Georgia Department of Natural Resources
Environmental Protection Division
2 Martin Luther King Jr. Drive, Suite 1456, Atlanta, Georgia 30334
Judson H. Turner, Director
(404) 656-4713

OCT 2 7 2014

Heather McTeer Toney
Regional Administrator
EPA Region 4
Atlanta Federal Center, 12th Floor
61 Forsyth Street, S.W.
Atlanta, Georgia 30303-8960

Subject: EPA's August 19, 2014 response to Georgia's designation recommendations for the 2012 $PM_{2.5}$ NAAQS

Dear Ms. Toney:

Thank you for the opportunity to comment on your August 19, 2014, letter responding to Georgia's designation recommendations for the 2012 primary annual fine particulate matter ($PM_{2.5}$) National Ambient Air Quality Standard (NAAQS). In your letter and the attached support documents, you stated your intentions to defer designations for five areas, designate three areas as "unclassifiable", and designate the remainder of the state as "unclassifiable/attainment". EPA's response differs from Georgia's recommendation for the five "deferred" areas and the three "unclassifiable" areas.

Deferred Areas

EPA has stated its intent to defer designations for the following five areas[1]:

Augusta Area: Richmond County, Columbia County, Aiken County (SC)
Columbus Area: Muscogee County, Russell County (AL)
Savannah Area: Chatham County, Effingham County
Valdosta Area: Lowndes County, Brooks County
Washington County Area: Washington County

EPD agrees with EPA's intentions to defer designations for the Georgia Counties in these areas under the authority of clause 107(d)(1)(B)(i) of the Clean Air Act. This provision allows the Administrator to extend designations for up to one year in the event that insufficient information is available to promulgate designations. Georgia EPD has committed to early certify 2014 ambient $PM_{2.5}$ data so that 2012-2014 design values can be used to designate these areas. EPD expects that all of these areas will have valid attaining design values following certification of this data.

EPD respectfully requests that Aiken County, South Carolina, and Russell County, Alabama, be designated "unclassifiable/attainment" since the $PM_{2.5}$ monitors in the South Carolina and Alabama portions of the Augusta and Columbus CBSA have valid attaining 2013 design values.

[1] EPA inadvertently included Dougherty County in the list of counties that would be deferred in the August 19, 2014, letter. The attached technical support document correctly includes Dougherty County as part of the Albany area.

Unclassifiable Areas

EPA has stated its intention to designate the following three areas as "unclassifiable":

Atlanta Area: Bartow County, Clayton County, Cobb County, Coweta County, DeKalb County, Fulton County, Gwinnett County, Cherokee County, Henry County, Forsyth County, Paulding County, Douglas County
Brunswick Area: Glynn County
Albany Area: Dougherty County

EPD respectfully requests that EPA defer designations for all of these counties for one full year as allowed by 107(d)(B)(i). The technical analysis for these unclassifiable areas states that EPA is not able to determine whether the counties with incomplete monitoring data are meeting or not meeting the NAAQS. 107(d)(B)(i) allows the Administrator to extend designations for up to one year if she has insufficient information to promulgate the designations. A full one-year extension will allow EPD time to prepare and submit additional information to help determine if the monitors in these areas are meeting or not meeting the NAAQS and whether nearby counties with incomplete data (following certification of 2014 data) are contributing to a violation of the NAAQS. Further justification for EPD's request is discussed below.

Albany Area

EPA's August 19, 2014, letter states that several areas, including Albany, had less than 50% data completeness for the first quarter of 2011 and therefore, do not meet the data handling requirements of 40 CFR 58, Appendix N, 4.1(c)(ii) for data substitution (i.e., data substitution test). However, this is incorrect for Albany. According to the attached AQS raw data report for the first quarter of 2011 (attached) there were 46 valid samples for January through March. The Albany monitor is a daily sample which had 90 sample days during this period. This results in a data completeness of (46/90 = 51%). All other quarters in 2011 through 2013 are above 50% as indicated in EPD's June 2, 2014, submittal. EPD did complete a data substitution test for the 2011-2013 Albany data, but it did not pass with a result of 13.89 $\mu g/m^3$. The results of the data substitution test was also included in the June 2, 2014 submittal. However, EPD has reason to believe that the Albany monitor will have valid, attaining data for 2012 to 2014 once the 2014 data is certified. The Albany monitor had incomplete data during first quarter, 2011, and second, third, and fourth quarter, 2012. A continuous Beta Attenuation Monitor (BAM) that meets EPA's Federal Equivalent Method (FEM) requirements has been operating since January, 2013. The FEM BAM helps to ensure that the Albany monitor meets the 75% quarterly data completeness requirement of 40 CFR 58 Appendix N. Once 2014 data is certified, the Albany monitor will have complete data for 2012 to 2014 except for second, third, and fourth quarter, 2012. All three incomplete 2012 quarters have date completeness exceeding 50% and will therefore be eligible for the data substitution test of Appendix N.

EPD has conducted analysis using 2012 and 2013 certified data, quality assured data for first and second quarter, 2014, and preliminary data for July and August, 2014. This analysis shows that the Albany monitor may have a valid, attaining 2012-2014 design value. A copy of this analysis is attached.

Furthermore, EPD has identified at least two days in July, 2014, where ambient $PM_{2.5}$ levels at the Albany monitor, among others, were influenced by an incursion of Saharan Dust brought about by the circulation of Hurricane Arthur. EPD expects to flag this data as exceptional events and submit documentation to justify excluding this data. If this data qualifies as an exceptional event, then it is important for EPD and EPA to complete the exceptional event analysis and approval prior to designations for the Albany area. This is because these high values, if not excluded as exceptional events, would be used in the data substitution test for the incomplete third quarter, 2012, and could result in an invalid design value over the NAAQS. (The highest 24-hour average value during third quarter in 2012 and 2013, was 20.8 $\mu g/m^3$ on 9/9/2013.)

Atlanta Area

EPA's August 16, 2014, letter indicates that 12 counties should be deemed unclassifiable due to PM2.5 monitoring sites in four counties (Fulton, Cobb, Gwinnett, and Paulding) having invalid design values for 2012 and a determination that the other eight counties have the potential to contribute to a violating monitor.

EPD believes that it is appropriate to defer designation of the Atlanta area for a full year for the following reasons.

- All of the monitors in the Atlanta CBSA, except for Atlanta - Fire Station #8, are expected to have valid, attaining design values following certification of the 2014 data.
- The Atlanta – Fire Station #8 would have a valid, attaining 2013 design value had it not been for an EPA audit of EPD's Ambient Monitoring Program. The EPA's Science and Ecosystem Support Division's Technical Systems Audit was conducted March 31-April 4, 2014, and final report issued May 5, 2014 (attached). As a result of this audit, approximately 1.75 months of $PM_{2.5}$ data in August, September, and October, 2012, was required to be removed from AQS for Fire Station #8 (pp. 24-25 of TSA report). This resulted in data completeness of less than 50% for third quarter, 2012. Since the Fire Station #8 2013 design value did not become invalid until after the TSA audit, EPD was not able to take this into consideration when submitting designation recommendations in December 13, 2013, or the revised recommendations submitted on May 30, 2014.
- EPA utilized their April 16, 2013, designation guidance for the 2012 PM2.5 NAAQS in determining which counties to include in the Atlanta Unclassifiable area. However, this guidance is intended to be used to identify areas that are violating or contributing to violations of the standard. There is no evidence of a violation of the $PM_{2.5}$ NAAQS in the Atlanta Area, only periods with incomplete data. In fact, data for valid quarters for 2011 through second quarter, 2014, indicate that all monitors in the Atlanta area are less than 12.0 $\mu g/m^3$. (See attached graph).

Deferring designations for the Atlanta area for a full year will allow EPD to prepare a comprehensive analysis to determine which, if any, counties should be included in an unclassifiable area. This would include additional analysis beyond that conducted by U.S. EPA as well as updated analysis based on more recent data than that use by EPA. This analysis may include the following:

- Use of 2012 to 2014 ambient air quality data in Factor 1: Air Quality data. Six of the seven monitors in the Atlanta area should have valid, attaining 2014 design values once the 2014 data is certified. EPD believes that this information will affect the analysis of Factor 1.
- EPD intends to conduct sensitivity modeling to quantify the amount that each county contributes to ambient $PM_{2.5}$ levels at the remaining invalid monitor, Fire Station #8.
- EPD conducted dispersion modeling to determine the effects of local sources to the $PM_{2.5}$ concentrations at Fire Station #8 as part of its Attainment Demonstration for the 1997 $PM_{2.5}$ NAAQS for the Atlanta area. This analysis can be found at http://www.georgiaair.org/airpermit/downloads/planningsupport/regdev/sips_and_revisions/atlanta_pm2.5/appendixm.pdf and could be included in a comprehensive analysis for the unclassifiable area. This work clearly shows that the elevated PM2.5 concentrations at FS#8 are coming from local sources as opposed to being transported from neighboring counties.
- Georgia Tech has conducted a monitoring and modeling study to characterize the impact of emissions from two rail yards adjacent to the Fire Station #8 monitor. Again, this work clearly shows that the elevated PM2.5 concentrations at FS#8 are coming from local sources as opposed to being transported from neighboring counties. See pp. 94-95 of the attached final report from that study.
- EPA developed wind roses from hourly observations of wind direction and speed from National Weather Service location. These wind roses were developed using all available data. EPD intends to analyze wind patterns using data only for days where the 24-hour average PM2.5 exceeded 15 $\mu g/m^3$.
- EPD intends to update emissions data used in Factor 2: Emissions and emissions-related data, to reflect recent significant changes in emissions from the 2011 data used by EPA. For example, one of the two coal-fired boilers at Georgia Power's Plant McDonough shut down in September 2011 and the second in January, 2012.

Early Certification of 2015 Data for Brunswick and Atlanta Areas

Following certification of 2014 ambient monitor data, only two monitors in Georgia, Brunswick and Atlanta – Fire Station #8 will have invalid design values. Both of these are due to the fact that the monitors do not qualify for the data substitution test due to having quarters below 50% data completeness (3rd quarter, 2012, for both Brunswick and Fire Station #8). All 2013 quarters and quality assured 2014 quarters had at least 50% data capture for both of these sites, thus making them eligible for the data substitution test. Because of measures established to increase data completeness for our entire $PM_{2.5}$ monitoring network, it is anticipated that both of these sites will have valid, attaining 2015 design values. If EPA were to defer attainment for Brunswick and Atlanta for a full year, designations would occur in December, 2015, and would become effective sometime in 2016. This should provide sufficient time for EPD to early certify 2015 data before designations become effective and allow EPA to classify both the Brunswick and Atlanta areas as attainment.

In summary, EPD requests that EPA defer designations for the Albany, Atlanta, and Brunswick areas for a full year as allowed under 107(d)(B)(i) of the Clean Air Act to allow for the use of more recent ambient monitoring data, provide EPD with an opportunity to complete a thorough analysis of areas potentially contributing to invalid monitors in the Atlanta area, and to allow for flagging and documentation of an exceptional event that would otherwise affect validity of 2014 design value for Albany. EPD also respectfully requests that the non-Georgia counties associated with the Augusta and Columbus areas be designated attainment.

If you have any questions or need more information, please contact Jimmy Johnston at (404) 363-7014 or via email at jimmy.johnston@dnr.state.ga.us.

Sincerely,

Judson H. Turner
Director

Attachments:
AQS Raw Data Report for Albany first quarter, 2011
Albany preliminary data substitution analysis
TSA report
2008-2014 PM2.5 Concentrations by Quarter in Atlanta CSA
Characterizing the Emissions of Fine Particulate Matter in the Vicinity of a Rail Yard - Final Report

c: Keith Bentley
Scott Davis, EPA Region 4
Lynorae Benjamin, EPA Region 4
Ron Gore, Alabama Department of Environmental Management
Myra Reece, South Carolina Department of Health & Environmental Control

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

User ID: JJJ

RAW DATA REPORT

Report Request ID: 1254646 Report Code: AMP350 Sep. 26, 2014

GEOGRAPHIC SELECTIONS

Tribal Code	State	County	Site	Parameter	POC	City	AQCR	UAR	CBSA	CSA	EPA Region
	13	095		88101							

PROTOCOL SELECTIONS

Parameter Classification	Parameter	Method	Duration
CRITERIA			

SELECTED OPTIONS

Option Type	Option Value
RAW DATA EVENTS	INCLUDE EVENTS
DAILY STATISTICS	MAXIMUM
UNITS	STANDARD
MERGE PDF FILES	YES
INCLUDE NULLS	YES
AGENCY ROLE	PQAO

SORT ORDER

Order	Column
1	STATE_CODE
2	COUNTY_CODE
3	SITE_ID
4	PARAMETER_CODE
5	POC

DATE CRITERIA

Start Date	End Date
2011 01 01	2011 03 31

APPLICABLE STANDARDS

Standard Description
CO 1-hour 1971
Lead 3-Month 2009
Lead 3-Month PM10 Surrogate 2009
Lead Quarterly 1978
NO2 Annual 1971
Ozone 1-hour Daily 2005
PM10 24-hour 2006
PM25 Annual 2013
SO2 1-hour 2010

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
AIR QUALITY SYSTEM
RAW DATA REPORT

Sep. 26, 2014

(88101) PM2.5 - Local Conditions

SITE ID: 13-095-0007 POC: 1
COUNTY: (095) Dougherty
CITY: (01052) Albany
SITE ADDRESS: Turner Elementary School, 2001 Leonard Ave, Albany, Georgia, 31705
SITE COMMENTS:
MONITOR COMMENTS:

STATE: (13) Georgia
AQCR: (059) SOUTHWEST GEORGIA
URBANIZED AREA: (0120) ALBANY, GA
LAND USE: RESIDENTIAL
LOCATION SETTING: SUBURBAN

CAS NUMBER:
LATITUDE: 31.5769170008
LONGITUDE: -84.100194
UTM ZONE:
UTM NORTHING:
UTM EASTING:
ELEVATION-MSL: 67
PROBE HEIGHT: 6

SUPPORT AGENCY: (0437) Georgia Air Protection Branch Ambient Monitoring Program
MONITOR TYPE: SLAMS
COLLECTION AND ANALYSIS METHOD: (120) Andersen RAAS2.5-300 PM2.5 SEQ w/WINS
POAO: (0437) Georgia Air Protection Branch Ambient Monitoring Program

REPORT FOR: 2011

DURATION: 24 HOUR
UNITS: Micrograms/cubic meter (LC)
MIN DETECTABLE: 2

Day	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
1	6.0	AR	7.8									
2	3.2	AR	18.2									
3	8.3	AR	19.9									
4	AN	AR	9.7									
5	14.6	AR	7.6									
6	8.5	AR	4.4									
7	6.2	AR	12.2									
8	5.3	AR	12.5									
9	4.5	AR	6.3									
10	4.7	AR	6.6									
11	AG	AR	11.2									
12	9.0	AR	25.7									
13	20.1	AR	19.9									
14	AR	AR	18.2									
15	AR	AR	12.7									
16	AR	AR	16.7									
17	AR	AR	20.8									
18	AN	AR	36.8 rl									
19	AN	AR	32.6									
20	AL	AR	29.1									
21	AR	AR	20.1									
22	AR	AR	18.6									
23	AR	AR	13.1									
24	AR	AR	10.3									
25	AR	9.1	11.5									
26	AR	14.8	18.6									
27	AR	19.3	8.1									
28	AR	9.3	4.8									
29	AR		8.8									
30	AR		8.3									
31	AR		6.4									
NO.:	11	4	31	0	0	0	0	0	0	0	0	0
MAX:	20.1	19.3	36.8									
MEAN:	8.22	13.13	15.02									

ANNUAL OBSERVATIONS: 46 ANNUAL MEAN: 13.23 ANNUAL MAX: 36.8

Note: Qualifier codes with regional concurrence are shown in upper case, and those without regional review are shown in lower case. An asterisk (***) indicates that the region has reviewed the value and does not concur with the qualifier.

QUALIFIER CODES:

Qualifier Code	Qualifier Description	Qualifier Type
AG	Sample Time out of Limits	NULL
AL	Voided by Operator	NULL
AN	Machine Malfunction	NULL
AR	Lab Error	NULL
rl	Other	REQEXC

Note: Qualifier codes with regional concurrence are shown in upper case, and those without regional concurrence are shown in lower case.

Preliminary Data Substitution Analysis
Albany, Georgia Monitor

Georgia EPD has conducted a preliminary data substation analysis for the Albany, Georgia, $PM_{2.5}$ monitor to determine if this site is likely to have an attaining, valid 2014 design value. This was done using certified data from 2012 and 2013, quality assured data for first and second quarter, 2014, and preliminary data from July and August, 2014.

The annual arithmetic mean values for 2012 and 2013 are 10.64 and 10.14 $\mu g/m^3$, respectively. The quarterly averages for first and second quarter, 2014, are 9.83 and 10.94 $\mu g/m^3$, respectively. The preliminary average for third quarter, 2014, using only July and Augusta data is 10.97 $\mu g/m^3$. EPD averaged first and second quarter, 2014, together with the average of the July and August data to get a "preliminary" value of 10.58 $\mu g/m^3$. EPD assumed that the 2014 annual arithmetic mean will remain at this level. It is very likely that the final 2014 average will be less than 10.58 $\mu g/m^3$ since September through December typically has low $PM_{2.5}$ levels. EPD averaged the 2012 and 2013 annual means with the preliminary 2014 design value. [(10.64 + 10.14 + 10.58)/3 = 10.45 $\mu g/m^3$.] This value is well below the 2012 $PM_{2.5}$ NAAQS of 12.0 $\mu g/m^3$. Thus, it is very likely that the Albany monitor will have an attaining 2014 design value.

There were three quarters in 2012 that did not meet the required 75% data criteria[1]. They were second, third, and fourth quarter, 2012. Data completeness for these three quarters was 60%, 57%, and 64%. The Maximum Data Substitution Test of 40 CFR 58, Appendix N was then applied. EPD used the maximum daily value for each quarter using data from 2012, 2013, and 2014 to date. The values used in the data substitution were:

Quarter 2: 34.6 $\mu g/m^3$, 4/1/2014
Quarter 3: 21.6 $\mu g/m^3$, 7/1/2014
Quarter 4: 25.7 $\mu g/m^3$, 12/19/2013

In selecting the days to use for substitution, EPD assumed that a high value observed on July 2, 2014, is excluded as an exceptional event. EPD intends to flag this day as an exceptional event due to an incursion of Saharan dust brought about by circulating winds form Hurricane Arthur.

The result of the data substitution test was 12.15 $\mu g/m^3$, which would slightly over the value needed to pass the test. EPD then calculated what 4th quarter, 2014, average would be necessary in order to pass the data substitution test. (This assumes that the 3rd quarter, 2014, value remains at 10.97 $\mu g/m^3$, which is a conservative assumption.) The 4th quarter, 2014, average needed to pass the data substitution test is 9.88 $\mu g/m^3$. A value this low could reasonably be assumed to occur since these months typically have low $PM_{2.5}$ values. It should be noted that 4th quarter, 2013, had an average of 9.44 $\mu g/m^3$.

[1] A continuous FEM monitor began operating at the Albany site at the beginning of January, 2013. Therefore, this site has met EPA's data completeness criteria since then and should continue to do so.

Lastly, EPD conducted a data substitution WITHOUT the assumption that the July 2, 2014, event is determined to qualify as an exceptional event. This resulted in a value of 12.82 $\mu g/m^3$, which would result in an invalid design value. EPD calculated, in a manner similar to above, that the 4th quarter average would need to be 1.88 $\mu g/m^3$, a value that is not attainable. Therefore, in order for the Albany monitor to have a chance of having a valid 2014 design value, it is critical that the July, 2014, exceptional event be flagged and documented by EPD and approved by EPA.

	Observation Site	Q1 2012 Conc.	% comp	Q2 2012 Conc.	% comp	Q3 2012 Conc.	% comp	Q4 2012 Conc.	% comp	Annual 2012 Average	Q1 2013 Conc.	% comp	Q2 2013 Conc.	% comp	Q3 2013 Conc.	% comp	Q4 2013 Conc.	% comp	Annual 2013 Average	Q1 2014 Conc.	% comp	Q2 2014 Conc.	% comp	Q3 2014 Conc. Thru Aug	Q4 2014 conc. required to pass Max result Sub Assuming current 2012-14 concentration
Data Substitution Test with July, 2014, Exceptional Events Excluded																									
EXCEV	Albany-Turner Elementary	12.67	0.86	19.46	0.60	14.21	0.57	16.62	0.64	15.74	12.97	1.00	9.35	0.99	8.80	1.00	9.44	1.00	10.14	9.83	0.94	10.94	0.99	10.97	9.88
Data Substitution Test with July, 2014, Exceptional Events NOT Excluded																									
NOEXCE	Albany-Turner Elementary	12.67	0.86	19.46	0.60	21.64	0.57	16.62	0.64	17.60	12.97	1.00	9.35	0.99	8.80	1.00	9.44	1.00	10.14	9.83	0.94	10.94	0.99	11.43	9.88

Maximum Substitution Applied

COMMENTS: Assuming Albany, 3rd quarter, 2014 remains at 10.97, it would need 9.88 or lower in the 4th quarter to pass the 2012-2014 substitution test.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4

Science and Ecosystem Support Division
Enforcement and Investigations Branch
980 College Station Road
Athens, Georgia 30605-2720

May 5, 2014

Mr. Keith Bentley
Environmental Protection Division
Georgia Dept of Natural Resources
4244 International Parkway, Suite 120
Atlanta, Georgia 30354

SESD Project ID: 14-0160

Dear Mr. Bentley:

This letter is to forward you the final report concerning the 2014 Technical System Audit (TSA) for your agency. On March 31 – April 4, 2014 Douglas Jager, Richard Guillot, Ray Terhune, and Michael Roberts with EPA Region 4's Science and Ecosystem Support Division (SESD) conducted a TSA of the Georgia Environmental Protection Division's ambient air monitoring program. The data collection period covered by this audit was from January 2011 through December 2013. The Technical System Audit Questionnaire, Air Quality System data reports, and the previous TSA reports were used in conducting the audit. The Technical System Audit Questionnaire that was completed by your staff is included as an appendix of the attached 2014 TSA.

I appreciate your agency's participation in the audit as well as your resolve to rapidly address the issues that were identified. The TSA report requires additional data validation and subsequent corrections to EPA's Air Quality System (AQS) database. These deliverables to the EPA are outlined in Section 4 of the attached TSA report. EPA Region 4 is requesting your agency develop a plan to address the issues identified in Section 4 of this TSA report and respond back to SESD by June 17, 2014. Please contact SESD if this date needs to be amended. If you have any questions regarding the attached audit report, please call Doug Jager of my staff at (706) 355-8618.

Sincerely,

Laura Ackerman, Chief,
Superfund and Air Section

cc: list provided on back of this page

cc (by email):	Susan Zimmer-Dauphine, GA-EPD	w/attachment
	David Jones, GA-EPD	w/attachment
	Gregg Worley, APTMD	w/attachment
	Todd Rinck, APTMD	w/attachment
	Lynorae Benjamin, APTMD	w/attachment
	Scott Davis, APTMD	w/attachment

United States Environmental Protection Agency
Region 4
Science and Ecosystem Support Division
980 College Station Road
Athens, Georgia 30605-2720

2014 Technical System Audit Report

Georgia Environmental Protection Division
Ambient Air Monitoring Program and Laboratory

Atlanta, GA
Audit Conducted March 31-April 04, 2014

SESD Project Identification Number: 14-0160

Requestor: Gregg Worley
U.S. EPA R4/APTMD/MTSB
61 Forsyth St. SW
Atlanta, Georgia 30303-8960

Project Leader: Douglas Jager
U.S. EPA R4/SESD/EIB/SAS
980 College Station Road
Athens, Georgia 30605-2720

Title and Approval Sheet

Title: 2014 Technical System Audit Report - Georgia Environmental Protection Division

FINAL REPORT

Approving Official:

Laura Ackerman, Chief
Superfund and Air Section
Enforcement Investigations Branch

05/05/14
Date

SESD Project Leader:

Douglas Jager, Environmental Scientist
Superfund and Air Section
Enforcement Investigations Branch

5/5/2014
Date

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1. Executive Summary

The Environmental Protection Agency (EPA) Region 4 Science and Ecosystem Support Division (SESD) conducted a Technical System Audit (TSA) of the Georgia Environmental Protection Division's (EPD) ambient air monitoring program during April 2014. The purpose of this TSA was to evaluate the current operation and performance of the EPD Air Protection Branch's Ambient Monitoring Program (AMP) as well as those functions in the EPD Laboratory that pertain to the ambient air monitoring program. The results of this audit indicate that the overall ambient air monitoring program is well documented and the personnel interviewed are knowledgeable with their respective roles and duties.

Documentation, proficiency with field instrumentation, data collection and analysis all appear to be areas where the EPD excels. The primary concern noted during this audit is the data validation performed by the EPD's AMP has not been sufficiently rigorous to demonstrate that the ambient air data in AQS is appropriately quality assured. As such, EPA Region 4 SESD is requiring the EPD's AMP to perform additional data validation to demonstrate that the data residing in AQS is accurate, representative, and defensible. This ambient air data must undergo a more rigorous data validation before it can be used for regulatory decision making purposes. Details of the additional data validation that are required by EPA Region 4 SESD can be found in Section 4 of this TSA report.

Another area of concern noted was the high turnover rate of staff at the entry level coupled with a lack of operational detail that is available in the AMP SOPs. At the time of this EPA Region 4 audit eight positions in the AMP were unfilled. While all of the personnel interviewed during this TSA appeared competent and knowledgeable, it is the opinion of the EPA Region 4 auditor that the EPD is highly dependent on senior staff and managers to successfully implement the ambient monitoring program. Many of these key staff and mangers are either currently eligible to retire or will be eligible to retire before the next TSA in 2017. Because EPD is not retaining a sufficient number of junior personnel that it has trained and because there is a lack of operational detail provided in the SOPs, when these key staff and managers retire the institutional knowledge that EPD is relying upon to run their program will no longer exist. The EPD should initiate training and succession planning in anticipation of these retirements. Failure to adequately implement this training and succession planning could easily result in the degradation of the quality of data currently being produced by the EPD ambient air monitoring program.

2. Introduction

EPA Region 4's SESD conducted a TSA the week of March 31 – April 4, 2014 on the Georgia EPD AMP. Ambient air monitoring stations were also visited on April 22, 2014 in the cities of Macon and Savannah to assess adherence to EPA siting criteria found in *40 CFR Part 58 Appendix E*. The audit also assessed EPD's Laboratory with respect to the ambient air samples collected by EPD for analytical and gravimetric analysis. The purpose of this audit was to assess the EPD's compliance with established regulations governing the collection, analysis, validation and reporting of ambient air quality data. TSA's are required by EPA regulations at least every 3 years as specified in *40 CFR Part 58 Appendix A, §2.5*. Data reviewed for this TSA included the 2011-2013 monitoring years. Data were queried from EPA's Air Quality System (AQS) database prior to the on-site audit. SESD's Ambient Air Monitoring Technical Systems Audit Form was completed by the AMP prior to the audit and is included as Appendix C of this report.

Due to time and resource constraints, this 2014 TSA focused on the field measurements used to quantify the criteria pollutant concentrations used for demonstrating compliance with the National Ambient Air Quality Standards (NAAQS). As such, this TSA did not focus on a review of the meteorological measurements, field measurements for Photochemical Assessment Monitoring Stations (PAMS), National Air Toxics Trends Stations (NATTS), and Particulate Matter (PM) Course measurements.

The Georgia EPD Laboratory program performs the analytical analysis for the PAMS, NATTS, and ambient air lead (Pb) samples. The SESD auditor for this analytical work was Ray Terhune (EPA Region 4 SESD) and the findings from that portion of the TSA will be issued in a separate audit report. Some findings pertaining to the analytical analysis of ambient air Pb samples used for NAAQS decision making is addressed in these audit findings.

The following personnel were interviewed during the TSA.

Ambient Monitoring Program (AMP)	Georgia EPD Laboratory Program
Susan Zimmer-Dauphine, Program Manager	David M. Jones, Laboratory Program Director
Ops 1 Unit Manager (Not interviewed - VACANT)	Phillip G. Mitchell, Quality Assurance Manager
Ken Buckley, Ops 2 Unit Manager	Tamiko Rivers, Laboratory Manager
Alex Yang, Quality Assurance Unit Manager	
Janet Aldredge-Byars, Data Analysis Unit Manager	
Victor Barr, Environmental Specialist	
Javier Sayago, Environmental Specialist	
Pooja Sharma, Environmental Specialist	
Cathryn Lee, Environmental Specialist	

The following monitoring sites were visited during the audit on April 22, 2014:

Macon Southeast	AQS# 13-021-0012
Savannah Mercer Middle	AQS# 13-051-0091
Savannah L&A	AQS# 13-051-1002
Savannah East President St.	AQS# 13-051-0021

The following AQS reports were reviewed in preparation for this TSA:

AMP 246:	Precision Report (2011-2013)
AMP 247:	Accuracy Report (2011-2013)
AMP 300:	Violation Day Count Report (2011-2013)
AMP 350:	Raw Data Report (2011-2013)
AMP 350MX:	Raw Data Report (SO_2 2011-2013)
AMP 430:	Data Completeness Report Annual (2011-2013)
AMP 480:	Design Value Report (2011-2013)
AMP 450:	Quicklook Criteria Parameters (2011-2013)
AMP 600:	Certification Evaluation and Concurrence (2011-2013)
AMP 504:	Extract QA Data (2011-2013)
AMP 503:	Extract Sample Blank Data (2011-2013)
AMP 502:	Extract P/A Data (for Pb-14129) (2011-2013)

3. Commendations

All staff interviewed by the EPA Region 4 SESD auditors appeared proficient in and knowledgeable of their roles and duties. The technical expertise demonstrated by field personnel in operating, maintaining, and calibrating their instrumentation was also evident. All certifications requested from the EPD Laboratory for the 2011-2013 timeframe were easily located and provided to EPA upon request. All certifications requested from the EPD's AMP were also all available and easily provided to the EPA auditors. The EPD Laboratory has been successful in addressing the findings from the previous TSA reports and has also been very helpful in assisting in providing and analyzing electronic datasets needed for this TSA report. Through the evaluation of EPD data and records the AMP's field staff demonstrated their technical abilities throughout the course of the audit. Additionally, the AMP's ability to not only capture and graph minute data for quality control assessments from their continuous gaseous analyzers, but also capture this minute data from the calibrators performing the calibrations and precision checks, is a quality system functionality that most other monitoring agencies in Region 4 have yet to begin employing routinely.

4. Findings and Recommendations

The observations and findings during the TSA are compared to the requirements and acceptance criteria located in validation templates found within the *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume 2, Ambient Air Quality Monitoring Program, Appendix D, May 2013* (*QA Handbook*). The criteria in the validation templates are from *40 CFR Part 50 Appendices*, *40 CFR Part 58 Appendix A and C and E*, *EPA Methods 2.11 and 2.12*, and from workgroup recommendations or guidance documents. The following internet address hyperlink should direct the reader to the most recent version of the *QA Handbook* and the validation template tables within:

http://www.epa.gov/ttn/amtic/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf

Corrective action recommendations are offered in this audit report that may help prevent future occurrences of the same problem or similar problems. Corrective action recommendations are based upon the *QA Handbook*, regulations, guidance documents, SOPs, instrument manuals, and professional judgment.

Data recommendations are also presented in this audit report. Appendix D of the *QA Handbook* contains recommended actions regarding the validity and usefulness of data that may have been affected by quality control or quality assurance issues. Paragraphs from the *QA Handbook* that describe the data handling criteria are quoted below:

Criteria that were deemed critical to maintaining the integrity of a sample or group of samples were placed in the first table (Critical Criteria Table). Observations that do not meet each and every criterion on the **Critical Criteria** table should be invalidated unless there are compelling reasons and justifications for not doing so. Basically, the sample or group of samples for which one or more of these criteria are not met is invalid until proven otherwise. The cause of not operating in the acceptable range for each and every violated criterion must be investigated and minimized to reduce the likelihood that additional samples will be invalidated.

Criteria that are important for maintaining and evaluating the quality of the data collection system are included in the second table, the **Operational Criteria.** Violation of a criterion or a number of criteria may be cause for invalidation. The decision maker should consider other quality control information that may or may not indicate the data are acceptable for the parameter being controlled. Therefore, the sample or group of samples for which one or more of these criteria are not met is suspect unless other quality control information demonstrates otherwise. The reason for not meeting the criteria must be investigated, mitigated, or justified.

Those criteria which are important for the correct interpretation of the data but do not usually impact the validity of a sample or group of samples are included on the third table, the **Systematic Criteria.** The data quality objectives are included in this table. If the data quality objectives are not met, this does not invalidate any of the samples but it may impact the error rate associated with the attainment/non-attainment decisions (*QA Handbook Appendix D*).

Some findings and recommendations based on the EPA regulations and the above mentioned critical, operational, and systematic criteria may result in data that currently resides in AQS needing to be invalidated or flagged with appropriate AQS quality assurance qualifier flags. Some data may be found to be invalidated improperly and the measurement results will need to be resubmitted to AQS. In these cases, the TSA report will state the "Data Deliverables" that will be required for AQS and/or submitted to EPA Region 4 SESD to address the findings and recommendations.

4.1 FIELD OPERATIONS

Overall, the field operations of the AMP were found to be satisfactory and are meeting EPA regulatory requirements. For the continuous gas analyzers [Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), and Ozone (O_3)], the automated zero/span/precision-checks are occurring at a frequency of once per week (twice the regulatory minimums). AMP staff are proactive and technically proficient with instrument maintenance and repair. When instrument failures do occur, staff promptly repair or replace, and calibrate the instrumentation prior to the subsequent data collection. As a result, data capture is high. For the manual samplers [Federal Reference Method (FRM) Particulate Matter 2.5µm and smaller ($PM_{2.5}$), FRM Particulate Matter 10µm and smaller (PM_{10}), and Pb], review of AMP records and data retrieved from EPA's AQS database demonstrated that the required regulatory monthly flow verifications are occurring at the appropriate frequencies and when the samplers fail these or other operational checks, AMP staff quickly repair or replace, and calibrate the instrumentation prior to the subsequent data collection.

Some occurrences have been found, however, where EPA critical, operational, and systematic criteria have not been achieved. Below are the TSA findings pertaining to field operations.

Finding 4.1.1:

The field Standard Operating Procedures (SOP)s that were examined as part of this TSA were found to lack sufficient detail for the operation of the ambient air analyzers and samplers utilized by the AMP.

Discussion:

The AMP field staff have demonstrated that they effectively operate and maintain the analyzers and samplers used to measure the ambient air. Data completeness for the continuous gaseous analyzers is very good. However, the SOPs that govern this operation do not capture all of the criteria needed to define the required activities that are taking place in the AMP.

Recommendation(s):

EPA Region 4 recommends that the AMP set as a priority updating their existing SOPs to make them more comprehensive. As part of preparing for this TSA, EPA Region 4 SESD examined the Standard

Operating Procedures in use by the AMP. Comments on the procedures are provided in Appendix A of this TSA report.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.1.2:

Unapproved Summary Table Forms in use by AMP field staff. Unique identification and version numbers were not present on Summary Table Forms.

Discussion:
While not explicitly a regulatory requirement, the utilization of unique identification and version numbers for quality system documents are considered a best practice. The EPD operating procedures utilize this best practice. However, summary tables in use by field staff were lacking this identification and are not officially approved. These summary tables have likely been developed as a result of the operating procedures not having enough detail and operational description (see *Finding 4.1.1*). To provide the additional guidance that is not available in the operational SOPs, field staff have developed one page tables to summarize critical and operational criteria required by EPA regulations and guidance, and the AMP Quality Assurance Project Plan (QAPP). These summary tables reside outside of approved SOPs. The summary tables have no identification that can be used to determine if they have expired, or to explain which QAPP revision that the table is summarizing.

Recommendation(s):
The one page tables summarizing EPA regulatory requirements and guidance and the AMP QAPP requirements are very useful tables and EPA Region 4 encourages their use. However, EPA Region 4 SESD requires that these summary tables be included as either a Table or Appendix in the AMP SOPs, or QAPP, or become controlled forms so that they are officially approved EPD and EPA documents. This will enable field staff to be able to quickly determine if the summary tables are official EPD documents and current or whether the forms have become obsolete and no longer reflect current AMP operating procedures.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.1.3:

AMP is not performing annual multipoint flow rate verifications for the $PM_{2.5}$ samplers per AMP SOP RP2025-PM2.5-SOP and as recommended in EPA Method 2.12, Section 6.7 and Table 6-1, and EPA guidance QA Handbook Vol. II, Appendix D, Rev 0, date 05/13.

Discussion:

The AMP is not performing annual multipoint flow rate verifications for the FRM $PM_{2.5}$ samplers and Federal Equivalent Method (FEM) $PM_{2.5}$ analyzers. The current AMP operational practice is to rely on the monthly single point flow rate verifications to determine if calibrations of the $PM_{2.5}$ samplers are required. This operational practice is in conflict with AMP SOP *RP2025-PM2.5-SOP Section 7.2* which states "*The calibration of the fine particulate matter sampler whose mass has an aerometric diameter of less than 2.5 microns (PM2.5) must be performed on a six month basis*". EPA considers multipoint verifications an important systematic criteria and the frequency of these multipoint verifications should be at least once per year.

Recommendation(s):

EPD's AMP must begin performing the multipoint flow rate verifications per AMP SOP *RP2025-PM2.5-SOP*, *EPA Method 2.12*, and EPA guidance in the *QA Handbook*. These multipoint verifications must occur when major maintenance is performed, the sampler is relocated to a different sampling station, or at least once per year (twice per year if adhering to AMP's SOP).

Data Deliverable(s) to AQS and SESD:

None.

Finding 4.1.4:

SO_2 Precision Check Results exceeding EPA recommended ±10% critical criteria

Discussion:

Review of single point quality control checks (precision checks) found many occurrences where the results of these quality control checks resided outside the recommended criteria in EPA's most current *QA Handbook*. Review of EPD documents found, however, that EPD has been adhering to their QAPP as well as the older version of the EPA *QA Handbook, version 2008*, which covers the data reviewed for this TSA. During the timeframe of the data assessed by this TSA (2011-2013), the EPD recalibrated their instrumentation based on the analyzer's response to test atmospheres provided at the span point, not by the results of the precision checks.

While EPD was adhering to their QAPP and the EPA *QA Handbook, version 2008*, the EPA Region 4 auditor spot checked the weekly precision checks performed by the AMP for a subset of their SO_2 ambient air monitoring network (five SO_2 ambient air monitoring stations) to investigate if there could have been a possible bias imposed on the SO_2 datasets. Comparison of ambient air measurements to the

weekly precision checks found that the only occurrences observed where a negative bias may have been imposed was at low design value SO_2 ambient air monitoring stations (regulatory low value stations). For those SO_2 stations where violations of the NAAQS have occurred or where SO_2 design values are near the level of the NAAQS, the results of the weekly precision checks were acceptable. The AMP has been effectively targeting its limited staffing resources to the appropriate SO_2 ambient air monitoring stations. See Appendix B of this TSA report for the graphs of the SO_2 data used for this assessment.

Recommendation(s):
None. EPD's AMP has already submitted a revised QAPP that is currently under review by EPA Region 4 SESD. The revised QAPP is in part based on EPA's revised *QA Handbook* and these revised quality control guidelines should be sufficient to address this concern.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.1.5:

Possible Future Siting Criteria issue at Savannah East President Street
AQS ID: 13-051-0021

Discussion:
The Savannah East President Street ambient air monitoring station has a tree line adjacent to the monitoring shelter. The monitoring shelter meets siting criteria as stated in *40 CFR Part 58 Appendix E*. The probes for the monitoring shelter are 15 meters from the tree line (the minimum criteria is 10 meters). However, there are some trees in the tree line that could become obstructions in the future. A laser rangefinder was used to determine the height and distance of the trees to the probe. The height of one of the taller trees was 14 meters and was 24 meters from the probe. The probe is approximately 4 meters above ground level. For the tree not to be considered an obstruction, the probe is required to be at least 20 meters away; the Savannah East President Street ambient air monitoring station meets this requirement.

Recommendation(s):
Savannah East President Street ambient air station currently meets EPA regulatory siting criteria. The EPA Region 4 recommends that AMP be mindful of the tree line near the monitoring shelter. The tree line in the future could begin to act as an obstruction. The AMP should review siting conditions for compliance with *40 CFR Part 58 Appendix E* annually per EPA guidance.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.1.6:

Possible Meteorological Sensor Misalignment at Savannah East President Street
AQS ID: 13-051-0021

Discussion:
The EPA Region 4 auditor noted that what appeared to be a directional sensor used for the sonic anemometer was oriented at ~330°. The sensor may be aligned per operating manual specifications; however, the sensors are usually oriented such that they are facing 360°.

Recommendation(s):
Confirm if the sonic anemometer is required to be oriented to 360°. If necessary, adjust directional sensor and validate the historic meteorological measurements.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.1.7:

$PM_{2.5}$ TEOM Analyzer's date and time were in error at Savannah L&A
AQS ID: 13-051-1002

Discussion:
The date and time reported by the $PM_{2.5}$ TEOM analyzer were not correct. The $PM_{2.5}$ TEOM was reporting the date to be April 24 when the correct date was April 22. The date and time error was noticed by the AMP site operator and was quickly corrected. This date and time stamp discrepancy for the analyzer may impacting the data reported back to the central polling computer at the AMP office. However, it is also possible the date and time are documented via the ESC 8832 datalogger and not by the TEOM analyzer.

Recommendation(s):
Confirm if the date and timestamp for the $PM_{2.5}$ measurements are controlled by the site datalogger or by the $PM_{2.5}$ TEOM analyzer. If the date and time of the measurements are documented via the $PM_{2.5}$ TEOM analyzer then the AMP will need to validate this data set appropriately.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.1.8:

Some obliterations noted on Chain of Custody (COC) for $PM_{2.5}$ samples

Discussion:

Some occurrences were noted where obliterations existed on the $PM_{2.5}$ COCs submitted to the EPD Laboratory. The legibility of some of the COCs were also problematic.

Recommendation(s):

EPD's AMP need to stress to staff the importance of legible writing on COCs and for making corrections with a single line strikeout followed by initials and date of correction on the COC.

Data Deliverable(s) to AQS and SESD:

None.

4.2 LABORATORY OPERATIONS

A separate audit report will be issued by EPA Region 4 SESD to address the analytical findings observed by Ray Terhune (EPA Region 4 SESD) and the recommendations pertaining to those findings. Ray Terhune evaluated the EPD Laboratory with respect to the analytical analysis of samples collected for the Photochemical Assessment Monitoring Stations (PAMS), National Air Toxics Trends Stations (NATTS), and the Pb NAAQS. The laboratory findings presented in this 2014 TSA report focus on the gravimetric laboratory used to weigh PM_{10} and $PM_{2.5}$ ambient air samples. In addition to the gravimetric lab findings, this 2014 TSA report also addresses some findings regarding the regulatory requirements of *40 CFR Part 58 Appendix A §3.3.4.2* for the preparation of Pb audit test strips.

The EPD Laboratory has implemented the recommendations from the previous EPA Technical System Audits. All certifications were easily retrievable by staff and record keeping was well organized. EPD Laboratory management are very familiar with EPA regulations, EPA Method 2.12, and EPA guidance.

$PM_{2.5}$ Weighing Laboratory:

Finding 4.2.1:

The $PM_{2.5}$ weighing laboratory at the EPD Laboratory has not been recording timestamps of the filter conditioning testing and filter weighing. Without the timestamp it is not possible to determine if the filters have satisfied the 24hr minimum equilibration time requirement (40 CFR Part 50 Appendix L §8.2.5 and EPA Method 2.12 §7.7).

Discussion:

Review of records at the EPD Laboratory has found that the Laboratory Information Management System (LIMS) used by EPD has not been capturing the time (timestamp) that filters are weighed and conditioned in the weighing laboratory. The dates of these activities are being captured in either the

LIMS or on forms but not the times. Without the timestamp it is not possible to determine if the filters have satisfied the 24hr minimum conditioning time requirement (*40 CFR Part 50 Appendix L §8.2.5* and *EPA Method 2.12 §7.7*) that is necessary to document that the filters have equilibrated to the laboratory weighing room.

EPA Region 4 has considered the weight of evidence provided by the EPD Laboratory and finds that this evidence demonstrates that the filters have been conditioned to the environmental conditions of the weigh laboratory prior to filters being weighed. Review of temperature and humidity records has demonstrated that the weigh lab is operated under an appropriately controlled environment. Records were also reviewed demonstrating that there are multiple management layers of review to ensure that filters are not weighed unless the weighing laboratory is in control for temperature and humidity. Additionally, the EPD Laboratory weighs stability blanks along with documenting the environmental conditions of the filter weighing room to ensure that the filters have equilibrated. In consultation with EPA's Office of Air Quality and Standards and Planning's (OAQPS), EPA Region 4 finds that there is sufficient evidence available to assert that the filters have appropriately conditioned prior to being weighed.

Recommendation(s):
The EPD Laboratory must record the filter condition times such that the required 24hr filter conditioning/equilibrium time can be readily determined. The filter conditioning/equilibration time is a regulatory requirement and is considered a critical criteria. In addition to capturing this critical criteria in the future, the EPA Region 4 auditor recommends that the EPD laboratory continue with the filter stability testing that the laboratory has employed as part of its routine operating process. The results from this stability testing, as well as the additional information provided by the EPD Laboratory to EPA Region 4 SESD, has served to provide a weight of evidence that the tare weighed filters have equilibrated to the weighing laboratory environmental conditions prior to being weighed on the microbalance.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.2.2:

The records in the files for the tare and post weighed filters do not have sufficient identification or pagination in place to uniquely and readily associate the individual records back to the files where they reside. Forms being used for the records did not have versions assigned.

Discussion:
While reviewing the $PM_{2.5}$ weighing session files for critical and operational criteria it was noted that the records in the files did not have sufficient unique identification in place to link the records in the files back to the files in which they reside. It was also noted that the form, *Pre-sampling Lot Exposure Blank Stability Test – $PM_{2.5}$ Form*, did not have a version number assigned to ensure that the most current version of the forms are being utilized. While not explicitly a regulatory requirement, the

utilization of unique identification records and version identification for controlled forms are considered a best practice.

Recommendation(s):
The EPD Laboratory should begin assigning Pre-Sample #ID and Post-Sample #ID identification to the records contained in their weighing session files. Controlled forms used for making records should have version numbers.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.2.3:

The $PM_{2.5}$ exposed filters being return to the EPD Laboratory have experienced a large number of Filter Damage Voids due to pinholes.

Discussion:
The EPD Laboratory has been operating in good faith in their inspection of $PM_{2.5}$ filters for damage. The EPD Laboratory is following and adhering to *EPA Method 2.12* as well as EPA guidance in the *QA Handbook*. Potential causes of the large number of pinholes being found by the EPD Laboratory are still being investigated both by EPD as well as EPA. The pinholes may have resulted from freezing the exposed filters after sampling (EPD has since ceased freezing the samples for sample preservation and refrigerates the samples). The pinholes may also be caused by shipping the filters in their magazines. The pinhole issue may also be partially attributable to EPA switching filter manufacturers in 2012. EPA Region 4 has begun inquires with other air monitoring agencies to determine whether these pinhole filter damage issues are a common systematic problem or an issue specific to EPD. EPA Region 4 has not finished with this inquiry, but current information suggests that while other agencies are observing pinholes in their exposed filters these air monitoring agencies are not observing the same rate of damage as is being experienced by Georgia EPD.

One possibility for the reduced frequency of observed filter damage at other agencies is that many agencies remove their filter cassettes from the magazines and ship in individual pouches. Georgia EPD ships their exposed $PM_{2.5}$ samples to the laboratory in the sampler magazines. Additionally, the EPD Laboratory inspects the exposed filters with a light box. Many other weigh laboratories do not perform the inspection for damage at the same level of detail that is being employed at EPD. As a result, the pinholes observed by the EPD laboratory may also be more common of an issue than previous understood by EPA. EPA is still investigating this issue. It is EPA Region 4's and OAQPS' position that while the pinholes found in the exposed filter sample media may warrant invalidating the $PM_{2.5}$ samples, cases exist where an observed pinhole for an exposed filter may only warrant qualifying the measurement and not data invalidation. An example would be for those cases where the pinholes are so small as to only be visible to a single weighing analyst while utilizing a light box and magnifying glass. Under this scenario, the observed damage may not qualify as "obvious" as stated in *EPA Method 2.12*

§3.2.3 bullet #3:

> *A sample collected on any filter that has obviously been damaged (i.e., torn, frayed, or has pinholes) during the collection process should be invalidated.*

EPA Region 4 SESD recommends that the EPD Laboratory develop a methodology to ensure that the determination of pinholes is consistent. One example could be that multiple weigh analysts or a weigh analyst and supervisor have to concur that the pinhole is present. Under some circumstances without a prescribed consistent process, it's possible that there is no pinhole present, but if the filter is examined using of a light box and possibly a magnifying glass, light could be visible through an un-ruptured "thin" area of the exposed filter.

Recommendation(s):
Ultimately, as long as minimum EPA requirements are met, it is Georgia EPD's responsibility to determine the quality of the data that will be used for regulatory decision making for its ambient air program. EPD may continue to use its current methodology for determining valid $PM_{2.5}$ samples with respect to filter damage, however, resulting data completeness issues may require data substitution to be implemented for computing design values for $PM_{2.5}$. Under extreme data loss scenarios, EPA may not be able to make regulatory decision to due low data completeness.

All exposed filters returning to the laboratory must be inspected for damage. The EPD Laboratory should continue to use its procedure for examining filters for damage; however, if the damages are very small pinholes and visible only through the use of a light box, the EPD Laboratory should weigh the exposed $PM_{2.5}$ and low volume PM_{10} filters. While EPA is still investigating this issue, it is EPA Region 4's and OAQPS' position that while the pinholes found in the exposed filter sample media may warrant invalidating the $PM_{2.5}$ samples, in some cases pinholes that are so small as to only be visible to a single weighing analyst may not qualify as "obvious" as stated in *EPA Method 2.12 §3.2.3.* For those pinholes that may not meet the EPD laboratory's definition of obvious, EPA Region 4 further recommends that these exposed filters be weighed and reported to EPA with the "2" quality assurance qualifier flag to denote that the filter may not meet an operational criteria (filter damage). All exposed filters that are determined by the EPD Laboratory to be impacted by other damage types (tears, scuffs, scratches, etc.) should be invalidated as the EPD laboratory deems necessary.

Data Deliverable(s) to AQS and SESD:
None.

