

Clean Air Status and Trends Network (CASTNET) Quarterly Data Summary for First Quarter 2021 (January through March)

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 first quarter 2021. 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 first quarter data and include completeness and precision of filter concentrations and hourly O_3 concentrations. This report also analyzes data for continuous, trace-level NO_y from eight sites, although NO_y data from DUK008 were not available for first quarter. Continuous SO_2 concentrations from three sites are also provided. Other QC statistics are given in the CASTNET First Quarter 2021 Quality Assurance Report (Wood, 2021).

Figure 1. Fourth Highest Daily Maximum 8-hour Average O_3 Concentrations (ppb) through First Quarter 2021



Figure 1 shows fourth highest daily maximum 8-hour average (DM8A) O₃ concentrations measured through first quarter 2021. No 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 first quarter. Trends in quarterly mean filter pack and O₃ concentrations are shown using box plots in Figures 2 through 13.

First Quarter Concentrations

Quarterly mean HNO₃, NO₃⁻, NH₄⁺, total NO₃⁻, SO₂, SO₄²⁻, Ca²⁺, K⁺, Mg²⁺, and Na⁺ concentrations increased at eastern sites in 2021, and Cl⁻ concentrations decreased. Quarterly mean HNO₃, NH₄⁺, and total NO₃⁻ concentrations decreased at western sites in 2021 while NO₃⁻, SO₂, SO₄²⁻, Cl⁻, Ca²⁺, K⁺, Mg²⁺, and Na⁺ concentrations increased.

Quarterly O₃ concentrations were analyzed using box plots constructed by averaging all valid hourly O₃ concentrations within first quarter 2021 by site and then averaging those averages for all eastern and western reference sites (Figure 13). The figure shows an overall increase in first quarter mean O₃ concentrations at both the eastern and western reference sites. Quarterly mean concentrations were higher at the western reference sites than at the eastern sites.

Figure 2. Trends in First Quarter Mean HNO₃ Concentrations

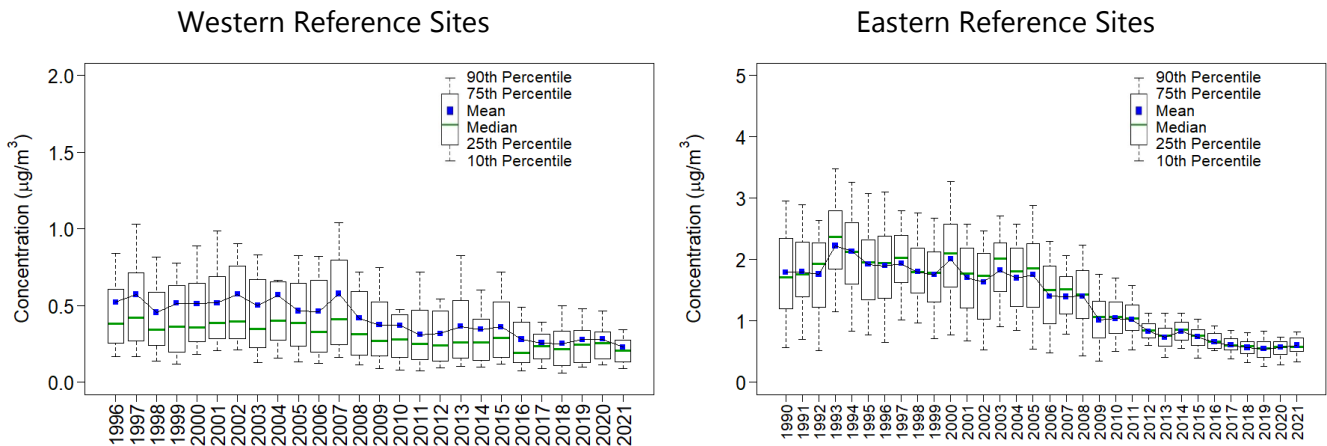
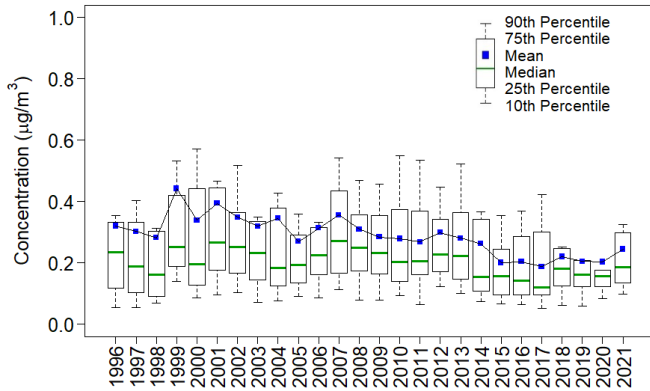


Figure 3. Trends in First Quarter Mean NO₃ Concentrations
Western Reference Sites



Eastern Reference Sites

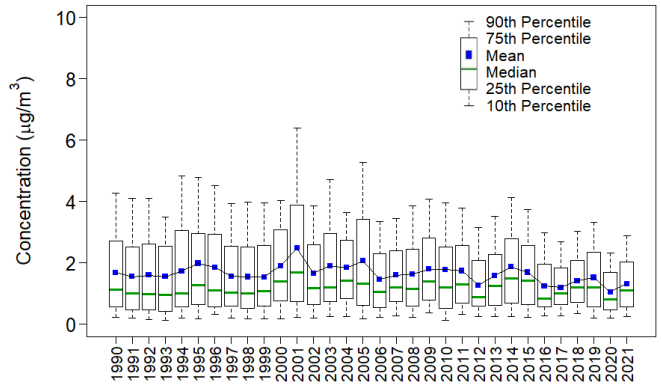
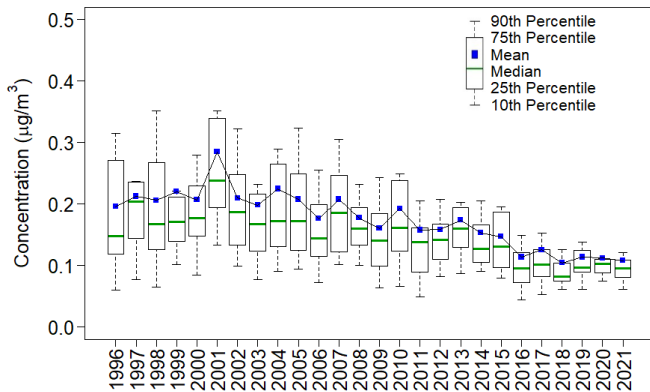


Figure 4. Trends in First Quarter Mean NH₄⁺ Concentrations
Western Reference Sites



Eastern Reference Sites

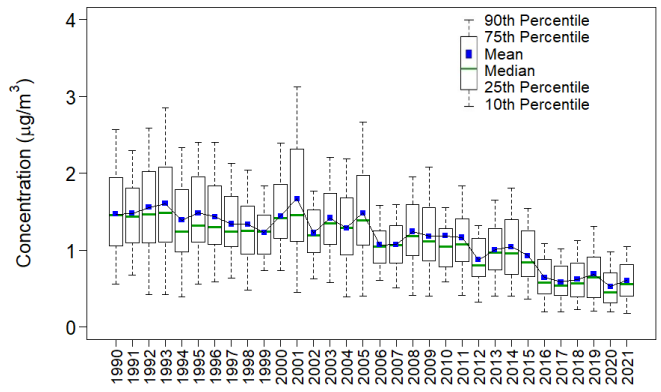
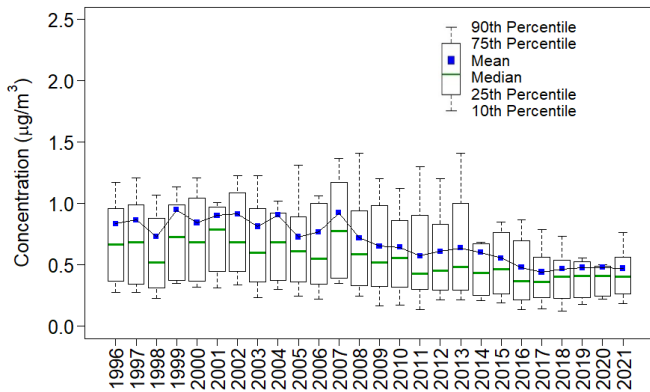


Figure 5. Trends in First Quarter Mean Total NO₃ Concentrations
Western Reference Sites



Eastern Reference Sites

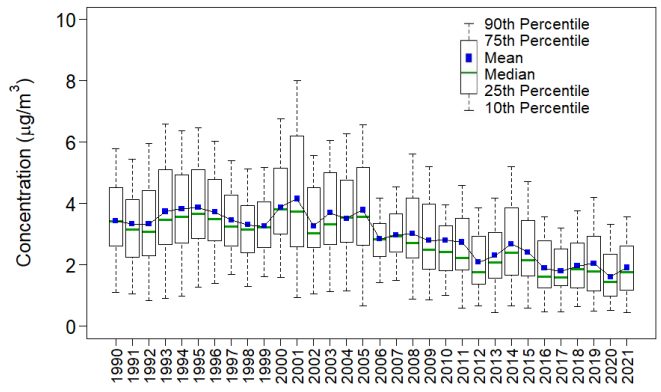
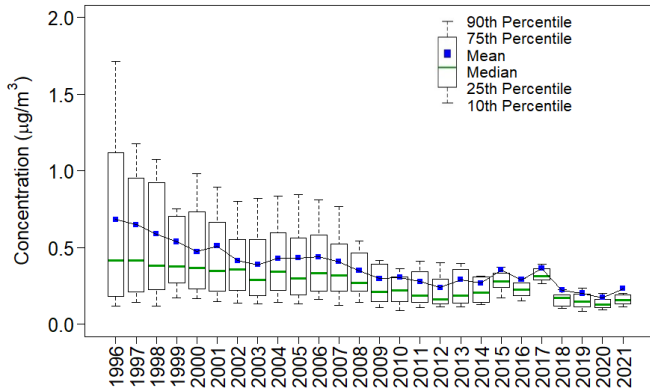


Figure 6. Trends in First Quarter Mean SO₂ Concentrations
Western Reference Sites



