

Clean Air Status and Trends Network (CASTNET) Quarterly Data Summary for Fourth Quarter 2020 (October through December)

Prepared for: U.S. Environmental Protection Agency (EPA), Clean Air Markets Division

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Introduction

This quarterly report summarizes the Clean Air Status and Trends Network (CASTNET) data collected during fourth quarter 2020. Trends in pollutants measured at eastern and western reference sites are shown. Results from the quality assurance/quality control (QA/QC) program are presented for fourth quarter data and include completeness and precision of filter concentrations and hourly O₃ concentrations. This report also analyzes data for continuous, trace-level NO_y from eight sites and continuous SO₂ concentrations from three sites. Other QC statistics are given in the CASTNET Fourth Quarter 2020 Quality Assurance Report (Wood, 2020).

Figure 1. Fourth Highest Daily Maximum 8-hour Average O₃ Concentrations (ppb) through Fourth Quarter 2020



Figure 1 shows fourth highest daily maximum 8-hour average (DM8A) O₃ concentrations measured through fourth quarter 2020. Five western sites exceeded the 0.070 parts per million (ppm) National Ambient Air Quality Standard for O₃.

Trends

Trend analyses were performed based on filter pack pollutant concentrations measured in micrograms per cubic meter (µg/m³) of air at the 34 eastern and 16 western reference sites during fourth quarter. Trends in quarterly mean filter pack and O₃ concentrations are shown using box plots in Figures 2 through 13.

Fourth Quarter Concentrations

Quarterly mean HNO₃, NO₃⁻, NH₄⁺, total NO₃⁻, SO₂, SO₄²⁻, and Na⁺ concentrations decreased at eastern sites in 2020 while Cl⁻, K⁺, Mg²⁺ concentrations increased. Eastern Ca²⁺ levels did not change. Quarterly mean HNO₃, NO₃⁻, NH₄⁺, total NO₃⁻, SO₂, SO₄²⁻, Ca²⁺, K⁺, and Mg²⁺ concentrations increased at western sites in 2020 while Cl⁻ and Na⁺ concentrations decreased.

Quarterly O₃ concentrations were analyzed using box plots constructed by averaging all valid hourly O₃ concentrations within fourth quarter 2020 by site and then averaging those averages for all eastern and western reference sites (Figure 13). The figure shows a overall continuing reduction in quarterly mean O₃ concentrations at eastern sites. Mean O₃ concentrations at western sites increased in fourth quarter 2020. Quarterly mean concentrations were higher at the western reference sites than at the eastern sites.

