Clean Air Status and Trends Network (CASTNET)
Quarterly Data Summary for Third Quarter 2021 (July through September)

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 third 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 third 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 Third Quarter 2021 Quality Assurance Report (Wood, 2021).

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

Figure 1 shows fourth highest daily maximum 8-hour average (DM8A) O_3 concentrations measured through third quarter 2021. Ten western sites and two eastern sites exceeded the 0.070 parts per million (ppm) National Ambient Air Quality Standard for O_3. The western sites include a new site at Carlsbad Caverns National Park, NM (CAV436) that began CASTNET ozone measurements on March 4, 2021.

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 third quarter. Trends in quarterly mean filter pack and O_3 concentrations are shown using box plots in Figures 2 through 13.

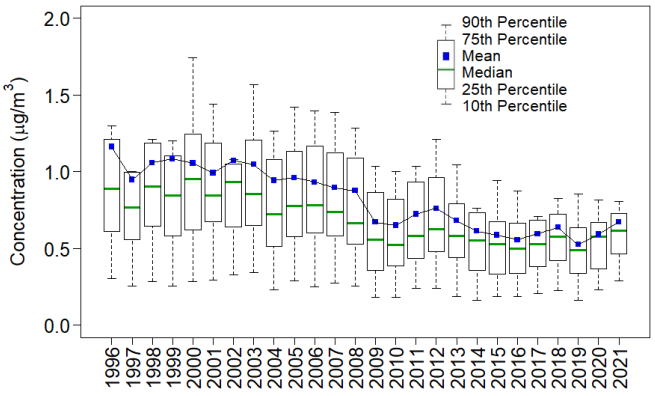
Third Quarter Concentrations

Quarterly mean concentrations for HNO_3, NH_4^+, total NO_3^-, SO_2, SO_4^{2-}, and Na^+ generally showed little change at eastern sites in 2021. Mean concentrations of NO_3^-, Cl^-, Ca^{2+}, and Mg^{2+} at eastern sites decreased while mean concentrations of K^+ increased. Quarterly mean NO_3^-, NH_4^+, SO_2, SO_4^{2-}, Ca^{2+}, K^+, and Mg^{2+} concentrations decreased at western sites in 2021 while HNO_3, total NO_3^-, Cl^-, and Na^+ concentrations increased.

Quarterly O_3 concentrations were analyzed using box plots constructed by averaging all valid hourly O_3 concentrations within third quarter 2021 by site and then averaging those averages for all eastern and western reference sites (Figure 13). The figure shows an increase in quarterly mean O_3 concentrations at eastern and western sites. Quarterly mean O_3 concentrations were higher at the western reference sites than at the eastern sites.

