

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

Air Quality Group | University of California, Davis | March 1, 2018

## 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  $\mu\text{m}$  ( $\text{PM}_{2.5}$ ) 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  $\text{PM}_{2.5}$  on nylon filters for ion chromatography (IC) analysis at Research Triangle Institute (RTI) International.
- Module-C: Collection of  $\text{PM}_{2.5}$  on quartz filters for thermal optical analysis (TOA) at Desert Research Institute (DRI).
- Module-D: Collection of particles with aerodynamic diameter less than 10  $\mu\text{m}$  ( $\text{PM}_{10}$ ) 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: <http://vista.cira.colostate.edu/Improve/>

Unless otherwise noted, data evaluated in this report cover sampling dates from January 2016 through December 2016.

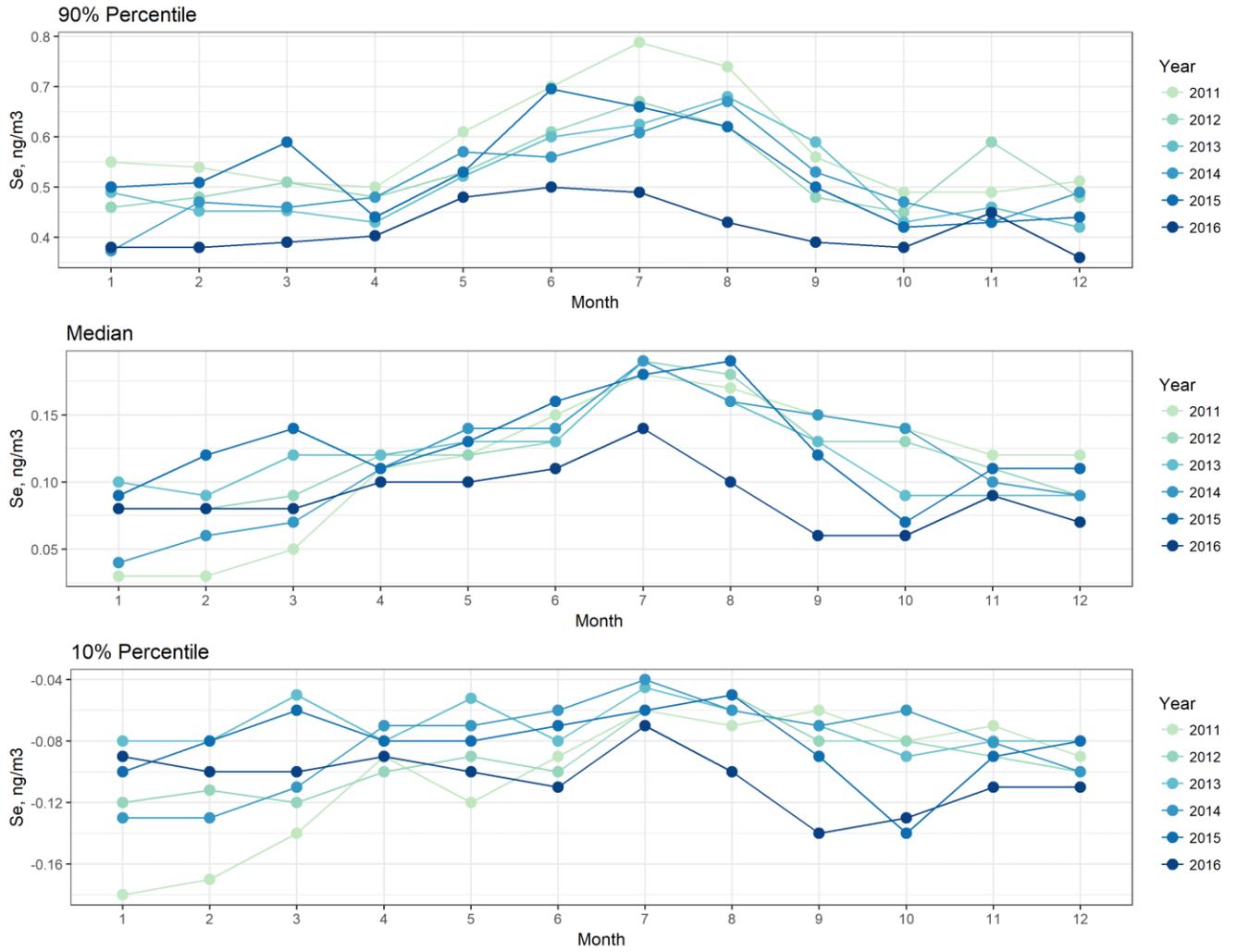
## 2. Concentration-Level QC Checks

### 2.1 Comparison Across Years

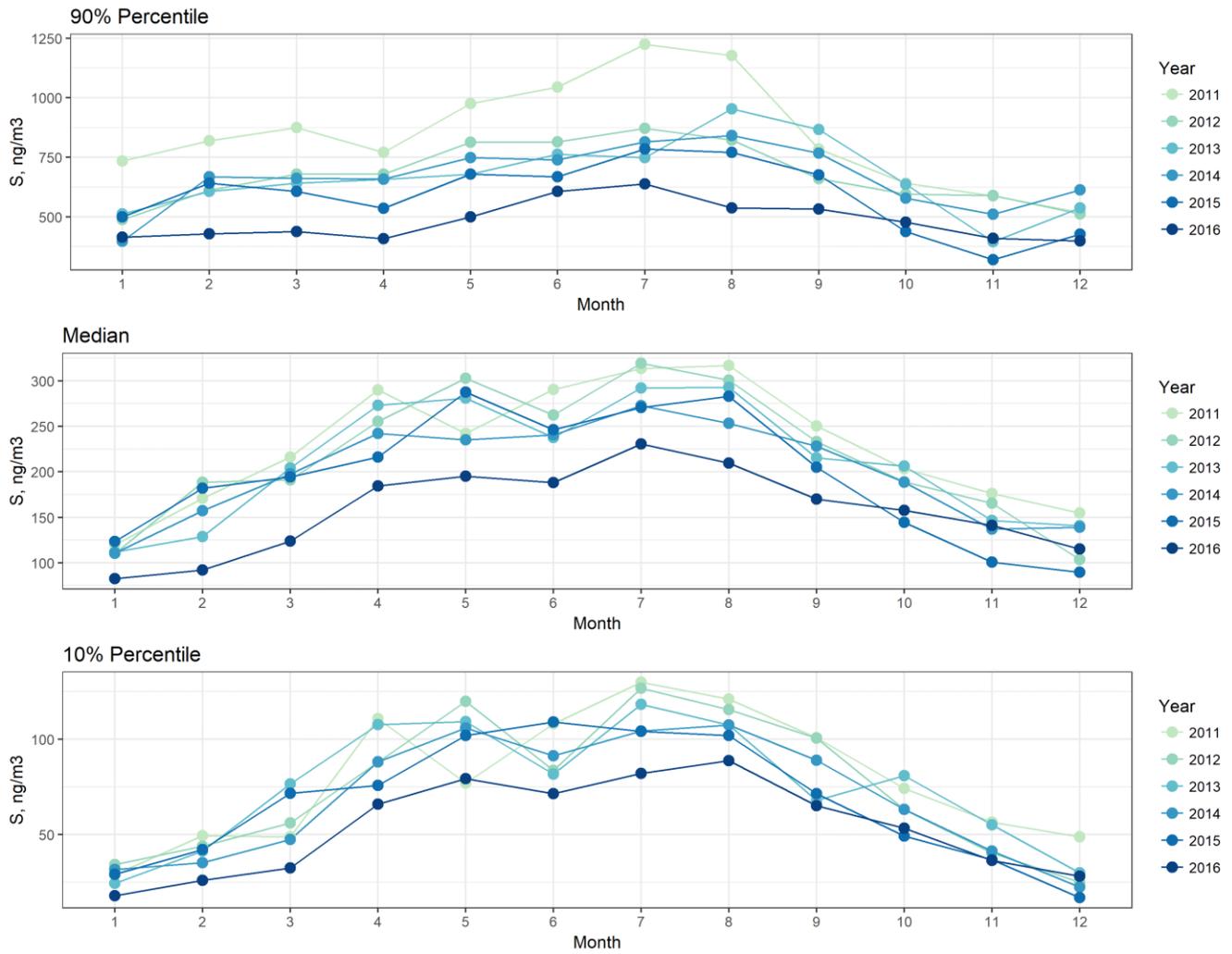
Time series plots of network-scale statistics can reveal possible effects associated with changes in procedures, instrumentation, or sampling media in the analytical laboratories at DRI, RTI, and UCD. Interpretation of these plots is complicated by the real atmospheric trends whose presence IMPROVE is intended to detect; these arise from intentional or adventitious changes in emissions, as well as inter-annual fluctuations in synoptic weather patterns. Figures 1 – 3 use selenium, a trace element often associated with coal combustion, to illustrate some of the considerations that arise.

Figure 1 shows 90<sup>th</sup> percentile, median (50<sup>th</sup> percentile), and 10<sup>th</sup> percentile concentrations of selenium, with five years of historical network data (2011-2015) providing context for the year currently under review (2016). Selenium concentrations were noticeably lower in 2016 than in previous years, particularly during the summer months. Figure 2 shows a similar 2016 drop for sulfur, a major element emitted during coal combustion. The sulfur/selenium ratios in Figure 3 show substantial variation between samples, but support a consistent pattern in the relationship between these elements over the years. Together, Figures 1 – 3 suggest that the 2016 selenium decline reflected a real change in atmospheric composition, likely driven by changes in the mix of fuels used in electric power generation.

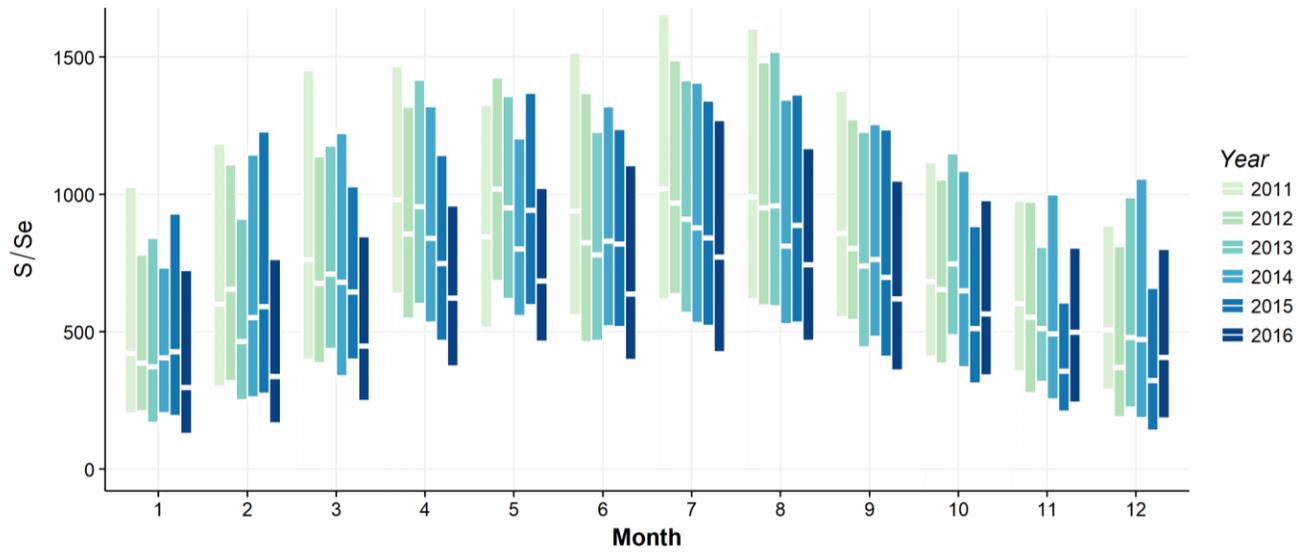
**Figure 1: Multi-year time series, selenium (Se).**



