HEI

APPENDIX AVAILABLE ON THE HEI WEB SITE

Research Report 178

National Particle Component Toxicity (NPACT) Initiative Report on Cardiovascular Effects

Sverre Vedal et al.

Section 1: NPACT Epidemiologic Study of Components of Fine Particulate Matter and Cardiovascular Disease in the MESA and WHI-OS Cohorts

Appendix K. NPACT Monitoring Data QA/QC

Note: Appendices that are available only on the Web have been assigned letter identifiers that differ from the lettering in the original Investigators' Report. HEI has not changed the content of these documents, only their identifiers.

Appendix K was originally Appendix J

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APPENDIX J: NPACT Monitoring Data QA/QC

Exposure Monitoring Quality Assurance/ Quality Control (QA/QC) Report for the NPACT Study

X-Ray Fluorescence and
Elemental Carbon/Organic Carbon Analysis

Table of Contents

1. Introduction

This supplement presents a summary of the exposure data that were analyzed for the MESA Air and Health Effects Institute/National Particle Components Toxicity studies (HEI/NPACT) studies by external laboratories. Cooper Environmental Services provided X-ray fluorescence (XRF) analysis of Teflon filters. These samples were deployed from the start of MESA Air

monitoring on July 12, 2005 through the conclusion of sampling on July 31, 2009[1]. XRF analysis of the Teflon filters deployed by MESA Air was funded jointly by MESA Air and by the Health Effects Institute/National Particle Components Toxicity study (HEI/NPACT). Sunset Laboratories provided elemental carbon and organic carbon (EC/OC) analysis of quartz filters, which was funded entirely by HEI/NPACT. The primary sampling campaign for these filters began on February 28, 2007 and ended on July 31, 2008. A supplemental sampling campain for these filters began on January 1, 2009 and ended on July 31, 2009.

Table 1, below, indicates the approximate number of fixed sites in each study area operating at any given time, along with the approximate number of rounds of sampling that occurred at these sites. Teflon filters that were intended for analysis by XRF were deployed at all sites and all rounds. Quartz filters were deployed at all sites during the primary exposure monitoring campaign for EC/OC. Quartz filters were deployed at a single site in each study area during the supplemental monitoring campaign. Table 2 shows the total number of residential outdoor, indoor, and personal Teflon samples deployed, by study area. Table 3 summarizes the sampling locations of quartz filters.

Table 1. Counts of fixed sites maintained in each study area, and the number of rounds of two-week samples collected at these fixed sites.

Study Area	Fixed sites	Rounds of Sampling[c]
Baltimore [a,b]	4	103
Chicago [b]	5	105
LA	2	92
Coastal	3	91
Riverside	2	92
NYC	2	104
Rockland [a]	1	76
St. Paul	3	103
Winston-Salem	4	104
Total	27	100[d]

[a]Sampling at 2 sites (1 in Baltimore and 1 in Rockland County) ended early due to logistical issues.
[b]One site in Baltimore and two in Chicago were relocated early in the study due to logistical issues.
[c]Maximum number of rounds of sampling at any site in the study area. Rounds of sampling were occasionally skipped at a site during holiday weeks if there was no access to the building.
[d]Average number of rounds of sampling across sites.

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1 Two additional rounds of sampling piggy-backed on the Coarse PM Study in Chicago during August, 2009.

Table 2. Counts of residential outdoor, indoor and personal two-week sampling deployments that included Teflon filters, by study area.

Study Area	Outdoor			Indoor		Personal	
	Round 1	Round 2*	Round 3*	Round 1	Round 2*	Round 1	Round 2*
Baltimore	88	64	23	60	53	14	12
Chicago	118	96	48	58	53	13	12
LA	66	57	0	61	57	10	10
Coastal	18	16	0	18	16	2	2
Riverside	36	27	0	34	28	4	4
NYC	96	63	29	65	54	16	15
Rockland	25	25	21	25	25	5	5
St. Paul	132	93	38	57	51	13	11
Winston- Salem	118	92	53	67	59	13	11
Total	697	533	212	445	396	90	82

*The "Round 2" through "Round 3" locations are a subset of "Round 1" locations.

Table 3. Counts of residential and fixed two-week sampling deployments that included quartz filters

Study Area	Residential Outdoor		Primary Fixed Site Sampling[a]	Supplemental Fixed Site Sampling
	Round 1	Round 2	Number of Rounds	Number of Rounds
Baltimore	62	54	37	13
Chicago	52	49	35	14
LA	32	12	34	12
Coastal	16	3	35	--
Riverside	33	9	33	12
NYC	34	29	37	12
Rockland	22	21	33	--
St. Paul	54	46	37	12
Winston- Salem	49	48	32	13
Total	354	271	35 [b]	88

[a]Maximum number of rounds of sampling at any site in the study area. Rounds of sampling were occasionally skipped at a site during holiday weeks if there was no access to the building.
[b]Average number of rounds of sampling across sites.

2. Sample Validity

Three types of samples were deployed in the MESA Air monitoring campaigns: primary samples, duplicate samples ("field" duplicates), and field blanks. Primary samples are the measurements used in the exposure modeling efforts to estimate air pollution. Duplicates were additional samples deployed concurrently with primary samples and were identical in all ways to the primary sample with which they were paired. However, instead of including resulting concentrations in sample datasets, duplicates were used exclusively to evaluate sample precision. "Field blanks" were shipped and handled with exactly the same protocols as the primary and duplicate samples, but were not deployed. Blanks are used to assess contamination attributable to handling. A second category of field blanks, called "dynamic blanks", were deployed with quartz filters. These filters were loaded into sampling units behind sample filters. Air passed through these filters, but particles were not deposited on them. These filters are used to assess the proportion of organic carbon on quartz filters that is attributable to volitale organic compounds.

The total numbers of Teflon and quartz filters deployed are summarized in this section. Teflon filters were deployed at all fixed sites (with one exception in St. Paul), indoors and outdoors at participant homes, and as part of personal monitoring. During personal monitoring events, Teflon filters were replaced approximately every 48 hours, when the technicians visited the participant's home to replace the personal pump batteries. Therefore, each personal monitoring sample includes between 4 and 7 individual Teflon filters. Quartz filters were deployed at fixed sites and outside participants' homes.

Tables 5 and 7 summarize the reasons for which some filters do not have XRF or EC/OC results.

Table 4. Counts of valid Teflon filters from primary sampling campaigns analyzed with XRF.

Study Area	Samples		Duplicates		Blanks		Total	
	Deployed	Valid	Deployed	Valid	Deployed	Valid	Deployed	Valid
Baltimore	834	725 (87%)	101	85 (84%)	91	90 (99%)	1026	900 (88%)
Chicago	968	696 (72%)	86	41 (48%)	90	81 (90%)	1144	818 (72%)
LA	543	383 (71%)	53	31 (58%)	48	44 (92%)	644	458 (71%)
Coastal	357	309 (87%)	46	39 (85%)	36	30 (83%)	439	378 (86%)
Riverside	355	275 (77%)	42	30 (71%)	34	29 (85%)	431	334 (77%)
NYC	570	403 (71%)	58	23 (40%)	61	60 (98%)	689	486 (71%)
Rockland	250	176 (70%)	26	12 (46%)	21	19 (90%)	297	207 (70%)
St. Paul	744	641 (86%)	65	41 (63%)	83	83 (100%)	892	765 (86%)
Winston-Salem	830	733 (88%)	90	72 (80%)	88	87 (99%)	1008	892 (88%)
Across all sites	**5451**	**4341 (80%)**	**567**	**374 (66%)**	**552**	**523 (95%)**	**6570**	**5238 (80%)**

Table 5. Counts of Teflon filters invalidated for XRF, by reason and study area.

Study Area	Duration issues	Flow issues	Not Selected	Other*	Total Number Fatal
Baltimore	75	18	15	18	126
Chicago	125	54	107	40	326
LA	77	54	33	22	186
Coastal	31	12	13	5	61
Riverside	27	25	38	7	97
NYC	62	95	29	17	203
Rockland	35	21	17	17	90
St. Paul	59	44	8	16	127
Winston-Salem	49	5	27	35	116
Across all sites	**540**	**328**	**287**	**177**	**1332**

*Other issues include torn filters, other sampler damage in the field or lab, or missing field or analysis records.

Table 6. Counts of valid quartz filters from primary sampling campaigns analyzed for EC/OC.

Study Area	Samples		Duplicates		Blanks		Dynamic Blanks		Total	
	Deployed	Valid	Deployed	Valid	Deployed	Valid	Deployed	Valid	Deployed	Valid
Baltimore	276	244 (88%)	28	19 (68%)	35	34 (97%)	57	50 (88%)	396	347 (88%)
Chicago	288	233 (81%)	18	8 (44%)	15	14 (93%)	48	39 (81%)	369	294 (80%)
LA	124	104 (84%)	11	7 (64%)	8	8 (100%)	21	17 (81%)	164	136 (83%)
Coastal	121	111 (92%)	12	12 (100%)	10	10 (100%)	23	20 (87%)	166	153 (92%)
Riverside	120	96 (80%)	10	7 (70%)	14	14 (100%)	19	16 (84%)	163	133 (82%)
NYC	149	119 (80%)	17	8 (47%)	13	12 (92%)	29	18 (62%)	208	157 (75%)
Rockland	76	56 (74%)	8	2 (25%)	5	5 (100%)	13	9 (69%)	102	72 (71%)
St. Paul	221	196 (89%)	20	10 (50%)	27	25 (93%)	46	43 (93%)	314	274 (87%)
Winston-Salem	225	198 (88%)	22	12 (55%)	25	23 (92%)	34	28 (82%)	306	261 (85%)
Across all sites	**1600**	**1357 (85%)**	**146**	**85 (58%)**	**152**	**145 (95%)**	**290**	**240 (83%)**	**2188**	**1827 (84%)**

Table 7. Counts of quartz filters invalidated for EC/OC analysis, by reason and study area.

Study Area	Duration issues	Flow issues	Not Selected	Other*	Total Number Fatal
Baltimore	11	6	12	20	49
Chicago	30	8	28	9	75
LA	7	11	10	0	28
Coastal	3	4	6	0	13
Riverside	10	11	7	2	30
NYC	24	15	10	2	51
Rockland	15	7	4	4	30
St. Paul	11	7	14	8	40
Winston-Salem	13	1	19	12	45
Across all sites	**124**	**70**	**110**	**57**	**361**

*Other issues include torn filters, other sampler damage in the field or lab, or missing field or analysis records.

Table 8. Counts of valid quartz filters from the supplemental sampling campaign analyzed for EC/OC.

Study Area	Samples		Duplicates		Dynamic Blanks		Total	
	Deployed	Valid	Deployed	Valid	Deployed	Valid	Deployed	Valid
Baltimore	13	9 (69%)	3	3 (100%)	16	12 (75%)	32	24 (75%)
Chicago	14	13 (93%)	4	4 (100%)	16	14 (88%)	34	31 (91%)
LA	12	11 (92%)	3	3 (100%)	15	14 (93%)	30	28 (93%)
Riverside	12	10 (83%)	3	3 (100%)	15	12 (80%)	30	25 (83%)
NYC	12	10 (83%)	3	0 (0%)	9	8 (89%)	24	18 (75%)
St. Paul	12	11 (92%)	5	3 (60%)	16	14 (88%)	33	28 (85%)
Winston-Salem	13	3 (23%)	2	0 (0%)	8	2 (25%)	23	5 (22%)
Across all sites	**88**	**67 (76%)**	**23**	**16 (70%)**	**95**	**76 (80%)**	**206**	**159 (77%)**

Table 9. Counts of quartz filters invalidated for EC/OC, by reason and study area.

Study Area	Duration issues	Flow issues	Not Selected	Other*	Total Number Fatal
Baltimore	2	0	4	2	8
Chicago	0	0	3	0	3
LA	0	0	1	1	2
Riverside	0	0	0	5	5
NYC	0	0	0	6	6
St. Paul	0	5	0	0	5
Winston-Salem	13	0	2	3	18
Across all sites	15	5	10	17	47

*Other issues include torn filters, other sampler damage in the field or lab, or missing field or analysis records.

In total, 84% of the quartz filters and 80% of the Teflon filters deployed for primary sampling provided valid results. Where duplicate pairs were deployed and one filter was invalidated, the valid filter was considered the "sample" and the invalid filter was considered the "duplicate". Therefore, the percentage of valid duplicates is lower than the overall percentage of valid samples. Filters deployed at fixed sites and homes were considered invalid (fatal) if the duration of sampling was less than 9 days' time or more than 16 days' time for the primary sampling campaign. For samples collected during the supplemental fixed site sampling campaign, the duration was required to be between 3 and 6 days.

The duration rules for personal filters were different, as filters deployed for personal sampling were changed out every 2-4 days. Individual filters within a given two-week personal sampling deployment were determined to be invalid if the sampling duration for that filter was less than one day. For a personal sampling event to be valid overall, the sum of the durations of the valid filters had to be at least 50% of the duration of the concurrent indoor Teflon filter sample.[2] Out of 804 personal filters, 130 were invalidated due to duration criteria, 75 of which failed to meet the 1-day sampling criterion and 55 because the total sampling deployment duration was less than 7 days. This translated to 128 of 172 personal sampling events of valid durations. These counts exclude duplicates (no personal duplicates were deployed) and blanks.

Overall, 8% of all Teflon filters were fatal for speciated elements based on duration issues due to incorrect field scheduling, pump failure, or failure to meet the personal sampling criteria. Duration issues were responsible for 41% of all Teflon filters fatal for speciated elements (see Tables 5 and 6).

Pump flow was measured for samples and duplicates at both deployment ("on-flow") and retrieval ("off-flow) with a rotameter (blanks were never attached to pumps). Rotameters were calibrated annually to a primary standard (bubble meter). Each of these measurements was temperature and pressure adjusted using the ideal gas law to convert from field conditions to flow volumes at standard temperature and pressure (STP). Converted on- and off-flow volumes were averaged to yield an average flow volume at STP. Finally, this average volume was converted back to an average flow at average field conditions, and divided by time to yield an average flow rate over the sampling period. Flow rates less than 1620 mL/min or greater than 1980 mL/min were deemed fatal. The TSI SP530 pumps also logged flow values each minute, but as the pumps were not calibrated to a primary standard, these values were used only to verify flow stability over the sampling period. If the standard deviation of the minute-by-minute flow was greater than 10% of the average flow, the sample was considered fatal. Overall, 5% of all Teflon filters were fatal for speciated elements due to unacceptably high, low, or unstable flow rates (25% of all fatal filters). The remaining filters fatal for speciated elements were due to "other issues", such as a torn filter, other sampler damage in the field or lab, or missing field or analysis records.

2If the concurrent indoor Teflon filter was invalid, the sum of the valid individual personal filter durations had to be seven days for the sampling deployment to be considered valid.

3. Data Flags and Unusual Circumstances

In any data collection effort, unusual circumstances and human error affect a small percentage of samples. A number of steps were taken to minimize the impact of these instances on the quality of the final dataset. MESA Air quality assurance efforts included comprehensive standard operating procedures (SOPs) for field activities and lab analyses, calibration and maintenance of equipment, and specific siting criteria for samplers (i.e. away from walls and firepits or other source points). Quality control checks included a thorough review of all hardcopies of all logs and notes. Field technicians were instructed to note any unusual observations during sample handling at the field center and in the field. Teflon filters were loaded into single-stage inertial impactors (Harvard Personal Environmental Monitors, HPEMs) before sampling at the field center, and unloaded after sampling. A log for this process included a space for unusual observations as to the color of the filter or contents of the HPEM (which occasionally return with insects in them). Other logs that accompanied samples into the field included spaces for dates of deployment and retrieval, spaces for flow measurements for samples that required a pump, and a space for notes of unusual observations, deviations from protocol, or other problems the technician might encounter.

All notes were reviewed as samples were received at the University of Washington. Teflon filters with weight changes that were negative or represented a concentration greater than 40 $\mu g/m^3$, field blanks with an estimated concentration above the tenth percentile of samples, and duplicate pairs with RPD/$\sqrt{2}$ > 10% were investigated[3]. The concentrations of elemental and organic carbon on the quartz filter were compared to the concentrations of PM on the Teflon filters; if the sum of EC and OC was higher than the total PM concentration, that pair of filters was scrutinized. These investigations included a review of all relevant paper logs from the field center and all relevant records from laboratory analysis. While analysts may choose exclude these measurements at their own discretion, these samples could not be identified as contaminated or damaged based on the documented MESA Air quality assurance and control procedures.

In addition to the samples that had notes that clearly invalidated them and those that lacked any such notes, a number of samples had notes whose meaning was inconclusive. As discussed in Section 1, samples were invalidated if there was strong evidence that the sample did not represent a two-week ambient concentration. Samples must meet duration criteria, flow criteria, must return to the University of Washington in a dry, undamaged condition, and must not have any invalidating notes (such as "sampler found in puddle", "HPEM contained spider", "Tubing was disconnected", etc.). Samples that met these criteria, but which were exposed to unusual environmental conditions or that were not handled according to the standard protocol may or may not accurately represent a typical concentration for the two-week period at that location. These samples were given various nonfatal flags so that they could be used at an analysts' discretion. The full description of the flagging system is provided in the final QA/QC report for MESA Air and in the QAPP.

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3 Relative percent difference (RPD) = {abs([sample]-[duplicate]) / average(sample, duplicate) }*100

Table 10. Counts of samples with non-fatal flags, which may indicate the flagged sample is not representative of the ambient concentration, and can be used at data analysts' discretion.

Flag	Type of Sample	
	Teflon Filter	Quartz Filter
Source Pollution	50	11
Location	2	0
Concentration	131	24
Duration/No Pumpfile	138	98
Total	321	133

An additional flag was created to distinguish those individual 2-4 day personal Teflon filters that were part of a two-week personal sampling deployment with short, but not fatally short, duration. Personal sampling filters were given this nonfatal flag if the sum of valid durations was less than 90% of the concurrent indoor sample[4]. Of the 600 valid filters deployed for personal sampling, 334 received this additional non-fatal flag.

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[4] If the concurrent indoor Teflon filter was invalid, this flag was applied if the total personal sampling deployment duration was less than 90% of a nominal 14-day period.

4. Co-located Monitoring Results

At least one fixed site near each field center was co-located with an Air Quality Systems (AQS) monitor. This section shows the relationships between MESA Air results and those recorded by the local air monitoring agencies.[5] In the QA/QC report for the primary pollutants, we noted that averages based on few AQS measurements compared poorly with our two-week integrated samples. This appears to be less of an issue for elemental species. Plots are provided for the elements that were selected for the primary exposure models.
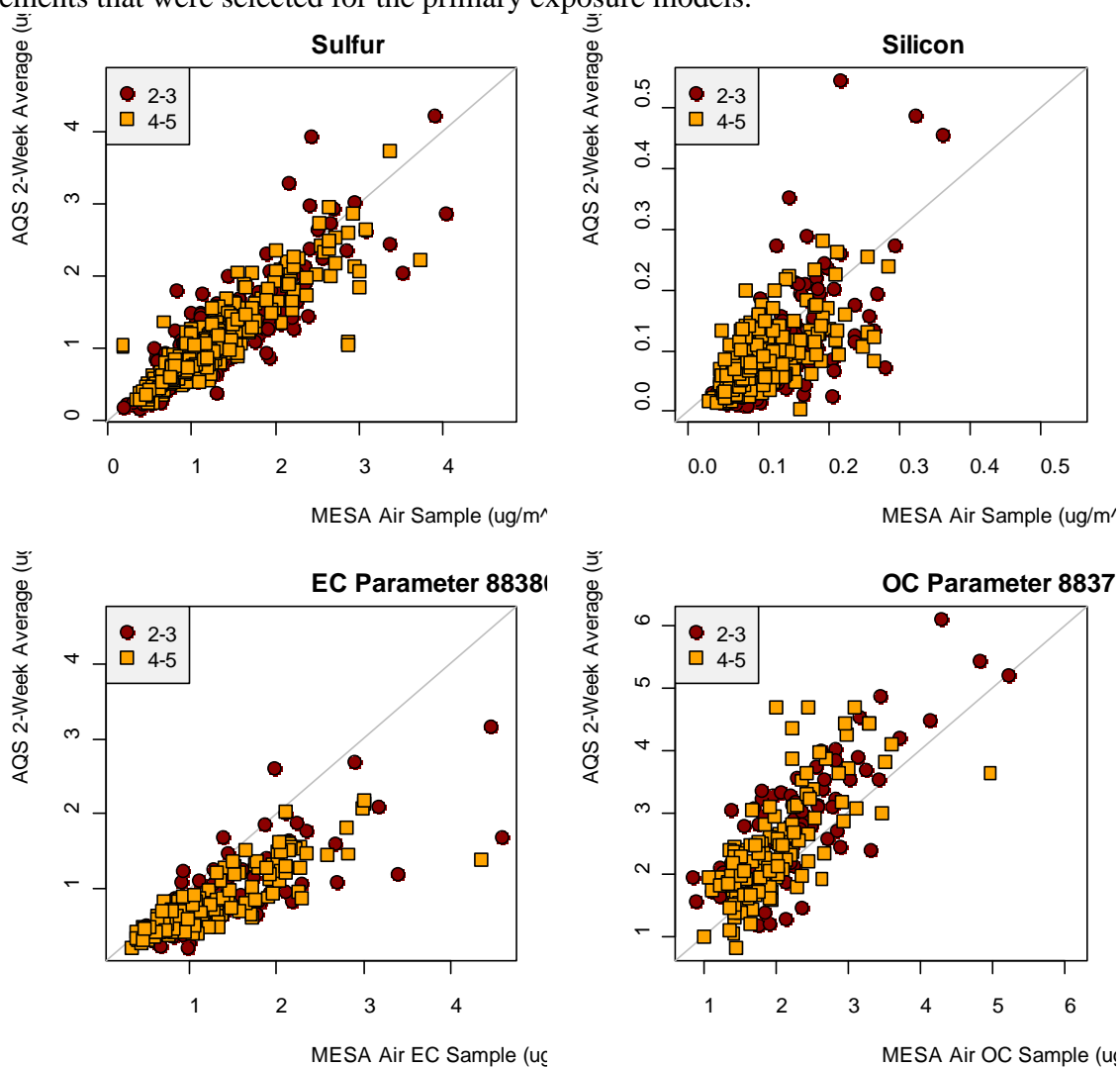
Figure 1. Scatterplot showing the relationship between MESA Air elemental species in $PM_{2.5}$ two-week measurements and AQS two-week averages during the same time period. The red circles represent MESA Air comparisons to two-week averages based on 2-3 AQS

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5 US Environmental Protection Agency. Air Quality System Data Mart [internet database] available at http://www.epa.gov/ttn/airs/aqsdatamart. Accessed March 25, 2010.

measurements. The orange squares represent MESA Air comparisons to two-week averages based on 4-5 AQS measurements.

