

Clean Air Status and Trends Network

Quarterly Data Summary for First Quarter 2024 (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 2024. 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 O₃ concentrations. This report also analyzes data for continuous, trace-level NO_y from five sites that were operational during first quarter and continuous SO₂ concentrations from one site. Other QC statistics are given in the CASTNET First Quarter 2024 Quality Assurance Report (WSP, 2024).

Figure 1. Fourth Highest Daily Maximum 8-hour Average O₃ Concentrations (ppb) through First Quarter 2024

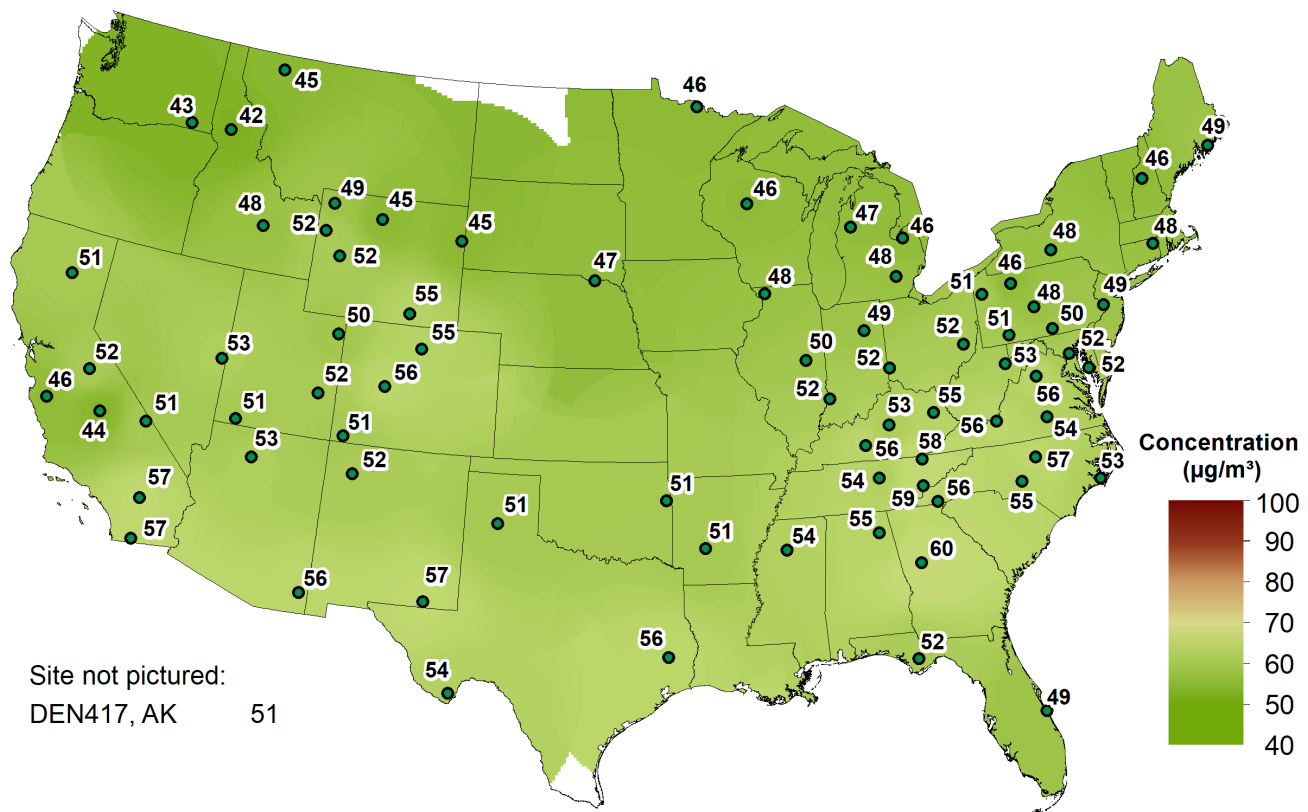


Figure 1 shows fourth highest daily maximum 8-hour average (DM8A) O₃ concentrations measured through first quarter 2024. No site exceeded the 0.070 parts per million (ppm) National Ambient Air Quality Standard for O₃.

Trends

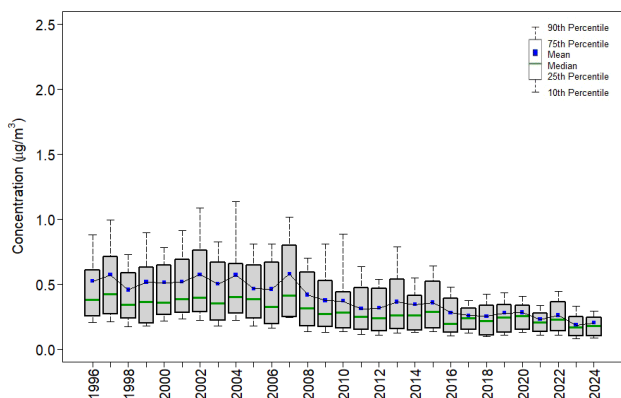
Trend analyses were performed on filter pack pollutant concentrations measured in micrograms per cubic meter (µg/m³) of air at the 27 eastern and 16 western reference sites during first quarter. The eastern reference sites were reduced from 34 sites to 27 sites due to the discontinuation of filter pack sampling in 2022 at sites ALH157, IL; ANA115, MI; ASH135, ME; CDR119, WV; DCP114, OH; PNF126, NC; and PSU106, PA. 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⁻, SO₄²⁻, and K⁺ concentrations decreased at eastern sites in 2024, and SO₂, Cl⁻, Ca²⁺, Mg²⁺, and Na⁺ concentrations increased. Quarterly mean NO₃⁻, NH₄⁺, total NO₃⁻, SO₄²⁻, Cl⁻, and Na⁺ concentrations decreased at western sites in 2024 while HNO₃, SO₂, Ca²⁺, K⁺, and Mg²⁺ concentrations increased.

Quarterly O₃ concentrations were analyzed using box plots constructed by averaging all valid hourly O₃ concentrations within first quarter 2024 by site and then averaging those averages for all eastern and western reference sites (Figure 13). The figure shows overall decreases in quarterly mean O₃ concentrations at eastern and western 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
Western Reference Sites



Eastern Reference Sites

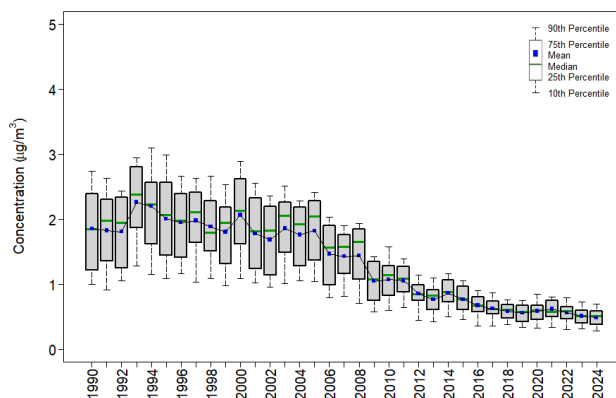
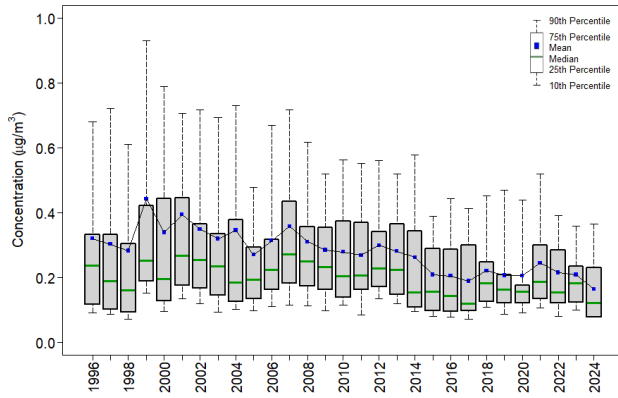


Figure 3. Trends in First Quarter Mean NO₃ Concentrations
Western Reference Sites



Eastern Reference Sites

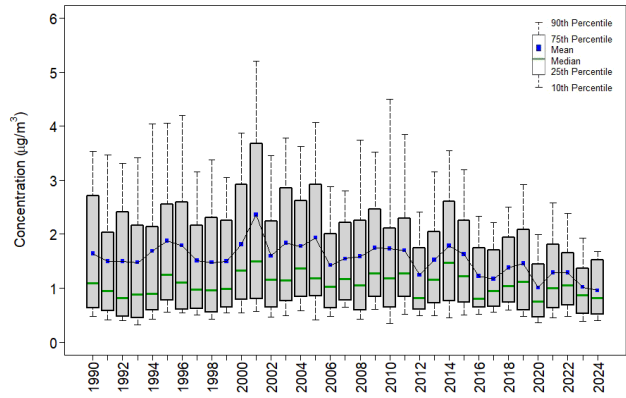
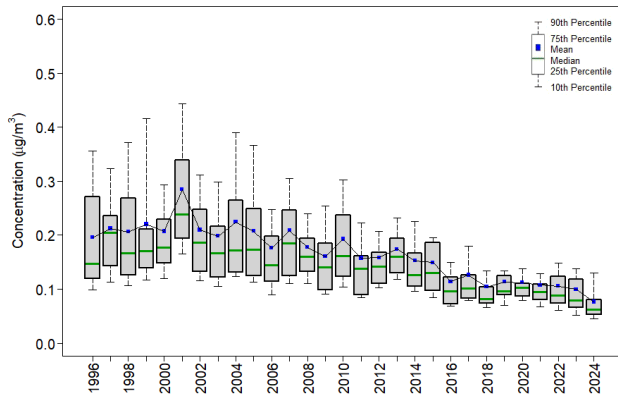


Figure 4. Trends in First Quarter Mean NH₄⁺ Concentrations
Western Reference Sites