Analytical Pb Analysis for samples supporting Pb NAAQS compliance:

Finding 4.2.4:

The EPD Laboratory is not using independent reagents for the preparation of the Pb audit test strips. The audit test strips are not being prepared with concentration ranges in the 30-100% Pb NAAQS and 200-300% Pb NAAQS equivalent ranges. (40 CFR Part 58 Appendix A §3.3.4.2)

Discussion:

EPA regulatory requirements, *40 CFR Part 58 Appendix A §3.3.4.2*, state "*The audit samples must be prepared using batches of reagents different from those used to calibrate the Pb analytical equipment being audited*". And that the Pb audit test strips have equivalent ambient Pb concentrations in the following two ranges:

Range	Equivalent ambient Pb concentration, µg/m^3
1	30 – 100% of Pb NAAQS
2	200 – 300% of Pb NAAQS

In 2012 there were several Pb audit test strips prepared at concentrations at equivalent ambient Pb concentrations of ~ 12% of the NAAQS (e.g., known Pb spike amount of 4 µg). The laboratory accuracy for these audit samples is good, but a % Difference function exaggerates error at low concentrations so usage of the % Difference function is not a good measure of the laboratory accuracy for these low Pb spikes.

Recommendation(s):

1. EPA recommends that the EPD Laboratory begin utilizing EPA's contract to procure Pb audit test strips. This should assist in meeting the regulatory requirement that the reagents used to prepare the Pb audit test strips are independent from the reagents used by the EPD Laboratory for the Pb analysis. If the EPD Laboratory wishes to continue making its own Pb audit test strips, the EPD must procure and begin using independent reagents to prepare the Pb audit test strips.
2. EPA guidance recommends evaluating the Pb audit test strip results on a % Difference basis. As such, if the EPD laboratory wishes to continue manufacturing its own Pb audit test strips then EPD should restrict the lower limit for preparing the Pb audit test strips to no less than 30% of the NAAQS as cited in the regulations.
3. If the EPD laboratory wishes to continue manufacturing its own Pb audit test strips the level 1 Range should be set at 20 µg/strip or ~60% of the equivalent Pb NAAQS. See below :
   Typical National Pb concentrations found in AQS for the two audit range levels are:
   i. Range 1: 15-20 µg/strip;
      Equivalent ambient Pb Conc. = 0.07-0.09 µg/m^3 = 46% to 60% of Pb NAAQS
   ii. Range 2: 69-75 µg/strip
      Equivalent ambient Pb Conc. = 0.31-0.34 µg/m^3 = 210% to 230% of Pb NAAQS

   [Assuming ≈ 2000m^3 for the Sample Vol and 9 strips per filter]

Data Deliverable(s) to AQS and SESD:
None.

4.3 DATA MANAGEMENT

Finding 4.3.1:

EPD's AMP has been assessing valid operating ranges for their FEM continuous analyzers based on an 18-32°C temperature shelter temperature range and not the FEM approved operational range of the analyzer.

Discussion:
EPD's AMP has been operating in good faith with validating their continuous ambient air measurements with respect to shelter temperature. The AMP is adhering to their Data Validation SOP (dated 2009) which states *"Review shelter temperature for raw hourly averages. Shelter temperature should be between 18 – 32 degrees Celsius. If out of this range or missing, then that number or space should be replaced with appropriate null data code."* for reviewing the environmental conditions (shelter temperature) in which the analyzers are operating. The AMP has also based their lower limit of the 18-32°C shelter temperature validation range on EPA guidance in the *QA Handbook, Vol II, Section 7.1.2, Date 2008* which can be interpreted to suggest that operating temperatures down to 18°C are acceptable (independent of the analyzer's FEM approved operational range). The current redbook, *QA Handbook, Vol II, Section 7.2.2, Date 2013,* also provides this same guidance.

The upper limit of 32°C has been justified as being used by referencing EPA guidance *QA Handbook, Vol II, Appendix D, Date 2013* that states that the accuracy of the temperature sensor in the monitoring shelter should be within ±2°C. Thus, the AMP has added +2°C to the typical 20-30°C operational range to give an upper bound of 32°C for valid measurements. Unlike the lower limit, this is not supported by EPA guidance.

In order for EPA to use the ambient air monitoring measurements for NAAQS compliance determinations, measurements must performed with either an FRM or FEM monitoring method (*40 CFR Part 58 Appendix C §2.1*). The valid operational temperature range that an analyzer must operate is defined by its FEM designation. As an example, Thermo 49i analyzers must operate between 20-30°C for their measurements to meet their FEM designation. Another example is the Thermo 42i analyzers, which must operate between 15-35°C for their measurements to meet FEM designation.

While EPD's AMP has been following their procedures, EPA Region 4 SESD encourages the AMP to begin validating their measurement data using the FRM and FEM operational criteria found in the "*List of Designated Reference and Equivalent Methods*".

Recommendation(s):
AMP should consult the "*List of Designated Reference and Equivalent Methods*" provided by EPA's Office of Research and Development. This document provides the exact operational temperature requirements for each of the continuous analyzers operated by EPD. This document can be found at the following URL:

http://www.epa.gov/ttnamti1/files/ambient/criteria/reference-equivalent-methods-list.pdf

While EPA Region 4 SESD recommends invalidating ambient air measurements that are not measured with an instrument that is not operating within its FRM/FEM designation criteria, the EPD AMP may utilize the guidance found in *QA Handbook, Vol II, Section 7.2.2, Date 2013* to retain such ambient air measurements down to temperatures as low as 18°C as valid measurements irrespective of its FRM/FEM designated operational range. However, if temperatures residing between ≥18°C to <20°C are not covered by the FRM/FEM operational range of the instrument, these measurements will need to be qualified in AQS as not meeting operational criteria.

Data Deliverable(s) to AQS and SESD:
For all CO, SO_2, NO_2, O_3, and FEM-$PM_{2.5}$ hourly measurements from 2011-2013:

1. Examine the measurements that were performed with analyzers at shelter temperatures between ≥18°C to <20°C and determine if the analyzer was operating within its FEM operational range. If the analyzer was not operating within its approved FEM operational range in conditions between ≥18°C to <20°C, these measurements must at a minimum be qualified in AQS by applying a "2" quality assurance qualifier flag to qualify the measurement in AQS as not meeting operational criteria. While flagging of the data is acceptable per EPA guidance, EPA Region 4 SESD recommends that any measurement performed by an FEM analyzer outside of that analyzer's operational range be invalidated.

2. Examine the measurements that were performed with analyzers at shelter temperatures >30°C and determine if the analyzer was operating within its FEM operational range. If the analyzer was not operating within its approved FEM operational range, these measurements must be invalidated in AQS with the "AE" null data code (Shelter Temperature Outside Limits).

All AMP SOP's that reference the 18-32°C shelter temperature range for the validation of ambient air monitoring measurements must be revised to reflect an 18-30°C shelter temperature range or the operating temperature range of each specific FEM analyzer. If AMP wishes to retain the lower temperature operational limit of 18°C, then all AMP SOPs that reference this 18°C shelter temperature range for the validation of ambient air monitoring measurements must also be revised to qualify measurements utilizing a "2" quality assurance qualifier flag for those measurements performed with analyzers operating outside their approved FEM operational temperature range but ≥18°C. However, EPA Region 4 SESD strongly recommends that the AMP begin validating their measurement data solely using the FRM and FEM operational criteria found in the "*List of Designated Reference and Equivalent Methods*".

Notify EPA Region 4 SESD when the 2011-2013 continuous hourly measurements have been revalidated with respect to shelter temperature and the corrections have been uploaded to AQS.

Finding 4.3.2:

The precision data values in AQS for the FEM gaseous pollutants (CO, SO_2, NO_2, and O_3) have not been zero adjusted like their corresponding ambient readings, and as such, the precision values are not representative of the precision of the zero adjusted ambient air measurements submitted to AQS.

Discussion:

Review of the electronic records in AMP's data acquisition system (DAS) found that the AMP is applying a zero adjust to their ambient measurements from their FEM continuous gaseous analyzers (CO, SO_2, NO_2, and O_3). This is an allowed practice. However, examination of the weekly precision checks in the DAS found that the zero adjust was not being applied to the precision check results that are supplied to EPA's AQS database. The DAS is computing a correct zero adjusted percent difference result for the precision check, but the zero corrected response value is not being exported and reported to EPA. As such, the precision values reported to EPA are not representative of the true precision of the zero adjusted ambient air measurements submitted to AQS.

Recommendation(s):

The precision values submitted to EPA's AQS must accurately represent the precision of the ambient air monitoring data that resides in AQS.

Data Deliverable(s) to AQS and SESD:

The AMP must re-compute all precision checks for CO, SO_2, NO_2, and O_3 from 2011-2013 by applying the zero adjust used in offsetting the ambient air monitoring measurements. Resubmit these corrected precision checks to AQS.

Notify EPA Region 4 SESD when this has been completed in AQS.

Finding 4.3.3:

Inconsistent naming of electronic deliverables provided from the EPD laboratory to the AMP.

Discussion:

The EPD Laboratory provides electronic deliverables to the AMP for both analytical and gravimetric analyses through the utilization of a Local Area Network (LAN) drive that is physically located at the EPD Laboratory (also known and referred to by EPD personnel as the "air drive"). The AMP is able to map the EPD Laboratory's air drive to their office network and transfer the analytical and gravimetric results to other locations on the AMP office network. While the overall system is functional, there is a lack of organization and structure to the files that reside on the "air drive". Naming conventions appear arbitrary and disorganized and little to no archiving of legacy files appears to be occurring.

Recommendation(s):
The AMP should modify its existing operating procedures or create a new data handling operating procedure that defines both the naming convention and formats for the electronic files that the EPD Laboratory provides to the AMP. This document could then be used as a reference resource by the EPD Laboratory for transmitting the analytical and gravimetric analysis results to the AMP. The EPD Laboratory should begin organizing the "air drive" so that older legacy files are archived into to sub-folders on the "air drive". One recommendation would be to archive electronic deliverables by calendar year.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.3.4:

Single point monthly flow rate verifications for the $PM_{2.5}$ samplers are not being reported to AQS.

Discussion:
The submission to AQS of the single point monthly flow rate verification results for $PM_{2.5}$ and PM_{10} samplers and analyzers is currently not required in EPA regulations. The submission of these quality control checks is highly encouraged by EPA Region 4. The creation of the electronic data transaction files and subsequent submission to EPA's AQS database will assist the AMP in including these quality control checks in their data validation of the $PM_{2.5}$ and PM_{10} ambient data. Also, EPA's draft revision to *40 CFR Part 58 Appendix A* currently includes requirements for the submission of these $PM_{2.5}$ and PM_{10} quality control checks to AQS.

Recommendation(s):
The AMP should begin submitting their single point monthly flow verifications to AQS. While not currently a regulatory requirement, EPA will likely make this a requirement in the near future and the AMP should begin preparing for this transition.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.3.5:

The EPD Laboratory and the AMP have not been transferring and communicating the results of the Pb audit test strips effectively. The success rate for accurately transmitting data from the EPD laboratory to the AMP and from the AMP to EPA's AQS database is occurring at ~23% success rate.

Discussion:
In preparing for the TSA, SESD staff queried an AMP502 Extract P/A Data Report from AQS to review the Pb audit test strip results. During the audit with the EPD laboratory it quickly became apparent that

the analytical audit results that were submitted to AQS could not be readily reconciled with the laboratory LIMS data. Further inspection performed by the EPD Laboratory Quality Assurance Manager has subsequently found that there have been numerous occurrences of transcription errors, mostly caused by AMP during converting the data from the EPD Laboratory into AQS input transaction files for uploading into AQS. However, a few occurrences have been found where the laboratory introduced some transcription errors as well. The collection date of the associated field sample and the analysis date of the Pb audit test strip were routinely interchanged. Duplicate record entries to AQS appear to have occurred for multiple dates. Miscommunication between the AMP and the Laboratory regarding the units (µg/strip vs µg/filter) appears very common. Overall, the EPD appears to only have uploaded correct results for the 2011-2013 analytical Pb audit test strips to AQS at success rate of~23%.

Recommendation(s):
The AMP should investigate if it is possible to construct an electronic deliverable for EPA's AQS database without having to manually re-key in the electronic data provided by the EPD Laboratory. The EPD Laboratory already provides the Pb audit test strip results electronically. The electronic file format currently provided to AMP is not in a transaction format ready for uploading to AQS. EPA Region 4 SESD recommends that AMP define for the EPD Laboratory an electronic file format that will either match the AQS transaction file or be close enough that only minimal editing of the file will be necessary.

If manual data entry is required, a second level of review is always necessary. In addition to a second level review before the data is entered into AQS, EPA Region 4 SESD recommends that after the data is uploaded to AQS, an AMP502 Extract P/A Data Report be retrieved from AQS and compared to the audit results provided by the EPD Laboratory. The frequency of this validation should be quarterly.

Data Deliverable(s) to AQS and SESD:
For 2011-2013, revalidate the Pb audit test strips to correct for errors discovered through this TSA. Errors include but are not limited to:

1. transcription errors
2. utilizing sample date instead of the preferred analysis date
3. reporting in incorrect units
4. duplicate record entries to AQS for the same Pb test audit strip

Notify EPA Region 4 SESD when this has been completed and resubmitted to AQS.

4.4 QUALITY ASSURANCE

Finding 4.4.1:

$PM_{2.5}$ measurements are not being appropriately validated by the AMP with respect to critical and operational criteria.

Discussion:

EPD does not currently submit their monthly flow verifications for their particulate matter samplers to AQS along with their ambient air quality measurements. The submission of these monthly quality control checks are currently not required by the EPA regulations to be submitted to AQS. As a result of these quality control checks not being submitted to AQS, EPA Region 4 could not review these monthly flow rate verifications prior to the TSA. A spot check of these required quality control checks was performed during the audit by randomly selecting three $PM_{2.5}$ monitoring stations and requesting all of the records documenting the monthly flow verification checks that occurred at these $PM_{2.5}$ stations for the 2011-2013 timeframe (totaling 108 flow rate verifications). The three $PM_{2.5}$ stations spot checked for their 2011-2013 monthly flow rate verifications were:

1.	Macon Allied	AQS ID: 13-021-0007
2.	South DeKalb	AQS ID: 13-089-0002
3.	Fire Station #8	AQS ID: 13-121-0039

The EPD AMP staff were able to quickly provide all of the documents requested which demonstrates that their records management practices are effective. Due to the resource and time constraints of the TSA, most of the spot-check review of these records were limited to the flow rate verifications and not the sampler datalogger downloads which records elapsed sample time, flow rate variability, etc.

Of the three years of monthly flow rate verifications reviewed at these three $PM_{2.5}$ stations, two had occurrences where the $PM_{2.5}$ sampler failed its flow rate verification (flow rates different from the audit device by more than ±4%). At Fire Station #8 (AQS ID: 13-232-0039) the August 20, 2012 flow rate verification was "warning high" at 3.6%. This monthly flow rate check was not followed with a calibration to bring the sampler back into control. The following flow rate verification on September 25, 2012 failed with a percent difference of -6.0%. No calibration was performed to bring the sampler back into control. The next flow rate verification on October 12, 2012 failed with a percent difference of +6.1%. The sampler was then recalibrated. At Macon Allied (AQS ID: 13-021-0007) the August 19, 2013 flow rate verification failed (-4.4%). The sampler was immediately recalibrated. On September 9, 2013 the flow rate verification failed again (+4.4%) and was immediately recalibrated. The review of the AMP monthly flow rate verifications demonstrate that calibrations are typically being performed after failed quality control checks of the $PM_{2.5}$ samplers.

The spot checked records for these $PM_{2.5}$ samplers also show that the samplers were operating outside of EPA regulatory requirements and no ambient $PM_{2.5}$ measurement results were invalidated in EPA's AQS database as a resulted of these failed quality control checks. Due to the two monthly failed flow rate verifications at Fire Station #8, approximately 1.75 months of $PM_{2.5}$ data must to be removed from

AQS for this site. Also at Macon Allied, approximately 1.75 months of $PM_{2.5}$ data must to be removed from AQS for this site due to the failed monthly flow rate verifications. These quality assurance issues were found through spot checks of only three $PM_{2.5}$ stations (for 2011-2013). It is likely that additional data will need to be invalidated as this finding demonstrates that there has been a lack of appropriate data validation being conducted with the $PM_{2.5}$ network.

Recommendation(s):
The AMP must revalidate all $PM_{2.5}$ FRM and FEM measurements from 2011-2013. The data must be validated to ensure that the monthly flow verifications are meeting EPA critical and operational criteria. For FRM $PM_{2.5}$ measurements, ensure the sampler data logger downloads are reviewed for EPA critical and operational criteria. Examples include but are not limited to:

1. FRM/FEM: Monthly flow verification checks greater than ±4% of the flow transfer standard.
2. FRM/FEM: Monthly flow verification checks greater than ±5% of the flow rate design standard.
3. FRM: Ensure sampler operated 1380-1500 minutes, unless <1380min and sample exceeded the NAAQS.
4. FRM/FEM: CV > ±2%.
5. FRM/FEM: average flow rate within 5% of 16.67 liters/min (design flow rate).
6. FRM: no flow rate excursions > ±5% of 16.67 liters/min for more than 5 minutes

Data Deliverable(s) to AQS and SESD:
The AMP must revalidate all $PM_{2.5}$ FRM and FEM measurements from 2011-2013. Ensure that the monthly flow verifications (and for the FRMs that the sampler data logger downloads) are reviewed for EPA critical and operational criteria.

Notify EPA Region 4 SESD when this has been completed in AQS.

Finding 4.4.2:

Some occurrences were found where ambient data measurements are not being appropriately bracketed by the AMP with either a quality control or quality assurance check.

Discussion:
While not a common finding in the 2011-2013 hourly data reviewed by the EPA Region 4 SESD, some occurrences were seen where not all ambient air monitoring measurements were appropriately bracketed by either a quality control or quality assurance check. All data that resides in EPA's AQS database needs to be of a known quality and as such data collection must commence and cease with these quality control or quality assurance checks. EPA Region 4 SESD considers the bracketing of the ambient air measurements a best business practice and required for having ambient air monitoring measurements with known quality.

Recommendation(s):
All ambient air monitoring measurements should be bracketed by either a quality control or quality assurance check. During the data validation process when data loss occurs due to major maintenance or equipment failure the EPD data validator should invalidate the ambient measurements in AQS back to the last good quality control or quality assurance check. Measurements that follow this block of invalidated data must begin with an acceptable quality control check. The data validation SOPs should be revised to include more details regarding this data validation process and/or more training be provided to staff in this data validation task.

Data Deliverable(s) to AQS and SESD:
None.

Finding 4.4.3:

Some unusually high field filter blanks result are present in AQS for the 2011-2013 dataset reviewed for this TSA.

Discussion:
While the occurrence of field filter blanks with high readings are not common, these quality control measurement results do not appear to be incorporated into the AMP quality system as part of a data validation process. No $PM_{2.5}$ ambient air monitoring sampling results were qualified with flags due to the high $PM_{2.5}$ field filter blanks. Additionally, while spot checking some of the field filter blank results at least one occurrence was observed where it is likely that a field filter blank was entered into AQS as an ambient sample and the corresponding ambient sample entered into AQS as a field filter blank. The spot checked example is as follows:

1. Field blank result for AQS Station ID (13-089-0002) on June 28, 2013 was 311 µg
2. Ambient sample concentration reported to AQS (13-089-0002) on June 28, 2013 was 0.4 µg/m^3

If the field blank for June 28, 2013 that currently resides in AQS was actually an ambient sample, then by dividing the filter weight by a standard volume of 24 m^3 provides a concentration of 13 µg/m^3, which is a more typical concentration for the month of June 2013 than the result reported to AQS (0.4 µg/m^3). Likewise, if the ambient concentration that was submitted to AQS for the June 28, 2013 were to be multiplied by a standard volume of 24 m^3 to convert the concentration back to a raw filter weight, the filter blank result would be 9.6 µg which is a much more typical filter blank result.

The previous TSA report (issued Jan. 4, 2012, SESD ID: 11-0699) stated that EPD was only performing filter blanks at a rate of 5% and required that EPD begin collecting and weighing filter blanks at the required 10% rate (*40 CFR Part 50, Appendix L, §8.3*). Review of 2011 records indicate that only 44 filter blank results were submitted to AQS for calendar year 2011; which is a rate of ~1%, not 5%. It should be noted that the previous TSA only evaluated data collected during 2010 and did not assess the 2011 $PM_{2.5}$ dataset. Records in AQS demonstrate that the EPD began meeting this requirement in 2012 when notified by EPA Region 4 through the transmittal of the previous TSA report.

Recommendation(s):
The $PM_{2.5}$ field filter blank results must be incorporated into the AMP's data validation process. Where appropriate, the ambient $PM_{2.5}$ measurement results that are associated with any anomalous field filter blanks results should have the AQS "FB" qualifier flag assigned alongside the measurement result. The AMP should continue with the spot checking methodology employed above in the discussion portion of this finding to assess if other high filter blank results were likely ambient air samples.

Data Deliverable(s) to AQS and SESD:
The AMP must examine the $PM_{2.5}$ field filter blank results for 2011-2013. Ambient measurements associated with field filter blanks with unusual results should be flagged with the "FB" qualifier flag. At a minimum, the AMP must investigate the field filter blank results to ascertain if it is possible to locate the highly suspect ambient samples that are likely field filter blanks accidentally uploaded as ambient samples. These field filter blanks that have been reported as ambient samples must be appropriately validated by either invalidating the sample, or if possible through a weight of evidence taking the filter weight used for the ambient sample and submitting that measurement as the field filter blank result; and taking the field filter blank weight and by applying the volume of air sampled for the ambient sample compute the correct $PM_{2.5}$ concentration (see example in Discussion).

Notify EPA Region 4 SESD when this has been completed in AQS.

5. Conclusions

This TSA has found that the data validation performed by the EPD's AMP has not been sufficiently rigorous to demonstrate that the ambient air data in AQS is appropriately quality assured. As such, EPA Region 4 SESD is requiring that the EPD's AMP perform some additional data validation to demonstrate that the data that resides in AQS is accurate, representative, and defensible. Until this ambient air data has undergone a more rigorous data validation, the ambient air monitoring data should not be certified by EPD. The validation issues found through this TSA pertain to the calendar years of 2011-2013. As such, after EPD has completed the data validation and associated corrections to the AQS database, Georgia EPD will need to recertify the calendar years of 2011 and 2012, as well as certify calendar year 2013. Details of the additional data validation that are required by EPA Region 4 SESD can be found in Section 4 of this TSA report. EPD's AMP quality system records are sufficiently detailed and organized such that the data validation should be able to be completed without excessive effort. The traceability and certification documentation was in order for both the EPD Laboratory and the AMP. The EPA laboratory has implemented the recommendations from the 2011 TSA. The major findings and recommendations indicate a need for the AMP to focus on strengthening the data validation portion of its program.

EPA Region 4 recommends that the AMP submit for review its standard operating procedures every five years. The AMP has already submitted its revised Quality Assurance Project Plan to EPA Region 4 SESD for review and approval.

EPA Region 4 is requesting your agency develop a plan to address the issues identified in Section 4 of this TSA report and respond back to SESD by June 17, 2014. Please contact SESD if this date needs to be amended.

Appendix A

Comments to Standard Operating Procedures

The standard operating procedures reviewed for this technical system audit gave only a broad outline to the procedures necessary for instrument operation. The SOP's lacked sufficient technical detail for an operator to be able to use the SOP as a guide for operation of the instrumentation.

Ambient Monitoring Program: Continuous Monitoring Unit: Ambient Ozone Monitoring
Ambient Monitoring Program, Ops Unit 2, Ozone O3 SOP, Version 1, May 29, 2009

Page 6: §2.6.1.4 #1. Cites Stainless Steel as an allowable option for probe material, this is incorrect. FEP Teflon and borosilicate glass are allowable. Spelling error in NOTE (…benecessary…) should read (… be necessary…)
Page 7: §2.6.1.5 #5 spelling error (… total low…) should be (…total flow…)
Page 8: §2.6.2.3 spacing error (… out put…) should be (…output…)
Page 14: §2.6.2.10. This section "recommends" a multipoint calibration be performed at various times. The SOP should specify if and when the calibrations will be performed.
Page 16: §2.6.2.1.4 #1. Cites a 10 minute stability period with the last 5 minutes readings recorded. The SOP should be clear on how these readings are selected, how many readings are needed and what precision they should have. A definition of "stability" is needed in the SOP to add clarity. If the electronic data system is used to record and average these readings – explain this. §2.6.3 #2 provides a little more information on this subject, but very limited. The explanation should occur with the 1st occurrence of the procedure or at each occurrence.
Page 16: §2.6.2.1.4 #5. Spelling error (…strip hart…) should be (…strip chart…).
Page 18: §2.6.2.1.5 #C4. This section instructs the operator to perform a calibration of the instrument analog output (RDAS). This operation should be included in the SOP or noted where it can be found.
Page 20: §2.6.3 #4. The last sentence states "Keeping an on site manual entry log is strongly encouraged." The requirement for a logbook record should be clearly defined by the SOP and not left to the judgment of the operator.
Page 20: §2.6.4 #1. The shelter temperature should be between 20-30 degrees Celsius. Temperature specifications are set according to Federal Reference Method or Federal Equivalent Method requirements.

Ambient Monitoring Program: Continuous Monitoring Unit: Ambient Sulfur Dioxide, and TRS Monitoring
Ambient Monitoring Program, Ops Unit 2, SO2_TRS_SOP, Version 1, May 29, 2009

Page 3: Instructions for Peripheral Equipment: The site temperature range given in this section is correct at (20-30 degrees Celsius) but the section also includes a citation of (+/- 2 deg C), a variance due to the accuracy of the temperature probe. This variance should not be considered to expand the temperature range of valid data to (18-32 degrees C). If the State wishes to account for the (+/-2 deg C) variance it should consider tightening the valid temperature range to (22-28 degrees C).
Page 4: Flows and Calibration Concentrations (continued): the standard temperature and pressure correction factor formula is unclear in its current form. The equation should clearly show the variables needed and proper aromatic functions.
Page 4: Calibration: The instrument warm up period given in this section is 30 minutes, on Page 3 of the SOP is a section entitled "Warm Up Procedures" which indicates a 1 hour timeframe is needed for the instrument warm up period. These should be reconciled with the manufacturer's recommendations.
Page 5: Absorbing Column: This section cites the charcoal used should be changed at a minimum of every 6 months. During the TSA the auditor was informed this is not the current procedure and the timeframe was adjusted according to operator judgment of instrument response.

Georgia Department of Natural Resources: Environmental Protection Division: Air Protection Branch: Ambient Monitoring Program: CO Monitoring: Standard Operating Procedure: TECO 48C Gas Filter Correlation CO Monitor
Ambient Monitoring Program, Operations Unit 2, Operation-CO-NAAQS SOP, Version 1, May 29, 2009

§2.5.2 Installation and Set Up #1: This item identifies acceptable probe line materials. Due to its non reactive nature CO is not required to meet the same probe material requirements as ozone, sulfur dioxide and nitrogen dioxide. The probe line materials cited here would be acceptable but may offer confusion (stainless steel) to operators of the reactive criteria pollutants. To avoid this potential confusion, EPA recommends following the same guidelines as the reactive pollutants and using only FEP Teflon or borosilicate glass for probe line material.
§2.5.3 Operating Functions of the 48C Sampler: This last sentence of this section state the output voltages are adjusted to match the zero and full scale of the instrument and used to give the concentration to the data logger. This section does not provide sufficient detail to complete this operation or information indicating where the full procedure can be found.
§2.5.6.3 Adjusted Calibration Procedure: Item 6: The example calculation cited is incorrect with respect to the mathematical formula given right above it. An addition function is shown in the formula and the example citing a multiplication function. This same error is repeated in §2.5.6.4 Unadjusted Calibration Procedure.
§2.5.6.3 Adjusted Calibration Procedure: Calibration Curve: During the 2014 technical systems audit it was asked if the operations staff actually produces a calibration curve, the response was negative. If part of the procedure is no longer needed or accomplished in another manner, i.e. electronically, the SOP's should be updated to reflect these changes.
§2.5.7 Ambient Maintenance Procedures: Item 4: This section contains information concerning the correct shelter temperature ranges. This has been previously discussed with GA DNR. The correct temperature range should be indicated here.

Standard Operating Procedure for *Sierra-Anderson / Graseby*: High Volume PM-10 Sampler
Ambient Monitoring Program, Ops Unit 1, PM10 2008 SOP, Version 1, May 29, 2009

III. Procedure for Flow Calibration: Item c: Specifies a 3-5 minute warm up period. EPA has consistently stated 10 minutes for Hi-Vol samplers. Please review and explain.

III. Procedure for Flow Calibration: correction for meteorological conditions – the formulas and procedure adds 30 degrees K to the temperature due to the "orifice exit plenum". This should be removed. Please contact EPA with any questions regarding this issue.

Standard Operating Procedures for Rupprecht & Patashnick Co.Inc., Partisol-Plus Model 2025 Sequential Air Sampler, (R&P Sequential FRM)
Ambient Monitoring Program, Ops Unit 2, RP2025-PM2.5-SOP, Version 1, May 29, 2009.

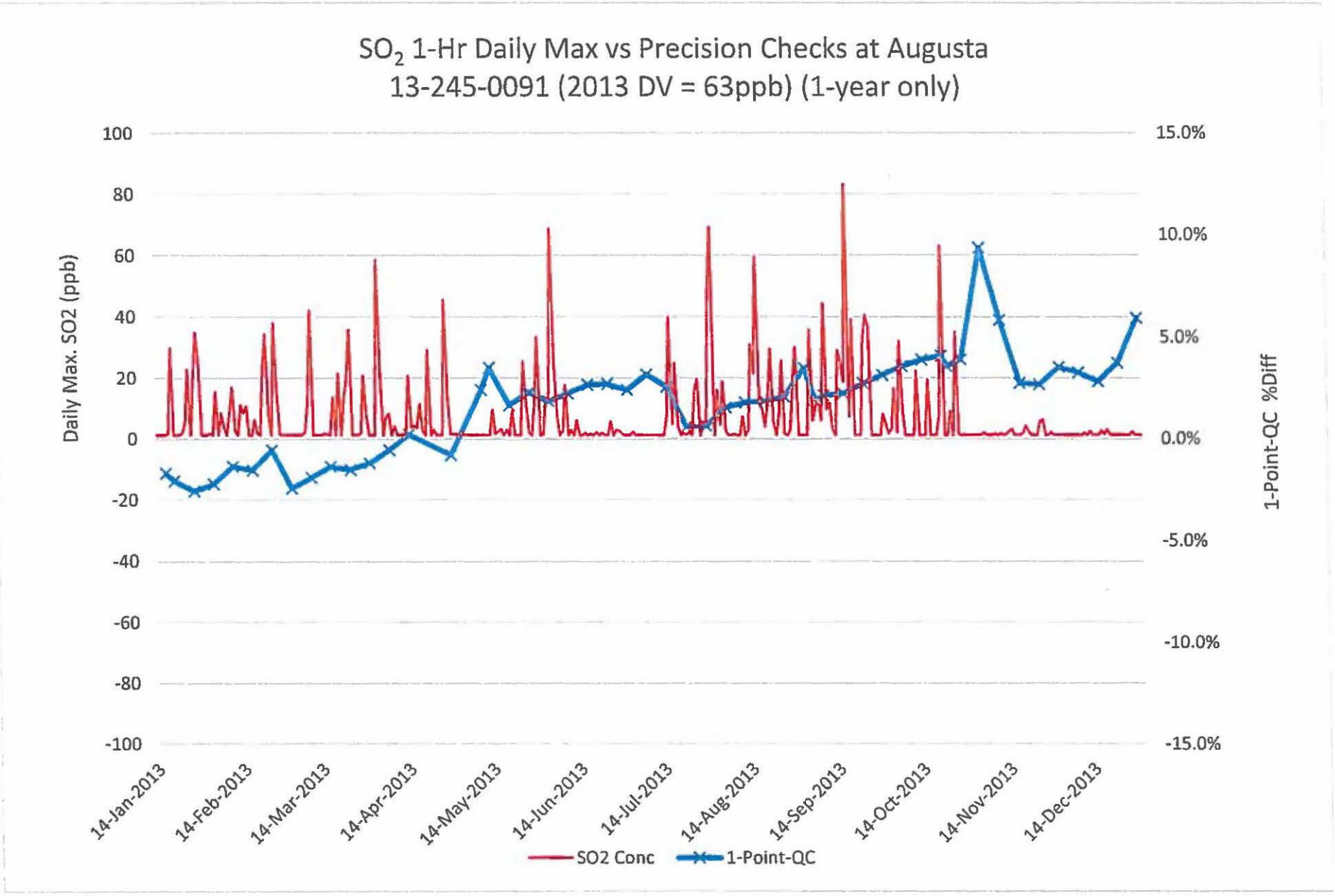
No comments.

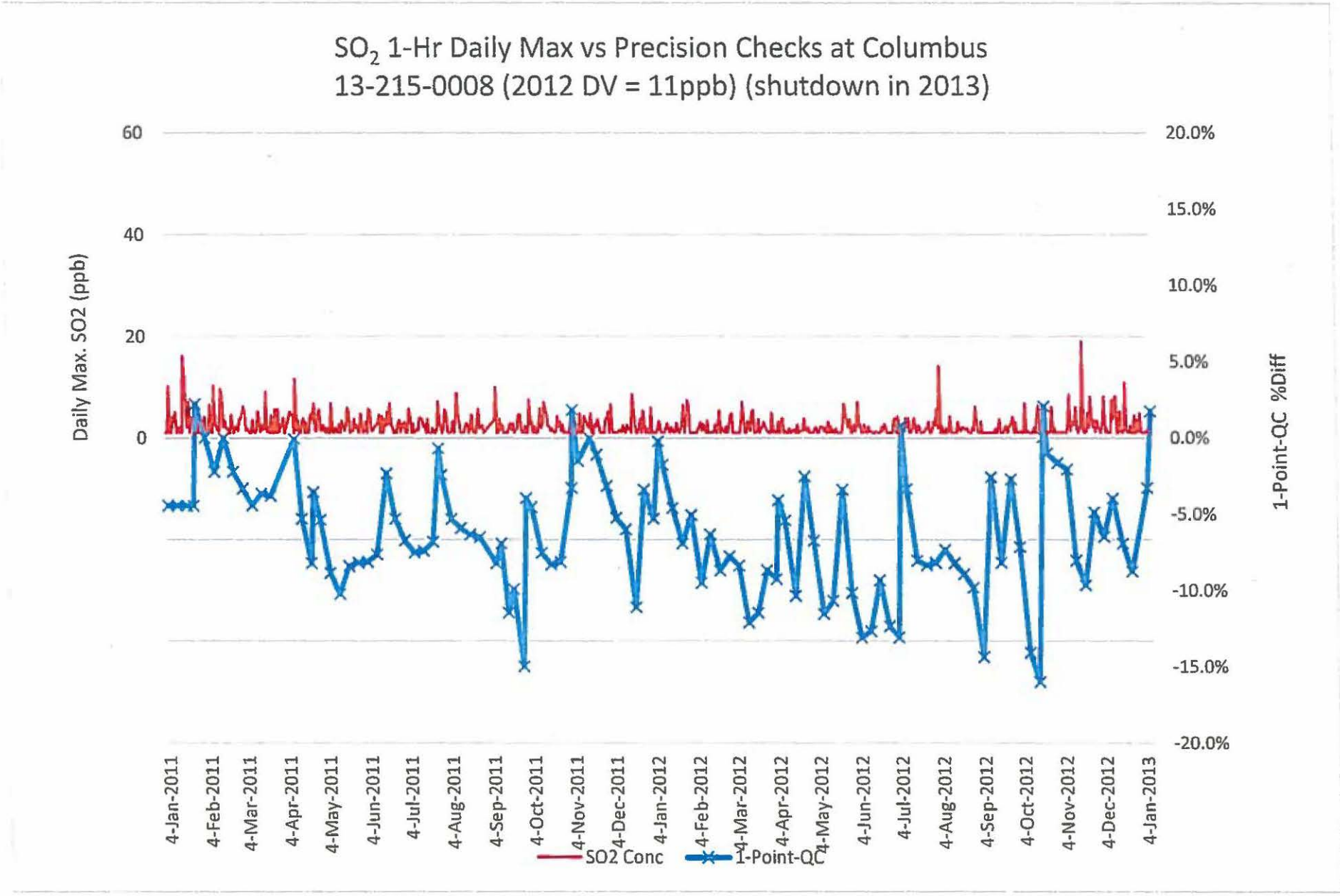
Standard Operating Procedures for Data Validation, Georgia Department of Natural Resources, Environmental Protection Division, Air Protection Branch, Ambient Monitoring.
Ambient Monitoring Program, Data Analysis Unit, Data Validation SOP, Version 1, May 29, 2009.

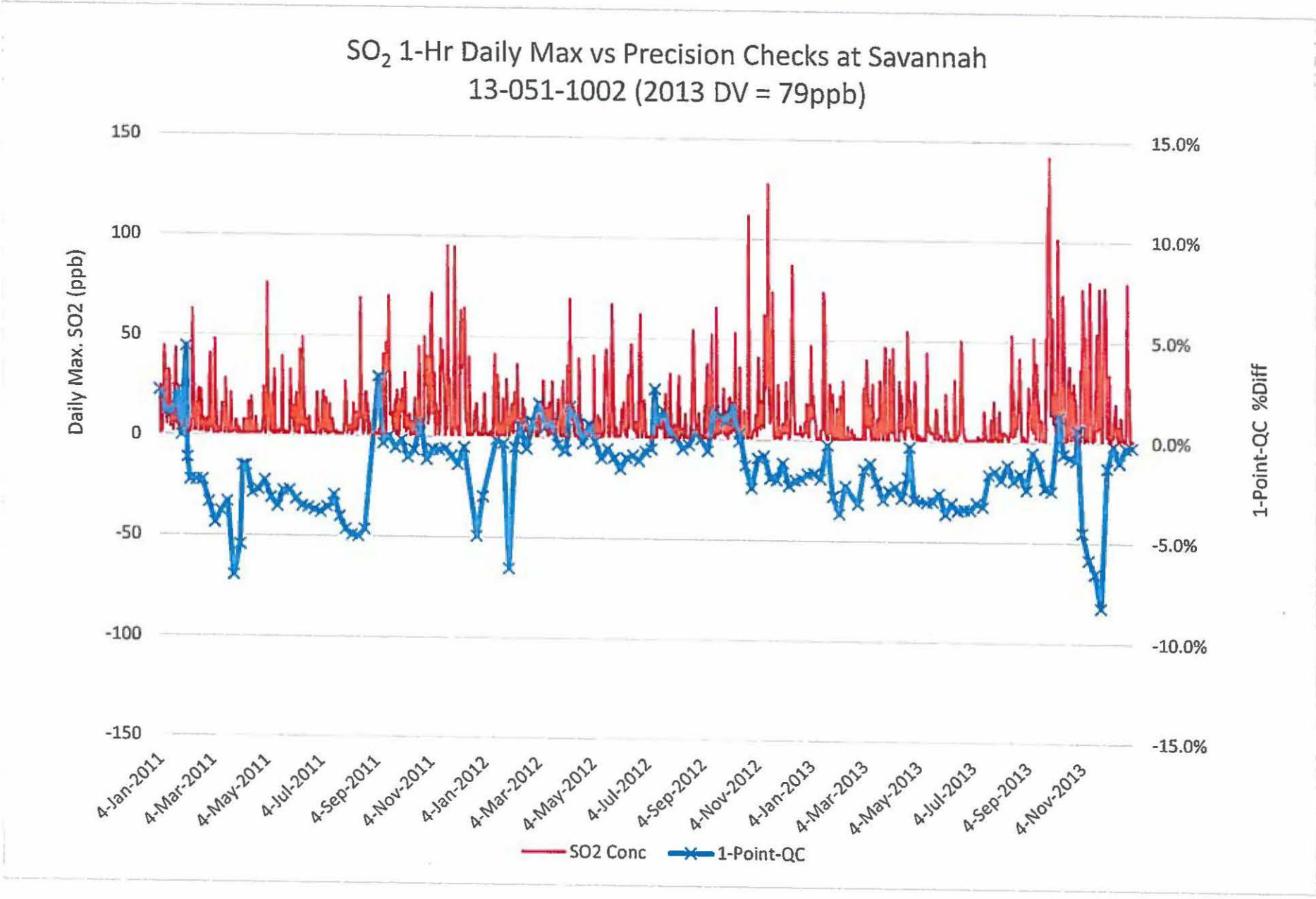
Data Review Process: Temperature range should be between 20-30 degrees Celsius.

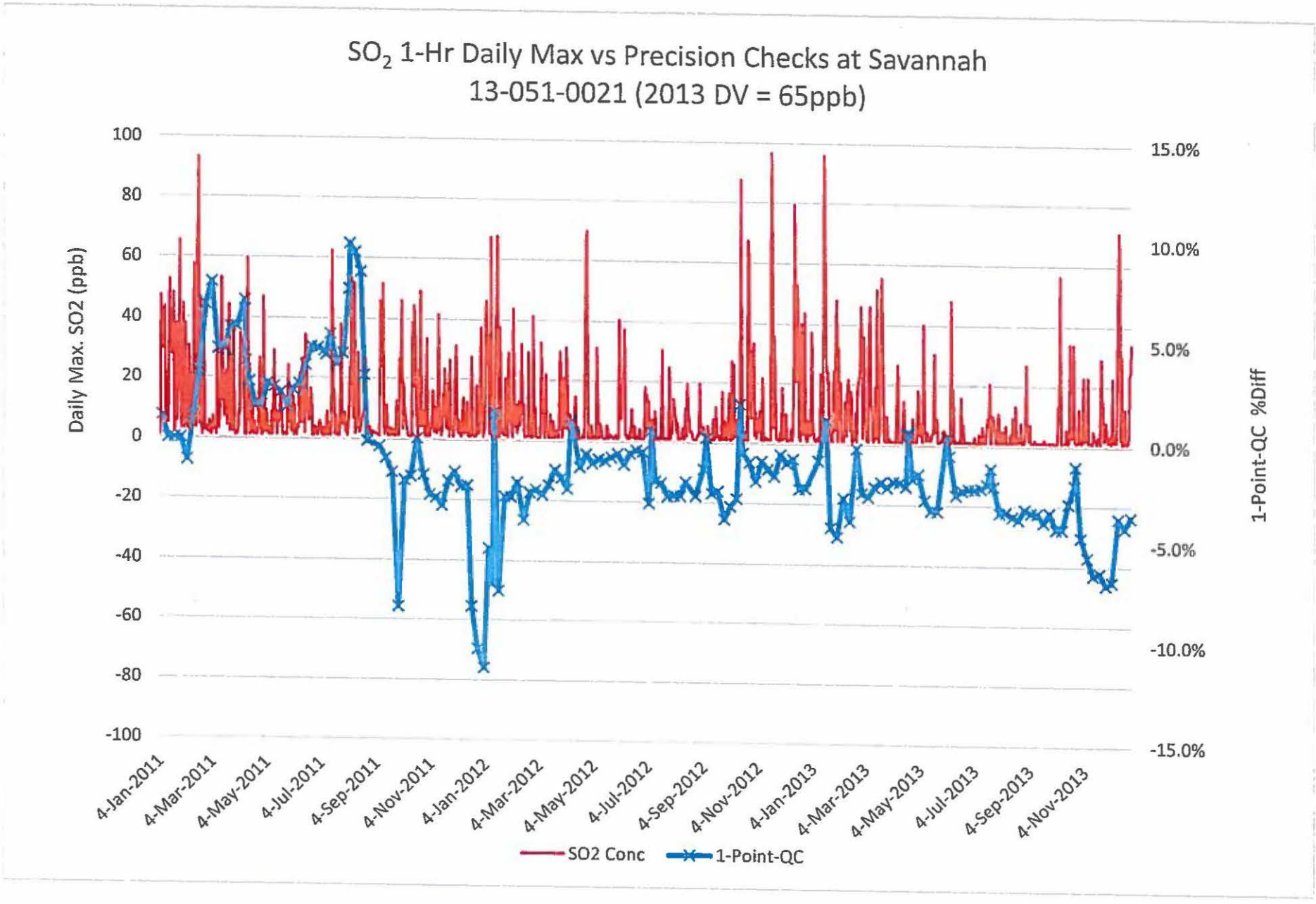
Appendix B

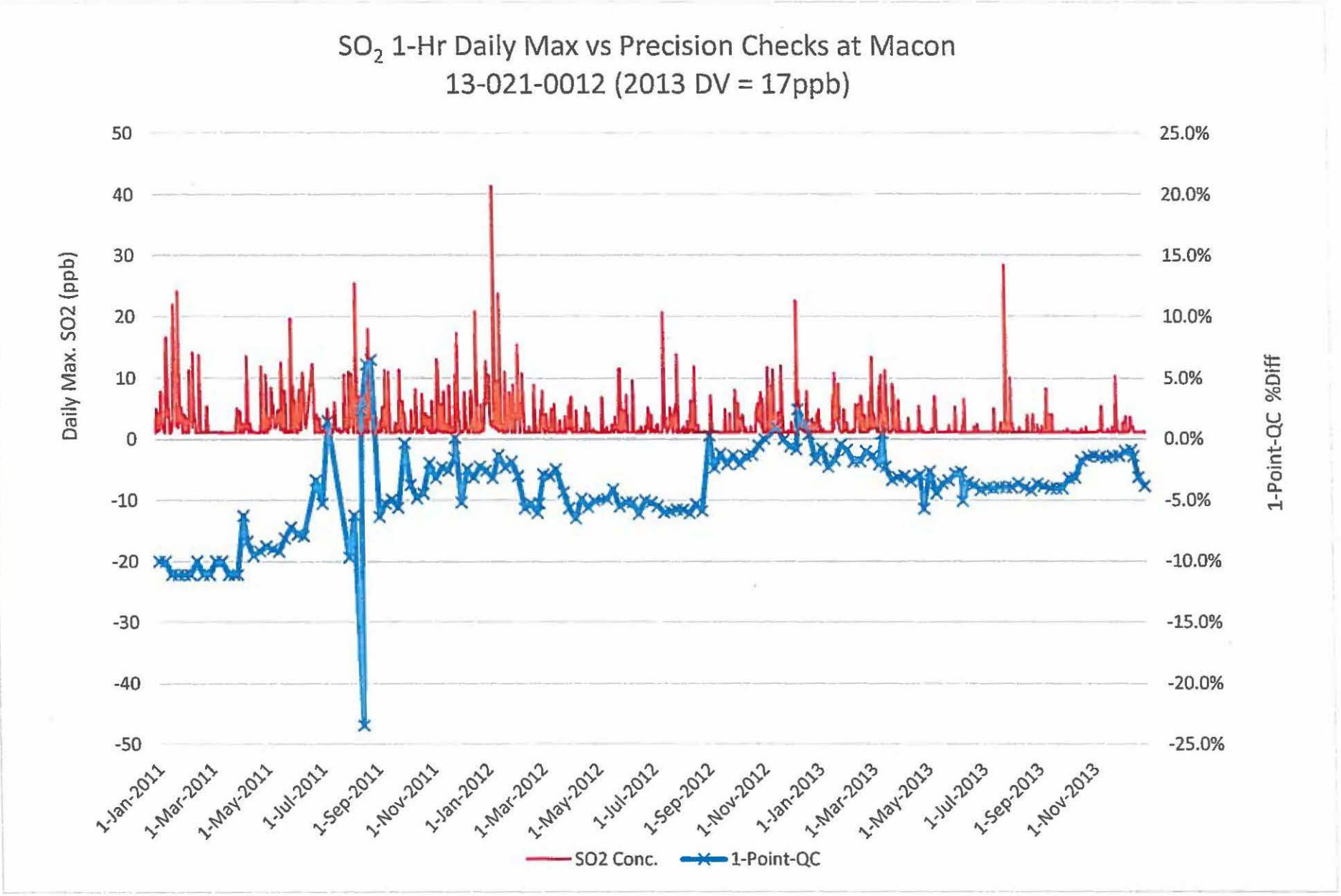
SO_2 Daily 1-hour Max Conc. vs 1-Point QC Check Graphs


SO_2 1-Hr Daily Max vs Precision Checks at Augusta
13-245-0091 (2013 DV = 63ppb) (1-year only)
Daily Max. SO2 (ppb)
1-Point-QC %Diff
100
80
60
40
20
0
-20
-40
-60
-80
-100
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
14-Jan-2013
14-Feb-2013
14-Mar-2013
14-Apr-2013
14-May-2013
14-Jun-2013
14-Jul-2013
14-Aug-2013
14-Sep-2013
14-Oct-2013
14-Nov-2013
14-Dec-2013
SO2 Conc
1-Point-QC


SO_2 1-Hr Daily Max vs Precision Checks at Columbus
13-215-0008 (2012 DV = 11ppb) (shutdown in 2013)
Daily Max. SO2 (ppb)
1-Point-QC %Diff
60
40
20
0
20.0%
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
-20.0%
4-Jan-2011
4-Feb-2011
4-Mar-2011
4-Apr-2011
4-May-2011
4-Jun-2011
4-Jul-2011
4-Aug-2011
4-Sep-2011
4-Oct-2011
4-Nov-2011
4-Dec-2011
4-Jan-2012
4-Feb-2012
4-Mar-2012
4-Apr-2012
4-May-2012
4-Jun-2012
4-Jul-2012
4-Aug-2012
4-Sep-2012
4-Oct-2012
4-Nov-2012
4-Dec-2012
4-Jan-2013
SO2 Conc
1-Point-QC


SO_2 1-Hr Daily Max vs Precision Checks at Savannah
13-051-1002 (2013 DV = 79ppb)
Daily Max. SO2 (ppb)
1-Point-QC %Diff
150
100
50
0
-50
-100
-150
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
4-Jan-2011
4-Mar-2011
4-May-2011
4-Jul-2011
4-Sep-2011
4-Nov-2011
4-Jan-2012
4-Mar-2012
4-May-2012
4-Jul-2012
4-Sep-2012
4-Nov-2012
4-Jan-2013
4-Mar-2013
4-May-2013
4-Jul-2013
4-Sep-2013
4-Nov-2013
SO2 Conc
1-Point-QC


SO2 1-Hr Daily Max vs Precision Checks at Savannah
13-051-0021 (2013 DV = 65ppb)
Daily Max. SO2 (ppb)
1-Point-QC %Diff
100
80
60
40
20
0
-20
-40
-60
-80
-100
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
4-Jan-2011
4-Mar-2011
4-May-2011
4-Jul-2011
4-Sep-2011
4-Nov-2011
4-Jan-2012
4-Mar-2012
4-May-2012
4-Jul-2012
4-Sep-2012
4-Nov-2012
4-Jan-2013
4-Mar-2013
4-May-2013
4-Jul-2013
4-Sep-2013
4-Nov-2013
SO2 Conc
1-Point-QC