4.1   Sulfur Co-Located Results

Six of the fixed sites were co-located with AQS sites that analyze $PM_{2.5}$ filters for elemental species. These sites were located in Baltimore, Chicago, LA, New York, St. Paul and Winston-Salem. MESA Air fixed sites collected two-week integrated $PM_{2.5}$ samples; the AQS sites collect 24-hour integrated samples every third or sixth day. For the comparisons shown below, AQS samples collected within a given two-week MESA Air sampling period were averaged to yield one AQS value. While this analysis results in an interesting and important comparison, it is not the same as comparing 1:1 co-located data, and a perfect correlation cannot be expected.

Figure 2. Scatterplot for sulfur showing the relationship between MESA Air two-week measurements and AQS two-week averages during the same time period ($R^2 = 0.77$).
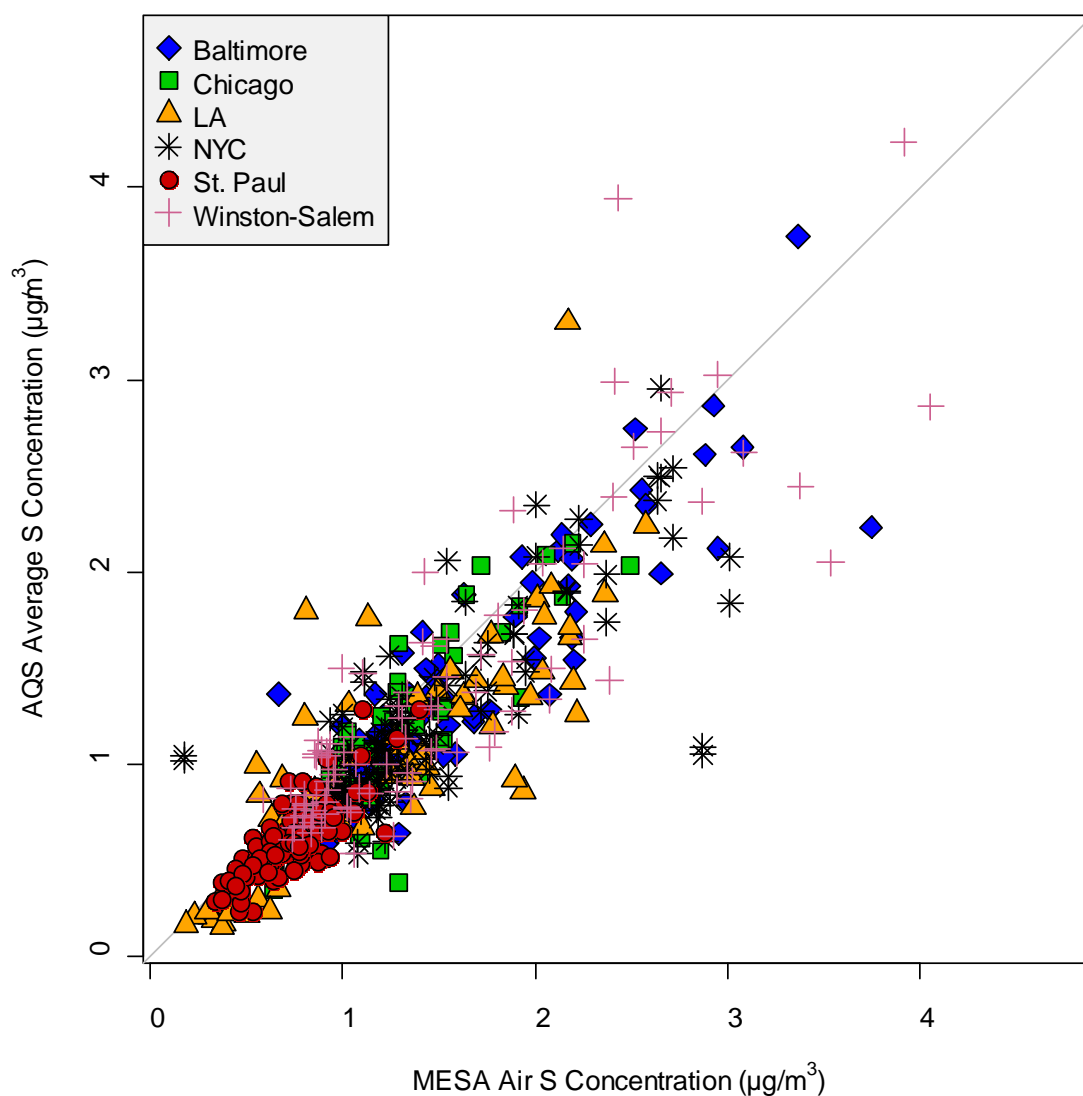
4.2   Silicon Co-Located Results
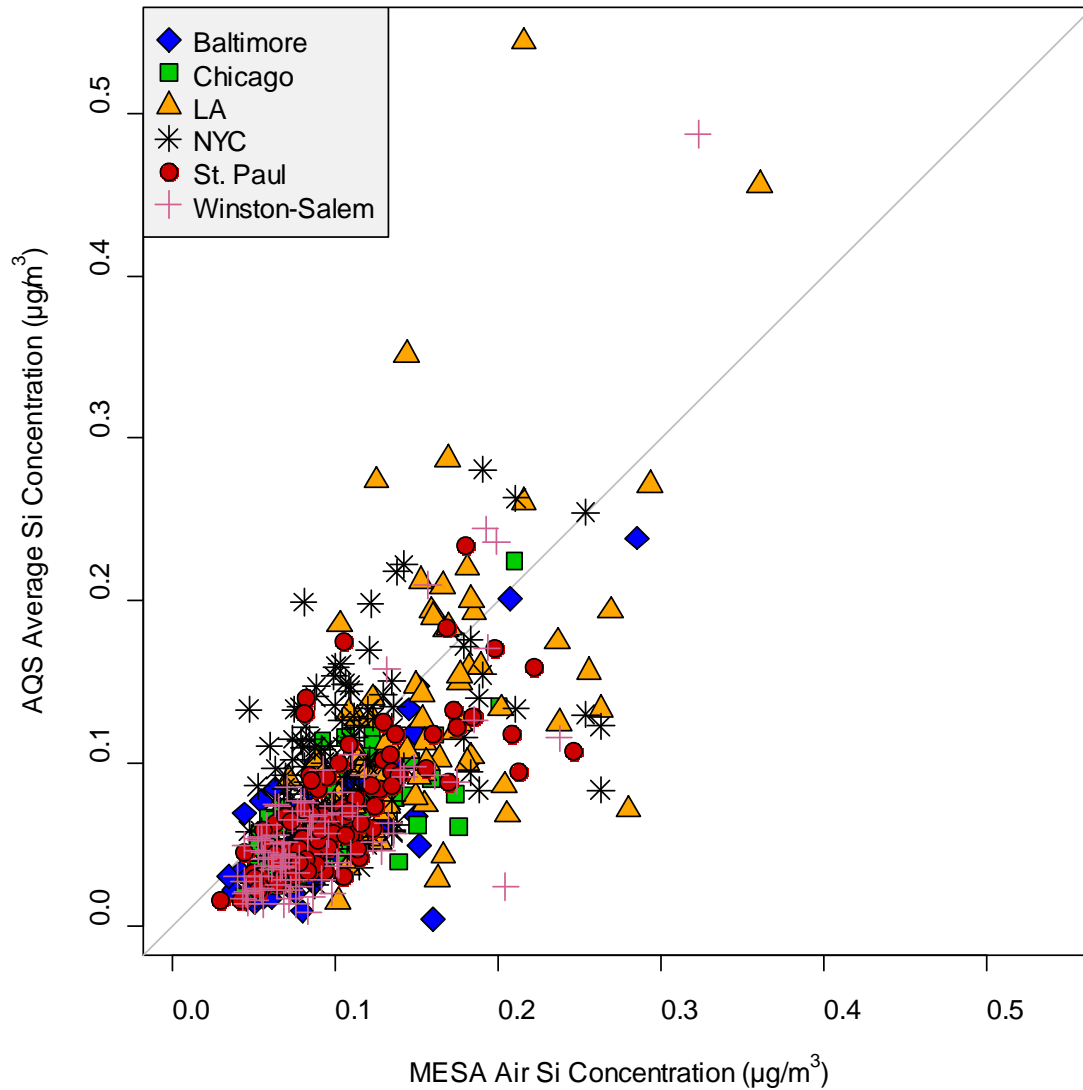
Figure 3. Scatterplot showing the relationship for silicon between MESA Air two-week measurements and AQS two-week averages during the same time period ($R^2 = 0.47$).

4.3   Nickel Co-Located Results
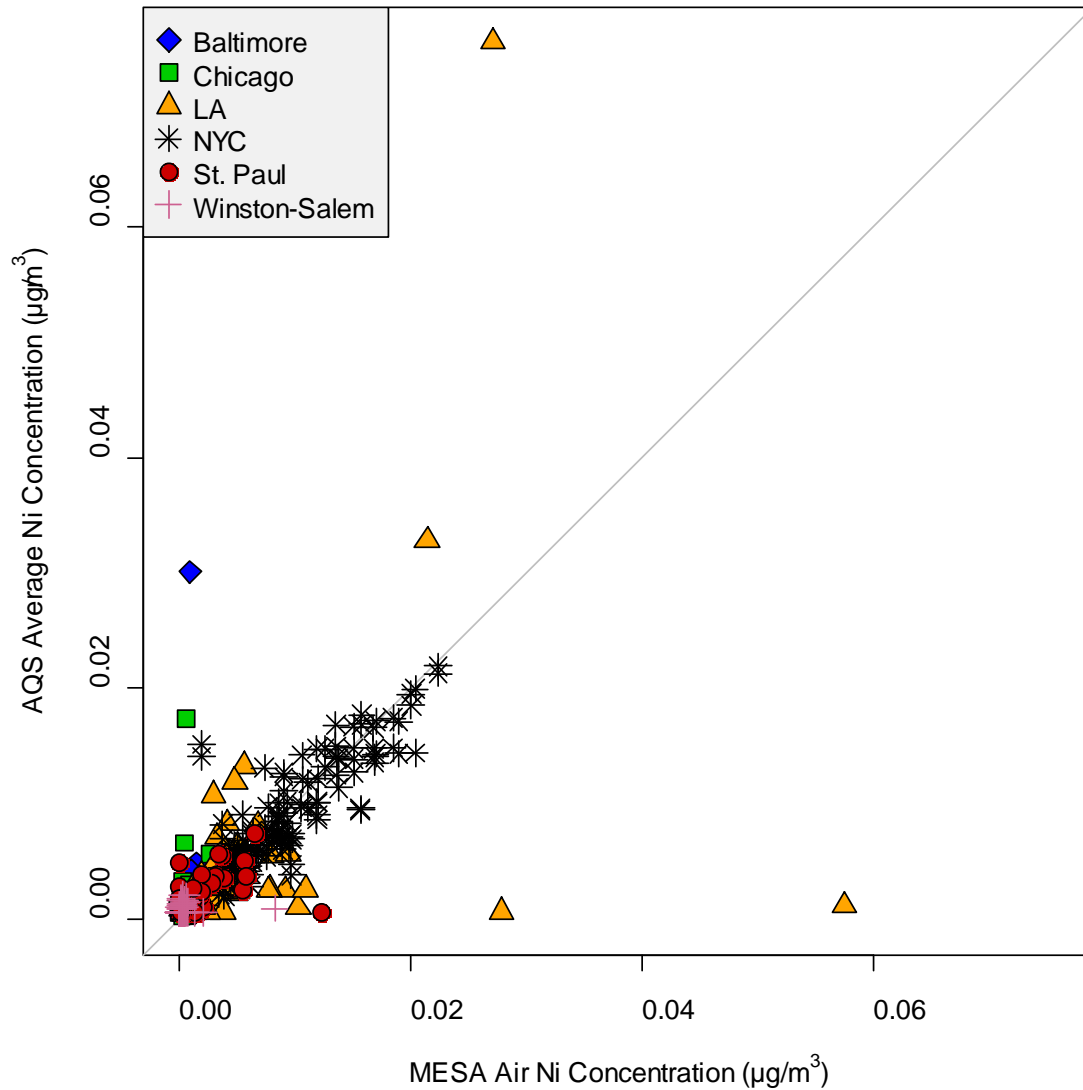
Figure 4. Scatterplot showing the relationship for nickel between MESA Air two-week measurements and AQS two-week averages during the same time period ($R^2 = 0.49$).

4.4 Vanadium Co-Located Results
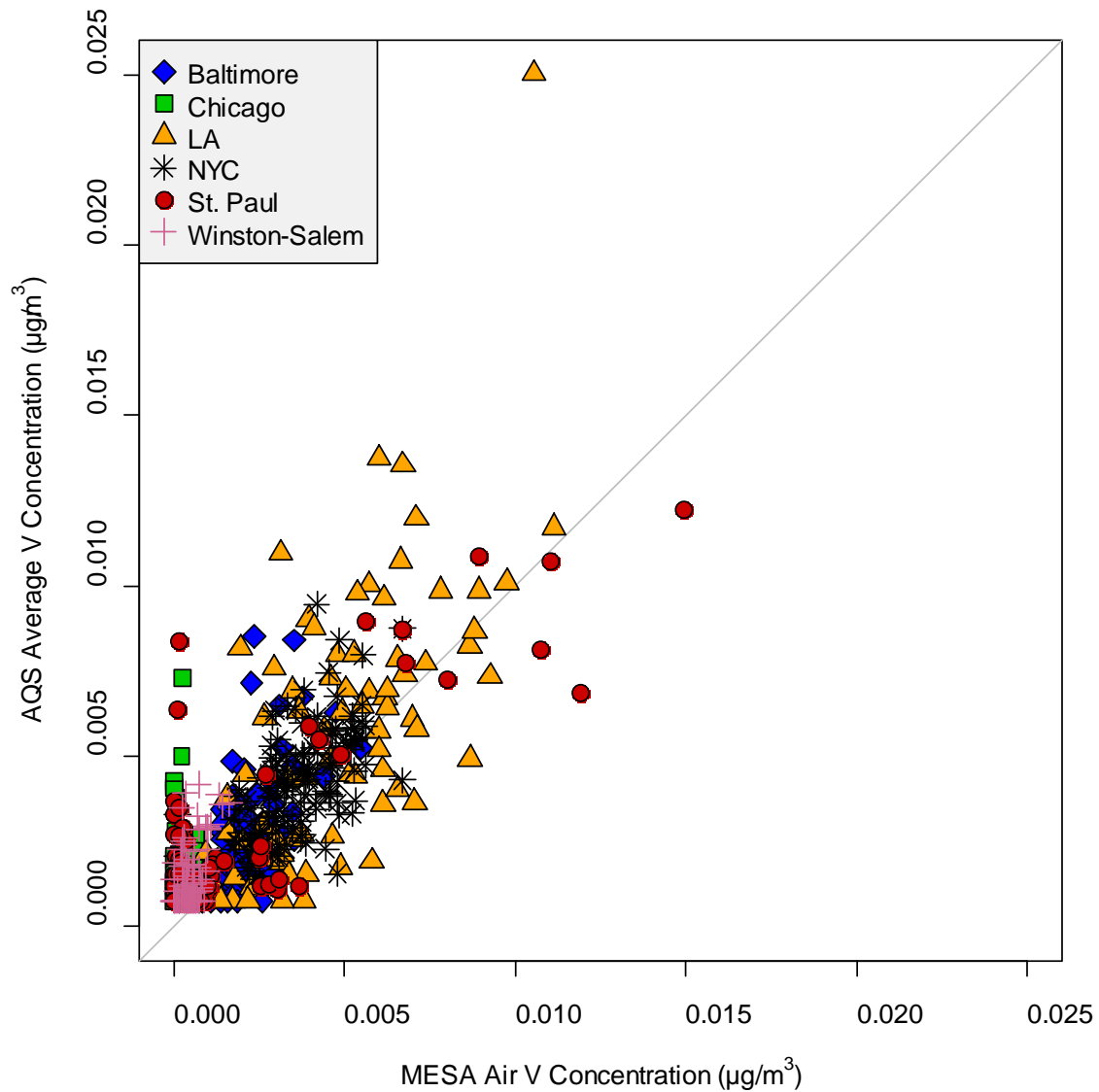
Figure 5. Scatterplot showing the relationship for vanadium between MESA Air two-week measurements and AQS two-week averages during the same time period ($R^2 = 0.60$).

4.5 Zinc Co-Located Results
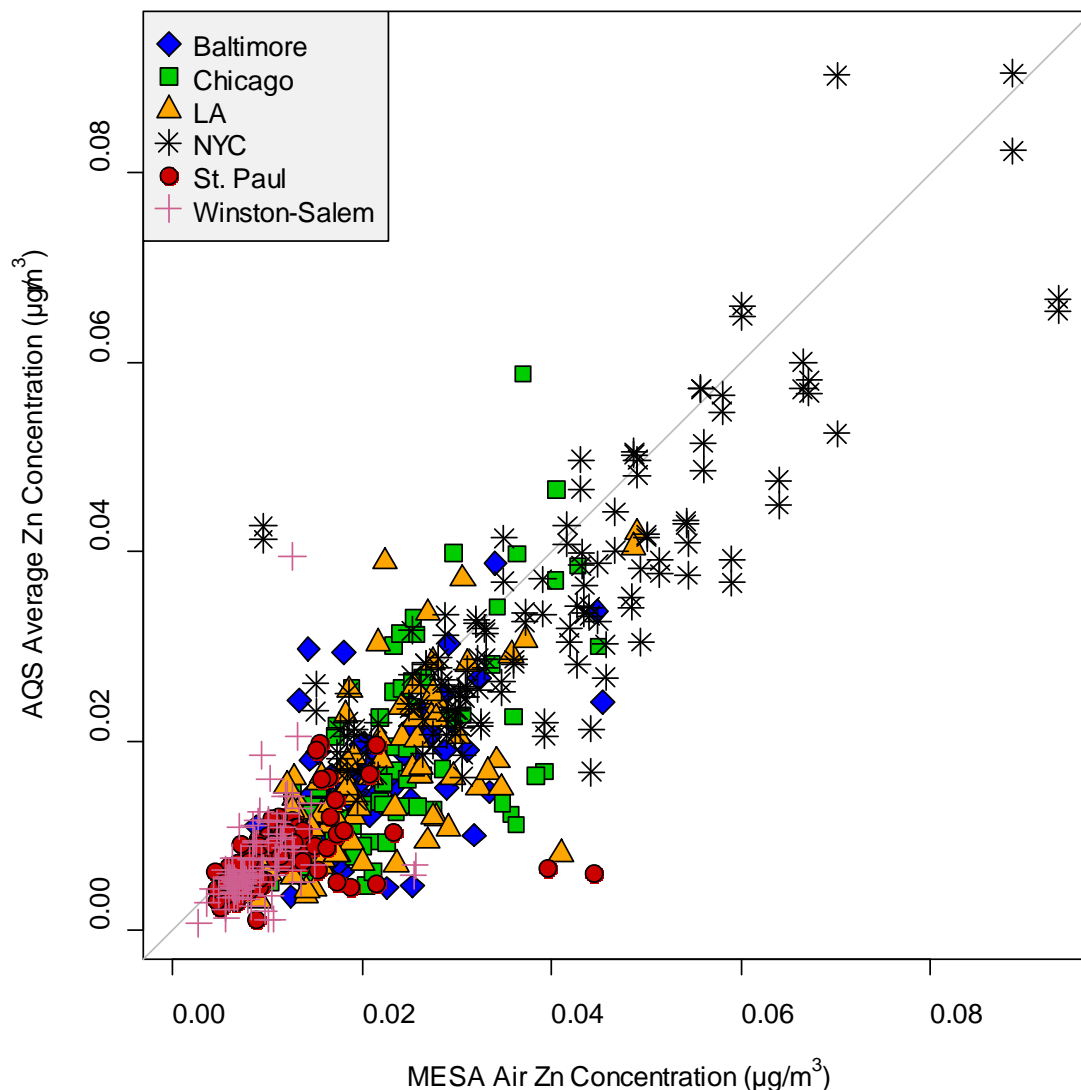
Figure 6. Scatterplot showing the relationship for zinc between MESA Air two-week measurements and AQS two-week averages during the same time period ($R^2 = 0.76$).