Eastern Reference Sites

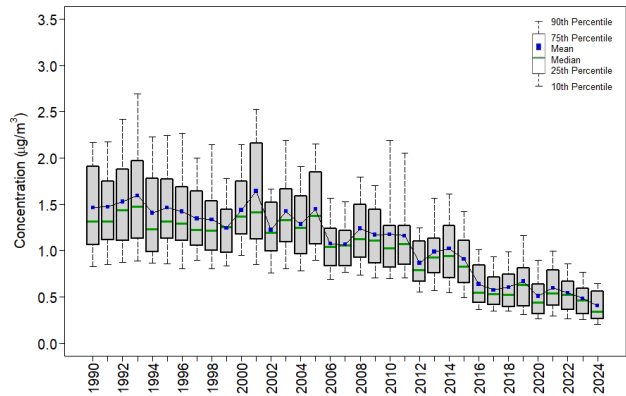
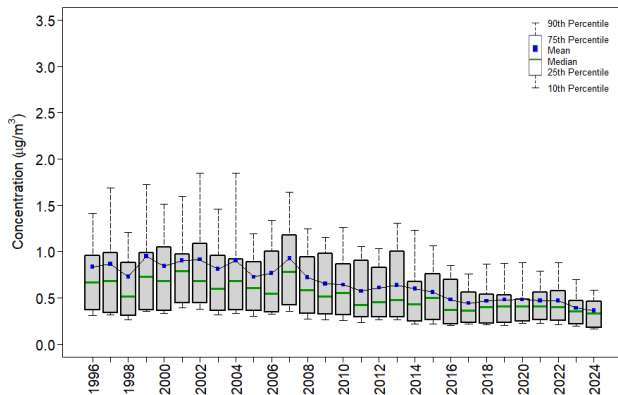


Figure 5. Trends in First Quarter Mean Total NO₃ Concentrations
Western Reference Sites



Eastern Reference Sites

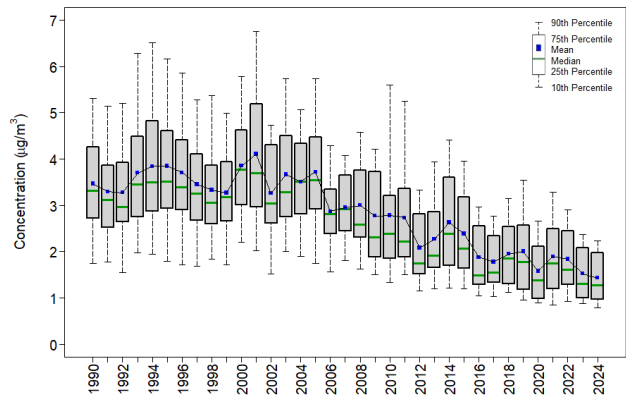
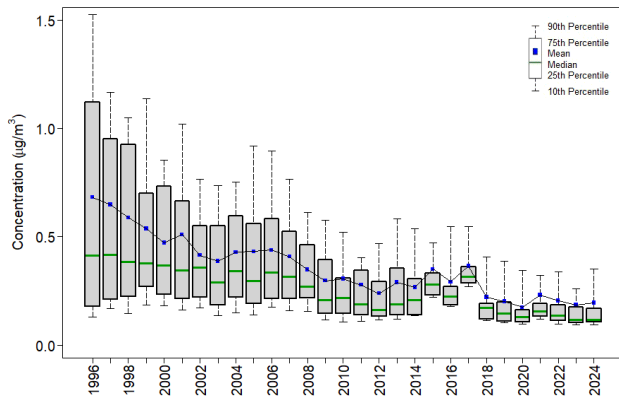


Figure 6. Trends in First Quarter Mean SO₂ Concentrations
Western Reference Sites



Eastern Reference Sites

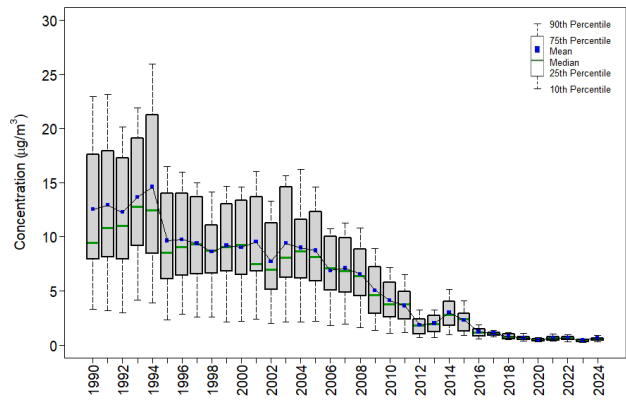
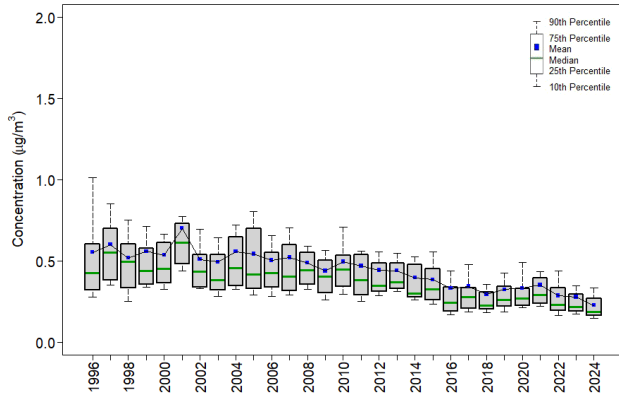


Figure 7. Trends in First Quarter Mean SO₄²⁻ Concentrations
Western Reference Sites



Eastern Reference Sites

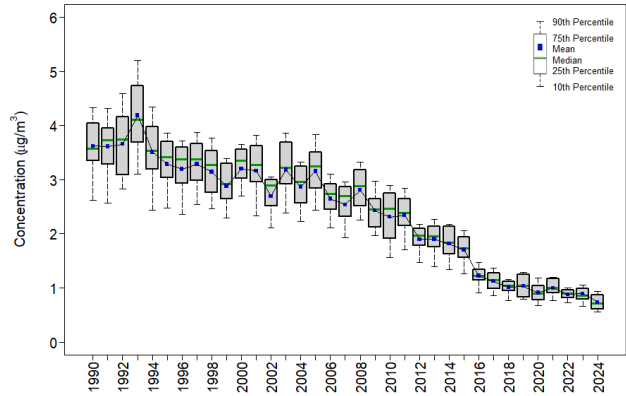
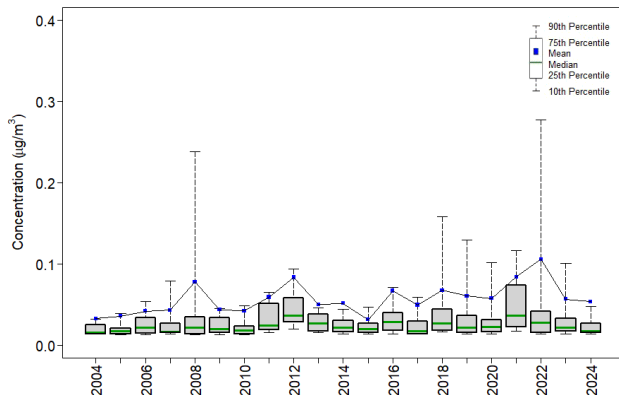


Figure 8. Trends in First Quarter Mean Cl⁻ Concentrations
Western Reference Sites



Eastern Reference Sites

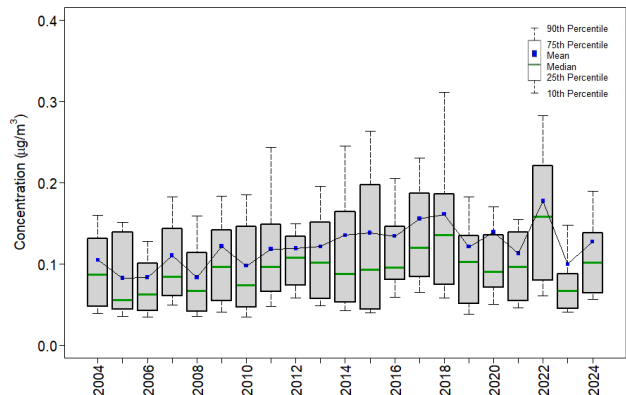
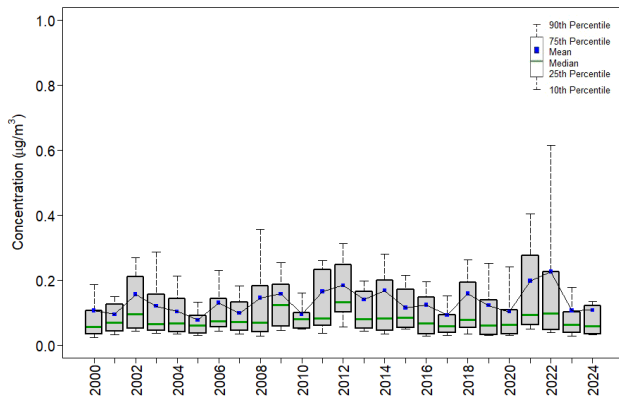


Figure 9. Trends in First Quarter Mean Ca²⁺ Concentrations
Western Reference Sites