Figure 2. Trends in Third Quarter Mean HNO_3 Concentrations

Western Reference Sites



Eastern Reference Sites

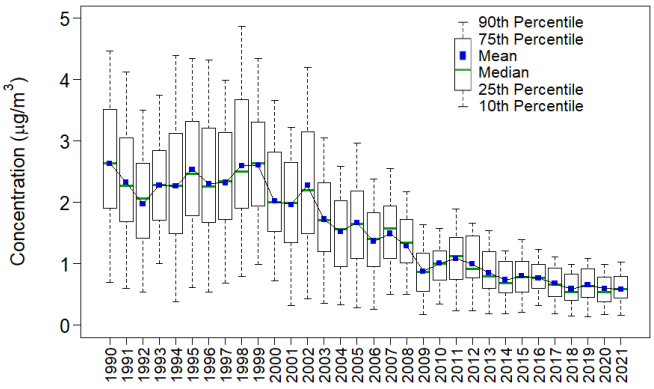


Figure 3. Trends in Third Quarter Mean NO_3^- Concentrations

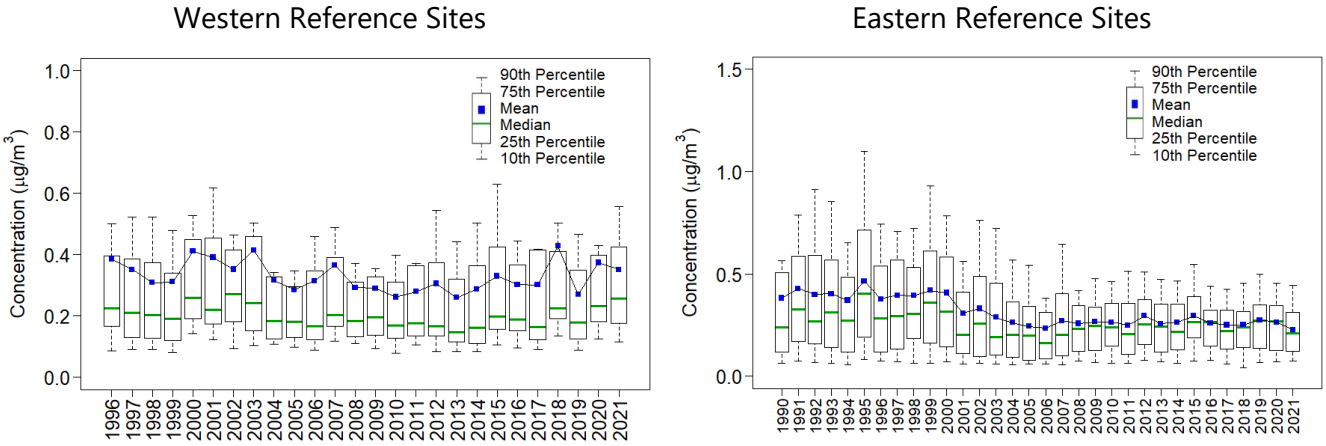


Figure 4. Trends in Third Quarter Mean NH_4^+ Concentrations

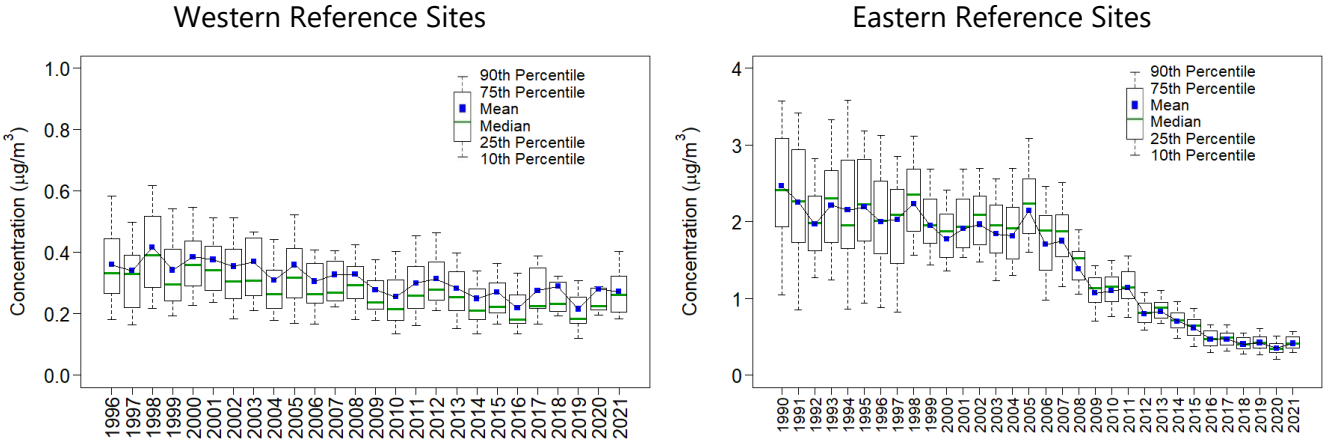


Figure 5. Trends in Third Quarter Mean Total NO_3^- Concentrations

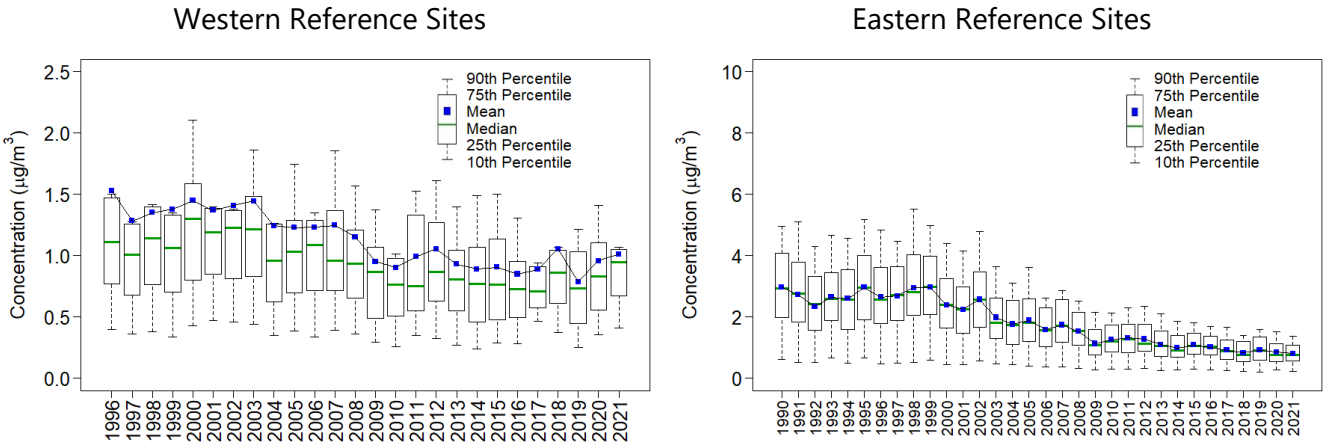


Figure 6. Trends in Third Quarter Mean SO_2 Concentrations

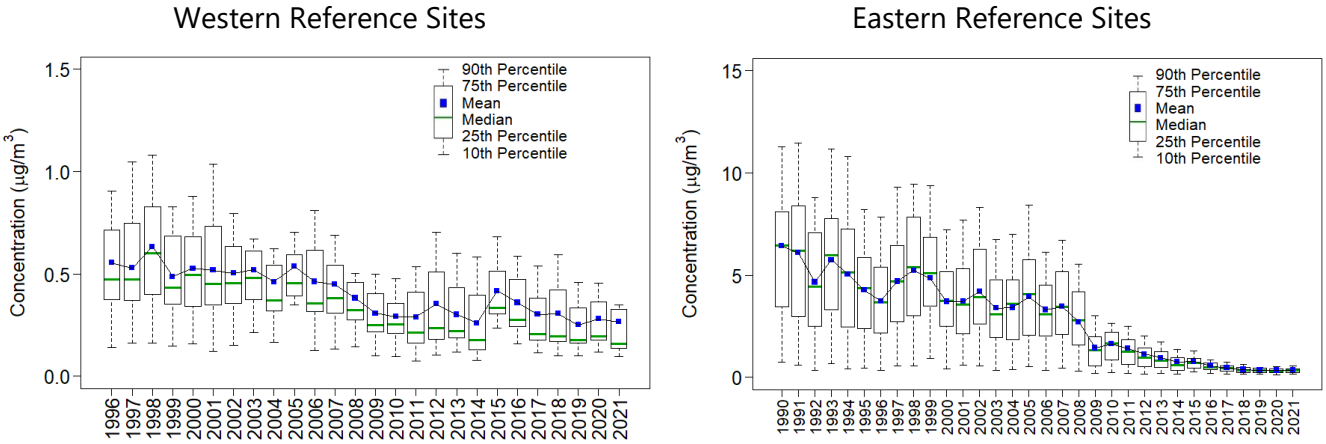


Figure 7. Trends in Third Quarter Mean SO_4^{2-} Concentrations

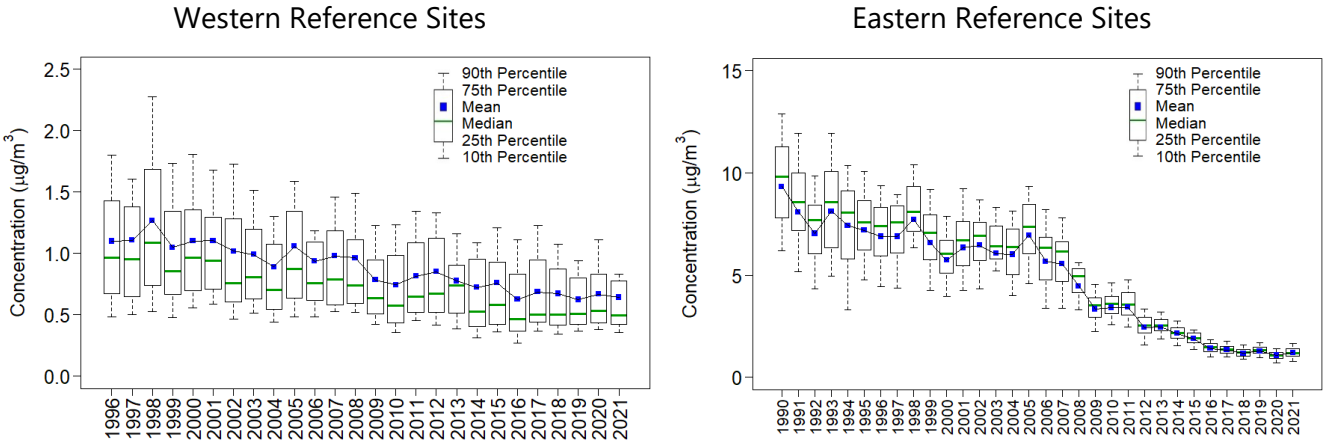


Figure 8. Trends in Third Quarter Mean Cl^- Concentrations

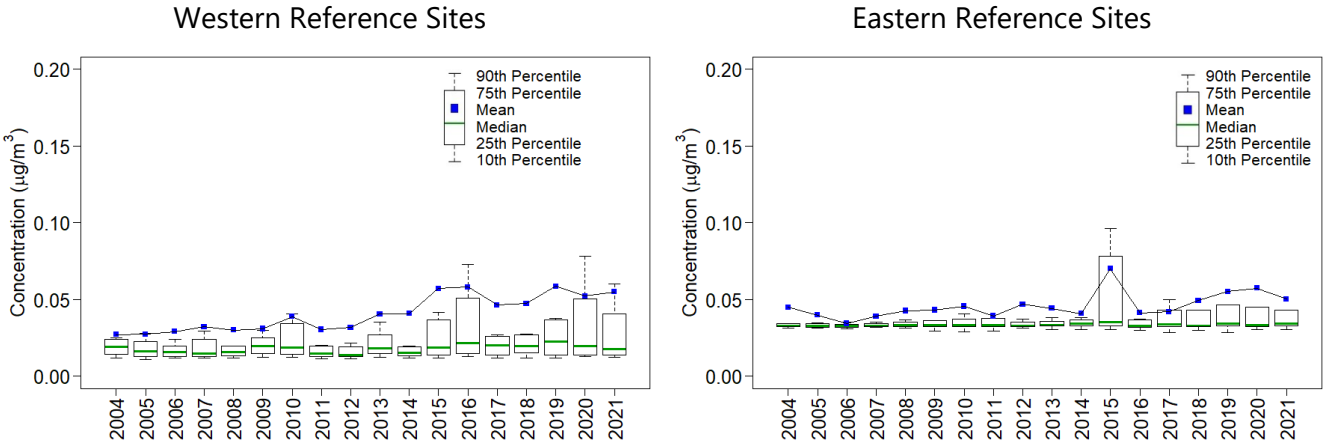


Figure 9. Trends in Third Quarter Mean Ca^{2+} Concentrations

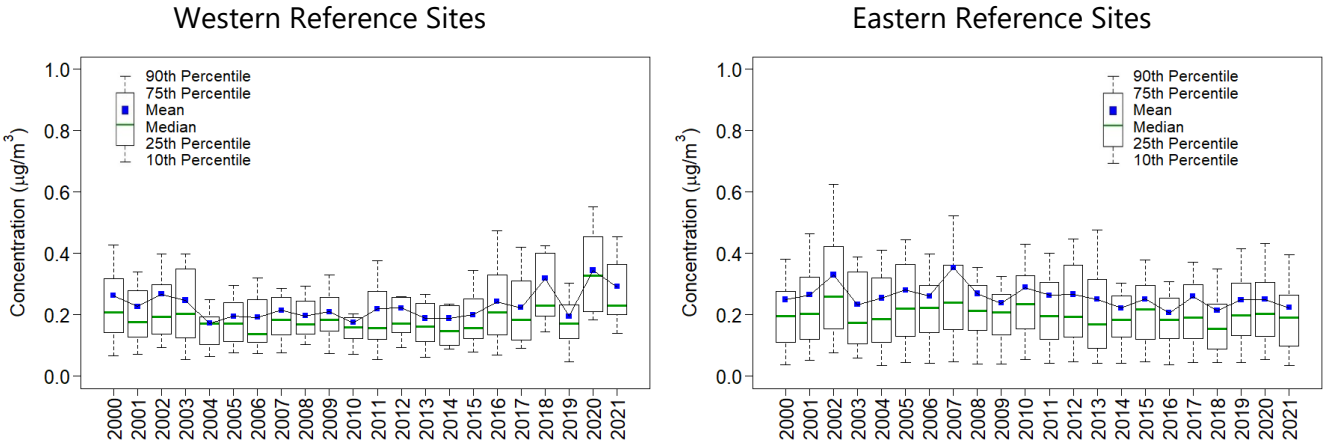


Figure 10. Trends in Third Quarter Mean K^{+} Concentrations

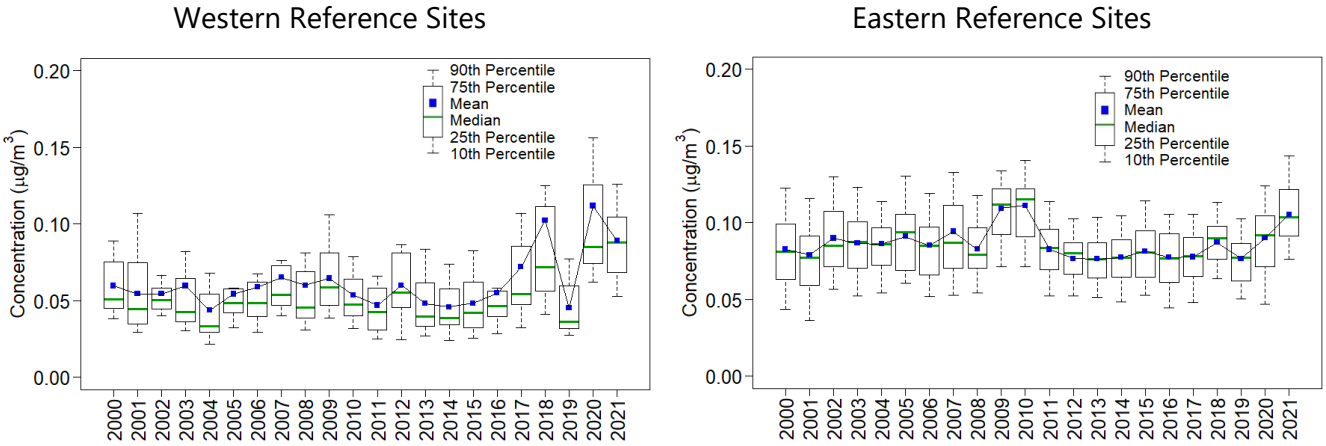


Figure 11. Trends in Third Quarter Mean Mg^{2+} Concentrations

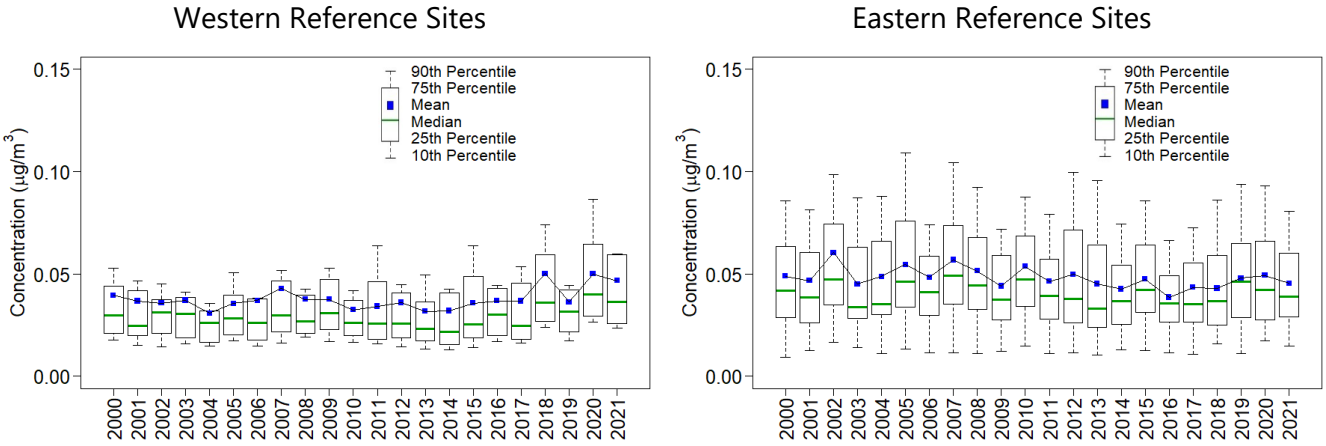


Figure 12. Trends in Third Quarter Mean Na^+ Concentrations

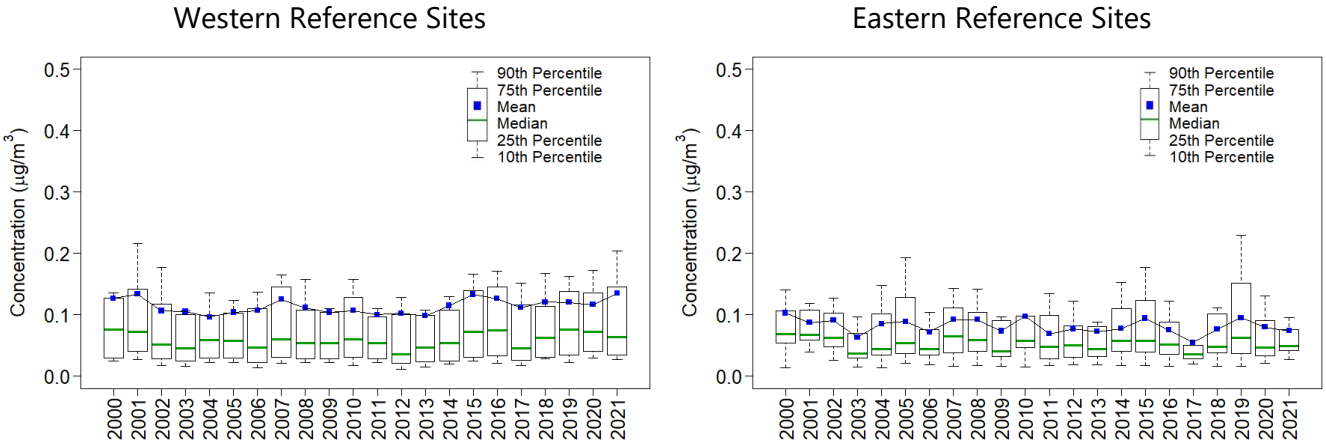
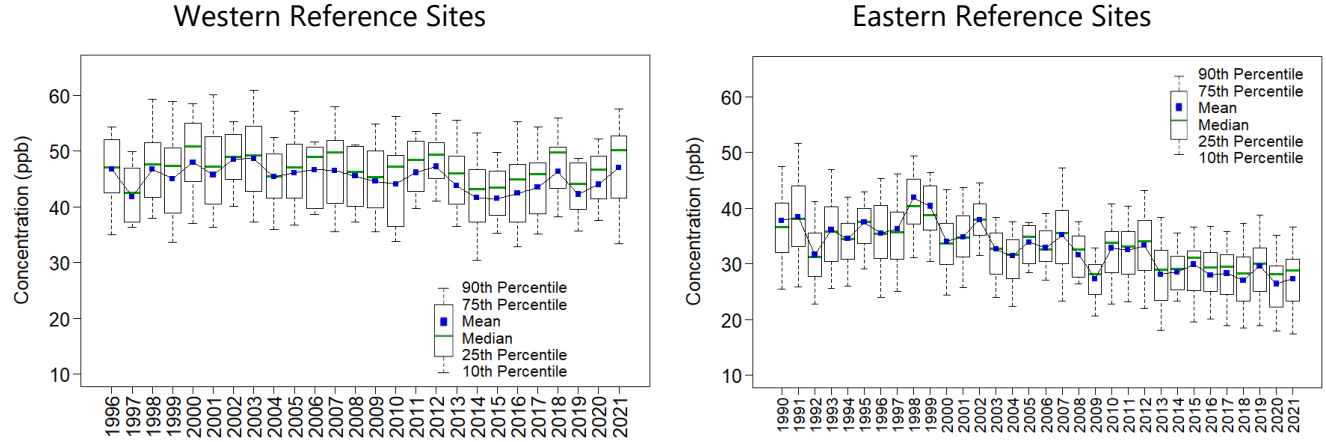


Figure 13. Trends in Third Quarter Mean O_3 Concentrations



Changes in 3-year Average Third Quarter Concentrations