4.6 Organic Carbon Co-Located Results

Six MESA Air fixed sites were co-located with AQS monitoring sites that collect elemental carbon and organic carbon data. These sites were located in Baltimore, Chicago, LA, New York, St. Paul, and Winston-Salem. As with the elemental species data, MESA Air collected two-week averages, while the AQS sites collect 24-hour integrated every third-day or every sixth-day samples. Again, for the comparisons shown below, AQS samples collected within a given two-week sampling period were averaged to yield one AQS value. Associations are shown separately for each of the parameters that may be considered organic carbon, as these may have different operational definitions.
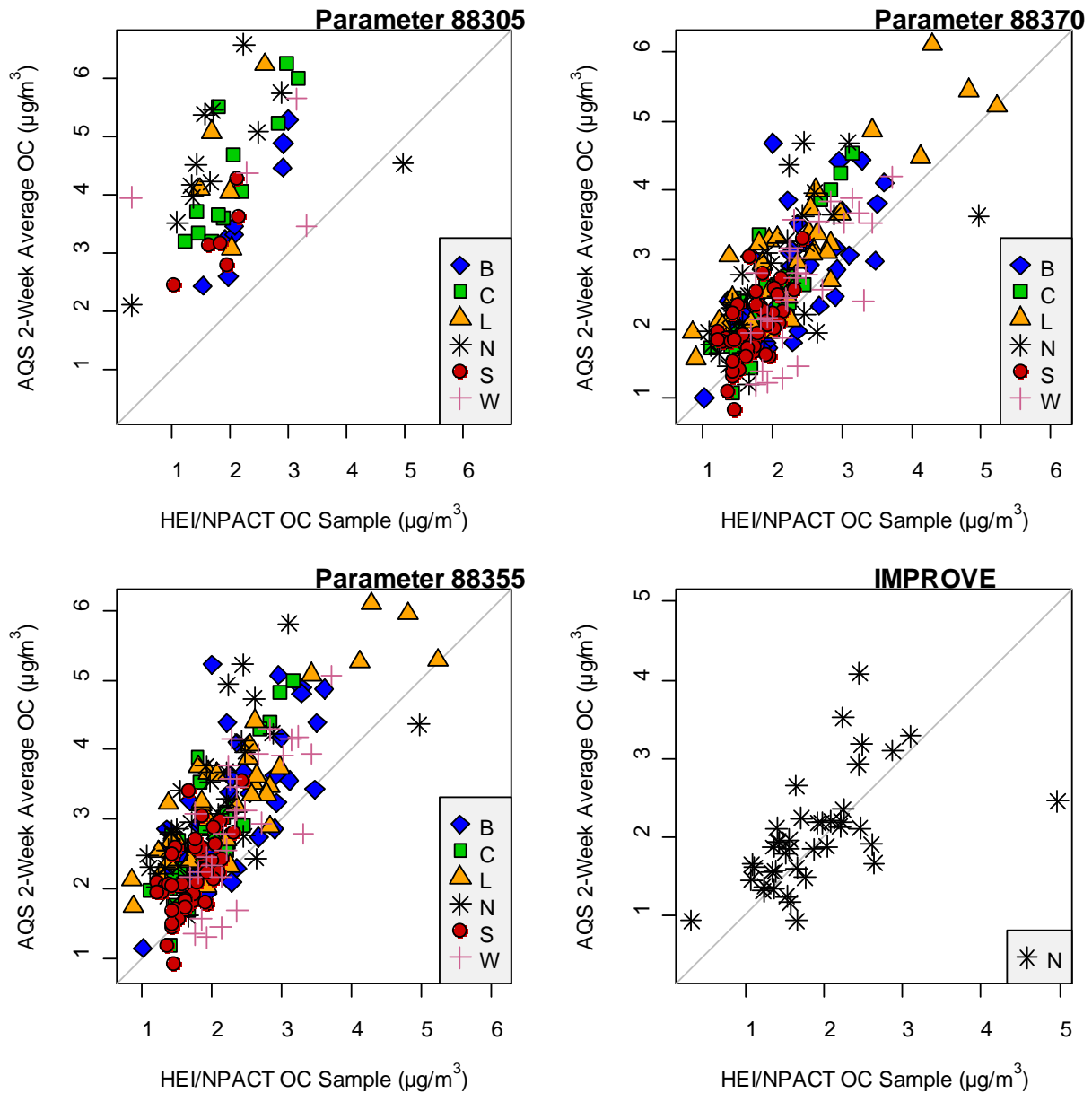
Figure 7. Scatterplot showing the relationship for organic carbon (OC) between HEI/NPACT two-week measurements and concurrent AQS two-week averages of organic carbon ($R^2 = 0.24$, 0.58, 0.57, and 0.35 for parameters 88305, 88370, 88355, and the IMPROVE method).

4.7   Elemental Carbon Co-Located Results

Elemental carbon results are available for all samples, locations, and time periods for which there are also organic carbon results.
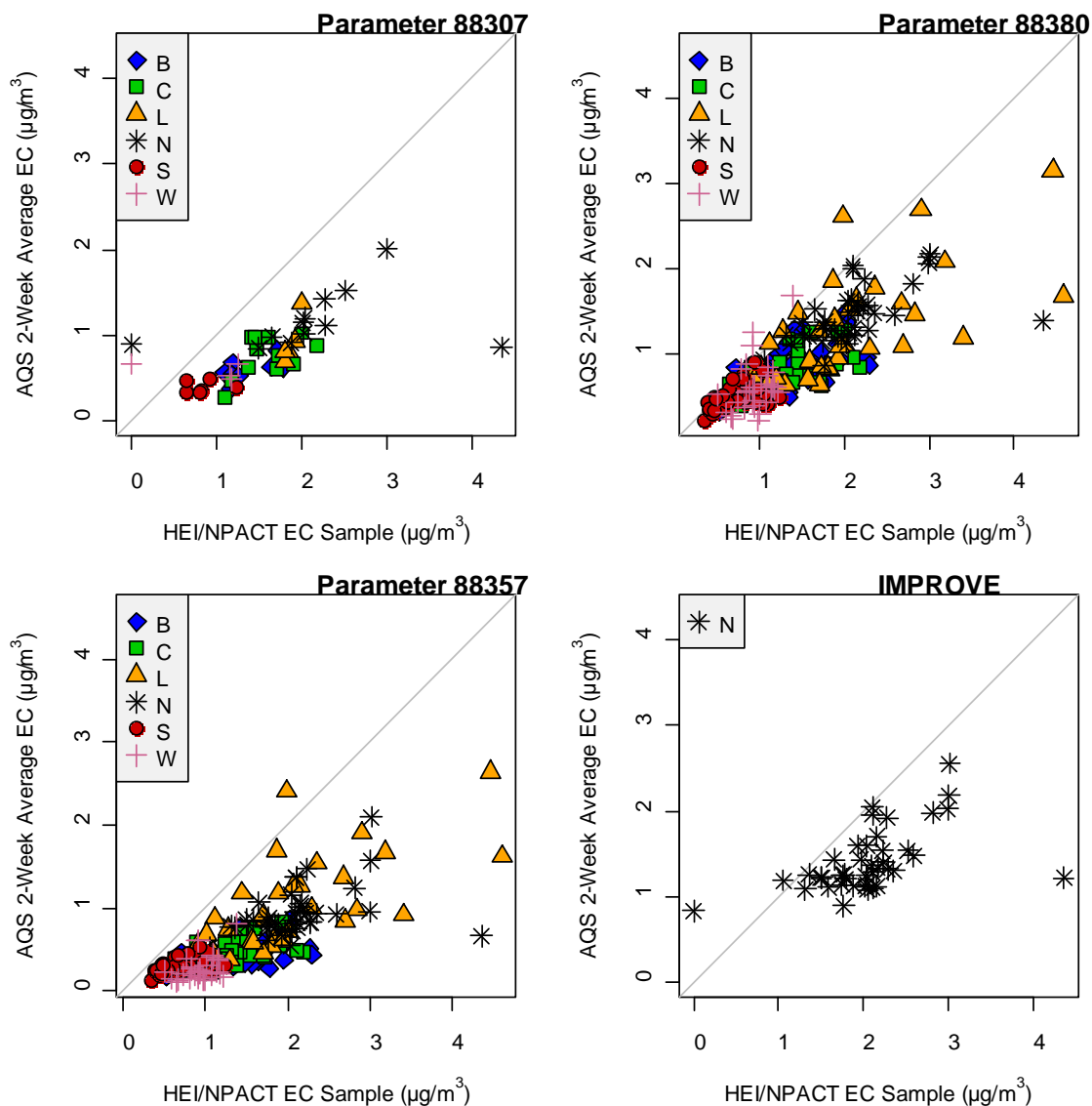
Figure 8. Scatterplot showing the relationship between HEI/NPACT two-week elemental carbon measurements and concurrent AQS two-week averages of elemental carbon (R^2 = 0.38, 0.64, 0.58, and 0.27 for parameters 88307, 88380, 88357 and the IMPROVE method).

5. Data Quality Objectives

Although data quality objectives (DQOs) were not established for the analysis methods at external laboratories, a small number of data quality objectives were established to ensure adequate numbers of quality assessment filters.

Basic Measurement	Data Quality Objective	Method of Determination	Result	DQO Met?
QC sample collection – Teflon filters	Number of field blanks collected ≥ 10% number of samples collected	Count	10%	Yes
	Number of field duplicates collected ≥ 10% number of samples collected	Count	10%	Yes
QC sample collection – quartz filters	Number of field blanks collected ≥ 10% number of samples collected	Count	9%	No
	Number of dynamic blanks collected ≥ 20% number of samples collected	Count	23%	Yes
	Number of field duplicates collected ≥ 10% number of samples collected	Count	9%	Yes

These goals were established to provide a ballpark for the sufficient number of QC samples. Although the number of field blanks and duplicates for quartz filters fell slightly short of the target, the number of QC samples collected has been adequate to assess data quality.

6. External Laboratory Data Quality Reporting

The QA/QC Committee established a number of data quality objectives in order to evaluate the performance of MESA Air's data analysis methods, but did not set similar metrics for analyses performed by the external laboratories. The contractors were expected to manage quality control internally. This section summarizes the data quality metrics as reported by the external laboratories.

6.1   XRF Replicate Analysis

Since X-ray fluorescence is a non-destructive process, Teflon filters may be analyzed repeatedly. Approximately 10% of filters (N = 435) were analyzed twice as a QC check.
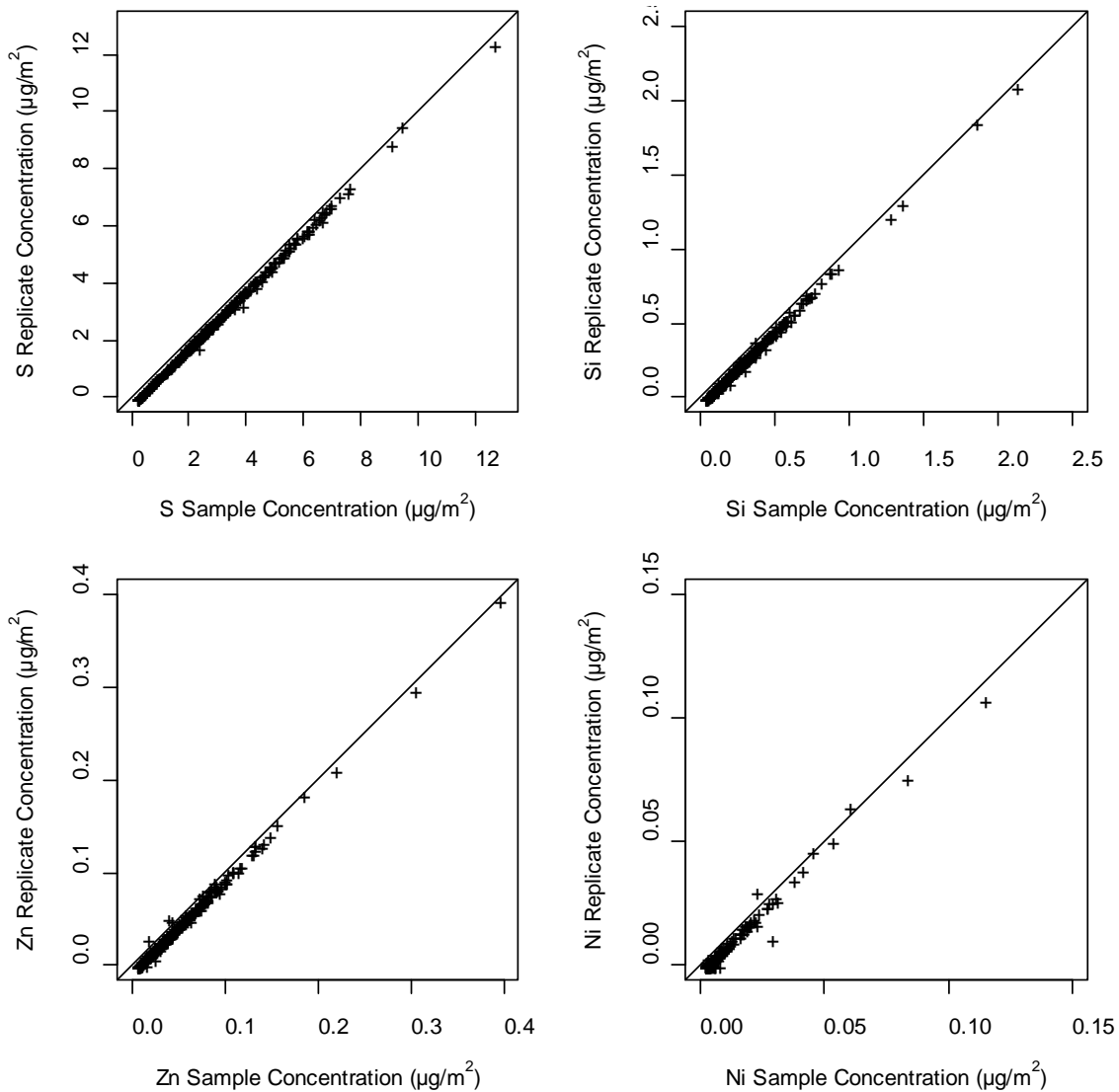
Figure 9. Scatterplot showing correlation between replicate analyses of the same sample, (for sulfur, silicon, zinc, and nickel, R^2 = 1.0, 1.0, 1.0, 0.98, RMSE = 0.049, 0.011, 0.0024, 0.0012 $\mu g/m^2$). Vanadium, not shown: R^2 = 0.98, RMSE = 0.0024 $\mu g/m^2$.

6.2   XRF Uncertainty

Multiple measurements are conducted on each filter at different excitation or energy levels of the incident X-ray beam. The analysis conditions are different combinations of tube voltage, current, and X-ray filter which are optimized to produce a detectable signal emitted from the particular elemental species of interest. Cooper Environmental uses six different analysis conditions to cover the set of elements reported in data output files.

The uncertainty in the analyte concentration is defined as:

Uncertainty = Analyte Concentration * $\sqrt{\{ (\text{stdev } C / C)^2 + (\text{stdev } I / I)^2 \}}$

where C = calibration factor, determined from thin film standards at each of the analysis conditions (different X-ray energies, etc.)
I = analyte peak intensity

The thin film standards are filters with known quantities of various metals uniformly distributed across the surface which are used to gauge the response signal to each metal under the various analytical conditions. The relative uncertainty of the mass density (mass/area) on these standards is 2% or less.

Uncertainty is proportional to the mass per area density measured for the same element, so it depends on the PM mass of the filter but more specifically to the total quantity of each individual element, so PM composition matters too. The analyte peak intensity depends on the quantity of element present and particular excitation condition that best detects that certain element given the energy of the emitted X-rays (function of atomic number). A few elements are identified by more than one analysis condition but the spectral deconvolution program accounts for the peak overlap and any interferences.

Calibration factors determined from the standards are referenced to each set of analysis conditions and used accordingly for the unknown samples under the same analysis conditions.

Analyte concentrations (as a two-dimensional deposition on the surface of the filter) are lower on personal monitoring filters than on integrated two-week filters. For the short duration filters, a more sensitive protocol was used (protocol B, rather than protocol A).

Table 11. Summaries of uncertainty values in samples for selected elements, converted to volume concentrations based on real air flow.

Protocol	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Sulfur Uncertainty ($10^{-2}\mu g/m^3$)							
A	3738	4.2	1.7	2.6	3.7	5.3	7.4
B	603	2.8	0.7	1.2	2.1	3.6	5.7
Total	4341	4.0	1.4	2.3	3.5	5.1	7.3
Silicon Uncertainty ($10^{-3}\mu g/m^3$)							
A	3738	4.3	2.1	2.7	3.7	5.1	7.0
B	603	8.5	4.0	5.0	6.7	9.5	13.5
Total	4341	4.9	2.2	2.8	4.0	5.7	8.0
Nickel Uncertainty ($10^{-4}\mu g/m^3$)							
A	3738	2.5	1.0	1.4	1.8	2.4	3.4
B	603	10.4	4.3	6.0	8.4	12.5	14.9
Total	4341	3.6	1.1	1.5	2.0	3.1	8.1
Vanadium Uncertainty ($10^{-4}\mu g/m^3$)							
A	3738	2.8	1.7	2.0	2.5	3.3	4.2
B	603	11.6	6.1	8.3	10.4	14.3	16.4
Total	4341	4.0	1.7	2.0	2.7	4.0	8.9
Zinc Uncertainty ($10^{-4}\mu g/m^3$)							
A	3738	9.1	3.7	4.5	6.1	9.6	15.5
B	603	19.9	8.2	10.6	13.9	18.7	29.2
Total	4341	10.6	3.8	4.7	6.9	11.4	17.9

6.3   EC/OC Replicate Analysis

EC/OC analysis is performed on a small cutout or "punch" of each filter. The 37 mm quartz filters used for this study are large enough to take two "punches"; a second punch was analyzed for approximately 10% of filters (N = 228) as a QC check.
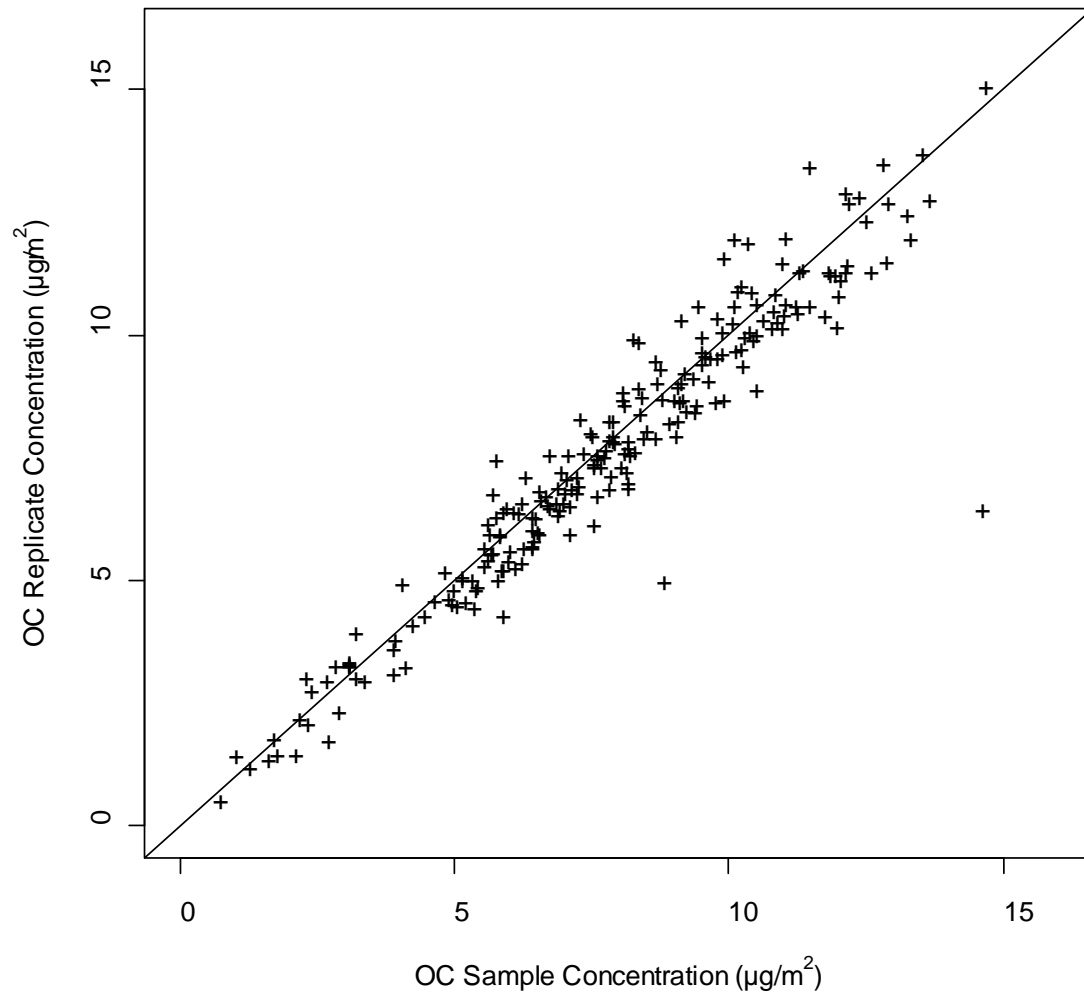
Figure 10. Scatterplot showing correlation between replicate analyses of the same sample ($R^2 = 0.91$, RMSE = 0.90 µg/m^2).
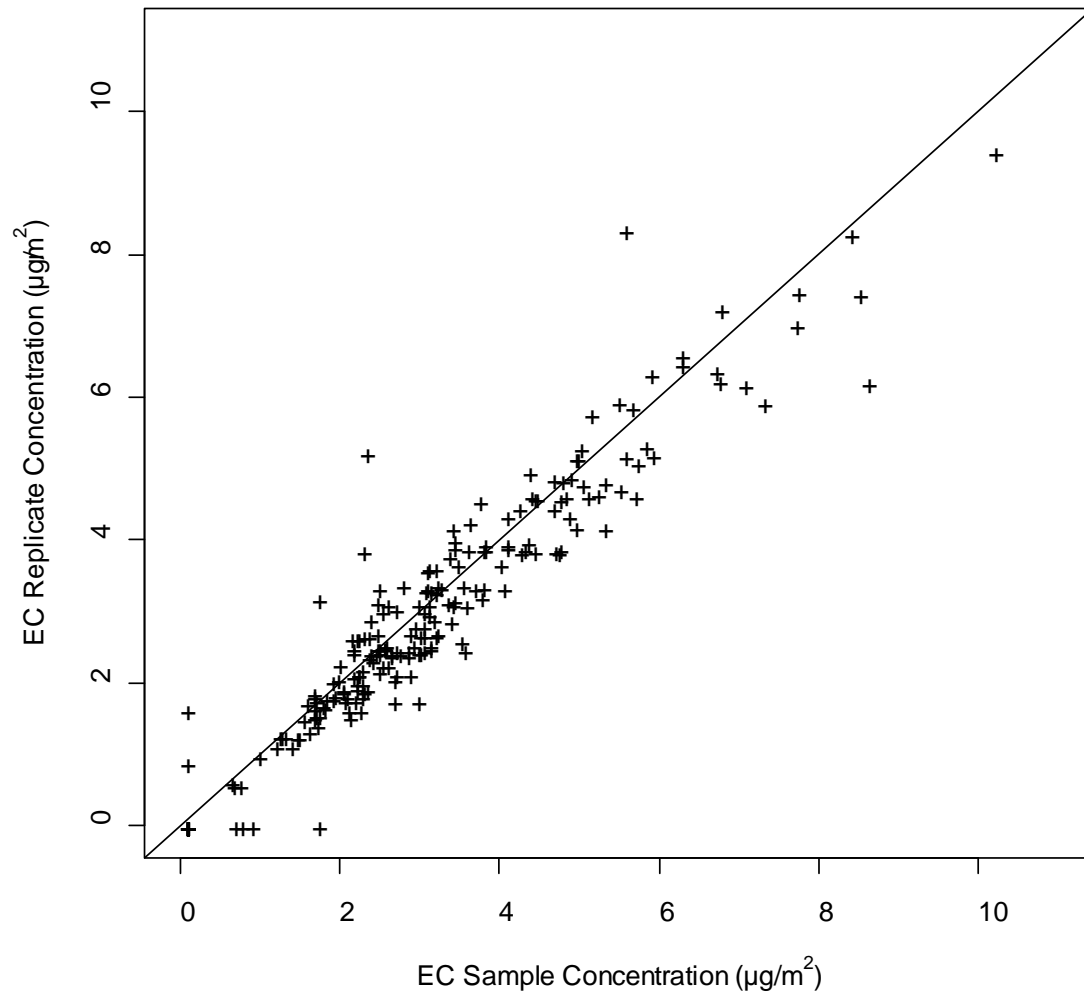
Figure 11. Scatterplot showing correlation between replicate analyses of the same sample ($R^2 = 0.91$, RMSE = 0.55 µg/m^2).

