Clean Air Status and Trends Network (CASTNET)
Quarterly Data Summary for Third Quarter 2019 (July through September)

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Introduction

This quarterly report summarizes the Clean Air Status and Trends Network (CASTNET) data collected during third quarter 2019. 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 2019 Quality Assurance Report (Wood, 2019).

Figure 1. Fourth Highest Daily Maximum 8-hour Average O_3 Concentrations through Third Quarter 2019 (ppb)

Figure 1 shows fourth highest daily maximum 8-hour average (DM8A) O_3 concentrations measured through third quarter 2019. Three sites exceeded the 0.070 parts per million National Ambient Air Quality Standard for O_3.

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 HNO_3, NO_3^-, NH_4^+, total NO_3^-, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, and Na^+ concentrations increased at eastern sites in 2019, and SO_2 and K^+ concentrations decreased. Quarterly mean HNO_3, NO_3^-, NH_4^+, total NO_3^-, SO_2, SO_4^{2-}, Ca^{2+}, K^+, and Mg^{2+} concentrations decreased at western sites in 2019 while 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 2019 by site and then averaging those averages for all eastern and western reference sites (Figure 13). The figure shows an overall reduction in quarterly mean O_3 concentrations at eastern sites with an increase in third quarter 2019. Mean O_3 concentrations at western sites decreased in third quarter 2019. Quarterly mean concentrations were higher at the western reference sites.

