Interagency Monitoring of Protected Visual Environments (IMPROVE): Semiannual Quality Assurance Report

Air Quality Group | University of California, Davis | October 12, 2018

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1. Introduction

The University of California Davis (UCD) Air Quality Group reviews quality assurance (QA) activities semiannually in this report series as a contract deliverable for the Interagency Monitoring of Protected Visual Environments (IMPROVE) program (contract #P15PC00384). The primary objectives of the series are to:

1. Provide the National Park Service (NPS) with graphics illustrating some of the comparisons used to evaluate the quality and consistency of measurements within the network.
2. Highlight observations that may give early indications of emerging trends, whether in atmospheric composition or measurement quality.

3. Serve as a record and tool for ongoing UCD QA efforts.

The graphics shown in this report are a small subset of the many QA evaluations that UCD performs on a routine basis. More finished analyses such as those available in data advisories are outside the scope of this report, which provides a snapshot of the network's internal consistency and recent trends.

Each network site has a sampler for collection of particulate matter on polytetrafluoroethylene (PTFE), nylon, and quartz filters. The IMPROVE sampler has four sampling modules:

- Module-A: Collection of fine particles with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) on polytetrafluoroethylene (PTFE) filters for gravimetric, x-ray fluorescence (XRF), and optical absorption by hybrid integrating plate/sphere (HIPS) analysis at UCD.
- Module-B: Collection of $PM_{2.5}$ on nylon filters for ion chromatography (IC) analysis at Research Triangle Institute (RTI) International.
- Module-C: Collection of $PM_{2.5}$ on quartz filters for thermal optical analysis (TOA) at Desert Research Institute (DRI).
- Module-D: Collection of particles with aerodynamic diameter less than 10 µm (PM_{10}) on PTFE filters for gravimetric analysis at UCD.

Additional information and detail regarding analytical and validation procedures can be found in the standard operation procedure (SOP) documents and Quality Assurance Project Plan (QAPP) available at the Colorado State University (CSU) Cooperative Institute for Research in the Atmosphere (CIRA) IMPROVE site at *http://vista.cira.colostate.edu/Improve/*

Unless otherwise noted, data evaluated in this report cover sampling dates from January 1, 2017 through December 31, 2017.

2. Concentration-Level QC Checks

2.1 Comparison Across Years

Time series plots of network-scale statistics can reveal possible effects associated with changes in procedures, instrumentation, or sampling media in the analytical laboratories at DRI, RTI, and UCD. Interpretation of these plots is complicated by real atmospheric trends whose presence IMPROVE is intended to detect; these arise from intentional or adventitious changes in emissions, as well as inter-annual fluctuations in synoptic weather patterns.

Figures 1-6 show 90th percentile, median (50th percentile), and 10th percentile concentrations of select species, with six years of historical network data (2011-2016) providing context for the year currently under review (2017).

Concentrations of lead (Figure 1) during both 2016 and 2017 are generally lower relative to previous years. Measurements of $PM_{2.5}$ (Figure 2) are also generally lower at the start of 2016 and 2017, however, August and September 2017 $PM_{2.5}$ concentrations at the 90th percentile are higher than all other years.

Figure 1: Multi-year time series, lead (Pb).

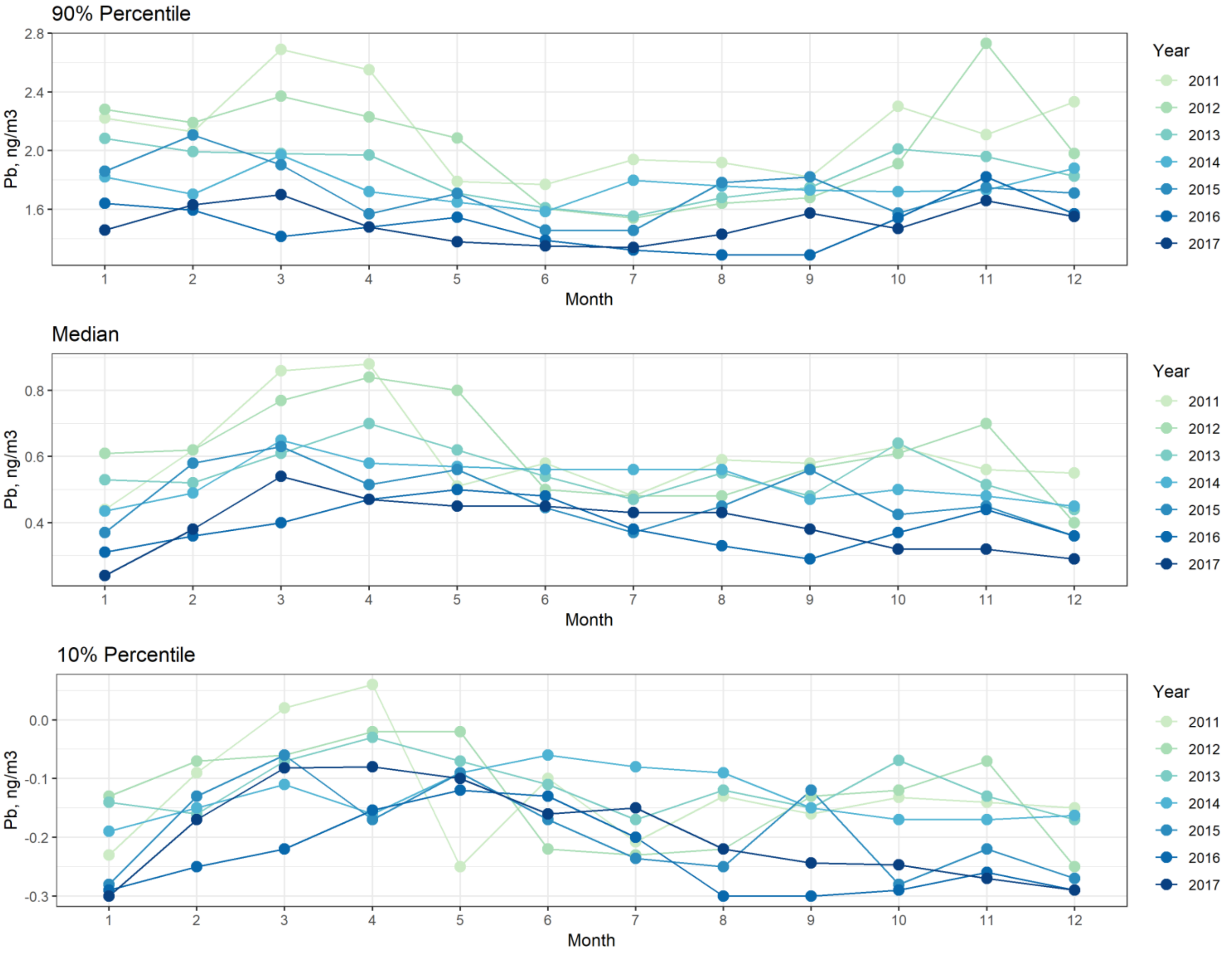
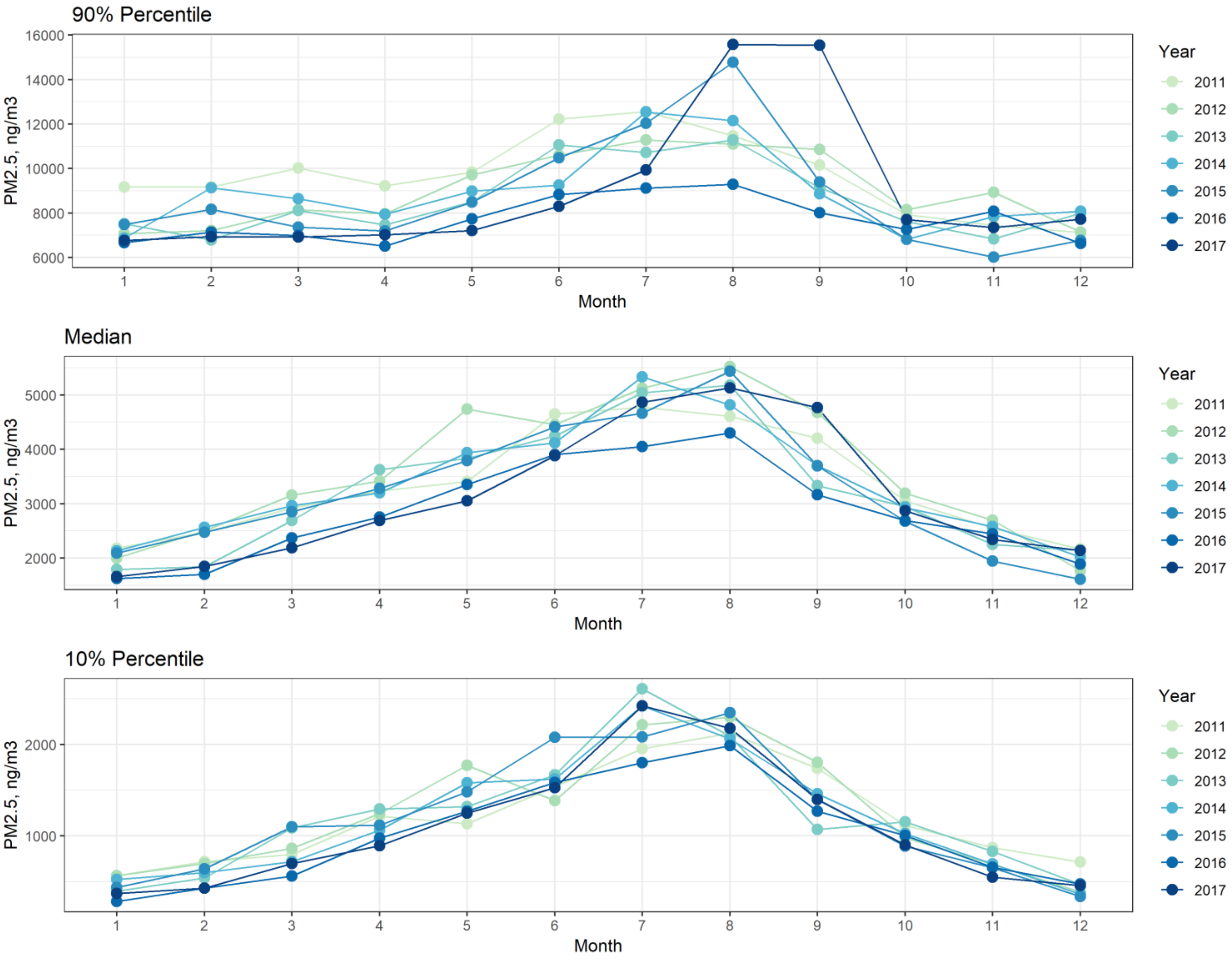


Figure 2: Multi-year time series, PM$_{2.5}$ mass by gravimetric analysis.



All carbon data shown in this report (and available through FED and AQS databases) is reprocessed with the revised integration threshold, as discussed in the previous Semiannual Quality Assurance Report (March 1, 2018). Reprocessed data was redelivered to the NPS on February 23, 2018. Concentrations of both OC (Figure 3) and EC (Figure 4) during 2017 are high during the summer months (particularly July, August, and September) relative to previous years. The elevated summer carbon concentrations are likely caused by wildfires and driving elevated PM$_{2.5}$ observed during the same timeframe (Figure 2).

Similar to trends observed from EC measurements, optical measurements from HIPS show elevated concentrations during summer 2017 (Figure 5).

Figure 3: Multi-year time series, organic carbon (OC).

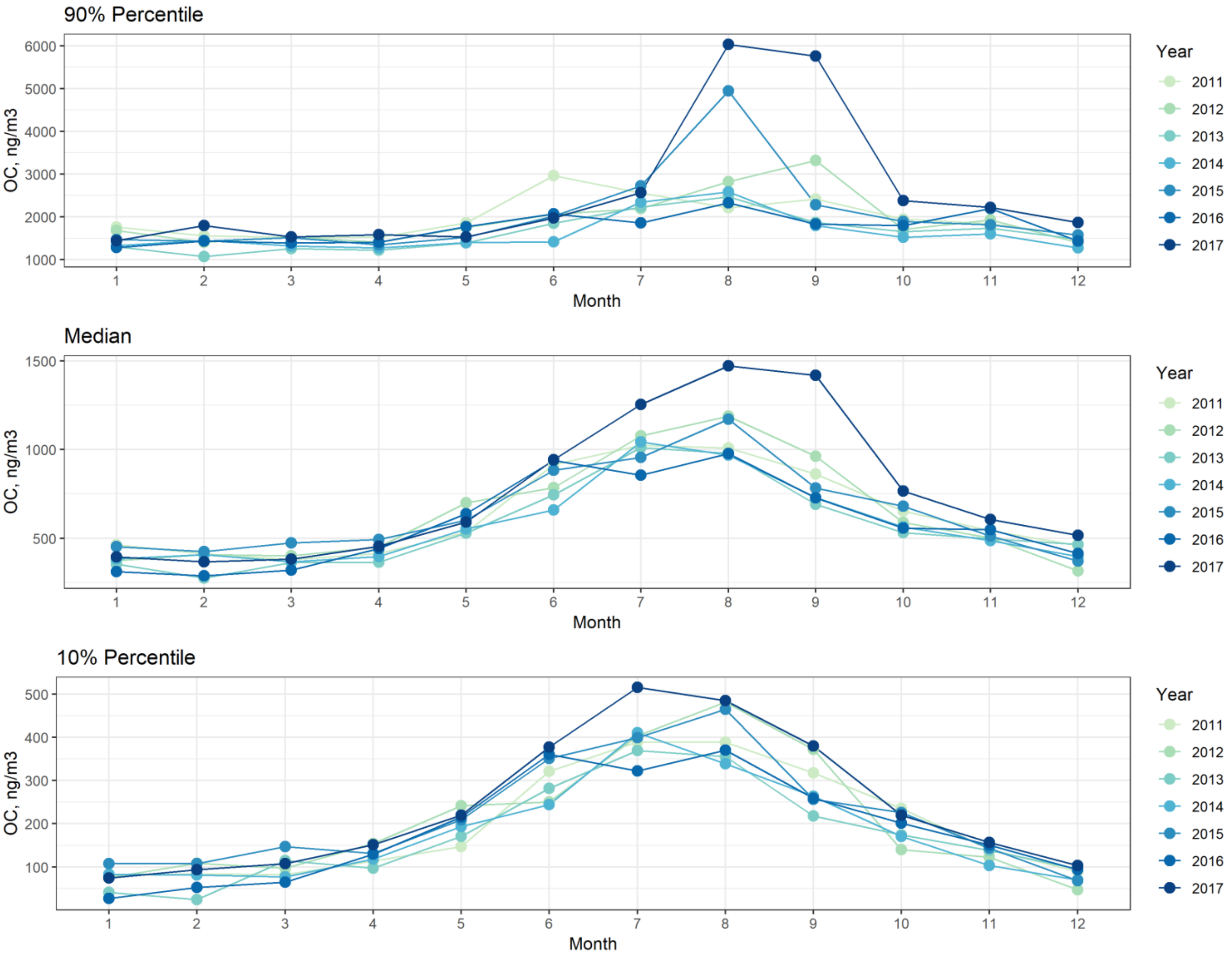


Figure 4: Multi-year time series, elemental carbon (EC).