Eastern Reference Sites

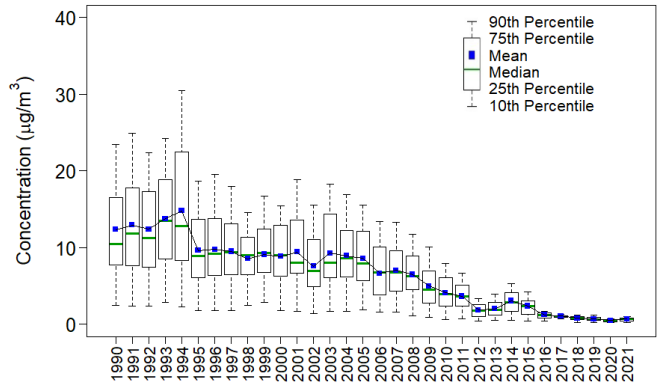
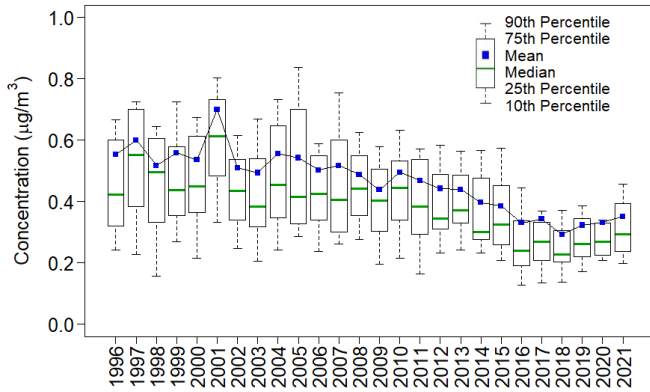


Figure 7. Trends in First Quarter Mean SO₄²⁻ Concentrations
Western Reference Sites



Eastern Reference Sites

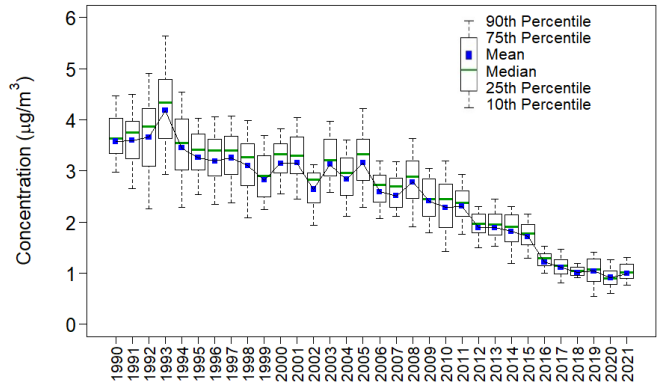
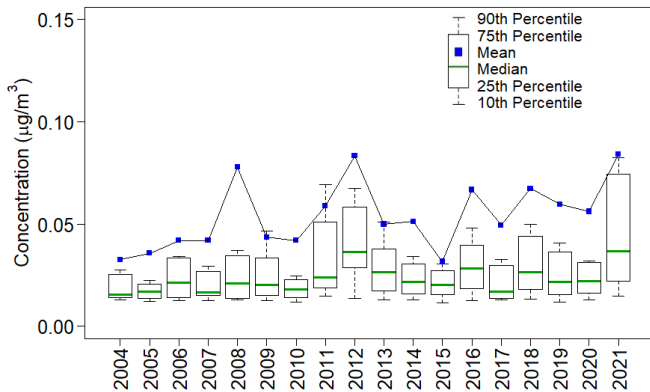


Figure 8. Trends in First Quarter Mean Cl⁻ Concentrations
Western Reference Sites



