Cloud and Dry Deposition Monitoring

Great Smoky Mountains National Park - Clingmans Dome, TN - 2004

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Prepared by:
MACTEC Engineering and Consulting, Inc.
Gainesville, Florida

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List of Acronyms and Abbreviations

°C	degrees Celsius
Ca^{2+}	calcium ion
CAAA	Clean Air Act Amendments
CASTNET	Clean Air Status and Trends Network
CLOUD	cloud water deposition computer model
Cl^{-}	chloride ion
CLASS™	Chemical Laboratory Analysis and Scheduling System
CLD303	Clingmans Dome, TN Sampling Station
cm	centimeter
cm/s	centimeters per second
CVS	continuing verification sample
DAS	data acquisition system
EPA	U.S. Environmental Protection Agency
$g/cm^2/min$	grams per square centimeter per minute
g/m^3	grams per cubic meter
H^+	hydrogen ion
Harding ESE	Harding ESE, Inc., now known as MACTEC Engineering and Consulting, Inc.
HNO_3	nitric acid
IC	ion chromatography
ICP-AES	inductively coupled argon plasma - atomic emission spectrometer
K^+	potassium ion
K_2CO_3	potassium carbonate
kg/ha	kilograms per hectare
Lpm	liters per minute
LWC	liquid water content
m	meter
m/sec	meters per second

List of Acronyms and Abbreviations (continued)

MACTEC	MACTEC Engineering and Consulting, Inc.
MADPro	Mountain Acid Deposition Program
MCCP	Mountain Cloud Chemistry Program
Mg^{2+}	magnesium ion
mL	milliliter
MLM	Multi-Layer Model
mm	millimeter
Na^{+}	sodium ion
NADP/NTN	National Atmospheric Deposition Program/ National Trends Network
NAPAP	National Acid Precipitation Assessment Program
NH_4^+	ammonium ion
NIST	National Institute for Standards and Technology
NO_3^-	nitrate ion
NO_x	oxides of nitrogen
NPS	National Park Service
pH	p(otential of) H(ydrogen)
PVC	polyvinylchloride
PVM	particle volume monitor
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RPD	relative percent difference
SO_4^{2-}	sulfate ion
SO_2	sulfur dioxide
SOP	standard operating procedure
SSRF	Site Status Report Form
TVA	Tennessee Valley Authority
µeq/L	microequivalents per liter
µg/filter	micrograms per filter
$\mu g/m^3$	micrograms per cubic meter

Acknowledgements

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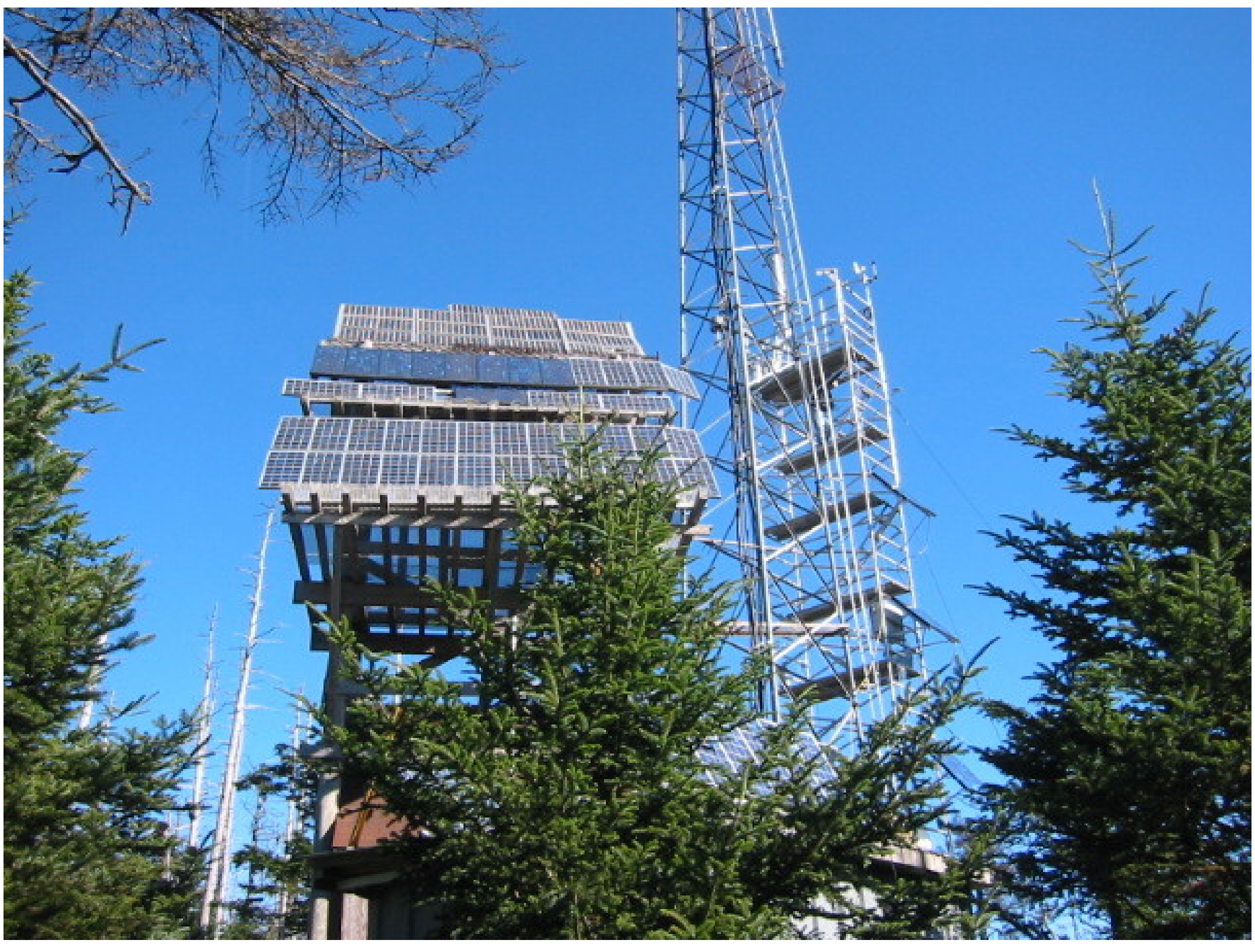


A view of the CLD303, TN tower and solar panels used to power the site

1.0 Introduction

The 1990 Clean Air Act Amendments (CAAA) established the Acid Deposition Control Program, which mandated significant reductions in sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions from electric generating plants. The SO_2 emission reductions were implemented in two phases. The first phase began in 1995 when large electric generating facilities reduced emissions. The second phase began in 2000 and targeted other power plants. Emission reductions of NO_x began in 1999. The Acid Deposition Control Program has resulted in substantive emission reductions over the last ten years. Titles IV and IX of the CAAA require that the environmental effectiveness of the Acid Deposition Control Program be assessed through environmental monitoring. This monitoring is required to gauge the impact of emission reductions on air pollution, atmospheric deposition, and the health of affected human populations and ecosystems. The Clean Air Status and Trends Network (CASTNET) was established by the U.S. Environmental Protection Agency (EPA) in 1991 to provide an effective monitoring and assessment network for determining the status and trends in air quality and pollutant deposition as well as relationships among emissions, air quality, deposition, and ecological effects. CASTNET measurements collected over the period 1990 through 2004 have shown significant declines in atmospheric sulfur pollutants [SO_2 and particulate sulfate (SO_4^{2-})] and more recently suggest declines in nitrogen pollutants [nitric acid (HNO_3) and particulate nitrate (NO_3^-)]. The Mountain Acid Deposition Program (MADPro) was initiated in 1993 as part of the research necessary to support CASTNET's objectives. MACTEC Engineering and Consulting, Inc. (MACTEC) operates both CASTNET and MADPro on behalf of EPA and other agencies.

MADPro's two main objectives are to develop cloud water measurement systems to be used in a network-monitoring environment and to update the cloud water concentration and deposition data collected in the Appalachian Mountains during the National Acid Precipitation Assessment Program (NAPAP) in the 1980s. MADPro measurements were conducted from 1994 through 1999 during the warm season (May through October) at three mountaintop sampling stations. These sampling stations were located at Whiteface Mountain, NY; Clingmans Dome, TN; and Whitetop Mountain, VA. A mobile manual sampling station also was operated at two locations in the Catskill Mountains in New York during 1995, 1997, and 1998. Measurements during the 2000 and 2001 sampling seasons were collected from two sites: Whiteface Mountain, NY and Clingmans Dome, TN. During the 2002 through 2004 sampling seasons, measurements were only collected from the one site at Clingmans Dome, TN (CLD303). Currently, CLD303 is being operated under direction of EPA, the National Park Service (NPS), and the Tennessee Valley Authority (TVA). This report is specifically for the activities and results from the CLD303 site during the 2004 field sampling season.

This report consists of five additional sections and three appendices. Section 2.0, Site Description and Methods, presents an overview of field, laboratory, and data operations and the quality assurance (QA) program. Section 3.0, Liquid Water Content and Cloud Water Chemistry, presents analyses of cloud frequency, liquid water content (LWC), cloud chemistry, and summary statistics for the 2004 data with comparisons to the 1994 through 2003 data set. Cloud deposition estimates are presented in Section 4.0. The deposition estimates were calculated by applying the cloud water deposition computer model (CLOUD) (Lovett, 1984), parameterized with site-specific cloud water chemistry and meteorological data. Section 5.0 presents filter pack concentrations, modeled dry deposition fluxes, and estimates of total (cloud and dry) deposition. Finally, Section 6.0 discusses the conclusions and recommendations for MADPro.

2.0 Site Description and Methods

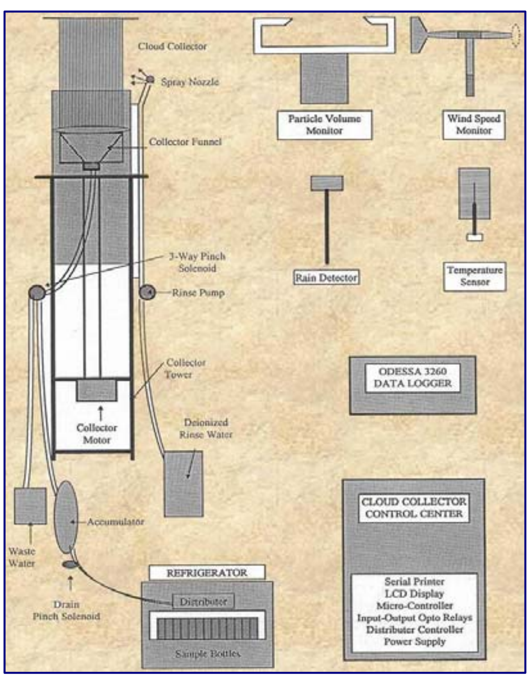
2.1 Site Description

Clingmans Dome (35'33'47"N, 83'29'55"W) is the highest mountain [summit 2025 meters (m)] in the Great Smoky Mountains National Park. The solar-powered MADPro site is situated at an elevation of 2,014 m approximately 100 m southeast of the summit tourist observation tower. Electronic instrumentation is housed in a small NPS building and the cloud water collector, particle volume monitor (PVM), and meteorological sensors are positioned on top of a 50-foot scaffold tower.

A View of the Tower

Collection at the site is initiated each spring as soon as local weather conditions will allow. The 2004 field season was officially underway on June 8 and continued through October 26, 2004.

2.2 Field Operations



Schematic of Cloudwater Sampling Instrumentation

The site collects cloud water and filter pack samples and measures meteorological parameters. The cloud collection system consists of an automated cloud water collector for bulk cloud water sampling; a PVM for continuous determination of cloud LWC; a meteorological station for continuous measurements of wind speed, wind direction, temperature, solar radiation, relative humidity, wetness, and precipitation; and a data acquisition system (DAS) for collection and storage of electronic information from the various monitors and sensors. In 2004, a microprocessor was added to the suite of instrumentation, specifically for monitoring cloud collector status and to control all sampler functions. The site deploys the same three-stage filter pack system for dry deposition estimation that is used at all CASTNET sites. Wet deposition data for use in estimating wet deposition are collected at Elkmont (TN11) which is operated by NPS for the National Atmospheric Deposition Network / National Trends Network (NADP/NTN).

The core of the automated cloud collection system is a passive string collector previously used in the Mountain Cloud Chemistry Program (MCCP) study. Collection occurs when ambient winds transport cloud water droplets onto 0.4-millimeter (mm) Teflon® fibers strung between two circular disks (Falconer and Falconer, 1980; Mohnen and Kadlecek, 1989). Once impacted, the droplets slide down the strings, are collected in a funnel, and flow through Teflon® tubing into sample bottles in a refrigerated carousel. The development and design of this system is described in detail in Baumgardner *et al.* (1997).

Particle Monitor

The PVM-100 by Gerber Scientific (Gerber, 1984) measures LWC and effective droplet radius of ambient clouds by directing a narrow laser beam from a 780-nanometer diode along a 40-centimeter (cm) path. The forward scatter of the cloud droplets in the open air along the path is measured, translated, and expressed as water in grams per cubic meter (g/m^3) of air. The microprocessor is programmed so that the collector will be activated and projected out of the protective housing when threshold levels for LWC (0.05 g/m^3) and ambient air temperature [≥ 2 degrees Celsius (°C)] are reached. In addition, the system is activated only when no precipitation is measured. Within the context of this work assignment, a cloud is defined by a LWC of 0.05 g/m^3 or higher, as measured by the PVM. This threshold was established to maintain comparability with the MCCP measurements, which were made for the most part with Mallant Optical Cloud Detectors set at a threshold of approximately 0.04 g/m^3 (Mohnen *et al*., 1990). In previous years, a wind speed threshold of 2.5 meters per second (m/sec) was also used because hourly cloud water collection is erratic and inefficient at lower wind speeds. Higher wind speeds were necessary to yield the minimum 30 milliliters (mL) of cloud water required for sample analysis. Since the commencement of 24-hour bulk sampling, however, the collection of at least 30 mL of sample has not been an issue. Therefore, the wind speed threshold criterion was eliminated for the 2004 season. The temperature limit serves to protect against damage from rime ice formation. The absence of rainfall is required because within the objectives of this study, as well as MCCP, only samples from non-precipitating clouds are collected. If a rain detector is activated, the string collector will retract into the protective case and collection will be suspended.

Beginning with the 1999 field season, a modified automated cloud collector has been used. The collector was modified by switching from a battery-powered to a pneumatically-powered system to send the collector up and down. This system measures and accumulates the cloud sample using a funnel positioned under a tipping bucket that is hooked up to the cloud collector with Teflon® tubing. The tipping bucket is calibrated so that the weight of 5.44 mL of collected liquid causes the apparatus to tip into the funnel. In 2004, the tipping bucket was removed from the cloud collection system as it was no longer necessary to track hourly collection volumes.


Automated Cloud Collector

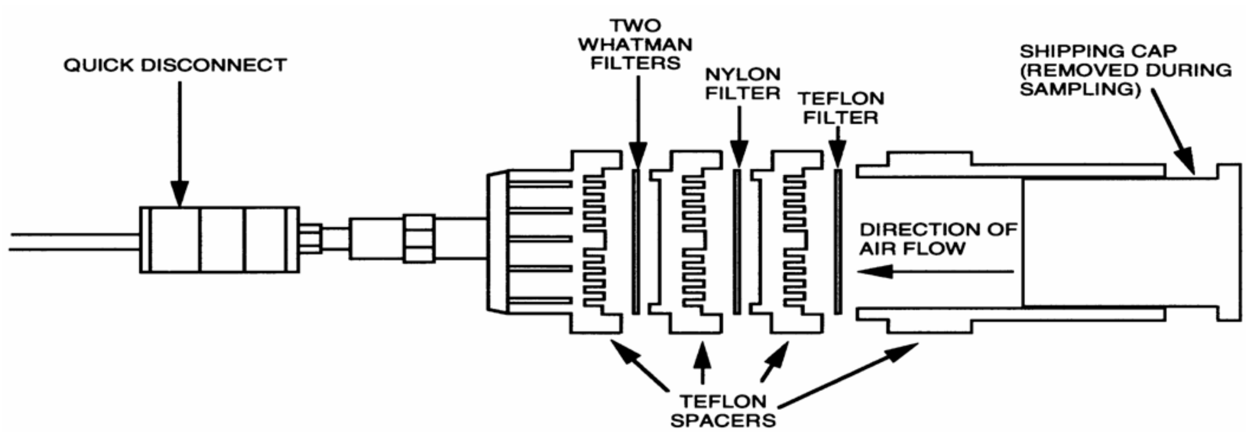
If the threshold criteria described above are not met for a 5-minute period, the collector comes down. A new collection bottle rotated into position after every 24-hour period allowing for the collection of daily bulked samples.

From 2000 to 2003, if the collector was down at midnight, an automatic rinse cycle was initiated for 20 seconds. The rinse water went through the sample line, cloud volume tipping bucket, and funnel. The rinse water was then diverted into a separate rinse water jug. No rinse cycle occurred if the collector was up at midnight. In 2004, the automatic midnight rinse was eliminated and a manual rinse was implemented. This change was initiated to ensure and document the rinsing of the collection apparatus.

The PVM is operated continuously. Consequently, collection of cloud samples only when the threshold criteria are met does not result in loss of cloud frequency and cloud duration information. All LWC values of 0.05 g/m^3 or greater, independent of the type of cloud (i.e., precipitating or non-precipitating), are used to calculate cloud frequency and cloud duration information. It is possible that the cloud deposition estimates presented later in Section 4 may be biased by not sampling for cloud deposition that occurs during precipitating clouds. However, the bias due to this lack of sampling during a precipitation event is offset by the fact that cloud deposition totals are estimated by multiplying the duration-weighted mean chemical fluxes by the cloud-hours for the month. The cloud-hours are calculated as the cloud frequency times the total hours in the month.

The site operator gathers cloud water samples from the collector every 48 hours, whether or not collection has occurred. The time, date, and volume of each bulk sample are recorded on the Cloud Water Sample Report Form. Each sample is then carefully decanted into one precleaned 250-mL sample bottle. Excess sample volume is discarded. The sample date and time are recorded on the sample bottle label. The site operator analyzes each sample for pH and conductivity and records the results on the Cloud Water Sample Report Form. The samples are then packed into coolers with the corresponding form and shipped to the CASTNET laboratory in Gainesville, FL. Periodically, selected rinse samples are included in shipments.

Filter packs for collection of dry deposition samples are prepared and shipped to the field on a weekly basis and exchanged at the site every Tuesday. For a description of the filter pack set-up, types of filters used, and the fraction collected on each filter, refer to the CASTNET Quality Assurance Project Plan (QAPP) (MACTEC, 2003) and/or the CASTNET Deposition Summary Report (EPA, 1998). A discussion of filter pack sampling artifacts can be found in Anlaulf *et al.* (1986). Filter pack flow is maintained at 3.0 liters per minute (Lpm) with a mass flow controller.



Three-stage Filter Pack

All field equipment received start-up and end-of-season calibrations. Calibration checks were performed weekly on the PVM throughout the field season and the results were used to adjust the instrument immediately after the calibration check. Calibrations on the remaining instruments were conducted using standards traceable to the National Institute for Standards and Technology

(NIST). The calibrations at the beginning and end of the 2004 field season were within the control limits stated in the CASTNET QAPP (MACTEC, 2003)

2.3 Laboratory Operations

Cloud water samples for the 2004 sampling season were analyzed for sodium (Na^+), potassium (K^+), ammonium (NH_4^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), NO_3^-, and SO_4^{2-} ions in the CASTNET laboratory. pH was analyzed in the field, and most samples were also analyzed for pH in the laboratory for comparison with the field pH meter.

Samples were stored at 4 °C until analysis. All analyses were performed within 30 days of sample receipt at the laboratory. The effects of storage on wet deposition samples have been addressed in NAPAP Report #6 (Sisterson *et al.*, 1991). This discussion applies, for the most part, to cloud water samples as well.

Concentrations of the three anions (SO_4^{2-}, NO_3^-, Cl^-) were determined by micromembrane-suppressed ion chromatography (IC). Analysis of Na^+, Mg^{2+}, Ca^{2+}, and K^+ was performed with a Perkin-Elmer Optima 3000 DV inductively coupled argon plasma-atomic emission spectrometer (ICP-AES). NH_4^+ concentrations were determined by the automated indophenol method using a Bran+Luebbe Autoanalyzer™ 3. Hydrogen (H^+) ion concentrations were determined for each sample based on field pH measurements.

Filter pack samples were loaded, shipped, received, extracted, and analyzed at the CASTNET laboratory. For specific extraction procedures refer to Anlauf *et al.* (1986) and the CASTNET QAPP (MACTEC, 2003). Filter packs contain three filter types in sequence: a Teflon® filter for collection of aerosols, a nylon filter for collection of HNO_3, and dual potassium carbonate (K_2CO_3)-impregnated cellulose filters for collection of SO_2. Following receipt from the field, exposed filters and unexposed blanks were extracted and analyzed for anions, NH_4^+, Na^+, Mg^{2+}, Ca^{2+}, and K^+ as described previously for cloud water samples. Refer to the CASTNET QAPP (MACTEC, 2003) for detailed descriptions of laboratory receipt, breakdown, storage, extraction, and analytical procedures.

Results of all valid analyses are stored in the laboratory data management system, Chemical Laboratory Analysis and Scheduling System (CLASS™). Atmospheric concentrations are calculated based on the volume of air sampled following validation of the hourly flow data. Atmospheric concentrations of particulate SO_4^{2-}, NO_3^-, NH_4^+, Na^+, K^+, Ca^{2+}, and Mg^{2+} are calculated based on analysis of Teflon® filter extracts; HNO_3 is calculated based on the NO_3^- found in the nylon filter extracts; and SO_2 is calculated based on the sum of SO_4^{2-} found in nylon and cellulose filter extracts.

2.4 Data Management

Continuous data (meteorological, LWC, and flow) are collected in hourly and 5-minute averages. Hourly data are collected by daily polling via telephone modem. The polling software also recovers status files and power failure logs from the previous seven days. The 5-minute data are downloaded to diskettes from the DAS cartridge at least once weekly. The hourly data and associated status flags are ingested into Microsoft® Excel™ spreadsheets. The continuous data are validated (flagged, adjusted, or invalidated) based on the end-of-season calibration results, periodic calibration check results (PVM only), and information provided by status flags and logbook entries.

Discrete data (filter pack and cloud water sample results) are managed by CLASS™. In CLASS™, the analytical batches are processed through an automated quality control (QC) check routine. For each analytical batch, an alarm flag is generated if any of the following occur:

1. Insufficient QC data were run for the batch;
2. The correlation coefficient of the standard curve was less than 0.995;
3. The 95-percent confidence limit of the Y-intercept exceeded the limit of quantitation;
4. Sample response exceeded the maximum standard response in the standard curve (i.e., sample required dilution);
5. Continuing verification samples (CVS) exceeded recovery limits; or
6. Reference samples exceeded accuracy acceptance limits.

A batch with one or more flags is accepted only if written justification is provided by the Laboratory Operations Manager.

Atmospheric concentrations for filter pack samples are calculated by merging validated continuous flow data with the laboratory data [micrograms per filter (µg/filter)]. For cloud water samples, a second check involves three interparameter consistency checks:

1. Percent difference of cations versus anions (ion balance),
2. Percent difference of predicted versus measured conductivity, and
3. pH versus conductivity relationship of the sample compared to the expected relationship when rainfall is assumed to be controlled by strong inorganic acid.

Evaluation of these interparameter consistency checks provides a method for determining whether the analysis should be repeated or verified.

2.5 Quality Assurance

The QA program consists of the same routine audits performed for CASTNET, if applicable, and testing/comparison of instruments unique to cloud water sampling.

2.5.1. Field Data Audits

The following audits are conducted for field data:

1. Review of all reported problems with sensors and equipment at the site and of the actions taken to solve such problems.
2. Review of calibration files for completeness and adherence to standard operating procedures (SOP). Certification results for transfer standards are also reviewed, and transfer sensor serial numbers are cross-referenced with the transfer sensor serial numbers on the calibration forms.
3. Comparison of final validated data tables to the raw data tables for identification and verification of all changes made to the data. Summary statistics and results of diagnostic tests for assessment of data accuracy are also reviewed.

2.5.2. Laboratory Data Audits

Laboratory data audits consist of:

1. Review of all media acceptance test results,
2. Review of chain-of-custody documentation, and
3. Review of all QC sample results associated with analytical batches.

2.5.3. Precision and Accuracy

With the exception of the automated cloud sampler and PVM, accuracy of field measurements (i. e., meteorological instruments) is determined by challenging instruments with standards that are traceable to NIST. Continuing accuracy is verified by end-of-season calibrations by MACTEC personnel. No certified standards are currently available for determination of cloud sampler and the PVM accuracy on a routine basis. Overall precision of field measurements is best determined by collocating instruments and assessing the difference between simultaneous measurements. Even though collocated sampling is not conducted at the CLD303 site, it is conducted at two other CASTNET sites. Since the meteorological instrumentation at CLD303 is identical to that used at CASTNET sites, precision of these instruments can be inferred from the precision and accuracy results presented in the CASTNET Deposition Summary Report (EPA, 1998) and the CASTNET annual reports for 1998 through 2003 (www.epa.gov/CASTNET/library.html).

Accuracy of laboratory measurements is determined by analyzing an independently prepared reference sample in each batch and calculating the percent recovery relative to the target value.

The percent recovery is expected to meet or exceed the acceptance criteria listed in the CASTNET QAPP (MACTEC, 2003). When possible, the references are traceable to NIST or obtained directly from NIST. On occasion, references are ordered from other laboratories.

Analytical precision within sample batches is assessed by calculating the relative percent difference (RPD) and percent recovery of CVS run within that batch. CVS are independently produced standards that approximate the midpoint of the analytical range for an analyte and are run after every tenth environmental sample. Precision within a batch is also assessed by replicating 5 percent of the samples within a run. Replicated samples are selected randomly.

3.0 Liquid Water Content and Cloud Water Chemistry

3.1 Cloud Frequency and Mean Liquid Water Content

Monthly mean cloud frequencies by year from 1994 through 2004 are summarized in Table 3-1. Cloud frequencies by month and year are also depicted as a bar chart in Figure 3-1. Monthly cloud frequencies were determined by calculating the relative percent of all hourly LWC values equal to or greater than 0.05 g/m^3, or:

$$CF = \frac{100 * \left(\#\ of\ valid\ hourly\ LWC\ values \geq 0.05\, g/m^3\right)}{n}$$

where: n is the number of valid hourly LWC values per month and
CF is cloud frequency

Any month with less than 70 percent valid LWC data was not considered representative of the monthly weather conditions for that month. Cloud frequencies vary from month to month, year to year, and from location to location. As can be seen from Table 3-1, the monthly cloud frequencies for all months in 2004 were higher than the historic means with June and October 2004 having the highest values for cloud frequency for these months thus far in the project.