**Figure 2: Multi-year time series, sulfur (S).**

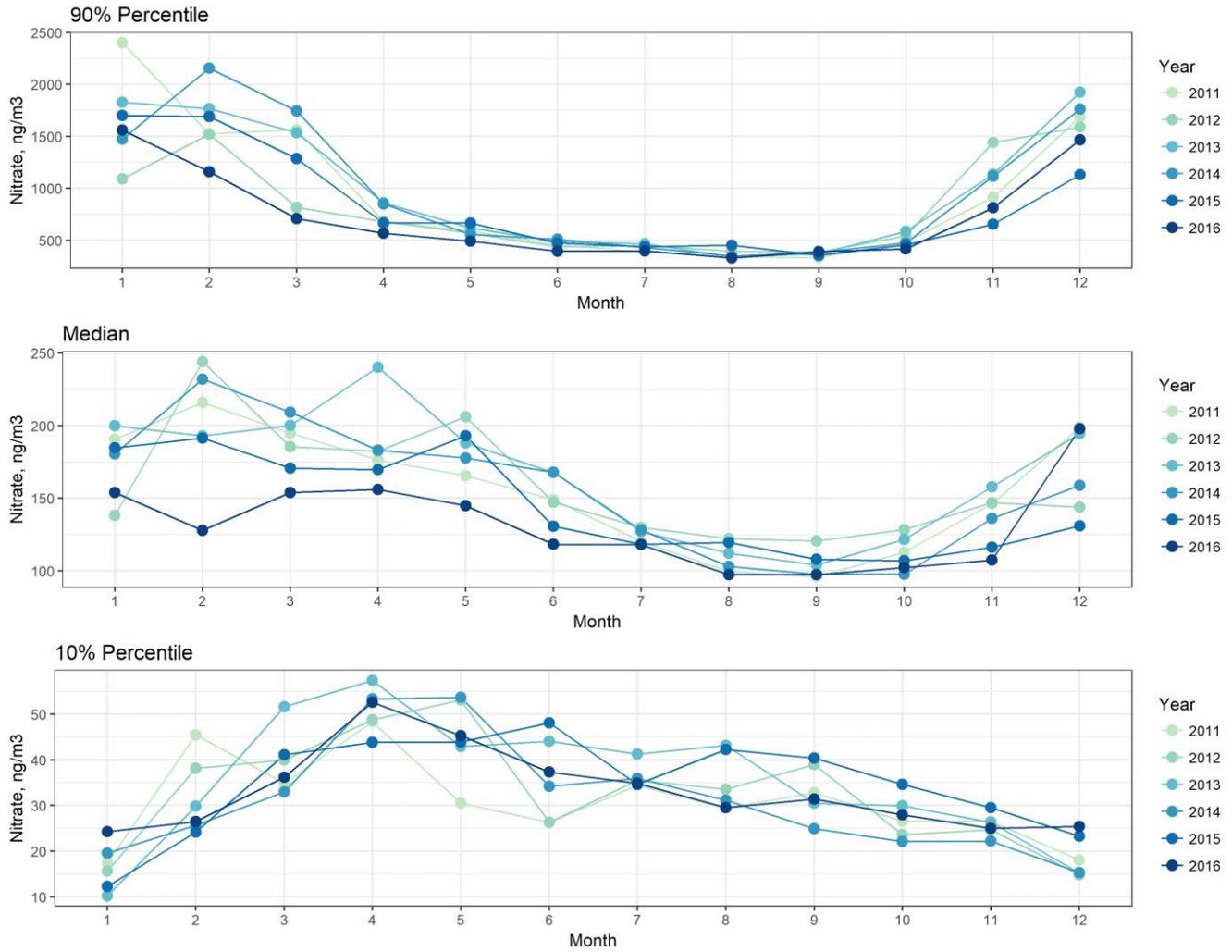


**Figure 3:** Multi-year time series of sulfur/selenium (S/Se) ratio.



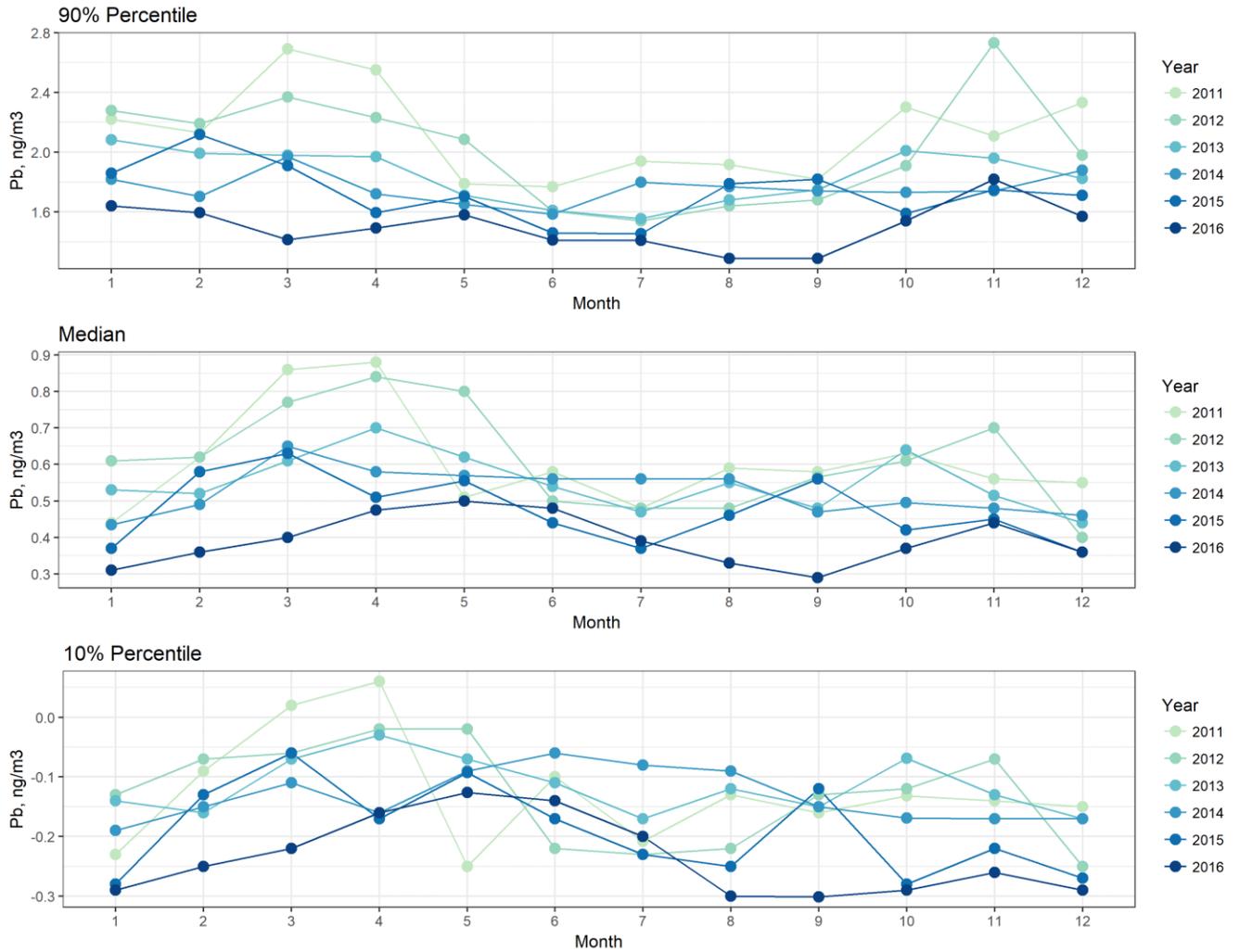
Nitrate concentrations were low during the first six months of 2016 at the median and 90<sup>th</sup> percentile. However, during the latter half of 2016, concentrations at the 10<sup>th</sup> percentile, median, and 90<sup>th</sup> percentile were generally similar to past years.

Figure 4: Multi-year time series, nitrate.

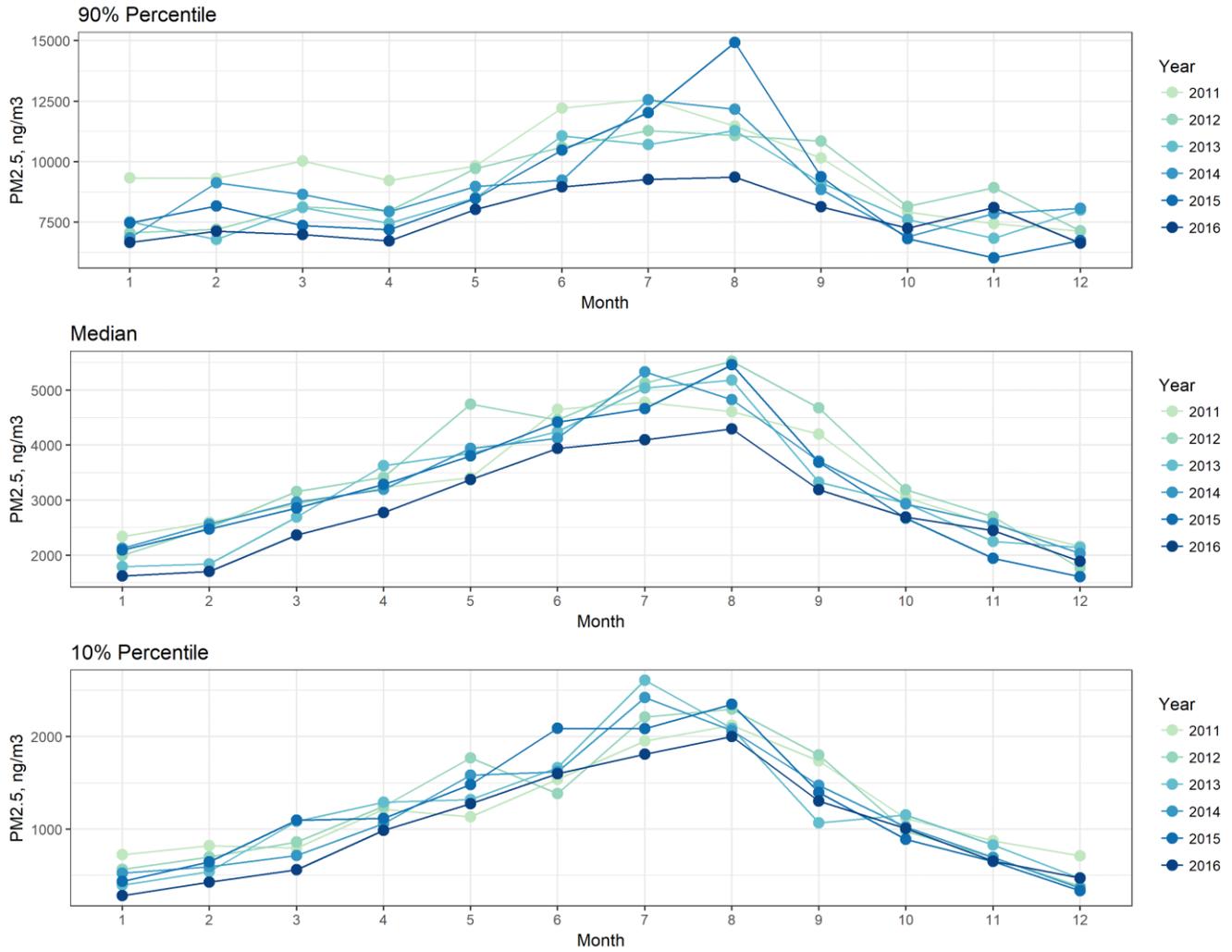


Concentrations of lead and PM2.5 were generally lower in 2016 relative to previous years, as shown in Figures 5 and 6, respectively.

**Figure 5:** Multi-year time series, lead (Pb).



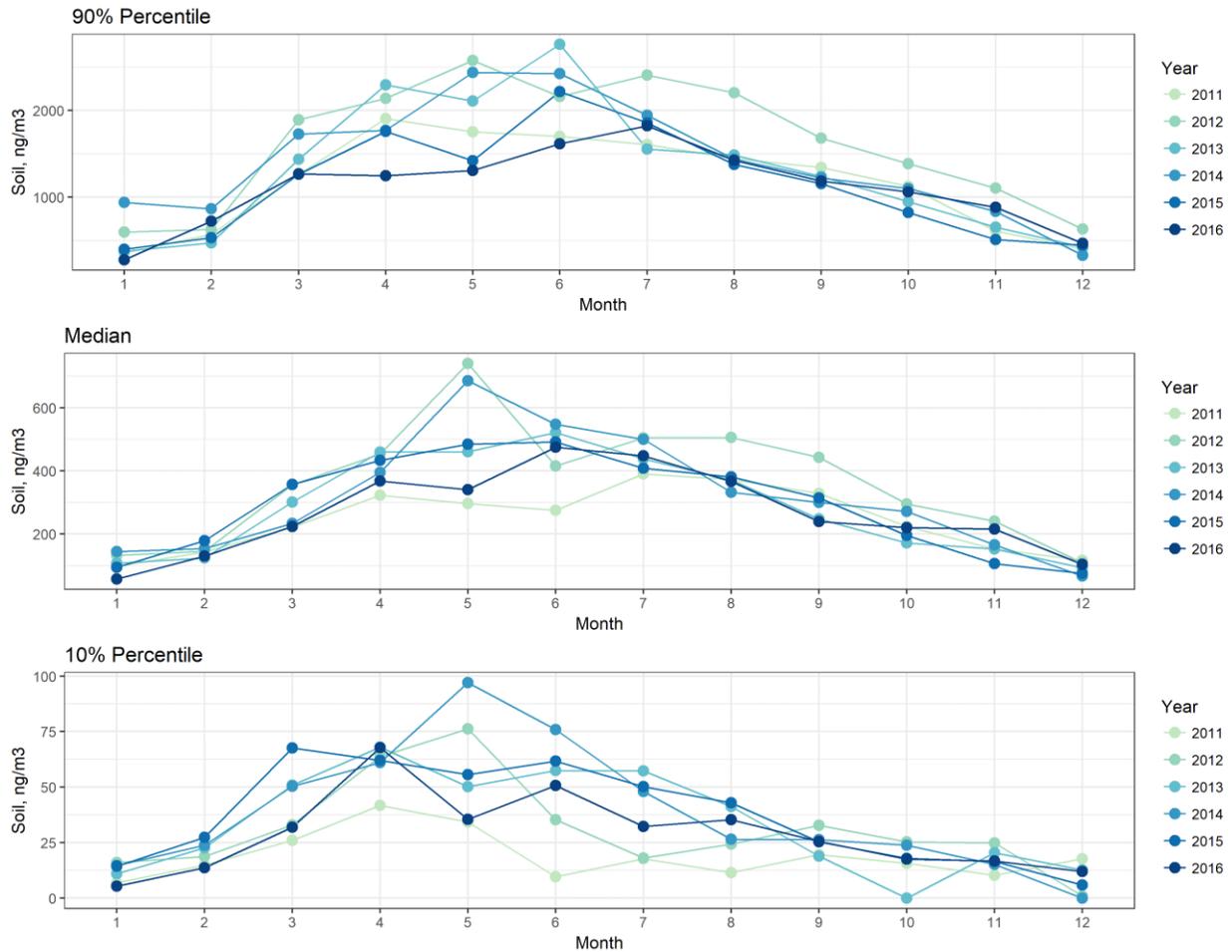
**Figure 6:** Multi-year time series, PM2.5.