Eastern Reference Sites

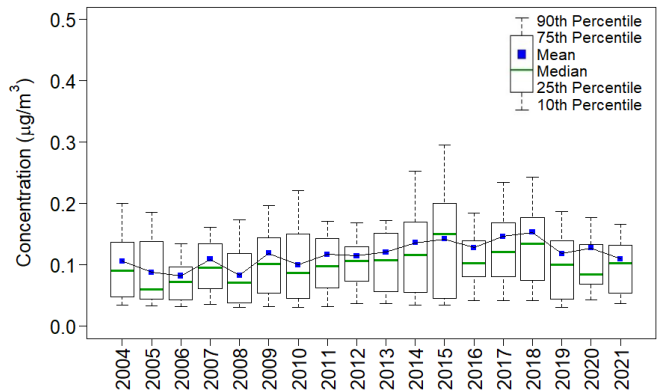


Figure 9. Trends in First Quarter Mean Ca²⁺ Concentrations

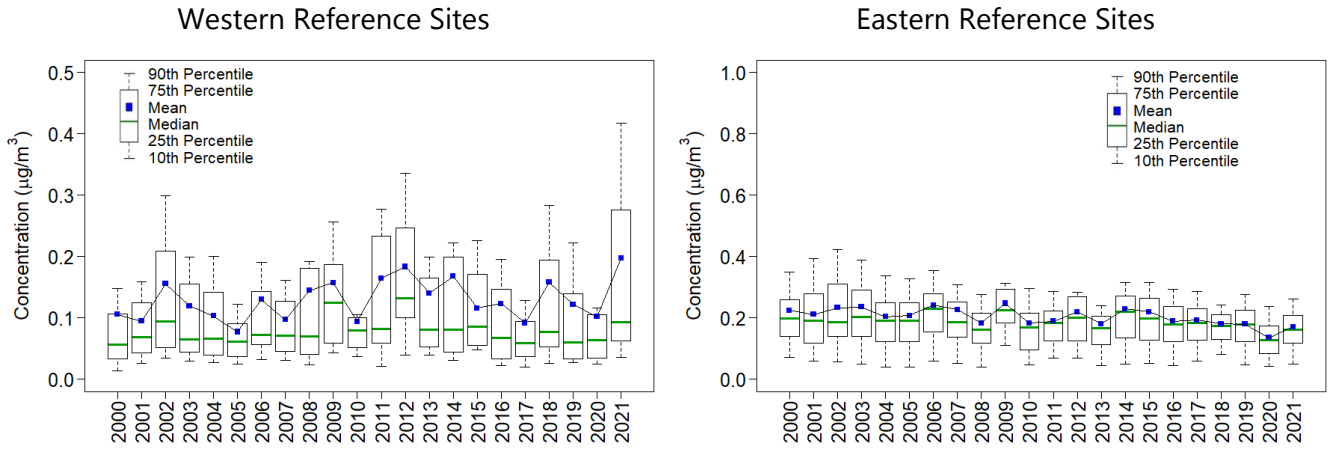


Figure 10. Trends in First Quarter Mean K⁺ Concentrations

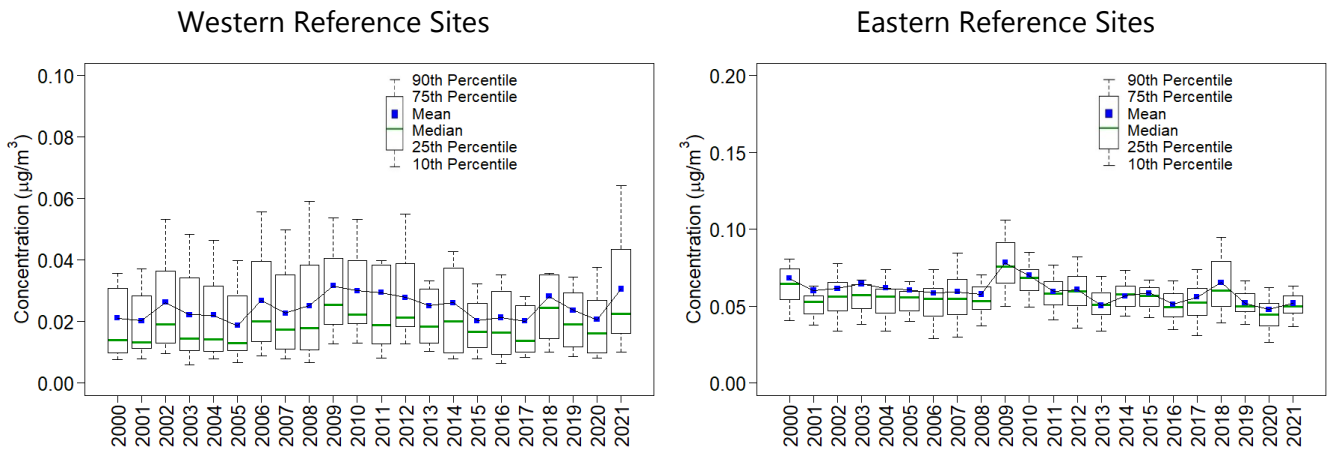


Figure 11. Trends in First Quarter Mean Mg²⁺ Concentrations

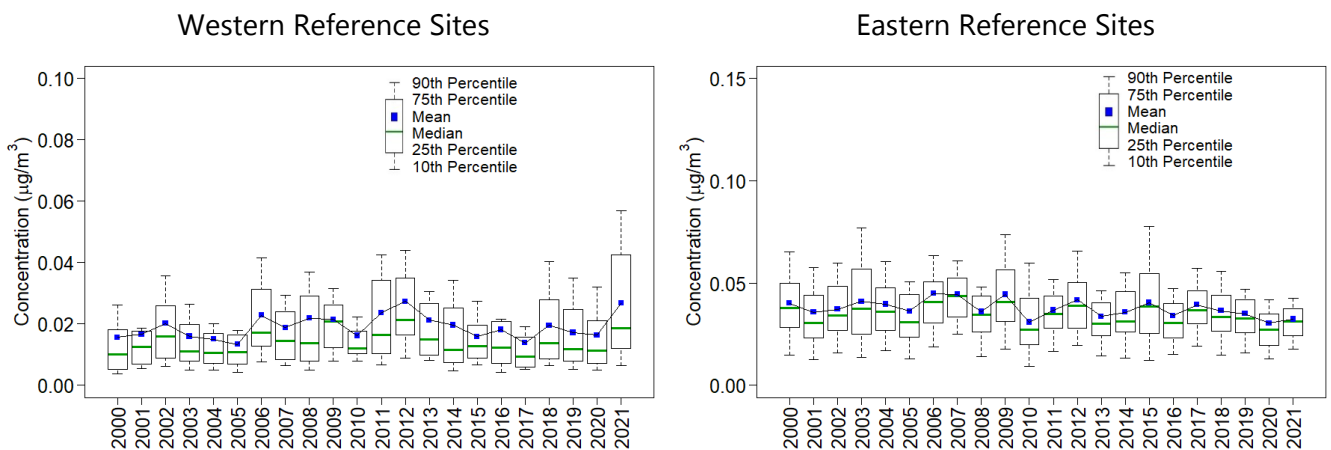


Figure 12. Trends in First Quarter Mean Na⁺ Concentrations

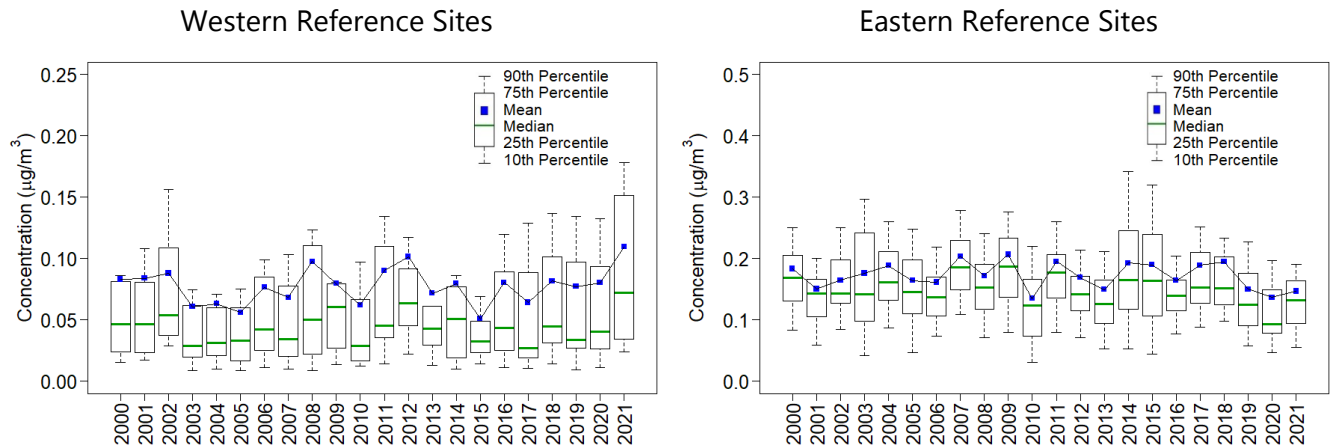
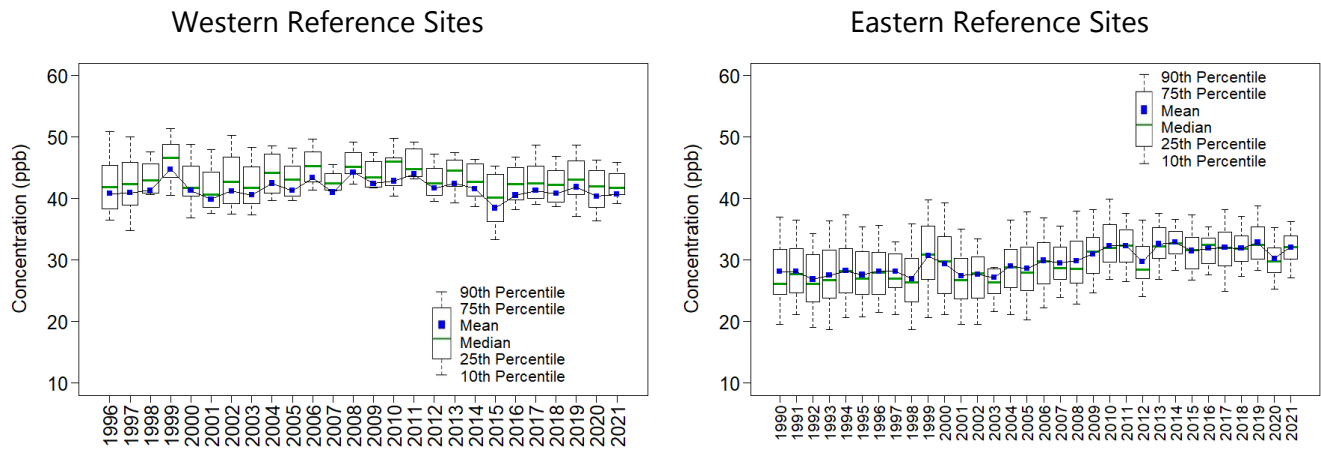


Figure 13. Trends in First Quarter Mean O₃ Concentrations



Changes in 3-year Average First Quarter Concentrations

Three-year averages of quarterly mean concentrations of total NO₃⁻, NH₄⁺, SO₂, SO₄²⁻, and O₃ were reduced over the period 1990–1992 through 2019–2021 for eastern reference sites and 1996–1998 through 2019–2021 for western reference sites. Tables 1 and 2 summarize changes in 3-year average first quarter concentrations. The tables show an increase in O₃ concentrations in the east and no change at western sites.

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	3.4	1.5	12.5	3.6	28
2019–2021	1.9	0.6	0.6	1.0	32
Percent Change	-45	-60	-95	-73	14

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

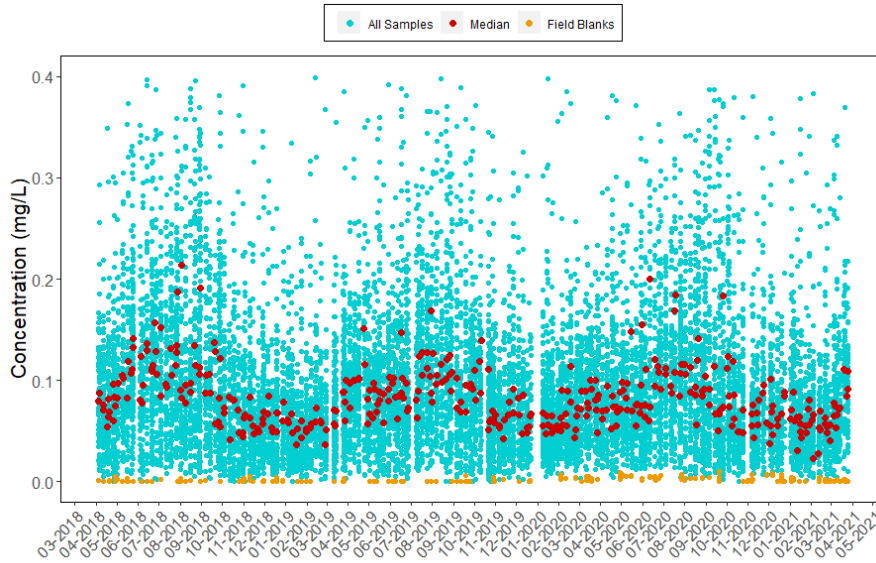
	Total NO ₃ ⁻ (µg/m ³)	NH ₄ ⁺ (µg/m ³)	SO ₂ (µg/m ³)	SO ₄ ²⁻ (µg/m ³)	O ₃ (ppb)
1996–1998	0.8	0.2	0.6	0.6	41
2019–2021	0.5	0.1	0.2	0.3	41
Percent Change	-41	-46	-68	-40	0

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 second quarter 2018 through first quarter 2021. These figures provide indications of potential issues with concentration measurements relative to detection and reporting limits.

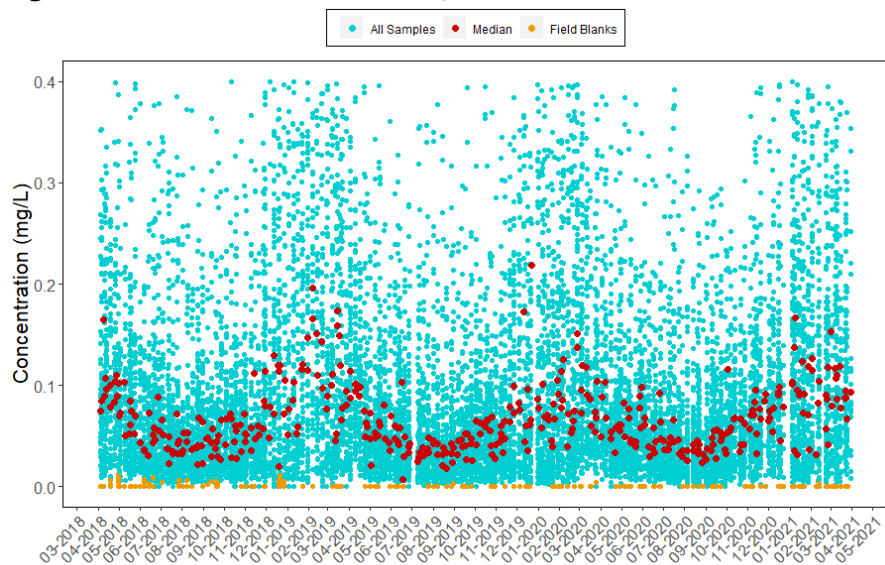
Previous review of filter pack analysis control charts indicated possible potassium contamination (Figure 22). Corrective actions were implemented, and subsequent testing indicated these actions have been effective.

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



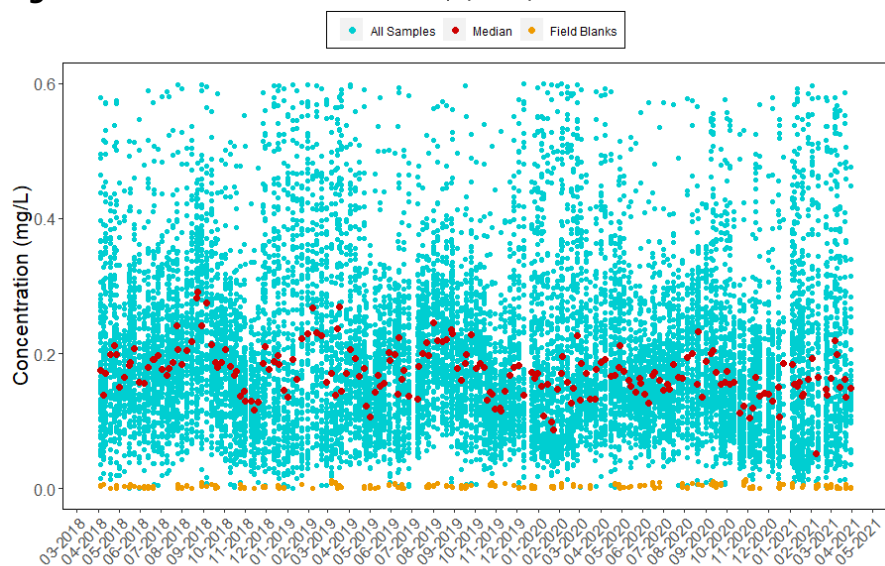
Note: Nominal reporting limit is 0.008 mg/L.