6.4   EC/OC Instrument Blanks and Calibration to Standard

For calibration and as a quality check, instrument blanks and samples of a known concentration are measured periodically during an analysis run. These QC samples are created and standardized by Sunset Labs, and are not shipped to the field. Measurements from these samples are reported as µg/cm^2, but have been converted to equivalent air concentrations based on a 10-day, 1.8 L/min air flow volume. These numbers can be compared to HEI/NPACT field blank concentrations and sample concentrations.

Table 12. EC from instrument blanks ($10^{-2} \mu g/m^3$).

Batch	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
1	43	0.9	-2.0	-0.4	0.0	0.6	3.9
2	116	0.0	0.0	0.0	0.0	0.0	0.0
3	52	0.0	0.0	0.0	0.0	0.0	0.0
4	59	0.0	0.0	0.0	0.0	0.0	0.0
5	66	-0.1	0.0	0.0	0.0	0.0	0.0
6	31	0.7	0.0	0.0	0.0	0.0	0.1
7	73	0.0	0.0	0.0	0.0	0.0	0.0
8	83	-0.1	0.0	0.0	0.0	0.0	0.0
9	32	0.0	0.0	0.0	0.0	0.0	0.0
10	31	0.0	0.0	0.0	0.0	0.0	0.0
Total	586	0.1	0.0	0.0	0.0	0.0	0.0

Table 13. OC from instrument blanks ($10^{-2} \mu g/m^3$).

Batch	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
1	43	-5.4	-10.3	-8.7	-5.9	-3.3	-0.5
2	116	-2.8	-14.2	-7.7	-3.5	3.1	8.8
3	52	2.9	-5.3	-2.7	2.3	6.5	10.0
4	59	2.3	-10.4	-4.8	2.1	9.2	14.7
5	66	-3.3	-12.4	-6.4	-2.7	0.0	3.5
6	31	7.4	0.9	3.6	7.7	11.4	16.1
7	73	-4.1	-10.1	-6.6	-3.7	-1.0	0.4
8	83	-2.2	-7.1	-4.3	-1.9	0.7	2.6
9	32	-3.0	-8.7	-7.4	-4.2	0.1	4.5
10	31	-3.1	-12.7	-5.0	-1.9	1.1	2.1
Total	586	-1.6	-10.2	-6.0	-2.1	2.5	8.5

Table 14. Difference in total carbon between known sucrose concentration and measured total carbon ($\mu g/m^3$).

Batch	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
1	33	-0.9	-2.9	-1.5	-0.5	0.4	1.5
2	60	-0.1	-1.1	-0.6	-0.2	0.4	1.0
3	29	-0.3	-1.2	-0.9	-0.4	0.2	0.8
4	30	0.0	-0.8	-0.6	0.1	0.7	0.8
5	31	-0.4	-1.0	-0.9	-0.6	0.0	0.3
6	18	-0.2	-1.1	-0.8	-0.3	0.1	0.7
7	41	-0.4	-1.0	-0.8	-0.6	0.0	0.7
8	39	-0.2	-0.9	-0.6	-0.2	0.2	0.6
9	17	0.2	-0.4	-0.2	0.1	0.5	1.1
10	17	-0.1	-0.6	-0.4	0.0	0.2	0.4
Total	315	-0.3	-1.1	-0.7	-0.3	0.2	0.8

6.5   EC/OC Uncertainty

Sunset reports the uncertainty of EC and OC as:
$0.02\ \mu g/cm^2$ + carbon concentration * 5%

This uncertainty is a measure of precision rather than accuracy. From the Sunset Labs analysis method description[6]:

> It is difficult to quantify the accuracy of the method for determining OC and EC species. Several experiments, however, have created mixtures of known quantities of OC and EC which act as real-world samples during the analysis by pyrolizing a fraction of the OC. These experiments give the predicted value for the speciation within 5-10%, depending on the relative quantities of OC and EC on the filter. Several method intercomparison studies have also yielded similar standard deviations.

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6 http://www.sunlab.com/uploads/assets/file/Sunlab-Analysis-Method.pdf

7. X-Ray Fluorescence Results

Teflon filters were deployed at fixed sites, indoors and outdoors at participants' homes, and as part of the personal monitoring effort. Sulfur mass is of interest for the analysis of infiltration rates. For this reason, indoor and personal sampling results are presented for this element. Other elements are more of interest for source apportionment or as tracers of particular sources. Indoor and personal sampling results are not presented for these elements, though the data will be made available upon request.

Sample species masses are corrected for blank masses by subtracting the median field center-specific field blank species mass (µg) from each of the sample results.

The field blanks are also used to calculate sample limits of detection (LOD), defined as three times the median absolute deviation of the mass of blank species mass. For the purpose of providing the blank results in an interpretable manner, the masses of the blanks and the LODs have been converted to concentrations. In order to estimate a reasonable, and yet conservative, blank concentration, a nominal 10-day duration and a nominal sampling rate of 1.8 L/min was assumed.

Sample concentrations are calculated based on the actual duration and air flow rate, unlike field blank concentrations, which are calculated based on an assumed nominal flow and duration. These values are available from the SidePak SP530 pump's datalogging files. This pump logs a flow rate, date, and time for each minute that the pump runs, so that a steady flow can be verified and the exact duration of sampling is known. A more extensive discussion of the pumps' limitations is available in section 2.

All boxplots and all calculations of standard deviations include all measurements, including those that were below the LOD. In other words, we used measurements as provided by the lab, rather than substituting a surrogate such as the detection limit or one-half the detection limit. It should be recognized, however, that we have less confidence in those values below the LOD.

7.1   Sulfur Field Blank and Sample Results

In Tables 18 and 22, the personal filters below are represented individually, rather than aggregated to the two-week period. Since masses for personal filters are much smaller than those for the two-week integrated indoor and outdoor filters, the LOD for the personal filters was relatively higher. The LOD for integrated two-week personal sampling deployments is also higher than the LOD for a single two-week integrated sample, as it averages several values that each have a high LOD. The mass LOD for personal samples with the same mass LOD for all filters is calculated as:

LOD = Single Filter Mass LOD * $\sqrt{}$Number of Filters

The mass LOD for personal samples with filters having different mass LODs is:

LOD = 3 * $\sqrt{\{ N_1 * (LOD_1/3)^2 + N_2 * (LOD_2/3)^2 \}}$
where N_1 is the number of filters having LOD_1, and N_2 is the number of filters having LOD_2.

Table 15. Sulfur in PM$_{2.5}$ blanks ($10^{-4}\mu g/m^3$).

Field Center	N	Percentiles					Median Abs Dev°	LOD
		10th	25th	50th	75th	90th		
*Estimated Sulfur Concentrations in PM$_{2.5}$ Field Blanks, by Field Center**								
Baltimore	90	0.0	0.0	0.0	8.1	18.0	0.0	0.0
Chicago	72	0.0	0.0	2.8	8.1	14.4	4.1	12.3
Chicago†	9	‡	0.0	0.0	0.0	‡	0.0	0.0
LA	103	0.0	0.0	0.0	0.0	20.3	0.0	0.0
New York	79	0.0	0.0	0.0	9.9	31.6	0.0	0.0
St. Paul	83	0.0	0.0	0.0	8.7	20.5	0.0	0.0
Winston-Salem	87	0.0	0.0	0.0	5.9	14.5	0.0	0.0

* Blank filter masses are converted into concentrations by assuming a sample volume of 25.92 m^3.

† Single technician

° Median{Abs[Each Value – Median(All Values)]}

‡ Statistic not meaningful for small number of samples

Table 16. Sulfur in $PM_{2.5}$ sample results (10^{-1} $\mu g/m^3$).

Study Area	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Outdoor Sulfur Concentrations in $PM_{2.5}$ Sample Results, by Study Area.							
Baltimore	505	9.6	11.2	13.6	20.4	25.4	6.5
Chicago	537	6.7	8.3	10.3	13.1	16.4	4.2
LA	254	3.2	6.0	10.9	17.0	20.7	6.3
Coastal	262	4.3	7.2	12.4	17.8	20.8	6.1
Riverside	194	3.2	5.1	8.4	13.8	16.0	4.9
NYC	287	8.2	10.3	12.2	16.7	22.2	5.9
Rockland	99	7.2	8.8	10.0	15.6	21.4	5.6
St. Paul	444	4.6	5.7	6.8	8.3	9.6	2.3
Winston-Salem	528	8.3	9.7	13.5	20.7	26.0	7.5
Indoor Sulfur Concentrations in $PM_{2.5}$ Sample Results, by Study Area.							
Baltimore	95	4.3	5.7	7.4	12.1	18.2	5.3
Chicago	83	3.3	4.3	5.9	8.0	11.5	3.7
LA	86	2.0	4.4	8.6	14.8	18.0	5.8
Coastal	28	2.5	5.5	11.7	16.0	19.4	6.0
Riverside	46	1.4	2.7	4.7	7.5	10.8	3.4
NYC	77	6.6	7.6	9.9	14.6	19.8	5.3
Rockland	31	3.7	4.8	6.2	11.8	18.0	5.7
St. Paul	90	1.7	2.5	3.9	5.3	7.3	2.6
Winston-Salem	95	3.8	4.9	7.2	9.6	13.9	4.1
Personal Sulfur Concentrations in $PM_{2.5}$ Filter Results, by Study Area.							
Baltimore	125	3.2	5.0	7.2	10.7	16.5	5.4
Chicago	76	1.6	3.1	5.5	10.0	17.0	11.0
LA	43	0.6	1.1	3.4	11.1	18.1	6.4
Coastal	19	3.7	7.7	8.5	10.5	16.8	4.9
Riverside	35	1.2	1.5	2.6	4.9	11.2	4.1
NYC	39	5.3	6.7	12.4	19.0	26.9	8.0
Rockland	46	1.7	2.9	4.8	7.3	13.7	5.4
St. Paul	107	1.3	2.1	3.5	5.3	9.0	3.9
Winston-Salem	110	3.0	4.5	6.7	10.4	13.4	4.5

Table 16, *continued*. Sulfur in PM$_{2.5}$ sample results ($10^{-1}\mu g/m^3$).

Study Area	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Personal Sulfur Concentrations in PM$_{2.5}$ Sample Results, by Study Area.							
Baltimore	25	4.6	5.9	7.5	11.6	14.3	3.6
Chicago	18	2.8	3.7	6.3	8.5	22.4	8.6
LA	9	‡	2.0	5.2	9.9	‡	4.7
Coastal	4	‡	‡	8.6	‡	‡	2.4
Riverside	7	‡	2.0	2.5	3.7	‡	3.0
NYC	8	‡	9.7	13.8	18.0	‡	4.2
Rockland	10	‡	4.2	5.6	6.4	‡	2.1
St. Paul	22	1.6	2.8	4.0	5.8	9.6	3.1
Winston-Salem	24	3.7	5.1	7.6	9.4	14.4	4.0

‡ Statistic not meaningful for small number of samples
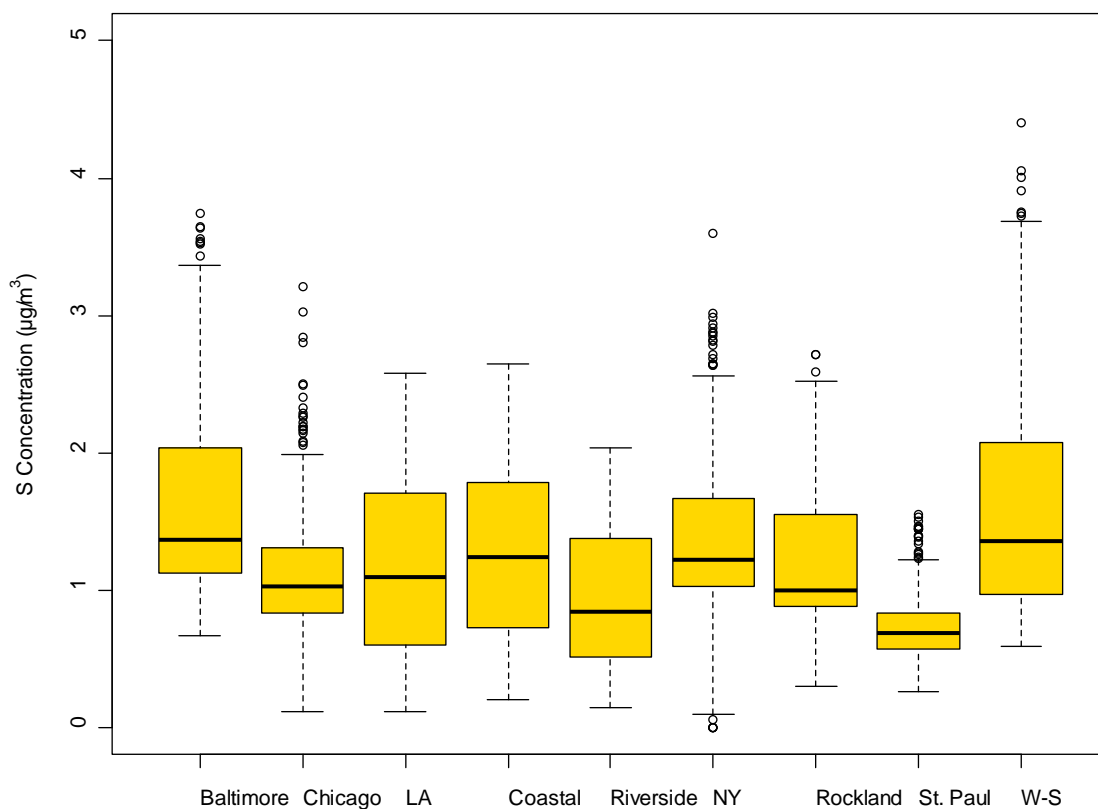
Figure 12. Boxplots of sulfur in outdoor PM$_{2.5}$ sample results ($\mu g/m^3$) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.
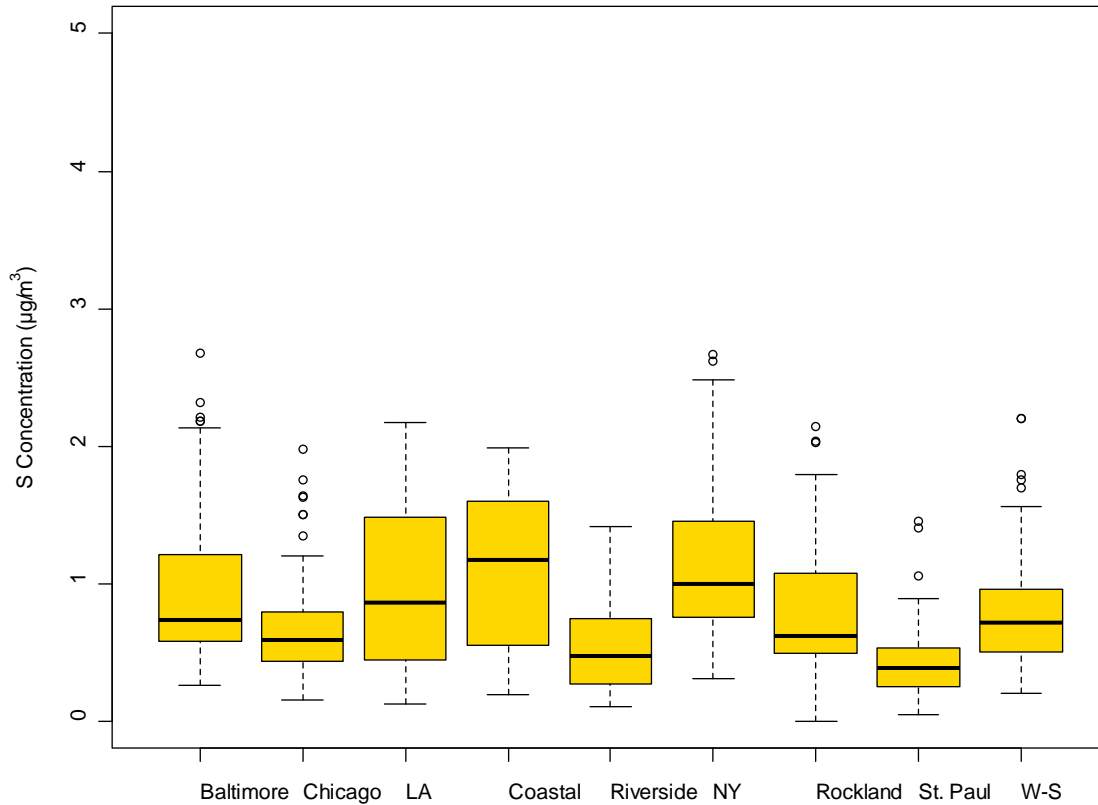
Figure 13. Boxplots of sulfur in indoor PM$_{2.5}$ sample results (μg/m^3) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.
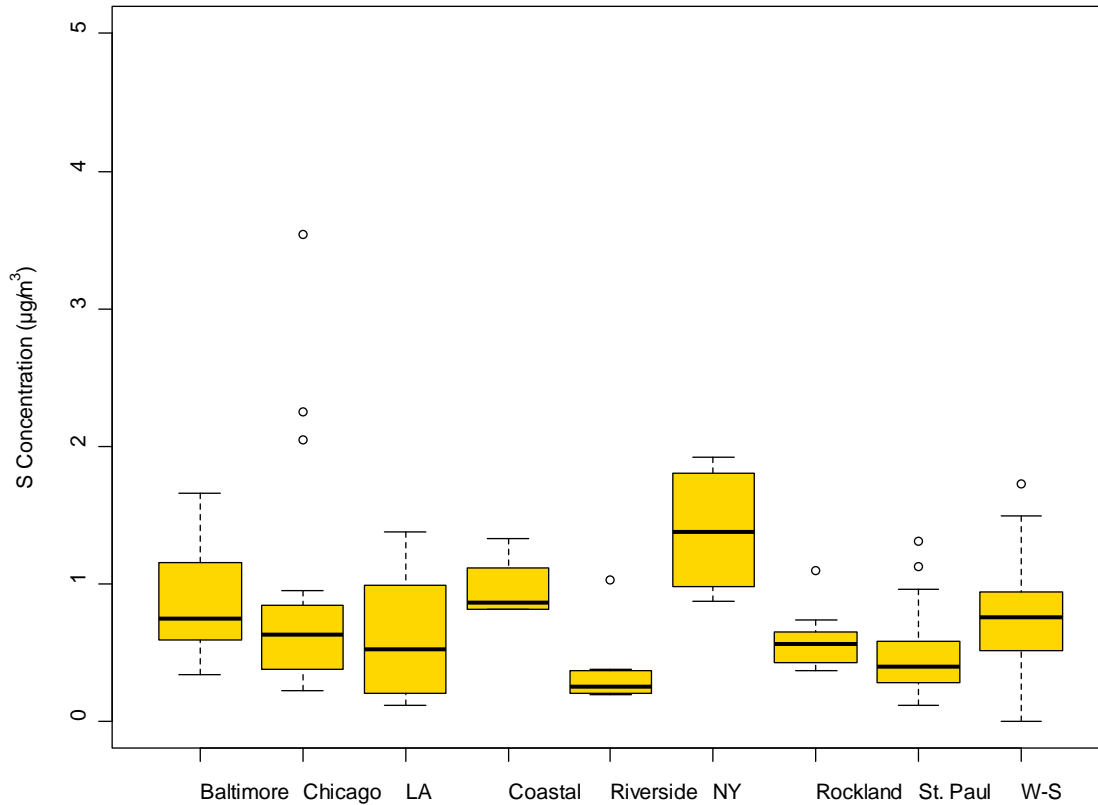
Figure 14. Boxplots of sulfur in personal PM$_{2.5}$ sample results (μg/m^3) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.

7.2 Sulfur Field Duplicate Results

Field duplicates were deployed alongside approximately 10% of samples. Precision is high when the average Relative Percent Difference (RPD)/$\sqrt{2}$, is less than 10%. Only pairs with both valid sample and valid duplicate are included.

Table 17. Sulfur concentrations in PM$_{2.5}$ duplicate results (RPD/$\sqrt{2}$%).

Field Center	N	Mean	Percentiles				
			10th	25th	50th	75th	90th
Baltimore	85	2.9	0.4	1.0	2.3	3.3	4.8
Chicago	36	6.0	0.3	0.8	1.7	4.1	7.7
LA	97	3.2	0.4	1.2	2.4	3.8	7.0
New York	35	9.1	0.2	1.1	3.3	4.7	6.9
St. Paul	41	2.6	0.4	1.0	2.6	3.5	5.0
Winston-Salem	71	2.4	0.4	0.7	1.8	3.8	4.5
Total	**365**	**3.7**	**0.4**	**1.0**	**2.2**	**3.7**	**5.6**

Across the study, the RPD/$\sqrt{2}$ was 3.7%. The relationship between sample and duplicate concentrations is shown below.

Figure 15. Scatterplot of sample concentrations against co-located duplicates. The overall R^2 is 0.91 and the RMSE is 0.21 $\mu g/m^3$.

7.3 Silicon Field Blank and Sample Results

Table 18. Silicon in $PM_{2.5}$ blanks (10^{-3} µg/m^3).

Field Center	N	Percentiles					Median Abs Dev°	LOD
		10th	25th	50th	75th	90th		
Estimated Silicon Concentrations in PM$_{2.5}$ Field Blanks, by Field Center*								
Baltimore	90	0.0	1.7	8.2	13.6	20.7	8.9	26.7
Chicago	72	0.0	0.0	1.4	8.0	15.3	2.1	6.2
Chicago†	9	‡	7.6	18.5	24.2	‡	16.1	48.3
LA	103	0.0	4.9	10.1	15.8	25.0	8.0	23.9
New York	79	1.5	5.1	12.6	19.6	29.7	10.3	30.8
St. Paul	83	0.0	0.0	9.8	15.3	23.7	11.8	35.5
Winston-Salem	87	0.0	1.8	10.8	14.6	21.3	6.6	19.8

* Blank filter mass values are converted into concentrations by assuming a sample volume of 25.92 m^3.
† Single technician
° Median{Abs[Each Value – Median(All Values)]}
‡ Statistic not meaningful for small number of samples

Table 19. Silicon in $PM_{2.5}$ samples (10^{-2} µg/m^3).