Figure 2. Trends in Third Quarter Mean HNO_3 Concentrations

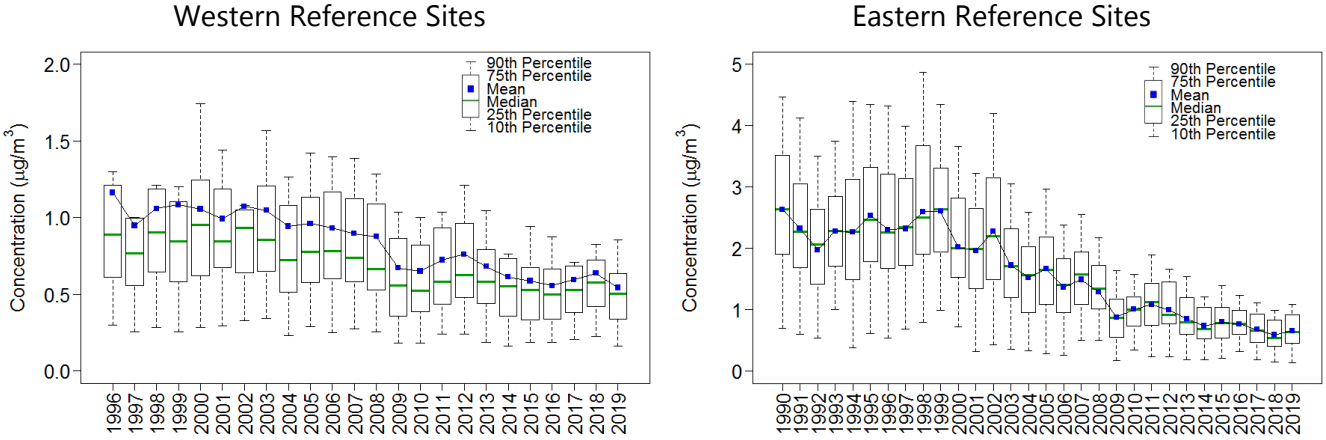


Figure 3. Trends in Third Quarter Mean NO_3^- Concentrations

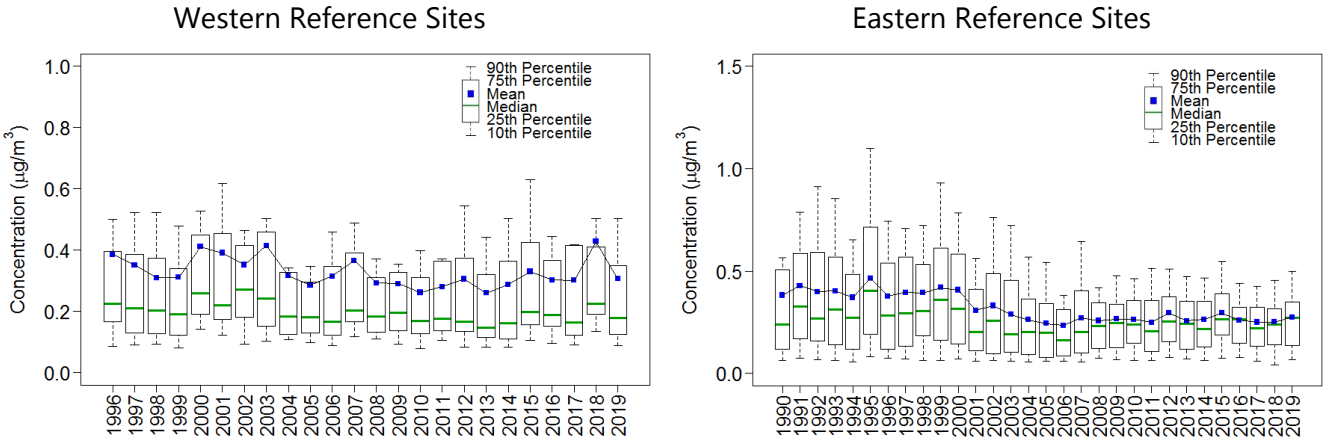


Figure 4. Trends in Third Quarter Mean NH_4^+ Concentrations

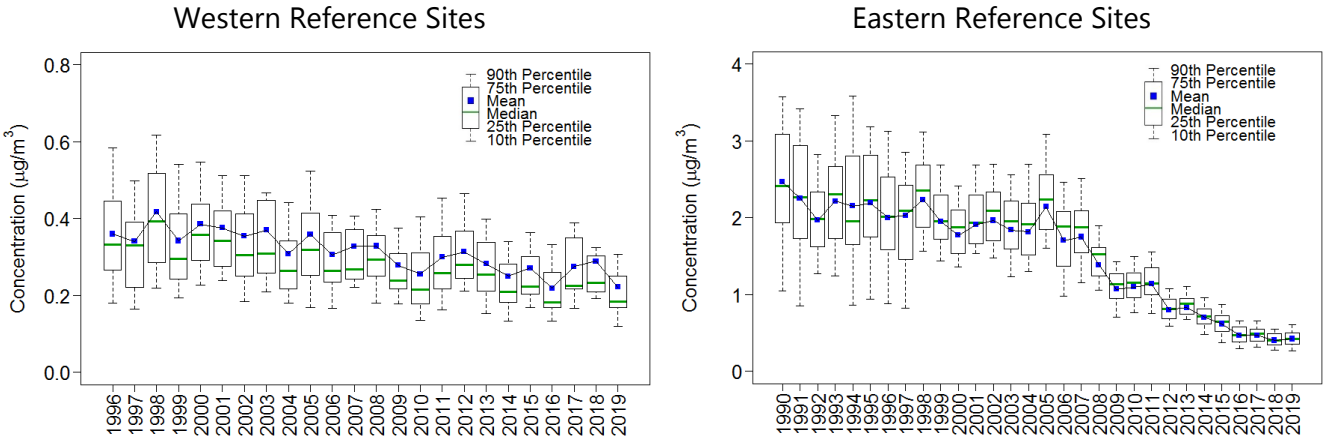


Figure 5. Trends in Third Quarter Mean Total NO_3^- Concentrations

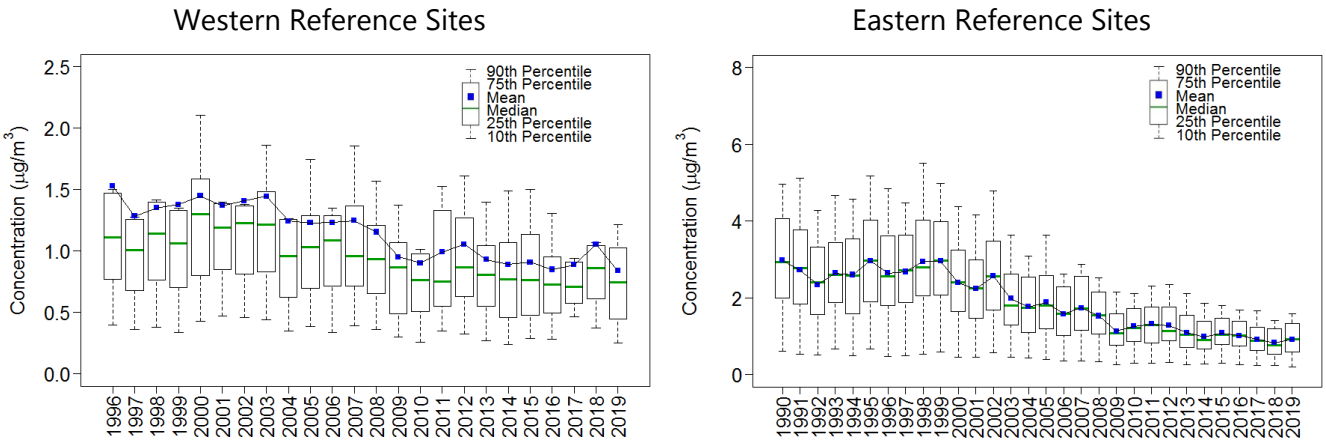


Figure 6. Trends in Third Quarter Mean SO_2 Concentrations

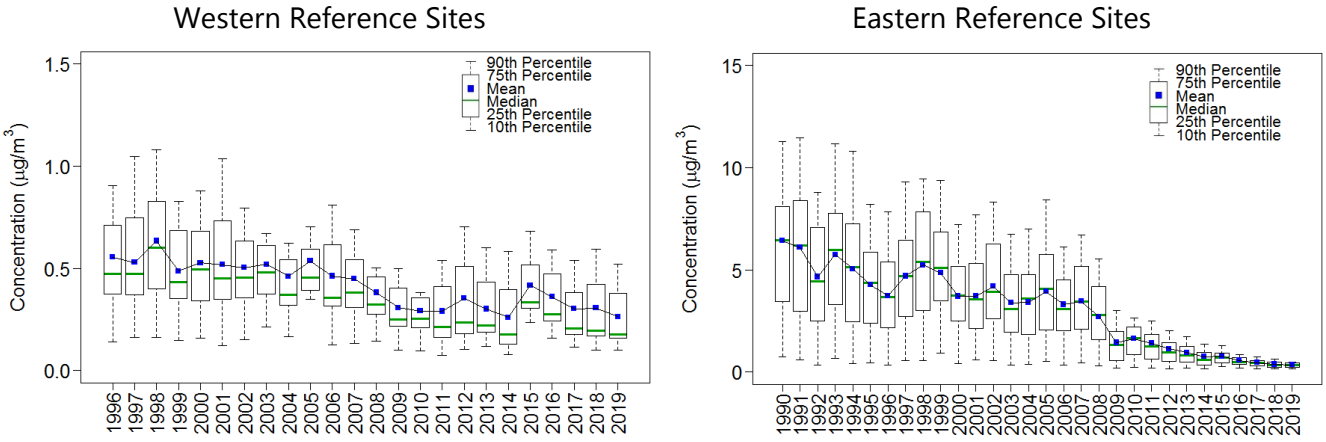


Figure 7. Trends in Third Quarter Mean SO_4^{2-} Concentrations

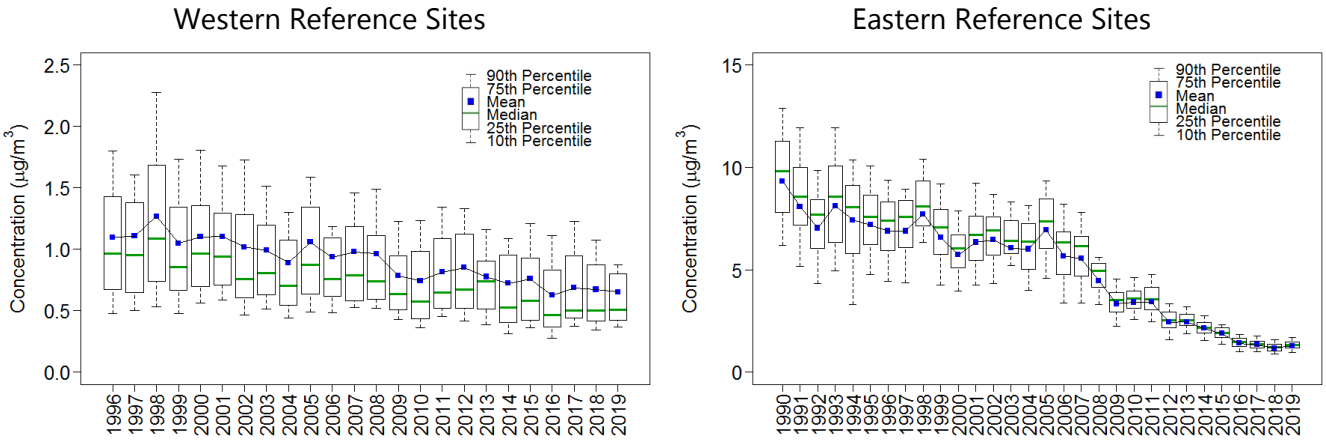


Figure 8. Trends in Third Quarter Mean Cl^- Concentrations

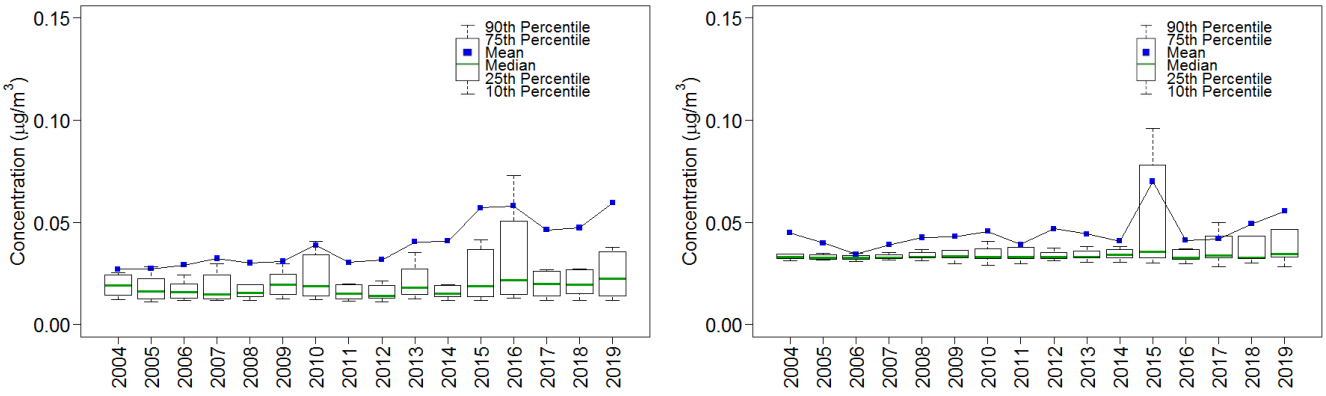


Figure 9. Trends in Third Quarter Mean Ca^{2+} Concentrations

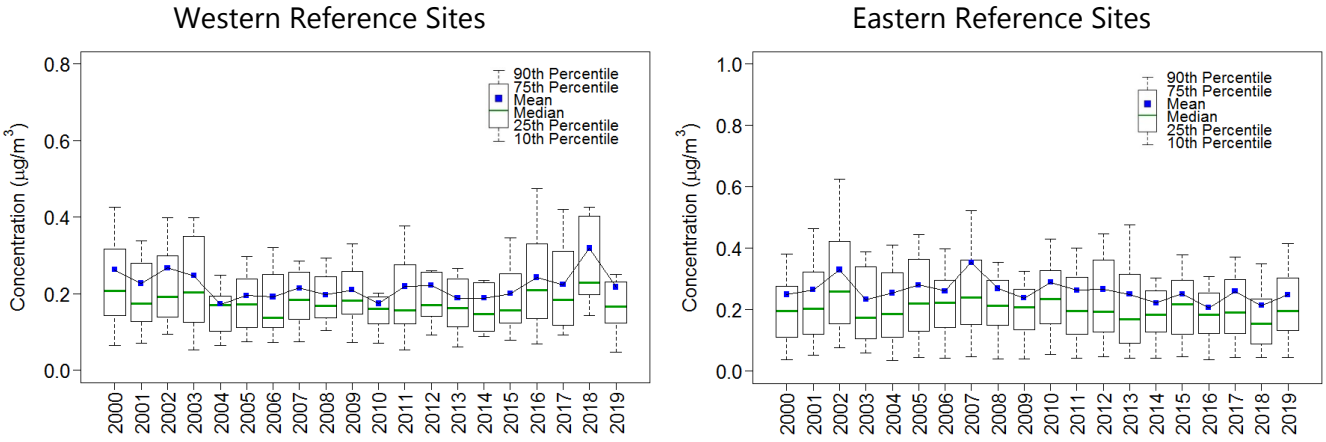


Figure 10. Trends in Third Quarter Mean K^{+} Concentrations

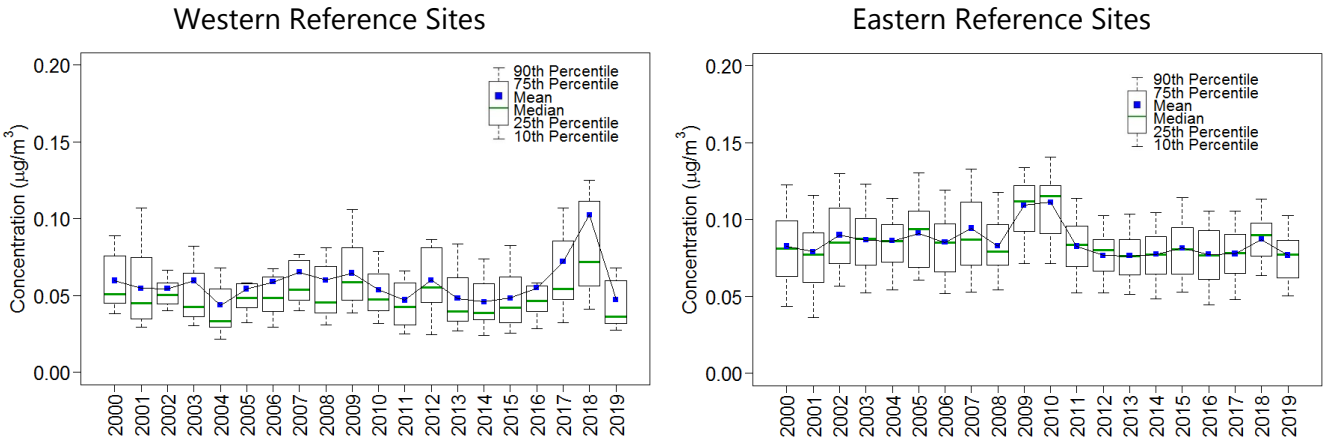


Figure 11. Trends in Third Quarter Mean Mg^{2+} Concentrations

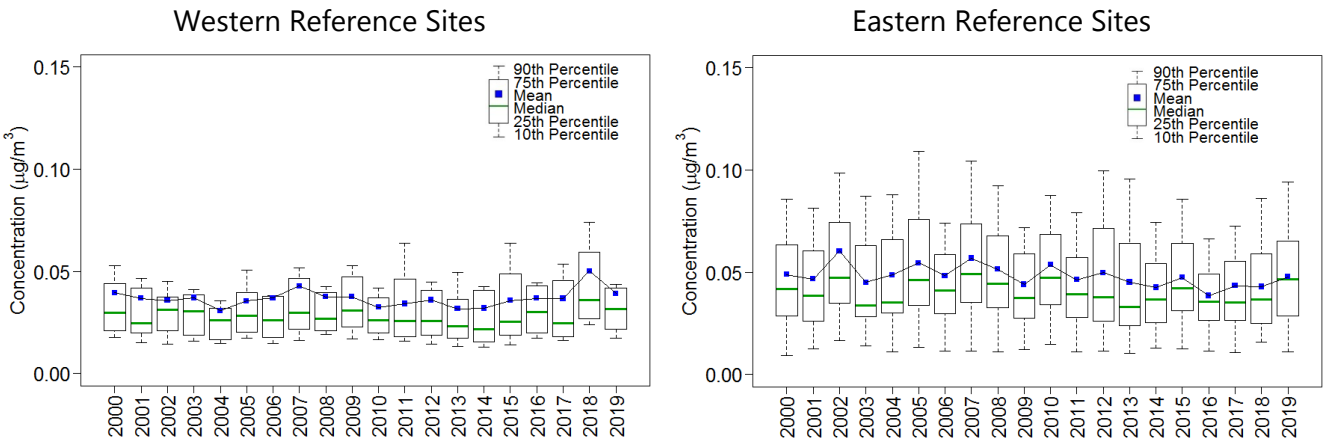


Figure 12. Trends in Third Quarter Mean Na^+ Concentrations

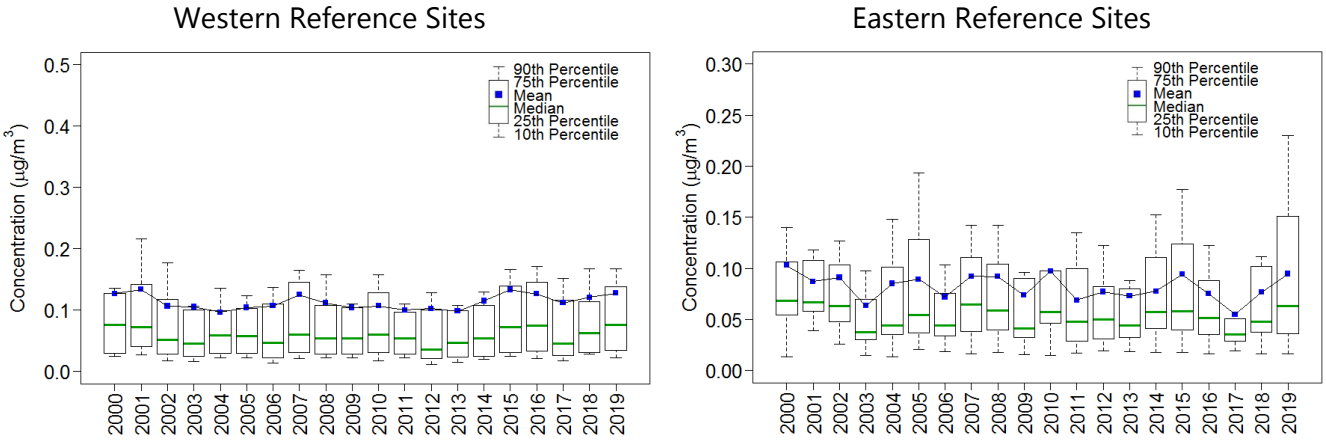
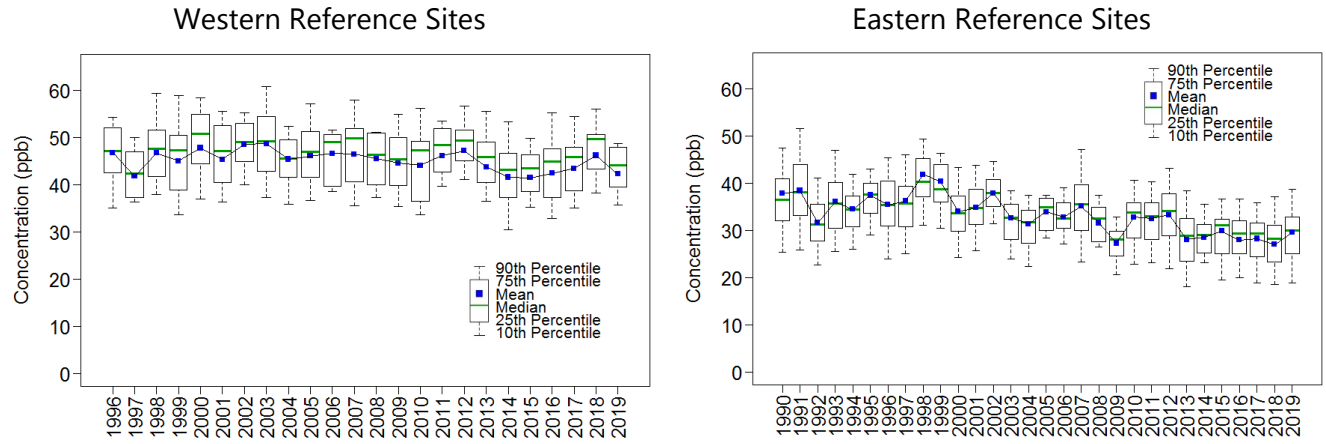


Figure 13. Trends in Third Quarter Mean O_3 Concentrations



