Clean Air Status and Trends Network (CASTNET)
Quarterly Data Summary for First Quarter 2022 (January through March)

Prepared for: U.S. Environmental Protection Agency (EPA), Clean Air Markets Division
EPA Contract No.: 68HERH21D0006, CASTNET Base Program (0003)
Prepared by: Wood Environment & Infrastructure Solutions, Inc. (Wood), Gainesville, Florida
Wood Project No.: 6064216003
Submitted: June 30, 2022

Introduction

This quarterly report summarizes the Clean Air Status and Trends Network (CASTNET) data collected during first quarter 2022. 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 and continuous SO_2 concentrations from three sites. Other QC statistics are given in the CASTNET First Quarter 2022 Quality Assurance Report (Wood, 2022).

Figure 1. Fourth Highest Daily Maximum 8-hour Average O_3 Concentrations (ppb) through First Quarter 2022

Figure 1 shows fourth highest daily maximum 8-hour average (DM8A) O_3 concentrations measured through first quarter 2022. No sites exceeded the 0.070 parts per million (ppm) National Ambient Air Quality Standard for O_3. The higher concentrations were less than 0.065 ppm (65 ppb).

Trends

Trend analyses were performed based on filter pack pollutant concentrations measured in micrograms per cubic meter ($\mu g/m^3$) of air at the 34 eastern and 16 western reference sites during first quarter. Trends in quarterly mean filter pack and O_3 concentrations are shown using box plots in Figures 2 through 13.

First Quarter Concentrations

Quarterly mean HNO_3, NO_3^-, NH_4^+, total NO_3^-, SO_2, and SO_4^{2-} concentrations decreased at eastern sites in 2022, and Cl^-, Ca^{2+}, K^+, Mg^{2+}, and Na^+ concentrations increased. Quarterly mean NO_3^-, NH_4^+, SO_2, SO_4^{2-}, Mg^{2+}, and Na^+ concentrations decreased at western sites in 2022 while HNO_3, total NO_3^-, Cl^-, Ca^{2+}, and K^+ concentrations increased.

Quarterly O_3 concentrations were analyzed using box plots constructed by averaging all valid hourly O_3 concentrations within first quarter 2022 by site and then averaging those averages for all eastern and western reference sites (Figure 13). The figure shows an overall increase in quarterly mean O_3 concentrations at eastern sites. Mean O_3 concentrations at eastern and western sites increased in first quarter 2022. Quarterly mean concentrations were higher at the western reference sites than at the eastern sites.