Eastern Reference Sites

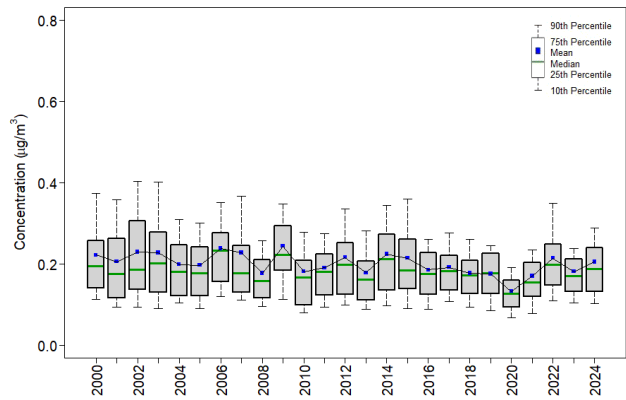
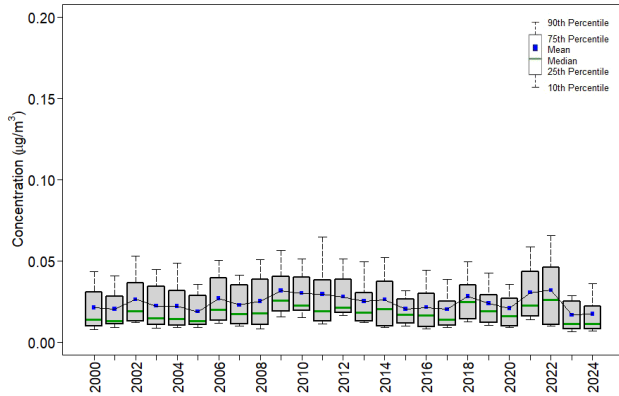


Figure 10. Trends in First Quarter Mean K⁺ Concentrations
Western Reference Sites



Eastern Reference Sites

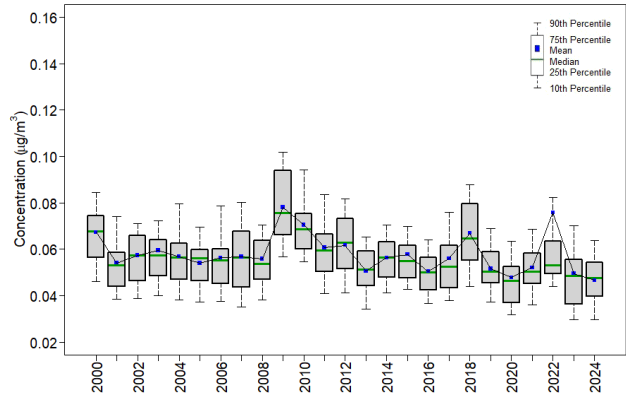
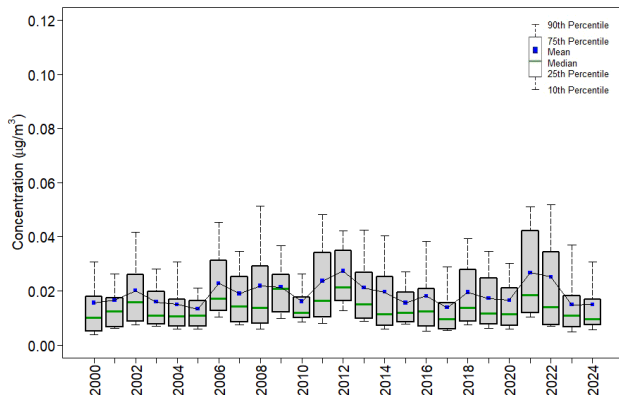


Figure 11. Trends in First Quarter Mean Mg²⁺ Concentrations
Western Reference Sites



Eastern Reference Sites

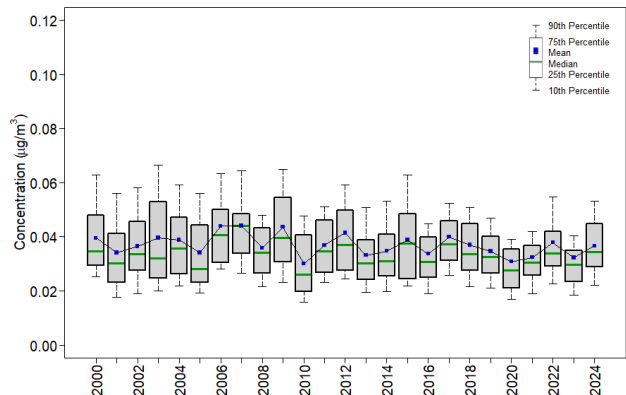
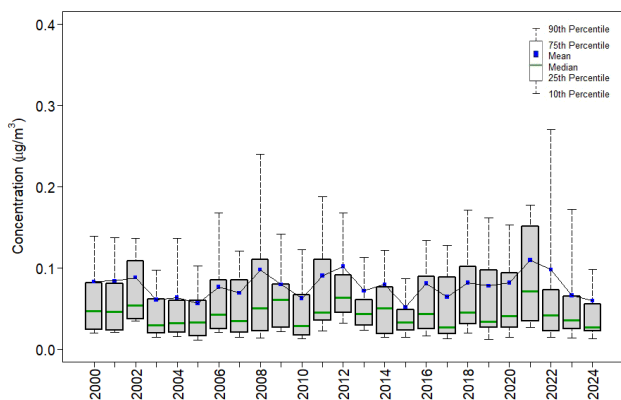


Figure 12. Trends in First Quarter Mean Na⁺ Concentrations
Western Reference Sites



Eastern Reference Sites

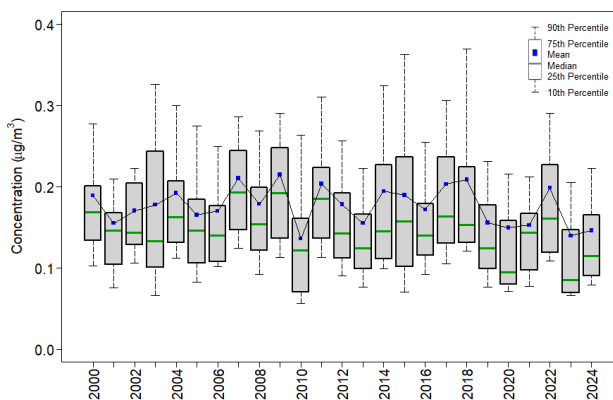
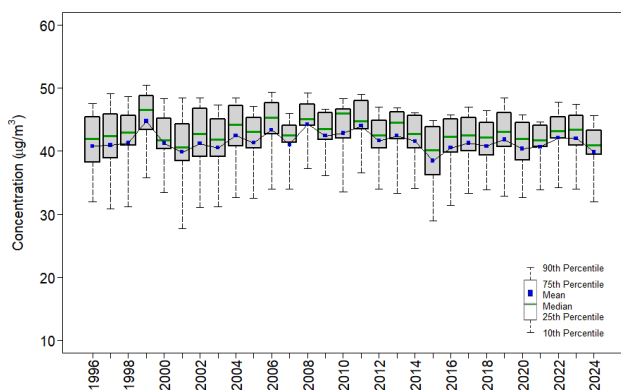
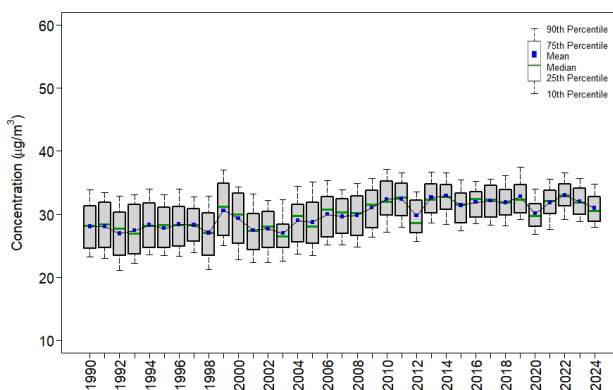


Figure 13. Trends in First Quarter Mean O₃ Concentrations
Western Reference Sites



Eastern Reference Sites



Changes in 3-Year Average First Quarter Concentrations

As shown in Table 1 and Table 2, three-year averages of quarterly mean concentrations of total NO₃⁻, NH₄⁺, SO₂, and SO₄²⁻ were reduced over the period 1990–1992 through 2022–2024 for eastern reference sites and 1996–1998 through 2022–2024 for western reference sites. O₃ concentrations increased at eastern sites and showed a one percent change at western reference sites. Ca²⁺, K⁺, Mg²⁺, and Na⁺ levels declined at eastern sites from 2004–2006 through 2022–2024. Cl⁻ values increased. At western sites, Cl⁻ and base cation concentrations, except for K⁺, increased.

Table 1. Eastern Reference Sites: 3-Year Mean Values (ppb or µg/m³)

Parameter	O ₃ (ppb)	Total NO ₃ ⁻	NH ₄ ⁺	SO ₂	SO ₄ ²⁻	Ca ²⁺	K ⁺	Mg ²⁺	Na ⁺	Cl ⁻
1990–1992	28	3.3	1.5	12.6	3.6					
2004–2006						0.21	0.06	0.04	0.18	0.09
2022–2024	32	1.6	0.5	0.6	0.8	0.20	0.06	0.04	0.16	0.13
Percent Change	15	-52	-68	-95	-77	-5	-3	-9	-8	49

Note: Ozone concentrations are given as ppb. Concentrations for all other parameters are in µg/m³.