Study Area	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Outdoor Silicon Concentrations in PM$_{2.5}$ Sample Results, by Study Area.							
Baltimore	505	3.9	5.1	6.9	9.9	14.1	5.3
Chicago	537	5.4	6.8	9.5	12.7	16.3	8.6
LA	254	8.0	10.0	12.4	16.1	20.8	5.7
Coastal	262	5.4	7.1	10.4	14.8	19.2	6.0
Riverside	194	11.3	16.5	21.5	26.6	34.3	10.4
NYC	287	5.8	7.5	9.9	13.1	17.8	6.4
Rockland	99	3.7	4.4	5.9	8.4	10.2	13.3
St. Paul	444	5.1	6.9	8.8	12.7	16.3	4.6
Winston-Salem	528	4.3	5.5	7.5	11.3	16.2	5.0
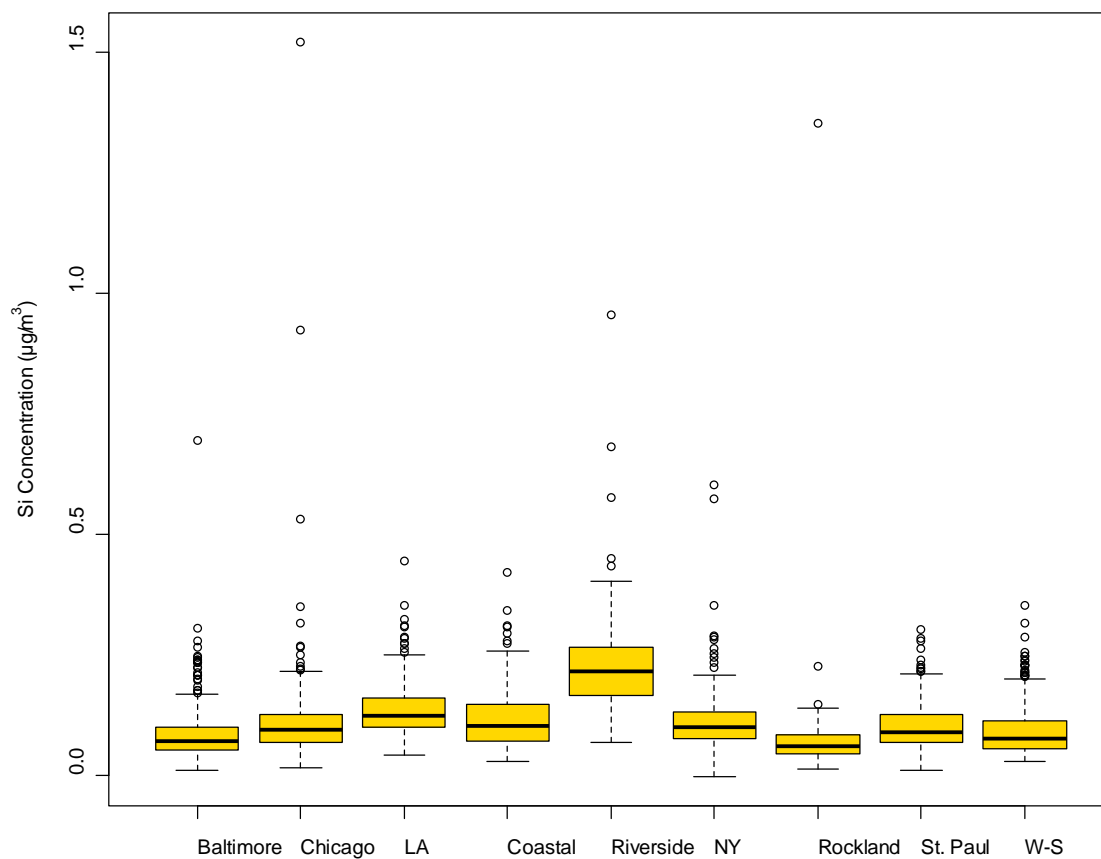
Figure 16. Boxplots of silicon in outdoor PM$_{2.5}$ sample results (μg/m^3) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.
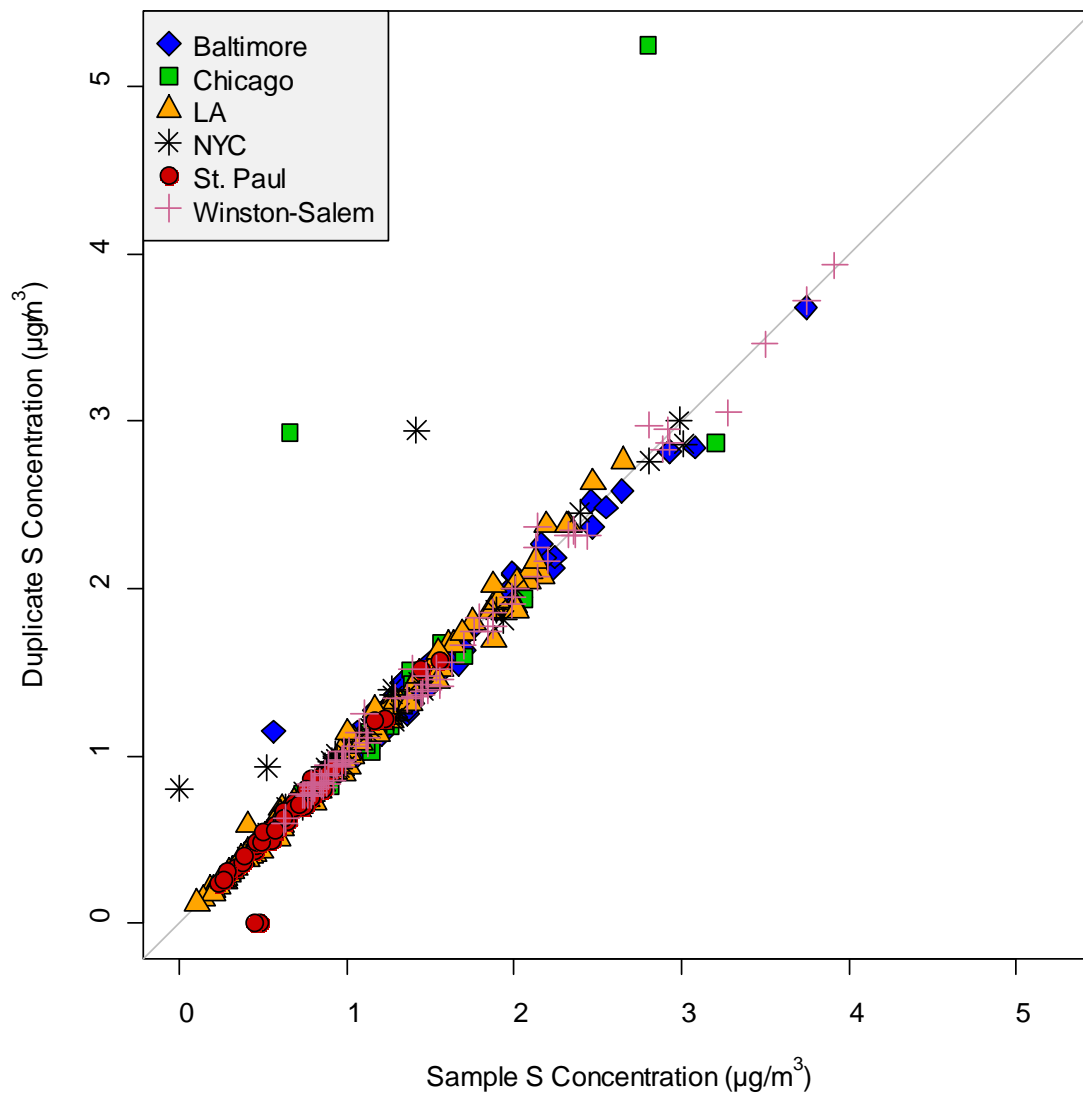
7.4 Silicon Field Duplicate Results

Field duplicates were collected alongside 10% of samples. Precision is high when the (RPD)/√2 is less than 10%. Only pairs where both the sample and duplicate were valid are included.

Table 20. Silicon in $PM_{2.5}$ duplicates (RPD/√2).

Field Center	N	Mean	Percentiles				
			10th	25th	50th	75th	90th
Baltimore	85	9.2	1.0	2.4	6.0	11.8	19.5
Chicago	36	7.9	0.4	2.1	4.2	7.3	12.2
LA	97	12.0	1.7	4.4	10.8	15.9	26.1
New York	35	17.4	1.9	2.4	7.4	16.6	55.8
St. Paul	41	13.8	1.5	4.1	7.7	13.4	37.3
Winston-Salem	71	7.4	1.0	2.6	5.3	10.9	16.3
Total	**365**	**10.8**	**1.3**	**3.0**	**6.8**	**13.2**	**23.0**

Across the study, our indicator for precision was 10.8%. The relationship between sample and duplicate concentrations is shown graphically below.

Figure 17. Scatterplot of sample concentrations against co-located duplicates. The overall R^2 is 0.79 and the RMSE is 0.032 µg/m^3.

7.5 Nickel Field Blank and Sample Results

Table 21. Nickel in PM$_{2.5}$ blanks (10^{-3} µg/m^3).

Field Center	N	Percentiles					Median Abs Dev°	LOD
		10th	25th	50th	75th	90th		
Estimated Silicon Concentrations in PM$_{2.5}$ Field Blanks, by Field Center*								
Baltimore	90	0.0	0.0	0.2	1.5	2.8	0.4	1.1
Chicago	72	0.0	0.0	0.0	1.1	2.1	0.0	0.0
Chicago†	9	‡	0.0	0.0	0.5	‡	0.0	0.0
LA	103	0.0	0.0	0.2	1.9	3.2	0.3	0.8
New York	79	0.0	0.0	0.6	2.5	5.1	0.8	2.5
St. Paul	83	0.0	0.0	0.0	1.7	3.4	0.0	0.0
Winston-Salem	87	0.0	0.0	0.4	1.7	2.6	0.6	1.8

* Blank filter mass values are converted into concentrations by assuming a sample volume of 25.92 m^3.
† Single technician
° Median{Abs[Each Value – Median(All Values)]}
‡ Statistic not meaningful for small number of samples

Table 22. Nickel in PM$_{2.5}$ samples (10^{-2} µg/m^3).

Study Area	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Outdoor Nickel Concentrations in PM$_{2.5}$ Sample Results, by Study Area.							
Baltimore	505	0.2	0.3	0.6	1.0	1.5	0.9
Chicago	537	0.1	0.2	0.3	0.5	0.7	0.3
LA	254	0.9	1.5	2.2	3.0	4.7	4.6
Coastal	262	1.3	1.7	2.2	2.8	3.5	0.9
Riverside	194	0.6	0.9	1.4	1.9	2.3	0.7
NYC	287	3.9	5.7	8.9	14.6	20.6	9.6
Rockland	99	0.5	0.7	1.2	1.8	2.3	0.9
St. Paul	444	0.0	0.1	0.2	0.4	0.8	1.0
Winston-Salem	528	<LOD	<LOD	<LOD	0.3	0.4	0.4
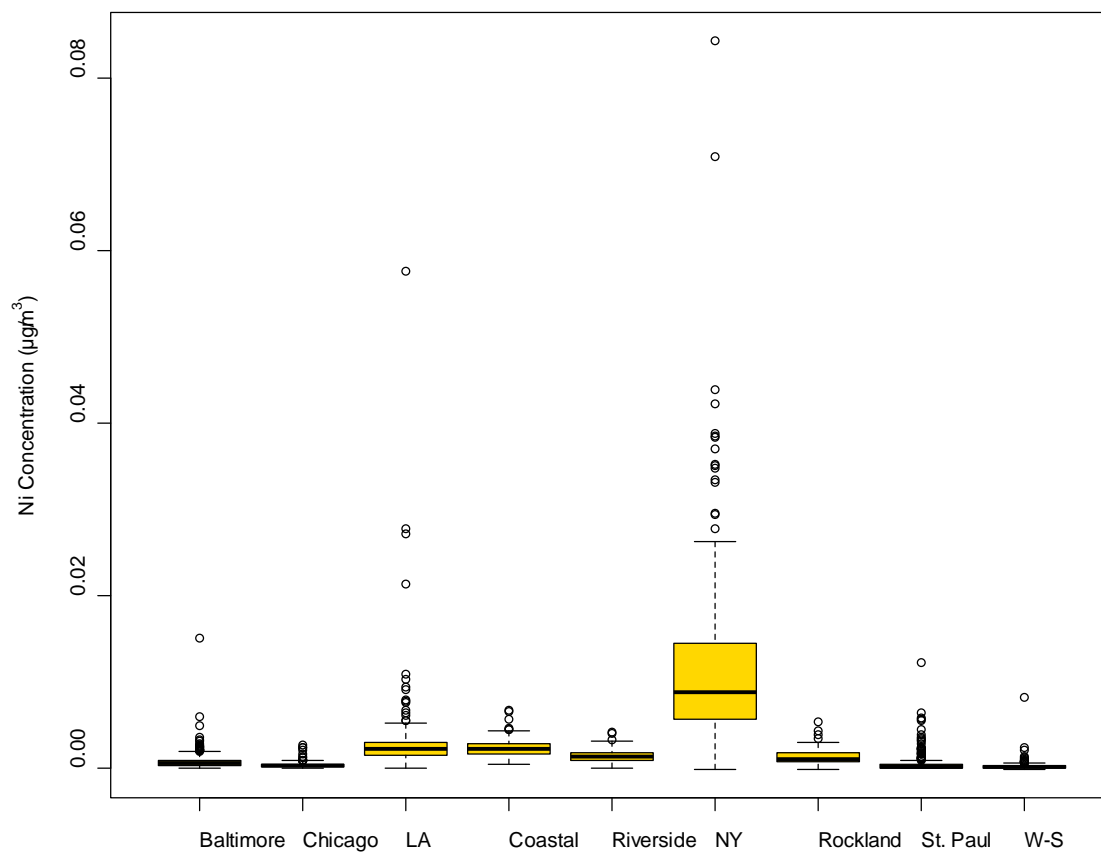
Figure 18. Boxplots of nickel in outdoor PM$_{2.5}$ sample results (μg/m^3) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.
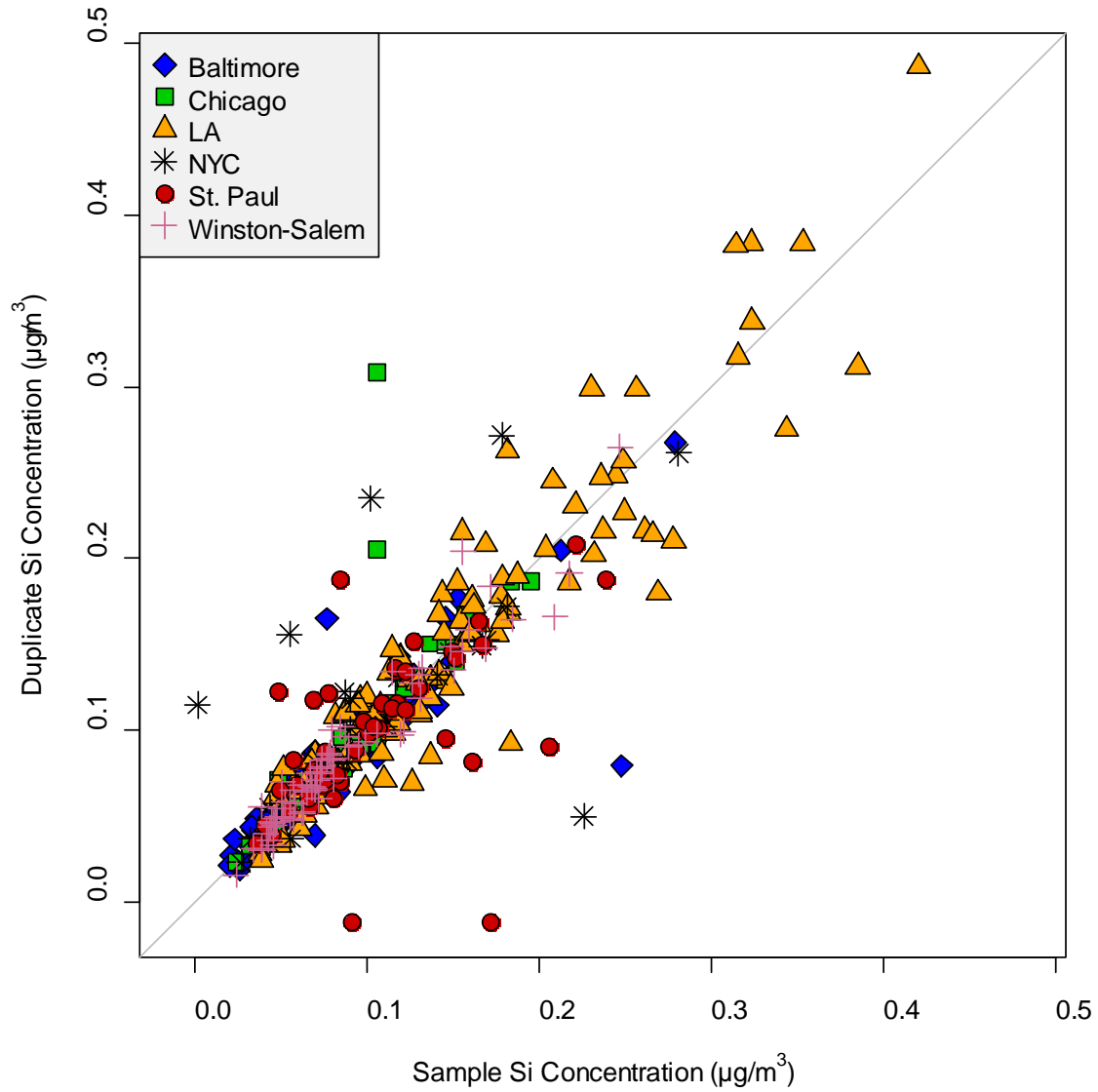
7.6   Nickel Field Duplicate Results

Field duplicates were collected alongside 10% of samples. Precision is high when the (RPD)/√2 is less than 10%. Only pairs where both the sample and duplicate were valid are included.

Table 23. Nickel in $PM_{2.5}$ duplicates (RPD/√2).

Field Center	N	Mean	Percentiles				
			10th	25th	50th	75th	90th
Baltimore	85	41.0	5.8	13.8	25.0	57.4	102.1
Chicago	35	46.4	6.6	12.5	41.8	69.1	125.7
LA	97	13.7	1.7	4.0	10.3	17.3	31.4
New York	35	18.5	1.7	3.6	7.2	23.7	46.9
St. Paul	40	85.7	19.7	24.3	91.0	141.4	141.4
Winston-Salem	71	143.7	11.7	34.4	64.4	172.8	289.4
Total	**363**	**57.1**	**3.3**	**8.7**	**23.5**	**61.8**	**141.4**

Across the study, our indicator for precision was 57.1%. The relationship between sample and duplicate concentrations is shown graphically below.

Figure 19. Scatterplot of sample concentrations against co-located duplicates. The overall R^2 is 0.86 and the RMSE is 9.2×10^{-4} µg/m^3.

7.7 Vanadium Field Blank and Sample Results

Table 24. Vanadium in PM$_{2.5}$ blanks (10^{-4} µg/m^3).

Field Center	N	Percentiles					Median Abs Dev°	LOD
		10th	25th	50th	75th	90th		
Estimated Vanadium Concentrations in PM$_{2.5}$ Field Blanks, by Field Center*								
Baltimore	90	0.0	0.0	0.0	0.9	1.9	0.0	0.0
Chicago	72	0.0	0.0	0.0	0.5	1.6	0.0	0.0
Chicago†	9	‡	0.0	0.0	0.5	‡	0.0	0.0
LA	103	0.0	0.0	0.0	1.2	2.7	0.0	0.0
New York	79	0.0	0.0	0.0	1.6	2.7	0.0	0.0
St. Paul	83	0.0	0.0	0.0	0.6	2.7	0.0	0.0
Winston-Salem	87	0.0	0.0	0.0	0.9	1.9	0.0	0.0

* Blank filter mass values are converted into concentrations by assuming a sample volume of 25.92 m^3.
† Single technician
° Median{Abs[Each Value – Median(All Values)]}
‡Statistic not meaningful for small number of samples

Table 25. Vanadium in PM$_{2.5}$ samples (10^{-2} µg/m^3).