Figure 2. Trends in Fourth Quarter Mean HNO₃ Concentrations

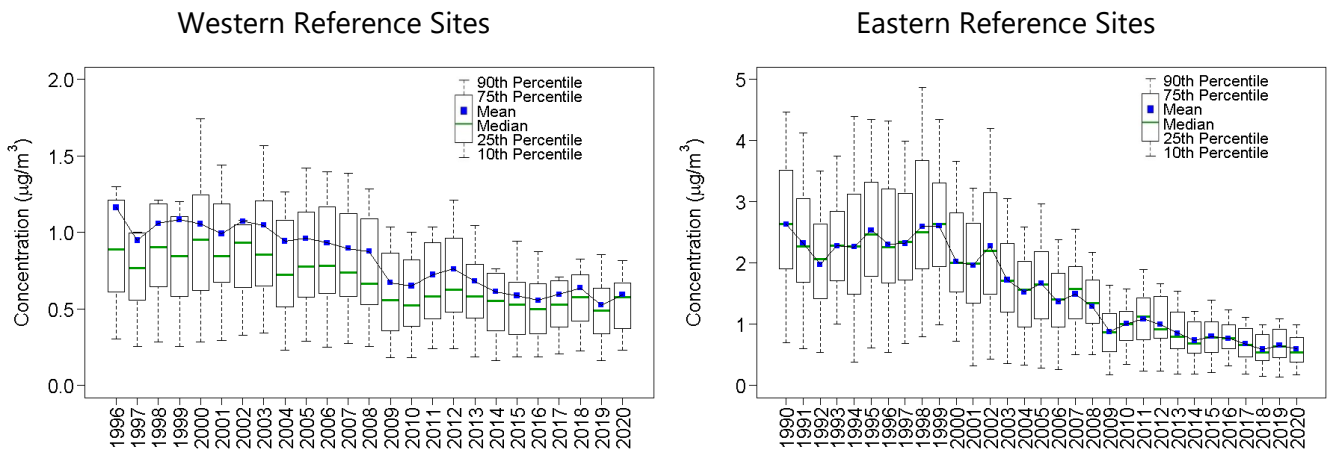


Figure 3. Trends in Fourth Quarter Mean NO₃ Concentrations

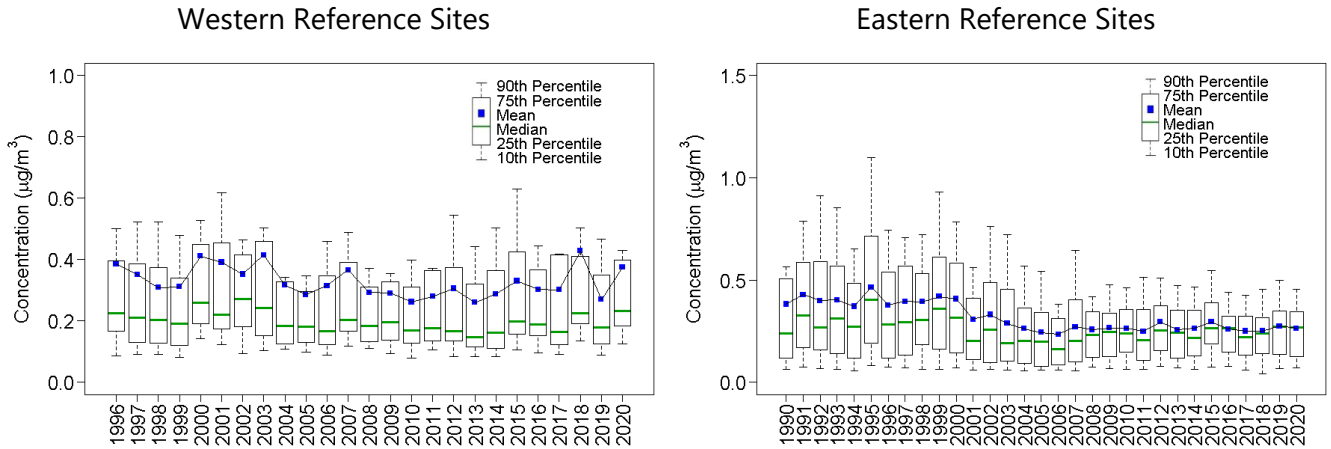


Figure 4. Trends in Fourth Quarter Mean NH₄⁺ Concentrations

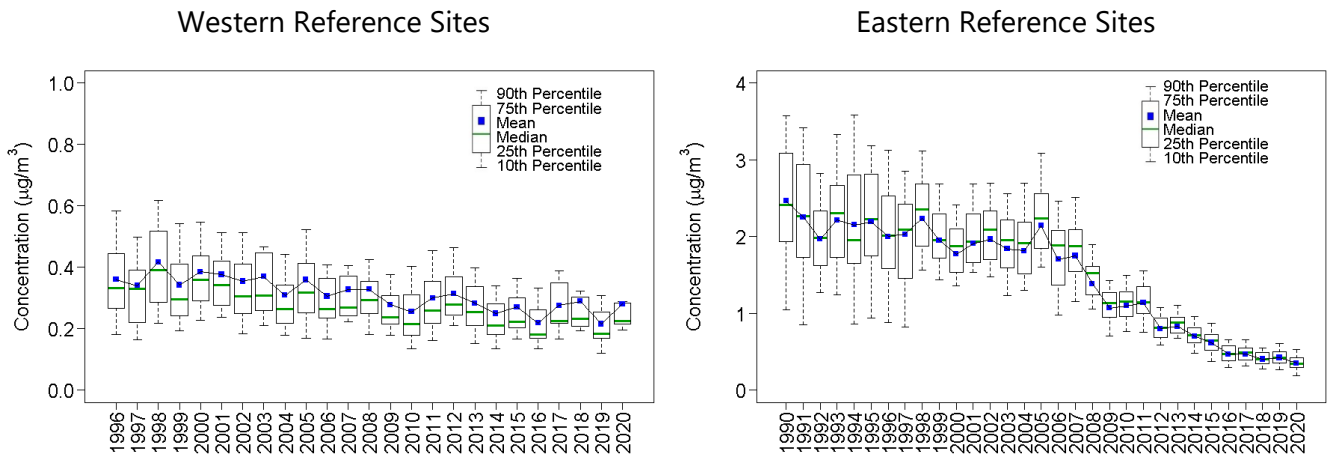


Figure 5. Trends in Fourth Quarter Mean Total NO₃ Concentrations

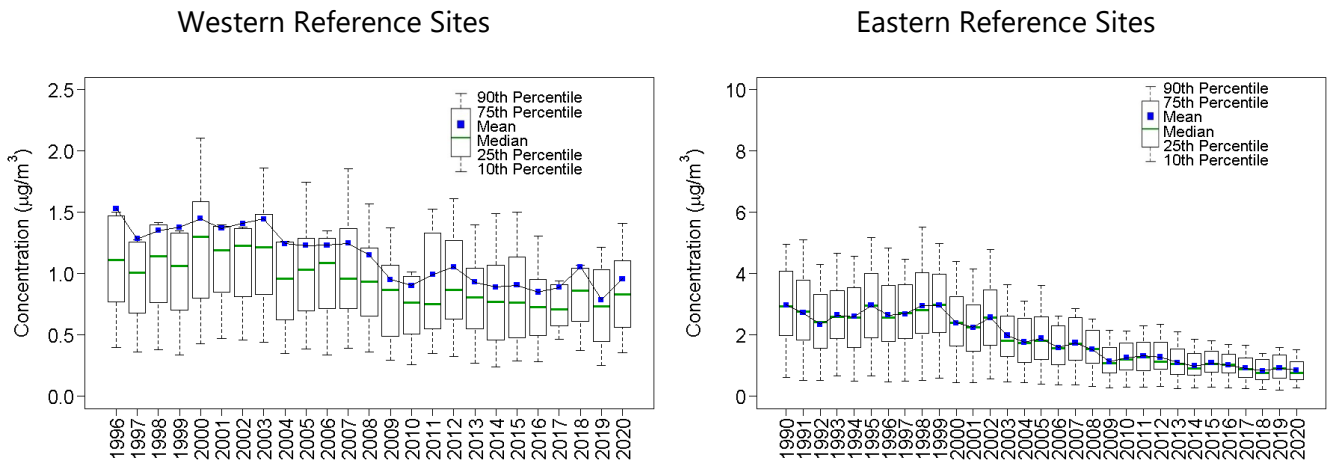


Figure 6. Trends in Fourth Quarter Mean SO₂ Concentrations

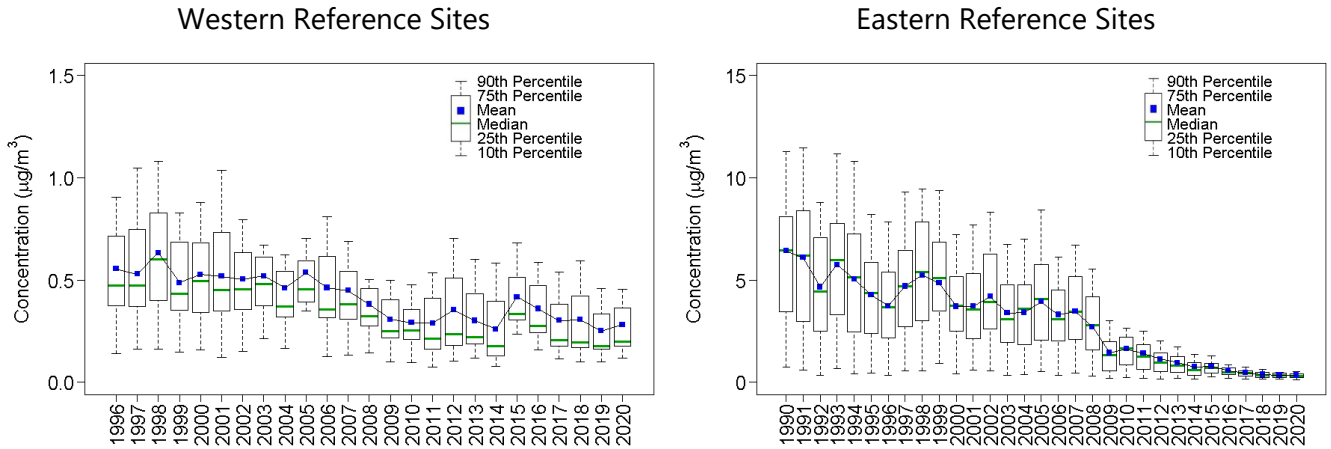


Figure 7. Trends in Fourth Quarter Mean SO₄²⁻ Concentrations

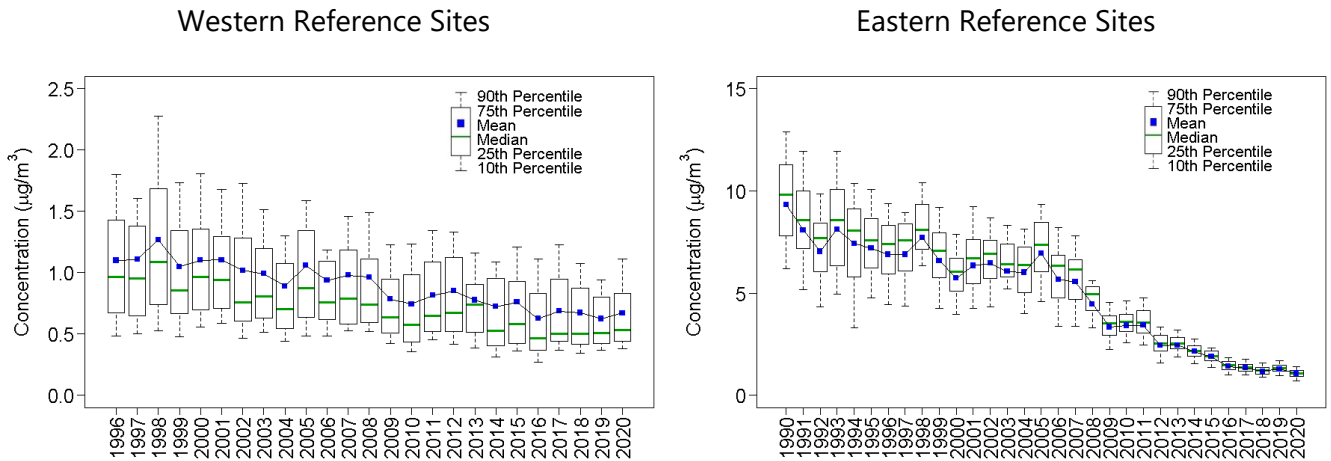


Figure 8. Trends in Fourth Quarter Mean Cl⁻ Concentrations

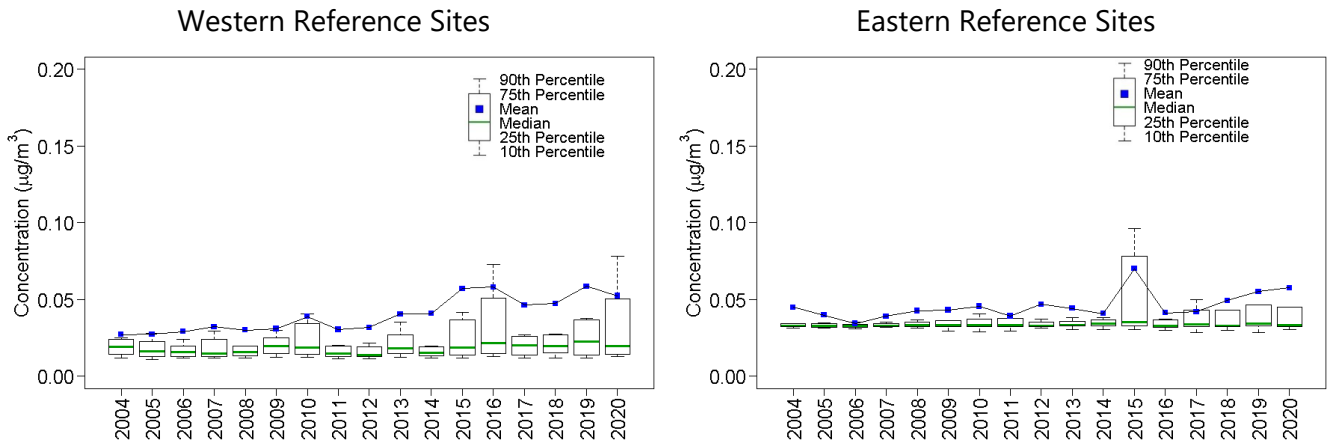


Figure 9. Trends in Fourth Quarter Mean Ca²⁺ Concentrations

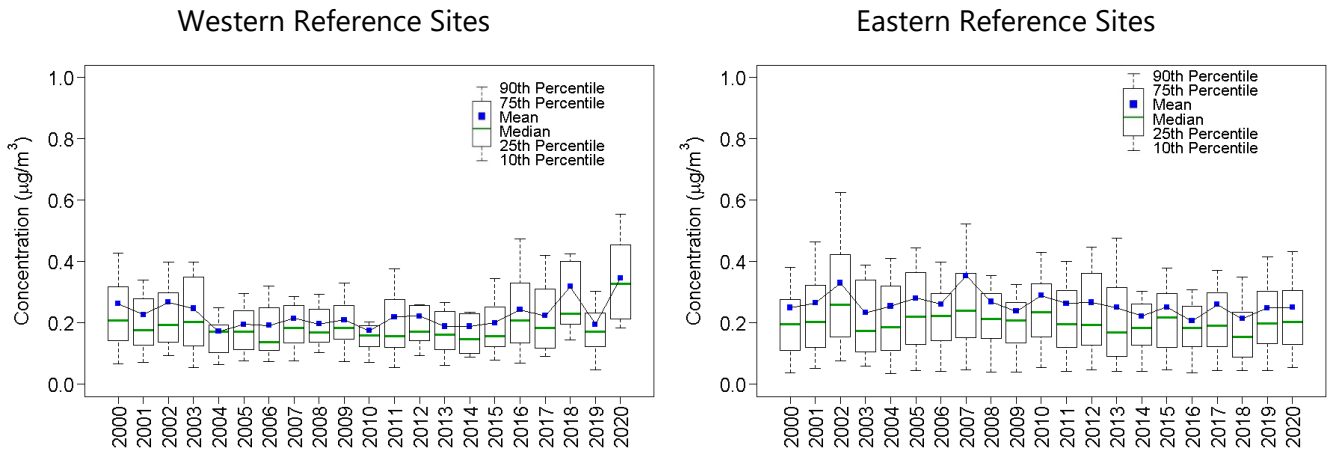


Figure 10. Trends in Fourth Quarter Mean K⁺ Concentrations

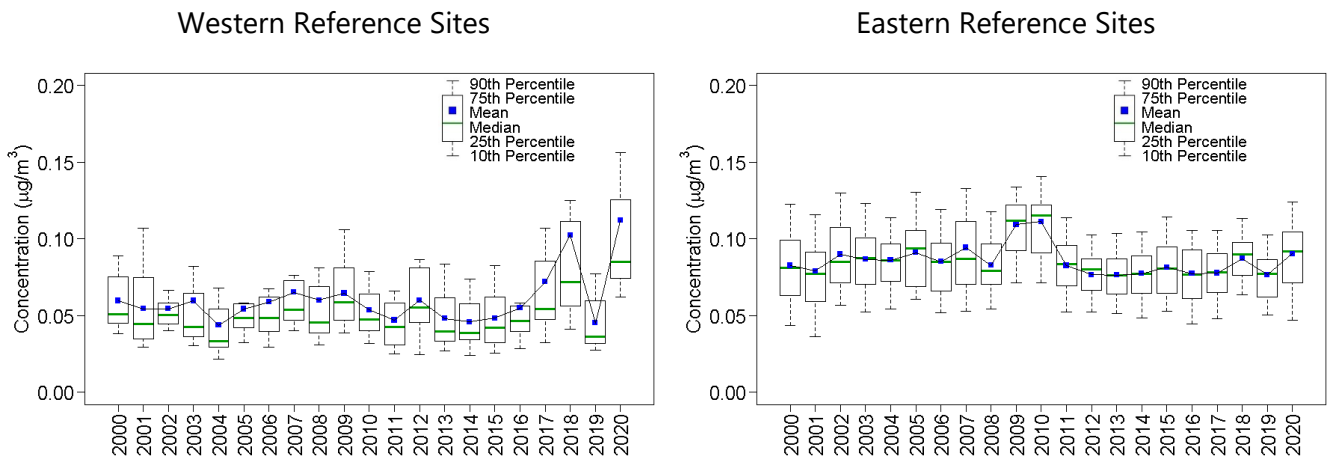


Figure 11. Trends in Fourth Quarter Mean Mg²⁺ Concentrations

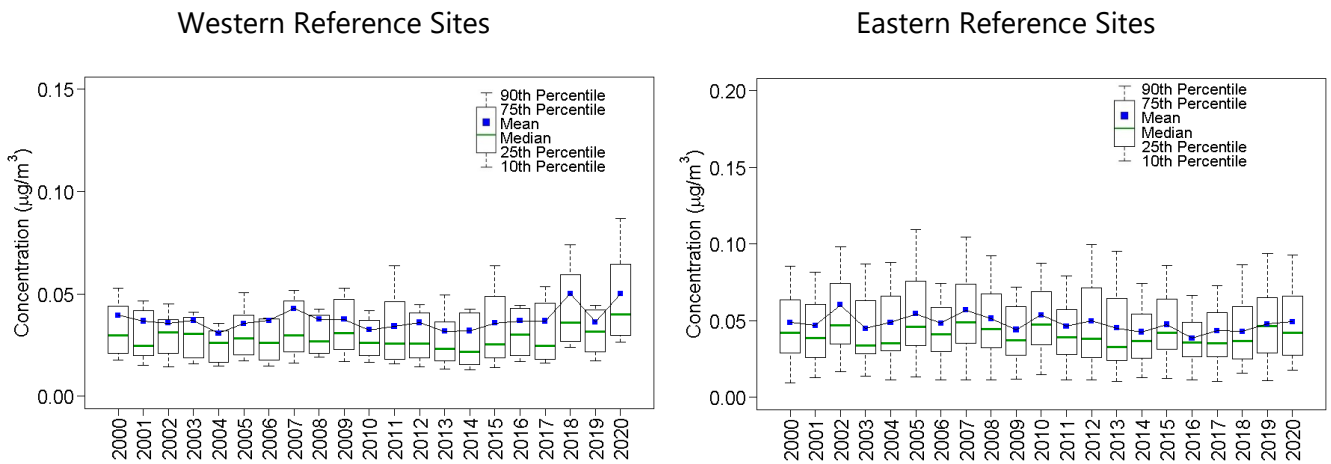


Figure 12. Trends in Fourth Quarter Mean Na⁺ Concentrations

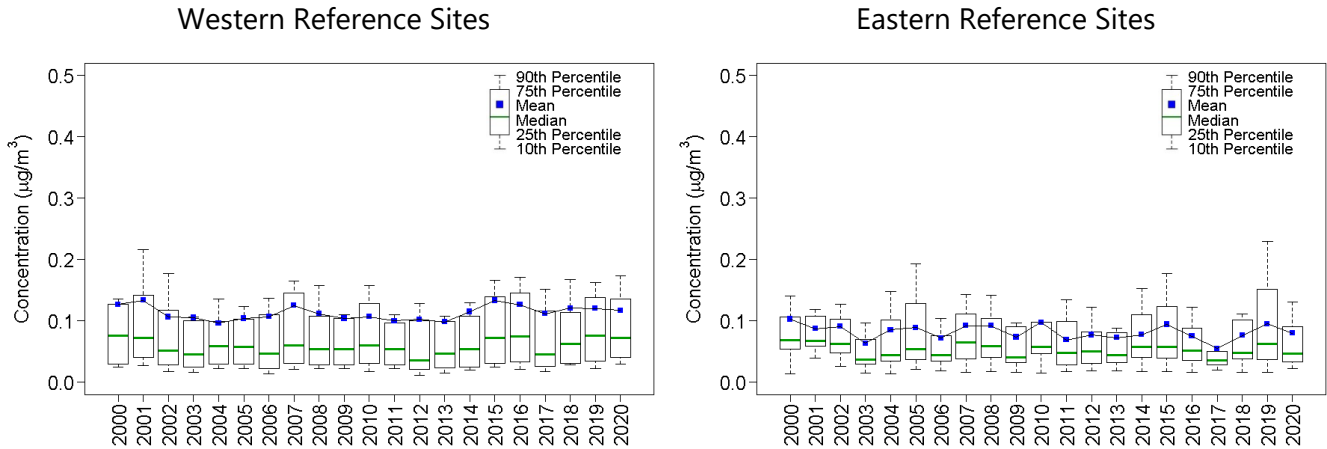
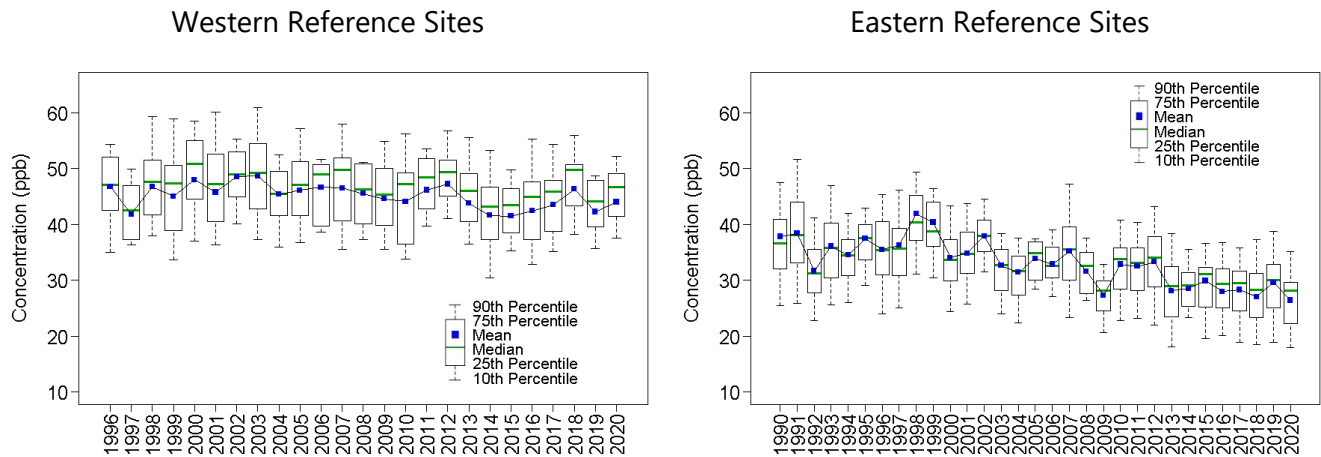


Figure 13. Trends in Fourth Quarter Mean O₃ Concentrations



Changes in 3-year Average Fourth Quarter Concentrations