Monthly mean LWC values for 1994 through 2004 are shown in Figure 3-2. Mean LWC was calculated by taking the average of all hourly LWC values equal to or greater than 0.05 g/m^3 during the month. Monthly mean LWC values for 2004 versus the historic monthly means are shown in Figure 3-3. Only those values passing the 70 percent completeness criterion were plotted. Even though, based on the cloud frequency data, 2004 was a cloudier year than average, the 2004 LWC values for the months of June, July, and August are comparable to values from previous years (Harding ESE, 2001, 2002, and 2003 and MACTEC, 2004). However, the monthly mean LWC values for September and October 2004 are higher than the historic means for these months and are the second highest LWC values ever recorded for these months. The high LWC of the clouds in September and October may be partly due to passage of two of the four hurricanes that hit Florida and then tracked inland over the Great Smoky Mountains.

3.2 Cloud Water Chemistry

During the 2004 sampling season, the CASTNET laboratory received 77 samples from CLD303. Seventy-three of the samples represented actual 24-hour bulk cloud water samples and the remaining four were rinse samples. All of the bulk samples received had sufficient volume for complete analysis except for three samples which were not analyzed for laboratory pH due to volume limitations. Samples sent to the CASTNET laboratory for analysis were packed in Styrofoam® coolers with frozen ice packs to keep the samples cool during shipping. Upon receipt of the samples, the sample receiving technician verified the condition of the samples and the contents of the shipment against the enclosed Cloud Water Sample Report Form. All samples were received in good condition.

Cloud water analytical and QC data for the sampling season are presented as Appendix B.

Annual summary statistics for cloud water chemistry and LWC are presented in Table 3-2. Table 3-3 lists the total number of samples or "records" that were collected each season of operation at CLD303. Samples were accepted and used for all subsequent analyses if they met acceptance criteria based on the cation-to-anion ratio. Samples were eliminated if:

1. Both the anion sum and cation sum were ≤ 100 microequivalents per liter (μeq/L) and the absolute value of the RPD was > 100 percent; or
2. Either the anion sum or the cation sum was > 100 μeq/L and the absolute value of the RPD was > 25 percent.

The RPD was calculated from the following formula:

$$\text{RPD} = 200 * (\text{cations} - \text{anions})/(\text{cations} + \text{anions})$$

3.2.1. Cloud Water pH

The pH values for CLD303 are shown in Figures 3-4 and 3-5. The frequency distribution in both figures shows that a majority of the 2004 samples (approximately 69 percent for laboratory pH and 82 percent for field pH) had values of pH 3.9 or lower. Historically, the majority of the pH values measured at CLD303 fall within the range of pH 3.2 to 3.8. This range is identified in the 1992 NAPAP report to Congress (1993) as "acidic cloud water." Therefore, these measured pH values, when in combination with other stresses, might affect the high elevation spruce forests of Clingmans Dome.

As can be seen from these figures and the summary statistics for pH and hydrogen ion concentrations in Table 3-2, the 2004 field pH values are lower than the laboratory pH values. The mean field hydrogen ion concentration (Table 3-2) is approximately 33 percent higher than the mean laboratory hydrogen ion concentration. Field pH values are known to be generally lower than pH values measured in the laboratory due to microbial activity, degradation of organic acids, dissolution of particulate matter, and ion exchange processes involving the walls and/or lid of the shipping container (Bigelow *et al*. 1984).

3.2.2. Major Ions in Cloud Water

The major ions are identified as SO_4^{2-}, H^+, NH_4^+, and NO_3^-. Figure 3-6 presents the mean seasonal major ion concentrations in cloud water samples for 1994 through 2004. The 2004 ammonium and nitrate mean concentrations show a decrease with respect to 2003 mean concentrations and also are the lowest thus far in the history of the project. The 2004 mean nitrate concentration (96.60 μeq/L) shows a 16.1 percent decrease from the 2003 mean. The mean sulfate concentration is the second lowest historically with the lowest sulfate concentration having been measured in 2002. The mean sulfate concentration (301.06 μeq/L) is 6.1 percent lower with respect to the 2003 mean. The months of August and October exhibited the highest major ion concentrations for 2004 (Figure 3-7). Summary statistics of all major ion concentrations, as well as calcium concentrations, averaged across all years (1994-2004) are presented in Table 3-4.

3.2.3. Minor Ions in Cloud Water

Mean seasonal concentrations of the minor ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, and Cl^-) for 1994 through 2004 are presented in Figure 3-8. Concentrations of calcium, magnesium, and potassium decreased with respect to 2003 mean concentrations while mean sodium and chloride concentrations increased. The monthly mean 2004 calcium and magnesium values are the lowest since 1995 (27.49 and 9.41 μeq/L, respectively). Sodium and chloride concentrations peaked in June (Figure 3-9), so the increase in seasonal concentration of these ions cannot be attributed to sea salt transported and deposited by the remnant hurricanes.

4.0 Cloud Deposition

This section presents the modeled cloud water deposition estimates for Clingmans Dome from 1994 through 2004. Deposition was estimated by applying the CLOUD model (Lovett, 1984), parameterized with site-specific cloud water chemistry and meteorological data from CLD303 as screened and provided by MACTEC. The complete report discussing 2004 cloud deposition modeling results by Gary M. Lovett, Ph.D., is presented in Appendix A. The following subsections present a summary of Lovett's results.

4.1 Cloud Water Deposition Model

Briefly, the CLOUD model uses an electrical resistance network analogy to model the deposition of cloud water to forest canopies. The model is one-dimensional, assuming vertical mixing of droplet-laden air into the canopy from the top. Turbulence mixes the droplets into the canopy space where they cross the boundary layers of canopy tissues by impaction and sedimentation. Sedimentation rates are strictly a function of droplet size. Impaction efficiencies are a function of the Stokes number, which integrates droplet size, obstacle size, and wind speed (Lovett, 1984). The impaction efficiency as a function of the Stokes number is based on wind tunnel measurements by Thorne *et al*. (1982).

The forest canopy is modeled as stacked 1-m layers containing specified amounts of various canopy tissues such as leaves, twigs, and trunks. Wind speed at any height within the canopy space is determined based on the above-canopy wind speed and an exponential decline of wind speed as a function of downward-cumulated canopy surface area. The wind speed determines the efficiency of mixing of air and droplets into the canopy and also the efficiency with which droplets impact onto canopy surfaces. The model is deterministic and assumes a steady-state, so that for one set of above-canopy conditions it calculates one deposition rate. The model requires as input data:

1. The surface area index of canopy tissues in each height layer in the canopy,
2. The zero-plane displacement height and roughness length of the canopy,
3. The wind speed at the canopy top,
4. The LWC of the cloud above the canopy, and
5. The mode of the droplet diameter distribution in the cloud.

From these input parameters, the model calculates the deposition of cloud water, expressed both as a water flux rate in grams per square centimeter per minute ($g/cm^2/min$), and as a deposition velocity [flux rate/LWC, in units of centimeters per second (cm/s)]. Deposition rates of ions are calculated by multiplying the water deposition velocity by the ion concentration in cloud water above the canopy. In the original version of the model, a calculation of the evaporation rate from the canopy was also included in order to estimate net deposition of cloud water. Starting with the 2002 sampling season, the calculation of the evaporation rate from the canopy was not invoked, resulting in estimation of only the gross deposition rate.

The structure of the CLOUD model and its application to these data followed exactly the procedures used to calculate fluxes for the MADPro cloud sites reported by Lovett (2000). After the model was run for all time periods, seasonal and monthly means and totals were calculated in a SAS® program. Approaches in data analysis that were different between this effort and the analysis reported by Lovett (2000) are:

1. The data provided to Lovett for this report were pre-screened by MACTEC.
2. Because there were no missing months, summed deposition fluxes were calculated for the season by simply summing all the monthly deposition amounts.

The 2004 data set contained 73 samples (or time periods) and the model was run for all 73 samples/time periods. Due to contractual and scheduling complications, data collection for all parameters did not begin until June 8, 2004. Collection continued through October, however, to offset the late start. Therefore, the season was identified as June 8 through October 26, 2004. All calculations for 2004 followed the same procedures as calculations for 2000, 2001, and 2002. Slightly different procedures were followed for the 2003 season because of a shorter sampling season and lack of data completeness for some of the months due to equipment malfunction. Please refer to the 2003 MADPro Report (MACTEC, 2004) for details of the 2003 procedures.

4.2 Results

4.2.1 Monthly Means

Slight variations were observed in mean wind speed from June through August (3.58, 4.40, and 3.42 m/s, respectively). However, a substantially higher mean monthly wind speed of 7.22 m/s was measured in September. Since even subtle differences in wind speed can cause substantial differences in cloud water deposition velocity, the September deposition velocity was a very high value of 33 cm/s. The cloud LWC was also highest in September. Despite these two high values, however, ion deposition rates for September were comparable to other months due to low ion concentrations and cloud frequency. The mean duration-weighted deposition velocity for all five months was 21.1 cm/s, very similar to the 1995 through 2004 mean of 21.3 cm/s.

The overall mean LWC for the season was 0.34 g/m^3, which is similar to the 2003 mean of 0.33 g/m^3.

Except for sodium and chloride, duration-weighted cloud water monthly concentrations peaked in August and October (Table I-2, Appendix A). Sodium and chloride both peaked in June and July. The duration-weighted mean seasonal sulfate concentration increased from 248.77 μeq/L in 2003 to 268.65 μeq/L in 2004, and the duration weighted mean hydrogen ion concentration also increased from 185.72 μeq/L in 2003 to 278.93 μeq/L in 2004 (Figure 2, Appendix A). With the exception of sodium and chloride, the rest of the mean seasonal concentrations all decreased with respect to 2003 values.

Monthly deposition estimates [kilograms per hectare (kg/ha)] for major ions, calcium, and water for 1994, 1995, 1997, 1998, and 2000 through 2004 are presented in Table 4-1. Despite the fact that sulfate concentrations peaked in August and October (Table I-2, Appendix A), total cloud deposition of sulfate was highest in September (Table I-3, Appendix A). This probably occurred because of the higher cloud water deposition in September. Nitrate and ammonium depositions, however, tracked the concentration peaks as both these depositions were highest in October. Overall, it is difficult to pinpoint a specific pattern or reason(s) for the deposition results for the various ions.

The monthly deposition estimates determined from the CLOUD model for years 2000 through 2004 are presented in Figures 4-1 and 4-2. In general, the monthly deposition estimates for May through September show a decline for the 2003 sampling season. For 2004, the monthly deposition estimates were higher with respect to 2003 for sulfate and hydrogen, and variable for nitrate, ammonium and calcium.

Table 4-2 presents the monthly deposition estimates as mean deposition averages for each year using those months with deposition estimates for 1995 through 1998, the months of May through September for 2000 through 2003, and June through October for 2004 (Table 4-1). Although it is difficult to make a direct comparison of the 2004 estimates to previous years since the 2004 rates were for June through October, the 2004 deposition estimates were higher in comparison to 2003 rates for all the ions except for calcium.

4.2.2 Seasonal Deposition Estimates

The seasonal deposition values for major ions are presented in Table 4-3. Only the data sets from 1997 and 2000 through 2004 are sufficiently complete to estimate a seasonal value. A season is defined as June through September and three of the four months are required to calculate the seasonal deposition. The 2004 data show an increase for hydrogen, ammonium, and sulfate with respect to 2003, whereas nitrate and calcium show a decrease compared to all other years in the table. The seasonal deposition estimates for 2004 for nitrate and calcium, therefore, were the lowest thus far in the history of the project.

5.0 Filter Pack Concentrations, Dry Deposition, and Total Deposition

Atmospheric sampling for sulfur and nitrogen species was integrated over weekly collection periods (Tuesday to Tuesday) using a three-stage filter pack. In this approach, particles and selected gases were collected by passing air at a controlled flow rate through a sequence of Teflon®, nylon, and Whatman filters. Weekly air pollutant concentrations measured during the 2004 field season, together with the weekly dry deposition values estimated from the concentrations and modeled deposition velocities, are presented in this section.

5.1 Filter Pack Concentrations

Over the course of the 2004 sampling season, the CASTNET laboratory analyzed 20 filter pack samples. The filter packs were installed on the sampling tower each Tuesday and then removed the following Tuesday. The site operator sealed each exposed filter pack with end caps and placed it in a resealable plastic bag for return shipment to MACTEC. Each filter pack was securely packed into a polyvinyl chloride (PVC) shipping tube with its corresponding Site Status Report Form (SSRF) and returned to MACTEC weekly. Any discrepancies or problems with the shipment were recorded on the SSRF by the receiving laboratory technician. All of the filter pack samples were received in good condition.

Upon receipt, all of the samples were logged in and unpacked. Each filter type was extracted and analyzed by the CASTNET laboratory for SO_4^{2-} and/or NO_3^-. The Teflon® filter received additional analysis for Cl^-, NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, and K^+. Sample handling and analyses followed the procedures described in the CASTNET Laboratory SOP (MACTEC, 2003) The filter pack analytical and QC data for the sampling season are presented in Appendix C.

Table 5-1 presents the atmospheric concentrations in micrograms per cubic meter (µg/m^3) resulting from analysis of each weekly filter pack exposed for sampling during the 2004 sampling season. Upon receipt of each weekly filter pack, the receiving technician assigned a sample number composed of various identifiers for sample type, year, week, and site. The on/off dates and times presented in Table 5-1 correspond with the entries recorded on the SSRF. Beginning with the 2000 sampling season, the valid hours column represents the total length of time the filter pack was installed on the collection tower. The hours sampled column shows the actual hours that flow went through the filter pack. Starting in 1996 and continuing through the 2003 sampling season, the flow to the filter pack was programmed to shut off during a cloud or rain event to allow for determination of dry deposition only. In 2004, the filter pack sampled during rain events as well and the flow was shut off only during a cloud event. The average flow is presented in units of Lpm and represents the average filter pack flow during dry deposition sampling events. The volume for each sample was determined by using the hours sampled and average flow in the following equation:

$$\textit{Volume in meters}^3 = \frac{\textit{hours sampled (hr) x average flow x 60}}{1{,}000}$$

The atmospheric concentrations for the filter pack samples were calculated by using the laboratory data (µg/filter) in the following equation.

$$\textit{Atmospheric Concentrations } (\mu g/m^3) = \frac{\mu g \textit{ of analyte/filter x analyte dependent constant}}{\textit{Volume}}$$

The following constants were used for converting the chemistry data:

Teflon®		Nylon		Whatman	
Parameter	Constant	Parameter	Constant	Parameter	Constant
SO_4^{2-}	1.0	SO_4^{2-}	1.0	SO_2	0.667
NO_3^-	4.429	HNO_3	4.5	NO_3^-	4.429
NH_4^+	1.286	NA	NA	NA	NA
Ca^{2+}	1.0	NA	NA	NA	NA
Mg^{2+}	1.0	NA	NA	NA	NA
Na^+	1.0	NA	NA	NA	NA
K^+	1.0	NA	NA	NA	NA
Cl^-	1.0	NA	NA	NA	NA

Note:

NA = not applicable

Table 5-1 presents the ambient concentrations for each sample and filter type for the captured particles and gases. Total ambient SO_2 was determined by this equation:

$$\textit{Total } SO_2 = \textit{Whatman } SO_2 + (\textit{Nylon } SO_4^{2-} * 0.667)$$

5.2 Dry Deposition

The Multi-Layer Model (MLM) was used to calculate dry deposition velocities (Meyers *et al*., 1998; Finkelstein *et al.*, 2000), which were combined with the measured concentrations to estimate dry deposition for Clingmans Dome. The filter pack system was collocated with the automated cloud sampler. The MLM calculations are considered reasonable and representative for Clingmans Dome because on-site meteorological measurements were used directly in the model. Although the MLM was developed and evaluated using measurements from flat terrain settings, the model evaluation results are considered roughly applicable to this site. The data from Meyers *et al.* (1998) show little overall bias and up to 100 percent differences for individual 1/2-hour simulations. More recent data (Finkelstein *et al.,* 2000) suggest that the MLM underestimates deposition velocities for SO_2 for complex, forested sites. The differences are expected to be lower for longer averaging times (i.e., monthly and seasonal periods). Consequently, the uncertainty in the dry deposition estimates is approximately 100 percent or lower, and the MLM calculations probably underestimate the dry fluxes.

The weekly dry deposition estimates, the seasonal fluxes, and the seasonal mean deposition velocities for 2004 are presented in Table 5-2. The seasonal fluxes were calculated by summing the weekly fluxes and then multiplying this sum by the number of weeks in the season and dividing by the number of weeks with valid flux estimates. The formula used for the 2004 field season is:

$$\text{(Sum of all valid weekly deposition estimates)} = \frac{17}{13} \text{ total seasonal flux}$$

Only 17 of the 20 filter packs analyzed were used to calculate deposition estimates as the last three filter packs were run completely during the month of October. The deposition season is defined as June through September.

5.3 Total Deposition

Total sulfur and nitrogen deposition estimates for the 2000 through 2004 sampling seasons are presented in Table 5-3. The sampling season is defined as the period from June through September. For cloud water, the total sulfur deposition was determined by converting the SO_4^{2-} deposition estimated from the CLOUD model to sulfur. Total sulfur for the dry component was determined by using the SO_2 and SO_4^{2-} total seasonal fluxes presented in Table 5-2. These values were converted to sulfur and then summed to determine the total dry sulfur deposition.

Total cloud water nitrogen deposition was determined by converting the NO_3^- and NH_4^+ deposition estimated from the CLOUD model to nitrogen. Total dry nitrogen deposition was determined by converting the HNO_3, NO_3^-, and NH_4^+ total seasonal fluxes presented in Table 5-2 to nitrogen. All of the nitrogen species were summed to provide the total nitrogen deposition.

Figure 5-1 presents total sulfur and nitrogen deposition for both the cloud water and dry components during the 2000 through 2004 sampling seasons. This figure shows that cloud water sulfur deposition for 2004 increased approximately 28 percent from 2003 measurements and dry sulfur deposition remained virtually the same (0.439 for 2003 versus 0.434 kg/ha for 2004). Total nitrogen deposition increased 8.4 percent for cloud water and 1.6 percent for dry deposition. The data show that dry deposition was a minor contributor to the deposition of pollutants to high elevations, while cloud deposition was a significant source. This figure does not present the contribution from deposition produced by precipitation.

6.0 Conclusions and Recommendations

The Clingmans Dome cloud water measurements show an overall decline in sulfur and nitrogen deposition over the last several years although 2004 estimates are somewhat higher than 2003 values. The estimate of 2004 cloud nitrate deposition is the lowest over the history of the network. Estimates of total deposition, i.e., deposition produced by clouds and dry deposition, also shows a general overall decline over the last several years. The estimates show that dry deposition is a minor contributor to the deposition of pollutants at high elevations. Cloud deposition is the significant pathway for deposition at these elevations.

The principal recommendation is to continue cloud sampling at Clingmans Dome during the 2005 season. The Clingmans Dome data constitute a major source of information on deposition to high elevation sensitive ecosystems and will continue to help gauge the effectiveness of the Acid Deposition Control Program in reducing atmospheric pollutant deposition.

It is further recommended for the 2005 season that pH and conductivity should be measured in the laboratory for at least 75 percent of the samples in order to verify proper operation of the field pH meter and probe, as well as to provide back up measurements for this important parameter.

Additionally, the microcontroller program should be updated to calculate sample durations. Deposition values for 1999 have still not been calculated. These data would be a valuable addition to the historical database.

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Tables

Table 3-1. Clingmans Dome Monthly Mean Cloud Frequency Summary

Clingmans Dome (CLD303)		**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**Mean[1]**
May	Cloud Frequency*				81.78%			31.07%	47.17%	34.50%	91.67%		37.58%
	Cloud-Hours**				82			560	742	742	360		
	Completeness				11%			75%	100%	100%	48%		
June	Cloud Frequency*				61.63%	48.58%	41.38%	49.72%	43.33%	43.47%	54.61%	67.89%	50.07%
	Cloud-Hours**				172	422	667	543	720	720	661	387	
	Completeness				24%	59%	93%	75%	100%	100%	92%	79%	
July	Cloud Frequency*		29.47%	46.64%	34.34%	55.42%	44.75%	41.67%	57.08%	49.06%	42.78%	56.66%	48.58%
	Cloud-Hours**		285	298	661	720	733	336	685	693	734	370	
	Completeness		38%	40%	89%	97%	99%	45%	92%	93%	99%	88%	
August	Cloud Frequency*		49.44%		41.49%	71.43%	24.93%	43.45%	67.84%	28.02%	42.58%	46.64%	43.12%
	Cloud-Hours**		710		617	7	742	702	541	721	357	347	
	Completeness		95%		83%	1%	100%	94%	73%	97%	48%	100%	
September	Cloud Frequency*	32.41%	30.37%		33.18%	43.93%	27.65%	50.65%	37.78%	51.60%	39.74%	47.18%	41.67%
	Cloud-Hours**	395	349		639	387	622	689	360	624	609	334	
	Completeness	55%	48%		93%	54%	86%	96%	50%	87%	85%	98%	
October	Cloud Frequency*	40.27%		23.64%	35.52%	30.32%		5.98%	41.72%			48.56%	32.13%
	Cloud-Hours**	663		330	563	696		562	338			287	
	Completeness	89%		44%	76%	94%		76%	46%[¥]			79%	
November	Cloud Frequency*				59.7%								
	Cloud-Hours**				67								
	Completeness				9%								

Note:

* Cloud frequency is not used in subsequent analyses if the completeness criterion of greater than 70 percent is not met. Monthly deposition estimates for 2003 were an exception.

** Number of records where LWC > 0.05 g/m^3

¥ Site was shutdown on 10/16. Completeness based at time of shutdown is 91.85 percent.

1 The average cloud frequency values are calculated only from those annual values that meet the completeness criterion.

Table 3-2. Summary Statistics for Cloud Water Samples (Clingmans Dome, TN) 2004

	2004 Total Records Accepted = 73				
	n	**mean**	**std dev**	**min**	**max**
LWC	73	0.31	0.12	0.078	0.63
pH - Field	72	3.53	0.40	3.09	4.94
pH - Lab	70	3.70	0.43	3.17	5.18
Cond - Field	72	125.79	85.44	5.5	383.00
Cond - Lab	70	197.84	146.89	6.61	676.08
H^+ - Field	71	294.94	194.04	11.48	812.83
H^+ - Lab	70	197.84	146.89	6.61	676.08
NH_4^+	73	148.25	127.61	0.71	539.60
SO_4^{2-}	73	301.06	228.39	8.06	938.96
NO_3^-	73	96.60	72.79	0.29	373.37
Ca^{2+}	73	27.49	25.34	0.30	117.67
Mg^{2+}	73	9.41	7.26	0.51	33.76
Na^+	73	13.52	14.93	0.51	76.82
K^+	73	4.11	3.82	0.33	18.92
Cl^-	73	15.23	11.42	1.04	62.34
Cations - Field	71	502.34	502.34	25.06	1370.65
Cations - Lab	71	402.76	402.76	11.04	1270.48
Anions	70	415.83	415.83	9.56	1312.34

Note:

All units are µeq/L except for LWC (g/m^3), pH (standard units), and conductivity (micro ohms/cm)

The following acceptance criteria were used based on the cation and anion concentrations:

(1) If both cation and anion sums were less than or equal to 100 µeq/L, then the RPD criterion (defined below) was ≤ 100 percent for a record to be accepted.

(2) If either or both of the cation or anion sums were greater than 100 µeq/L, then the RPD criterion was ≤ 25 percent for a record to be accepted.

(3) max = maximum
min = minimum
n = sample size used in calculations
RPD = The absolute value of difference in cation and anion concentrations divided by the average of the cation and anion concentrations multiplied by 200
std dev = sample standard deviation

Table 3-3. Number of Cloud Water Samples Accepted for Analyses

Site ID	Year	Total Number of Samples	Number of Samples Accepted	Percent Accepted
CLD303	1994*	14	9	64%
	1995*	142	136	96%
	1996*	122	105	86%
	1997*	334	324	97%
	1998*	341	269	79%
	1999*	174	174	100%
	2000**	104	102	98%
	2001***	73	70	96%
	2002***	75	65	87%
	2003***	78	78	100%
	2004***	73	73	100%
Total	**1994-2004**	**1530**	**1405**	**92%**

Note:
- * Hourly samples — sample collection bottle changed every hour.
- ** Hourly + bulk samples (62 hourly and 42 bulk samples in year 2000)
- *** Bulk samples — sample collection bottle changed every 24 hours.

Table 3-4. Summary Statistics of Major Ion and Calcium Concentrations (µeq/L) of Cloud Water Samples for Clingmans Dome 1994 – 2004

		H^+	NH_4^+	SO_4^{2-}	NO_3^-	Ca^{2+}
CLD303	Mean	339.90	225.26	420.13	175.57	47.45
	Minimum	0.54	0.71	3.54	0.29	0.15
	Maximum	2137.96	1650.01	3686.91	1342.88	1051.89
	Median	257.04	179.12	320.78	137.95	24.85

Table 4-1. Cloud Water Monthly Deposition Estimates Produced by the CLOUD Model (kg/ha)*

Site	Year	Month	H^+	SO_4^{2-}	NO_3^-	NH_4^+	Ca^{2+}	H_2O (cm)
CLD303	1994	October	0.04	3.90	2.30	1.05	0.24	6.42
	1995	August	0.13	9.33	4.96	1.67	0.35	9.83
	1997	July	0.23	14.13	6.87	3.03	0.54	5.54
		August	0.24	14.16	8.37	3.04	0.69	8.74
		September	0.18	11.10	4.52	2.03	0.28	10.43
		October	0.31	19.71	12.22	4.71	0.67	7.02
	1998	July	0.45	23.58	13.33	7.61	0.75	10.76
		October	0.22	11.79	9.83	3.02	0.78	9.10
	2000	May	0.05	6.88	4.46	2.00	0.56	4.74
		June	0.18	13.00	9.40	2.89	0.93	9.68
		August	0.41	25.54	12.52	3.78	1.31	10.22
		September	0.30	14.36	5.85	1.84	0.11	12.82
		October	0.09	4.63	2.86	1.14	0.15	1.11
	2001	May	0.09	8.19	6.72	2.83	0.64	5.01
		June	0.28	18.84	18.92	3.87	3.53	9.34
		July	0.30	16.85	9.22	2.63	0.64	9.16
		August	0.44	26.77	18.88	4.35	1.20	10.50
	2002	May	0.14	9.51	4.08	1.97	0.50	9.50
		June	0.15	8.84	5.34	1.95	0.53	5.98
		July	0.17	9.33	5.40	1.64	0.36	10.80
		August	0.17	10.18	5.12	1.84	0.33	4.90
		September	0.29	21.41	10.61	3.92	1.10	14.86
	2003	May**	0.09	7.32	4.23	1.60	0.60	14.52
		June	0.11	7.35	3.18	1.32	0.42	8.53
		July	0.11	6.72	3.69	1.25	0.37	7.63
		August***	0.19	10.93	5.01	1.83	0.42	5.89
		September	0.17	10.68	5.43	2.20	0.50	7.20
	2004	June	0.17	9.43	3.77	1.67	0.34	9.69
		July	0.27	11.12	4.82	1.83	0.46	11.81
		August	0.25	11.88	4.57	2.08	0.30	6.44
		September	0.28	13.12	3.97	2.05	0.25	16.96
		October	0.35	12.10	6.71	2.69	0.46	8.06

Note:

* Deposition estimates for 1996 and 1999 were not calculated.