Figure 2. Trends in First Quarter Mean HNO_3 Concentrations

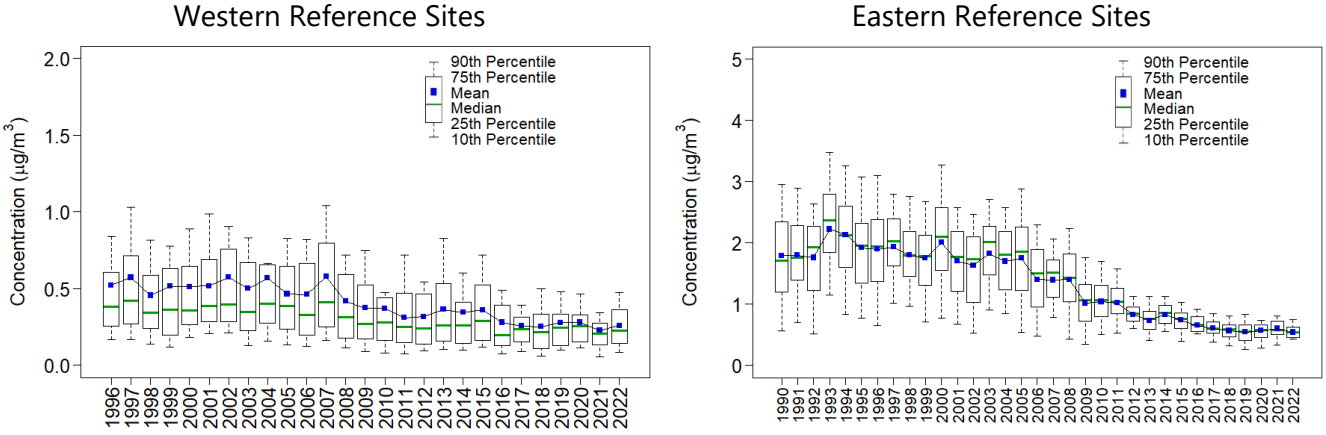


Figure 3. Trends in First Quarter Mean NO_3^- Concentrations

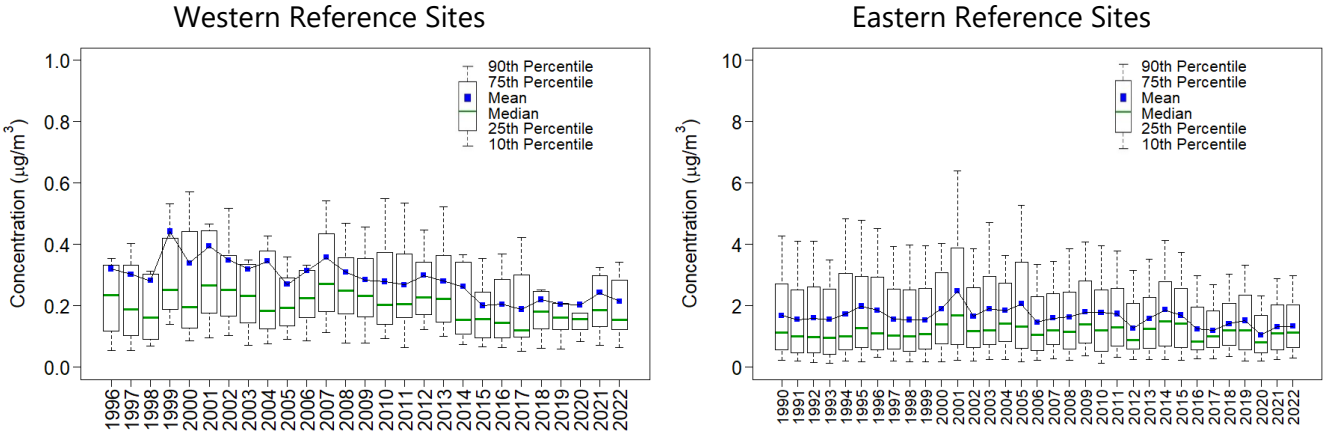


Figure 4. Trends in First Quarter Mean NH_4^+ Concentrations

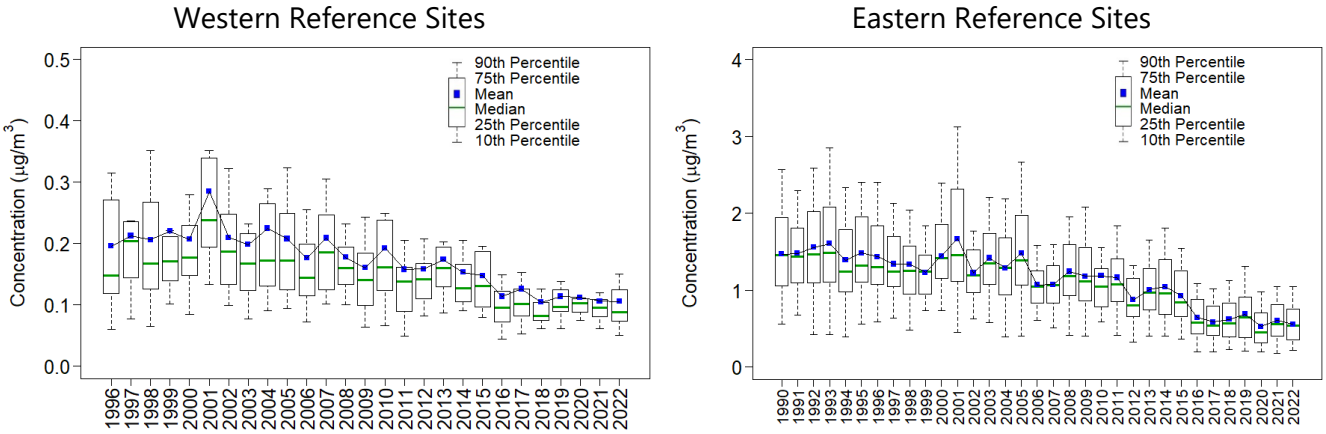


Figure 5. Trends in First Quarter Mean Total NO_3^- Concentrations

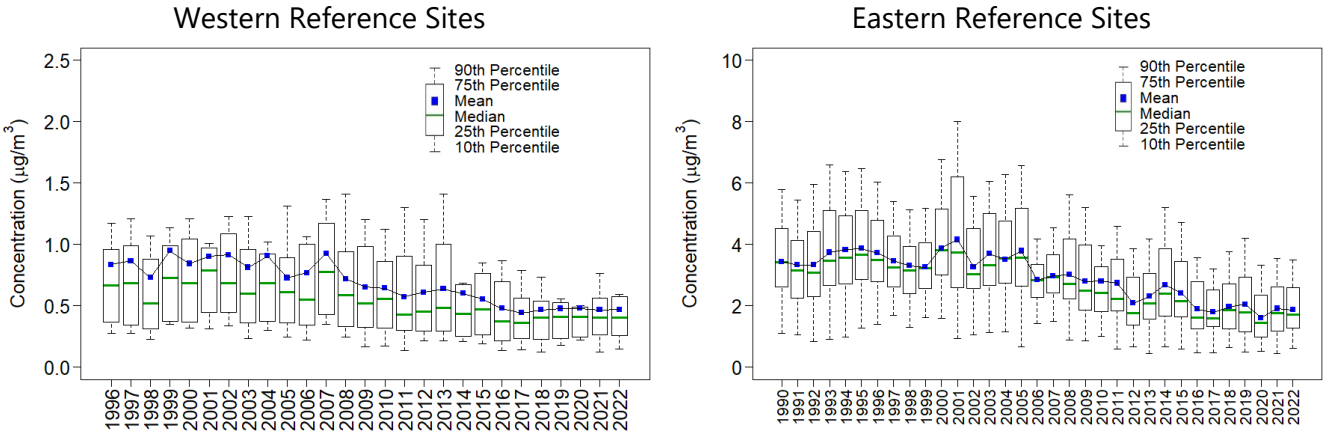


Figure 6. Trends in First Quarter Mean SO_2 Concentrations

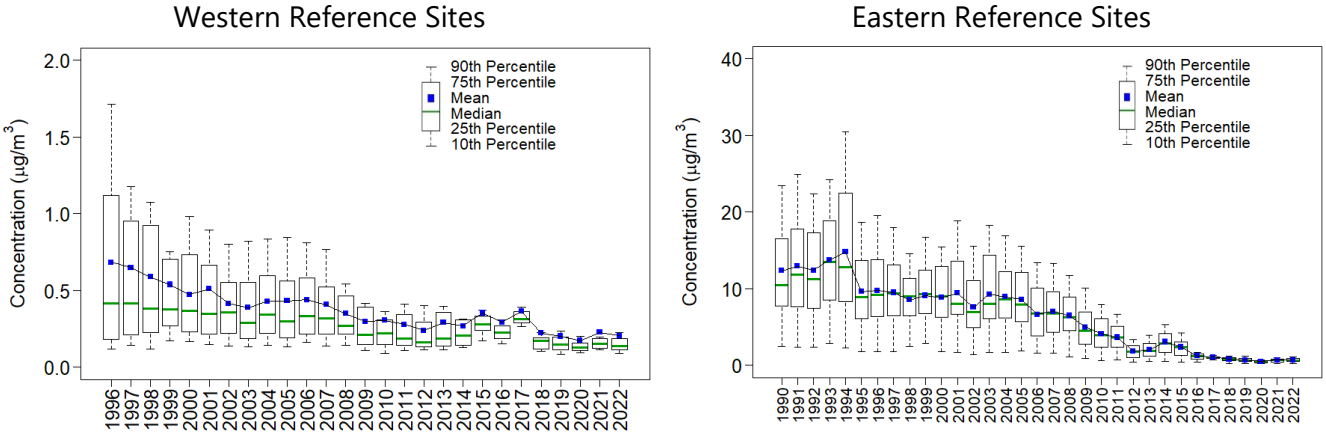


Figure 7. Trends in First Quarter Mean SO_4^{2-} Concentrations

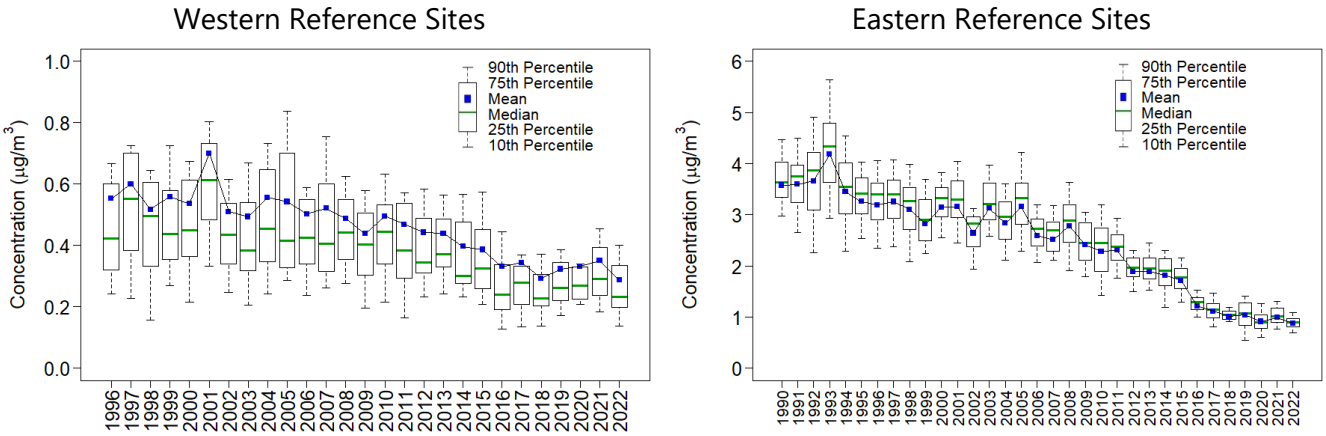


Figure 8. Trends in First Quarter Mean Cl^- Concentrations

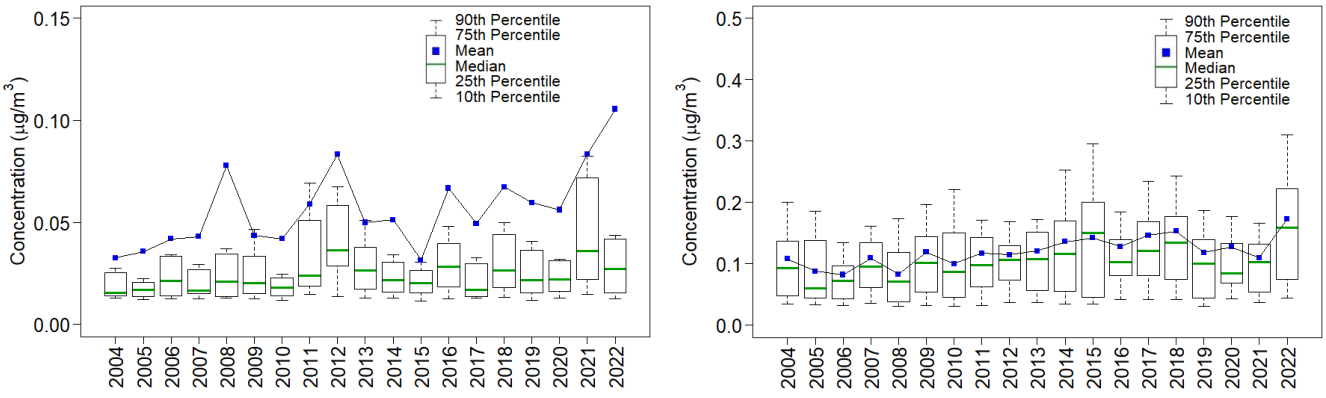


Figure 9. Trends in First Quarter Mean Ca^{2+} Concentrations

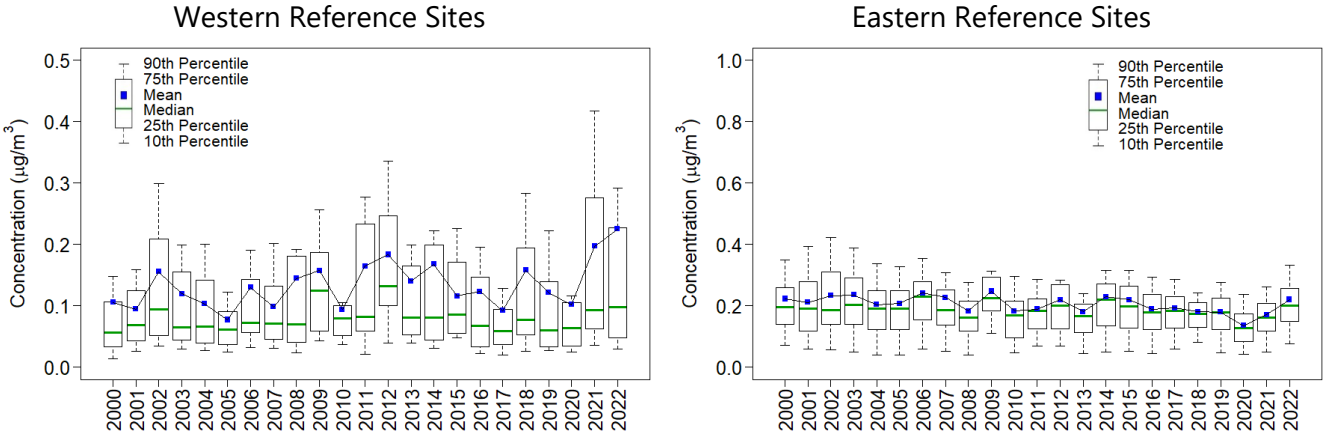


Figure 10. Trends in First Quarter Mean K^{+} Concentrations

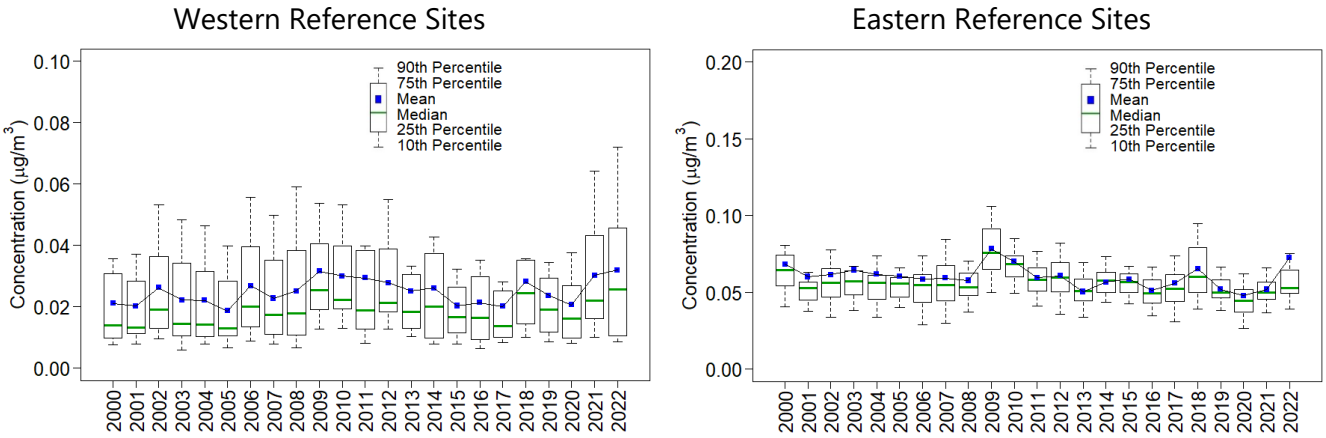


Figure 11. Trends in First Quarter Mean Mg^{2+} Concentrations

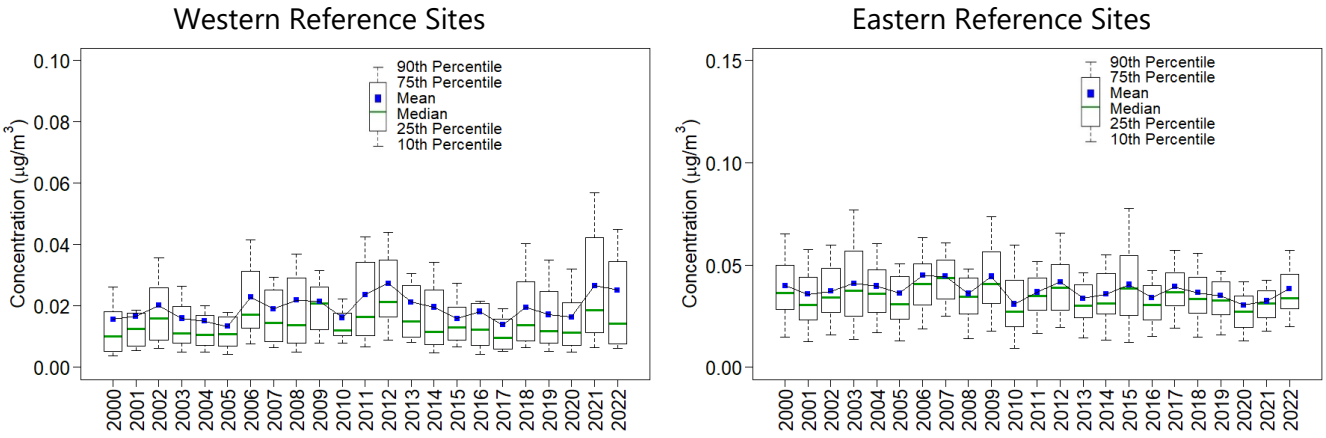


Figure 12. Trends in First Quarter Mean Na^+ Concentrations

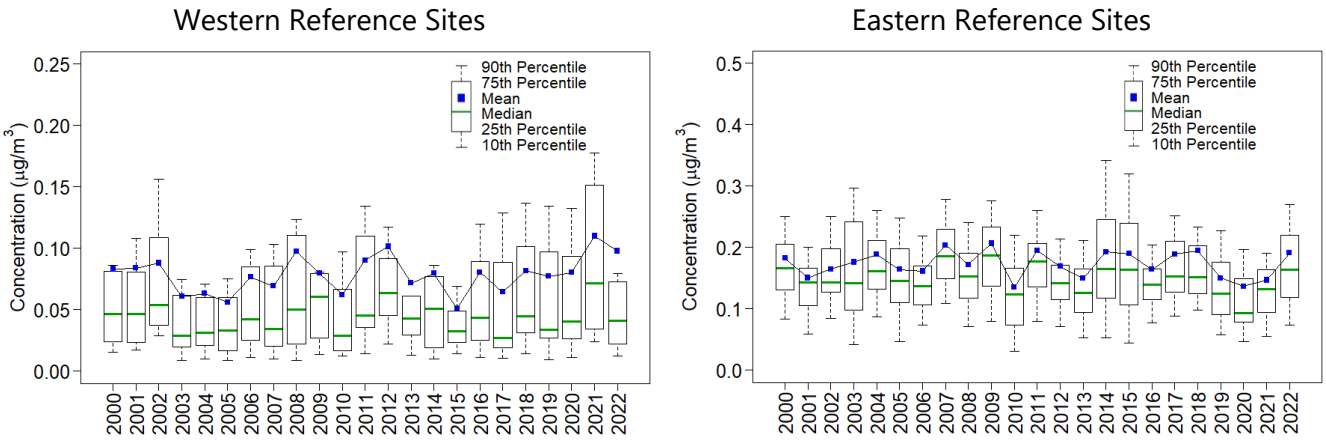
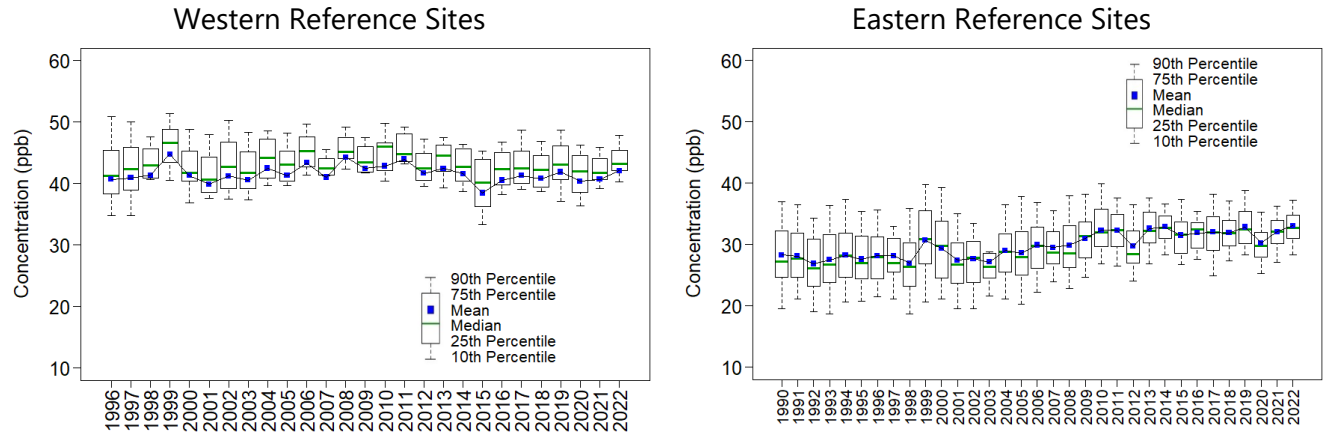


Figure 13. Trends in First Quarter Mean O_3 Concentrations



Changes in 3-year Average First Quarter Concentrations

Three-year averages of quarterly mean concentrations of total NO_3^-, NH_4^+, SO_2, and SO_4^{2-} were reduced over the period 1990–1992 through 2020–2022 for eastern reference sites and 1996–1998 through 2020–2022 for western reference sites. O_3 concentrations increased at eastern sites and showed no change at western reference sites. Ca^{2+}, K^+, Mg^{2+}, and Na^+ levels declined at eastern sites from 2004-2006 through 2020-2022. Cl^- values increased. At western sites, Cl^- and base cation concentrations increased.