Three-year averages of quarterly mean concentrations of total NO₃⁻, NH₄⁺, SO₂, and SO₄²⁻ were reduced over the period 1990–1992 through 2018–2020 for eastern reference sites and 1996–1998 through 2018–2020 for western reference sites. O₃ concentrations increased at eastern sites by 4 percent and showed no change at western sites. Tables 1 and 2 summarize changes in 3-year average fourth quarter concentrations.

Table 1. Eastern Reference Sites: 3-Year Mean Nitrogen, Sulfur, and O₃ Pollutant Concentrations

	Total NO ₃ ⁻ (µg/m ³)	NH ₄ ⁺ (µg/m ³)	SO ₂ (µg/m ³)	SO ₄ ²⁻ (µg/m ³)	O ₃ (ppb)
1990–1992	2.9	1.4	10.6	3.6	23
2018–2020	1.5	0.5	0.5	0.9	24
Percent Change	-48	-64	-95	-76	4

Table 2. Western Reference Sites: 3-Year Mean Nitrogen, Sulfur, and O₃ Pollutant Concentrations

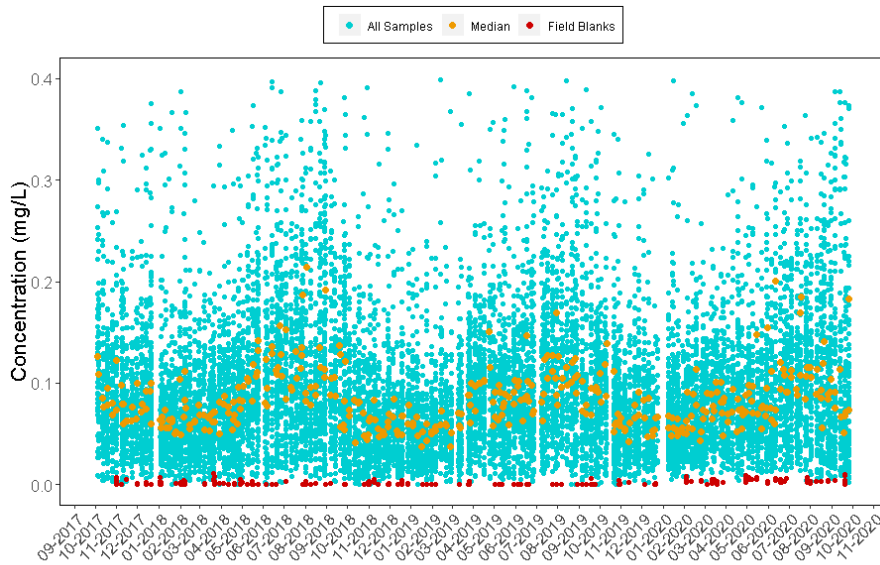
	Total NO ₃ ⁻ (µg/m ³)	NH ₄ ⁺ (µg/m ³)	SO ₂ (µg/m ³)	SO ₄ ²⁻ (µg/m ³)	O ₃ (ppb)
1996–1998	0.8	0.2	0.7	0.6	38
2018–2020	0.5	0.1	0.2	0.3	38
Percent Change	-37	-38	-69	-46	0

Time Series of Laboratory Analysis Parameters for All Sites

Figures 14 through 24 give time series of laboratory-analyzed concentrations of field samples and field blanks in milligrams per liter (mg/L) of 11 parameters from fourth quarter 2017 through fourth quarter 2020. These figures provide indications of potential issues with concentration measurements relative to detection and reporting limits.

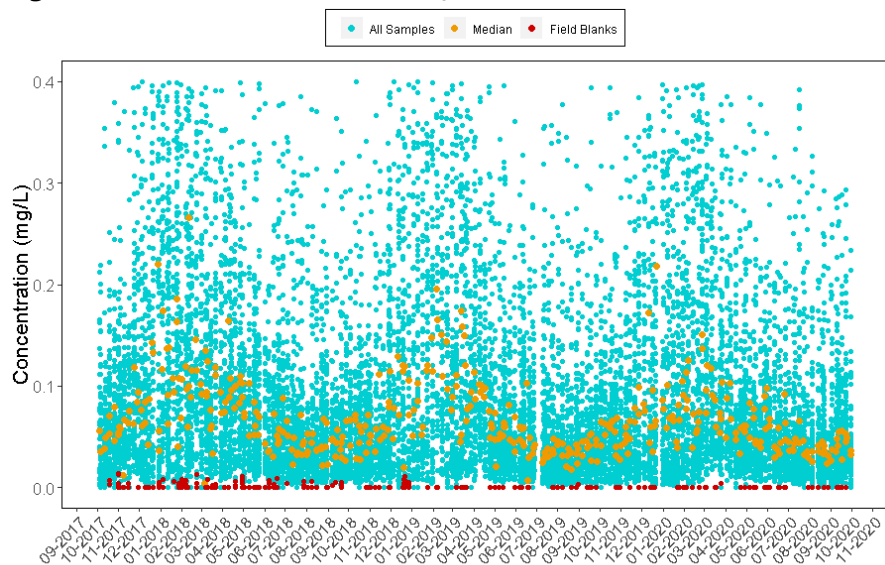
Previous review of filter pack analysis control charts indicated possible potassium contamination (Figure 22). Corrective actions were implemented, and subsequent testing indicated these actions have been effective.