Despite the observed 2016 decreases in sulfur, selenium, nitrate, lead, and PM2.5, the soil composite variable, derived from chemical measurements and calculated as shown below, is similar to past years (Figure 7).

$$\text{Soil} = 2.2 \times \text{Aluminum} + 2.49 \times \text{Silicon} + 1.63 \times \text{Calcium} + 2.42 \times \text{Iron} + 1.94 \times \text{Titanium}$$

**Figure 7: Multi-year time series, soil composite variable.**

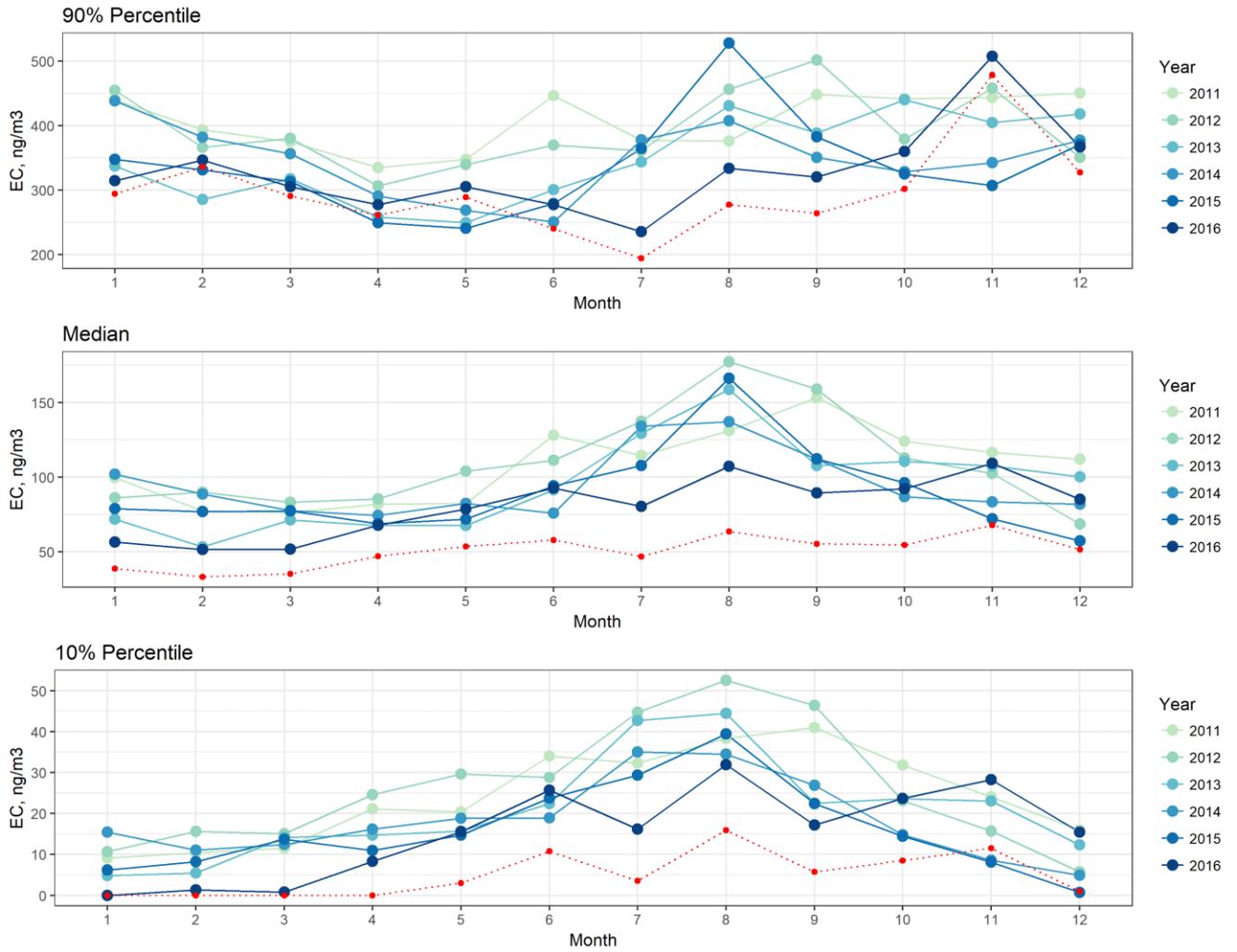


## 2.2 Carbon Redelivery Comparison

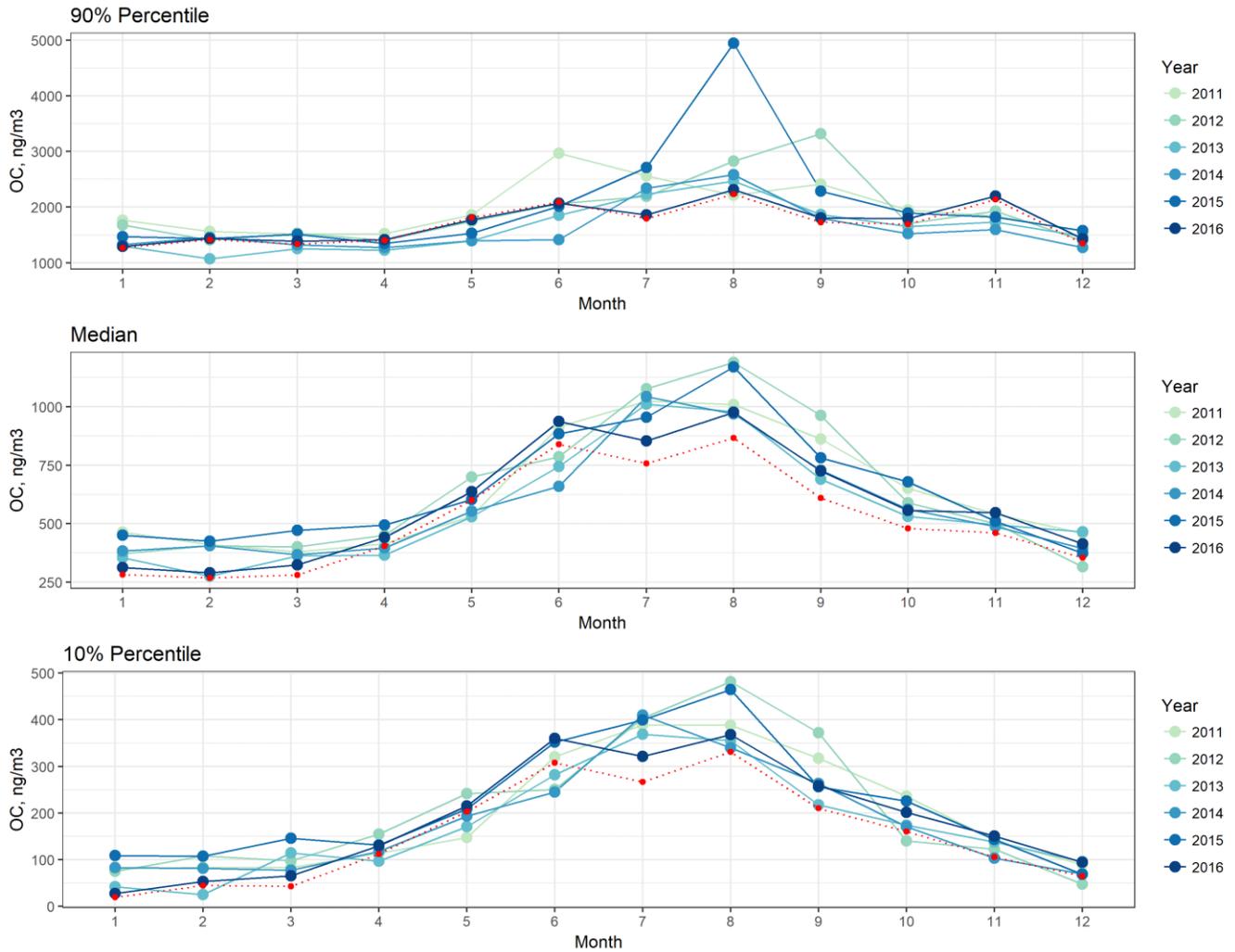
The previous QA report (August 2017; <http://vista.cira.colostate.edu/Improve/quality-assurance/>) called attention to a 2016 drop in EC, both in terms of median concentrations and relative to the HIPS Fabs measurement. This drop coincided with DRI's introduction of their new Model 2015 Carbon Analyzer for TOR analysis of quartz filters from January 2016 onward. DRI subsequently determined that the integration threshold used for the Model 2015 analyzer carbon signal was inappropriate.

In February 2018, UCD received reprocessed carbon data from DRI for January 2016 through February 2017. The difference between the original and reprocessed data for elemental carbon (EC) and organic carbon (OC) is shown in Figures 8 and 9, respectively.

**Figure 8:** Multi-year time series, elemental carbon (EC). 2016 carbon data prior to reprocessing shown as the red dotted line.

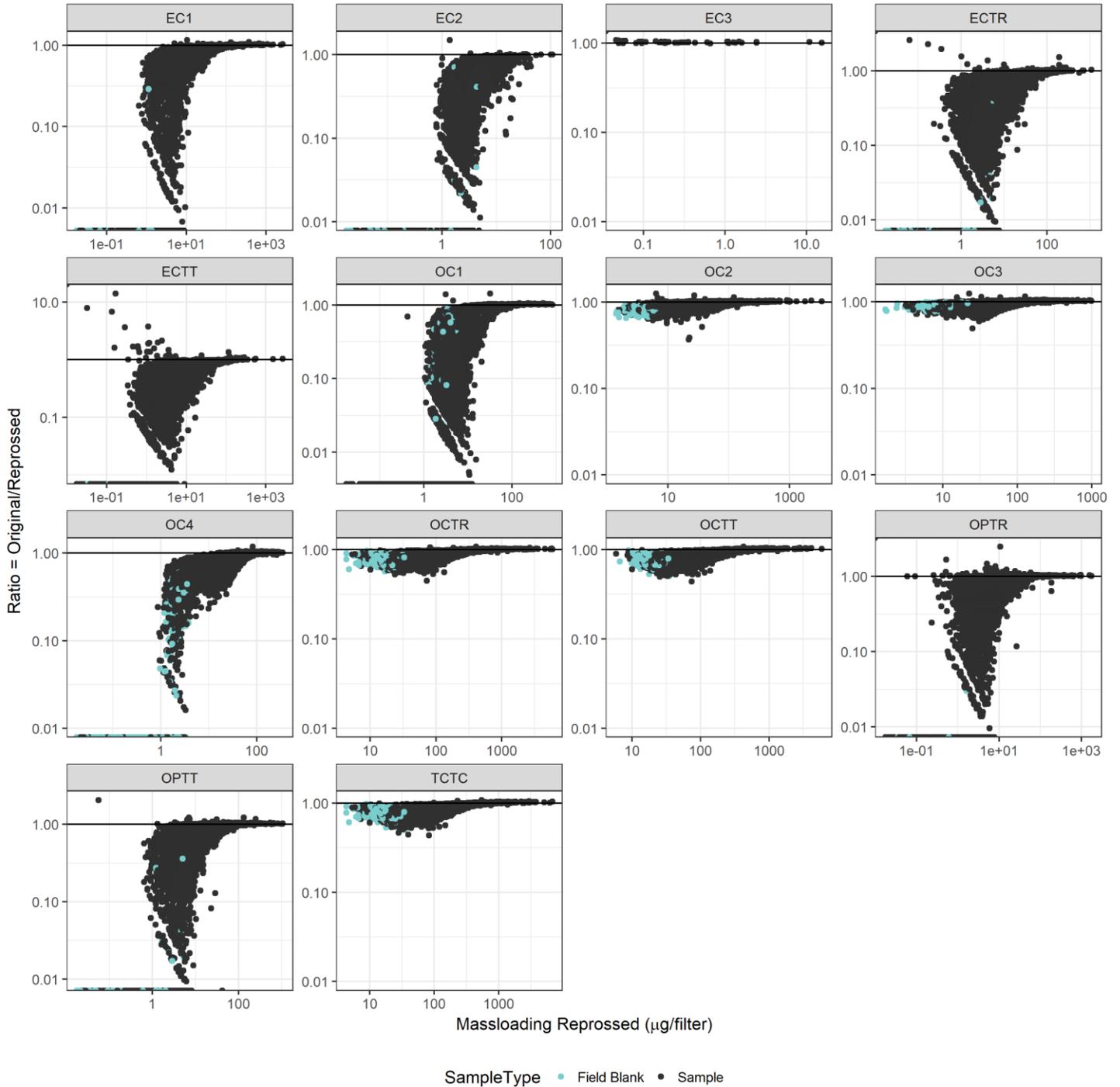


**Figure 9:** Multi-year time series, organic carbon (OC). 2016 carbon data prior to reprocessing shown as the red dotted line.

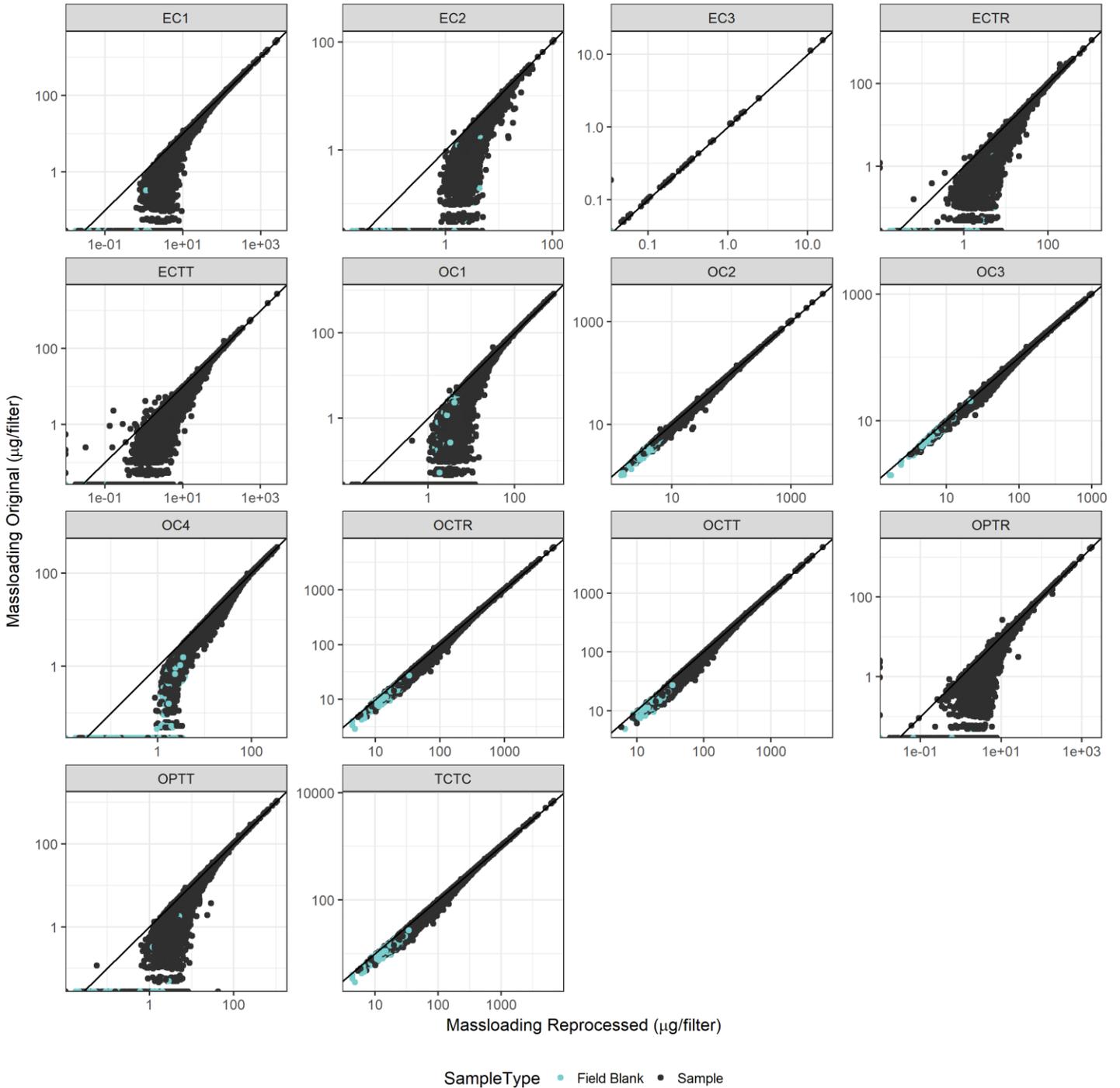


Scatter plots for carbon fractions of the original/reprocessed ratio and original mass loadings versus reprocessed mass loadings are shown in Figures 10 and 11, respectively. Total carbon (TCTC) shows relatively good agreement; however, reprocessed data for the elemental carbon fractions – and to a lesser extent organic carbon fractions – have higher mass loadings, particularly at lower concentrations. The EC2 fraction has the most distinct deviation between original and reprocessed data (Figure 12).