Table 1. Eastern Reference Sites: 3-Year Mean O_3, Nitrogen, Sulfur, Base Cations, and Cl^- Pollutant Concentrations

Parameter	1990–1992 (µg/m^3)	2004–2006 (µg/m^3)	2020–2022 (µg/m^3)	Percent Change
O_3	28		32	14
Total NO_3^-	3.4		1.8	-47
NH_4^+	1.5		0.6	-63
SO_2	12.5		0.6	-95
SO_4^{2-}	3.6		0.9	-74
Ca^{2+}		0.22	0.18	-19
K^+		0.06	0.06	-5
Mg^{2+}		0.04	0.03	-16
Na^+		0.17	0.16	-8
Cl^-		0.09	0.14	48

Table 2. Western Reference Sites: 3-Year Mean O_3, Nitrogen, Sulfur, Base Cations, and Cl^- Pollutant Concentrations

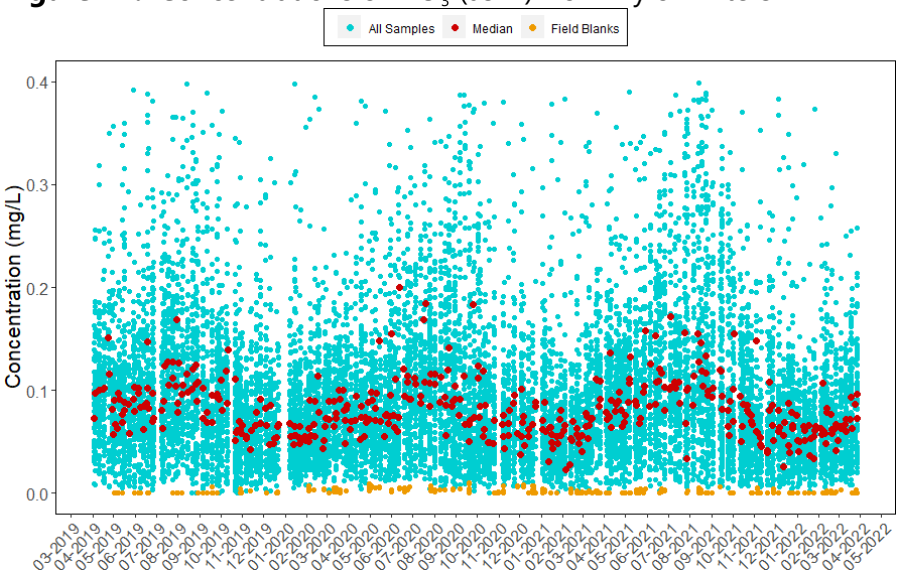
Parameter	1996–1998 (µg/m^3)	2004–2006 (µg/m^3)	2020–2022 (µg/m^3)	Percent Change
O_3	41		41	0
Total NO_3^-	0.8		0.5	-42
NH_4^+	0.2		0.1	-47
SO_2	0.6		0.2	-68
SO_4^{2-}	0.6		0.3	-42
Ca^{2+}		0.10	0.17	69
K^+		0.02	0.03	23
Mg^{2+}		0.02	0.02	33
Na^+		0.07	0.10	47
Cl^-		0.04	0.08	122

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 April 2019 through April 2022. These figures provide indications of potential issues with concentration measurements relative to detection and reporting limits.

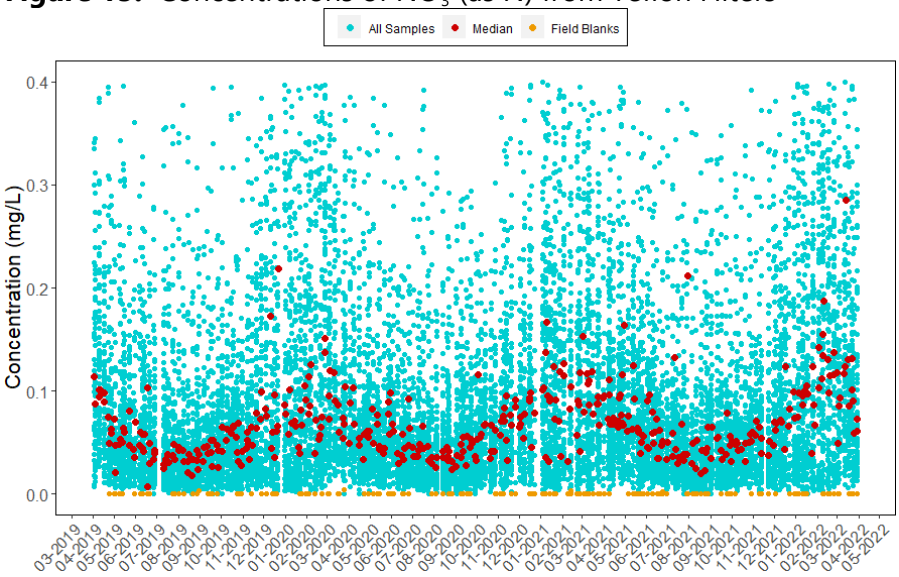
Figure 20 shows a small gap between 0.00 and 0.01 mg/L for reported concentrations during the fourth quarter 2021. The reporting limit for chloride is 0.02 mg/L. The CASTNET Laboratory Operations Manager reviewed these data and instrument method detection limit (MDL) runs and determined that there is no bias in reported results. Initial analysis of second quarter 2022 results indicates no gap in measurements between 0.00 and 0.01 mg/L.