** May 2003 data represent May 17-31, 2003 only

*** August 2003 had only 48% completeness

Table 4-2. Cloud Water Mean Monthly (May – September*) Deposition Rates for Several Ions (in kg/ha/month) and Water

Site	Year	Water (cm/month)	H^+	NH_4^+	SO_4^{2-}	NO_3^-	Ca^{2+}
CLD303	1995-98	8.1	0.23	3.0	14.3	7.7	0.54
	2000	9.7	0.29	3.0	16.9	8.8	0.68
	2001	8.6	0.31	3.3	18.4	12.5	1.28
	2002	9.2	0.18	2.3	11.9	6.1	0.56
	2003	10.5	0.14	1.8	9.3	4.7	0.53
	2004*	10.6	0.27	2.1	11.5	4.8	0.36

Note:
* June through October for 2004

Table 4-3. Cloud Water Seasonal Deposition Estimates Produced by the CLOUD Model (kg/ha)

Site	Year	H^+	NH_4^+	SO_4^{2-}	NO_3^-	Ca^{2+}
CLD303	1997	0.86	10.20	52.53	26.35	2.01
	2000	1.40	12.76	77.87	39.80	2.84
	2001	1.47	13.76	83.69	55.79	5.78
	2002	0.78	9.35	49.76	26.47	2.32
	2003	0.58	6.60	35.68	17.31	1.71
	2004	0.97	7.63	45.55	17.13	1.35

Note:
* Season is defined from June through September
Three of the four months were required to calculate seasonal deposition. The 3-month deposition was multiplied by 4/3.

Table 5-1. Clingmans Dome Ambient Concentrations (µg/m^3) – June through October 2004

			Teflon®								Nylon		Whatman						
Sample Number	**On Date/Time**	**Off Date/Time**	**SO_4^{2-}**	**NO_3^-**	**NH_4^+**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**	**Cl^-**	**SO_4^{2-}**	**HNO_3**	**SO_2**	**NO_3^-**	**Comment Codes**	**Valid Hours**	**Hours Sampled**	**Average Flow**	**Actual Volume**
DD04-24*85	6/8/04 10:40	6/15/04 8:00	1.050	0.033u	0.231	0.014	0.006	0.011	0.012	0.019u	0.320	1.302	0.107	N	T1 W3	164	154	2.864	26.461
DD04-25*85	6/15/04 8:00	6/22/04 8:00	3.584	0.171u	0.970	0.040	0.014	0.024	0.029	0.096u	0.496	1.678	0.470	N	W3	165	44	1.967	5.192
DD04-26*85	6/22/04 8:00	6/29/04 8:40	3.493	0.038u	0.789	0.041	0.008	0.009	0.040	0.021u	0.191	1.070	0.057u	N		167	137	2.850	23.428
DD04-27*85	6/29/04 8:40	7/6/04 7:30	3.512	0.044u	0.754	0.056	0.016	0.040	0.033	0.025u	0.294	1.016	0.067u	N		162	140	2.387	20.051
DD04-28*85	7/6/04 7:30	7/13/04 8:00	4.284	0.048u	1.100	0.090	0.026	0.075	0.050	0.027u	0.654	1.770	0.344	N	N3	164	133	2.295	18.316
DD04-29*85	7/13/04 8:00	7/20/04 7:40	I	I	I	I	I	I	I	I	I	I	I	N		24	19	4.686	5.342
DD04-30*85	7/20/04 7:40	7/27/04 12:30	6.239	0.142u	1.706	0.100	0.017	0.020	0.043	0.080u	0.683	2.217	0.257	N	W3	101	59	1.762	6.237
DD04-31*85	7/27/04 12:30	8/3/04 9:15	5.161	0.074u	0.791	0.032	0.019	0.096	0.030	0.042u	0.273	1.465	0.123	N		160	108	1.843	11.942
DD04-32*85	8/3/04 9:15	8/10/04 7:30	2.130	0.032u	0.445	0.029	0.006	0.007	0.016	0.018u	1.086	1.553	0.896	N	W3	162	162	2.884	28.035
DD04-33*85	8/10/04 7:30	8/17/04 8:45	6.472	0.053u	1.338	0.052	0.016	0.035	0.035	0.030u	0.594	1.637	0.283	N		165	146	1.912	16.750
DD04-34*85	8/17/04 8:45	8/24/04 13:40	6.909	0.059u	1.643	0.138	0.019	0.027	0.078	0.033u	0.803	1.538	0.331	N		170	142	1.775	15.124
DD04-35*85	8/24/04 13:40	8/31/04 9:00	5.636	0.045u	0.997	0.056	0.020	0.052	0.033	0.026u	0.467	1.935	0.100	N		160	153	2.122	19.481
DD04-36*85	8/31/04 9:00	9/7/04 8:30	2.124	0.058u	0.421	0.027	0.009	0.025	0.016	0.032u	0.465	1.853	0.167	N	W3	162	111	2.312	15.397
DD04-37*85	9/7/04 8:30	9/14/04 9:00	7.111	0.097u	1.224	0.055	0.012	0.018	0.036	0.055u	1.351	1.975	1.072	N		163	50	3.037	9.112
DD04-38*85	9/14/04 9:00	9/21/04 8:30	0.476	0.208u	0.247	0.077	0.018	0.029	0.029	0.117u	0.709	0.945	0.493	N	T1	157	46	1.544	4.260
DD04-39*85	9/21/04 8:30	9/28/04 7:50	2.335	0.042	0.682	0.089	0.018u	0.042u	0.028	0.022u	0.479	1.479	0.458	N	T1	164	128	2.978	22.867
DD04-40*85	9/28/04 7:50	10/5/04 12:00	6.277	0.075	1.792	0.186	0.024	0.022	0.052	0.023u	0.972	2.808	2.241	N		172	129	2.801	21.683
DD04-41*85	10/5/04 12:00	10/12/04 9:30	3.134	0.158	1.204	0.143	0.021	0.018	0.046	0.052u	1.182	1.324	1.549	N		161	47	3.390	9.561
DD04-42*85	10/12/04 9:30	10/19/04 9:15	0.625	0.129	0.238	0.041	0.006	0.009u	0.015	0.037u	0.472	0.479	0.308	N	W3	165	82	2.742	13.491
DD04-43*85	10/19/04 9:15	10/26/04 8:00	3.236	0.059u	0.827	0.104	0.023	0.056	0.040	0.033u	0.463	1.532	0.514	N		147	102	2.452	15.009
		Mean	3.819	0.087	0.903	0.073	0.016	0.033	0.034	0.044	0.636	1.519	0.507						
		Std Dev	2.105	0.055	0.478	0.045	0.006	0.023	0.015	0.029	0.315	0.523	0.553						

Data Status Flags: **I** = Sample invalidated **M** = Missing or completely invalid flow data **N** = Sample not analyzed **U** = Value is less than detection limit **NA** = Not available

Comment Codes: **1** = unidentified debris/particles on filter **3** = excessively wet filter noted during unpacking

Filter Type Abbreviation: **T** = Teflon® **N** = Nylon **W** = Whatman

Table 5-2. Clingmans Dome Dry Deposition Fluxes (kg/ha) Report for the 2004 Sampling Season (June through September)

			Fluxes (kg/ha)					Deposition Velocities (cm/sec)		
Sample Number	**On Date**	**Off Date**	**SO_2**	**HNO_3**	**SO_4^{2-}**	**NO_3^-**	**NH_4^+**	**SO_2**	**HNO_3**	**Particle**
DD04-24*85	6/8/2004	6/15/2004	0.0085	0.2124	0.0085	0.0002	0.0019	0.4387	2.7151	0.1344
DD04-25*85	6/15/2004	6/22/2004	0.0218	0.3635	0.0344	0.0016	0.0093	0.4510	3.5780	0.1587
DD04-26*85	6/22/2004	6/29/2004	M	M	M	M	M	M	M	M
DD04-27*85	6/29/2004	7/6/2004	M	M	M	M	M	M	M	M
DD04-28*85	7/6/2004	7/13/2004	0.0211	0.3286	0.0409	0.0005	0.0105	0.4468	3.0693	0.1580
DD04-29*85	7/13/2004	7/20/2004	M	M	M	M	M	M	M	M
DD04-30*85	7/20/2004	7/27/2004	M	M	M	M	M	M	M	M
DD04-31*85	7/27/2004	8/3/2004	0.0078	0.2412	0.0399	0.0005	0.0062	0.4113	2.6818	0.1276
DD04-32*85	8/3/2004	8/10/2004	0.0462	0.2756	0.0226	0.0003	0.0048	0.4737	2.9390	0.1739
DD04-33*85	8/10/2004	8/17/2004	0.0178	0.2583	0.0493	0.0004	0.0102	0.4323	2.6044	0.1261
DD04-34*85	8/17/2004	8/24/2004	0.0224	0.2603	0.0503	0.0004	0.0119	0.4271	2.7949	0.1203
DD04-35*85	8/24/2004	8/31/2004	0.0105	0.2365	0.0325	0.0003	0.0058	0.4062	2.0408	0.0944
DD04-36*85	8/31/2004	9/7/2004	0.0123	0.3129	0.0183	0.0005	0.0036	0.4248	2.7965	0.1429
DD04-37*85	9/7/2004	9/14/2004	0.0481	0.3757	0.0495	0.0007	0.0085	0.4034	3.1376	0.1151
DD04-38*85	9/14/2004	9/21/2004	0.0242	0.2530	0.0070	0.0030	0.0036	0.4153	4.3982	0.2400
DD04-39*85	9/21/2004	9/28/2004	0.0210	0.2997	0.0251	0.0004	0.0073	0.4337	3.2740	0.1748
DD04-40*85	9/28/2004	10/5/2004	0.0753	0.5072	0.0551	0.0006	0.0157	0.4312	2.9845	0.1450
		Total Seasonal Flux	0.4668	5.4347	0.6000	0.0133	0.1376			
		Mean Seasonal Deposition						0.4304	3.0011	0.1470

Data Status Flags: M = Missing or invalid flow or met data

Note: MLM simulations were performed for each 24-hour period from 0800 on the On Date to 0800 on the Off Date.

Table 5-3. Cloud Water and Dry Sulfur and Nitrogen Deposition for Clingmans Dome (June through September 2000-2004)

	Year	Total Sulfur (kg/ha)	Total NO_3^--N (kg/ha)	Total NH_4^+-N (kg/ha)	Total Nitrogen (kg/ha)
Cloud Water	2000	28.288	10.003	11.460	21.463
	2001	30.670	14.127	12.882	27.009
	2002	16.610	5.982	7.260	13.242
	2003	11.917	3.912	5.129	9.041
	2004	15.210	3.871	5.925	9.796
Dry	2000	0.572	1.453	0.124	1.577
	2001	0.843	2.043	0.214	2.257
	2002	0.675	1.904	0.183	2.087
	2003	0.439	1.027	0.107	1.134
	2004	0.434	1.212	0.107	1.319

Note:

Season is defined from June through September

Total sulfur deposition includes SO_4^{2-} in cloud water plus ambient SO_2 and SO_4^{2-}

Total nitrogen deposition includes NO_3^- and NH_4^+ in cloud water plus ambient NO_3^-, NH_4^+, and HNO_3

Figures

Figure 3-1. Monthly Cloud Frequency (1994 – 2004) Clingmans Dome, TN

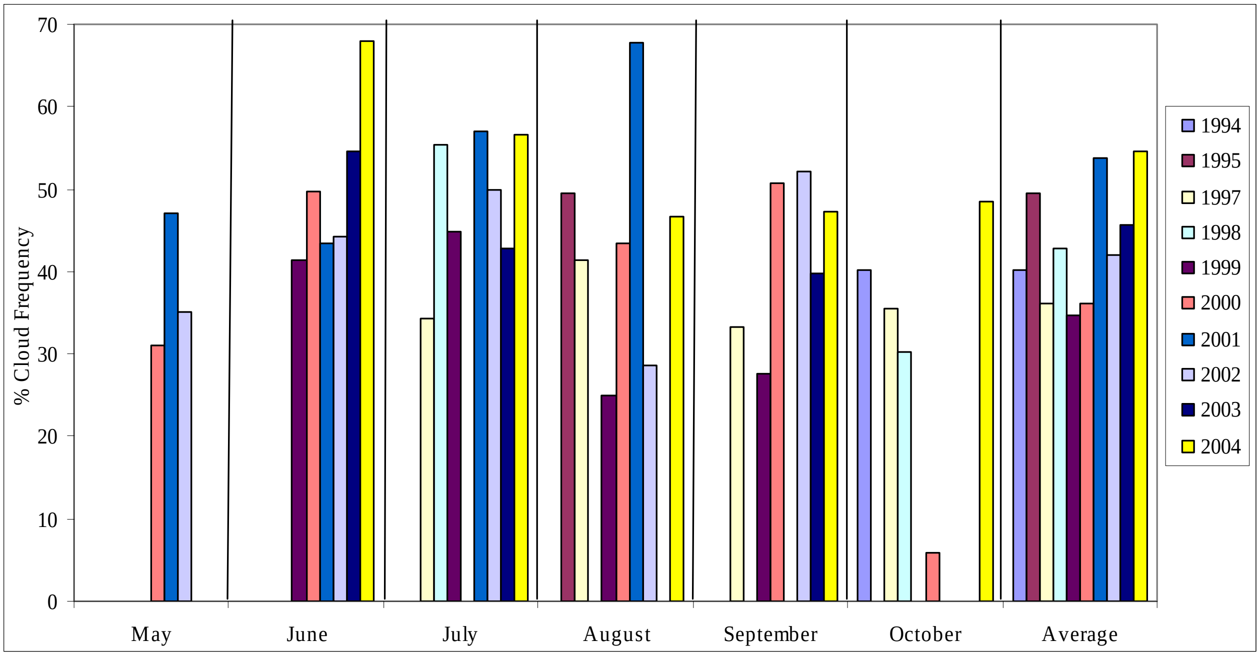


Figure 3-2. Monthly Mean Liquid Water Content (g/m^3) of Clouds (1994-2004) Clingmans Dome, TN

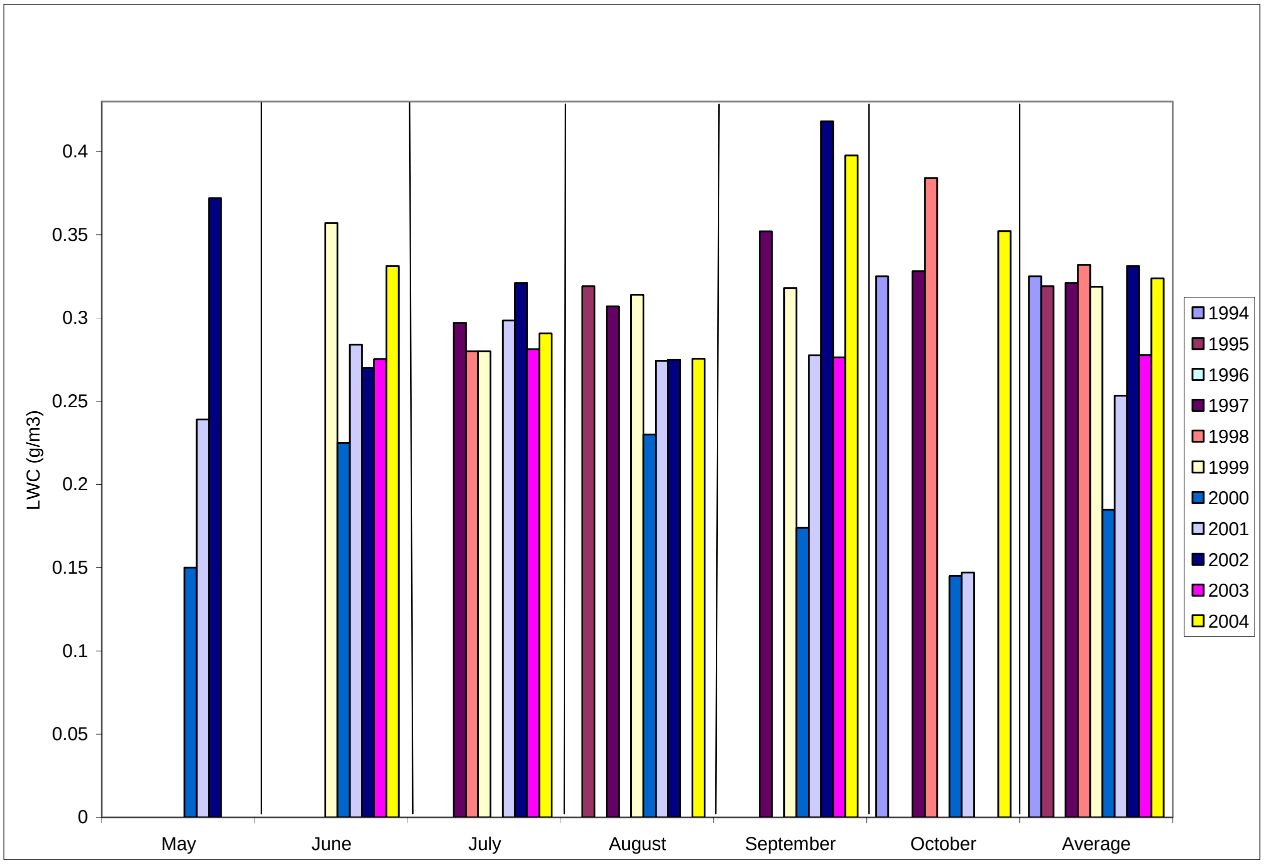


Figure 3-3. Monthly Mean Liquid Water Content (g/m^3), 2004 versus Historic Mean Values (1994-2003)

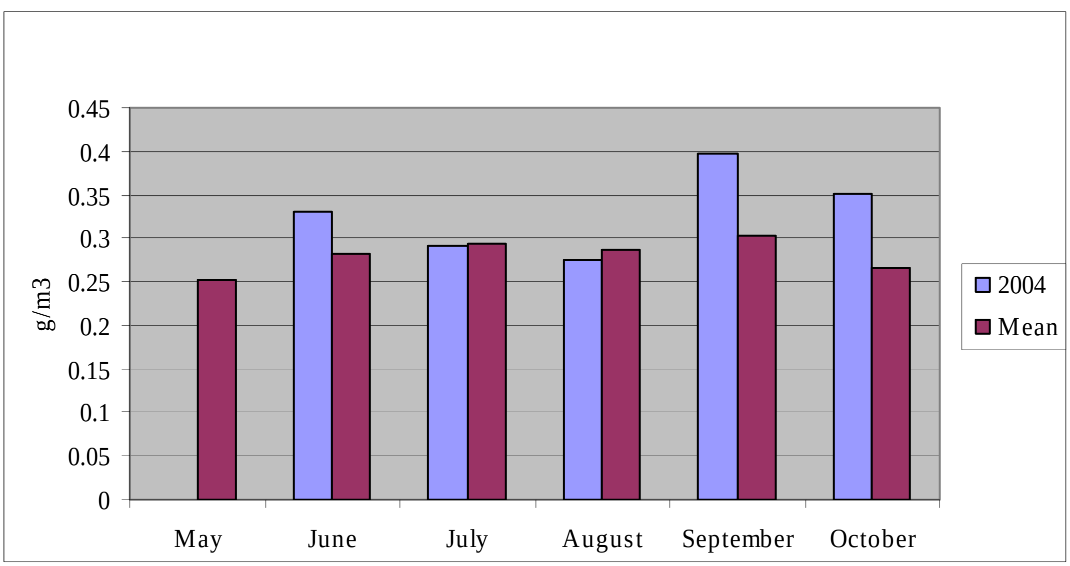


Figure 3-4. Frequency Distribution for Cloud Water pH (Laboratory) at Clingmans Dome, TN (2004)

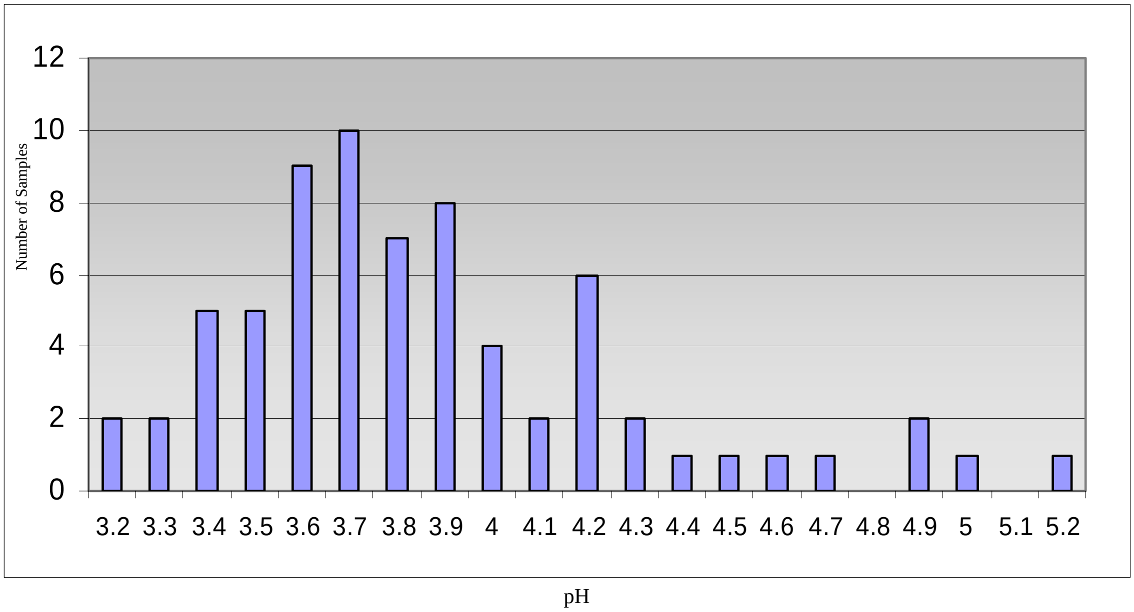


Figure 3-5. Frequency Distribution for Cloud Water pH (Field) at Clingmans Dome, TN (2004)

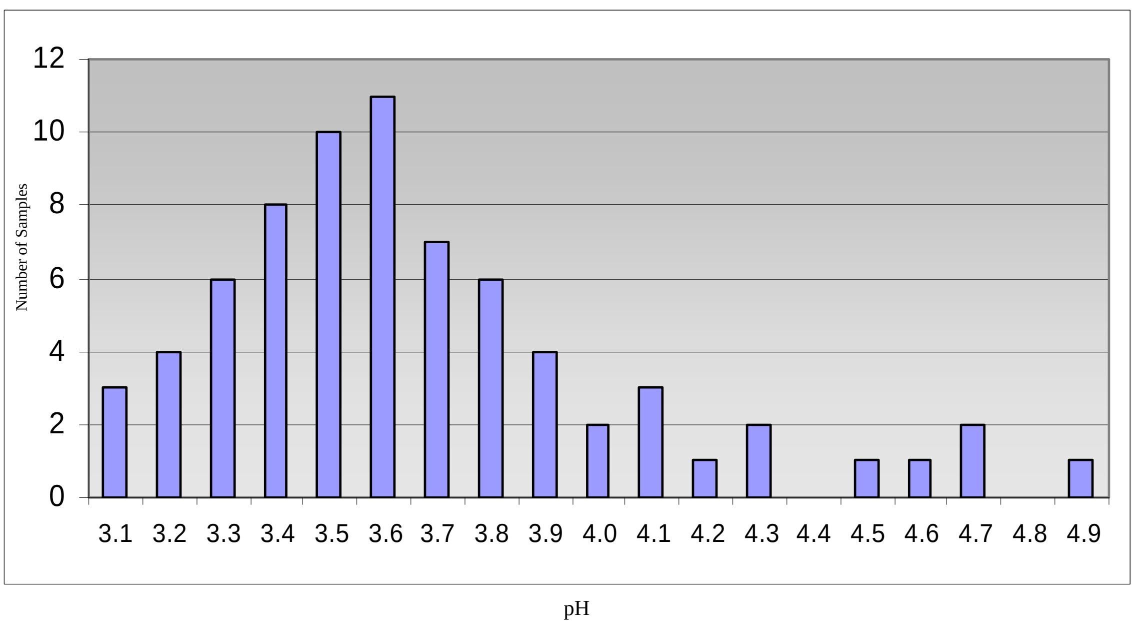


Figure 3-6. Major Mean Ion Concentrations of Cloud Water Samples, Clingmans Dome, TN (1994 – 2004)