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



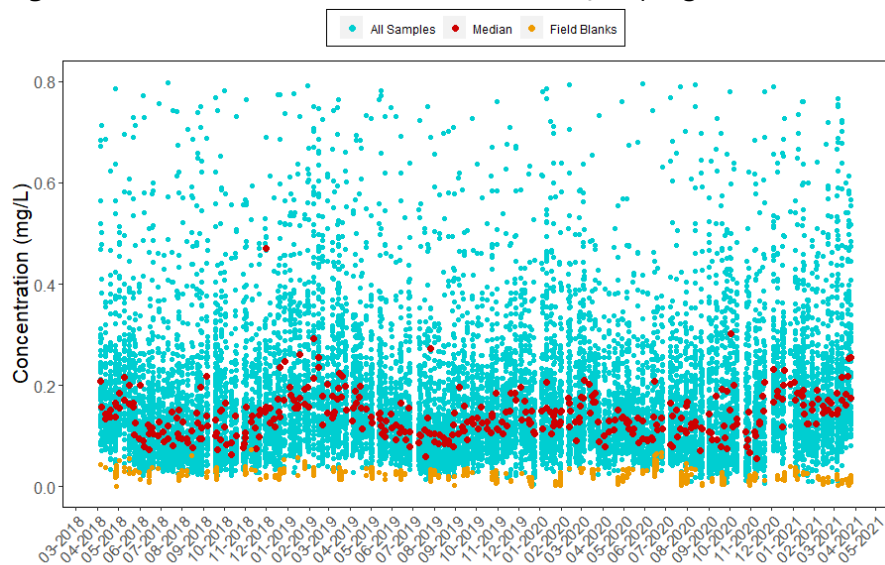
Note: Nominal reporting limit is 0.008 mg/L.

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



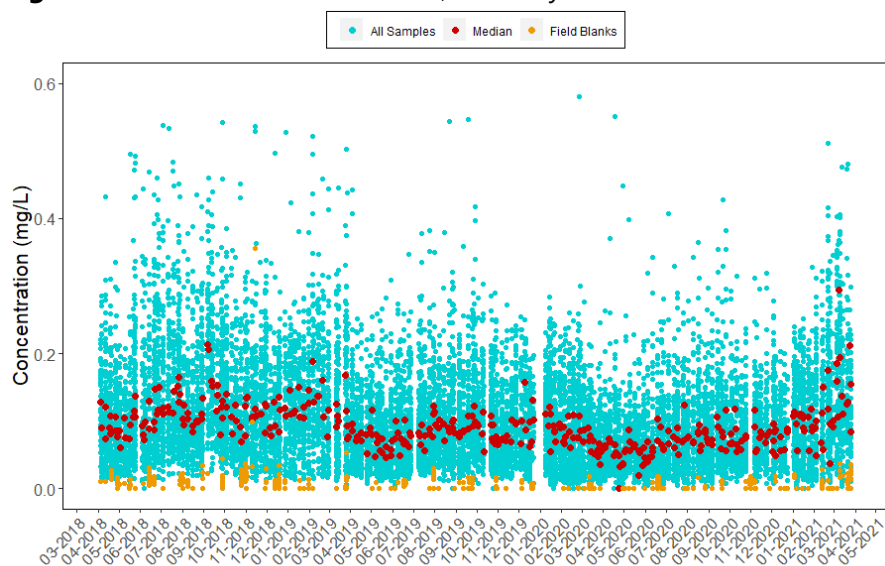
Note: Nominal reporting limit is 0.020 mg/L.

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



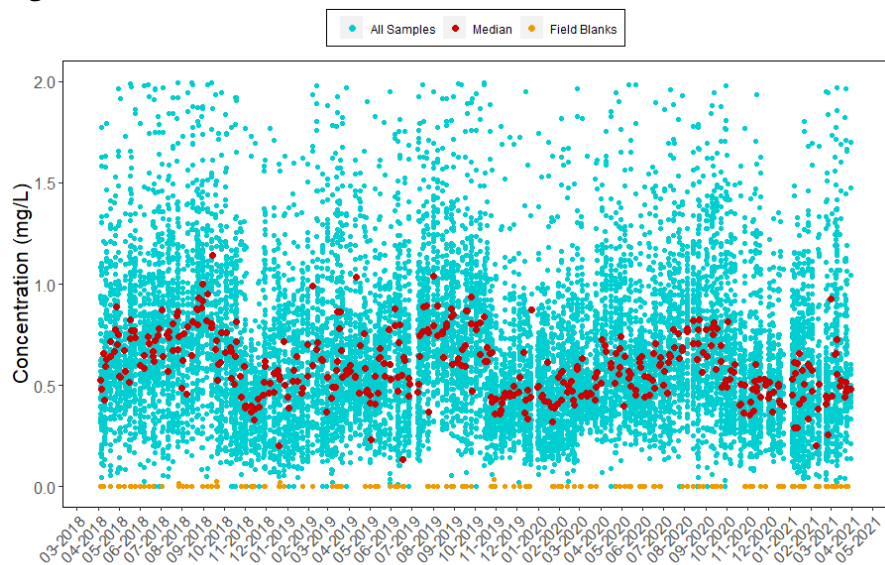
Note: Nominal reporting limit is 0.040 mg/L.

Figure 18. Concentrations of SO₄²⁻ from Nylon Filters



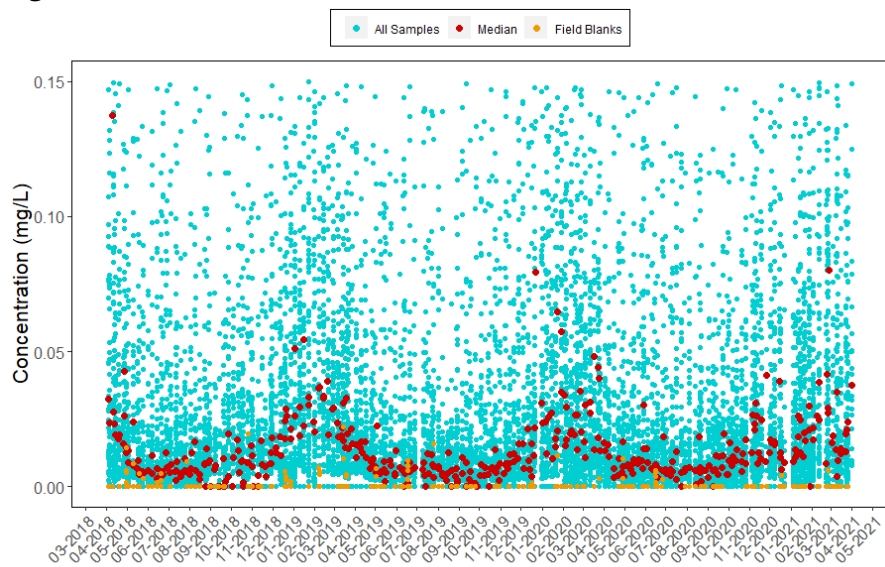
Note: Nominal reporting limit is 0.040 mg/L.

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



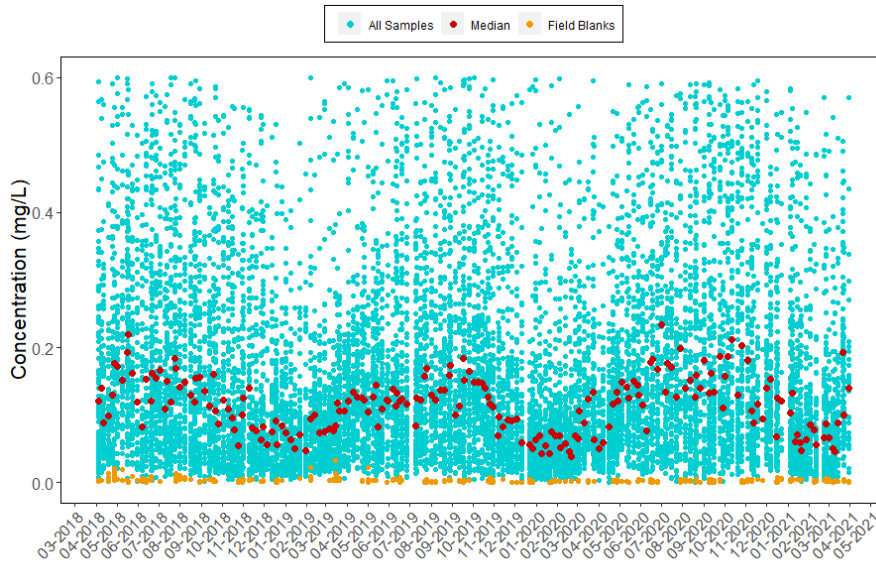
Note: Nominal reporting limit is 0.040 mg/L.

Figure 20. Concentrations of Cl^- from Teflon Filters



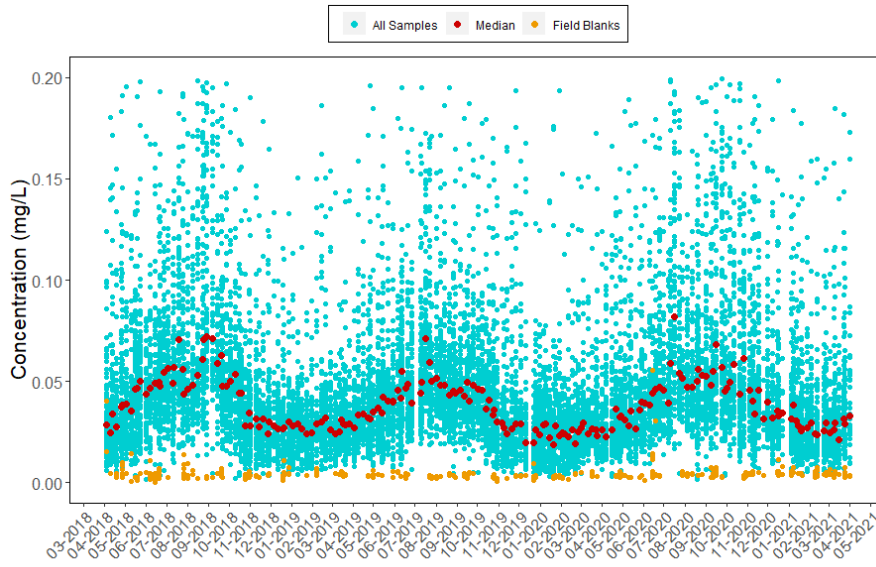
Note: Nominal reporting limit is 0.020 mg/L.

