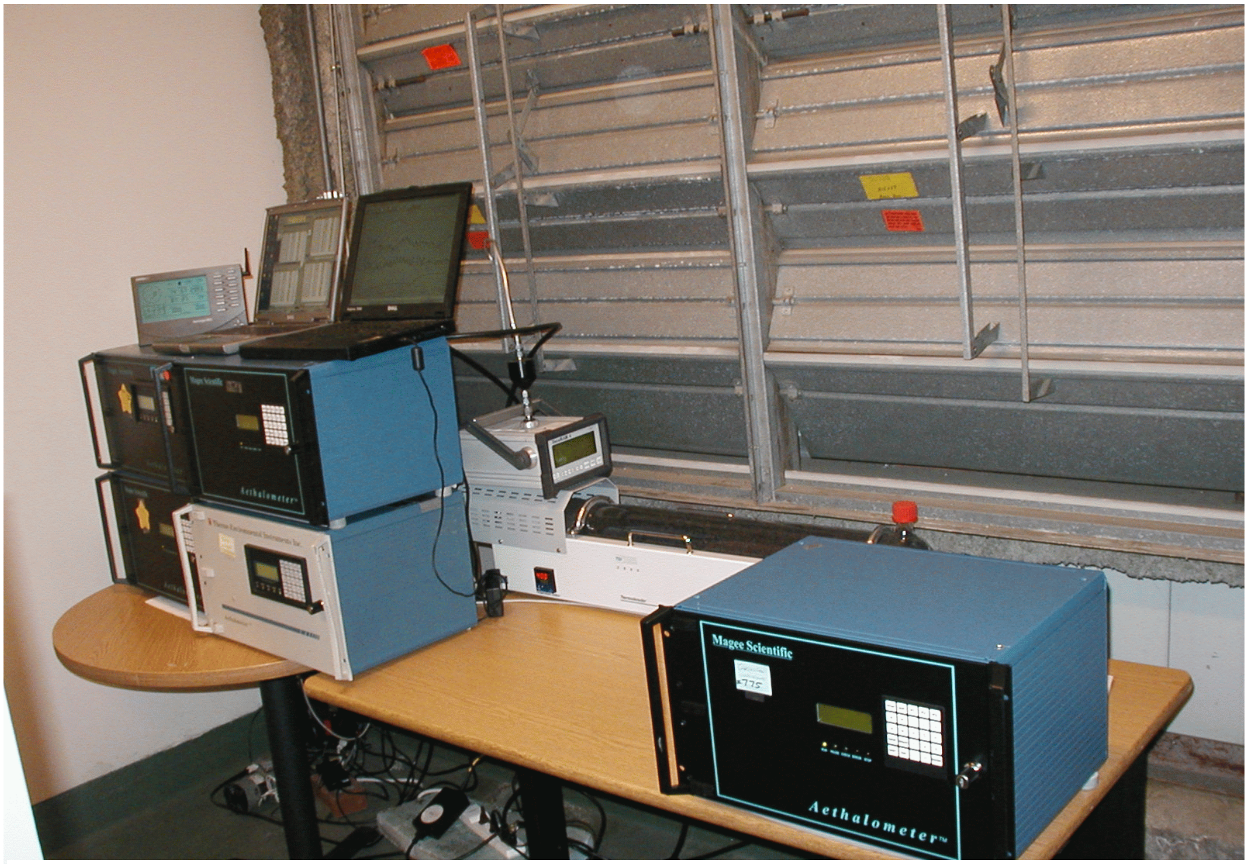
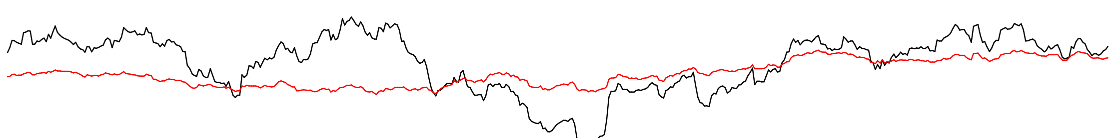
Evaluation of the Aethalometer™ BC Spot Matrix Effect





Prepared for:
Massachusetts Dept. of Environmental Protection
Bureau of Waste Prevention

by:
NESCAUM
December 12, 2007

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Project Contributors:

George Allen, NESCAUM
Paul Miller, NESCAUM
Jay Turner, Washington University in St. Louis

Acknowledgments

NESCAUM gratefully acknowledges the funding support provided by Mass. DEP, BWP.

This report was developed by staff at NESCAUM. NESCAUM is an association of the eight Northeast state air pollution control programs. NESCAUM provides technical guidance and policy advice to its member states.

NESCAUM also thanks the following individuals for contributing to this effort:

Christina Gilbert, NESCAUM intern, for assistance with measurement operations.
Tony Hansen, Magee Scientific, for loan of equipment.
Pat Arnott, DRI, for his 2002 Reno Aerosol Optical Study work describing the problem.
Aki Virkkula, Finnish Meteorological Institute, for his demonstration of the correction approach.

TABLE OF CONTENTS

Executive Summary

An Aethalometer™ can provide excellent aerosol monitoring information for evaluating urban mobile source activity as well as biomass combustion, and is a core component of the National Air Toxics Trends Site (NATTS) program. Recent research, however, has shown that the method has a substantial artifact ("filter spot matrix effect") that can affect most data analysis approaches. This project was undertaken by NESCAUM as part of an effort to assist decision makers in better understanding the importance of data quality issues with Aethalometer black carbon (BC) and Delta-C ("DC", the difference between UV-Carbon and BC) optical absorption data collected as part of the U.S. EPA NATTS program as well as through non-NATTS Aethalometer monitoring. Accurate measurement of both BC and DC are important from a health effect perspective. BC is a surrogate of elemental carbon and an indicator of mobile source particulate matter (PM), and DC is an indicator of biomass combustion (usually wood smoke).

Project Goals: 1) Empirically evaluate Aethalometer black carbon "filter spot matrix effect" data quality issues; 2) provide quantitative estimates of measurement bias and precision from this effect; 3) evaluate and inform data post-processing approaches to minimize the impact on BC and DC data quality from this method artifact; and 4) assess the difference between original and corrected BC and DC data at existing Mass. DEP monitoring sites.

Background: The Aethalometer reports BC concentrations by measuring the rate of change of red light transmission through a sample filter; the faster the filter gets dark from collected particles, the higher the BC concentrations are (UV-C is the same measurement but at a near-UV shorter wavelength). After a fixed threshold of filter spot "darkness" is reached, the filter tape automatically advances to a clean spot. Recent research has shown that the method has substantial BC and DC artifacts related to the amount and type of particles deposited on the Aethalometer filter. This artifact can be positive or negative, is both short term (hours to days) and long term (seasonal), and can be as large as a factor of two -- thus affecting most data analysis approaches. The artifact occurs because the Aethalometer method assumes a linear relationship between rate of change of light transmission and BC; in most cases this is not true.

Published literature presents data post-processing approaches that remove most of the bias and stabilize the instrument's response to BC. For this project, we perform a detailed empirical evaluation of the spot loading artifact and determine how well available data post-processing solutions perform. We use the results of this evaluation to improve the post-processing algorithm used in the Washington University (WUAQL) Aethalometer "Data Masher."

Approach: We investigated and quantified the effects of this artifact using summertime BC measurements collected in Boston, MA. Saturation (reduced response) from the "filter spot matrix effect" is usually masked with the mix of particles found in the northeast US during the summer. Under these conditions, BC can actually be over-estimated due to enhanced optical absorption from "white" particles (sulfate, organic carbon). In the winter in Boston (with darker particles), it has been shown that the saturation effect usually results in an under-measurement of BC and DC, as well as degraded hourly precision.

The winter saturation effect can be reproduced during the summer by removing much of the non-BC "white" particles from the sample stream using thermal-denuder techniques. The resulting sample should show the negative bias from filter spot saturation even during the summer.

We made several other related measurements to assess the extent of the observed artifact and the ability to correct for it. These measurements include several non denuded Aethalometers run in different spot loading configurations, and light scattering (nephelometry) measurements.

Data Analysis: Post-processing software to correct BC and DC data for the filter spot matrix effect determines the spot loading artifact for each filter spot interval by calculating the difference between the BC and UV-C just before the filter tape advance to the BC and UV-C after the advance. Any change in reported data from an old (loaded) to a new (clean) filter spot is (on average) a measure of the artifact. A custom version of this software was developed under this project for use with this experimental 1-minute dataset.

One year of existing Aethalometer BC data from the MA-DEP Roxbury NATTS and the North End and Springfield DEP sites was processed with this correction software and compared to the original uncorrected data to assess the nature and extent of this artifact on existing Mass. DEP Aethalometer data.