Three-year averages of quarterly mean concentrations of total NO_3^-, NH_4^+, SO_2, SO_4^{2-}, and O_3 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 third quarter concentrations.

Table 1. Eastern Reference Sites: 3-Year Mean Nitrogen, Sulfur, and O_3 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	2.7	2.2	5.7	8.1	36
2019–2021	0.9	0.4	0.3	1.2	28
Percent Change	-68	-82	-94	-86	-23

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

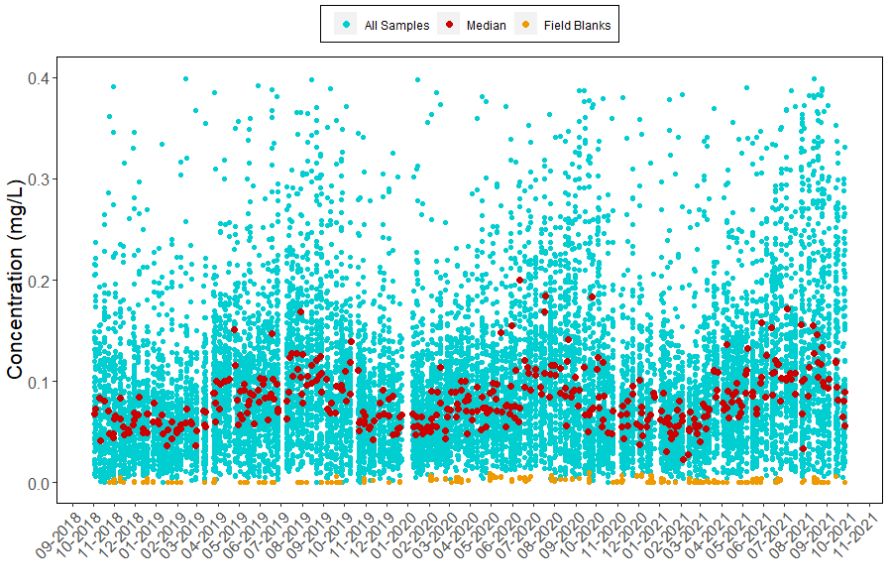
	Total NO_3^- ($\mu g/m^3$)	NH_4^+ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	SO_4^{2-} ($\mu g/m^3$)	O_3 (ppb)
1996–1998	1.4	0.4	0.6	1.2	45
2019–2021	0.9	0.3	0.3	0.6	44
Percent Change	-34	-31	-54	-44	-1

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

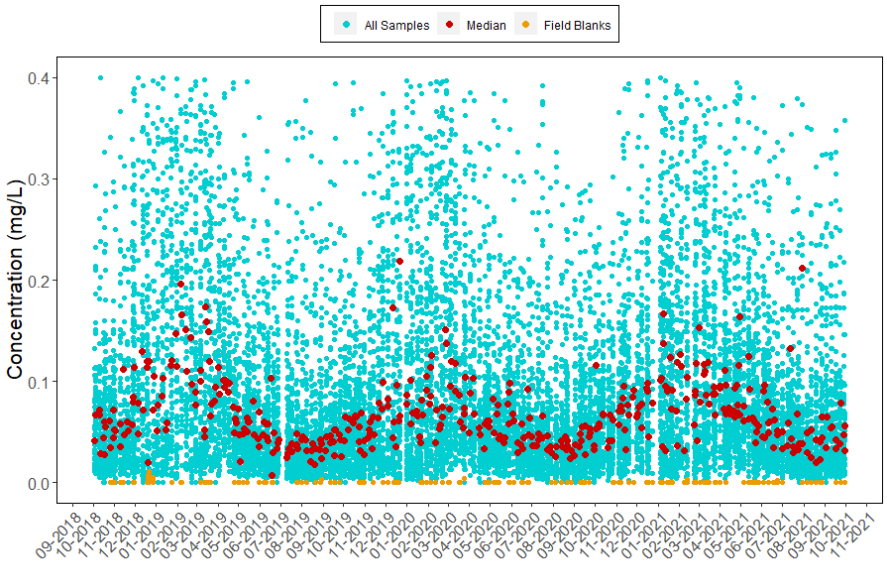
Figure 17 shows unusual results from the cellulose filter field blanks at end of second quarter 2021. The eluent from Wood's established supplier was not available. Therefore, another eluent was purchased. Prior to use, the laboratory tested and approved the replacement eluent. Reanalysis of field blanks confirmed that results with the replacement eluent were below reporting limits. Results for reanalysis of field samples indicate the initial analyses were comparable within CASTNET sample replicate criteria.