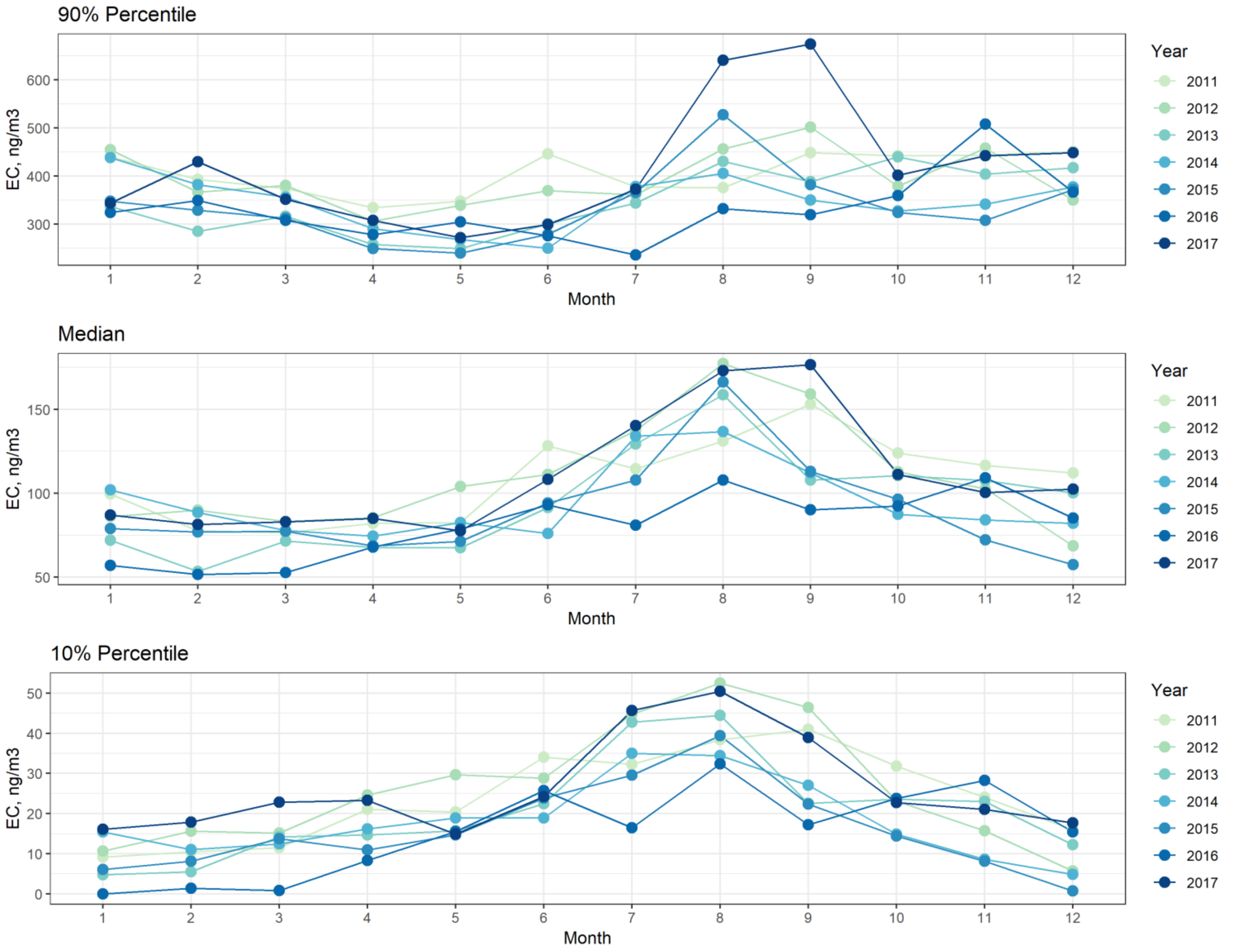
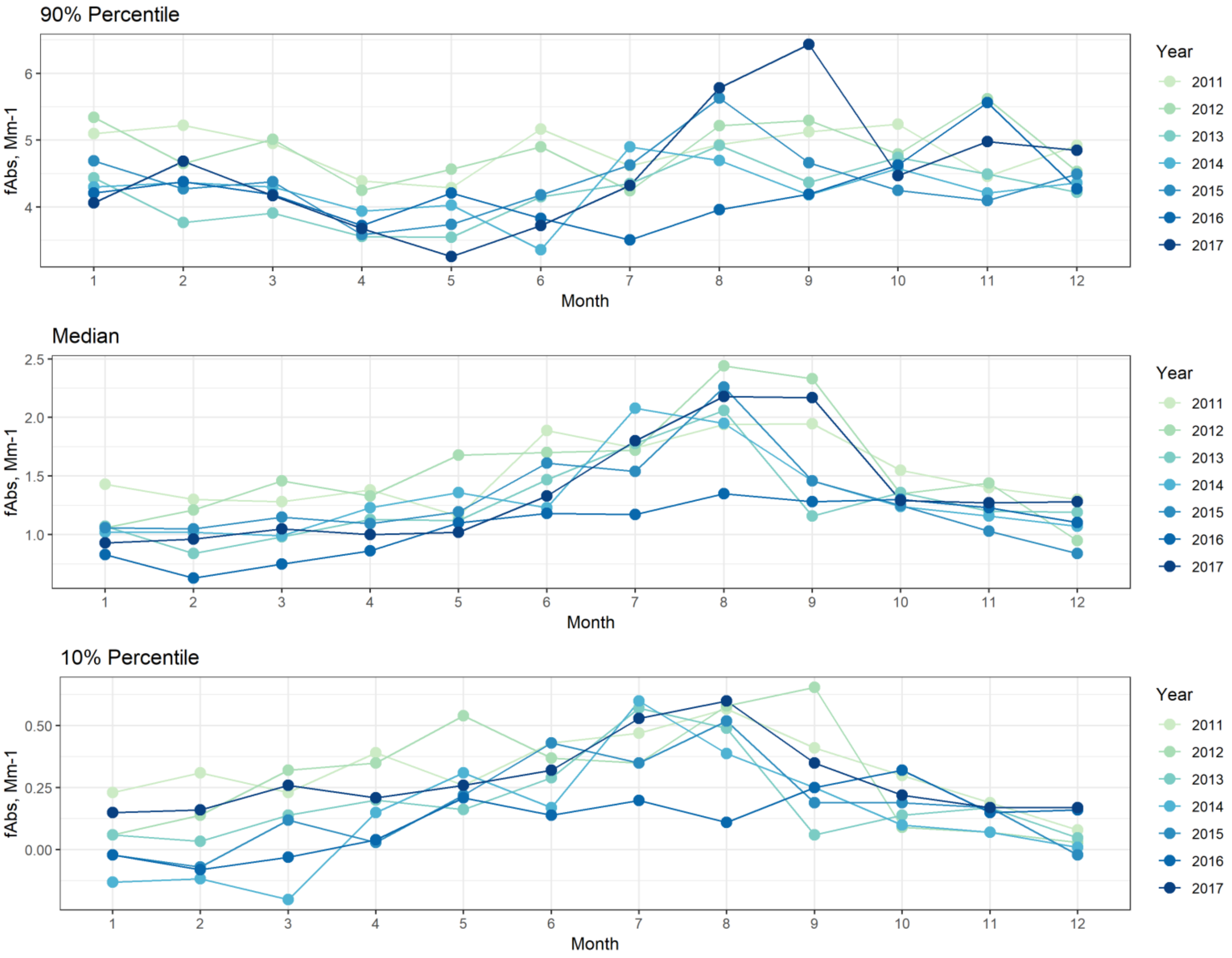


Figure 5: Multi-year time series, optical absorption by HIPS (fAbs).



Sulfur concentrations generally continue to decrease across the network, with 2016 and 2017 concentrations lower relative to previous years (Figure 6). Sulfur concentrations are generally higher during the summer months. Seen on a longer timescale (1990-2017; Figure 7), the decreasing sulfur trend is even more apparent, with particularly dramatic decreases in sulfate concentrations observed at sites in the eastern United States. As expected, sulfate concentrations exhibit the same trend (Figure 8).

Figure 6: Multi-year time series, sulfur (S).

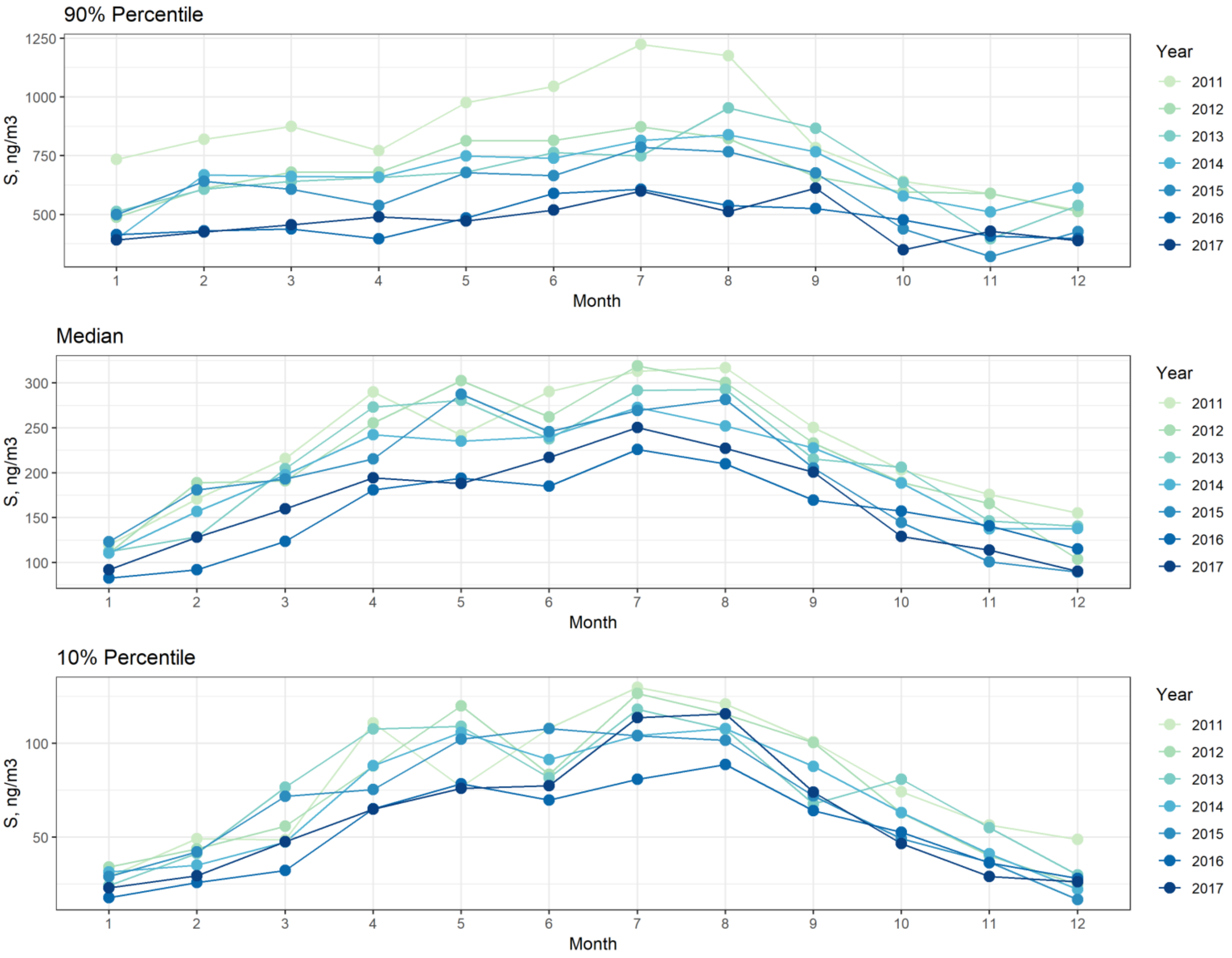


Figure 7: Summer (June through August) mean sulfur by site, where color is gradiated by site longitude.

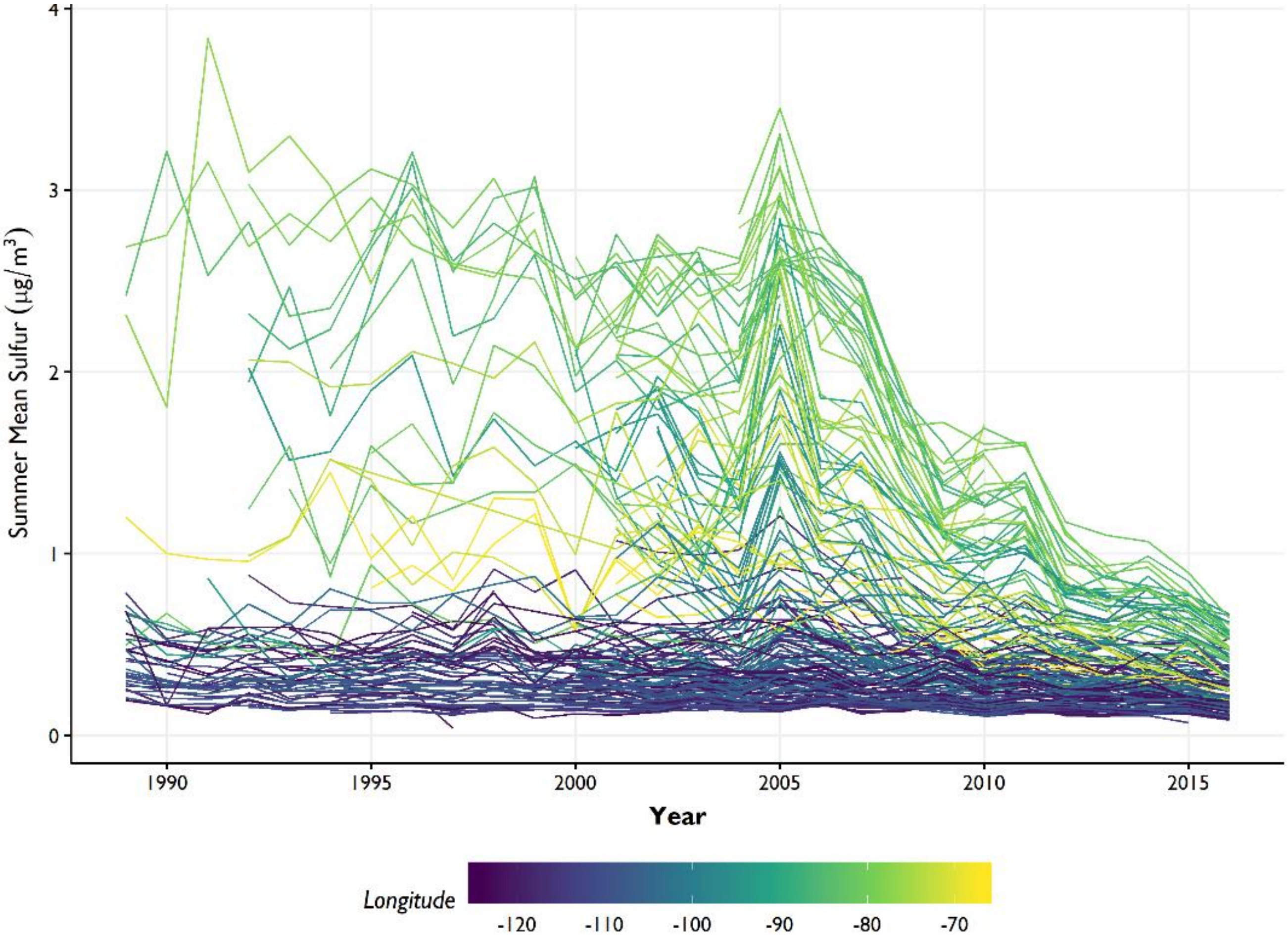
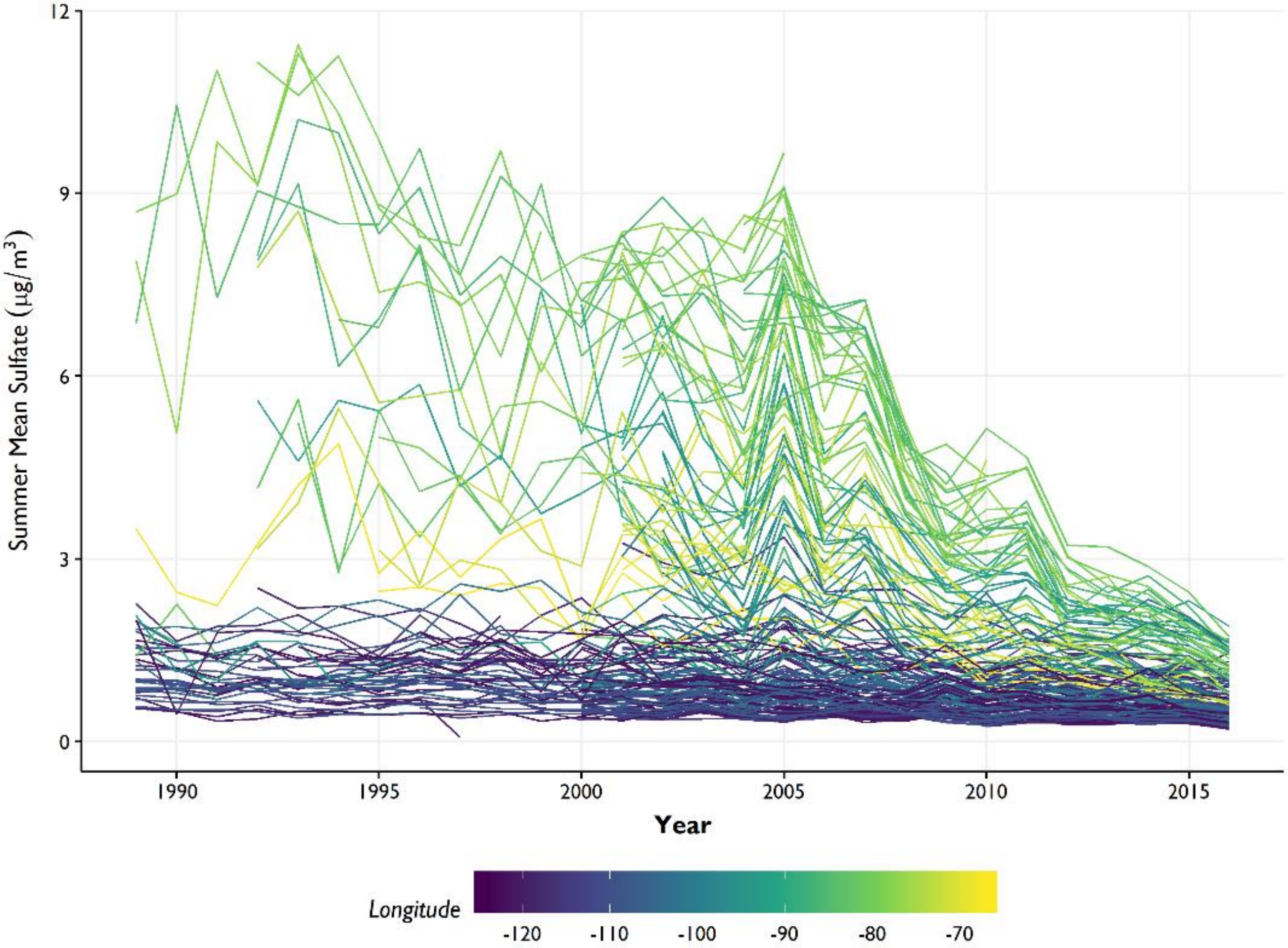


Figure 8: Summer (June through August) mean sulfate by site, where color gradiated by site longitude.