Results: The core effort of reproducing a more winter-like aerosol with the thermodenuder was successful; the calculated correction factor for the filter spot saturation effect was substantially larger for the thermodenuded Aethalometer. As expected, the correction factor decreased as sample scattering increased for the non-denuded Aethalometers. In addition, we were able to identify moisture as a primary cause of short-term (1 to 5 minute) noise in BC data. Finally, we developed and evaluated a working version of the Aethalometer "Data Masher" that incorporates saturation correction algorithms for 1-minute data. This software can also use the more standard 5 minute Aethalometer data format as input.

Using this software, we processed Aethalometer BC and UV-C data collected in Boston from the MA-DEP Roxbury NATTS site, and the North End and Springfield sites to quantify the saturation artifact. The Roxbury correction factor varied from significantly positive in the winter to slightly negative in the summer (during a period of high PM2.5, as expected). Since the Aethalometer at that site was a 2-channel instrument, the effective maximum attenuation value (the particle loading that causes a filter change) on the BC channel was usually in the 40's, a relatively low value. This resulted in only a modest under-estimate of BC for 2006, on the order of 12 percent (on an annual mean basis -- larger in the winter). There may have been other years when the Aethalometer at that site was run as a single channel instrument; this would result in a higher maximum attenuation value for BC and a larger seasonal bias in the BC (potentially up to 50 percent).

The other interesting aspect of the Roxbury and Springfield Aethalometer data was a large and persistent winter Delta C (biomass combustion indicator) signal after saturation correction. This has not been observed before at these sites (although it may have been present but smaller with uncorrected data, and missed by the data review process). North End Aethalometer data had a similar correction pattern to Roxbury but never went negative (the two time periods are not the same; the North End correction was for more recent data to overlap with the study period). The Delta-C biomass combustion indicator was not as strong for the North End site.

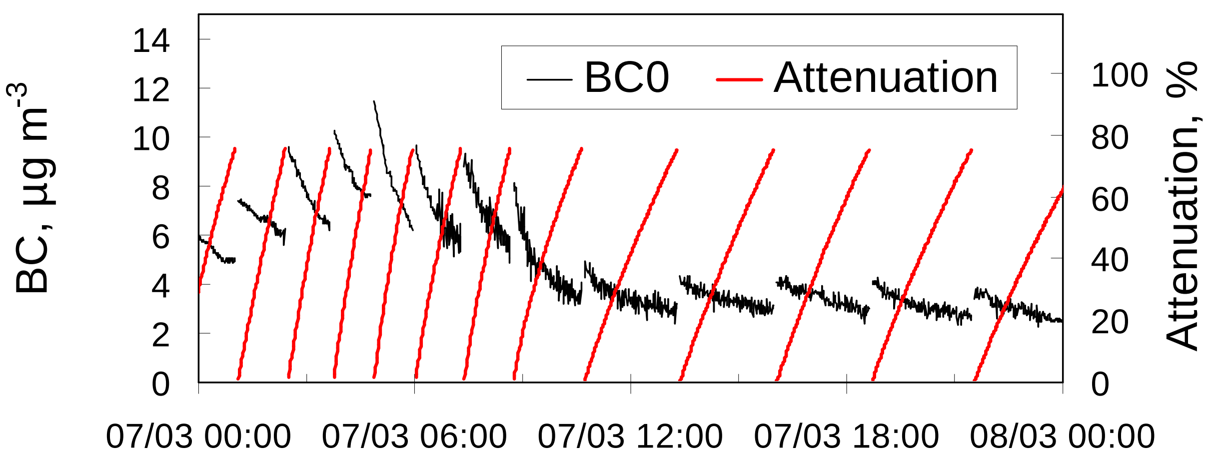
All data from the study, the enhanced version of the WUAQL "data masher" program, all references in this report, and additional background material are available on request or at: ftp://airbeat.org/private/Aeth-test-data/ . This site is accessible with a web browser, but is not available to the public.

1. INTRODUCTION

Measurement of Black Carbon Soot (BC) is made at NATTS sites using a Magee Scientific Aethalometer™ (www.mageesci.com), Berkeley CA. This a widely used method to monitor atmospheric BC using an optical technique that measures the light absorbed by particles accumulating on a quartz fiber tape over time. The Aethalometer has been available for over 15 years. It has historically been assumed by the manufacturer and users that the method reported BC concentrations that were independent of the amount of particles collected on the filter tape.

However, several recent articles have shown that reported BC often decreases with increased spot loading -- a saturation effect-- that is a function of the mix of particles on the filter (the "aerosol matrix"), and is strongest when the aerosol is dominated by soot (BC). Most of these reports have been laboratory or non-ambient air studies. Work done as part of the 2002 Reno Aerosol Optical Study helped clarify the saturation effect (Arnott et al. and other papers in Jan. 2005 Aerosol Sci. & Tech). More recently, Kirchstetter and Novakov (Atmos. Environ., 2007) quantified the effect parameters using laboratory generated soot. Turner et al. (AWMA-2007 San Francisco Methods Conference proceedings paper) outlines the background of current work based on their ambient BC data analysis in St. Louis. Virkkula et al. (JAWMA Oct. 2007) show a severe saturation effect on a subway sample dominated by diesel emissions (Figure 1), and show a similar but less severe effect on ambient air samples. They also demonstrate a simple method for ambient data correction. This and earlier work by Virkkula forms the basis of the correction approach used here.

Figure 1. Decrease of BC with filter spot loading with a sooty aerosol (Virkkula, 2007)



Boston winter BC samples also show this effect. Figure 2a and 2b below show examples of collocated Aethalometer BC data for summer (2a: 5-minute data from Dedham) and winter (2b: 1-hour data from Joy St. near the Massachusetts State House). The winter scatter plot (from a BC-only Aethalometer with max-attn of 125 -- a worst case) shows relatively poor correlation even though the data are 1-hour means and should be more stable than the summer 5-minute data; the correlation is degraded due to a severe winter spot saturation effect.

Figure 2a. Summer 5-min. Collocated BC

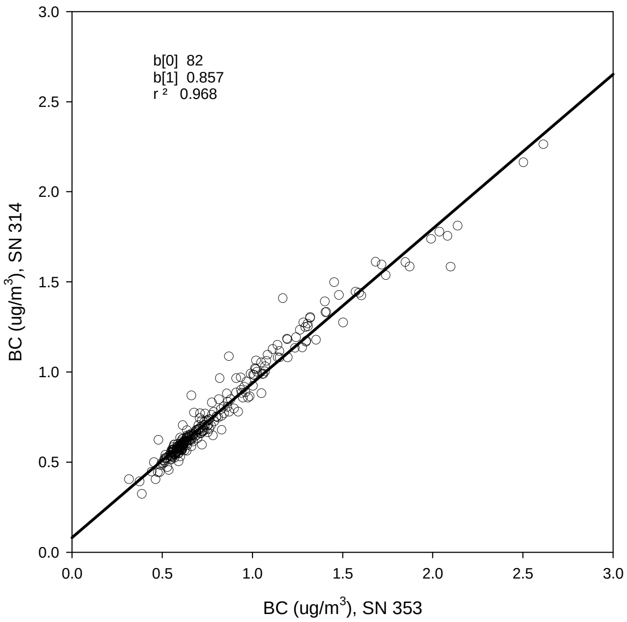
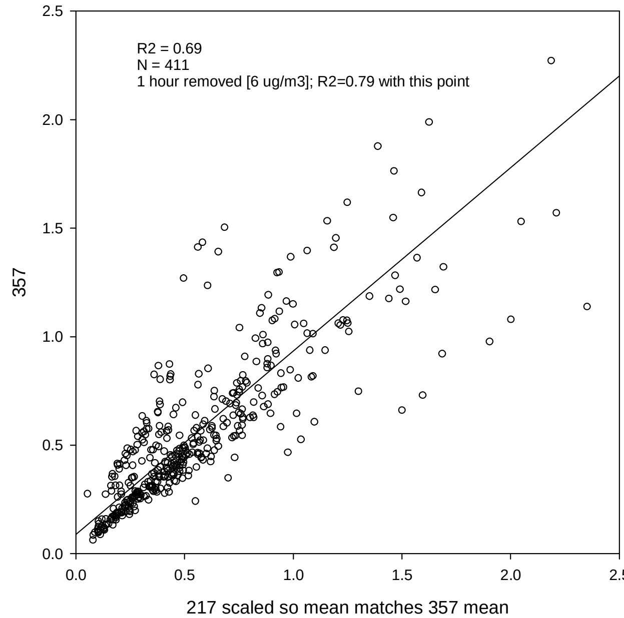


Figure 2b. Winter 1-hr. Collocated BC



This report is a preliminary examination of this effect with Boston MA ambient air during the summer using a range of Aethalometer operating conditions. These data are used to inform development and evaluation of correction algorithms in post-processing software (the WU-AQL "Data Masher").