Table 2. Western Reference Sites: 3-Year Mean Values (ppb or $\mu\text{g}/\text{m}^3$)

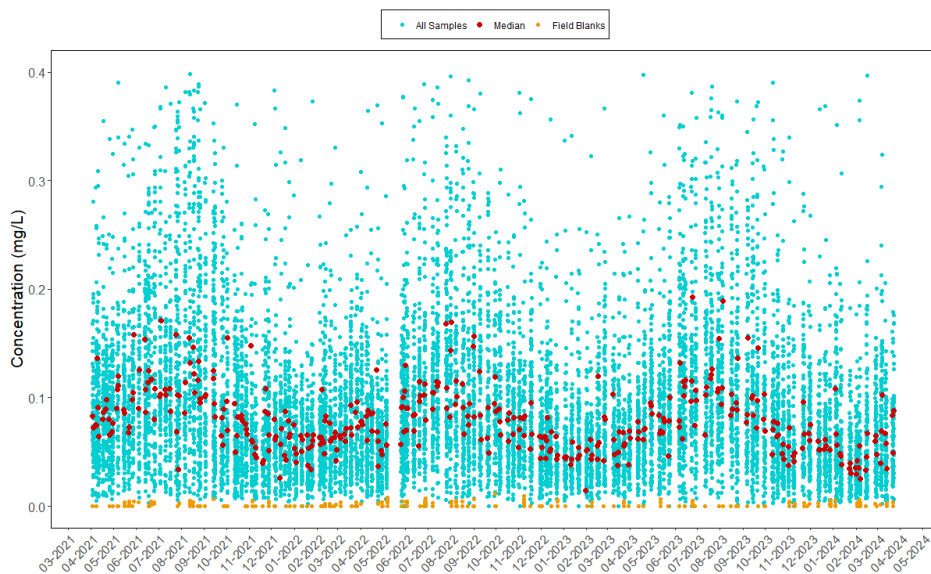
Parameter	O ₃ (ppb)	Total NO ₃ ⁻	NH ₄ ⁺	SO ₂	SO ₄ ²⁻	Ca ²⁺	K ⁺	Mg ²⁺	Na ⁺	Cl ⁻
1996–1998	41	0.8	0.2	0.6	0.6					
2004–2006						0.10	0.02	0.02	0.07	0.04
2022–2024	41	0.4	0.1	0.2	0.3	0.15	0.02	0.02	0.07	0.07
Percent Change	1	-50	-54	-69	-53	41	-3	8	14	96

Note: Ozone concentrations are given as ppb. Concentrations for all other parameters are in $\mu\text{g}/\text{m}^3$.

Time Series of Laboratory Analysis Parameters for All Sites

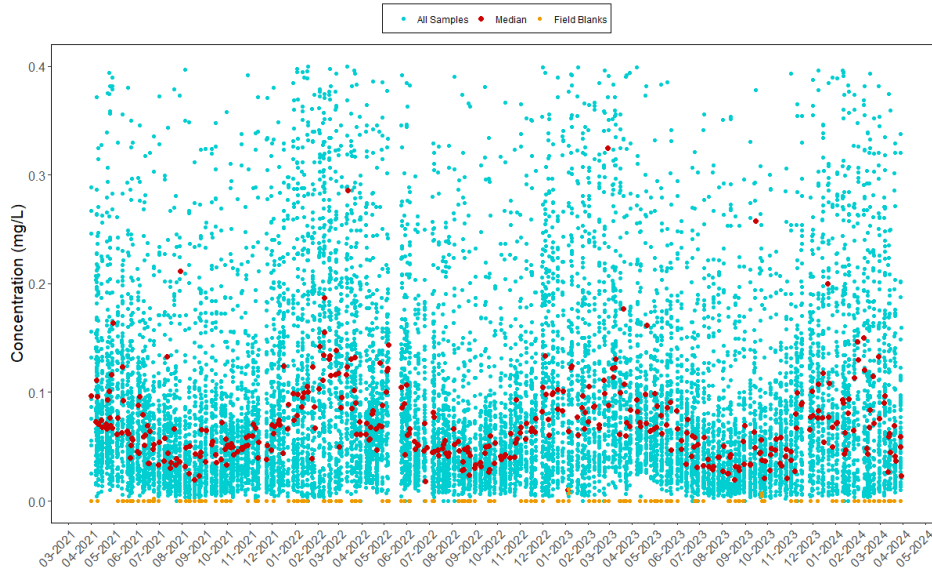
Figures 14 through 24 give time series of laboratory-analyzed concentrations of field samples and field blanks in milligrams per liter (mg/L) of 11 parameters from second quarter 2021 through first quarter 2024. These figures provide indications of potential issues with concentration measurements relative to detection and reporting limits.

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



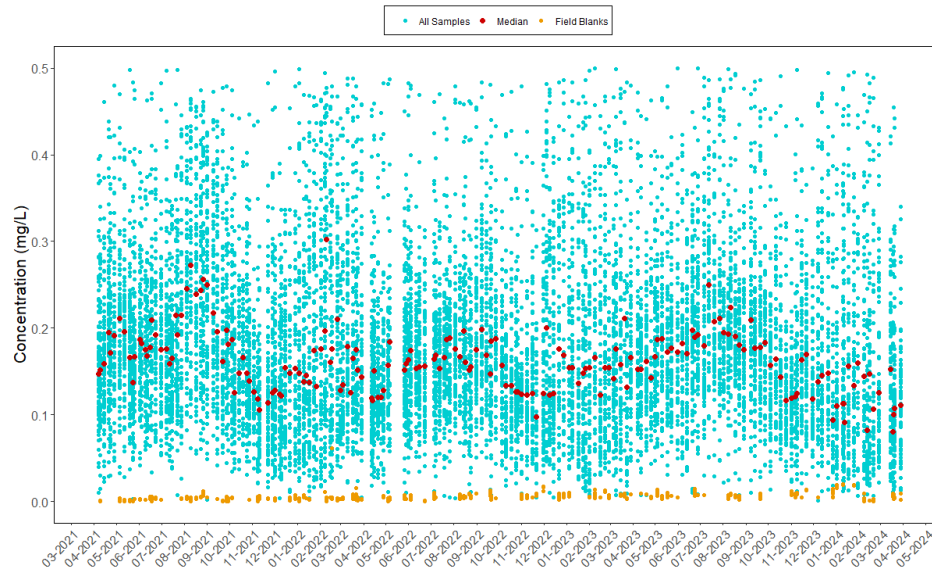
Note: Nominal reporting limit is 0.008 mg/L

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



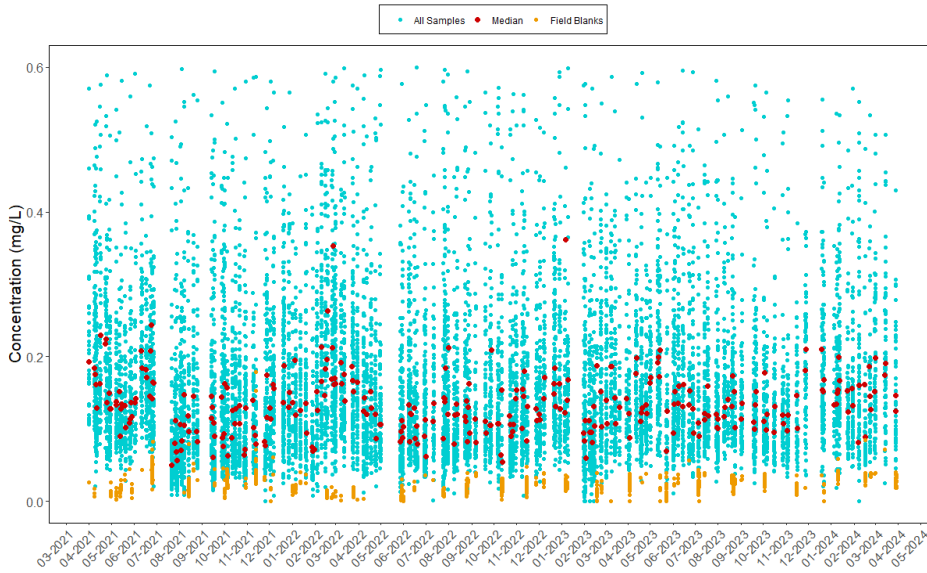
Note: Nominal reporting limit is 0.008 mg/L

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



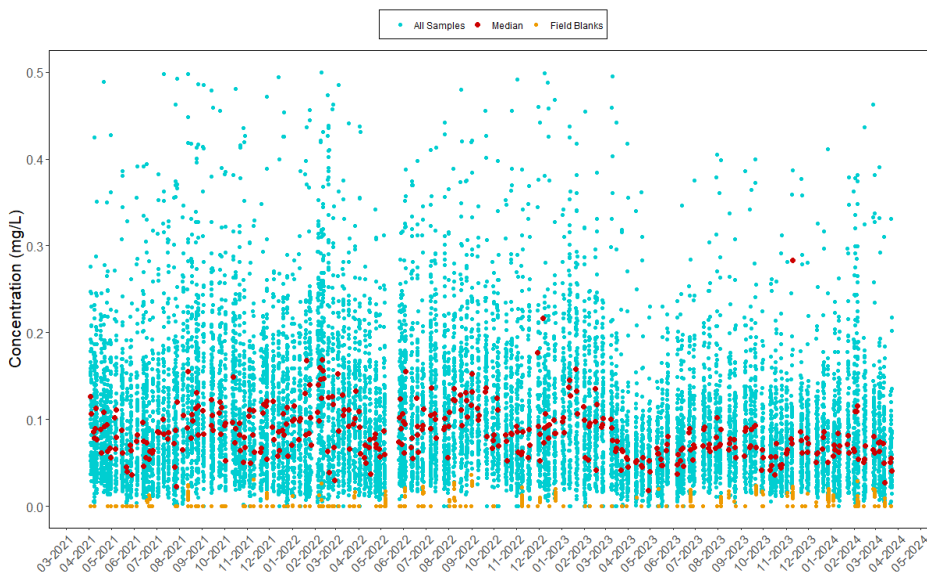
Note: Nominal reporting limit is 0.020 mg/L