Study Area	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Outdoor Vanadium Concentrations in PM$_{2.5}$ Sample Results, by Study Area.							
Baltimore	505	0.5	0.8	1.4	2.0	2.9	1.1
Chicago	537	0.0	0.0	0.2	0.4	0.6	0.2
LA	254	1.7	3.2	5.1	6.7	8.2	2.5
Coastal	262	3.2	4.6	6.1	7.8	9.6	2.6
Riverside	194	1.4	2.4	3.5	4.7	6.2	1.8
NYC	287	2.3	3.0	4.1	5.6	7.2	2.7
Rockland	99	0.6	0.8	1.3	1.6	2.2	0.6
St. Paul	444	0.0	0.1	0.3	0.5	0.9	1.4
Winston-Salem	528	0.1	0.2	0.4	0.6	0.9	0.3
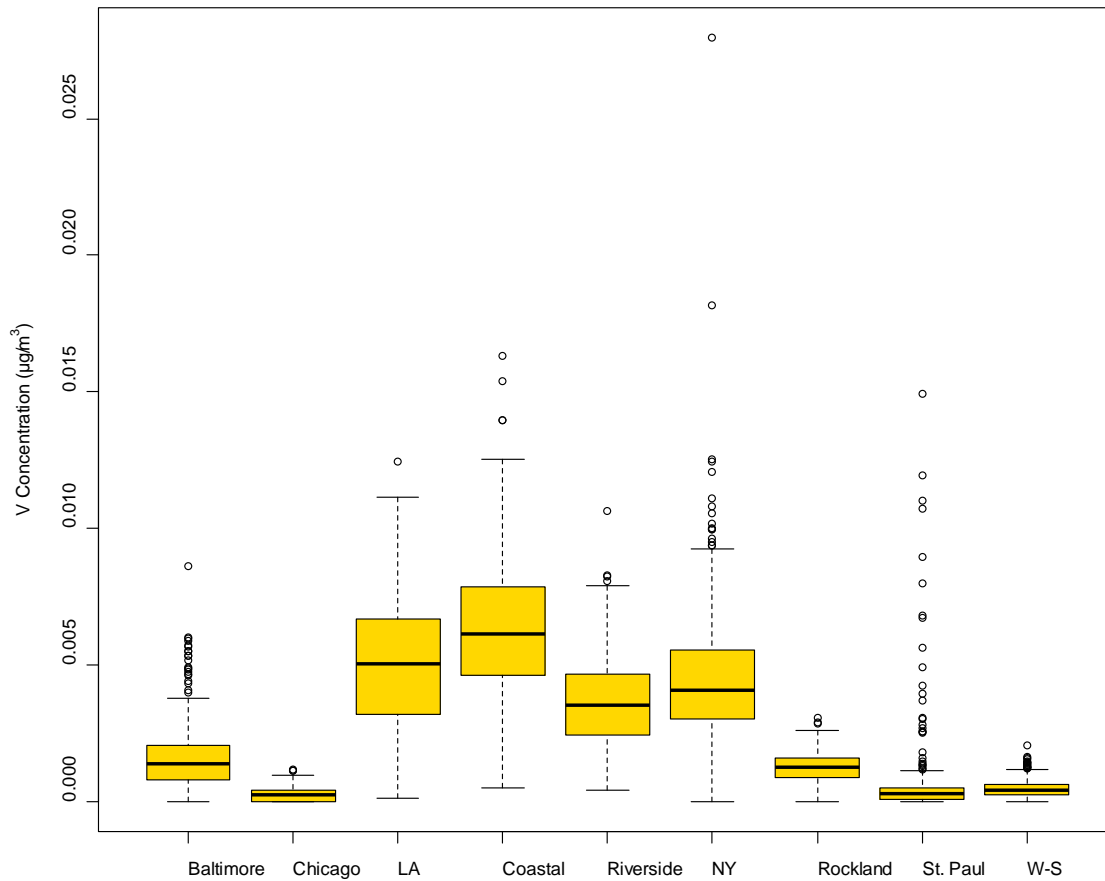
Figure 20. Boxplots of vanadium in outdoor PM$_{2.5}$ sample results ($\mu g/m^3$) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.
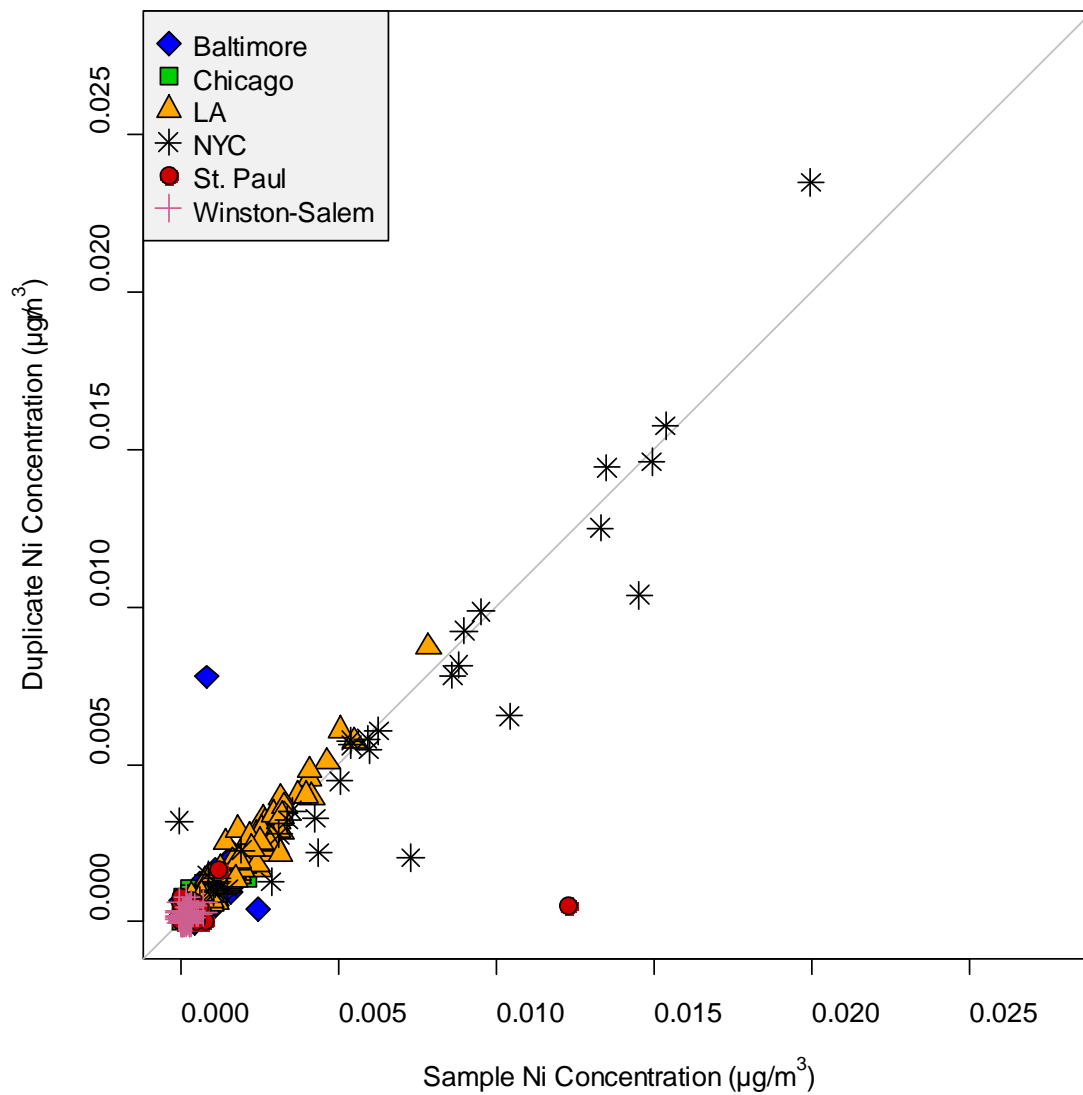
7.8 Vanadium Field Duplicate Results

Field duplicates were collected alongside 10% of samples. Precision is high when the (RPD)/√2 is less than 10%. Only pairs where both the sample and duplicate were valid are included.

Table 26. Vanadium in $PM_{2.5}$ duplicates (RPD/√2).

Field Center	N	Mean	Percentiles				
			10th	25th	50th	75th	90th
Baltimore	85	22.5	1.8	4.8	14.3	22.7	52.6
Chicago	36	77.0	11.9	24.8	60.8	141.4	141.4
LA	97	10.2	0.6	3.0	5.7	10.6	21.2
New York	35	19.4	0.6	3.7	6.8	19.4	54.9
St. Paul	37	71.2	6.0	15.7	55.4	141.4	141.4
Winston-Salem	69	53.2	6.2	11.7	33.3	82.5	141.4
Total	**359**	**35.3**	**1.9**	**5.3**	**13.8**	**47.0**	**136.1**

Across the study, our indicator for precision was 35.3%. The relationship between sample and duplicate concentrations is shown graphically below.
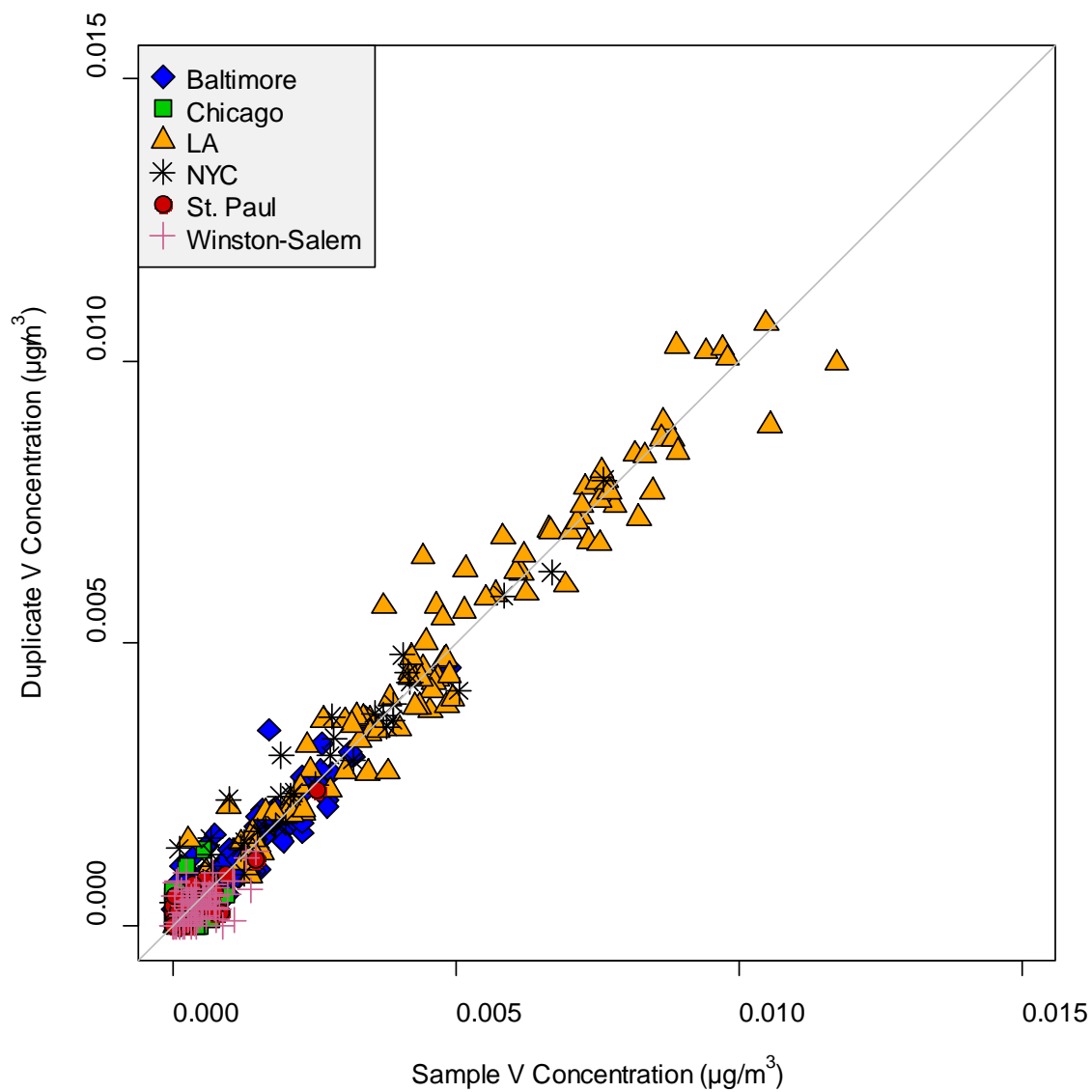
Figure 21. Scatterplot of sample vanadium concentrations against co-located duplicates. One extreme outlier (3.7, 0) was excluded to preserve scale. Including this point, the overall R^2 is 0.001 and the RMSE is 0.19 $\mu g/m^3$. Excluding this point, the overall R^2 is 0.97 and the RMSE is 4.5 x 10^{-4} $\mu g/m^3$.

7.9 Zinc Field Blank and Sample Results

Table 27. Zinc in PM$_{2.5}$ blanks (10^{-3} µg/m^3).

Field Center	N	Percentiles					Median Abs Dev°	LOD
		10th	25th	50th	75th	90th		
*Estimated Zinc Concentrations in PM$_{2.5}$ Field Blanks, by Field Center**								
Baltimore	90	0.0	0.0	0.5	1.1	2.7	0.8	2.4
Chicago	72	0.0	0.0	0.3	0.6	1.2	0.5	1.4
Chicago†	9	0.0	0.0	0.4	1.3	3.5	0.5	1.6
LA	103	0.0	0.3	0.6	1.0	3.6	0.5	1.6
New York	79	0.0	0.2	0.7	1.4	4.9	0.8	2.3
St. Paul	83	0.0	0.1	0.5	1.1	2.3	0.7	2.1
Winston-Salem	87	0.0	0.1	0.5	1.1	1.6	0.6	1.8

* Blank filter mass values are converted into concentrations by assuming a sample volume of 25.92 m^3.
† Single technician
° Median{Abs[Each Value – Median(All Values)]}
‡ Statistic not meaningful for small number of samples

Table 28. Zinc in PM$_{2.5}$ samples (10^{-2} µg/m^3).

Study Area	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Outdoor Zinc Concentrations in PM$_{2.5}$ Sample Results, by Study Area.							
Baltimore	505	0.7	0.9	1.4	2.1	3.0	1.0
Chicago	537	1.3	1.7	2.5	3.5	4.5	1.5
LA	254	0.9	1.3	1.7	2.4	3.0	0.8
Coastal	262	0.4	0.6	0.9	1.6	2.4	1.0
Riverside	194	1.0	1.1	1.5	2.2	3.3	1.0
NYC	287	2.0	2.6	3.7	5.1	7.2	2.6
Rockland	99	0.6	0.7	1.0	1.3	1.7	0.5
St. Paul	444	0.7	0.8	1.2	1.6	2.0	0.9
Winston-Salem	528	0.5	0.6	0.8	1.0	1.2	0.3
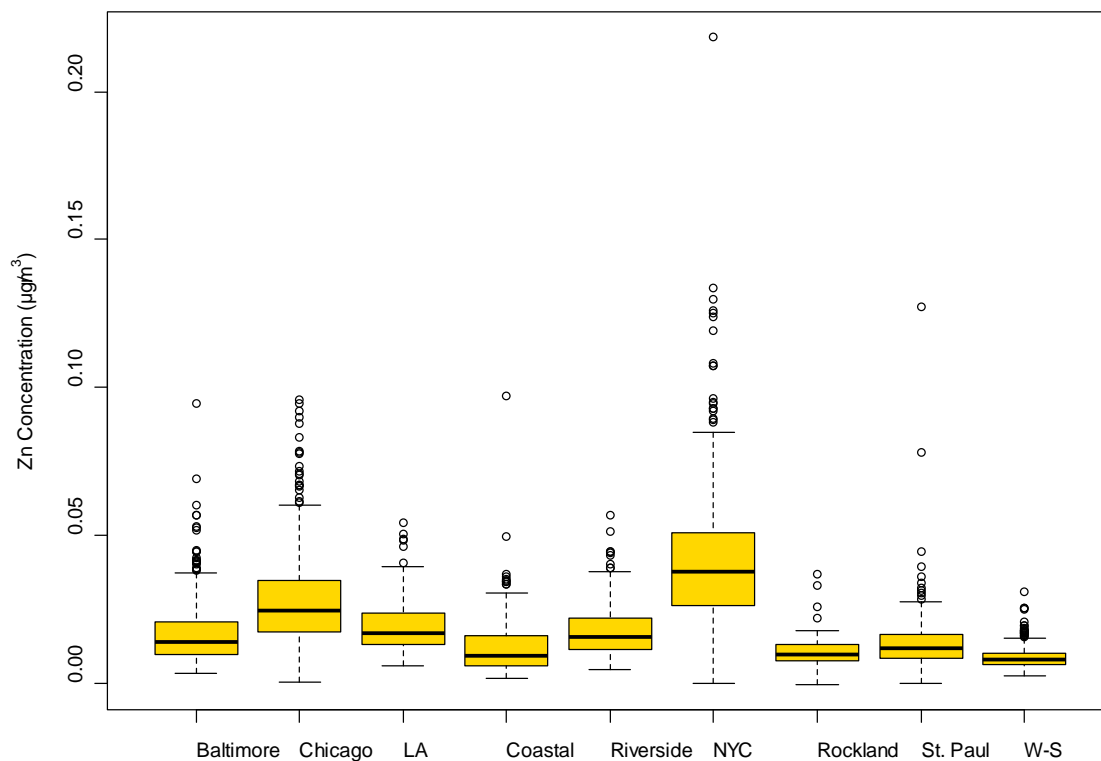
Figure 22. Boxplots of zinc in outdoor $PM_{2.5}$ sample results ($\mu g/m^3$) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.

7.10 Zinc Field Duplicate Results

Field duplicates were collected alongside 10% of samples. Precision is high when the (RPD)/$\sqrt{2}$ is less than 10%. Only pairs where both the sample and duplicate were valid are included.

Table 29. Zinc in $PM_{2.5}$ duplicates (RPD/$\sqrt{2}$).

Field Center	N	Mean	Percentiles				
			10th	25th	50th	75th	90th
Baltimore	85	13.7	0.9	2.7	5.6	8.1	13.0
Chicago	36	14.2	0.5	1.1	3.6	8.8	19.4
LA	97	7.8	0.6	1.8	4.6	10.0	16.6
New York	35	30.5	1.1	2.7	6.8	14.0	51.0
St. Paul	41	19.4	2.4	3.3	5.1	9.5	23.2
Winston-Salem	71	7.4	2.0	3.0	5.7	9.3	15.3
Total	**365**	**15.1**	**1.0**	**2.6**	**5.4**	**9.4**	**16.4**

Across the study, our indicator for precision was 15.1%. The relationship between sample and duplicate concentrations is shown graphically below.
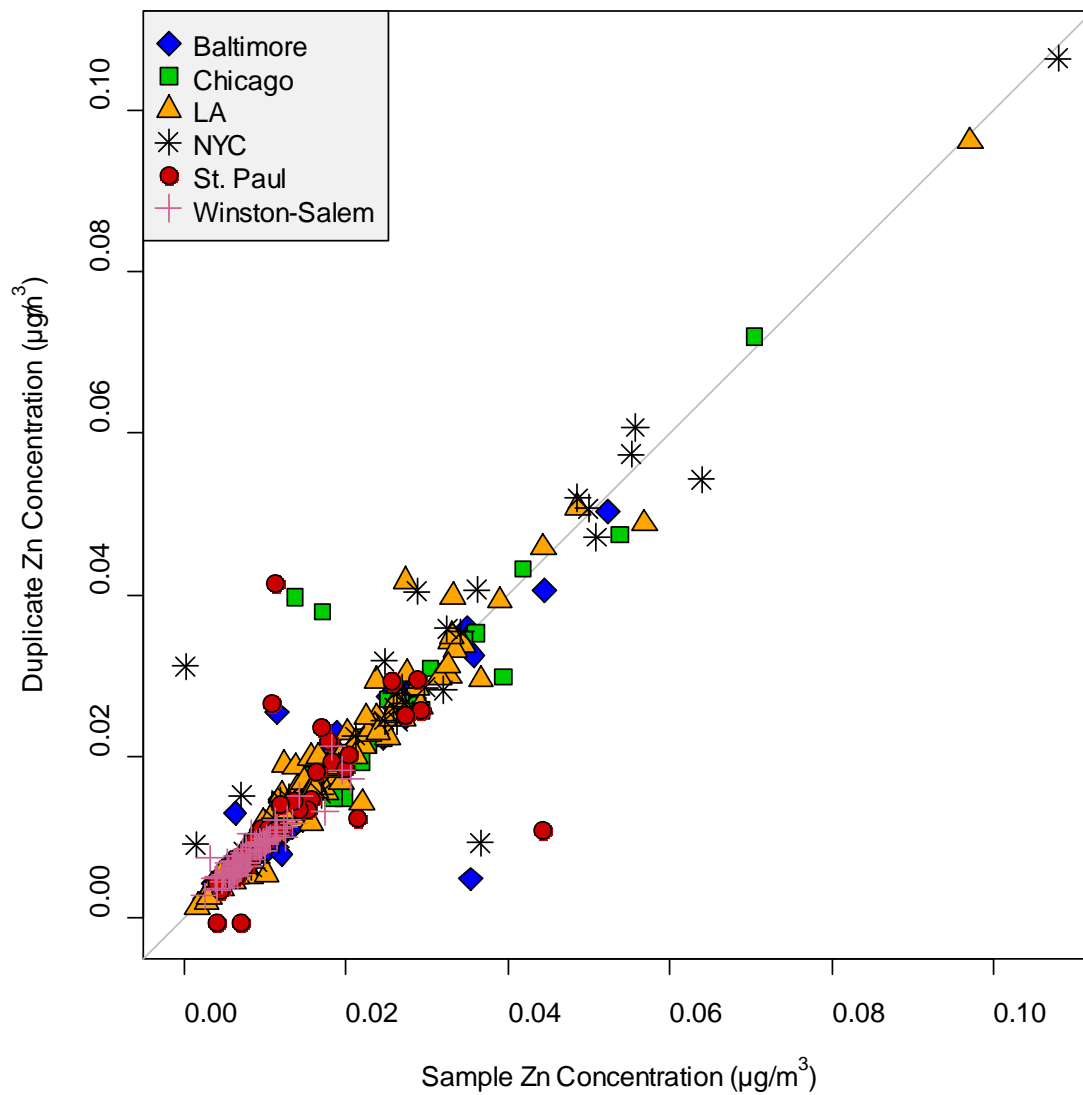
Figure 23. Scatterplot of sample concentrations against co-located duplicates. The overall R^2 is 0.87 and the RMSE is 4.7 x 10^{-3} µg/m^3.

7.11 All Field Blank and Sample Results

An abbreviated summary of blanks and outdoor measurements of all elements across all study areas is provided.

Table 30. Element concentrations in $PM_{2.5}$ blanks (10^{-4} µg/m³).

Element	N	Percentiles					Median Abs Dev°	LOD
		10th	25th	50th	75th	90th		
*Estimated Element Concentrations in PM$_{2.5}$ Field Blanks *￼*								
Ag	523	0.0	0.0	0.0	1.3	2.8	0.0	0.0
Al	523	0.0	0.0	0.0	0.0	3.6	0.0	0.0
As	523	0.0	0.0	0.0	0.2	0.3	0.0	0.0
Au	523	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Ba	523	0.0	0.0	0.6	1.4	2.2	0.8	2.4
Br	523	0.0	0.0	0.1	0.2	0.4	0.1	0.4
Ca	523	0.2	0.6	1.3	2.7	5.2	1.4	4.1
Cd	523	0.0	0.0	0.1	2.1	4.3	0.1	0.3
Ce	523	0.0	0.0	0.0	0.6	1.1	0.0	0.0
Cl	523	0.0	0.0	0.0	0.8	3.3	0.0	0.0
Co	523	0.0	0.0	0.0	0.1	0.2	0.0	0.0
Cr	523	0.0	0.0	0.2	0.4	0.6	0.2	0.7
Cs	523	0.0	0.0	0.0	0.7	1.4	0.0	0.0
Cu	523	0.0	0.2	0.4	0.9	1.6	0.4	1.2
Eu	523	0.0	0.0	0.0	0.3	0.7	0.0	0.0
Fe	523	0.6	0.9	1.4	2.0	3.3	0.8	2.4
Ga	523	0.0	0.0	0.0	0.3	0.5	0.0	0.0
Hf	523	0.0	0.0	0.2	0.7	1.3	0.3	1.0
Hg	523	0.0	0.0	0.0	0.3	0.7	0.0	0.0
In	523	0.0	0.0	0.0	2.3	5.0	0.0	0.0
Ir	523	0.0	0.0	0.0	0.4	1.0	0.0	0.0
K	523	0.0	0.3	1.1	2.1	4.3	1.2	3.7
La	523	0.0	0.0	0.0	0.0	0.7	0.0	0.0
Mg	523	0.0	0.0	0.0	30.4	39.3	0.0	0.0
Mn	523	0.0	0.0	0.1	0.3	0.6	0.1	0.4
Mo	523	0.0	0.0	0.0	0.4	0.9	0.0	0.0
Na	523	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nb	523	0.0	0.0	0.0	0.2	0.5	0.0	0.0
Ni	523	0.0	0.0	0.0	0.2	0.3	0.0	0.1
P	523	0.0	0.0	1.8	4.9	6.3	2.6	7.9
Pb	523	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Rb	523	0.0	0.0	0.1	0.3	0.5	0.2	0.5
S	523	0.0	0.0	0.0	0.7	1.8	0.0	0.0

Table 30. *(continued)*

Element	N	Percentiles					Median Abs Dev°	LOD
		10th	25th	50th	75th	90th		
Sb	523	0.0	0.0	0.8	5.6	12.0	1.2	3.6
Sc	523	0.0	0.0	0.0	0.3	0.5	0.0	0.0
Se	523	0.0	0.0	0.0	0.1	0.3	0.0	0.0
Si	523	0.0	1.4	9.3	14.9	23.8	10.2	30.5
Sm	523	0.0	0.0	0.0	0.1	0.5	0.0	0.0
Sn	523	0.0	0.0	1.6	5.3	9.3	2.4	7.3
Sr	523	0.0	0.0	0.0	0.2	0.7	0.0	0.0
Ta	523	0.0	0.0	0.0	0.7	1.3	0.0	0.0
Tb	523	0.0	0.0	0.0	0.3	0.6	0.0	0.0
Ti	523	0.0	0.0	0.1	0.4	0.8	0.1	0.2
V	523	0.0	0.0	0.0	0.1	0.2	0.0	0.0
W	523	0.0	0.0	0.6	1.3	2.1	0.8	2.5
Y	523	0.0	0.0	0.0	0.4	0.7	0.0	0.0
Zn	523	0.0	0.1	0.5	1.0	2.8	0.7	2.1
Zr	523	0.0	0.0	0.0	0.4	0.7	0.0	0.1

* Blank filter mass values are converted into concentrations by assuming a sample volume of 25.92 m³.