A TSI [Topas] 3065 thermodenuder run at 400C and 2-LPM was used to remove a substantial fraction of the scattering aerosol on one Aethalometer. This makes the urban aerosol more "winter" like (less white scattering material relative to the BC). Although the TSI thermodenuder is known to have substantial limitations relative to a laboratory quality thermodenuder (Wehner et al., 2002), it performs well enough for the purposes of this study.

The spot loading effect is quantified for 4 other collocated instruments with different max-Attn settings (from 15 to 125). Data from the "max-Attn=15" instrument is not used in this analysis; there were many more spot changes but a much smaller pre/post spot change signal that proved to not work well with the correction algorithm. In theory with a winter urban aerosol, this instrument would serve as a minimally biased analyzer, but the difference in the summer turned out to be negligible.

Particle scattering (B-scat) collocated nephelometer measurements were also made using a Thermo model DR-4 run in scattering mode. The data from this instrument explains some of the trends in the BC artifact, since scattering is primarily an indication of “white” or light colored aerosol -- the kind that masks the BC saturation effect.

Data Correction Algorithm.

As noted above, a Virkkula-like data compensation method is used to correct the BC data. A new "K" value is developed for each spot change; this K adjusts the data in a way that forces data from the end of an old spot to match the data from the subsequent new spot data. The underlying assumption is that data from a spot with little or no loading is correct, and the data from a fully loaded spot is biased by the spot saturation effect. The correction is function of Attn for each data point as follows:

corrected BC= measured BC * (1+K*Attn)

K values typically range from about -0.002 to + 0.01. A positive K means corrected BC is higher than the reported BC; a negative K reduces reported BC (positive saturation effect). Some examples of how BC data are changed by different K values when the filter is fully loaded and the spot attn is 125 follow:

K of .004 and attn of 125 = BC * 1.5
K of .01 and attn of 125 = BC * 2.25
K of -.002 and attn of 125 = BC * 0.75

This correction method assumes there is no change in the real BC concentration over the interval of a spot change, which is generally not true in urban areas. For a single Aethalometer, this causes a single K value to be noisy. To create a more stable K, a centered running average of many K values (at least 20, usually 40) is used to correct the data. Since most urban Aethalometer installations change the tape spot once or twice a day, the BC correction dynamic is on the order of one to four weeks (longer than either sub-daily or regional-scale variations in aerosol composition). This correction approach is therefore unable to correct for errors on these shorter time-scales, but does improve the BC short-term precision and minimizes any seasonal or between site bias due to differences in aerosol composition. A complete description of this algorithm is in Virkkula et al. (JAWMA 2007).

Finally, the influence of changes in Aethalometer filter RH on BC noise with a clean filter is examined. There have been brief mentions in the literature of a potential for short-term RH interferences with methods similar to the Aethalometer (Arnott, GRL 2003). A limited amount of laboratory tests were performed for this project with multiple Aethalometers to assess this effect. A substantial RH effect was observed. This work and other observations regarding the source of short-term noise in BC data indicate that changes in RH (or ambient dew point) on the time-scale of a few to several minutes may be the dominant source of noise in current generation Aethalometers. This effect is a concern for this project, since short-term noise degrades the BC correction process. Because of this, one-minute ambient dew point and room temperature were measured as part of this project; these data were not used in the data analysis presented here.

2. MEASUREMENT METHODS

For this project, five Aethalometers were run collocated in Boston, MA from June 11 to the end of October, 2007 (some preliminary instrument testing was done in May). The core study period ended Sept. 21, 2007; data collected after that were for diagnostic purposes (determining between instrument bias, etc). The monitoring site was on the 11th floor of 101 Merrimac St., approximately 130 feet above street level. This location is approximately 0.5 km west of the MA-DEP North End monitoring site (PM2.5 and BC).

All Aethalometers were run on a 1-min timebase, with a single channel configuration (BC only) as follows:

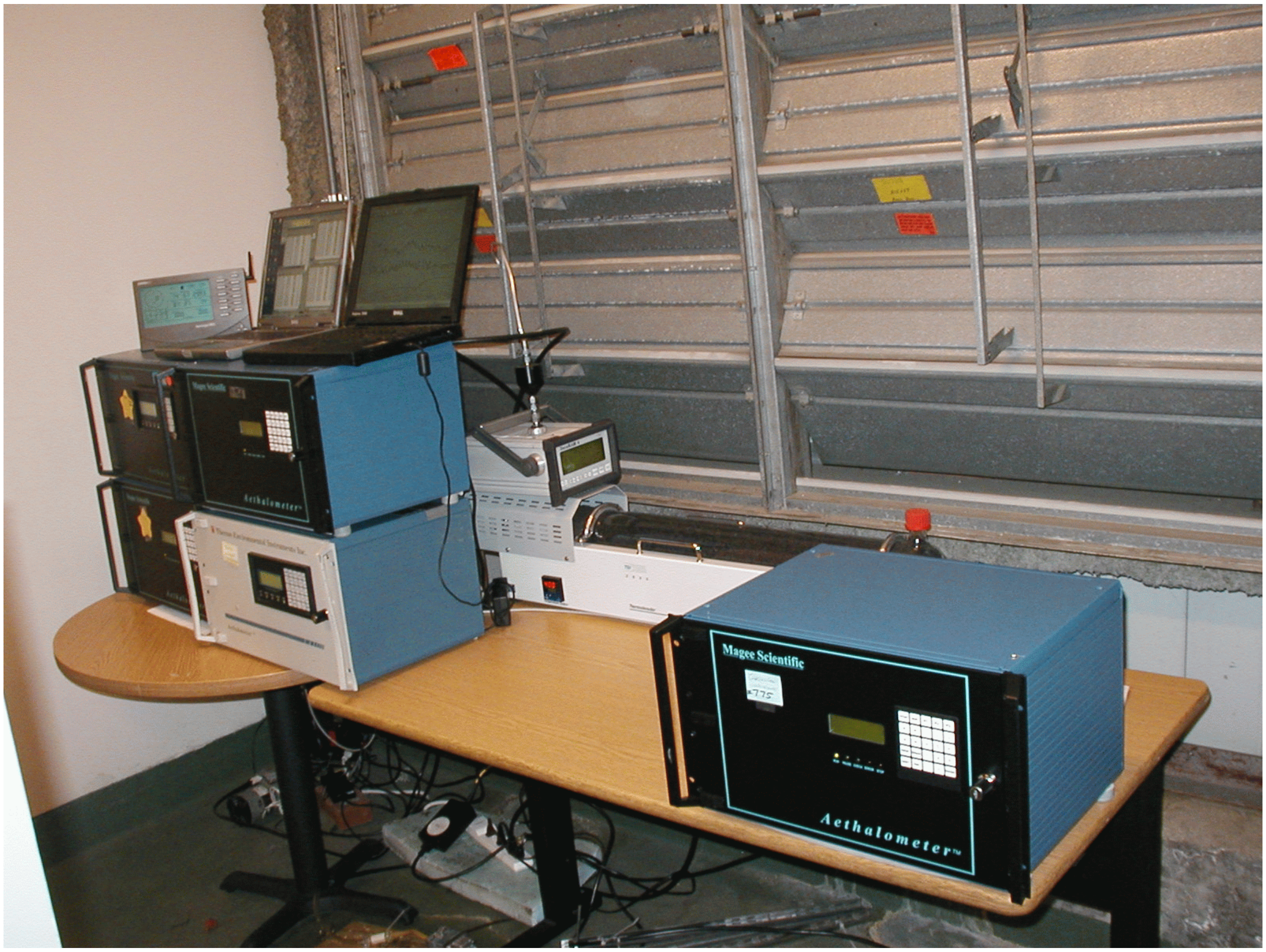
1. S/N 775: Small spot 2 lpm with Thermodenuder, max attn = 50
2. S/N 776: Small spot 2 lpm, nafion drier (minimize dew point related noise), max attn = 75
3. S/N 219: Small spot 4 lpm, max attn = 75
4. S/N 375: Small spot 4 lpm, max attn = 125
5. S/N 766: Large spot 4 lpm, max attn = 15 (should have minimal spot loading effect)

All instruments were run with either PM-1 (2 lpm) or PM2.5 (4 lpm) size-cut inlets.

In the 1-minute BC-only mode, a spot change results in only 5 minutes of missing data. This shorter data gap (it is 15 minutes for Aethalometers in the MA-DEP network) gives a better estimate of the K correction value since the real change in BC is smaller with a shorter interval. There has been some concern for a "new spot effect" -- noise after a filter change. Earlier work showed no observed new-spot noise on dynamic blanks after 4 minutes, so we do not block out any data after a filter change. The one exception to this is S/N 775, the thermodenuded Aethalometer. During data analysis it was found to require an extra minute of post-spot data removed because of an extended new-spot effect.