Figure 21. Concentrations of Ca²⁺ from Teflon Filters



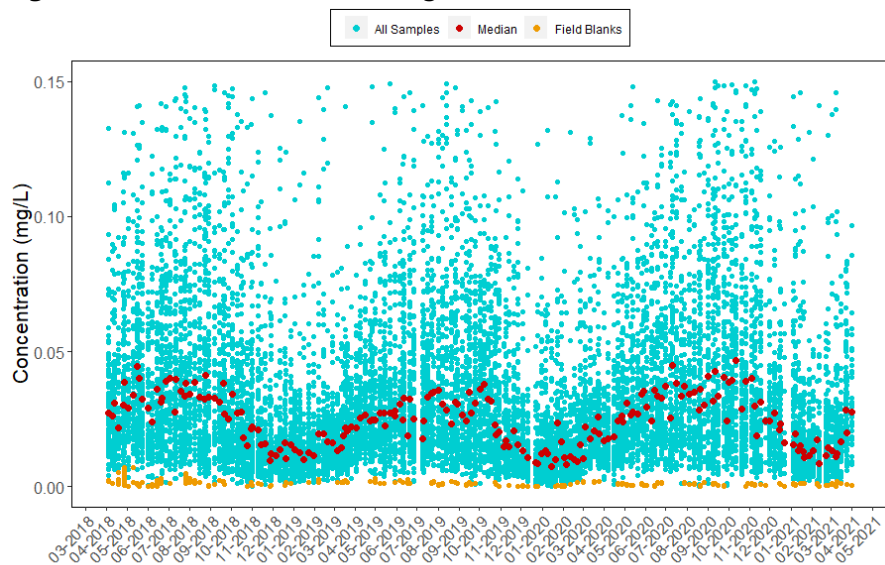
Note: Nominal reporting limit is 0.006 mg/L.

Figure 22. Concentrations of K⁺ from Teflon Filters



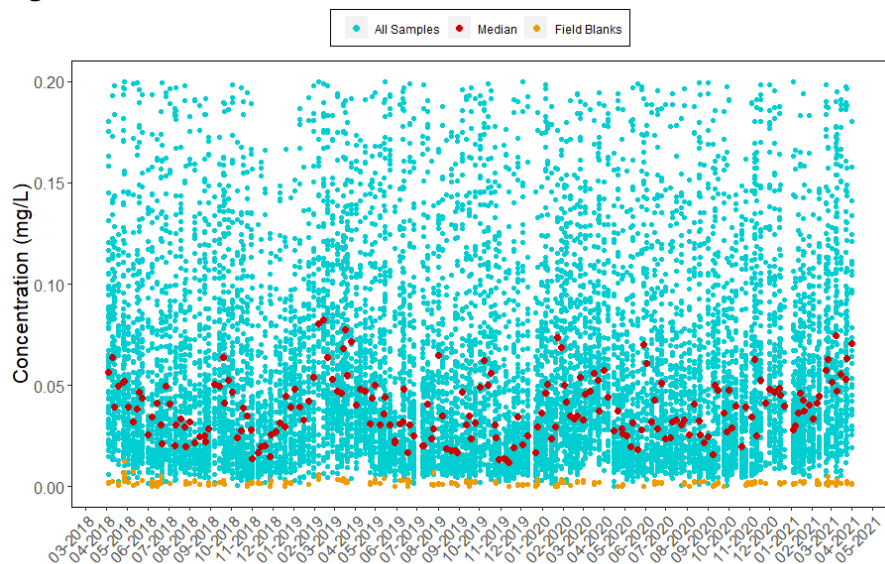
Note: Nominal reporting limit is 0.006 mg/L.

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 filters collected at MCK131 and MCK231 for the week of 2/9/21 were noticeably dirty, and the delivery of the MCK131 filter pack (the higher HNO₃ concentration) was delayed by the USPS for three weeks. The delay allowed particulate NO₃ to volatilize to higher HNO₃ concentrations as shown in Figure 25.

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

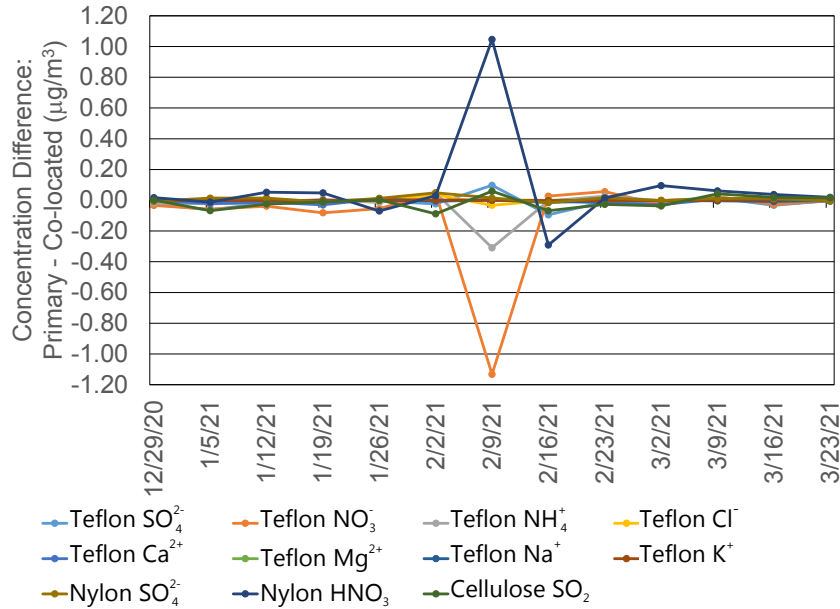
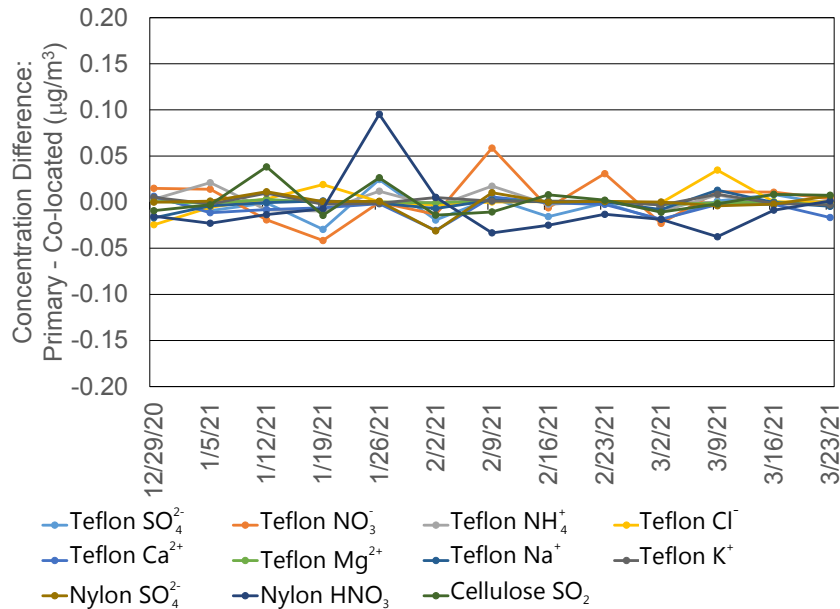


Figure 26. Time Series of Filter Concentration Differences between ROM406 and ROM206, CO



Precision of Filter Pack Concentrations

Table 3 shows mean absolute relative percent differences (MARPD) for concentrations measured at MCK131/231 and ROM406/206 during first quarter 2021. The MARPD values met the 20 percent criterion except for ROM406/206 K^+ and Cl^- , which were calculated from very low concentrations.

Table 3. Precision (MARPD) for Co-located Filter Pack Data during First Quarter 2021

	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} ($\mu g/m^3$)	1.24	1.45	0.73	0.16	0.03	0.11	0.06	0.05	1.08	0.74	2.52
\bar{Y} ($\mu g/m^3$)	1.25	1.55	0.75	0.17	0.03	0.11	0.06	0.05	1.01	0.75	2.54
MAD	0.03	0.12	0.04	0.01	0.00	0.00	0.00	0.01	0.13	0.03	0.07
MARPD	2.08	5.21	3.85	7.14	5.60	3.29	3.41	8.92	7.97	4.19	2.70
ROM406/206, CO											
\bar{X} ($\mu g/m^3$)	0.32	0.34	0.17	0.08	0.01	0.04	0.02	0.03	0.26	0.16	0.60
\bar{Y} ($\mu g/m^3$)	0.33	0.34	0.17	0.09	0.01	0.04	0.02	0.03	0.27	0.16	0.60
MAD	0.01	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.03	0.02	0.03
MARPD	5.59	11.59	7.76	12.53	16.65	11.40	22.35	22.03	13.68	10.49	9.00

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 First Quarter 2021 (1 of 2)

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
DUK008, NC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	The sampling tower was down and awaiting repair during first quarter.
NEC602, WY	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2	Flow data were missing or invalid during January and February.
ALC188, TX	69.2	69.2	69.2	69.2	69.2	69.2	69.2	69.2	A leak in the filter pack flow system affected all March samples.
SAN189, NE	69.2	69.2	69.2	69.2	69.2	69.2	69.2	69.2	Four 2-week samples affected data completeness during the quarter.
BFT142, NC	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	The week 4 filter pack was not received by the lab and was marked as lost. The quarter included one 2-week sample. A power failure in mid-March affected the week 11 filter sample.
BWR139, MD	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	Two 2-week samples were collected during the quarter. The week 4 filter pack was not received by the lab and was marked as lost.
CAN407, UT	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	Two 2-week samples were collected during the quarter.
CAT175, NY	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	Two 2-week samples were collected during the quarter. Power failures affected the week 6 sample.
MEV405, CO	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	A 2-week sample was collected during the first sampling period. The week 6 sample was affected by a power failure. Flow data were not collected for week 9 because of a data logger malfunction.
KNZ184, KS	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	The flow pump failed in late February affecting two samples.