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



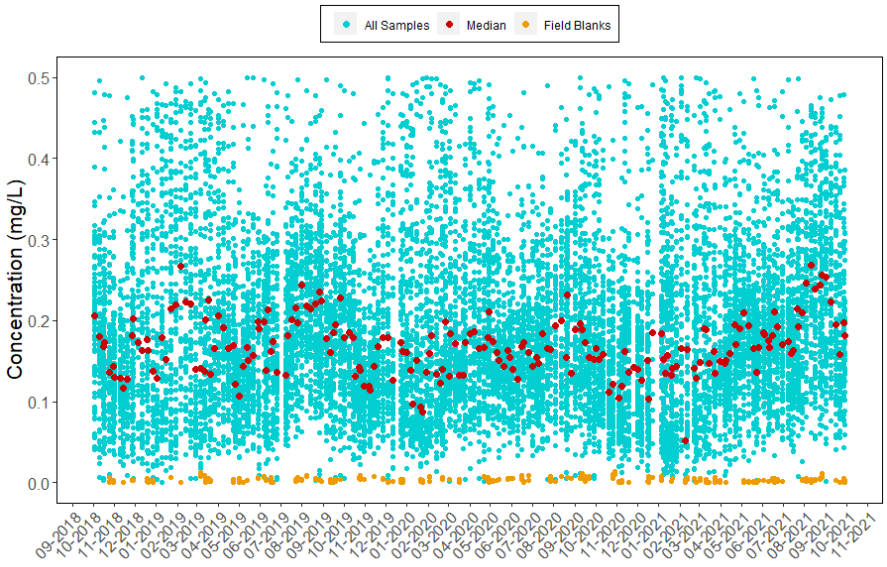
Note: Nominal reporting limit is 0.008 mg/L.

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



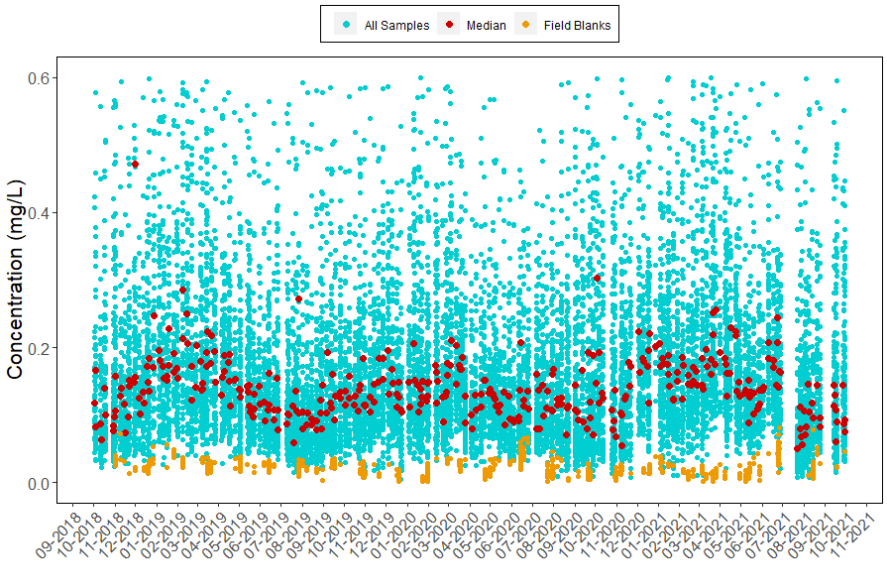
Note: Nominal reporting limit is 0.008 mg/L.

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



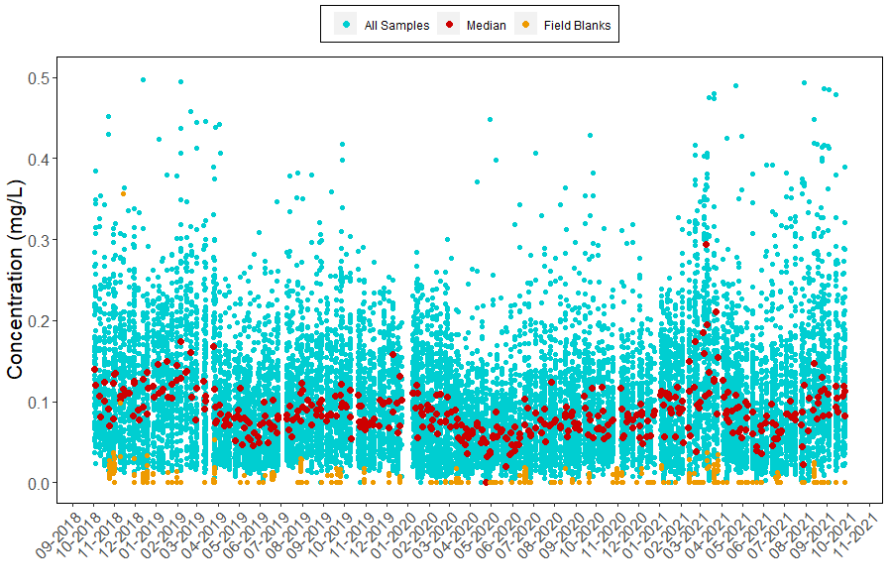
Note: Nominal reporting limit is 0.020 mg/L.

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



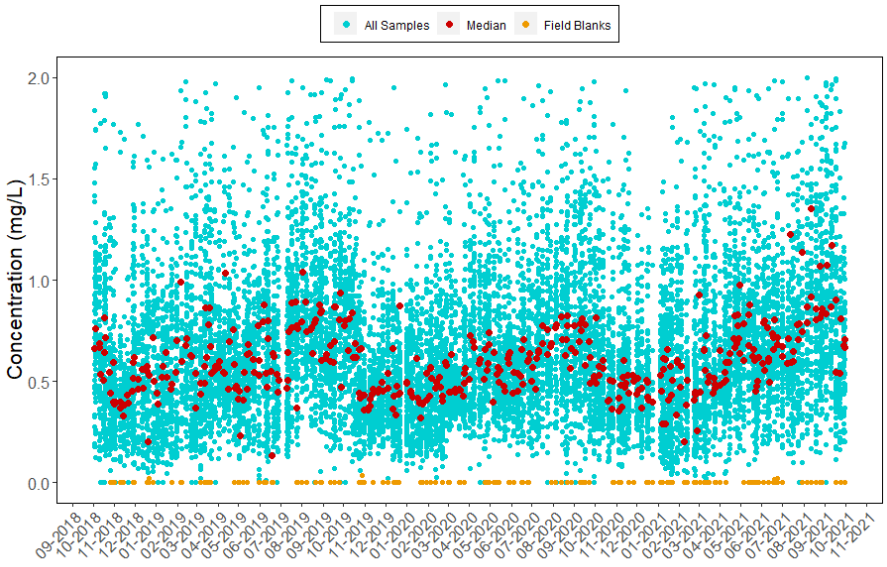
Note: Nominal reporting limit is 0.040 mg/L.

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



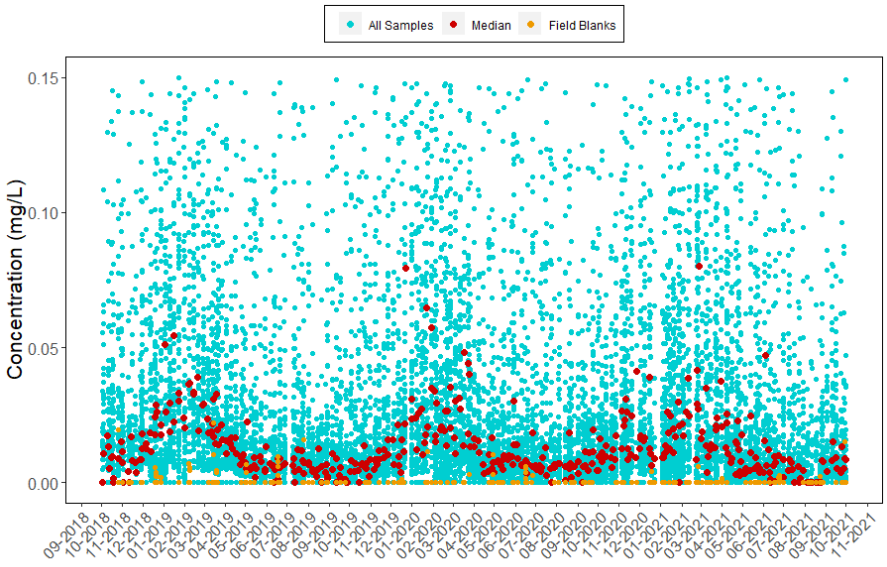
Note: Nominal reporting limit is 0.040 mg/L.

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



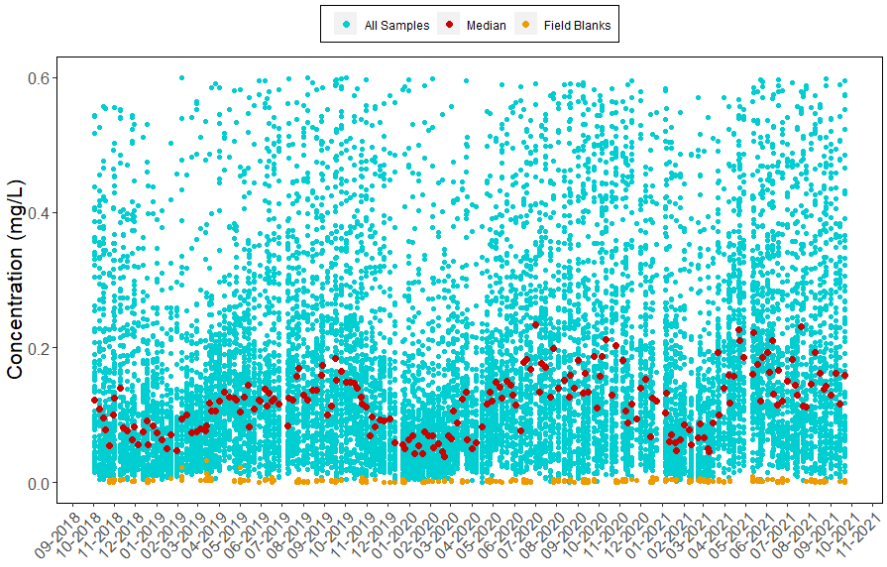
Note: Nominal reporting limit is 0.040 mg/L.