SO2 1-Hr Daily Max vs Precision Checks at Macon
13-021-0012 (2013 DV = 17ppb)
Daily Max. SO2 (ppb)
1-Point-QC %Diff
50
40
30
20
10
0
-10
-20
-30
-40
-50
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
-20.0%
-25.0%
1-Jan-2011
1-Mar-2011
1-May-2011
1-Jul-2011
1-Sep-2011
1-Nov-2011
1-Jan-2012
1-Mar-2012
1-May-2012
1-Jul-2012
1-Sep-2012
1-Nov-2012
1-Jan-2013
1-Mar-2013
1-May-2013
1-Jul-2013
1-Sep-2013
1-Nov-2013
SO2 Conc.
1-Point-QC

Appendix C

United States Environmental Protection Agency

Ambient Air Monitoring Technical System Audit Form

Table of Contents

1) GENERAL INFORMATION

a) Program Organization

Organization Name:
- Georgia Environmental Protection Division

Address: (include physical and mailing addresses if different)
- 4244 INTERNATIONAL PKWY, Suite 120

City, State, and Zip Code:
- Atlanta, Georgia, 30354

Phone:
- 404-363-7000

Agency Director:
- Judson Turner

Ambient Air Monitoring (AAM) Network Manager:
- Susan Zimmer-Dauphinee

Quality Assurance Manager:
- Alex Yang

QA Auditors:
- Rob Brown
- Cathryn Lee
- Wayne Revels
- Javier Sayago
- Glen Vaughn
- Dorrethea Hollman-Colwell

Field Operations Supervisor / Lead:
- VACANT
- Bill Murphey
- Ken Buckley

Laboratory Supervisor:
- David Jones

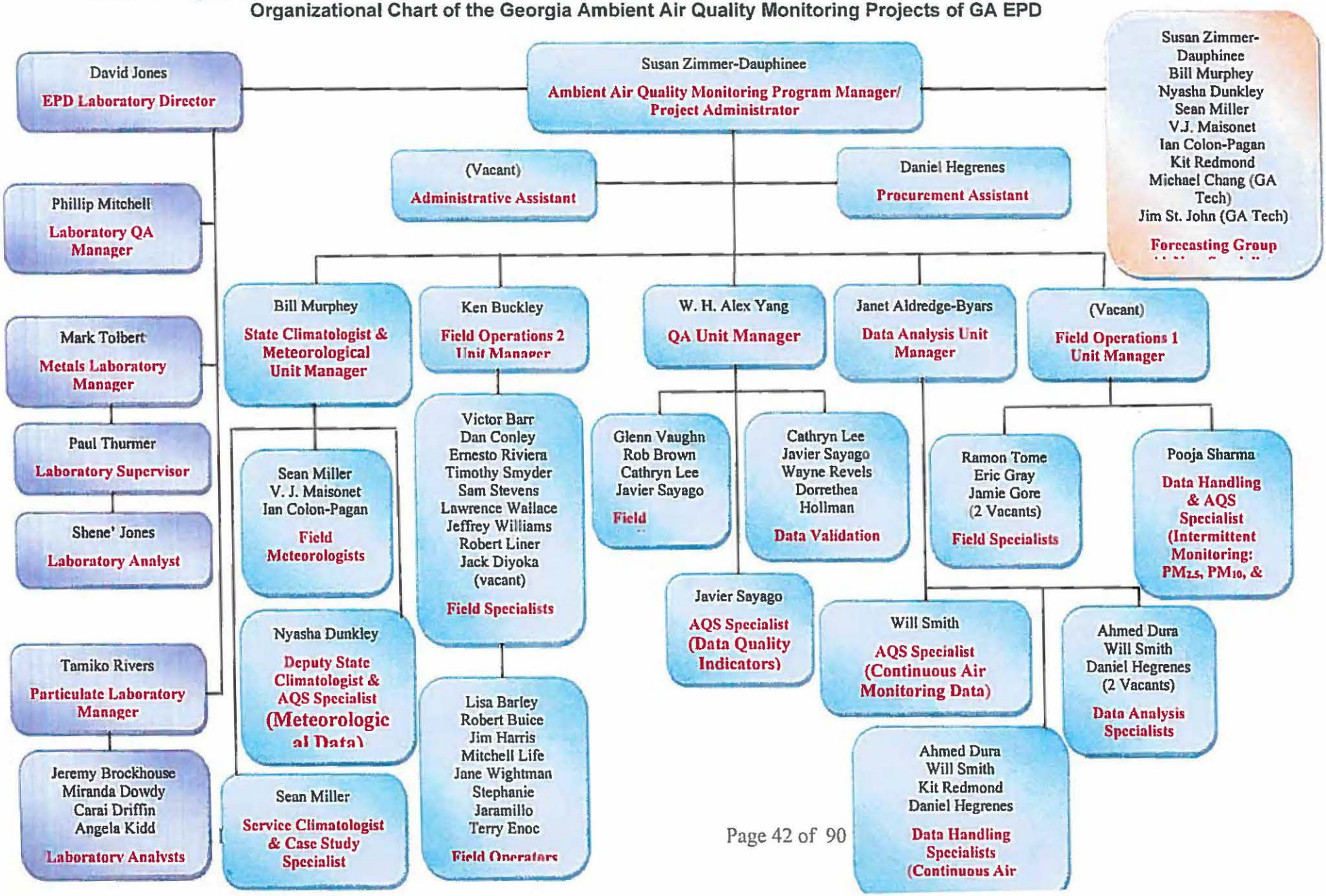
Laboratory QA Manager:
- Philip Mitchell

Data Management Supervisor / Lead:
- Janet Aldredge-Byars

AQS Submitter:
- Pooja Sharma
- Nyasha Dunkley
- Janet Aldredge-Byars
- Will Smith
- Javier Sayago
- Ramon Tome

Insert an Organizational Chart (or provide a hard copy during the audit):

Organizational Chart of the Georgia Ambient Air Quality Monitoring Projects of GA EPD



b) **Personnel**

List available personnel and select their primary duties:								
Name	Network Design and Siting	QC Activities	QA Activities	Equipment Repair & Maintenance	Data & Data Management	Financial Management	Site Operation (PM, Gaseous, Met)	Other Non-Ambient Air Monitoring Duties
Susan Zimmer-Dauphinee	X	X	X	X	X	X	X	X
Bill Murphey	X	X		X	X		X	X
VACANT	X	X		X	X		X	X
Ken Buckley	X	X		X	X		X	
Janet Aldredge-Byars	X	X (if include data validation		X (if include data validation)	X	X (if include data validation		Purchasing X
Alex Yang	X		X	X (QA equipment)	X (data validation)			X (QA equipment)

In your agency, are site operators responsible for running all of the instruments at their assigned sites, certain instruments (ex. O_3) at multiple sites, or a combination of the two? Combination of two options
Yes

List personnel who have authority or are responsible for:		
Activity	Name	Title
QA Training Field/Lab	Susan Zimmer-Dauphinee/Alex Yang (Field)/Phillip Mitchell(Lab)	Program Manager/Manager I
Grant Management	Lynne Collier/Susan Zimmer-Dauphinee	/Program Manager
Purchases Greater than $500	Daniel Hegrenes/Susan Zimmer-Dauphinee/Sakina Strozier	Env Compliance Specialist/Program Manager/Manager I
Equipment and Service Contract Management	Daniel Hegrenes/Susan Zimmer-Dauphinee	Env Compliance Specialist/Program Manager
Staff Appointment	Judson Turner	EPD Director
Monitoring Operations	Susan Zimmer-Dauphinee	Program Manager

Questions	Yes	No	Comments
Does your agency utilize any contractors in your air monitoring program? If no, skip to the next table.	X		
Who is responsible for oversight of contract personnel?	EPA We use EPA approved contract laboratory for PM2.5 speciation, Also Susan Zimmer-Dauphinee for forecasting		
What steps are taken to ensure contract personnel meet training and experience criteria?	Unknown for EPA Results of forecasting tools		
Does the contractor follow an EPA approved QAPP?			NA-pollution forecasting
- Where/how is this documented?			
How often are contracts reviewed and/or renewed?	Unknown Forecasting-contract renewed annually		

Comment on the need for additional personnel, if applicable:

- Need vacancies filled.

List your district offices and associated staff below (State Agencies Only)		
Name	Address	Staff
Columbus	3100 Airport Thruway Rd.	Ernesto Rivera
Savannah	2500 E. President St.	Dan Conley
Macon	5645 Riggins Mill Rd.	Vacant
Augusta	4431 Hardy McManus Rd.	Jeffrey Williams

Part-time statewide	Brunswick, Savannah, Coffee Co, Rome, Valdosta, Summerville, Rossville	

c) Training

Question	Yes	No	Comments
Does the agency have a training program and training plan?	X		Has a training program planned,
Where is it documented?	On shared directory in GA Air Protection Branch (S:\Ambient\Personnel Training and Evaluation Records)		
Does it make use of seminars, courses, and/or EPA sponsored courses?	X		Course APTI 452 (10/ 21-23/2013) Course APTI 400 (12/9-11/2013) Region 4 meeting
Are personnel cross-trained for other ambient air monitoring duties?	X		AQS
Are training funds specifically designated in the annual budget?	X		
Does the Training Plan Include: 1. Training requirements by position	X		
2. Frequency of Training	X		
3. Training for contract personnel		X	
4. A list of core QA related courses	X		

Indicate below the three most recent training events and identify the personnel participating in them:		
Event	Date(s)	Participant(s)
1. Excelling as a manager or Supervisor	1/23/2014 & 3/13/2014	Janet Aldredge-Byars Ken Buckley Susan Zimmer-Dauphinee Alex Yang Bill Murphey
2. The Three dimensions of safe driving	Throughout year	Entire Program
3. EPA APTI 400 Introduction to Hazardous Air Pollutants	12/9-11/2013	Cathryn Lee Javier Sayago Wayne Revels

		Dorrethea Hollman-Colwell
4. EPA APTI 452: Principals and Practices of Air Pollution	10/21-23/2013	Alex Yang Cathryn Lee Javier Sayago Rob Brown Wayne Revels Dorrethea Hollman-Colwell Victor Barr Jack Diyoka Robert Liner Ernesto Rivera Tim Smyder Sam Stevens Lawrence Wallace Jeffery Williams

d) Facilities

Identify the principle facilities where the agency conducts work related to air monitoring. Do not include monitoring stations, but include facilities where work is performed by contractors or other organizations. Select which purpose(s) each facility serves. Add additional lines as necessary

Facility Address	General Office Space	Data Verification and Processing	Criteria Gas Instrument Maintenance and Storage	Standards Certification/ Calibration	PM Filter Weighing	Records Storage	Air Toxics Maintenance and Storage	Air Toxics Laboratory
GA EPD Air Protection Branch 4244 International Pkwy, Suite 120, Atlanta GA 30354	X	X						
Work Shop			X	X			X	
Warehouse			X			X	X	
GA EPD Laboratory (5804 Peachtree Corners E. Norcross, GA 30092)		X			X			X

Are monitoring sites ever used for storage of equipment, spare parts or supplies?

- Yes, cylinders and cartridges

Identify any facilities that should be upgraded. Identify by function and any suggested improvements or recommendations.
We have upgraded the electrical and deck for several sites including General Coffee, Augusta, Yorkville, and Athens

- Yorkville's PAMS trailer needs to be replaced. Roof leaks, floor sags, mold inside.

Are facilities adequate concerning safety? If not, please explain and give suggested improvements or recommendations.

- Yes. Evaluate roof top sites.

Are there any significant changes likely to be implemented to agency facilities within the next three years? No		
Facility	Function	Proposed Change - Date

Comment on the agency's need for additional physical space (laboratory, office, storage, etc.)

2) QUALITY MANAGEMENT

a) Quality Assurance and Quality Control

i) Status of Quality Assurance Program

QA activities are performed and supported by sources uniquely different from those used in routine QC activities. Independent / dedicated equipment, different personnel and calibration methodologies are purposely used in performing QA audits, performance checks, etc.

Question	Yes	No	Comments
Does the agency perform QA activities with internal personnel? If no, skip this table.	X		
Does the agency maintain a separate laboratory to support quality assurance activities?		X	Separate work and equipment storage area
Has the agency documented and implemented specific audit procedures separate from monitoring procedures?	X		
Are there two levels of management separation between QA and QC operations? Please explain:	X		We have monitoring, Manager 1, and Manger 2 and QA manager. See Org chart
Does the agency have separate auditing equipment and standards (specifically intended for sole use) for audits?	X		

Do you conduct mandatory biweekly precision point checks?
Yes

Are they automated or conducted manually?
Automated

Select which of the following <u>additional</u> QC you conduct at your gaseous sites				
Precision Checks	Typically Performed?	How?		Frequency
		Manually	Automated	
Precision Point	**Yes**	**X**	**X**	**Weekly or as needed**
Zero Precision Span	**Yes**	**X**	**X**	**Weekly or as needed**
Zero Precision	**Yes**	**X**	**X**	**Weekly or as needed**
Probe Line Integrity Checks	**Yes**	**X**		**Quarterly Or as needed**
Other: _____				

ii) <u>Audits</u>

Question	Yes	No	Comments
Does the agency have separate facilities to support audits and calibrations?	X		
If the agency has in place contracts or agreements with another agency/contractor to perform audits/calibrations, please name the organization and briefly describe the type of agreement.	NA		
Does the agency maintain independence of audit standards and personnel?	X		
Do any site operators audit their own sites?		X	
Does the agency have a certified source of zero air for performance audits?	X		
How do you generate your zero air?	Use zero air cylinder or generator		
Does the agency have procedures for auditing and/or validation performance of meteorological monitoring?	X		
Has the agency established and documented criteria to define agency-acceptable audit results?	X		

Question	Yes	No	Comments
Are your sites regularly reviewed for Appendix E siting criteria?	X		Frequency: annually
Do you conduct internal audits of your air monitoring agency?	X		
(1) How frequently?	At least annually for each monitor and 25% quarterly for each pollutant network		
(2) What type of audit is conducted (e.g., performance or systems audit)?	QC document review, performance and system audits		
(3) Who receives the results of these audits?	Monitoring Project Administrator, Field QA Manager, and Field Operation Managers		
(4) Do you report these results to EPA?	X		Uploaded to AQS

Please provide a list of internal audit standards currently being used (these do not include standards used for calibrations and/or biweekly checks). Add additional lines as necessary.

Name	Model Number	Date of Last Certification	Approximate Age (years)
Thermo Electron Corp 49i-PS. (O_3)	Second level S/N:817730775 Third level S/N: 1027444435 S/N: 817730776	12/17/2013 (by EPA) 2/4/2014 (by QA Unit) 2/4/2014 (by QA Unit)	
Thermo Electron Corp 146i. (CO, SO_2, and NO_2)	S/N:0724223933 Analyte MFC Diluent MFC	11/12/2013 12/13/2013	
Environic 6100	S/N: 5890 Analyte MFC Diluent MFC	11/12/2013 12/03/2013	
Anderson orifice transfer standard (Pb)	C-207	Shipped off 3/16/14	
BGI Flow Transfer Standard with thermometer and barometer (PM_{10} & $PM_{2.5}$)	TetraCal S/N: 289	4/8/13	
BGI Flow Transfer Standard with thermometer and barometer (PM_{10} & $PM_{2.5}$)	TetraCal S/N: 114	10/16/2013	
BGI Flow Transfer Standard with thermometer and barometer (PM_{10} & $PM_{2.5}$)	DeltaCal S/N: 45	10/16/2013	

BGI Flow Transfer Standard with thermometer and barometer (PM_{10} & $PM_{2.5}$)	DeltaCal S/N: 39	4/8/2013	
BGI Flow Transfer Standard with thermometer and barometer (PM_{10} & $PM_{2.5}$)	DeltaCal S/N: 645	10/16/2013	
Chinook Flow Transfer Standard with thermometer and barometer (PM_{10} & $PM_{2.5}$)	S/N: S100606	11/26/2013	
CO EPA Protocol Std. Cylinder	Airgas	2/21/2011	
$CO/SO_2/NO/NO_x$ EPA Protocol Std.Cylinder	Scott-Marrin S/N: FF39446	06/28/2012	**2 yrs**

****Please have certifications of standards available for viewing during the audit**

Question	Yes	No	Comments
Does your agency participate in NPAP, $PM_{2.5}$ PEP, Pb PEP and other performance audits performed by an external party and/or using external standards?	X		
If the agency does not participate, please explain why:			
Are NPAP audits performed by QA staff, site operators, calibration staff, and/or another group?	X		Performed by EPA contractor
Is your agency audited by the State (if you are a local agency)?			NA
(1) How frequently?			
(2) What type of audit is conducted (e.g., performance or systems audit)?			
(3) Who receives the results of these audits?			
(4) Do you report these results to EPA?			

Who is primarily responsible for coordinating participation in:

(1) The National Performance Audit Program (NPAP)? Ken Buckley

(2) $PM_{2.5}$ Performance Evaluation Program (PEP)? Ken Buckley

(3) Lead Performance Evaluation Program (PEP)? Ken Buckley

Please complete the table below:	
Parameter Audited	Date of Last NPAP and/or PEP Audit
CO	06/06/13
O_3	08/14/13
SO_2	08/14/13
NO_2	5/16/2007
$PM_{2.5}$	02/24/14
Pb	Jan 2014 (failed to run)

b) Planning Documents

QMP Questions	Yes	No	Comments
Has the QMP been approved by EPA within the last five years?	X		Date of Original Approval: Date of Last Revision: June 2010 Date of Last Approval: 2010
QAPP Questions	**Yes**	**No**	**Comments**
Has the QAPP been reviewed by EPA annually?		X	QAPP for Criteria Air Pollutants Date of Original Approval: 2/24/1983 Date of Last Revision: 2/28/2014 Date of Last Approval: Waiting for internal review and EPA to approve
Has the QAPP been reviewed by EPA annually?		X	QAPP for NCore Date of Original Approval: 5/23/2011 Date of Last Revision: 6/30/2010 Date of Last Approval: 5/23/2011
Has the QAPP been reviewed by EPA annually?		X	QAPP for $PM_{2.5}$ Date of Original Approval: Date of Last Revision: 1/22/2013 Date of Last Approval: 1/23/2009
Has the QAPP been reviewed by EPA annually?		X	QAPP for NATTS Date of Original Approval: 3/19/2007 Date of Last Revision: 4/26/2011 Date of Last Approval: 3/19/2007
Has the QAPP been reviewed by EPA annually?		X	QAPP for PAMS Date of Original Approval: Date of Last Revision: 2/24/2010 Date of Last Approval: 7/21/2010
Does the State review your QAPP prior to EPA review? (local agencies only)			NA
Does your agency have any revisions to your QAPP pending?	X		
How does the agency verify the QAPP is fully implemented?	By calibration review, internal and external audits, site assessment, and data validation.		
How is the QAPP available to the staff (e.g.., electronically, hard copies at site, etc.)	Hard copies are available in office. Available electronically in program computer network.		
SOP Questions	**Yes**	**No**	**Comments**
How does the agency verify that the SOPs are implemented as provided (e.g., staff are regularly observed for correct implementation of SOPs)?	Staff are regularly trained and observed for correct implementation of SOPs. All associates have signed that have read respective SOPs for their unit (paperwork on file).		
How are revisions to the SOP distributed?	Distributed through printed copies with outdated sections returned to Program office.		
How are SOPs available to the staff (e.g.., electronically, hard copies at site, etc.)	All specialists and operators have hard copies. Available electronically in program computer network.		
Are any new monitoring SOPs needed? If yes, please list in comments section.	X		Lead and PM course awaiting approval

			Data Validation of Continuous Monitoring Data awaiting approval

List all of the agencies current SOPs: QA SOPS

Title	Date of Last EPD Update	Date of Last EPA Approval	Pollutant of Concern (if applicable)
TSP High-Volume Sampler Field Audit (Metals)	3/11/13	9/11/09	
Semi-VOCs Sampler Field Audit	10/31/13	9/11/09	
VOCs ATEC 2200 sampler Field Audit	11/26/13	9/11/09	
VOCs AVOC Sampler Field Audit	11/13/13	9/11/09	
Carbonyls ATEC 100 Sampler Field Audit	11/05/13	9/11/09	
Carbonyl ATEC 8000 Sampler Field Audit	12/17/13	9/11/09	
Continuous CO Monitoring Field Audit	11/06/13	9/11/09	
Continuous NO-NO_2-NO_x Monitor Field Audit	10/30/13	9/11/09	
Continuous NOy Monitor Field Audit	11/01/13	9/11/09	
Continuous SO_2 Monitor Field Audit	11/05/13	9/11/09	
Continuous O_3 Monitor Field Audit	3/18/13	9/11/09	
PAMS Speciated VOCs Monitor Field Audit	12/17/13	9/11/09	
Continuous $PM_{2.5}$ (BAM) Sampler Field Audit	3/12/13	9/11/09	
Continuous $PM_{2.5}$ (TEOM) Sampler Field Audit	3/12/13	9/11/09	
Intermittent $PM_{2.5}$ Sampler Field Audit	3/12/13	9/11/09	
Intermittent PM_{10} Sampler Field Audit	11/13/13	9/11/09	
$PM_{2.5}$ Speciation Sampler Field Audit	3/12/13	9/11/09	
$PM_{2.5}$ Speciation URG 3000N Sampler Field Audit	3/12/13	9/11/09	
Athalometer OC-EC Monitor Field Audits	11/07/13	9/11/09	
Meteorological Instruments Field Audit	3/12/13	9/11/09	
Criteria Air Pollutants Data Validation	12/12/13	9/11/09	

Continuous PAMS Speciated VOCs Data Validation	12/17/13	9/11/09	
Integrated PM2.5 Data Validation	3/12/13	9/11/09	
Site Assessment	12/18/13		
AQS Upload for Data Quality Indicators	3/14/14	9/11/09	
Thermo 146i Gas Mixer Calibration	3/14/14		

	List all of the agencies current SOPs: Monitoring SOPS				
	Title	Date of Last EPA Approval	Pollutant of Concern (if applicable)		
Aethalometer				9/11/09	
ATEC 8000 1223				9/11/09	
ATEC 2200				9/11/09	
ATEC 3400-2F				9/11/09	
AVOCS				9/11/09	
BAM 1020				9/11/09	
CO-trace				9/11/09	
CO NAAQS				9/11/09	
Data validation				9/11/09	
EDAS				9/11/09	
Gas chromatography-Perkin Elmer				9/11/09	
Improve				9/11/09	
Lead				9/11/09	
Metals				9/11/09	
Meteorological				9/11/09	
Met One SASS				9/11/09	
NOx				9/11/09	
Ozone				9/11/09	
Partisol				9/11/09	
PM10				9/11/09	
PUF 1223-NATTS				9/11/09	
PUF Toxics				9/11/09	
RP 2025 PM2.5				9/11/09	
SO2-TRS				9/11/09	
TEOM				9/11/09	
URG 3000N				9/11/09	
WUAQLAETJDATAMASHER				9/11/09	

c) General Document Policies

Question	Yes	No	Comments
Does the agency have a documented records management plan?	X		State Retention
Does the agency have a list of files considered official records and their media type? (i.e., paper, electronic)	X		
Does the agency have a schedule for retention and disposition of records?	X		
Are records maintained for at least three years?	X		
Who is responsible for the storage and retrieval of records?	Administrative		
What security measures are utilized to protect records?	Redundant backup		
Where/when does the agency rely on electronic files as primary record?	Electronic raw data polled from sites. Maintenance, QA/QC, and Calibration forms.		
What is the system for storage, retrieval and backup of these files?	Electronic files backed up nightly		

g) Corrective Action(s)

Question	Yes	No	Comments
Does the agency have a comprehensive corrective action program in place?	X		Confirm or refute. Correct & Calibrate if needed. Re-audit.
Have the procedures been documented?	X		SOPs
1. As a part of the QA project plan?	X		
2. As a separate standard operating procedure?		X	
Does the agency have established and documented corrective action limits for QA and QC activities?	X		MQO, QA Handbook Vol. II
Are procedures implemented for corrective actions based on results of the following which fall outside of established limits:			
1. Performance Evaluations	X		Verify, correct, calibrate.
2. Precision Goals	X		
3. Bias Goals	X		
4. NPAP Audits	X		Verify, correct, calibrate
5. PEP Audits	X		Verify, correct, calibrate
6. Validation of one point QC Check Goals	X		Verify, correct, calibrate
7. Completeness Goals	X		
8. Data Audits	X		
9. Calibrations and Zero Span Checks	X		Verify, correct, calibrate
10. Technical Systems Audit	X		Verify, correct, calibrate
Have the procedures been documented?	X		Variable by specific issue.

How is responsibility for implementing corrective actions assigned? Briefly discuss
The auditor notifies the site operator immediately following the audit of any deficiencies found. The site operator implements any corrective action needed as soon as possible, preferably before the next sampling event. The auditor provides the report to management which follows up on the corrective action results.

How does the agency follow up on implemented corrective actions? Perform internal follow-up audit.

Please fill out the table below for precision			
Pollutant	**Action Level**	**Corrective Action (if exceeded)**	**Redbook Guidance Action Level Reference**
O_3	≤ ±7%	Re-calibration	QA Handbook Volume II, Appendix D Revision May 2013 Page 35 of 48
CO	≤±10%	Re-calibration	QA Handbook Volume II, Appendix D Revision May 2013 Page of 48
NO_2	≤±15%	Re-calibration	QA Handbook Volume II, Appendix D Revision May 2013 Page 10 of 30 48
SO_2	≤±10%	Re-calibration	QA Handbook Volume II, Appendix D Revision May 2013 Page 913 of 48

Please fill out the table below for accuracy			
Pollutant	**Action Level**	**Corrective Action (if exceeded)**	**Redbook Guidance Action Level**
O_3	Audit levels 3-10 ≤±15% Audit levels 1-2 ≤ 1.5 ppb or ≤± 15%	Re-calibration and then re-audit	QA Handbook Volume II, Appendix D Revision May 2013 Page 35 of 48
CO	Audit levels 3-10 outside ±15% Audit levels 1-2 > 0.03ppm or ≤± 15%	Re-calibration and then re-audit	QA Handbook Volume II, Appendix D Revision May 2013 Page 8 of 48
NO_2	Audit levels 3-10 >±15 % Audit levels 1-2 > 1.5 ppb or ≤± 15%	Re-calibration and then re-audit	QA Handbook Volume II, Appendix D Revision - May 2013 Page 10 of 48
SO_2	Audit levels 3-10 >±15 % Audit levels 1-2 > 1.5 ppb or ≤± 15%	Re-calibration and then re-audit	QA Handbook Volume II, Appendix D Revision May 2013 Page 913 of 48

At what point do you invalidate data?

Point to invalidate data for each monitor			
Pollutant	**Action Level**	**Invalid Data**	**Redbook Guidance Action Level Reference**
O_3	One-point QC check outside ±7% Zero drift outside ± 1.5 ppb Span drift outside ± 7%	Yes Review case by case Yes	QA Handbook Volume II, Appendix D Revision May 2013 Page 5 of 48
CO	One-point QC check outside ±10% Zero drift outside ± 0.03 ppm Span drift outside ± 10%	Yes Review case by case Yes	QA Handbook Volume II, Appendix D Revision May 2013 Page 8 of 48
NO_2	One-point QC check outside ±15% Zero drift outside ± 1.5 ppb Span drift outside ± 10% Converter efficiency outside 96%-104%	Yes Review case by case Yes Review case by case	QA Handbook Volume II, Appendix D Revision May 2013 Page 10 of 48
SO_2	One-point QC check outside ±10% Zero drift outside ± 1.5 ppb Span drift outside ± 10%	Yes Review case by case Yes	QA Handbook Volume II, Appendix D Revision May 2013 Page 13 of 48

h) Quality Improvement

Question	Yes	No	Comments
Have all deficiencies indicated on the previous TSA been corrected? If not, explain.	X		
What actions were taken to improve the quality system since the last TSA?	Much more and better communications among AAQMP, EPA Region 4, and GA EPD Laboratory. Much more specific and customized in updating QAPPs and SOPs in accordance to most recent version of the EPA QA Handbooks		
Since the last TSA, do your control charts indicate that the overall data quality for each pollutant steady or improving?	X		
For areas where data quality appears to be declining, has a cause been determined?	X		
Are there pending plans for quality improvement such as purchase of new or improved equipment, standards, or instruments?	X		

3) NETWORK MANAGEMENT/FIELD OPERATIONS

a) Network Design

Complete the table below for each of the sites in your air monitoring network (active in the last three years) with the number of instruments measuring each pollutant (including NCore low level instruments – e.g. 1 low level CO + 1 regular CO = 2 CO instruments).

AQS ID	Common Site Name	Pb	CO	SO_2	NO_2	O_3	Manual				Collocated		Continuous		Meteorology
							$PM_{2.5}$	PM_{10}	$PM_{2.5}$ speciation	$PM_{2.5}$ Carbon	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	
	See Monitoring Plan														

Complete the table below with the number of spare monitor(s) you have on hand for measuring each pollutant (including NCore low level instruments).													
Pb	CO	SO_2	NO_2	O_3	Manual				Collocated		Continuous		Meteorology
					$PM_{2.5}$	PM_{10}	$PM_{2.5}$ Speciation	$PM_{2.5}$ Carbon	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	
4	3	4	6	9	4	4	3	3			3	3	9 wind 2 rad 10 bp 4humid/temp 8 aspir sheild

In addition to the extra analyzers listed above, Georgia has ten (10) extra gas blender calibrators for use with the CO, SO_2 and NO_2 analyzers and nine (9) extra ozone calibrators. Additionally, Georgia has three (3) extra VOC samplers, two (2) carbonyl samplers, twenty (20) extra motors to use with the PUF and PM_{10} samplers, one (1) gas chromatograph and one (1) extra TD.

Select which of the following are typically found at your Gaseous and PM sites		
Equipment/ Supplies	Gaseous	PM
Data Logger	X	Some
Calibrator	X	
Gas Blender	As Needed	
Zero Air System	X	
Perm Tube Oven		
Paper Strip Chart		
Permanent Site Computer	X	
Phone		
Modem		
DSL Connection	Some	
Cellular Modem Connection	All	Most
Meteorological Station	Some	Some
Interior Temperature Probe	X	Some
Interior Min/Max Thermometer	X	
Air Conditioner / Heater	X	
Uninterrupted Power Supply or Backup Power	Some	
Instrument Manuals	X (operator)	X (operator)
Instrument Logbooks	X/Digital	X/Paper
Site Logbook	X/Digital	X/Paper
SOP's	X (operator)	X (operator)
Other:_____		
Other:_____		

Select which of the following are typical of your Probe System	
Tee'd Probe System	
Retractable Probe System	
Glass Manifold within Probe System	
Heat Tape for Moisture Control	PAMS

If none of the above is applicable, please describe your probe system.

- Savilex inlet under rain shield with Teflon filter and integrity line connected at inlet.

How often do you clean / replace your probe lines?

- Quarterly or as needed.

What material are your probe lines made of?

- Teflon.

What material are your inlet funnels made of (e.g. glass, Teflon, plastic)?

- Stainless Steel.

How often do you change the particulate filter on the back of the instrument?

- Quarterly or as needed.

How often do you clean your glass manifold (if applicable)? Once a year or as needed

How do you connect your instrument to your data logger (analog, RS232, or Ethernet)?
Primarily analog. Working toward digital / Ethernet.

Question	Yes	No	Comments
What is the date of the most current Monitoring Network Plan?	2013		
Is it available for public inspection?	X		

Has EPA granted waivers for any of your monitoring sites? EPA granted waiver to stop running Cartersville lead monitor with 2013 Annual Monitoring Plan

Are you aware of any sites that are not currently meeting the requirements of 40 CFR Part 58 Appendix D & E? No

Question	Yes	No	Comment
Are hard copy site information files retained by the agency for all air monitoring stations within the network?	X		
Does each station have the required information including:			
1. AQS Site ID Number?	X		
2. Photographs/slides to the four cardinal compass points?	X		
3. Startup and shutdown dates?	X		
4. Documentation of instrumentation?	X		
Who has custody of the current network documents?	Name:Susan Zimmer-Dauphinee Title:Program Manager		
Does the current level of monitoring effort, station placement, instrumentation, etc., meet requirements imposed by current grant conditions?	X		
How often is the network siting reviewed?	Annually		
Do any sites vary from the required frequency in 40 CFR 58.12?		X	
Does the number of collocated monitoring stations meet the requirements of 40 CFR 58 Appendix A?	X		
Is each method for PM monitoring collocated with the same method type? (40 CFR 58 Appendix A Section 3.2.5.2 paragraph (a))	X		

b) Changes to the Network since the Last Audit

Please provide information on any site changes since the last audit:				
Pollutant	Site ID	Site Address	Site Added/Deleted/ Relocated	Reason (Assessment, lost lease, etc.) Provide documentation of reason for each site change
See Monitoring Plan, 2013, Section 1.7, pages 6-7				
See Monitoring Plan 2012, Section 1.7 pages 6-7				
See Monitoring Plan 2011, Section 1.7, pages 6-7				

c) Proposed Changes to Network

Please provide information on proposed site changes, including documentation of the need for change and any required approvals:				
Pollutant	Site ID	Site Address	Site to be Added/Deleted/ Relocated	Reason (Assessment, lost lease, etc.) Provide documentation of reason for each site change
SO2				
NO2	New	Georgia Tech	Add	New Regulations, near road
Lead				
CO	New	Georgia Tech	Add	New Regulations, near road

d) Field Support

Question	Yes	No	Comments
On average, how often are most of your stations visited by a field operator?	1.5 per wk		
Is this visit frequency consistent for all reporting organizations within your agency?	X		

i) Instrument Inventory

Please list instruments in your inventory:			
Pollutant	Manufacturer	Models	Reference or Equivalent Method Number
SO_2	Thermo	43C / 43i	EQSA-0486-060
NO_2	Thermo Teledyne	42C / 42i T200UP	RFNA-1289-074 EQNA-0512-200
CO	Thermo	48C / 48i	RFCA-0981-054
O_3	Thermo	49C / 49i	EQOA-0880-047
PM_{10}	Thermo Met One	Partisol 2000 BAM 1020	RFPS-0694-098 EQPM-0798-122
$PM_{2.5}$	Thermo Met One R&P	2025 BAM1020 TEOM	RFPS-0598-120 RFPS-0498-118 EQPM-0308-170
Pb	Graesby Andersen (etc)	HiVol	
Multi gas calibrator	Thermo Environics	146C / 146i 6103/9100	
$PM_{2.5}$ speciation	Met One URG	SASS 3000N	
$PM_{10-2.5}$ speciation			
$PM_{10-2.5}$ FRM mass	Met One	BAM 1020	EQPM-0709-185
Continuous $PM_{2.5}$ mass	Met One R&P	BAM 1020 TEOM	
Trace levels (CO)	Thermo	48iTLE	
Trace levels (SO_2)	Thermo	43iTLE	
Trace levels (NO)	Thermo	42C / 42i	
Trace levels (NO_y)	Thermo	42CYTL	
Surface Meteorology	Sonic/R.M. Young R.M. Young R.M. Young Nova Lynx	81000/85000/05305VM WSP 41375VC Temp/RH 61302/61201 BP 2602501 Precip	
Data Logger	ESC	8832 / 8816	
Others	Zero Air Generators	Environics 7000 Teledyne 701	
PAMS	Perkin/Elmer	AutoSystem XL Clarus 500 Autosystem ATD400 TurboMatrix TD	

VOCs	ATEC	2200	
CARBONYL	ATEC	8000	
PUF	TISCH		
METALS	TISCH	HI-VOL	

ii) Calibration

Please indicate the frequency of multi point calibrations:		
Pollutant	Frequency	Name of Calibration Method
SO2, NO2, CO, O3,	Startup, then quarterly or as needed following maintenance or repairs.	Gas Blender or O3 Calibrator.
PM2.5, PM10, Speciation	Startup, then monthly QC and Annual Calibration or as needed following maintenance or repairs.	Chinook/Delta Cal or Tetra Cal.
Pb, VOC, PUF, Metals, Carbonyls	Startup, then quarterly or as needed following maintenance or repairs.	Calibrated Orifice, Gilibrator.
PAMS	At startup/shutdown and when necessary	4-point-Slope of least square regression line

Please list the authoritative standards used for each type of flow measurement, indicate the certification frequency of standards to maintain field material/device credibility:		
Flow Device	Primary Standard	Frequency of Certification
HiVol Orifice	Sent to Mfg. For recert.	Annual
Streamline	""	""
Trical	Sent to Mfg. For recert.	Annual
Bios	Sent to Mfg. For recert.	Annual
DeltaCal	Sent to Mfg. For recert.	Annual
Gilibrators	Sent to Mfg. For recert.	Annual
Other	Sent to Mfg. For recert.	Annual

Please list the authoritative standards and frequency of each type of dilution, permeation and ozone calibrator and indicate the certification frequency:		
Calibrator	Primary Standard	Frequency of Certification
Permeation Calibrator Flow Controller		
Permeation Calibrator Temperature		
Dilution Calibrator air and gas Flow Controllers	Gilibrator	Quarterly or as needed.
Field/Working Standard Photometer	EPD Bench 49CPS / 49iPS	Annual / EPA Reg 4
Ozone Generator	EPD Site 49CPS / 49iPS	Seasonal / EPD workshop
ENVIRONICS DILUTER	2-component NIST	Annually

Please identify station standards for gaseous pollutants at representative air monitoring stations			
Parameter	Station(s)	Identification of Standard(s)	Recertification Date(s)
CO	Roswell Rd. Yorkville S. Dekalb	Gas cylinder	1/04/14 9/09/18 2/21/14
NO_2	Conyers Yorkville S. Dekalb	Gas cylinder	1/11/13 1/11/13 2/28/13
SO_2	Confed. Ave Sav. E. Pres Sav. L&A Rome Macon S. Dekalb Augusta	Gas cylinder	12/24/20 12/24/20 12/17/20 1/18/19 12/24/20 11/1/16 12/24/20
O_3	23sites	Site Calibrator	Annual
PAMS	Yorkville South Dekalb Conyers	GAS CYLINDER NIST	Annually

If an instrument goes down, at what length of time would you recalibrate the instrument before bringing it back online (24 hours, 48 hours, etc.)?

Depending on the reason it goes down, we might perform an Unadjusted check as soon as conditions are stabilized and diagnostic readings are acceptable; followed by an Adjusted Calibration if needed. If the initial failure was catastrophic then an Adjusted Calibration would be performed following the equipment repair or replacement, just as when starting up a new site or parameter.

Question	Yes	No	Comments
Are field calibration procedures included in the document SOPs?	X		Location (site, lab, etc.): Operator
Are calibrations performed in keeping with the guidance in section Vol II of the QA Handbook for Air Pollution Measurements Systems?	X		If no, why not?
Are calibration procedures consistent with the operational requirements of Appendices to 40 CFR 50 or to analyzer operation/instruction manuals?	X		If no, why not?
Have changes been made to calibration methods based on manufacturer's suggestions for a particular instrument?		X	
Do standard materials used for calibrations meet the requirements of appendices to 40 CFR 50 (EPA reference methods) and Appendix A to 40 CFR 58 (traceability of materials to NIST-SRMs or CRMs)?	X		
Where do field operations personnel obtain gaseous standards?	EPD Field Operations/Vendor		
Are those standards certified by: 1. The agency laboratory?		X	
2. EPA/NERL standards laboratory?		X	
3. A lab separate from this agency's but part of the same reporting organization?	X		
4. The vendor?	X		EPA Protocol / NIST traceable
5. Other (describe)			
How are the gas standards verified after receipt?	An Unadjusted check is performed onsite with the old gas standard and then repeated with the new gas standard to show the relationship between the two before any adjustments are made to the equipment.		
Are you involved in the EPA protocol gas certification program?	X		
What equipment is used to perform calibrations (e.g., dilution devices) and how is the performance of this equipment verified?	Gas blenders, quarterly flow calibrations, independent audits		
Does the documentation include expiration date of certification?	X		
1. Reference to primary standard used?	X		
2. What traceability is used?	X		
Is calibration equipment maintained at each station?	X		
How is functional integrity of this equipment documented?	Certification records of standards and Calibration documents for equipment.		
Who has responsibility for maintaining field calibration standards?	EPD Field Operations / Site Specialist		

iii) Repair

a) **Who is responsible for performing preventative maintenance?**
Field staff

b) **Is special training provided to them for performing preventative maintenance? Briefly comment on background or courses.**
Manufacturer's training when available, hands on work in our repair and refurbishing facility, onsite real-time experience shared with peers.

c) **Is this training routinely reinforced? If no, why not?**
Annually with O3 refurbishing and recertification as well as when needed with new equipment or specific issues.
For PAMS, training is reinforced throughout the season.

d) **What is your preventative maintenance schedule for each type of field instrumentation?**
All Particulate monitors are routinely maintained monthly, while the continuous gaseous analyzers are serviced quarterly.
For PAMS, at startup and throughout the sampling season

e) **If preventative maintenance is MINOR, it is performed at (check one or more):**
_X_ Field Station
_X_ Headquarters Facilities
___ Equipment is sent to Manufacturer

f) **If preventative maintenance is MAJOR, it is performed at (check one or more):**
___ Field Station
_X_ Headquarters Facilities
_X_ Equipment is sent to Manufacturer

g) **Does the agency have service contracts or agreements in place with instrument manufacturers? Indicate below which instrumentation is covered.**
Yes, for PAMS. Thermal Desorbers & Gas Chromatographs/Flame Ionization Detector.

h) **Comment briefly on the adequacy of availability of the supply of spare parts, tools and manuals available to the field operator to perform any necessary maintenance activities. Do you feel that this is adequate to prevent any significant data loss?**
For the most part we should be OK, but you don't know for sure until something happens.

i) **Is the agency currently experiencing any recurring problem with equipment or manufacturer(s)? If so, please identify the equipment manufacturer, and comment on steps taken to remedy the problem.**

Some recurring issues with BAMs. We are working with the manufacturers to try and get a better handle on the nuances of these machines.

j) Have you ever lost any data due to repairs in the last 2 years?

More than 24 hours?
More than 48 hours.
More than a week? yes

Most significant chunks of data lost at any one time have been related to failures of air conditioners and the time it takes arrange for and coordinate with a service provider to accomplish the repair and get the equipment restarted and back online. The other issue is when there is an equipment failure at a remote site and we have to arrange for delivery of special replacement components to the site or its specialist or a special site trip to accomplish the repairs.

k) Explain any situations where instrument down time was due to lack of preventative maintenance or unavailability of parts.

iv) Logbooks and Records

Question	Yes	No	Comments
What type of station logbooks are maintained at each monitoring station? (maintenance logs, calibration logs, personal logs, etc.)	Equipment operation records, Digital chart-stamps.		
What information is included in the station logbooks?	Time, date, personnel onsite, observations, actions performed.		
Who reviews and verifies the logbooks for adequacy of station performance?	Field Manager		
How often are logbooks reviewed?	Quarterly or as needed for special events.		
How is control of logbook maintained?	Digital backup / Hard copy filing		
Where is the completed logbook archived?	Main Office		
What other records are retained?	QC / Maintenance / Calibration / Certification forms		
1. Zero span record?	X		Digital chart-stamps
2. Gas usage log?		X	
3. Maintenance log?	X		Hard copy and/or digital chart-stamps
4. Log of precision checks?	X		Digital chart-stamps
5. Control charts		X	Digital chart-stamps
6. A record of audits?	X		
Please describe the use and storage of these documents.	Used for the evaluation of data validity and accuracy. Stored digitally and in files.		
Are calibration records, or at least calibration constants, available to field operators?	X		
Are logbooks backed up regularly to ensure against theft/vandalism?	X		Digital chart-stamps are downloaded from the sites to the central office every two weeks or as needed.

3) DATA MANAGEMENT

a) Data Handling

Question	Yes	No	Comments
Is there a procedure, description, or a chart which shows a complete data sequence from point of acquisition to point of submission of data to EPA?	X		
Please describe or provide a data flow diagram from collection to submittal of data. Please include detail regarding data review and validation.	SOP		
Are procedures for data handling (e.g. data reduction, review, etc.) documented?	X		

In what media (e.g., diskette, data cartridge, or telemetry) and formats do data arrive at the data processing location? Please list below:

Category of Data (by Pollutant)	Data Media and Formats
BAMs	Comet used to remotely retrieve data on monthly basis
Continuous data	Log Me In, Flash Drives
PM 10, PM 2.5	Electronic transfer in excel format

How often are data received at the processing location from the field sites and laboratory?	Hourly data polled hourly, minute data polled biweekly. On a monthly basis from EPD lab.		
Is there documentation accompanying the data regarding any media changes, transcription, or flags which have been placed into the data before data are released to agency internal data processing?	X		
- Describe the type of documentation	Chart stamps in data processing software. Lab reports, field data sheets and electronic data.		
How is data actually entered into the computer system (e.g. computerized transcription (copy from disk or data transfer device), manual entry, digitization of strip charts, or other)?	Data transfer and manual entry; Electronic transfer from EPD lab, processed using Acclaims Software and Excel.		
For manual data, is a double-key entry system used (e.g., a second pair of eyes double checking for transcription errors)?	X		With BAMs, QA double checks manual entries, data for Pb and PM 2.5

b) Software Documentation

Question	Yes	No	Comments
Does your agency submit data directly to AQS?	X		
Does your agency participate in AirNow?	X		
How does your agency process P/A data?	P/A data is preloaded using MS Excel enabling Macros. Then processed with a "generate transaction" application; converted into a text file; and finally uploaded into AQS as a text file (Notepad).		
Does the agency have information on the reporting of precision and accuracy data available?	X		
What software is used to prepare air monitoring data for release into the AQS and AirNow database? Please list the documentation for the software currently in use for data processing, including the names of the software packages, vendor or author, revision numbers, and the revision dates of the software.	MS Excel, Notepad, EDAS Digitrend, Acclaims software for PB, PM 10 and PM 2.5.		
What is the recovery capability in the event of a significant computer problem (i.e. how much time and data would be lost)?	Site CPU stored data a week, central server backup daily therefore to minimal data lost.		
Has your agency tested the data processing software to ensure its performance of the intended function is consistent with the QA Handbook, Volume II, and Section 14.0?		?	EPA approved, globally used
Does your agency document software tests?			If yes, provide the documentation

c) Data Validation and Correction

Question	Yes	No	Comments
Has your agency established and documented the validation criteria?	X		
Does documentation exist on the identification and applicability of flags (i.e., identification of suspect values) within the data as recorded with the data in the computer files?	X		
Does your agency document the data validation criteria including limits for values such as flow rates, calibration results, or range tests for ambient measurements?	X		
1. If yes, please describe what action the data validator will take if he/she find data with limits exceeded (e.g., flags, modifies, deletes, etc.)	Flags and applies null data codes		
2. If yes, give examples to illustrate actions taken when limits are exceeded.	ZPS's are run per reporting period. If one fails, the other is relied upon for validation. If the calibration results exceed required limits, an adjusted calibration is performed. The data is adjusted accordingly by the validator when correcting the zero.		
How does the agency track missing data?	Chart stamps		
Please describe how changes made to data that were submitted to AQS and AirNow are documented.	On hard copy, in folders, and in chart stamps, data handling logbook		
Who has signature authority for approving corrections?	Name: Susan Zimmer-Dauphinee Program Function: Program Manager 2		
What criteria are used to determine a data point should be deleted? Discuss briefly	Validator compares data to surrounding sites, looks for instrument issues, checks wind speed and direction change, checks operator notes for localized problems		
What criteria are used to determine if data need to be reprocessed? Discuss briefly	The data is reprocessed when the zero drifts out of the required range.		
Are corrected data resubmitted to the issuing group for cross-checking prior to release?		X	

d) Data Processing

Question	Yes	No	Comments
Does the agency generate data summary reports?	X		
Please list at least three reports routinely generated, including the information requested below.			
Report Title	Distribution		Period Covered
AMP430: Data Completeness Report	Program Manager 2, Operation Unit Manager		Previous month reporting and previous calendar year
AMP480: Design Value Report	Data Analysis Unit Manager		Monthly
AMP600, AMP450, AMP450NC	EPA, EPD Program Manager 2		Annually

Question	Yes	No	Comment
How often are data submitted to AQS and AirNow?	AQS: monthly, AirNow: hourly		
Briefly comment on difficulties the agency may have encountered in coding and submitting data following the guidance of AQS guidelines	When unit change, aligning data coming from site, through EDAS		
Does the agency routinely request a hard copy printout on submitted data from AQS?	X		
Are records kept for at least 3 years by the agency in an orderly, accessible form?	X		
If yes, does this include: 1. Raw Data?	X		
2. Calculation?	X		
3. QC Data?	X		
4. Reports?	X		
If no, please comment			
Has your agency submitted data along with the appropriate calibration equations used to the processing center?	?		All records are available
Are PM_{10} concentrations corrected to EPA standard temperature and pressure conditions (i.e. 298°K, 760 mm Hg) before input to AQS?	X		
Are $PM_{2.5}$ and Lead concentrations reported to AQS under actual (volumetric) conditions?	X		
Are audits on data reduction procedure performed on a routine basis?	X		Frequency - ?
Are data precision and accuracy checked each time they are calculated, recorded, or transcribed to ensure incorrect values are not submitted to EPA?	X		

e) Internal Reporting

What internal reports are prepared and submitted as a result of the audits required under 40 CFR 58, Appendix A?	
Report Title	Frequency
AMP600: Data Certification Report	Annually
Ambient Air Surveillance Report	Annually
Precision and Accuracy Data	Quarterly

What internal reports are prepared and submitted as a result of precision checks also required under 40 CFR 58, Appendix A?	
Report Title	Frequency
AMP255: Data Quality Indicator Report	Annually
Ambient Air Surveillance Report	Annually
Precision and Accuracy Data	Quarterly

Question	Yes	No	Comments
Do either the audit or precision check reports indicated include a discussion of corrective actions initiated based on audit or precision check results?	X		

Who has the responsibility for the calculation and preparation of data summaries? To whom are such summaries delivered?			
Name	Title	Type of Report	Recipient
Janet Aldredge-Byars	Data Analysis Unit Manager	AMP430:Data Completeness Report	Program Manager 2, Operations I Manager
Janet Aldredge-Byars	Data Analysis Unit Manager	Ambient Air Surveillance Report	Program Manager 2, EPA, Public
Janet Aldredge-Byars	Data Analysis Unit Manager	Data Certification Documents (AMP600, AMP450, AMP450NC)	Program Manager 2, EPA

f) **External Reporting**

For the past 3 calendar years, please list all quarters that data were submitted beyond the 90 day requirement:
Aethelometer – Jan 2011-May 2013- Data masher software developed bug which did not allow submittal. EPA contractor developed a fix and now the data has been caught up and is now being submitted well within the 90 days.