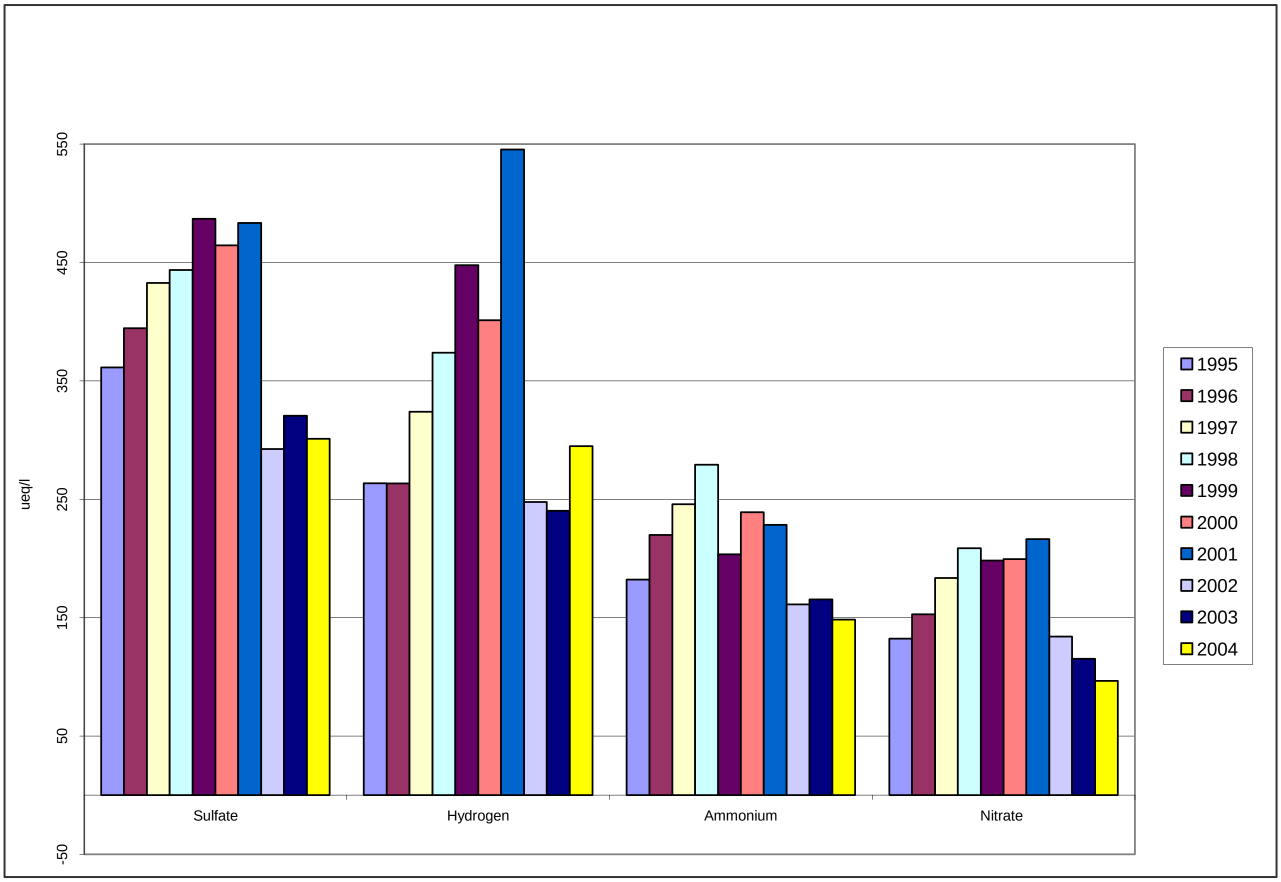


Figure 3-7. Monthly Mean Major Ion Concentrations, Clingmans Dome, TN – 2004

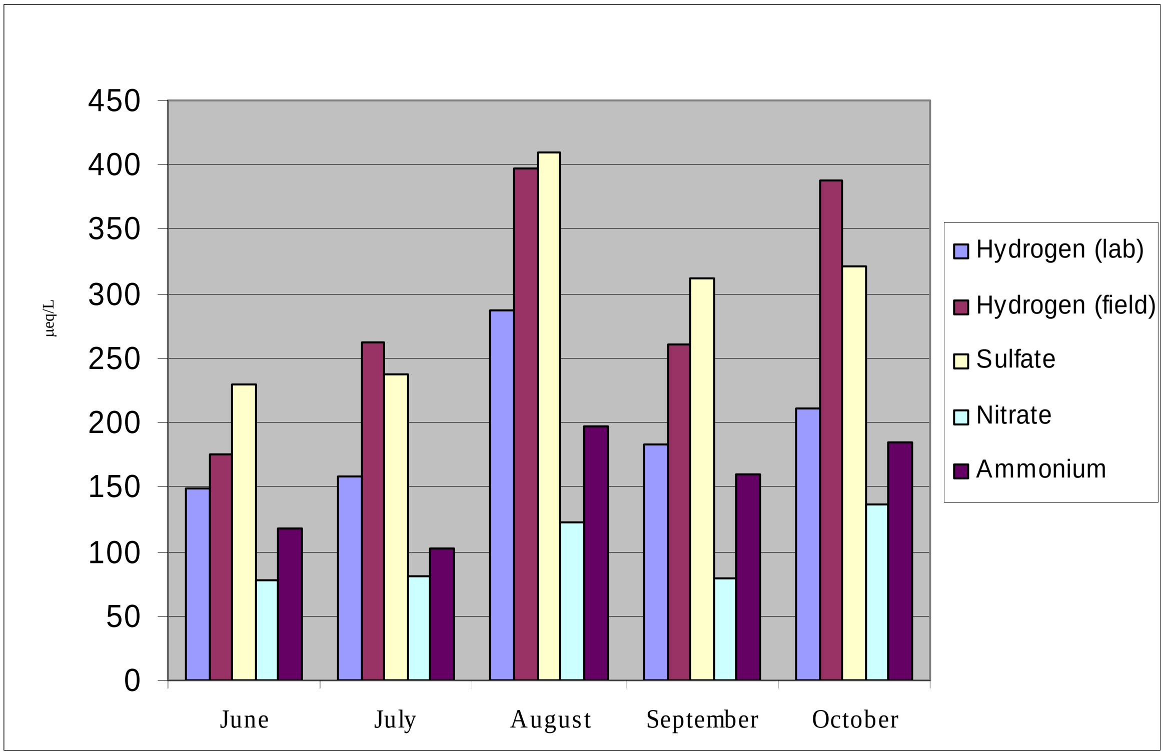


Figure 3-8. Mean Minor Ion Concentrations of Cloud Water Samples (Cations and Chloride) Clingmans Dome, TN (1994 – 2004)

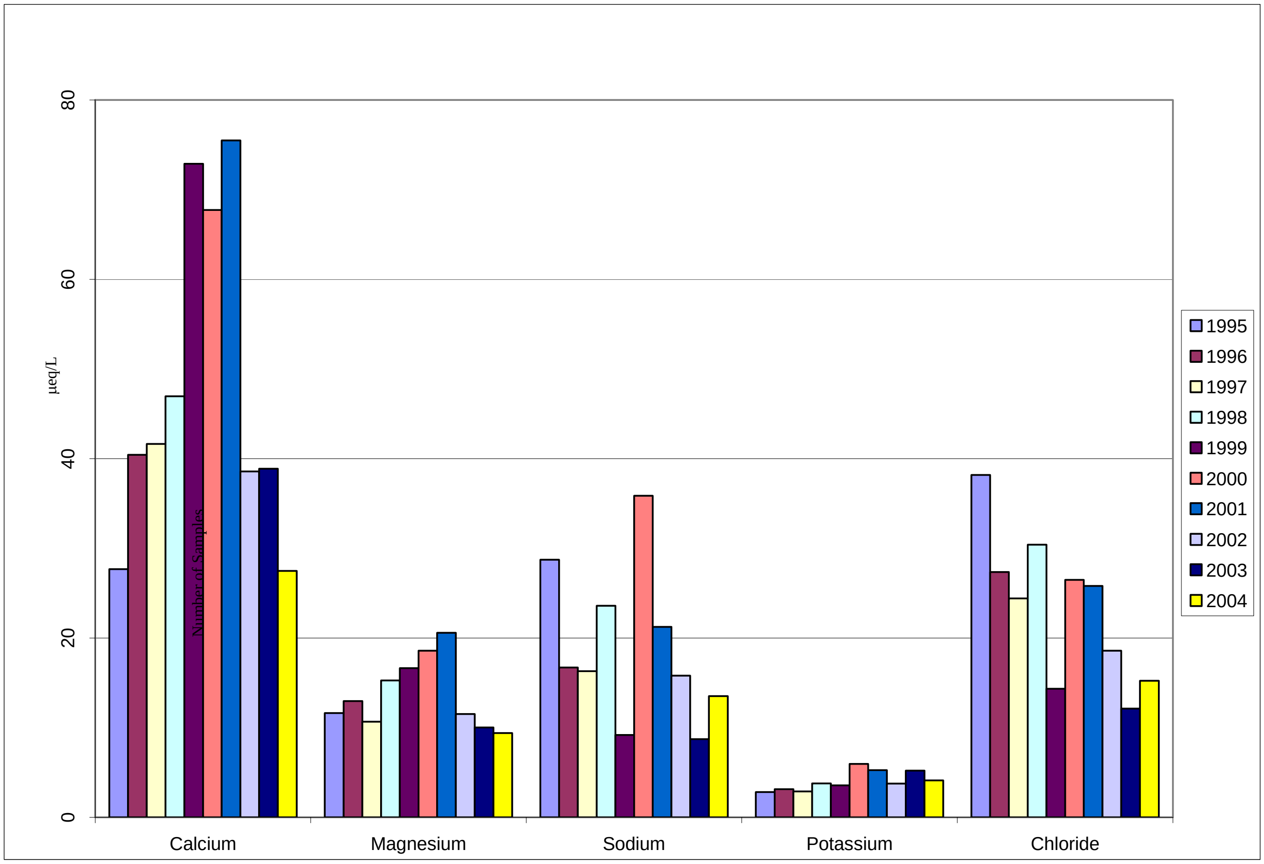


Figure 3-9. Monthly Mean Minor Ion Concentrations, Clingmans Dome, TN – 2004

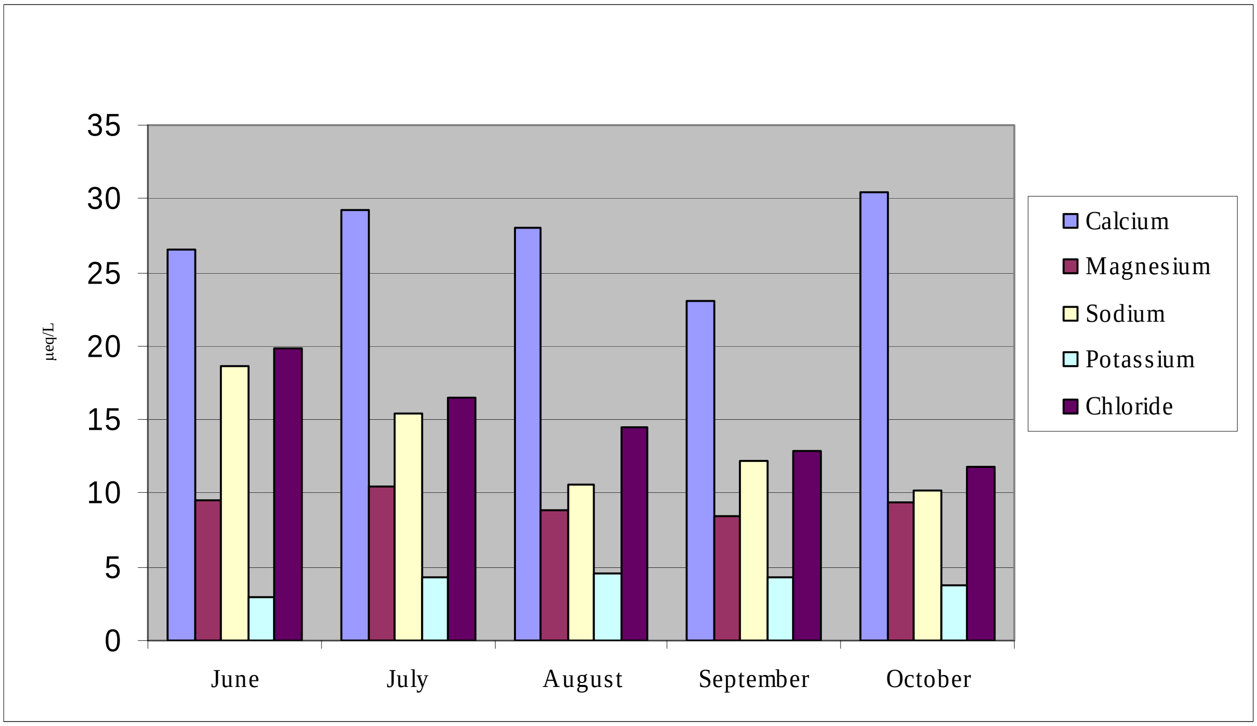
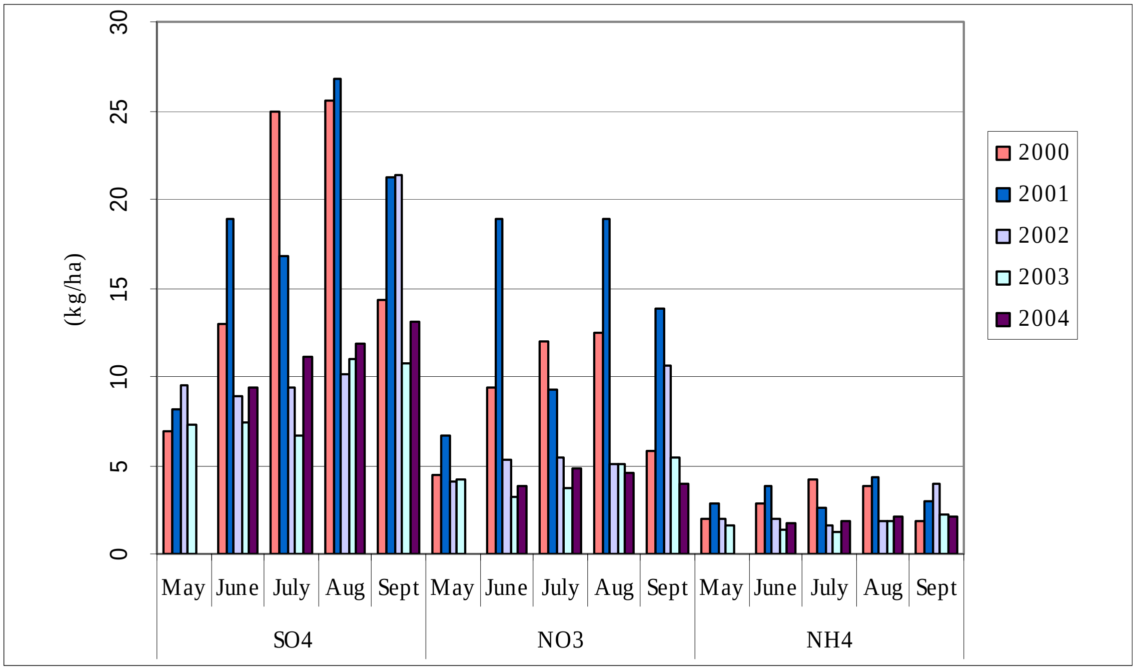
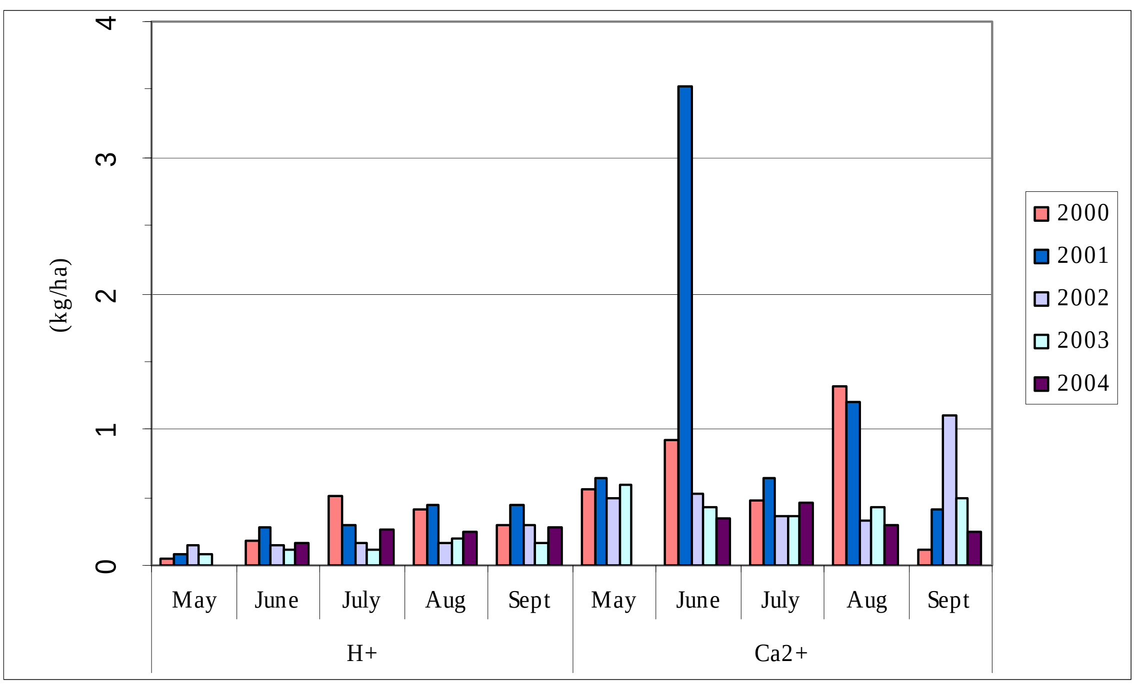


Figure 4-1. Monthly Deposition Estimates – CLOUD Model (SO_4^{2-}, NO_3^-, NH_4^+)



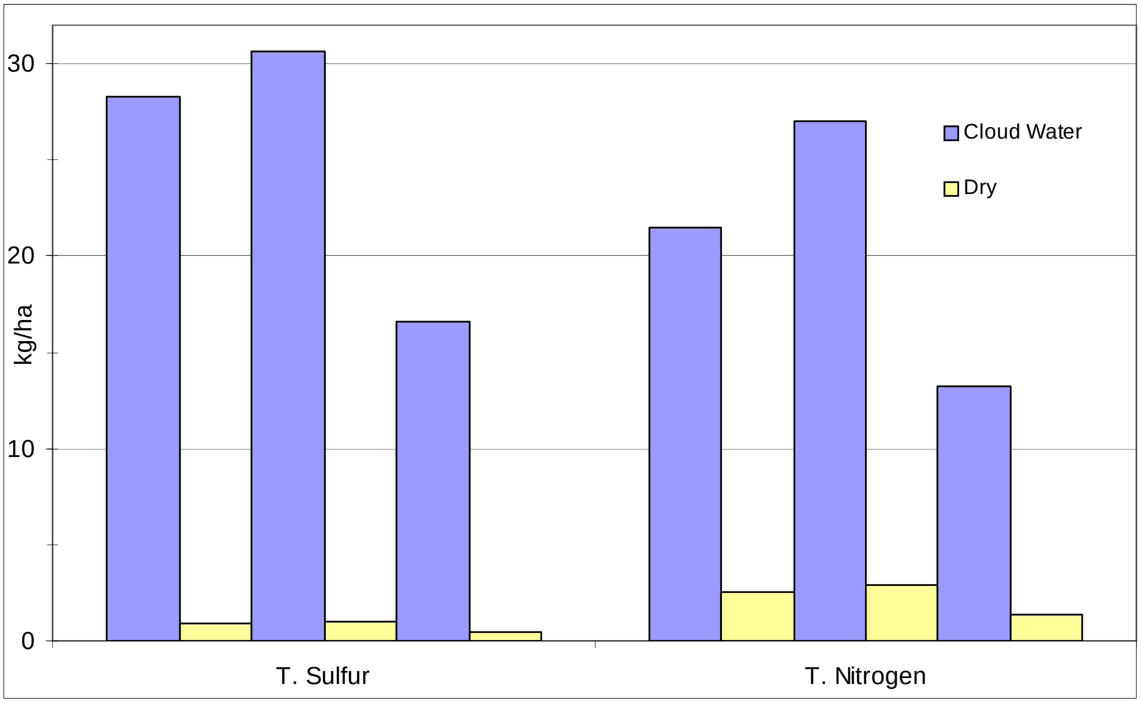
Note:
** May 2003 data represent May 17-31, 2003 only
*** August 2003 had only 48% completeness

Figure 4-2. Monthly Deposition Estimates – CLOUD Model (H^+, Ca^{2+})



Note:
** May 2003 data represent May 17-31, 2003 only
*** August 2003 had only 48% completeness

Figure 5-1. Total Sulfur and Nitrogen Cloud Water and Dry Deposition for Clingmans Dome (June – September)



Appendix A

Cloud Water Deposition to Clingmans Dome

in 2004

Cloud Water Deposition to Clingmans Dome in 2004

Report to MACTEC by

Gary M. Lovett
Institute of Ecosystem Studies
Millbrook, NY 12545

Report Date: April 11, 2005

Introduction

This brief report accompanies the Excel spreadsheet CLD 2004.xls, which gives the results of the cloud water deposition modeling for the Clingmans Dome (CLD303) site for the summer of 2004. Raw chemical concentration, meteorological, and cloud frequency data were provided to me by MACTEC (Selma Isil). I ran the CLOUD model (Lovett 1984) on these data to estimate cloud water deposition to this site.

Briefly, the CLOUD model uses an electrical resistance network analogy to model the deposition of cloud water to forest canopies. The model is one-dimensional, assuming vertical mixing of droplet-laden air in to the canopy from the top. Turbulence mixes the droplets into the canopy space, where they cross the boundary layers of canopy tissues by impaction and sedimentation. Sedimentation rates are strictly a function of droplet size. Impaction efficiencies are a function of the Stokes number, which integrates droplet size, obstacle size, and wind speed (Lovett 1984). The impaction efficiency is calculated as a function of the Stokes number based on wind tunnel measurements by Thorne et al (1982).

The forest canopy is modeled as stacked 1-m layers containing specified amounts of various canopy tissues such as leaves, twigs, and trunks. Wind speed at any height within the canopy space is determined based on the above-canopy wind speed and an exponential decline of wind speed as function of downward-cumulated canopy surface area. The wind speed determines the efficiency of mixing of air and droplets into the canopy and also the efficiency with which droplets impact onto canopy surfaces. The model is deterministic and assumes a steady-state, so that for one set of above-canopy conditions it calculates one deposition rate. The model requires as input data:

1) the surface area index of canopy tissues in each height layer in the canopy,
2) the zero-plane displacement height and roughness length of the canopy
3) the wind speed at the canopy top
4) the liquid water content (LWC) of the cloud above the canopy
5) the mode of the droplet diameter distribution in the cloud

From these input parameters, the model calculates the deposition of cloud water, expressed both as a water flux rate (g cm^{-2} min^{-1}), and as a deposition velocity (flux rate/LWC, in units of cm/s). Deposition rates of ions are calculated by multiplying the water deposition velocity by the ion concentration in cloud water above the canopy. In the original version of the model, a calculation of the evaporation rate from the canopy was also included in order to estimate net deposition of cloud water. For this project, only gross deposition rate was required so the evaporation routine was not invoked.

The 2004 data set covered the period June-October 2004, and there were 73 sample periods. The data provided for this report were pre-screened by MACTEC, so that no further screening was done by me. All months had sampling completeness values greater than 75%.

The calculations done here for 2004 followed closely those done for the Clingmans Dome site for 2000-2003 (Lovett 2001, 2002, 2003, 2004). After the model was run for all sample periods, seasonal and monthly means and totals were calculated in a SAS program. I calculated total seasonal deposition by summing the five monthly totals.

As in previous results, these model runs were made assuming a 10-m tall, intact, homogeneous conifer canopy. The actual canopy structure at Clingmans Dome has not been quantified, but I have observed that there are many dead trees at that site, and those still alive are generally taller than 10m. Consequently, this deposition estimate is best viewed an index of cloud deposition that can be used to compare the effects of changing meteorological and cloud chemical conditions across different sites and different times, assuming the same "standard" canopy were present at each site and time.

Because the measurement periods vary in length, I weighted all the means presented here by the duration of the sampling event. In this way, when calculating seasonal and monthly means, I avoided giving the same weight to a 10-minute event as I do to a 10-hour event.

Results

The model was run on 73 time periods as discussed above, and the results are presented as deposition velocities and deposition fluxes in the CLD 2004.xls spreadsheet and in Appendix I.

The period of measurement was June-October 2004 (as opposed to May-September in 2003). Monthly mean concentrations of ions in cloud water and in meteorological and deposition variables are given in Appendix I. During the measurement period, concentrations of hydrogen ion and sulfate were highest in August and October (Fig. 1).

Seasonal mean concentrations (duration weighted) of these ions in 2004 showed some changes from the trends set in previous years (Fig. 2). Sulfate concentration was increased slightly compared to 2003, and hydrogen ion concentration increased substantially based on field pH measurements. In general, lab pH values are higher (i.e. lower H^+ concentration, less acidic) than field pH values because H^+ is very reactive and is consumed during the sample holding period prior to laboratory analysis. In this analysis, I used all samples in which the cation/anion balance was within the acceptance criteria based on lab pH. Lab pH is a better measure to use with ion balance calculations, because it represents the H^+ concentration that is more contemporaneous with the other laboratory analyses. Assuming that both lab and field measurements are accurate, I believe that field pH represents a better estimate of actual H^+ deposition to the site, and I have used field pH values in these deposition calculations. I am uncertain whether the large decrease in field pH (increase in H^+ concentration) in 2004 is a result of measurement inaccuracies or a real change in acidity of cloud water at the site. Further research should focus on understanding the causes of this pH change.

Note that the trends shown in Figure 2 are based on duration-weighted mean concentrations and represent only those data supplied to me for the purpose of modeling cloud water deposition (i.e. those events for which liquid water content and wind speed were also measured). These trends may not match other calculations of trends if more complete chemistry datasets or non-duration-weighted means are used.

Subtle variation in mean wind speed from month to month can cause substantial differences in cloud water deposition velocity. There was a relatively high mean wind speed in September (7.2 m/s), which led to a very high calculated deposition velocity of over 33 cm/s (Figure 3). Cloud liquid water content (LWC) was also highest in September, but because the September ion concentrations (Fig. 1) and cloud frequency were rather low, there was not a particularly high ion deposition rate in September (Appendix I, Table I-3).

Mean duration-weighted deposition velocity for the 2004 season was 21.1 cm/s, very similar to the 1995-2004 mean of 21.3 cm/s. The overall mean LWC for the season was 0.34 g/m^3, slightly higher than the 1995-2004 mean of 0.31 g/m^3. The long-term average is influenced by the low value of 0.17 g/m^3 in 1996, but because of instrument malfunction only 29 LWC measurements were made that year, and that number is probably insufficient to represent the entire season. If 1996 is not included, the long-term mean is 0.33 g/m^3.

Seasonal deposition totals were calculated by summing the values across all five months. For comparison with the results of the previous reports (Lovett 2000, 2001, 2002, 2003,2004), I express these in Table 1 as the mean monthly deposition rate in kg/ha/month. For 2004, the means in Table 1 represent June-October, compared to May-September for previous years. Ion deposition rates for 2004 were somewhat higher than the rates for 2003 (Table 1).

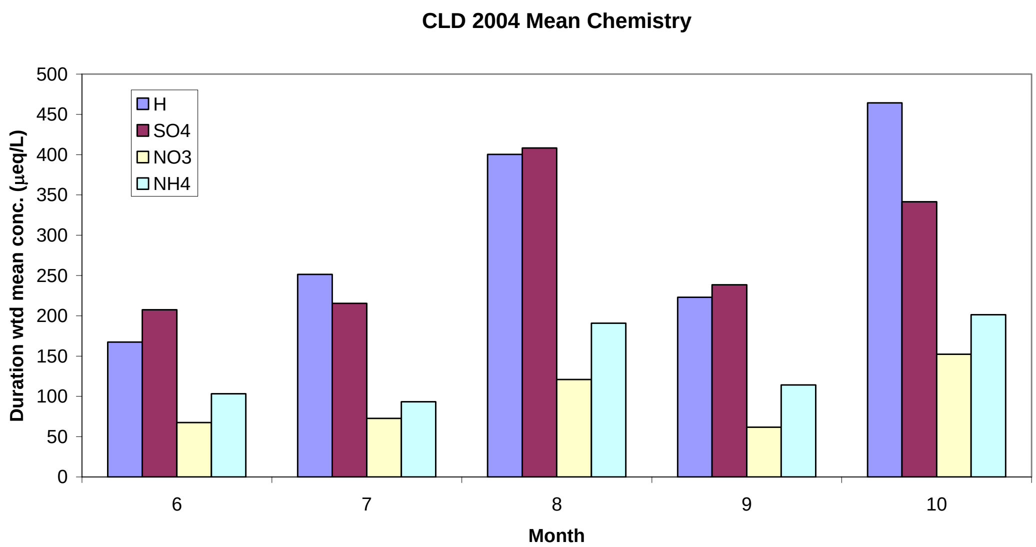


Figure 1. Duration-weighted mean concentration of four ions in cloud water, calculated by month.