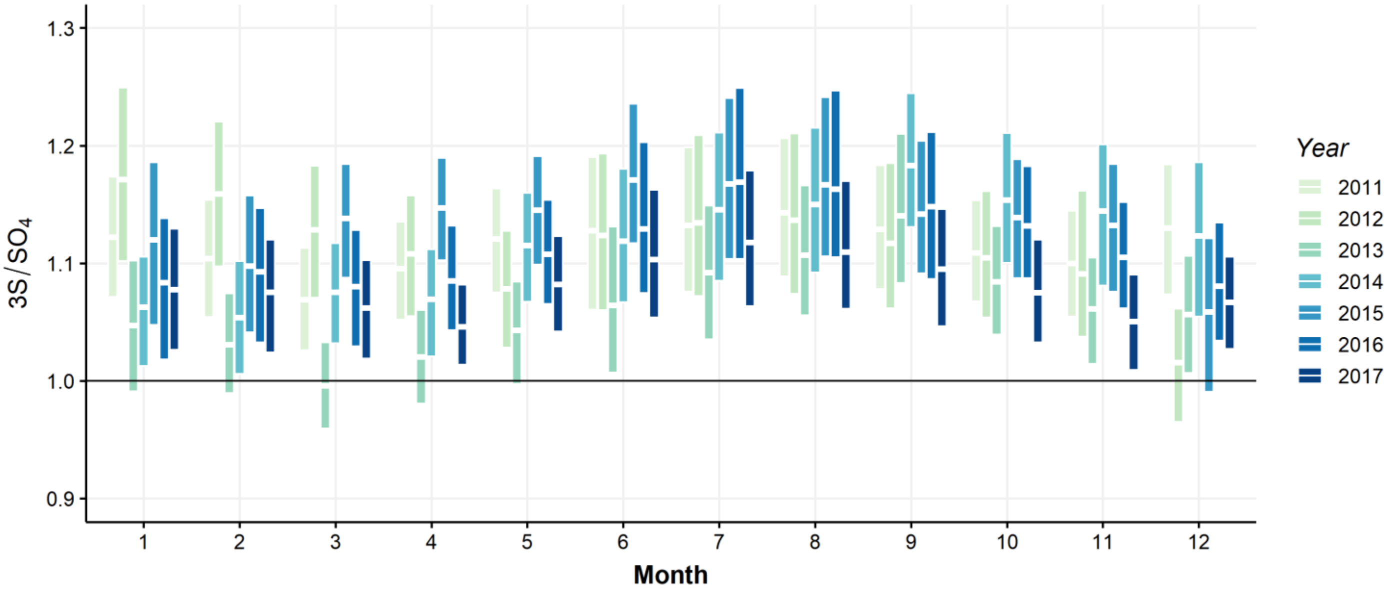
2.2 Comparisons Between Modules

The following graphs compare two independent measures of aerosol properties that are expected to correlate. Graphs presented in this section explore variations in the correlations, which can result from real atmospheric and anthropogenic events or analytical and sampling issues.

2.2.1 Sulfur versus Sulfate

PTFE filters collected from the A-Module are analyzed for elemental sulfur using XRF, and nylon filters collected from the B-Module are analyzed for sulfate (SO_4) using IC. The molecular weight of SO_4 (96 g/mol) is three times the atomic weight of S (32 g/mol), so the concentration ratio $(3 \times S)/SO_4$ should be one if all particulate sulfur is present as water-soluble sulfate. In practice, real measurements routinely yield a ratio greater than one (Figure 9), suggesting the presence of some sulfur in a non-water soluble form of sulfate or in a chemical compound other than sulfate. While still above one, the $(3 \times S)/SO_4$ ratio is lower during 2017 relative to the previous two years.

Figure 9: Multi-year time series of (3×S)/SO_4.



2.2.2 PM2.5 versus Reconstructed Mass (RCMN)

PTFE filters from the A-Module are analyzed gravimetrically (i.e., weighed before and after sample collection) to determine $PM_{2.5}$ mass. Gravimetric data are compared to reconstructed mass (RCMN), where the RCMN composite variable is estimated from chemical speciation measurements. The formulas used to estimate the mass contributions from various chemical species are taken from *UCD IMPROVE SOP 351*, *Data Processing and Validation*. In the simple case where valid measurements are available for all needed variables, reconstructed mass is the following sum:

$$\mathrm{RCMN} = (4.125 \times \mathrm{S}) + (1.29 \times \mathrm{NO_3^-}) + (1.8 \times \mathrm{OC}) + (\mathrm{EC}) +$$

$$(2.2 \times \mathrm{Al} + 2.49 \times \mathrm{Si} + 1.63 \times \mathrm{Ca} + 2.42 \times \mathrm{Fe} + 1.94 \times \mathrm{Ti}) + (1.8 \times \mathrm{chloride})$$

The parenthesized components represent the mass contributions from, in order, ammonium sulfate, ammonium nitrate, organic compounds, elemental carbon, soil, and sea salt.

If the RCMN completely captures and accurately estimates the different mass components, the RCMN/$PM_{2.5}$ ratio is expected to be near one. The gravimetric mass likely includes some water associated with hygroscopic species, which is not accounted for by any of the chemical measurements. Conversely, some ammonium nitrate measured on the retentive nylon filter may volatilize from the inert PTFE filter during and after sampling.

The RCMN/$PM_{2.5}$ ratio exhibits seasonal variability, with the lowest ratios during the summer months (Figure 10). The 2017 RCM/$PM_{2.5}$ ratios are generally high relative to recent years, though in some cases align well with ratios from 2011 and 2012. Exploration of individual RCMN constituents relative to $PM_{2.5}$ revealed an elevated OC/$PM_{2.5}$ ratio (Figure 11) and an increased contribution of OC relative to other components (Figure 12) during 2017 relative to previous years. These findings are also in alignment with elevated 2017 OC observed in Figure 3.

The elevated 2017 RCMN/PM2.5 ratio, in conjunction with evidence of elevated OC, could suggest that the 1.8 OC multiplier is not representative of the OC contribution.

Figure 10: Multi-year time series of RCMN/PM2.5 ratio.

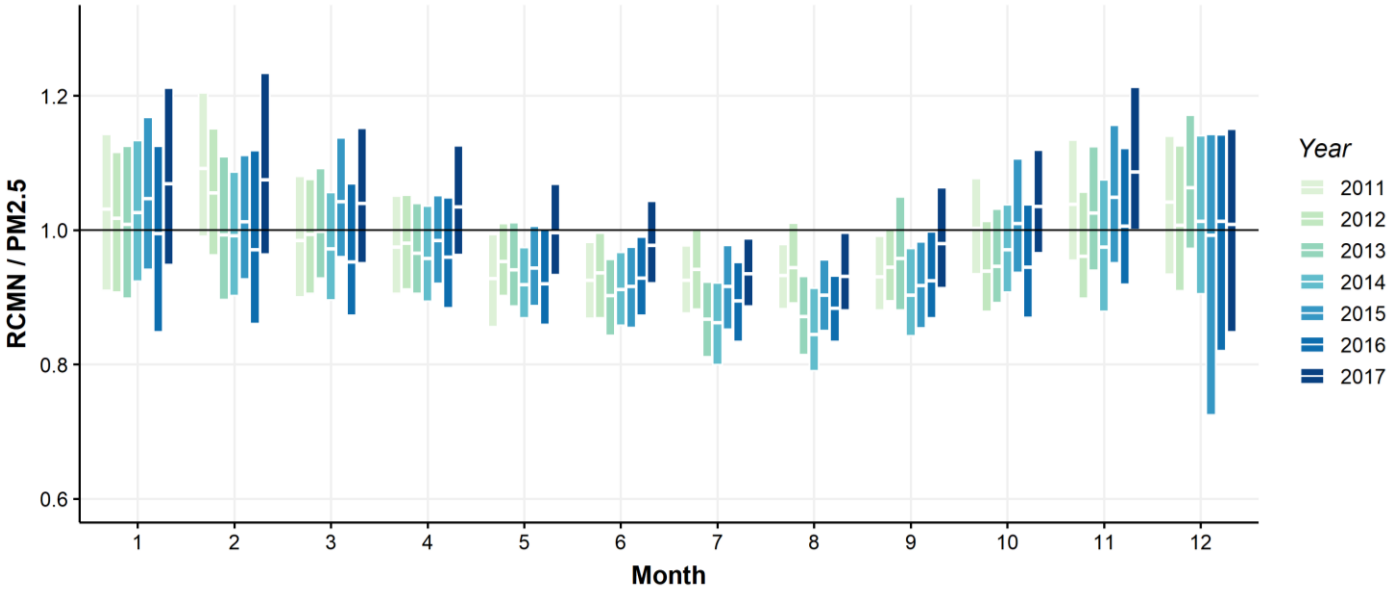


Figure 11: Multi-year time series of OC/PM2.5 ratio.

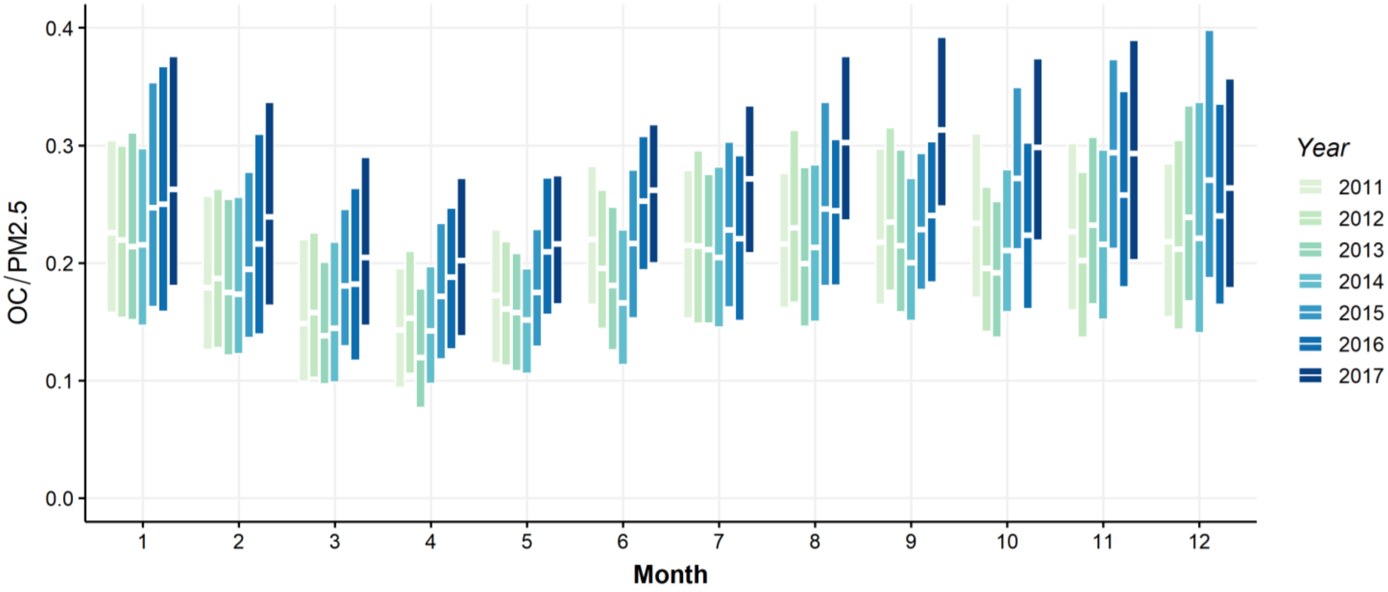
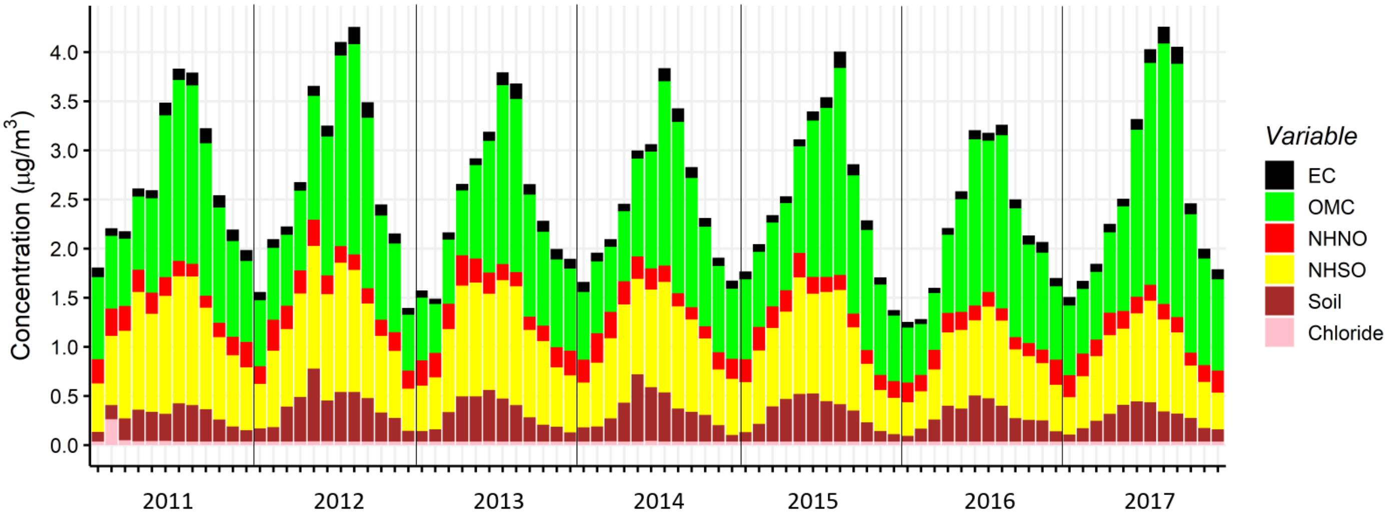


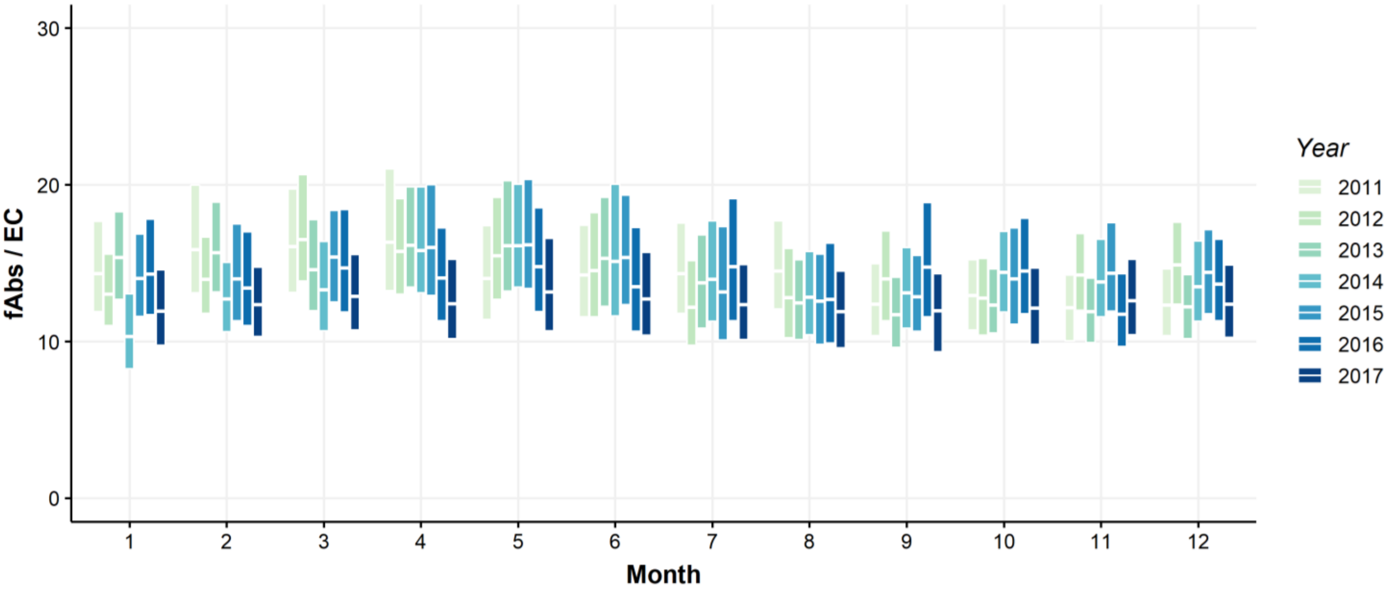
Figure 12: Stacked time series of RCMN component concentrations from 2011 to 2017.



2.2.3 Optical Absorption versus Elemental Carbon

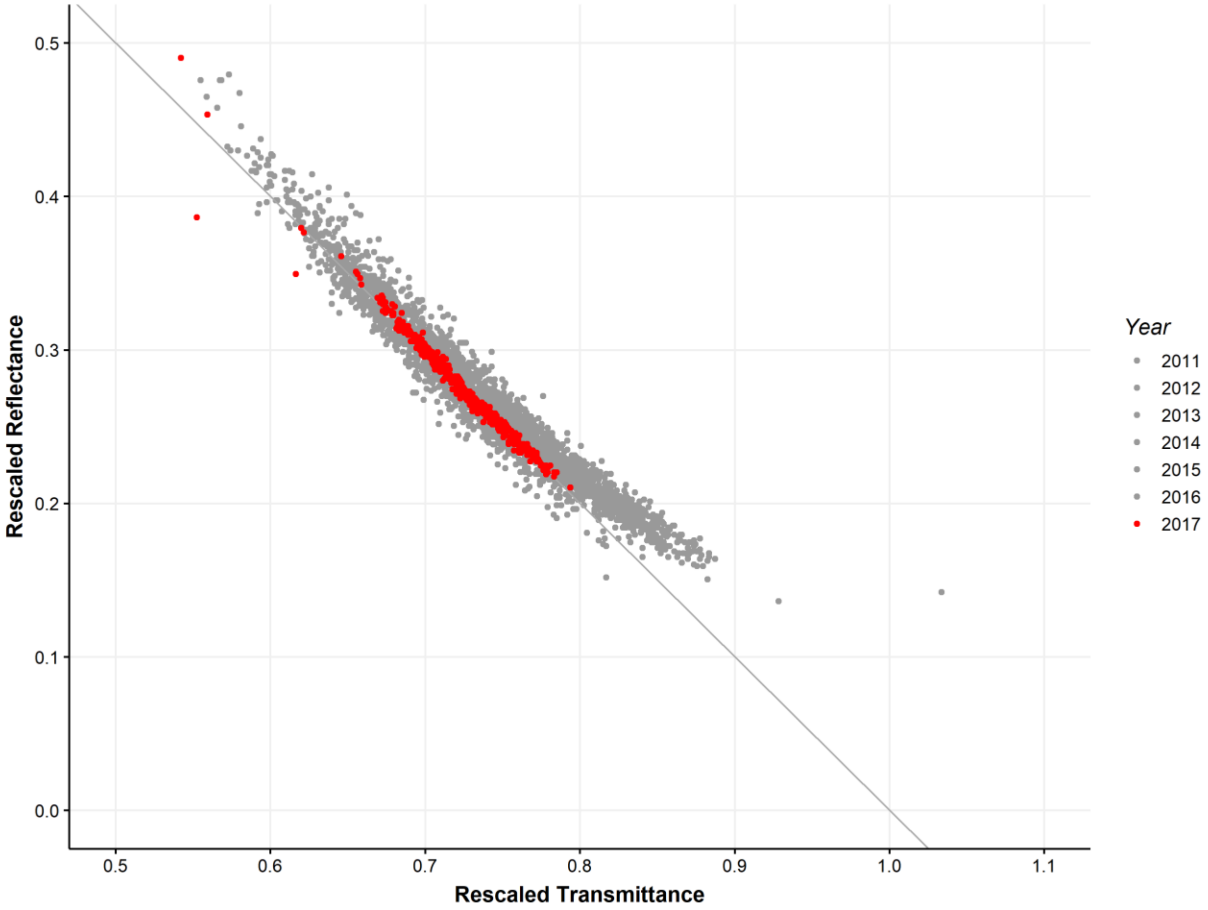
The hybrid integrating plate/sphere (HIPS) instrument measures optical absorption, allowing for calculation of absorption coefficients (fAbs, where units are Mm^{-1}) from A-Module PTFE filters. Absorption coefficients are expected to correlate with C-Module elemental carbon (EC, where units are $\mu g/m^3$) measured by thermal optical reflectance (TOR). The fAbs/EC ratio (with units m^2/g) exhibits seasonal variability with lower ratios during the summer months, corresponding with higher concentrations of EC (Figure 13).