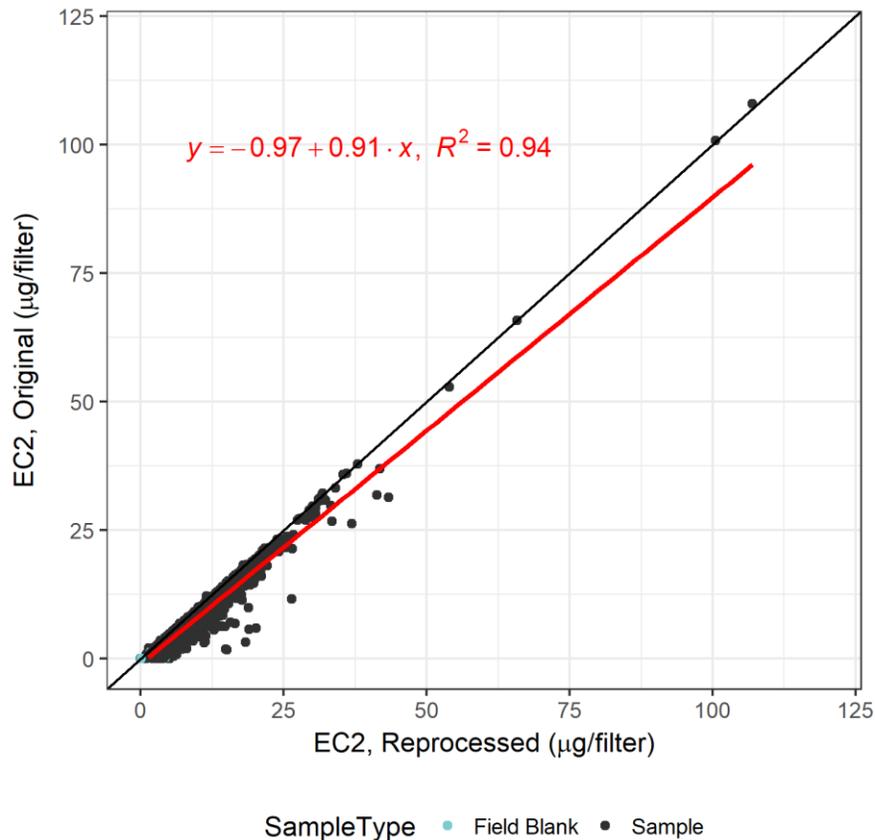
**Figure 10:** Log scale scatter plot for carbon fractions showing ratio of original/reprocessed mass loading versus reprocessed mass loading, January 2016 through December 2016. Where EC1-3 are elemental carbon fractions, ECTR is total elemental carbon by reflectance, ECTT is elemental carbon by transmittance, OC1-4 are organic carbon fractions, OCTR is organic carbon by reflectance, OCTT is organic carbon by transmittance, OPTR is organic pyrolyzed carbon by reflectance, OPTT is organic pyrolyzed carbon by transmittance, and TCTC is total carbon. The lower limit of y-axis (mass loading ratio) is fixed at 0.01. Plot omits data for EVER1 (4/12/2016) and EVER1 (4/15/2016) samples, which had exceptionally high OC and EC mass loadings.



**Figure 11:** Log scale scatter plot for carbon fractions showing original mass loading versus reprocessed mass loading, January 2016 through December 2016. Where EC1-3 are elemental carbon fractions, ECTR is total elemental carbon by reflectance, ECTT is elemental carbon by transmittance, OC1-4 are organic carbon fractions, OCTR is organic carbon by reflectance, OCTT is organic carbon by transmittance, OPTR is organic pyrolyzed carbon by reflectance, OPTT is organic pyrolyzed carbon by transmittance, and TCTC is total carbon. The solid black line is the 1:1 line. Plot omits data for EVER1 (4/12/2016) and EVER1 (4/15/2016) samples, which had exceptionally high OC and EC mass loadings.



**Figure 12:** Linear scale scatter plot for EC2 carbon fraction showing original mass loading versus reprocessed mass loading, January 2016 through December 2016. The solid black line is the 1:1 line. The solid red line is the linear regression line, with its equation and correlation coefficient displayed alongside. Plot omits data for EVER1 (4/12/2016) and EVER1 (4/15/2016) samples, which had exceptionally high OC and EC mass loadings.



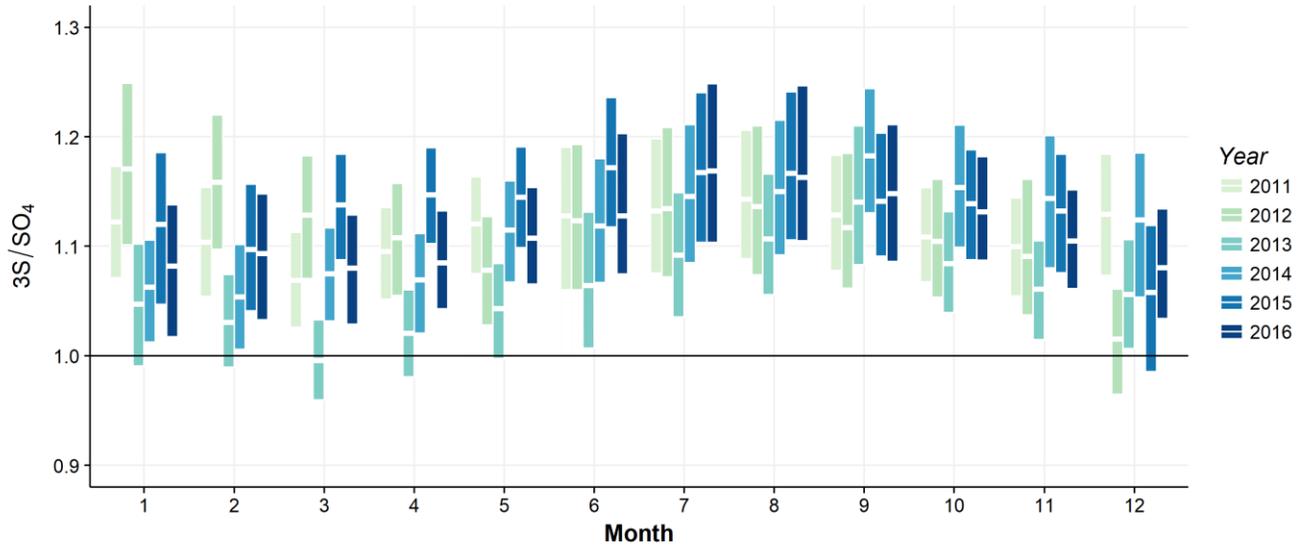
## 2.3 Comparisons Between Modules

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.

### 2.3.1 Sulfur vs. 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 ( $\text{SO}_4$ ) using IC. The molecular weight of  $\text{SO}_4$  (96 g/mol) is three times the atomic weight of S (32 g/mol), so the concentration ratio  $(3 \times \text{S})/\text{SO}_4$  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 13), suggesting the presence of some sulfur in a non-water soluble form of sulfate or in a chemical compound other than sulfate.

**Figure 13:** Multi-year time series of  $(3 \times S)/SO_4$ .



### 2.3.2 PM<sub>2.5</sub> vs. Reconstructed Mass (RCMN)

PTFE filters from the A-Module are analyzed gravimetrically (i.e., weighed before and after sample collection) to determine PM<sub>2.5</sub> 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:

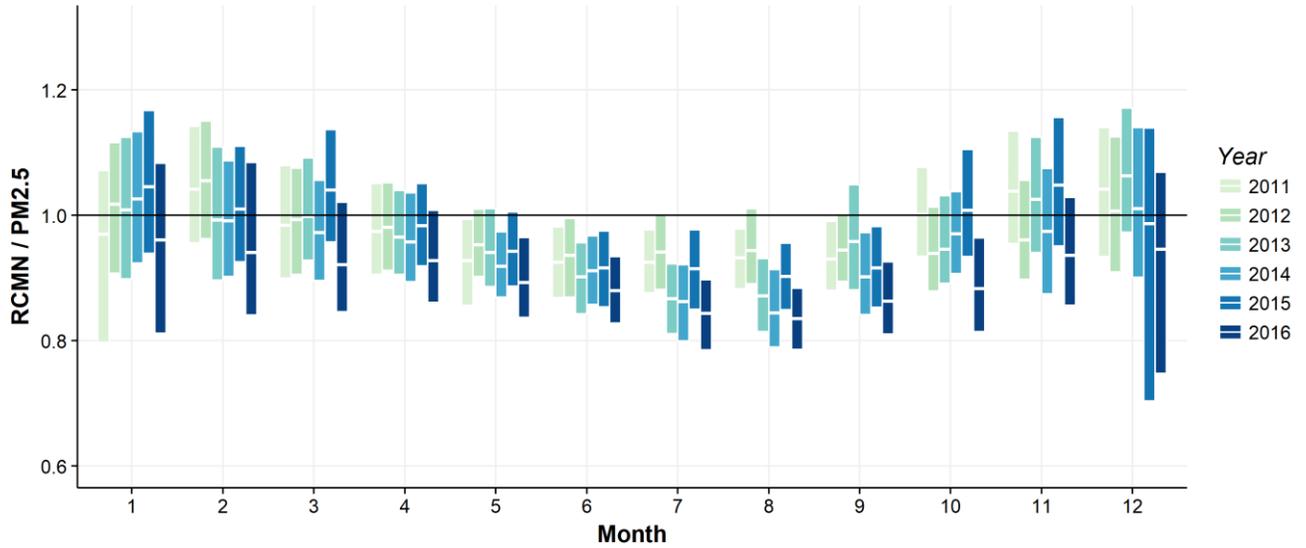
$$\begin{aligned} \text{RCMN} = & (4.125 \times S) + (1.29 \times \text{NO}_3^-) + (1.8 \times \text{OC}) + (\text{EC}) + \\ & (2.2 \times \text{Al} + 2.49 \times \text{Si} + 1.63 \times \text{Ca} + 2.42 \times \text{Fe} + 1.94 \times \text{Ti}) + (1.8 \times \text{chloride}) \end{aligned}$$

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

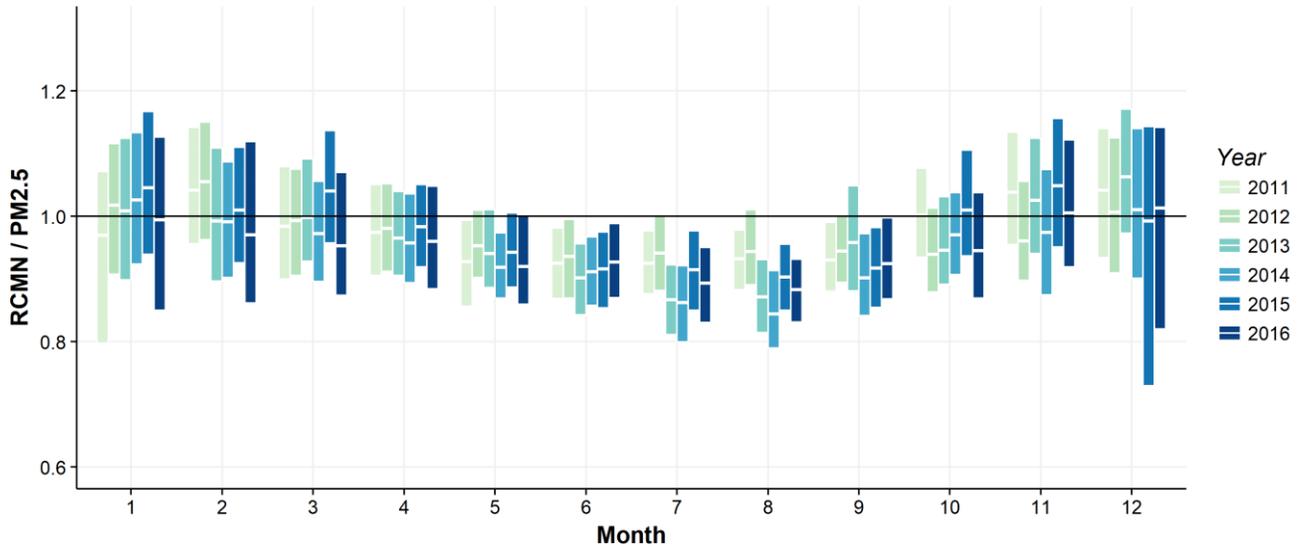
If the RCMN completely captures and accurately estimates the different mass components, the RCMN/PM<sub>2.5</sub> ratio is expected to be near one. The gravimetric mass likely includes some water associated with hygroscopic species, which is not accounted for by any of the chemical measurements. Conversely,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

The RCMN/PM<sub>2.5</sub> ratio exhibits seasonal variability, with the lowest ratios during the summer months (Figures 14 and 15). Prior to reprocessing the carbon data, the 2016 ratios were notably lower relative to previous years (Figure 14). Using reprocessed carbon data to calculate the RCMN, the 2016 RCMN/PM<sub>2.5</sub> ratios are in better agreement with previous years (Figure 15).

**Figure 14:** Multi-year time series of RCMN/PM2.5, with RCMN calculated using original carbon data.



**Figure 15:** Multi-year time series of RCMN/PM2.5, with RCMN calculated using reprocessed carbon data.



## 2.4 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. This uncertainty is conventionally reported as collocated precision.