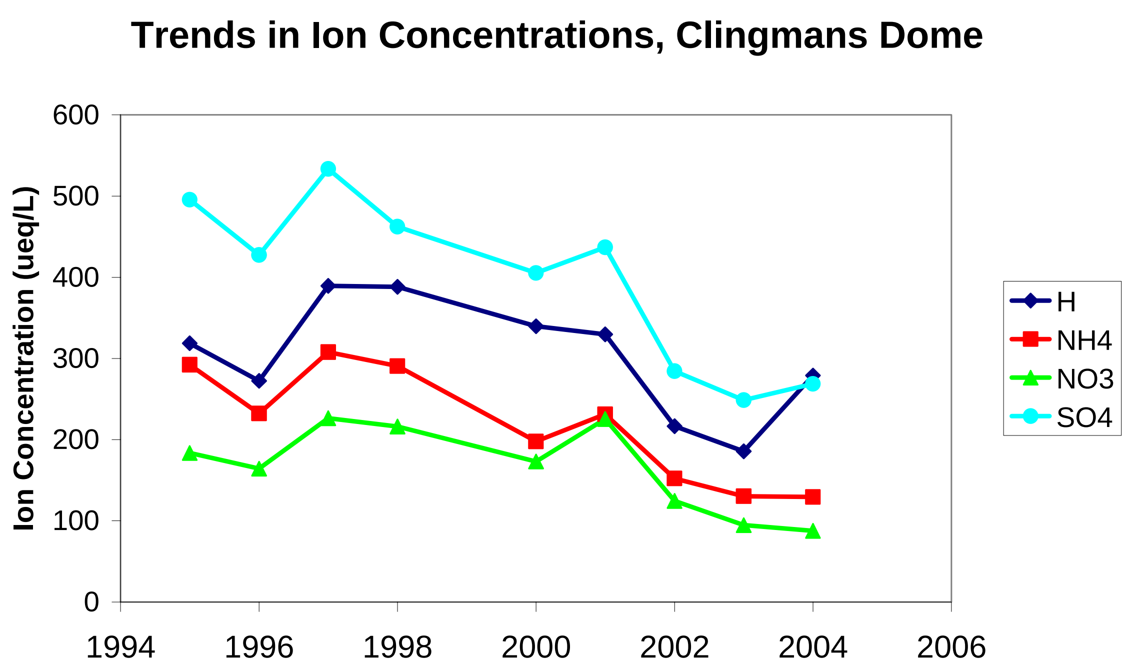


Figure 2. Trends in ion concentrations at Clingmans Dome, 1995-2004. Data are duration-weighted means for the warm season and include only the samples for which deposition was modeled (i.e. LWC and meteorological data were also present).

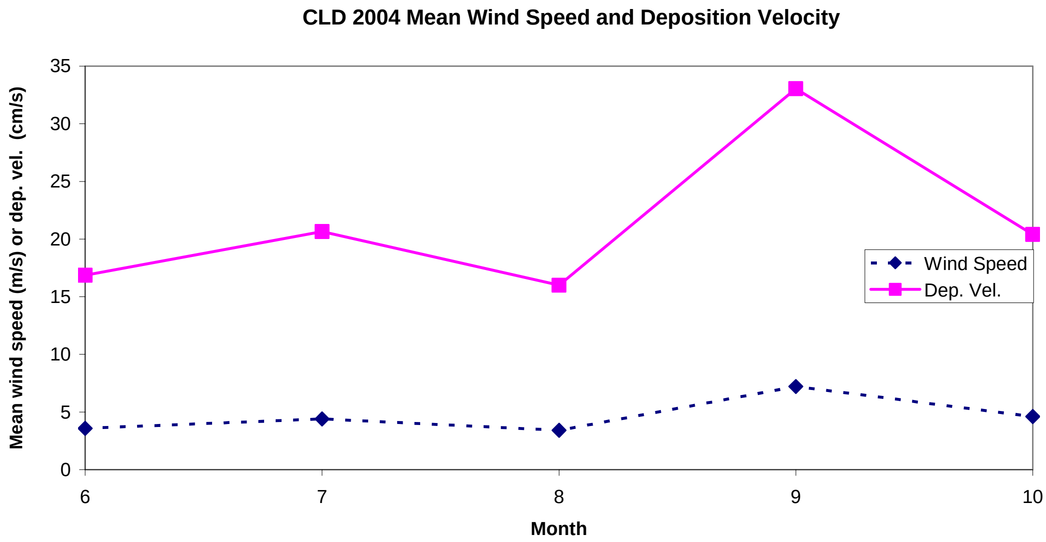


Figure 3. Mean wind speed and deposition velocity for each month.

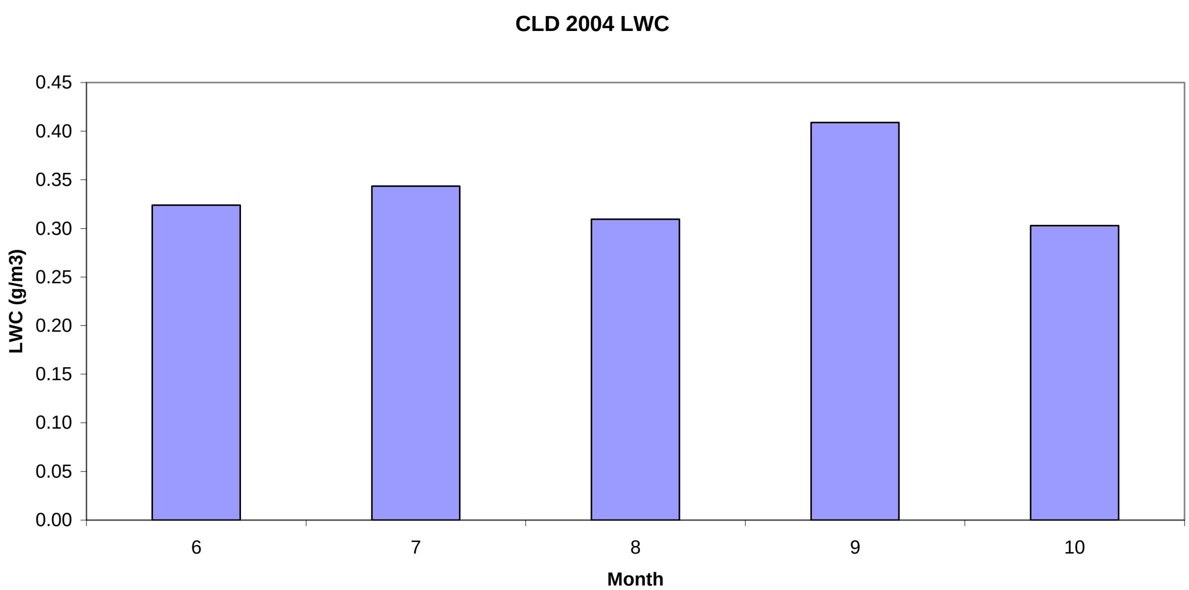


Figure 4. Mean liquid water content for each month of the study.

Table 1. Mean monthly deposition rates for several ions (in kg/ha/month) and water (cm/month) for the Clingmans Dome site for the 2004, 2003, 2002, 2001, 2000 and 1995-1998 data. The seasonal averages include the months of June-October in 2004 and May-September for previous years.

	Water	H+	NH4	SO4	NO3
CLD 2004	10.6	0.27	2.1	11.5	4.8
CLD 2003	10.5	0.14	1.8	9.3	4.7
CLD 2002	9.2	0.18	2.3	11.9	6.1
CLD 2001	8.6	0.31	3.3	18.4	12.5
CLD 2000	9.7	0.29	3.0	16.9	8.8
CLD 1995-98	8.1	0.23	3.0	14.3	7.7

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Appendix I.

Table I-1. Monthly mean meteorological and deposition variables. All means are duration-weighted. TUBFLUX , SEDFLUX and TOTFLUX are turbulent, sedimentation and total water fluxes ($g/cm^2/min$) for the time period, and TURBVD, SEDVD and TOTVD are the corresponding deposition velocities (cm/s). WS is wind speed (m/s) and LWC is cloud liquid water content in g/m^3.

MONTH	OBS	DURATION	VOLUME	WS	LWC	TURBFLUX	SEDFLUX	TOTFLUX	TURB VD	SED VD	TOT VD
6	11	17.97	3670.33	3.58	0.324	0.000194	0.000137	0.000330	10.07	6.78	16.85
7	22	14.93	3794.83	4.40	0.343	0.000321	0.000146	0.000467	13.88	6.77	20.65
8	17	12.41	1817.80	3.42	0.309	0.000180	0.000129	0.000309	9.34	6.65	15.99
9	14	15.40	2677.20	7.22	0.409	0.000652	0.000180	0.000832	26.09	6.95	33.05
10	9	12.66	1081.83	4.62	0.303	0.000255	0.000117	0.000372	14.17	6.23	20.40

Table I- 2. Monthly mean ion concentrations (μeq/L). All means are duration- weighted.

Month	H (field)	Ca	Mg	K	Na	NH4	SO4	NO3	Cl
6	167.32	21.36	8.00	2.56	17.00	103.30	207.67	67.61	18.26
7	251.44	22.09	7.98	3.07	14.73	93.31	215.36	72.82	16.56
8	400.32	28.66	8.30	3.89	10.95	190.70	408.25	121.04	14.75
9	223.00	15.70	5.44	2.05	7.77	114.22	238.62	61.68	9.90
10	464.41	32.24	9.08	3.26	10.01	201.39	341.59	152.41	11.29

Table I-3. Monthly deposition in kg/ha/month. Water deposition in cm/month.

Month	HDEP	KDEP	NADEP	CADEP	MGDEP	NH4DEP	SO4DEP	NO3DEP	CLDEP	H2ODEP
6	0.17	0.08	0.32	0.34	0.08	1.67	9.43	3.77	0.56	9.69
7	0.27	0.12	0.43	0.46	0.11	1.83	11.12	4.82	0.78	11.81
8	0.25	0.07	0.12	0.30	0.05	2.08	11.88	4.57	0.30	6.44
9	0.28	0.07	0.23	0.25	0.06	2.05	13.12	3.97	0.46	16.96
10	0.35	0.09	0.16	0.46	0.08	2.69	12.10	6.71	0.31	8.06

Appendix B

Cloud Water Data and QC Summary

Cloud Water Data and QC Summary

Analytical data for the 73 cloud deposition samples are presented in Table B-1 including measured field pH, field conductivity, sample volume, average LWC, valid hours, average scalar wind speed, and calculated cations and anions. A cumulative volume-weighted mean is shown for the various indicated analytes and ions.

Table B-2 presents the analytical concentrations of the field rinse samples received from the site. The field rinse samples were collected by the site operator during selected site visits. For the field rinse sample, the site operator rinsed the cloud string collector with deionized water and collected the final rinse water for analysis. These samples show very low levels of the measured analytes.

Tables B-3, B-4, and B-5 provide summaries of the QC results associated with the samples. The QC results for all parameters are within the measured criteria of the CASTNET QC program (MACTEC, 2003). Table B-3 summarizes the QC data for the reference samples for each parameter in each analytical batch. The reference sample is traceable to NIST and is supplied in a matrix similar to the cloud samples. An outside laboratory supplies these reference samples with a certificate of analysis stating the target values. A reference sample is analyzed at the beginning and end of each analytical batch to verify the accuracy and stability of the calibration curve. The QC limits require the measured value be within ± 5 percent of the known value for anions and within ± 10 percent of the known value for cations. For pH, the QC limits require the measured value be within ± 10 percent of the known value. The data from all required reference samples analyzed with the Clingmans Dome samples are within the CASTNET QC criteria.

The results of the analyses of the CVS for each parameter in each analytical batch are provided in Table B-4. A CVS is a NIST traceable solution supplied in a matrix similar to that of the sample being analyzed with a target value at approximately the midpoint of the calibration curve. This QC solution is supplied to MACTEC by an outside laboratory independent of the laboratory supplying reference sample solution. A CVS is analyzed after every 10 environmental samples to verify that the instrument calibration has not drifted more than ± 5 percent for anions and ± 10 percent for cations. The results of the CVS analyzed with the Clingmans Dome samples are within the CASTNET QC criteria.

Table B-5 summarizes the percent difference between samples reanalyzed within the same analytical batch. Five percent of the samples in each analytical batch were randomly selected for replicate analysis. This table presents only the samples that were replicated. The replicate percent difference criteria are ± 20 percent for anions and cations for samples with concentrations greater than five times the analytical detection limit. For samples with lower concentrations, the difference between the two values cannot be more than the analytical detection limit. The data from all required replicate samples are within the CASTNET QC criteria.

Table B-1. Cloud Deposition 2004 Sampling Season – Clingmans Dome, TN (Page 1 of 3)

No.	Sample Date	pH Field	pH Lab	Cond. Field	Volume mL	LWC g/m^3	Valid Hours	Scalar Wind m/sec	Ca^{2+} mg/L	Mg^{2+} mg/L	K^+ mg/L	Na^+ mg/L	NO_3^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	NH_4^+ mg/L	Field Cation µeq/L	Lab Cation µeq/L	Anion µeq/L	Field Cation/ Anion	Lab Cation/ Anion
1	6/12/2004	3.82	3.72	95.8	M	0.315	10.38	1.8	0.59	0.14	0.09	0.64	2.85	1.100	11.60	14.94	317.71	356.90	350.35	-9.77	1.85
2	6/15/2004	4.94	4.72	20.8	2781	0.298	13.91	3.7	0.54	0.09	0.09	0.33	1.48	0.423	3.27	4.21	95.93	103.50	108.50	-12.29	-4.71
3	6/16/2004	4.22	4.22	38.5	4370	0.385	25.80	3.0	0.18	0.08	0.08	0.48	2.14	0.710	4.17	5.37	131.12	131.12	134.33	-2.42	-2.42
4	6/17/2004	3.79	3.88	106.9	1770	0.215	7.94	4.2	1.25	0.35	0.25	1.77	7.82	2.210	14.20	18.29	507.53	477.18	488.62	3.80	-2.37
5	6/18/2004	3.66	3.77	121.5	3550	0.251	24.00	4.1	0.68	0.17	0.17	0.71	3.16	1.080	14.90	19.19	489.16	440.21	444.19	9.64	-0.90
6	6/19/2004	3.58	3.68	120.2	3861	0.372	13.86	3.4	0.38	0.05	0.08	0.06	0.26	0.351	14.10	18.16	421.10	367.00	371.85	12.42	-1.31
7	6/20/2004	3.55	3.62	158.9	215	0.090	4.11	3.3	1.11	0.20	0.26	0.20	0.90	0.471	22.00	28.33	680.39	638.44	615.53	10.01	3.65
8	6/21/2004	3.49	3.62	146.4	5220	0.406	22.02	4.2	0.22	0.04	0.06	0.08	0.36	0.317	15.70	20.22	492.69	408.98	414.34	17.28	-1.30
9	6/22/2004	3.62	3.71	124.6	188	0.224	10.95	4.5	0.77	0.11	0.15	0.31	1.38	0.475	14.00	18.03	461.75	416.85	424.81	8.33	-1.89
10	6/23/2004	4.14	4.29	33.0	5695	0.301	20.43	3.9	0.09	0.02	0.03	0.09	0.40	0.159	2.73	3.52	110.23	89.07	91.88	18.16	-3.11
11	6/24/2004	3.83	3.90	63.0	2312	0.478	9.94	2.4	0.03	0.01	0.02	0.01	0.05	0.443	4.51	5.81	162.90	140.88	146.66	10.49	-4.02
12	7/1/2004	3.47	4.15	127.6	155	0.121	6.55	1.1	0.28	0.10	0.11	0.10	0.44	0.154	3.64	4.69	376.18	108.13	109.97	109.52	-1.69
13	7/2/2004	3.94	4.13	46.9	241	0.129	9.45	1.9	0.23	0.07	0.11	0.12	0.52	0.180	3.86	4.97	171.21	130.53	126.85	29.77	2.86
14	7/3/2004	4.09	3.84	41.1	3496	0.214	8.52	2.9	0.35	0.10	0.15	0.43	1.89	0.550	9.38	12.08	256.51	319.78	312.89	-19.80	2.18
15	7/4/2004	3.68	4.37	93.5	637	0.410	16.18	3.6	0.55	0.13	0.11	0.59	2.62	0.672	4.60	5.92	329.37	163.09	167.48	65.16	-2.66
16	7/5/2004	3.69	3.91	76.9	3183	0.239	9.47	5.4	0.17	0.05	0.08	0.21	0.91	0.384	7.23	9.31	285.57	204.42	208.48	31.21	-1.96
17	7/6/2004	3.69	3.86	119.7	341	0.162	5.88	3.5	2.36	0.41	0.36	1.56	6.92	1.530	14.90	19.19	584.33	518.19	541.85	7.54	-4.46
18	7/7/2004	3.91	4.03	63.5	637	0.273	11.12	5.2	0.35	0.09	0.10	0.41	1.80	0.490	6.48	8.35	256.06	226.36	231.55	10.06	-2.27
19	7/9/2004	3.56	3.72	129.4	62	0.229	1.10	3.2	1.00	0.29	0.40	0.41	1.81	0.436	13.90	17.90	497.52	412.65	434.48	13.53	-5.16
20	7/10/2004	3.48	3.56	158.7	1038	0.113	5.88	2.4	0.73	0.13	0.14	0.43	1.88	0.789	15.60	20.09	548.20	492.49	501.96	8.81	-1.91
21	7/12/2004	3.58	3.78	110.1	2329	0.350	16.35	3.5	0.31	0.07	0.07	0.29	1.30	0.456	9.74	12.54	392.76	295.69	304.17	25.42	-2.83
22	7/13/2004	3.36	3.50	172.8	2702	0.451	16.77	3.1	0.97	0.15	0.11	0.42	1.88	0.778	20.30	26.14	668.19	547.90	562.38	17.20	-2.61
23	7/14/2004	-	-	-	62	0.226	0.20	5.4	1.07	0.26	0.22	0.43	1.89	0.543	10.30	13.26	NA	NA	NA	NA	NA
24	7/22/2004	3.40	3.52	190.5	635	0.387	7.50	2.3	1.39	0.16	0.21	0.05	0.22	0.552	23.80	30.65	745.11	649.00	648.86	13.81	0.02
25	7/23/2004	3.52	3.65	125.8	7783	0.471	18.90	6.4	0.91	0.09	0.07	0.03	0.13	0.324	14.70	18.93	509.07	430.95	427.99	17.31	0.69
26	7/24/2004	3.60	3.69	122.2	1282	0.269	7.48	3.6	0.80	0.10	0.12	0.04	0.18	0.233	15.30	19.70	456.89	409.87	407.21	11.50	0.65
27	7/25/2004	3.41	3.65	151.3	303	0.275	12.40	3.9	0.33	0.06	0.06	0.04	0.15	0.290	12.40	15.97	476.57	311.40	313.89	41.16	-0.80
28	7/26/2004	3.52	3.65	118.3	6561	0.342	19.40	4.1	0.14	0.02	0.03	0.02	0.09	0.224	13.70	17.64	433.35	355.23	353.09	20.41	0.61
29	7/27/2004	3.79	3.98	60.4	1214	0.334	18.33	2.8	0.03	0.02	0.05	0.03	0.12	0.112	5.94	7.65	225.46	167.99	164.09	31.50	2.35
30	7/28/2004	3.32	-	221.0	43	0.351	6.10	4.2	0.53	0.16	0.74	0.10	0.44	0.736	28.00	36.06	NA	NA	NA	NA	NA
31	7/29/2004	3.56	3.69	112.2	11572	0.377	19.52	5.3	0.09	0.09	0.05	0.59	2.62	1.050	10.90	14.04	393.28	322.03	330.08	17.47	-2.47
32	7/30/2004	4.28	4.45	23.6	10769	0.511	23.40	8.1	0.05	0.06	0.03	0.45	1.99	0.778	1.88	2.42	100.47	83.47	83.79	18.11	-0.38

Table B-1. Cloud Deposition 2004 Sampling Season – Clingmans Dome, TN (Page 2 of 3)

No.	Sample Date	pH Field	pH Lab	Cond. Field	Volume mL	LWC g/m^3	Valid Hours	Scalar Wind m/sec	Ca^{2+} mg/L	Mg^{2+} mg/L	K^+ mg/L	Na^+ mg/L	NO_3^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	NH_4^+ mg/L	Field Cation µeq/L	Lab Cation µeq/L	Anion µeq/L	Field Cation/ Anion	Lab Cation/ Anion
33	7/31/2004	3.50	4.91	128.8	98	0.357	14.18	6.5	0.24	0.17	0.36	1.09	4.80	1.570	3.96	5.10	453.05	149.13	147.22	101.90	1.29
34	8/1/2004	4.51	-	22.6	55	0.178	11.82	2.1	0.74	0.17	0.30	0.29	1.26	0.403	4.040	5.20	NA	NA	NA	NA	NA
35	8/2/2004	3.40	3.48	181.2	858	0.200	6.73	5.3	0.77	0.15	0.19	0.43	1.90	0.469	24.400	31.42	661.72	594.74	634.03	4.27	-6.39
36	8/11/2004	3.11	3.20	373.0	1771	0.145	9.87	3.3	1.70	0.33	0.33	1.09	4.84	1.370	45.100	58.08	1351.27	1205.99	1260.32	6.97	-4.41
37	8/12/2004	4.05	4.24	34.6	4226	0.392	16.25	3.2	0.06	0.01	0.01	0.03	0.14	0.062	3.460	4.46	126.43	94.84	94.42	28.99	0.45
38	8/14/2004	3.71	3.85	86.0	1404	0.283	4.02	3.8	0.09	0.02	0.08	0.03	0.12	0.138	8.930	11.50	339.04	285.31	291.19	15.19	-2.04
39	8/17/2004	3.17	3.38	287.0	162	0.340	3.52	2.4	0.77	0.18	0.40	0.15	0.67	0.510	34.400	44.30	1124.02	864.80	922.62	19.68	-6.47
40	8/18/2004	3.15	3.25	347.0	671	0.251	7.07	3.6	0.80	0.15	0.28	0.17	0.77	0.618	41.800	53.83	1194.75	1049.15	1111.15	7.25	-5.74
41	8/19/2004	3.51	3.66	145.8	1351	0.309	10.47	2.9	1.49	0.11	0.07	0.17	0.74	0.438	18.300	23.57	647.91	557.65	562.55	14.10	-0.87
42	8/20/2004	3.32	3.41	211.0	4970	0.371	20.45	4.5	0.58	0.06	0.08	0.09	0.41	0.646	23.700	30.52	704.57	614.99	641.58	9.36	-4.23
43	8/21/2004	4.29	4.58	17.0	435	0.372	1.67	3.4	0.05	0.01	0.02	0.01	0.06	0.037	1.490	1.92	65.53	40.54	43.84	39.65	-7.82
44	8/24/2004	3.57	3.82	166.0	166	0.182	2.55	3.6	0.20	0.10	0.42	0.15	0.67	0.355	13.600	17.51	518.85	401.05	410.96	23.21	-2.44
45	8/25/2004	3.50	3.60	148.5	515	0.381	19.88	3.9	0.21	0.05	0.11	0.23	1.02	0.379	17.200	22.15	552.91	487.88	495.15	11.02	-1.48
46	8/26/2004	3.40	3.55	156.8	2562	0.461	11.68	2.6	0.23	0.05	0.07	0.17	0.77	0.435	17.600	22.67	581.95	465.68	488.64	17.43	-4.81
47	8/27/2004	3.40	3.59	150.7	1139	0.348	9.95	3.3	0.30	0.08	0.14	0.33	1.44	0.482	18.000	23.18	603.00	461.93	483.30	22.04	-4.52
48	8/28/2004	3.38	3.57	178.1	510	0.199	8.00	3.2	0.58	0.14	0.19	0.46	2.06	0.533	22.900	29.49	740.18	592.47	620.31	17.62	-4.59
49	8/30/2004	3.58	3.79	94.4	284	0.274	3.68	2.3	0.27	0.09	0.13	0.16	0.72	0.295	9.770	12.58	369.83	268.98	288.83	24.59	-7.12
50	8/31/2004	3.21	3.36	257.0	470	0.213	6.50	3.2	0.70	0.13	0.23	0.18	0.79	1.520	30.300	39.02	950.51	770.43	839.34	12.42	-8.56
51	9/1/2004	3.27	3.39	224.0	2032	0.396	10.48	4.2	0.20	0.04	0.06	0.08	0.34	0.354	25.900	33.36	754.71	625.06	660.58	13.30	-5.53
52	9/2/2004	3.60	3.76	98.8	2570	0.628	20.07	5.9	0.03	0.01	0.02	0.03	0.15	0.132	10.500	13.52	326.07	248.66	265.88	20.34	-6.69
53	9/5/2004	3.20	3.31	292.0	425	0.226	3.42	5.3	0.32	0.21	0.38	1.30	5.75	1.160	39.600	51.00	1087.56	946.38	1000.67	8.32	-5.58
54	9/12/2004	3.88	4.03	65.4	159	0.078	0.23	2.4	0.11	0.10	0.46	0.34	1.52	0.401	9.820	12.65	256.45	217.95	236.82	7.96	-8.30
55	9/14/2004	3.52	3.58	148.5	2265	0.518	6.33	5.7	0.11	0.04	0.13	0.11	0.49	0.285	17.300	22.28	457.41	418.44	438.54	4.21	-4.69
56	9/15/2004	3.85	4.05	56.8	3505	0.359	10.27	6.0	0.05	0.05	0.03	0.33	1.47	0.612	5.110	6.58	202.51	150.38	162.42	21.97	-7.69
57	9/16/2004	4.69	4.98	6.8	2564	0.445	23.68	10.2	0.01	0.01	0.01	0.04	0.20	0.082	0.556	0.72	25.06	15.11	15.53	46.95	-2.73
58	9/17/2004	4.63	4.90	8.1	6300	0.444	18.43	8.0	0.01	0.01	0.02	0.04	0.17	0.072	0.669	0.86	27.31	16.46	16.24	50.81	1.30
59	9/18/2004	4.65	5.18	5.5	624	0.448	2.00	9.7	0.01	0.01	0.05	0.02	0.11	0.043	0.387	0.50	26.82	11.04	9.56	94.92	14.41
60	9/24/2004	3.74	3.88	114.3	420	0.238	4.08	2.6	1.88	0.33	0.70	0.29	1.26	0.443	18.600	23.95	634.92	584.77	563.94	11.84	3.63
61	9/25/2004	3.32	3.48	219.0	2415	0.293	15.58	4.9	1.19	0.17	0.14	0.11	0.48	0.416	27.300	35.16	894.35	746.85	765.02	15.59	-2.40