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 2017–2019 for eastern reference sites and 1996–1998 through 2017–2019 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
2017–2019	0.9	0.4	0.4	1.3	28
Percent Change	-67	-81	-93	-85	-21

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

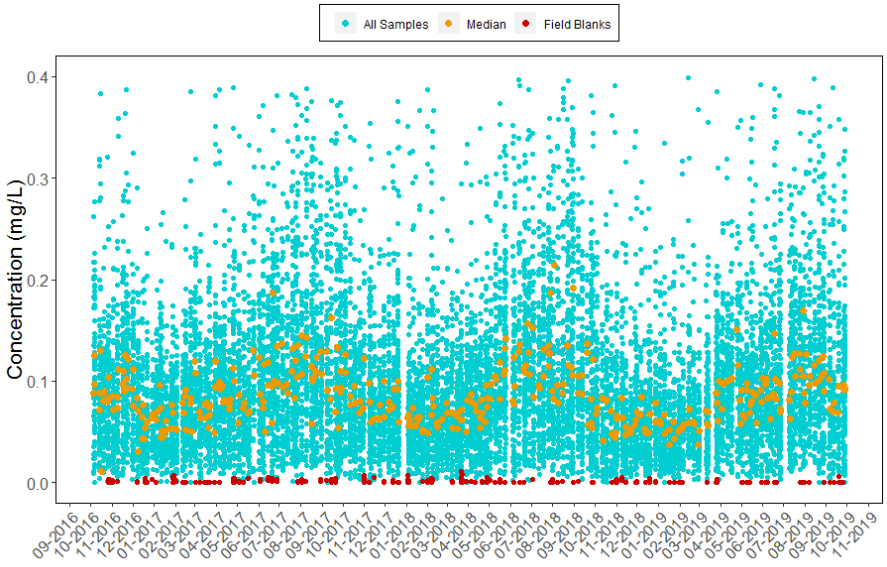
	Total NO_3^- ($\mu g/m^3$)	NH_4^+ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	SO_4^{2-} ($\mu g/m^3$)	O_3 (ppb)
1996–1998	1.4	0.4	0.6	1.2	45
2017–2019	0.9	0.3	0.3	0.7	44
Percent Change	-33	-30	-49	-42	-2

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 2016 through third quarter 2019. These figures provide indications of potential issues with concentration measurements relative to detection and reporting limits.

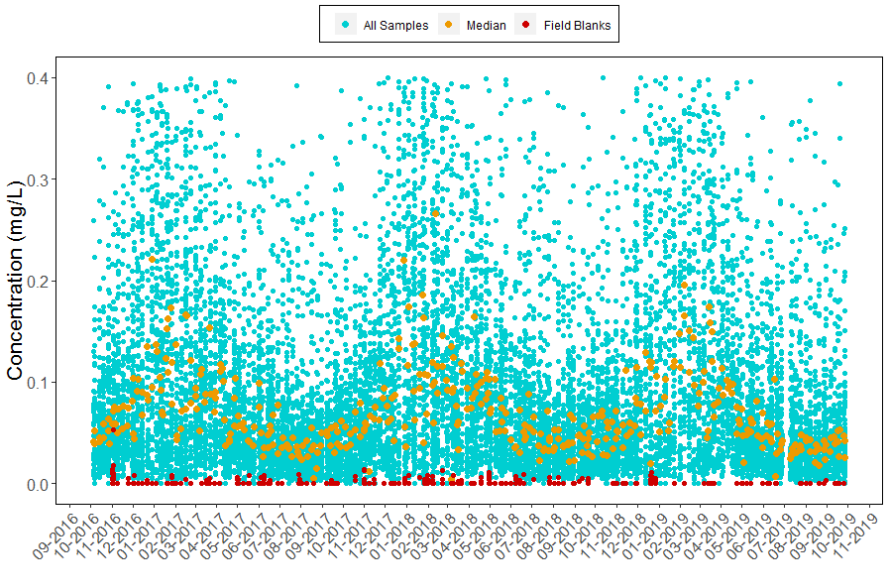
Previous review of filter pack analysis control charts indicated possible potassium contamination (Figure 22). Corrective actions were implemented and subsequent testing indicated these actions have been effective. Consider the recent 15-month data record in Figure 22.

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



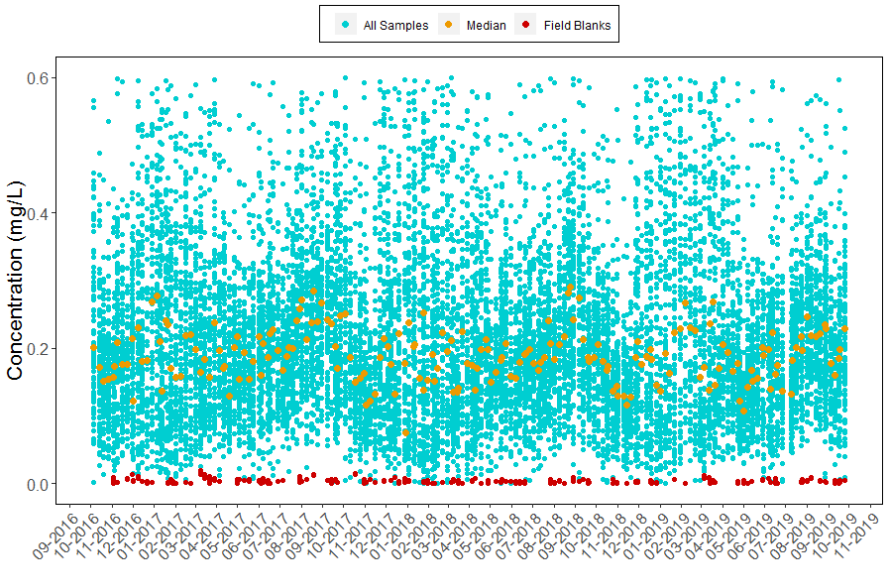
Note: Nominal reporting limit is 0.008 mg/L.