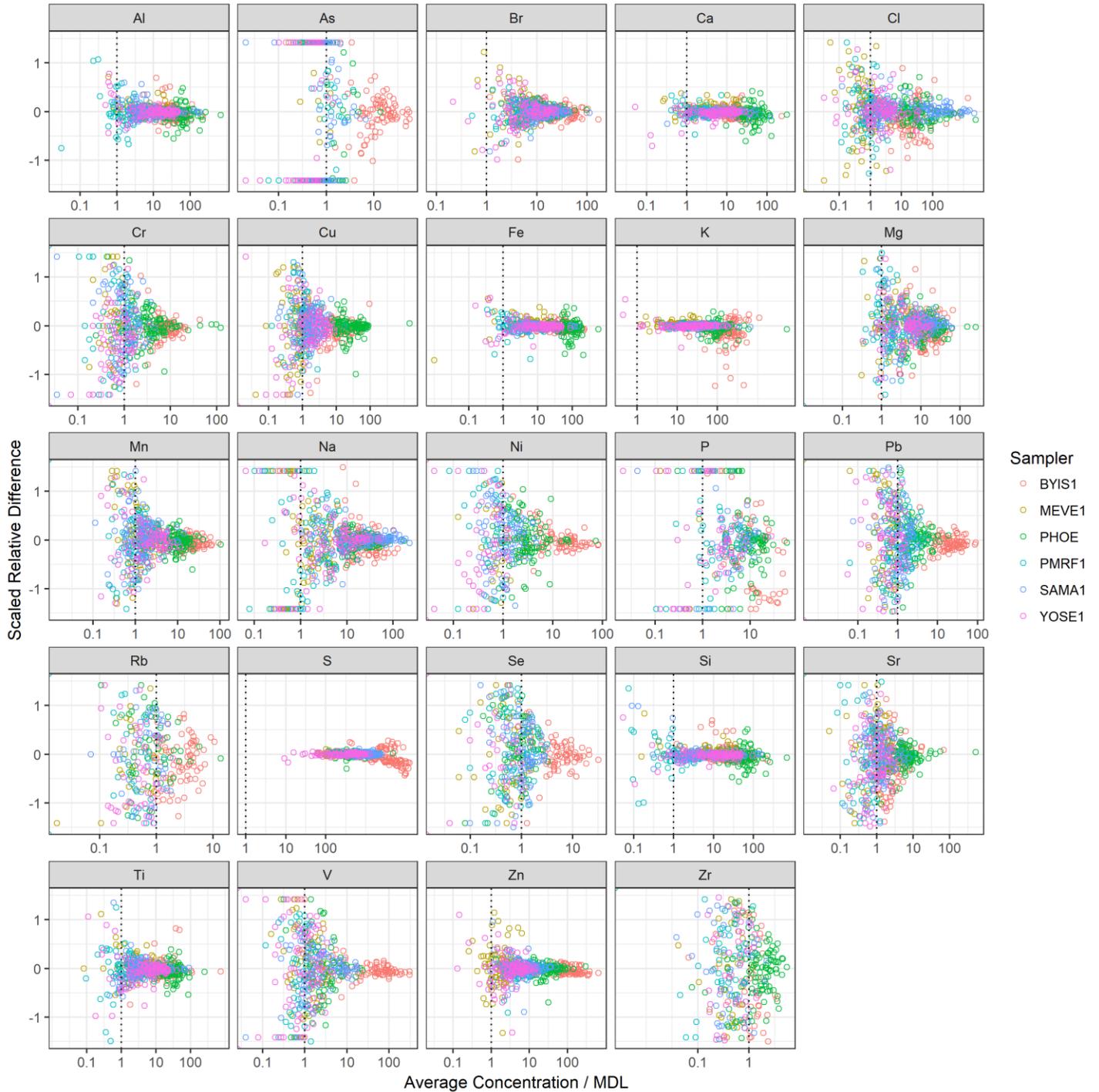
Collocated precision is calculated from the scaled relative differences (SRD) between the collocated sample pairs,

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

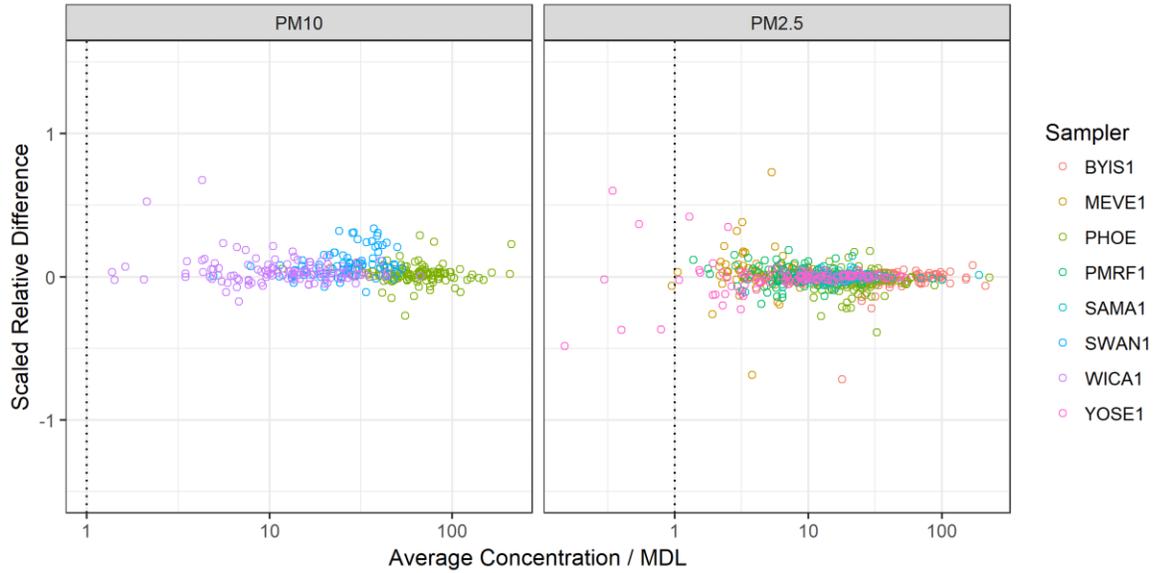
$$\text{Collocated Precision (\%)} = 100 \times \sqrt{\frac{1}{n} \sum_i \text{SRD}_i^2}$$

The scaled relative differences are  $\pm\sqrt{2}$  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 16, elements; Figure 17, mass; Figure 18, ions; Figure 19, carbon). Note that this convergence is not observed for elements and carbon fractions that are rarely measured above the MDL. The BYIS collocated and routine modules use different size filters, with one collecting samples on the normal 25mm PTFE and the other 37mm PTFE filters. The module with the 37mm filters was installed to explore the cause of unusually high differences between the sulfur and sulfate measurements at BYIS, and the sulfur measurements on the 37mm filters compare much better to the sulfate measurements than do the 25mm filter sulfur measurements at BYIS. The disagreement between the sulfur (and potassium) measurements at BYIS, compared to the other identical collocated modules, stands out in Figure 16.

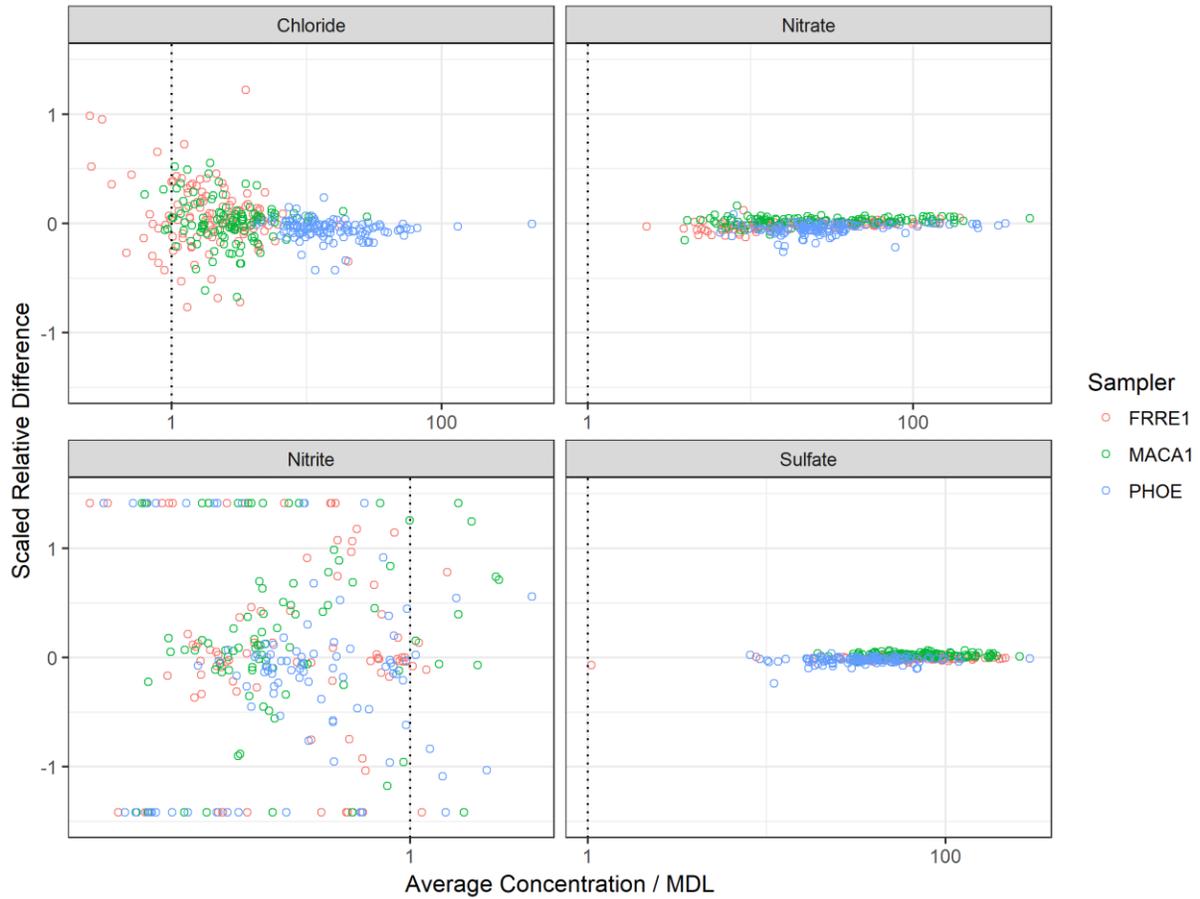
**Figure 16:** Scaled relative difference for element measurements at sites with collocated modules across the IMPROVE network (2016). Dotted vertical lines indicate the detection limits.



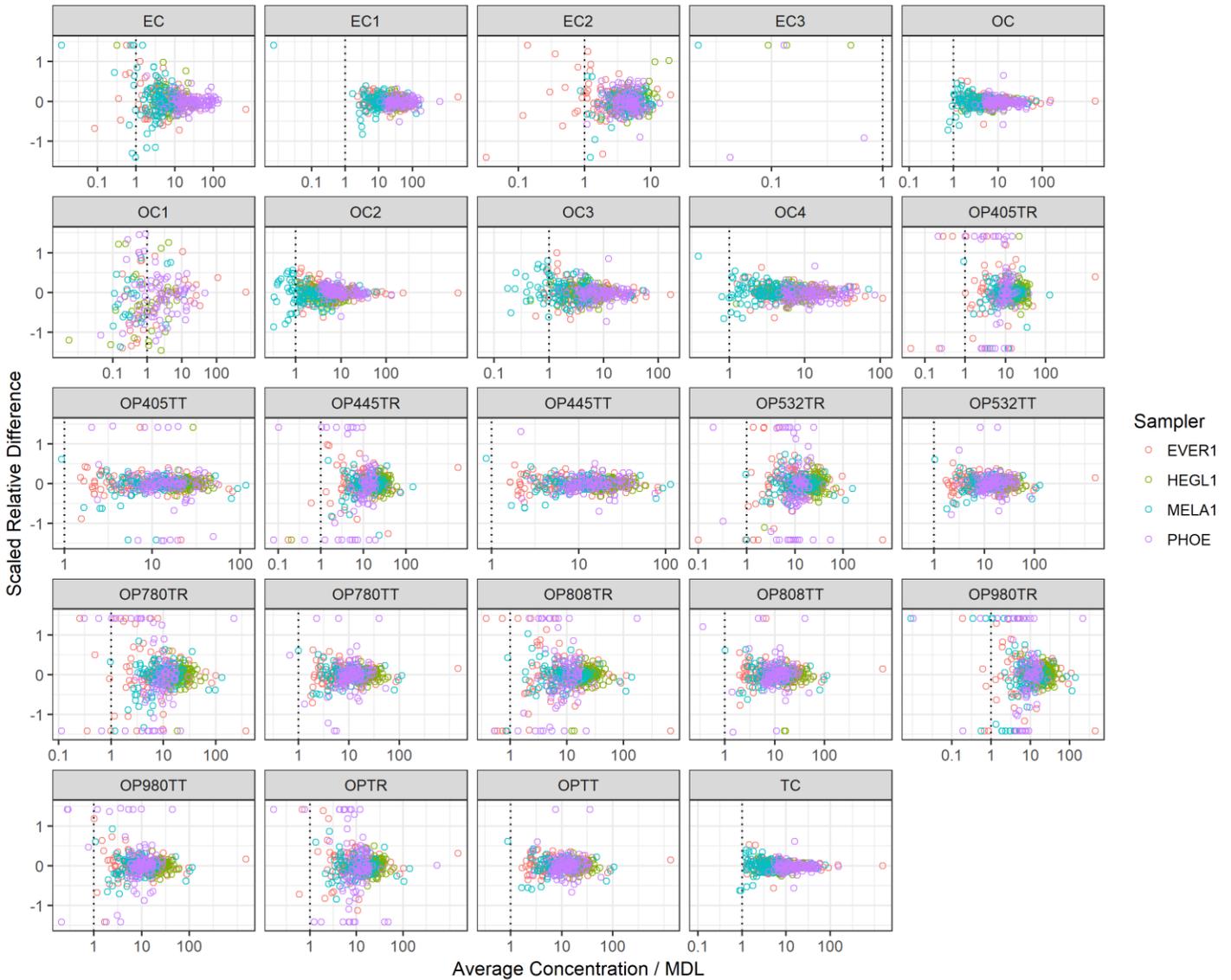
**Figure 17:** Scaled relative difference for PM10 and PM2.5 at sites with collocated modules across the IMPROVE network (2016).



**Figure 18:** Scaled relative difference for ions measurements at sites with collocated modules across the IMPROVE network (2016).



**Figure 19:** Scaled relative difference for carbon measurements at sites with collocated modules across the IMPROVE network (2016).



*UCD IMPROVE SOP 351, Data Processing and Validation* documents the calculation of collocated precision. Collocated precision for the 2016 IMPROVE data is calculated using 2005-2013 collocated measurements, as reported in the previous Semiannual Quality Assurance Report, August 2017. Collocated precision for the 2017 IMPROVE data will be calculated using the 2016 collocated measurements, and will be updated annually moving forward.