Hourly GC Submitted 120 days after the end of the monitoring quarter.
2011 (July 2012 3months)
2012 (July 2013 three months)
2013 (May 2014 expect completed 1 month late)

Identify the individual within the agency with the responsibility for reviewing and submitting the data to AQS. Continuous data: Data Analysis Unit, Filter-based data: Operations 1 Unit, Pooja Sharma: PAMS, Toxics, Lead, PM-2.5, PM-10, Aethelometer. Ramon Tome: PAMS, Toxics, PM-2.5, PM-10, Aethelometer.
Meteorological data: Meteorological Unit, QA data: QA Unit

Question	Yes	No	Comments
Does your agency report the Air Quality Index?	X		
Has your agency submitted its annual data summary report (as required in 40 CFR 58.26)?	X		
If yes, did your agency's annual report include the following:			
1. Annual precision and accuracy information described in Section 4 of Appendix A?	X		
2. Location, date, pollution source and duration of all episodes reaching the significant harm levels?			N/A
Is Data Certification signed by a senior officer of your agency?	X		

4) LABORATORY OPERATIONS

a) Routine Operations

What analytical methods are employed in support of your air monitoring network? Add other pollutants not listed to the table.		
Pollutant	Analysis	Name or Description of Method
PM_{10}	PM10 Teflon Filter	40 CFR 50 App. J
$PM_{2.5}$	PM2.5 Teflon Filter	40 CFR 50 App. L
$PM_{10-2.5}$	ATN Quartz Filters	40 CFR 50 App. G
Pb	TSP Lead Glass Filter	40 CFR 50 App. B \ EQL-0995-110
Carbonyls	Toxic Organic Compounds in Ambient Air	TO-11A
PAHs	Toxic Organic Compounds in Ambient Air	TO-13A
VOCs	Toxic Organic Compounds in Ambient Air	TO-15/PAMS
Air Toxic Metals	Lead in Ambient Air	IO3.5

Please describe areas where there have been difficulties meeting the regulatory requirements for any of the above analytical methods.

Please identify the current versions of written methods, supplements, and guidelines that are used in your agency. Add other pollutants not listed to the table.	
Analysis	Documentation of Method
PM_{10}	SOP 4-005 Rev. 3
$PM_{2.5}$	SOP 4-002 Rev. 6
$PM_{10-2.5}$	SOP 4-006 Rev. 3
Pb	SOP 2-018 Rev. 4
Carbonyls	SOP 1-011 Rev. 9
PAHs	SOP 1-041 Rev. 0; SOP 7-042 Rev. 0; SOP 7-041 Rev. 0; SOP 7-007 Rev. 3
VOCs	SOP TO-15-7 Rev. 23
Air Toxic Metals	SOP 2-018 Rev. 4

Question	Yes	No	Comments
Were procedures for the methods listed above included in the agency's QA Project Plan or SOPs and reviewed by EPA?	X		
Are the SOPs easily/readily accessible for use and reference?	X		
Does your lab have sufficient instrumentation to conduct analyses?	X		

Please describe needs for laboratory instrumentation

b) Laboratory Quality Control

Please identify laboratory standards used in support of the air monitoring program, including standards which may be kept in an analytical laboratory and standards which may be kept in a field support area or quality assurance laboratory that is dedicated to the air monitoring program (attach additional sheets if appropriate):

Parameter	Type	ID / Serial Number	Last Recertification Date
Weights	Troemner Class 1 or Ultra Class	See Below	See Below
Temperature	Dickson TP125	09092008 / 08248023	10/7/13 / 4/12/13
Relative Humidity	TH621	12083065 / 11220005	10/8/13
Barometric Pressure			
Balance	XP6 / XPE105	B015025828 / B01903395	10/31/13
Other			
Carbonyls	TO-11A Primary Std	Supelco 47649-U	Current Lot# LC00945 Expiration June 2016
	TO-11A Secondary Std	Restek 566827	Current Lot# A086614 Expiration Aug 2015
VOCs	TO-15 Internal Std	CYL# FF-22071	10-24-2013
	TO-15 Primary Std	CYL# CC-346224	03-27-2013
	TO-15 2nd Source Std	CYL# ALM059545	10-21-2013
PAHs	TO-13A Field Surr.	Absolute # 93646	Multiple
	TO-13A Lab Surr.	Absolute # 93324	Multiple
	TO-13A Primary Std.	Absolute # 10017 + 90828 + 90506	Multiple
	TO-13A 2nd Source Std.	Absolute # 10017 + 90828 + 90506 (Different Lots from Primary Std.)	Multiple
	TO-13A Int. Std.	Absolute # 10009	Multiple
Metals (including Pb)	Metals Primary Std.	Environmental Express HP1635-500	Multiple
	Metals 2nd Source Std.	High Purity SM106-032	Multiple

****Please have certifications of standards available for viewing during the audit**

Weights Cont.

Class	Nominal Value	Serial Number	Certification Date
Class 1	2 g	1000081442	11/13/2013
Class 1	5 g	1000081441	11/13/2013
Class 1	100 µg	1000081444	11/13/2013
Class 1	200 µg	1000081445	11/13/2013
Class 1	300 µg	1000081446	11/13/2013
Class 1	500 µg	1000081443	11/13/2013

Ultra	2 g	1000081440	11/13/2013
Ultra	5 g	1000081435	11/13/2013
Ultra	100 µg	1000081436	11/13/2013
Ultra	200 µg	1000081439	11/13/2013
Ultra	300 µg	1000081438	11/13/2013
Ultra	500 µg	1000081437	11/13/2013
Ultra	300 µg	1000083175	12/17/2013
Ultra	500 µg	1000083174	12/17/2013

Question	Yes	No	Comments
Are all chemicals and solutions clearly marked with an indication of shelf life?	X		
Are chemicals removed and properly disposed of when shelf life expires?	X		
Are only ACS grade chemicals used by the laboratory?	X		

Comment on the traceability of chemicals used in the preparation of calibration standards.

All standards are NIST traceable. Certificates of Analysis (CoAs) are kept on file for all standards. Chemical standard prepared from vendor stocks are assigned unique IDs and recorded in log books.

Question	Yes	No	Comment
Does the laboratory purchase standard solutions such as those for use with lead or other metals analysis?	X		
Are all calibration procedures documented?	X		Title: Revision Number: Document Location: See SOPs
Are at least one duplicate, on blank, and one standard or spike included with a given analytical batch?	X		
Briefly describe the laboratory's use of data derived from blank analyses:	Blanks are used to indicate contamination of samples in the field or lab. Sources of contamination are investigated and corrective actions taken to eliminate the problem.		
Are criteria established to determine whether blank data is acceptable?	X		

How frequently and at what concentration ranges does the lab perform duplicate analysis? What constitutes an acceptable agreement?

Frequency and agreement are method dependent criteria. See SOPs.

Please describe how the lab uses data obtained from spiked samples, including the acceptance criteria (e.g., acceptable percent recovery).

Accuracy and precision data are used to uncover field, laboratory, or matrix related issues. Acceptance criteria are method dependent (see SOPs).

Question	Yes	No	Comments
Does the laboratory routinely include samples of reference material within an analytical batch?	X		
If yes, indicate frequency, level, & material Used	Varies with method. See SOPs.		
Are mid-range standards included in analytical batches?	X		
Please describe the frequency, level, and compound used in the comments section.	Varies with method. See SOPs.		
Are criteria for real time quality control established that are based on results obtained for the mid-range standards discussed above?	X		
If yes, briefly discuss them in the comments section or indicate the documentation in which they can be found:	See SOPs.		
Are appropriate acceptance criteria for each type of analysis documented?	X		See SOPs.

c) Laboratory Preventative Maintenance

Question	Yes	No	Comments
For laboratory equipment, who has the responsibility for performing preventative maintenance?	GC/MS and Metals: Analyst Organic Lab: Analyst and Service Technician Air Lab: Analyst and Manager		
Is most maintenance performed in the lab?	X		
Is a maintenance log maintained for each major laboratory instrument?	X		
Are service contracts in place for major analytical instruments?	X		Varies by lab and specific equipment.

d) Laboratory Record Keeping

Question	Yes	No	Comments
Are all samples that are received by the laboratory logged in?	X		
If appropriate, is sample shipping temperature recorded upon arrival?	X		
Discuss sample routing and special needs for analysis (or attach a copy of the latest SOP which covers this). Attach a flow chart if possible.	Varies. See SOPs.		
Are log books kept for all analytical laboratory instruments?	X		Balances service records are maintained in the Air lab.
Are there log books or other records that indicate the checks made on materials and instruments such as weights, humidity indicators, balances, and thermometers?	X		

Are log books maintained to track the preparation of filters for the field?	X		
1. Are they current?	X		
2. Do they indicate proper use of conditioning?	X		Room condition reports with 24-hr room condition data are maintained with batches.
3. Weighings?	X		
4. Stamping and numbering?	X		
Are log books kept which track filters returning from the field for analysis?	X		
How are date records from the laboratory archived?	Air data is held in the Lab for at least 2 years before archiving is state contracted storage facility. Air data records are destroyed after 7 years.		
1. Where?	Lab ≥ 2 yrs; External facility until 7 yr holding time elapsed.		
2. Who has the responsibility? Title?	Each lab is responsible for storage within the lab. The Laboratory Director directs external storage.		
3. How long are records kept?	7 years total for Air data.		
Does a chain-of-custody procedure exist for laboratory samples?	X		Title & Date: EPD Laboratory QAM, Oct. 2011 Revision Number: 8 Location:

e) Laboratory Data Acquisition and Handling

Question	Yes	No	Comments
Identify those laboratory instruments which make use of computer interfaces directly to record data. Which ones use strip charts? Integrators?	Balances, GCs, GC/MSs, ICP-MSs all interface with data collection computers. No strip charts or integrators used for data collection.		
Are QC data readily available to the analyst during a given analytical run?	X		
What is the laboratory's capability with regard to data recovery? In case of problems, can they recapture data or are they dependent on computer operations? Discuss briefly.	Raw computer data for all instruments but balances are routinely transferred to network drives which are backed up nightly. Hardcopies of all raw data are stored in the lab.		
Has a user's manual been prepared for the automated data acquisition instrumentation?	X		

Please provide below a data flow diagram which establishes, by a short summary flow chart: transcriptions, validations, and reporting format changes the data goes through before being released by the laboratory.

Air Lab:

Receive → Pre Log → Login LIMS → Trouble Shoot → Analyze → Reweigh → Peer Check → Archive → Validate

Organic Lab:
Analyst creates and analyzes sample batch with QC Samples and Field Samples. All data printed and reviewed by Analyst and then Supervisor. If all QC for the batch passes and is valid then results are manually uploaded from the computer into the LIMS system.

Supervisor reviews LIMS system to verify all printed results for all samples correct in LIMS. All QC for the batch reviewed as passing and valid. Supervisor then validates samples in LIMS. Data is exported to our Air Branch via LIMS.

GC/MS Lab:

Analyst creates and analyzes sample batch with QC Samples and Field Samples. All data printed and reviewed and results directly uploaded from the computer into the LIMS system. All QC for the batch reviewed as passing and valid.

Supervisor reviews all printed QC and field sample data in the sample batch. Supervisor reviews LIMS system to verify all printed results for all samples correct in LIMS. All QC for the batch reviewed as passing and valid.

Manager reviews all printed QC and field sample data in the sample batch. Supervisor reviews LIMS system to verify all printed results for all samples correct in LIMS. All QC for the batch reviewed as passing and valid. Manager makes final sample validation in LIMS to release data.

Metals Lab:

1. The Instrument collects data.
2. The scientist electronically transfers data to Labworks.
3. The scientist compares the hard copy data to the Labworks data.
4. The data pack is given to another qualified scientist for peer review.
5. The peer reviewed data pack is submitted to the supervisor for review and validation,
6. The Labworks data is exported to a shared drive.

f) Specific Pollutants: Particulate Matter

High Vol PM_{10}			
Question	**Yes**	**No**	**Comments**
Does the agency use filters supplied by EPA?	X		
Do filters meet the specifications in 40 CFR 50?	X		
Are filters visually inspected for defects before exposure?	X		
Where does the laboratory keep records of the serial numbers of filters?	Filter Inventory Logbook		
Are the temperature and humidity monitors calibrated?	X		
Are balances checked with Class S or Class M weights each day when they are used?	X		Class 1 or Ultra Class
To what sensitivity are filter weights recorded?	µg		
What method of documentation is used to record filter weighing sessions? (e.g., logbook, computer software, etc.)	Computer software → Excel → LIMS		
During conditioning, are the following true:			
(1) Filters equilibrate for a minimum of 24 hours	X		

(2) The temperature range is from 15°C-30°C	X		
(3) Temperature control is ±3°C SD over 24 hrs	X		
(4) Humidity range is 20% - 45% RH	X		
(5) Humidity control is ± 5% SD over 24 hrs	X		
(6) Pre/post sampling RH difference in 24-hr means is ≤± 5% RH	X		
(7) Balance is located in the conditioning environment	X		
Are filters packaged for protection while transporting to and from the monitoring stations?	X		
Are filters shipped at ambient temperature to the monitoring stations?	X		
Are filters shipped at ambient temperature from the field to the laboratory?	X		
Are exposed filters reconditioned for at least 24 hrs in the same conditioning environment as for unexposed filters?	X		
Briefly describe how exposed filters are prepared for conditioning	Opened in weighing room and inspected for damage and irregularities with a UV light box. Stored in Desiccator.		
Briefly describe how exposed filters are stored after being weighed	In 6" x 9" manila envelope in a storage box.		
Are blank filters reweighed?	X		
Are chemical analyses performed on filters?	X		
If yes, what analysis is performed?	Lead on TSP filters.		

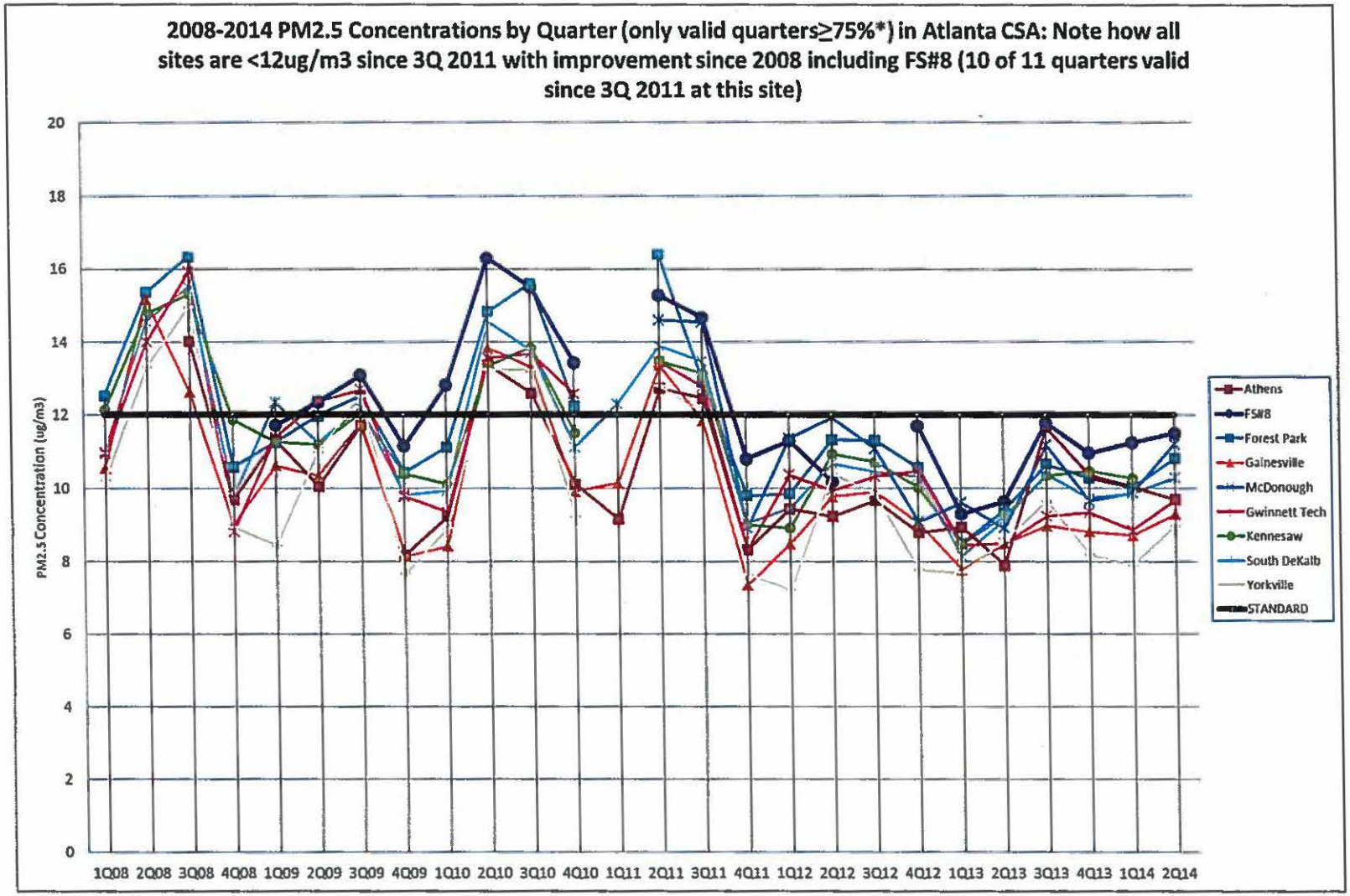
$PM_{10-2.5}$/ Low Vol PM_{10} / $PM_{2.5}$			
Question	**Yes**	**No**	**Comments**
Does the agency use filters supplied by EPA?	X		
Do filters meet the specifications in 40 CFR 50?	X		
Are filters visually inspected via strong light from a view box for defects before exposure?	X		
Where does the laboratory keep records of the serial numbers of filters?	Filter inventory log		
Are temperature and humidity monitors calibrated?	X		
Are balances checked with Class 1 weights each day when they are used?	X		
To what sensitivity are filter weights recorded?	µg		
What method of documentation is used to record filter weighing sessions? (e.g., logbook, computer software, etc.)	Computer software → Excel → LIMS		
During conditioning, are the following true:			
(1) Filters equilibrate for a minimum of 24 hours	X		
(2) The temperature range is 20°C-23°C for the 24-hr mean	X		
(3) Temperature control is ±2°C SD over 24 hrs	X		And ±2°C over 24 hrs

(4) Humidity range is 30%-40% RH for 24-hr mean OR ≤5% sampling RH but >20% RH	X		
(5) Humidity control is ± 5% SD over 24 hrs	X		And ± 5% over 24 hrs
(6) Pre/post sampling RH difference in 24-hr means is ≤± 5% RH	X		
(7) Balance is located in the conditioning environment	X		
Are filters packaged for protection while transporting to and from the monitoring stations?	X		
Are filters shipped at ambient temperature to the monitoring stations?	X		
Are filters shipped at ≤ 4°C from the field to the laboratory?	X		
Are filters post-weighed in ≤30 days?	X		
Are filters post-weighed in ≤10 days if they arrive >4°C?	X		Or if receipt temp is > average ambient at time of collection.
Are exposed filters reconditioned for at least 24 hrs in the same conditioning environment as for unexposed filters?	X		
Briefly describe how exposed filters are prepared for conditioning	Opened, inspected and placed on metal tray in clean room conditioning environment.		
Briefly describe how exposed filters are stored after being weighed	Boxed and stored in refrigerator in Lab.		
Are blank filters reweighed?	X		
Are chemical analyses performed on filters?		X	
If yes, what analysis is performed?			

Lead			
Question	**Yes**	**No**	**Comments**
Does the agency use filters supplied by EPA?	X		
Is analysis for lead being conducted using atomic absorption spectrometry with air acetylene flame?		X	ICP-MS
If not, has the agency received an equivalency designation for their procedure?	X		EQL-0995-110
Is either the hot acid or ultrasonic extraction procedure being followed precisely?	X		Which? Hot acid.
Is Class A borosilicate glassware used throughout the analysis?		X	Lab uses precleaned, certified HDPE Plastic.
Is all glassware cleaned with detergent, soaked and rinsed three times with distilled or deionized water?			NA
If extracted samples are stored, are linear polyethylene bottles used?			NA – Extracts are not stored

Are all batches of glass fiber filters tested for background lead content?	X		Laboratory Blanks are run with each batch of filters analyzed.
At a rate of 20 to 30 random filters per batch of 500 or greater?			Indicate Rate – See above
Are ACS reagent grand HNO_3 and HCl used in the analysis?	X		
Is a calibration curve available having concentrations that cover the linear absorption range of the atomic absorption instrumentation?	X		
Is the stability of the calibration curve checked by alternately re-measuring every 10^{th} sample a concentration # 1Fg Pb/ml; # 10 Fg Pb/ml?	X		A 25 µg/L standard (curve mid-level standard) is checked.

END OF QUESTIONNAIRE


2008-2014 PM2.5 Concentrations by Quarter (only valid quarters≥75%*) in Atlanta CSA: Note how all sites are <12ug/m3 since 3Q 2011 with improvement since 2008 including FS#8 (10 of 11 quarters valid since 3Q 2011 at this site)
PM2.5 Concentration (ug/m3)
0
2
4
6
8
10
12
14
16
18
20
1Q08 2Q08 3Q08 4Q08 1Q09 2Q09 3Q09 4Q09 1Q10 2Q10 3Q10 4Q10 1Q11 2Q11 3Q11 4Q11 1Q12 2Q12 3Q12 4Q12 1Q13 2Q13 3Q13 4Q13 1Q14 2Q14
Athens
FS#8
Forest Park
Gainesville
McDonough
Gwinnett Tech
Kennesaw
South DeKalb
Yorkville
STANDARD

Characterizing the Emissions of Fine Particulate Matter in the Vicinity of a Rail Yard

Final Report

December, 2013

From

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Funded through GDOT Project Number: CSCMQ-0009-00(186) P.I. # 0009186

Characterizing the Emissions of Fine Particulate Matter in the Vicinity of a Rail Yard

Final Report

Summary

Aerosol emissions from diesel combustion and other activities in rail yards can affect the health of urban populations. Fine particulate ($PM_{2.5}$) concentrations monitored at Fire Station 8 near the Inman and Tilford rail yards in Atlanta, Georgia, are, on average, the highest measured in the state. These high levels are of concern. The rail yard complex is surrounded by homes, schools, businesses and other industries. The levels measured at Fire Station 8 are very near the National Ambient Air Quality Standard (NAAQS), posing non-attainment concerns. However, it is difficult to tell from routine measurements the degree to which rail yard activities contribute to the observed levels. To address this issue, a novel research study was conducted. A detailed description of the study is contained in the Ph.D. study of Dr. Boris Galvis, which is attached. Results are summarized below.

The impact of the aerosol emissions from these rail yards on local concentrations of $PM_{2.5}$ was quantified both using field experimental approaches and by dispersion modeling. Specifically 1) black carbon and $PM_{2.5}$ fuel-based emission factors from the rail yards were estimated by carbon balance using high time-resolution monitoring, 2) a BC and $PM_{2.5}$ emissions inventory was estimated and dispersion modeling was applied to assess the impact of the rail yard activities on local air quality and 3) the cost and benefits of upgrading locomotive engines with cleaner technologies was assessed. Further, baseline information that will allow a later evaluation of the improvement of local air quality as locomotives operating in the rail yards are upgraded was generated, and a composition profile of the rail yard aerosols was developed using chemical speciation techniques.

These studies found that activities in the Inman and Tilford Rail yards lead to an average emission factor of 6.0 ± 0.5 g of $PM_{2.5}$ per gallon of fuel and are responsible for increases in annual average concentrations of up to approximately 1.3 $\mu g/m^3$ of $PM_{2.5}$ near the rail yards. The rail yards were found to be important sources of hydrocarbon-like organic aerosols (HOA) and black carbon from fuel (BCf). Upgrading the engines at the rail yards would decrease $PM_{2.5}$ emissions by about 9 t/year, reducing $PM_{2.5}$ concentrations around 0.5±0.1 $\mu g/m^3$ and producing monetized health benefits of approximately 24 million dollars per year. A decrease of 0.5 $\mu g/m^3$ would help, if not enable, Atlanta to meet the $PM_{2.5}$ NAAQS.

While a number of scientific advances and important findings were achieved in this project, specific points that have implications for future policies and actions include:

- The detailed sampling provides strong support for the hypothesis that emissions from the rail yard complex area lead to elevated concentrations observed at the Firestation 8 monitor, and that those elevated concentrations are likely also found in surrounding neighborhoods. The estimated impact at the Firestation 8 monitor can explain much of the higher levels found at that monitor versus other monitors in Atlanta.
- Air quality modeling is consistent with the observations and suggests that emissions from the rail yard lead to $PM_{2.5}$ impacts in the surrounding area. These elevated levels lead to increased human exposures. While this modeling did find that elemental carbon levels at Firestation 8 were significantly impacted by the railyard complex emissions, levels were also impacted by local traffic. Thus, Firestation 8 is reasonably well, but not perfectly, located to capture the impacts of the rail yard complex emissions on air quality.
- Reduction in rail yard emissions that would be achieved by using cleaner technology switcher engines can reduce PM2.5 levels that, along with other controls planned in the region, should lead to the levels found at Firestation 8 being very near, or below, the current NAAQS for $PM_{2.5}$
- Estimating emissions from the rail yard complex, as done here, required using multiple fast response instruments (both pollutant and meteorological) applied

over a relatively long period. 1-hour and 24-hour integrated measurements would not have been able to capture the short term increases in both black carbon and carbon dioxide that were most useful. Adequately assessing if future emission changes from the rail yard are being effective will likely require a similar approach.

- One limitation in the approach was that we were only able to deploy two monitors. Development of compact and inexpensive integrated monitors that measure carbon dioxide and particulate matter can provide an opportunity to deploy many more monitors, improving our ability to estimate emissions from the complex. It would be useful to deploy such monitors within and around the rail yard.
- Our measurements find that there is significant variability in pollutant levels, and there are both long and short term trends. This makes it more difficult to identify the impacts of emissions changes. Enhanced monitoring to capture the impacts of utilizing cleaner technology switcher engines should begin at least a month before those technologies are introduced and continue for at least a month after.

CHARACTERIZING THE EMISSIONS OF FINE PARTICULATE MATTER IN THE VICINITY OF A RAIL YARD

A Dissertation
Presented to
The Academic Faculty

by

Boris Galvis

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in the
School of Civil and Environmental Engineering

Georgia Institute of Technology
December, 2013

CHARACTERIZING THE EMISSIONS OF FINE PARTICULATE MATTER IN THE VICINITY OF A RAIL YARD

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Date Approved: August 09, 2013

To Luz Dary, Santiago, Hannah and to all my family

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SUMMARY

Aerosol emissions from diesel combustion and other activities in rail yards can affect the health of urban populations. Fine particulate ($PM_{2.5}$) concentrations near the Inman and Tilford rail yards in Atlanta, Georgia, are the highest measured in the state. The rail yard complex is surrounded by homes, schools, businesses and other industries. The impact of the aerosol emissions from these rail yards on local concentrations of $PM_{2.5}$ was quantified. Specifically, black carbon and $PM_{2.5}$ fuel-based emission factors from the rail yards were estimated by carbon balance using high time-resolution monitoring, a BC and $PM_{2.5}$ emissions inventory was estimated and dispersion modeling was applied to assess the impact of the rail yard activities on local air quality and the cost and benefits of upgrading locomotive engines with cleaner technologies was assessed. Further, baseline information that will allow a later evaluation of the improvement of local air quality as locomotives operating in the rail yards are upgraded was generated, and a composition profile of the rail yard aerosols was developed using chemical speciation techniques.

These results found that activities in the Inman and Tilford Rail yards lead to and an average emission factor of 6.0 ± 0.5 g of $PM_{2.5}$ per gallon of fuel and are responsible for increases in annual average concentrations of approximately 1.3 $\mu g/m^3$ of $PM_{2.5}$. The rail yards were found to be important sources of hydrocarbon-like organic aerosols (HOA) and black carbon from fuel (BCf). Upgrading the engines at the rail yards would decrease $PM_{2.5}$ emissions by about 9 t/year, reducing $PM_{2.5}$ concentrations around 0.5 ± 0.1 $\mu g/m^3$ and producing monetized health benefits of approximately 24 million dollars per year.

CHAPTER 1

INTRODUCTION

The rail industry is fundamental to the U.S. economy and is the most energy efficient mode of land transportation. It moves almost half of the nation's freight through a system of 140,000 miles of tracks and generates roughly $265 billion in total annual economic activity (AAR, 2011). The amount of freight transported by rail in the U.S. has followed an increasing trend since the 1960's. In 2008, approximately 1.8 billion ton-miles were carried by the industry (BTS, 2011). Intermodal freight is the fastest growing sector of the railroad industry, accounting for nearly 22 percent of rail revenue in 2010 (DOI, 2011). The rail industry is found in all the major cities in the U.S., concentrating its activities in rail yards.

Rail yards have the potential to significantly influence local fine particulate matter (aerodynamic diameter ≤ 2.5 mm; $PM_{2.5}$) concentrations through emissions from diesel-electric locomotives and supporting activities (Cahill et al., 2011;Campbell et al., 2009;Kam et al., 2011;Kim et al., 2004). Emissions from rail yards include black or elemental carbon and organic carbon (Cahill et al., 2011; Sawant et al., 2007), nitrogen oxides (Cahill et al., 2011; Starcrest Consulting Group, 2004), sulfur dioxide, hydrocarbons, carbon monoxide and carbon dioxide, metals and polycyclic aromatic hydrocarbons (Cahill et al., 2011). These emissions are of concern in urban areas where rail yards are in proximity to dwellings, exposing populations to elevated concentrations of these pollutants.

One of the main components of diesel emissions is black carbon (BC). BC is a primary pollutant formed by incomplete combustion and emitted as fine particulate. It affects visibility (Park et al., 2003; Prasad et al., 2010) and is considered the second most important human emission for climate forcing in the industrial-era atmosphere after CO_2

(Bond et al., 2013; Jacobson, 2010; Roberts et al., 2004). The US emits about 640 thousand tons of BC per year. Approximately half of the BC emissions in the U.S. come from mobile sources, and around 90% of BC emissions from mobile sources come from diesel engines (EPA, 2012a, b, c). Other sources of BC are residential heating, industry and biomass burning. Emission estimates indicate that mobile diesel engines, which include non-road diesel-electric locomotives, offer the greatest potential area for BC mitigation applying currently available control technologies (EPA, 2012c).

Diesel emissions have been classified as carcinogenic and are thought to have other suspected negative effects on human health (WHO, 2012). Epidemiological studies of occupational exposure have demonstrated increased risk of death from lung cancer in exposed workers (Attfield et al., 2012; Silverman et al., 2012). Stringent regulations have been put in place to curb diesel emissions in developed nations. New technologies burn diesel fuel more efficiently and reduce emissions through exhaust controls. These new regulations and technologies, along with other measures to reduce BC emissions will need time to have an effect; more so, in developing countries with lax standards, older technologies and more limited resources. Yet, measures to reduce BC emissions from major sources are likely to provide near-term environmental and public health benefits at low relative cost, and implemented in conjunction with substantial methane (CH_4) and CO_2 emissions reductions, could help limit global mean warming below the 2°C threshold during the following 6 decades (Shindell et al., 2012). More research is needed to fully understand what improvements in air quality and in health can be achieved by reductions in diesel emissions (WHO, 2012).

Northwest of Atlanta, Georgia, Inman and Tilford rail yards are located beside residential neighborhoods, industries, and schools. $PM_{2.5}$ concentrations in Atlanta have been decreasing over the past ten years (EPRI, 2012; GAEPD, 2012), but the Fire Station 8 site (FS) near the rail yards has consistently showed the highest annual average $PM_{2.5}$ concentration reported at any of the monitoring sites operated by the state of Georgia

(GAEPD, 2013), suggesting that rail yard associated emissions play an important but still undetermined role in local air quality. This dissertation details a comprehensive research program aimed to quantify the impact of the aerosol emissions from Inman and Tilford railyards on local air quality. The thesis is organized as follows:

Chapter 1: Introduction.

Chapter 2: Fuel-based fine particulate and black carbon emission factors from a rail yard area in Atlanta. The impact on local $PM_{2.5}$ concentrations of the emissions from the Inman and Tilford rail yards in Atlanta was determined. High-time-resolution measurements of BC, $PM_{2.5}$, CO_2, and wind speed and direction were made at two locations, north and south of the rail yards for one year. Emissions factors (i.e., the mass of BC or $PM_{2.5}$ per gallon of fuel burned) were estimated by using the downwind/upwind difference in concentrations, wavelet analysis, and an event-based approach.

Chapter 3: Impacts on fine particulate, black carbon and health of converting rail yard locomotives to lower emission technologies. A local emission inventory for northwest Atlanta was estimated and dispersion modeling was used to assess the impact on local $PM_{2.5}$ and BC concentrations coming from the Inman and Tilford rail yard emissions. Modeling results were evaluated against data from two monitoring sites. Potential reductions in $PM_{2.5}$ and BC concentrations that could be accomplished by upgrading traditional switcher locomotives used in this rail yard complex were assessed and the health benefits of these reductions were evaluated. A comparison with costs of upgrades was also made.

Chapter 4: Aerosol chemical speciation and source impact analysis near rail yards. Aerosols near the Inman and Tilford rail yard complex in Atlanta were characterized using an aerosol chemical speciation monitor and an Aethalometer. Source apportionment and positive matrix factorization techniques were used to estimate sources and factors for black carbon and organic aerosols respectively. Meteorological information was used to identify locations of sources of different species of pollutants.

Chapter 5: Conclusions and future research. In addition to summarize the results and conclusions from this study, Chapter 5 identifies directions for future research. Such research includes the assessment of changes in air quality after the implementation of cleaner technologies at the rail yard complex, investigating NOx concentrations in the area and accessing or retrieving information on rail yard activity. Also, suggestions for expanding monitoring capacity at low cost for these and other similar sources, broadening the scope of modeling for rail yard impact evaluation and completing the analysis of chemical composition of aerosols emitted by rail yard activities.

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CHAPTER 2

FUEL-BASED FINE PARTICULATE AND BLACK CARBON EMISSION FACTORS FROM A RAIL YARD AREA IN ATLANTA

(Galvis, B. Bergin, M., and Russell A.G. *Journal of the Air & Waste Management Association*, 63(6):648–658, 2013.)

2.1. Abstract

Rail yards have the potential to influence local fine particulate matter (i.e. particulates with an aerodynamic diameter $\leq$ 2.5 mm; $PM_{2.5}$) concentrations through emissions from diesel locomotives and supporting activities. This is of concern in urban regions where rail yards are in proximity to residential areas. Northwest of Atlanta, Georgia, the Inman and Tilford rail yards are located beside residential neighborhoods, industries, and schools. The $PM_{2.5}$ concentrations near the rail yards is the highest measured amongst the state-run monitoring sites (Georgia Environmental Protection Division, 2012; http://www.georgiaair.org/amp/report.php). The authors estimated fuel-based black carbon (BC) and $PM_{2.5}$ emission factors for these rail yards in order to help determine the impact of rail yard activities on $PM_{2.5}$ concentrations, and for assessing the potential benefits of replacing current locomotive engines with cleaner technologies. High-time-resolution measurements of BC, $PM_{2.5}$, CO_2, and wind speed and direction were made at two locations, north and south of the rail yards. Emissions factors (i.e., the mass of BC or $PM_{2.5}$ per gallon of fuel burned) were estimated by using the

downwind/upwind difference in concentrations, wavelet analysis, and an event-based approach. By the authors' estimates, diesel-electric engines used in the rail yards have average emission factors of 2.8 ± 0.2 g of BC and 6.0±0.5 g of $PM_{2.5}$ per gallon of diesel fuel burned. A broader mix of rail yard supporting activities appear to lead to average emission factors of 0.7 ± 0.03 g of BC and 1.5 ± 0.1 g of $PM_{2.5}$ per gallon of diesel fuel burned. Rail yard emissions appear to lead to average enhancements of approximately 1.7 ± 0.1 $\mu g/m^3$ of $PM_{2.5}$ and approximately 0.8 ± 0.01 $\mu g/m^3$ of BC in neighboring areas on an annual average basis. Uncertainty not quantified in these results could arise mainly from variability in downwind/upwind differences, differences in emissions of the diverse zones within the rail yards, and the influence of on-road mobile source emissions.

2.2. Implications

In-use fuel-based black carbon and fine particulate emission factors for rail yard activities were quantified by novel approaches using near-source high-time-resolution monitoring of ambient concentrations at two sites. Results can reduce the uncertainty in rail yard emission inventories and the approach can be replicated and extended to assess trends and evaluate emission reduction alternatives

2.3. Introduction

Rail yard emissions are thought to originate largely from diesel-electric locomotives called "switchers" that are used to gather cars and assemble them into trains. Switchers are potentially high emitters because they are typically older model locomotives and have low-power duty cycles (U.S. Environmental Protection Agency [EPA], 2011a). Emissions from switchers include primary fine particulate matter (aerodynamic diameter ≤ 2.5 mm; $PM_{2.5}$), elemental and organic carbon (EC/OC),

nitrogen oxides (NOx), sulfur dioxide (SO_2), hydrocarbons, carbon monoxide (CO), and carbon dioxide (CO_2). Diesel emissions have suspected negative effects on human health (World Health Organization [WHO], 2012). Black carbon (BC) from diesel and other fossil fuels absorb solar radiation, affecting visibility (Prasad and Bella, 2010) and climate (Roberts and Jones, 2004). Rail yards have been identified as local sources of particulates (Kam et al., 2011), EC/OC (Sawant et al., 2007; Cahill et al., 2011), NOx (Starcrest Consulting Group, 2004; Cahill et al., 2011), CO_2, SO_2, metals, and polycyclic aromatic hydrocarbons (PAHs) (Cahill et al., 2011).

The contribution of particulate matter from rail yards to U.S. emissions, as estimated in the National Emissions Inventory (NEI), is small compared with on-road mobile sources or power plants (EPA, 2012). Switcher locomotives have been estimated to emit less than 0.1% of the total PM_{10} (PM with an aerodynamic diameter $\leq$ 10 mm) and $PM_{2.5}$ in the United States EPA, 2008a). Yet, emissions from rail yards located close to residential areas are of new interest because of recent regulations (EPA, 2008b), intensity of operations in limited areas, and the fast growing economic activity of switchyards and intermodal terminals (Laurits R. Christensen Associates, 2009).

In Atlanta, $PM_{2.5}$ concentrations have been decreasing over the past 10 yr (Electric Power Research Institute [EPRI], 2012; Georgia Environmental Protection Division [Georgia EPD], 2012), but near Inman and Tilford rail yards, the Fire Station 8 site (FS) has consistently showed the highest annual average $PM_{2.5}$ concentration reported at any of the Georgia state-run monitoring locations (Figure 2.1.). Georgia EPD (2009) applied the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) using emission estimates based on NEI methodology, and

found that rail yards contribute approximately 1.9 $\mu g/m^3$ to the concentration of $PM_{2.5}$ at FS.

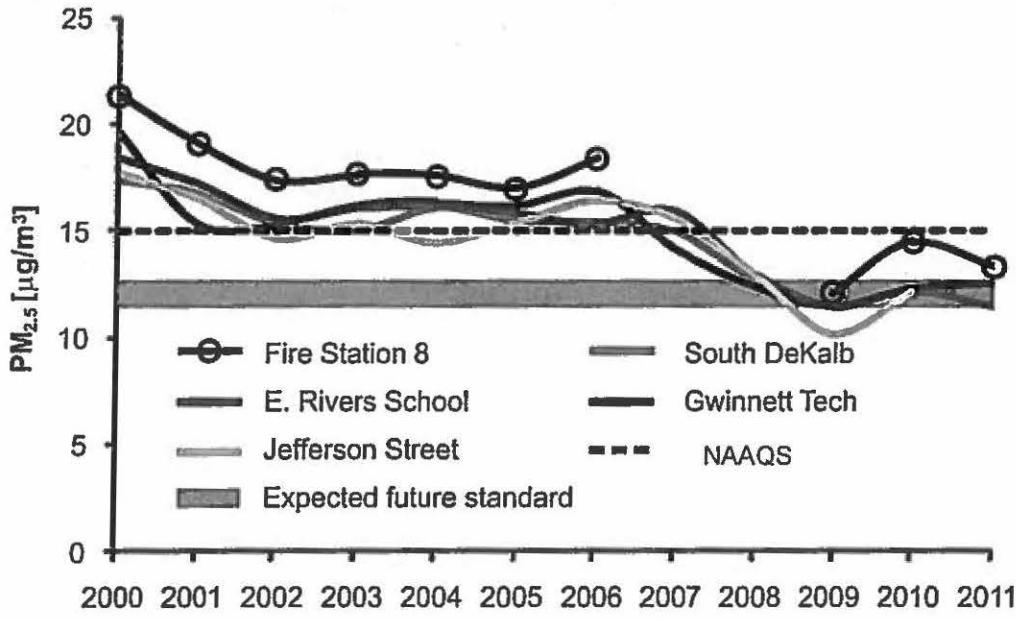

Figure 2.1. $PM_{2.5}$ annual arithmetic means at Atlanta urban sites (Georgia EPD, 2012).

Rail yard emissions are viewed as highly uncertain (Simon et al., 2008). Recently, a 27-state committee called ERTAC Rail developed top-down nationwide rail yard, line-haul, and shortline/regional emission inventories for the years 2007/2008 using confidential information from the railroad companies (Bergin et al., 2012). This inventory was used to update the 2011 EPA - NEI. Previous NEIs used the conventional approach quantify rail yard emissions. Inventories were calculated multiplying state-level yearly average fuel consumption data by nationwide fleet average fuel-based yard emission factors. States currently estimate rail yard emissions using methods based on the same approach (Sierra Research, 2004). Sources of uncertainty are estimated fuel use, distribution of consumption data to each rail category (i.e., switcher vs. Class I

locomotives), allocation of emissions to county level using local activity data (National Cooperative Freight Research Program [NCFRP], 2010), and yard emission factors that don't necessarily represent the variability in engine technologies, specific yard operating conditions, and the yard fleet mix (Simon et al., 2008). Furthermore, the yard emission factors may not adequately account for yard-associated emissions (i.e., emissions from testing and maintenance of locomotives and drayage trucks) (Fritz and Cataldi, 1991). Disaggregated fuel consumption data required to address the fuel related sources of uncertainty are unavailable mainly because companies view fuel consumption as proprietary information (NCFRP, 2010).

Rail yard emission estimates are developed mainly using emission factors for switchers that are an average of engine emissions over a cycle of stationary sequential operation at low and normal idle, and at eight other discrete power levels, called notches, weighted by numerical factors that reflect the time the engine is operated at each notch (CFR-40-92.101-133, 2011). These emissions factors have high reproducibility but may not represent real-world emissions from particular operating conditions (St. Denis et al., 1994; Cocker et al., 2004) and they may not have a quantitative indication of uncertainty. Previous work has been directed to obtain real-word emission factors from small samples of diesel-electric switcher locomotives measuring directly from the stack, varying fuel or type of engine (Fritz and Cataldi, 1991; Honc et al., 2006; Sawant et al., 2007), but little work has been aimed at quantifying their uncertainties, or to estimate emission factors that account for actual activities going on in and around rail yards.

The objective of this work is to advance the understanding of rail yard emissions by estimating $PM_{2.5}$ and BC fuel-based emission factors to reduce uncertainty in emission

inventories. The emission factors will account for the particular operating conditions of the rail yards using near-source high-time-resolution monitoring. This information may be used to improve air quality modeling results, aid in the development of effective air quality management strategies, and, as part of a joint government industry project (Congestion Mitigation and Air Quality Improvement Program, Georgia Environmental Protection Division [CMAQEPD], 2009), to assess the improvement in local air quality as cleaner technologies replace old switcher engines used at Inman and Tilford rail yards.

2.4. Experimental Methods

2.4.1. Monitoring sites

The study was carried out in Atlanta, Georgia, at locations near Inman and Tilford rail yards (Figure 2.2.). CSX's Tilford Yard is a hump terminal that handles approximately 80 trains per week and operates 10 switcher locomotives (Georgia EPD, 2009). Inman Yard is a large Norfolk Southern intermodal facility with 17 switcher locomotives (Georgia EPD, 2009). The yards are adjacent to each other, northwest of downtown Atlanta, inside the perimeter freeway I285 (Figure 2.2.). Other pollution sources in the area include Howells Yard (a small intermodal yard with 15 tracks), Georgia Power Company's McDonough-Atkinson Plant, Ennis Paint, and a Metropolitan Atlanta Rapid Transit Authority (MARTA) garage facility. The McDonough-Atkinson Plant was being converted from coal to natural gas during this study.

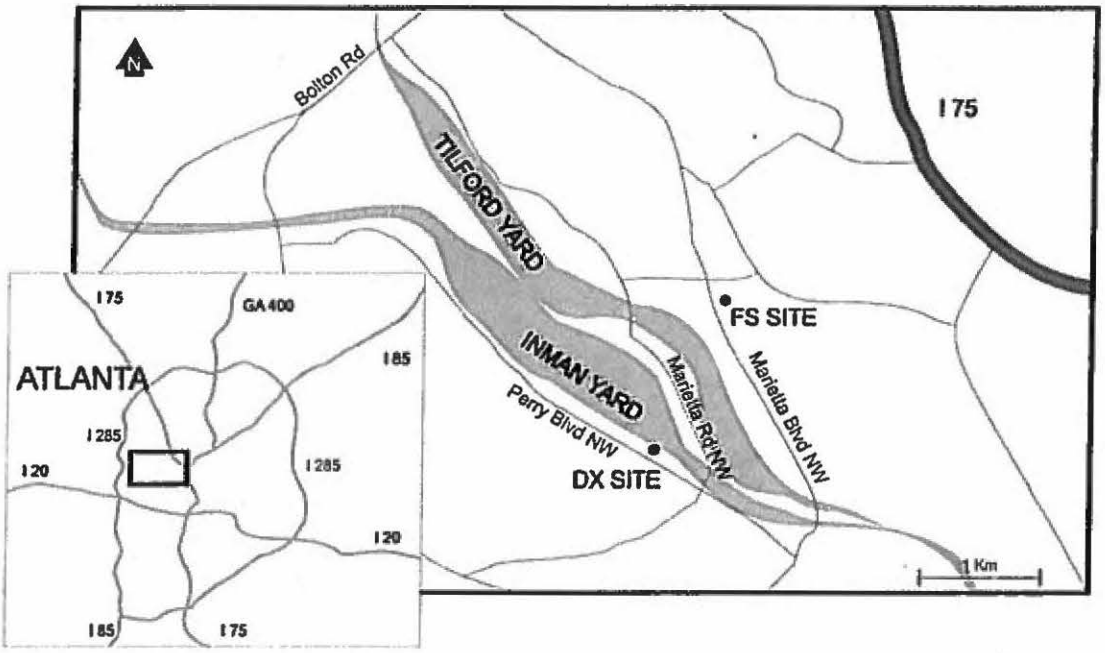

Figure 2.2. Schematic of the location of the study. The two monitoring sites are at the Dixie (DX) and Fire Station 8 (FS) locations.

Two monitoring sites were used: Fire Station 8 (FS) (coordinates: 33.80176°N, -84.43559°W) and Dixie (DX) (coordinates: 33.79080°N,- 84.44026°W), north and south of the rail yards (Figure 2.2.). Sites are 1.3 km apart. The FS site is part of the Assessment of Spatial Aerosol Composition Network (ASACA) (Butler et al., 2003) and is located at approximately 300 m of the arrival section of Tilford Yard and 30 m of Marietta Boulevard NW(17,000 annual average daily traffic [AADT] approximately), which runs between the FS site and the rail yards. Other roads with less traffic (>2000 AADT), such as Marietta Road, Bolton Road, and Perry Boulevard, surround and run through the rail yards. DX is contiguous to the intermodal terminal at Inman Yard, approximately 80 m from the tracks. The MARTA garage is located southwest of DX.

2.4.2. Air pollutant measurements

BC (multiangle absorption photometer [MAAP]; model 5012; Thermo Scientific, Franklin, MA), $PM_{2.5}$ (1400ab tapered element oscillating microbalance [TEOM]; R & P Thermo Scientific, Franklin, MA; operated at 50°C), wind speed and wind direction (Young 03002-L wind sentry set; Young-Campbell Scientific, Logan, UT) were measured from December 2010 to December 2011 at both sites. CO_2 (NDIR 41i analyzer; Thermo Scientific, Franklin, MA) was measured from April to December 2011. Coarse particles were removed from the TEOM and the MAAP sample lines by model 2000-30EH 16.7 liters per minute (LPM) 2.5-mm cutoff cyclones (URG, Chapel Hill, NC). Three meters of 1/8 inch outer diameter (OD) Teflon tubing was used to draw 1 LPM to the CO_2 monitors. Samples were taken at a height of approximately 3 m. One-minute averages of all variables were logged as a text file to a field computer and later loaded to a database. CO_2 analyzers were calibrated with a CO_2 certified standard Nexair gas mixture. Rail yard operations were recorded from the DX site using a camera (Hero Gopro 960; Woodman Labs, Inc., Half Moon Bay, CA) to take photos every minute on 42 days between September 15, 2011, and November 14, 2011. A table with the specific dates is available as supplemental material.

The pairs (one for each site) of CO_2 analyzers, TEOMs, and MAAPs were run for 2 weeks side by side at the Georgia Tech campus before deployment. One-minute concentrations measured with CO_2 analyzers and MAAPs were within 5%. Thirty minute $PM_{2.5}$ concentrations reported by the TEOM instruments were within 5%. During monitoring at the rail yards, zero and span checks of the CO_2 analyzers and flow checks

for the TEOMs and MAAPs were carried out on weekly basis and monthly basis, respectively.

2.4.3. Data analysis

We applied the carbon balance method (Singer and Harley, 1996) to calculate fuel-based emission factors, relating the amount of pollutant emitted to the amount of fuel burned (eq 2.1.):

$$EF=Q/(1+Q_{Others})*\omega_c \quad (2.1.)$$

where EF is the emission factor in units of grams of pollutant emitted per gallon of fuel burned, Q is the ratio of the mass of pollutant to mass of carbon from CO_2, and Q_{Others} is the ratio of the mass of other carbonaceous species, such as unburned hydrocarbons or CO, to the mass of carbon form CO_2. Three methods were used to calculate Q, including what we refer to as the "delta," the wavelet, and the regression approaches discussed below. It was assumed that CO_2 dominates the carbon balance for the rail yard diesel sources, with carbonaceous species besides CO_2 (e.g., hydrocarbons and CO) playing a minor role in the carbon budget (Yanowitz et al., 2000). Consequently, Q_{Others} is assumed to be significantly less than 1 and is neglected in our calculations. ω_c is the carbon content per gallon of diesel fuel specified by the Code of Federal Regulations (CFR-40-600.113–78) as 2,778 g C/gal. Uncertainties in the properties of the fuel were neglected. All uncertainties reported were calculated as the 95% confidence interval of the mean.