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



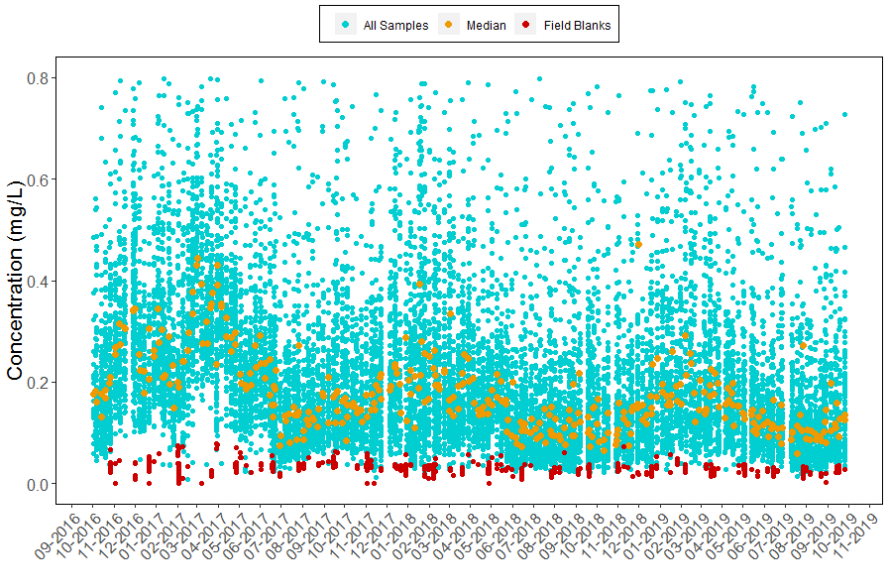
Note: Nominal reporting limit is 0.008 mg/L.

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



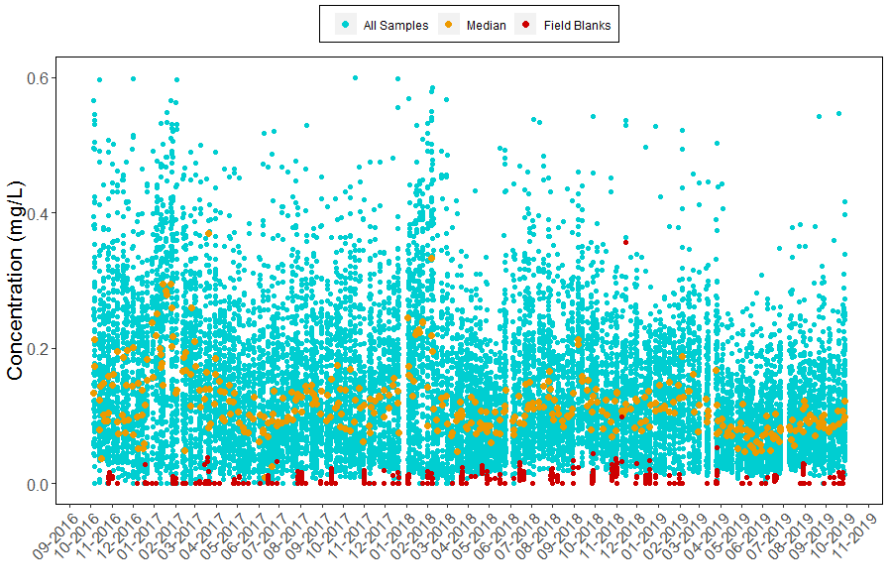
Note: Nominal reporting limit is 0.020 mg/L.

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



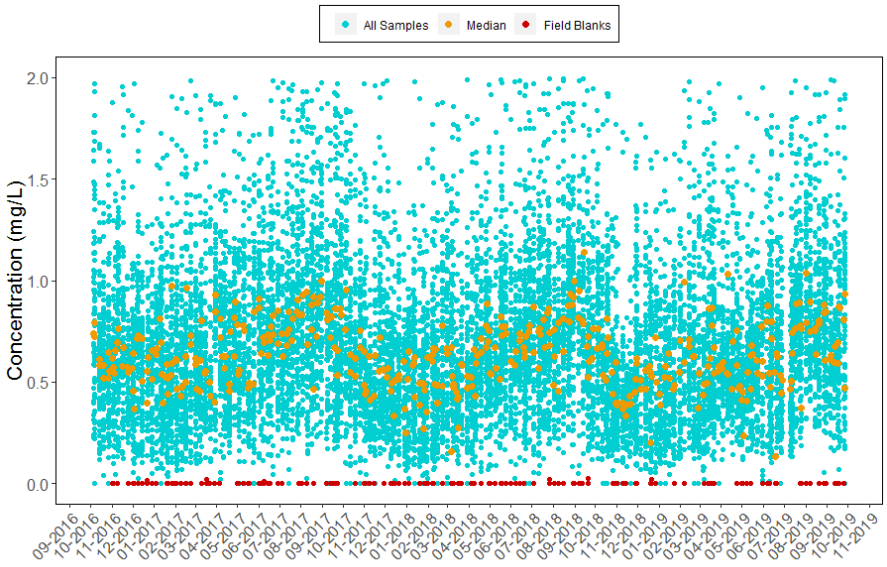
Note: Nominal reporting limit is 0.040 mg/L.

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



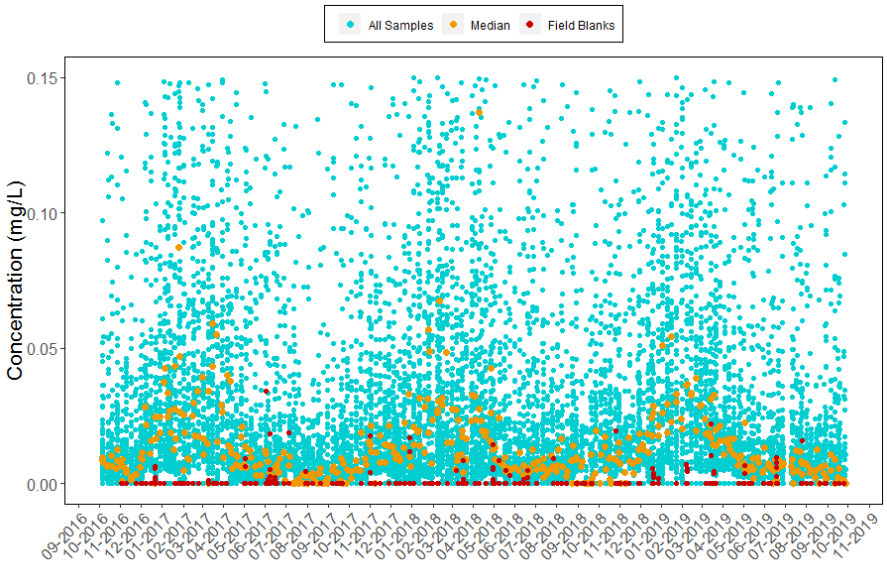
Note: Nominal reporting limit is 0.040 mg/L.

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



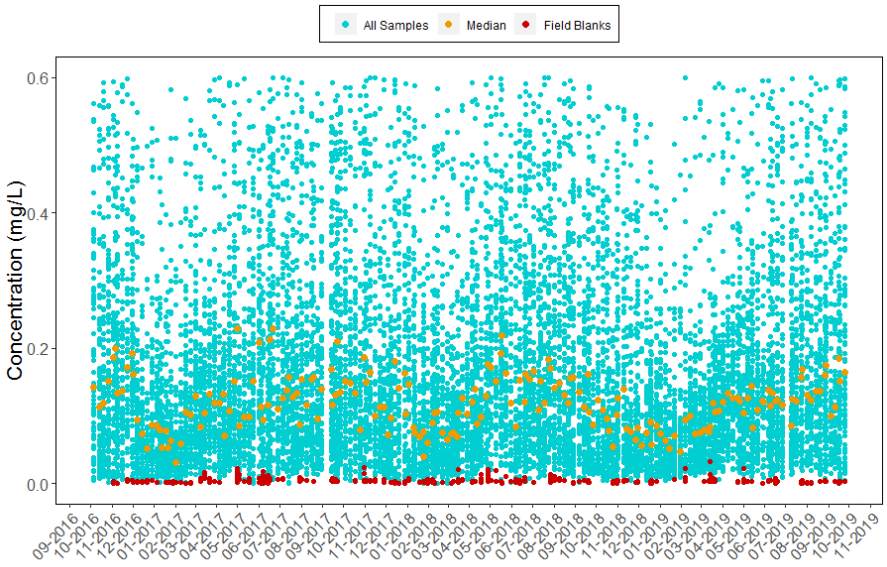
Note: Nominal reporting limit is 0.040 mg/L.

Figure 20. Concentrations of Cl^- from Teflon Filters



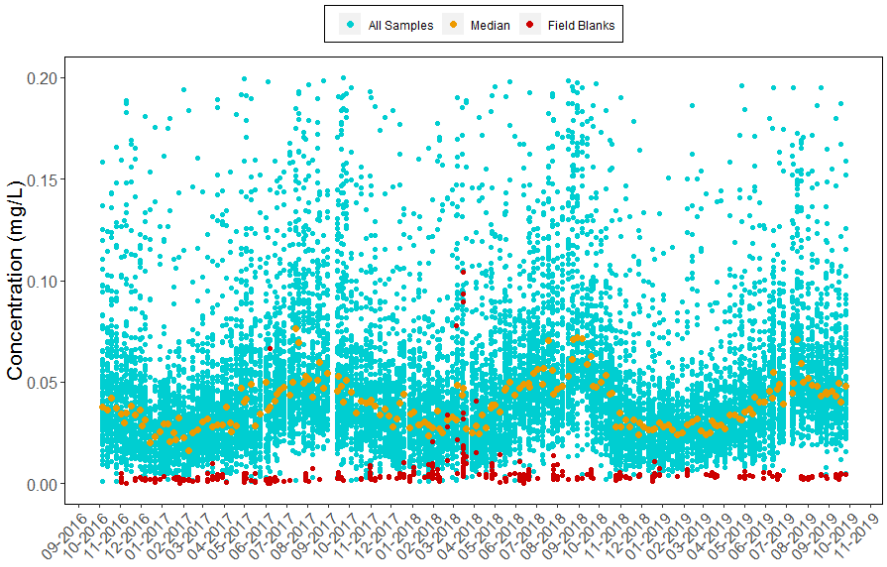
Note: Nominal reporting limit is 0.020 mg/L.