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



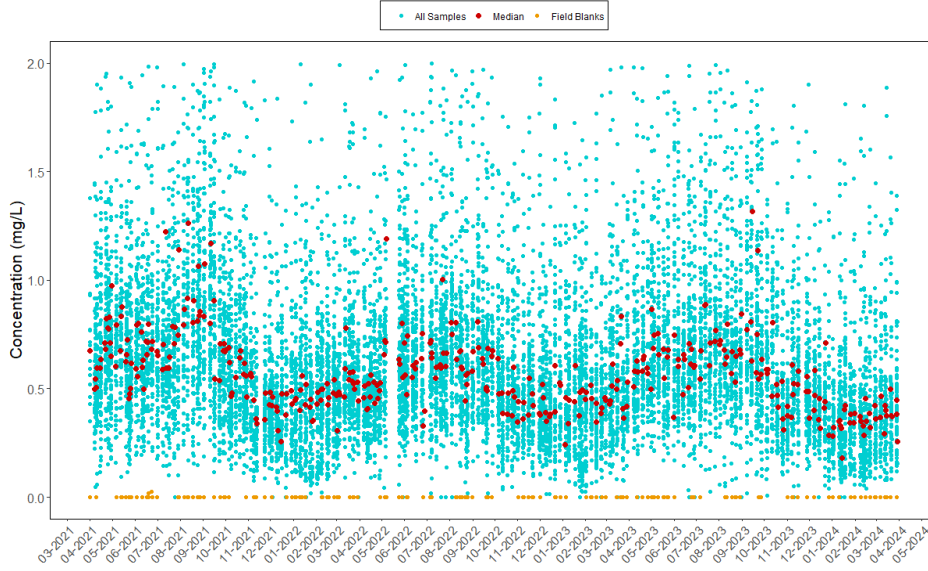
Note: Nominal reporting limit is 0.040 mg/L

Figure 18. Concentrations of SO₄²⁻ from Nylon Filters



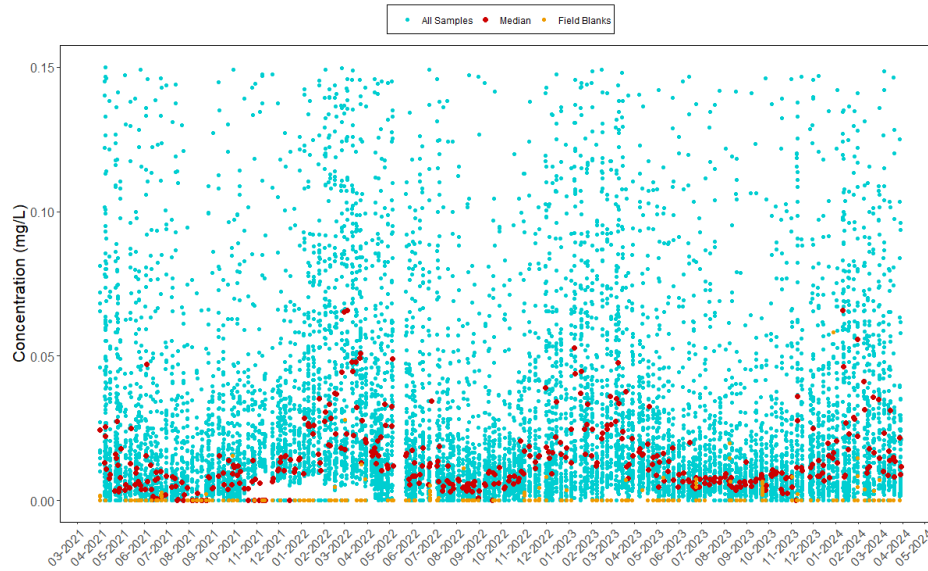
Note: Nominal reporting limit is 0.040 mg/L

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



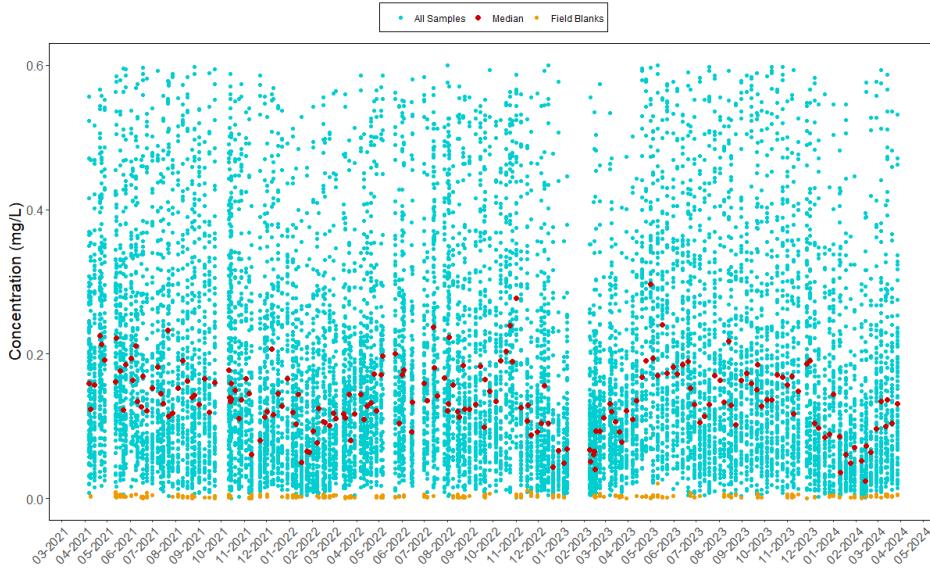
Note: Nominal reporting limit is 0.040 mg/L

Figure 20. Concentrations of Cl^- from Teflon Filters



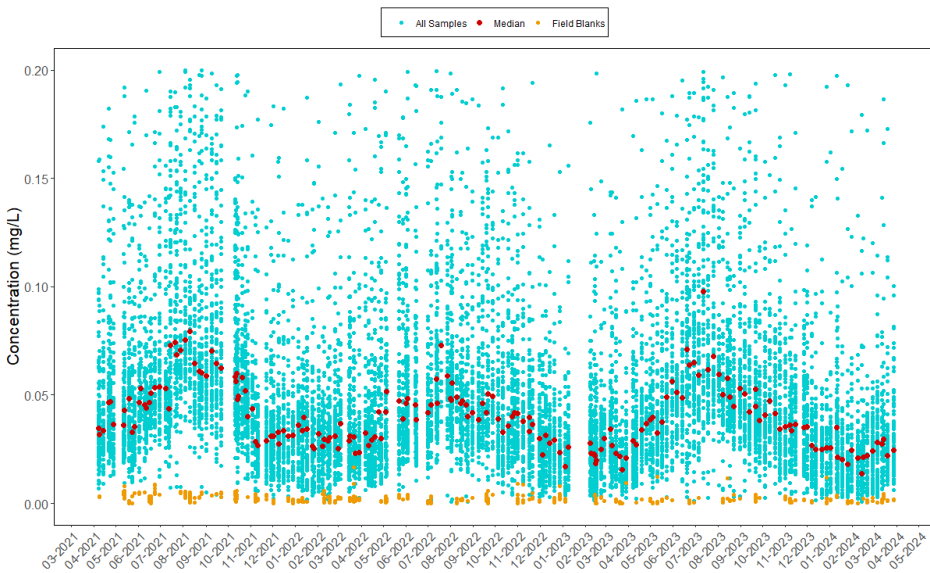
Note: Nominal reporting limit is 0.020 mg/L

Figure 21. Concentrations of Ca²⁺ from Teflon Filters



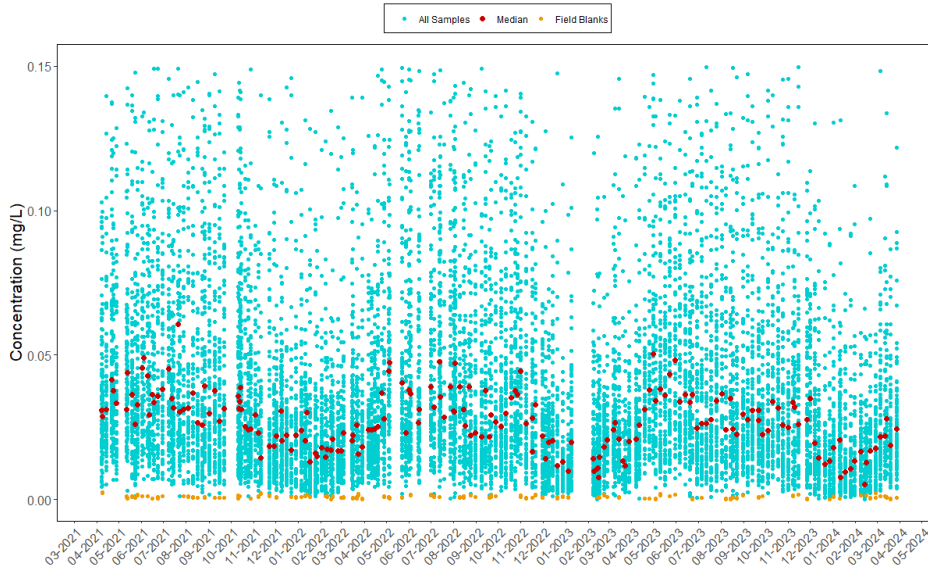
Note: Nominal reporting limit is 0.006 mg/L

Figure 22. Concentrations of K⁺ from Teflon Filters



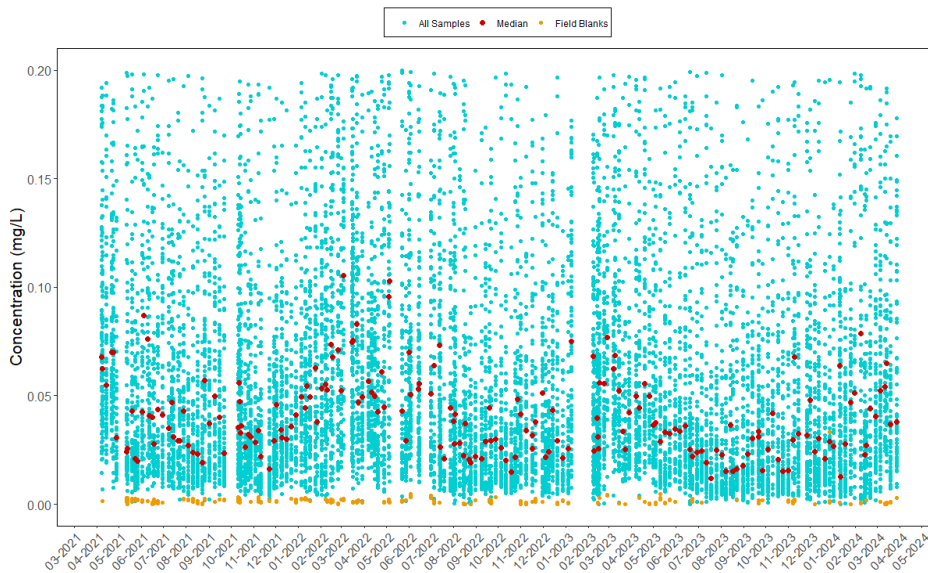
Note: Nominal reporting limit is 0.006 mg/L

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.