All the approaches to calculate the ratio Q were based on averages from concentration data occurring when wind with velocities greater or equal to 0.5 m/sec and directions between 320°and 360°and between 0°and 90°at DX and between 170°and

280°at FS were measured. These wind sectors comprise approximately the complete area of the rail yards.

The "delta" approach was based on the downwind–upwind difference in pollutant concentrations. The ratio obtained by this method (Q_Δ) is in units of mass of pollutant emitted per mass of C (eq 2):

$$Q_\Delta = \frac{\overline{[P]}_{DW} - \overline{[P]}_{UW}}{\left(\overline{[CO_2]}_{DW} - \overline{[CO_2]}_{UW}\right) \times 12/44} \qquad (2.2.)$$

where [P] and [CO_2] are the mean pollutant (BC or $PM_{2.5}$) concentration and mean CO_2 concentration respectively in $\mu g/m^3$, the subscripts DW and UW indicate when the average is from the downwind or upwind site, respectively. The factor of 12/44 is the atomic mass of carbon over the molecular mass of CO_2. The delta approach is thought to represent emissions from a broad mix of rail yard sources.

A second method used wavelet analysis (Daubechies, 1992) to separate the concentration signals into high- and low frequency components (Figure 2.3). The ratio Qw calculated by this approach is in units of mass of pollutant emitted per mass of C (eq 3).

$$Q_W = \frac{\overline{[P]}}{\overline{[CO_2]} \times 12/44} \qquad (2.3.)$$

where [P] and [CO_2] are the mean pollutant (BC or $PM_{2.5}$) concentration and mean CO_2 concentration, respectively, in $\mu g/m^3$. The factor of 12/44 is the atomic mass of carbon over the molecular mass of CO_2. It was assumed that the high frequency components extracted by the wavelet-based algorithm are predominantly near-field emissions from a variety of rail yard sources (e.g., drayage trucks, cranes, welding facilities, or switcher locomotives) and from diesel trucks and gasoline vehicles in the surroundings. Low-

frequency contributions are assumed to be associated with non-rail yard activities and represent the background concentrations in the vicinity. A MATLAB (MathWorks, Natick, MA) algorithm was used for this analysis and it is available as supplementary material. Wavelet analysis has been applied previously by Klems et al. (2011) to a similar problem in order to determine the contribution of motor vehicles near a roadway intersection to the ambient ultrafine particle mass by correlating high frequency contributions with fast changes in ultrafine particle chemical composition.

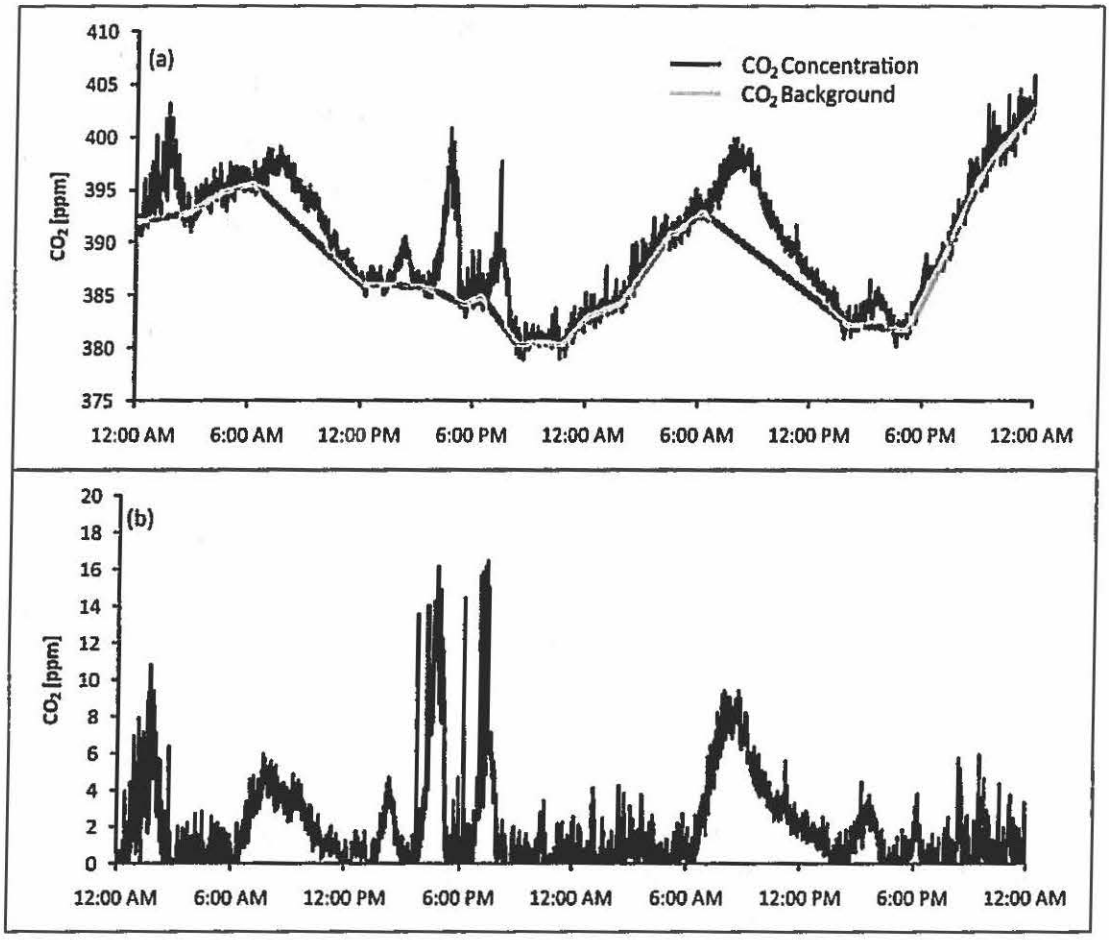

Figure 2.3. CO_2 concentration (a) at DX from 12:00 a.m. on September 5, 2011, to 11:59 p.m. on September 6, 2011. The CO_2 concentration signal was separated into spikes and background components by wavelet analysis. (b) Spikes in CO_2 concentration.

The regression approach, the third technique employed, focused on events of high BC concentrations. Events were identified by selecting groups of 5–20 consecutive-minute data points when the maximum BC concentration of the set was greater than the mean plus 3 times the standard deviation of the BC concentrations occurring in the same hour at the same site and when a linear relationship with a correlation coefficient greater than or equal to 0.90 at a 0.95 confidence level between CO_2 and BC concentrations was obtained (Figure 2.4). Events were selected from data occurring for wind speeds and wind directions with the restrictions described for all the approaches. The ratio, Qr, was calculated as the mean of the slopes of the BC to CO_2 regressions. The ratio of concentrations was converted to a ratio of mass of BC to mass of C from CO_2 by dividing it by the atomic mass of carbon over the molecular mass of CO_2. The minimum concentration measured during the event was taken as the baseline. This approach is likely to represent near-field brief emission events from a subset of rail yard sources (e.g., a passing switcher or line-haul engine). A comparable approach was formulated by Dallmann et al. (2011) to measure BC emission factors from diesel exhaust emissions of trucks used to move containers with in a rail yard and by Hansen and Rosen (1990) to measure BC emission factors from automobiles.

2.5. Results

2.5.1. Concentrations of BC and $PM_{2.5}$

Differences in annual average $PM_{2.5}$ concentrations between Georgia EPD Fire Station 8 and other urban sites have become smaller in recent years (Figure 2.1), due in large part to a combination of factors set in place by the 2008 economic downturn, higher-than-

average annual rainfall in 2009 (National Oceanic and Atmospheric Administration [NOAA], 2012), and air quality policies. In 2011, annual average $PM_{2.5}$ and BC concentrations at DX and FS were comparable (Table 2.1). Annual average $PM_{2.5}$ concentrations are below the current National Ambient Air Quality Standard (NAAQS; 15 μg/m3), but above the proposed level (12 μg/m3) (EPA, 2011b).

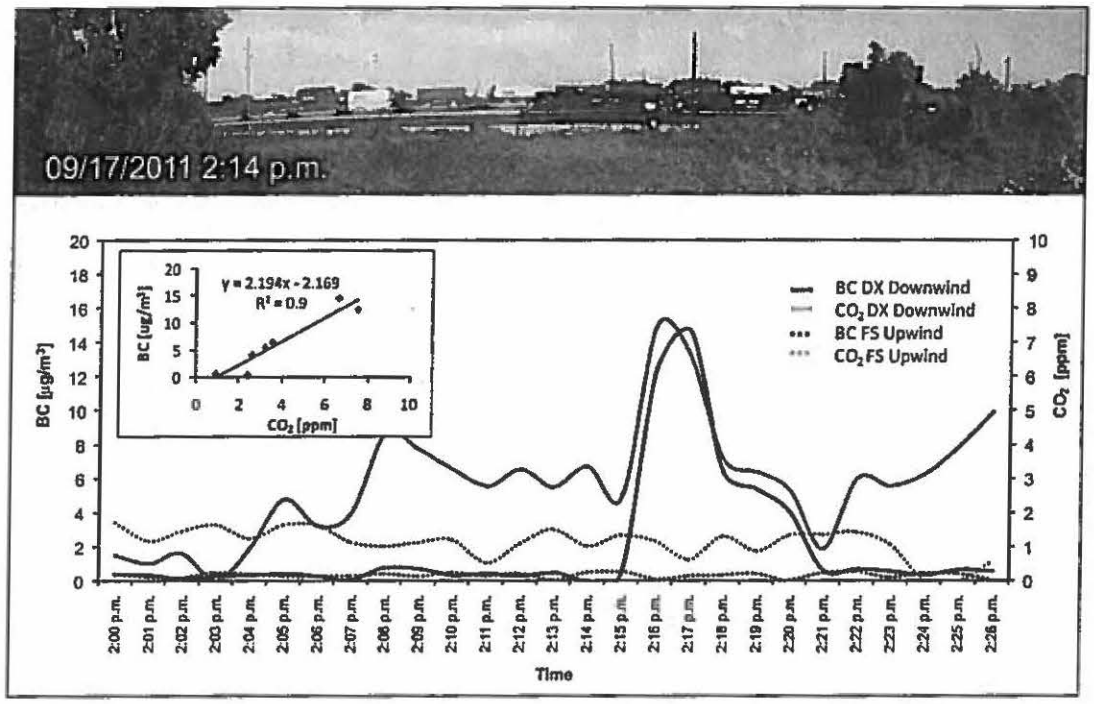

Figure 2.4. Event associated with a locomotive at the DX site on September 17, 2011. At 2:14 p.m. a train passes by the monitoring site. An event is detected shortly after. The subplot shows the lineal regression of the event detected.

Table 2.1. Concentrations of $PM_{2.5}$ and BC for FS, DX, and other Atlanta urban sites in 2011

Site	Method	$PM_{2.5}$ [μg/m^3] †	Method	BC [μg/m^3] †
FS	TEOM	12.3(7.1)	MAAP	1.5(1.4)
DX	TEOM	13.1(8.0)	MAAP	1.3(1.2)
Fire Station 8	FRM [a]	13.3(5.8)		
South DeKalb	FRM [a]	12.4(6.0)	TOR [b]	1.3 (0.9)
Gwinnett Tech	FRM [a]	12.5(6.7)		
E. Rivers School	FRM [a]	11.4(5.0)		

Notes: [a] Federal Reference Method. [b] Thermal/optical reflectance. †Mean (standard

deviation).

2.5.2. Wind speed and direction and pollutants

During the study, the predominant wind direction was west southwest at both the DX and FS sites (Figure 2.5.). Average wind speeds of 1.5 m/sec at DX and 1.2 m/sec at FS were measured. The highest speeds were recorded when the wind came from the southeast and southwest quadrants at FS and from the northeast and southeast quadrants at DX. Structures and trees located southwest of DX and northeast of FS could have hindered wind circulation to some extent.

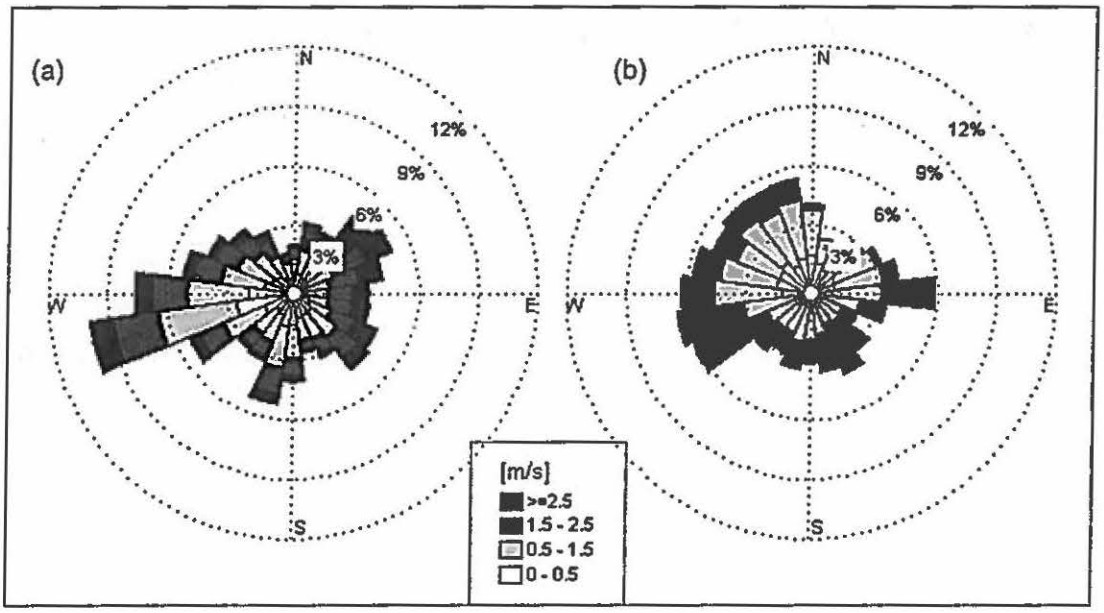

Figure 2.5. Wind Roses for (a) the DX site and (b) the FS site.

We plotted normalized pollutant concentrations to gain insight on the location of the sources that impact DX and FS (Figure 2.6.). Pollutant concentration roses were constructed by normalizing the concentrations subtracting the mean and dividing by the

standard deviation and adding one. Normalized pollutant roses show local concentrations of BC, $PM_{2.5}$, and CO_2 approximately 1.5 times greater than average coming from the direction where the rail yards are located, that is, the northeast quadrant at DX and southeast quadrant at FS, as their main feature (Figure 2.6.). There is a source of BC, $PM_{2.5}$, and CO_2 north of FS. FS could as well be impacted to some degree by BC, CO_2, and $PM_{2.5}$ emissions coming from activities on Marietta Boulevard. The roses suggest that BC is a better tracer for yard activities than $PM_{2.5}$. At both sites, directions of higher than average BC concentrations closely follow the layout of the rail yard. $PM_{2.5}$ and CO_2 concentration roses at DX show sources south and west-southwest, respectively, but no significant BC is associated with those directions.

Somewhat higher concentrations of BC were measured at FS (Table 2.1). FS downwind conditions were measured 44.5% of the time, whereas DX was downwind 32.5 % of the time during the months of this study. Also, wind speed was slightly lower (1.7 m/sec on average) when FS was downwind than when DX was downwind (1.9 m/sec on average). Greater time downwind with lower wind speeds is one reason for the slightly greater BC concentrations at FS. It was much harder to detect $PM_{2.5}$ and CO_2 enhancements from the rail yards due to greater background levels and variability for these contaminants, as well as the variety of their sources.

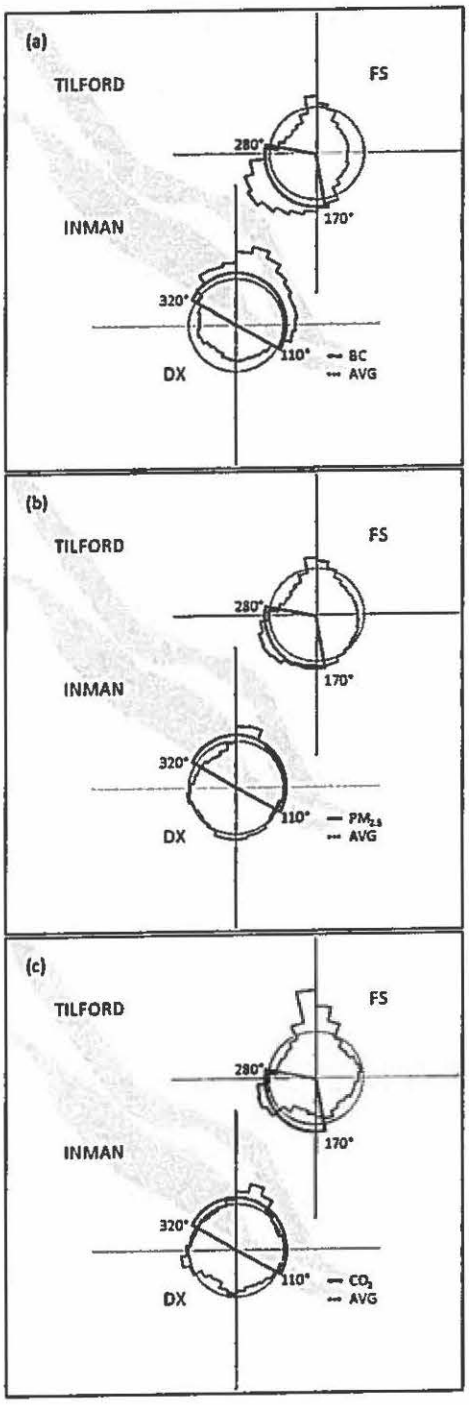

Figure 2.6. Normalized pollutant concentration roses for (a) BC, (b) $PM_{2.5}$, and (c) CO_2 at the DX and FS monitoring sites. Downwind sectors are marked in gray.

2.5.3. Downwind–upwind differences and high-frequency components

Enhancements in $PM_{2.5}$, BC, and CO_2 concentrations come from the directions where the rail yards are located. $PM_{2.5}$, BC, and CO_2 enhancements are statistically significant (two-sample t tests, with $P < 1E\text{-}10$ in the least satisfactory conditions with 99% confidence). Yet, $PM_{2.5}$, BC, and CO_2 downwind–upwind differences have large variability, showing standard deviations much larger than their means (Table 2.2.). This variability will lead to uncertainty in the emission factors calculated by this method. Histograms of downwind–upwind differences and concentrations time series are presented in the supplemental materials.

Table 2.2. Downwind/ Upwind concentration differences for DX and FS sites.

	Downwind Site	
	DX	FS
$PM_{2.5}$		
Mean [$\mu g/m^3$]	1.5	1.9
Standard deviation [$\mu g/m^3$]	± 8.6	± 10.8
Uncertainty of the mean [$\mu g/m^3$]	± 0.1	± 0.1
Number of observations	25,105	31,123
BC		
Mean [$\mu g/m^3$]	0.7	1.0
Standard deviation [$\mu g/m^3$]	± 1.2	± 1.7
Uncertainty of the mean [$\mu g/m^3$]	± 0.01	± 0.01
Number of observations	27,161	40,998
CO_2		
Mean [ppm]	6.3	5.9
Standard deviation [ppm]	± 28.6	± 33.2
Uncertainty of the mean [ppm]	± 0.3	± 0.3
Number of observations	18,110	33,865

At both sites, means of the high-frequency components of $PM_{2.5}$, BC, and CO_2 concentrations obtained by the wavelet approach are higher when the wind blows from the rail yards than from any other direction. Wavelet analysis helps to rectify the noise and baseline drift of the instruments to a considerable degree, and reduces to some extent the interference of the signals from sources with extremely high frequencies (i.e., fast-

moving gasoline vehicles and diesel trucks). This is apparent in the variability of the results of wavelet approach, which is less than the variability of the results of the delta approach (Table 2.3.). Consequently, the uncertainty derived from this variability could be expected to be smaller in the wavelet approach than in the delta approach. Yet, as mentioned before, spikes could be predominantly near-field emissions from a variety of rail yard sources but also from diesel trucks and gasoline vehicles. This contribution from non-rail yard sources could still confound the results.

Table 2.3. High-frequency components from wavelet analysis for the DX and FS sites.

	Downwind Site	
	DX	FS
$PM_{2.5}$		
Mean [$\mu g/m^3$]	1.8	1.9
Standard deviation [$\mu g/m^3$]	± 3.0	± 4.0
Uncertainty of the mean [$\mu g/m^3$]	± 0.02	± 0.02
Number of observations	57,908	82,223
BC		
Mean [$\mu g/m^3$]	0.7	0.9
Standard deviation [$\mu g/m^3$]	± 1.2	± 1.3
Uncertainty of the mean [$\mu g/m^3$]	± 0.01	± 0.01
Number of observations	53,805	73,134
CO_2		
Mean [ppm]	8.2	6.6
Standard deviation [ppm]	± 19.1	± 11.1
Uncertainty of the mean [ppm]	± 0.1	± 0.1
Number of observations	51,711	50,697

Greater enhancements in $PM_{2.5}$ and BC concentrations were found when FS was downwind (Table 2.2). The same result was observed by the wavelet approach. The means of $PM_{2.5}$ spikes and BC spikes were greater when wind blew from the rail yards to FS than when it was blowing from the rail yards to DX (Table 2.3). Results from this part of our analysis are comparable to those obtained by Campbell and Fujita (2009), at the Roseville rail yard in California for 2008 whom measured a downwind–upwind delta of

0.73 ± 0.01 and 1.14 ± 0.01 μg/m^3 of BC and 2.5 ± 0.6 and 2.4 ± 0.7 μg/m^3 of $PM_{2.5}$ at two monitoring sites. Our results support the modeling study by Georgia EPD (2009), which estimated that the rail yard emissions led to an additional 1.9 μg/m^3 of $PM_{2.5}$.

2.5.4. Emission factors

Means of BC and $PM_{2.5}$ emission factors obtained by the delta and the wavelet approaches were similar between both sites (Table 2.4.). For both approaches, FS reported higher emission factors than DX. Results obtained at FS could be confounded by emissions from traffic. There is also uncertainty related to the emissions of the different zones within the rail yards. FS is located near the arrival section of Tilford Yard, where there is also a turntable and fuel storage and repair facilities. The DX site is close to tracks where a mix of locomotives cruise, accelerates, and idle. The intermodal terminal of Inman Yard where there is heavy-duty diesel truck traffic is also close by. Emission factors calculated by the delta approach when the wind is not blowing from the rail yards are presented in the supplemental materials (Table A.1.). As shown, the small values derived (approximately an order of magnitude less than when using concentrations found from the downwind–upwind pairing) support our results.

Table 2.4. Emission Factors for the DX and FS sites

	Downwind Site		Other works
	DX	FS	
EF_{BC} [g of BC /gal fuel]			
Delta approach	0.6±0.04	0.9±0.05	
Wavelet approach	0.5±0.01	0.7±0.01	
Regression approach	3.1±0.2	2.4±0.2	3.8[b]
$EF_{PM_{2.5}}$ [g of $PM_{2.5}$ /gal fuel]			
Delta approach	1.3±0.1	1.8±0.1	
Wavelet approach	1.2±0.02	1.6±0.03	
Regression approach [a]	7.2±0.8	4.8±0.6	4.5[c], 4.7[d]

Notes: [a] $PM_{2.5}$ emission factor was not calculated directly by the regression approach but estimated from the ratio of BC to PM2.5 and the BC emission factor from the regression approach. [b] Sawant et al. (2007). [c] Expected fleet average PM_{10} emission factor for 2011 (EPA, 2009). [d] Fritz and Cataldi (1991).

BC emission factors from the regression approach are higher than those obtained from the delta and wavelets approaches (Table 2.4.), which is anticipated because the BC events, identified when BC levels rise by 3 standard deviations or more above the mean value during the hour of the event, are likely due to activities with high BC emissions (i.e., switchers or line-haul engines). Results of the regression approach are comparable to elemental carbon emission factors of 3.8 g of BC per gallon of diesel fuel measured directly from the stacks of switcher locomotives (Sawant et al., 2007). The DX site was equipped to photograph rail yard activity to link with pollutant data and investigate the possibility of the recorded events originating from sources other than the rail yards. Photos indicate locomotives, either idling or passing by, shortly (1–3 min) before an event was registered. During the event shown (Figure 2.4), the wind was blowing north-northeast, from the rail yards to DX, with speeds that varied between 1 and 2.5 m/sec. The minimum concentration measured during the corresponding hour was taken as baseline. Overlapping signals of concentrations of BC and CO_2 were registered on the downwind monitoring site, whereas the upwind site showed steady concentrations. Photographs also showed that when no locomotives were present and the wind was blowing from the direction of the rail yards, BC and CO_2 concentrations were poorly correlated. The scenario depicted in Figure 2.4.is an example of the many events used to determine the emissions factors by the regression approach.

Events of high BC concentrations detected at DX were generated inside the rail yards and were less likely to be influenced by other sources. At FS, there is the possibility that some of events were influenced by traffic on Marietta Boulevard. The regression approach yields a smaller average emission factor for FS (Table 2.4). Some events with

higher BC concentrations were detected at DX, but on average BC concentrations during events show an increase of about 3 $\mu g/m^3$ of BC at both sites and their respective standard deviations were comparable, as high as 6 $\mu g/m^3$ and as low as 1 $\mu g/m^3$ above baseline (Figure 2.7.). Differences between FS and DX regression approach results (Table 2.4.) likely derive from the higher variability in CO_2 concentration at FS. Incremental CO_2 concentrations at FS used in the regression approach show an average and standard deviation approximately 2 and 1.4 ppm greater than at DX (Figure 2.7.), leading to lower emissions factors. Given that BC is found to be a good tracer of rail yard activity, and that emission factors calculated by the regression approach show little dependency on the hour of the day or the day of the week (Figures A.5.–A.8.), we infer that most of the events detected at FS were generated inside the rail yards.

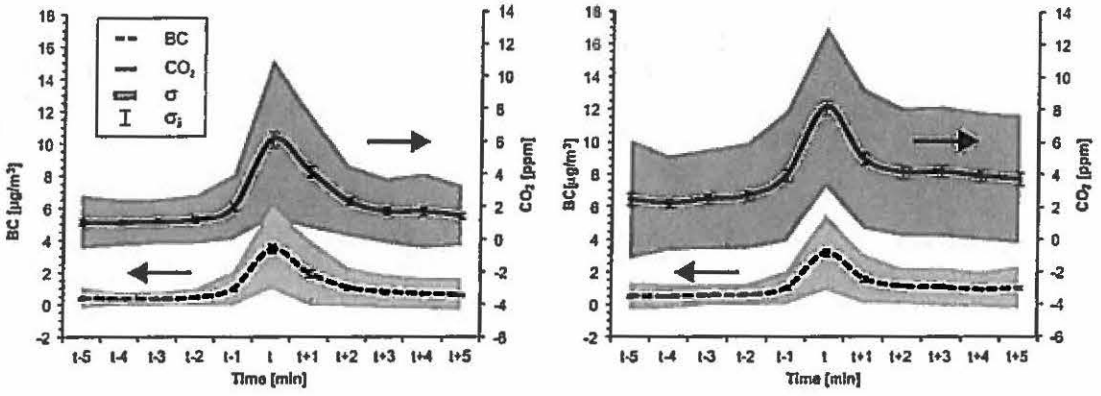

Figure 2.7. Events of high BC and corresponding CO_2 concentrations at (a) DX and (b) FS. The minimum concentration measured during each event was taken as baseline. Events were centered at the time when the maximum BC concentration was measured (*t*). Average concentrations 5 min before and 5 min after are shown along with standard deviations (σ) and uncertainties of the mean (σ_x).

BC emission factors calculated by the regression approach show similar frequency distributions at the two sites (Figure 2.8), with 423 and 399 events detected at

FS and DX, respectively. Several events, likely coming from high-emitting locomotive engines, produced BC emission factors 1 order of magnitude higher than the PM_{10} emissions standards published by EPA (2009).

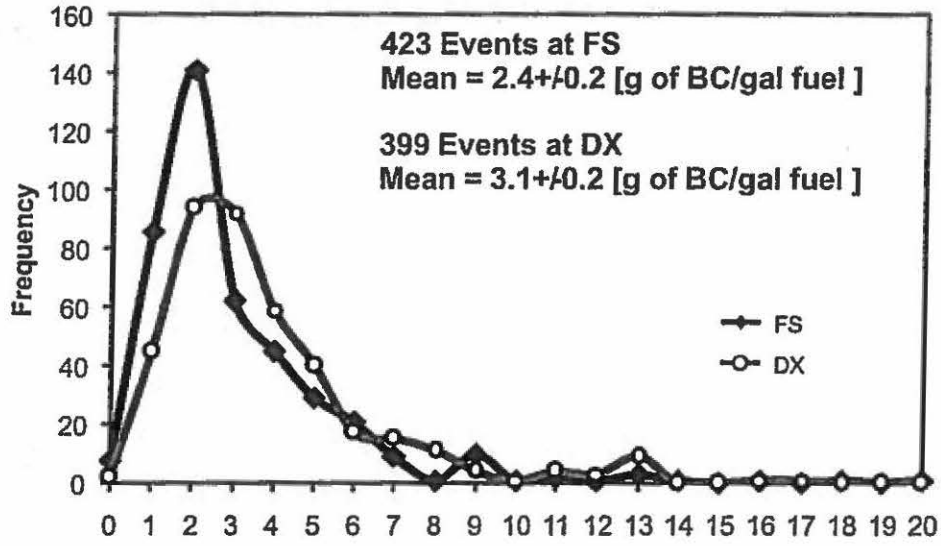

Figure 2.8. Frequency distributions of emission factors obtained from BC events at the FS and DX sites.

Results of the application of the regression approach to estimate $PM_{2.5}$ emission factors were less satisfactory and are not presented. This was expected, given the noise in TEOM data on time scales less than 30 min. However, $PM_{2.5}$ emission factors could be estimated using the ratio of BC to $PM_{2.5}$ obtained from wavelet and delta approaches (0.43 ± 0.02 g BC/g $PM_{2.5}$ at DX and 0.5 ± 0.02 g BC/g $PM_{2.5}$ at FS). Using these ratios, emission factors of 7.2 ± 0.6 g $PM_{2.5}$/gal fuel at DX and 4.8 ± 0.6 g $PM_{2.5}$/gal fuel at FS are obtained.

Total BC and $PM_{2.5}$ emissions can be estimated based on the fuel use at the rail yards and the fuel-based emission factors calculated in this study. Line haul and switching activity at Tilford and Inman rail yards consumed 1.6 and 2.5 million of

gallons of diesel fuel, respectively, during 2011. This was calculated using the method described (Georgia EPD, 2009), which is based on scaling state-level yearly average fuel consumption dividing the gross ton-miles transported in the yard by system-wide fuel combustion efficiency. Gross ton-miles data have been provided in the past for each rail yard by Norfolk Southern and CSX Transportation (Georgia EPD, 2009). System-wide fuel combustion efficiency for 2011 was obtained from data contained in the Class I Railroad Surface Transportation Board R-1 Annual Report from each company (Norfolk Southern, 2011; CSX Transportation, 2011). This estimation does not include the fuel consumed in other activities occurring in the yard. Approximately 11.7 tons of BC and 26 tons of $PM_{2.5}$ per year were emitted from the rail yards in 2011.

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CHAPTER 3

IMPACTS ON FINE PARTICULATE, BLACK CARBON AND HEALTH OF CONVERTING RAIL YARD LOCOMOTIVES TO LOWER EMISSION TECHNOLOGIES

(Galvis, B. Bergin, M., Huang Y., Boylan J., and Russell A.G. *Atmospheric Environment.* Submitted)

3.1. Abstract

Reductions in emissions from major sources of fine particulate ($PM_{2.5}$) and black carbon (BC) that affect densely populated regions such as the surrounding area of a major rail yard complex in Atlanta, Georgia can provide near-term environmental and public health benefits at low relative cost. We estimated the potential reductions in $PM_{2.5}$ and BC concentrations that could be accomplished by upgrading traditional switcher locomotives used in this rail yard complex and evaluated the health benefits of these reductions for comparison with upgrade costs.

Analysis indicates that the line-haul and switcher activities at the Tilford and Inman rail yards are responsible for increases in annual average concentrations of 0.5 $\mu g/m^3$ (39%) and 0.7 $\mu g/m^3$ (56%) of BC, and for 1.0 $\mu g/m^3$ (7%) and 1.6 $\mu g/m^3$ (14%) of $PM_{2.5}$ at two monitoring sites located north and south of the rail yards, respectively. Upgrading the engines of the switcher locomotives used at the rail yards with lower emitting technologies would decrease $PM_{2.5}$ and BC emissions by about 9 and 3 t/year respectively, reducing $PM_{2.5}$ concentrations between 0.3 ± 0.1 $\mu g/m^3$ and 0.6 ± 0.1 $\mu g/m^3$

and BC concentrations between 0.1 ±0.02 $\mu g/m^3$ and 0.2±0.03 $\mu g/m^3$ at the monitoring sites north and south of the rail yards respectively. This measure would facilitate $PM_{2.5}$ NAAQS attainment in the area. We estimate that health benefits of approximately 24 million dollars per year could be gained.

3.2. Introduction

The rail industry is reducing emissions from rail yards across de the nation, with the support of the US Department of Transportation's Congestion Mitigation and Air Quality Improvement Program (CMAQ) and other federal, state and private funding. Some of the measures taken to reduce emissions involve rail yard switcher locomotives typically regarded as high emitters (EPA, 2011). Switcher locomotives can be retrofitted with new generator set (Genset) technologies. A Genset is a computer controlled electric generator coupled to an array of two or three off–road EPA Tier II/III diesel engines. Gensets have low emissions and would reduce fuel consumption by about 25% (Honc et al., 2006). Switcher locomotives could also be replaced with "mother-slug sets". In a mother-slug set a conventional diesel locomotive called "mother" transmits the excess power generated by its diesel electric engine at low speeds to a "slug" which is a locomotive with only traction motors but no engine nor electric generator. The slug contains a large block of ballast to provide sufficient weight for traction. A mother-slug set replaces 2 switcher locomotives, can save approximately 33% of the fuel consumed and can meet EPA tier II/III emissions standards (NS, 2011).

The Georgia Environmental Protection Division (GAEPD) along with the rail industry is currently pressing forward with a project to replace older switcher locomotives operating in the 'urban core' of Atlanta. This area is currently in non-

attainment of the $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS). Funding has been awarded by the Georgia Department of Transportation to the GAEPD through the CMAQ Program (CMAQ, 2009) as part of this effort. Initially using Gensets was favored but recently the mother-slug alternative is also being considered.

Changes of $PM_{2.5}$ and BC concentrations from the implementation of rail yard emission reduction measures have seldom been quantified. The same is true for the associated health benefits. A few prior studies assessed impacts from rail yard emissions using Gaussian dispersion models. However, estimates of emissions from rail yards are typically highly uncertain due to inadequacies in emission factors and activity indicators, and there can be sources around rail yards that confound or are not captured in modeling results. Generic emission factors normally used may fail to effectively represent operating conditions, technologies and yard fleet mix (Galvis et al., 2013), and often, construction of activity indicators is not suited to a specific rail yard because it does not describe the particular freight services and geographic characteristics (Gould et al., 2009). These factors lead to significant uncertainties in modeling rail yard impacts and raise the need for thorough model evaluation. However, insufficient spatial and temporal coverage of monitoring data around rail yard areas often hinders this task.

Previous work carried out by Sierra Research (2011) compared modeled diesel particulate matter (DPM) and nitrogen oxides (NOx) ground-level concentrations to measured upwind-downwind concentration differences of BC, elemental carbon (EC), organic carbon (OC), $PM_{2.5}$ and NOx measured at 4 monitoring stations operated during the Roseville Rail yard Air Monitoring Project (RRAMP) in California. Gaussian dispersion models were used to assess the impact of rail yard emissions on local air

quality. Models were run with rural and urban dispersion coefficients and two different meteorological data sets. In all cases, both measurements and models, found reductions in DPM and NOx impacts over the four-year period of the RRAMP study. Reductions observed were mostly attributed to the decrease of emissions at the rail yard over that period. Comparisons of the measured $PM_{2.5}$ and NOx concentrations with simulated DPM and NOx concentrations predicted by the models did not show good agreement (Campbell et al., 2009).

Feinberg et al. (2011) estimated impacts on local air quality of the CSXT Rougemere rail yard in Dearborn, Michigan using a Gaussian atmospheric dispersion model, though did not include a model evaluation. They developed a bottom-up temporally and spatially allocated $PM_{2.5}$ emissions inventory before and after a Genset retrofit of the switchers in the yard. Results of the inventory estimated a reduction in $PM_{2.5}$ emissions from 2007 to 2008, attributed to Genset retrofits and reductions in the sulfur content of the diesel fuel.

Health risk assessments for several rail yards have been carried out by the California Air Resources Board (CARB, 2011).They used emissions inventories and air quality modeling results previously prepared for the rail yards, to characterize potential cancer and non-cancer risks associated with exposure to DPM. They estimated impacted areas and exposed population associated with different cancer risk levels for different exposure durations. They also reported near-source cancer risks.

GAEPD (2006) assessed benefits of avoided mortality and morbidity of several emissions control strategies including reducing 10% of emissions of ground level anthropogenic primary carbon $PM_{2.5}$ (EC and OC) throughout the state of Georgia. EC is

one of the main emissions from rail yard areas. They used the Community Multiscale Air Quality Modeling System to estimate changes in ambient air pollution levels and the Environmental Benefits Mapping and Analysis Program (BenMAP) (ABT, 2012) to assess the health benefits of the changes. They concluded that ground level controls of primary carbon significantly reduced exposure and have the highest health benefits of all the strategies evaluated saving 223 million dollars annually.

The objectives of this research are to estimate the impact on local air quality of $PM_{2.5}$ and BC emissions from Tilford and Inman rail yards in Atlanta, GA, and to assess the reduction on the $PM_{2.5}$ and BC concentrations that could be accomplished by converting the switcher locomotives at the rail yards to low emission technologies. Emissions from the rail yards are estimated using available fuel consumption data and emission factors measured for the rail yards (Galvis et al., 2013). First a 2011 base case is simulated, and results are compared to measurements of BC and $PM_{2.5}$ made at monitoring sites near the rail yards over the same period. Two scenarios are simulated; the first one simulates all the switcher locomotives at both yards are retrofitted with Gensets. The second one simulates all the switcher locomotives at both yards are substituted by mother-slug sets. The change in local PM2.5 concentrations between the base and controlled scenarios are used to determine health benefits by using BenMAP.

3.3. Material and Methods

3.3.1. Study location

The Inman and Tilford rail yard complex is located in Norwest Atlanta, Georgia inside the I-285 perimeter freeway (Figure 3.1.). Inman is operated by Norfolk Southern (NS) and Tilford by CSX Transportation (CSXT). Descriptions of the rail yard complex

can be found in previous works (Galvis et al., 2013;GAEPD, 2009a). Marietta Blvd NW (~15,000 annual average daily traffic [AADT]) and Bolton Rd (~ 18,000 AADT) run alongside northwest and northeast of the rail yards, respectively. Marietta Rd NW (~ 2,000 AADT) separates the Inman intermodal section from the arrival section of Tilford yard.

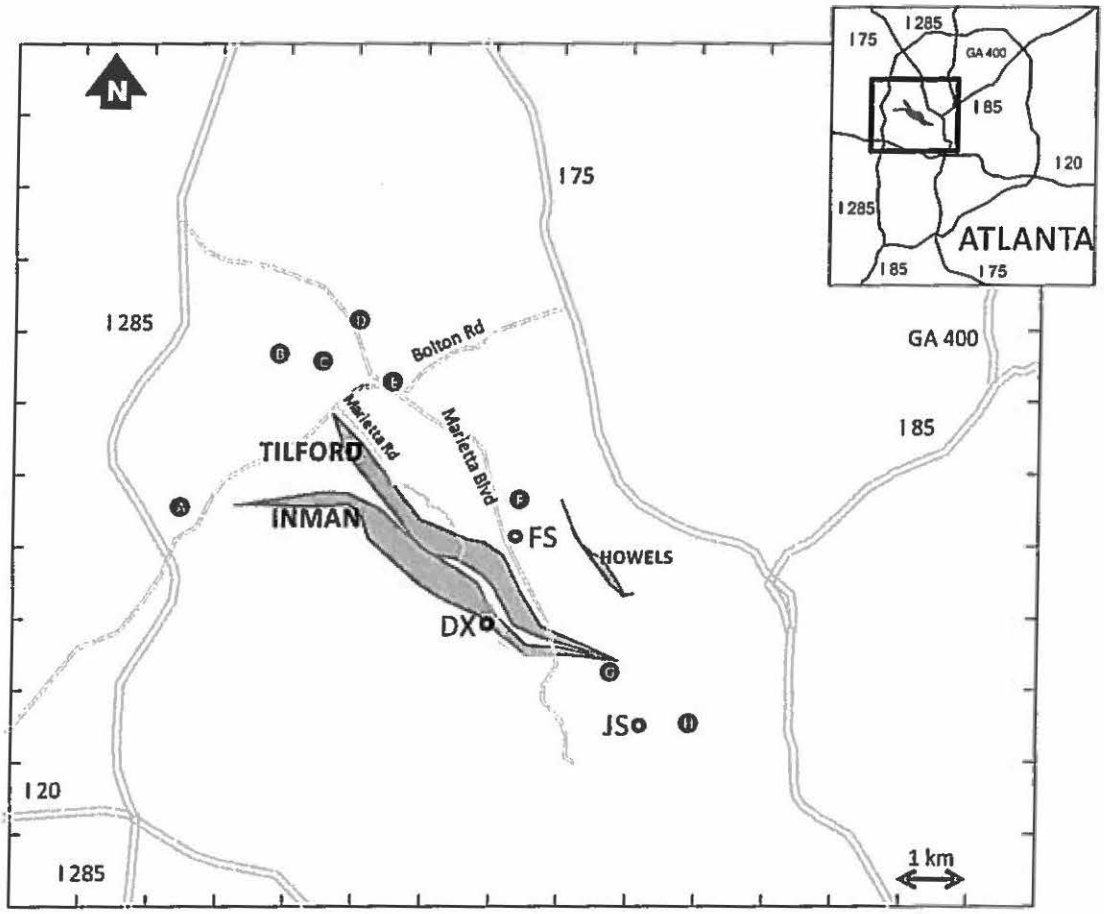

Figure 3.1. Study location and model domain. Layout of the rail yards in gray. Major industrial sources include A) General Shale Brick Inc plant, B) Georgia Power Company McDonough-Atkinson plant, C) Lafarge Building Materials, Inc, D) Cobb County R.L. Sutton water reclamation facility, E) Atlanta R.M. Clayton water reclamation facility, F) Ennis Paint, Inc., G) Mead Packaging Co. and H) Central Metals Co. Major streets included in the model are shown. Interstate highways are shown for geographic reference. Monitoring sites, denoted (o), are Fire station 8 (FS), Dixie (DX) and Jefferson Street (JS).

During 2011, BC and $PM_{2.5}$ concentrations were monitored at the Fire Station 8 (FS) (33.80176 N,-84.43559 W) ASACA network site (Butler et al., 2003), and at the Dixie Driveline & Spring Co. (DX) (33.79080 N,-84.44026 W) (Figure 3.1.). $PM_{2.5}$ measurements were made with Tapered Elements Oscillating Microbalances [TEOMs] (model 1400ab; R&P Thermo Scientific, Franklin, MA). BC measurements were made with Multi Angle Absorption Photometers [MAAPs] (model 5012; Thermo Scientific, Franklin, MA). A full description of the monitoring sites and measurements can be found elsewhere (Galvis et al., 2013). These monitoring data, along with $PM_{2.5}$ concentrations measured by GAEPD (2013) using a Federal Reference Method sampler (FRM) at FS, were used to evaluate modeling results.

3.3.2. Dispersion modeling

Emission impacts from Inman and Tilford rail yards, the nearby smaller Howells yard, major surface streets and 8 industrial sources were assessed using an atmospheric Gaussian dispersion model, the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) (EPA version 12345) (EPA, 2012b). The model domain was set to cover a 15km by 12 km area centered at FS (Figure 3.1.). A 500-meter spaced gridded receptor network was defined in the model and discrete receptors were set at FS and DX sites. Gridded and discrete receptors were assigned terrain elevations using Digital Elevation Model data (USGS, 2012). AERMOD was applied using the urban option to account for the urban heat island effect. A population of 156,000 was used for the simulations. The population was calculated by multiplying the population density of the Atlanta census county division (Census, 2010), 869 inhabitants/km^2 by the domain area of 180 km^2. AERMET (EPA version 12345) was

used to preprocess 2011 meteorological upper air data at 12Z GMT from the Peachtree City, GA NWS station and from hourly surface observations at the Atlanta Hartsfield Airport, GA NWS station. AERSURFACE (EPA version 13016) with the NCLD92 dataset was used to estimate land use characteristics and micrometeorological parameters (i.e., albedo, Bowen ratio and surface roughness) (Table B1).

3.3.3. Sources

3.3.3.1. Mobile Sources

The Inman and Tilford rail yard complex, the Howells Yard, and the on-road mobile sources on Marietta Blvd, Marietta Rd, and Bolton Rd (Figure 3.1.) were defined in the model as multiple volume sources. Inman and Tilford yards were defined each as two volume sources (Inman-A, Inman-B, Tilford-A, and Tilford-B) while Howells was treated as a single volume source. Emissions from line haul and switcher operations were split, but used the same source parameters (Table B2). The release height and initial vertical coordinate for rail yard sources was set to 4.6 m, which is an estimated average height of the diesel locomotive engines in the rail yards (Table B2). The initial lateral coordinates (Table B2) were estimated from the rail yards' width and length (GAEPD, 2012a; EPA, 1995). Bolton Rd and Marietta Rd are represented in the model as three volume sources each. Marietta Blvd is represented as a total of 27 volume sources, corresponding to eleven 50 m, ten 120 m, four 300 m, and two ~ 1500 m segments. Relatively fine segments are defined close to FS and coarse further away. On-road emission release heights and initial vertical coordinates are set to 2.44 m, an estimated average height of vehicles in the area. The initial lateral coordinates were calculated from each segment width and length (Table B2). Perry Blvd NW runs next to DX. This is a

minor road (~1000 AADT) though it does serve a Metropolitan Atlanta Rapid Transit Authority (MARTA) garage. Emissions from this and the rest of the roads in the domain were not included.

3.3.3.2. Industrial Sources

Emissions from the major industrial sources in the domain were modeled. Seven facilities are modeled as point sources, and the stack information was obtained from Integrated Air Information Platform (IAIP) or from Aeromatic Information Retrieval System (AIRS) (Table B3). Ennis Paint was modeled as a volume source, with parameters estimated following GAEPD (2012a) and EPA (1995). Central Metals Co is simulated as three point sources with 2/6, 1/2 and 1/6 of total emissions, respectively.

3.3.4. Emissions

Emissions from the rail yards (Table 3.1) were calculated by multiplying $PM_{2.5}$ and BC rail yard specific emissions factors (R_{EF}) measured in a previous study (Galvis et al., 2013) by the 2011 fuel consumption in the modeling domain. The fuel consumption in the domain was calculated separately for switchers (SFC_D) and line-haul locomotives (LH_{FCD}).

SFC_D for the yards was obtained from GAEPD (2012b).We used the result of the adjusted tonnage method, which is based on link-level line-haul tonnage data and yard and fleet specific information provided by NS. Fuel usage for switcher locomotives retrofitted with Gensets was calculated as 75% of 2011 SFC_D. Fuel consumption for mother-slug sets was obtained from a personal communication with Michelle Bergin.

Table 3.1. Fuel consumption, emission factors and emissions from Inman and Tilford rail yards.

	Unit	TILFORD	INMAN
Base Case. Traditional Switcher Locomotives			
Switchers Fuel Usage [a]	gal/year (m^3/year)	600,000 (2,270)	1,007,000 (3,810)
BC Emission Factor [b]	g/gal (g/m^3)	2.4±0.2 (634±53)	3.1±0.2 (819±53)
$PM_{2.5}$ Emission Factor [b]	g/gal (g/m^3)	4.8±0.6 (1,268±159)	7.2±0.8 (1,9024±211)
Line-haul + Switcher BC Emissions	t/year	3.3±0.3	7.8±0.5
Line-haul + Switcher $PM_{2.5}$ Emissions	t/year	6.6±1.0	18.1±2.0
Scenario 1. New Gensets			
Gensets Fuel Usage [c]	gal/year (m^3/year)	450,000 (1,700)	490,000 (1,850)
Gensets $PM_{2.5}$ and BC Emission Factor [c]	g/gal (g/m^3)	0.8±0.4 (211±106)	0.8±0.4 (211±106)
Line-haul + Gensets switcher BC Emission	t/year	2.2±0.3	5.0±0.5
Line-haul + Gensets switcher $PM_{2.5}$ Emission	t/year	4.1±0.6	11.2±1.4
Scenario 2. Mother-slug sets			
Gensets Fuel Usage [c]	gal/year (m^3/year)	475,000 (1,800)	560 ,000 (2,220)
Gensets $PM_{2.5}$ and BC Emission Factor [c]	g/gal (g/m^3)	2.9±0.4 (766±106)	1.6±0.4 (423±106)
Line-haul + Gensets switcher BC Emission	t/year	3.2±0.3	5.5±0.5
Line-haul + Gensets switcher $PM_{2.5}$ Emission	t/year	5.14±0.6	11.8.±1.4

[a] (GAEPD, 2012b)
[b] (Galvis et al., 2013)
[c] (GAEPD, 2009b;EPA, 2010a;Honc et al., 2006)
[d] Personal communication with Michelle Bergin.

$LHFC_D$ was obtained for each rail yard by dividing the gross ton miles (GTM) transported in the modeling domain (G_D) by the system-wide fuel combustion efficiency (η) as follows:

$$LHFC_D\,[gal] = (G_D\,[GTM])/(\eta\,[GTM/gal]) \quad (3.1.)$$

where G_D was calculated as the GTM transported in the county (G_C) times the ratio of the track miles in the modeling domain (T_D) to the track miles in the county (T_C) as follows:

$$G_D[GTM] = G_C[GTM] \times \frac{T_D[miles]}{T_C[miles]} \quad (3.2.)$$

η was calculated by dividing the GTM transported system-wide (G_S) by the system-wide fuel consumption (FC_S), as follows:

$$\eta\,[GTM/gal] = (G_S\,[GTM])/(FC_S\,[gal]) \quad (3.3.)$$

G_C, T_D and T_C were provided for each rail yard by NS and CSXT companies GAEPD (2009a). G_S and FC_S are data contained in NS (2012) and CSXT (2012) Class I Railroad R-1 Annual Report to the Surface Transportation Board (Table B4). Line-haul fuel usage was 779,000 gal/year (2950 m^3/year) and 1,500,000 gal/year (5680 m^3/year) for Tilford and Inman respectively. These values were used in all scenarios simulated, to calculate total rail yard emissions.

