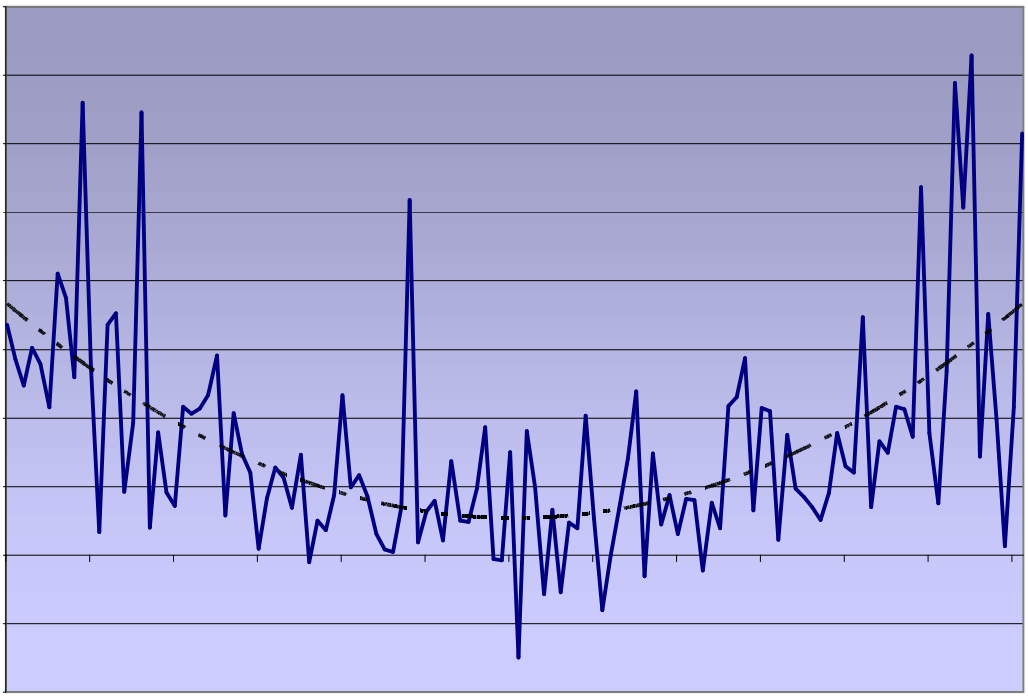
2002
A Year in Review

prepared by
Northeast States for Coordinated Air Use Management
(NESCAUM)

for the
Mid-Atlantic/Northeast Visibility Union (MANE-VU)

December 29, 2004



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Unit, Species, Acronyms

Acronyms

ABL – Atmospheric Boundary Layer
AIRMAP – Atmospheric Investigation, Regional Modeling, Analysis & Prediction
AQI – Air Quality Index
ASOS – Automated Surface Observation System
CFR – Code of Federal Regulations
CM – Coarse Mass
CY – Calendar year
DEP – Department of Environmental Protection
DoW – Day-of-week
EDAS – Eta Data Assimilation System
EST – Eastern Standard Time
FRM – Federal Reference Method
FWS – Fish and Wildlife Service
ICARTT – International Consortium for Atmospheric Research on Transport and Transformation
IMPROVE – Interagency Monitoring of Protected Visual Environments
HYSPLIT – Hybrid Single-Particle Lagrangian Integrated Trajectory model
JD – Julian Day
MANE-VU – Mid-Atlantic/Northeast Visibility Union
MARAMA – Mid Atlantic Regional Air Management Association
NAAQS – National Ambient Air Quality Standards
NCEP – National Center for Environmental Prediction
NEAQS – New England Air Quality Study
NESCAUM – Northeast States for Coordinated Air Use Management
NOAA – National Oceanic and Atmospheric Administration
NPS – National Park Service
NWS – National Weather Service
PM – particulate matter
RAMMPP – Regional Atmospheric Measurement Modeling and Prediction Program
RPO – Regional Planning Organization
SIC – Standard Industrial Classification
SIP – State Implementation Plan
SIRD – Supersite Integrated Relational Database
STI – Sonoma Technology Inc.
STN – Speciation Trends Network
TASS – Tethered Atmospheric Sounding System
TEOM – Tapered Element Oscillating Microbalance
UMD – University of Maryland
USEPA – United States Environmental Protection Agency