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

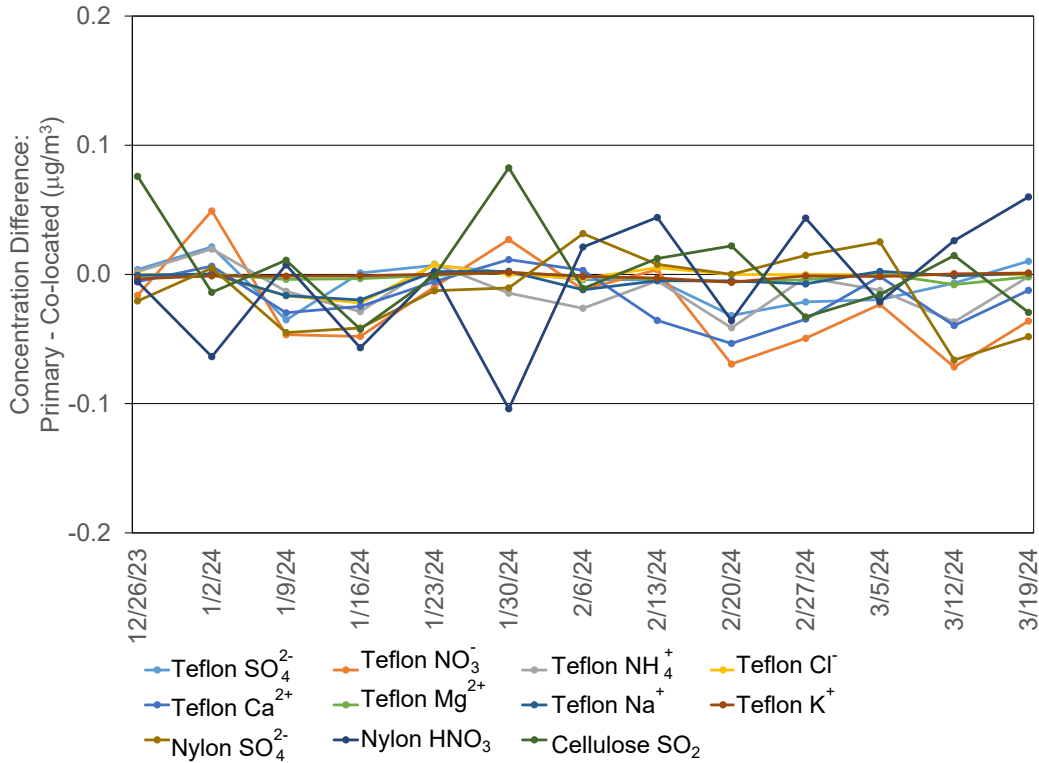
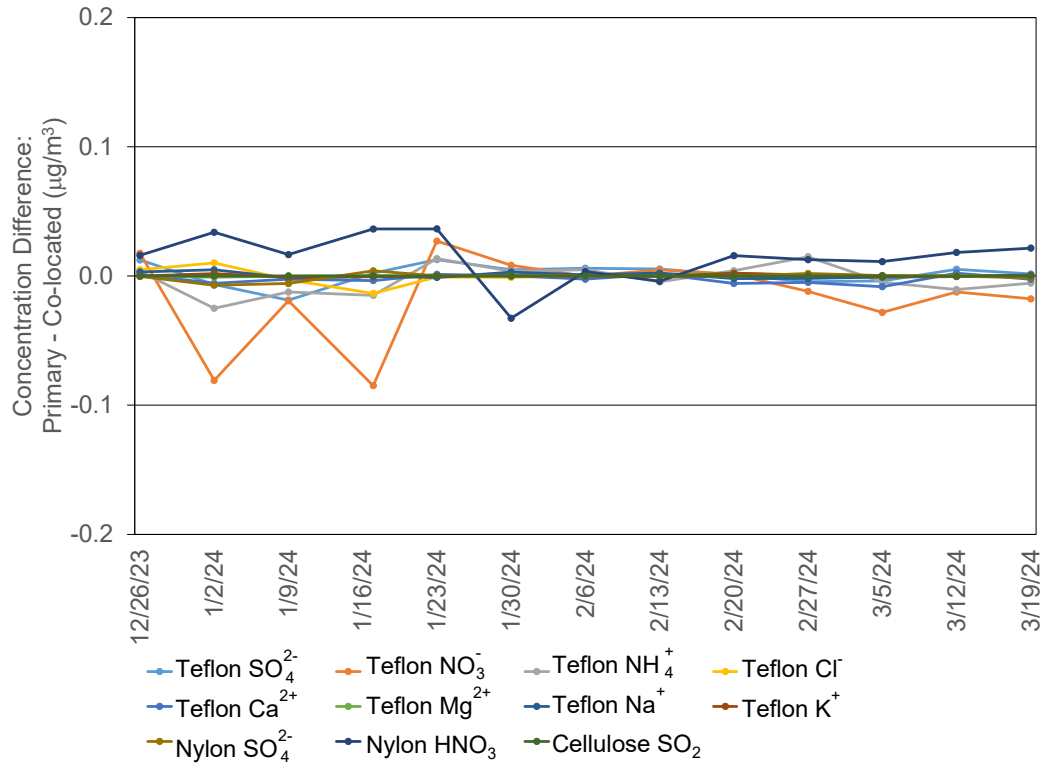


Figure 26. Time Series of Filter Concentration Differences between ROM406 and ROM206, CO



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 2024. The MARPD values met the 20 percent criterion.

Table 3. Precision (MARPD) for Co-located Filter Pack Data during First Quarter 2024

	Total NO ₃ ⁻	HNO ₃	NO ₃ ⁻	NH ₄ ⁺	SO ₂	SO ₄ ²⁻	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Cl ⁻
MCK131/231, KY											
\bar{X} (μg/m ³)	1.67	0.70	0.98	0.47	0.56	0.81	0.20	0.03	0.08	0.05	0.06
\bar{Y} (μg/m ³)	1.70	0.70	1.00	0.48	0.56	0.82	0.22	0.03	0.09	0.05	0.07
MAD	0.04	0.04	0.03	0.02	0.03	0.01	0.02	0.00	0.01	0.00	0.00
MARPD	2.47	5.27	5.32	3.77	5.40	1.62	10.07	8.59	6.80	3.63	4.34
ROM406/206, CO											
\bar{X} (μg/m ³)	0.39	0.24	0.15	0.09		0.22	0.07	0.01	0.03	0.01	0.03
\bar{Y} (μg/m ³)	0.39	0.23	0.17	0.09	0.14	0.21	0.07	0.01	0.03	0.01	0.03
MAD	0.03	0.03	0.03	0.01		0.01	0.00	0.00	0.00	0.00	0.00
MARPD	6.99	12.46	18.86	13.26		5.66	8.73	9.10	8.88	7.93	9.55

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 of Weeks having a Successful Filter Pack Deployment during First Quarter 2024

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	Comments
CAT175, NY	69.2	69.2	69.2	69.2	69.2	69.2	69.2	69.2	This solar powered site experienced a long-term power failure due to weather and subsequently needed battery replacement.
CVL151, MS	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	After a power failure, the site mass flow controller required a service visit which was delayed by road conditions. Two samples were affected.
GLR468, MT	76.9	76.9	76.9	76.9	76.9	76.9	76.9	N/A	There was one 2-week sample this quarter. The site operator noted that one sample was received too late to install and one sampled filter pack was lost in the mail.
KEF112, PA	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	One sample failed a leak check, and another was affected by power failure.
MKG113, PA	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	The site operator suffered a broken foot in December 2023 and was unable to perform duties through first quarter 2024. A calibrator technician visited the site on 3/24 and installed a filter pack.
SAN189, NE	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	There were three 2-week filter packs during the quarter. Another sample was not properly seated during sampling.
SHE604, WY	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	Two samples were invalidated for suspect data.
VOY413, MN	76.9	76.9	76.9	76.9	76.9	76.9	76.9	N/A	There were two 3-week samples during the quarter.
YOS404, CA	84.6	84.6	84.6	84.6	84.6	84.6	84.6	N/A	There were two 2-week samples during the quarter.