Table 4. Sites with less than 90 Percent Data Completeness for Filter Concentrations for First Quarter 2021 (2 of 2)

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
NPT006, ID	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	A 2-week sample was collected during the first sampling period. Week 5 sampling was affected by a power failure.
PIN414, CA	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	Week 8 sample was installed for 2 weeks. Flow for this sample was invalidated by ARS.
SEK430, CA	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	The filter packs for weeks 2 and 3 were not received by the lab and were marked as lost.
YEL408, WY	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	A 2-week sample was collected during the first sampling period. Week 12 sampling was affected by power failure.

Precision of Ozone Concentrations

Time series of co-located hourly O₃ concentration differences for first quarter 2021 are provided in Figures 27 and 28 for MCK131/231 and ROM406/206, respectively. The figures indicate no consistent bias between the co-located analyzers at these site locations, although the ROM406/206 O₃ difference data changed around 3/12/21 because ARS replaced the analyzer on 3/11/21.

Figure 27. Time Series of the Differences in Co-located O₃ Concentrations for MCK131/231, KY

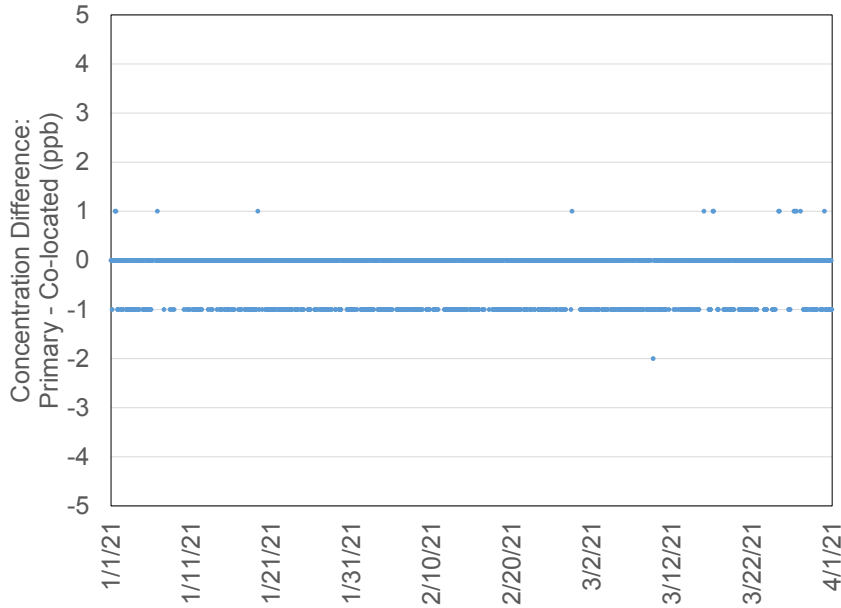


Figure 28. Time Series of the Differences in Co-located O₃ Concentrations for ROM406/206, CO

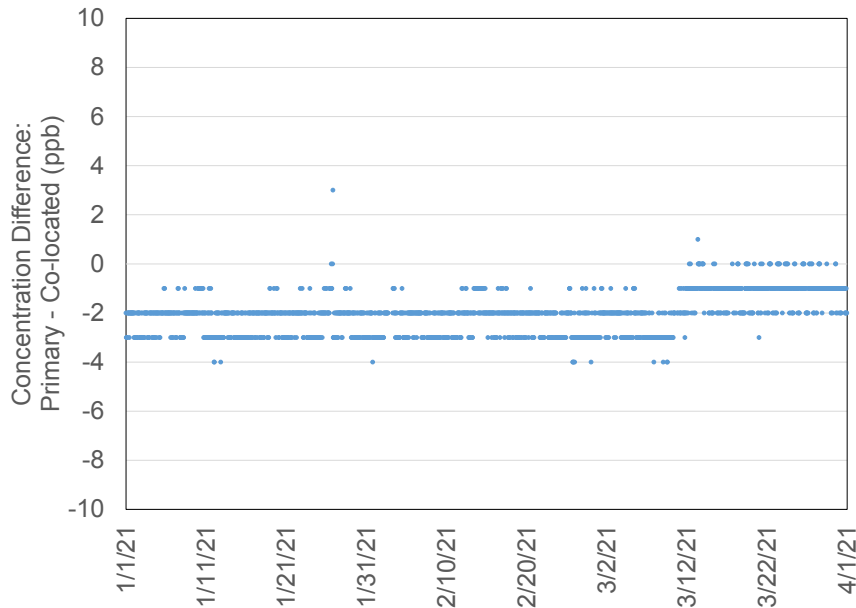


Table 5 gives MARPD data for O₃ data measured at the two co-located sites.

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

Site Pair	Quarter	Start Date	MARPDP	Records
MCK131/231, KY				
	2	4/1/20	0.8	1986
	3	7/1/20	1.8	2086
	4	10/1/20	1.5	2069
	1	1/1/21	1.0	2046
ROM406/206, CO				
	2	4/1/20	1.3	2028
	3	7/1/20	1.7	2023
	4	10/1/20	3.3	1996
	1	1/1/21	4.5	2015

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 First Quarter 2021

Site ID	Percent Completeness	Comments
NEC602, WY	75.6	Data were not collected from 1/1/21 to 1/20/21.
MEV405, CO	76.7	Power outages occurred during February. The data logger malfunctioned and was replaced in March.
BFT142, NC	85.6	The Nafion dryer failed. This failure affected one week of sampling in early February. A power failure in mid-March affected an additional week.

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	Q1 2021	Q2 2020– Q1 2021	Comments
NEC602, WY	77.7	92.6	Data were not collected from 1/1/21 to 1/20/21.
MEV405, CO	81.2	95.0	Power outages occurred during February. The data logger malfunctioned and was replaced in March.
BFT142, NC	86.1	96.1	The Nafion dryer failed. This failure affected one week of sampling in early February. A power failure in mid-March affected an additional week.

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 sites with NO_y measurements during first quarter. The tower was down at the DUK008 site, and no measurements were recorded. 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 sites with available data are shown in Table 8. Ratios of NO_y to total NO₃⁻ varied from 3.97 at PNF126 to 7.42 at ROM206.

Table 8. Summary of Total NO₃⁻ and NO_y Measurements for First Quarter 2021

Site ID	Elevation	Total NO ₃ ⁻ (ppb)	NO _y (ppb)	Ratio
DUK008, NC	164	-	-	-
BVL130, IL	213	1.42	4.89	5.05
MAC426, KY	243	0.97	3.42	3.99
HWF187, NY	497	0.23	1.11	5.37
GRS420, TN	793	0.39	2.06	6.07
PNF126, NC	1216	0.30	1.10	3.97
PND165, WY	2386	0.11	0.63	6.07
ROM206, CO	2742	0.19	1.21	7.42