Chemical Species

EC – elemental carbon
NH_4 - ammonium
NO_X – oxides of nitrogen (NO_2 and NO)
NO – nitric oxide
NO_2 – nitrogen dioxide
NO_3 – nitrate
OC – organic carbon
$PM_{2.5}$ – particulate matter up to 2.5 μm in size
PM_{10} – particulate matter up to 10 μm in size
SO_4 – sulfate

Units

Length
mm - millimeter
Concentration
$\mu g/m^3$ – micrograms per cubic meter

Executive Summary

The Mid-Atlantic/Northeast Visibility Union (MANE-VU) regional planning organization (RPO) is one of five RPOs established to assist states and tribes with regional haze compliance. MANE-VU is striving to provide technical analyses spanning emissions inventory, monitoring, data analysis and modeling which will document the nature and extent of visibility impairment in the Eastern U.S. As part of these activities, a special emphasis was placed on coordinating monitoring activities during the 2002 modeling base year to ensure that a robust dataset for model validation purposes would be available. This report provides an overview of monitoring sites and platforms that were active during the year and presents initial findings based on analysis of their results.

A variety of measurement and observing platforms have been used to characterize the year 2002 from the perspective of air quality. Analysis to date suggests the following generalized findings:

- Fine particulates in the Northeast and Mid-Atlantic U.S. consist of approximately half sulfate, with the balance consisting of a mix of organic material, nitrates, elemental carbon, soil, and other trace components.

- Fine particle concentrations tend to peak during summer months and winter months with relatively few high PM episodes occurring during the spring or fall.

- During the summer, sulfates are highest in concentration over the southern and western portion of the MANE-VU region, closer to source regions associated with high SO_2 emissions.

- Limited atmospheric mixing during the winter months, changes in thermodynamic stability of secondary organic aerosol and particulate nitrate, as well as potential increases of local emission sources during winter months all contribute to PM episodes during winter which, though usually less severe, tend to be more localized in urban locations where the greatest potential for human exposure exists. Winter PM tends to contain higher levels of secondary organic aerosol and nitrate relative to summer PM.

- In general, sites tend to track together across very broad geographic scales suggesting the regional influence on ambient fine particulate concentrations. The most significant differences are observed between coastal and inland sites and those in the far southern portions of the MANE-VU domain relative to the Northeast portions.

I. Introduction

Under the U. S. Environmental Protection Agency's (USEPA) 1999 Regional Haze Rule, states and participating tribes are required to submit State Implementation Plans (SIPs) three years after $PM_{2.5}$ designations or by January, 2008 at the latest. These plans must include long-term monitoring and emissions management strategies for achieving the national visibility goals of reducing anthropogenic influences on visibility at Class I national parks and wilderness areas.[1] The structure of this regulatory program is such that the baseline period (2000-2004) plays a special role in establishing the benchmark against which progress is measured and thus affecting the stringency of necessary control measures. In addition, the central year of the baseline period, 2002 has been selected as a year of special focus for modeling simulations and other technical analysis for SIP development.

The Mid-Atlantic/Northeast Visibility Union (MANE-VU) regional planning organization (RPO) is one of five RPOs established to assist states and tribes with regional haze compliance. MANE-VU is striving to provide technical analyses spanning emissions inventory, monitoring, data analysis and modeling which will document the nature and extent of visibility impairment in the Eastern U.S. As part of these activities, a special emphasis was placed on coordinating monitoring activities during the 2002 modeling base year to ensure that a robust dataset for model validation purposes would be available. This report provides an overview of monitoring sites and platforms that were active during the year and presents initial findings based on analysis of their results.