### **3. Analytical QC Checks**

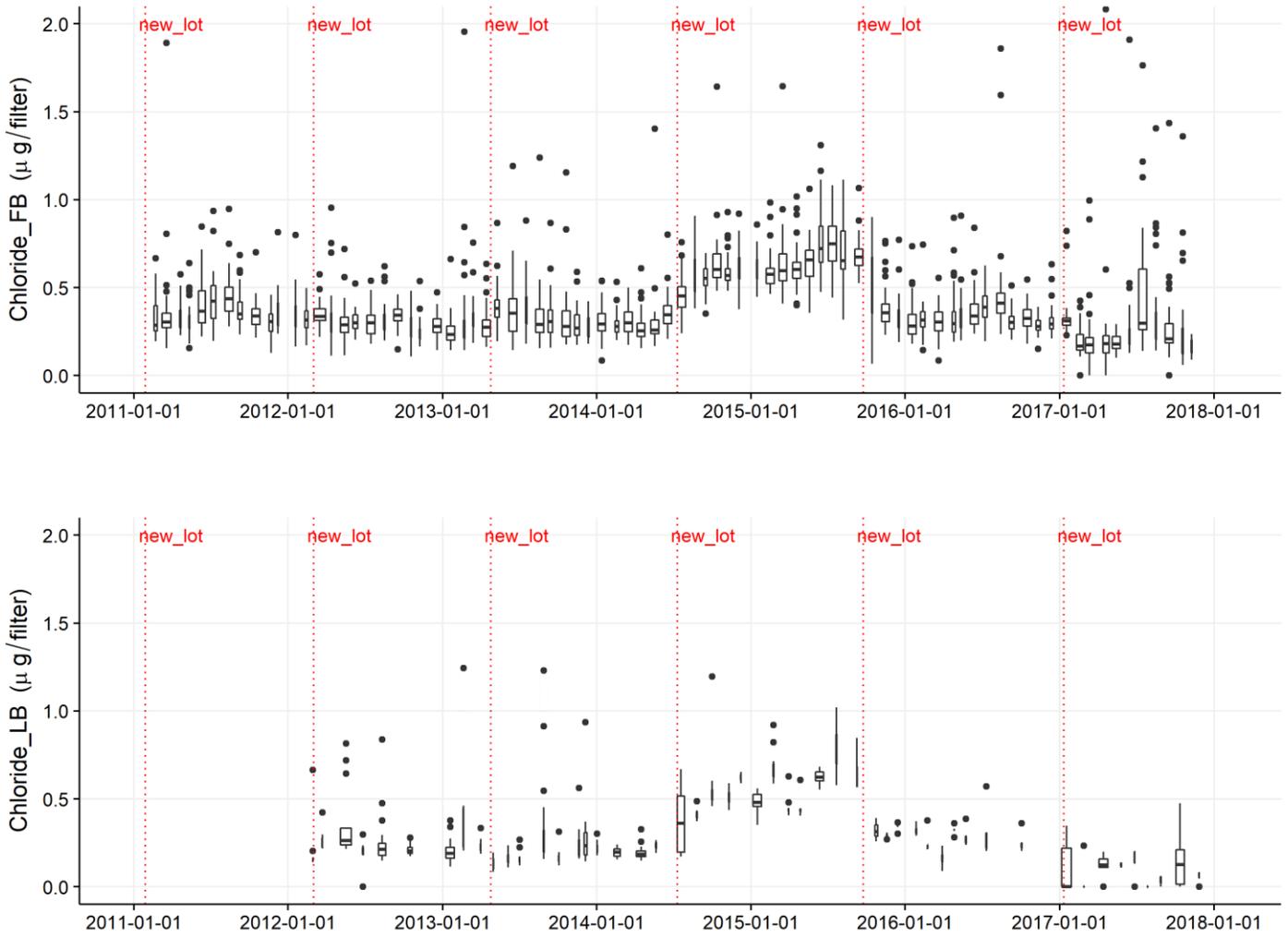
#### **3.1 Blanks**

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.

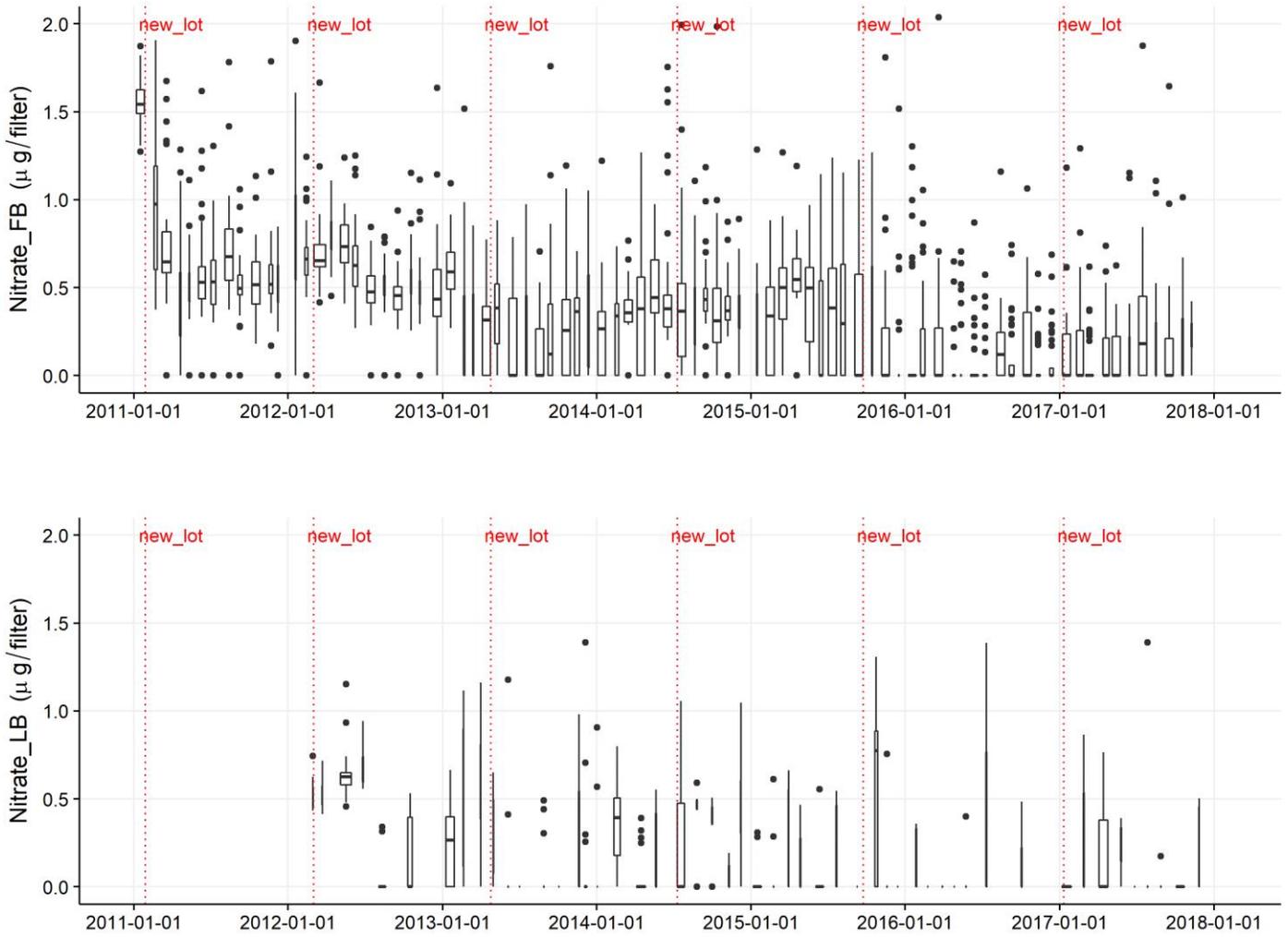
Field blanks are an integral part of the QC process, and analysis results allow for artifact correction of the sampled filters as part of the concentration calculation. Artifacts result from contamination in the filter material or handling and analysis.

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 20-23). Transition to new lots occurs over a period of weeks; thus the shift in field blank concentrations gradually manifest over time rather than abruptly.

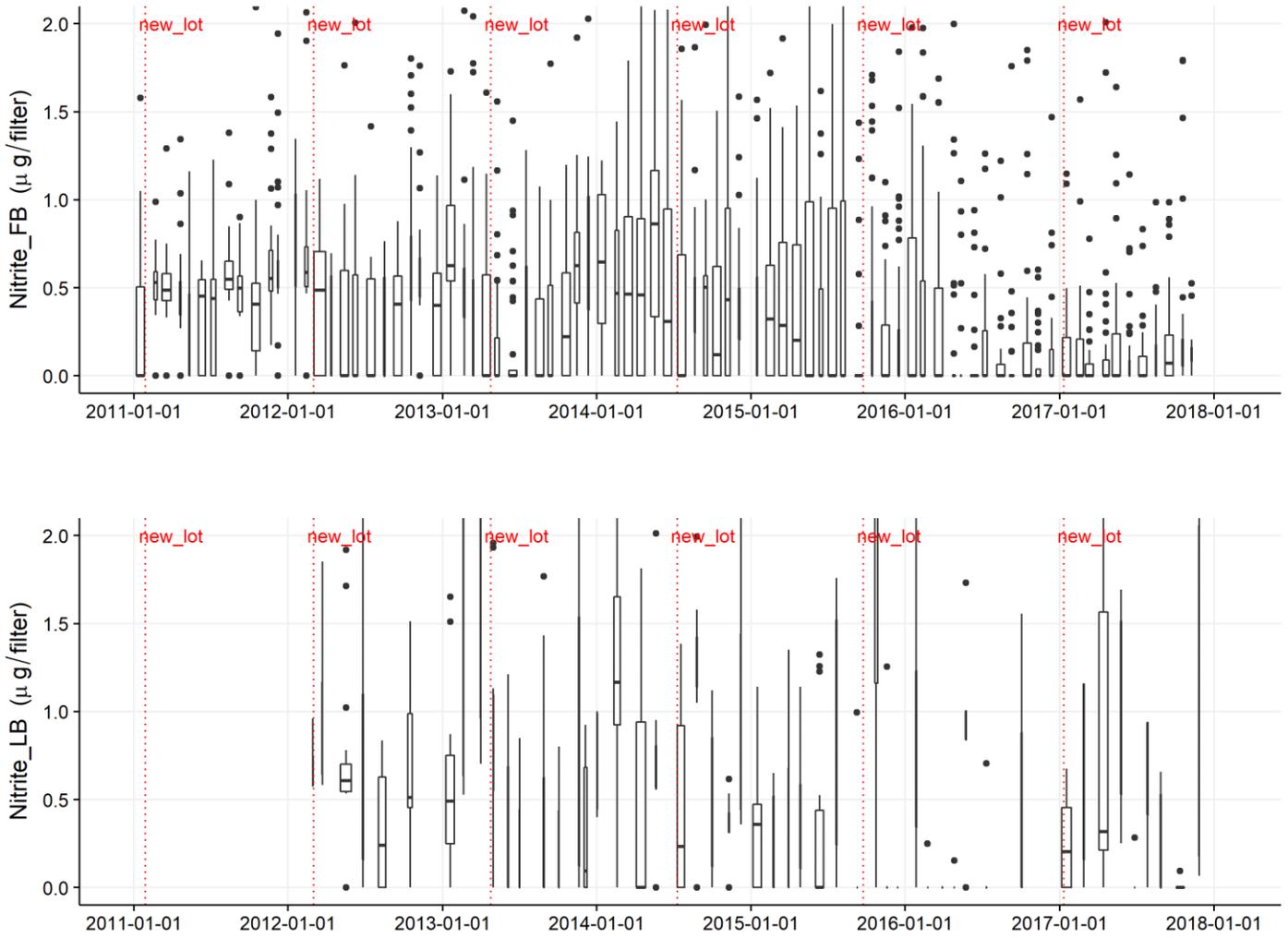
**Figure 20:** Time series of chloride measured on nylon filter field (FB) and lab (LB) blanks.



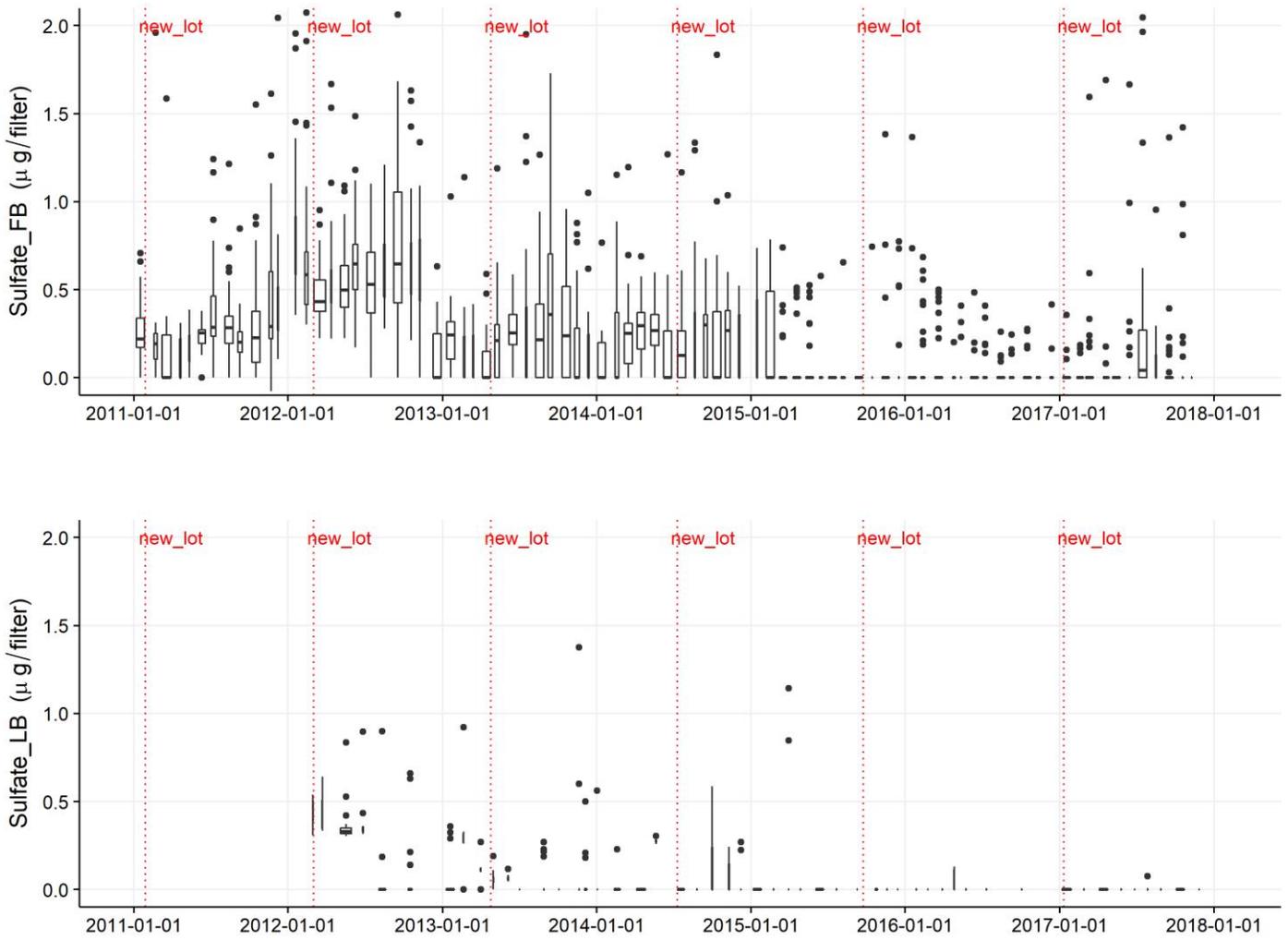
**Figure 21:** Time series of nitrate measured on nylon filter field (FB) and lab (LB) blanks.