Other measurements also made for this project include:
Thermo DR-4 run in scattering mode (10-min data with auto-zero on) with a PM2.5 size-cut inlet.
1-minute on-site Indoor/Outdoor temperature and RH, and outdoor dew point.
Data for all instruments was collected using digital data streams; analog outputs were not used.

Figure 3. Instrumentation setup for this study.



Left to right: weather console, four Aethalometers, DR-4 nephelometer, thermodenuder, thermodenuded Aethalometer.

3. RESULTS

There are two major categories of data analysis for this project:

1. Optimization of the data correction algorithm; this includes determining the most appropriate algorithm parameters by comparing “solo” vs. more the precise collocated K factors (a sensitivity analysis) and assessing the effect of the thermodenuder on the spot matrix effect.
2. Application of the data correction algorithm to existing Roxbury and N. End BC data to assess the real-world impact of the spot saturation effect on BC and Delta-C Aethalometer data.

In addition, the results of limited tests on relative humidity effects are presented.

Optimization of the data correction algorithm.

A custom version of WU-AQL Aethalometer data masher was developed for this project to process 1-minute data to valid 1 and 60 minute mean BC from raw data input files, and to generate and apply correction factors to these data with two user-chosen parameters:

[a] # of 1-min datapoints used for pre and post spot change means
Varies from 4 to 10 minutes; creates a raw per-spot K factor

[b] # of spot changes used to create running mean smoothed K for data correction
Varies from 10 to 40

Varying these parameters changes the value, temporal dynamics, and precision of "K", so determining which set of parameters is most appropriate for a data set is an important step in this analysis. There are two approaches to generating K factors. One is the “solo” method described above, and only uses data from a single Aethalometer. The “colo” (collocated) approach uses data from two or more collocated instruments; when one instrument’s spot changes, data from the other instruments is used to measure any true change in BC concentration. This information is applied to the before and after spot-change BC values to improve the per-spot estimate of K, removing most of the random error inherent with the solo approach that is due to actual changes in BC during the spot-change interval.

Since the spot loading artifact is primarily of concern in the winter for urban sites in the northeast U.S., this discussion will focus primarily on the data from the thermodenuded Aethalometer, since it is most “winter-like” -- e.g., has the largest K -- of all the instruments run in this study. For purposes of demonstrating the effect of the thermodenuder on the nature of the data and the need for a relative large smoothing value for generating “solo” K values, Figures 3 and 4 show data for four Aethalometers (excluding the one with a very small max-attn setting of 15).

Figure 4 shows the K factor for these four instruments with a 10-minute mean and a smoothing of 20 spots (“10-20"). The K here is very noisy (not stable over time), and there is no clear trend. Figure 5 shows the same data, but with 40-spot smoothing (10-40). The K value is more stable and a clear trend emerges, with the thermodenuded instrument showing a higher K as expected. This figure also shows the inverse of smoothed light scattering data (with a log-scale on the right-axis); the K value for the non-thermodenuded Aethalometers increases with decreasing light scattering (e.g., a more "sooty" aerosol) as expected. Note that for these and all time-series plots of smoothed K, the data shown are limited to the period when the algorithm is fully smoothed -- e.g., the first and last 20 spot changes are excluded for a smooth of 40. This is why these data don't cover the full June 11-Sept. 21 core study time period.

Figure 4. 10-20 smoothed K factor: 1 thermodenuded and 3 normal Aethalometers

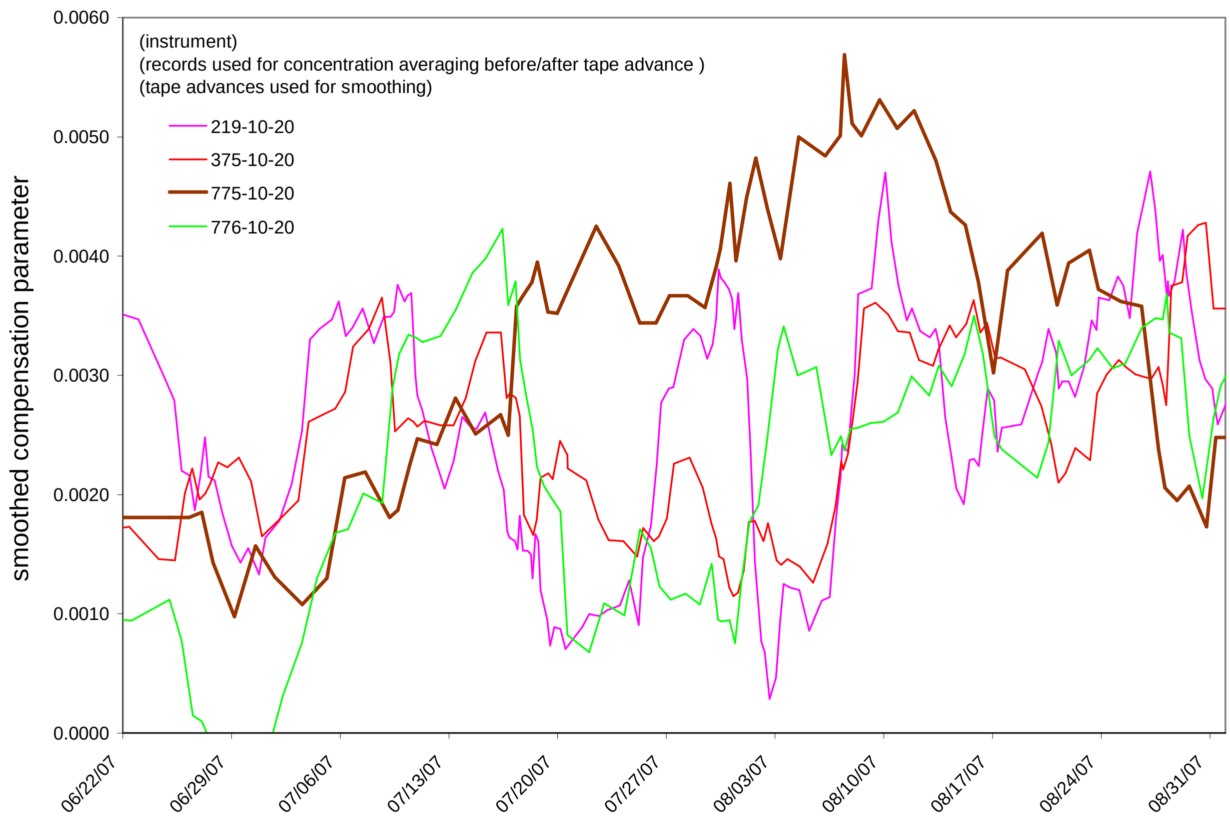
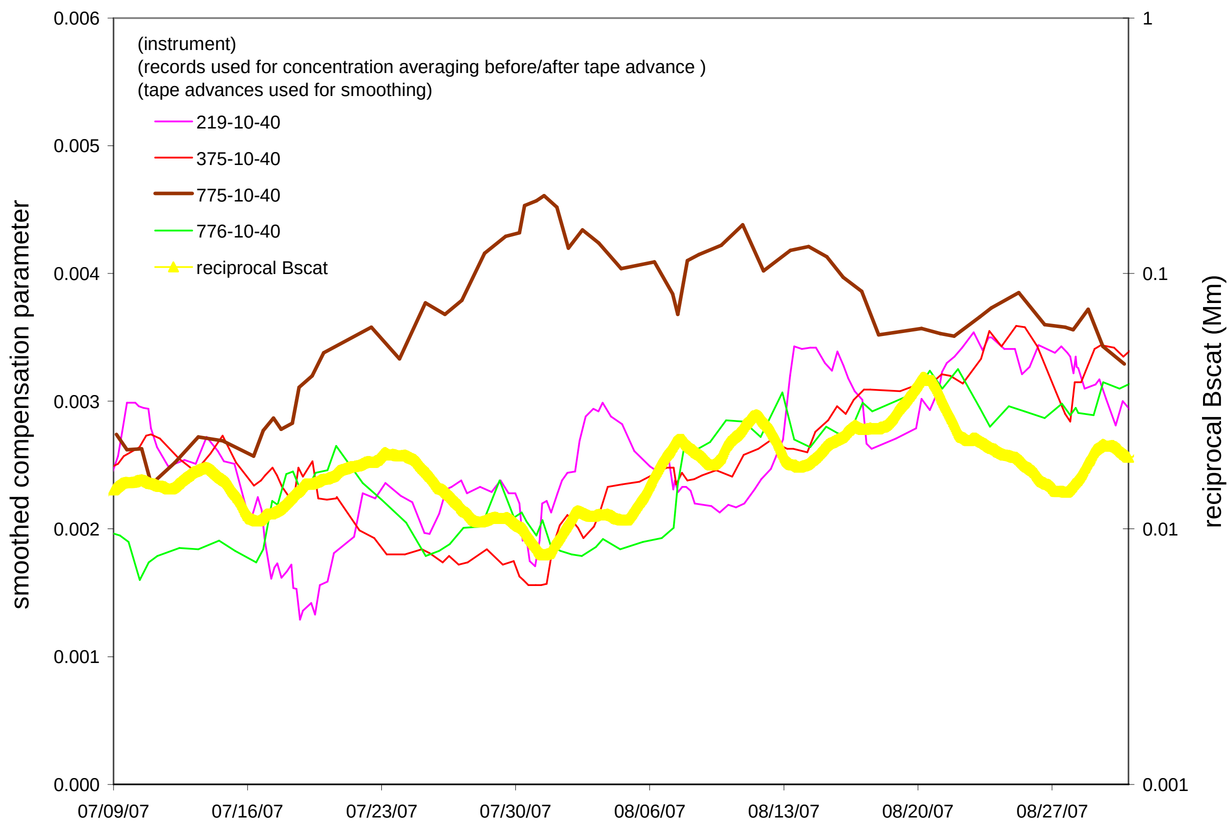