Two types of emission factors were reported by (Galvis et al., 2013), one for the mix of sources inside the rail yards, (i.e. trucks, cranes and locomotives) and another for switcher and line haul locomotives. A specific emission factor was reported for each of the rail yards. In this work we applied the emission factor for switcher and line haul locomotives to estimate rail yard emissions, given that fuel consumption from trucks and other sources inside the intermodal rail yards was not available, and the focus is on

controlling switcher emissions. This could lead to an underestimate of rail yard emissions.

Emissions from rail yard sources were split in proportion to their size. Both Inman-A and Inman-B are assumed to each produce half of the switcher and line-haul emissions from the Inman yard, while Tilford-A and Tilford-B are assumed to produce two-thirds and one-third of the of the switcher and line-haul emissions of the Tilford yard respectively, based on approximate physical size of each. Emissions of switcher locomotives retrofitted with Gensets or replaced by mother-slug sets were calculated using $PM_{2.5}$ estimates of fuel consumption and emission factors reported previously (GAEPD, 2009b; EPA, 2010a; Honc et al., 2006) and obtained by personal communication with Michelle Bergin. Uncertainties in emission factors were considered in our emission inventory, but no information on uncertainties of fuel consumption was available.

The on-road mobile emissions from Bolton Road (between James Jackson Parkway and Marietta Blvd), Marietta Rd, and Marietta Blvd (Table 3.2) were obtained from Atlanta Regional Commission link-based Vehicle Miles Traveled (VMT) database for 2010 (ARC, 2011). Marietta Blvd is a four-lane arterial road with high volume of heavy-duty trucks transporting goods to and from the rail yard; therefore, its emissions are considerably larger than Bolton Rd and Marietta Rd which are two-lane minor collector roads. The emissions for each segment of the roads were set to be proportional to its length relative to the total length of the road (Table B5). BC emissions are a proportion to $PM_{2.5}$ emissions calculated using ratios reported by EPA (2012a) and traffic splits between diesel and gasoline vehicles (ARCADIS, 2005) (Table B5).

Table 3.2. Emissions from major on-road mobile sources at the modeling domain.

	$PM_{2.5}$ Emissions* [t/year]	BC Emissions** [t/year]
Bolton Rd	0.3	0.1
Marietta Blvd	1.2	0.4
Marietta Rd	0.4	0.1

*(ARC, 2011).
**BC emissions are a proportion to $PM_{2.5}$ emissions calculated using ratios reported by EPA (2012a).

For industrial sources, $PM_{2.5}$ emission rates (Table 3.3) were estimated based on information contained in the CERR emission inventory and the GAEPD permitting database. Whenever $PM_{2.5}$ emissions were not available, PM_{10} emissions or PM emissions were modeled (Table B6). As a result, $PM_{2.5}$ impacts from industrial sources are likely overestimated. BC emissions are found from $PM_{2.5}$ emissions using ratios reported for each type of industrial activity by EPA (2012a).

Table 3.3. Emissions from major industrial sources at the modeling domain.

	$PM_{2.5}$ Emissions* [t/year]	Ratio BC to $PM_{2.5}$** [g BC]/ [g $PM_{2.5}$]	BC Emissions [t/year]
Georgia Power Company McDonough-Atkinson plant	132.4	0.38	50.3
Lafarge Building Materials, Inc.	40.8	0.02	0.8
General Shale Brick Inc. plant	24.9	0.02	0.5
Cobb County R.L. Sutton water reclamation facility	36.6	0.02	0.7
Atlanta R.M. Clayton water reclamation facility	9.5	0.02	0.2
Mead Packaging Co.	19.1	0.02	0.4
Central Metals Co.	7.3	0.02	0.1

* CERR emission inventory and the GAEPD permitting database
**BC emissions are a proportion to $PM_{2.5}$ emissions calculated using ratios reported by EPA (2012a).

3.3.5. Background concentrations

Background concentrations were obtained from monitoring data reported by the Southeastern Aerosol Research and Characterization Network (EPRI, 2012) at Jefferson Street (JS) (33.777627 N,-84.416672 W) , which is situated well away from the rail yards and the other major sources being modeled (Figure 3.1.). They measure $PM_{2.5}$ with a TEOM and BC with an Aethalometer. Wavelet analysis (Daubechies, 1992) was used to separate the low frequency components of five minute average $PM_{2.5}$ and BC concentrations. A linear regression between local minima of the low frequency components produced five-minute background concentrations that were averaged by hour, by day of the week and by month. Background annual average concentrations in 2011 were approximately 9.9 $\mu g/m^3$ of $PM^{2.5}$ and 0.52 $\mu g/m^3$ of BC.

3.3.6. Health impacts

BenMAP was used to assess the avoided health impacts brought about by the conversion to lower emitting switcher locomotives and to estimate their associated economic value. The reduction in PM2.5 concentrations accomplished by changes to switcher locomotives at both rail yards along with population calculated for the model domain using data from the Atlanta census county division (Census, 2010) were used as main inputs. BenMAP calculates health related benefits using concentration-response (C-R) functions. C-R functions (Table S7) relate a change in the concentration of a pollutant with a relative change in the incidence of a health endpoint. Next BenMAP calculates the economic value of avoided health effects multiplying the incidence in health effects by a monetary value of the health effect. We used the current EPA-default options for PM health impact assessments to obtain incidence and valuation results (EPA, 2010b). We used the value of

statistical life (VSL) recommended by the EPA Science Advisory Board (EPA, 2010b) to calculate the health benefits of avoided mortality.

3.4. Results and Discussion

3.4.1. Model evaluation

Annual average concentrations estimated with AERMOD at FS and DX are within 8% and 20% of measured $PM_{2.5}$ and BC concentrations, respectively (Figure 3.2). Simulated $PM_{2.5}$ concentrations at FS agree with TEOM measurements and BC measurements at the same site are found to be 0.3 $\mu g/m^3$ higher than the model result (Figure 3.2a).Simulated concentrations at DX underestimate $PM_{2.5}$ annual average concentrations by about 1.1 $\mu g/m^3$ and slightly overestimate BC (Figure 3.2b). Discrepancies at DX could be attributed to AERMOD limitations when reproducing concentrations close to the sources (Holmes et al., 2006) and at FS to uncertainty in on-road mobile sources emissions, as well as other modeling uncertainties.

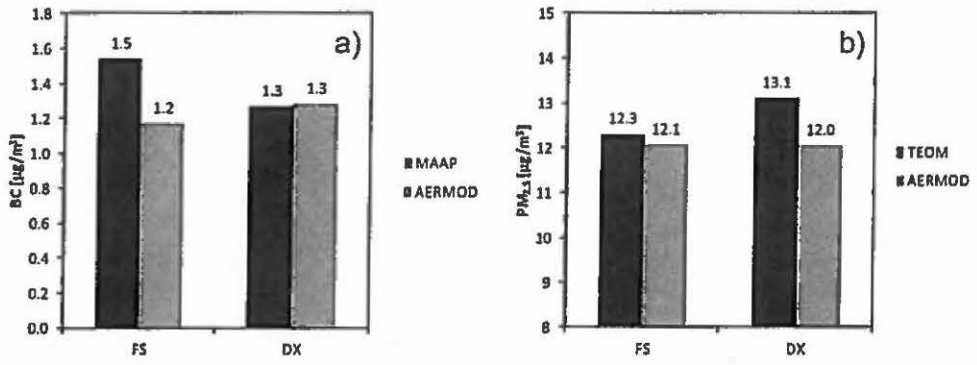

Figure 3.2. Modeled and measured a) BC and b) $PM_{2.5}$ annual average concentrations.

Simulated daily averages of BC at FS compared well with MAAP measurements. Model results explained about 50% of the variability in the measurements at this site

(Figure 3.3a.).The BC measured concentrations at DX showed more variability than modeled. $PM_{2.5}$ concentrations at both sites produced by the model agreed well (Figure 3.3b. and Fig B1). The model falls short to a slight extent when trying to reproduce the variability of the daily average $PM_{2.5}$ measurements. Modeled $PM_{2.5}$ daily averages closely follow TEOM and FRM measurements trend during winter and spring. Summer and fall daily averages are underestimated and overestimated respectively. Further investigation of the fall overestimate found that there was a major change at Plant McDonough that lowered its emissions (EPA, 2013).

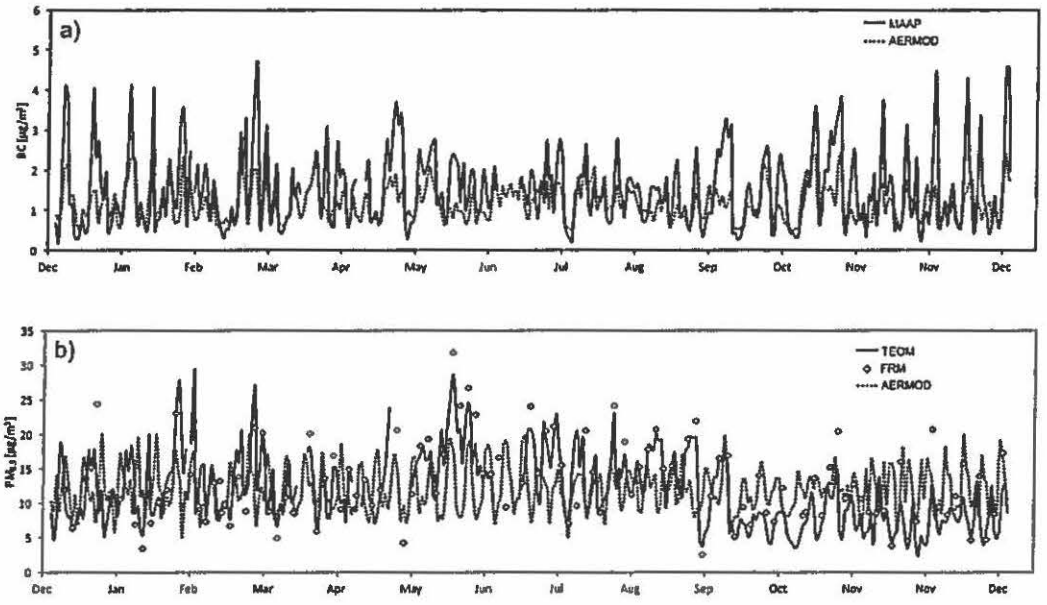

Figure 3.3. Modeled and measured a) BC b) $PM_{2.5}$ daily average concentrations at FS.

Modeled daily averages overestimate low concentrations and underestimate high concentrations by up to 50% in the worst case (Figure 3.4.). Estimates of BC daily averages at DX show an opposite behavior, underestimating low concentrations by around 20% and overestimating concentrations between the 90th and 98th percentile by around 30% (Figure 3.4a.). Given that BC emissions at DX come mainly from the rail

yards and that the site is 80m from the tracks this is a demanding situation for accurate modeling.

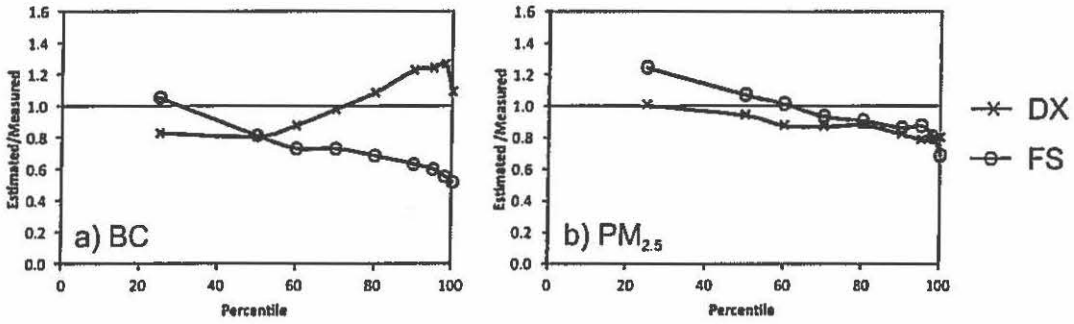

Figure 3.4. Modeled to measured ratios of daily average concentrations by percentile for a) BC and b) $PM_{2.5}$.

Comparisons between measured hourly average concentrations and model results indicate that the model exhibits slight under dispersion in the early morning and evening, and over dispersion in the afternoon. Results do not fully capture morning rush hour peaks for both contaminants and other short-term features (Figure 3.5.).

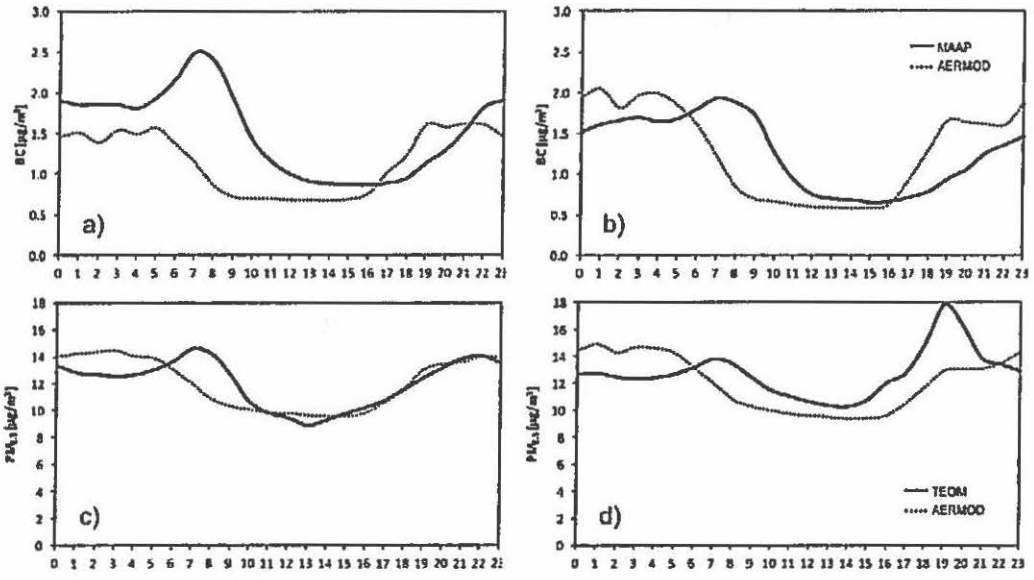

Figure 3.5. Modeled (AERMOD) and measured (MAAP and TEOM) hourly average concentrations for BC at a) FS and b) DX, and PM2.5 at c) FS and d) DX.

3.4.2. Source apportionment

Apportionment of BC and $PM_{2.5}$ from AERMOD results indicates that the line-haul and switcher activities in the rail yards are the most important source of BC in the domain, accounting for approximately 0.5±0.03 $\mu g/m^3$ (39%) and 0.7±0.04 $\mu g/m^3$ (56%) of BC at FS and DX respectively, and for approximately 1±0.1 $\mu g/m^3$ (7%) and 1.6±0.2 $\mu g/m^3$ (14%) of $PM_{2.5}$ at FS and DX respectively (Figure 3.6.). Calculations indicate a greater impact on $PM_{2.5}$ at DX and FS came from the Inman yard. Approximately 5% and 13% of $PM_{2.5}$ at FS and DX respectively are apportioned to Inman yard, whereas 2% and 1.5% of $PM_{2.5}$ at FS and DX respectively are attributed to Tilford yard. Line-haul activities at both yards were found to have slightly higher impacts than switchers, accounting for roughly 4% and 9 % of $PM_{2.5}$ at FS and DX respectively. Switchers at both yards were responsible for roughly 4% and 5.5% of $PM_{2.5}$ at FS and DX respectively.

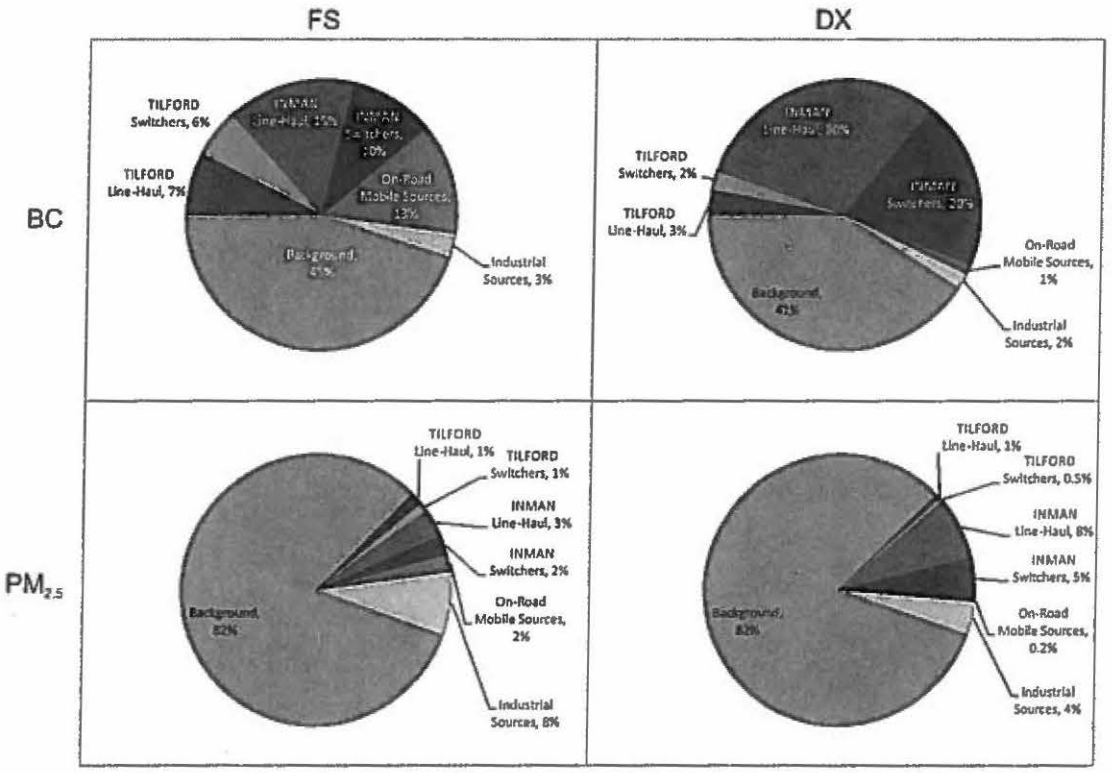

Figure 3.6. Source apportionment for BC and $PM_{2.5}$ at FS and DX.

3.4.3. Air quality impact evaluation

The spatial distributions of BC correspond to the rail yard layout whereas distributions of $PM_{2.5}$ also correspond to the location of the industrial sources (Figure 3.7a. and 3.7b.). BC concentrations of approximately 1 $\mu g/m^3$ outline the rail yards up to 2 km from the center of the complex (Figure 3.7a.).

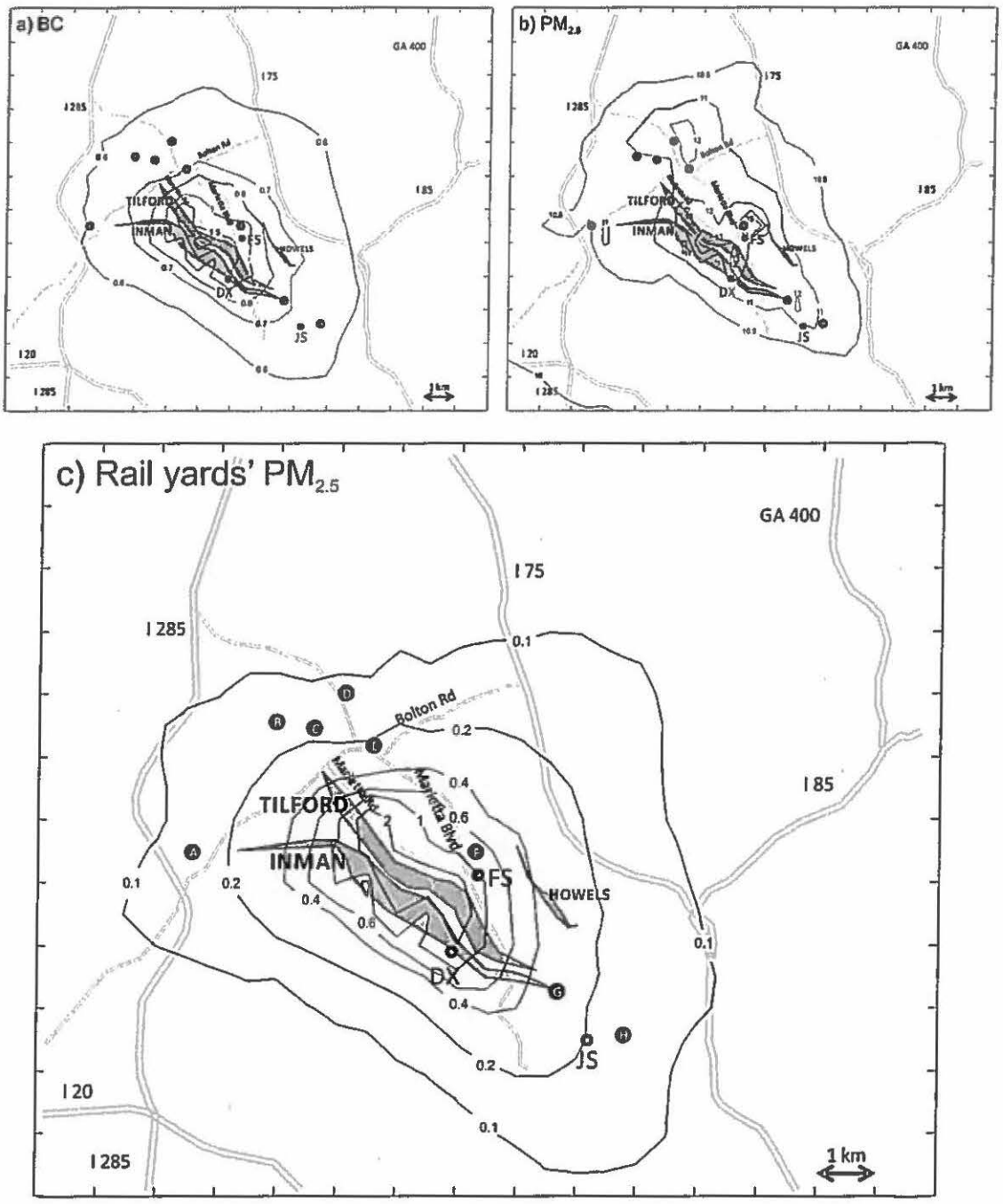

Figure 3.7. Spatial distribution of annual average concentrations of a) BC, b) $PM_{2.5}$ from all sources in the domain and c) $PM_{2.5}$ from the rail yards. Units of the isolines are $\mu g/m^3$. Industrial sources include (A) General Shale Brick Inc plant, (B) Georgia Power Company McDonough-Atkinson plant, (C) Lafarge Building Materials, Inc, (D) Cobb County R.L. Sutton water reclamation facility, (E) Atlanta R.M. Clayton water reclamation facility, (F) Ennis Paint, Inc., (G) Mead Packaging Co. and (H) Central Metals Co.

The spatial distribution of $PM_{2.5}$ annual average concentrations over the domain indicates hot spots, 5 to 2 $\mu g/m^3$ above background, at the center of the rail yard complex and east of D trough G (Figure 3.7b.). Higher impacts of $PM_{2.5}$ from the rail yards are located to the northeast of the domain. Annual average $PM_{2.5}$ concentrations from the rail yards are about 1 $\mu g/m^3$ up to 1 km northeast from the center of the complex (Figure 3.7c.).

Reductions of $PM_{2.5}$ concentrations by retrofitting switchers with new Genset units (Figure 3.8.) are 0.4±0.1 $\mu g/m^3$ and 0.6±0.1 $\mu g/m^3$ at FS and DX respectively (i.e. 3% and 5% of total $PM_{2.5}$ concentration at each site). Conversion to mother-slug sets could gain reductions of about 0.3±0.1 $\mu g/m^3$ and 0.6±0.1 $\mu g/m^3$ at FS and DX respectively. In both scenarios, $PM_{2.5}$ reductions of about 1 $\mu g/m^3$ are located over the rail yards and extend mostly toward the northeast of the domain. $PM_{2.5}$ impacts from the switcher locomotives at the rail yards are reduced on average by 35%.

BC from the rail yards would be reduced by approximately 23% if mother-slug sets are implemented and by 35% retrofitting with new Gensets. BC concentrations will be diminished by 0.1 ±0.02 $\mu g/m^3$ and 0.2±0.03 $\mu g/m^3$ at FS and DX respectively, when the conversions take effect.

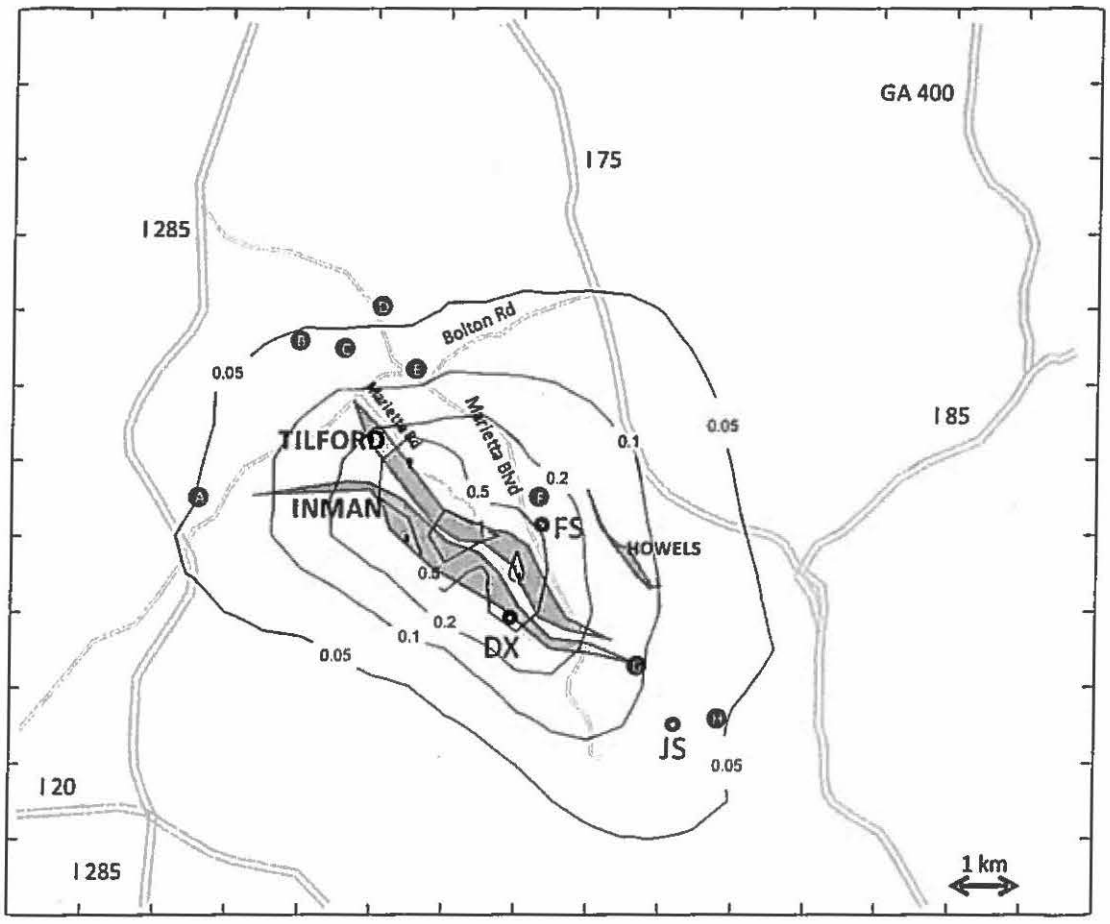

Figure 3.8. Spatial distribution of annual average $PM_{2.5}$ reduction by retrofitting switcher locomotives with new Gensets. Units of the isolines are $\mu g/m^3$. Industrial sources include (A) General Shale Brick Inc plant, (B) Georgia Power Company McDonough-Atkinson plant, (C) Lafarge Building Materials, Inc, (D) Cobb County R.L. Sutton water reclamation facility, (E) Atlanta R.M. Clayton water reclamation facility, (F) Ennis Paint, Inc., (G) Mead Packaging Co. and (H) Central Metals Co.

3.4.4. Health incidence and valuation

We used BenMAP to calculate the avoided incidence in health impacts and the economic value saved by the reduction in primary $PM_{2.5}$ concentrations. Annual avoided incidence results (Table 3.4.) are based on estimates of reduced exposure to $PM_{2.5}$ of the population in the model domain. Results show approximately 3 avoided cases of premature mortality in the 25-99 age group per year and less than one avoided case for

infants. Minor restricted activity days have the highest incidence with approximately 1200 cases. Reductions in asthma exacerbation and work loss days are also important.

Table 3.4. Annual avoided health incidences.

Health endpoint | Age group	Mean reduction in incidence ± standard deviation	
	Scenario 1 Gensets retrofit	Scenario 2 Conversion to mother-slug sets
Mortality, All Cause | 30-99	1.1±0.2	1±0.1
Mortality, All Cause | 25-99	2.5±0.6	2.1±0.5
Mortality, All Cause | infants	0.01±0.01	0.01±0.01
Emergency Room Visits, Asthma | 0-99	0.8±0.3	0.7±0.2
HA, All Respiratory |65-99	0.3±0.1	0.2±0.03
HA, Asthma |0-17	0.03±0.01	0.02±0.01
HA, Chronic Lung Disease | 18-64	0.1±0. 02	0.08±0.01
HA, All Cardiovascular (less Myocardial Infarctions) | 65-99	0.3±0.03	0.3±0.03
HA, All Cardiovascular (less Myocardial Infarctions) | 18-64	0.2±0.04	0.2±0.03
Work Loss Days | 18-64	201±15	166±12
Minor Restricted Activity Days | 18-64	1168±103	966±85
Acute Bronchitis | 8-12	2±1	1.4±0.8
Lower Respiratory Symptoms | 7-14	21±6	18±5
Upper Respiratory Symptoms | 9-11	31±12	25±10
Asthma Exacerbation, Cough | 6-18	412±198	340±164
Asthma Exacerbation, Shortness of Breath | 6-18	146±155	121±128
Asthma Exacerbation, Wheeze | 6-18	49±19	40±16

HA: Hospital Admissions.

Economic value is assigned by BenMAP (ABT, 2012). based on specific cost factors for each health endpoint. Cost factors correspond to research compiled in BenMAP. Reductions in primary $PM_{2.5}$ concentrations due to retrofitting switcher locomotives at Inman and Tilford rail yards save approximately $20 to $24 million in annual avoided health costs (Table 3.5). Converting switchers at the yards to mother-slug sets produces $4 million less savings that retrofitting them with new Gensets. Avoided mortality accounts for 99% of the savings in both scenarios.

Table 3.5. Annual reductions in health costs and premature mortality valuation.

Endpoint | Valuation Method | Age Group	Mean yearly benefits ± Standard deviation [$]					
	Scenario 1 Gensets retrofit			Scenario 2 Conversion to mother-slug sets		
Mortality | VSL, based on 26 value of life studies. | 0-99	24,100,000	±	17,300,000	19,900,000	±	14,400,000
Hospital Admissions, Respiratory | COI: med costs + wage loss | 65-99	5,600	±	4,000	4,700	±	3,300
Hospital Admissions, Respiratory | COI: med costs + wage loss | 0-64	600	±	200	500	±	150
Hospital Admissions, Cardiovascular | COI: med costs + wage loss | 65-99	7,500	±	3,400	6,200	±	3,100
Hospital Admissions, Cardiovascular | COI: med costs + wage loss | 18-64	9,300	±	2,100	7,700	±	1,800
Acute Respiratory Symptoms | WTP: 1 day, CV studies | 18-99	80,000	±	20,000	66,000	±	17,000
Lower Respiratory Symptoms | WTP: 1 day, CV studies | 0-17	450	±	200	370	±	170
Upper Respiratory Symptoms | WTP: 1 day, CV studies | 0-17	1,000	±	600	800	±	500
Work Loss Days | Median daily wage, county-specific | 18-65	38,000	±	2,800	31,500	±	2,300
Asthma Exacerbation | WTP: bad asthma day | 18-99	4,700	±	7,700	4,900	±	6,400
Emergency Room Visits, Respiratory | COI | 0-99	300	±	180	240	±	150
Acute Bronchitis | WTP: 6 day illness, CV studies | 0-17	800	±	800	670	±	500
Total	**24,200,000**	**±**	**17,000,000**	**20,000,000**	**±**	**14,400,000**

VSL: Value of statistical life, COI: Cost of illness, WTP: Willingness to pay, CV: cardiovascular

3.3.5. Cost - benefit

Funding for retrofitting switcher locomotives awarded through CMAQ and matched by industry are expected to amount to 3 annual disbursements, each of 17

million (GAEPD, 2009b). The retrofitted switcher locomotives will remain in service for at least 10 years. With a discount rate of 0.75% (Federal discount rate for April 2013), the resulting positive net present value (NPV) of retrofitting switcher locomotives at Inman and Tilford yards with new genset or replacing them with mother slugs sets is $ 179 million and $ 140 million respectively. This result doesn't take in to account additional pollutants or other factors such as fuel savings or maintenance costs that could affect the cash flows of the project.

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CHAPTER 4

AEROSOL CHEMICAL SPECIATION AND SOURCE IMPACT ANALYSIS NEAR RAIL YARDS

(Galvis, B. Bergin, M., Ng. N. L., Kollman, M.S. and Russell A.G. In preparation)

4.1. Abstract

Chemical speciation of aerosols near the Inman and Tilford rail yard complex in Atlanta, GA indicates that the rail yards are an important source of hydrocarbon like organic aerosols (HOA) and black carbon from fuel (BCf). The rail yard complex contributed to about 1.2 and 1 $\mu g/m^3$ of HOA and BCf respectively during a monitoring campaign in 2011. Elemental carbon (EC) concentrations from wind sector selective filter based measurements confirm downwind upwind continuous measurements and dispersion modeling results for $PM_{2.5}$ BC. A ratio of BCf/HOA of 0.8 at FS from ACSM and aethalometer measurements and a downwind upwind EC/OC ratio of 0.9 from wind sector selective filter based measurements might be characteristic for the emissions from the rail yard complex in Atlanta. Wind sector selective filter based measurements also indicate that the rail yards is a source of Lead, Antimony and Barium likely from a welding facility located inside the complex. Trajectory analysis founds that oxidized organic aerosols (OOA), biomass burning organic aerosols (BBOA), sulfates, nitrates and ammonia were associated with air masses from directions other than the location of the rail yard complex.

4.2. Introduction

The importance of rail yard activities for air quality and climate change (NCFRP, 2010) and the serious health effects of diesel fuel combustion fumes (WHO, 2012), which are their most important emissions, compel extensive work to improve the chemical characterization of atmospheric aerosols around rail yards. Current understanding of emissions from rail yards has identified black carbon (BC) and oxygenated carbonaceous species as their main components. Cahill et al. (2011) carried out a characterization of the inorganic and organic constituents of aerosols from the Roseville rail yard and repair facility in California. They found that rail yard emissions consisted of ultra-fine and very fine aerosols associated with diesel exhaust. They identified species such as black carbon (BC), organic matter, polycyclic aromatic hydrocarbons (PAHs) (particularly, high concentrations of benzo[a]pyrene), phosphorus, zinc, and sulfur. They also found coarse soil aerosols contaminated with anthropogenic metals and petroleum-derived n-alkanes. Sawant et al. (2007), analyzed emissions from three in-use diesel-electric switching locomotives and also found PAHs (predominantly, naphthalene and its derivatives) and n-alkanes.

Organic aerosols (OA) are a mix of thousands of compounds with extremely different properties that can change its composition in the atmosphere and has diverse primary and secondary sources (Zhang et al., 2007). OA can be one of the main components of fine particulate (Kanakidou et al., 2005; Zhang et al., 2007). In Atlanta, OA dominates atmospheric aerosols composition (Budisulistiorini et al., 2013; Lin et al., 2013; Xu et al., 2013). Investigating OA concentrations near rail yards is essential to advance the chemical characterization of emissions from these sources, improve their

representation in models and develop efficient strategies to control their impact on air quality.

The objective of this work is to advance the understanding of the impact of emissions from rail yards by performing a chemical characterization of OA, metals and BC near the Inman and Tilford rail yard complex in Atlanta, GA. And provide a composition profile of aerosol rail yard emissions that can be used to improve air quality modeling.

4.3. Experimental Methods

4.3.1. Study description

Two monitoring sites were used to perform measurements of concentrations of aerosol species near the Inman and Tilford rail yard complex in Atlanta, GA (Figure 4.1.). Fire Station 8 (FS) (33.80176°N,-84.43559°W) and Dixie (DX) (coordinates: 33.79080°N,-84.44026°W), north and south of the rail yard complex. FS site is part of the Assessment of Spatial Aerosol Composition Network (ASACA) (Butler et al., 2003). Analyses of concentrations of non-refractory (NR) species in PM_1 (particulate matter with an aerodynamic diameter ≤ 1 μm) were performed with an Aerosol Chemical Speciation Monitor (ACSM) (Aerodyne, Billerica, MA, US) (Ng et al., 2011) during a winter 2011 monitoring campaign at FS. At the same site, black carbon concentrations in fine particulate ($PM_{2.5}$ BC) were measured with a 7-wavelengt Aethalometer (model AE30 Magee Scientific Corporation, Berkeley, CA, US) from November 2010 until April 2011 and from December 2012 until March 2012. $PM_{2.5}$ BC was also measured at DX and FS with a multi-angle absorption photometer (MAAP) (Thermo Scientific Model 5012) (Petzold et al., 2004; Petzold et al., 2002). MAAP measurements were made from

November 2010 until March 2012. Analysis of MAAP $PM_{2.5}$ BC concentrations was published previously (Galvis et al., 2013) and results at FS are used here for validation of Aethalometer findings. Other long standing measurements at FS include $PM_{2.5}$ mass (particulate matter with aerodynamic diameter less than 2.5 μm) as part of the ASACA project. Filter based measurements of metals, elemental and organic carbon (EC/OC) and ions were carried out during summer and fall 2011 at FS and at DX. Descriptions of the rail yard complex and the monitoring sites can be found in previous works (Galvis et al., 2013). Marietta Blvd NW (17.000 AADT approximately), a road with heavy duty diesel traffic, runs between FS and the rail yard complex.

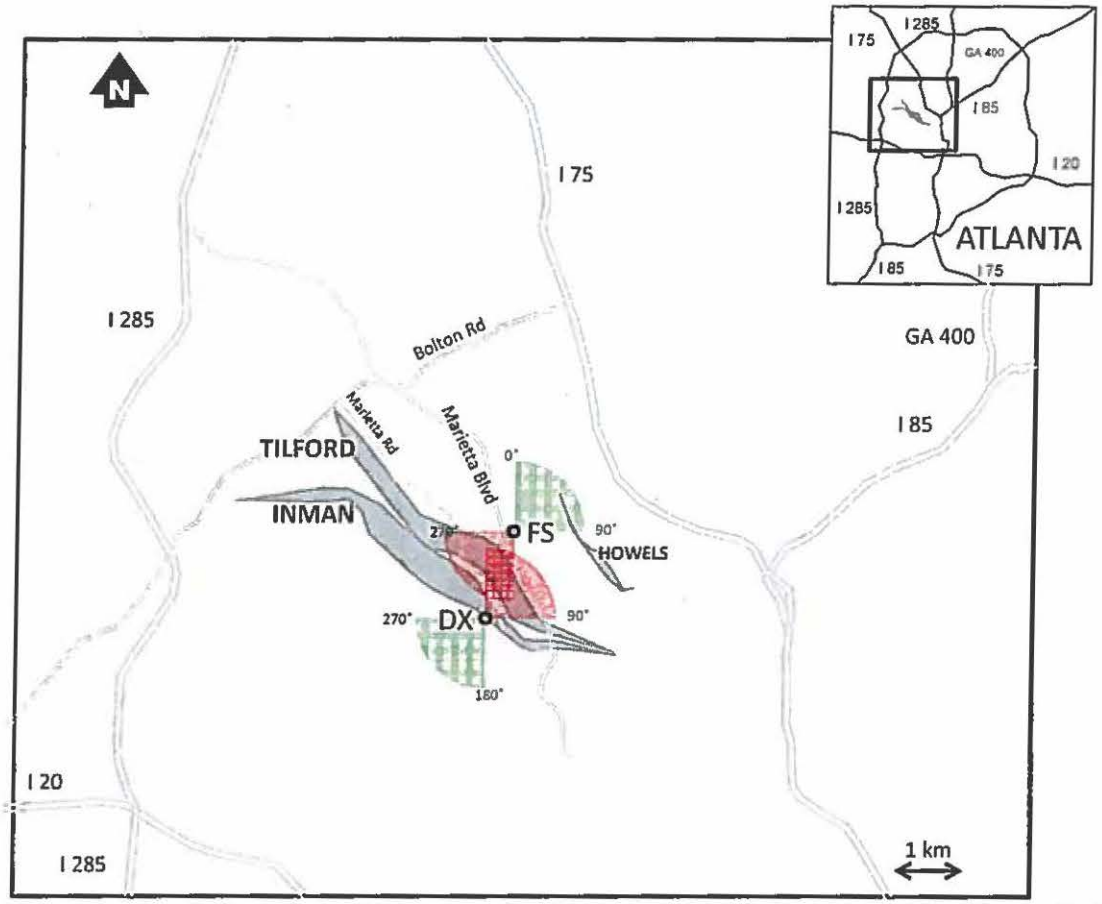


Figure 4.1. Study location. Wind sectors for filter sampling are marked red for downwind and green for upwind.

4.3.2. Aerosol chemical speciation monitor

An ACSM was used between 11/22/2011 and 1212/2011 to measure quantitative mass spectra of the NR species with aerodynamic diameters between 30 and 700 nm (~PM_1) where NR species are operationally defined as those that flash vaporize at 600 °C and 10−5 torr (Ng et al., 2011). These NR species include organics, sulfates, nitrates, ammonia and chlorides and exclude black carbon, metals, mineral dust, and sea salt. Measurements were carried out during three weeks, from November 22 to December 12 of 2011. The ACSM samples aerosols through an aerodynamic lens at 0.1 L min^{-1}, which focuses particles into a narrow beam and carries them in to a high vacuum detection chamber; there the NR components flash vaporize on impact with a heated surface. The resulting gas molecules are detected and chemically characterized by 70eV electron impact quadrupole mass spectrometry. A detailed description of these instruments can be found in Ng et al. (2011). ACSM spectra were recorded with a time resolution of 33 min. The aerosol sampling inlet (2.5 µm URG cyclone with 3L min^{-1} flow, Chapel Hill, NC) was located 3m above the ground. The aerosol was dried and the enclosure at FS was maintained at approximately 20°C. ACSM spectra were analyzed using the toolkit provided by Aerodyne for the IGOR Pro software package (Wavemetrics, Inc., Portland, OR, US). The collection efficiency due to particle bounce (CE) was estimated at 0.5. A response factor for ammonium ($RIENH_4$) was set to 4.

4.3.3. Positive matrix factorization

Many approaches have been taken to analyze organics contribution to atmospheric aerosols. A comprehensive review of these approaches (Ulbrich et al., 2009) found that the recently developed real-time aerosol chemical speciation instruments based

on mass spectrometry, such as the ACSM, combined with Positive Matrix Factorization (PMF) has become the most commonly used technique for OA source apportioning. Briefly, PMF is an unmixing model in which a dataset is presumed to be the result of the linear combination of factors with constant profiles that have variable contributions (Paatero et al., 1994). All of the values in the profiles and contributions are constrained to be positive (Paatero, 1997). PMF is based on mass conservation and does not require information about factor profiles. The drawback of the method is that the number of factors for the model must be selected by the user, aiming to obtain a solution that in his eyes best explains the data (Ulbrich et al., 2009). This leads to subjective results (Engel-Cox et al., 2007; Reff et al., 2007). Further, multiple solutions can be obtained from distinct linear transformations or "rotations" of the factors during the matrix unmixing operation. Ulbrich et al. (2009) developed a procedure and computational tools to interpret the PMF analysis of organics spectra from aerosol mass spectrometers. This work follows their recommendations to choose a number of factors and a particular rotation and uses PMF2 v4.2 and PMF Evaluation Tool (PET) developed by them to execute the analysis and interpret the results. The ambiguities associated with choosing the number of factors and their best rotations are reported.

4.3.4. Aethalometer and black carbon apportionment

A 7-wavelentght Aethalometer was used to measure $PM_{2.5}$ BC concentrations. BC mass loadings reported by the Aethalometer are based on the optical absorption of aerosol deposited on a quartz fiber filter. The instrument measures the attenuation of 370, 470, 520, 590, 660, 880, and 950 nm wavelength radiation. The BC mass concentrations reported are estimated from the absorption coefficient calculated using the factory

defined mass absorption efficiencies for each wavelength. Data was recorded with a 2-min time resolution. The aerosol was sampled using a URG 2.5 μm cyclone with 3 L min^{-1} flow. The instrument was operated without the filter saver option to avoid high loadings in the filter tape. Possible artifacts in the attenuation measurements reported by the Aethalometer were corrected applying a previously published algorithm (Weingartner et al., 2003). A linear regression model, developed by Sandradewi et al. (2008), apportioned BC in ambient air using light absorption measurements made with 7-wavelength Aethalometers and provides information on the amount of BC from biomass burning and fossil fuel combustion. Briefly, the aerosol absorption coefficient (b_{abs}) is equal to $\lambda^{-\alpha}$, where λ is the wavelength and α is the source-specific wavelength dependence of BC light absorption, called the Angstrom exponent. The model uses b_{abs}, measured by the Aethalometer and, α to apportion biomass burning and fuel sources of BC. Values of α for biomass burning BC vary between 1.9 and 2.2 (Sandradewi et al., 2008). For fuel emissions, a value of 1±0.1 has been reported (Bond et al., 2006; Bond et al., 2004). We selected α values of 1 and 2 for fuel and biomass burning, respectively, and the measurements reported by the 7 - wavelength Aethalometer at 470 and 880 nm as recommended by Crippa et al. (2013), to apply the Sandradewi et al.,(2008) model to obtain BC apportionment to biomass burning and fuel.

4.3.5. Multi-angle absorption photometer

A multi-angle absorption photometer (MAAP) (Thermo Scientific Model 5012) (Petzold et al., 2004; Petzold et al., 2002) was used to measure $PM_{2.5}$ BC concentrations. MAAP measurements were made from November 2010 until March 2012 at FS and DX. Data was recorded with a 1 min time resolution. The MAAP determines BC mass

loadings based on aerosol optical absorption at 670 nm. It simultaneously measures radiation scattered back from and passing through a particle-loaded filter. It measures the scattered back radiation at three angles to account for its angular distribution created by the light-scattering properties of the aerosol components. The optical absorption coefficient of the aerosol is determined by a radiative transfer algorithm (Petzold et al., 2004; Petzold et al., 2002), which account for multiple scattering effects and absorption enhancement due to reflections from the filter. The aerosol measured with the MAAP was sampled using a URG 2.5 μm cyclone with 16.7L min^{-1} flow.

4.3.6. Tapered element oscillating microbalance

$PM_{2.5}$ mass concentrations were measured using a1400ab tapered element oscillating microbalance [TEOM] (R & P Thermo Scientific, Franklin, MA, US), operated at 50°C with a Nafion dryer (Permapure Inc. Toms River, NJ) and reporting data every minute.

4.3.7. Wind sector selective filter based measurements

Upwind and downwind wind sector selective filter based measurements of $PM_{2.5}$ metals, elemental and organic carbon (EC/OC) and ions were performed at FS and DX. The sector selective technique is based on controlling a vacuum pump to draw air in to the aerosol sampling system only when wind from a given sector is detected. Wind sectors where set between 0 and 90 degrees at FS and 180 and 270 at DX for upwind samples, and between 180 and 270 at FS and 0 and 90 degrees at DX for downwind samples (Figure 4.1). Sample periods varied between 8 at 42 hours and took up to 5 days to complete. Sample periods were recorded with an electronic timer that kept count of the time when the pump was operating. 42 samples were collected between June and

November 2011 (Appendix C). Two un-denuded particle composition monitors (PMCs) were constructed for this task. The systems drew 16.7 liters per minute (LPM) of air through 2.5 μm cutoff cyclones (URG, Chapel Hill, NC) on to Teflon (2 μm PP ring supported, Whatman Inc., Florham Park, NJ), Nylon (2 μm Nylasorb, Pall Corporation, Ann Arbor, MI) and quartz (AQFA4700, EMD Millipore Billerica, MA) 47 mm filters. The flow through each filter was controlled using three identical critical orifices (O'Keeffe Controls Co, Monroe, CT), set to guarantee that each filter collected a third of the flow. Aluminum filter holders were used for quartz filters and acrylic filter holders for Nylon and Teflon filters. Acetal copolymer 3/8" three way splitters and fittings (John Guest USA Inc., Fairfield, NJ) were used to secure the filter holders and the cyclones. Pieces of less than 2.5 cm of Tygon tubing were used to connect the three way splitter to the cyclone and to the aluminum filter holder and to the two acrylic filter holders. The flow was checked with a Bios DryCcal Defender 520 volumetric primary flow standard (Mesa Labs, Butler, NJ) at the beginning of each sampling period each time a filter was changed. Filter holders were washed with 17.8 megohm-cm deionized water between each use. Nitric acid washed Teflon filters were provided by the Wisconsin State Laboratory of Hygiene at the University of Wisconsin-Madison, where the metals were analyzed by inductively coupled plasma mass spectrometry (ICPMS). Filters were transported to the ASACA laboratory in Atlanta and back to Madison in Petri dishes sealed with Teflon tape. Filter holders were loaded with quartz, Teflon and Nylon filters at the ASACA laboratory and transported to and from the field in portable coolers, where they were kept refrigerated at 4℃ until analysis. Carbonaceous and ionic species analysis was made at the ASACA laboratory. Analysis of EC/OC was made using a thermal-

optical transmission carbon aerosol analyzer (Sunset labs, Tigard, OR) (Birch et al., 1996) following the NIOSH Method. Ionic species were analyzed using ion chromatography (IC) (Baumann et al., 2003). 4 lab blanks and 8 field transport blanks where collected. Lab blanks were kept in the lab with at same storage conditions than the samples. Field transport blanks were taken to the monitoring sites, placed in the PCMs for one hour and returned. Volume of air filtered was calculated by multiplying the flow in each filter (5.67 LPM) by the sampled time. Concentrations were obtained from mass data from analysis and volume data. Metals concentration data were disregarded if it was less than the average blanks concentration plus 2 standard deviations of the blanks. Uncertainties reported by analysis instruments were propagated to downwind upwind differences.