**Figure 22:** Time series of nitrite measured on nylon filter field (FB) and lab (LB) blanks.

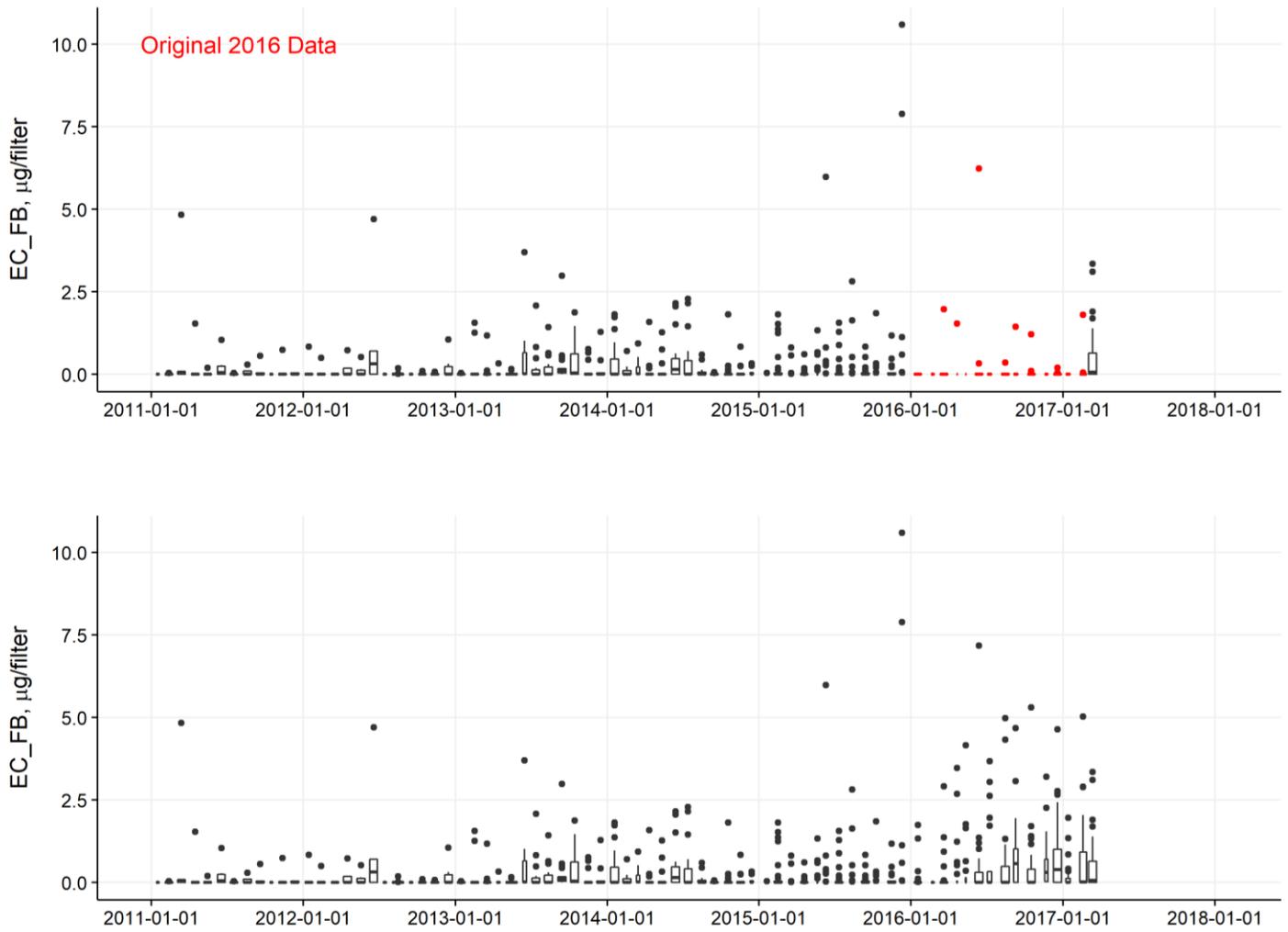


**Figure 23:** Time series of sulfate measured on nylon filter field (FB) and lab (LB) blanks.

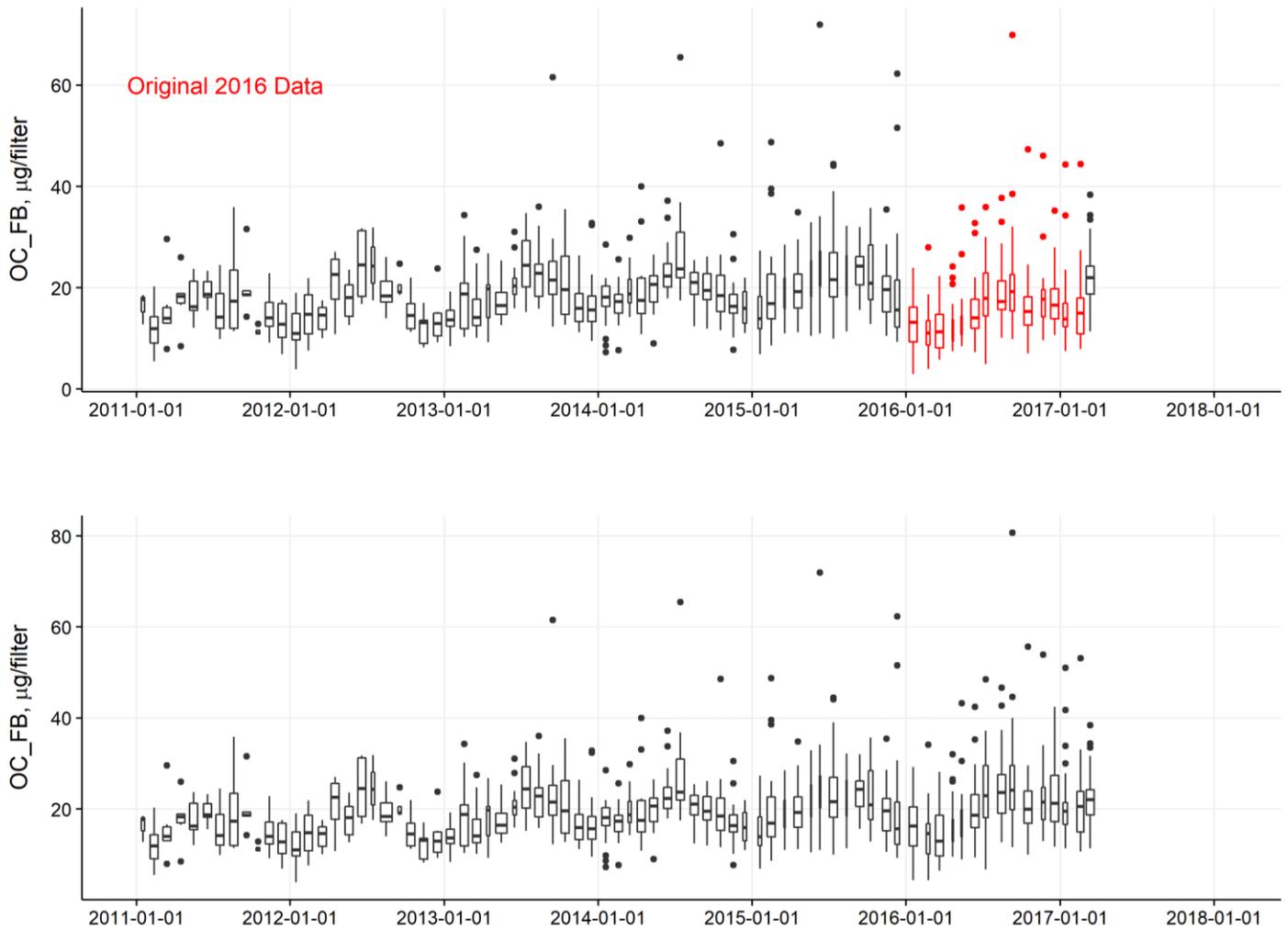


Quartz filters are pre-fired by DRI. Quartz filter field blanks have low concentrations of EC, typically below 0.5 µg/filter, with no seasonal pattern (Figures 24). Conversely, higher field blank concentrations are observed for OC, with the highest values during summer months often over 5 µg/filter (Figures 25). However, the reprocessed EC field blank concentrations are high, relative to the original values (Figure 24). The reprocessed organic carbon field blank concentrations show little to no difference relative to the original values (Figure 25).

**Figure 24:** Time series of elemental carbon (ECTR) artifact on quartz filter field blanks. In the top plot, original data prior to reprocessing is shown in red. The bottom plot shows reprocessed data.

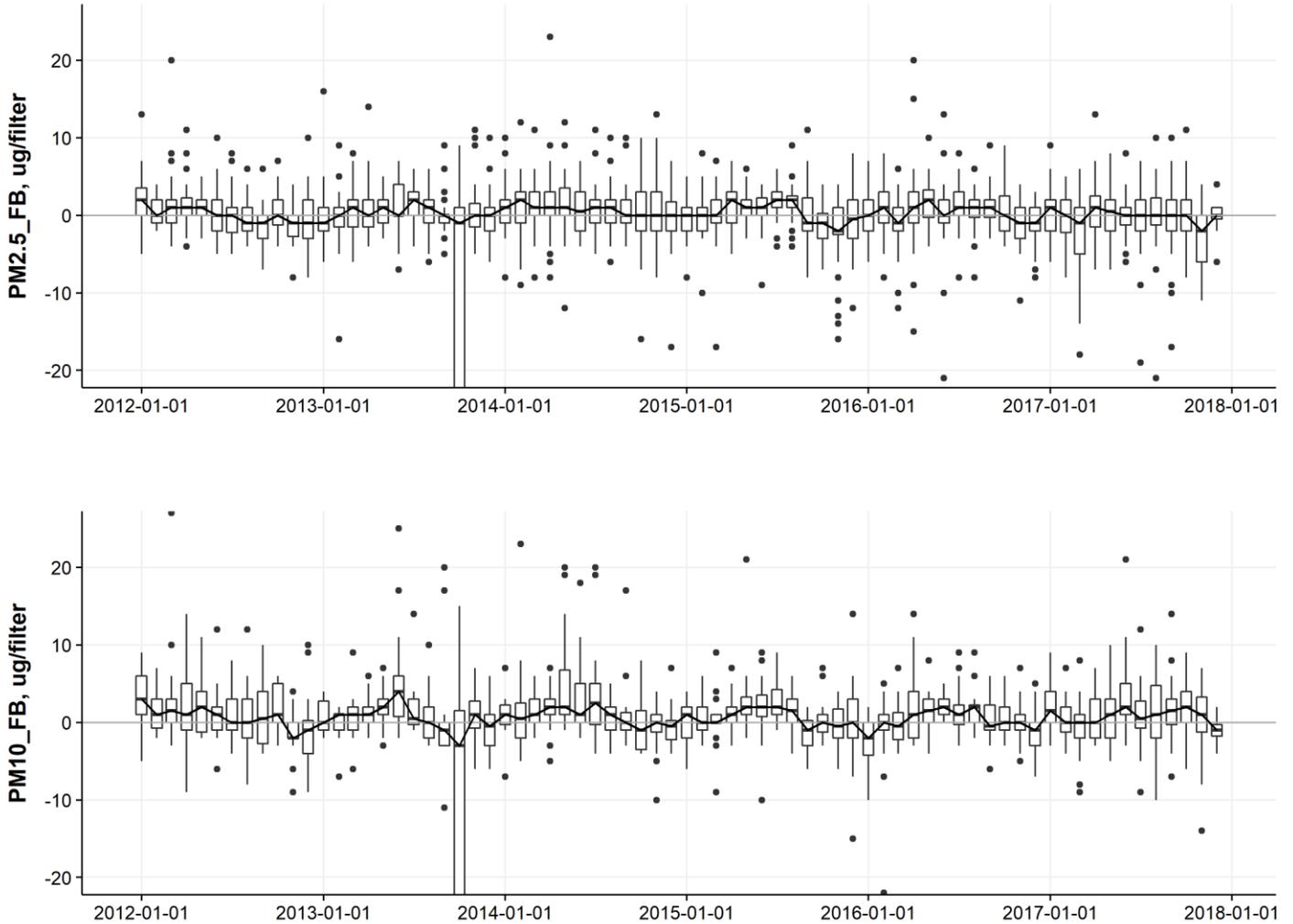


**Figure 25:** Time series of organic carbon (OCTR) artifact on quartz filter field blanks. In the top plot, original data prior to reprocessing is shown in red. The bottom plot shows reprocessed data.



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 26). The distributions span zero, but exhibit slight seasonality with more positive values in the summer.

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



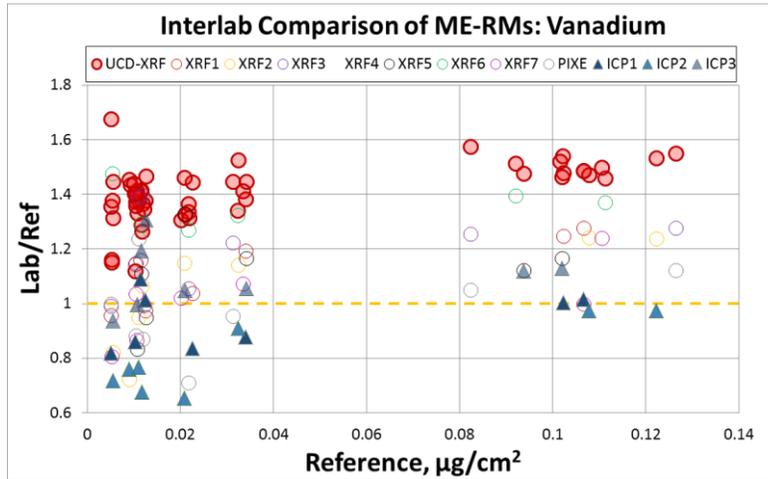
### 3.2 XRF Calibration

Reported elemental concentrations rest on linear calibrations of the Panalytical Epsilon 5 instruments used since the 2011 sample year for EDXRF analysis. The calibration factors are derived from observed instrumental responses to a variety of certified standards and reference materials of known composition. In recent years UCD has begun to certify and calibrate with standards created in their own laboratory, aerosolizing known materials and collecting them on PTFE filters using IMPROVE samplers. The resulting deposits better mimic actual IMPROVE samples than do the vacuum-deposited thin-film membranes traditionally obtained from commercial vendors. Such in-house standards have so far been certified for 16 of the 24 elements reported for IMPROVE. Calibrations for vanadium were based solely on two commercial standards in continuous use for samples collected January 2011 through October 2017.