Figure 5. 10-40 smoothed K: 3 non-thermodenuded and 1 TD Aeths plus 1/Bscat (log-scale)



In this figure, the brown line is the K factor from the thermodenuded Aethalometer. It has a higher K factor, indicating a more sooty (winter-like) aerosol. The thick yellow line is the inverse of the scattering data, plotted on a log scale. The K factor for the non-denuded Aethalometers roughly follows this line as expected, since an aerosol with higher scattering would produce less spot saturation and thus a lower K factor.

The sensitivity to correction parameters is evaluated for the thermodenuded Aethalometer using an additional 1-minute of post-change data blocking as noted above. The number of spots averaged before and after a spot change is the most important parameter since the resulting average K can be a function of this number. The smoothing parameter is less important and easier to evaluate; it doesn't change the average K, and a simple visual assessment for excessive short term noise is all that's needed to determine what smoothing value should be used. Figure 6 below shows a 40-spot smoothed K for four different values of spot averaging: 2, 4, and 8 minutes. The 2-minute average is not realistic (too short, introducing large noise artifacts), but is included here for trend evaluation purposes. Numerically, it lies between the 4 and 8-minute spot averages. Both the 4 and 8-minute averages show similar amounts of noise and temporal trends, but the 8-minute average is somewhat higher. In general, the smallest value that gives a stable result should be used; in this case that value is 4 minutes. This is consistent with what Virkkula used (3-minutes) for his 1-minute data set.

Figure 6. Thermodenuded BC with different averaging times and 40-spot smoothing.

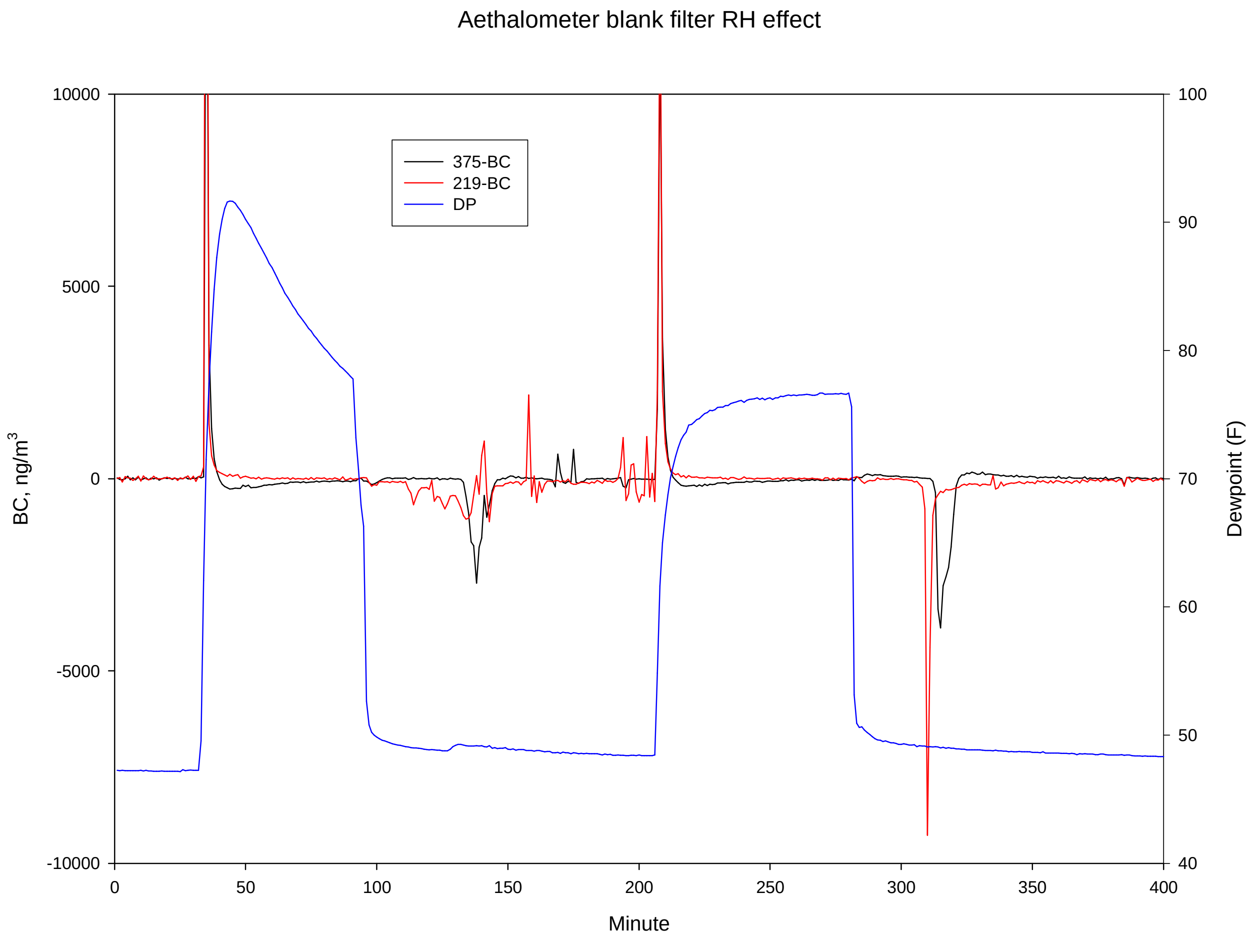
A direct comparison of BC from the thermodenuded Aethalometer to the other Aethalometers is not practical in this project. The process of thermodenuding introduces two different types of aerosol loss inherent in any thermodenuder: thermophoretic and mechanical (Wehner et al., JAS 2002) . Thermophoretic losses are caused by temperature gradients across the heated airstream that drive particles toward the wall. Mechanical losses are both from diffusion (for very small particle sizes) and settling (larger particle sizes). Taken together, the losses are on the order of 30 to 40%, making a quantitative comparison of thermodenuded BC data with the other BC data difficult.

Humidity Effects on Transient Instrument Noise.

Some limited non-ambient tests were run as part of the preliminary evaluation of Aethalometer performance for this project. Excessive short-term (1-5 min) dynamic blank noise has been observed even with a stable instrument temperature environment. The source of this noise appears to be short-term fluctuations in ambient dew point causing changes in RH at the Aethalometer filter. Tests to confirm this were run by varying the sample RH from low to high on dynamic blanks with several instruments.

The results shown below (Figure 7) clearly show a strong filter RH effect on blank filters; a positive RH step change gives a short but large positive response followed by a lesser negative response. It should be noted that the RH effect on filters loaded with aerosol is likely to be larger. Arnott (JGR, 2003) hypothesis that optical transmission measurements (Aethalometer, PSAP, etc.) on a filter with aerosol loading could be subject to RH artifacts by formation of a so-called ‘‘Janus interface’’ (Zhang, Science, 2002). Although the Aethalometer filters used in this laboratory test were “clean”, there will always be some organic carbon material on the filter from gas-phase OC absorbed by the quartz fiber media.

Figure 7. Moisture effects on blank Aethalometer filters.