Table B-1. Cloud Deposition 2004 Sampling Season – Clingmans Dome, TN (Page 3 of 3)

No.	Sample Date	pH Field	pH Lab	Cond. Field	Volume mL	LWC g/m^3	Valid Hours	Scalar Wind m/sec	Ca^{2+} mg/L	Mg^{2+} mg/L	K^+ mg/L	Na^+ mg/L	NO_3^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	NH_4^+ mg/L	Field Cation µeq/L	Lab Cation µeq/L	Anion µeq/L	Field Cation/ Anion	Lab Cation/ Anion
62	9/26/2004	3.65	3.89	92.2	412	0.136	2.92	7.4	0.91	0.19	0.10	0.49	2.18	0.900	12.300	15.84	441.96	346.91	357.14	21.23	-2.91
63	9/27/2004	3.82	4.16	51.3	1175	0.338	16.22	10.4	0.21	0.08	0.04	0.44	1.97	0.787	5.210	6.71	227.40	145.23	153.59	38.75	-5.59
64	9/30/2004	3.26	3.44	250.0	1595	0.195	4.07	7.3	1.42	0.21	0.22	0.29	1.29	0.693	36.700	47.26	1196.02	1009.55	1012.08	16.66	-0.25
65	10/1/2004	3.40	3.55	205.0	663	0.210	8.50	6.3	1.26	0.22	0.38	0.19	0.83	0.519	31.700	40.82	949.72	833.45	861.67	9.72	-3.33
66	10/2/2004	3.11	3.17	383.0	1192	0.270	9.44	4.9	0.77	0.11	0.11	0.14	0.60	0.664	44.200	56.92	1370.65	1270.48	1312.34	4.35	-3.24
67	10/14/2004	3.97	4.17	46.0	437	0.419	4.28	3.0	0.37	0.11	0.14	0.38	1.69	0.604	5.800	7.47	205.33	165.79	184.84	10.50	-10.87
68	10/15/2004	3.59	3.91	72.8	289	0.545	0.90	3.2	0.40	0.12	0.24	0.11	0.50	0.298	8.790	11.32	349.56	215.55	239.60	37.33	-10.57
69	10/19/2004	3.98	4.32	32.9	554	0.198	4.50	5.8	0.20	0.04	0.05	0.19	0.84	0.242	3.290	4.24	173.72	116.87	125.08	32.55	-6.79
70	10/20/2004	3.79	4.18	39.0	1300	0.285	8.70	4.3	0.26	0.05	0.06	0.29	1.28	0.410	3.950	5.09	231.54	135.42	140.28	49.09	-3.52
71	10/22/2004	3.09	3.45	200.0	576	0.229	12.48	3.4	1.45	0.24	0.20	0.51	2.27	0.486	21.900	28.20	1177.76	719.75	766.65	42.29	-6.31
72	10/23/2004	3.27	3.76	84.4	1892	0.364	18.72	4.3	0.10	0.03	0.03	0.10	0.45	0.213	8.950	11.53	628.84	265.59	278.73	77.15	-4.83
73	10/24/2004	3.47	3.99	80.7	941	0.350	16.92	5.2	0.68	0.10	0.10	0.19	0.83	0.328	10.400	13.39	553.12	316.60	317.87	54.02	-0.40

Table B-2. Cloud Deposition 2004 Field Rinse/Blank Sample Data Summary – Clingmans Dome, TN

Sample Key	Sample Date	pH Lab	pH Field	Conductivity Lab	Conductivity Field	h_eq Lab	h_eq Field	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^{+} mg/L	K^{+} mg/L	NH_4^{+} mg/L	SO_4^{2-} mg/L	NO_3^{-} mg/L	Cl^{-} mg/L
C04303R	7/6/2004	4.50	4.23	33.4	33.3	31.62	58.88	0.65	0.14	0.47	0.18	0.78	3.71	3.42	0.38
C04303R	8/3/2004	4.08	3.85	64.4	63.3	83.18	141.25	1.47	0.15	0.17	0.27	0.96	9.73	2.68	0.26
C04303R	8/31/2004	4.59	4.05	17.5	18.9	25.70	89.13	0.05	0.02	0.05	0.20	0.32	1.77	0.87	0.15
C04303R	10/26/2004	5.28	4.69	4.5	25.4	5.25	20.42	0.03	0.01	0.02	0.09	0.17	0.33	0.20	0.03

Table B-3. Cloud Deposition 2004 Sampling Season – QC Batch Summary for Cloud Samples – Reference Samples – Clingmans Dome, TN
(Page 1 of 3)

Batch Number	Lab Key	Lab pH Target STD Units	Found STD Units	Percent Recovery
G99220	P106977*1	6.1	6.10	100.00
G99281	P106977*1	6.1	6.10	100.00
G99354	P106977*1	6.1	6.11	97.72
G99429	P106977*1	6.1	6.11	97.72
G99475	P106977*1	6.1	6.12	95.50
G99220	P106977*2	6.1	6.10	100.00
G99281	P106977*2	6.1	6.10	100.00
G99354	P106977*2	6.1	6.11	97.72
G99429	P106977*2	6.1	6.12	95.50
G99475	P106977*2	6.1	6.13	93.33
Mean				**97.75**
Std Dev				**2.36**
Count				**10**

Batch Number	Lab Key	NH_4^+-N Target STD Units	Found STD Units	Percent Recovery
G99488	ERAP108505*1	1.038	1.0115	97.45
G99488	ERAP108505*2	1.038	1.0043	96.75
G99197	ERAPO90505*1	0.893	0.8857	99.18
G99222	ERAPO90505*1	0.893	0.8860	99.22
G99323	ERAPO90505*1	0.893	0.8958	100.31
G99296	ERAPO90505*1	0.893	0.9108	101.99
G99324	ERAPO90505*1	0.893	0.8875	99.38
G99380	ERAPO90505*1	0.893	0.8994	100.72
G99412	ERAPO90505*1	0.893	0.9000	100.78
G99197	ERAPO90505*2	0.893	0.8753	98.02
G99222	ERAPO90505*2	0.893	0.8813	98.69
G99323	ERAPO90505*2	0.893	0.9023	101.04
G99296	ERAPO90505*2	0.893	0.9050	101.34
G99324	ERAPO90505*2	0.893	0.8855	99.16
G99380	ERAPO90505*2	0.893	0.9020	101.01
G99412	ERAPO90505*2	0.893	0.9205	103.08
Mean				**99.88**
Std Dev				**1.70**
Count				**16**

Batch Number	Lab Key	SO_4^{2-} Target STD Units	Found STD Units	Percent Recovery
G99191	HP329414*1	10.1	10.0	99.01
G99306	HP329414*1	10.1	10.2	100.99
G99357	HP329414*1	10.1	10.1	100.00
G99191	HP329414*2	10.1	10.1	100.00
G99306	HP329414*2	10.1	10.2	100.99
G99357	HP329414*2	10.1	10.1	100.00
G99191	HP329414*3	10.1	10.0	99.01
G99191	HP329414*4	10.1	10.0	99.01
G99426	HP418836*1	10.1	10.1	100.00
G99474	HP418836*1	10.1	10.2	100.99
G99426	HP418836*2	10.1	10.2	100.99
G99474	HP418836*2	10.1	10.2	100.99
Mean				**100.17**
Std Dev				**0.83**
Count				**12**

Table B-3. Cloud Deposition 2004 Sampling Season – QC Batch Summary for Cloud Samples – Reference Samples – Clingmans Dome, TN
(Page 2 of 3)

Batch Number	Lab Key	NO_3^--N Target STD Units	Found STD Units	Percent Recovery	Batch Number	Lab Key	Cl^- Target STD Units	Found STD Units	Percent Recovery	Batch Number	Lab Key	Ca^{2+} Target STD Units	Found STD Units	Percent Recovery
G99191	HP329414*1	1.6	1.59	99.38	G99191	HP329414*1	0.98	1.020	104.08	G99183	HP329414*1	0.051	0.0532	104.31
G99306	HP329414*1	1.6	1.60	100.00	G99306	HP329414*1	0.98	0.979	99.90	G99276	HP329414*1	0.051	0.0535	104.90
G99357	HP329414*1	1.6	1.60	100.00	G99357	HP329414*1	0.98	0.971	99.08	G99352	HP329414*1	0.051	0.0518	101.57
G99191	HP329414*2	1.6	1.60	100.00	G99191	HP329414*2	0.98	0.970	98.98	G99183	HP329414*2	0.051	0.0533	104.51
G99306	HP329414*2	1.6	1.62	101.25	G99306	HP329414*2	0.98	0.988	100.82	G99276	HP329414*2	0.051	0.0533	104.51
G99357	HP329414*2	1.6	1.59	99.38	G99357	HP329414*2	0.98	0.971	99.08	G99352	HP329414*2	0.051	0.0522	102.35
G99191	HP329414*3	1.6	1.58	98.75	G99191	HP329414*3	0.98	0.971	99.08	G99183	HP329414*3	0.051	0.0529	103.73
G99191	HP329414*4	1.6	1.59	99.38	G99191	HP329414*4	0.98	0.968	98.78	G99276	HP329414*3	0.051	0.0533	104.51
G99426	HP418836*1	1.6	1.59	99.38	G99426	HP418836*1	0.98	0.962	98.16	G99352	HP329414*3	0.051	0.0533	104.51
G99474	HP418836*1	1.6	1.61	100.63	G99474	HP418836*1	0.98	0.972	99.18	G99276	HP329414*4	0.051	0.0531	104.12
G99426	HP418836*2	1.6	1.61	100.63	G99426	HP418836*2	0.98	0.955	97.45	G99411	HP418836*1	0.052	0.0514	98.85
G99474	HP418836*2	1.6	1.62	101.25	G99474	HP418836*2	0.98	0.972	99.18	G99461	HP418836*1	0.052	0.0528	101.54
										G99411	HP418836*2	0.052	0.0520	100.00
										G99461	HP418836*2	0.052	0.0538	103.46
										G99411	HP418836*3	0.052	0.0520	100.00
										G99461	HP418836*3	0.052	0.0538	103.46
Mean				**100.00**	**Mean**				**99.48**	**Mean**				**102.90**
Std Dev				**0.80**	**Std Dev**				**1.66**	**Std Dev**				**1.94**
Count				**12**	**Count**				**12**	**Count**				**16**

Table B-3. Cloud Deposition 2004 Sampling Season – QC Batch Summary for Cloud Samples – Reference Samples – Clingmans Dome, TN
(Page 3 of 3)

Batch Number	Lab Key	Mg^{2+} Target STD Units	Mg^{2+} Found STD Units	Mg^{2+} Percent Recovery	Batch Number	Lab Key	Na^{+} Target STD Units	Na^{+} Found STD Units	Na^{+} Percent Recovery	Batch Number	Lab Key	K^{+} Target STD Units	K^{+} Found STD Units	K^{+} Percent Recovery
G99183	HP329414*1	0.051	0.0505	99.02	G99183	HP329414*1	0.4	0.3848	96.20	G99183	HP329414*1	0.097	0.0966	99.59
G99276	HP329414*1	0.051	0.0518	101.57	G99276	HP329414*1	0.4	0.3789	94.73	G99276	HP329414*1	0.097	0.1018	104.95
G99352	HP329414*1	0.051	0.0503	98.63	G99352	HP329414*1	0.4	0.3749	93.73	G99352	HP329414*1	0.097	0.0963	99.28
G99183	HP329414*2	0.051	0.0506	99.22	G99183	HP329414*2	0.4	0.3842	96.05	G99183	HP329414*2	0.097	0.0965	99.48
G99276	HP329414*2	0.051	0.0513	100.59	G99276	HP329414*2	0.4	0.3786	94.65	G99276	HP329414*2	0.097	0.0991	102.16
G99352	HP329414*2	0.051	0.0503	98.63	G99352	HP329414*2	0.4	0.3737	93.43	G99352	HP329414*2	0.097	0.0956	98.56
G99183	HP329414*3	0.051	0.0503	98.63	G99183	HP329414*3	0.4	0.3798	94.95	G99183	HP329414*3	0.097	0.0954	98.35
G99276	HP329414*3	0.051	0.0512	100.39	G99276	HP329414*3	0.4	0.3780	94.50	G99276	HP329414*3	0.097	0.0990	102.06
G99352	HP329414*3	0.051	0.0509	99.80	G99352	HP329414*3	0.4	0.3867	96.68	G99352	HP329414*3	0.097	0.0974	100.41
G99276	HP329414*4	0.051	0.0512	100.39	G99276	HP329414*4	0.4	0.3773	94.33	G99276	HP329414*4	0.097	0.0987	101.75
G99411	HP418836*1	0.050	0.0504	100.80	G99411	HP418836*1	0.4	0.3780	94.50	G99411	HP418836*1	0.093	0.0982	105.59
G99461	HP418836*1	0.050	0.0504	100.80	G99461	HP418836*1	0.4	0.3794	94.85	G99461	HP418836*1	0.093	0.0980	105.38
G99411	HP418836*2	0.050	0.0507	101.40	G99411	HP418836*2	0.4	0.3797	94.93	G99411	HP418836*2	0.093	0.0993	106.77
G99461	HP418836*2	0.050	0.0510	102.00	G99461	HP418836*2	0.4	0.3828	95.70	G99461	HP418836*2	0.093	0.0972	104.52
G99411	HP418836*3	0.050	0.0507	101.40	G99411	HP418836*3	0.4	0.3774	94.35	G99411	HP418836*3	0.093	0.0989	106.34
G99461	HP418836*3	0.050	0.0510	102.00	G99461	HP418836*3	0.4	0.3829	95.73	G99461	HP418836*3	0.093	0.0980	105.38
Mean				**100.33**	**Mean**				**94.95**	**Mean**				**102.54**
Std Dev				**1.21**	**Std Dev**				**0.90**	**Std Dev**				**3.00**
Count				**16**	**Count**				**16**	**Count**				**16**

Table B-4. Cloud Deposition 2004 Sampling Season – QC Batch Summary for Cloud Samples CVS – Clingmans Dome, TN (Page 1 of 3)

		Lab pH		
Batch Number	**Lab Key**	**Target STD Units**	**Found STD Units**	**Percent Recovery**
G99220	167594IA*1	4.83	4.84	97.72
G99281	167594IA*1	4.83	4.82	102.33
G99354	167594IA*1	4.83	4.84	97.72
G99429	167597IA*1	4.83	4.85	95.50
G99475	167597IA*1	4.83	4.84	97.72
G99220	167594IA*1	4.83	4.84	97.72
G99281	167594IA*1	4.83	4.82	102.33
G99354	167594IA*1	4.83	4.83	100.00
G99429	167597IA*1	4.83	4.85	95.50
G99475	167597IA*1	4.83	4.83	100.00
G99220	167594IA*1	4.83	4.85	95.49926
G99281	167594IA*1	4.83	4.83	100.00
G99354	167594IA*1	4.83	4.82	102.3293
G99429	167597IA*1	4.83	4.85	95.49926
G99475	167597IA*1	4.83	4.84	97.72372
G99220	167594IA*1	4.83	4.85	95.49926
G99281	167594IA*1	4.83	4.82	102.3293
G99354	167594IA*1	4.83	4.82	102.33
G99429	167597IA*1	4.83	4.86	93.33
G99220	167594IA*1	4.83	4.84	97.72372
G99354	167594IA*1	4.83	4.83	100.00
Mean				**98.51**
Std Dev				**2.81**
Count				**21**

		NH_4^+ -N		
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
G99197	QC*1	1	0.995	99.5
G99222	QC*1	1	0.9943	99.4
G99323	QC*1	1	0.9883	98.8
G99296	QC*1	1	1.0126	101.3
G99324	QC*1	1	0.9867	98.7
G99380	QC*1	1	0.9941	99.4
G99412	QC*1	1	0.9799	98.0
G99488	QC*1	1	0.9951	99.5
G99197	QC*1	1	0.9833	98.3
G99222	QC*1	1	0.9927	99.3
G99323	QC*1	1	0.9924	99.2
G99296	QC*1	1	1.0128	101.3
G99324	QC*1	1	0.9957	99.6
G99380	QC*1	1	1.0141	101.4
G99412	QC*1	1	1.0107	101.1
G99488	QC*1	1	0.992	99.2
G99197	QC*1	1	0.9838	98.4
G99323	QC*1	1	0.9902	99.0
G99296	QC*1	1	1.0094	100.9
G99324	QC*1	1	0.9902	99.0
G99412	QC*1	1	1.0117	101.2
G99488	QC*1	1	0.9945	99.5
G99323	QC*1	1	0.9901	99.0
Mean				**1.00**
Std Dev				**0.01**
Count				**23**

		SO_4^{2-}		
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
G99191	QC*1	2.5	2.49	99.6
G99306	QC*1	2.5	2.49	99.6
G99357	QC*1	2.5	2.5	100.0
G99426	QC*1	2.5	2.46	98.4
G99474	QC*1	2.5	2.50	100.0
G99191	QC*1	2.5	2.50	100.0
G99306	QC*1	2.5	2.49	99.6
G99357	QC*1	2.5	2.48	99.2
G99426	QC*1	2.5	2.45	98.0
G99474	QC*1	2.5	2.50	100.0
G99191	QC*1	2.5	2.49	99.6
G99306	QC*1	2.5	2.50	100.0
G99357	QC*1	2.5	2.49	99.6
G99426	QC*1	2.5	2.46	98.4
G99474	QC*1	2.5	2.50	100.0
G99191	QC*1	2.5	2.45	98.0
G99306	QC*1	2.5	2.49	99.6
G99357	QC*1	2.5	2.46	98.4
G99426	QC*1	2.5	2.47	98.8
G99474	QC*1	2.5	2.57	102.8
G99191	QC*1	2.5	2.52	100.8
G99306	QC*1	2.5	2.50	100.0
G99357	QC*1	2.5	2.49	99.6
G99426	QC*1	2.5	2.47	98.8
G99474	QC*1	2.5	2.59	103.6
G99306	QC*1	2.5	2.50	100.0
G99357	QC*1	2.5	2.53	101.2
G99426	QC*1	2.5	2.49	99.6
G99306	QC*1	2.5	2.50	100.0
G99357	QC*1	2.5	2.52	100.8
G99426	QC*1	2.5	2.50	100.0
G99306	QC*1	2.5	2.51	100.4
Mean				**99.83**
Std Dev				**1.18**
Count				**32**

Table B-4. Cloud Deposition 2004 Sampling Season – QC Batch Summary for Cloud Samples CVS – Clingmans Dome, TN (Page 2 of 3)

		NO_3^--N					Cl^-					Ca^{2+}		
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
G99191	QC*1	0.5	0.487	97.4	G99191	QC*1	0.5	0.499	99.8	G99183	QC*1	0.5	0.4986	99.7
G99306	QC*1	0.5	0.499	99.8	G99306	QC*1	0.5	0.495	99.0	G99276	QC*1	0.5	0.5047	100.9
G99357	QC*1	0.5	0.502	100.4	G99357	QC*1	0.5	0.504	100.8	G99352	QC*1	0.5	0.5006	100.1
G99426	QC*1	0.5	0.489	97.8	G99426	QC*1	0.5	0.487	97.4	G99411	QC*1	0.5	0.4970	99.4
G99474	QC*1	0.5	0.492	98.4	G99474	QC*1	0.5	0.492	98.4	G99461	QC*1	0.5	0.4959	99.2
G99191	QC*1	0.5	0.489	97.8	G99191	QC*1	0.5	0.503	100.6	G99183	QC*1	0.5	0.5008	100.2
G99306	QC*1	0.5	0.503	100.6	G99306	QC*1	0.5	0.493	98.6	G99276	QC*1	0.5	0.5034	100.7
G99357	QC*1	0.5	0.499	99.8	G99357	QC*1	0.5	0.497	99.4	G99352	QC*1	0.5	0.5015	100.3
G99426	QC*1	0.5	0.486	97.2	G99426	QC*1	0.5	0.486	97.2	G99411	QC*1	0.5	0.4973	99.5
G99474	QC*1	0.5	0.489	97.8	G99474	QC*1	0.5	0.517	103.4	G99461	QC*1	0.5	0.4991	99.8
G99191	QC*1	0.5	0.488	97.6	G99191	QC*1	0.5	0.503	100.6	G99183	QC*1	0.5	0.5011	100.2
G99306	QC*1	0.5	0.502	100.4	G99306	QC*1	0.5	0.498	99.6	G99276	QC*1	0.5	0.4994	99.9
G99357	QC*1	0.5	0.499	99.8	G99357	QC*1	0.5	0.499	99.8	G99352	QC*1	0.5	0.4905	98.1
G99426	QC*1	0.5	0.492	98.4	G99426	QC*1	0.5	0.483	96.6	G99411	QC*1	0.5	0.5037	100.7
G99474	QC*1	0.5	0.494	98.8	G99474	QC*1	0.5	0.492	98.4	G99461	QC*1	0.5	0.4998	100.0
G99191	QC*1	0.5	0.480	96.0	G99191	QC*1	0.5	0.491	98.2	G99183	QC*1	0.5	0.5005	100.1
G99306	QC*1	0.5	0.501	100.2	G99306	QC*1	0.5	0.494	98.8	G99276	QC*1	0.5	0.5003	100.1
G99357	QC*1	0.5	0.495	99.0	G99357	QC*1	0.5	0.498	99.6	G99352	QC*1	0.5	0.5110	102.2
G99426	QC*1	0.5	0.490	98.0	G99426	QC*1	0.5	0.485	97.0	G99411	QC*1	0.5	0.5049	101.0
G99474	QC*1	0.5	0.506	101.2	G99474	QC*1	0.5	0.505	101.0	G99461	QC*1	0.5	0.5022	100.4
G99191	QC*1	0.5	0.502	100.4	G99191	QC*1	0.5	0.510	102.0	G99276	QC*1	0.5	0.4998	100.0
G99306	QC*1	0.5	0.504	100.8	G99306	QC*1	0.5	0.496	99.2	G99352	QC*1	0.5	0.4995	99.9
G99357	QC*1	0.5	0.497	99.4	G99357	QC*1	0.5	0.511	102.2	G99461	QC*1	0.5	0.5001	100.0
G99426	QC*1	0.5	0.493	98.6	G99426	QC*1	0.5	0.489	97.8	G99276	QC*1	0.5	0.4980	99.6
G99474	QC*1	0.5	0.511	102.2	G99474	QC*1	0.5	0.534	106.8	G99461	QC*1	0.5	0.5002	100.0
G99306	QC*1	0.5	0.503	100.6	G99306	QC*1	0.5	0.492	98.4	G99461	QC*1	0.5	0.4998	100.0
G99357	QC*1	0.5	0.508	101.6	G99357	QC*1	0.5	0.520	104.0	G99461	QC*1	0.5	0.4968	99.4
G99426	QC*1	0.5	0.492	98.4	G99426	QC*1	0.5	0.490	98.0					
G99306	QC*1	0.5	0.503	100.6	G99306	QC*1	0.5	0.499	99.8					
G99357	QC*1	0.5	0.508	101.6	G99357	QC*1	0.5	0.506	101.2					
G99426	QC*1	0.5	0.495	99.0	G99426	QC*1	0.5	0.494	98.8					
G99306	QC*1	0.5	0.504	100.8	G99306	QC*1	0.5	0.500	100.0					
Mean				**99.39**	**Mean**				**99.76**	**Mean**				**100.05**
Std Dev				**1.51**	**Std Dev**				**2.18**	**Std Dev**				**0.72**
Count				**32**	**Count**				**32**	**Count**				**27**

Table B-4. Cloud Deposition 2004 Sampling Season – QC Batch Summary for Cloud Samples CVS – Clingmans Dome, TN (Page 3 of 3)

Mg^{2+}					Na^{+}					K^{+}				
Batch Number	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch Number**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
G99183	QC*1	0.5	0.4977	99.5	G99183	QC*1	0.5	0.5000	100.0	G99183	QC*1	0.5	0.4977	99.5
G99276	QC*1	0.5	0.5027	100.5	G99276	QC*1	0.5	0.4986	99.7	G99276	QC*1	0.5	0.4995	99.9
G99352	QC*1	0.5	0.4965	99.3	G99352	QC*1	0.5	0.4977	99.5	G99352	QC*1	0.5	0.5048	101.0
G99411	QC*1	0.5	0.4955	99.1	G99411	QC*1	0.5	0.4935	98.7	G99411	QC*1	0.5	0.4948	99.0
G99461	QC*1	0.5	0.4950	99.0	G99461	QC*1	0.5	0.4957	99.1	G99461	QC*1	0.5	0.4966	99.3
G99183	QC*1	0.5	0.5010	100.2	G99183	QC*1	0.5	0.4976	99.5	G99183	QC*1	0.5	0.4968	99.4
G99276	QC*1	0.5	0.5046	100.9	G99276	QC*1	0.5	0.5030	100.6	G99276	QC*1	0.5	0.5061	101.2
G99352	QC*1	0.5	0.4925	98.5	G99352	QC*1	0.5	0.4921	98.4	G99352	QC*1	0.5	0.5011	100.2
G99411	QC*1	0.5	0.4906	98.1	G99411	QC*1	0.5	0.4914	98.3	G99411	QC*1	0.5	0.4945	98.9
G99461	QC*1	0.5	0.4959	99.2	G99461	QC*1	0.5	0.4953	99.1	G99461	QC*1	0.5	0.4981	99.6
G99183	QC*1	0.5	0.5015	100.3	G99183	QC*1	0.5	0.5016	100.3	G99183	QC*1	0.5	0.5007	100.1
G99276	QC*1	0.5	0.5007	100.1	G99276	QC*1	0.5	0.4999	100.0	G99276	QC*1	0.5	0.5025	100.5
G99352	QC*1	0.5	0.4893	97.9	G99352	QC*1	0.5	0.4829	96.6	G99352	QC*1	0.5	0.4887	97.7
G99411	QC*1	0.5	0.5007	100.1	G99411	QC*1	0.5	0.5003	100.1	G99411	QC*1	0.5	0.5010	100.2
G99461	QC*1	0.5	0.4996	99.9	G99461	QC*1	0.5	0.5004	100.1	G99461	QC*1	0.5	0.5005	100.1
G99183	QC*1	0.5	0.4997	99.9	G99183	QC*1	0.5	0.5042	100.8	G99183	QC*1	0.5	0.5024	100.5
G99276	QC*1	0.5	0.5015	100.3	G99276	QC*1	0.5	0.5036	100.7	G99276	QC*1	0.5	0.5067	101.3
G99352	QC*1	0.5	0.5083	101.7	G99352	QC*1	0.5	0.5141	102.8	G99352	QC*1	0.5	0.5048	101.0
G99411	QC*1	0.5	0.5017	100.3	G99411	QC*1	0.5	0.4995	99.9	G99411	QC*1	0.5	0.4998	100.0
G99461	QC*1	0.5	0.5018	100.4	G99461	QC*1	0.5	0.5008	100.2	G99461	QC*1	0.5	0.5003	100.1
G99276	QC*1	0.5	0.4993	99.9	G99276	QC*1	0.5	0.5000	100.0	G99276	QC*1	0.5	0.5018	100.4
G99352	QC*1	0.5	0.4993	99.9	G99352	QC*1	0.5	0.5042	100.8	G99352	QC*1	0.5	0.5020	100.4
G99461	QC*1	0.5	0.4996	99.9	G99461	QC*1	0.5	0.4987	99.7	G99461	QC*1	0.5	0.4967	99.3
G99276	QC*1	0.5	0.4982	99.6	G99276	QC*1	0.5	0.5010	100.2	G99276	QC*1	0.5	0.5034	100.7
G99461	QC*1	0.5	0.5000	100.0	G99461	QC*1	0.5	0.4981	99.6	G99461	QC*1	0.5	0.4974	99.5
G99461	QC*1	0.5	0.4986	99.7	G99461	QC*1	0.5	0.4970	99.4	G99461	QC*1	0.5	0.4973	99.5
G99461	QC*1	0.5	0.4977	99.5	G99461	QC*1	0.5	0.4966	99.3	G99461	QC*1	0.5	0.4954	99.1
Mean				**99.77**	**Mean**				**99.76**	**Mean**				**99.94**
Std Dev				**0.81**	**Std Dev**				**1.08**	**Std Dev**				**0.81**
Count				**27**	**Count**				**27**	**Count**				**27**