Figure 14. Concentrations of NO₃⁻ (as N) from Nylon Filters



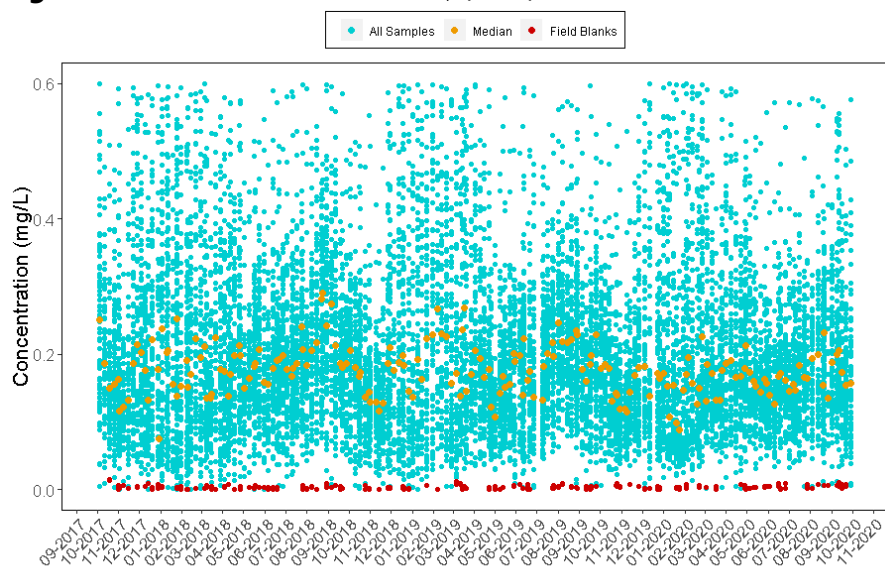
Note: Nominal reporting limit is 0.008 mg/L.

Figure 15. Concentrations of NO_3^- (as N) from Teflon Filters



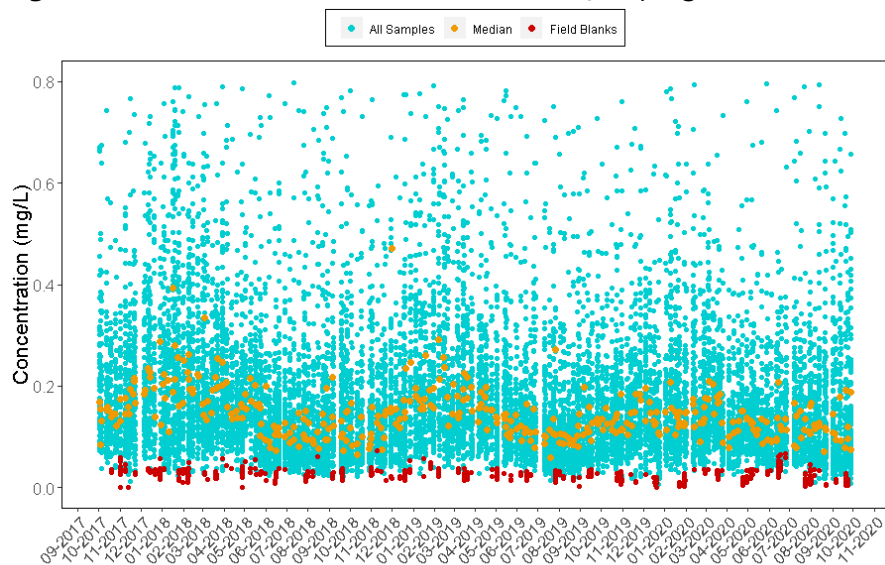
Note: Nominal reporting limit is 0.008 mg/L.

Figure 16. Concentrations of NH_4^+ (as N) from Teflon Filters



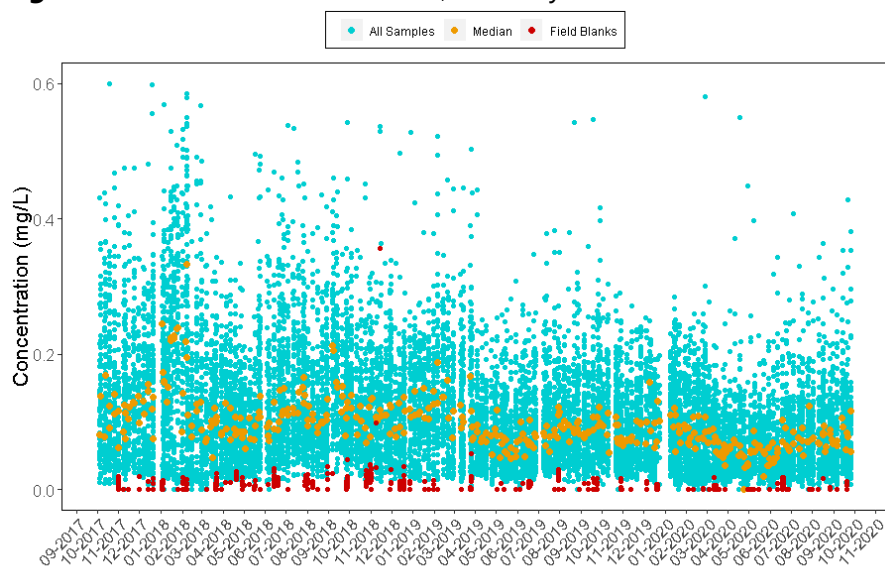
Note: Nominal reporting limit is 0.020 mg/L.

Figure 17. Concentrations of SO₂ from K₂CO₃-impregnated Cellulose Filters



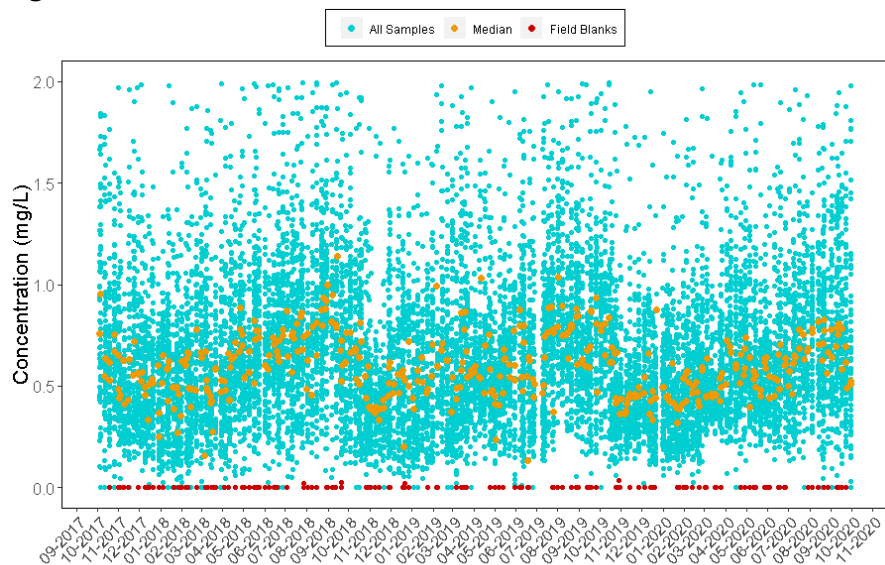
Note: Nominal reporting limit is 0.040 mg/L.

Figure 18. Concentrations of SO₄²⁻ from Nylon Filters



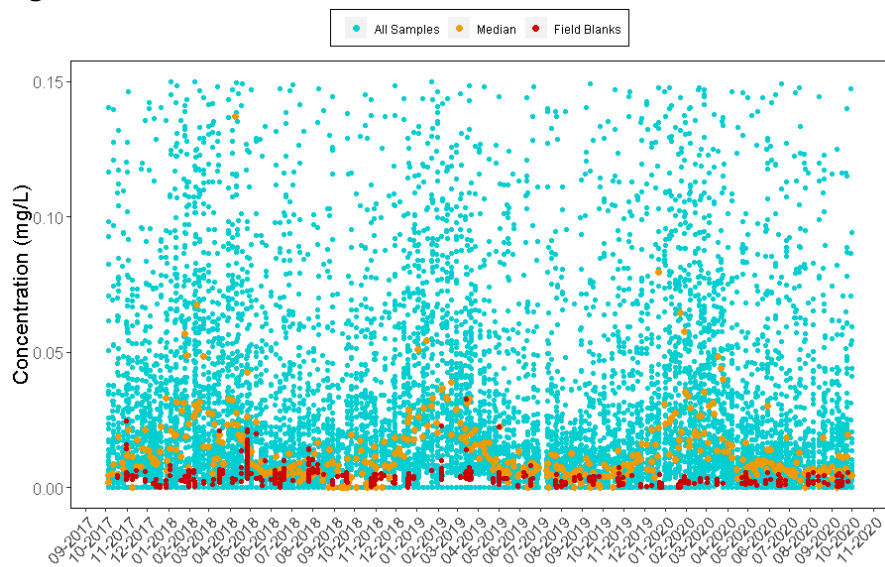
Note: Nominal reporting limit is 0.040 mg/L.

Figure 19. Concentrations of SO_4^{2-} from Teflon Filters



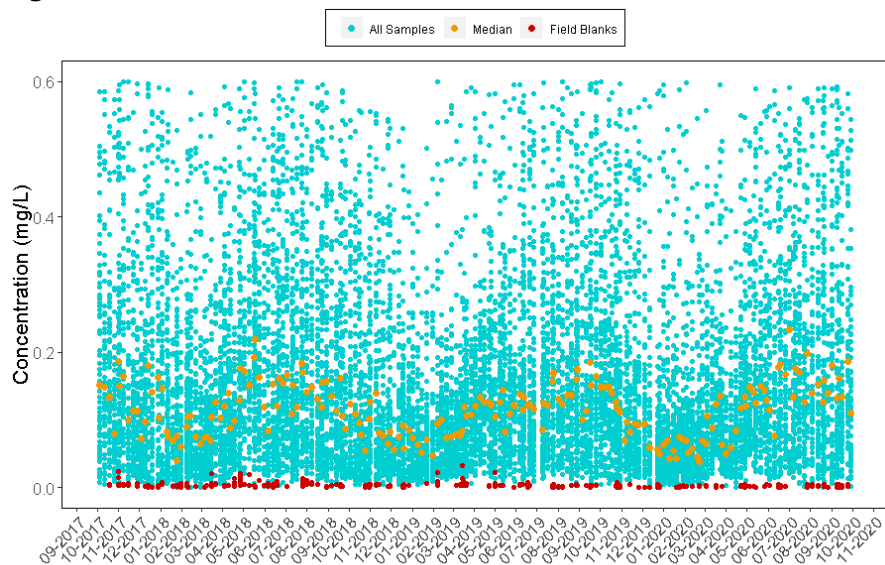
Note: Nominal reporting limit is 0.040 mg/L.