° Median{Abs[Each Value – Median(All Values)]}

Table 31. Element concentrations in PM$_{2.5}$ outdoor samples (10^{-3} μg/m³).

Element	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Outdoor Element Concentrations in PM$_{2.5}$ Sample Results.							
Ag	3110	0.0	0.0	0.0	0.1	0.2	0.1
Al	3110	0.9	1.8	2.9	4.2	6.2	2.4
As	3110	0.0	0.1	0.1	0.1	0.2	0.1
Au	3110	0.0	0.0	0.0	0.0	0.0	0.0
Ba	3110	0.2	0.3	0.6	1.0	1.8	1.0
Br	3110	0.2	0.3	0.4	0.5	0.6	0.2
Ca	3110	2.5	3.8	6.3	9.7	13.8	5.7
Cd	3110	0.0	0.0	0.0	0.2	0.3	0.2
Ce	3110	0.0	0.0	0.0	0.1	0.2	0.1
Cl	3110	0.0	0.0	0.0	0.0	1.7	7.0
Co	3110	0.0	0.0	0.0	0.0	0.1	0.1
Cr	3110	0.0	0.0	0.1	0.1	0.1	0.1
Cs	3110	0.0	0.0	0.0	0.1	0.2	0.1
Cu	3110	0.2	0.2	0.4	0.7	1.1	0.6
Eu	3110	0.0	0.0	0.0	0.1	0.2	0.1
Fe	3110	4.2	5.8	9.2	15.0	22.9	15.9
Ga	3110	0.0	0.0	0.0	0.0	0.1	0.0

Table 31. *(continued)*

Element	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Hf	3110	0.0	0.0	0.0	0.1	0.2	0.1
Hg	3110	0.0	0.0	0.0	0.0	0.1	0.0
In	3110	0.0	0.0	0.0	0.2	0.4	0.2
Ir	3110	0.0	0.0	0.0	0.1	0.1	0.1
K	3110	4.5	5.5	7.1	9.1	13.0	11.2
La	3110	0.0	0.0	0.0	0.1	0.2	0.1
Mg	3110	-0.9	0.0	0.9	2.9	4.2	2.1
Mn	3110	0.1	0.2	0.3	0.4	0.6	0.3
Mo	3110	0.0	0.0	0.0	0.1	0.2	0.1
Na	3110	0.0	0.0	0.0	0.0	11.7	9.4
Nb	3110	0.0	0.0	0.0	0.0	0.1	0.0
Ni	3110	0.0	0.0	0.1	0.2	0.4	0.5
P	3110	0.4	1.3	2.1	3.0	4.1	1.5
Pb	3110	0.1	0.2	0.3	0.5	0.6	0.7
Rb	3110	0.0	0.0	0.0	0.0	0.1	0.0
S	3110	58.1	80.2	110.1	153.4	216.4	64.2
Sb	3110	-0.1	-0.1	0.2	0.6	1.1	0.5
Sc	3110	0.0	0.0	0.0	0.0	0.0	11.5
Se	3110	0.0	0.1	0.1	0.1	0.2	0.1
Si	3110	4.7	6.4	9.2	13.4	19.0	7.6
Sm	3110	0.0	0.0	0.0	0.0	0.0	0.1
Sn	3110	-0.2	-0.1	0.1	0.5	0.8	0.4
Sr	3110	0.0	0.0	0.1	0.1	0.2	0.2
Ta	3110	0.0	0.0	0.0	0.1	0.1	0.1
Tb	3110	0.0	0.0	0.3	0.8	1.6	1.1
Ti	3110	0.2	0.3	0.4	0.7	1.0	0.4
V	3110	0.0	0.0	0.1	0.3	0.6	0.3
W	3110	-0.1	-0.1	0.0	0.0	0.1	0.1
Y	3110	0.0	0.0	0.0	0.0	0.1	0.0
Zn	3110	0.6	0.9	1.4	2.4	3.7	1.6
Zr	3110	0.0	0.0	0.1	0.1	0.2	0.1

8. Organic Carbon and Elemental Carbon Results

Quartz filters were deployed at fixed sites and outdoors at participants' homes.

8.1 Organic and Elemental Carbon Blank Correction

Most of MESA Air's blank corrections are obtained by calculating the median pollutant contamination level for the medium on which the pollutant is measured. Organic carbon has a different blank correction, since volitile organic compounds in the atmosphere adsorb onto the quartz filters. The amount of contamination by volitile organic compounds is expected to be linearly related to the concentration of organic carbon that is measured on the filter[7]. The default robust regression options in SAS were used to determine this relationship. Since a high proportion of the samples and duplicates deployed during the supplemental sampling campaign were paired with dynamic blanks, those samples were included in the calculations. Table 32, below, lists the counts of samples from each campaign that were included in the regression.

Table 32. Sources of sample-dynamic blank pairs used to determine blank correction.

| Study Area	Primary Samples	Supplemental Samples	Supplemental Duplicates	Total
Baltimore	50	9	3	62
Chicago	39	13	1	53
LA	17	11	3	31
Coastal	20	0	0	20
Riverside	16	9	3	28
NYC	18	8	0	26
Rockland	9	0	0	9
St. Paul	43	11	3	57
Winston-Salem	29	2	0	31
Total	241	63	13	317

All EC/OC samples, regardless of sampling campaign, were corrected by subtracting the expected dynamic blank concentration from the unadjusted sample concentration.

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7 Expected Dynamic Blank Concentration = Intercept + Slope * Unadjusted Sample Concentration
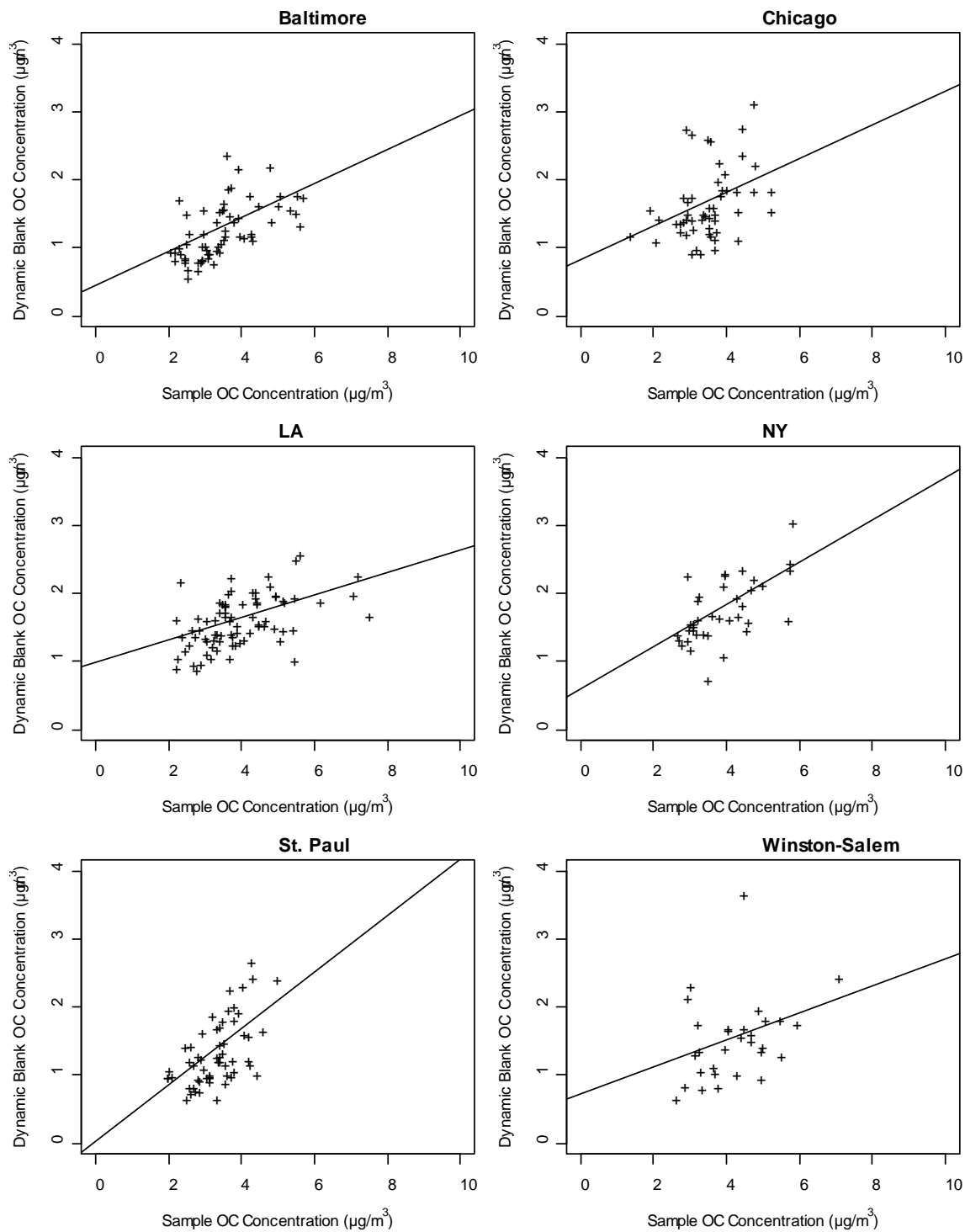
Figure 24. Linear regression of dynamic blank OC concentrations on sample OC concentrations.
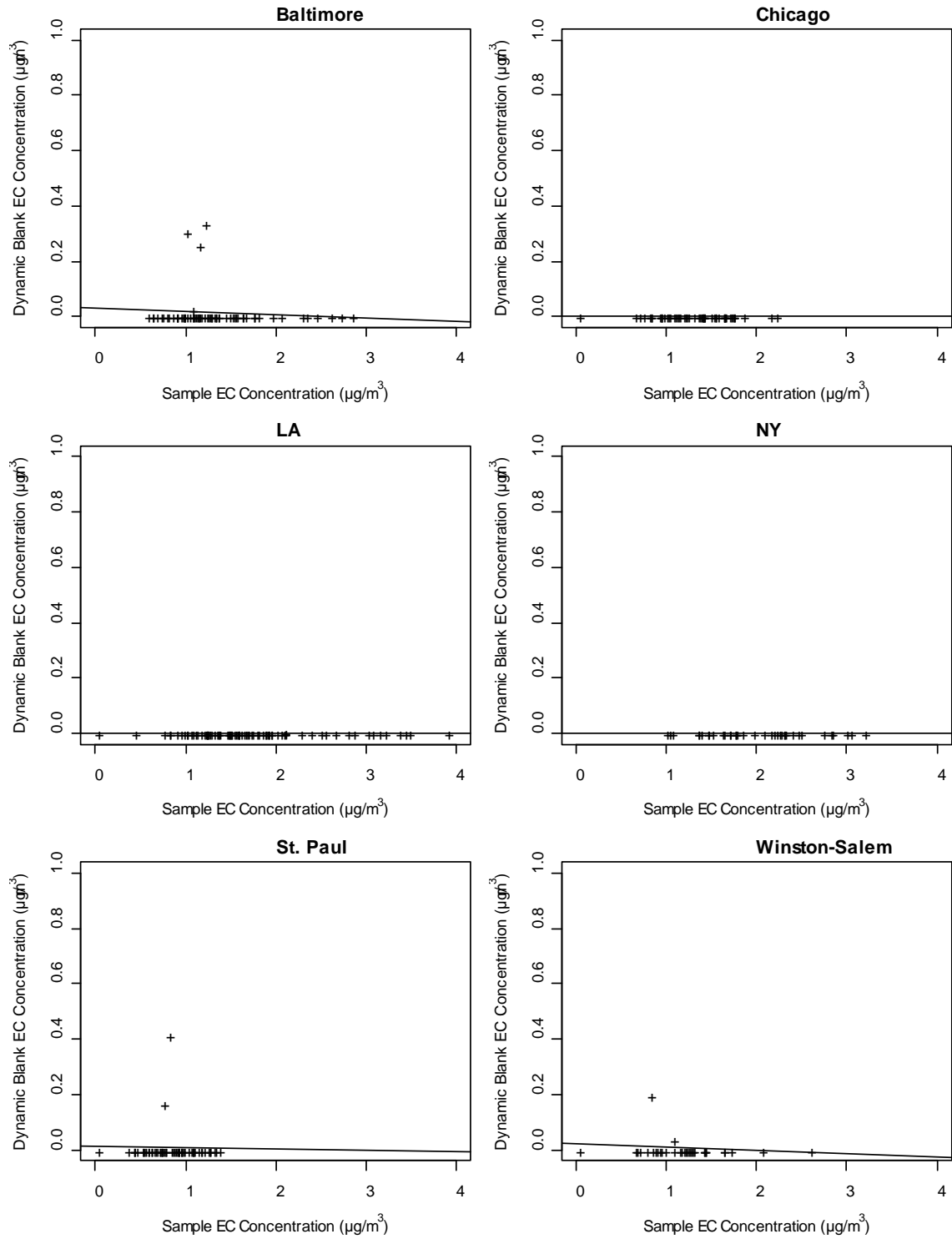
Figure 25. Linear regression of dynamic blank EC concentrations on sample EC concentrations.

Table 33. Organic carbon (OC) dynamic blank residuals ($10^{-1}\mu g/m^3$).

Field Center	N	Percentiles					Median Abs Dev*
		10th	25th	50th	75th	90th	
Estimated Organic Carbon Concentrations in Dynamic Blanks, by Field Center							
Baltimore	62	-2.8	-2.0	-0.6	2.2	5.2	2.8
Chicago	53	-4.5	-1.8	0.1	2.8	10.0	3.4
LA	79	-3.9	-2.3	-0.3	2.4	3.8	3.4
New York	35	-4.4	-1.9	0.0	1.3	4.8	2.3
St. Paul	57	-4.5	-2.7	-0.6	3.7	5.2	3.5
Winston-Salem	31	-4.0	-2.3	0.6	3.1	5.9	4.1

*Median{Abs[Each Value – Median(All Values)]}

Table 34. Elemental Carbon (EC) dynamic blank residuals ($10^{-5}\mu g/m^3$).

| Field Center	N	Percentiles					Median Abs Dev*
		10th	25th	50th	75th	90th	
Estimated Organic Carbon Concentrations in Dynamic Blanks, by Field Center							
Baltimore	62	-1.0	-0.4	0.2	1.1	6.3	1.0
Chicago	53	-1.0	-0.5	0.1	0.6	1.4	0.9
LA	79	-1.1	-0.6	-0.1	0.9	2.9	0.9
New York	35	-1.1	-0.7	0.2	0.6	1.2	0.8
St. Paul	57	-1.5	-0.5	0.0	0.6	1.7	0.9
Winston-Salem	31	-1.0	-0.6	0.2	0.4	1.1	0.8

*Median{Abs[Each Value – Median(All Values)]}

The dynamic field blanks were also used to calculate field center-specific limits of detection, defined as three times the prediction error[8] of the concentrations of the dynamic blanks based on the sample concentrations.

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[8] Prediction Error = $\sqrt{(\text{Standard Error of Prediction})^2 + (\text{Deviation of Residuals})^2}$. The standard error of the prediction represents the certainty with which the theoretical mean of all the dynamic blanks that could exist for that sample measurement has been estimated. The deviation of the residuals is calculated as the MAD of the residuals, such that MAD = Median{Abs[Each Value – Predicted Value]}.
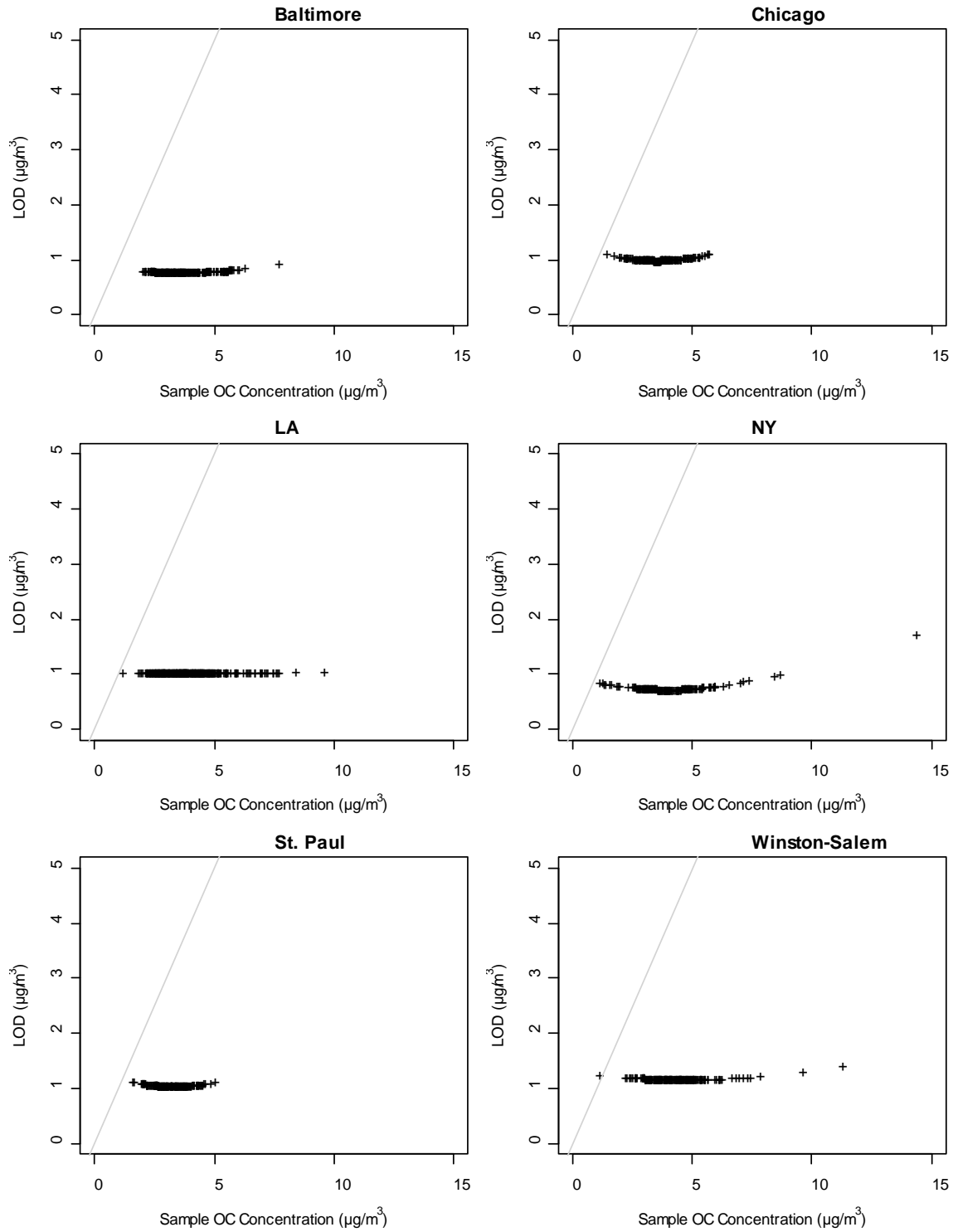
Figure 26. Limits of detection for OC sample measurments. Points to the left of the 1-1 line represent those measurements that are below the LOD.
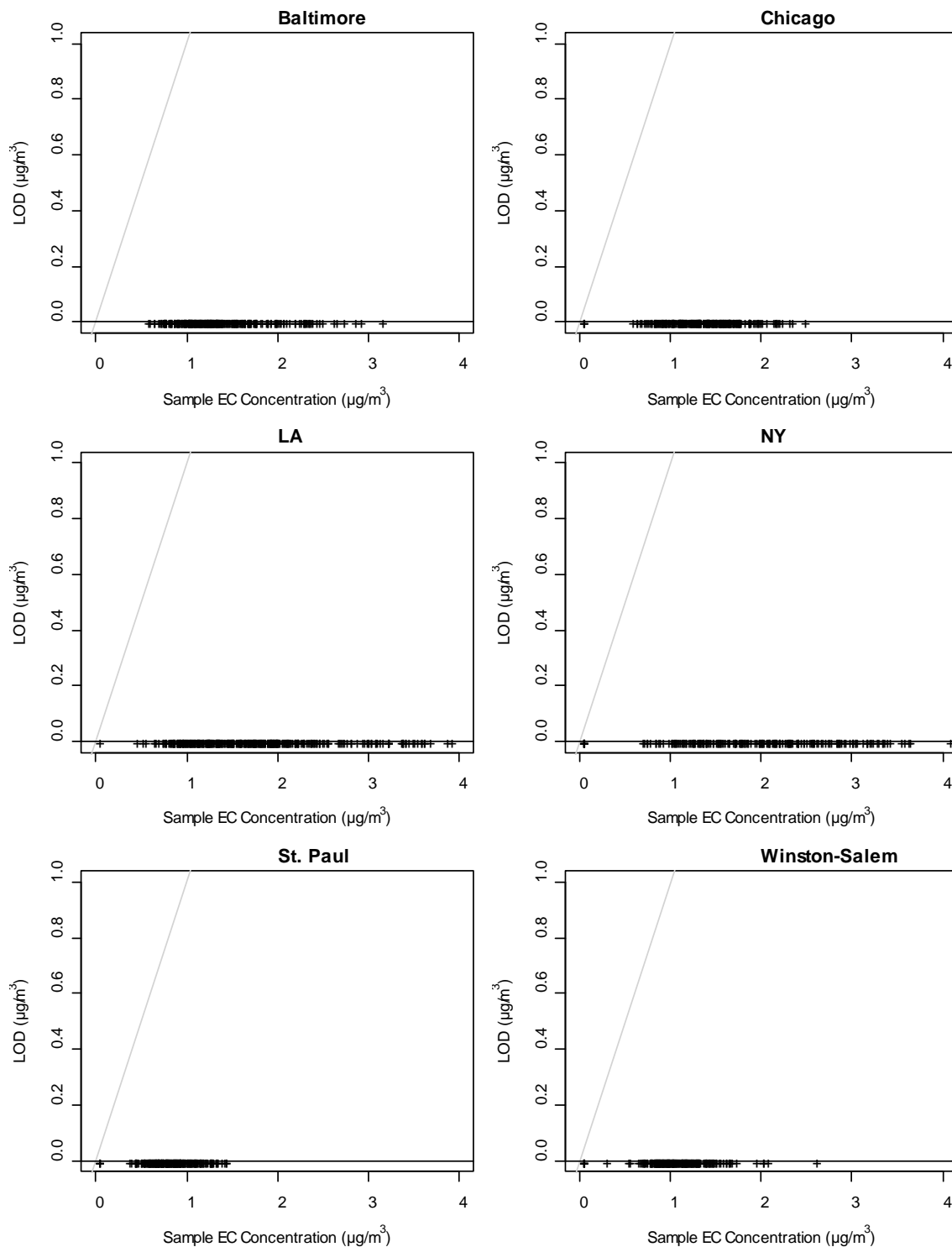
Figure 27. Limits of detection for EC sample measurments. Points to the left of the 1-1 line represent those measurements that are below the LOD.