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

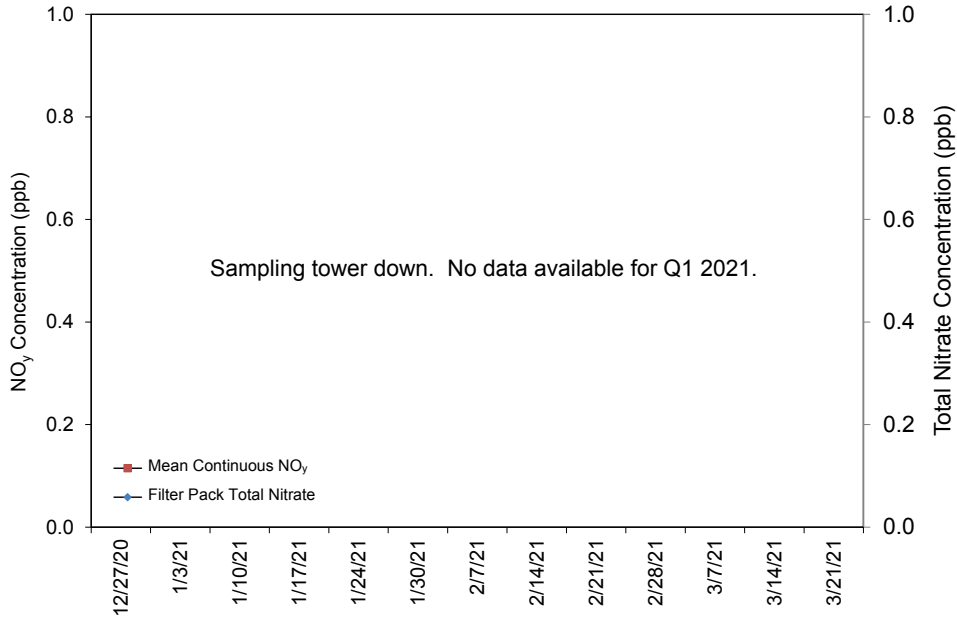


Figure 30. Comparison of BVL130 Weekly Mean NO_y and Total NO₃⁻ Concentrations

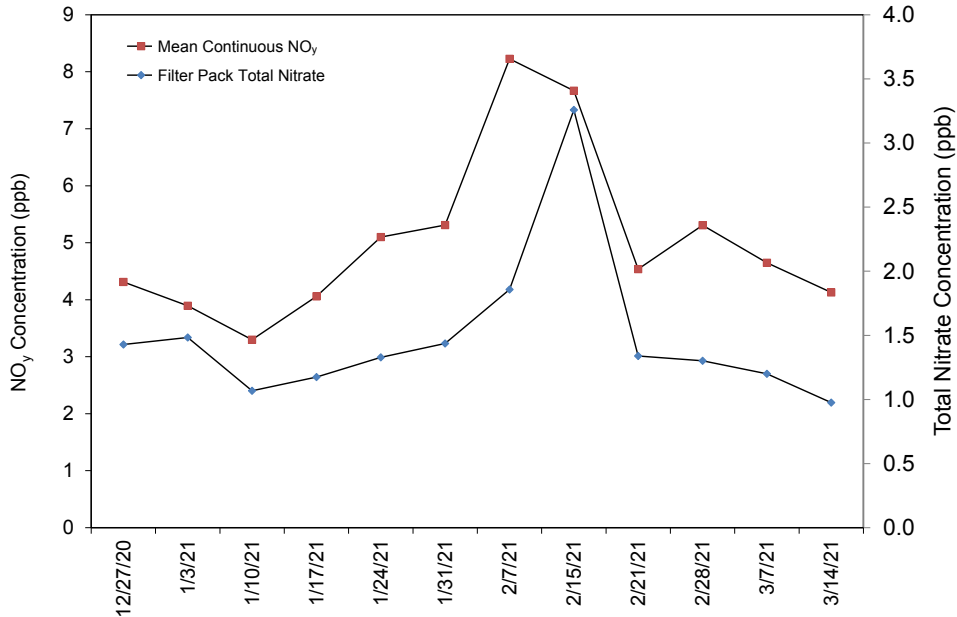


Figure 31. Comparison of MAC426 Weekly Mean NO_y and Total NO_3^- Concentrations

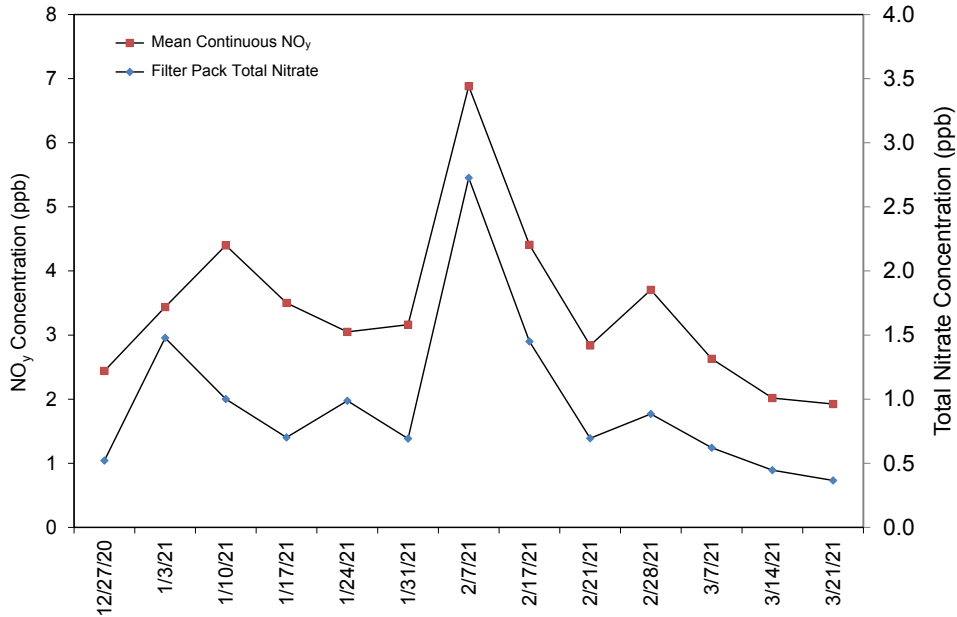


Figure 32. Comparison of HWF187 Weekly Mean NO_y and Total NO_3^- Concentrations

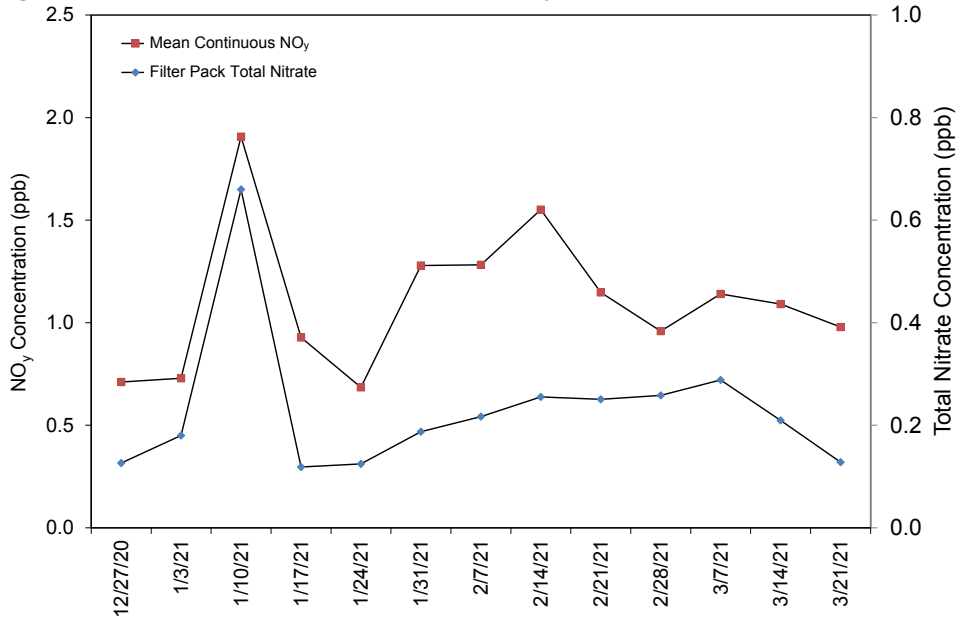


Figure 33. Comparison of GRS420 Weekly Mean NO_y and Total NO₃ Concentrations

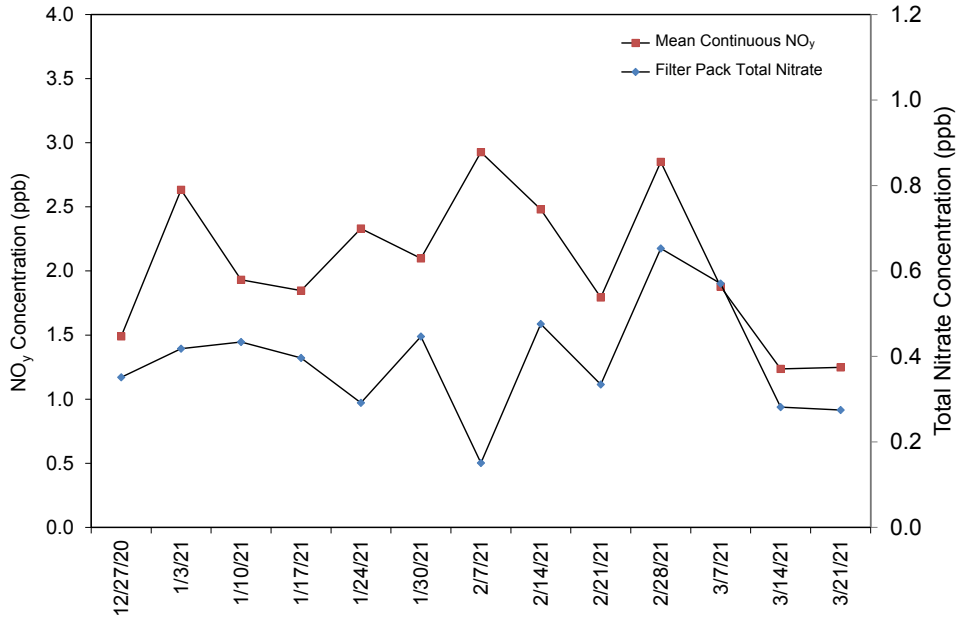


Figure 34. Comparison of PNF126 Weekly Mean NO_y and Total NO₃ Concentrations

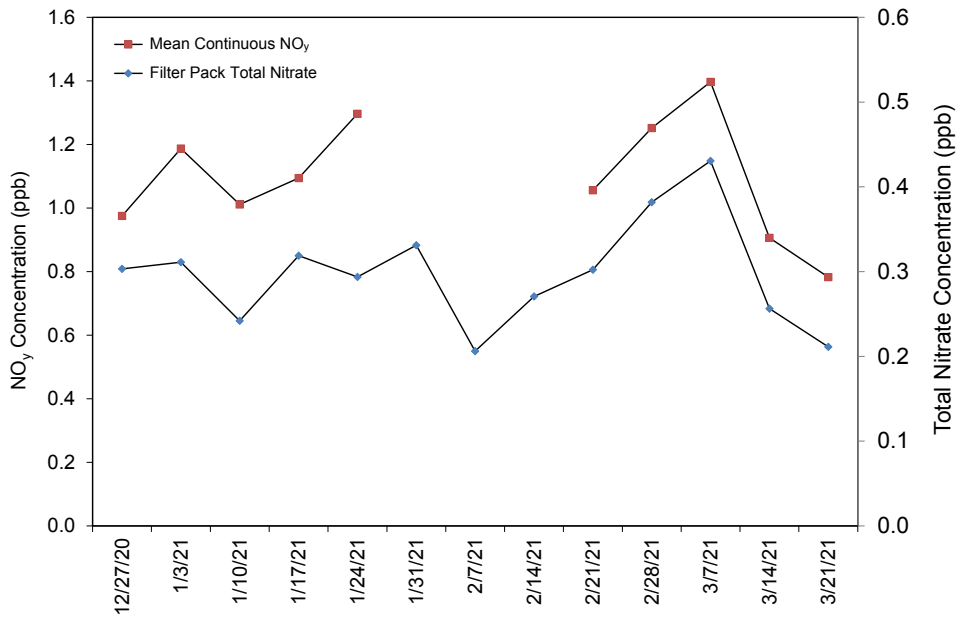


Figure 35. Comparison of PND165 Weekly Mean NO_y and Total NO_3^- Concentrations

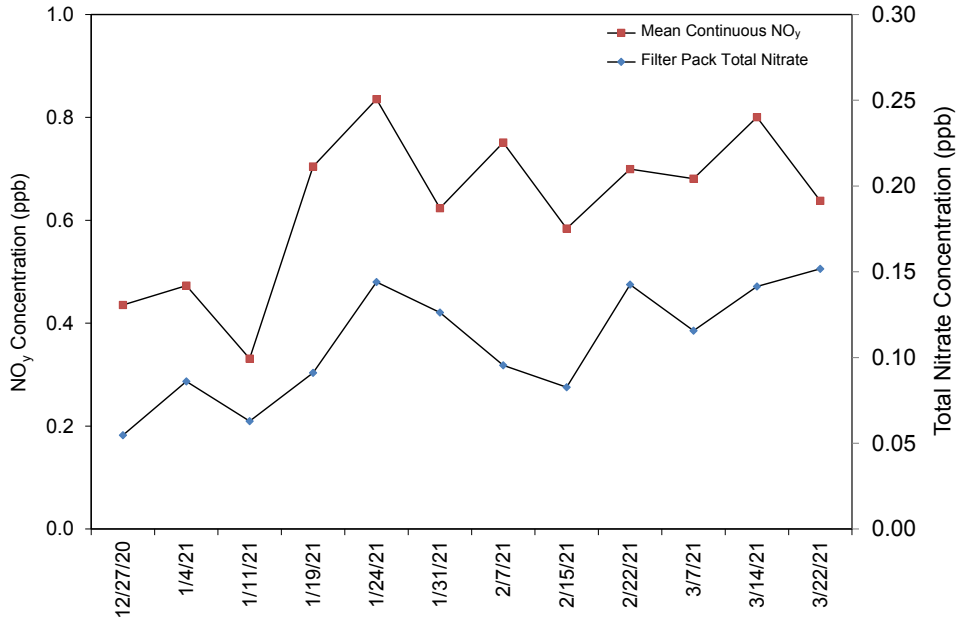
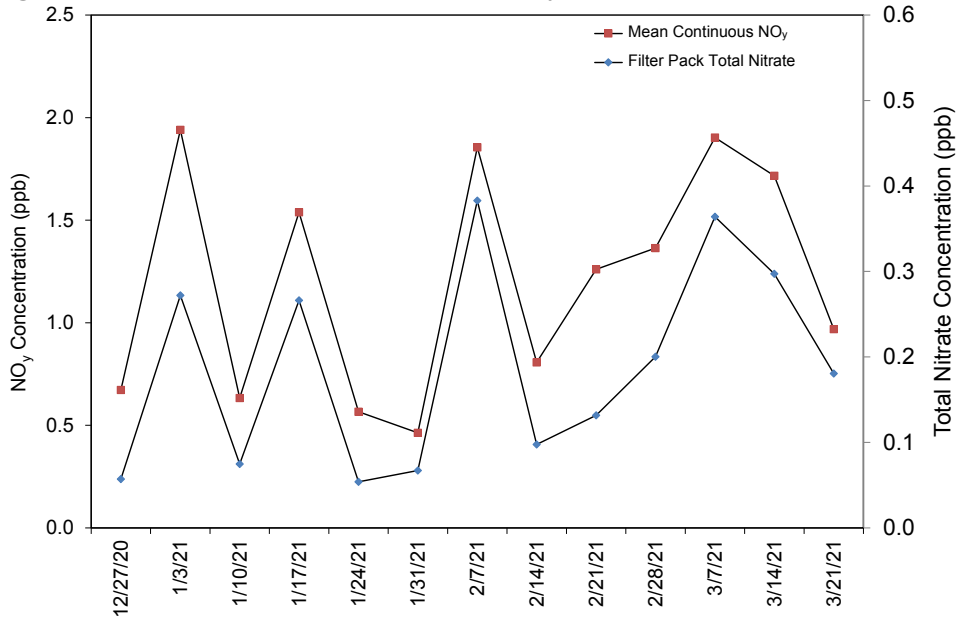


Figure 36. Comparison of ROM206 Weekly Mean NO_y and Total NO_3^- Concentrations



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 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

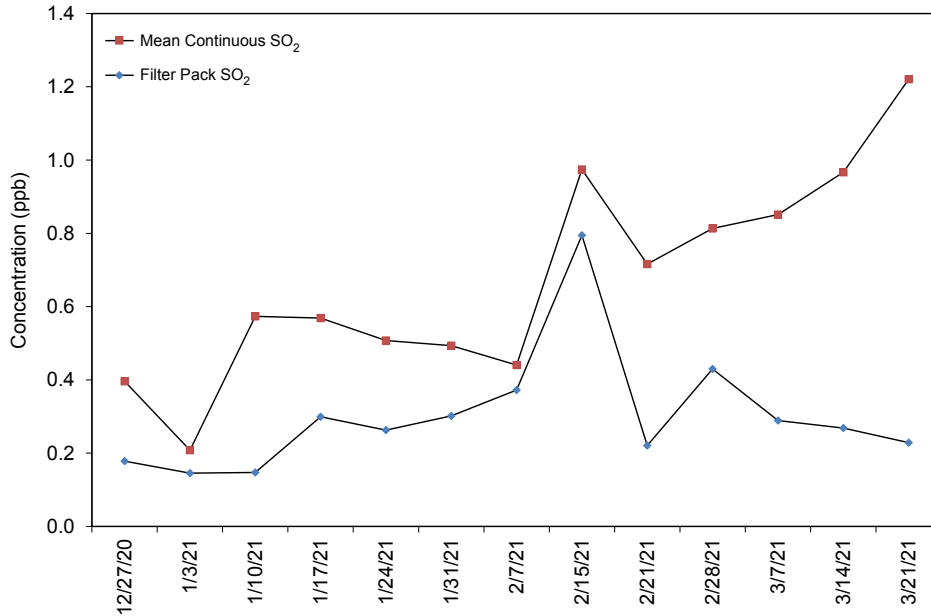


Figure 38. Comparison of MAC426 Weekly Mean SO₂ Concentrations

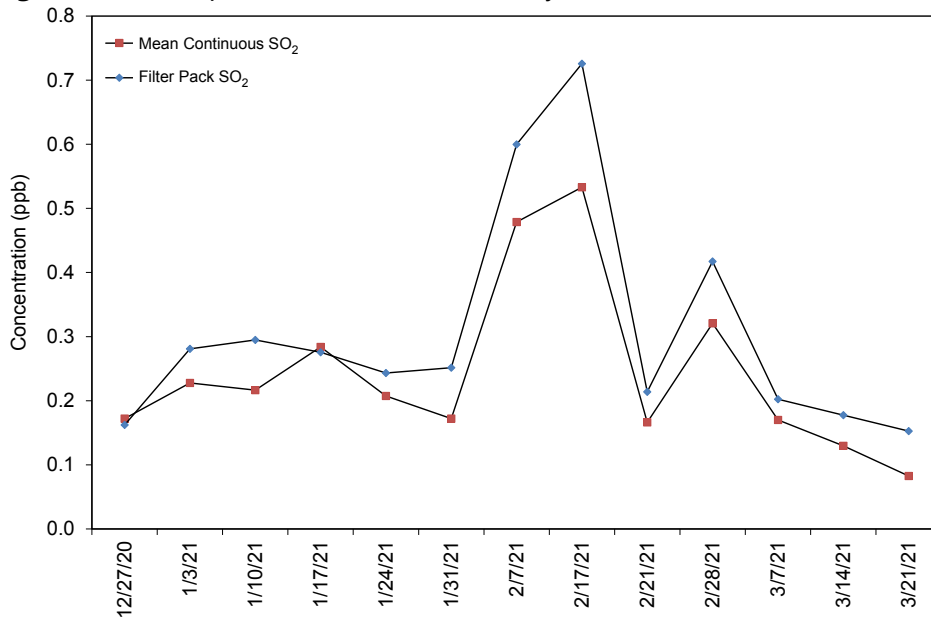
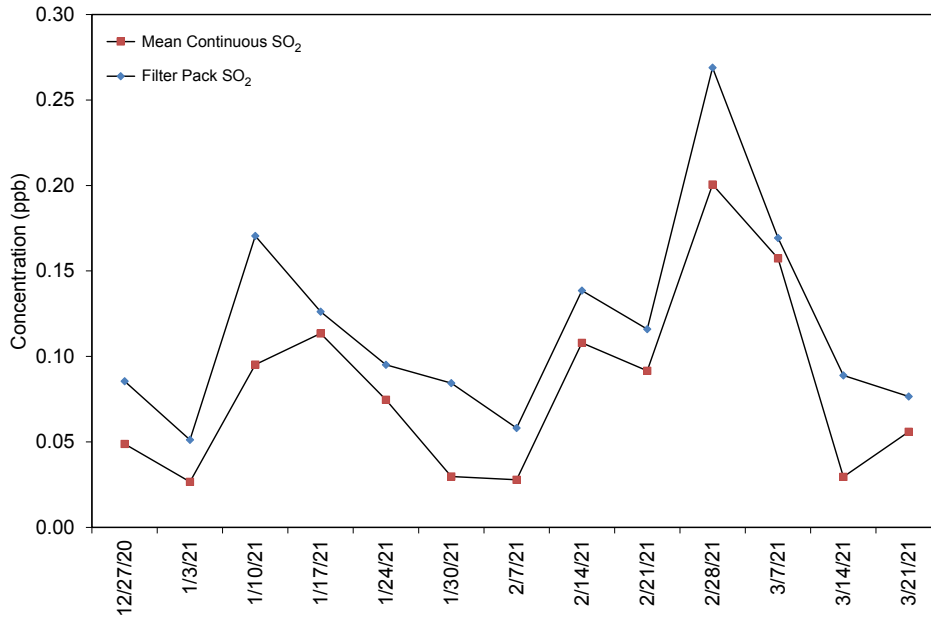


Figure 39. Comparison of GRS420 Weekly Mean SO₂ Concentrations



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 first quarter 2021. The average for second quarter 2020 through first quarter 2021 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*	Q1 2021	Q2 2020 – Q1 2021	Comments