This report does not present findings related to specific source contributions or pollution apportionment as these topics will be addressed in a forthcoming MANE-VU report focused on modeling and data analysis techniques related to contribution assessment. Rather, this document presents and interprets monitoring data to provide a comprehensive look at the data collected, spatial and temporal patterns of ambient pollution concentrations, and meteorological factors that may have been associated with the observed variations.

The monitoring data can be grouped into three broad categories including integrated measurements, continuous or semi-continuous methods and special studies which consist of research grade observations that are typically confined to intensive periods of study. Integrated measurements include the Federal Reference Method (FRM) network operated by state and local regulatory agencies which acquire 24-hour average $PM_{2.5}$ mass every day or every third day depending on site. The Interagency Monitoring of Protected Visual Environments (IMPROVE) program and the Speciation Trends Network (STN) sites are operated on a consistent 1-in-3 day schedule collecting 24-hr integrated measurements of major ionic constituents of $PM_{2.5}$, including SO_4, NO_3, NH_4, elemental carbon, organic carbon and a host of elemental components such as selenium, iron, nickel, vanadium.

[1]There are seven designated Class I areas in the Northeast and Mid-Atlantic States. They include Acadia National Park and Moosehorn Wilderness Area in Maine; Roosevelt-Campobello International Park in New Brunswick and Maine; the Lye Brook Wilderness Area in Vermont; the Great Gulf and Presidential Range-Dry River Wilderness Areas in New Hampshire; and the Brigantine Wilderness Area in New Jersey.

Continuous and semi-continuous techniques that were utilized on a routine basis during 2002 are largely restricted to a suite of instruments used to measure $PM_{2.5}$ in real time. The TEOM was perhaps most widely deployed and provides a measure of fine particle mass every 5 minutes, but requires temperature correction in order to provide reliably consistent results with FRM monitors.

Finally, a number of special studies were conducted during 2002 and MANE-VU has made an effort to collect data from these activities as available. These special studies include the AIRMAP program which operated four field stations across New Hampshire, a NOAA instrumented ship, a Department of Energy Aircraft, and a number of academic partners who made simultaneous measurements in or near the New England airshed during the summer of 2002 with special emphasis on the period between July 10 and August 9, 2002. MANE-VU also contracted with the University of Maryland to fly an instrumented aircraft during summer 2002 and operated a continuous sulfate detector on the summit of Mt. Washington at an AIRMAP field station. PM Health centers operated in Boston and New York, and NOAA operated a network of radar profilers across the region.

All of these measurement and observing platforms have contributed to characterizing the year 2002 from the perspective of air quality. MANE-VU, in this document, attempts to distill and summarize the information coming from these various platforms, place the year 2002 in context of the long term climatological average conditions and provide a description of noteworthy or unusual air quality characteristics that are examined in greater detail.

II. Monitoring Networks in the MANE-VU Region

To a large extent, the routine measurement of fine particulate and its components are conducted by regulatory agencies at either the federal or state level to support compliance efforts with Federal, State and/or local air quality rules and regulations. These sites tend to produce long-term records, although they may have sparse geographic coverage. Science-oriented networks tend to be focused on highly specific topics and may supply information which is linked to regulatory issues. However, these networks are not intended to support or enforce air quality standards and typically operate for short periods of time (weeks to 1-2 years).[2] Some academic field measurement campaigns provide spatial coverage at levels unmatched by regulatory networks.

A. Routine PM Mass Measurements

USEPA requires 24-hour aerosol mass sampling in all large metropolitan areas (MAs) of the U.S. in order to determine whether that MA has attained the National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ (*40 CFR, Part 58, Appendix D, Section 2.8.1.3.8.*). USEPA further stipulates that only samplers meeting Federal Reference Method or Equivalent Method specifications can be used for NAAQS attainment-related purposes. Large MAs are required to issue a daily Air Quality Index (AQI) to inform citizens when PM concentrations are high or are expected to become high (*40 CFR 58, Appendix G, Section 4).* Therefore, in addition to 24-hour duration FRM measurements, states, local agencies and tribal nations (SLTs) must also make near real-time (hourly) measurements of fine particles.