4.4. Results and Discussion

4.4.1. Organic and elemental carbon and Ions

OC species dominate aerosols composition north and south the rail yards (Table 4.1.and Appendix C). Concentrations found are consistent with previous measurements in and around Atlanta (Blanchard et al., 2011; Weber et al., 2007). The contribution of rail yards to EC concentrations as found by downwind upwind differences from filter based analysis confirms previous results from continuous measurements (Galvis et al., 2013). Rail yards were found responsible for an enhancement of about 0.6 $\mu g/m^3$ of EC concentrations during the filter based measurement campaign and for an annual average enhancement of 0.7 to 1 $\mu g/m^3$ of $PM_{2.5}$ BC concentrations during 2011. Similar enhancements in concentrations due to rail yard activity were reported by Cahill et al.

(2011), who observed a nighttime downwind upwind enhancement of 0.7 $\mu g/m^3$ of BC from the Roseville yard in California. A downwind upwind EC/OC ratio of 1.1 found in this work is similar to ratios found in aerosols from combustion of diesel fuel in locomotives at different power levels with an average of 1.7 and a standard deviation of 1.8 (Sawant et al., 2007). However, uncertainty of OC and EC downwind upwind differences, derived from propagation of error, is high (68% and 217%). This is expected given the great variability in concentrations of these species, especially of OC. Uncertainties of downwind upwind differences were not reported in the previous work by Cahill et al. (2011).

Table 4.1. Organic and elemental carbon downwind and upwind of the Inman and Tilford rail yard between 06/20/2011 and 11/08/2011.

	OC ($\mu g/m^3$)	EC($\mu g/m^3$)	OC/EC
AVG DW	6.4 ± 0.9	1.3 ± 0.3	4.8
AVG UW	5.8 ± 0.9	0.7 ± 0.3	7.8
DW-UW	0.6 ± 1.3	0.6 ± 0.4	1.1

Concentrations of ions from wind sector selective filter based measurements indicated no evident differences between downwind and upwind locations and will not be discussed further. A table with these measurements can be found in Appendix C.

4.4.2. Metals

Average measured concentrations of metals at DX and FS (Appendix C) are comparable to measurements done during 2011 by the SEARCH network at Jefferson Street site near the rail yards (EPRI, 2012). Of the 49 metals analyzed, Sulfur (S), Vanadium (V), Antimony (Sb), Lead (Pb) and Arsenic(As) and Barium (Ba) have more than 50% of the samples with signals greater than the average blank concentration minus

twice the standard deviation of the blanks. Ba, Sb and Pb are commonly emitted in welding processes (EPA, 1994; NSRP, 2002) and likely are coming from Norfolk Southern's rail flash welding and track assembly facility at Inman yard.

Table 4.2. Metals downwind and upwind of the Inman and Tilford rail yard between 06/20/2011 and 11/08/2011.

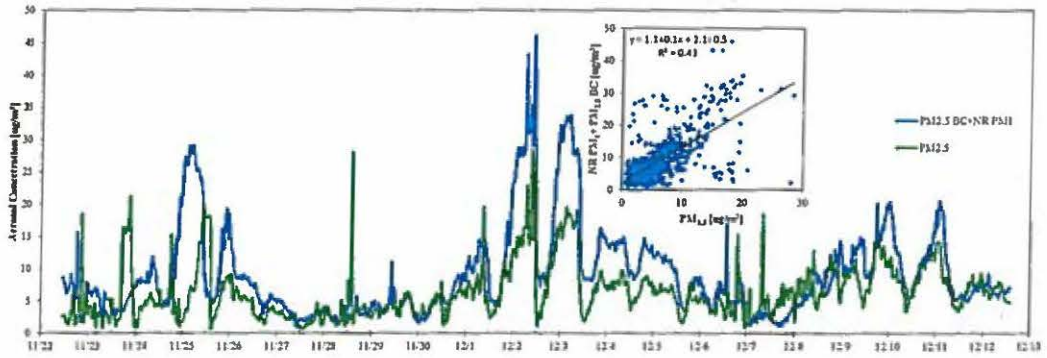
	S (ng/m^3)		V (ng/m^3)		Sb (ng/m^3)		Pb (ng/m^3)		As (ng/m^3)		Ba (ng/m^3)	
AVG DW	420.84	±42.8	0.42	±0.06	0.47	±0.03	1.11	±0.10	0.44	±0.22	2.61	±0.28
AVG UW	392.16	±39.2	0.37	±0.07	0.38	±0.04	0.60	±0.06	0.40	±0.16	1.76	±0.23
DW-UW	28.7	±58.0	0.05	±0.09	0.09	±0.07	0.51	±0.15	0.04	±0.35	0.85	±0.35

4.4.3. ACSM results validation

Average aerosol concentrations during the period measured were 7.4 $\mu g/m^3$, 1.25 $\mu g/m^3$, 6.45 $\mu g/m^3$ for NR PM_1 ACSM, MAAP BC and TEOM $PM_{2.5}$ respectively. Given that NR PM_1 excludes aerosols with aerodynamic diameters greater than 1 μm, BC and other species, NR PM1 concentration should be less than $PM_{2.5}$ concentration, though TEOM operation at 50°C causes the loss of volatile species such as ammonium nitrate and some organics (Eatough et al., 2003; Hering et al., 2004) which can partially account for the difference between the measurements. Average nitrate concentration measured by the ASACA network between 11/22/2011 and 12/12/2011 were 0.6 $\mu g/m^3$. Average nitrate concentration measured by the SEARCH network at the Jefferson Street site near the rail yard complex between 11/22/2011 and 12/12/2011 was 0.7 $\mu g/m^3$. The correlation coefficient between NR PM_1+ BC vs. TEOM $PM_{2.5}$ is 0.42 (Figure 2a). Bias is within the expected amount for the ACSM (Ng et al., 2011) and the MAAP (Petzold et al., 2002; Petzold et al., 2004). There are several periods of time in which the ACSM

reports higher loadings than the TEOM. There are also a few short periods of time with high loadings recorded by the TEOM, but not the ACSM or the MAAP (Figure 2a). Vibration, humidity and temperature changes can cause noise in the TEOM measurements. Comparing $PM_{2.5}$ daily averages reported by the TEOM and BC+NR PM_1 averages reported by the MAAP and the ACSM to daily $PM_{2.5}$ FRM measured by GAEPD (2013) and SEARCH (2012) is evident that TEOM measurements are biased low whereas MAAP+ACSM measurements agree with FS $PM_{2.5}$ FRM (R^2=0.96) and JS $PM_{2.5}$ FRM (R^2=0.93) and (Figure 2b).

a)



b)

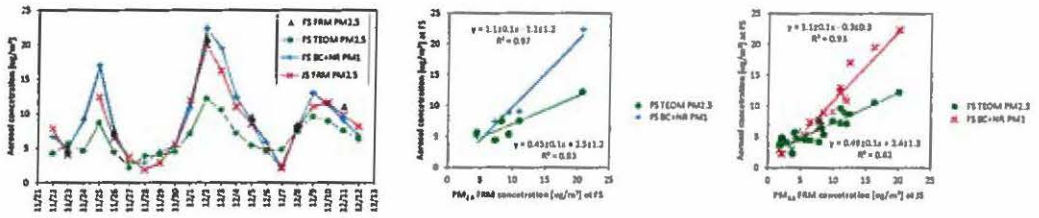


Figure 4.2. Time series and regression comparisons of a) 33 minute average concentrations of TEOM $PM_{2.5}$ and BC+NR PM_1 and b) daily averages of TEOM $PM_{2.5}$, FRM $PM_{2.5}$ and $PM_{2.5}$ BC+NR PM_1 at FS and FRM $PM_{2.5}$ at JS.

Sulfate and nitrate concentrations reported for the SEARCH network at the Jefferson Street site (EPRI, 2012) agree well (R^2 = 0.81 and R^2 = 0.88 respectively) with ACSM measurements at FS, but they are biased low, approximately %35 and 20%

respectively (Figure 4.3.). As expected NR PM_1 ACSM sulfate and nitrate measurements are slightly lower than filter based $PM_{2.5}$ sulfate and nitrate.

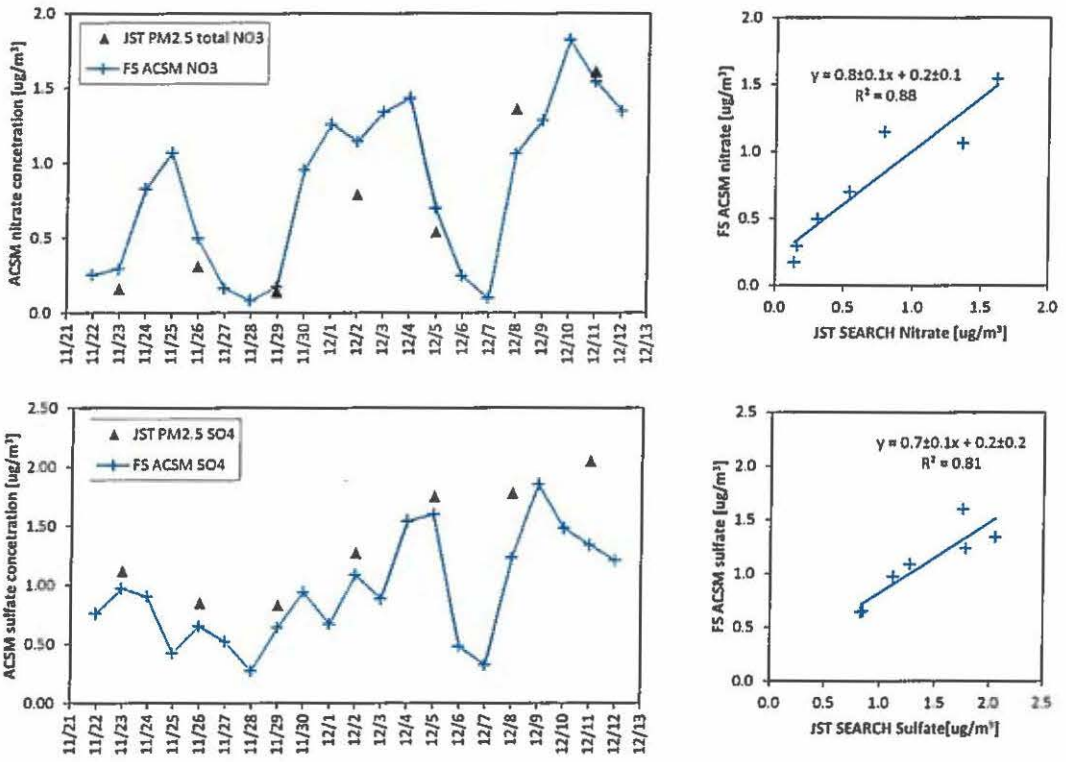


Figure 4.3. Daily average sulfate and nitrate concentrations reported by ACSM at FS vs. SEARCH at Jefferson street site.

4.4.4. Organics PMF solution

Organics ACSM spectra were further deconvoluted using PMF. A three 3 factor solution (Figure 4.4) was chosen based on the fraction of the signal represented by tracers at specific mass-to-charge (m/z) ratios compared to reference mass spectra, the change in residuals and the comparison of the time series of the factors and of other observed species. Uncertainty of the selected factor solution was investigated using a seed parameter equal to 1 and no bootstrapping was run. Different rotational forcing (FPEAK) parameters were tested but no evidence was found that a FPEAK value different from 0

was needed. The criteria listed by Zhang et al. (2012) were followed to choose the solution presented in this work. The sum of the weighed squared residuals (Q) for a 2 factor solution, a 3 factor solution and a 4 factor solution were 2.095%, 1.3% and 0.05 % respectively. No new information was gained from the mass spectra when considering more than three factors and the split of factors was evident. The residual was significantly smaller when considering 3 factors instead of 2. Marginal diminishing of the residual was gained when including a fourth factor and above.

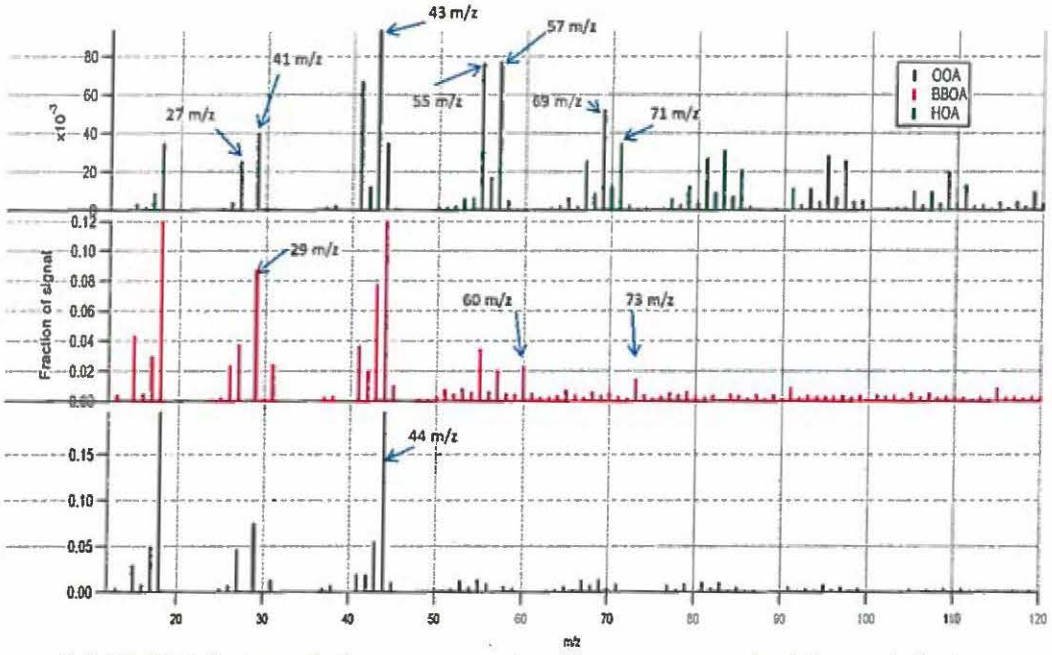


Figure 4.4. PMF 3 factor solution mass spectra. Tracers are marked for each factor.

A first factor was identified as hydrocarbon like organic aerosols (HOA). It showed specific tracers at 27, 41, 43, 55, 57, 69, 71 m/z and other aliphatic hydrocarbon fragments (Canagaratna et al., 2004; Aiken et al., 2010; Ng et al., 2010). A second factor was identified as primary biomass burning organic aerosol (BBOA). It showed specific tracers at 29, 60 and 73 m/z, which are associated to fragments of sugars such as levoglucosan (Alfarra et al., 2007; Ng et al., 2010). The last factor was identified as

oxidized organic aerosol (OOA), a highly oxygenated factor indicated by the peak associated with the tracer CO_2^+ at 44 m/z (Aiken et al., 2010; Ng et al., 2010).

4.4.2.1. Organic factors time series

The HOA time series shows concentration spikes that occur in short periods of time. Some of these spikes are seen in HOA time series, but not in BBOA or OOA time series, suggesting they could come from fresh emissions from mobiles sources (Figure 4.5. marked in blue). Some peaks are simultaneously present in both BBOA and HOA time series, suggesting a fresh biomass burning source in the vicinity (Figure 4.5. marked in orange). Features shared by HOA, BBOA and OOA time series (Figure 4.5. marked in light green) suggest distant burn sources, far enough for oxidized organic aerosols to be important. One interesting feature of the time series is how some of the peaks look like the top has been cut off; the loading will increase and then remain at that level for some time. These plateau shapes seem to begin and end in mid-afternoon and could indicate impact from and specific nearby source, but further research is needed to investigate the cause of this feature in the time series.

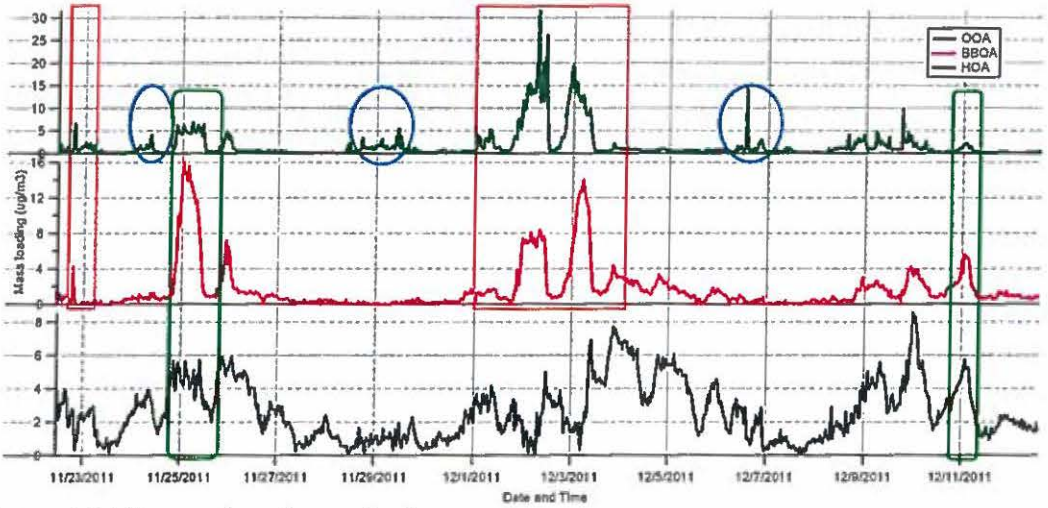


Figure 4.5. Time series of organic factors.

FS ACSM HOA correlate with FS MAAP $PM_{2.5}$ BC (R^2= 0.94) (Figure 4.6a), which is expected given that both relate to primary emissions. Analysis supporting their rail yard origin is discussed later. FS ACSM BBOA correlate (R^2= 0.97) with potassium $PM_{2.5}$ filter based measurements (Figure 4.6b) at the Jefferson Street SEARCH site (EPRI, 2012). Potassium is regarded as a tracer for biomass burning (Watson et al., 2001). ACSM OOA correlate well (R^2= 0.82) with $PM_{2.5}$ TOR OC filter based measurements (Figure 4.6c) at the Jefferson Street SEARCH site (EPRI, 2012). Most of organic carbon in Atlanta is secondary in origin (Lin et al., 2013). Correlation between ACSM OOA and $PM_{2.5}$ TOR OC suggests a secondary origin for OOA . FS ACSM OOA correlates with FS ACSM sulfates and nitrates (R^2= 0.3 and 0.6 respectively). Given that NO_3 is more volatile than SO_4, this suggests that part of the OOA is semi-volatile (SV-OOA), as opposed to low-volatile (LV-OOA), or may be formed from sources that also emit nitrate precursors (NOx).

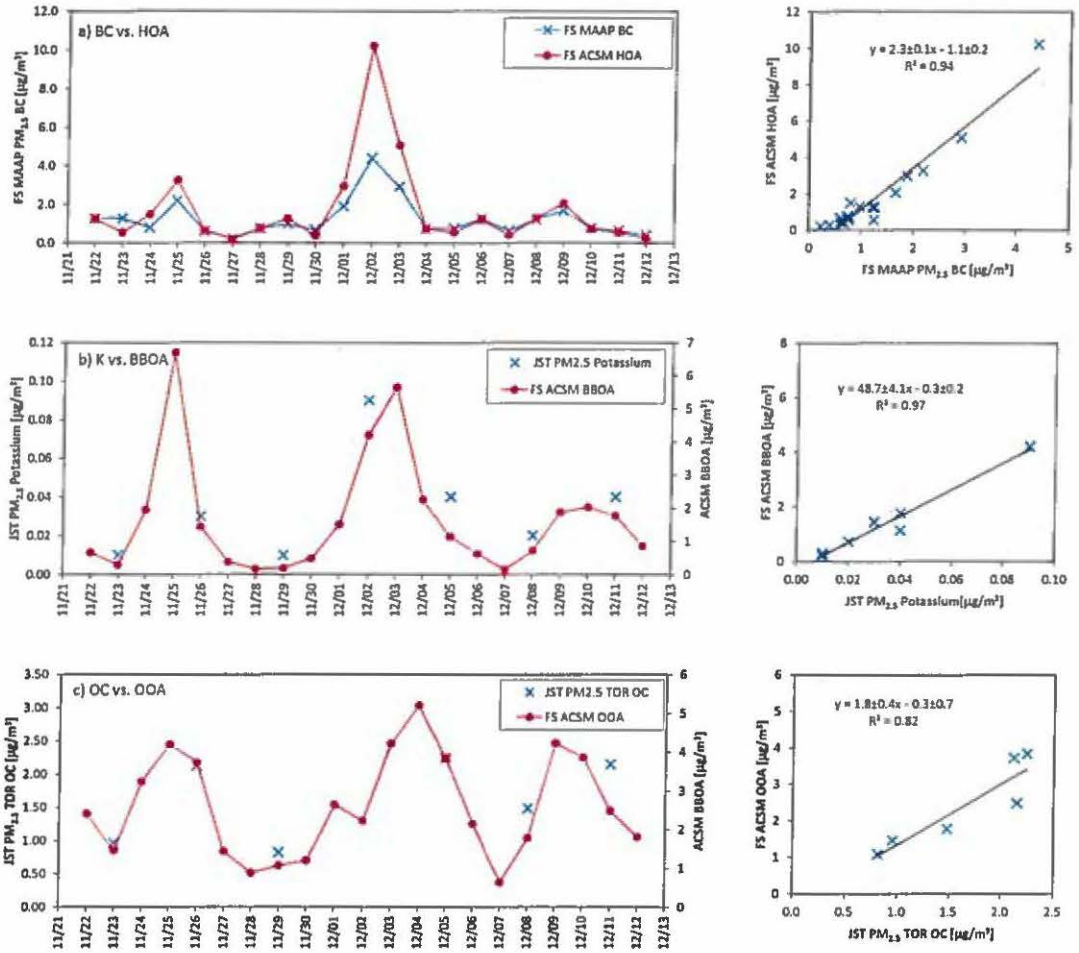


Figure 4.6. Daily averages of organic factor concentrations vs. other observed species near the rail yards. a) BC vs. HOA. b) K vs. BBOA and c) OC vs. OOA.

4.4.5. MAAP and 7-wavelength Aethalometer

We compared BC measurements made with the MAAP and the Aethalometer between 12/6/2011 and 12/12/2011. The MAAP measures BC concentration by determining aerosol optical absorption at 670 nm. The MAAP was designed to avoid shadowing and scattering artifacts (Petzold et al., 2004; Petzold et al., 2002). Hourly averages of BC concentrations measured at 670 nm by the MAAP and at 660 nm by the Aethalometer correlated well (R^2=0.64), with a small bias (Figure 4.7.).

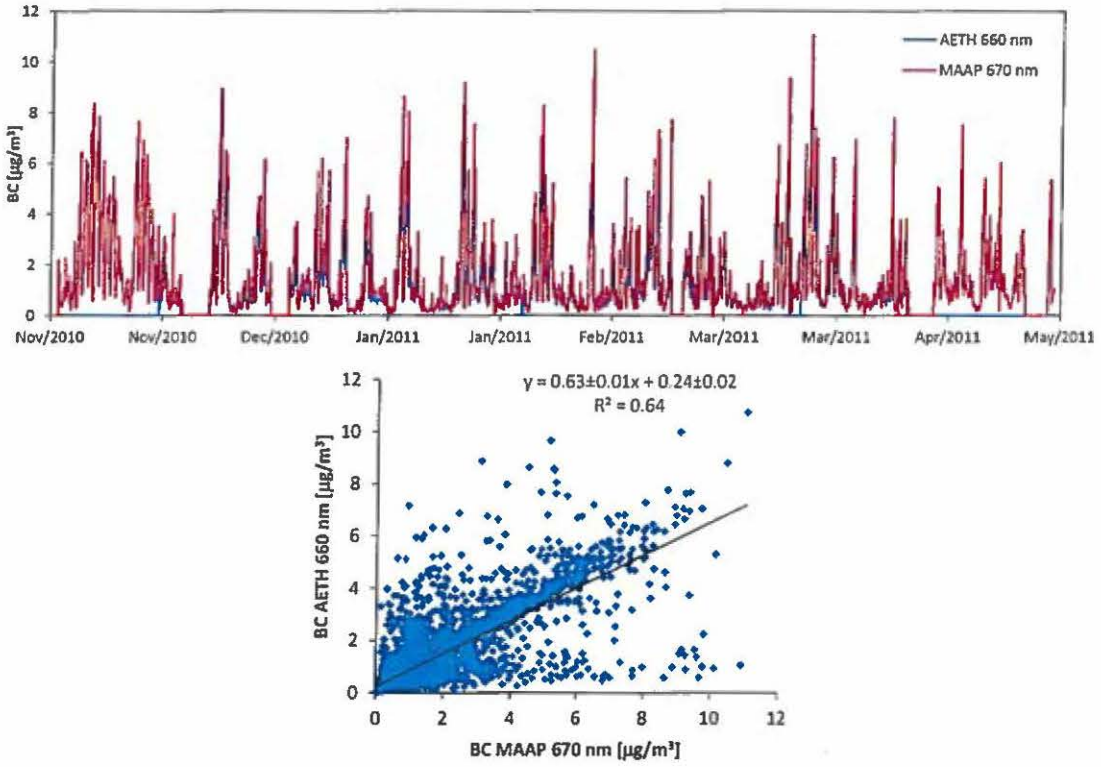


Figure 4.7. BC from MAAP at 670 nm vs. BC from Aethalometer at 660 nm.

4.4.6. Black carbon speciation

Attenuation measurements done with the Aethalometer are thought to have artifacts produced by the shadowing effect of impacted particles at high mass accumulation and by scattering from the filter fibers. Corrections for these artifacts were implemented applying a previously published algorithm (Weingartner et al., 2003). With the corrected attenuation data, $PM_{2.5}$ BC mass was apportioned using the model proposed by Sandradewi et al. (2008) and applied by Crippa et al. (2013). The model resolves the contribution of biomass burning (BCb) and fuel combustion (BCf) to BC, using the dissimilarity in the wavelength-dependent light absorption of these two sources. $PM_{2.5}$ BC apportionment obtained from Aethalometer measurements was compared with PM_1 OA factors from ACSM measurements. Agreement of BCb with BBOA and of BCf with

HOA respectively was found (Figure 4.8. and Table 4.3.). Correlation between NR PM_1 OA factors and $PM_{2.5}$ BC optical apportionment results is comparable to results obtained by Crippa et al. (2013), for the metropolitan area of Paris during winter 2010. The ratio of HOA to BCf (Table 4.1) is also similar to the ratio reported by Crippa et al. (2013). The average HOA to BCf and BBOA to BCb observed ratios are comparable to average organic matter (OM) to BC ratios from smog chamber experiments for diesel vehicle emissions (0.28±0.15)(Chirico et al., 2011) and for a modern log wood burners (0.12±0.04) (Heringa et al., 2011), respectively.

Table 4.3. HOA vs. BCf and BBOA vs. BCb regression results.

	ACSM NR PM_1 HOA vs. Aethalometer $PM_{2.5}$ BCf			ACSM NR PM_1 BBOA vs. Aethalometer $PM_{2.5}$ BCb		
This Study	Slope	0.3±0.02		Slope	0.10±0.004	
	Intercept	0.2±0.03		Intercept	0.02±0.01	
	R^2	0.50		R^2	0.71	
Crippa et al. (2013)	Slope	0.37	0.61	Slope	3.16	3.62
	Intercept	0.33	-0.12	Intercept	0.11	-0.12
	R^2	0.48	0.77	R^2	0.73	0.59

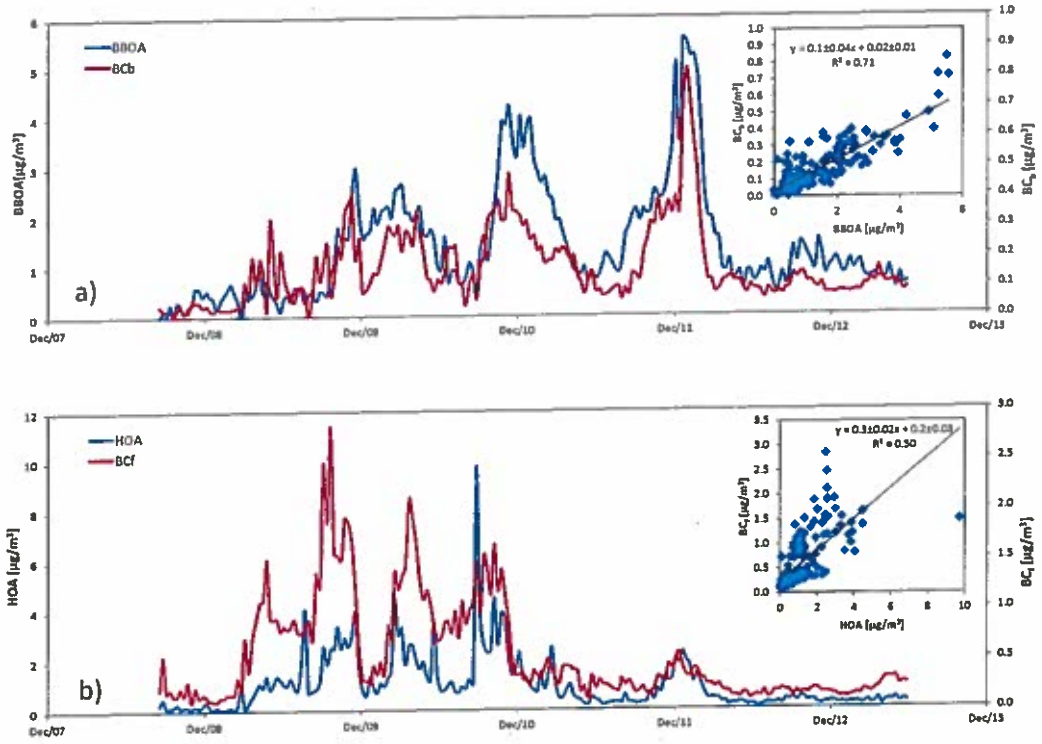


Figure 4.8. Black carbon apportionment and ACSM results comparison. a) Aethalometer $PM_{2.5}$ BCb vs. ACSM NR PM_1 BBOA and b) Aethalometer $PM_{2.5}$ BCf vs. ACSM NR PM_1 HOA.

Measurements indicate that during the period when the ACSM and the Aethalometer were simultaneously measuring (December 7 to 12, 2011), FS was significantly impacted by biomass burning aerosols. BCb and BCf accounted for 28% and 72% of the black carbon mass respectively. Longer term measurements during fall and winter 2010-2011 and fall and winter 2011-2012 (Figure 4.9.) indicate that the site is impacted 82% by BCf and 18% by BCb with average ± standard deviation of 0.9±0.7 $\mu g/m^3$ BCf and 0.2±0.1 $\mu g/m^3$ BCb, respectively.

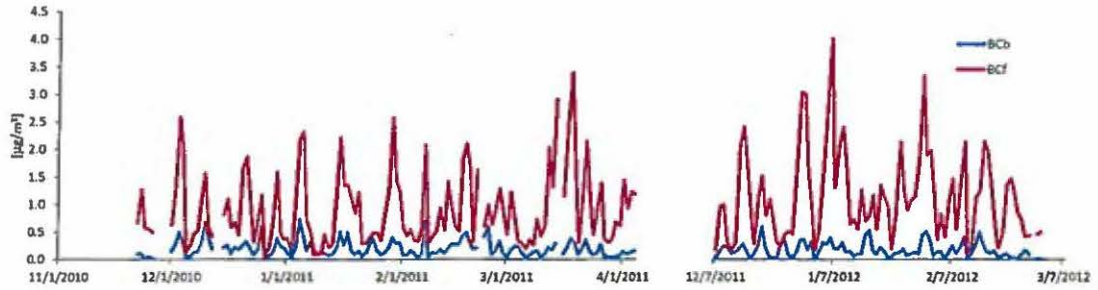


Figure 4.9. Black carbon apportionment during fall and winter 2010-2011 and fall and winter 2011-2012 at FS.

4.4.7. Chemical species and wind direction.

From November 22 to December 12, the mass NR PM_1 aerosols at FS was mostly organic (72%), with few nitrates (11%) , sulfates (12%) and ammonia (5%). Organics were composed of 31% OOA, 20% HOA and 21 % BBOA. A majority of NR PM_1 mass being organics has also has been observed at other Atlanta sites during different seasons (Budisulistiorini et al., 2013; Lin et al., 2013; Xu et al., 2013).

Concentration roses were plotted to identify the direction from which the different chemical species of the aerosols originated (Figure 4.10.). Roses show the direction from where the wind was blowing and the average pollutant concentration from that direction during the monitoring campaign. The $PM_{2.5}$ rose is slightly skewed to the northeast and northwest quadrants but without sharply defined directions suggesting a diverse set of sources. The highest contribution to $PM_{2.5}$ came from the north (up to 9 $\mu g/m^3$average). The BC rose shows two defined lobes, one from the southwest quadrant with average concentrations impacts up to 2 $\mu g/m^3$, where the rail yards and Marietta street are located, and another from the north and north northeast quadrants with average concentrations impact up to 1.5 $\mu g/m^3$. NR PM_1 Organics come mainly from the northeast quadrant with average concentration impacts up to 10 $\mu g/m^3$. NR PM_1 OOA dominates the organics and

shares their northeast quadrant origin with up to 6 $\mu g/m^3$of average concentration. NR PM_1 HOA concentrations have main features southwest (up to 2 $\mu g/m^3$ on average) and north northeast (up to 1.5 $\mu g/m^3$ on average), similar to what was observed in $PM_{2.5}$ BC, which is expected given that those two components are strongly correlated (Figure 4.6a). Emissions from the rail yards and from Marietta Blvd are likely the source of the $PM_{2.5}$ BC and NR PM_1 HOA southwest concentrations. NR PM_1BBOA concentrations come from the northeast quadrant (up to 2.5 $\mu g/m^3$ average concentration). Nitrates show a defined lobe north northeast with average concentrations up to 3 $\mu g/m^3$. Sulfates and ammonia impact the FS mainly from the north, sulfate being more uniformly distributed in all directions.

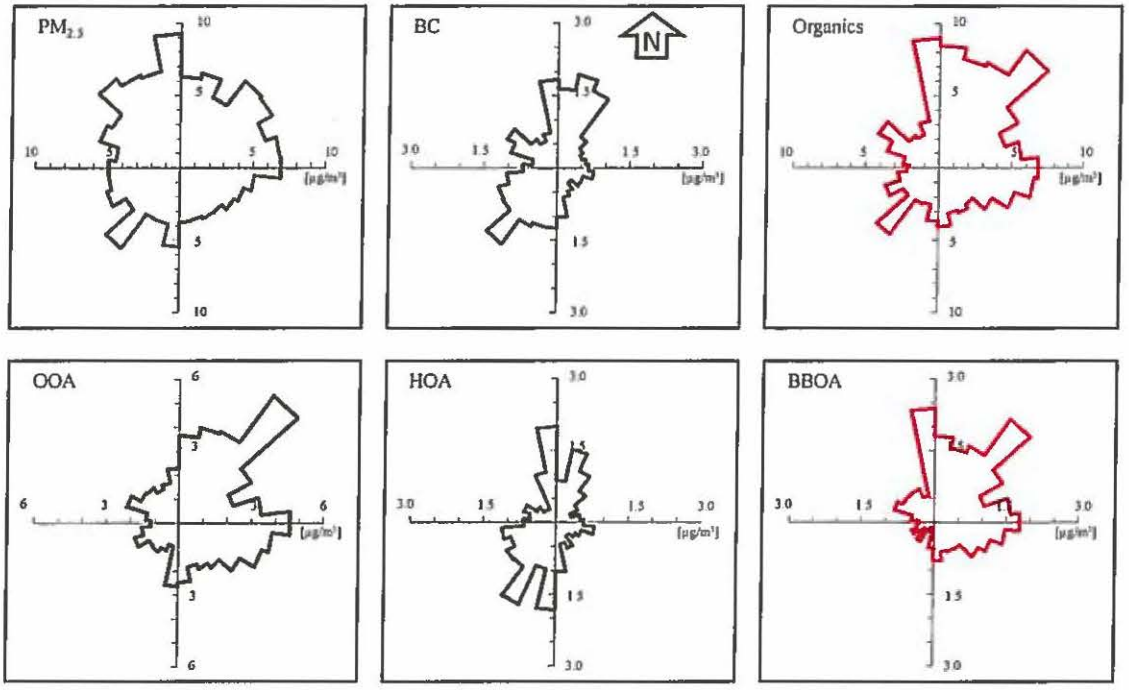


Figure 4.10. Concentration roses of chemical species at FS during the winter 2011

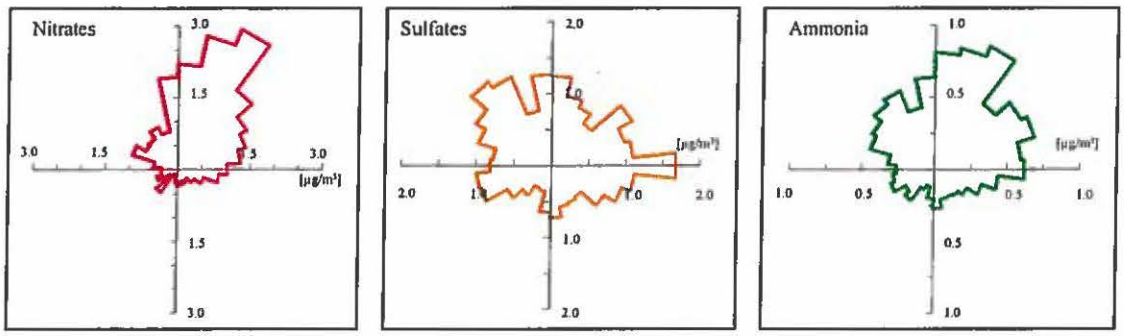


Figure 4.10. (continued). Concentration roses of chemical species.

The rose of $PM_{2.5}$ BCf speciation results, obtained with monitoring data from the fall and winter 2010-2011 and the fall and winter 2011-2012 indicate that $PM_{2.5}$ BCf comes from the direction where the rail yards and Marietta Blvd are located (Figure 4.11). $PM_{2.5}$ BCf rose is similar to annual average $PM_{2.5}$ BC rose found previously at FS, and together with annual average $PM_{2.5}$ BC rose at DX point in the direction of the rail yards (Galvis et al., 2013). Average BCf concentrations from the southwest quadrant are 1.2 $\mu g/m^3$, 60 % greater than the average over all directions. This result parallels annual average $PM_{2.5}$ BC downwind upwind concentration differences obtained previously, 1.0 $\mu g/m^3$ at FS and 0.7 $\mu g/m^3$ at DX (Galvis et al., 2013) and are similar to annual average impact of $PM_{2.5}$ BC concentrations coming from the rail yards and on road mobile sources estimated by dispersion modeling, 0.6 and 0.7 $\mu g/m^3$ at FS and DX respectively (Chapter 3). BCb optical apportionment results indicate biomass burning impacts distributed evenly from the east and southwest quadrants.

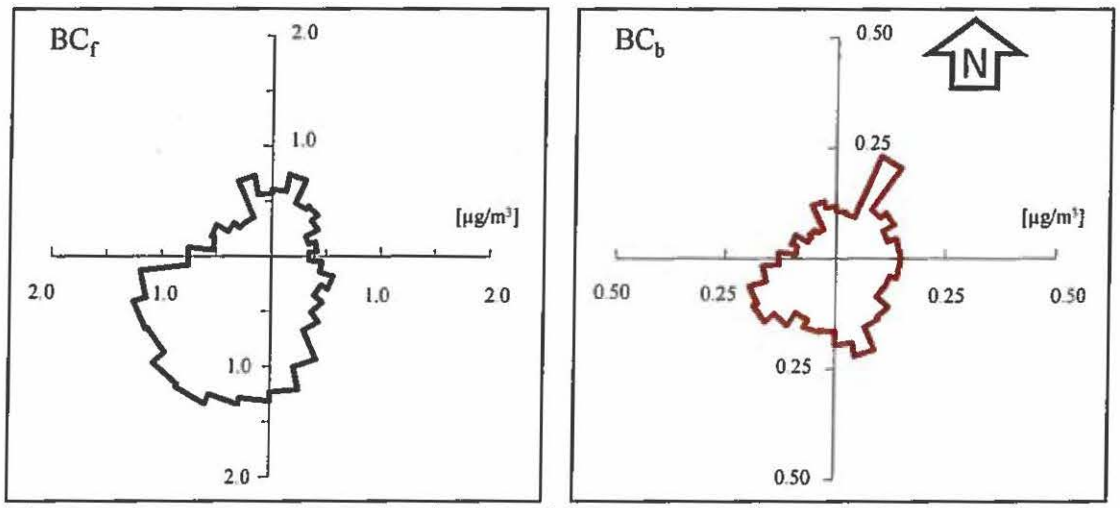


Figure 4.11. Concentration roses of BC speciation results

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CHAPTER 5

CONCLUSIONS AND FUTURE RESEARCH

5.1. Conclusions

The impact of the aerosol emissions from Inman and Tilford rail yards on local concentrations of $PM_{2.5}$ was quantified. BC and $PM_{2.5}$ fuel-based emission factors from the rail yards were estimated by carbon balance using high time resolution monitoring. A composition profile of the rail yard aerosols was identified using chemical speciation techniques. A local BC and $PM_{2.5}$ emissions inventory was calculated and dispersion modeling was applied to assess the impact of the rail yards. Baseline information that will allow evaluation of the improvement in local air quality after locomotives operating in the rail yards are replaced by cleaner technologies was generated.

5.1.1. Fuel-based fine particulate and black carbon emission factors from a rail yard area in Atlanta.

In-use emission factors were quantified for diesel-electric engines and supporting activities at the Inman-Tilford rail yard complex in Atlanta, Georgia, using near-source high-time resolution monitoring of ambient concentrations at two monitoring sites.

Three approaches were used to estimate the emission factors. The delta approach was based on the downwind–upwind difference in concentrations, the wavelet approach analyzed spikes of black carbon (BC), fine particulate ($PM_{2.5}$), and carbon dioxide (CO_2) concentrations, and the regression approach utilized events of correlated BC and CO_2 concentrations. The delta and the wavelet approaches are thought to represent emissions of a broad mix of rail yard sources, whereas the regression approach is likely to represent

emissions from switchers and line-haul engines passing by monitoring sites. The average estimated emission factors from the delta and wavelet approaches are 0.6 ± 0.03 g of BC and 1.3 ± 0.1 g of $PM_{2.5}$ per gallon of diesel fuel burned at DX and 0.8 ± 0.03 g of BC and 1.7 ± 0.1 g of $PM_{2.5}$ per gallon of diesel fuel burned at FS. Emission factors estimated by the delta and wavelet approaches were statistically similar. The regression approach yielded an average emission factor of 2.8 ± 0.2 g of BC and 6.0 ± 0.5 g of $PM_{2.5}$ per gallon of fuel.

Rail yard emissions led to average enhancements of approximately 1.7 ± 0.1 $\mu g/m^3$ of $PM_{2.5}$ and approximately 0.85 ± 0.01 $\mu g/m^3$ of BC on an annual basis. Events of high BC concentrations, likely generated by switchers and line-haul engines in the rail yards, lead to a typical increase of about 3 $\mu g/m^3$ of BC and about 6 ppm of CO_2 above baseline.

Uncertainties not quantified in these results arise in part from variability in downwind–upwind differences, differences in emissions of the diverse zones within the rail yards, and influence of on-road mobile sources other than the ones of interest.

5.1.2. Impacts on fine particulate, black carbon and health of converting rail yard locomotives to lower emission technologies.

Local air quality impacts of $PM_{2.5}$ and BC emissions from line-haul and switcher activities at the Tilford and Inman rail yards were determined using dispersion modeling and site-specific emission characterization. Emissions from these activities were calculated with previously measured emission factors and reported fuel consumption for switchers and line-haul locomotives. Model evaluation found agreement between measured and simulated concentrations. Simulations found that line-haul and switcher

activities the Tilford and Inman rail yards account for approximately for 0.5 $\mu g/m^3$ and 0.7 $\mu g/m^3$ of BC, and for approximately 1 $\mu g/m^3$ and 1.6 $\mu g/m^3$ of $PM_{2.5}$ at FS and DX respectively.

Retrofitting the switcher locomotives at the Tilford and Inman rail yards with new generator sets would reduce $PM_{2.5}$ and BC emissions by 9.4±0.9 and 3.8±0.6 t/year. Replacing traditional switchers with mother-slug sets would reduce $PM_{2.5}$ and BC emissions by 7.8±0.9 and 2.4±0.6 t/year. A reduction of approximately 0.4±0.1 $\mu g/m^3$ and 0.6±0.2 $\mu g/m^3$ of $PM_{2.5}$ and approximately 0.2±0.1 $\mu g/m^3$ and 0.3±0.1 $\mu g/m^3$ of BC at FS and DX respectively can be achieved. Greater reductions are located over the rail yards and to the northeast of the domain. Primary $PM_{2.5}$ and BC impacts from the rail yards are reduced by 38% and 29%.

The spatial distribution of annual average BC concentrations resembles the rail yard layout whereas distributions of $PM_{2.5}$ also show structure near industrial sources. BC concentrations of approximately 1 $\mu g/m^3$ outline the rail yards up to 2 km from the center of the complex. The spatial distribution of annual average $PM_{2.5}$ concentrations over the domain indicates hot spots, 2 - 5 $\mu g/m^3$ above background, at the center of the rail yard complex and near specific industrial sources. Higher impacts of $PM_{2.5}$ from the line-haul and switcher activities at the rail yards are located to the northeast of the domain. Annual average $PM_{2.5}$ concentrations from these activities at the rail yards are about 1 $\mu g/m^3$ up to 1 km northeast from the center of the complex. Modeling results indicate that at FS emissions from on-road mobile sources on Marietta Blvd. and other important surface roads in the domain have 1/4 and 1/3 of the impact of the emissions from rail yard line-haul and switchers sources on $PM_{2.5}$ and BC concentrations respectively.

Significant reductions in $PM_{2.5}$ and BC concentrations over the domain can be achieved by converting switcher locomotives at Inman and Tilford rail yards to lower emission technologies. Greatest reductions, about 1 $\mu g/m^3$, are located over the rail yards. Reductions extend mostly toward the northeast of the domain. Reductions in $PM_{2.5}$ concentrations can save approximately $24 million in annual avoided health costs and premature mortality. The measure has a positive net present value of about $179 million through a ten year period.

5.1.3. Aerosol chemical speciation and source impact analysis near rail yards

The Inman and Tilford rail yard complex in Atlanta, GA is an important source of hydrocarbon like organic aerosols (HOA) and black carbon from fuel (BCf). On average during the monitoring period they were been simultaneously measured, 1.2 and 1 $\mu g/m^3$ of HOA and BC_f respectively, came from the direction of the rail yards. Elemental carbon (EC) concentrations from wind sector selective filter based measurements confirm downwind upwind continuous measurements and dispersion modeling results for $PM_{2.5}$ BC, indicating that the rail yards were responsible for about 0.6±0.4 $\mu g/m^3$ of EC during the filter based campaign at FS, for an annual average enhancement of 1 $\mu g/m^3$ of $PM_{2.5}$ BC concentrations during 2011 at FS, and for about 0.5±0.1 $\mu g/m^3$ of BC from modeling results respectively. A ratio of BCf/HOA of 0.8 af FS from ACSM and aethalometer measurements and a downwind upwind EC/OC ratio of 0.9 from wind sector selective measurements might be characteristic for rail yard emissions from the Atlanta complex. Wind sector selective filter based samples indicate that the rail yards is a source of Lead, Antimony and Barium likely from a welding facility located inside the complex. The main sources of oxidized organic aerosols (OOA), biomass burning organic aerosols

(BBOA), sulfates, nitrates and ammonia in the area of this study were not located in the direction of the rail yard complex.

5.2 Future research

Assessment of changes in air quality after the implementation of cleaner technologies at the Inman and Tilford rail yard complex is a key topic for future research to complement the present work. Approaches developed here could be applied and extended to address this matter. Fuel-based emission factors for the new technologies should be obtained. High time-resolution monitoring, as used here, was found to be an effective approach to develop in-use emission factors for a source such as the rail yards. Additional monitoring sites near the rail yard complex could facilitate the calculation of emission factors and impact evaluation. Monitoring coverage could be augmented using low cost BC, $PM_{2.5}$ and CO_2 micro sensors which could simplify the location of new monitoring sites around the railyard complex.

The regression approach used here could be extended by monitoring NO_x concentrations and accessing or retrieving information on rail yard activity. NO_x concentration measurements could further the detection of high concentrations events coming from the rail yards, given that locomotive activity near monitoring sites should increase NO_x, CO_2 and BC concentrations simultaneously and all three should be well correlated. Monitoring NO_x concentrations may be used to differentiate between new switcher and line-haul locomotives. New switchers are thought to have low BC and NO_2 emissions but given low background of NO_x in the area this contaminant might be easier to detect than low BC concentrations coming from cleaner switcher locomotives. If no information on rail yard activity is provided by the industry, small motion sensor cameras

with night vision could be placed at the monitoring sites to record locomotive traffic and link it to pollutant concentrations as was done here.

Fuel-based emission factors could be measured for other rail yards and similar sources. Expanded monitoring capacity permitted by the recent developments in miniaturization and simplification of monitoring sensors for CO_2, CO, BC, NO_x could provide sufficient data at low cost and with improved spatial coverage to permit successful application of the approaches taken here. This could help lower uncertainties in emission inventories.

Evaluation of impacts of rail yard emissions by dispersion modeling could benefit from including emissions from other surface streets in the area, such as James Jackson Parkway NW, Hollywood Road NW, Chattahoochee Ave NW and Howell Mill Road. Estimates of emissions from these roads and the much larger roads already included in this work could reduce discrepancies between simulated and measured concentrations and better capture the morning rush hour peaks and other short-term features in the concentrations of simulated contaminants.

Analysis of monitoring data from the Atlanta Rail Yard Study (ARYS), a campaign carried out by Georgia Tech, EPA and Aerodyne Research Inc. during May 2012 will supplement the present work. Data on aerosol chemical speciation, aerosol size and number distributions, O_3, BC, NOx, CO, CO_2, formaldehyde and VOCs was collected and has yet to be analyzed. It will further elucidate the chemical composition of aerosols and gases emitted by rail yard activities. Specific chemical profiles for rail yard locomotives, trucks and cranes, other various in-yard sources might be extracted. Measurements of spatial gradients of gas and particulate near the rail yard complex done

in the ARYS campaign will help to further evaluate results of dispersion modeling presented in this work.