Figure 20. Concentrations of Cl^- from Teflon Filters



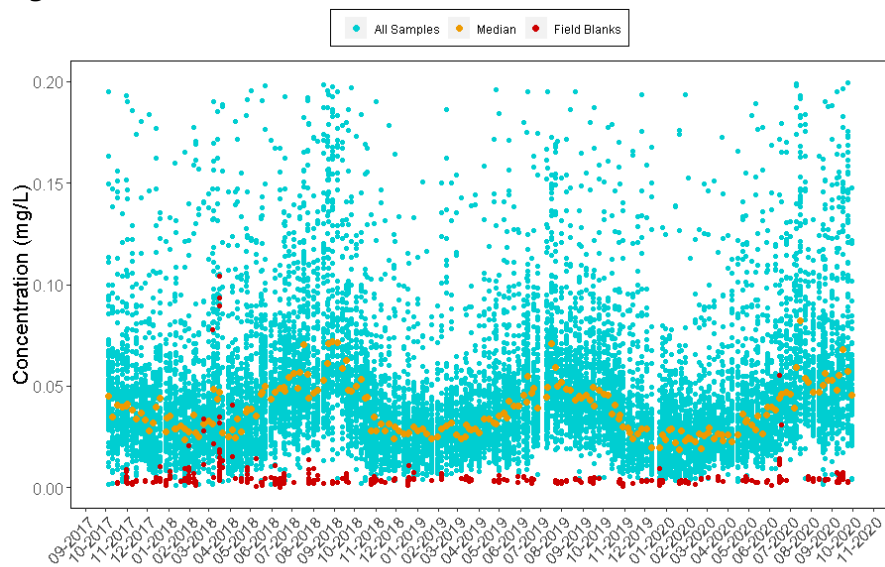
Note: Nominal reporting limit is 0.020 mg/L.

Figure 21. Concentrations of Ca²⁺ from Teflon Filters



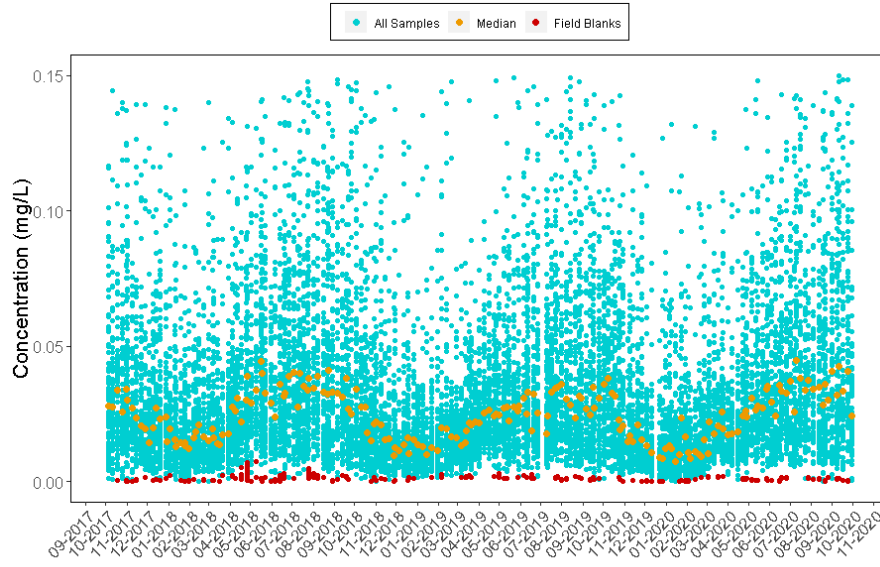
Note: Nominal reporting limit is 0.006 mg/L.

Figure 22. Concentrations of K⁺ from Teflon Filters



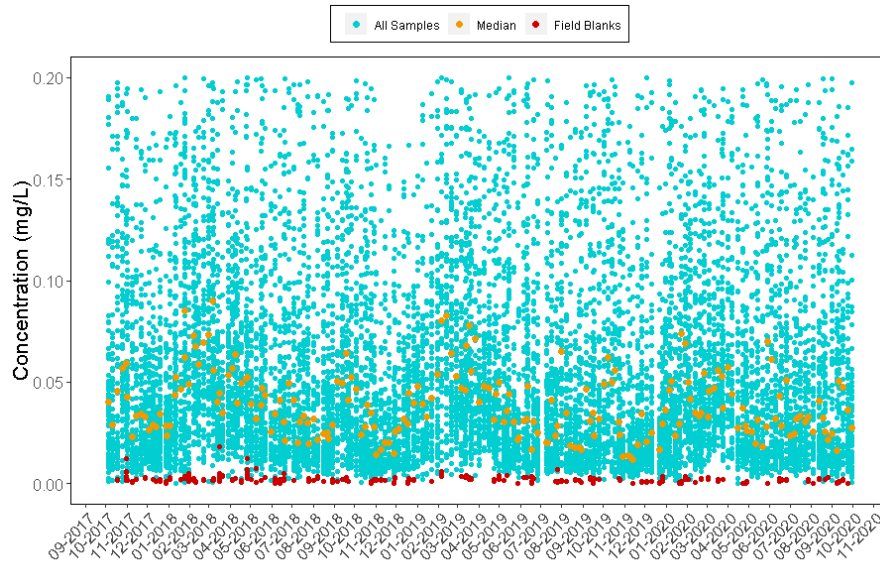
Note: Nominal reporting limit is 0.006 mg/L.

Figure 23. Concentrations of Mg^{2+} from Teflon Filters



Note: Nominal reporting limit is 0.003 mg/L.

Figure 24. Concentrations of Na^{+} from Teflon Filters



Note: Nominal reporting limit is 0.005 mg/L.

Time Series of Concentration Differences from Co-located Sites

Figures 25 and 26 show times series of concentration differences between the two sets of co-located sites. The mass flow controller at MCK231 failed in December. The last two filter packs will eventually be invalidated, and the concentration data will be updated.

Figure 25. Time Series of Filter Concentration Differences between MCK131 and MCK231, KY

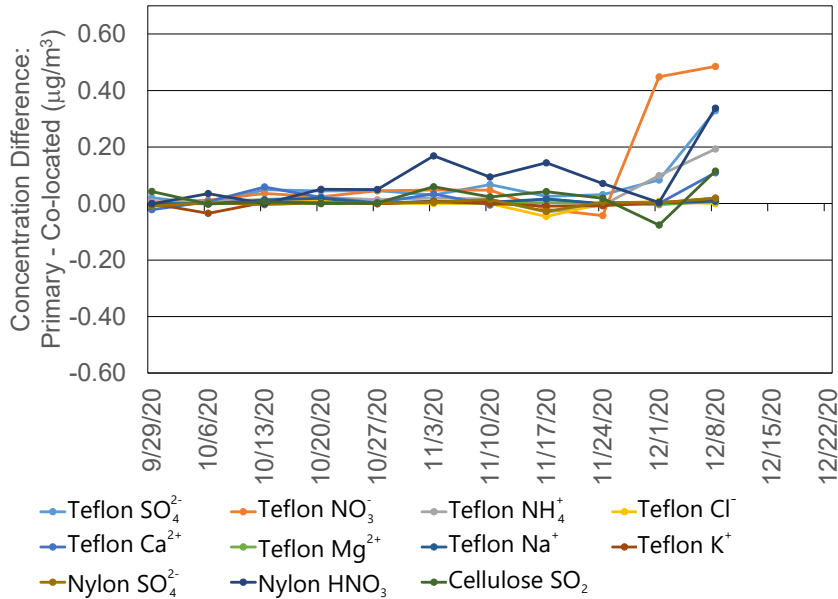
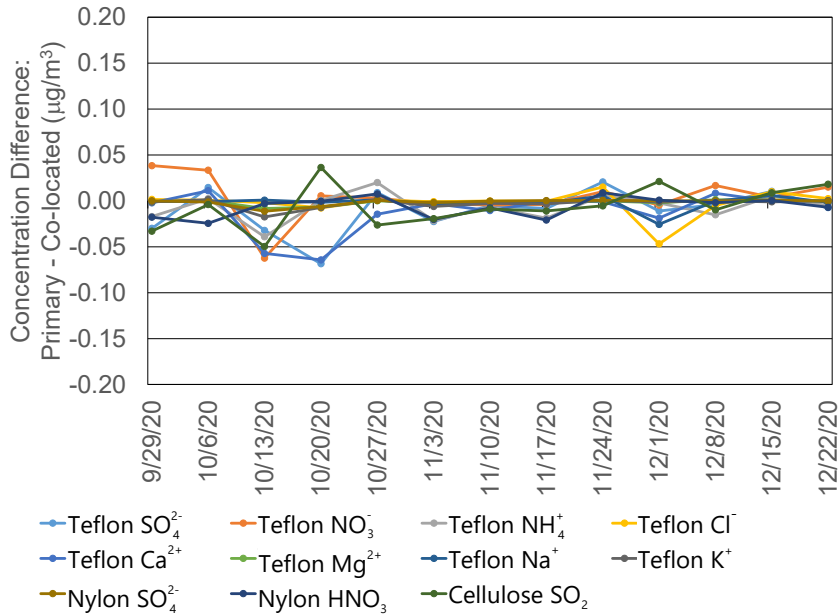


Figure 26. Time Series of Filter Concentration Differences between ROM406 and ROM206, CO



Precision of Filter Pack Concentrations

Table 3 shows mean absolute relative percent differences (MARPD) for concentrations measured at MCK131/231 and ROM406/206 during fourth quarter 2020. The table was prepared excluding the last two weekly concentrations measured at MCK131/231. The MARPD values met the 20 percent criterion.

Table 3. Precision (MARPD) for Co-located Filter Pack Data during Fourth Quarter 2020

	SO ₄ ²⁻	NO ₃ ⁻	NH ₄ ⁺	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Cl ⁻	HNO ₃	SO ₂	Total NO ₃ ⁻
MCK131/231, KY											
\bar{X} (μg/m ³)	0.84	1.02	0.42	0.31	0.05	0.10	0.07	0.06	0.80	0.48	1.80
\bar{Y} (μg/m ³)	0.77	0.92	0.39	0.29	0.04	0.09	0.07	0.07	0.71	0.46	1.50
MAD	0.06	0.11	0.04	0.03	0.00	0.01	0.01	0.01	0.09	0.03	0.18
MARPD	7.17	8.58	7.28	8.08	5.95	6.50	9.56	5.27	9.96	6.10	8.22
ROM406/206, CO											
\bar{X} (μg/m ³)	0.33	0.30	0.14	0.27	0.03	0.03	0.07	0.03	0.23	0.20	0.53
\bar{Y} (μg/m ³)	0.35	0.30	0.15	0.29	0.03	0.04	0.07	0.04	0.24	0.21	0.54
MAD	0.02	0.02	0.02	0.02	0.00	0.01	0.00	0.01	0.01	0.03	0.02
MARPD	7.27	9.52	12.24	10.03	13.08	11.63	10.36	18.97	4.97	12.27	4.86

Completeness for Filter Pack Concentrations

Table 4 shows CASTNET sites with less than 90 percent completeness for weekly filter pack concentrations. Comments are included to provide information on why these sites experienced low data completeness.