In this work, the short-term (1-minute) noise from both the Aethalometer with the Nafion drier and the thermodenuded Aethalometer was substantially lower than "normal" Aethalometers. A simple metric of short-term noise is the standard deviation of the difference between subsequent 1-minute BC data points. For the post-test period Sept. 21-Oct. 8 and using normalized data to remove between instrument bias, this sigma in $\mu g/m^3$ is as follows:

SN 219: 1.22 (4 lpm)
SN 375: 1.38 (4 lpm)
SN 766: 1.50 (4 lpm large spot)
SN 776: 1.36 (2 lpm dry)

Adjusting the sigma for 776 down by a factor of two to reflect its lower flow gives a sigma of 0.68, much smaller than any of the other Aethalometers. Noise data for 775 is not presented here because of the difficulties in normalizing the BC response for that thermodenuded instrument. Although the thermodenuded Aethalometer was not dried, it appears that the charcoal bed of the thermodenuder dampens short-term fluctuations in moisture and thus reducing RH-induced noise. As a result of this work, the Aethalometer manufacturer plans to add an option for sample drying in the near future.

Application of the data correction algorithm to existing ambient MA-DEP BC data.

The spot saturation effect algorithm was applied to two existing MA-DEP Aethalometer data sets, at the Roxbury NATTS site and the North End site. One year of uncorrected and corrected data was generated from the original disk data files. Both these sites are running 2-channel Aethalometers; this allows evaluation of the behavior of the K factor for UV-C as well as an assessment of the spot effect algorithm's improvement of the "Delta-C" biomass burning signal. For these 5-min data sets, a 2 measurement cycle average was used (10-minutes), consistent with Virkkula's ambient work with a 5-minute data set. A 40 spot smooth was applied, consistent with the experimental work presented above.

Figures 8 and 9 are Roxbury Aethalometer data from November 2005 to December 2006, Figures 10 and 11 are North End data from October 17, 2006 to October 24, 2007, and Figures 12 and 13 are Springfield data from July 2006 to October 2007. Two plots are shown for each site: a time-series plot of the smoothed K factor for BC and UVC with smoothed PM2.5 from each site, and a smoothed plot of uncorrected and corrected BC and UVC data.

The Roxbury BC K factor in Figure 8 below varies from .008 during cold weather to -.002 during warm weather with high PM2.5 concentrations. This is consistent with what would be expected. It is worth noting that the UV-C K factor shows relatively little variation over time; this remains unexplained, with both the Aethalometer manufacturer and Virkkula (who also observed this behavior) unable to offer any insight as to why. Figure 9 shows a 10% (annual average) increase between uncorrected and corrected BC. This difference is relatively small, and is due to the relatively small effective BC max-attn of about 50 for a 2-channel Aethalometer with a max-attn setting of 125 (for the UV channel). For the Delta-C biomass combustion contribution to PM2.5 during cold weather, the corrected DC is about 30% higher than the uncorrected DC, and peaks at about 8 μg/m^3 PM2.5 during the winter of 2005-2006 (DC is somewhat less the next winter). The estimate of biomass combustion PM comes from previous work (Allen et al., 2004) that showed Delta-C was specific to biomass cmbustion, and developed a factor for scaling of Aethalometer Delta-C to PM of ~12 to 15.

The North End BC K factor in Figure 10 below is similar to that from Roxbury, but peaking slightly higher during the winter of 2007, and never going negative during summer high-PM2.5 events. This is consistent with the North End site having higher BC levels than Roxbury. The UV-C K factor is again relatively stable over the year. Figure 11 shows a slightly higher annual BC correction than Roxbury, at 12.5%. The corrected Delta-C biomass combustion contribution to PM2.5 during cold weather peaks at about 4 μg/m^3 PM2.5 during the winter of 2006-2007, less than observed at Roxbury for the winter of 2005-2006.

The Springfield BC K factor (Figure 12) is very dynamic, ranging from slightly negative during a summer high PM event to 0.010 during the winter. The UV-C K factor is also more dynamic at this site than the others, but still much less than for BC, ranging from .002 to .005. As expected, the largest difference between raw and corrected BC is during the winter. DC also peaks during that season (Figure 13).

Finally, this data correction approach is applied to 14 months of BC data collected during the 2003 Nescaum spatial BC study, from the Joy St. site near the Massachusetts State House (Figure 14). This Aethalometer was run with a max-attn setting of 125 and BC only (no UV-C channel). Because of the resulting high aerosol spot loading for this configuration, the BC correction is significant -- 30% on an annual basis, and up to 80% during some winter periods. Figure 11 shows a time series of uncorrected and corrected BC data from this site, using the same 2-cycle (10-minute) average and 40-spot smooth parameters as the N.End and Roxbury time series plots. The magnitude of this correction is a worst case scenario, but is what a user would get in an urban area with a BC-only Aethalometer (or a 2-channel Aethalometer with the UV-C channel turned off) using the manufacturer's default settings. The implication of this is that by simply turning off the UV channel on the Aethalometers presently run in the MA-DEP network would increase the error from 10% annual average to 30%.