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



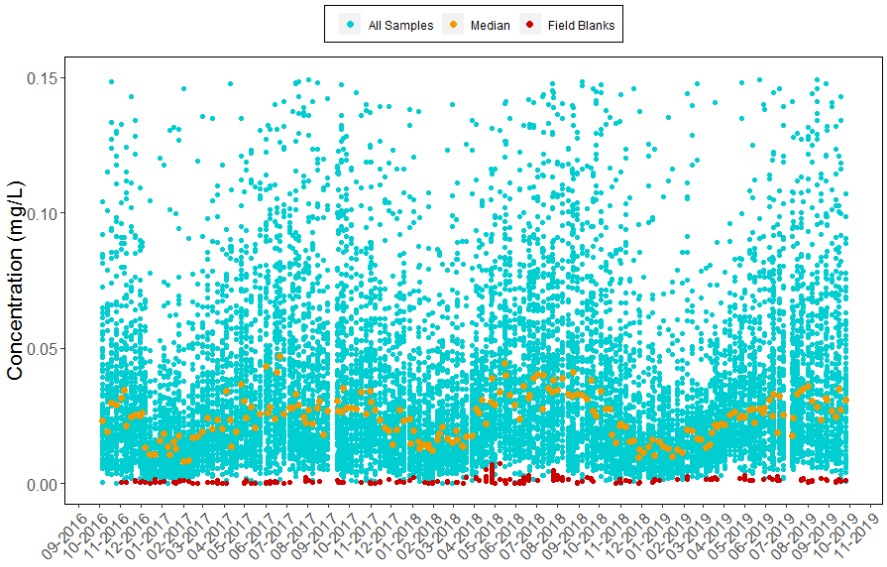
Note: Nominal reporting limit is 0.006 mg/L.

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



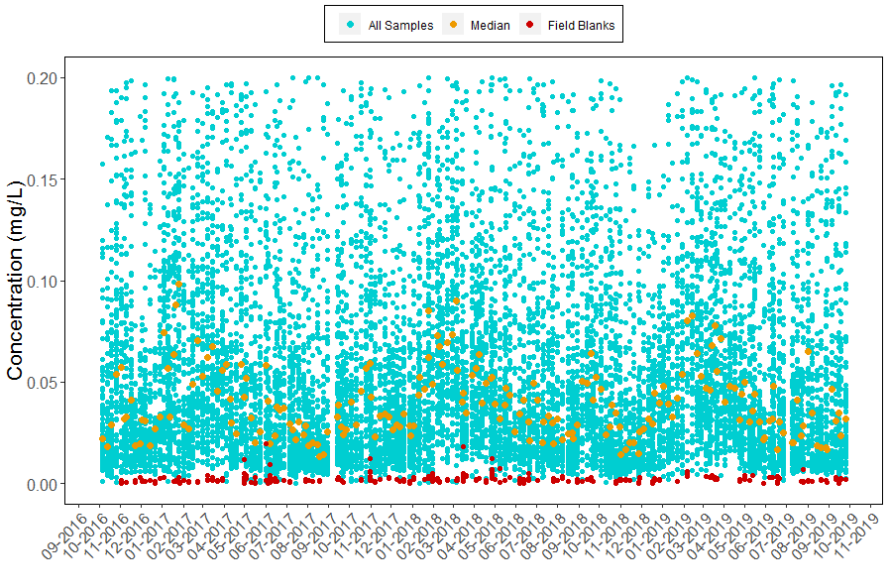
Note: Nominal reporting limit is 0.006 mg/L.

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

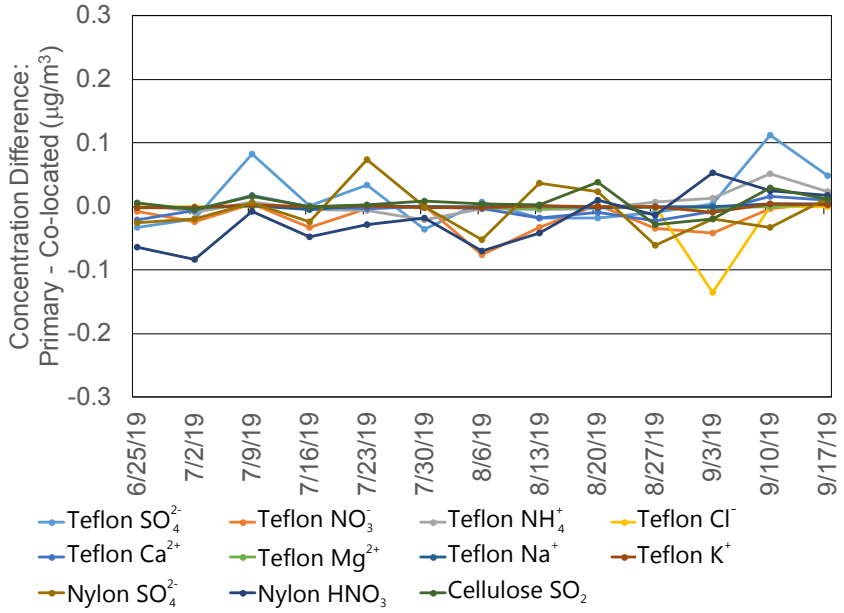
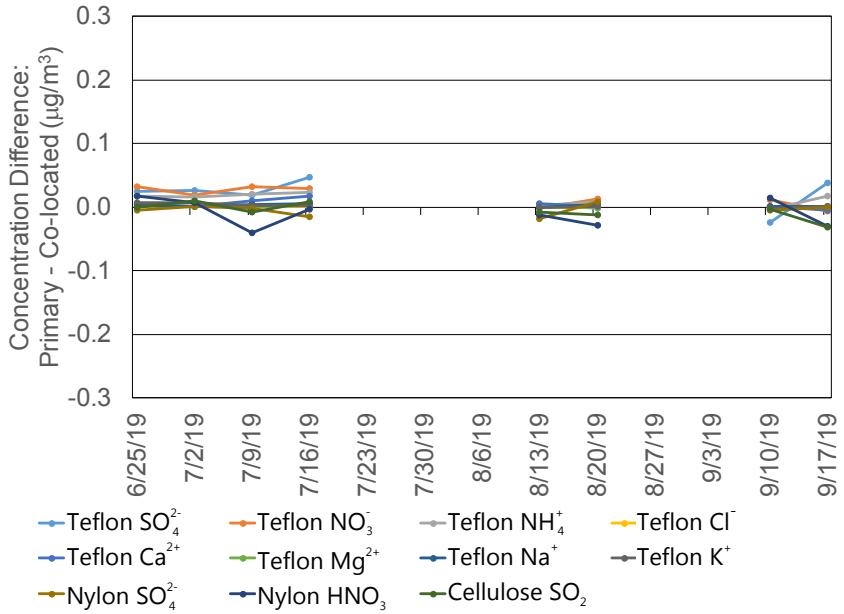


Figure 26. Time Series of Filter Concentration Differences between ROM406 and ROM206, CO



Precision of Filter Pack Concentrations

Table 3 shows mean absolute relative percent differences (MARPD) for concentrations measured at MCK131/231 and ROM406/206 during third quarter 2019. The MARPD values met the 20 percent criterion.

Table 3. Precision (MARPD) for Co-located Filter Pack Data during Third Quarter 2019

	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)	1.73	0.35	0.62	0.32	0.05	0.09	0.08	0.04	1.00	0.47	1.33
$\overline{Y}$ (µg/m^3)	1.71	0.37	0.62	0.32	0.05	0.09	0.08	0.04	1.01	0.46	1.36
MAD	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.04	0.03	0.05
MARPD	2.29	6.52	2.17	3.09	3.68	2.71	3.33	0.66	3.55	7.13	3.64
ROM406/206, CO											
$\overline{X}$ (µg/m^3)	0.66	0.23	0.26	0.20	0.03	0.05	0.05	0.02	0.54	0.19	0.77
$\overline{Y}$ (µg/m^3)	0.65	0.22	0.25	0.19	0.03	0.05	0.05	0.02	0.56	0.19	0.74
MAD	0.03	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.03
MARPD	4.14	10.72	5.97	4.01	4.73	5.81	7.10	2.87	4.28	9.44	4.04

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 2019

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
ALH157, IL	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	The mass flow controller malfunctioned resulting in two invalid samples.
BBE401, TX	23.1	23.1	23.1	23.1	23.1	23.1	23.1	23.1	The Teflon filters for 10 filter packs were perforated. The cause of filter damage was not determined, but damage from the local bird population is suspected.
BFT142, NC	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	The mass flow controller suffered storm damage in July and affected three samples. An additional sample was invalidated for suspect values.
CHA467, AZ	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	Missing flow data affected one sample and another was invalidated because the shipping cap was on during sampling.
CHE185, OK	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	The mass flow controller malfunctioned affecting three samples.
EGB181, ON	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	Two samples were invalidated due to suspect data.
FOR605, WY	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	The site was struck by lightning on July 8. The site resumed operation on October 16.
JOT403, CA	38.5	38.5	38.5	38.5	38.5	38.5	38.5	38.5	A polling issue caused missing data.
ROM406, CO	61.5	61.5	61.5	61.5	61.5	61.5	61.5	61.5	Two samples were invalidated due to failing leak checks.
UND002, VT	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	The flow pump malfunctioned and affected three samples.
WST109, NH	84.6	84.6	84.6	84.6	84.6	84.6	84.6	84.6	The mass flow controller malfunctioned and affected two samples.