Precision of Ozone Concentrations

Time series of co-located hourly O₃ concentration differences for first quarter 2024 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 Difference in Co-located O₃ Concentrations for MCK131/231, KY

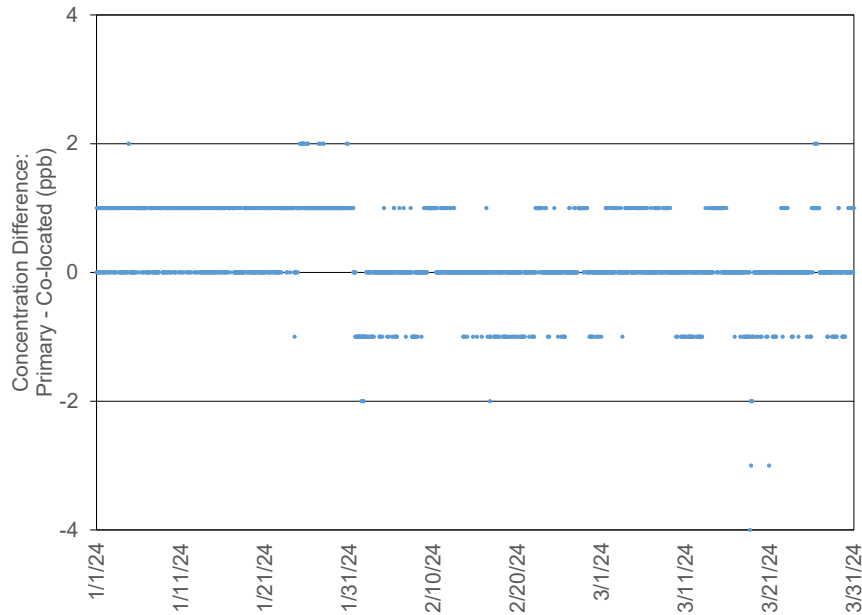


Figure 28. Time Series of the Difference in Co-located O₃ Concentrations for ROM406/206, CO

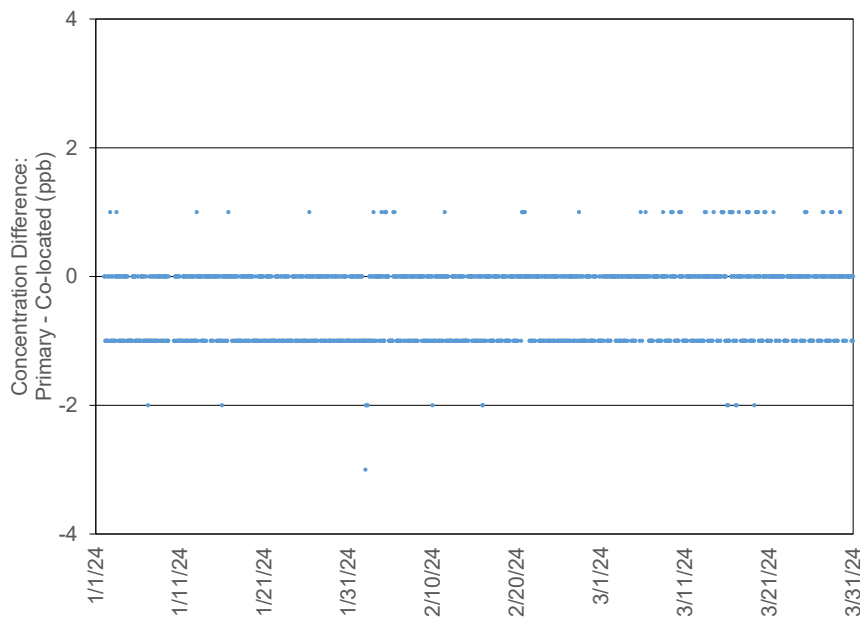


Table 5 gives MARPD data for O₃ data measured at the two co-located sites.

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

Site Pair	Quarter	Start Date	MARPD	Records
MCK131/231, KY				
	2	4/1/2023	1.7	2036
	3	7/1/2023	3.6	1912
	4	10/1/2023	2.2	2031
	1	1/1/2024	1.7	2068
ROM406/206, CO				
	2	4/1/2023	1.6	2052
	3	7/1/2023	1.6	2038
	4	10/1/2023	1.2	2072
	1	1/1/2024	1.1	2054

Completeness for Ozone 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.

Tables 6. Sites with less than 90 Percent Data Completeness for DM8A Concentrations during First Quarter 2024

Site ID	Percent Completeness	Comments
VOY413, MN	35	The site analyzer began to malfunction in October and was replaced in December. During the semi-annual visit in February 2024 the compressor and pump were found plugged into the shelter wall outlet and were pressurizing the analyzer. Data were invalidated up to the semi-annual visit in February.
ANA115, MI	82	The data logger required replacement following a power failure. Data were affected from mid to late January.
QAK172, OH	82	The data logger malfunctioned and required replacement. Data were affected from mid to late January.
ALC188, TX	86	The data logger malfunctioned, affecting data from early to mid-January.
SUM156, FL	86	Occasional QC failures occurred in late January, early February, and early March. In addition, there was a power failure in late March.
ESP127, TN	87	The data logger malfunctioned and required replacement. Data were affected from mid to late January.
CHE185, OK	88	The ozone channel of the data logger was down between the February 20 and February 27 site visits.
GRT434, WY	89	O ₃ precision checks were outside acceptance criteria due to a failing pump. This caused data to be invalid from 2/7-2/11/24 and 2/19-2/21/24.
BVL130, IL	89	The site analyzer pump failed in late January and was replaced early February.

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 2024	Q2 2023 – Q1 2024	Comments
ALC188, TX	89	96	The data logger malfunctioned, resulting in invalid data from early to mid-January.
ANA115, MI	83	95	The data logger required replacement following a power failure. Data were affected from mid to late January.
QAK172, OH	85	93	The data logger malfunctioned and required replacement. Data were affected from mid to late January.
SUM156, FL	87	93	Occasional QC failures in late January, early February, and early March resulted in invalid data. In addition, there was a power failure in late March.
VOY413, MN	35	60	The site analyzer began to malfunction in October and was replaced in December. Data were invalidated until the semi-annual visit in February 2024.

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

Figures 29 through 33 show a comparison of weekly average continuous NO_y measurements with weekly filter pack total NO₃⁻ concentrations collected at the five 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 five sites are shown in Table 8. Ratios of NO_y to total NO₃⁻ varied from 4.27 at GRS420, TN to 10.76 at PND165, WY.

Table 8. Summary of Total NO₃⁻/NO_y Measurements for Q1 2024

Site ID	Elevation	Total NO ₃ ⁻ (ppb)	NO _y (ppb)	Ratio
DUK008, NC	164*	0.48	2.84	5.74
BVL130, IL	213	0.95	4.18	4.51
GRS420, TN	793	0.41	1.56	4.27
PND165, WY	2386	0.08	0.78	10.76
ROM206, CO	2742	0.12	0.85	6.73