BVL130, IL	CO	40	51	The analyzer required recalibration in February. It malfunctioned in March and was replaced.
	NO	94	93	
	NOY	94	93	
	NOYDIF	94	93	
	SO2_GA	87	85	Data logger communications were interrupted. The analyzer was rebooted to fix the problem.
CHC432, NM	NO	98	98	
	NOX	98	98	
	NOXDIF	98	98	
DUK008, NC	HNO3	tower down	70	The sampling tower was down during first quarter. As a result, the percent complete column for all DUK008 parameters is for Q2 2020 through Q4 2020.
	NH3	tower down	64	
	NO	tower down	79	
	NO2_TRUE	tower down	76	
	NOX_TRUE	tower down	77	
	NOY	tower down	72	
	NOY_MINUS	tower down	78	
	NOYDIF	tower down	72	
TNX	tower down	71		
GRS420, TN	CO	94	94	
	NO	90	94	
	NOY	90	94	
	NOYDIF	92	95	
	SO2_GA	98	96	
HWF187, NY	NO	95	95	
	NOY	95	95	
	NOYDIF	95	95	
MAC426, KY	CO	89	84	Analyzer readings flat-lined on several occasions during the quarter, requiring a remote reset.
	NO	97	94	
	NOY	97	94	
	NOYDIF	97	94	
	SO2_GA	97	97	
PND165, WY	NO	90	88	ZPS failure occurred in late March.
	NOY	85	87	
	NOYDIF	85	86	

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

Site ID	Parameter*	Q1 2021	Q2 2020 – Q1 2021	Comments
PNF126, NC	NO	71	84	Bypass box was offline from mid- to late February because of power failures.
	NOY	71	70	
	NOYDIF	71	70	
ROM206, CO	NO	94	90	
	NOY	94	89	
	NOYDIF	94	89	

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) First Quarter 2021 Quality Assurance Report.*

<https://java.epa.gov/castnet/documents.do>