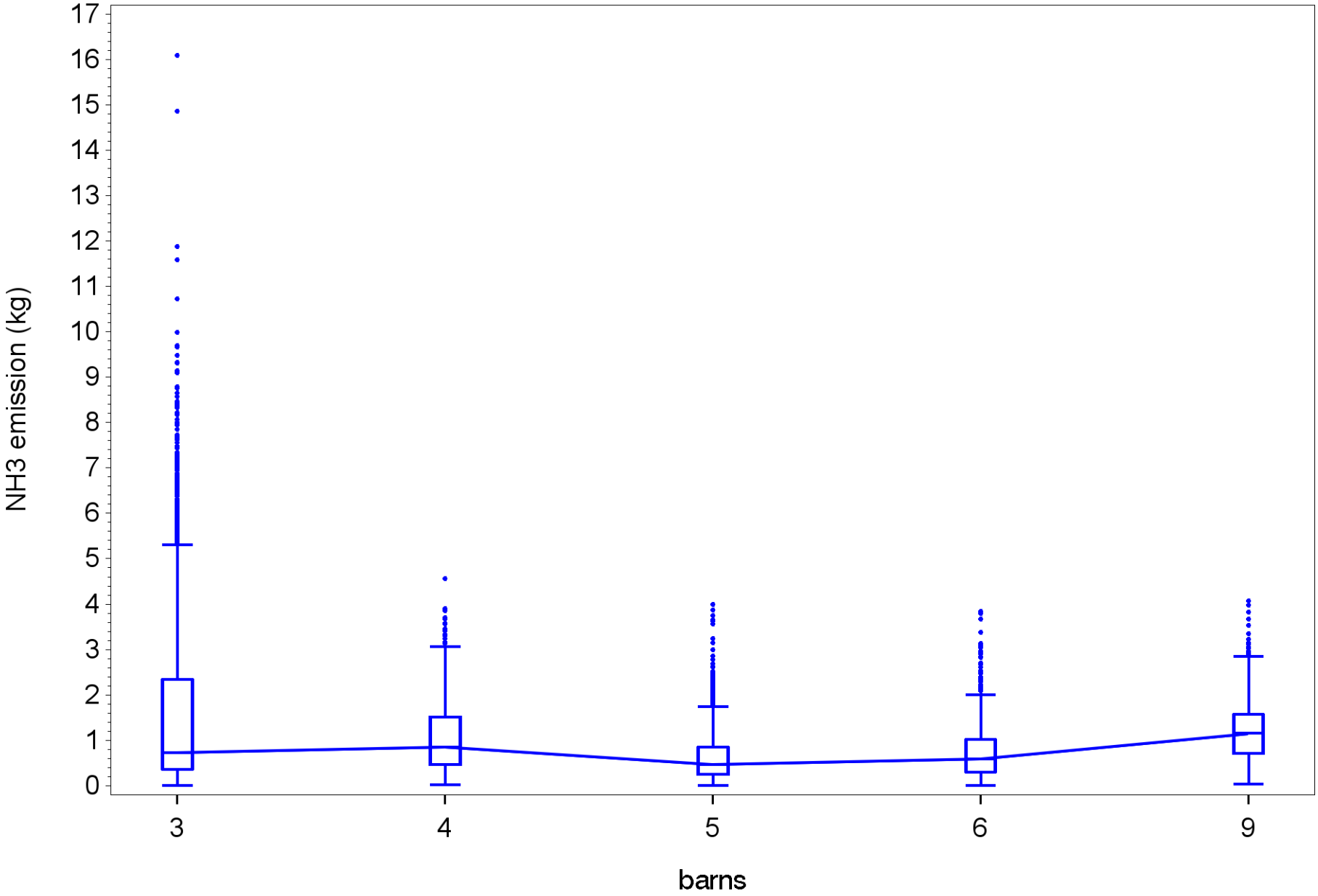
1.5 Categorical Variables

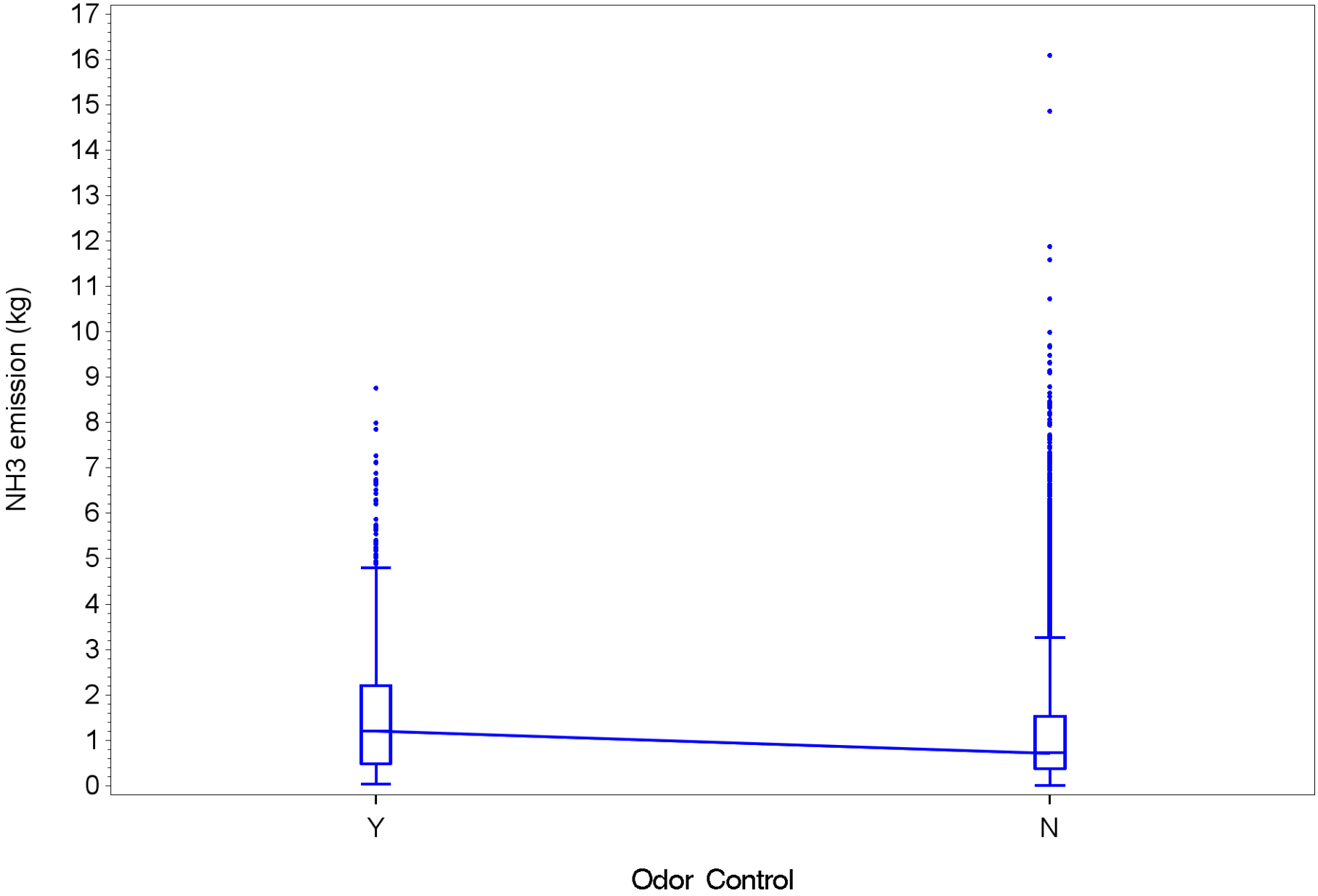


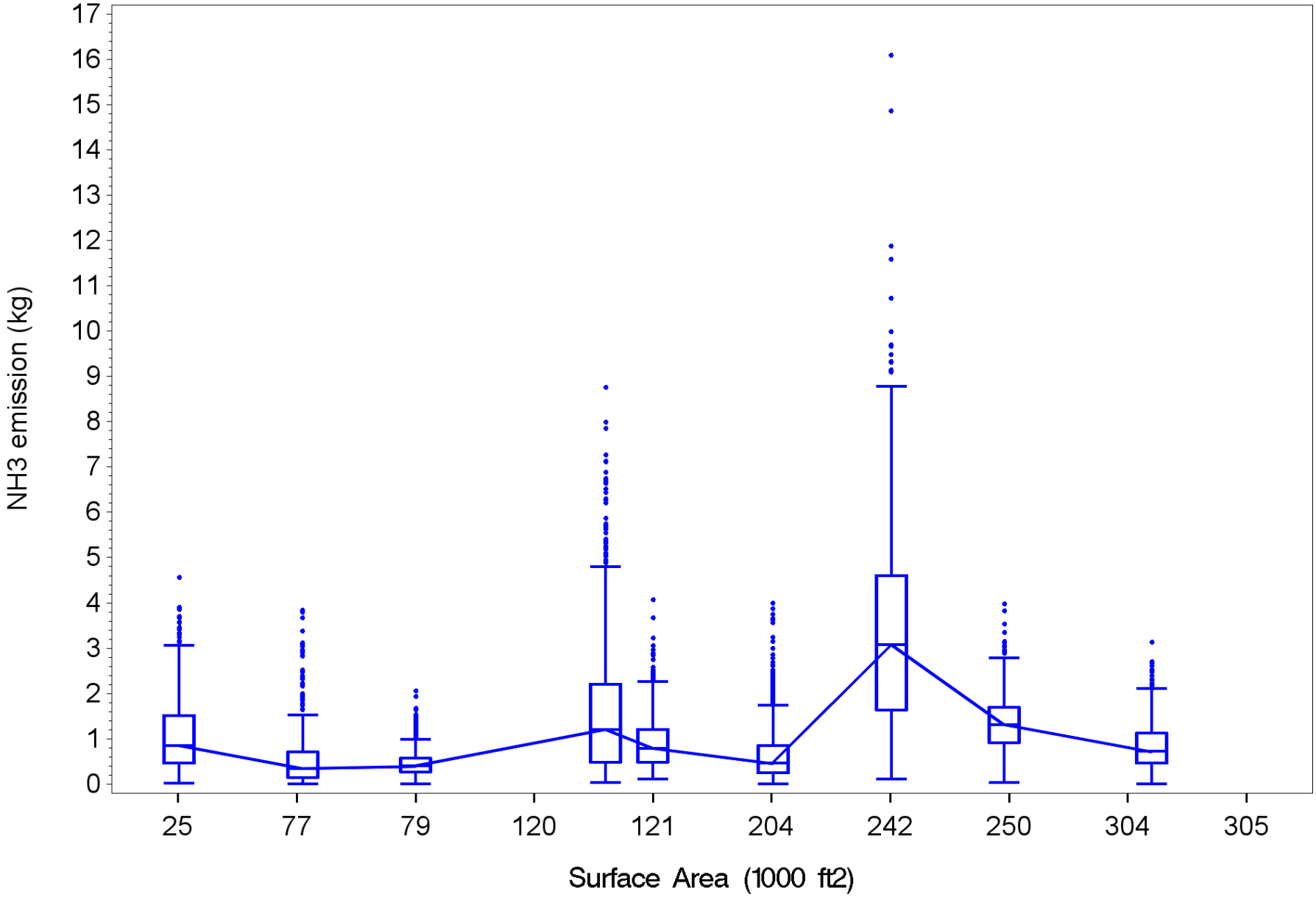

NH3 emission (kg)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
135
150
170
433
475
490
1400
1500
Adult Weight (kg)


NH3 emission (kg)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
514
576
665
866
1080
1364
2380
3900
7840
Size (1,000 lb)


NH3 emission (kg)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
PP
PPR
FS
S
Manure Management System


NH3 emission (kg)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
3
4
5
6
9
barns


NH3 emission (kg)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Y
N
Odor Control


NH3 emission (kg)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
25
77
79
120
121
204
242
250
304
305
Surface Area (1000 ft2)