Table B-5. Cloud Deposition 2004 Sampling Season – Replicate Summary for Cloud Samples – Clingmans Dome, TN (Page 1 of 3)

			SO_4^{2-}			
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**% Diff**
C04303*11	RP*C04303*11	CLD303	7/8/2004	4.51	4.51	0.00
C04303*37	RP*C04303*37	CLD303	9/20/2004	3.46	3.46	0.00
C04303*5	RP*C04303*5	CLD303	7/8/2004	14.90	14.90	0.00
C04303*53	RP*C04303*53	CLD303	10/21/2004	39.60	39.30	0.76
C04303*64	RP*C04303*64	CLD303	10/22/2004	36.70	36.70	0.00
C04303*71	RP*C04303*71	CLD303	11/9/2004	21.90	21.80	0.46
C04303R*1	RP*C04303R*1	RINSE	8/30/2004	3.71	3.68	0.81
				Mean Percent Difference		0.29
				Standard Deviation		0.38

			NO_3^- - N			
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**% Diff**
C04303*11	RP*C04303*11	CLD303	7/8/2004	0.564	0.560	0.71
C04303*35	RP*C04303*35	CLD303	8/31/2004	1.580	1.590	-0.63
C04303*37	RP*C04303*37	CLD303	9/20/2004	0.289	0.289	0.00
C04303*48	RP*C04303*48	CLD303	9/20/2004	1.800	1.810	-0.56
C04303*5	RP*C04303*5	CLD303	7/8/2004	1.450	1.450	0.00
C04303*53	RP*C04303*53	CLD303	10/21/2004	2.010	2.010	0.00
C04303*64	RP*C04303*64	CLD303	10/22/2004	3.200	3.180	0.63
C04303*71	RP*C04303*71	CLD303	11/9/2004	4.160	4.140	0.48
C04303R*1	RP*C04303R*1	RINSE	8/30/2004	0.773	0.771	0.26
				Mean Percent Difference		0.10
				Standard Deviation		0.48

			Cl^-			
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**% Diff**
C04303*11	RP*C04303*11	CLD303	7/8/2004	0.443	0.447	-0.90
C04303*35	RP*C04303*35	CLD303	8/31/2004	0.469	0.469	0.00
C04303*37	RP*C04303*37	CLD303	9/20/2004	0.062	0.064	-3.23
C04303*48	RP*C04303*48	CLD303	9/20/2004	0.533	0.534	-0.19
C04303*5	RP*C04303*5	CLD303	7/8/2004	1.080	1.070	0.93
C04303*53	RP*C04303*53	CLD303	10/21/2004	1.160	1.160	0.00
C04303*64	RP*C04303*64	CLD303	10/22/2004	0.693	0.694	-0.14
C04303*71	RP*C04303*71	CLD303	11/9/2004	0.486	0.485	0.21
C04303R*1	RP*C04303R*1	RINSE	8/30/2004	0.381	0.381	0.00
				Mean Percent Difference		-0.37
				Standard Deviation		1.17

Table B-5. Cloud Deposition 2004 Sampling Season – Replicate Summary for Cloud Samples – Clingmans Dome, TN (Page 2 of 3)

			NH_4^+-N			
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**% Diff**
C04303*16	RP*C04303*16	CLD303	7/13/2004	0.8137	0.8048	1.09
C04303*18	RP*C04303*18	CLD303	8/25/2004	1.2280	1.2249	0.25
C04303*19	RP*C04303*19	CLD303	7/22/2004	1.6892	1.6895	-0.02
C04303*21	RP*C04303*21	CLD303	7/22/2004	1.3101	1.2767	2.55
C04303*35	RP*C04303*35	CLD303	8/25/2004	2.6553	2.6842	-1.09
C04303*44	RP*C04303*44	CLD303	9/7/2004	3.0015	3.0319	-1.01
C04303*49	RP*C04303*49	CLD303	9/8/2004	1.0531	1.0405	1.20
C04303*52	RP*C04303*52	CLD303	9/30/2004	0.9927	0.9871	0.56
C04303*63	RP*C04303*63	CLD303	10/25/2004	0.5406	0.5385	0.39
C04303*66	RP*C04303*66	CLD303	11/18/2004	7.5332	7.5192	0.19
C04303*72	RP*C04303*72	CLD303	11/18/2004	1.1109	1.1044	0.59
C04303*9	RP*C04303*9	CLD303	7/13/2004	2.1951	2.1783	0.77
			Mean Percent Difference			**0.46**
			Standard Deviation			**0.97**

			Ca^{2+}			
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**% Diff**
C04303*28	RP*C04303*28	CLD303	8/16/2004	0.1392	0.1390	0.14
C04303*43	RP*C04303*43	CLD303	9/20/2004	0.0478	0.0476	0.42
C04303*58	RP*C04303*58	CLD303	10/15/2004	0.0104	0.0101	2.88
C04303*73	RP*C04303*73	CLD303	11/9/2004	0.6779	0.6769	0.15
C04303*9	RP*C04303*9	CLD303	7/8/2004	0.7717	0.7656	0.79
			Mean Percent Difference			**0.88**
			Standard Deviation			**1.15**

			Mg^{2+}			
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**% Diff**
C04303*28	RP*C04303*28	CLD303	8/16/2004	0.0222	0.0222	0.00
C04303*43	RP*C04303*43	CLD303	9/20/2004	0.0099	0.0099	0.00
C04303*58	RP*C04303*58	CLD303	10/15/2004	0.0062	0.0060	3.23
C04303*73	RP*C04303*73	CLD303	11/9/2004	0.0968	0.0966	0.21
C04303*9	RP*C04303*9	CLD303	7/8/2004	0.1124	0.1118	0.53
			Mean Percent Difference			**0.79**
			Standard Deviation			**1.38**

Table B-5. Cloud Deposition 2004 Sampling Season – Replicate Summary for Cloud Samples – Clingmans Dome, TN (Page 3 of 3)

			Na^+			
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**% Diff**
C04303*28	RP*C04303*28	CLD303	8/16/2004	0.0210	0.0216	-2.86
C04303*43	RP*C04303*43	CLD303	9/20/2004	0.0142	0.0138	2.82
C04303*58	RP*C04303*58	CLD303	10/15/2004	0.0378	0.0375	0.79
C04303*73	RP*C04303*73	CLD303	11/9/2004	0.1864	0.1859	0.27
C04303*9	RP*C04303*9	CLD303	7/8/2004	0.3111	0.3082	0.93
				Mean Percent Difference		0.39
				Standard Deviation		2.06

			K^+			
Sample No.	**Replicate No.**	**Station ID**	**Analysis Date**	**Sample Result**	**Replicate Result**	**% Diff**
C04303*28	RP*C04303*28	CLD303	8/16/2004	0.0322	0.0324	-0.62
C04303*43	RP*C04303*43	CLD303	9/20/2004	0.0179	0.0176	1.68
C04303*58	RP*C04303*58	CLD303	10/15/2004	0.0188	0.0185	1.60
C04303*73	RP*C04303*73	CLD303	11/9/2004	0.1036	0.1038	-0.19
C04303*9	RP*C04303*9	CLD303	7/8/2004	0.1507	0.1482	1.66
				Mean Percent Difference		0.82
				Standard Deviation		1.13

Appendix C

Filter Pack Data and QC Summary

Filter Pack Data and QC Summary

Table C-1 presents the total microgram data for each filter type from each sample.

Table C-2 presents the results of the analyses of the laboratory filter blank samples. Laboratory filter blanks are prepared weekly while the filter packs are being prepared for the field. Each laboratory blank is prepared using filters from the same lot of filters used to prepare the field filter packs. The analytical results of the laboratory blanks demonstrate no significant contamination. There are five laboratory blanks for Whatman filters with "hits" for sulfate. Such "hits" are not uncommon with Whatman filters. The field and laboratory blank results indicate that logistical and analytical processes did not contribute to the measured analytes.

The QC results for all parameters are within the measurement criteria of the CASTNET program. Table C-3 summarizes the reference sample QC data for each filter type and parameter in each analytical batch. Each reference sample is a NIST-traceable solution in a matrix similar to the filter sample extracts. An outside laboratory supplies these reference samples with a certificate of analysis stating the known or target value. A reference sample is analyzed at the beginning and end of each analytical batch to verify the accuracy and stability of the instrument response. The QC limits require the measured value be within ±5 percent of the known value for anions and within ± 10 percent of the known value for cations. The data from all reference samples analyzed with the Clingmans Dome samples are within the CASTNET QC criteria.

Summary statistics from the analysis of CVS for each parameter and filter type are presented in Table C-4. A CVS is a NIST-traceable solution supplied in a matrix similar to that of the sample being analyzed with a target value at approximately the midpoint of the calibration curve. This QC solution is supplied to MACTEC by a second outside laboratory. A CVS is analyzed after every 10 environmental samples to verify that the instrument calibration has not drifted more than ± 5 percent for anions and ± 10 percent for cations. All CVS analyzed with the Clingmans Dome samples are within the CASTNET QC criteria.

Table C-5 summarizes the percent difference of replicate samples reanalyzed within the same analytical batch. Samples are randomly selected from each analytical batch for replicate analysis. This table presents only the samples that were replicated. The replicate percent difference criteria are ± 20 percent for anions and cations for samples with concentrations greater than five times the analytical detection limit. For samples with lower concentrations, the difference between the two values cannot be more than the analytical detection limit. All of the Clingmans Dome replicated samples are within the QC criterion.

Table C-1. Dry Deposition 2004 Sampling Season – Clingmans Dome, TN

Sample No.	Station ID	Filter Date	Teflon SO_4^{2-} T.µg	Teflon NO_3^--N T.µg	Nylon SO_4^{2-} T.µg	Nylon NO_3^--N T.µg	Whatman SO_4^{2-} T.µg	Teflon NH_4^+-N T.µg	Teflon Ca^{2+} T.µg	Teflon Mg^{2+} T.µg	Teflon Na^+ T.µg	Teflon K^+ T.µg	Teflon Cl^- T.µg
DD04-24*85	CLD303	6/8/2004	27.780	<0.200	8.460	7.659	4.252	4.7600	0.3750	0.15250	0.28000	0.3150	<0.500
DD04-25*85	CLD303	6/15/2004	18.610	<0.200	2.577	1.936	3.660	3.9175	0.2100	<0.07500	<0.12500	0.1500	<0.500
DD04-26*85	CLD303	6/22/2004	81.830	<0.200	4.474	5.569	<2.000	14.3675	0.9525	0.19500	0.20000	0.9450	<0.500
DD04-27*85	CLD303	6/29/2004	70.430	<0.200	5.886	4.529	<2.000	11.7600	1.1250	0.33000	0.80000	0.6625	<0.500
DD04-28*85	CLD303	7/6/2004	78.470	<0.200	11.980	7.205	9.449	15.6650	1.6425	0.47750	1.37000	0.9100	<0.500
DD04-29*85	CLD303	7/13/2004	13.800	<0.200	4.105	0.958	2.385	2.7750	0.4200	0.09750	0.19000	0.1475	<0.500
DD04-30*85	CLD303	7/20/2004	38.910	<0.200	4.258	3.073	2.401	8.2750	0.6250	0.10750	<0.12500	0.2700	<0.500
DD04-31*85	CLD303	7/27/2004	61.640	<0.200	3.256	3.889	2.198	7.3450	0.3850	0.23250	1.14750	0.3525	<0.500
DD04-32*85	CLD303	8/3/2004	59.720	<0.200	30.460	9.673	37.640	9.7025	0.8250	0.17000	0.19500	0.4375	<0.500
DD04-33*85	CLD303	8/10/2004	108.400	<0.200	9.948	6.092	7.110	17.4275	0.8725	0.27250	0.58500	0.5925	<0.500
DD04-34*85	CLD303	8/17/2004	104.500	<0.200	12.150	5.170	7.516	19.3225	2.0850	0.2875	0.40750	1.1850	<0.500
DD04-35*85	CLD303	8/24/2004	109.800	<0.200	9.103	8.376	2.923	15.1025	1.0825	0.39500	1.02250	0.6475	<0.500
DD04-36*85	CLD303	8/31/2004	32.710	<0.200	7.160	6.340	3.846	5.0450	0.4200	0.14250	0.38750	0.2500	<0.500
DD04-37*85	CLD303	9/7/2004	64.790	<0.200	12.310	4.000	14.640	8.6750	0.5000	0.10500	0.16500	0.3275	<0.500
DD04-38*85	CLD303	9/14/2004	2.029	<0.200	3.020	0.895	3.149	0.8175	0.3300	<0.07500	<0.12500	<0.1250	<0.500
DD04-39*85	CLD303	9/21/2004	53.400	0.217	10.950	7.515	15.700	12.1250	2.0425	0.40250	0.96000	0.6300	<0.500
DD04-40*85	CLD303	9/28/2004	136.100	0.365	21.080	13.530	72.840	30.2125	4.0375	0.51250	0.48500	1.1300	<0.500
DD04-41*85	CLD303	10/5/2004	29.960	0.342	11.300	2.813	22.200	8.9500	1.3675	0.19750	0.17250	0.4400	<0.500
DD04-42*85	CLD303	10/12/2004	8.428	0.392	6.367	1.437	6.225	2.4925	0.5525	0.08500	<0.12500	0.1975	<0.500
DD04-43*85	CLD303	10/19/2004	48.570	<0.200	6.946	5.110	11.560	9.6550	1.5675	0.34500	0.84250	0.5950	<0.500

Table C-2. Dry Deposition 2004 Sampling Season - Laboratory Filter Pack Blanks – Clingmans Dome, TN

			Teflon		Nylon		Whatman	Teflon				
Lab Key	Station ID	Date	SO_4^{2-} T.µg	NO_3^--N T.µg	SO_4^{2-} T.µg	NO_3^--N T.µg	SO_4^{2-} T.µg	NH_4^+-N T.µg	Ca^{2+} T.µg	Mg^{2+} T.µg	Na^+ T.µg	K^+ T.µg
LB04-27*1	LAB	6/17/2004	<1.000		<1.000	<0.200						
LB04-27*2	LAB	6/17/2004	<1.000		<1.000	<0.200						
LB04-28*1	LAB	6/24/2004	<1.000	<0.200				<0.500	<0.075	<0.075	<0.125	<0.125
LB04-28*2	LAB	6/24/2004	<1.000	<0.200				<0.500	<0.075	<0.075	<0.125	<0.125
LB04-30*1	LAB	7/8/2004	<1.000	<0.200	<1.000	<0.200	<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-30*2	LAB	7/8/2004	<1.000	<0.200	<1.000	<0.200	<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-31*1	LAB	7/14/2004	<1.000	<0.200	<1.000	<0.200	<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-31*2	LAB	7/14/2004	<1.000	<0.200	<1.000	<0.200	<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-32*1	LAB	7/22/2004	<1.000	<0.200	<1.000	<0.200	<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-32*2	LAB	7/22/2004	<1.000	<0.200	<1.000	<0.200	<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-34*1	LAB	8/5/2004	<1.000	<0.200	<1.000	<0.200		<0.500	<0.075	<0.075	<0.125	<0.125
LB04-34*2	LAB	8/5/2004		<0.200	<1.000	<0.200		<0.500	<0.075	<0.075	<0.125	<0.125
LB04-35*1	LAB	8/12/2004		<0.200			<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-35*2	LAB	8/12/2004		<0.200			<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-36*1	LAB	8/18/2004			<1.000	<0.200						
LB04-36*2	LAB	8/18/2004			<1.000	<0.200						
LB04-37*1	LAB	8/26/2004	<1.000	<0.200	<1.000	<0.200	<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-37*2	LAB	8/26/2004	<1.000	<0.200	<1.000	<0.200	<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-38*1	LAB	9/2/2004	<1.000	<0.200	<1.000	<0.200		<0.500	<0.075	<0.075	<0.125	<0.125
LB04-38*2	LAB	9/2/2004	<1.000	<0.200	<1.000	<0.200		<0.500	<0.075	<0.075	<0.125	<0.125
LB04-39*1	LAB	9/9/2004	<1.000	<0.200			2.386	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-39*2	LAB	9/9/2004	<1.000	<0.200			<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-40*1	LAB	9/16/2004	<1.000	<0.200	<1.000	<0.200		<0.500	<0.075	<0.075	<0.125	<0.125
LB04-40*2	LAB	9/16/2004	<1.000	<0.200	<1.000	<0.200		<0.500	<0.075	<0.075	<0.125	<0.125
LB04-41*1	LAB	9/23/2004			<1.000	<0.200	4.064					
LB04-41*2	LAB	9/23/2004			<1.000	<0.200	4.272					
LB04-42*1	LAB	9/30/2004	<1.000	<0.200	<1.000	<0.200		<0.500	<0.075	<0.075	<0.125	<0.125
LB04-42*2	LAB	9/30/2004	<1.000	<0.200	<1.000	<0.200		<0.500	<0.075	<0.075	<0.125	<0.125
LB04-43*1	LAB	10/7/2004					2.685					
LB04-44*1	LAB	10/14/2004	<1.000	<0.200				<0.500	<0.075	<0.075	<0.125	<0.125
LB04-44*2	LAB	10/14/2004	<1.000	<0.200	<1.000	<0.200		<0.500	0.12	<0.075	<0.125	<0.125
LB04-45*1	LAB	10/21/2004			<1.000	<0.200						
LB04-45*2	LAB	10/21/2004			<1.000	<0.200						
LB04-46*1	LAB	10/28/2004	<1.000	<0.200	<1.000	<0.200	2.264	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-46*2	LAB	10/28/2004	<1.000	<0.200			<2.000	<0.500	<0.075	<0.075	<0.125	<0.125
LB04-47*1	LAB	11/4/2004	<1.000	<0.200				<0.500	<0.075	<0.075	<0.125	<0.125
LB04-47*2	LAB	11/4/2004	<1.000	<0.200				<0.500	<0.075	<0.075	<0.125	<0.125

Table C-3. Dry Deposition 2004 Sampling Season – QC Batch Summary for Teflon® Filters – Reference Samples – Clingmans Dome, TN (Page 1 of 8)

SO_4^{2-}					NO_3^- - N					NH_4^+ - N				
Batch	Lab Key	Target mg/L	Found mg/L	Percent Recovery	Batch	Lab Key	Target mg/L	Found mg/L	Percent Recovery	Batch	Lab Key	Target mg/L	Found mg/L	Percent Recovery
G99163	HP329414*1	10.1	10.08	99.80	G99163	HP329414*1	1.6	1.625	101.56	G99161	ERAPO90505*1	0.893	0.8933	100.03
G99163	HP329414*2	10.1	10.25	101.49	G99163	HP329414*2	1.6	1.653	103.31	G99161	ERAPO90505*2	0.893	0.9107	101.98
G99174	HP329414*1	10.1	10.06	99.60	G99174	HP329414*1	1.6	1.634	102.13	G99171	ERAPO90505*1	0.893	0.8981	100.57
G99174	HP329414*2	10.1	10.08	99.80	G99174	HP329414*2	1.6	1.635	102.19	G99171	ERAPO90505*2	0.893	0.9127	102.21
G99196	HP329414*1	10.1	10.06	99.60	G99196	HP329414*1	1.6	1.628	101.75	G99189	ERAPO90505*1	0.893	0.9016	100.96
G99196	HP329414*2	10.1	10.15	100.50	G99196	HP329414*2	1.6	1.638	102.38	G99189	ERAPO90505*2	0.893	0.9203	103.06
G99206	HP329414*1	10.1	10.03	99.31	G99206	HP329414*1	1.6	1.626	101.63	G99213	ERAPO90505*2	0.893	0.8725	97.70
G99206	HP329414*2	10.1	10.09	99.90	G99206	HP329414*2	1.6	1.635	102.19	G99213	ERAPO90505*1	0.893	0.8901	99.68
G99219	HP329414*1	10.1	10.06	99.60	G99219	HP329414*1	1.6	1.622	101.38	G99218	ERAPO90505*1	0.893	0.8874	99.37
G99219	HP329414*2	10.1	10.29	101.88	G99219	HP329414*2	1.6	1.662	103.88	G99218	ERAPO90505*2	0.893	0.8765	98.15
G99229	HP329414*1	10.1	10.01	99.11	G99229	HP329414*1	1.6	1.62	101.25	G99234	ERAPO90505*2	0.893	0.8935	100.06
G99229	HP329414*2	10.1	10.15	100.50	G99229	HP329414*2	1.6	1.64	102.50	G99234	ERAPO90505*1	0.893	0.8778	98.30
G99266	HP329414*1	10.1	9.96	98.61	G99266	HP329414*1	1.6	1.62	101.25	G99265	ERAPO90505*1	0.893	0.8956	100.29
G99266	HP329414*2	10.1	10.13	100.30	G99266	HP329414*2	1.6	1.646	102.88	G99265	ERAPO90505*2	0.893	0.9150	102.46
G99272	HP329414*1	10.1	9.991	98.92	G99272	HP329414*1	1.6	1.616	101.00	G99275	ERAPO90505*1	0.893	0.8806	98.61
G99272	HP329414*2	10.1	10.12	100.20	G99272	HP329414*2	1.6	1.643	102.69	G99275	ERAPO90505*2	0.893	0.8583	96.11
G99287	HP329414*1	10.1	9.966	98.67	G99287	HP329414*1	1.6	1.618	101.13	G99294	ERAPO90505*2	0.893	0.8831	98.89
G99287	HP329414*2	10.1	10.07	99.70	G99287	HP329414*2	1.6	1.633	102.06	G99294	ERAPO90505*1	0.893	0.9019	101.00
G99304	HP329414*1	10.1	9.852	97.54	G99304	HP329414*1	1.6	1.604	100.25	G99311	ERAPO90505*2	0.893	0.8924	99.93
G99304	HP329414*2	10.1	9.804	97.07	G99304	HP329414*2	1.6	1.598	99.88	G99311	ERAPO90505*1	0.893	0.9072	101.59
G99332	HP329414*3	10.1	9.995	98.96	G99332	HP329414*3	1.6	1.637	102.31	G99329	ERAPO90505*1	0.893	0.8998	100.76
G99332	HP329414*2	10.1	10.03	99.31	G99332	HP329414*2	1.6	1.641	102.56	G99329	ERAPO90505*2	0.893	0.9078	101.66
G99332	HP329414*1	10.1	9.96	98.61	G99332	HP329414*1	1.6	1.631	101.94	G99336	ERAPO90505*1	0.893	0.8898	99.64
G99337	HP329414*1	10.1	9.945	98.47	G99337	HP329414*1	1.6	1.629	101.81	G99336	ERAPO90505*2	0.893	0.8906	99.73
G99337	HP329414*2	10.1	10	99.01	G99337	HP329414*2	1.6	1.638	102.38	G99362	ERAPO90505*2	0.893	0.8989	100.66
G99348	HP329414*1	10.1	9.826	97.29	G99348	HP329414*1	1.6	1.615	100.94	G99362	ERAPO90505*1	0.893	0.8943	100.15
G99348	HP329414*2	10.1	9.877	97.79	G99348	HP329414*2	1.6	1.621	101.31	G99370	ERAPO90505*2	0.893	0.9108	101.99
G99367	HP329414*1	10.1	9.849	97.51	G99367	HP329414*1	1.6	1.624	101.50	G99370	ERAPO90505*1	0.893	0.8899	99.65
G99367	HP329414*2	10.1	9.953	98.54	G99367	HP329414*2	1.6	1.636	102.25	G99386	ERAPO90505*1	0.893	0.9081	101.69
G99384	HP329414*1	10.1	10.01	99.11	G99384	HP329414*1	1.6	1.642	102.63	G99386	ERAPO90505*2	0.893	0.9366	104.88
G99384	HP329414*2	10.1	9.84	97.43	G99384	HP329414*2	1.6	1.619	101.19	G99392	ERAPO90505*2	0.893	0.9331	104.49
G99393	HP329414*1	10.1	9.764	96.67	G99393	HP329414*1	1.6	1.614	100.88	G99392	ERAPO90505*1	0.893	0.9070	101.57
G99393	HP329414*2	10.1	9.946	98.48	G99393	HP329414*2	1.6	1.638	102.38	G99408	ERAPO90505*1	0.893	0.9031	101.13
G99415	HP418836*1	10.1	9.96	98.61	G99415	HP418836*1	1.6	1.639	102.44	G99408	ERAPO90505*2	0.893	0.9558	107.03
G99415	HP418836*2	10.1	10.07	99.70	G99415	HP418836*2	1.6	1.663	103.94	G99420	ERAPO90505*1	0.893	0.9181	102.81
G99433	HP418836*1	10.1	9.967	98.68	G99433	HP418836*1	1.6	1.635	102.19	G99420	ERAPO90505*2	0.893	0.9711	108.75
G99433	HP418836*2	10.1	10.01	99.11	G99433	HP418836*2	1.6	1.639	102.44	G99453	ERAP108505*1	1.038	1.0434	100.52
G99452	HP418836*1	10.1	9.863	97.65	G99452	HP418836*1	1.6	1.631	101.94	G99453	ERAP108505*2	1.038	1.0628	102.39
G99452	HP418836*2	10.1	9.837	97.40	G99452	HP418836*2	1.6	1.648	103.00	G99469	ERAP108505*2	1.038	1.0190	98.17

Table C-3. Dry Deposition 2004 Sampling Season – QC Batch Summary for Teflon® Filters – Reference Samples – Clingmans Dome, TN (Page 2 of 8)