APPENDIX A

SUPPORTING INFORMATION FOR CHAPTER 2

A.1. Photos of Rail yard Activity

Rail yard operations were recorded from the DX site, flanking the tracks of the arrival section of Inman Yard. A Hero Gopro 960 camera was used to take pictures every minute on 42 days between 9/15/2011 and 11/14/2011 for a total of 60,384. Photos were look at one by one to identify rail yard activity. Photos corresponding to low light conditions during night time were unusable. Photos show trains, accelerating, idling or passing by before an event of overlapping signals of concentrations of BC and CO_2 were registered. Photos also showed that when no locomotives were present and the wind was from blowing from the direction of the rail yards, BC and CO_2 concentrations were poorly correlated.

Table A.1. Dates of photographic surveillance of Inman rail yard.

Initial Date	End Date	# Days
9/15/2011 9:37	9/18/2011 15:19	3
9/20/2011 16:38	9/27/2011 9:25	7
9/28/2011 11:27	10/1/2011 11:08	4
10/1/2011 12:03	10/7/2012 21:34	7
10/10/2011 16:56	10/17/2011 15:05	7
10/21/2011 9:49	10/27/2011 14:44	7
11/8/2011 12:30	11/14/2011 17:43	7

A.2. Algorithm for wavelet analysis

The Matlab algorithm to separate the high and low frequency components of the signals is presented next. Comments of each step are provided with in the code.

```
function [baselineCorrected, smoothSpec, baselineEst] =
WavletDenoiseBaselineRemove3(P,tolerance)
% baselinecorected is to be the high frequency components of the signal
% corrected for background concentrations
% smoothSpec is the pollutant signal smoothed by application of wavelet
% decomposition.
% baselineEst is the approximation of the background concentration obtained
% from lineal regressions between local minima.
% P is the variable to denoise and correct baseline. In our case it is BC,
% CO2 or PM2.5 data.
% tolerance is the level of concentration allowed to be disregarded when is
% below the baseline approximation. We used 0.5 ug/m3 for PM2.5 and BC and
% 1 ppb for CO2

iempty=isnan(P);
P(iempty)=mean(P(~iempty));
% nans are patched with the mean pollutant concentration, to be able to do
% the wavelet decomposition. The array of empty data is saved to discard the
% patched data later on.


L=5;
% L is the decomposition level.  A typical value of 5 was used.

[c,l] = wavedec(P,L,'db8');
% Matlab function wavedec performs a multilevel one-dimensional wavelet
analysis using either a specific wavelet, in this case db8 Daubechies wavelet
filter. The output decomposition structure contains the wavelet decomposition
vector c and the bookkeeping vector l.

a(length(P),L)=1;
% preallocate variable "a" to storage reconstructions of the signal at
different % levels

for i=1:L;
a(:,i)= wrcoef('a',c,l,'db8',i);
end
% Reconstruct approximation at level L, from the wavelet decomposition
% structure [c,l].

base=a(:,L);
% L Level is selected to construct the baseline approximation

d=diff(base);
% Matlab function diff(x)calculates differences between adjacent elements of
% x, that can be used approximate derivatives to identify local minima.

q(:,1)=d<=0;
q(:,2)=d>0;
k(1,length(base))=0;
% preallocate variables q, and k to storage minima localization
```

```
for j=3:length(q(:,1))-3;
 if ((q(j,1)>=1)&&(q(j,2)<=0))&&((q(j+1,1)<=0)&&(q(j+1,2)>=1))
     k(j+1)=1;
 end
end
% locate local minima

x = find(k>0); x=x';
y = base(x);
% assigns local minima to construct initial baseline estimation
xi = 1:1:length(base); xi=xi';
yi = interp1(x,y,xi,'linear');

% Matlab function interp1(x,Y,xi) does a lineal interpolation to find yi, the
% values of the underlying function Y at the points in the vector or array
% xi.

offset=yi-base;
% Offset is defined as the concentration data that is under the initial
% baseline approximation.

tol=sum(offset>=0);
% initial value of a tolerance level

while tol>100;
    Arraycopy = offset;
    for j = 1:500
       [~, IND(j)] = max(Arraycopy);
       Arraycopy(IND(j)) = 0;
    end
    k(IND)=1;
    x = find(k>0); x=x';
    y = a(x,3);
    xi = 1:1:length(a(:,3)); xi=xi';
    yi = interp1(x,y,xi,'linear');
    offset=yi-a(:,3);
    tol=sum(offset>=tolerance);
end
% this while cycle looks for the baseline approximation accounting for as
% much concentration data as possible, minimizing signal loss.
smoothSpec=a(:,1);
smoothSpec(iempty)=nan;
% assigns the first level reconstruction to output smoothSpec and eliminates
% data previously patched.
baselineEst=yi;
baselineEst(iempty)=nan;
% assigns the estimated base line reconstruction to output baselineEst and
% eliminates data previously patched.
baselineCorrected = smoothSpec - baselineEst;
% assigns the high frequency components minus the estimated base line to
% output baselineEst.
```

A.3. Histograms and time series plots of Downwind/Upwind data

To visualize the effectiveness of the delta approach to calculate emission factors and the origin of the variability of the results we plotted the time series of the downwind and upwind data. In green is the upwind data and in red de downwind data at both monitoring sites.

Whereas time series and histograms show a clear difference for BC downwind vs. upwind concentrations the same is harder to see in the CO_2 and $PM_{2.5}$ time series.

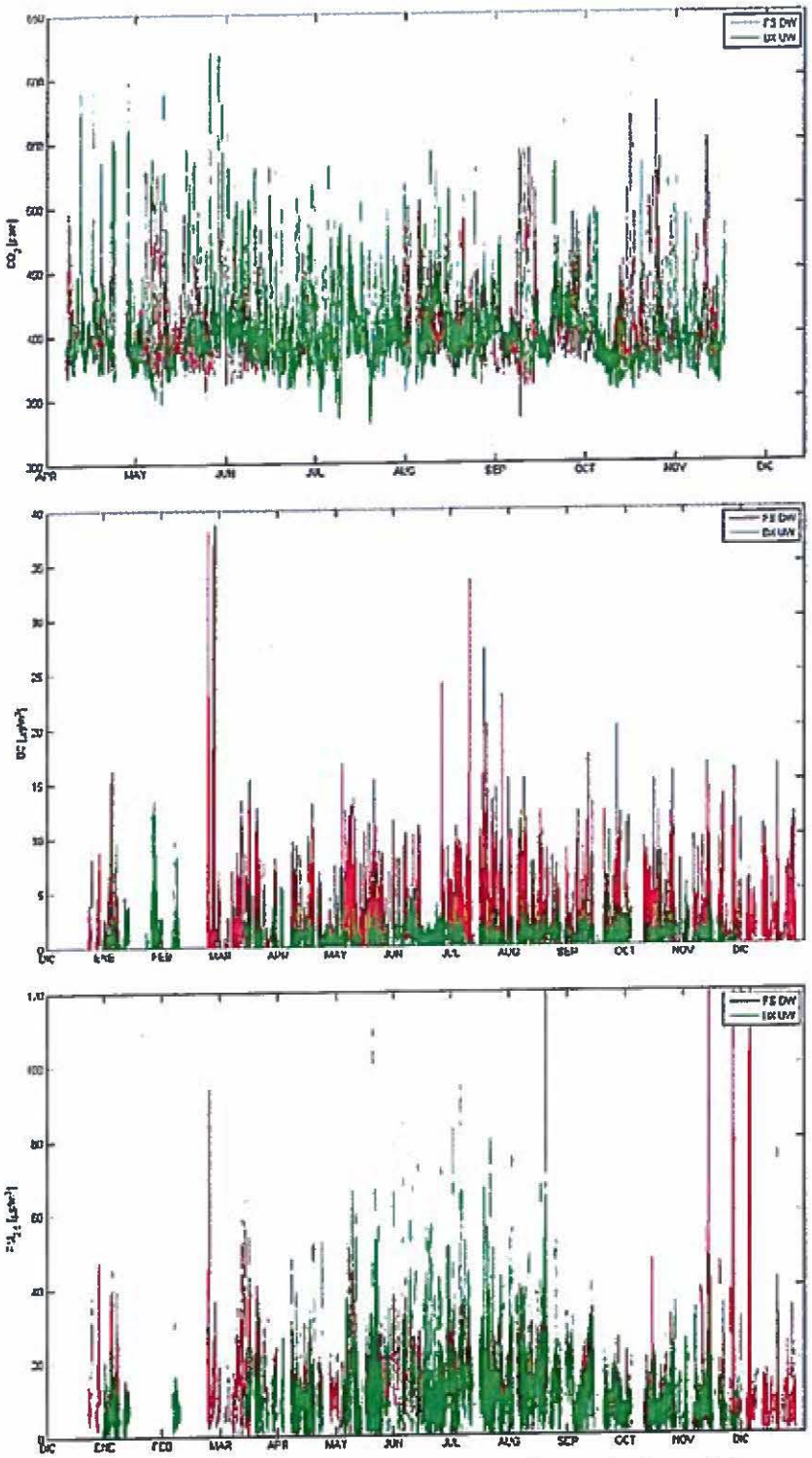

Figure A.1. CO_2, BC and $PM_{2.5}$ time series for FS downwind conditions.

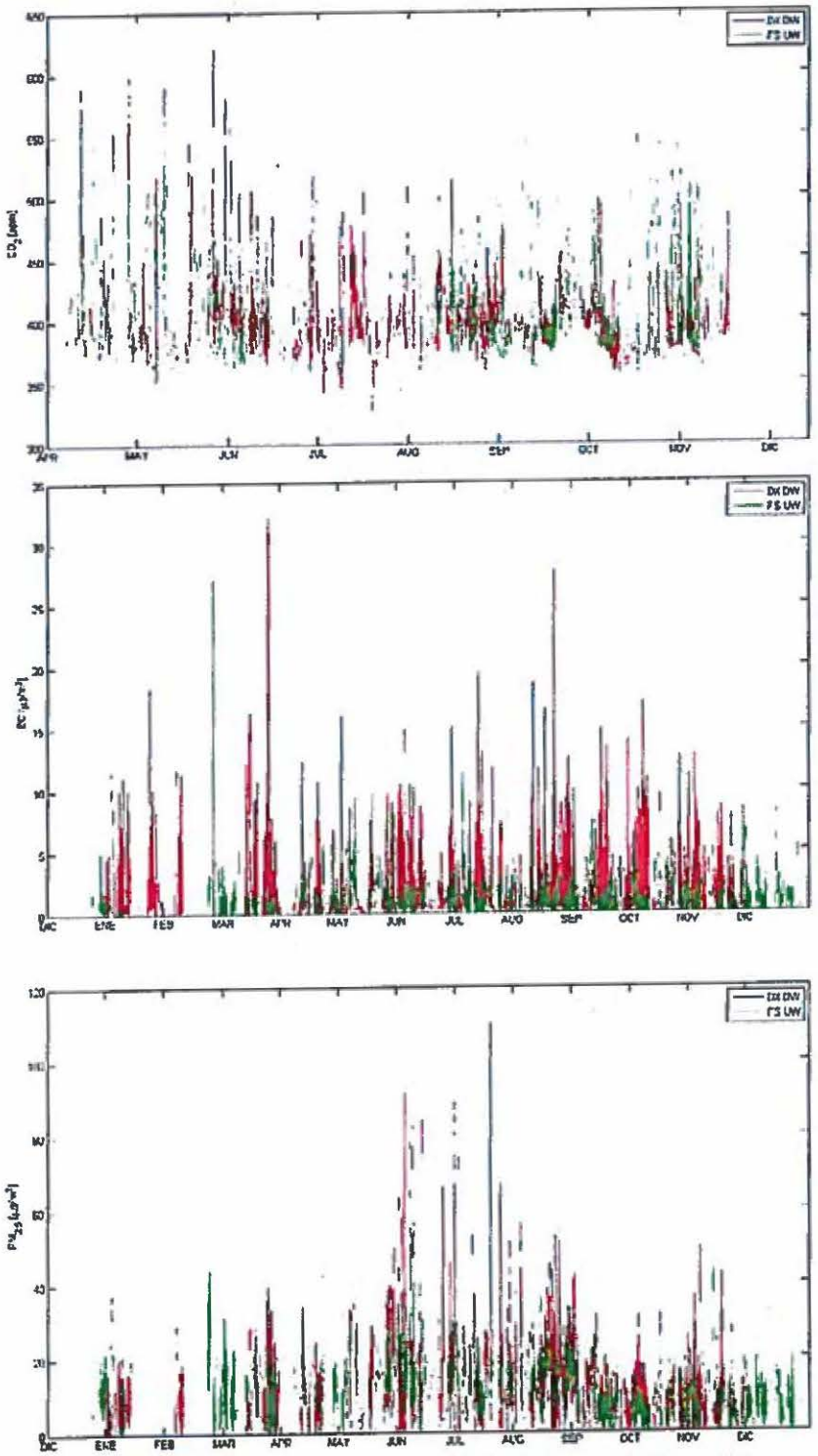

Figure A.2. CO_2, BC and $PM_{2.5}$ time series for DX downwind conditions.

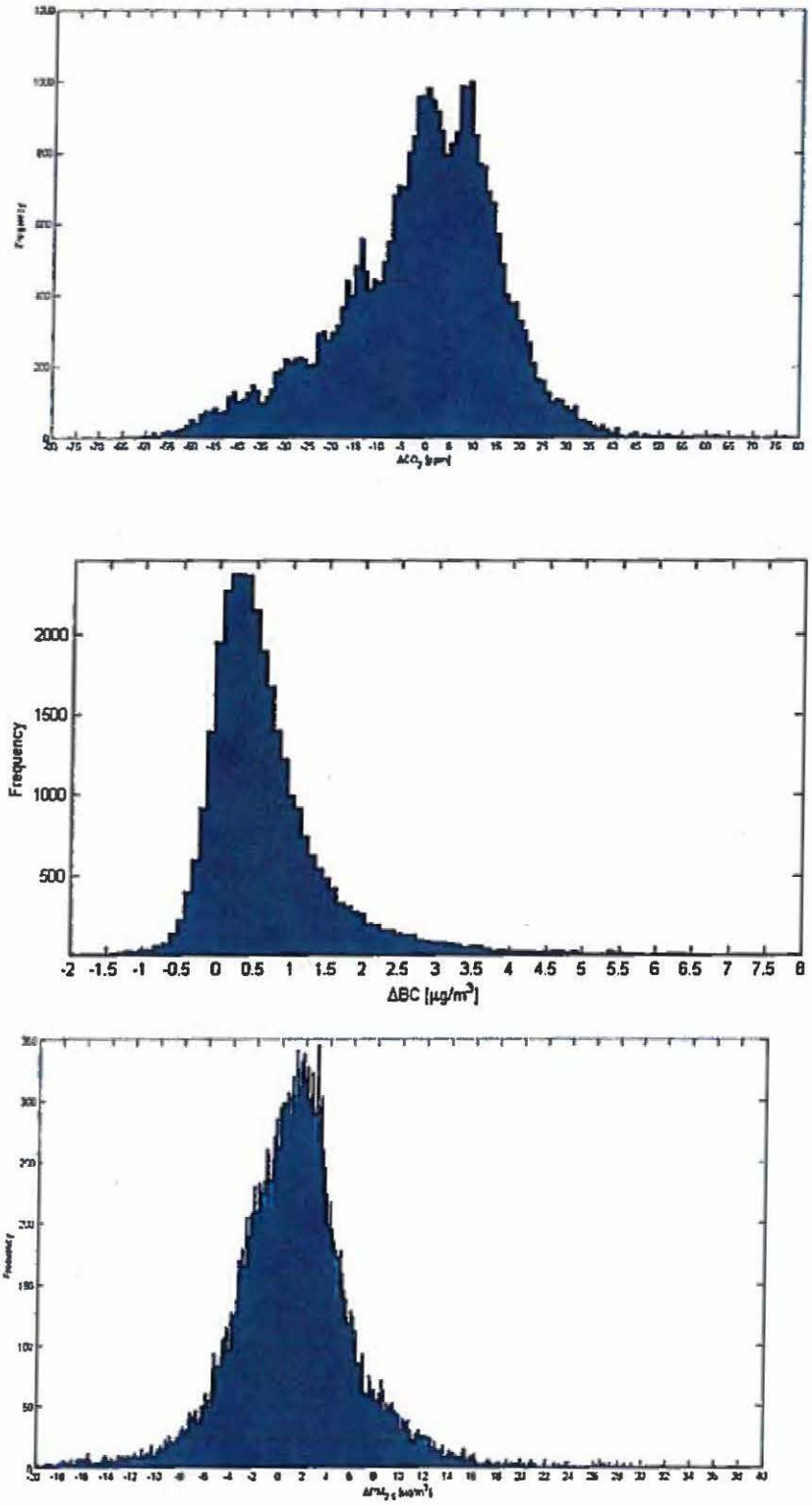

Figure A.3. Histograms of CO_2, BC and $PM_{2.5}$ for FS downwind conditions.

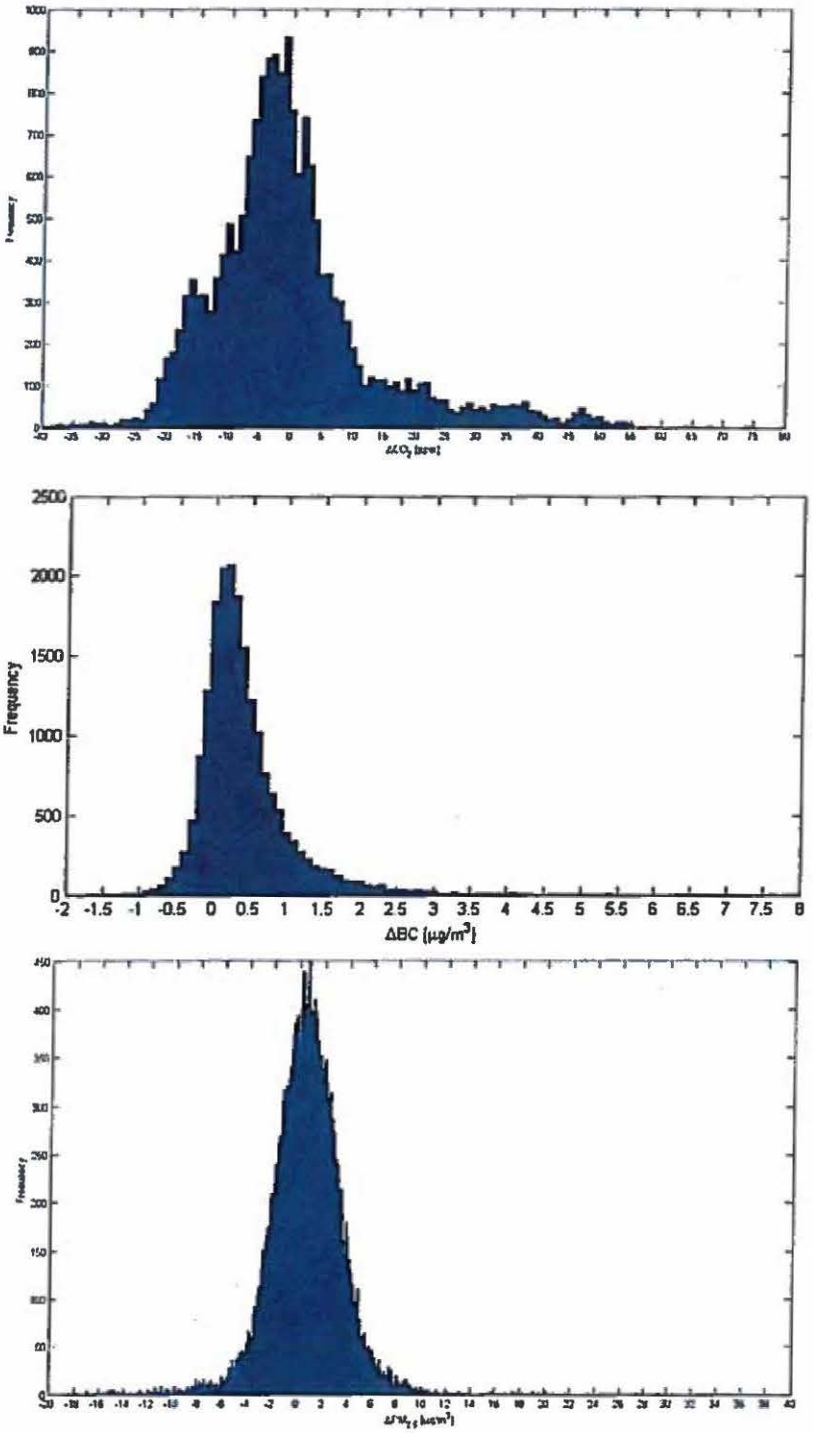

Figure A.4. Histograms of CO_2, BC and $PM_{2.5}$ for DX downwind conditions.

A.4. Boxplots of BC emission factors

To explore whether the FS spikes may be partly attributed to the near-field emissions along Marietta Blvd. we plotted the emission factors at both sites by the time of day and day of week at both sites, during conditions of wind from the rail yard area. Traffic on Marietta Blvd. during weekends and by night and early morning is scarce. The plots tell us that there is no significant difference between events detected at different times of the day or at different days of the week. Behavior of emission factors calculated does not appear to match peak hours or valleys of traffic, or to be different during the weekends.

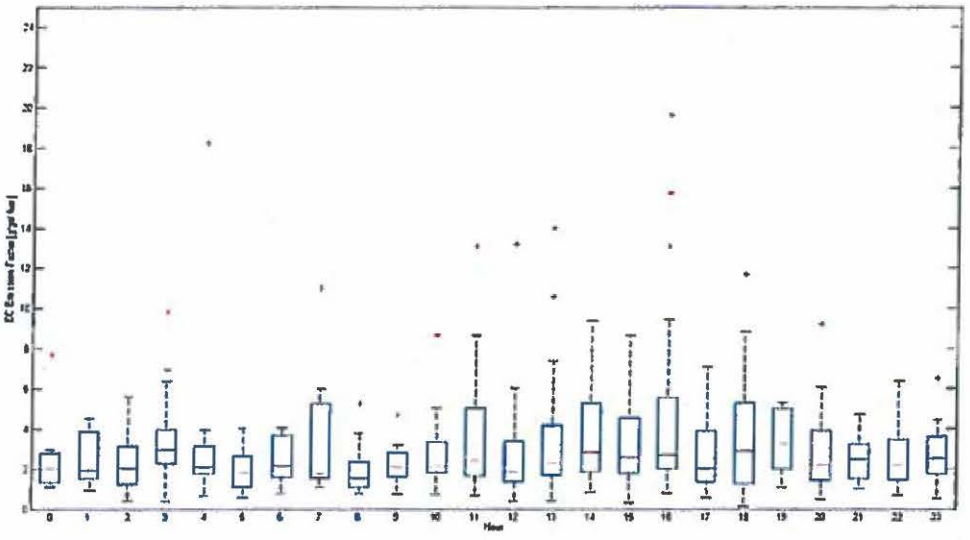

Figure A.5. Boxplot of BC emission factor by hour of the day at DX site.

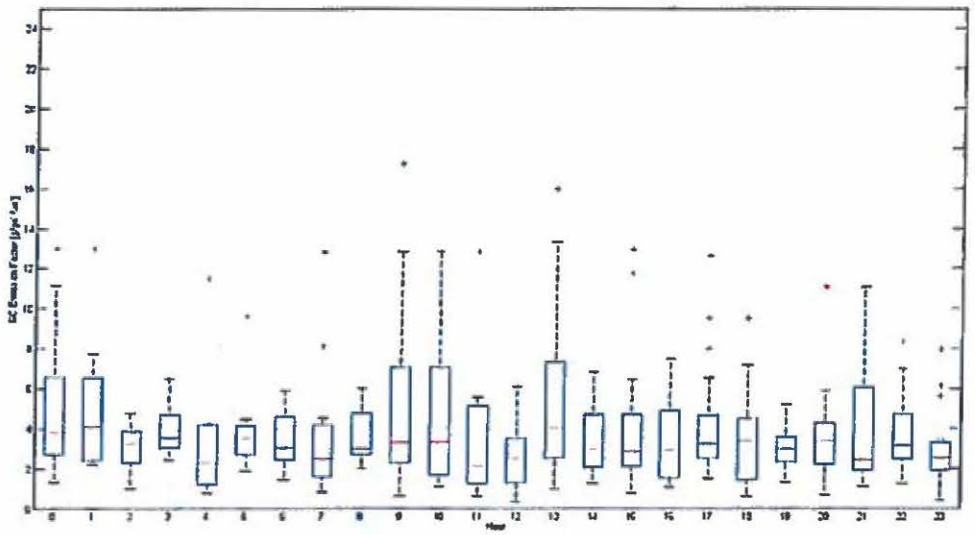

Figure A.6. Boxplot of BC emission factor by hour of the day at FS site.

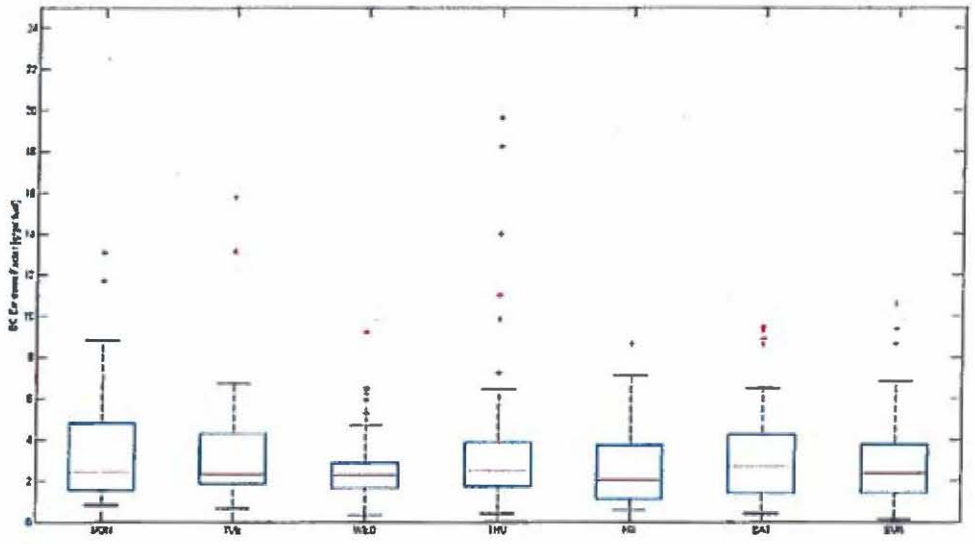

Figure A.7. Boxplot of BC emission factor by day of the week at DX site.

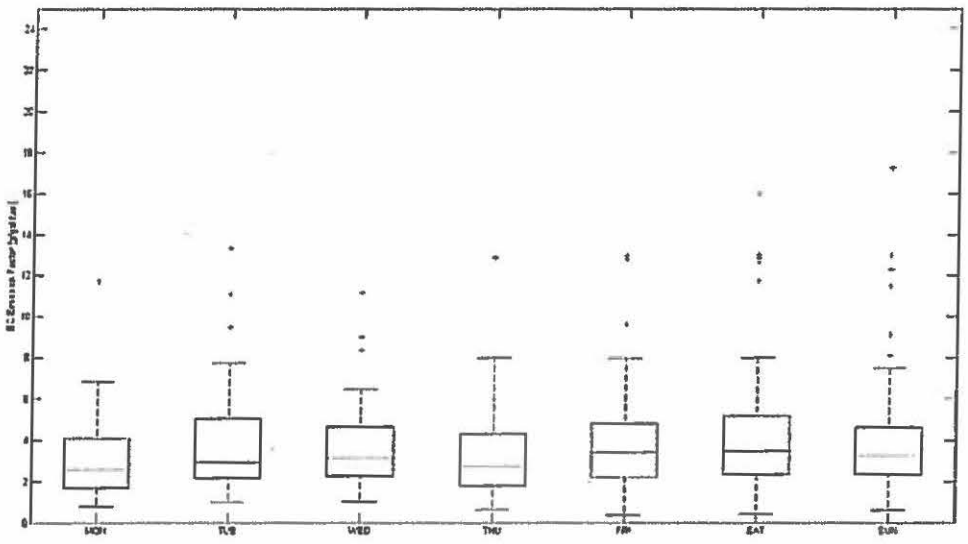

Figure A.8. Boxplot of BC emission factor by day of the week at FS site.

A.5. Emission factors results calculated when the wind was not blowing from the rail yards

The Delta method implies uncertainties. One way to check that the results obtained from this method are meaningful is to calculate emission factors when the wind was not blowing from the rail yards, between 110◦ and 170◦ for FS downwind, and 280◦ and 320◦ for DX downwind. Emission factors obtained this way are very small in comparison with the results when the wind blows from the rail yards.

Table A.2. Control Emission factors.

	Downwind Site	
	DX	FS
EF_{BC} [g of BC /gal fuel]	0.02±0.03	0.04±0.07
$EF_{PM_{2.5}}$ [g of $PM_{2.5}$ /gal fuel]	0.1±0.2	0.3±0.6

APPENDIX B

SUPPORTING INFORMATION FOR CHAPTER 3

B.1. Surface characteristics

Surface characteristics are used by AERMET in the computation of the fluxes and stability of the atmosphere. The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The Bowen ratio is the ratio of the sensible heat flux to the latent heat flux it is an indicator of surface moisture. The surface roughness length is the height at which the mean horizontal wind speed is zero. It relates to the height of obstacles to the wind flow.

Table B.1. Surface characteristics generated with AERSURFACE.

Season	Section	Albedo	Bowen Ratio	Surface Roughness (m)
Winter	0-30	0.17	1.09	0.093
	30-60	0.17	1.09	0.069
	60-90	0.17	1.09	0.050
	90-120	0.17	1.09	0.035
	120-150	0.17	1.09	0.047
	150-180	0.17	1.09	0.122
	180-210	0.17	1.09	0.145
	210-240	0.17	1.09	0.087
	240-270	0.17	1.09	0.037
	270-300	0.17	1.09	0.056
	300-330	0.17	1.09	0.082
	330-360	0.17	1.09	0.093
Spring	0-30	0.16	0.90	0.094
	30-60	0.16	0.90	0.074
	60-90	0.16	0.90	0.057
	90-120	0.16	0.90	0.042
	120-150	0.16	0.90	0.057
	150-180	0.16	0.90	0.139
	180-210	0.16	0.90	0.168
	210-240	0.16	0.90	0.102
	240-270	0.16	0.90	0.046
	270-300	0.16	0.90	0.062
	300-330	0.16	0.90	0.086
	330-360	0.16	0.90	0.094
Summer	0-30	0.16	0.70	0.095
	30-60	0.16	0.70	0.078
	60-90	0.16	0.70	0.062
	90-120	0.16	0.70	0.048
	120-150	0.16	0.70	0.066
	150-180	0.16	0.70	0.151
	180-210	0.16	0.70	0.185
	210-240	0.16	0.70	0.114
	240-270	0.16	0.70	0.052
	270-300	0.16	0.70	0.067
	300-330	0.16	0.70	0.088
	330-360	0.16	0.70	0.095
Fall	0-30	0.16	1.08	0.094
	30-60	0.16	1.08	0.074
	60-90	0.16	1.08	0.057
	90-120	0.16	1.08	0.042
	120-150	0.16	1.08	0.038
	150-180	0.16	1.08	0.141
	180-210	0.16	1.08	0.175
	210-240	0.16	1.08	0.103
	240-270	0.16	1.08	0.046
	270-300	0.16	1.08	0.062
	300-330	0.16	1.08	0.086
	330-360	0.16	1.08	0.094

B.2. Modeling parameters for non-road and on-road mobile sources

AERMOD algorithms need the following parameters for the mobile sources modeled in this work: The source ID is the identification of the source, the source type, the location in the domain X and Y in meters and Z in meters above mean sea level, the release height (center of volume) above ground in meters, Sigma Y0 the initial lateral dimension of the volume in meters, and Sigma Z0 the initial vertical dimension of the volume in meters. These parameters were determined using EPA (1995) and GAEPD (2012). Switching and line-haul activities were defined to occupy the same location, and have the same source parameters, but emissions rates for each are different.

Table B.2. Modeling parameters for non-road and on-road mobile sources.

Rail yard line-haul							
Source ID	Source Type	X (m)	Y (m)	Z (MAMSL)	Height (m)	Sigma Y0 (m)	Sigma Z0 (m)
HINMNA	VOLUME	735660	3743145	274	4.6	115.11	1.7
HINMNB	VOLUME	736580	3742440	278	4.6	97.29	1.7
HTLFDA	VOLUME	735635	3743825	264	4.6	80.56	1.7
HTLFDB	VOLUME	736720	3742972	275	4.6	44.12	1.7
Rail yard switchers							
Source ID	Source Type	X (m)	Y (m)	Altitude (MAMSL)	Height (m)	Sigma Y0 (m)	Sigma Z0 (m)
SINMNA	VOLUME	735660	3743145	274	4.6	115.11	1.7
SINMNB	VOLUME	736580	3742440	278	4.6	97.29	1.7
STLFDA	VOLUME	735635	3743825	264	4.6	80.56	1.7
STLFDB	VOLUME	736720	3742972	275	4.6	44.12	1.7

Table B.2. (continued). Modeling parameters for non-road and on-road mobile sources.

Other mobile non-road and on-road sources							
Source ID	Source Type	X (m)	Y (m)	Altitude (MAMSL)	Height (m)	Sigma Y0 (m)	Sigma Z0 (m)
HOWELLS	VOLUME	738850	3742690	278	4.6	115.11	1.7
BOLTON1	VOLUME	733940	3744220	272	2.44	16.48	1.7
BOLTON2	VOLUME	734586	3744670	263	2.44	16.48	1.7
BOLTON3	VOLUME	735200	3745210	235	2.44	15.85	1.7
MRTRD1	VOLUME	735390	3744400	251	2.44	21.97	1.7
MRTRD2	VOLUME	736560	3743400	285	2.44	21.97	1.7
MRTRD3	VOLUME	737220	3742200	277	2.44	21.97	1.7
MRTBLV01	VOLUME	736165	3744868	254	2.44	30.81	1.7
MRTBLV02	VOLUME	736921	3744475	267	2.44	28.13	1.7
MRTBLV03	VOLUME	737053	3744202	257	2.44	28.13	1.7
MRTBLV04	VOLUME	737096	3743996	254	2.44	17.79	1.7
MRTBLV05	VOLUME	737124	3743884	251	2.44	17.79	1.7
MRTBLV06	VOLUME	737154	3743766	253	2.44	17.79	1.7
MRTBLV07	VOLUME	737190	3743647	255	2.44	17.79	1.7
MRTBLV08	VOLUME	737225	3743530	256	2.44	17.79	1.7
MRTBLV09	VOLUME	737255	3743446	257	2.44	11.48	1.7
MRTBLV10	VOLUME	737266	3743400	259	2.44	11.48	1.7
MRTBLV11	VOLUME	737277	3743355	260	2.44	11.48	1.7
MRTBLV12	VOLUME	737294	3743306	261	2.44	11.48	1.7
MRTBLV13	VOLUME	737312	3743257	262	2.44	11.48	1.7
MRTBLV14	VOLUME	737325	3743210	265	2.44	11.48	1.7
MRTBLV15	VOLUME	737341	3743165	265	2.44	11.48	1.7
MRTBLV16	VOLUME	737358	3743118	265	2.44	11.48	1.7
MRTBLV17	VOLUME	737375	3743071	265	2.44	11.48	1.7
MRTBLV18	VOLUME	737398	3743025	265	2.44	11.48	1.7
MRTBLV19	VOLUME	737421	3742980	266	2.44	11.48	1.7
MRTBLV20	VOLUME	737462	3742904	267	2.44	17.79	1.7
MRTBLV21	VOLUME	737521	3742796	267	2.44	17.79	1.7
MRTBLV22	VOLUME	737580	3742688	266	2.44	17.79	1.7
MRTBLV23	VOLUME	737638	3742581	265	2.44	17.79	1.7
MRTBLV24	VOLUME	737693	3742474	266	2.44	17.79	1.7
MRTBLV25	VOLUME	737793	3742292	271	2.44	28.13	1.7
MRTBLV26	VOLUME	737932	3742027	278	2.44	28.13	1.7
MRTBLV27	VOLUME	738073	3741150	283	2.44	32.35	1.7

B.3.Modeling parameters for industrial sources

AERMOD algorithms need the following parameters for the point sources defined in this work: The source ID is the identification of the source, the source type, the location in the domain X and Y in meters and Z in meters above mean sea level, the stack height which is the release height above ground in meters, the stack gas exit temperature in Kelvin, the stack gas exit velocity in m/s, and the stack inside diameter in meters. Ennis plant was defined as a volume source following the above description for that type of source.

Table B.3. Modeling parameters for industrial sources.

Point sources

Source ID	Source Type	X (m)	Y (m)	Z (MAMSL)	Stack Height (m)	Stack Temperature (K)	Stack exit velocity (m/s)	Stack Diameter (m)
GAPOWER	POINT	733900	3745661	240	254.8	405.4	20.27	7.9
LAFARGE	POINT	734534	3745561	240	13.4	389.8	20.98	0.7
SHBRICK	POINT	732475	3743547	233.5	20.1	586	13.1	1.98
SUTTON	POINT	735080	3746126	238	17.7	302	8.99	0.55
RMCLYTN	POINT	735565	3745276	242	9.76	302.6	18.29	0.4
MEADPKG	POINT	738760	3741287	290	44.2	312.6	7.01	1.06
CMETAL1	POINT	739930	3740537	300	16.8	298.15	15.02	1.37
CMETAL2	POINT	739930	3740537	300	16.5	298.15	35.22	0.91
CMETAL3	POINT	739930	3740537	300	9.76	1283.15	7.6	0.61

Volume sources

Source ID	Source Type	X (m)	Y (m)	Z (m)	Height (m)	Sigma Y0 (m)	Sigma Z0 (m)
ENNISPT	VOLUME	737418	3743629	257	6	16.44	2.78

B.4. Emissions from rail yards

Emission factors correspond to previous works (Galvis et al., 2013; Georgia-EPD 2009; EPA 2010; Honc et al. 2006) and also where obtained from personal communication with Michelle Bergin. Class I railroad operations of Norfolk Southern (NS) which operates Inman and CSX Transportation (CSXT) which operates Tilford were split into two categories: line-haul and switching activity. Line-haul emissions were estimated using data from the surface transportation board R-1 annual reports (NS, 2012; CSXT, 2012). Switcher emissions were obtained from GAEPD (2012b). There are 17 switchers in Inman, 10 in Tilford, and 1 in Howells yard. Emissions rates must be converted to g/s for use in AERMOD.

Table B.4. Emissions from rail yards.

Emission factors R_{EF}	Units	TILFORD	INMAN
BC	g/gal	2.4	3.1
$PM_{2.5}$	g/gal	4.8	7.2
BC and $PM_{2.5}$ after GenSet retrofit	g/gal	0.8	0.8
BC and $PM_{2.5}$ after conversion to Mother-slug sets	g/gal	2.9	1.6

	Units	TILFORD	INMAN
R-1 schedule 750 line 1 system diesel oil consumption	[gal/year]	4.51E+08	4.40E+08
R-1schedule 755 line 104 system-wide gross ton miles	[GTM]	4.56E+11	3.92E+11
System-wide fuel combustion efficiency η	[GTM /gal/year]	1.01E+03	8.91E+02
County-level GTM from NS and CSX reports to GA-EPD Fulton Cobb	[GTM]	 2.71E+09 2.44E+09	 1.74E+09 1.87E+09
County level track miles (T_C) Fulton Cobb	[miles]	 67 37	 23 17
Domain Level Track miles (T_D) Fulton Cobb	[miles]	 14.0 3.4	 14.2 2.3
Gross ton miles transported in the modeling domain (G_D) Fulton Cobb	[GTM]	 5.66E+08 2.21E+08	 1.08E+09 2.64E+08
Line-Haul Domain-level Fuel consumption ( ) Fulton Cobb Total	[gal/year]	 5.60E+05 2.19E+05 7.79E+05	 1.21E+06 2.97E+05 1.51E+06

Table B.4.(Continued). Emissions from rail yards.

Line-haul rail yard emissions		Units	TILFORD	INMAN
Switchers fuel use in the domain		[gal/year]	6.00E+05	1.01E+06
Switchers fuel use in the domain	after GenSet retrofit	[gal/year]	4.50E+05	4.89E+05
Switchers fuel use in the domain mother-slugs sets	after conversion to	[gal/year]	4.75E+05	5.59E+05

Line-haul rail yard emissions	Units	TILFORD	INMAN
BC	[t/year]	1.9	4.7
$PM_{2.5}$		3.7	10.9
Switchers rail yard emissions	Units	TILFORD	INMAN
BC	[t/year]	1.4	3.1
$PM_{2.5}$		2.9	7.2
Switchers rail yard emissions after upgrades	Units	TILFORD	INMAN
GenSet BC and $PM_{2.5}$	[t/year]	0.3	0.4
Mother-slug sets BC and $PM_{2.5}$		1.4	0.9

BC emissions	**Inman A [g/s]**	**Inman B [g/s]**	**Tilford A [g/s]**	**Tilford B [g/s]**	**Howells [g/s]**
Line-Haul	0.0741	0.0741	0.0395	0.0198	0.0021
Switchers	0.0495	0.0495	0.0304	0.0152	0.0016
Switchers after GenSet retrofit	0.0059	0.0059	0.0072	0.0036	0.0004
Switchers after conversion to mother-slug sets	0.0145	0.0145	0.0290	0.0145	0.0015
$PM_{2.5}$ emissions	**Inman A [g/s]**	**Inman B [g/s]**	**Tilford A [g/s]**	**Tilford B [g/s]**	**Howells [g/s]**
Line-Haul	0.1722	0.1722	0.0790	0.0395	0.0041
Switchers	0.1150	0.1150	0.0609	0.0304	0.0032
Switchers after GenSet retrofit	0.0059	0.0059	0.0072	0.0036	0.0004
Switchers after conversion to mother-slug sets	0.0145	0.0145	0.0290	0.0145	0.0015

B.5. Emissions from on-road mobile sources.

Table B.5. Emissions from on-road mobile sources.

Road	$PM_{2.5}$ [t/year]	BC [t/year]
Bolton 1 (between James Jackson Parkway and Hollywood Road)	0.11	0.03
Bolton 2 (between Hollywood Road and Marietta Road)	0.12	0.03
Bolton 3 (between Marietta Road and Marietta Boulevard)	0.07	0.02
Marietta Boulevard	1.23	0.36
Marietta Road	0.36	0.10

Table B.5. (continued). Emissions from on-road mobile sources.

Road Segment	$PM_{2.5}$ [g/s]	BC [g/s]
BOLTON1	0.00337	0.00097
BOLTON2	0.00368	0.00106
BOLTON3	0.00221	0.00064
MRTRD1	0.00384	0.00109
MRTRD2	0.00384	0.00109
MRTRD3	0.00384	0.00109
MRTBLV01	0.00939	0.00277
MRTBLV02	0.00196	0.00058
MRTBLV03	0.00196	0.00058
MRTBLV04	0.00078	0.00023
MRTBLV05	0.00078	0.00023
MRTBLV06	0.00078	0.00023
MRTBLV07	0.00078	0.00023
MRTBLV08	0.00078	0.00023
MRTBLV09	0.00033	0.00010
MRTBLV10	0.00033	0.00010
MRTBLV11	0.00033	0.00010

Road Segment	$PM_{2.5}$ [g/s]	BC [g/s]
MRTBLV12	0.00033	0.00010
MRTBLV13	0.00033	0.00010
MRTBLV14	0.00033	0.00010
MRTBLV15	0.00033	0.00010
MRTBLV16	0.00033	0.00010
MRTBLV17	0.00033	0.00010
MRTBLV18	0.00033	0.00010
MRTBLV19	0.00033	0.00010
MRTBLV20	0.00078	0.00023
MRTBLV21	0.00078	0.00023
MRTBLV22	0.00078	0.00023
MRTBLV23	0.00078	0.00023
MRTBLV24	0.00078	0.00023
MRTBLV25	0.00196	0.00058
MRTBLV26	0.00196	0.00058
MRTBLV27	0.01036	0.00305

B.6. Emissions from industrial sources.

Table B.6. Emissions from industrial sources.

Facility Name	AIRS No.	Latitude	Longitude	$PM_{2.5}$ [t/year]	BC [t/year]
Georgia Power Company McDonough/Atkinson Plant	06700003	33.820865	-84.484080	132.4	50.3
General Shale Brick Inc. Plant	12100004	33.808896	-84.486768	40.8	0.8
Lafarge Building Materials, Inc.	12100401	33.821937	-84.471987	24.9	0.5
Cobb County R L. Sutton water reclamation facility	06700018	33.829254	-84.459795	36.6	0.7
Central Metals Co.	12100033	33.777804	-84.408952	9.5	0.2
Mead Packaging Co	12100070	33.784353	-84.422530	19.1	0.4
Atlanta R M. Clayton water reclamation facility	12100268	33.821438	-84.456540	2.4	0.05
Ennis Paint, Inc	12100617	33.805794	-84.436891	3.6	0.07

B.7. Concentration-response functions.

Table B7. Concentration-response functions.

Health endpoint | Age group	Author	Function
Mortality, All Cause | 30-99	Krewski et al.	(1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Mortality, All Cause | 25-99	Lepeule et al.	(1-EXP(-Beta*DELTAQ))*Incidence*POP
Mortality, All Cause | infants	Woodruff et al.	(1-(1/(((1-Incidence)*EXP(Beta*DeltaQ)+Incidence)))*Incidence*POP
Emergency Room Visits, Asthma | 0-99	Mar et al.	(1-EXP(-Beta*DELTAQ))*Incidence*POP
HA, All Respiratory |65-99	Zanobetti et al	(1-EXP(-Beta*DELTAQ))*Incidence*POP
HA, Asthma |0-17	Sheppard	(1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
HA, Chronic Lung Disease | 18-94	Moolgavkar	(1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
HA, All Cardiovascular (less Myocardial Infarctions) | 65-99	Zanobetti et al	(1-EXP(-Beta*DELTAQ))*Incidence*POP
HA, All Cardiovascular (less Myocardial Infarctions) | 18-64	Moolgavkar	(1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Work Loss Days | 18-64	Ostro	(1-(1/EXP(Beta*DELTAQ)))*Incidence*POP
Minor Restricted Activity Days | 18-64	Ostro and Rothschild	(1-(1/EXP(Beta*DELTAQ)))*A*POP
Acute Bronchitis | 8-12	Dockery et al.	(1-(1/(((1-Incidence)*EXP(Beta*DeltaQ)+Incidence)))*Incidence*POP
Lower Respiratory Symptoms | 7-14	Schwartz and Neas	(1-(1/((1-A)*EXP(Beta*DeltaQ)+A)))*A*POP
Upper Respiratory Symptoms | 9-11	Pope et al.	(1-(1/((1-A)*EXP(Beta*DeltaQ)+A)))*A*POP*Prevalence
Asthma Exacerbation, Cough | 6-18	Mar et al.	(A - (A/((1-A)*exp(Beta*DELTAQ)+A)))*POP*Prevalence
Asthma Exacerbation, Shortness of Breath | 6-18	Mar et al.	(A - (A/((1-A)*exp(Beta*DELTAQ)+A)))*POP*Prevalence
Asthma Exacerbation, Wheeze | 6-18	Ostro et al.	(1-(1/((1-A)*EXP(Beta*DeltaQ)+A)))*A*POP*Prevalence

B.8. Concentration-response functions.

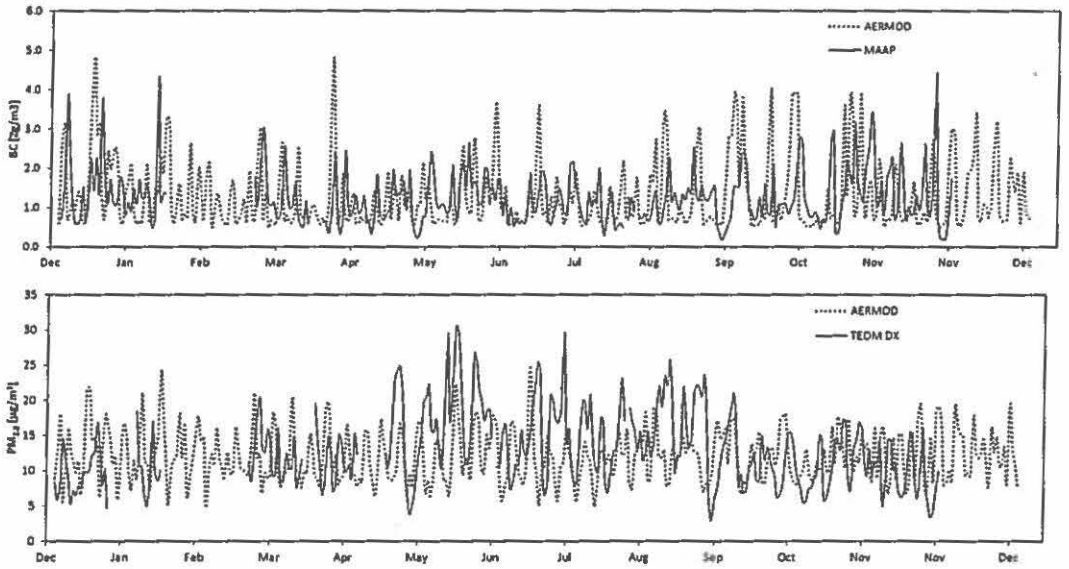

Figure B.1. Simulated and measured daily averages of BC and $PM_{2.5}$ at DX.

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APPENDIX C

DATABASE OF MEASUREMENTS

A data base with measurements for $PM_{2.5}$, BC, CO_2 wind speed and direction and tables with metals, EC/OC and Ions filter based measurements is contained in digital format as Appendix C. There are data base tables for each of the pollutants continuous measurements at each of the two monitoring sites. Two instruments were used to measure BC at fire station 8 sites, an Aethalometer and a multi-angle absorption photometer. An access table is provided for the measurements of each of these instruments. Data is marked with time stamps, formatted month day year hour: minute (mm-dd-yyy hh:mm).

VITA

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BORIS GALVIS was born in San Gil, Santander, Colombia. He received a B.S. in Chemical Engineering from the Industrial University of Santander, Bucaramanga, Colombia in 1998. He worked for several environmental government agencies in Colombia. He was married in 2001 to Luz Dary Carreño. He obtained a M.S. in Environmental Engineering from University of the Andes, Bogota, Colombia in 2006. He joined Environmental Engineering faculty at Universidad de La Salle in Bogota in 2006. In 2008, he decided to pursue a doctorate in Environmental Engineering with full support of his wife. The Colombian Institute for the Development of Science and Technology awarded him a fellowship to aid him in this endeavor. He came to Georgia Tech pursuing a Doctorate and also obtained a M.S. in Environmental Engineering, in 2010. Boris enjoys very much using environmental monitoring instruments and tinkering with them. He also likes to ride his bike and to take road trips with his family to small towns, beaches, natural parks and museums. He enjoys dancing with his wife, reading to his daughter and going to the movies with his son.