Figure 14. Concentrations of NO_3^- (as N) from Nylon Filters



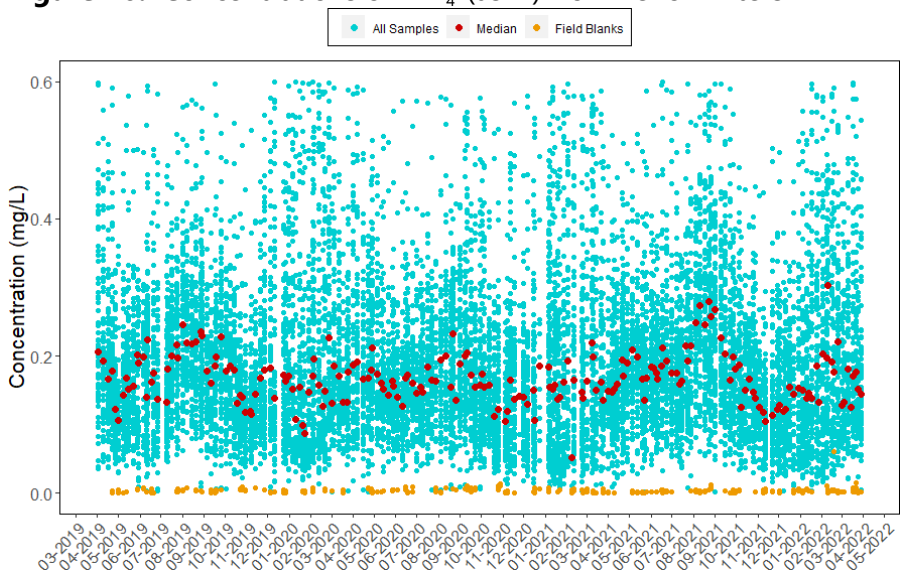
Note: Nominal reporting limit is 0.008 mg/L.

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



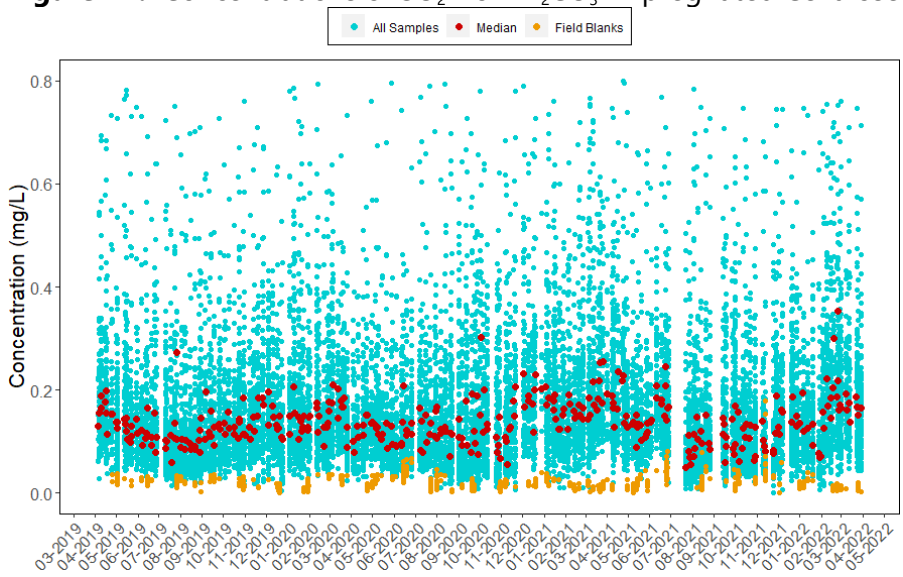
Note: Nominal reporting limit is 0.008 mg/L.

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



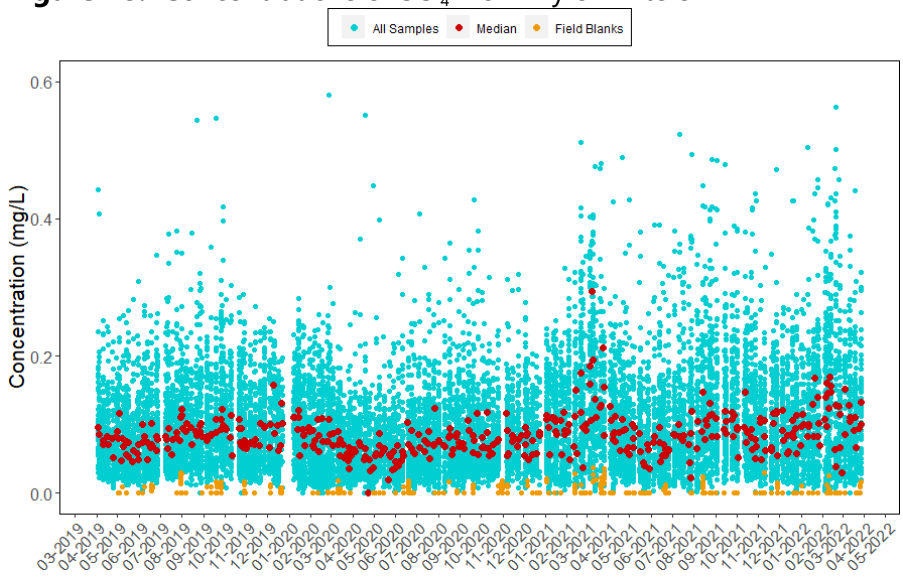
Note: Nominal reporting limit is 0.020 mg/L.

Figure 17. Concentrations of SO_2 from K_2CO_3-impregnated Cellulose Filters



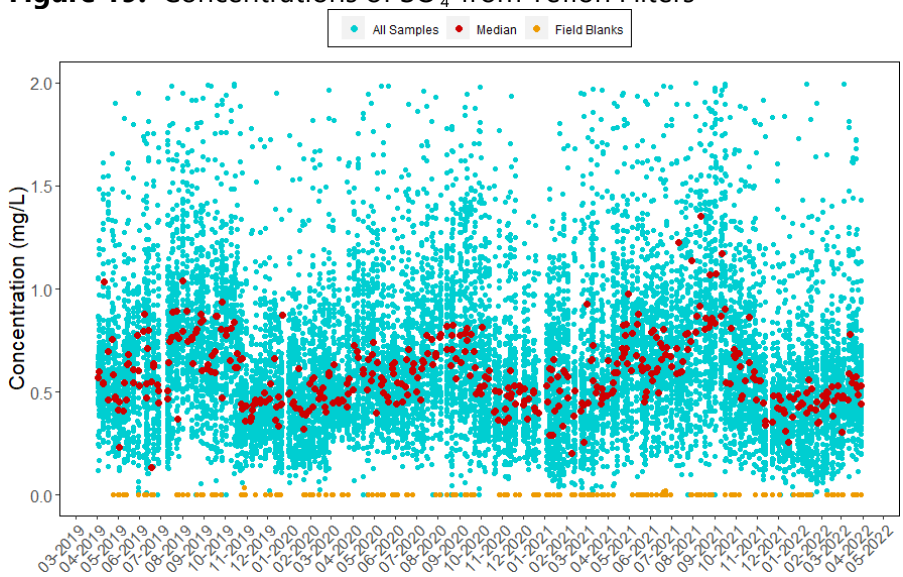
Note: Nominal reporting limit is 0.040 mg/L.

Figure 18. Concentrations of SO_4^{2-} from Nylon Filters



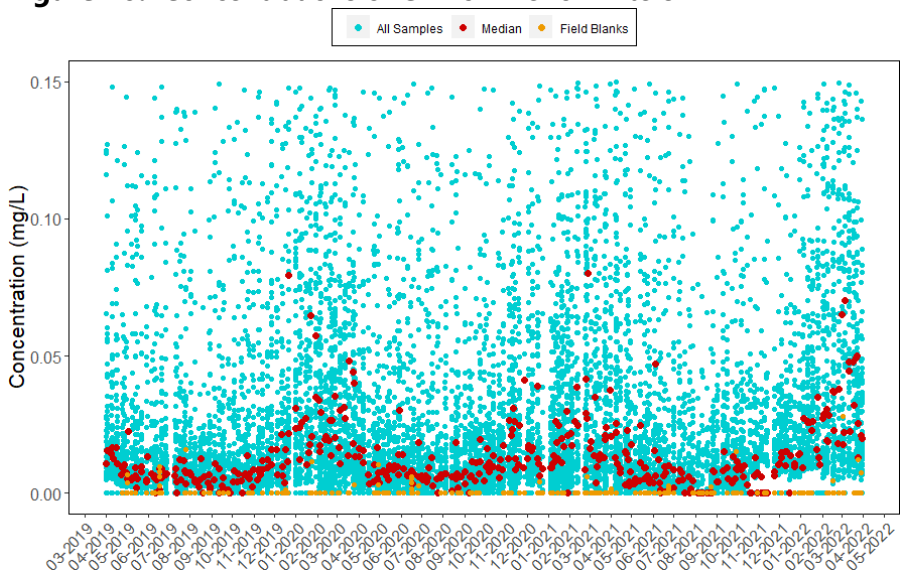
Note: Nominal reporting limit is 0.040 mg/L.

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



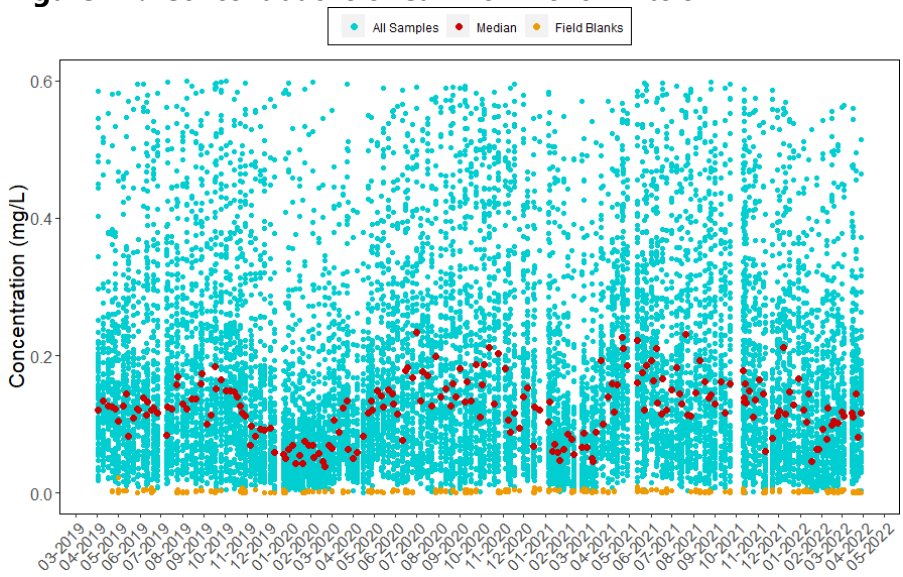
Note: Nominal reporting limit is 0.040 mg/L.