Table 4. Sites with less than 90 Percent Data Completeness for Filter Concentrations for Fourth Quarter 2020

Site ID	Teflon SO ₄ ²⁻	Teflon NO ₃ ⁻	Teflon NH ₄ ⁺	Teflon Minor Cations	Teflon Cl ⁻	Nylon HNO ₃	Nylon SO ₄ ²⁻	Cellulose SO ₂	Comment
BEL116, MD	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	The site experienced an extended power outage.
CNT169, WY	69.2	69.2	69.2	69.2	69.2	69.2	69.2	69.2	Site equipment was removed for two weeks in October because of fires in the area. Two more samples were invalidated because the data logger charger was not plugged in during reinstallation.
EGB181, ON	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	The operator visited the site only twice during October due to pandemic restrictions.
GTH161, CO	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	The sampling tower was broken by high winds in mid-November and repaired in early December.
LAV410, CA	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	The site experienced an extended power outage.

Table 5 gives MARPD data for O₃ data measured at the two co-located sites.

Table 5. Quarterly Precision (MARPD) for Co-located O₃ Concentrations

Site Pair	Quarter	Start Date	MARPD	Records
MCK131/231, KY				
	1	1/1/20	1.0	2063
	2	4/1/20	0.8	1986
	3	7/1/20	1.8	2086
	4	10/1/20	1.5	2069
ROM406/206, CO				
	1	1/1/20	0.8	2004
	2	4/1/20	1.3	2028
	3	7/1/20	1.7	2023
	4	10/1/20	3.3	1996

Completeness for O₃ Concentrations

Calculation of an annual O₃ value requires 75 percent completeness. However, calculation of the 3-year design value used for regulatory purposes requires 90 percent completeness. Table 6 shows CASTNET sites with less than 90 percent completeness for DM8A O₃ concentrations. Comments are provided for these sites.

Table 6. Sites with less than 90 Percent Data Completeness for DM8A Concentrations during Fourth Quarter 2020

Site ID	Percent Completeness	Comments
CHC432, NM	65.2	Communications issues that began in early October were resolved with installation of a directional antenna in early December.
CNT169, WY	71.7	Site equipment was removed for two weeks in October because of fires in the area. Two additional weeks were lost because the data logger charger was not plugged in during reinstallation.
GTH161, CO	75.0	The sampling tower was broken by high winds in mid-November and repaired in early December.
YEL408, WY	80.4	The analyzer pump failed in mid-December and was replaced in late December.
BBE401, TX	84.8	The analyzer malfunctioned in mid-November and was replaced in early December.
DCP114, OH	85.9	There was a leak in the sample line in November 2020.
IRL141, FL	89.1	High bench temperatures occurred in early October. The air conditioner was replaced.
PAL190, TX	89.1	A power outage in early November caused some data loss.

Table 7 shows CASTNET sites with less than 90 percent completeness for hourly O₃ concentrations. Comments are provided for these sites. The annual average for each of these sites is included for reference.

Table 7. Sites with less than 90 Percent Data Completeness for O₃ Concentrations

Site ID	Q4 2020	Q1 2020– Q4 2020	Comments
CHC432, NM	65.5	89.7	Communications issues that began in early October were resolved with installation of a directional antenna in early December.
CNT169, WY	75.9	93.1	Site equipment was removed for two weeks in October because of fires in the area. Two additional weeks of data were lost because the data logger charger was not plugged in during reinstallation.
GTH161, CO	76.0	91.1	The sampling tower was broken by high winds in mid-November and repaired in early December.
YEL408, WY	81.3	94.2	The analyzer pump failed in mid-December and was replaced in late December.
DCP114, OH	85.2	92.8	There was a leak in the sample line in November 2020.
BBE401, TX	89.4	95.1	The analyzer malfunctioned in mid-November and was replaced in early December.

Filter Pack Total Nitrate and Continuous Trace-level NO_y Concentrations at Eight CASTNET Sites

Figures 29 through 36 show a comparison of weekly average continuous NO_y measurements with weekly filter pack total NO₃⁻ concentrations collected at the eight sites with NO_y measurements. The NO_y concentrations were consistently higher than the total NO₃⁻ levels at all sites. The average weekly NO_y levels, the weekly total NO₃⁻ concentrations, and their ratios for the eight sites with available data are shown in Table 8. Ratios of NO_y to total NO₃⁻ varied from 3.71 at PNF126 to 11.29 at ROM206.

Table 8. Summary of Total NO₃⁻ and NO_y Measurements for Fourth Quarter 2020

Site ID	Elevation	Total NO ₃ ⁻ (ppb)	NO _y (ppb)	Ratio
DUK008, NC	164	0.48	2.94	6.21
BVL130, IL	213	0.94	4.28	5.52
MAC426, KY	243	0.74	3.05	4.35
HWF187, NY	497	0.20	0.87	4.28
GRS420, TN	793	0.38	1.80	4.94
PNF126, NC	1216	0.28	0.90	3.71
PND165, WY	2386	0.09	0.36	4.08
ROM206, CO	2742	0.16	1.51	11.29