Figure 8 . Nov 2005-Dec. 2006 Roxbury K factors for BC and UVC

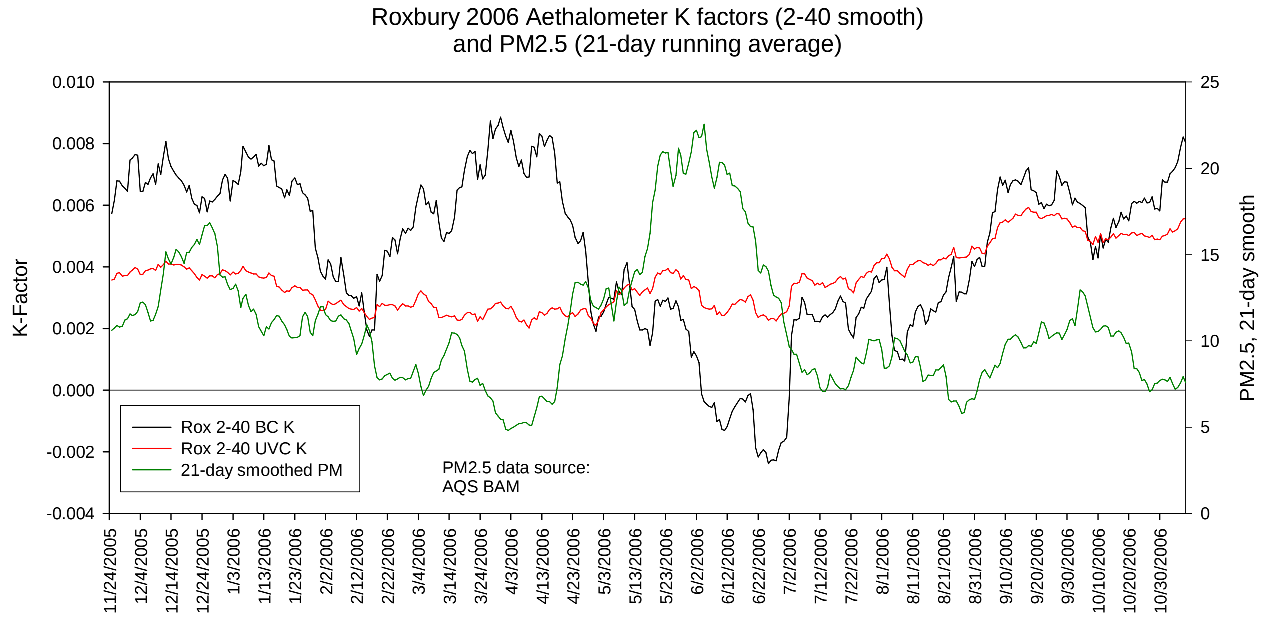


Figure 9. 21-day smooth of corrected and uncorrected Roxbury BC and Delta-C

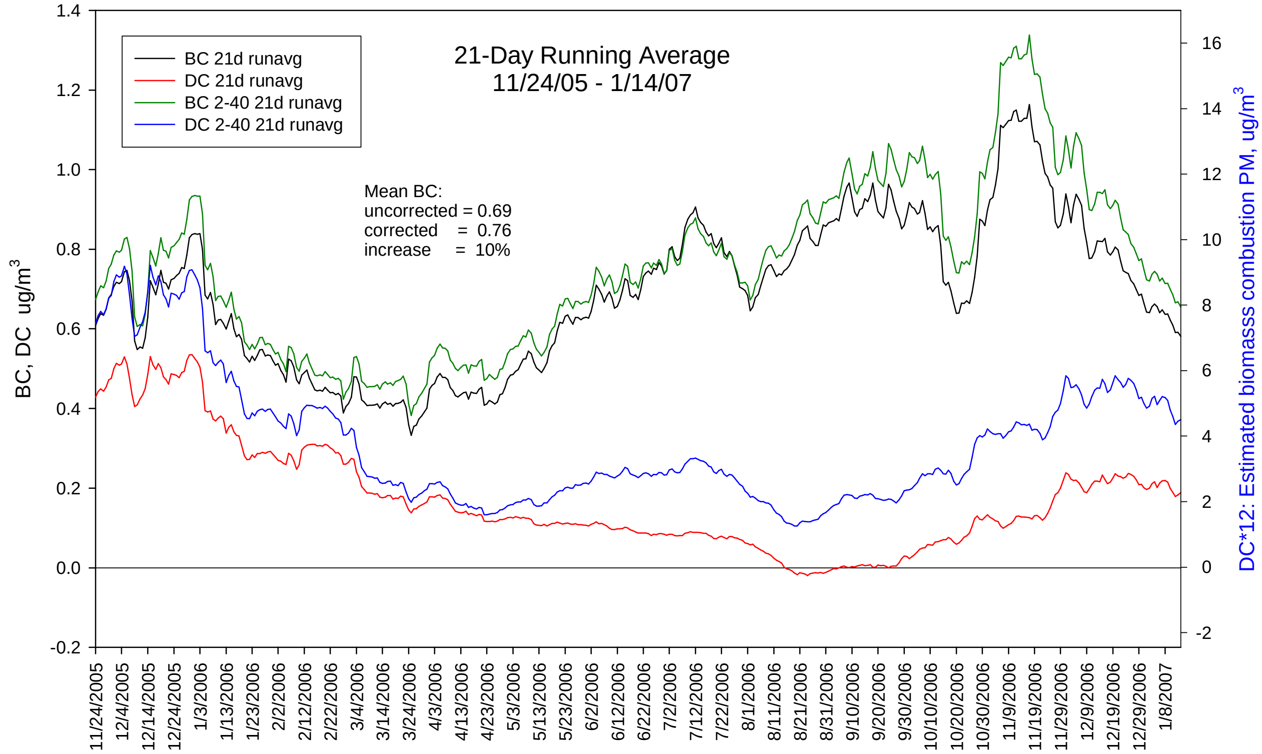


Figure 10. North End BC/UVC smoothed K factors and smoothed PM2.5

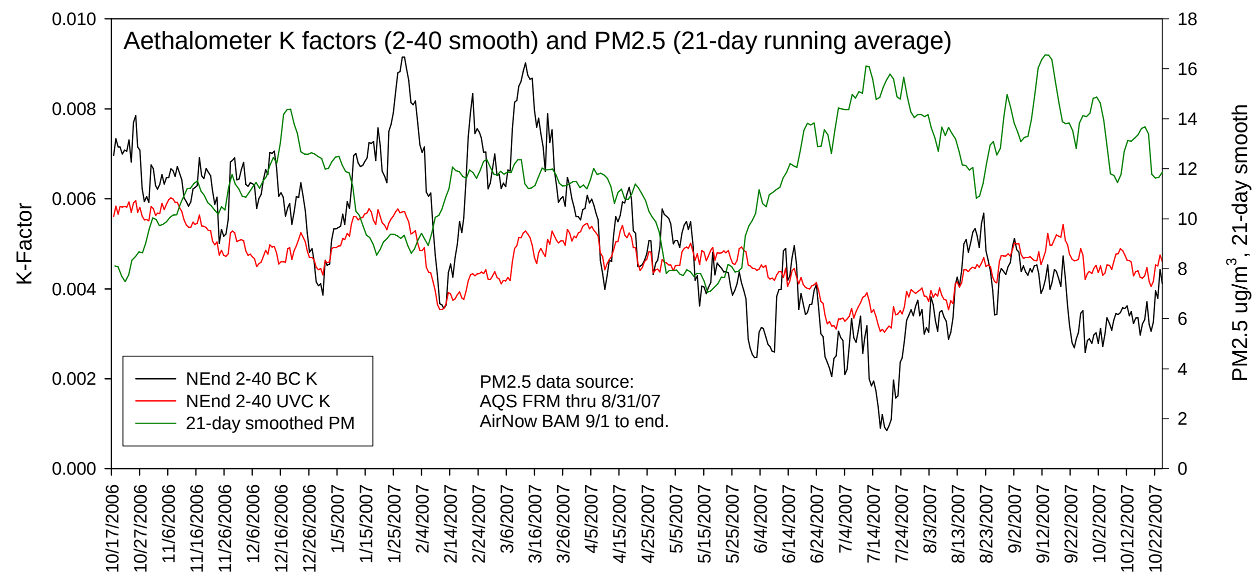


Figure 11. North End smoothed BC and Delta-C, uncorrected and corrected.