Figure 13: Multi-year time series of fAbs/EC ratio, where fAbs is in Mm^{-1} and EC is in $\mu g/m^3$.



Prior to analysis of 2017 samples the HIPS integrating sphere was changed from the legacy 2-inch Spectraflect-coated sphere described in White et al. (2016) to a newer 4-inch Spectralon sphere from the same manufacturer, and the laser was replaced. After appropriate recalibration, the new system gives results that agree well with those from the legacy version (Figure 14).

Figure 14: Calibration of HIPS showing rescaled reflectance and transmittance for 2017 relative to previous years (2011-2016).



2.3 Comparisons Between Collocated Samples

Select IMPROVE network sites have collocated modules, where duplicate samples are collected and analyzed using the same analytical protocols. Differences between the resulting data provide a measure of the total uncertainty associated with filter substrates, sampling and handling in the field, and laboratory analysis. Collocated precision is reported as fractional uncertainty, allowing determination of uncertainty without the influence of field blank outliers.

Collocated precision is calculated for each sample year from the scaled relative differences (SRD) between the collocated sample pairs. The collocated precision formula is a robust estimate of the standard deviation of the differences. To obtain an estimate of the mean standard deviation over multiple years, the mean of the variances is calculated, and the fractional uncertainty is the square root of the mean variance.

$$Scaled\ Relative\ Difference = \frac{(\text{collocated} - \text{routine}) / \sqrt{2}}{(\text{collocated} + \text{routine}) / 2}$$

$$Collocated\ Precision\ (cp) = \frac{(84th\ percentile\ of\ SRD) - (16the\ percentile\ of\ SRD)}{2}$$

$$Fractional\ Uncertainty = 100 \times \sqrt{\frac{1}{n}\sum_{i=1}^{n}(cp)_i^2}$$

The scaled relative differences are ±√2 when one of the two measurements is zero, and vary between these limits at concentrations close to the detection limit. They generally decrease with increasing concentration and are expected to converge to a distribution representative of multiplicative measurement error when the concentration is well above the detection limit (Figure 15, elements; Figure 16, mass; Figure 17, ions; Figure 18, carbon; Figure 19, optical absorption). Note that this convergence is not observed for elements and carbon fractions that are rarely measured above the MDL.

The collocated comparisons for elements (particularly soil elements: Al, Si, Ca, Fe, and Ti) and mass ($PM_{2.5}$ and PM_{10}) at the Phoenix, AZ site (PHOE) have notably larger scaled relative differences, with a low bias were PHOE5 is measured lower than PHOE1. This is a known issue that was previously explored and is possibly related to a highly localized source of dust (i.e., a dog run at the neighboring house) but remains unresolved.

Figure 15: Scaled relative difference for element measurements at sites with collocated modules across the IMPROVE network (2017). Dotted vertical lines indicate method detection limits.

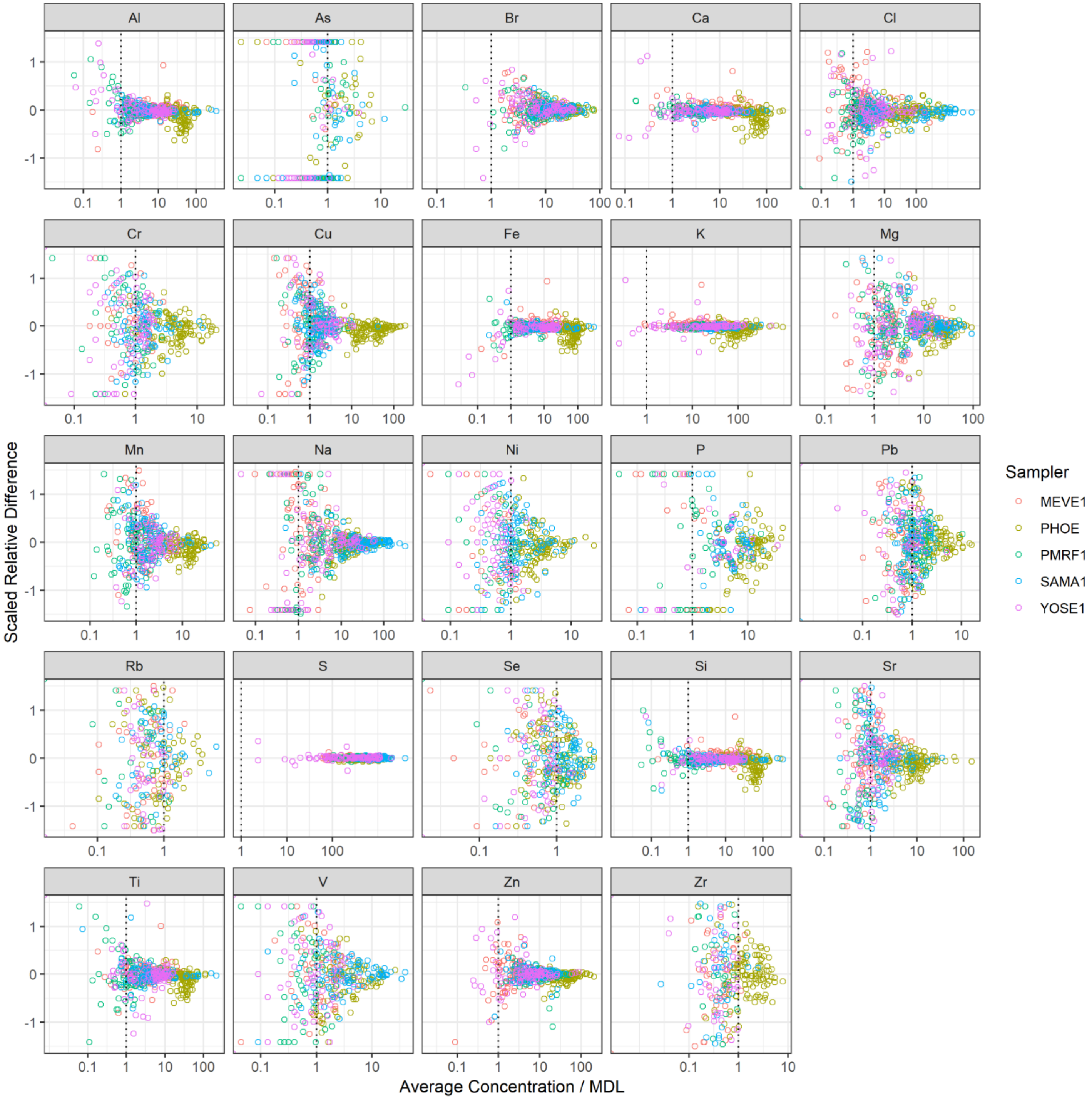


Figure 16: Scaled relative difference for PM_{10} and $PM2_{.5}$ at sites with collocated modules across the IMPROVE network (2017). Dotted vertical lines indicate method detection limits.

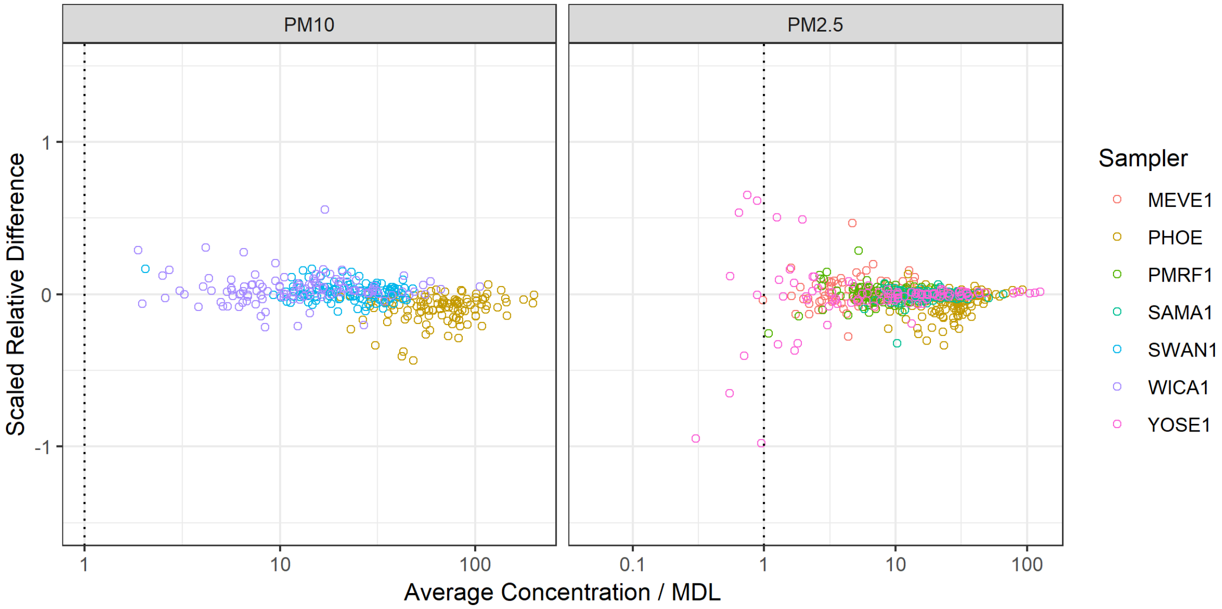


Figure 17: Scaled relative difference for ions measurements at sites with collocated modules across the IMPROVE network (2017). Dotted vertical lines indicate method detection limits.

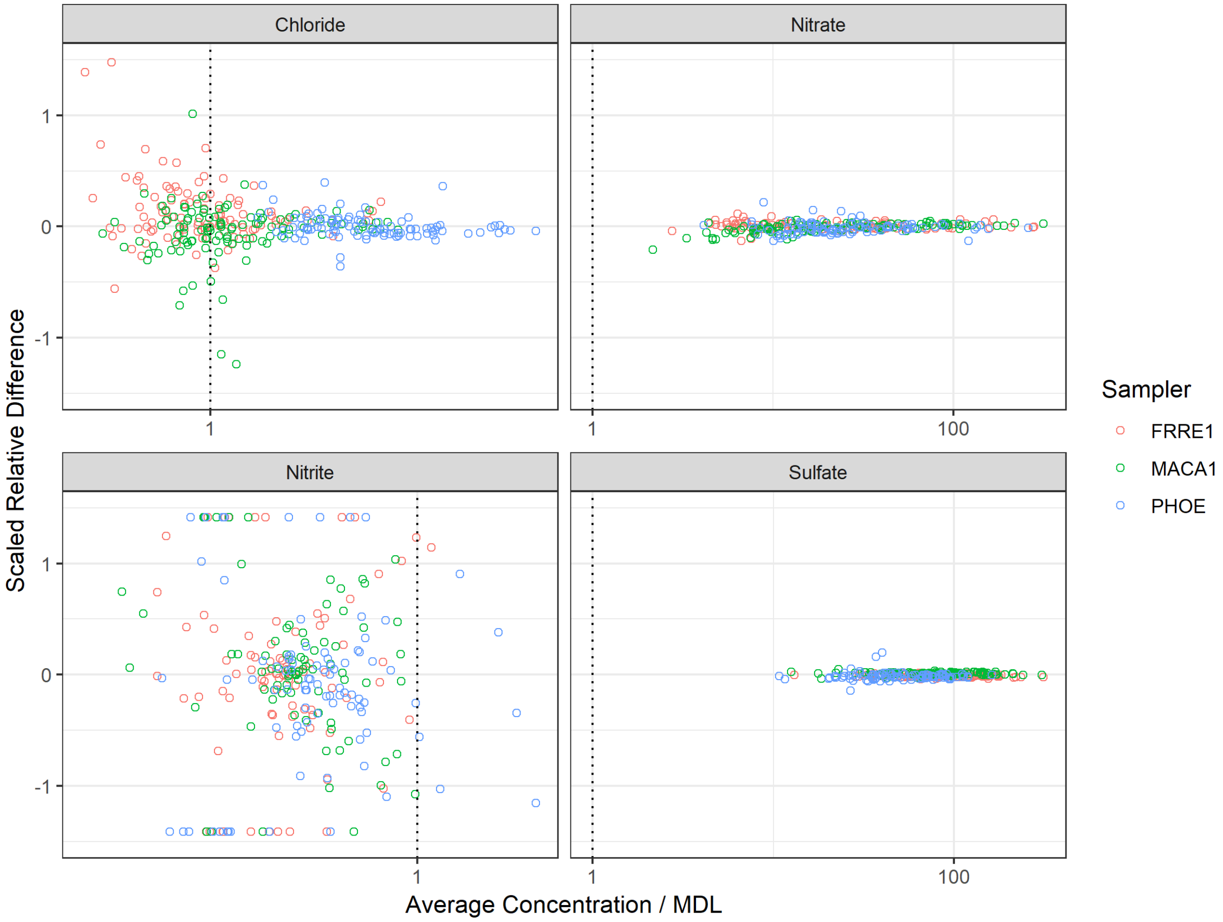


Figure 18: Scaled relative difference for carbon measurements at sites with collocated modules across the IMPROVE network (2017). Elemental carbon (EC) fractions are indicated as (1) through (3), organic carbon (OC) fractions are indicated as (1) through (4), TR indicates measurement by reflectance, and TT indicates measurement by transmittance. Dotted vertical lines indicate method detection limits.