A.1 Federal Reference Method (FRM)

Although the term "$PM_{2.5}$" is associated with a wide variety of aerosol measurements, for compliance purposes it is operationally defined and, in theory, should only be used when describing measurements made by FRM samplers. Here, we use the phrases "fine aerosol(s)" or "fine particulate(s)" when referring to mass measurement data that is not obtained from FRM samplers.

$PM_{2.5}$ samples are collected from midnight to midnight in order to represent a calendar day. Samples are collected either everyday or on an every third day basis on a schedule set by USEPA. Samplers for everyday collection are required in areas expected to have the highest 20% of $PM_{2.5}$ concentrations within a monitoring organization's area *(40 CFR 58, Appendix D, Section 3.7.7.1-4*).

The more numerous 1-in-3 day samplers can be located in "top 20" areas but in practice are generally sited to represent areas with high population density that also experience typical $PM_{2.5}$ concentrations. As a result, "everyday" samplers tend to report higher concentrations than 1-in-3 day samplers.

[2] Notable exceptions include the long term PM measurements being made by SUNY-Albany at the Atmospheric Science Research Center (ASRC) or the Harvard School of Public Health. The University of New Hampshire AIRMAP program has begun a long-term monitoring effort focused on ozone and its precursors.

USEPA requires 75% data capture from FRM samplers in each calendar quarter in order to consider annual data from that site to be valid. A less stringent requirement - 75% of the annual data - has been adopted for this report in order to increase the $PM_{2.5}$ database (especially for 1-in-3 day samples). Data from 133 FRM sites, out of 171 in the MANE-VU domain, operating on the 1-in-3 day schedule met the annual completeness criterion and are utilized in the Chapter 3 as are data from 31 "everyday" sites.

The 1-in-3 data set, although predominantly from urban/suburban sites, includes 17 rural (or remote) sites while the everyday FRM data set includes five rural sites (there are 116 urban/suburban sites on the 1-in-3 schedule and 26 everyday sites). The impact of rural FRM data on results varies with the type of analysis. Therefore, each analysis will specify whether the rural $PM_{2.5}$ data has been included. Note that the designations "rural" and "urban/suburban" are assigned by the organization performing the monitoring at the site. Determining the character of an area and its surrounding land use classification is somewhat inexact so classifications may vary by organization, e.g., three of the "rural" 1-in-3 sites are classified as being in a rural location while the land use is classified as "commercial".

A.2 Continuous (hourly) methods

As noted above, many large cities must report and forecast fine aerosol concentrations as part of the daily AQI program. Although there have been many calls for approval of a near-real time mass measurement method, USEPA does not recognize any continuous fine particle measurement technique as being equivalent to the current $PM_{2.5}$ technique. USEPA's reluctance to approve a continuous method is based on comparison studies which have repeatedly demonstrated that continuous monitors do not accurately reproduce FRM results throughout the year on a national basis.

Continuous method inaccuracies are generally linked to the above-ambient temperatures present in the monitors which prevent collection or formation of liquid water within the monitor. Because the sample filter in the FRM sampler is maintained at no more than 5^oC above ambient temperature, some percentage of the volatile and semi-volatile materials that collect on the filter remain there. However, raising the collection filter temperature to 30^oC or 50^oC (typical internal temperatures in continuous monitors) can drive off a considerable portion of the volatile and semi-volatile mass. The further that ambient temperatures depart from the operating temperature of the continuous monitor, the larger the potential loss of mass. Thus, in the MANE-VU region where the vast majority of fine particle monitors operate at elevated internal temperature, continuous mass data historically has needed the largest correction during the winter season. Note that for some of the newer technologies deployed after 2002 are better at preventing volatile losses and do not necessarily require temperature correction.