Figure 20. Concentrations of Cl^- from Teflon Filters



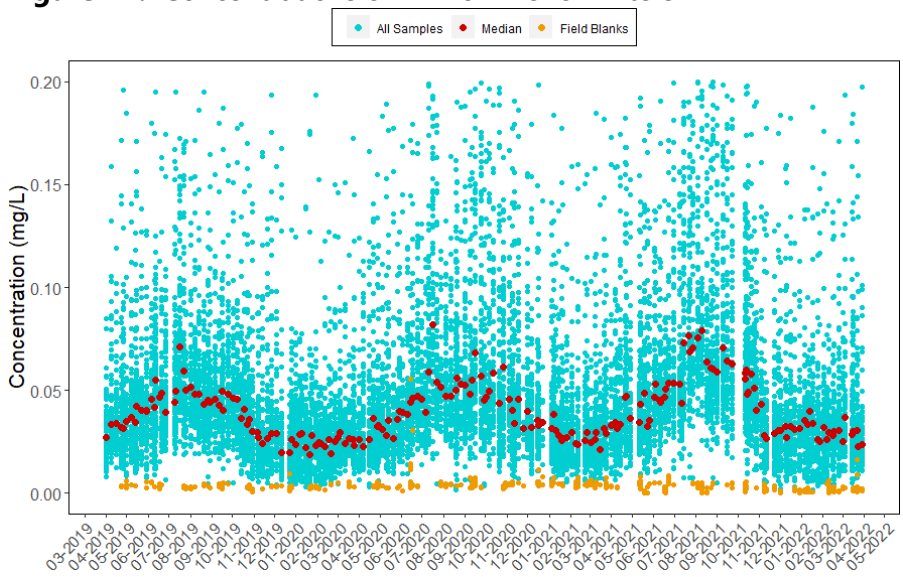
Note: Nominal reporting limit is 0.020 mg/L.

Figure 21. Concentrations of Ca^{2+} from Teflon Filters



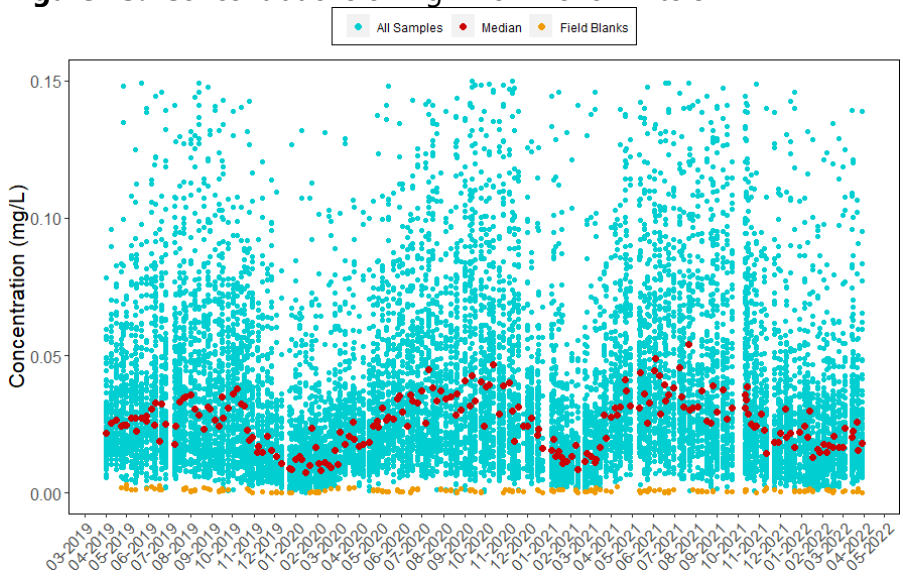
Note: Nominal reporting limit is 0.006 mg/L.

Figure 22. Concentrations of K^+ from Teflon Filters



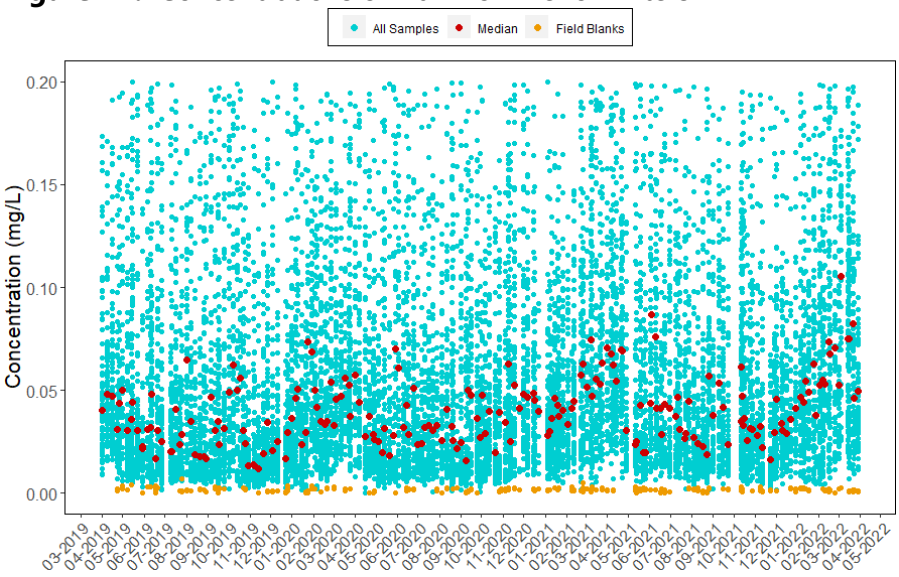
Note: Nominal reporting limit is 0.006 mg/L.

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.

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

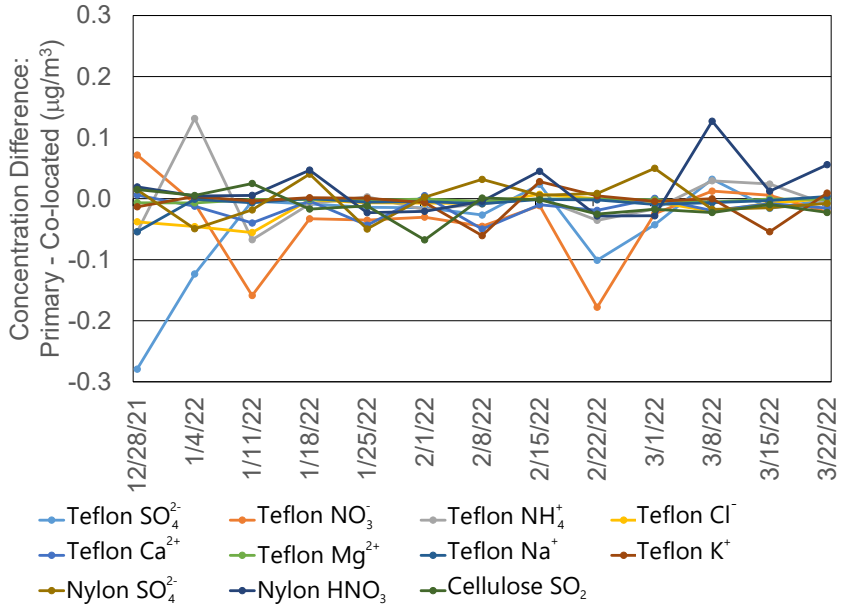
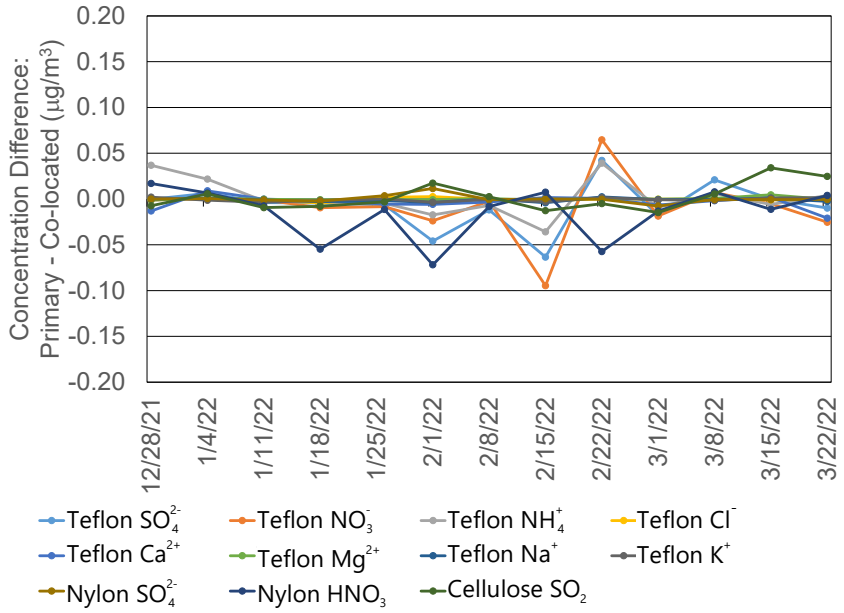


Figure 26. Time Series of Filter Concentration Differences between ROM406 and ROM206, CO



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 2022. The MARPD values met the 20 percent criterion except for MCK131/231 K^+ and Cl^-. The high MARPD values were caused by low filter pack flow (7 cubic meters) during one week. These data are currently not validated at level 3 and are subject to change during subsequent data validation.

Table 3. Precision (MARPD) for Co-located Filter Pack Data during First Quarter 2022

	Total NO_3^-	HNO_3	NO_3^-	NH_4^+	SO_2	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-
MCK131/231, KY											
$\overline{X}$ (µg/m³)	2.16	0.76	1.42	0.66	0.66	0.99	0.26	0.03	0.10	0.05	0.06
$\overline{Y}$ (µg/m³)	2.18	0.74	1.45	0.66	0.67	1.03	0.27	0.03	0.11	0.06	0.07
MAD	0.07	0.03	0.05	0.03	0.02	0.05	0.02	0.00	0.01	0.01	0.02
MARPD	3.30	4.00	3.59	5.07	3.66	4.48	6.17	8.93	10.88	20.73	26.30
ROM406/206, CO											
$\overline{X}$ (µg/m³)	0.40	0.24	0.17	0.12	0.13	0.27	0.07	0.01	0.02	0.01	0.02
$\overline{Y}$ (µg/m³)	0.37	0.22	0.16	0.12	0.13	0.26	0.07	0.01	0.02	0.01	0.02
MAD	0.04	0.03	0.02	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00
MARPD	10.69	11.12	14.42	17.42	12.46	9.23	18.71	18.07	10.28	18.75	6.33

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 2022

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
EGB181, ON	0	0	0	0	0	0	0	0	The monitoring shelter was being refurbished.
BWR139, MD	57	57	57	57	57	57	57	57	There were three 2-week samples during the quarter, one of which was invalidated due to suspect values. One sample was invalidated because particles were observed on the nylon filter.
CDR119, WV	79	79	79	79	79	79	79	79	A polling issue caused missing data. Additionally, the data logger malfunctioned and was replaced on 1/25/2022.
PIN414, CA	79	79	79	79	79	79	79	79	Flow was invalidated for the first three sampling weeks of the quarter.
ABT147, CT	86	86	86	86	86	86	86	86	One sample was invalidated for low flow volume, and one was affected by a polling issue.
BFT142, NC	86	86	86	86	86	86	86	86	There were two 2-week samples during the quarter.
DEN417, AK	86	86	86	86	86	86	86	86	A 3-week sample installed late December 2021 resulted in removal of two samples from the first quarter sample count.
LAV410, CA	86	86	86	86	86	86	86	86	A 3-week sample installed mid-December 2021 resulted in removal of a sample from the first quarter sample count, and there was a 2-week sample during the quarter.
SHN418, VA	86	86	86	86	86	86	86	86	There was a 2-week sample during the quarter, and a power failure affected one sample.
VOY413, MN	86	86	86	86	86	86	86	86	There were two 2-week samples during the quarter.