Figure 20. Concentrations of Cl^- from Teflon Filters



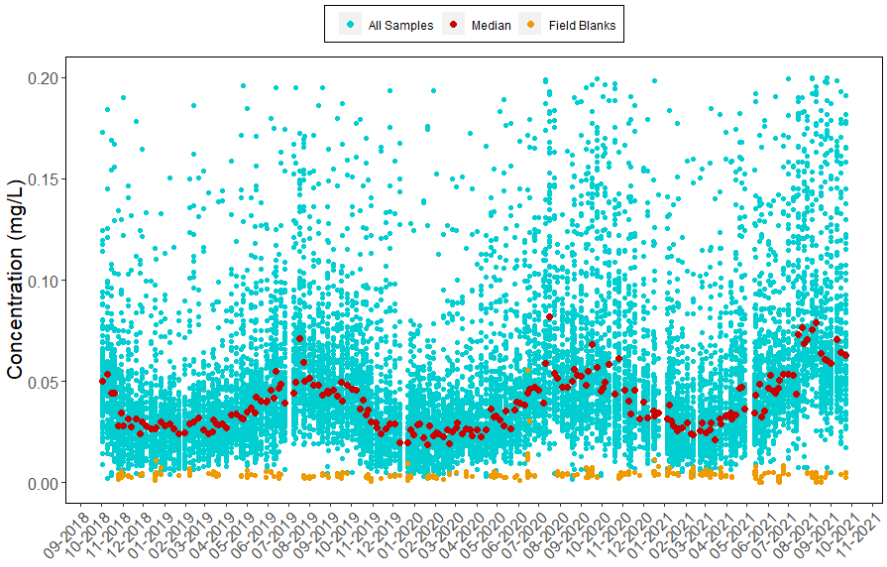
Note: Nominal reporting limit is 0.020 mg/L.

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



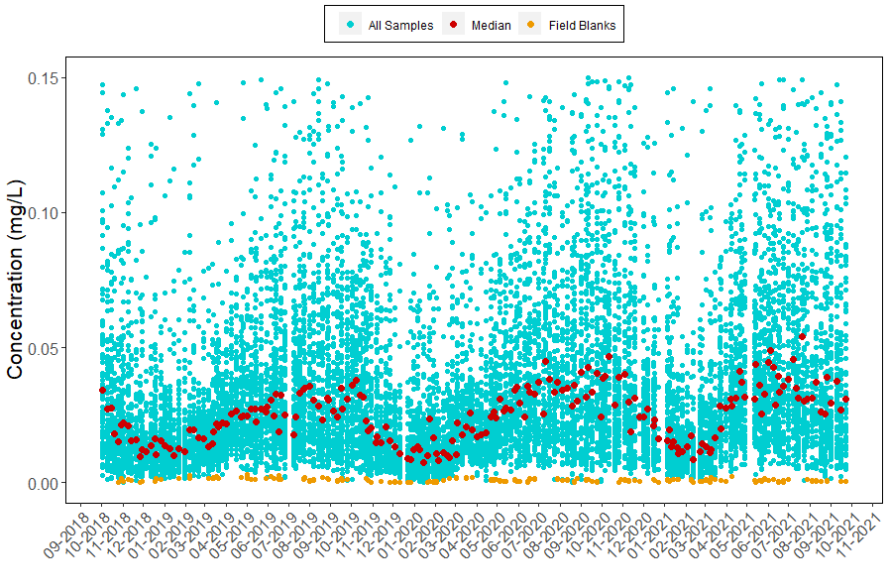
Note: Nominal reporting limit is 0.006 mg/L.

Figure 22. Concentrations of K^{+} from Teflon Filters



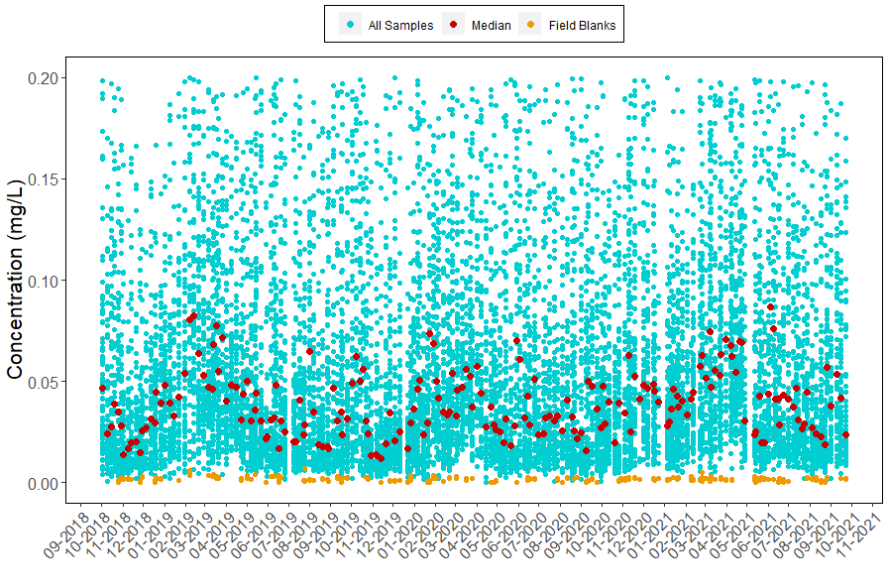
Note: Nominal reporting limit is 0.006 mg/L.

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 time 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

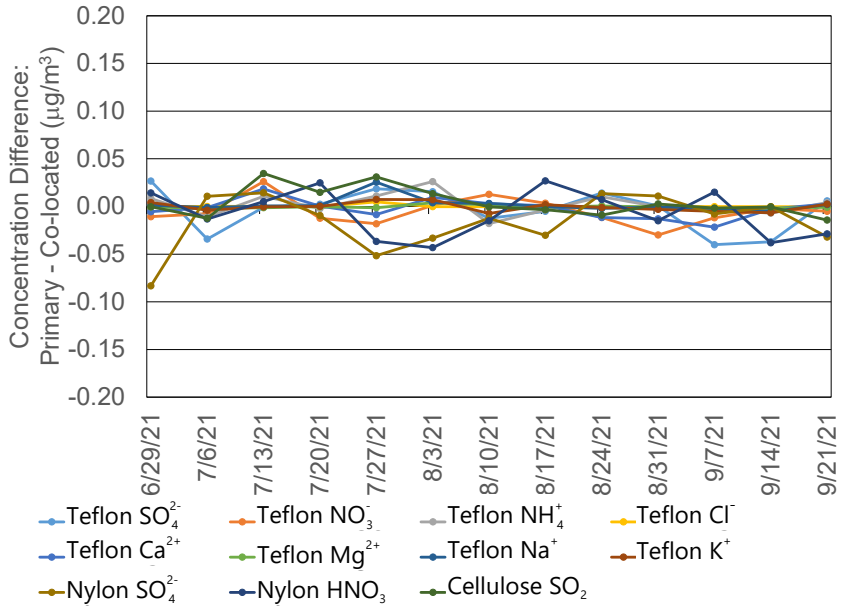
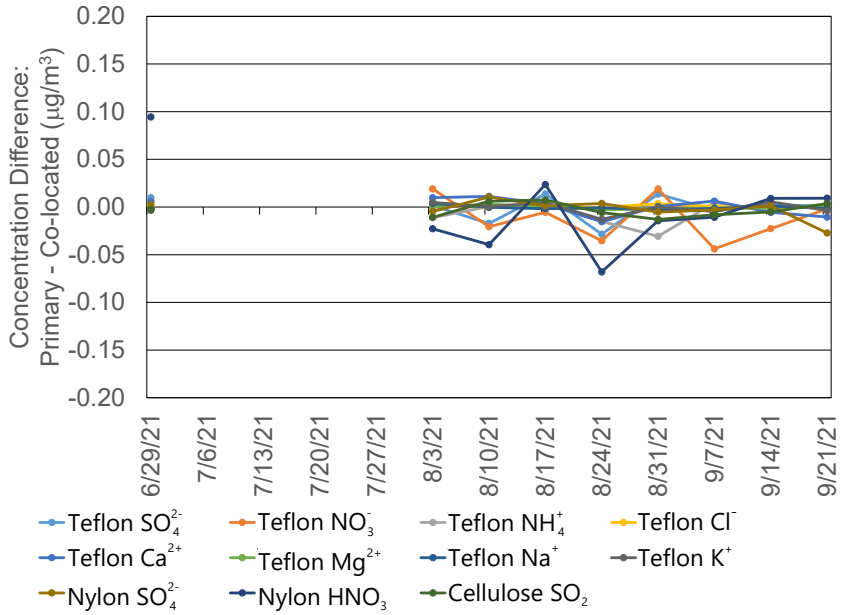


Figure 26. Time Series of Filter Concentration Differences between ROM406 and ROM206*, CO



Note: *The mass flow controller at ROM206 failed July 5, 2021 and was repaired August 3, 2021.

Precision of Filter Pack Concentrations

Table 3 shows mean absolute relative percent differences (MARPD) for concentrations measured at MCK131/231 and ROM406/206 during third quarter 2021. The MARPD values met the 20 percent criterion.

Table 3. Precision (MARPD) for Co-located Filter Pack Data during Third 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											
$\overline{X}$ (µg/m^3)	1.45	0.26	0.53	0.21	0.04	0.06	0.12	0.03	0.76	0.36	1.01
$\overline{Y}$ (µg/m^3)	1.45	0.26	0.53	0.21	0.04	0.06	0.12	0.03	0.77	0.36	1.02
MAD	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.03
MARPD	1.57	4.76	1.88	3.77	4.77	8.72	3.79	1.75	3.27	4.94	2.86
ROM406/206, CO											
$\overline{X}$ (µg/m^3)	0.56	0.30	0.34	0.27	0.03	0.05	0.11	0.02	0.63	0.20	0.92
$\overline{Y}$ (µg/m^3)	0.56	0.32	0.35	0.27	0.03	0.05	0.11	0.02	0.64	0.20	1.00
MAD	0.01	0.03	0.01	0.01	0.00	0.00	0.01	0.00	0.04	0.01	0.05
MARPD	2.30	8.03	3.35	4.05	5.83	5.71	7.98	7.63	6.81	6.43	5.81

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 Third Quarter 2021

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	Sampling ceased while repairs are made to the monitoring shelter.
CAT175, NY	54	54	54	54	54	54	54	54	Flow calibration failure
THR422, ND	62	62	62	62	62	62	62	62	The flow tower fell on 6/15/21. It was repaired on 8/8/21.
ROM406, CO	69	69	69	69	69	69	69	69	The mass flow controller failed 7/5/21. The system was repaired 8/3/21.
WST109, NH	69	69	69	69	69	69	69	69	The mass flow controller would not hold tare value starting late August. It was replaced mid-September.
QAK172, OH	77	77	77	77	77	77	77	77	Storm damage affected two samples. A power failure affected an additional sample.
SEK430, CA	77	77	77	77	77	77	77	77	Wildfire in the park resulted in its extended closure. Power to the site was turned off. The filter pack installed 9/7/21 was on the tower until 10/14/21.
CDR119, WV	85	85	85	85	85	85	85	85	A power failure affected two samples.
FOR605, WY	85	85	85	85	85	85	85	85	Power failures affected two samples.
OXF122, OH	85	85	85	85	85	85	85	85	The mass flow controller malfunctioned and was replaced affecting two samples.