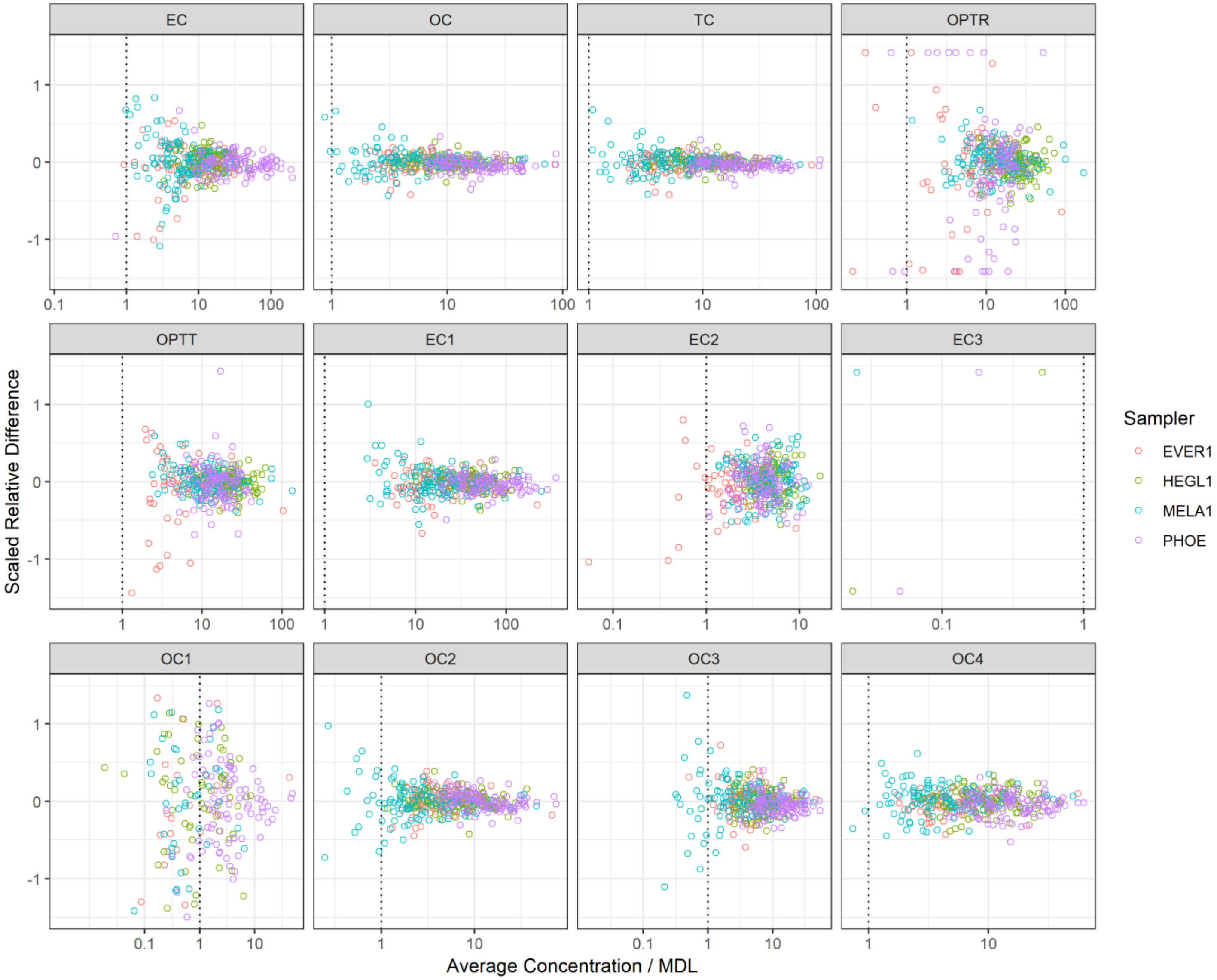
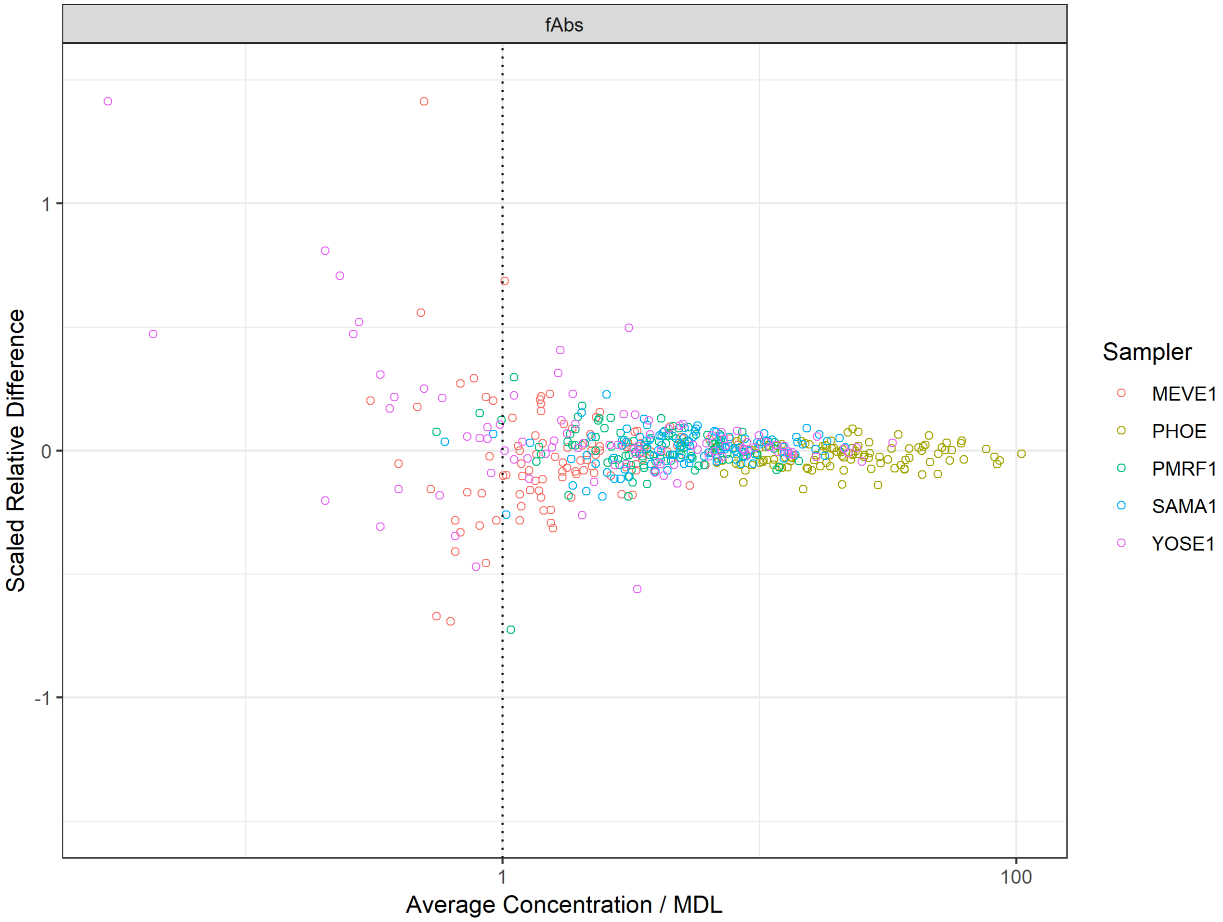


Figure 19: Scaled relative difference for optical absorption measurements at sites with collocated modules across the IMPROVE network (2017). Dotted vertical line indicates method detection limit.



UCD IMPROVE SOP 351, Data Processing and Validation documents the calculation of scaled relative difference, collocated precision, and fractional uncertainty. Fractional uncertainty for the 2017 IMPROVE data is calculated using 2013- 2016 collocated measurements (Table 1).

Table 1: Fractional uncertainty calculated from 2013-2016 measurements (reported with data from 2017 samples) and 2005-2013 measurements (reported with data from samples prior to 2017).

Species	Fractional Uncertainty, 2005-2013	Fractional Uncertainty, 2013-2016
Chloride	0.08	0.08
Nitrite	0.22	0.25
Nitrate	0.04	0.04
Sulfate	0.02	0.02
Organic Carbon	0.08	0.09
Elemental Carbon	0.12	0.14
Total Carbon	0.08	0.08
Organic Carbon (1)	0.23	0.26
Organic Carbon (2)	0.15	0.13
Organic Carbon (3)	0.13	0.13
Organic Carbon (4)	0.15	0.13
Organic Pyrolyzed (TR)	0.13	0.16
Elemental Carbon (1)	0.10	0.10
Elemental Carbon (2)	0.17	0.18
Elemental Carbon (3)	0.42	0.25
Na	0.14	0.14
Mg	0.15	0.15
Al	0.09	0.08
Si	0.10	0.07
P	0.25	0.23
S	0.03	0.02
Cl	0.14	0.17
K	0.03	0.04
Ca	0.06	0.06
Ti	0.11	0.09
V	0.12	0.16
Cr	0.22	0.17
Mn	0.13	0.13
Fe	0.06	0.06
Ni	0.16	0.20
Cu	0.12	0.09
Zn	0.06	0.07
As	0.25	0.25
Se	0.25	0.25
Br	0.10	0.11
Rb	0.25	0.25
Sr	0.16	0.13
Zr	0.25	0.25
Pb	0.13	0.16
PM2.5	0.03	0.03
PM10	0.03	0.07
fAbs	0.03	0.06

3. Analytical QC Checks

3.1 Replicate versus Routine

Analytical precision is evaluated by comparing data from replicate and routine analyses, where the replicate analysis is a second analysis performed on the same sample. Reliable laboratory measurements should be repeatable with good precision. Analytical precision includes only the uncertainties associated with the laboratory handling and analysis, whereas collocated precision (Section 2.4) also includes all the uncertainties associated with sample preparation, field handling, and sample collection. As such, collocated precision (Table 1) is reported, whereas analytical precision is used internally as a QC tool (Figure 20 and 21).

Replicate XRF analyses are not performed on the routine IMPROVE samples. Rather, long-term reanalysis are performed to assess both the short- and long-term stability of the XRF measurements as described in *IMPROVE SOP 301, XRF Analysis*.

Figure 20: Comparison of ion mass loading from replicate and routine filters (data from 2015-2017), shown on log scale.

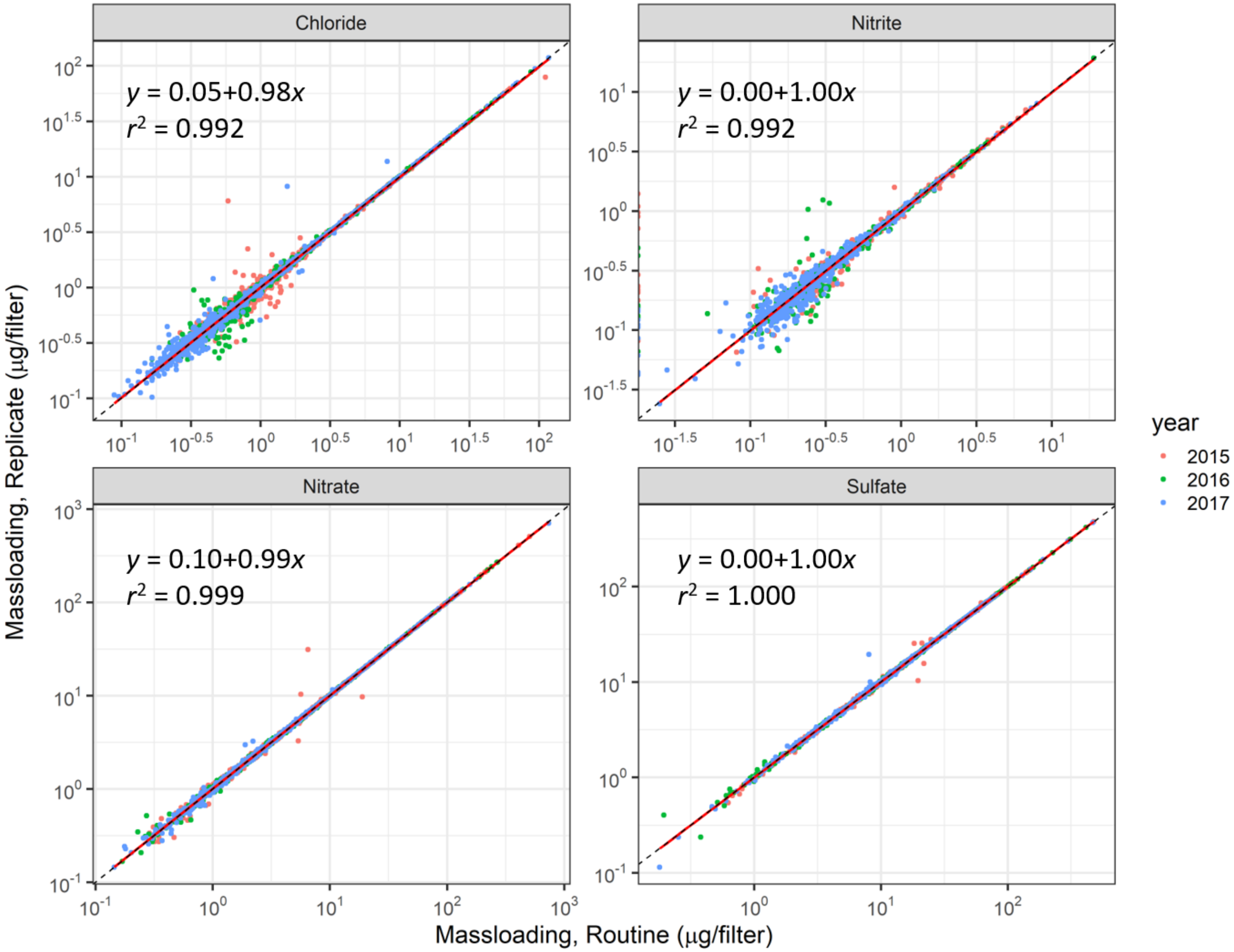
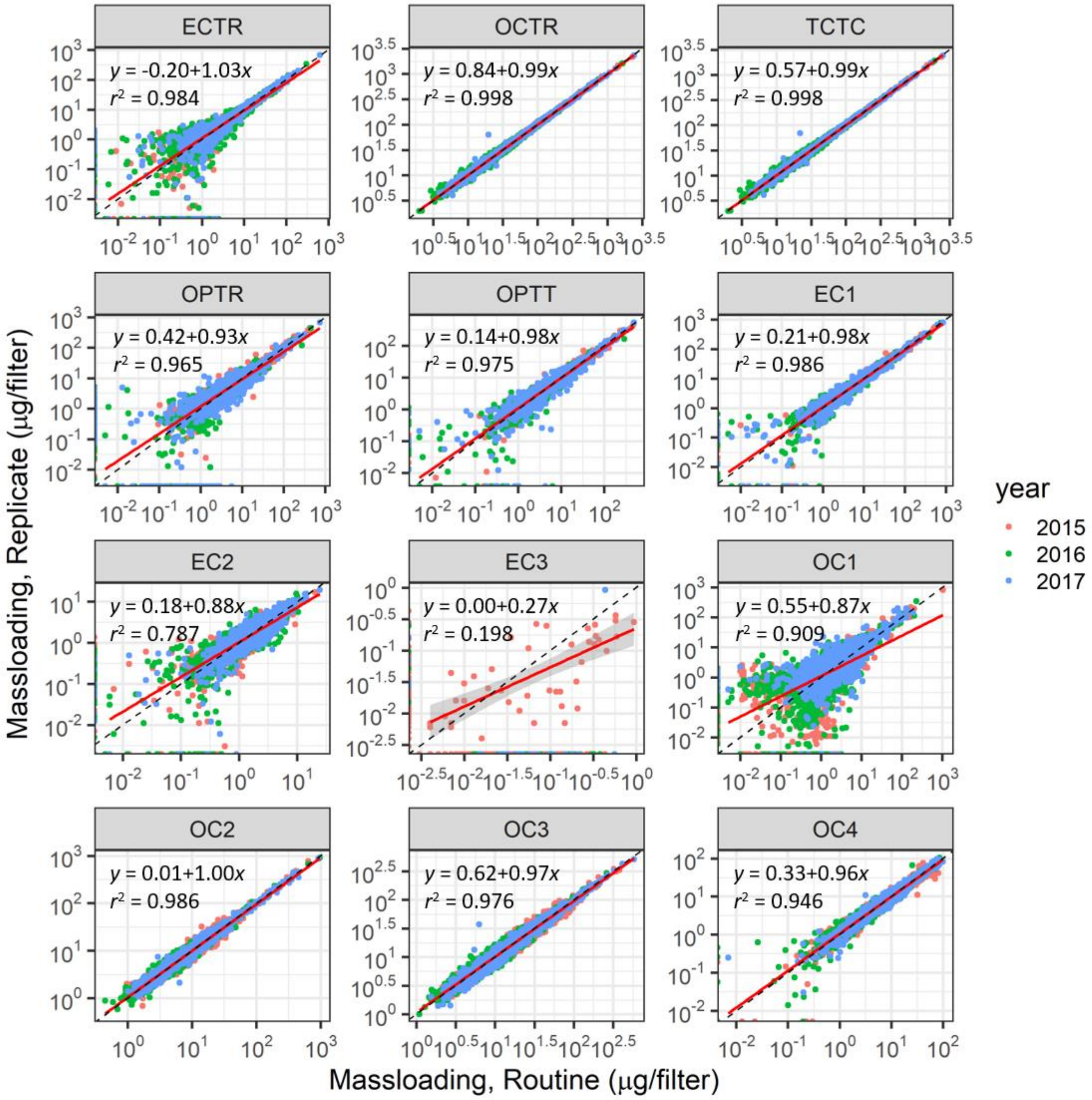


Figure 21: Comparison of carbon mass loading from replicate and routine filters (data from 2015-2017), shown on log scale. Elemental carbon (EC) fractions are indicated as (1) through (3), organic carbon (OC) fractions are indicated as (1) through (4), TR indicates measurement by reflectance, and TT indicates measurement by transmittance.



3.2 Blanks

Lab blanks and field blanks are handled and analyzed in the laboratory using the same process as sampled filters. Lab blanks are only handled in a laboratory environment and have the least opportunity for mishandling and contamination. Field blanks are collected at sampling sites across the network by exposing filters to the same conditions and handling that a sampled filter experiences but without pulling air through the filter. Considering that field blanks capture artifacts from both field and laboratory processes, it is expected that field blank mass loadings will be generally higher than lab blanks.

Field blanks are an integral part of the QC process, and analysis results allow for artifact correction of sampled filters as part of the concentration calculation. Artifacts result from contamination in the filter material or handling and analysis.

Nylon filters are received from the manufacturer in lots that typically last one year. Acceptance criteria are established to evaluate background concentrations for each new lot of filters, however, there can be substantial variability in ion species across different lots (Figures 22-25). Transition to new lots occurs over a period of weeks; thus the shift in field blank concentrations gradually manifest over time rather than abruptly. A known contamination issue occurred at the RTI laboratory during summer 2017, and evidence of the event are seen in both the chloride (Figure 22) and sulfate (Figure 25) field blank time series. An earlier contamination issue in 2011 from lack of refrigeration is also observed in the chloride field blank time series (Figure 22). This issue was resolved with implementation of sample refrigeration beginning early 2011, and corresponds with a decrease in intermittent high chloride field blank concentrations.

Figure 22: Time series of chloride measured on nylon filter field (FB) and lab (LB) blanks. Red vertical lines indicate lot transition.