It has been demonstrated that by collocating an FRM sampler with a continuous monitor, site-specific correction factors can be generated to create "FRM-like" hourly data, and several such schemes have been developed. The approach selected for use here, is based on the Julian Day (JD) of the year which acts as a surrogate for ambient temperature.[3] When properly

[3] The Julian Day correction method was developed by Dirk Felton of the New York State Department of Environmental Conservation. Note the following points when regarding Chapter 3 discussions of hourly fine particle data. FRM sampler data used in creating FRM-like hourly values was from collocated FRMs at the continuous

processed in conjunction with FRM data, the method produces FRM-like data that substantially exceeds the USEPA-required correlation (R^2) of 0.81 or greater. Appendix B has a detailed description on how to convert hourly fine particle data to FRM-like data via the Julian Day method.

Hourly data from 20 sites met the 75% seasonal completeness criterion and was adjusted to "FRM-like" status. However, two of those 20 sites (10%) were in rural locations and due to their relatively large contribution to the data pool, they have either been removed from the data set or (where indicated) treated separately.

A.3 Routine PM Speciation

A coalition composed of the National Park Service (NPS), the Fish and Wildlife Service (FWS), the Bureau of Land Management (BLM), the Forest Service (FS) and the USEPA established the Interagency Monitoring of Protected Visual Environments (IMPROVE) program in response to the 1977 amendments to the Clean Air Act. This monitoring network has collected speciated fine aerosol and related visibility data in or near Federal Class 1 areas in the United States since 1988.

In order to better support the USEPA's 1999 Regional Haze Rule, the network was significantly expanded, extending spatial coverage of aerosol characterization. The IMPROVE sampling schedule was also harmonized with USEPA's $PM_{2.5}$ sampling program at that time. Simultaneous with the IMPROVE expansion, USEPA developed the Speciation Trends Network (STN) which examines the chemical composition of fine particles. The STN program serves to both assist states in understanding fine particle composition in urban areas and to illuminate rural/urban differences in fine particulate composition.

Both of these speciation programs are important sources of information. However, key differences between the networks' sampling and analysis protocols necessitate some care in comparing results between the two.

IMPROVE data

The IMPROVE aerosol sampler has four channels for particle collection. The A and D channels collect $PM_{2.5}$ and PM_{10} on Teflon filters and are weighed gravimetrically to yield the mass of fine and coarse particulate. The B channel uses a 25 or 37 mm nylon filter for collection of water soluble ions, after the sample stream has passed through an annular sodium carbonate denuder to remove acid gases. Finally, quartz filters are used in the C channel and analyzed for elemental (EC) and organic (OC) carbon. The demarcation between these two carbon components is operationally defined based on the analytical technique and analysis protocol. The

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monitor site – no "nearby" sites were used. Military time is employed and hours refer to the start of sample collection in EST, e.g., the timestamp associated with a summer sample collected between 2:00PM and 3:00PM local time is "13:00". Unlike FRM data, seasonal completeness was used in screening hourly data. This was due to the large quantity of hourly data available and to the need to prevent seasonal bias in the JD correction scheme. The winter season consists of the months November, December, January and February, summer includes May, June, July and August and the combination spring/fall season consists of March, April, September and October. Since EST is used year-round for continuous data, some smearing of diurnal patterns driven by local activities can occur.

IMPROVE program uses Thermal Optical Reflectance (TOR) and splits EC and OC as the point during analysis at which the filter reflectance reaches its original value.

For many years, IMPROVE samplers operated only on Wednesdays and Saturdays but beginning in September 2000 the program adopted USEPA's every third day schedule. In 2002 there were seventeen IMPROVE samplers in operation in the MANE-VU region.

STN data

The National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ requires the collection of fine particulate for speciated analysis. The rule specifies that at a minimum, measurements of metals, certain ions and carbon are to be conducted as part of a National Air Monitoring Stations (NAMS) network of fifty sites [40CFR58 revised 7-1-99, Appendix D, section 3.7.6]. These sites operate under uniform conditions nationally and will be used to establish trends in fine particle constituents and also serve as models for a more extensive network of speciation samplers. As of January 2002, 24 STN sites were in place in the MANE-VU region.