Precision of Ozone Concentrations

Time series of co-located hourly O_3 concentration differences for third 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.

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

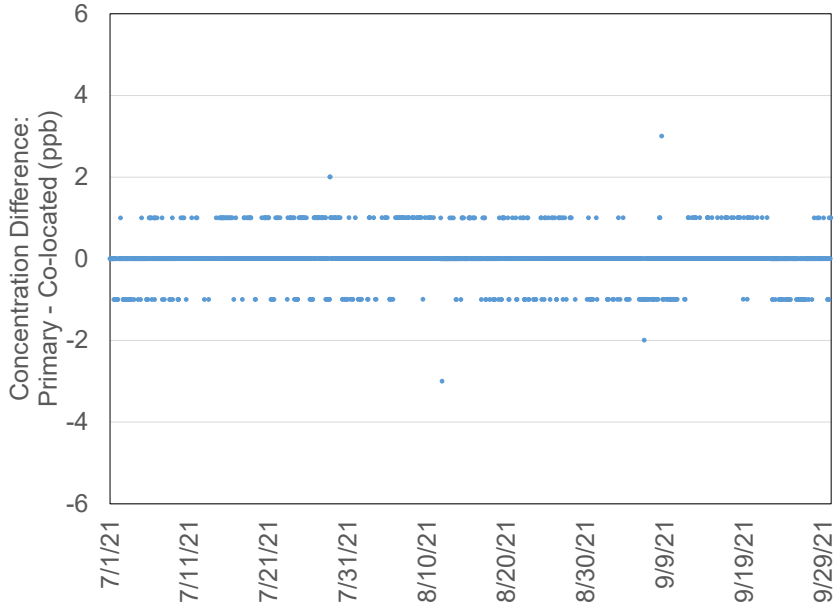


Figure 28. Time Series of the Differences in Co-located O_3 Concentrations for ROM406/206, CO

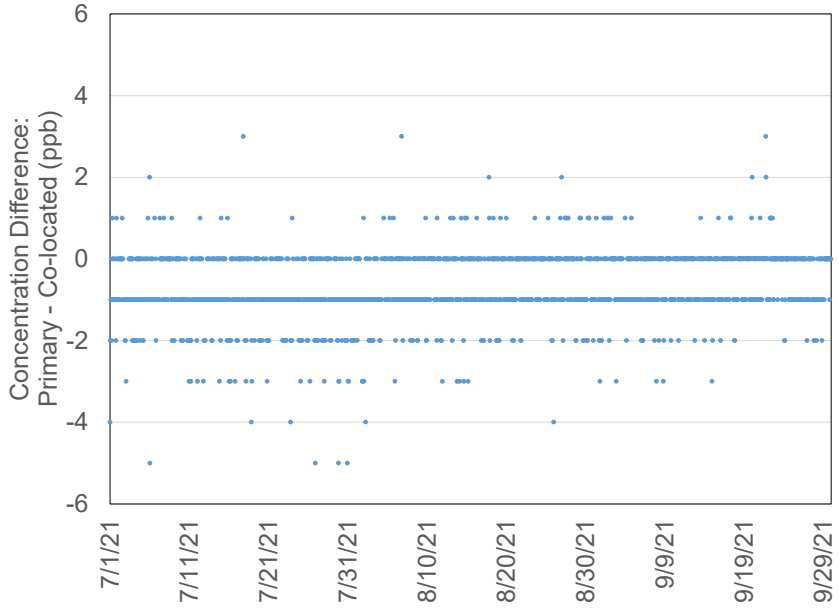


Table 5 gives MARPD data for O_3 data measured at the two co-located sites.

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

Site Pair	Quarter	Start Date	MARPD	Records
MCK131/231, KY				
	4	10/1/20	1.5	2069
	1	1/1/21	1.0	2046
	2	4/1/21	0.6	2075
	3	7/1/21	0.8	2082
ROM406/206, CO				
	4	10/1/20	3.3	1996
	1	1/1/21	4.5	2015
	2	4/1/21	1.9	2013
	3	7/1/21	1.4	2078

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 O_3 Concentrations during Third Quarter 2021

Site ID	Percent Completeness	Comments
SEK430, CA	82.4	Fire in the park resulted in its extended closure during September. Power to the site was turned off.
ANA115, MI	82.4	The analyzer pump failed on 8/25/2021 and was replaced on 8/31/2021.
QAK172, OH	85.7	A lightning strike hit the site in late June. Equipment was replaced 7/9/21. A power pole breaker failed and was replaced in early August.
WSP144, NJ	87.9	Elevated bench temperatures affected O_3 levels from mid- to late August.
PET427, AZ	87.9	The analyzer malfunctioned (solenoid) in early July and was replaced.
UVL124, MI	89.0	The analyzer pump failed in late August and was replaced. A power failure affected three days in early September.

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	Q3 2021	Q4 2020–Q3 2021	Comments
SEK430, CA	81.0	94.4	Fire in the park resulted in its extended closure during September. Power to the site was turned off.
ANA115, MI	85.3	95.9	The analyzer pump failed on 8/25/2021 and was replaced on 8/31/2021.
QAK172, OH	87.4	95.8	A lightning strike occurred in late June. Equipment was replaced 7/9/21. A power pole breaker failed and was replaced in early August.
PET427, AZ	87.9	92.4	The analyzer malfunctioned (solenoid) in early July and was replaced.

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 sites with available data are shown in Table 8. Ratios of NO_y to total NO_3^- varied from 3.05 at GRS420 to 9.56 at HWF187.

Table 8. Summary of Total NO_3^- and NO_y Measurements for Third Quarter 2021

Site ID	Elevation	Total NO_3^- (ppb)	NO_y (ppb)	Ratio
DUK008, NC	164*	0.40	NA	NA
BVL130, IL	213	0.59	2.86	5.19
MAC426, KY	243	0.34	1.02	3.21
HWF187, NY	497	0.09	0.81	9.56
GRS420, TN	793	0.30	0.92	3.05
PNF126, NC	1216	0.20	0.58	2.72
PND165, WY	2386	0.26	1.10	4.19
ROM206, CO	2742	0.29	1.37	4.76