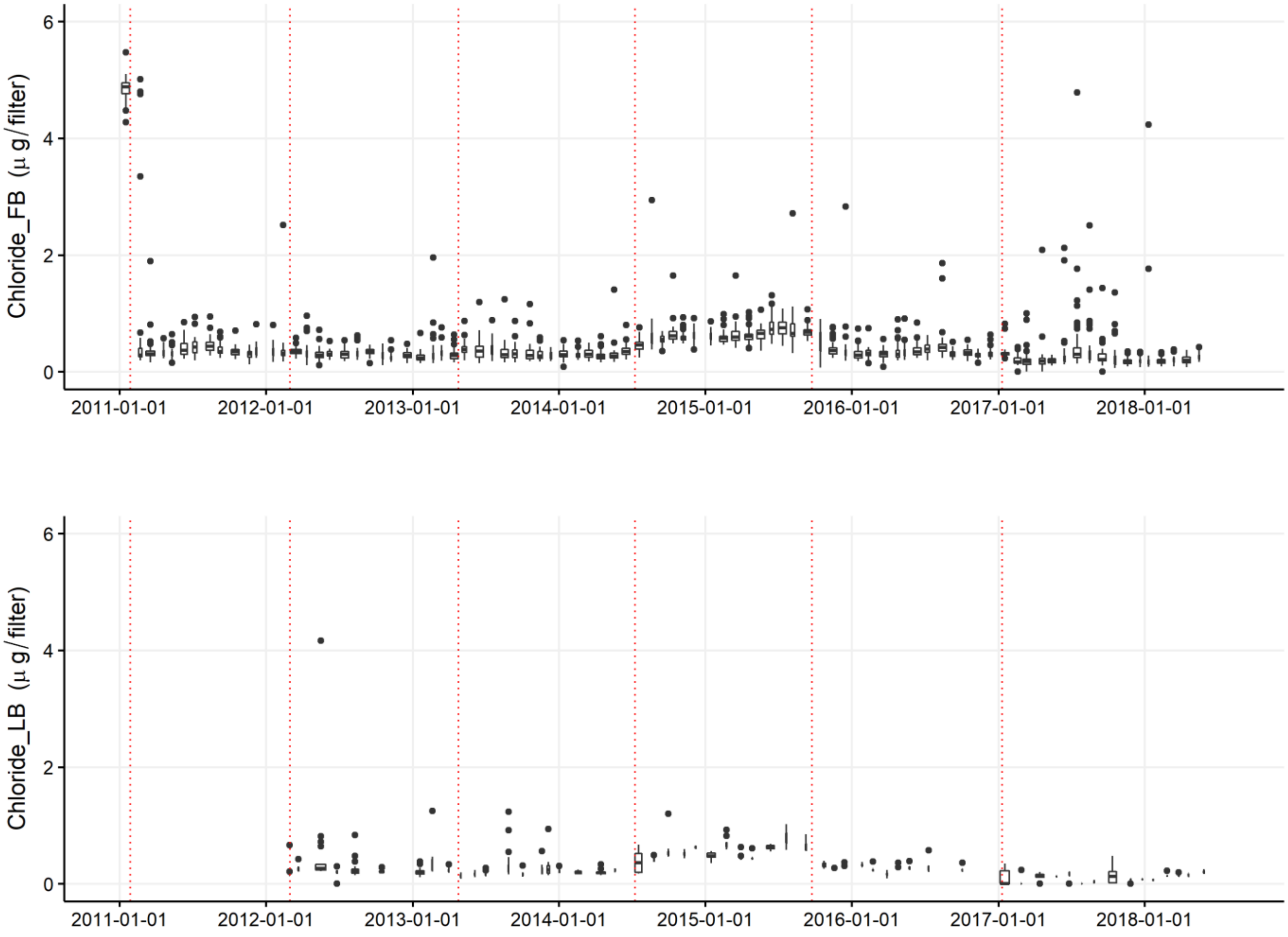


Figure 23: Time series of nitrate measured on nylon filter field (FB) and lab (LB) blanks. Red vertical lines indicate lot transition.

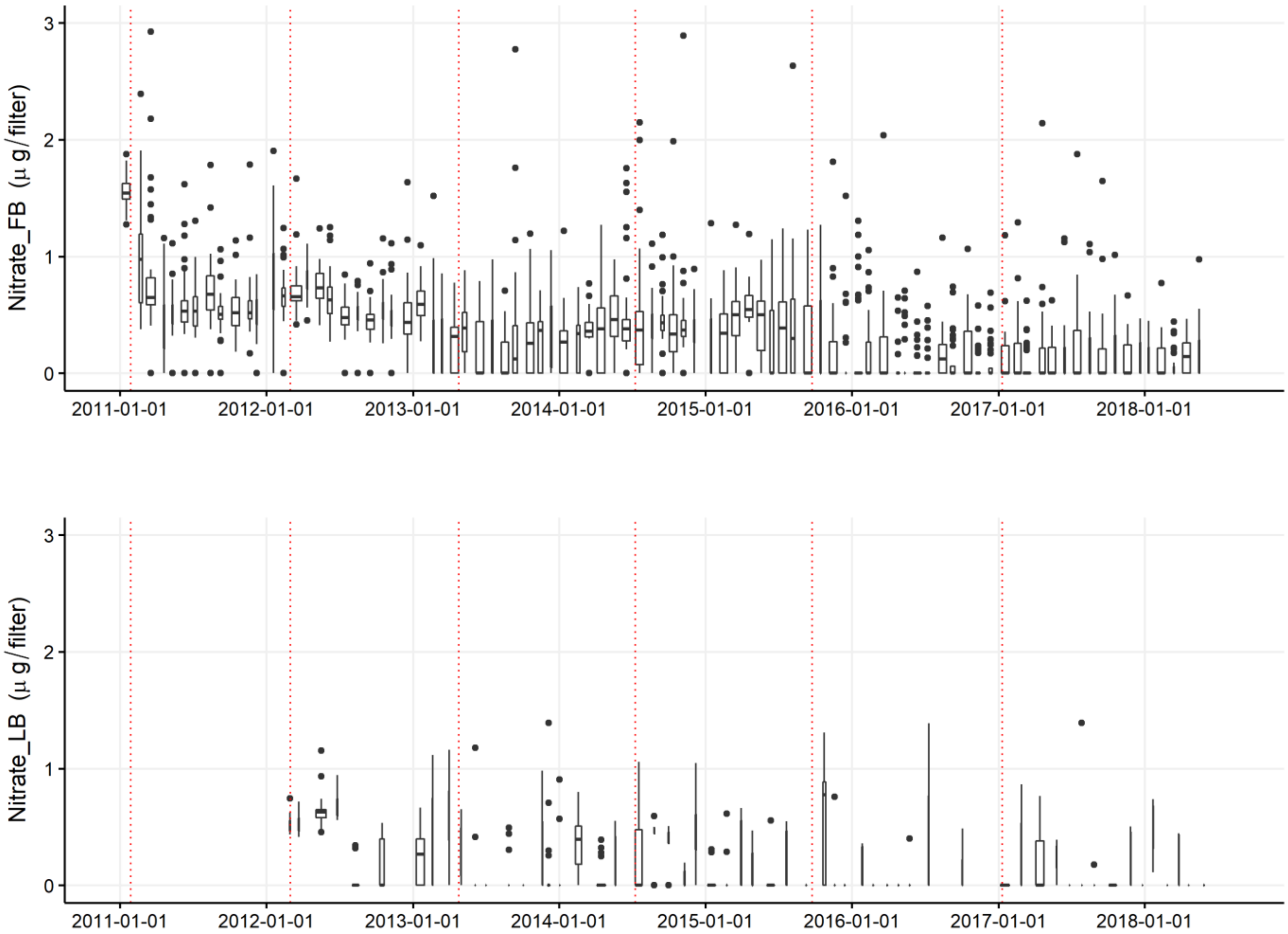


Figure 24: Time series of nitrite measured on nylon filter field (FB) and lab (LB) blanks. Red vertical lines indicate lot transition.

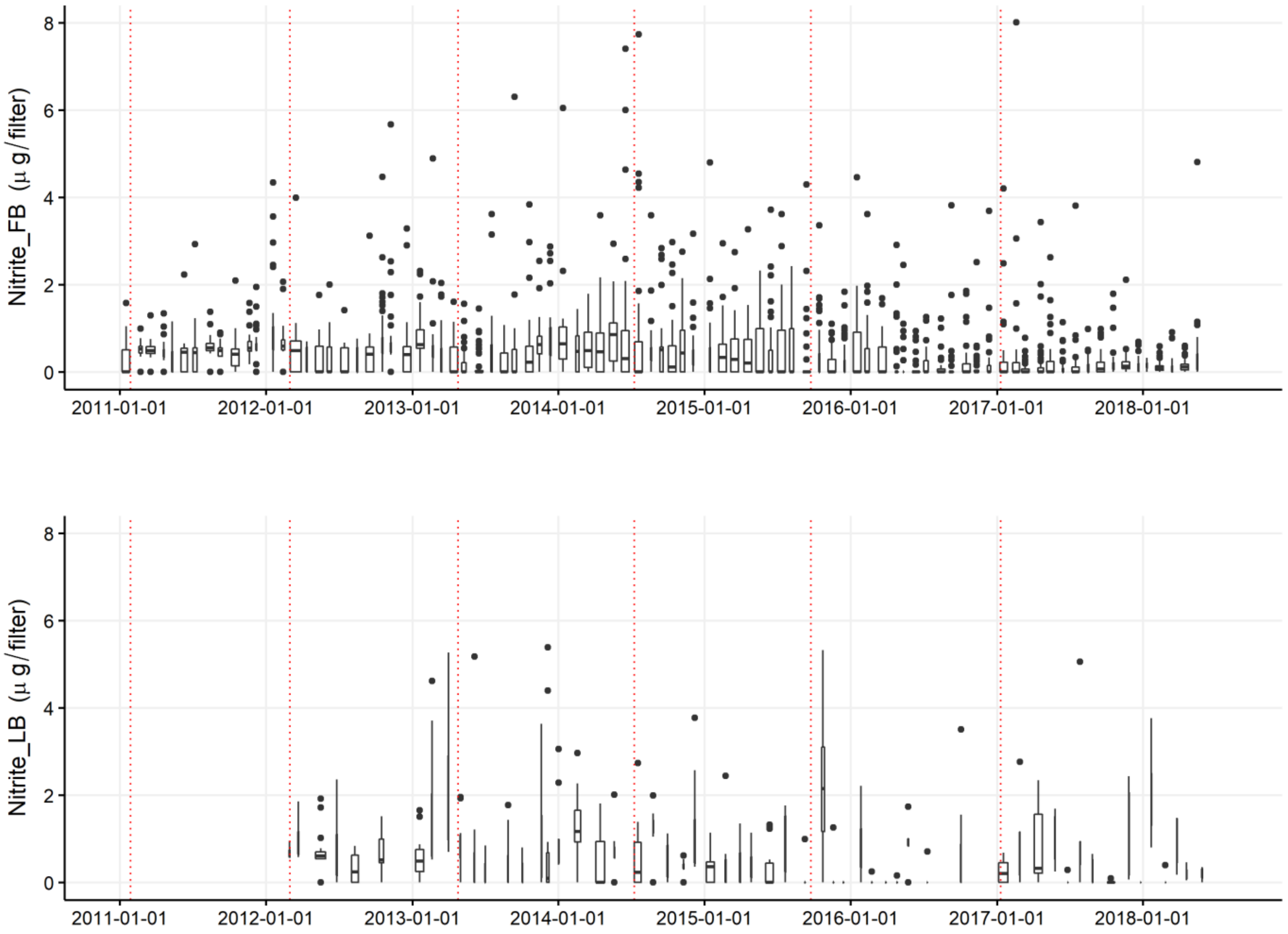
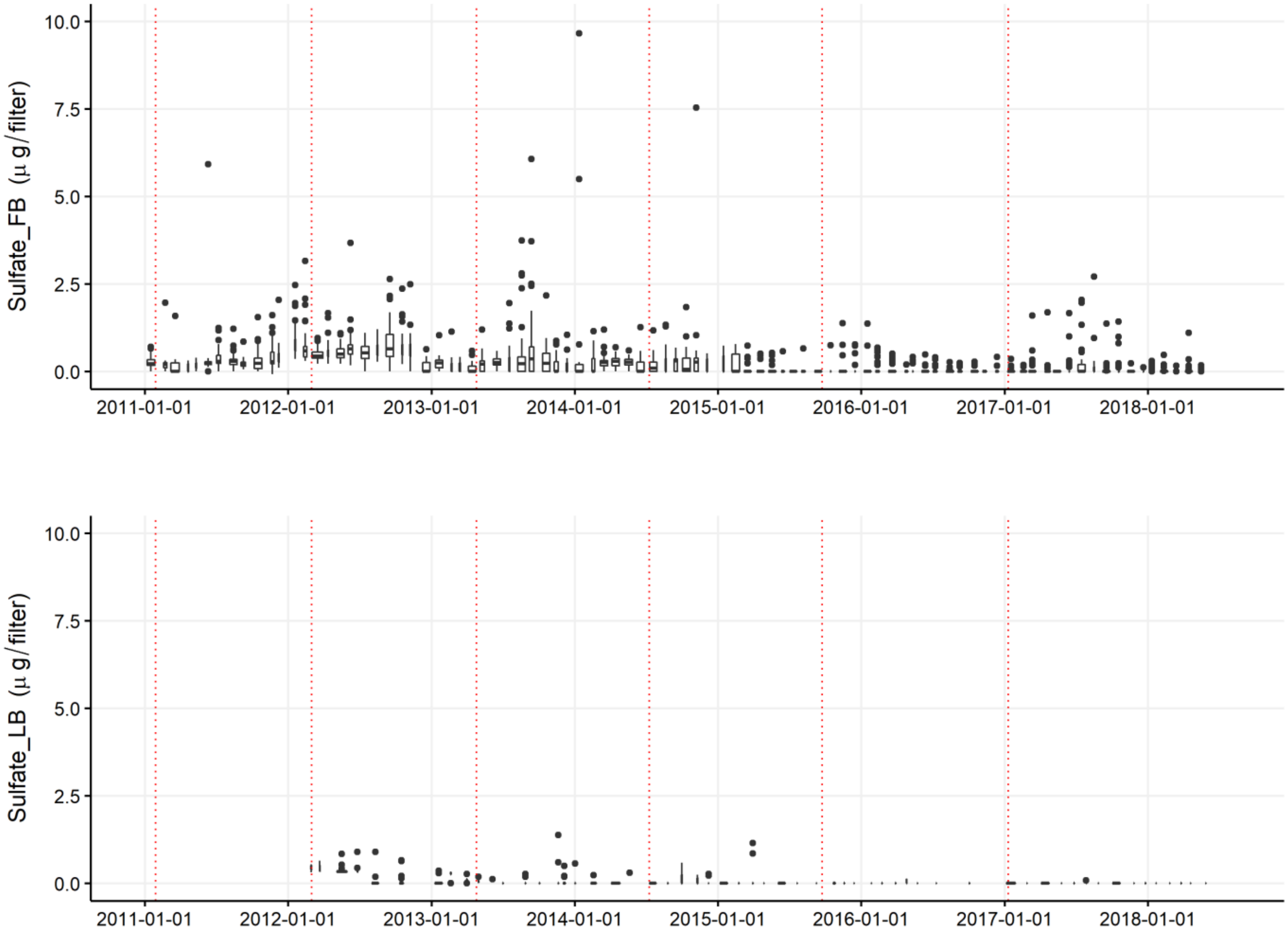
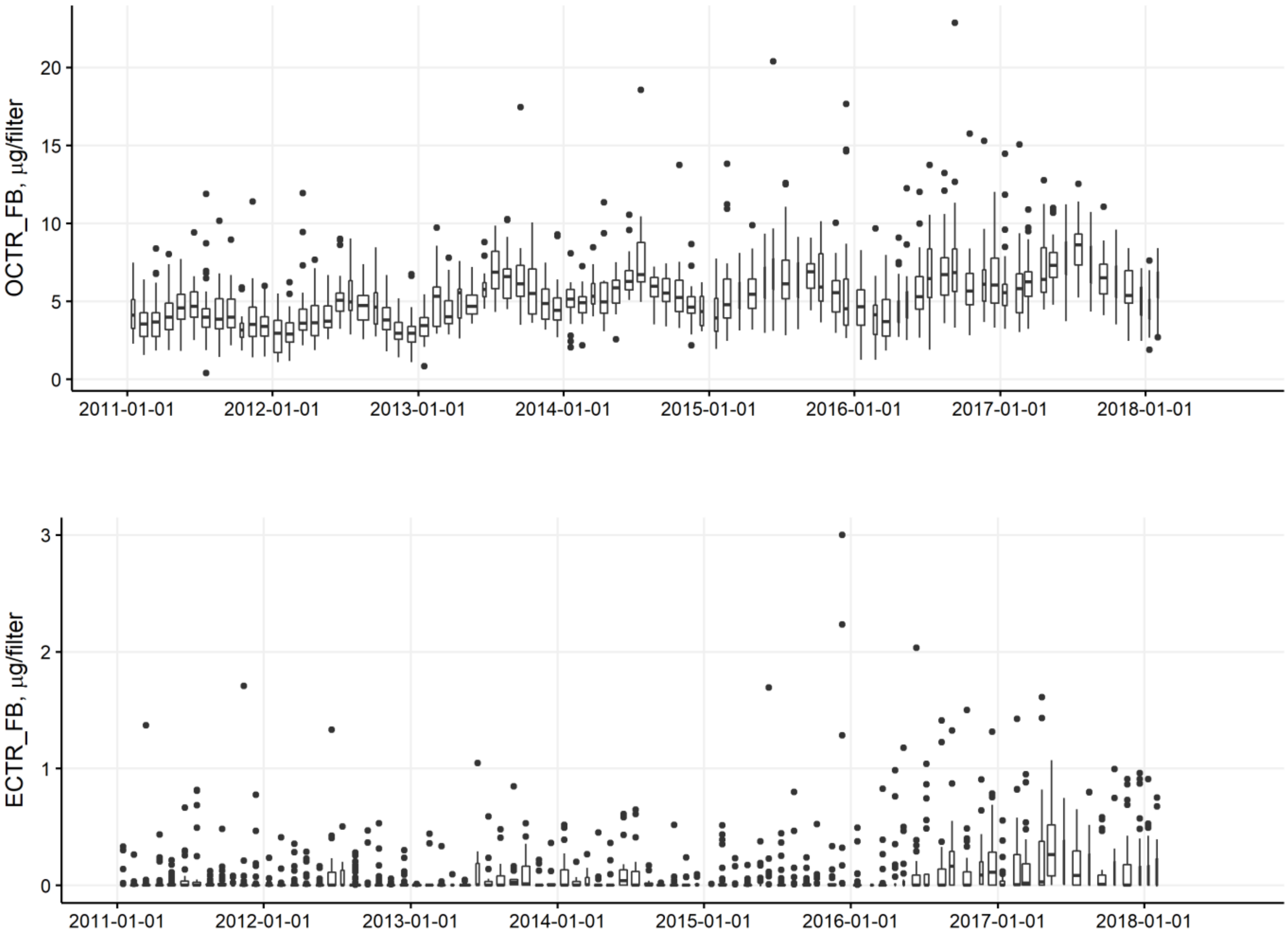


Figure 25: Time series of sulfate measured on nylon filter field (FB) and lab (LB) blanks. Red vertical lines indicate lot transition.