Figure 29. Comparison of DUK008 Weekly Mean NO_y and Total NO₃⁻ Concentrations

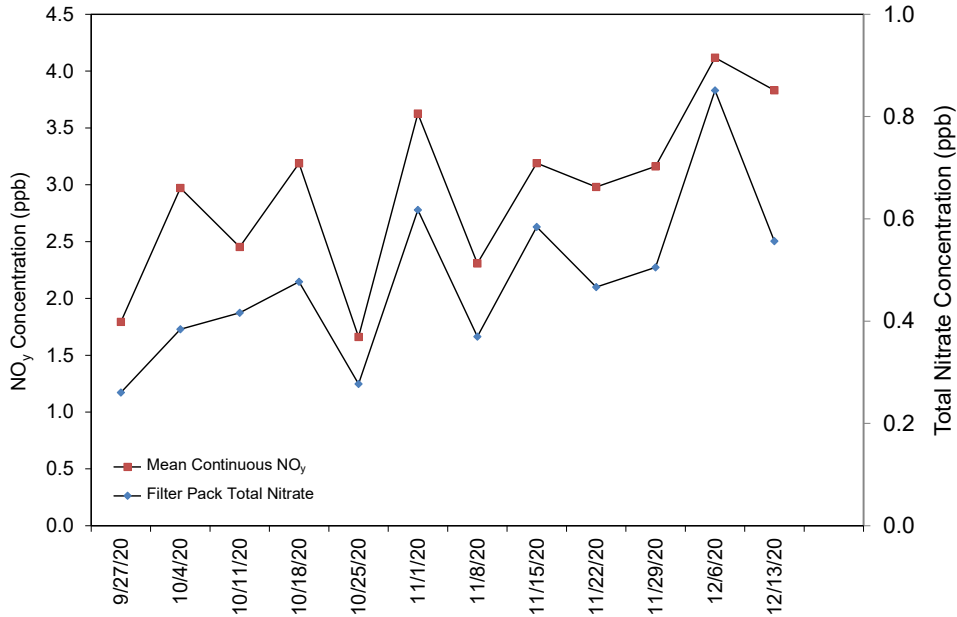


Figure 30. Comparison of BVL130 Weekly Mean NO_y and Total NO₃⁻ Concentrations

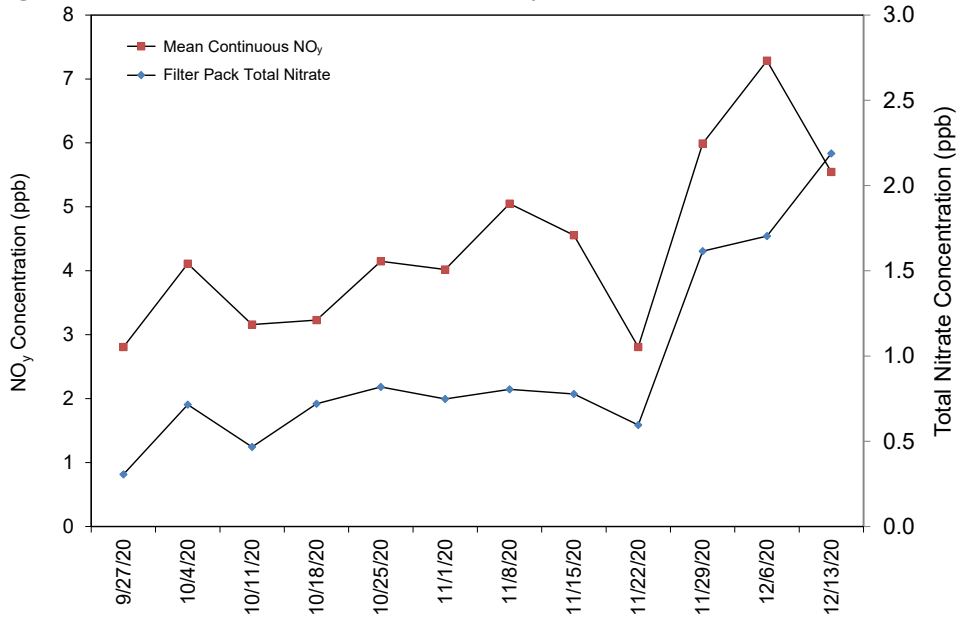


Figure 31. Comparison of MAC426 Weekly Mean NO_y and Total NO_3^- Concentrations

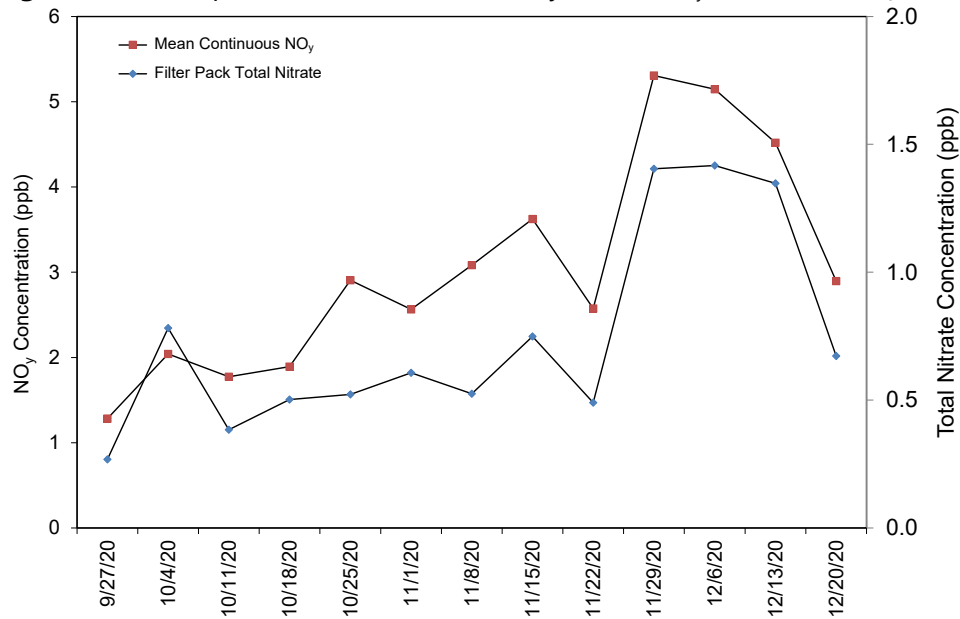


Figure 32. Comparison of HWF187 Weekly Mean NO_y and Total NO_3^- Concentrations

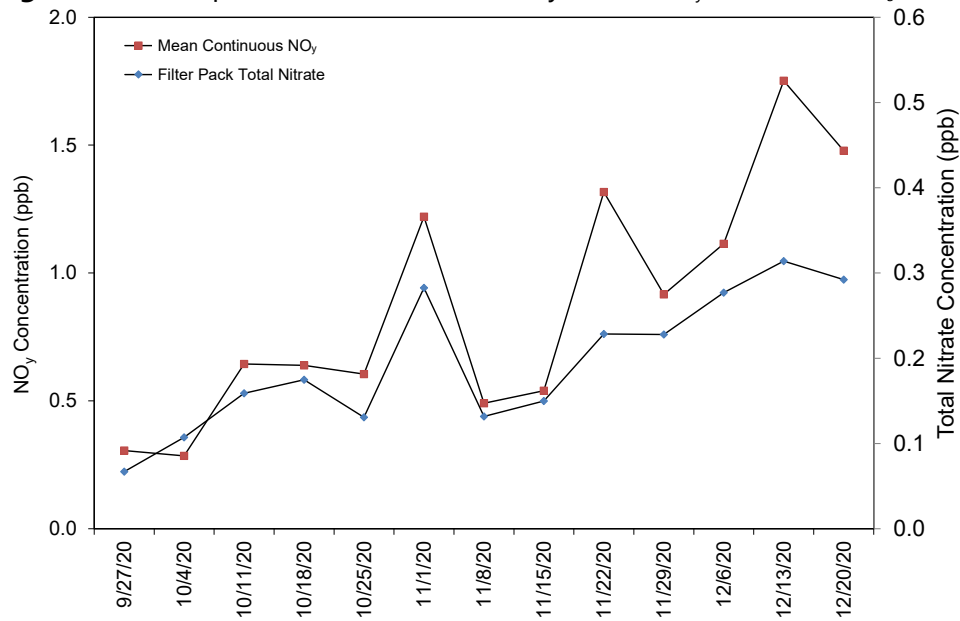


Figure 33. Comparison of GRS420 Weekly Mean NO_y and Total NO₃ Concentrations

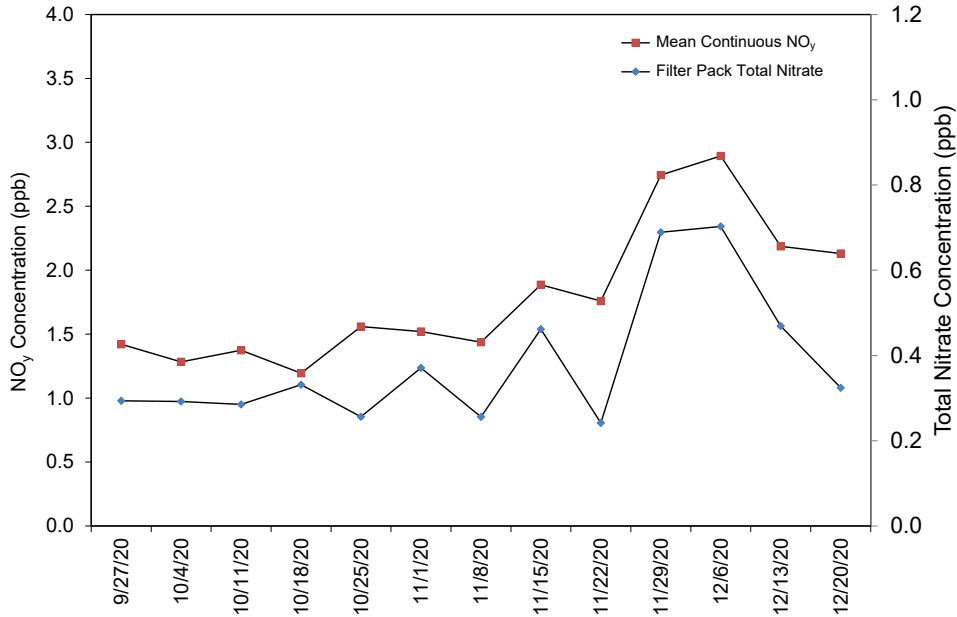


Figure 34. Comparison of PNF126 Weekly Mean NO_y and Total NO₃ Concentrations

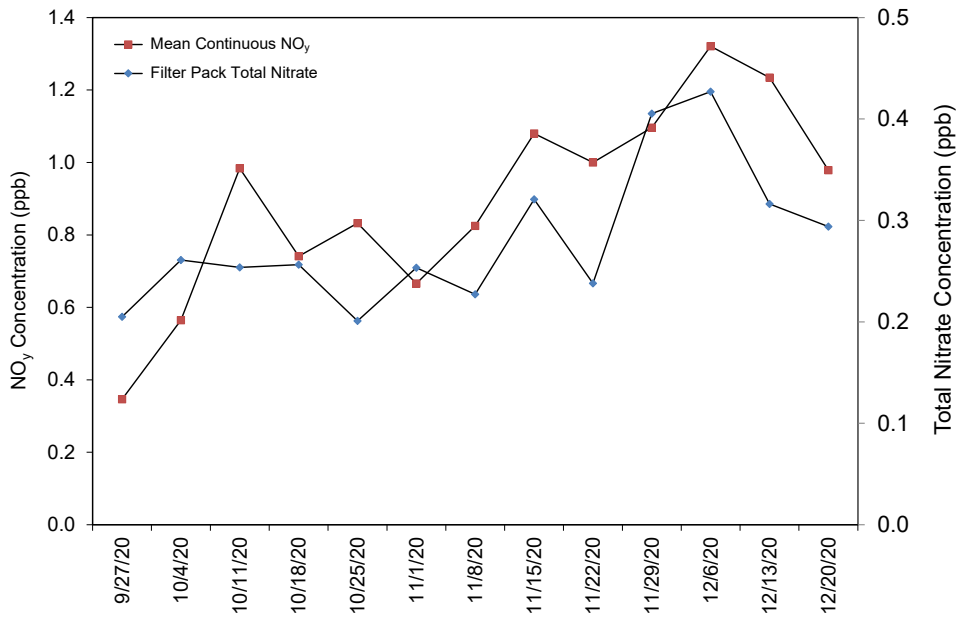


Figure 35. Comparison of PND165 Weekly Mean NO_y and Total NO_3^- Concentrations

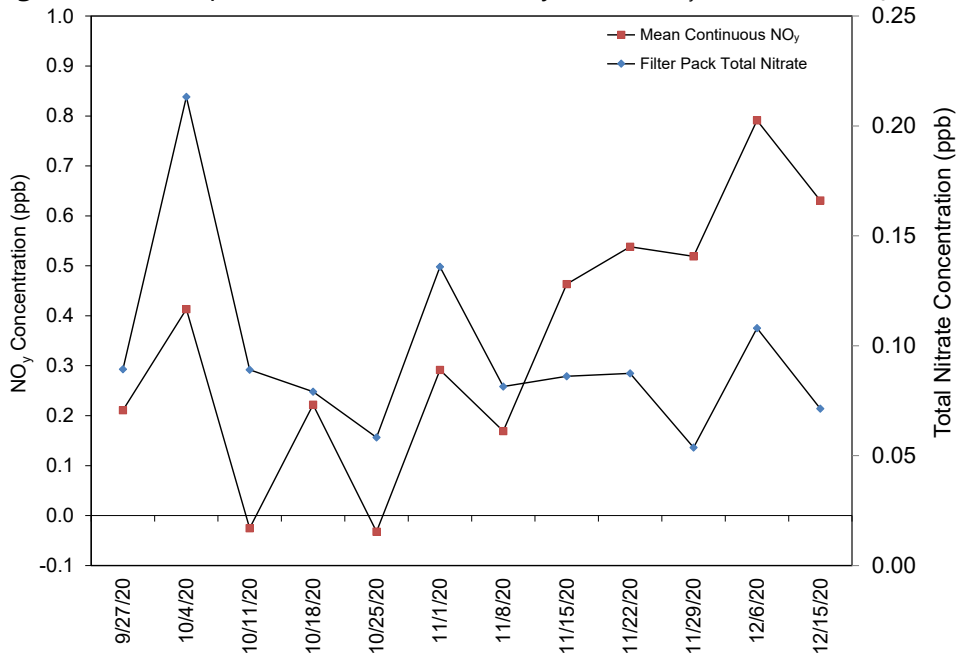
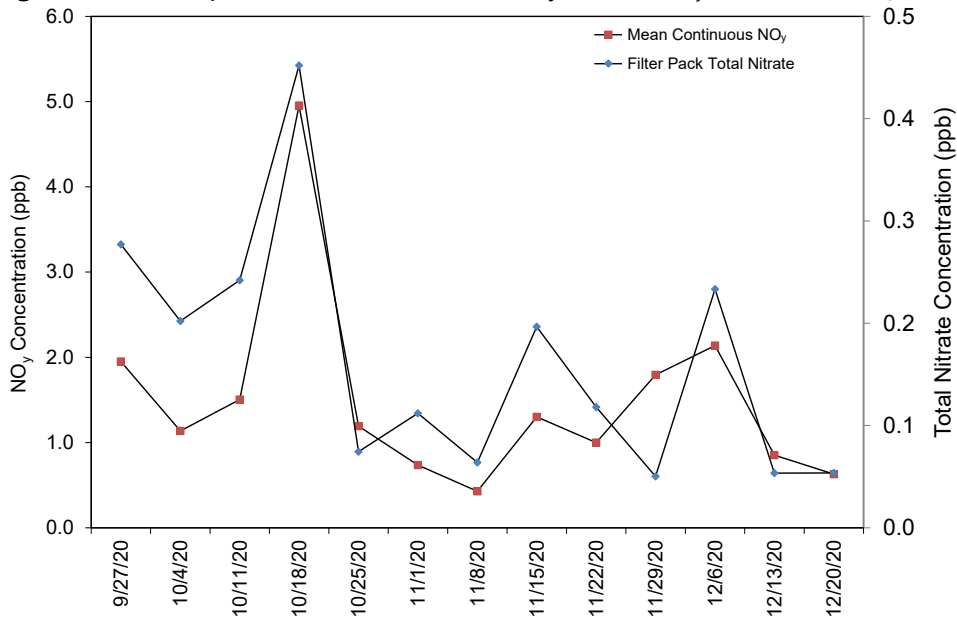


Figure 36. Comparison of ROM206 Weekly Mean NO_y and Total NO_3^- Concentrations



Filter Pack and Continuous Trace-level Gas Sulfur Dioxide Concentrations

Figures 37 through 39 provide diagrams that compare weekly filter pack SO₂ concentrations with continuous trace-level gas data measured at BVL130, MAC426, and GRS420. The continuous analyzers provide a gross check of the filter pack measurements despite the analyzers' occasional uncorrected baseline drift. The continuously measured trace-level concentrations were higher than filter pack concentrations at BVL130 and were comparable at MAC426 and GRS420.