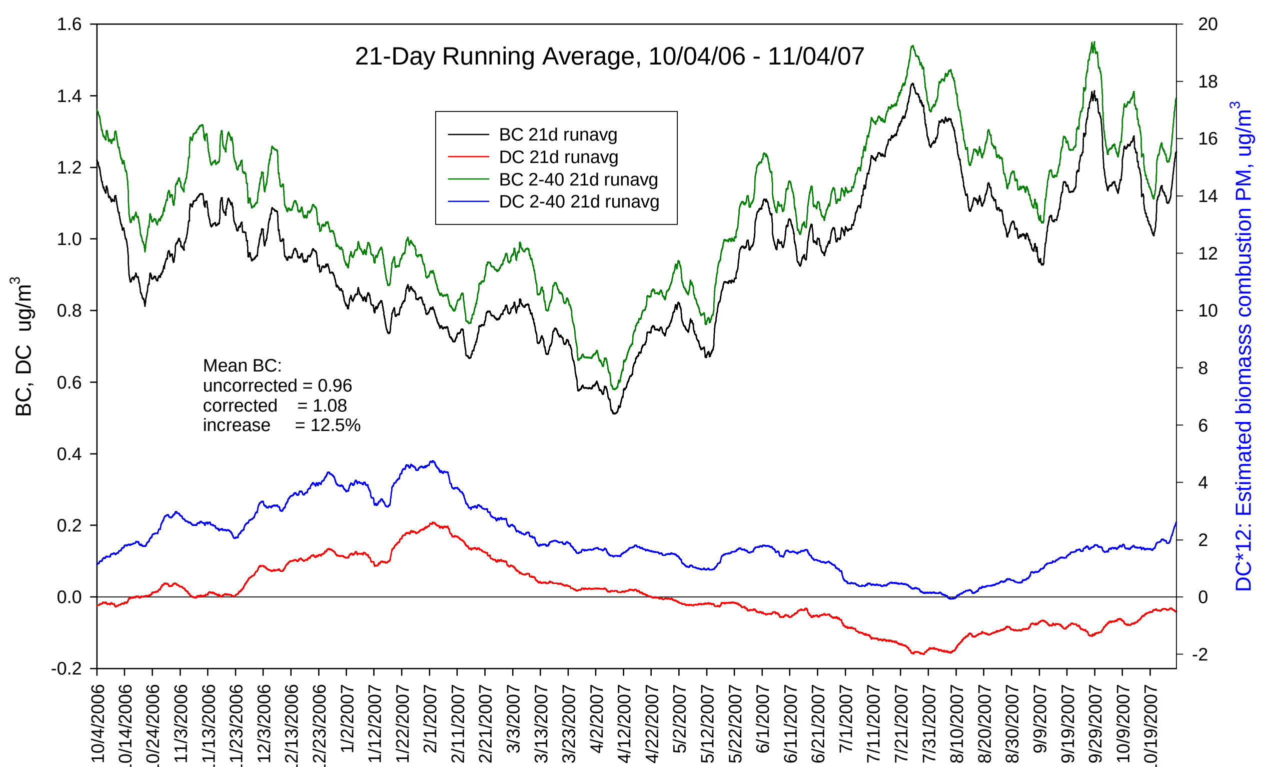


Figure 12. Springfield BC- UVC K and smothed PM2.5

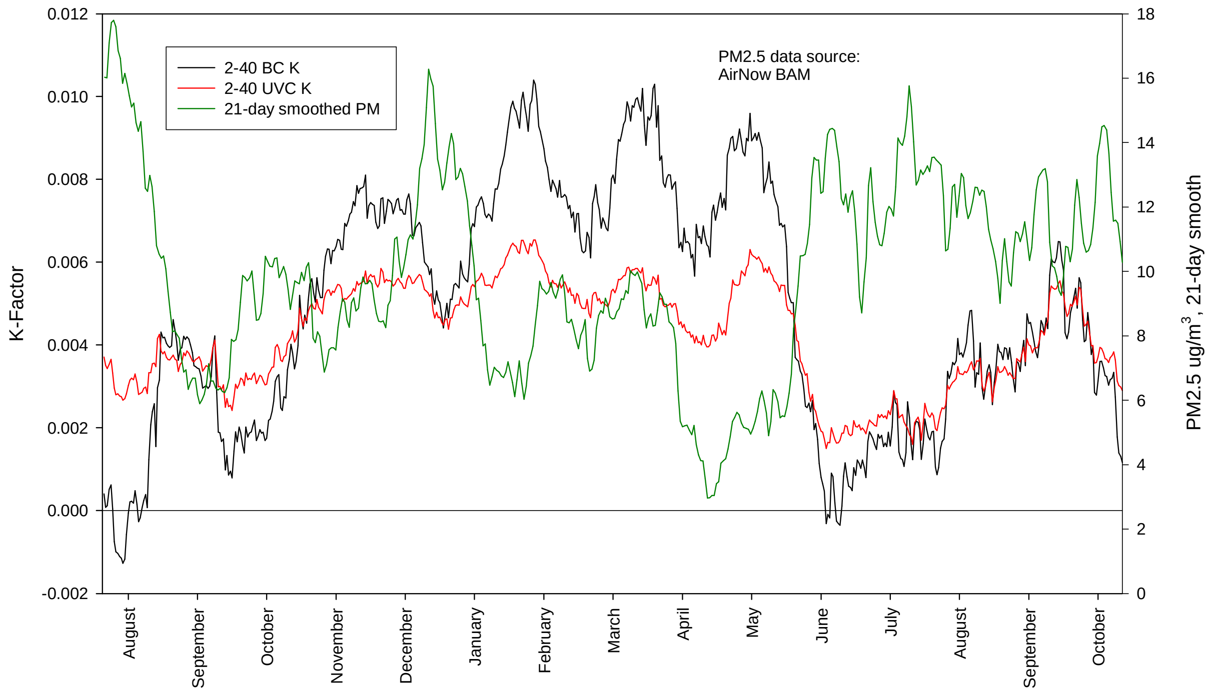


Figure 13. Springfield July 2006-Oct. 2007 BC and DC 3-week running mean

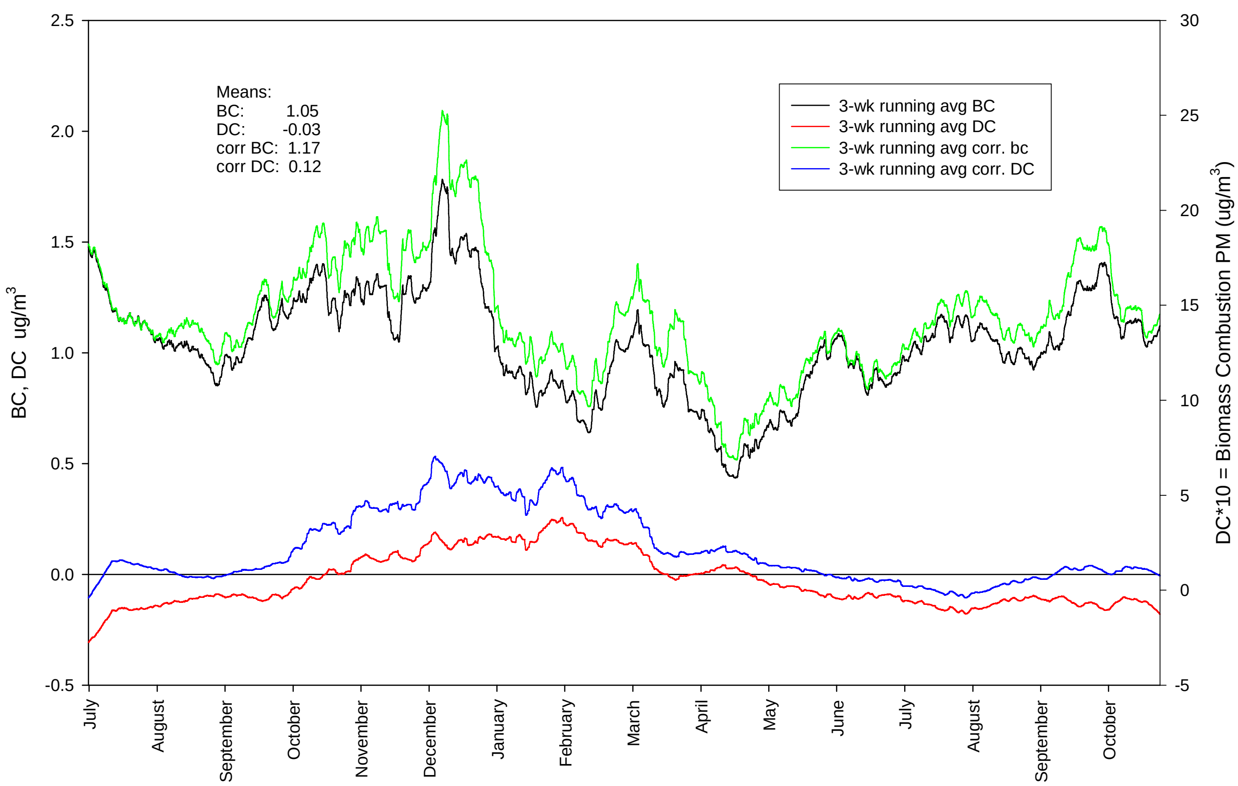
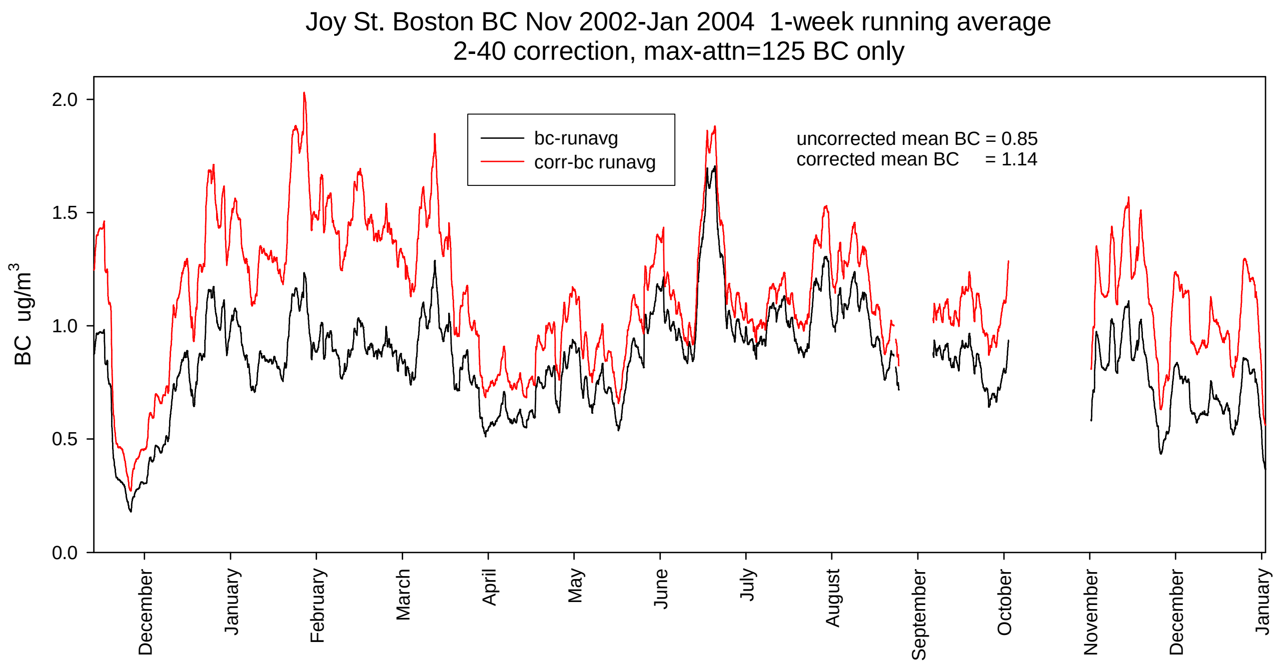


Figure 14.



4. CONCLUSIONS

Thermodenuder sample processing techniques produce an aerosol that consistently shows a strong spot loading saturation effect even for summer particles. An Aethalometer post-processing software program has been shown to generate useful spot matrix effect corrections for both experimental 1-minute data and ambient 5-minute data. This correction tightens scatter between instruments with similar aerosol matrix loadings, and removes the worst of the saturation bias. It also substantially improves the estimate of biomass burning from the Delta-C Aethalometer signal. There are some limitations of this approach; the required smoothing (40 spots) limits the dynamics of the correction to time scales of weeks to a month -- longer than the local sub-daily or several day regional time scales that the aerosol composition varies at. Applicaiton of the correction program to Roxbury, N. End, and Springfield Aethalometer data show modest saturation effects for BC and stronger effects for the DC biomass burning indicator; biomass burning in Roxbury and Springfield is a substantial component of the total PM2.5 during the winter. Short term changes in relative humidity at the filter caused by either shelter temperature changes or ambient dew point changes can result in large short-term noise in the Aethlometer signal that can degrade the saturation correction process.

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