The types of measurements made by the STN samplers are similar to those of IMPROVE. There are three channels for collection of fine particulate using a Teflon, nylon and quartz filter in respective channels. Unlike IMPROVE, PM_{10} is not collected as part of this program. In addition, there are four different sampler types used in the network, each with its own sample flow rate and collection volume.[4] Finally, STN filter samples are shipped cold whereas IMPROVE filters are not. Depending on a wide range of factors, STN and IMPROVE data may or may not be comparable.

A.4 Routine Visibility

CAMNET is a network of near real-time high-resolution digital scene cameras run by NESCAUM that is used to demonstrate the degradation in visibility due to air pollution. It serves two primary roles: public outreach and education, and archival documentation for later technical use. Funding for the ongoing operation of the network by Air Resource Specialists comes from MANE-VU. Funds for new site implementation comes from other sources, including state air agencies, NPS, FWS, and USEPA.

CAMNET pictures are updated every 15 minutes; the most recent pictures and related content (air pollution and meteorological information) are at: http://hazecam.net/

The network started in the spring of 1999 with the Boston site. During 2002, there were six sites operating: Boston, Hartford, Burlington, Mt. Washington, Acadia NP, and New York City (in Newark). Two of these sites (Mt. Washington and Acadia NP) are in or show scenes of class one airsheds. All images are archived and available on request to NESCAUM.

The sites include both urban and rural scenes; for urban sites the cameras are located outside of the city looking back at the city from a distance of 8 to 12 miles. Visibility at rural

[4] The four types include: Andersen Reference Ambient Air Sampler-RAAS, MET ONE Spiral Aerosol Speciation Sampler-SASS, URG Mass Aerosol Speciation Sampler-MASS, and Rupprecht & Patashnick (R&P) 2300

sites is impacted primarily by regional haze. For the urban sites, there is a second source of visibility impairment: local mobile source emissions. This can produce a distinct low-lying "brown cloud" over the urban core during morning rush hours as shown in Figure II-1.

Figure II-1: CAMNET picture of Boston on November 4, 2002 at 9 AM.

During 2002, CAMNET also captured the visual impact of the Quebec forest fire smoke fumigation across the northeast. On July 7, 2002, most of the area was impacted by the smoke from these fires. The pictures displayed in Figure II-2 show all six sites at 4:30 PM EDT on that date. All the sites except Acadia have severely degraded visibility. The Burlington, VT site has a very unusual orange hue.

Automated Surface Observation System (ASOS)

The Automated Surface Observing System (ASOS) is an automated meteorological network sponsored by the Federal Aviation Administration, National Weather Service (NWS) and the Department of Defense (DOD). ASOS provides weather observations which include: temperature, dew point, wind, altimeter setting, visibility, sky condition, and precipitation. A total of 882 ASOS systems are installed at airports throughout the country. Automated observing systems are designed to provide pilots and other users with airport weather observations. The observing systems update observations every minute, 24 hours a day, every day of the year. By providing timely information on the atmosphere these systems are designed to improve the safety and efficiency of aviation operations as well as aiding in improving forecasts and warnings. ASOS data available through NWS data sources are limited to a single 1-minute observation a few minutes before each hour, and visibility greater than 10 miles is reported as 10 miles; however, recent efforts to obtain raw, un-truncated ASOS observations may result in increased data availability in the near future.

Figure II-2: CAMNET photos from across the region on July 7, 2002 during Quebec smoke event

B. Special Studies

During 2002, MANE-VU was fortunate to have several special studies concluding or underway. Highly time-resolved and speciated datasets were collected during portions of calendar year 2002 which may be useful to understanding specific aspects of fine particle formation and transport across the region. Unfortunately, due to their "non-routine" status, the

periods when these data are available are limited. In addition, many of these datasets come from state-of-the-science techniques which require special post-processing and some of the academic research centers that have collected these measurements have not yet released final, quality assured data. The major sources of special studies data are listed here and some of these data sets have been used to complement routine data in chapter IV which focuses on specific episodes of interest.