Precision of Ozone Concentrations

Time series of co-located hourly O_3 concentration differences for first quarter 2022 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.

Figure 27. Time Series of the Differences in Co-located O_3 Concentrations for MCK131/231, KY

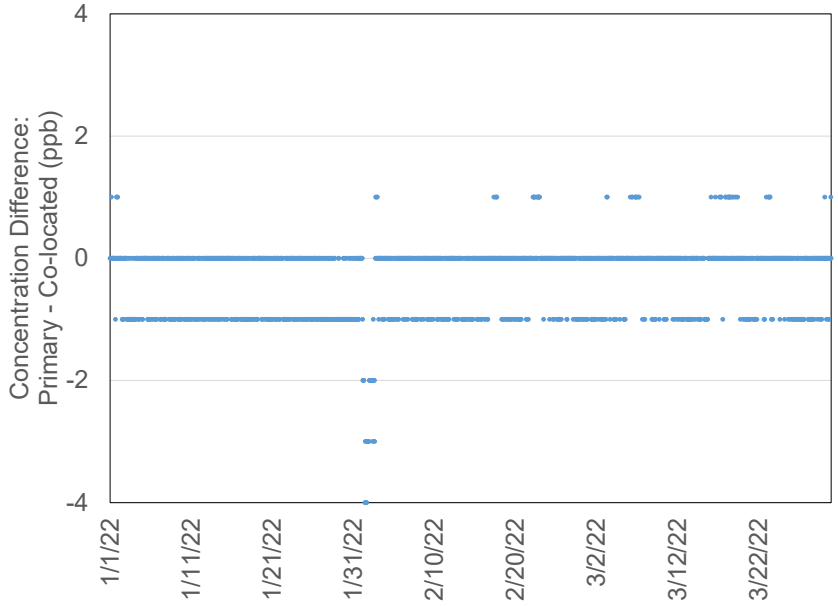


Figure 28. Time Series of the Differences in Co-located O_3 Concentrations for ROM406/206, CO

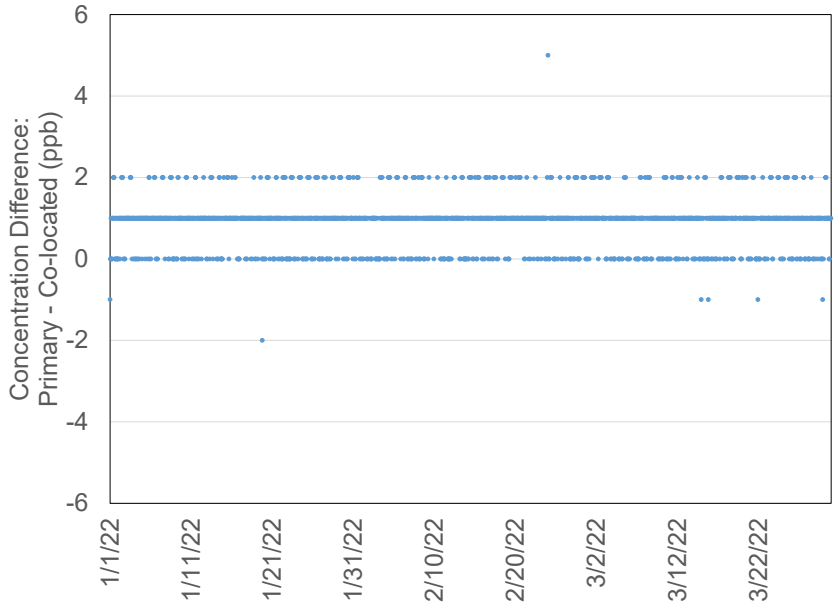


Table 5 gives MARPD data for O_3 data measured at the two co-located sites.

Table 5. Quarterly Precision (MARPD) for Co-located O_3 Concentrations

Site Pair	Quarter	Start Date	MARPD	Records
MCK131/231, KY				
	2	4/1/21	0.6	2075
	3	7/1/21	0.8	2082
	4	10/1/21	1.0	2086
	1	1/1/22	1.1	2046
ROM406/206, CO				
	2	4/1/21	1.9	2013
	3	7/1/21	1.4	2078
	4	10/1/21	1.7	2075
	1	1/1/22	2.0	1970

Completeness for O_3 Concentrations

Calculation of an annual O_3 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 O_3 concentrations. Comments are provided for these sites.

Table 6. Sites with less than 90 Percent Data Completeness for DM8A Concentrations during First Quarter 2022

Site ID	Percent Completeness	Comments
CDR119, WV	77.8	The data logger software programming was lost in early January. The data logger was replaced in late January.
STK138, IL	83.3	A sampling system leak occurred in mid-February.
GAS153, GA	84.4	A sampling system leak occurred in early February.
NPT006, ID	87.8	A power failure occurred in early January along with intermittent analyzer malfunctions in early February and mid-March.
ALH157, IL	88.9	Communication was lost in early February requiring reset of the modem. The data logger required resetting in mid-February.

Table 7 shows CASTNET sites with less than 90 percent completeness for hourly O_3 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 O_3 Concentrations

Site ID	Q1 2022	Q2 2021–Q1 2022	Comments
CDR119, WV	79.4	93.1	The data logger software programming was lost in early January. The data logger was replaced in late January.
STK138, IL	83.8	95.0	A sampling system leak occurred in mid-February.
GAS153, GA	86.1	93.2	A sampling system leak occurred in early February.
NPT006, ID	88.4	96.2	A power failure occurred in early January along with intermittent analyzer malfunctions in early February and mid-March.

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 NO_3^- concentrations collected at the eight sites with NO_y measurements. The NO_y concentrations were consistently higher than the total NO_3^- levels at all sites. The average weekly NO_y levels, the weekly total NO_3^- concentrations, and their ratios for the eight sites are shown in Table 8. Ratios of NO_y to total NO_3^- varied from 3.57 at MAC426 to 6.71 at ROM206.

Table 8. Summary of Total NO_3^- and NO_y Measurements for First Quarter 2022

Site ID	Elevation	Total NO_3^- (ppb)	NO_y (ppb)	Ratio
DUK008, NC	164*	0.60	3.25	5.49
BVL130, IL	213	1.21	4.10	5.02
MAC426, KY	243	0.90	3.05	3.57
HWF187, NY	497	0.31	1.53	5.53
GRS420, TN	793	0.44	2.44	5.81
PNF126, NC	1216	0.39	1.60	4.32
PND165, WY	2386	0.11	0.60	5.29
ROM206, CO	2742	0.12	0.81	6.71

Note: * The inlet of the enhanced NO_y monitor is located at the top of the 30-meter tower.