Precision of Ozone Concentrations

Time series of co-located hourly O_3 concentration differences for third quarter 2019 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

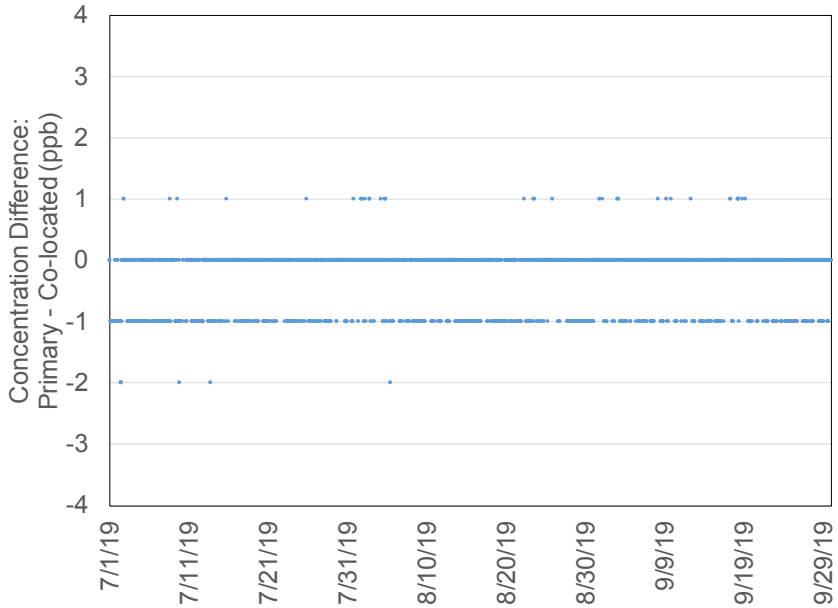


Figure 28. Time Series of the Differences in Co-located O_3 Concentrations for ROM406/206, CO

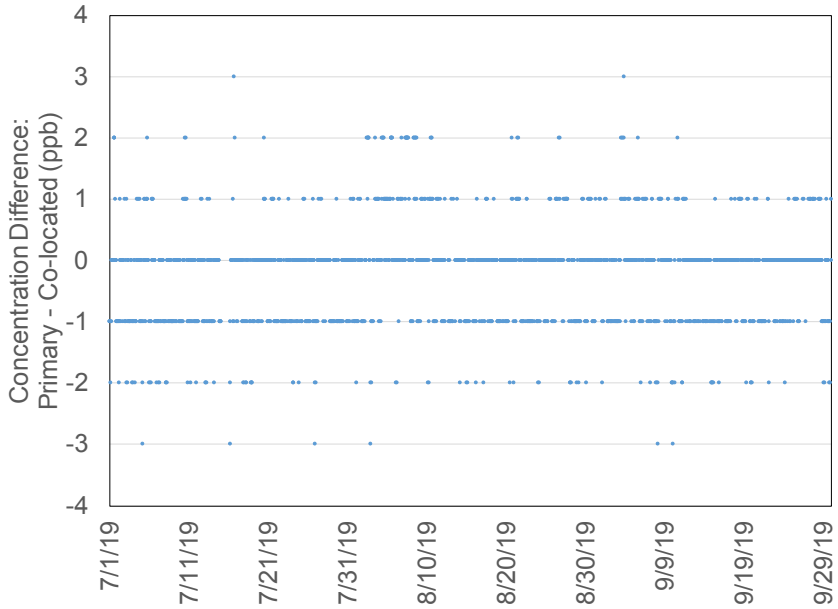


Table 5 gives MARPD data for O_3 data measured at the two co-located sites.

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

Site Pair	Quarter	Start Date	MARPD	Records
MCK131/231, KY				
	4	10/1/18	1.0	2025
	1	1/1/19	2.0	1873
	2	4/1/19	1.5	2064
	3	7/1/19	0.8	2085
ROM406/206, CO				
	4	10/1/18	1.9	1973
	1	1/1/19	1.5	1983
	2	4/1/19	1.3	1949
	3	7/1/19	1.4	2030

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 Third Quarter 2019

Site ID	Percent Completeness	Comments
BFT142, IL	73.9	High bench temperatures occurred on several occasions during July and August, resulting in invalid O_3 concentrations. Equipment was removed from site 9/4/19 to 9/17/19 in preparation for a hurricane.
ALC188, TX	77.2	The sample pump failed in July. High bench temperatures occurred on several occasions during September.
IRL141, FL	80.4	QC failures affected approximately one week of data during July and August. Equipment was removed from site 8/30/19 to 9/6/19 in preparation for a hurricane.
CDR119, WV	82.6	High bench temperatures occurred on several occasions during July.
CHE185, OK	83.7	Communication issues during the quarter resulted in approximately nine days of missing data.
OXF122, OH	88.0	QC failures affected approximately one week of data during July.
PND165, WY	88.0	The air conditioner fan failed resulting in high bench temperatures on extended occasions during July and August. Communication issues in August resulted in periods of missing data.
CDZ171, KY	88.0	A sample pump failure in July affected nine days of sampling.
MKG113, PA	89.1	High bench temperatures occurred on several occasions during July and September. Communications were lost in August.
SPD111, TN	89.1	QC failures affected approximately one week of data during the quarter.

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 2019	Q4 2018–Q3 2019	Comments
BFT142, NC	75.2	46.1	High bench temperatures occurred on several occasions during July and August. Equipment was removed from site 9/4/19 to 9/17/19 in preparation for a hurricane.
ALC188, TX	80.9	94.7	The sample pump failed in July. High bench temperatures occurred on several occasions during September.
IRL141, FL	82.1	93.3	QC failures affected approximately one week of data during July and August. Equipment was removed from site 8/30/19 to 9/6/19 in preparation for a hurricane.
YEL408, WY	83.8	91.3	Communication issues prevented data collection 7/9/19 to 7/23/19.
PND165, WY	88.5	96.7	The air conditioner fan failed resulting in high bench temperatures on extended occasions during July and August. Communication issues in August resulted in periods of missing data.
OXF122, OH	89.8	95.6	QC failures affected approximately one week of data during July.

Filter Pack Total Nitrate and Continuous Trace-level NO_y Concentrations at Six 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 with available data are shown in Table 8. Ratios of NO_y to total NO_3^- varied from 3.44 at GRS420 to 9.85 at HWF187.

Table 8. Summary of Total NO_3^- and NO_y Measurements for Third Quarter 2019

Site ID	Elevation	Total NO_3^- (ppb)	NO_y (ppb)	Ratio
DUK008, NC	164	0.46	2.29	5.42
BVL130, IL	213	0.65	3.18	5.13
MAC426, KY	243	0.41	1.74	4.28
HWF187, NY	497	0.09	0.78	9.85
GRS420, TN	793	0.40	1.39	3.44
PNF126, NC	1216	0.21	0.77	3.77
PND165, WY	2386	0.18	0.72	4.19
ROM206, CO	2742	0.22	1.03	4.78