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 NO₃⁻ Concentrations

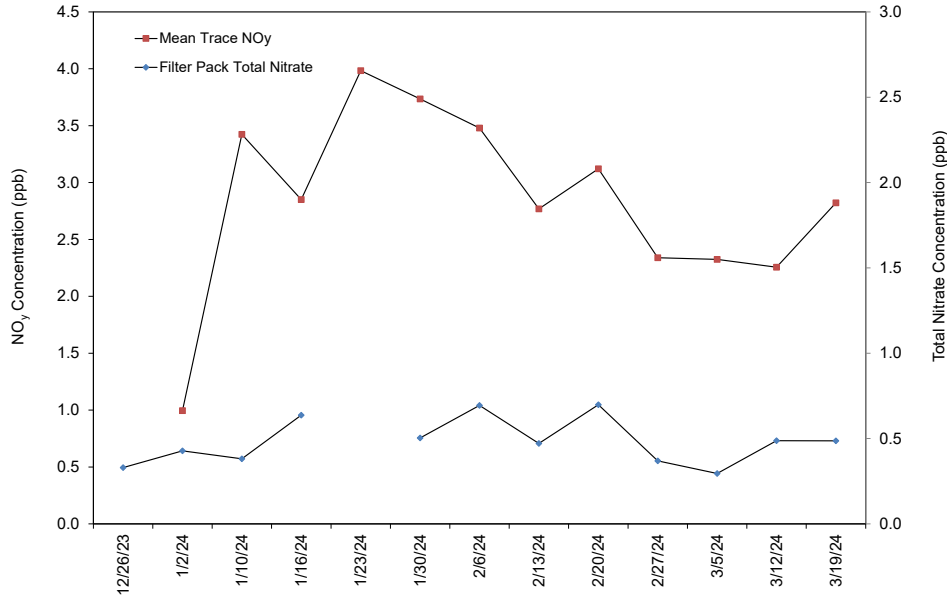


Figure 30. Comparison of BVL130 Weekly Mean NO_y and Total NO₃⁻ Concentrations

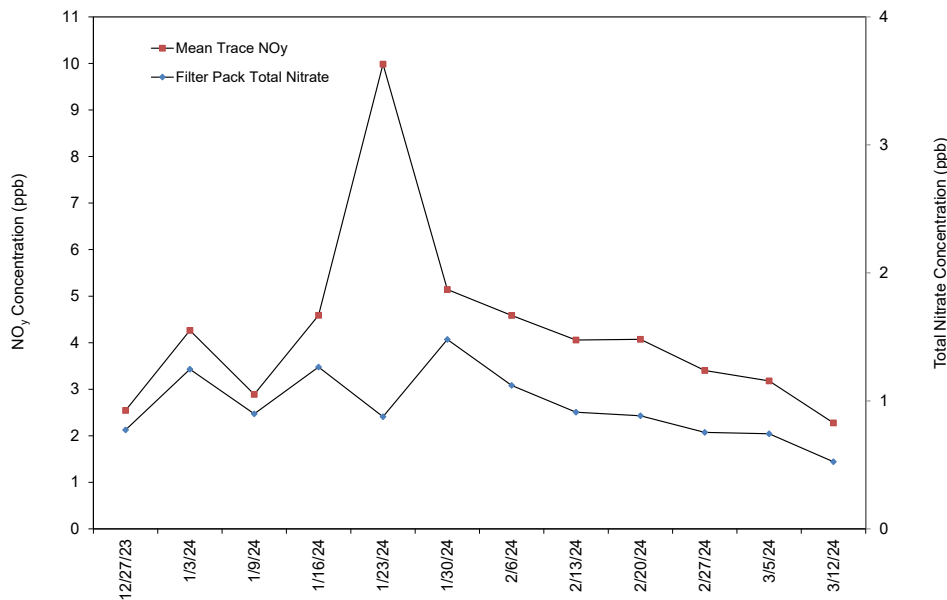


Figure 31. Comparison of GRS420 Weekly Mean NO_y and Total NO₃ Concentrations

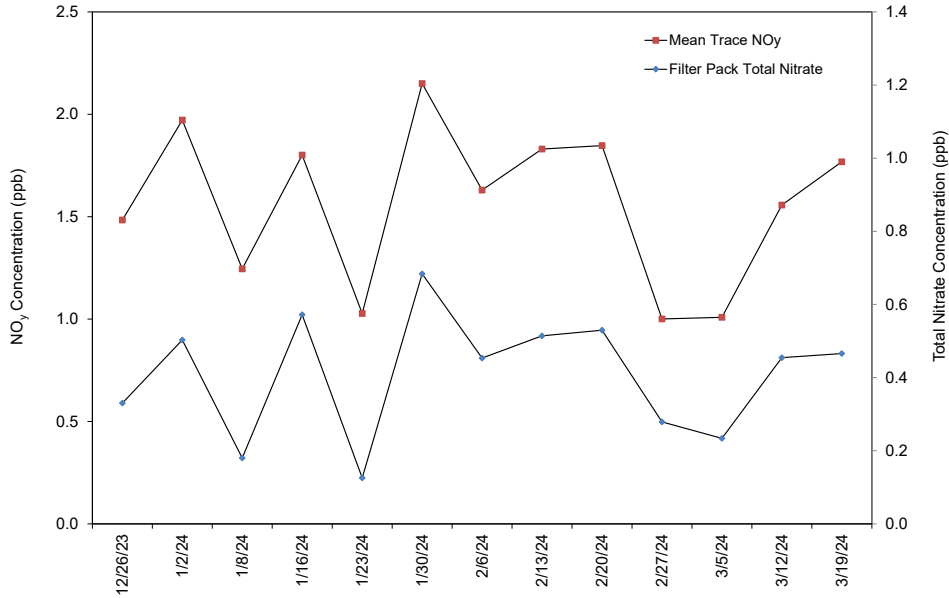


Figure 32. Comparison of PND165 Weekly Mean NO_y and Total NO₃ Concentrations

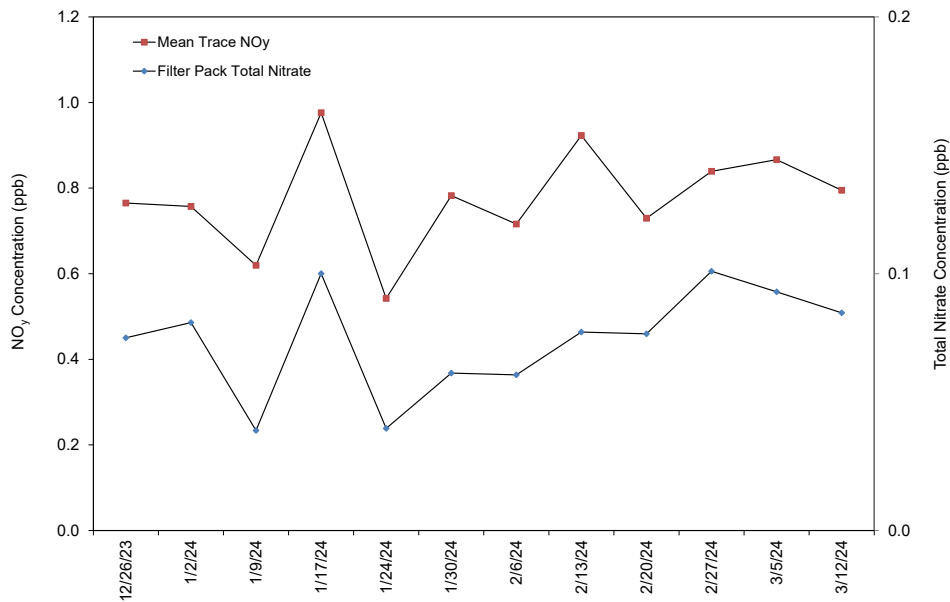
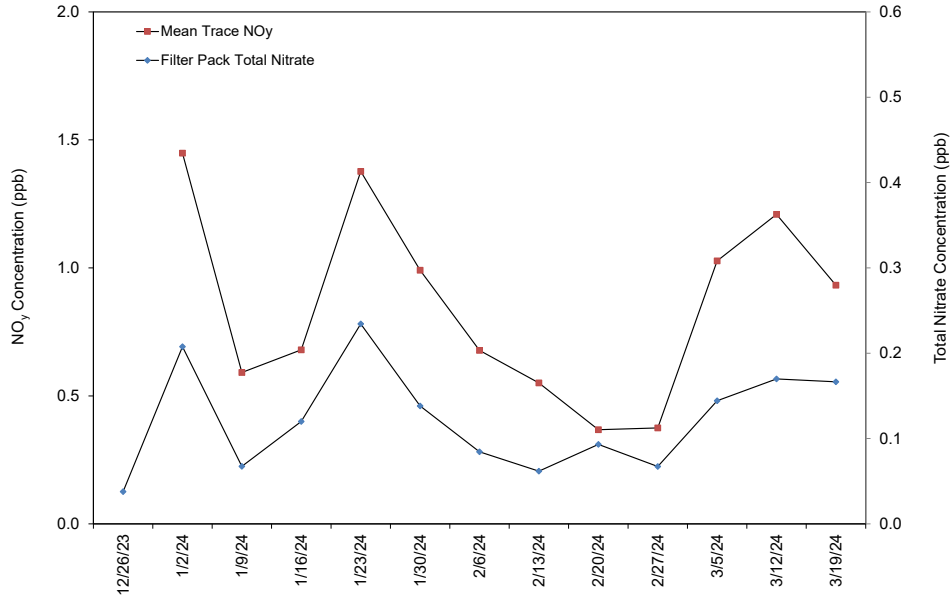


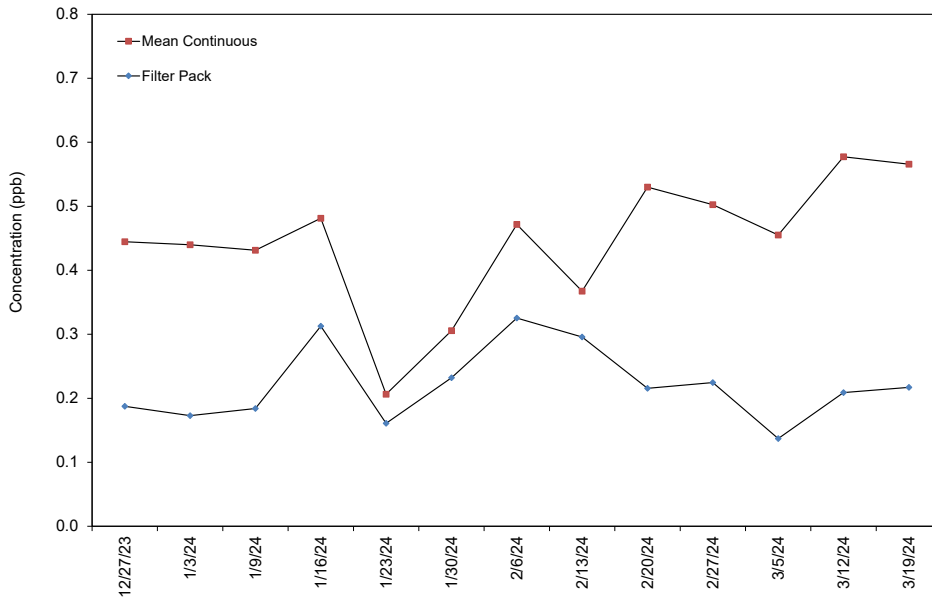
Figure 33. Comparison of ROM206 Weekly Mean NO_y and Total NO₃ Concentrations



Filter Pack and Continuous Trace-level Gas Sulfur Dioxide Concentrations

Figure 34 provides a diagram that compare weekly filter pack SO₂ concentrations with continuous trace-level gas data measured at BVL130. The continuously measured trace-level concentrations were higher than filter pack concentrations.

Figure 34. Comparison of BVL130 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 2024. The average for second quarter 2023 through first quarter 2024 for each of the sites is included for reference.

Table 9. Percent Data Completeness for Continuous trace-level Gas Measurements

Site ID	Parameter	Q1 2024	Q2 2023– Q1 2024	Comments
BVL130, IL	CO	85	91	Some data were invalidated due to calibration drift in January. The analyzer was recalibrated 1/22/24.
	NO	92	89	
	NOY	92	88	
	NOYDIF	92	88	
	SO2_GA	94	88	
CHC432, NM	NO	98	96	
	NOX	98	96	
	NOXDIF	98	96	
DUK008, NC	HNO3	83	82	The analyzer was stuck running a ZSP on the zero point, affecting data from 1/1/24 to 1/8/24. Data were invalidated during periods in late January when the shelter temperature criterion was exceeded. Lastly, data associated with a QC failure on 3/13/24 were invalidated.
	NH3	84	82	
	NO	83	82	
	NO2_TRUE	83	82	
	NOX_TRUE	83	82	
	NOY	84	82	
	NOY_MINUS	83	82	
	NOYDIF	83	82	
	TNX	84	82	
GRS420, TN	CO	95	91	
	NO	95	86	
	NOY	95	86	
	NOYDIF	92	88	
	SO2_GA	95	92	
PND165, WY	NO	97	92	
	NOY	97	92	
	NOYDIF	97	92	
ROM206, CO	NO	94	89	
	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	Obtained How	Description of Process
CO	Measured	Gas filter correlation
HNO3	Calculated	NOY minus NOY-MINUS
NH	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 convert at 315° Celsius

Reference

WSP USA Environment & Infrastructure Inc. 2024. Clean Air Status and Trends Network (CASTNET) First Quarter 2024 Quality Assurance Report. <https://java.epa.gov/castnet/documents.do>