B.1 AIRMAP/NEAQS

The University of New Hampshire (UNH) runs the "Atmospheric Investigation, Regional Modeling, Analysis and Prediction" (AIRMAP) program. AIRMAP started in 1999 with year-round monitoring at four locations in NH. Its primary objectives are analysis of existing climate data, the development of new air quality monitoring programs to address New England's changing climate and air quality, improving our understanding of the relationship between air quality and weather, and determining the causes of climate change in New England.

The National Oceanic and Atmospheric Administration (NOAA) and AIRMAP/UNH organized and carried out the New England Air Quality Study (NEAQS) during the summer of 2002. NEAQS-2002 served as a pilot study for a much larger research study centered over the Northeast/New England region in the summer of 2004. The 2002 NEAQS pilot study included enhanced surface observation stations at the four existing AIRMAP sites spanning a range of elevations in New Hampshire. Eight radar profilers for vertical wind and temperature were in place in the northeast for the summer period and a heavily instrumented research vessel (the NOAA R.V. Ron Brown) was deployed for the intensive period between July 10 and August 9, 2002. The DOE G1 research aircraft was also deployed during this period. Several other organizations performed non-routine measurements during this period, including NESCAUM (continuous sulfate on Mt. Washington), Maine DEP (daily FRM sampling at Acadia NP), Pennsylvania State University and PA DEP (NEOPS-Philadelphia), and MANE-VU (the UMD aircraft program).

For the summer of 2004, AIRMAP has become the operational base of a large international program called "International Consortium for Atmospheric Research on Transport and Transformation (ICARTT). ICARTT includes investigators from five countries stretching from the South East U.S. across New England and the North Atlantic into Western Europe.

B.2 PM Supersites

The USEPA PM Supersite program's primary goal is to characterize PM, its constituents, precursors, co-pollutants, atmospheric transport, and source categories that affect the PM in a region. This information is essential for understanding source-receptor relationships and the factors that affect PM at a given site (e.g., meteorology, sources, transport distances). A related goal is to compare and evaluate different methods of characterizing PM (e.g., emerging sampling methods, routine monitoring techniques, and Federal Reference Methods). There are three supersites in the MANE-VU domain: New York City, Baltimore, and Pittsburgh. NY and Pittsburgh did long-term monitoring from 2001 into the summer of 2002; some components of

the NY supersite continued through the end of 2002. The Baltimore supersite was more focused on shorter term intensive monitoring periods.

The NY supersite also did some intensive monitoring at two rural sites during 2002: Pinnacle State Park (Addison NY) and Whiteface Mountain (in the Adirondacks). Continuous PM and some aerosol species were measured at these sites during these intensive periods. The Pittsburgh supersite also ran a wide range of continuous aerosol measurements but only until early August 2002. Overall, there is less relevant supersite data for 2002 than had been originally anticipated.

B.3 PM Health Centers

In addition to the PM Supersites, USEPA funded five PM-Centers in 1999. Three of these are in the MANE-VU domain: Boston MA (HSPH), New York City (NYU), and Rochester NY (University of Rochester). The purpose of these centers is to advance scientific understanding of the health effects of PM across several areas in an interdisciplinary manner. Topics include assessment of personal exposures to PM in normal human populations and in sensitive populations, development of new models for the amount of particulate matter that is deposited in the lungs, identify which components or properties of PM are driving the observed human health effects, and improving our understanding of which sub-groups are susceptible to PM health effects.

The Boston PM-Center is run by the Harvard School of Public Health. During 2002, measurements included daily PM_{10}, $PM_{2.5}$, $PM_{1.0}$, speciation (ions and elemental and organic carbon), and real-time $PM_{2.5}$, sulfate, number concentration, and black carbon soot. Neither the Rochester nor the NYC PM-centers did routine ongoing ambient measurements during 2002. Some limited intensive monitoring was done at the Rochester PM center.