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

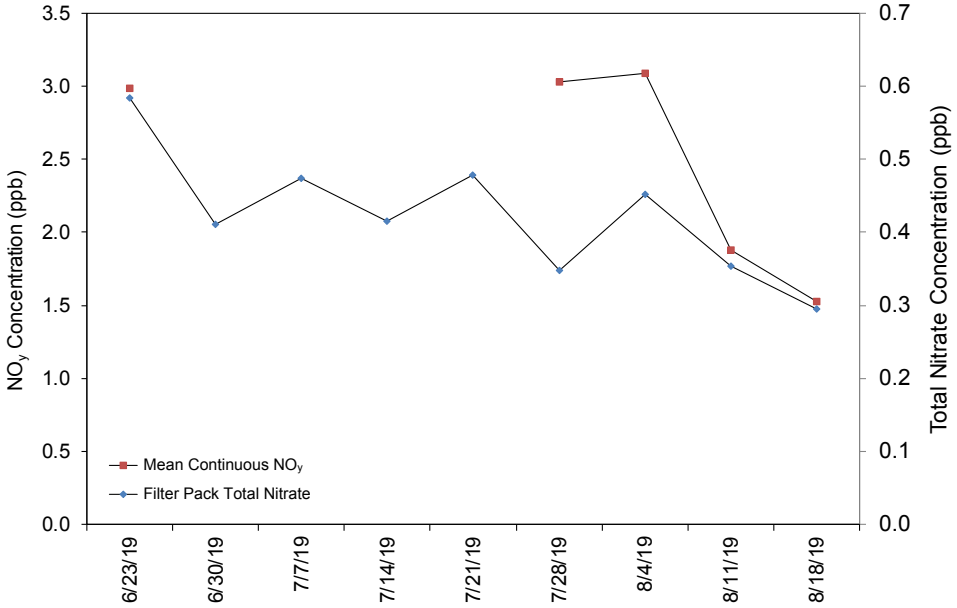


Figure 30. Comparison of BVL130 Weekly Mean NO_y and Total NO_3^- Concentrations

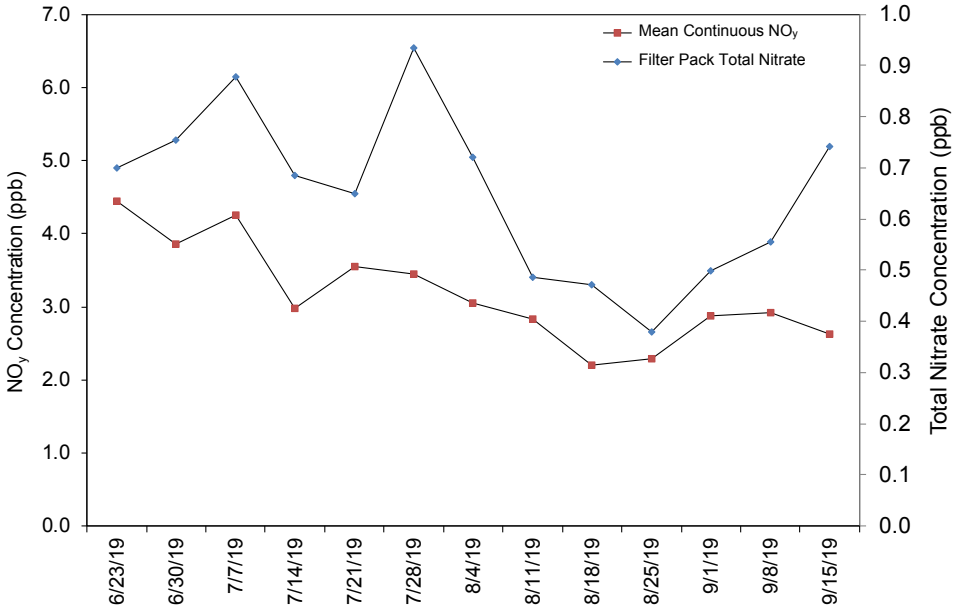


Figure 31. Comparison of MAC426 Weekly Mean NO_y and Total NO_3^- Concentrations

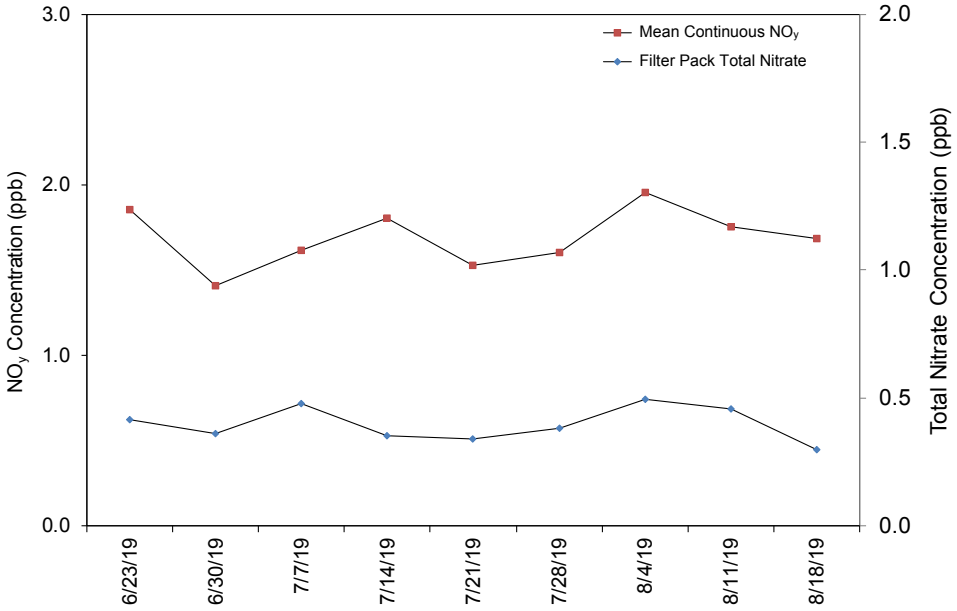


Figure 32. Comparison of HWF187 Weekly Mean NO_y and Total NO_3^- Concentrations

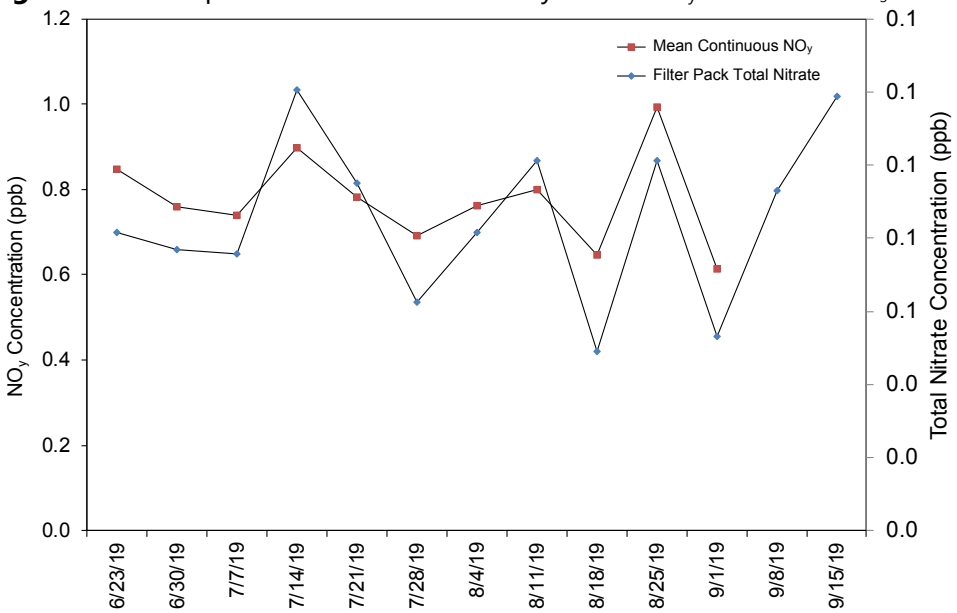


Figure 33. Comparison of GRS420 Weekly Mean NO_y and Total NO_3^- Concentrations

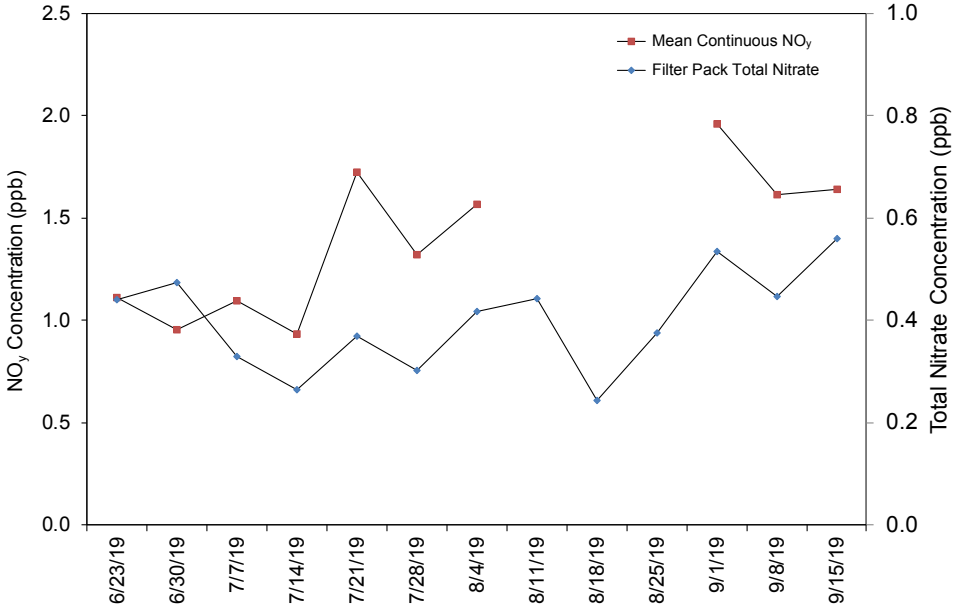


Figure 34. Comparison of PNF126 Weekly Mean NO_y and Total NO_3^- Concentrations

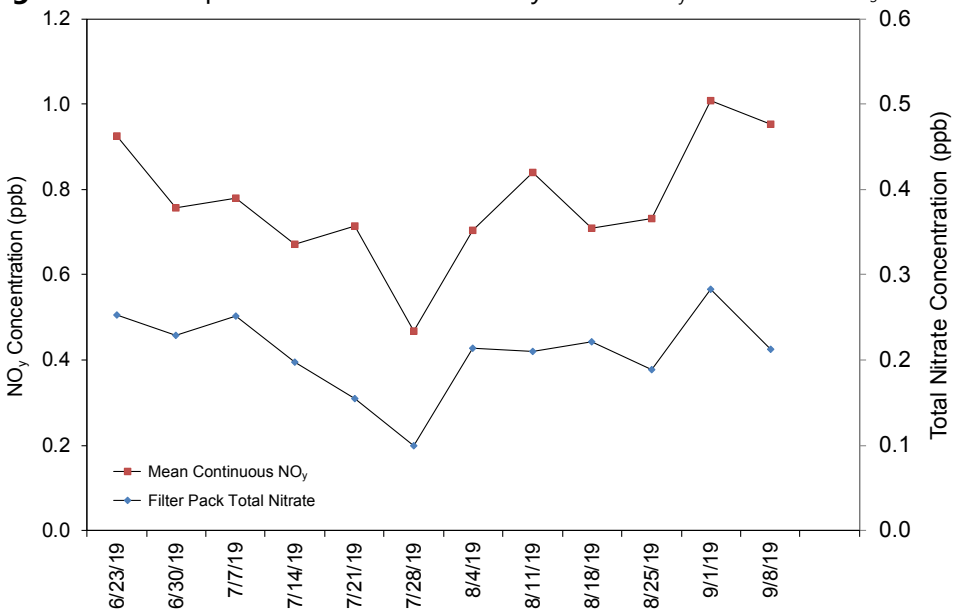


Figure 35. Comparison of PND165 Weekly Mean NO_y and Total NO_3^- Concentrations

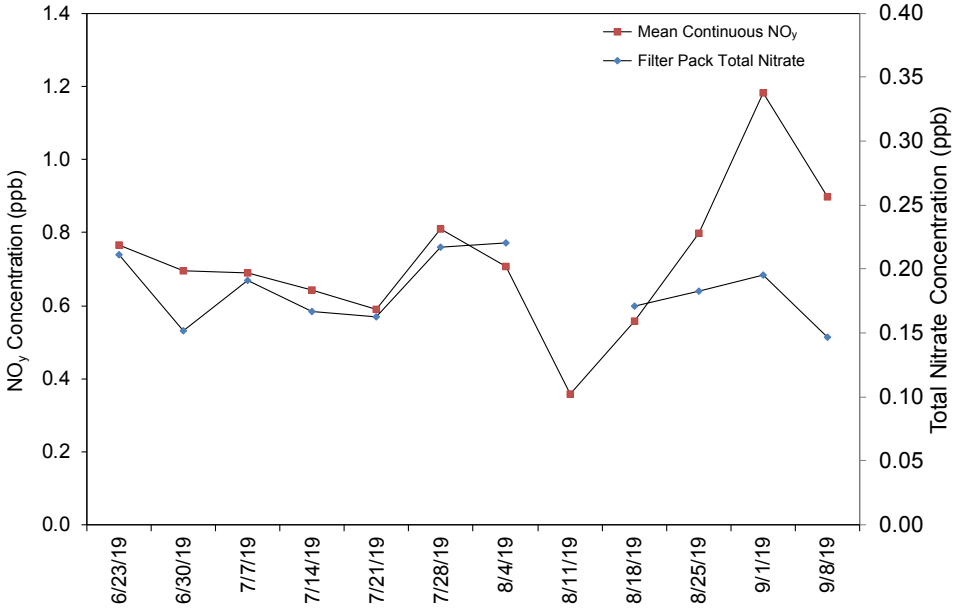
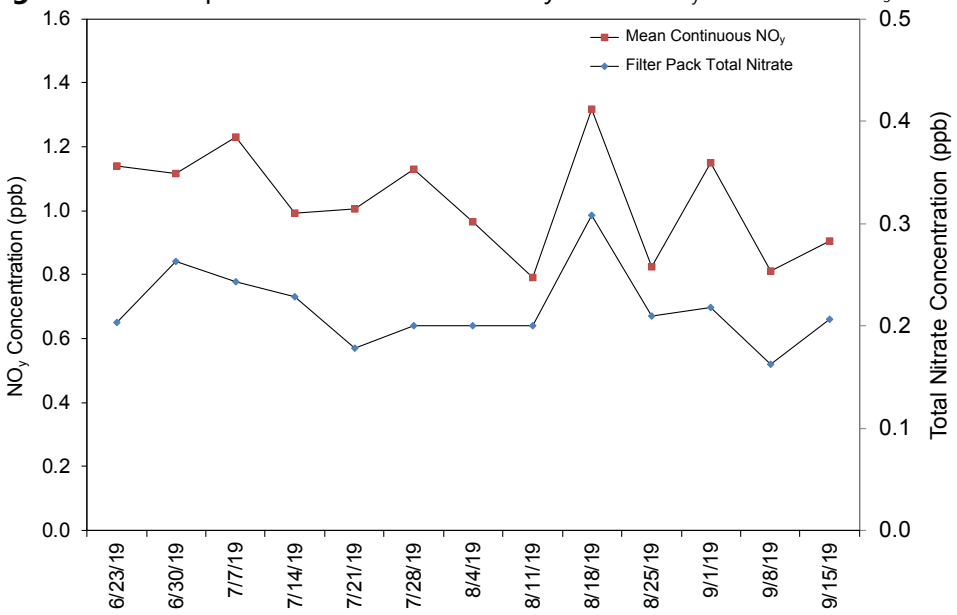


Figure 36. Comparison of ROM206 Weekly Mean NO_y and Total NO_3^- Concentrations



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 generally comparable at MAC426 and GRS420.

Figure 37. Comparison of BVL130 Weekly Mean SO_2 Concentrations

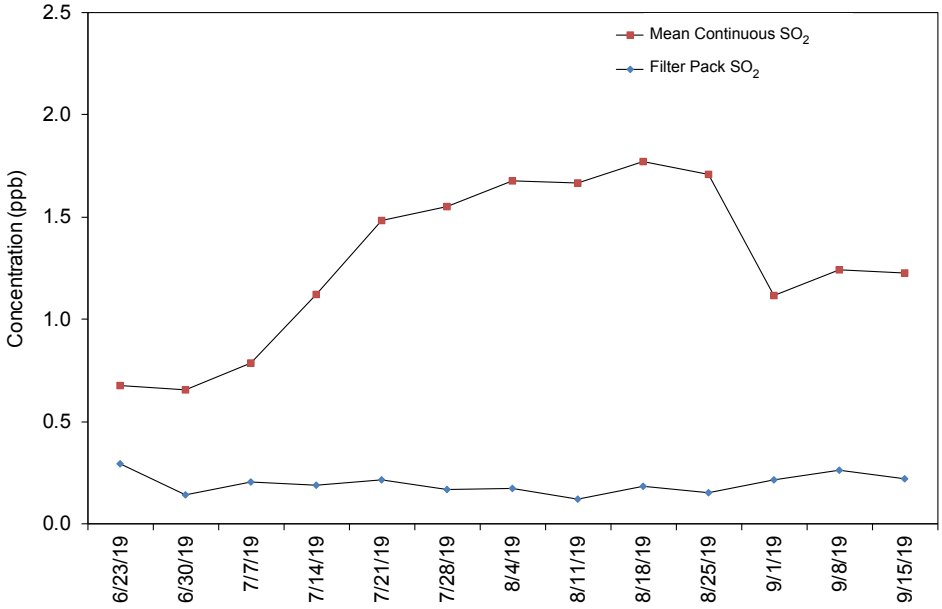


Figure 38. Comparison of MAC426 Weekly Mean SO_2 Concentrations

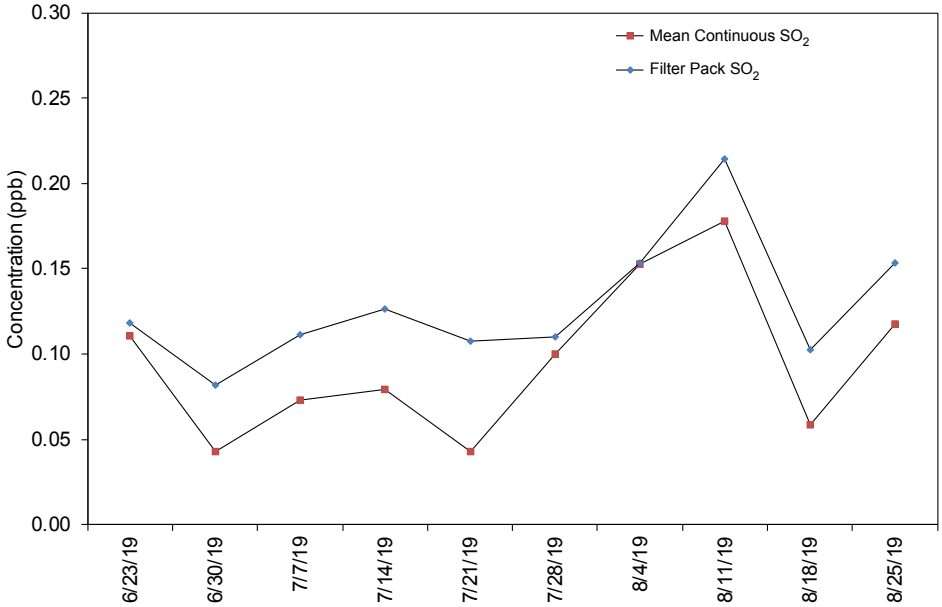
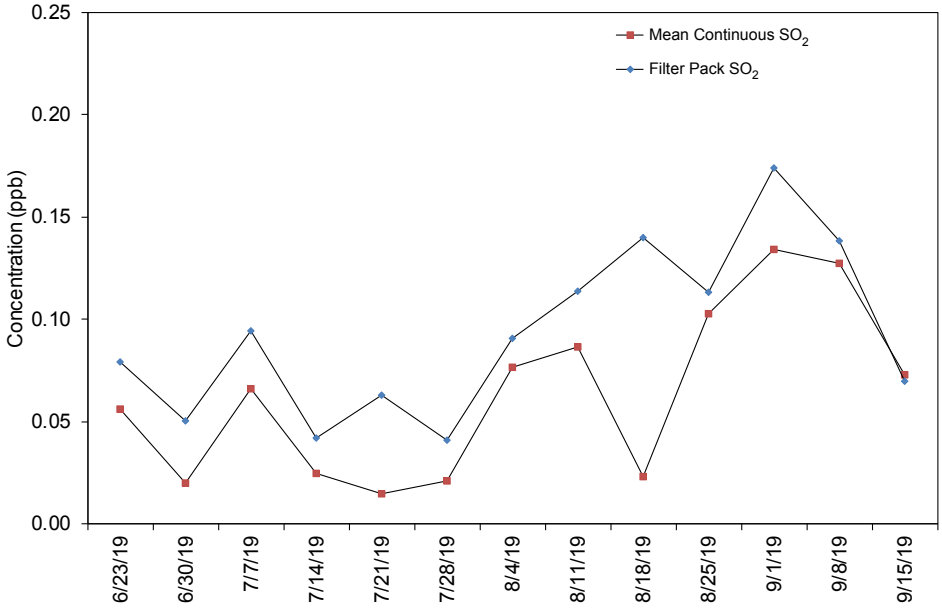


Figure 39. Comparison of GRS420 Weekly Mean SO_2 Concentrations



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 2019. The annual hourly average for each of the sites is included for reference.

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

Site ID	Parameter*	Q3 2019	Q4 2018 – Q3 2019	Comments