Note: * 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

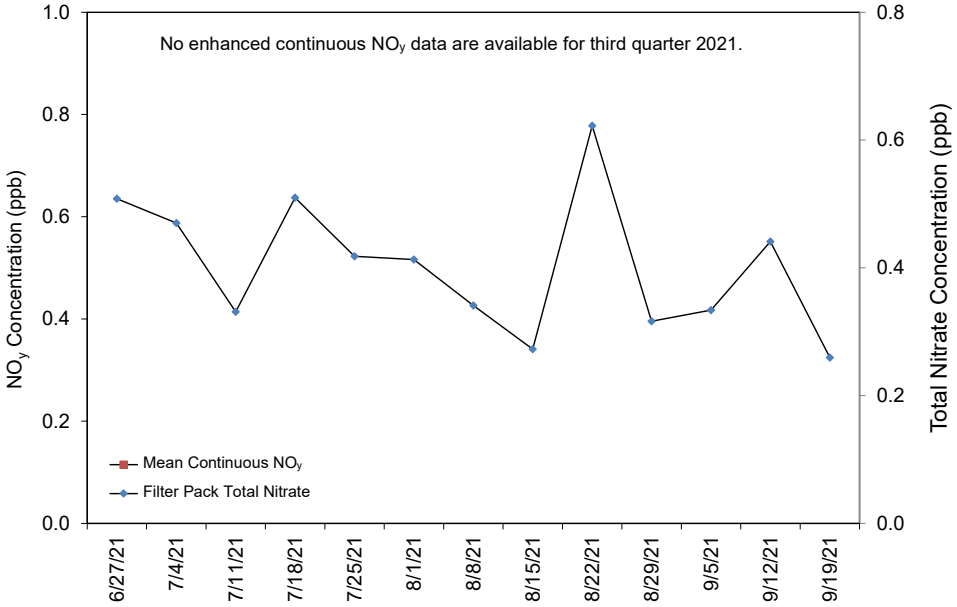


Figure 30. Comparison of BVL130 Weekly Mean NO_y and Total NO_3^- Concentrations

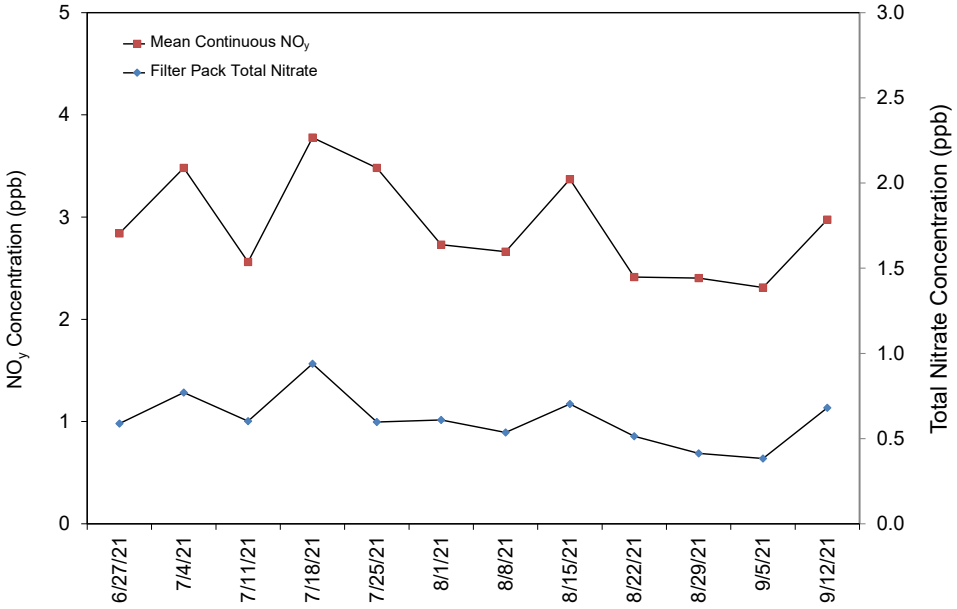


Figure 31. Comparison of MAC426 Weekly Mean NO_y and Total NO_3^- Concentrations

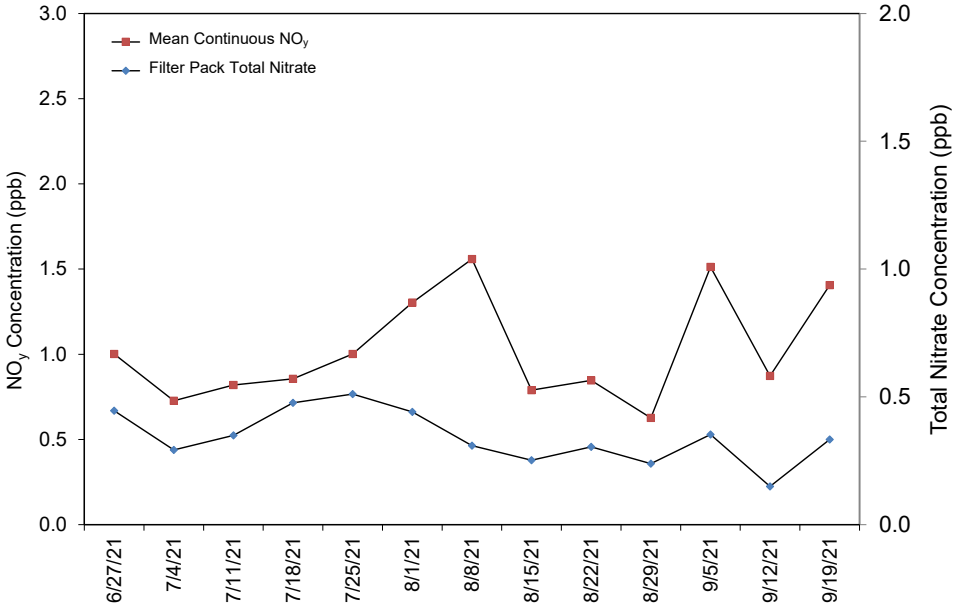


Figure 32. Comparison of HWF187 Weekly Mean NO_y and Total NO_3^- Concentrations

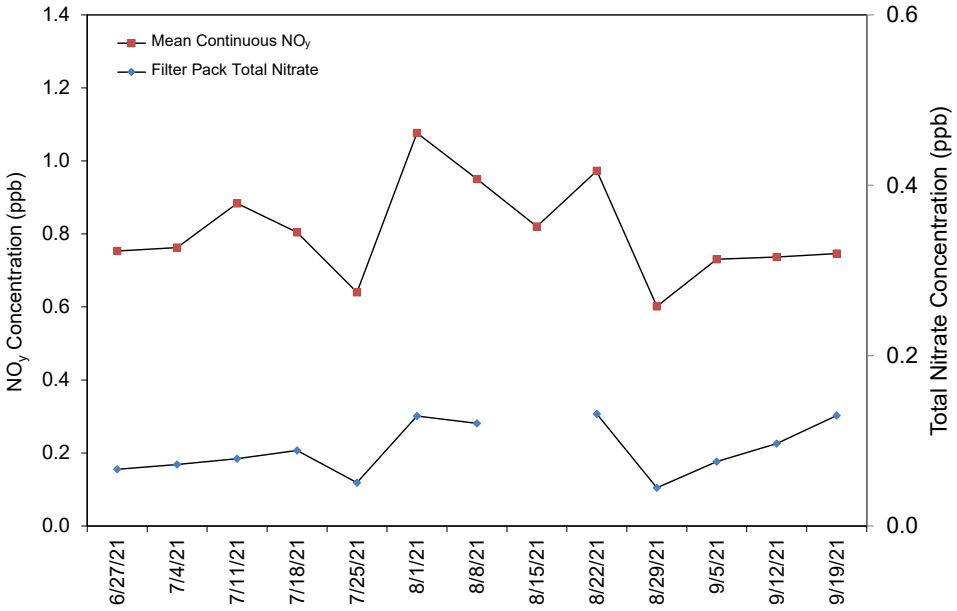


Figure 33. Comparison of GRS420 Weekly Mean NO_y and Total NO_3^- Concentrations

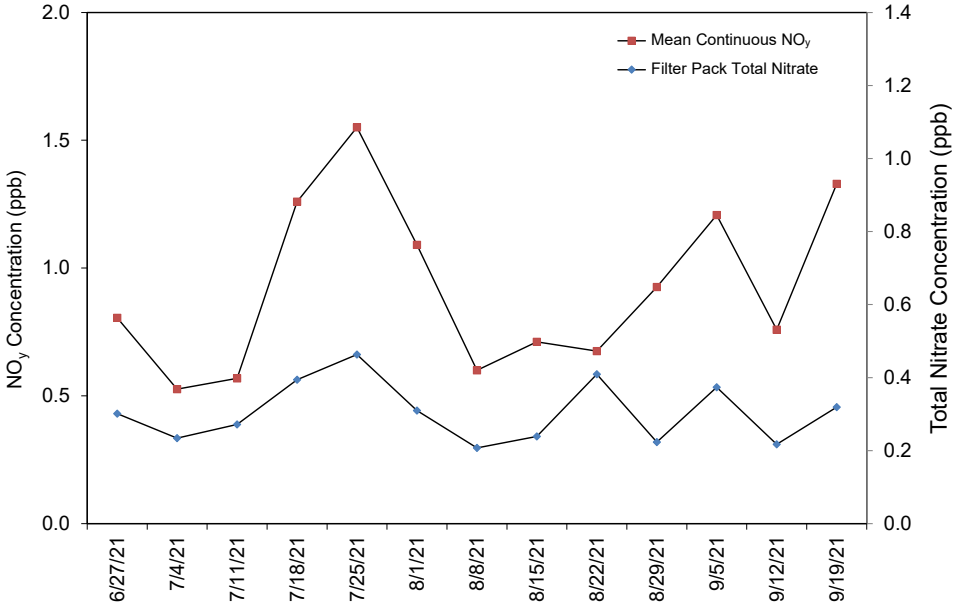


Figure 34. Comparison of PNF126 Weekly Mean NO_y and Total NO_3^- Concentrations

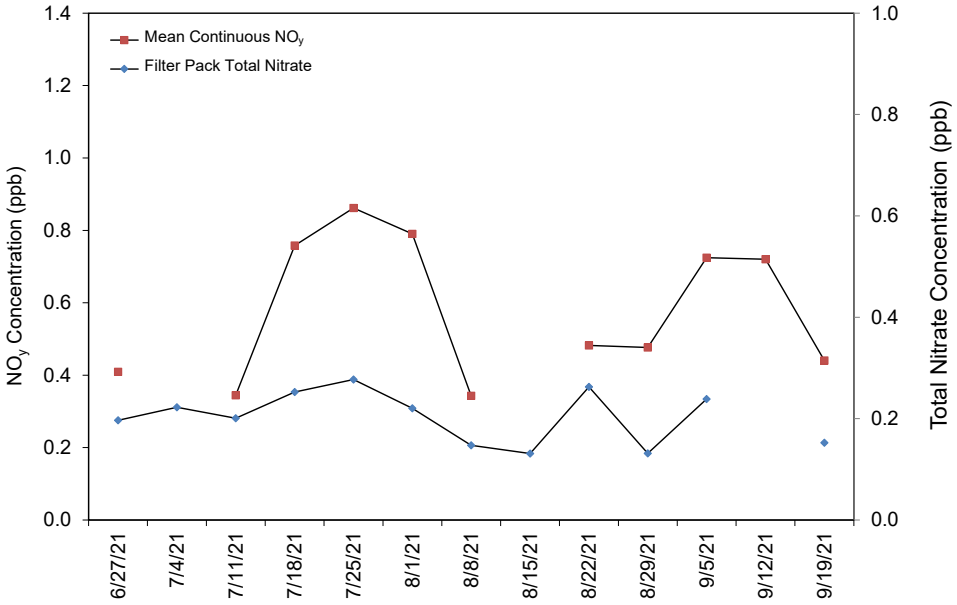


Figure 35. Comparison of PND165 Weekly Mean NO_y and Total NO_3^- Concentrations

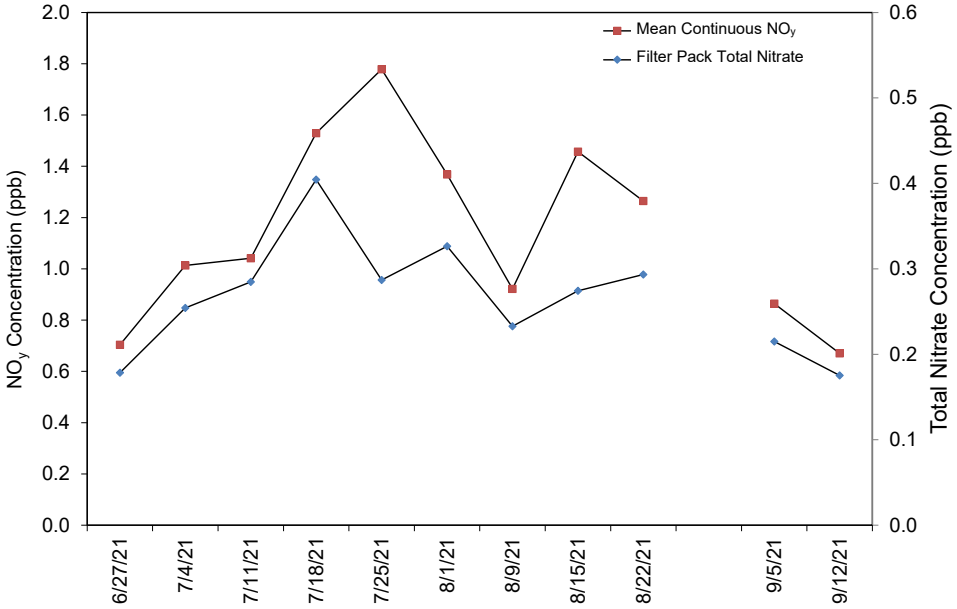
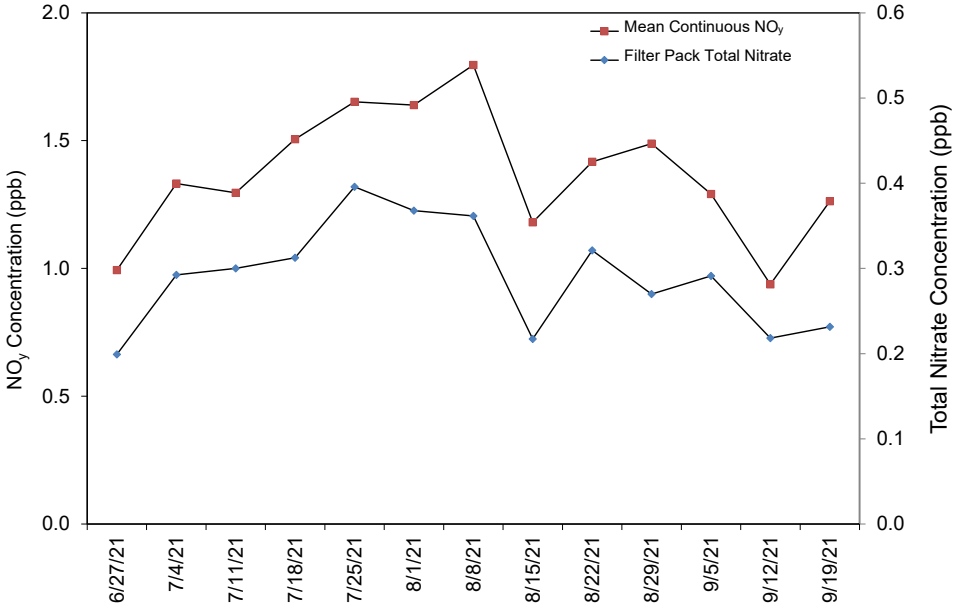


Figure 36. Comparison of ROM206 Weekly Mean NO_y and Total NO_3^- Concentrations



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 were comparable at MAC426 and GRS420.

Figure 37. Comparison of BVL130 Weekly Mean SO_2 Concentrations

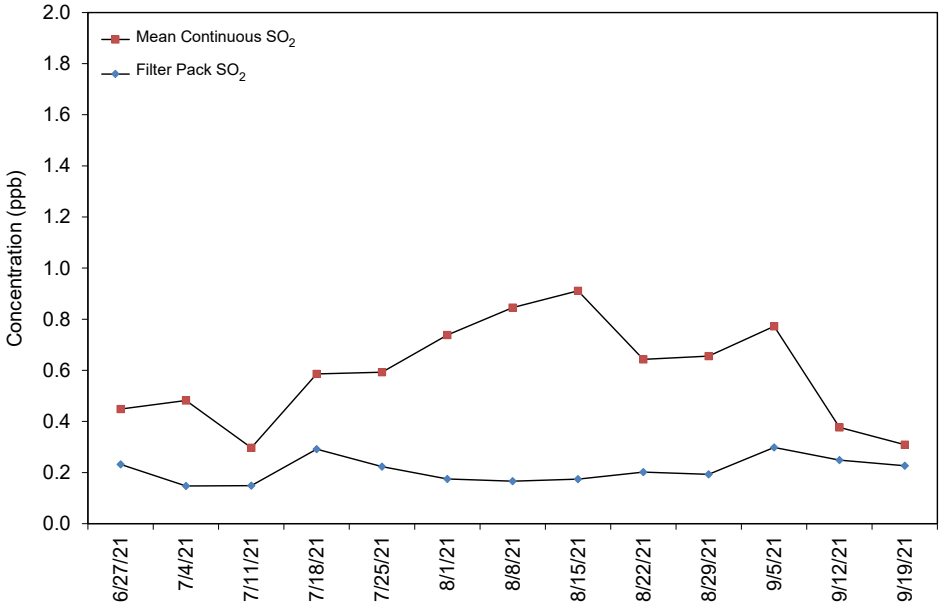


Figure 38. Comparison of MAC426 Weekly Mean SO_2 Concentrations

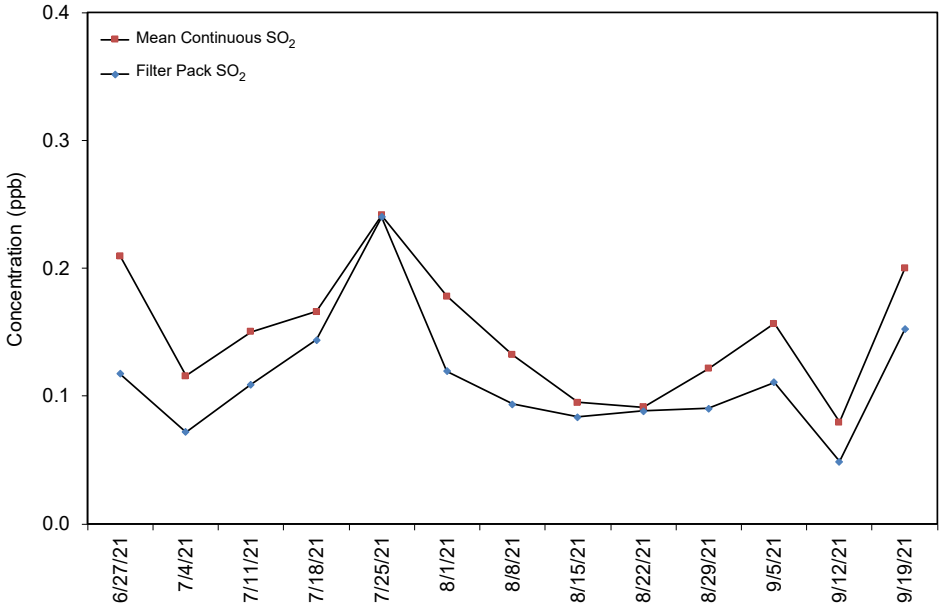
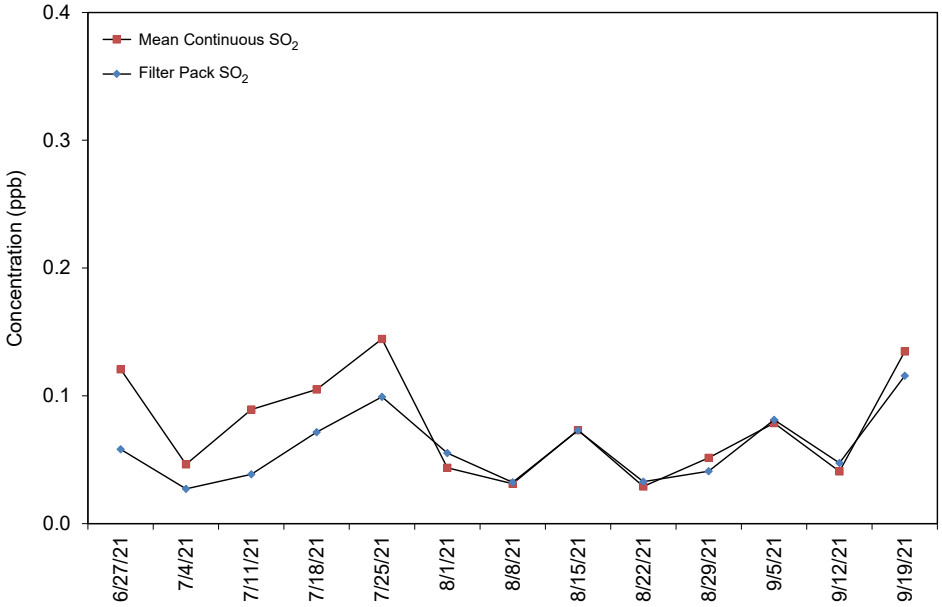


Figure 39. Comparison of GRS420 Weekly Mean SO_2 Concentrations