Figure 29. Comparison of DUK008 Weekly Mean NO_y and Total NO_3^- Concentrations

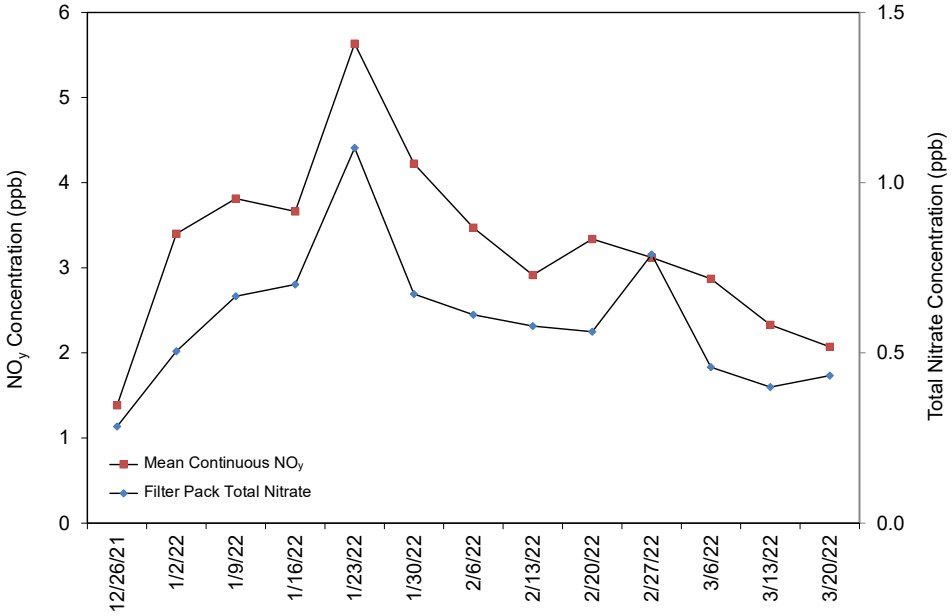


Figure 30. Comparison of BVL130 Weekly Mean NO_y and Total NO_3^- Concentrations

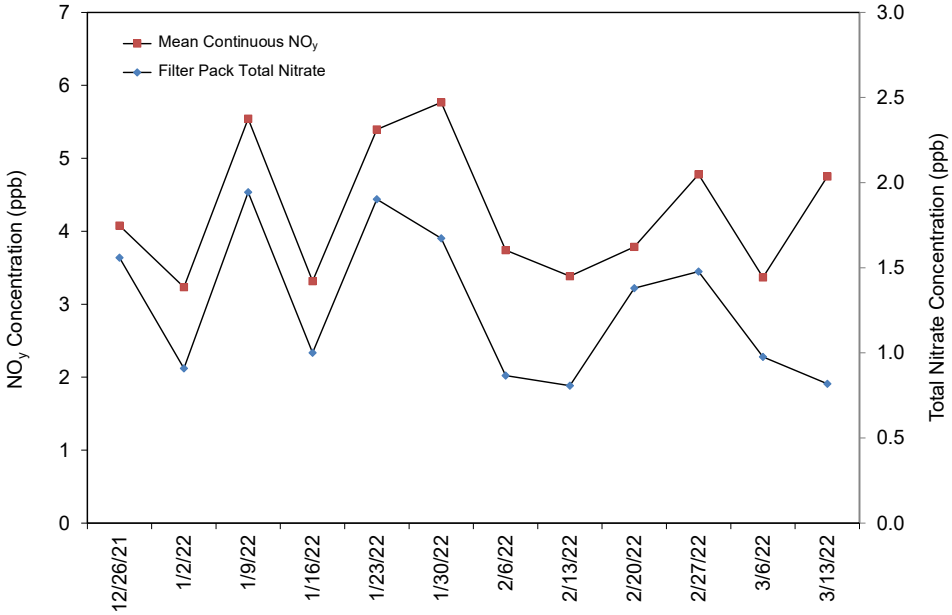


Figure 31. Comparison of MAC426 Weekly Mean NO_y and Total NO_3^- Concentrations

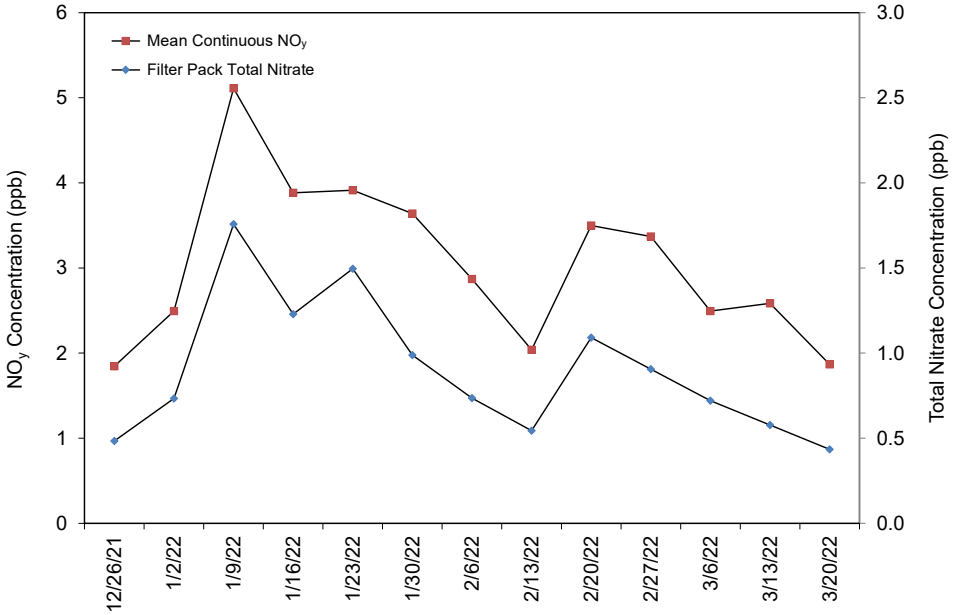


Figure 32. Comparison of HWF187 Weekly Mean NO_y and Total NO_3^- Concentrations

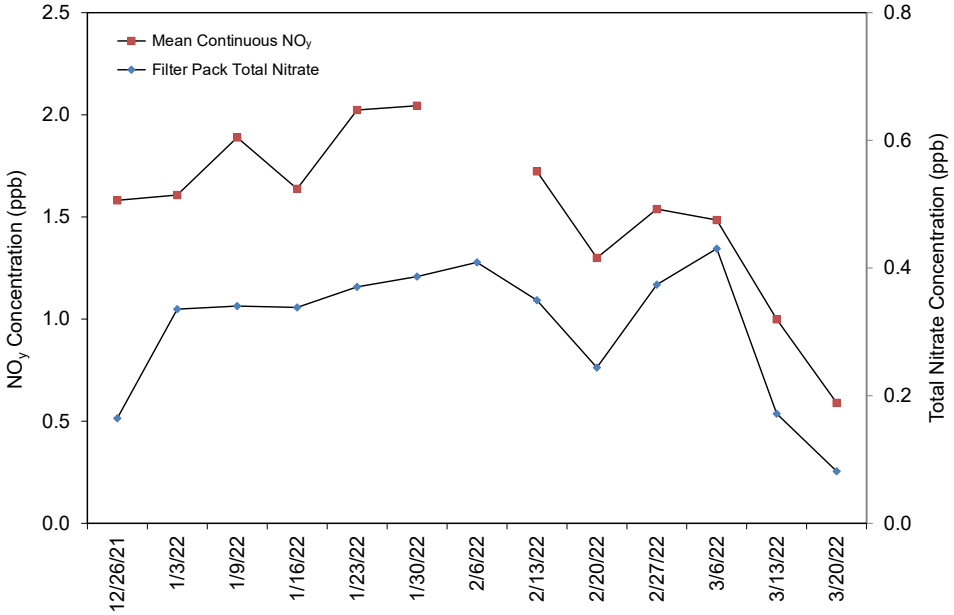


Figure 33. Comparison of GRS420 Weekly Mean NO_y and Total NO_3^- Concentrations

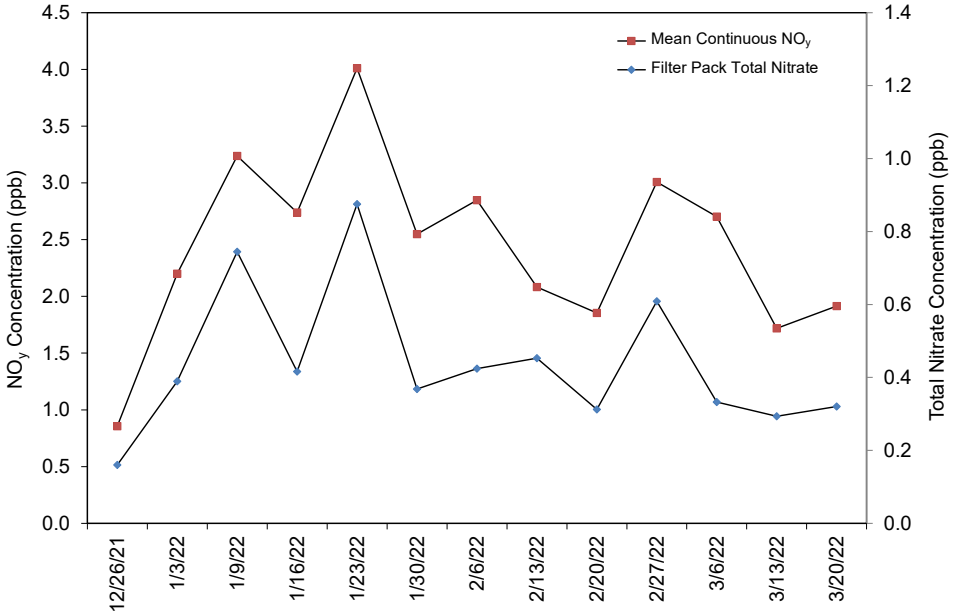


Figure 34. Comparison of PNF126 Weekly Mean NO_y and Total NO_3^- Concentrations

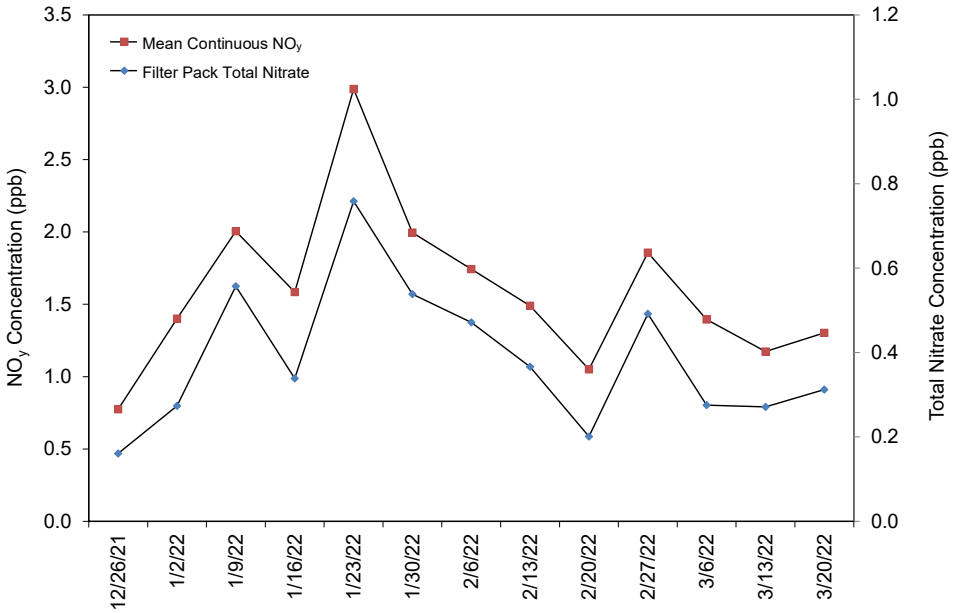


Figure 35. Comparison of PND165 Weekly Mean NO_y and Total NO_3^- Concentrations

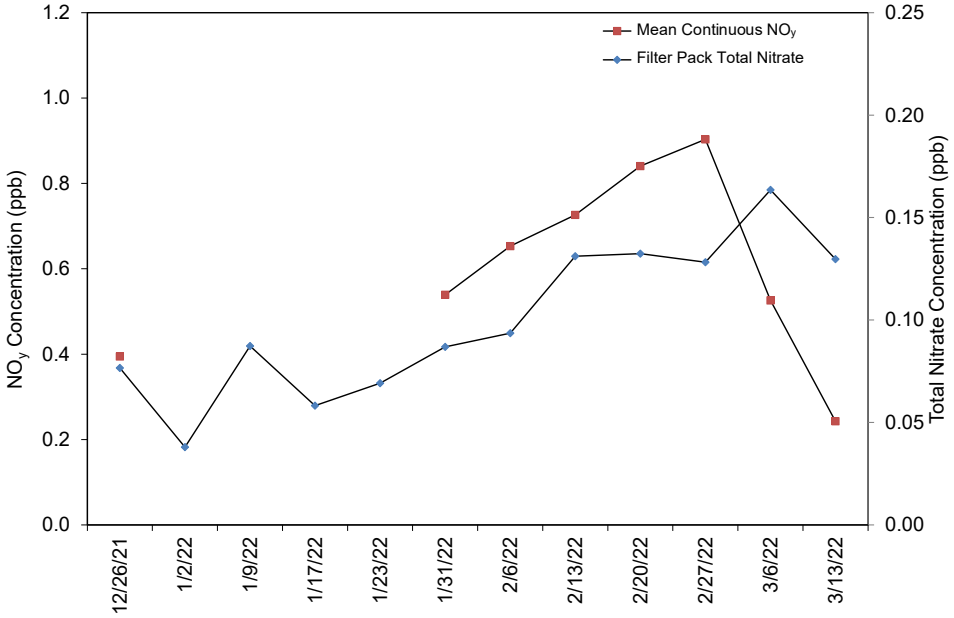
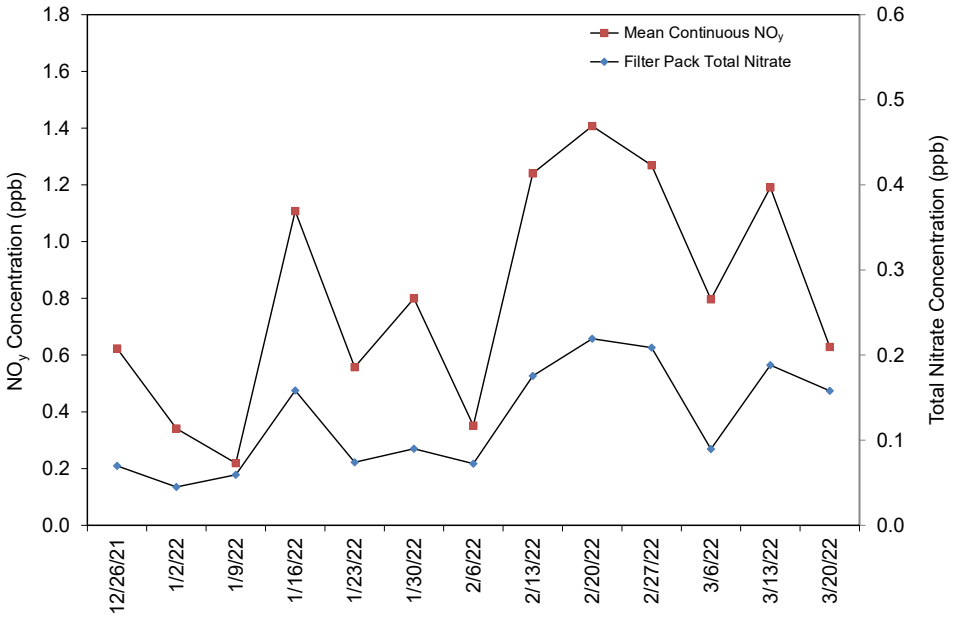


Figure 36. Comparison of ROM206 Weekly Mean NO_y and Total NO_3^- Concentrations



Filter Pack and Continuous Trace-level Gas Sulfur Dioxide Concentrations

Figures 37 through 39 provide diagrams that compare weekly filter pack SO_2 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 lower at GRS420. SO_2 concentrations were comparable at MAC426.

Figure 37. Comparison of BVL130 Weekly Mean SO_2 Concentrations

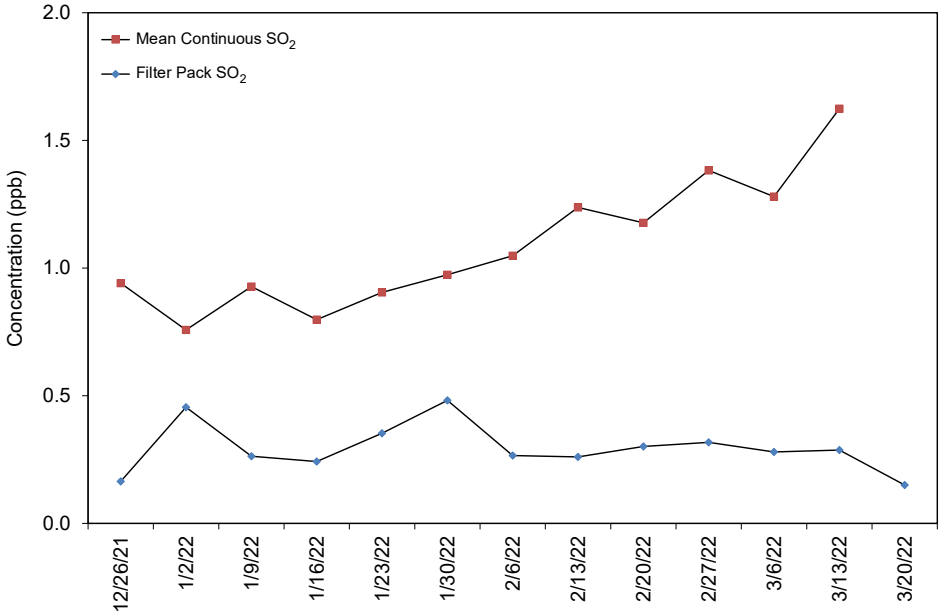


Figure 38. Comparison of MAC426 Weekly Mean SO_2 Concentrations

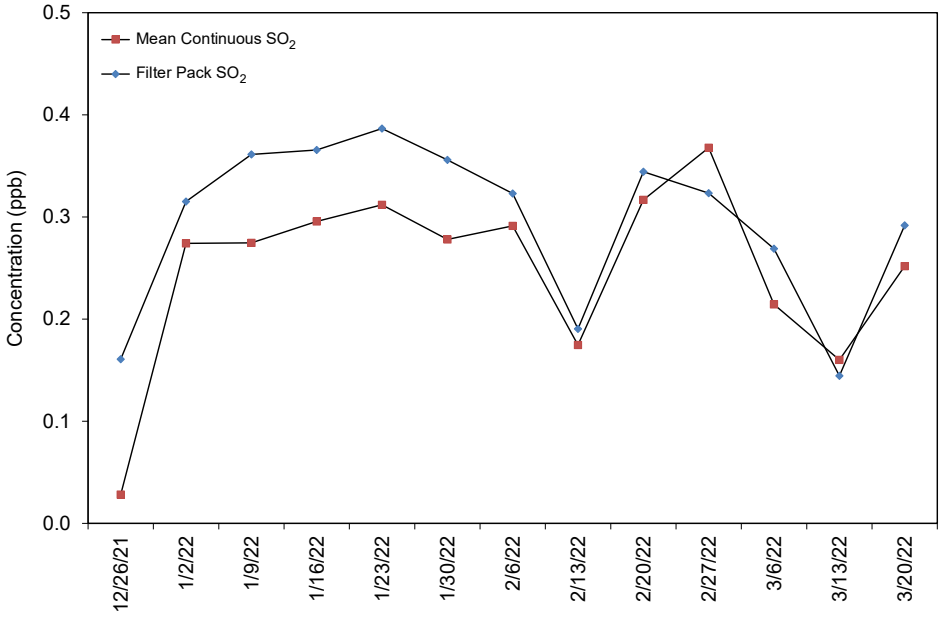
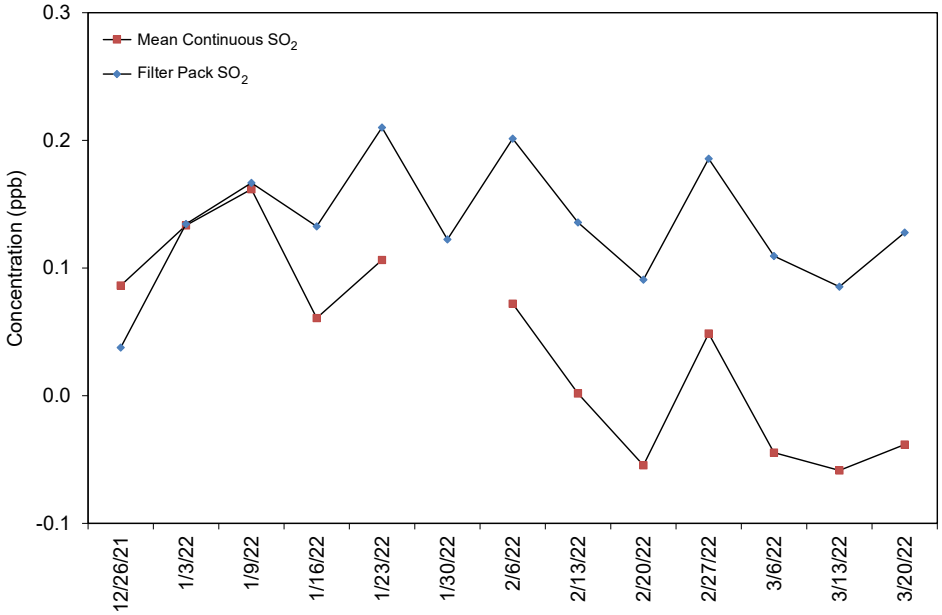


Figure 39. Comparison of GRS420 Weekly Mean SO_2 Concentrations



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 2022. The average for second quarter 2021 through first quarter 2022 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 2022	Q2 2021 – Q1 2022	Comments