An important component of QA is the exchange of reference materials with other laboratories for comparative analyses. During inter-laboratory comparison studies of novel multi-element (ME) reference materials (RM) under development, it was discovered that UCD XRF results for

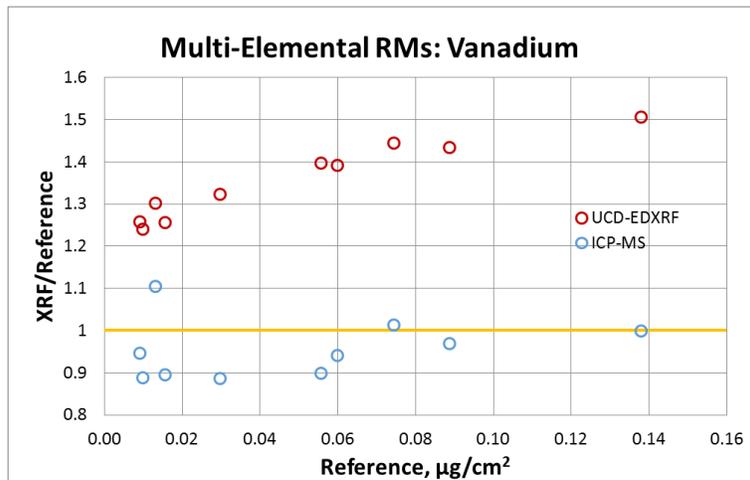
vanadium (V) were higher than expected by about 30-50% while results from other laboratories (including XRF lab, PIXE and ICP-MS) were within 20% of expected values (Figure 27).

**Figure 27:** Inter-laboratory comparison of multi-element reference materials for vanadium (V), where the UCD results are shown as filled red circles and results from other laboratories are shown as circles and triangles.



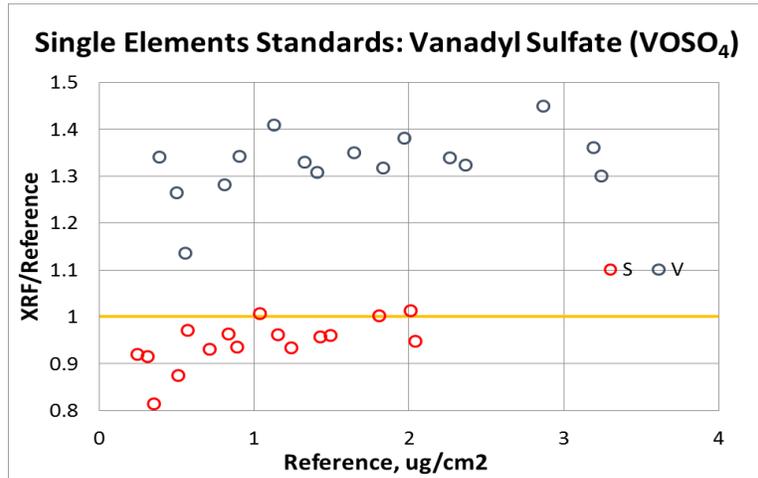
Overestimation by UCD XRF analysis was confirmed by further comparisons with ICP-MS analysis, the preferred technique for vanadium analysis, from a collaborating laboratory (Figure 28).

**Figure 28:** Comparison of multi-element reference materials for vanadium (V) at UCD using EDXRF and a Canadian laboratory using ICP-MS.



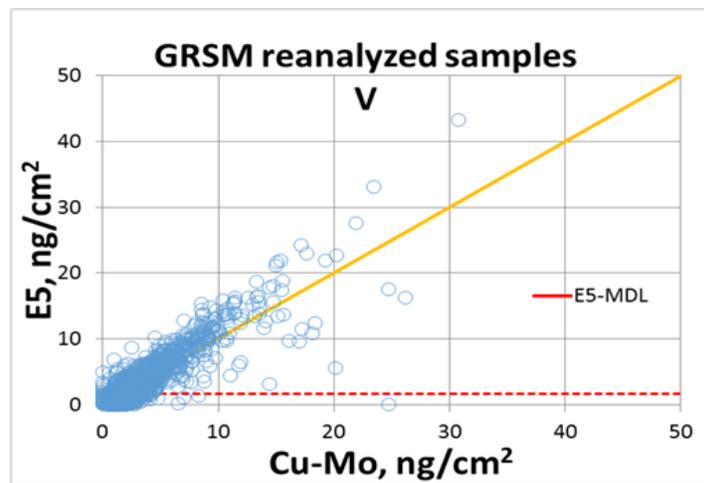
UCD's ability to design and generate custom reference materials provided further confirmation with single-compound (vanadyl sulfate) standards of known hydration, whose loadings could be gravimetrically certified (Figure 29).

**Figure 29:** UCD XRF results for vanadyl sulfate standards that conform to expectations for sulfur but are high for vanadium.



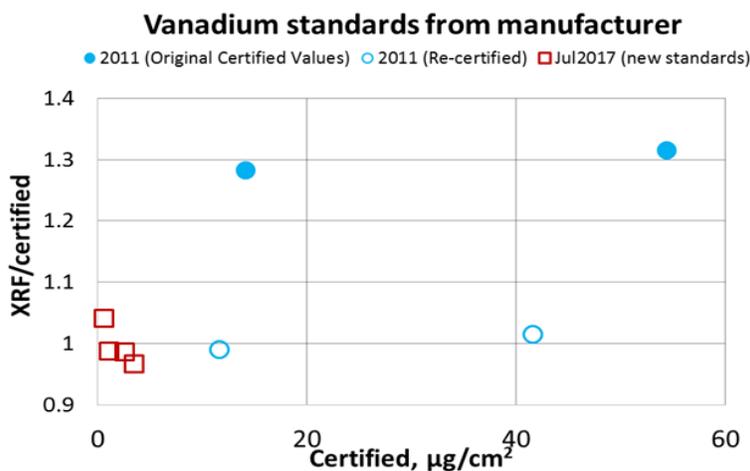
Inter-laboratory comparison studies of UCD multi-element RMs, together with UCD custom single-compound standards, converged to indicate that the existing calibration of the UCD Panalytical Epsilon-5 instruments for vanadium was about 30% high. Continuity of the historical vanadium record was already tested, when the newer Epsilon 5 (E5) instruments were used to reanalyze the 15-year archive of samples collected from 1995 to 2009 at Great Smoky Mountains NP (GRSM). These had previously been analyzed and reported from the UCD-built copper- and molybdenum-anode XRF systems, which had been calibrated using a different set of standards. The new measurements were about 30% higher than those previously reported (Figure 30).

**Figure 30:** Reanalyses by Panalytical Epsilon 5 (E5) of 1995 – 2009 samples from Great Smoky Mountains NP previously analyzed versus earlier Cu-Mo XRF system.



As a final step, UCD returned the certified calibration standards from 2011 to the manufacturer for recalibration. UCD also purchased an additional set of standards. Recalibrated standards' values for vanadium mass loadings are about 30% lower compared to previously certified values and in agreement with newly purchased standards and standards generated at UCD (Figure 31).

**Figure 31:** Reported versus quoted V mass loadings for commercial thin-film standards. The reported XRF values are based on a calibration to the loadings certified in 2017 for the two standards originally purchased in 2011.



Annual calibration records show the Panalytical analyzers’ raw response to the two original standards was consistent throughout 2011 – 2017, indicating that the recertified values can be applied retroactively. Figure 31 appears in a data advisory recently issued, recommending the adjustment of vanadium data from January 2011 through October 2017: [http://vista.cira.colostate.edu/improve/Data/QA\\_QC/Advisory/da0038/da0038\\_V\\_advisory.pdf](http://vista.cira.colostate.edu/improve/Data/QA_QC/Advisory/da0038/da0038_V_advisory.pdf)

## 4. Documentation

Current standard operations procedures (SOPs) are available at: <http://airquality.crocker.ucdavis.edu/improve/standard-operating-procedures-sop/>

**Table 1:** Summary of upcoming project documentation deliverables.

Deliverable	Upcoming Delivery Date
SOPs and TI documents	November 30, 2018
Quarterly Site Status Report	May 15, 2018 (Q1) August 15, 2018 (Q2)
Semiannual Quality Assurance Report	August 31, 2018

## 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 2 summarizes the equipment shipped to sites for sampler repairs, July 1, 2017 through December 31, 2017.

**Table 2:** Summary of major repair items shipped to IMPROVE sites, 7/1/2017 through 12/31/2017.

Item	Quantity	Sites
Controller	29	GRCA1, NOCA1, CEBL1, YELL1, SYCA2, LIGO1, BADL1, DENA1, KAIS1, YOSE1, CABI1, GRGU1, COHU1, SULA1 (x3), CANY1, BRIS1, HOOV1, WHIT1, STIL1, WHIT1, FLAT1, MONT1, NOAB1, PEFO1, CACR1, IKBA1 (x2)
Pump	96	BADL1 (x2), BAND1, BIBE1 (x2), BOAP1 (x2), BOWA1 (x3), BYIS1, CABI1 (x4), CAVE1, CHAS1, CRMO1 (x3), DENA1, EGBE1 (x2), EVER1 (x8), FRES1 (x2), FRRE1, GAMO1, GICL1 (x2), GRSM1, GUMO1 (x4), HAVO1, HOOV1, JARB1 (x2), KAIS1 (x3), KALM1 (x4), LABE1 (x4), LAVO1 (x3), MAVI1 (x4), MEVE1, MING1, MONT1, NOGA1 (x2), OWVL1 (x2), PHOE5 (x2), PUSO1, QUCI1, REDW1 (x2), SACR1, SAGA1, SAWT1, SEQU1 (x3), SHEN1, STILL1, SYCA2, TALL1 (x2), THSI1, VOYA1, WHPA1, WHPE1, WIMO1, ZICA1 (x2)
Electronic boxes	43	OLYM1, MONT1, COHU1, SAWT1, HECA1, MONT1, COHU1, SAWT1, HECA1, SAWT1, NOCA1, CANY1, NOCA1, CANY1, SAWT1 (x3), JARB1, WHIT1, SIME1, KPBO1, CACR1, CANY1, KAIS1, MOOS1, CANY, BADL1, BRIS1, FOPE1, PHOE1, FLTO1, TRCR1, CRMO1, MEVE1, TRCR1, LOST1, TRCR1, NOAB1, TRCR1, CRMO1 (x2), WHPA1, SULA1
Module Cable	5	CANY1, CAVE1, NOAB1, LOND1, OWVL1
Relay Box	5	BRIS (x2), BYIS, SACR, SEQU
Sierra PM <sub>10</sub> Inlet	3	HAVO1 (x3)
PM2.5 Inlet Cap	1	HAVO1
Flow Check Kits	13	FCPC1, LASU1, FRRE1 (x2), MEAD1, WHPE1, BADL1 (x2), SAGU1, FLTO1, SULA1, GICL1, CACR1
Module	1	WHPE1

## 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 3 summarizes the field audits that CSU CIRA performed January 1, 2017 through December 1, 2017.

**Table 3:** CSU CIRA field audits 1/1/2017 through 12/31/2017.

Site Audits		
Apr	May	Sep
PEFO1	JOSH1	QUCI1
SIAN1	BALD1	SHEN1
SYCA2	TONT1	LASU1
GRCA1		BOND1
IKBA1		BRIG1
AGTI1		CEBL1
SAGO1		DOSO1
GRSA1		FRRE1
		GRSM1
		JARI1
		MACA1
		NEBR1
		TALL1
		VILA1

### 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. UCD has developed and is currently deploying new sampler controllers. In the latter six months of 2017 UCD installed six new controllers in the field: DENA, CAVE, GRBA, THRO, MAVI, and TRIN. Table 4 summarizes the visits that UCD performed July 1, 2017 through December 31, 2017.

**Table 4:** UC Davis field visits to IMPROVE sites, 7/1/2017 through 12/31/2017.

Site Name	Date Visited	Notable / Unusual Repair Notes	Improvements Requested
ZICA1	7/1/2017		
DENA1	7/19/2017	New controller installed	
TRCR1	7/20/2017	Manifold thread drive replaced.	
KPBO1	7/22/2017	A-Module tee plug missing.	
BIBE1	7/25/2017	Tripplite replaced.	
SIME1	7/25/2017		Walls are rotting and need patching or replacement.
GUMO1	7/27/2017	D-Module inlet guywire secured.	
CAVE1	7/28/2017	New site installed with new controller.	
SACR1	7/29/2017		
WHIT1	7/30/2017		
GICL1	7/31/2017		
BOAP1	8/1/2017		
BAND1	8/2/2017	Replaced A-Module EBox	
SAPE1	8/3/2017		

MEVE1-X	8/4/2017	Rerouted power outlets to distribute load from five pumps across two 20A breakers. Replaced D-Module Ebox	
WEMI1	8/5/2017		Stand needs replacement.
MOZI1	8/7/2017	Reconfigured pump house. B- and D-Module pumps replaced.	Plan to remove air conditioning and lower modules 1.5 feet.
MELA1	8/25/2017	Minor controller/module repairs.	
GRBA	9/7/2017	New controller installed.	
NEBR1	9/8/2017	Controller and C-Module valve replaced.	
JARB1	9/9/2017		
CRES1	9/10/2017	Site shutdown in 2015; all equipment removed.	
CRMO1	9/10/2017		
WICA1	9/11/2017		
SAWT1	9/11/2017	Investigated newly installed fall safety equipment.	
BADL1	9/12/2017	Repaired D-Module motor and replaced Ebox.	
STAR1	9/12/2017		
THBA	9/13/2017		Stand needs replacement.
HECA1	9/13/2017		
NOCH	9/14/2107	Replaced A-Module valve.	
THRO1	9/15/2017	New controller installed.	
SULA1	9/15/2017		
FOPE1	9/16/2017		
HACR1	9/16/2017		
LOST1	9/17/2017		
HAVO1	9/18/2017		Shed needs replacement.
MAVI1	10/2/2017	New controller installed.	
TRIN1	12/20/2017	New controller installed.	