SO_4^{2-}					$NO_3^- - N$					$NH_4^+ - N$				
Batch	Lab Key	Target mg/L	Found mg/L	Percent Recovery	Batch	Lab Key	Target mg/L	Found mg/L	Percent Recovery	Batch	Lab Key	Target mg/L	Found mg/L	Percent Recovery
G99472	HP418836*1	10.1	9.78	96.83	G99472	HP418836*1	1.6	1.633	102.06	G99469	ERAP108505*1	1.038	1.0107	97.37
G99472	HP418836*2	10.1	9.914	98.16	G99472	HP418836*2	1.6	1.654	103.38					
Mean Percent Recovery				**98.91**	**Mean Percent Recovery**				**102.02**	**Mean Percent Recovery**				**100.90**
Standard Deviation				**1.20**	**Standard Deviation**				**0.87**	**Standard Deviation**				**2.46**
Count				**41.00**	**Count**				**41.00**	**Count**				**40.00**

Table C-3. Dry Deposition 2004 Sampling Season – QC Batch Summary for Teflon® Filters – Reference Samples – Clingmans Dome, TN (Page 3 of 8)

		Ca^{2+}					Mg^{2+}					Na^{+}		
Batch	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
G99166	HP329414*3	0.051	0.0525	102.94	G99166	HP329414*1	0.051	0.0503	98.63	G99166	HP329414*1	0.4	0.374	93.50
G99166	HP329414*1	0.051	0.0522	102.35	G99166	HP329414*3	0.051	0.0503	98.63	G99166	HP329414*3	0.4	0.375	93.75
G99166	HP329414*2	0.051	0.0528	103.53	G99166	HP329414*2	0.051	0.0504	98.82	G99166	HP329414*2	0.4	0.3761	94.03
G99167	HP329414*3	0.051	0.0531	104.12	G99167	HP329414*2	0.051	0.0503	98.63	G99167	HP329414*2	0.4	0.3754	93.85
G99167	HP329414*2	0.051	0.0513	100.59	G99167	HP329414*3	0.051	0.0513	100.59	G99167	HP329414*3	0.4	0.3798	94.95
G99167	HP329414*1	0.051	0.0528	103.53	G99167	HP329414*1	0.051	0.0505	99.02	G99167	HP329414*1	0.4	0.3822	95.55
G99190	HP329414*5	0.051	0.0524	102.75	G99190	HP329414*6	0.051	0.0507	99.41	G99190	HP329414*4	0.4	0.3775	94.38
G99190	HP329414*4	0.051	0.0525	102.94	G99190	HP329414*4	0.051	0.0512	100.39	G99190	HP329414*3	0.4	0.3802	95.05
G99190	HP329414*6	0.051	0.0528	103.53	G99190	HP329414*5	0.051	0.0509	99.80	G99190	HP329414*6	0.4	0.3759	93.98
G99190	HP329414*2	0.051	0.0524	102.75	G99190	HP329414*3	0.051	0.0506	99.22	G99190	HP329414*5	0.4	0.3725	93.13
G99190	HP329414*3	0.051	0.0523	102.55	G99190	HP329414*1	0.051	0.0501	98.24	G99190	HP329414*2	0.4	0.3845	96.13
G99190	HP329414*1	0.051	0.0527	103.33	G99190	HP329414*2	0.051	0.0507	99.41	G99190	HP329414*1	0.4	0.3835	95.88
G99224	HP329414*3	0.051	0.0511	100.20	G99224	HP329414*2	0.051	0.0509	99.80	G99224	HP329414*3	0.4	0.3775	94.38
G99224	HP329414*1	0.051	0.0516	101.18	G99224	HP329414*3	0.051	0.0507	99.41	G99224	HP329414*2	0.4	0.3778	94.45
G99224	HP329414*2	0.051	0.0512	100.39	G99224	HP329414*1	0.051	0.0505	99.02	G99224	HP329414*1	0.4	0.3696	92.40
G99240	HP329414*1	0.051	0.0528	103.53	G99240	HP329414*1	0.051	0.0511	100.20	G99240	HP329414*2	0.4	0.3782	94.55
G99240	HP329414*2	0.051	0.0525	102.94	G99240	HP329414*2	0.051	0.0499	97.84	G99240	HP329414*1	0.4	0.3871	96.78
G99241	HP329414*3	0.051	0.0528	103.53	G99241	HP329414*2	0.051	0.0509	99.80	G99241	HP329414*2	0.4	0.3766	94.15
G99241	HP329414*2	0.051	0.0525	102.94	G99241	HP329414*1	0.051	0.0506	99.22	G99241	HP329414*3	0.4	0.3791	94.78
G99241	HP329414*1	0.051	0.0523	102.55	G99241	HP329414*3	0.051	0.0509	99.80	G99241	HP329414*1	0.4	0.3814	95.35
G99263	HP329414*2	0.051	0.0529	103.73	G99263	HP329414*3	0.051	0.0512	100.39	G99263	HP329414*3	0.4	0.3822	95.55
G99263	HP329414*3	0.051	0.0529	103.73	G99263	HP329414*2	0.051	0.0514	100.78	G99263	HP329414*2	0.4	0.3826	95.65
G99263	HP329414*1	0.051	0.0528	103.53	G99263	HP329414*1	0.051	0.0512	100.39	G99263	HP329414*1	0.4	0.3788	94.70
G99271	HP329414*2	0.051	0.0524	102.75	G99271	HP329414*3	0.051	0.0512	100.39	G99271	HP329414*2	0.4	0.3831	95.78
G99271	HP329414*3	0.051	0.0526	103.14	G99271	HP329414*2	0.051	0.0511	100.20	G99271	HP329414*1	0.4	0.3782	94.55
G99271	HP329414*1	0.051	0.0522	102.35	G99271	HP329414*1	0.051	0.051	100.00	G99271	HP329414*3	0.4	0.3822	95.55
G99289	HP329414*1	0.051	0.0522	102.35	G99289	HP329414*2	0.051	0.0506	99.22	G99289	HP329414*3	0.4	0.3752	93.80
G99289	HP329414*3	0.051	0.0523	102.55	G99289	HP329414*1	0.051	0.0506	99.22	G99289	HP329414*1	0.4	0.3733	93.33
G99289	HP329414*2	0.051	0.0524	102.75	G99289	HP329414*3	0.051	0.0502	98.43	G99289	HP329414*2	0.4	0.3763	94.08
G99302	HP329414*1	0.051	0.0531	104.12	G99302	HP329414*2	0.051	0.0512	100.39	G99302	HP329414*1	0.4	0.3779	94.48

Table C-3. Dry Deposition 2004 Sampling Season – QC Batch Summary for Teflon® Filters – Reference Samples – Clingmans Dome, TN (Page 4 of 8)

Ca^{2+}					Mg^{2+}					Na^{+}				
Batch	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**	**Batch**	**Lab Key**	**Target mg/L**	**Found mg/L**	**Percent Recovery**
G99302	HP329414*2	0.051	0.0532	104.31	G99302	HP329414*1	0.051	0.0512	100.39	G99302	HP329414*2	0.4	0.3776	94.40
G99333	HP329414*3	0.051	0.0513	100.59	G99333	HP329414*3	0.051	0.051	100.00	G99333	HP329414*3	0.4	0.3798	94.95
G99333	HP329414*1	0.051	0.0514	100.78	G99333	HP329414*2	0.051	0.051	100.00	G99333	HP329414*2	0.4	0.3785	94.63
G99333	HP329414*2	0.051	0.0513	100.59	G99333	HP329414*1	0.051	0.0507	99.41	G99333	HP329414*1	0.4	0.378	94.50
G99335	HP329414*2	0.051	0.0535	104.90	G99335	HP329414*2	0.051	0.0512	100.39	G99335	HP329414*1	0.4	0.3772	94.30
G99335	HP329414*1	0.051	0.053	103.92	G99335	HP329414*1	0.051	0.0511	100.20	G99335	HP329414*2	0.4	0.3801	95.03
G99346	HP329414*3	0.051	0.0529	103.73	G99346	HP329414*3	0.051	0.051	100.00	G99346	HP329414*3	0.4	0.3756	93.90
G99346	HP329414*2	0.051	0.0533	104.51	G99346	HP329414*2	0.051	0.0513	100.59	G99346	HP329414*2	0.4	0.3766	94.15
G99346	HP329414*1	0.051	0.0538	105.49	G99346	HP329414*1	0.051	0.0516	101.18	G99346	HP329414*1	0.4	0.3823	95.58
G99361	HP329414*2	0.051	0.0506	99.22	G99361	HP329414*1	0.051	0.05	98.04	G99361	HP329414*3	0.4	0.3777	94.43
G99361	HP329414*3	0.051	0.0506	99.22	G99361	HP329414*2	0.051	0.0503	98.63	G99361	HP329414*2	0.4	0.3766	94.15
G99361	HP329414*1	0.051	0.0499	97.84	G99361	HP329414*3	0.051	0.0502	98.43	G99361	HP329414*1	0.4	0.3721	93.03
G99383	HP329414*1	0.051	0.0529	103.73	G99383	HP329414*1	0.051	0.0505	99.02	G99383	HP329414*2	0.4	0.378	94.50
G99383	HP329414*2	0.051	0.0533	104.51	G99383	HP329414*2	0.051	0.0508	99.61	G99383	HP329414*1	0.4	0.3724	93.10
G99389	HP329414*1	0.051	0.0536	105.10	G99389	HP329414*1	0.051	0.0512	100.39	G99389	HP329414*1	0.4	0.3795	94.88
G99389	HP329414*2	0.051	0.0532	104.31	G99389	HP329414*2	0.051	0.0507	99.41	G99389	HP329414*2	0.4	0.3793	94.83
G99409	HP418836*3	0.052	0.0523	100.58	G99409	HP418836*1	0.05	0.0502	100.40	G99409	HP418836*2	0.4	0.3823	95.58
G99409	HP418836*2	0.052	0.0525	100.96	G99409	HP418836*2	0.05	0.0511	102.20	G99409	HP418836*1	0.4	0.3746	93.65
G99409	HP418836*1	0.052	0.0518	99.62	G99409	HP418836*3	0.05	0.0508	101.60	G99409	HP418836*3	0.4	0.3812	95.30
G99421	HP418836*3	0.052	0.0532	102.31	G99421	HP418836*3	0.05	0.0521	104.20	G99421	HP418836*2	0.4	0.3896	97.40
G99421	HP418836*2	0.052	0.0535	102.88	G99421	HP418836*2	0.05	0.0519	103.80	G99421	HP418836*1	0.4	0.3807	95.18
G99421	HP418836*1	0.052	0.052	100.00	G99421	HP418836*1	0.05	0.0512	102.40	G99421	HP418836*3	0.4	0.3856	96.40
G99451	HP418836*3	0.052	0.0543	104.42	G99451	HP418836*3	0.05	0.0517	103.40	G99451	HP418836*3	0.4	0.3905	97.63
G99451	HP418836*2	0.052	0.054	103.85	G99451	HP418836*2	0.05	0.0518	103.60	G99451	HP418836*2	0.4	0.3899	97.48
G99451	HP418836*1	0.052	0.0536	103.08	G99451	HP418836*1	0.05	0.0513	102.60	G99451	HP418836*1	0.4	0.3833	95.83
G99470	HP418836*1	0.052	0.0553	106.35	G99470	HP418836*1	0.05	0.0517	103.40	G99470	HP418836*1	0.4	0.3854	96.35
G99470	HP418836*2	0.052	0.0549	105.58	G99470	HP418836*2	0.05	0.0517	103.40	G99470	HP418836*2	0.4	0.3885	97.13
Mean Percent Recovery				**102.73**	**Mean Percent Recovery**				**100.21**	**Mean Percent Recovery**				**94.85**
Standard Deviation				**1.77**	**Standard Deviation**				**1.55**	**Standard Deviation**				**1.15**
Count				**57**	**Count**				**57**	**Count**				**57**

Table C-3. Dry Deposition 2004 Sampling Season – QC Batch Summary for Teflon® Filters – Reference Samples – Clingmans Dome, TN (Page 5 of 8)

Batch	Lab Key	K^+ Target mg/L	Found mg/L	Percent Recovery
G99166	HP329414*1	0.097	0.0964	99.38
G99166	HP329414*2	0.097	0.0949	97.84
G99166	HP329414*3	0.097	0.0951	98.04
G99167	HP329414*1	0.097	0.0965	99.48
G99167	HP329414*2	0.097	0.0982	101.24
G99167	HP329414*3	0.097	0.1008	103.92
G99190	HP329414*4	0.097	0.0960	98.97
G99190	HP329414*5	0.097	0.0955	98.45
G99190	HP329414*6	0.097	0.0963	99.28
G99190	HP329414*2	0.097	0.0978	100.82
G99190	HP329414*3	0.097	0.0980	101.03
G99190	HP329414*1	0.097	0.0996	102.68
G99224	HP329414*3	0.097	0.0978	100.82
G99224	HP329414*2	0.097	0.0986	101.65
G99224	HP329414*1	0.097	0.0981	101.13
G99240	HP329414*1	0.097	0.1000	103.09
G99240	HP329414*2	0.097	0.0989	101.96
G99241	HP329414*2	0.097	0.0968	99.79
G99241	HP329414*1	0.097	0.0972	100.21
G99241	HP329414*3	0.097	0.0976	100.62
G99263	HP329414*3	0.097	0.0971	100.10
G99263	HP329414*1	0.097	0.0993	102.37
G99263	HP329414*2	0.097	0.0980	101.03
G99271	HP329414*2	0.097	0.0988	101.86
G99271	HP329414*1	0.097	0.0981	101.13
G99271	HP329414*3	0.097	0.0991	102.16
G99289	HP329414*1	0.097	0.0950	97.94
G99289	HP329414*2	0.097	0.0951	98.04
G99289	HP329414*3	0.097	0.0947	97.63
G99302	HP329414*1	0.097	0.0981	101.13
G99302	HP329414*2	0.097	0.0964	99.38
G99333	HP329414*3	0.097	0.0964	99.38
G99333	HP329414*2	0.097	0.0967	99.69
G99333	HP329414*1	0.097	0.0966	99.59
G99335	HP329414*1	0.097	0.0973	100.31
G99335	HP329414*2	0.097	0.0969	99.90
G99346	HP329414*3	0.097	0.0982	101.24
G99346	HP329414*2	0.097	0.0977	100.72
G99346	HP329414*1	0.097	0.1007	103.81
G99361	HP329414*3	0.097	0.0956	98.56
G99361	HP329414*1	0.097	0.0962	99.18

Batch	Lab Key	Cl^- Target mg/L	Found mg/L	Percent Recovery
G99163	HP329414*1	0.98	0.9751873	99.51
G99163	HP329414*2	0.98	0.9953001	101.56
G99196	HP329414*1	0.98	0.9846392	100.47
G99196	HP329414*2	0.98	0.9930177	101.33
G99219	HP329414*1	0.98	0.9898754	101.01
G99219	HP329414*2	0.98	1.012102	103.28
G99287	HP329414*1	0.98	0.984599	100.47
G99287	HP329414*2	0.98	0.990036	101.02
G99332	HP329414*1	0.98	0.9958888	101.62
G99332	HP329414*3	0.98	1.008576	102.92
G99332	HP329414*2	0.98	1.011612	103.23
G99337	HP329414*2	0.98	1.003546	102.40
G99337	HP329414*1	0.98	0.9946707	101.50
G99348	HP329414*1	0.98	0.9900422	101.02
G99367	HP329414*1	0.98	1.000493	102.09
G99367	HP329414*2	0.98	1.003144	102.36
G99384	HP329414*2	0.98	1.023419	104.43
G99393	HP329414*1	0.98	1.007234	102.78
G99393	HP329414*2	0.98	1.023736	104.46
G99415	HP418836*2	0.98	0.9981302	101.85
G99433	HP418836*2	0.98	0.9974325	101.78
G99433	HP418836*1	0.98	0.9922245	101.25
G99472	HP418836*2	0.98	1.002198	102.27
G99472	HP418836*1	0.98	0.9942335	101.45
G99472	HP418836*2	0.98	1.002198	102.27
Mean Percent Recovery				**101.93**
Standard Deviation				**1.17**
Count				**25.00**

Table C-3. Dry Deposition 2004 Sampling Season – QC Batch Summary for Teflon® Filters – Reference Samples – Clingmans Dome, TN (Page 6 of 8)

Batch	Lab Key	K^+ Target mg/L	Found mg/L	Percent Recovery
G99361	HP329414*2	0.097	0.0961	99.07
G99383	HP329414*1	0.097	0.0962	99.18
G99383	HP329414*2	0.097	0.0965	99.48
G99389	HP329414*1	0.097	0.0988	101.86
G99389	HP329414*2	0.097	0.0973	100.31
G99409	HP418836*3	0.093	0.0980	105.38
G99409	HP418836*1	0.093	0.0979	105.27
G99409	HP418836*2	0.093	0.0989	106.34
G99409	HP418836*4	0.093	0.0983	105.70
G99421	HP418836*3	0.093	0.0994	106.88
G99421	HP418836*2	0.093	0.1010	108.60
G99421	HP418836*1	0.093	0.0987	106.13
G99451	HP418836*3	0.093	0.0976	104.95
G99451	HP418836*2	0.093	0.0968	104.09
G99451	HP418836*1	0.093	0.0976	104.95
G99470	HP418836*1	0.093	0.0993	106.77
G99470	HP418836*2	0.093	0.0983	105.70
Mean Percent Recovery				**101.49**
Standard Deviation				**2.71**
Count				**58**

Table C-3. Dry Deposition 2004 Sampling Season – QC Batch Summary for Teflon® Filters – Reference Samples – Clingmans Dome, TN (Page 7 of 8)

Batch	Lab Key	SO_4^{2-} Target mg/L	Found mg/L	Percent Recovery	Batch	Lab Key	NO_3^- Target mg/L	Found mg/L	Percent Recovery
G99154	HP329414*1	10.1	10.013	99.14	G99154	HP329414*1	1.6	1.5875	99.22
G99154	HP329414*2	10.1	9.8917	97.94	G99154	HP329414*2	1.6	1.5835	98.97
G99170	HP329414*1	10.1	10.092	99.93	G99170	HP329414*1	1.6	1.6043	100.27
G99170	HP329414*2	10.1	10.184	100.83	G99170	HP329414*2	1.6	1.6235	101.47
G99187	HP329414*2	10.1	9.8839	97.86	G99187	HP329414*2	1.6	1.5947	99.67
G99187	HP329414*1	10.1	9.9561	98.58	G99187	HP329414*1	1.6	1.6026	100.16
G99204	HP329414*1	10.1	9.9499	98.51	G99204	HP329414*1	1.6	1.6062	100.39
G99204	HP329414*2	10.1	9.9040	98.06	G99204	HP329414*2	1.6	1.6065	100.41
G99226	HP329414*2	10.1	9.9089	98.11	G99226	HP329414*1	1.6	1.6049	100.31
G99226	HP329414*1	10.1	9.9241	98.26	G99226	HP329414*2	1.6	1.6140	100.88
G99233	HP329414*1	10.1	9.8423	97.45	G99233	HP329414*1	1.6	1.6011	100.07
G99233	HP329414*2	10.1	9.7171	96.21	G99233	HP329414*2	1.6	1.5911	99.44
G99247	HP329414*1	10.1	10.069	99.70	G99247	HP329414*1	1.6	1.6039	100.24
G99247	HP329414*2	10.1	10.340	102.38	G99247	HP329414*2	1.6	1.6516	103.23
G99270	HP329414*1	10.1	9.8077	97.11	G99270	HP329414*1	1.6	1.5955	99.72
G99270	HP329414*2	10.1	9.8136	97.17	G99270	HP329414*2	1.6	1.6019	100.12
G99300	HP329414*3	10.1	10.229	101.28	G99300	HP329414*1	1.6	1.5968	99.80
G99300	HP329414*2	10.1	10.133	100.33	G99300	HP329414*2	1.6	1.6095	100.59
G99300	HP329414*1	10.1	10.106	100.07	G99300	HP329414*3	1.6	1.6290	101.81
G99317	HP329414*2	10.1	10.039	99.40	G99317	HP329414*1	1.6	1.5971	99.82
G99317	HP329414*1	10.1	10.034	99.35	G99317	HP329414*2	1.6	1.6019	100.12
G99334	HP329414*2	10.1	10.031	99.32	G99334	HP329414*2	1.6	1.6105	100.66
G99334	HP329414*1	10.1	10.012	99.14	G99334	HP329414*1	1.6	1.6032	100.20
G99358	HP329414*2	10.1	9.9627	98.64	G99358	HP329414*2	1.6	1.6028	100.18
G99358	HP329414*1	10.1	9.9506	98.52	G99358	HP329414*1	1.6	1.5954	99.71
G99371	HP329414*2	10.1	9.8589	97.61	G99371	HP329414*2	1.6	1.6015	100.09
G99371	HP329414*1	10.1	9.8830	97.85	G99371	HP329414*1	1.6	1.5942	99.64
G99385	HP418836*1	10.1	10.04	99.41	G99385	HP418836*2	1.6	1.641	102.56
G99385	HP418836*2	10.1	10.15	100.50	G99385	HP418836*1	1.6	1.611	100.69
G99397	HP329414*1	10.1	9.892	97.94	G99397	HP329414*2	1.6	1.597	99.81
G99397	HP329414*2	10.1	9.85	97.52	G99397	HP329414*1	1.6	1.604	100.25
G99424	HP418836*1	10.1	10.06	99.60	G99424	HP418836*1	1.6	1.605	100.31
G99424	HP418836*2	10.1	10.12	100.20	G99424	HP418836*2	1.6	1.625	101.56
G99423	HP418836*1	10.1	9.806	97.09	G99423	HP418836*1	1.6	1.607	100.44
G99423	HP418836*2	10.1	9.746	96.50	G99423	HP418836*2	1.6	1.605	100.31
G99443	HP418836*3	10.1	9.879	97.81	G99443	HP418836*3	1.6	1.631	101.94
G99443	HP418836*1	10.1	9.798	97.01	G99443	HP418836*4	1.6	1.629	101.81
G99443	HP418836*4	10.1	9.885	97.87	G99443	HP418836*2	1.6	1.623	101.44
G99443	HP418836*2	10.1	9.885	97.87	G99443	HP418836*1	1.6	1.614	100.88
G99457	HP418836*2	10.1	9.749	96.52	G99457	HP418836*1	1.6	1.607	100.44
G99457	HP418836*1	10.1	9.76	96.63	G99457	HP418836*2	1.6	1.612	100.75
Mean Percent Recovery				**98.57**	**Mean Percent Recovery**				**100.50**
Standard Deviation				**1.41**	**Standard Deviation**				**0.88**
Count				**41**	**Count**				**41**

Table C-3. Dry Deposition 2004 Sampling Season – QC Batch Summary for Teflon® Filters – Reference Samples – Clingmans Dome, TN (Page 8 of 8)

Batch	Lab Key	SO_4^{2-} Target mg/L	Found mg/L	Percent Recovery
G99152	HP329414*1	10.1	10.12	100.20
G99152	HP329414*2	10.1	10.16	100.59
G99165	HP329414*1	10.1	10.13	100.30
G99165	HP329414*2	10.1	10.1	100.00
G99198	HP329414*2	10.1	10.14	100.40
G99198	HP329414*1	10.1	10.17	100.69
G99203	HP329414*2	10.1	10.06	99.60
G99203	HP329414*1	10.1	10.1	100.00
G99227	HP329414*1	10.1	10.09	99.90
G99227	HP329414*2	10.1	10.12	100.20
G99228	HP329414*1	10.1	10.18	100.79
G99228	HP329414*2	10.1	10.13	100.30
G99257	HP329414*2	10.1	10.19	100.89
G99257	HP329414*1	10.1	10.13	100.30
G99279	HP329414*1	10.1	10.12	100.20
G99279	HP329414*2	10.1	10.2	100.99
G99283	HP329414*1	10.1	10.12	100.20
G99283	HP329414*2	10.1	10.18	100.79
G99313	HP329414*1	10.1	10.3	101.98
G99313	HP329414*2	10.1	10.26	101.58
G99327	HP329414*2	10.1	10.19	100.89
G99327	HP329414*1	10.1	10.19	100.89
G99338	HP329414*1	10.1	10.31	102.08
G99338	HP329414*2	10.1	10.22	101.19
G99366	HP329414*1	10.1	10.19	100.89
G99366	HP329414*2	10.1	10.2	100.99
G99377	HP418836*1	10.1	10.18	100.79
G99377	HP418836*2	10.1	10.13	100.30
G99391	HP418836*1	10.1	10.16	100.59
G99391	HP418836*2	10.1	10.14	100.40
G99399	HP418836*1	10.1	10.21	101.09
G99399	HP418836*2	10.1	10.16	100.59
G99422	HP418836*1	10.1	10.19	100.89
G99422	HP418836*2	10.1	10.16	100.59
G99440	HP418836*2	10.1	10.2	100.99
G99440	HP418836*1	10.1	10.2	100.99
G99450	HP418836*2	10.1	10.21	101.09
G99450	HP418836*1	10.1	10.17	100.69
Mean Percent Recovery				**100.68**
Standard Deviation				**0.52**
Count				**38**

Table C-4. Dry Deposition 2004 Sampling Season – CVS (%R) – Clingmans Dome, TN

Filter Type	Parameter	Mean	Standard Deviation	Count
Teflon	SO_4^{2-}	100.12	1.07	223
	NO_3^- - N	100.33	1.52	223
	Cl^-	99.70	1.03	223
	NH_4^+ - N	100.27	2.16	216
	Ca^{2+}	100.31	0.77	216
	Mg^{2+}	99.88	0.61	216
	Na^+	99.82	0.87	216
	K^+	99.98	0.86	216
Nylon	SO_4^{2-}	99.77	0.50	204
	NO_3^- - N	100.13	1.45	204
Whatman	SO_4^{2-}	99.19	0.91	143

Note:
%R = percent recovery

Table C-5. Dry Deposition 2004 Sampling Season – Replicate Summary – Clingmans Dome, TN

Sample No.	Replicate No.	Date	Parameter	Filter Type	Sample Result	Replicate Result	Percent Difference	Mean Percent Difference	Standard Deviation	Count
DD04-31*85	RP*DD04-31*85	7/27/2004	SO_4^{2-}	Teflon	2.4656	2.4680	-0.10			
DD04-39*85	RP*DD04-39*85	9/21/2004	SO_4^{2-}	Teflon	2.1360	2.1410	-0.23	-0.17	0.10	2
DD04-31*85	RP*DD04-31*85	7/27/2004	NO_3^- - N	Teflon	0.0080	0.0080	0.00			
DD04-39*85	RP*DD04-39*85	9/21/2004	NO_3^- - N	Teflon	0.0087	0.0090	-3.69	-1.84	2.61	2
DD04-31*85	RP*DD04-31*85	7/27/2004	Cl^-	Teflon	0.0200	0.0200	0.00			
DD04-39*85	RP*DD04-39*85	9/21/2004	Cl^-	Teflon	0.0200	0.0200	0.00	0.00	0.00	2
DD04-43*85	RP*DD04-43*85	10/19/2004	SO_4^{2-}	Whatman	0.2312	0.2510	-8.56	-8.56		1