BVL130, IL	CO	56	46	The analyzer required calibration in late January. QC check failures were observed in March.
	NO	76	90	The analyzer required calibration in March.
	NOY	93	94	
	NOYDIF	76	90	The analyzer required calibration in March.
	SO2_GA	88	87	Data were invalid for several days in March during site calibration activities.
CHC432, NM	NO	98	97	
	NOX	98	97	
	NOXDIF	98	97	
DUK008, NC	HNO3	84		Monitoring restarted in August 2021, but QC functions were not fully operational until December 2021. Since no valid data are available until December 2021, the average for Q2 2021 through Q1 2022 was not calculated.
	NH3	85		
	NO	85		
	NO2_TRUE	85		
	NOX_TRUE	85		
	NOY	85		
	NOY_MINUS	85		
	NOYDIF	85		
	TNX	85		
GRS420, TN	CO	71	85	QC runs are performed every five hours at this site. These runs were lengthened during first quarter requiring an hour to be invalidated. Intermittent power failures resulted in 3 days data loss.
	NO	72	89	
	NOY	72	89	
	NOYDIF	71	89	
	SO2_GA	68	88	Same QC runs as for the above parameters caused an hour data loss for each run, plus five days were invalidated for failure of 1-point QC checks.
HWF187, NY	NO	94	93	
	NOY	91	92	
	NOYDIF	91	92	
MAC426, KY	CO	95	87	
	NO	97	96	
	NOY	97	96	
	NOYDIF	97	96	
	SO2_GA	97	97	

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

Site ID	Parameter*	Q1 2022	Q2 2021 – Q1 2022	Comments
PND165, WY	NO	62	81	The analyzer malfunctioned in early January and required replacement in late January. An additional four days in late March were lost when channels were left down. These may be recovered.
	NOY	62	81	
	NOYDIF	62	81	
PNF126, NC	NO	95	86	
	NOY	95	86	
	NOYDIF	95	85	
ROM206, CO	NO	96	92	
	NOY	96	95	
	NOYDIF	96	92	

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. 2022. *Clean Air Status and Trends Network (CASTNET) First Quarter 2022 Quality Assurance Report.* https://java.epa.gov/castnet/documents.do