Figure 37. Comparison of BVL130 Weekly Mean SO₂ Concentrations

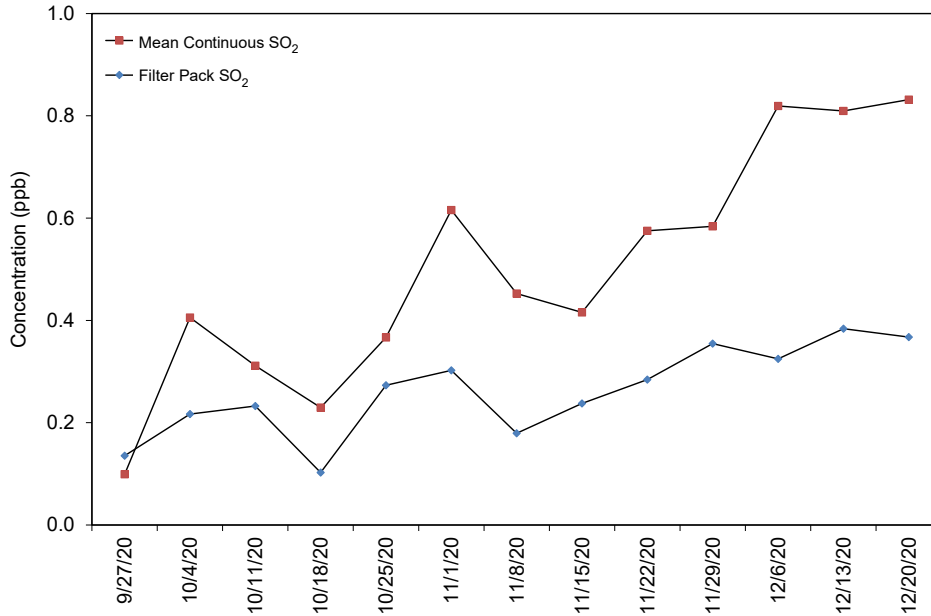


Figure 38. Comparison of MAC426 Weekly Mean SO₂ Concentrations

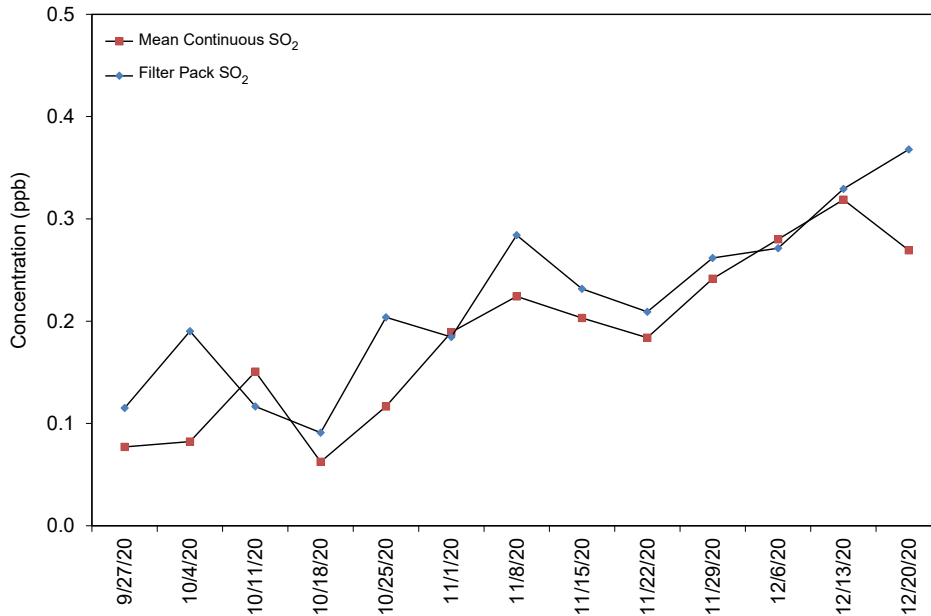
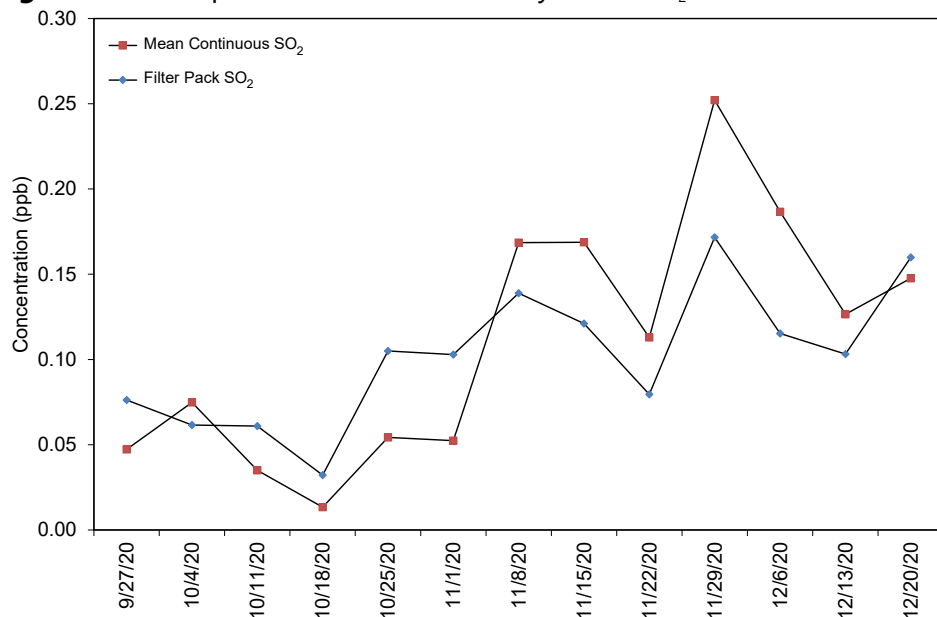


Figure 39. Comparison of GRS420 Weekly Mean SO₂ Concentrations



Completeness for Continuous Trace-level Gas Measurements

Table 9 shows the percent completeness for CASTNET trace-level gas measurements. Comments are provided for sites with less than 90 percent completeness for hourly trace-level gas concentrations during fourth quarter 2020. The annual hourly average for each of the sites is included for reference.

Table 9. Percent Data Completeness for Continuous Trace-level Gas Measurements (1 of 2)

Site ID	Parameter*	Q4 2020	Q1 2020– Q4 2020	Comments
BVL130, IL	CO	68	55	The analyzer malfunctioned in December. The CO source was replaced in January.
	NO	94	92	
	NOY	94	92	
	NOYDIF	94	92	
	SO2_GA	90	85	
CHC432, NM	NO	98	98	
	NOX	98	98	
	NOXDIF	98	98	
DUK008, NC	HNO3	75	68	High shelter temperatures during October and, specific to NH3 and TNX, QC failures during November caused some data loss. Sampling tower was down from 12/25/20 through the end of the year.
	NH3	57	61	
	NO	79	74	
	NO2_TRUE	79	72	
	NOX_TRUE	79	72	
	NOY	79	69	
	NOY_MINUS	75	74	
	NOYDIF	79	69	
TNX	57	67		
GRS420, TN	CO	92	93	
	NO	95	94	
	NOY	95	94	
	NOYDIF	95	95	
	SO2_GA	95	94	
HWF187, NY	NO	95	94	
	NOY	95	94	
	NOYDIF	95	94	
MAC426, KY	CO	76	86	The analyzer pump failed in mid-October and was replaced in late October.
	NO	96	94	
	NOY	96	94	
	NOYDIF	96	94	
	SO2_GA	96	97	
PND165, WY	NO	87	89	Analyzer malfunctions resulted in several periods of invalid data during October and November.
	NOY	87	89	
	NOYDIF	87	88	

Table 9. Percent Data Completeness for Continuous Trace-level Gas Measurements (2 of 2)

Site ID	Parameter*	Q4 2020	Q1 2020– Q4 2020	Comments
PNF126, NC	NO	88	89	The analyzer required recalibration in November.
	NOY	83	76	
	NOYDIF	83	76	
ROM206, CO	NO	87	91	The solenoid pre-reactor was disabled. The entire solenoid assembly was replaced. Ambient data were affected late October and early November.
	NOY	83	90	
	NOYDIF	83	90	

Note: * See Table 10

The parameters listed in Table 9 are both calculated and measured. Table 10 provides information on how the parameters listed in Table 9 are obtained.

Table 10. CASTNET Trace-level Gas Measurements

Parameter Name	How Obtained	Description of Process
CO	Measured	Gas filter correlation
HNO3	Calculated	NOY minus NOY_MINUS
NH3	Calculated	TNX minus NOY
NO	Measured	Chemiluminescence reaction/no converter used
NO2_TRUE	Calculated	NOX_TRUE minus NO
NOX_TRUE	Measured	Photolytic converter
NOY	Measured	Molybdenum converter at 315° Celsius
NOYDIF	Calculated	NOY minus NO
NOY_MINUS	Measured	Sodium carbonate denuder followed by molybdenum converter at 315° Celsius
NOX	Measured	Molybdenum converter at 325° Celsius
NOXDIF	Calculated	NOX minus NO
SO2_GA	Measured	Ultraviolet fluorescence
TNX	Measured	Platinum/stainless steel converter at 825° Celsius followed by molybdenum converter at 315° Celsius

References

Wood Environment & Infrastructure Solutions, Inc. 2021. *Clean Air Status and Trends Network (CASTNET) Fourth Quarter 2020 Quality Assurance Report with 2020 Annual Summary*. <https://java.epa.gov/castnet/documents.do>