BVL130, IL	CO	28	16	The CO analyzer was reinstalled in late July after manufacturer servicing. The reinstalled unit continued to malfunction.
	NO	92	84	
	NOY	92	87	
	NOYDIF	92	84	
	SO2_GA	84	89	Reinstallation of the CO analyzer in July affected the SO_2 analyzer's internal pressure and flows. The SO_2 analyzer was not compensating adequately following CO reinstallation. The sampling trains were separated in September to address this issue.
CHC432, NM	NO	91	96	
	NOX	91	96	
	NOXDIF	91	96	
DUK008, NC	HNO3	37	64	July NO_y-related data were invalidated due to a failed instrument solenoid. Recurring QC failures due to analyzer drift affected data in September. Data captured in the 70 percent range were not affected by the solenoid issue.
	NH3	37	65	
	NO	74	77	
	NO2_TRUE	74	77	
	NOX_TRUE	74	77	
	NOY	37	65	
	NOY_MINUS	70	75	
	NOYDIF	37	65	
	TNX	70	76	
GRS420, TN	CO	93	88	
	NO	73	81	The temperature board in the NO_y analyzer failed due to a bad IC chip. The chip was replaced on 9/1, and data were invalidated from 8/15 through 9/1.
	NOY	73	81	
	NOYDIF	78	84	
	SO2_GA	93	92	
HWF187, NY	NO	71	87	The analyzer's pre-reactor valve assembly malfunctioned during the quarter. It was replaced in September, and the analyzer was recalibrated.
	NOY	71	87	
	NOYDIF	71	87	
MAC426, KY	CO	91	88	
	NO	92	87	
	NOY	92	87	
	NOYDIF	92	87	
	SO2_GA	92	89	
PND165, WY	NO	88	86	QC failures affected data capture in August.
	NOY	88	86	
	NOYDIF	88	85	
PNF126, NC	NO	95	93	
	NOY	95	94	
	NOYDIF	95	93	
ROM206, CO	NO	92	92	
	NOY	92	93	
	NOYDIF	92	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. 2019. *Clean Air Status and Trends Network (CASTNET) Third Quarter 2019 Quality Assurance Report.* https://java.epa.gov/castnet/documents.do