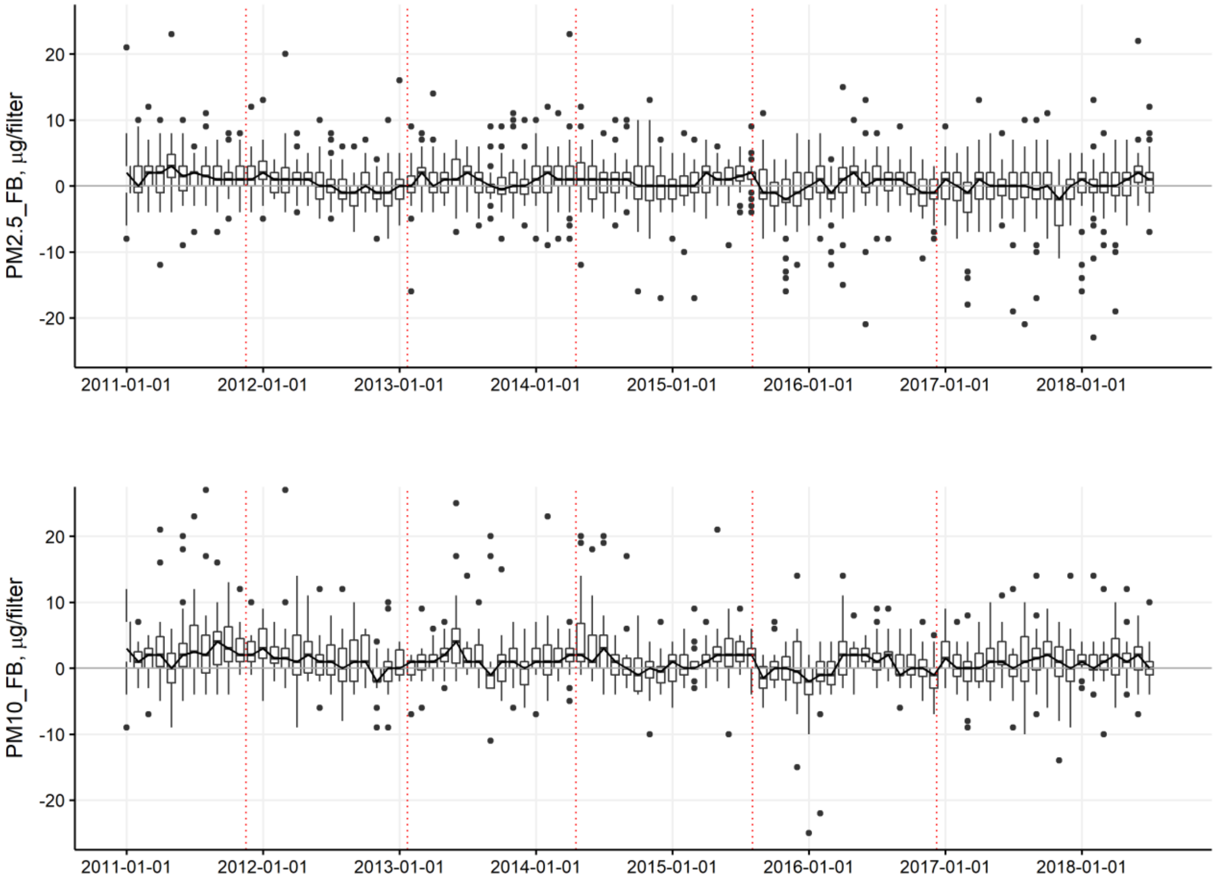
Quartz filters are pre-fired by DRI. Quartz filter field blanks have low concentrations of elemental carbon (EC), typically below 0.5 µg/filter, with no seasonal pattern (Figures 26, bottom panel). Conversely, higher field blank concentrations are observed for organic carbon (OC), with the highest values during summer months often over 5 µg/filter (Figures 26, top panel).

Figure 26: Time series of organic carbon (OCTR) and elemental carbon (ECTR) artifacts on quartz filter field blanks.



PTFE filter field blanks from the A-module (fine particles, $PM_{2.5}$) and D-module (coarse particles, PM_{10}) are gravimetrically analyzed to monitor contamination levels and balance stability (Figure 27).

Figure 26: Time series of PM2.5 and PM10 on PTFE filter field blanks.



Field blanks are used for calculation of method detection limits (MDLs), reported for each species. Currently, and including all 2017 data, MDLs for ions and carbon species are calculated as 2× the standard deviation of the field blank loadings. For elements, the MDLs are calculated as 95th percentile minus median of field blank loadings. Beginning with the 2018 data, UCD will harmonize the MDL calculation to be 95th percentile minus median for all species. It is anticipated that this change will result in a more stable MDLs that are less susceptible to influence from field blank outliers.

3.3 Validation Updates

3.3.1 Organic Carbon (OC) and Elemental Carbon (EC) Artifact Calculation

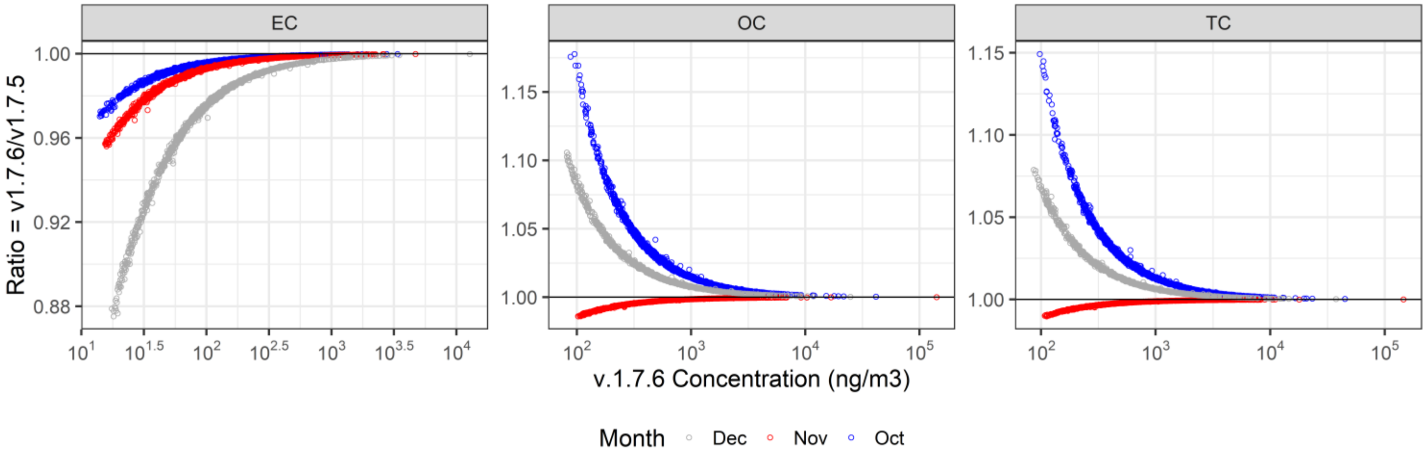
Two different methods have been applied to the IMPROVE data to correct organic carbon (OC) and elemental carbon (EC) measurements for the sampling artifacts observed in field blanks. The methods differ in the order in which they take sums and medians; these two operations do not necessarily commute (i.e., the sum of medians does not necessarily equal the median of sums).

Represented as different data processing versions, the methods are as follows:

> v.1.7.5: OC and EC loadings (ug/filter) of the individual samples and field blanks are first calculated from the uncorrected fractions, as OC = OC1+OC2+OC3+OC4+OP and EC = EC1+EC2+EC3-OP. OC and EC loadings in each sample are then artifact-corrected by subtracting the median OC and median EC loadings of the field blanks, and converted to concentrations.
>
> v.1.7.6: The loadings of individual fractions in each sample are first artifact corrected by subtracting the median loadings observed in field blanks, and converted to concentrations. Artifact-corrected OC and EC concentrations are then calculated from the artifact-corrected fraction concentrations: OC = OC1+OC2+OC3+OC4+OP and EC = EC1+EC2+EC3-OP.

The methods yield slightly different results which become more apparent at lower concentrations (Figure 28). For samples from November 2015 through December 2017, data were submitted to AQS using the v.1.7.5 method, whereas data were submitted to FED using the v.17.6 method. To resolve the discrepancy between FED and AQS databases, UCD will redeliver data to AQS, thus harmonizing the databases to have OC and EC concentrations calculated using method v.1.7.6.

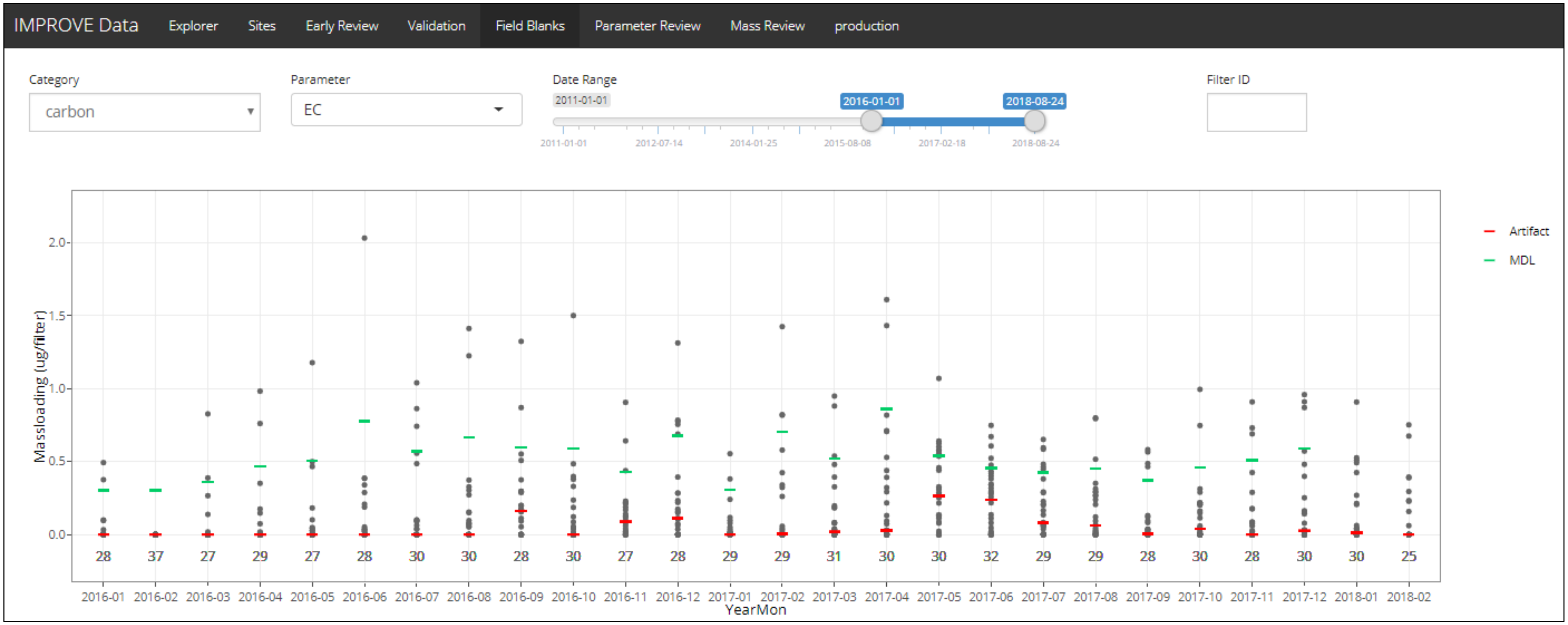
Figure 28: Difference between artifact correction calculation methods for elemental carbon (EC), organic carbon (OC), and total carbon (TC) for three months (October, November and December) in 2017.



3.3.2 Tool Development

UCD continuously develops and improves the data validation methods, creating tools and visualizations to better evaluate data. Figures 29-33 are recent tool development examples.

Figure 29: Interactive plot on the UCD IMPROVE data validation site that displays mass loadings of field blanks, MDLs, and artifacts for elements, ions, carbon, and mass.



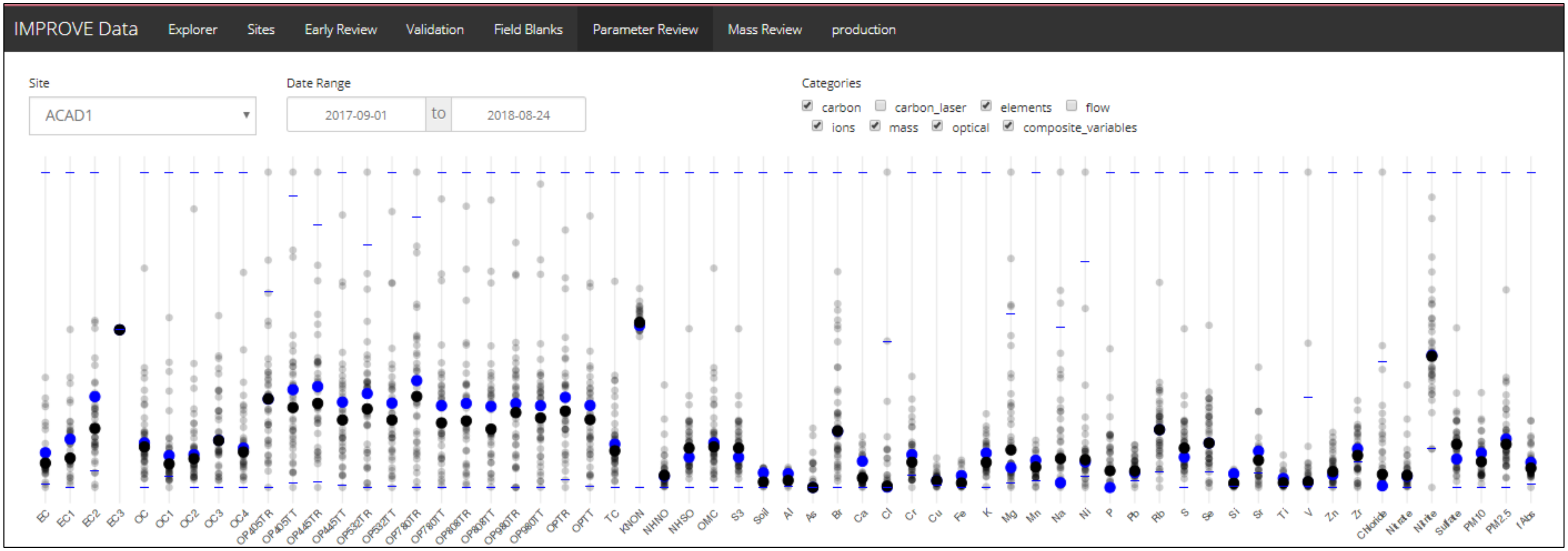
Category: carbon

Parameter: EC

Date Range: 2011-01-01 – 2016-01-01 to 2018-08-24

Filter ID:

Figure 30: Interactive plot on the UCD IMPROVE data validation site that displays a parameter-level data overview for each site.



Site: ACAD1

Date Range: 2017-09-01 to 2018-08-24

Categories:
☑ carbon ☐ carbon_laser ☑ elements ☐ flow
☑ ions ☑ mass ☑ optical ☑ composite_variables

Figure 31: Interactive plot on the UCD IMPROVE data validation site that displays both network-wide and site-specific comparisons between HIPS optical absorption (fAbs) and TOR elemental carbon (EC).