Field technicians produced static field blanks as well as dynamic blanks. The static field blanks, like field blanks for Teflon filters, were assembled, disassembled, and shipped as samples were, but no air was drawn through them. The equivalent concentrations collected on these filters is

expected to be similar to the intercept for the linear relationship between the unadjusted sample concentration and the dynamic blank concentration, but drawing air through the dynamic blanks concentrations in ways that are not perfectly understood. Therefore, the static blank concentrations (based on a 10-day duration and 1.8 L/min air flow rate) are reported as a point of interest only. These concentrations are not used to determine any correction.

Table 35. Organic carbon concentration on static quartz filter field blanks ($\mu g/m^3$).

Field Center	N	Percentiles					Median Abs Dev*
		10th	25th	50th	75th	90th	
Estimated Organic Carbon Concentrations in Static Blanks, by Field Center							
Baltimore	34	0.9	1.1	1.5	1.7	2.0	0.3
Chicago	14	1.6	1.8	2.1	2.3	2.9	0.5
LA	32	0.5	0.6	1.0	1.6	2.1	0.7
New York	17	0.8	1.1	1.7	2.1	2.5	0.8
St. Paul	25	0.8	1.0	1.1	1.2	1.7	0.2
Winston-Salem	23	0.8	1.2	1.8	2.0	2.1	0.6

  *Median{Abs[Each Value – Median(All Values)]}

Table 36. Elemental carbon (EC) concentration on static quartz filter field blanks ($10^{-4}\mu g/m^3$).

| Field Center	N	Percentiles					Median Abs Dev*
		10th	25th	50th	75th	90th	
Estimated Elemental Carbon Concentrations in Static Blanks, by Field Center							
Baltimore	34	-1.6	-0.7	-0.2	0.6	2.7	1.1
Chicago	14	-3.1	-2.0	-1.0	0.0	1.7	1.5
LA	32	-1.1	-0.7	-0.3	0.3	1.8	0.7
New York	17	-4.3	-1.2	-0.3	0.0	0.6	1.0
St. Paul	25	-2.0	-1.5	-0.4	0.0	1.4	1.1
Winston-Salem	23	-2.4	-2.0	-0.6	0.0	0.9	1.1

  *Median{Abs[Each Value – Median(All Values)]}

8.2   Organic Carbon Sample Results

This section contains the organic carbon sample results, along with a summary of estimated air concentration (in $\mu g/m^3$) of field blanks, based on 10-day durations and a 1.8 L/min air flow rate. All sample concentrations were field blank-corrected and were calculated based on the actual sampling duration and meteorological conditions.

All boxplots and all calculations of standard deviations include all measurements, including those below the LOD.

Table 37. Organic carbon results ($10^{-1}\mu g/m^3$).

Study Area	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Outdoor Organic Carbon Sample Results, by Study Area.							
Baltimore	253	13.2	15.8	20.1	26.8	34.9	7.7
Chicago	246	10.8	14.2	18.1	21.7	27.3	6.2
LA	115	13.9	17.5	22.2	27.3	35.0	9.8
Coastal	111	8.1	10.3	13.3	19.8	28.7	8.4
Riverside	106	13.0	18.5	22.3	28.8	37.5	10.4
NYC	129	12.3	15.6	19.6	24.8	30.9	9.3
Rockland	56	11.2	13.1	15.7	19.7	27.5	7.1
St. Paul	207	12.7	14.2	17.3	19.9	22.2	3.9
Winston-Salem	201	17.2	20.5	25.4	30.6	35.2	7.6
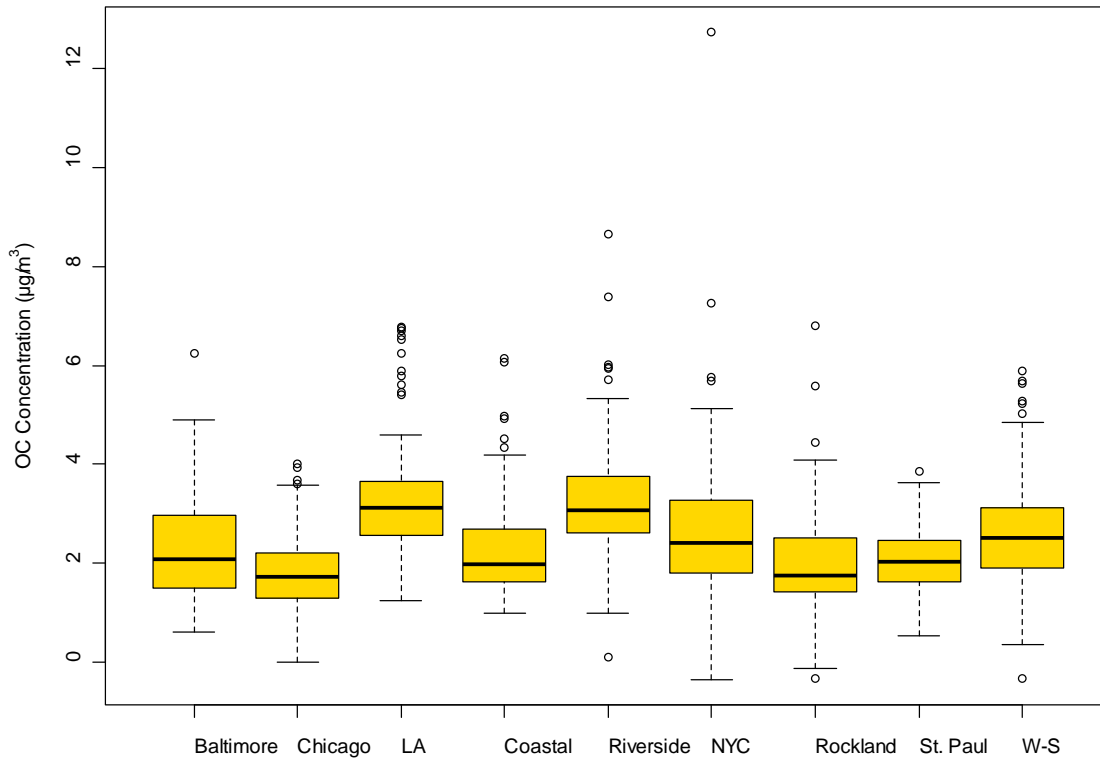
Figure 28. Boxplots of organic carbon in outdoor $PM_{2.5}$ sample results ($\mu g/m^3$) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.
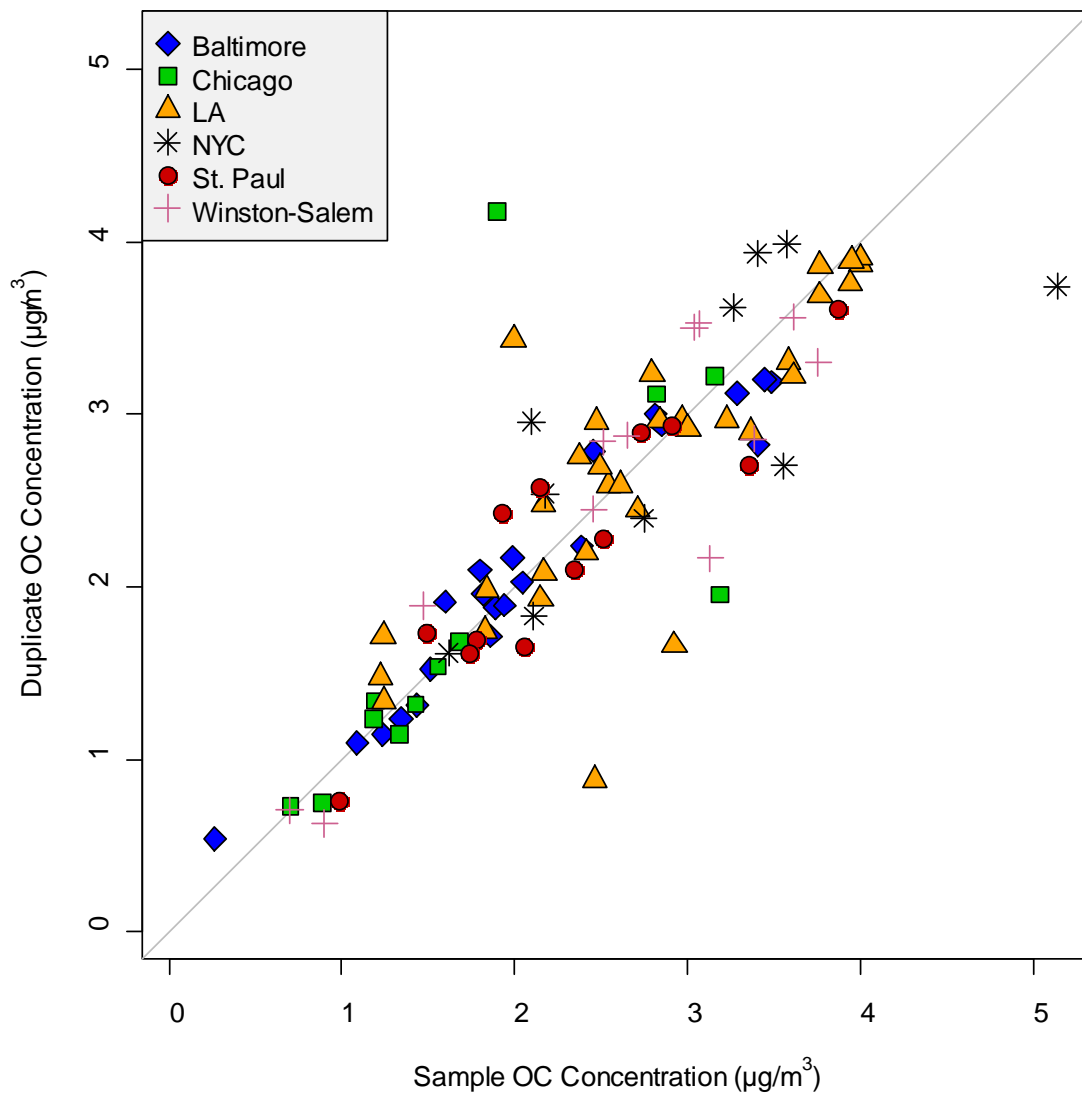
8.3 Organic Carbon Field Duplicate Results

Field duplicates were collected alongside 10% of samples. Precision is considered high when the average Relative Percent Difference (RPD)/$\sqrt{2}$ is less than 10%. Only pairs where both the sample and duplicate were valid are included.

Table 38. Organic carbon duplicate results (RPD/$\sqrt{2}$).

Field Center	N	Mean	Percentiles				
			10th	25th	50th	75th	90th
Baltimore	19	5.0	0.3	1.7	5.1	6.2	12.8
Chicago	8	8.8	0.7	2.4	6.3	9.4	33.8
LA	26	11.5	1.8	3.3	6.2	10.5	37.6
New York	10	12.1	3.7	7.7	10.1	19.3	23.2
St. Paul	10	7.7	1.9	4.1	6.0	10.8	16.6
Winston-Salem	12	10.5	0.8	3.4	9.5	14.8	24.8
Total	**85**	**9.3**	**0.7**	**3.3**	**6.3**	**10.6**	**22.2**

Across the study, the value of our indicator for precision was 9.7%. The relationship between sample and duplicate concentrations is shown graphically below.

Figure 29. Scatterplot of sample organic carbon concentrations against co-located duplicates. The overall R^2 is 0.74 and the RMSE is 0.49 µg/m^3.

8.4   Elemental Carbon Sample Results

Elemental carbon results are available for the sample samples that were analyzed for organic carbon. Blank corrections were determined as described in section 8.1.

Table 39. Elemental carbon results ($10^{-1}\mu g/m^3$).

Study Area	N	Percentiles					Std Dev
		10th	25th	50th	75th	90th	
Outdoor Elemental Carbon Sample Results, by Study Area.							
Baltimore	253	8.3	10.0	12.4	15.7	19.9	4.7
Chicago	246	8.4	10.5	12.8	15.5	18.2	3.9
LA	115	12.1	15.7	18.8	23.5	33.7	8.2
Coastal	111	8.0	9.2	11.7	15.4	22.5	6.9
Riverside	106	9.7	12.9	17.4	20.6	26.5	7.2
NYC	129	14.2	18.4	22.3	28.0	32.9	9.0
Rockland	56	7.1	9.8	12.1	14.3	16.6	4.7
St. Paul	207	4.9	6.2	7.8	9.6	11.5	2.6
Winston-Salem	201	7.4	8.5	10.1	12.0	13.8	2.9
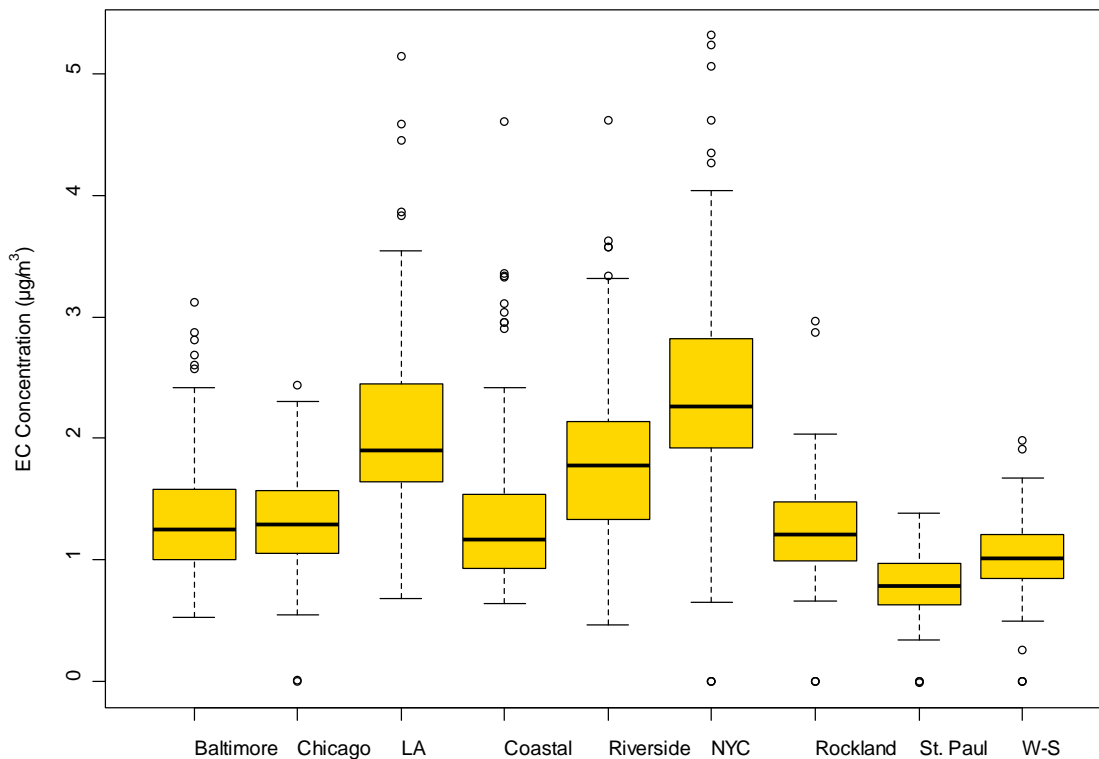
Figure 30. Boxplots of elemental carbon in outdoor $PM_{2.5}$ sample results ($\mu g/m^3$) by study area and season. Lower and upper ends of boxes demonstrate the 25th and 75th percentiles, respectively, and the black center lines represent the medians. The extent of the lines above and below the boxes represents the range of observations within 1.5 times the interquartile range above and below the median. Outliers beyond this range are shown as points.

8.5 Elemental Carbon Field Duplicate Results

Field duplicates were collected alongside 10% of samples. Precision is considered to be high when the average Relative Percent Difference (RPD)/$\sqrt{2}$ is less than 10%. Only pairs where both the sample and duplicate were valid are included.

Table 40. Elemental carbon duplicate results (RPD/$\sqrt{2}$%).

Field Center	N	Mean	Percentiles				
			10th	25th	50th	75th	90th
Baltimore	19	7.4	1.0	1.7	5.6	10.6	18.8
Chicago	8	7.2	0.7	1.7	5.8	13.6	15.0
LA	26	11.9	1.7	2.3	7.5	13.4	27.6
New York	10	13.6	0.7	4.6	11.2	19.9	32.8
St. Paul	10	7.6	0.5	1.3	5.0	10.2	20.8
Winston-Salem	12	39.2	0.9	1.9	4.8	11.2	204.3
Total	**85**	**14.0**	**0.9**	**2.0**	**6.1**	**12.8**	**25.9**

The mean value of the indicator of precision across the study was 14%. The relationship between sample and duplicate concentrations is shown below.
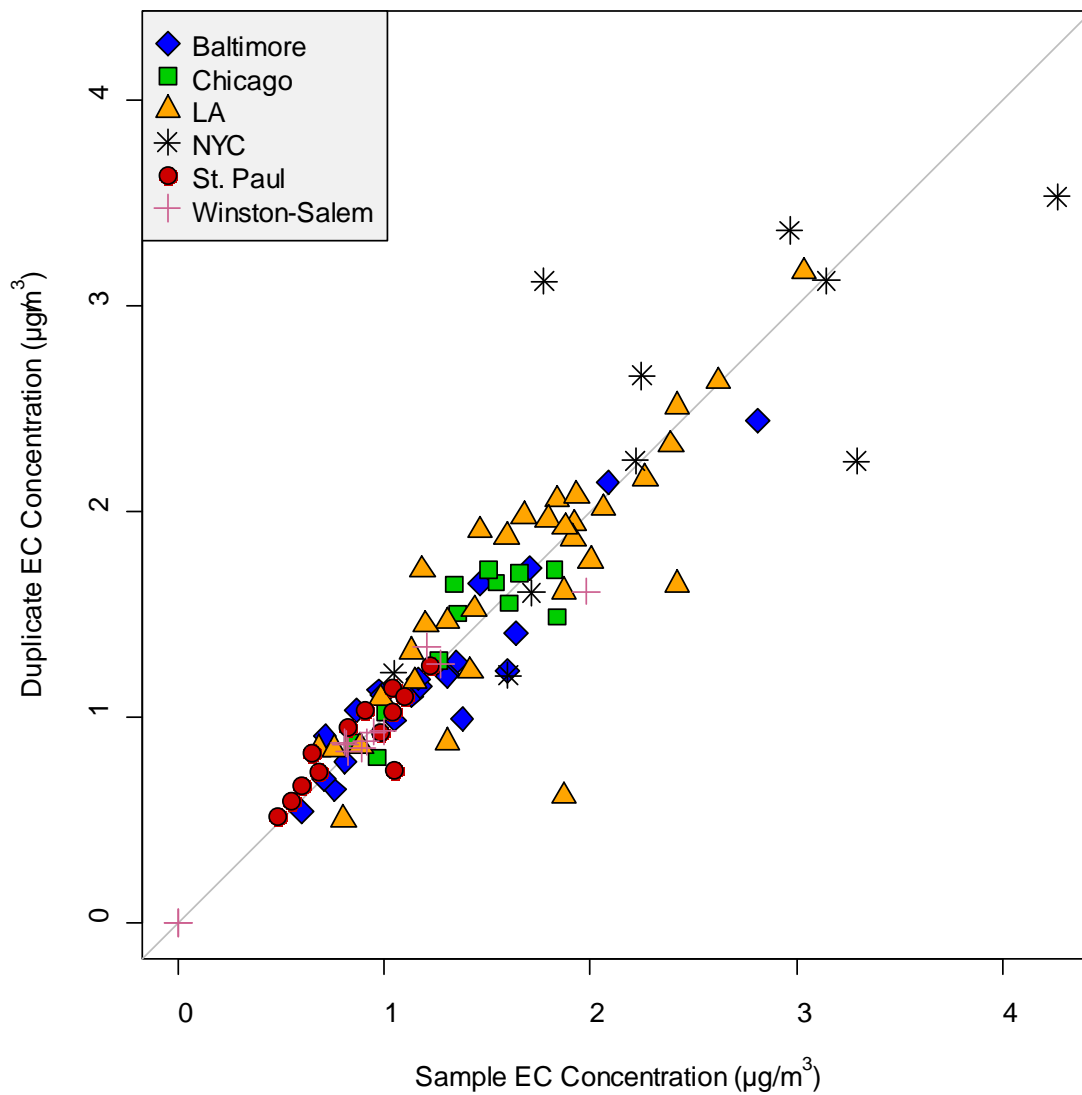
Figure 31. Scatterplot of sample elemental carbon concentrations against co-located duplicates. The overall R^2 is 0.83 and the RMSE is 0.30 $\mu g/m^3$.