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 third quarter 2021. The average for fourth quarter 2020 through third 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*	Q3 2021	Q4 2020 – Q3 2021	Comments
BVL130, IL	CO	80	52	The CO analyzer required recalibration in mid-July and also malfunctioned in late September.
	NO	92	94	
	NOY	92	94	
	NOYDIF	92	94	
	SO2_GA	87	86	The analyzer pump failed in mid-September.
CHC432, NM	NO	98	98	
	NOX	98	98	
	NOXDIF	98	98	
DUK008, NC	HNO3	0		Monitoring restarted in August 2021, but QC functions were not fully operational until December 2021. Since no valid data are available for first through third quarter 2021, the average for Q4 2020 through Q3 2021 was not calculated.
	NH3	0		
	NO	0		
	NO2_TRUE	0		
	NOX_TRUE	0		
	NOY	0		
	NOY_MINUS	0		
	NOYDIF	0		
	TNX	0		
GRS420, TN	CO	89	92	Elevated shelter temperatures affected CO in mid-July.
	NO	94	94	
	NOY	94	94	
	NOYDIF	94	95	
	SO2_GA	94	96	
HWF187, NY	NO	93	94	
	NOY	93	94	
	NOYDIF	93	94	
MAC426, KY	CO	96	81	
	NO	97	95	
	NOY	97	95	
	NOYDIF	97	95	
	SO2_GA	96	96	
PND165, WY	NO	93	86	
	NOY	93	84	
	NOYDIF	93	84	

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

Site ID	Parameter*	Q3 2021	Q4 2020 – Q3 2021	Comments
PNF126, NC	NO	78	80	The analyzer required recalibration in late July. The bypass box was off from 8/17/21 to 8/24/21.
	NOY	76	79	
	NOYDIF	76	78	
ROM206, CO	NO	94	89	
	NOY	94	91	
	NOYDIF	94	88	

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) Third Quarter 2021 Quality Assurance Report.* https://java.epa.gov/castnet/documents.do