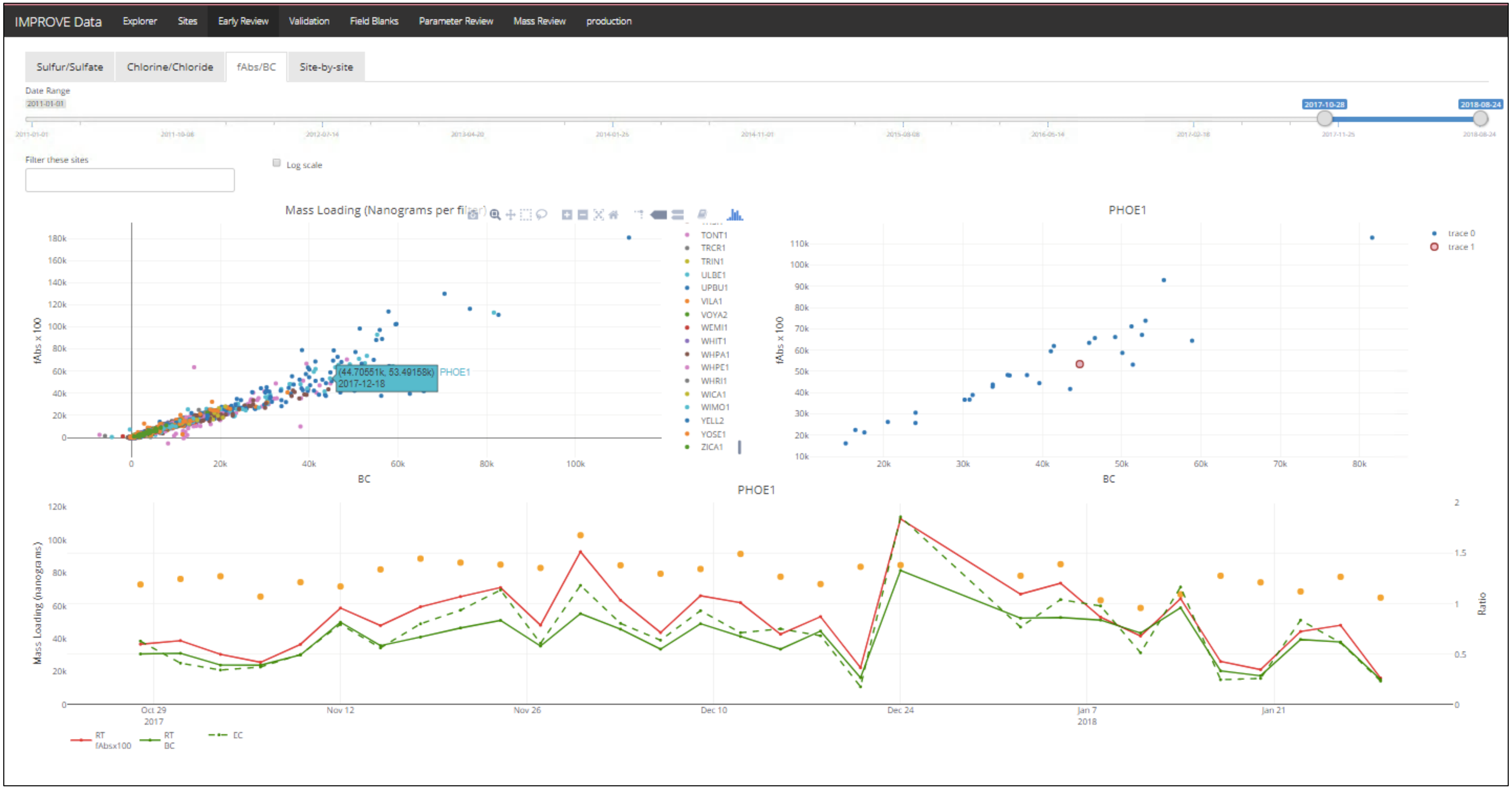


Figure 32: Interactive plot on the UCD IMPROVE data validation site that displays both network-wide and site-specific comparisons between XRF chlorine and IC chloride.

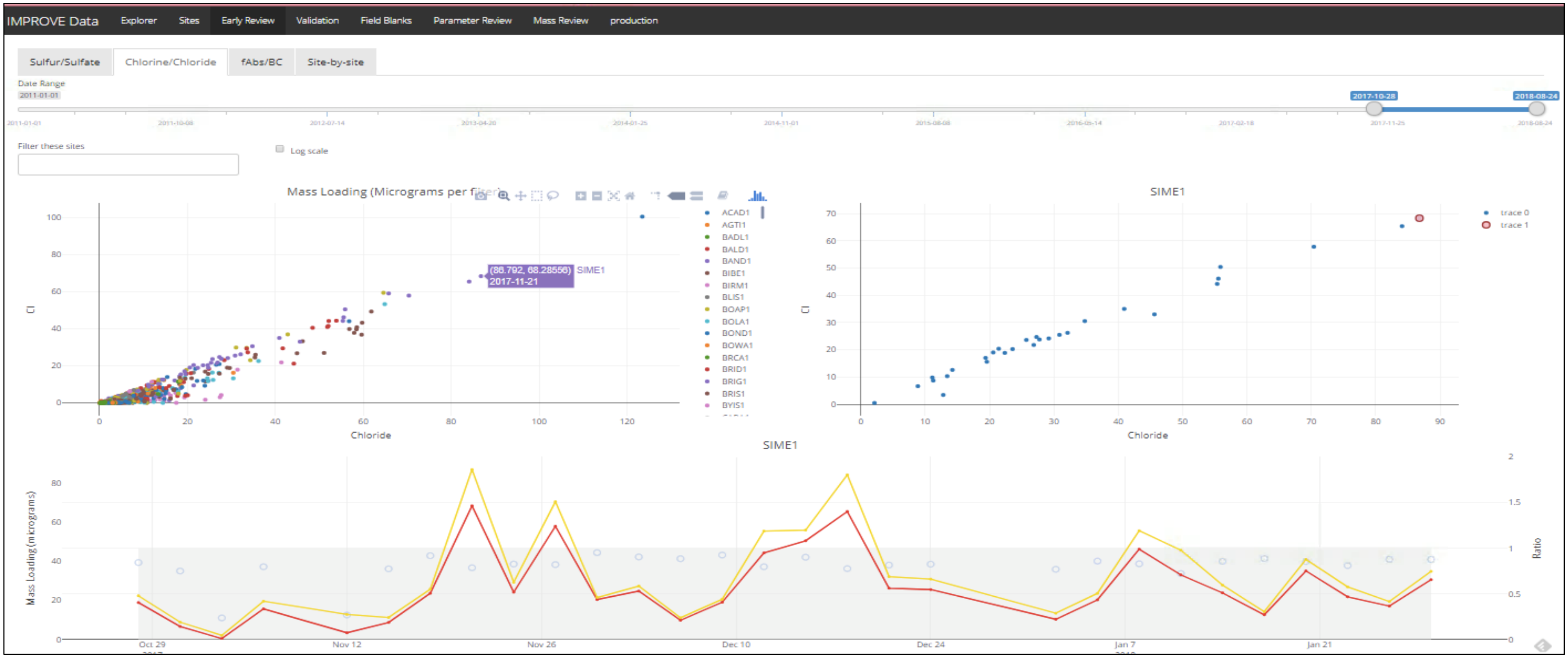
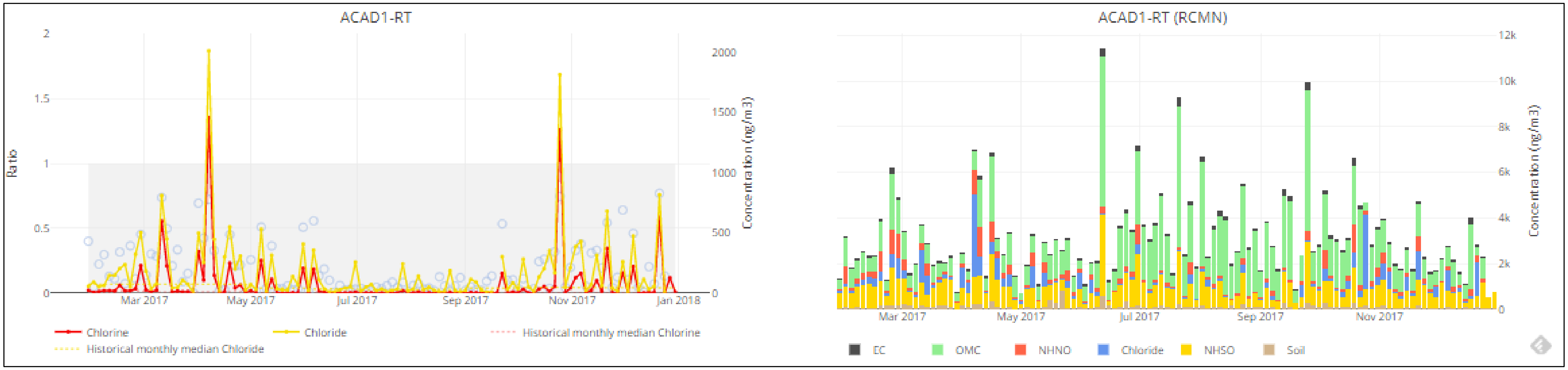


Figure 33: Interactive plots on IMPROVE data validation site that displays site specific time series of XRF chlorine and IC chloride (left) and speciated reconstructed PM$_{2.5}$ mass (right).



4. Documentation

Current standard operations procedures (SOPs) are available at:

http://vista.cira.colostate.edu/Improve/

http://airquality.crocker.ucdavis.edu/improve/standard-operating-procedures-sop/

Table 2: Summary of upcoming project documentation deliverables.

Deliverable	Upcoming Delivery Date
SOPs and TI documents	January 30, 2019
Quarterly Site Status Report	November 15, 2018 (2018 Q3) February 15, 2019 (2018 Q4)
Semiannual Quality Assurance Report (January – June 2018 data)	April 30, 2019

5. Site Maintenance Summary

5.1 Summary of Repair Items Sent

UCD maintains and repairs samplers at each IMPROVE site. The UCD Field Group works closely with site operators to address maintenance and repair issues to ensure continuous operation and sample collection at the sites. UCD maintains an inventory of sampler components for shipment to the sites on short notice. Table 3 summarizes the equipment shipped to sites for sampler repairs, January 1, 2018 through June 30, 2018.

Table 3: Summary of major repair items shipped to IMPROVE sites, 1/1/2018 through 6/30/2018.

Item	Quantity	Sites
Controller	36	IKBA1, LASU2, CHIR1, TONT1 (x2), GAMO1, BIBE1, CABI1 (x4), EVER1, THRO1 (x2), GRSM1, KALM1, SHEN1, PORE1, PHOE5, GLAC1, FOPE1 (x2), MONT1, BRIG1 (x2), TRIN1, FRRE1, EGBE1, YOSE1 (x2), CAVE1, FCPC1, NOAB1, BYIS1, SAPE1, WHIT1
Pump	84	AGTI1, BALD1, BAND1, BOAP1 (x2), BOLA1 (x6), BOND1 (x2), BOWA1 (x2), BRID1 (x2), BRIG1, CEBL1 (x2), CHAS1, EGBE1, EVER1, FLAT1 (x4), GAMO1 (x3), GICL1, GLAC1 (x2), GRCA2 (x4), GUMO1, HEGL1, HOOV1, KALM1, LAVO1, LOST1, LTCC1 (x3), MELA1, MEVE1 (x2), MOHO1, MONT1 (x4), PENO1, PHOE1 (x3), SACR1 (x2), SAGA1, SAWE1 (x3), SAWT1 (x3), SHEN1, SHRO1, TALL1, THBA1, THRO1 (x2), TRCR1, VILA1, VOYA2, WHIT1, WHRI1, WIMO1, YELL2 (x4), YOSE1
Electronic boxes	34	BALD1, BOAP1, BOND1, BRID1, BRIG1, BYIS1, CABI1 (x4), CAVE1 (x4), EGBE1, GAMO1, HACR1, LOND1, MEAD1 (x2), MEVE1, NOAB1, OKEF1 (x2), OLYM1, OWVL1, ROMO1, SAGA1, SAPE1, SAWE1, SHEN1 (x2), WHIT1, YOSE1
Module Cable	1	SAPE1
Relay Box	8	GAMO1, EVER1 (x2), GRSM1, GAMO1, CACO1 (x2), SYCA2
Sierra PM_{10} Inlet	3	BLIS1, SAGA1, GAMO1
PM2.5 Inlet Cap	0	
Flow Check Kits	6	MOOS1, GICL1, SHMI1, OLYM1, SACR1, SAGA1
Module	3	GAMO1, SAGA1, SHRO1

5.2 Field Audits

CSU CIRA performs field audits at IMPROVE sites to measure and evaluate sampler flow. Results are reported to the UCD Field Group, and issues are addressed during site visits and through coordination with site operators. Table 4 summarizes the field audits that CSU CIRA performed January 1, 2018 through June 30, 2018.

Table 4: CSU CIRA field audits 1/1/2018 through 6/30/2018.

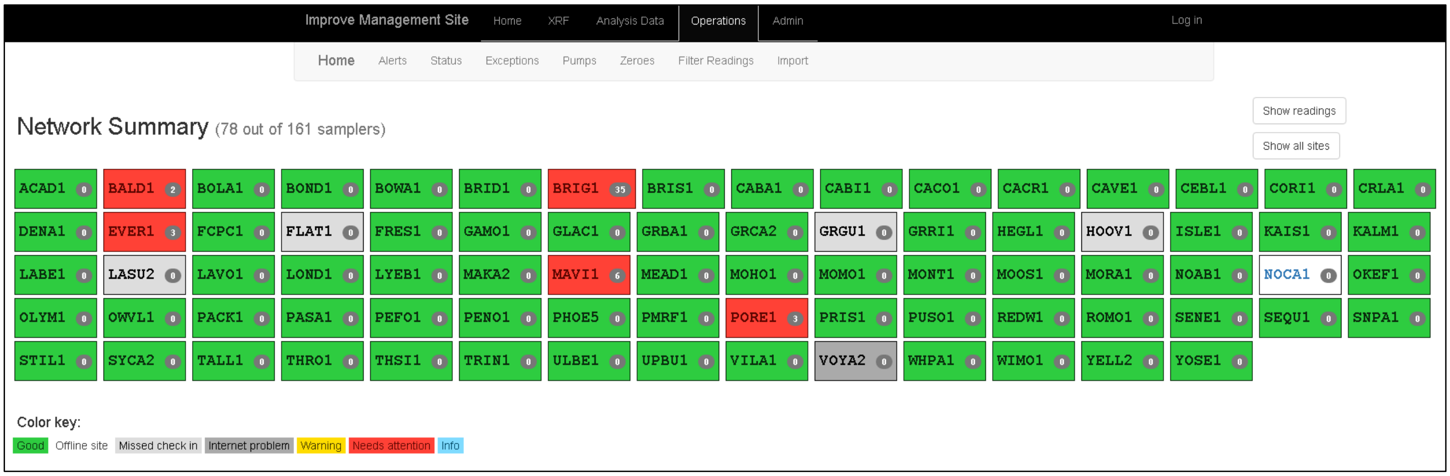
Site Audits (2018)					
January	**February**	**March**	**April**	**May**	**June**
		MELA1	CHAS1	MEAD1	GRCA2
			COHU1		HEGL1
			EVER1		PEFO1
			ROMA1		SYCA2
			SAMA1		
			SHRO1		
			UPBU1		
			BRIS1		
			CACR1		
			OKEF1		
			SIPS1		
			STIL1		
			SWAN1		
			WIMO1		

5.3 Summary of Site Visits

The UCD Field Group visits IMPROVE network sites biennially to provide routine maintenance and cleaning. Sites are occasionally visited more frequently to address emergency issues. Table 5 summarizes the visits that UCD performed January 1, 2018 through June 30, 2018.

UCD has developed and is currently deploying new sampler controllers. Between January 1, 2018 and June 30, 2018 UCD installed 25 new controllers (Table 5). As of June 30, 2018 there were a total of 31 new controllers installed across the network, with additional controllers being installed during the remaining summer maintenance season. Prior to new controller installation, availability of internet access is evaluated at each site, and in cases where it is not available a hot spot device is installed. All sites with new controllers are monitored in real time (Figure 34) by UCD technicians, allowing faster follow up and recovery in cases where samples are being lost or equipment has failed.

Figure 34: Screen shot of site status page showing real time status of sites with new controllers.



Network Summary (78 out of 161 samplers)

ACAD1 0	BALD1 2	BOLA1 0	BOND1 0	BOWA1 0	BRID1 0	BRIG1 35	BRIS1 0	CABA1 0	CABI1 0	CACO1 0	CACR1 0	CAVE1 0	CEBL1 0	CORI1 0	CRLA1 0
DENA1 0	EVER1 3	FCPC1 0	FLAT1 0	FRES1 0	GAMO1 0	GLAC1 0	GRBA1 0	GRCA2 0	GRGU1 0	GRRI1 0	HEGL1 0	HOOV1 0	ISLE1 0	KAIS1 0	KALM1 0
LABE1 0	LASU2 0	LAVO1 0	LOND1 0	LYEB1 0	MAKA2 0	MAVI1 6	MEAD1 0	MOHO1 0	MOMO1 0	MONT1 0	MOOS1 0	MORA1 0	NOAB1 0	NOCA1 0	OKEF1 0
OLYM1 0	OWVL1 0	PACK1 0	PASA1 0	PEFO1 0	PENO1 0	PHOE5 0	PMRF1 0	PORE1 3	PRIS1 0	PUSO1 0	REDW1 0	ROMO1 0	SENE1 0	SEQU1 0	SNPA1 0
STIL1 0	SYCA2 0	TALL1 0	THRO1 0	THSI1 0	TRIN1 0	ULBE1 0	UPBU1 0	VILA1 0	VOYA2 0	WHPA1 0	WIMO1 0	YELL2 0	YOSE1 0		

Color key:

Good Offline site Missed check in Internet problem Warning Needs attention Info

Table 5: UC Davis field visits to IMPROVE sites, 1/1/2018 through 6/30/2018.

Site Name	Date Visited	Notable / Unusual Repair Notes	Improvements Requested
SAGA1	2/6/2018	Cleared water out of system and replaced inlet.	
PORE1	4/10/2018	Installed new controller.	
YOSE1	4/24/2018	Installed new controller.	
REDW1	5/7/2018	Installed new controller. Electrical overhaul of breaker.	
KALM1	5/8/2018	Installed new controller.	
THSI1	5/9/2018	Installed new controller and satellite internet.	
CRLA1	5/10/2018	Installed new controller.	
LABE1	5/11/2018	Installed new controller.	
TRIN1	5/14/2018	Installed new controller.	
LAVO1	5/15/2018	Installed new controller.	
MEAD1	6/4/2018	Installed new controller.	
GRCA2	6/5/2018	Installed new controller.	
BALD1	6/7/2018	Installed new controller.	
PEFO1	6/8/2018	Installed new controller. Major electrical overhaul.	
SYCA2	6/9/2018	Installed new controller.	
EVER1	6/11/2018	Installed new controller. Site relocation.	
OKEF1	6/13/2018	Installed new controller. Site relocation	
BOND1	6/19/2018	Installed new controller.	
LASU2	6/20/2018	Installed new controller.	
VILA1	6/21/2018	Installed new controller. Added bracing for shed	Site needs shed replaced.
GRRI1	6/23/2018	Installed new controller.	
FCPC1	6/24/2018	Installed new controller.	
SENE1	6/25/2018	Installed new controller.	
ISLE1	6/26/2018	Installed new controller.	
VOYA2	6/28/2018	Installed new controller.	
BOWA1	6/29/2018	Installed new controller.	