B.4 Upper Air Measurements

MANE-VU funded UMD's Regional Atmospheric Measurement Modeling and Prediction Program (RAMMPP) to fly an instrumented small aircraft during the summer of 2002 under a contract with NESCAUM. The RAMMPP flight operations are based out of Maryland. Their Aztec aircraft is equipped with CO, O_3, SO_2, black carbon soot, meteorology, light scattering, 6-bin particle number concentration between 0.3 and 1 μm, and related basic measurements in real time. Approximately 56 hours of flights were done in support of MANE-VU between July 2 and August 14, 2002. Two papers have been published in peer-reviewed journals describing measurements made during the Quebec forest fire event and the mid-August regional haze event. A third article describes measurements made over PA during the August 2003 blackout; RAMMPP data from the 2002 MANE-VU flights is used for comparison in that paper. All three papers are available on request.

A related upper-air MANE-VU funded project was the Millersville University "Balloon Study" during January and February 2004 in Millersville PA (six miles southwest of Lancaster PA) in the Susquehanna River Valley. A brief description of this project based on the proposal is included here since the results from this study may have value in interpretation of 2002 data.

A balloon-tethered atmospheric vertical profiling system was used to obtain measurements of the atmospheric boundary layer (ABL) up to 700 meters during January and early February 2004. A tethered balloon sensor platform in conjunction with surface measurements has the unique ability to sample the ABL with high spatio-temporal resolution and characterize the link between the surface and free atmosphere. The mobile tethered atmospheric sounding system (TASS) carries a meteorological sensor package (T, p, RH, wind), a portable nephelometer (TSI DustTrak), CCN particle counter to 10 nm (TSI Model 3007), and for selected periods, 8-10 hour integrated aloft sampling using low-volume Teflon filters with a $PM_{2.5}$ size cut. The TASS can be employed in two modes: 1) as a profiler to delineate the vertical structure of the ABL; 2) as a platform for constant altitude integrated samples or time series with fast-response-rate sensors. Two tethered balloons were used in order to capture profiles and integrated samples or time series simultaneously.

Surface instruments include a portable meteorological package, trace NO/NO_2 and SO_2, a TSI 3-wavelength nephelometer, a 2-wavelength aethalometer (black carbon by light absorption), and low-volume $PM_{2.5}$ Teflon filter samples. Eta gridded data, satellite and radar imagery, and regional surface and upper data will be archived. A complete archive of Eta model grids, imagery, surface and upper air data from the NWS network, and HYSPLIT trajectories during the field campaign will also be provided.

These data are still being analyzed. Two conference proceedings by Rich Clark (Millersville University) on this work are available on the 2002 FTP data archive. Data from this study will also be posted there when they are finalized.

Radar Profiler Network

To support the NEAQS 2002 and 2004 intensive northeast studies, the NOAA-Forecast Systems Laboratory (FSL) installed several profilers in the MANE-VU domain. A profiler consists of two systems: a radio acoustic sounding system (RASS) to measure hourly winds and virtual temperature in the lower boundary layer, and a radar system to measure hourly winds at a coarser but deeper vertical resolution in the bulk of the boundary layer (approximately 2-3 km). More information on the NOAA profiler network as well as data from it and non-NOAA profilers are at: http://www.profiler.noaa.gov . MANE-VU funded STI to perform site visits in June 2002 for the three non-NOAA profiler systems at Ft. Meade MD, Stow MA and Rutgers (New Brunswick, NJ) sites. Operational checks were performed during these visits, with corrective action taken as needed. The contract with STI also included data review and validation services for four months of Stow and eight months of Rutgers profiler data, starting in early June 2002. Those data and a report detailing the site review findings are available on request to NESCAUM. No MANE-VU funded site reviews were done in 2004, since the non-NOAA profiler sites were being reviewed either by the organizations running them (for MD and NJ) or by NOAA (for the MA-DEP Stow site) at NESCAUM's request.

Maps of the profiler systems in and near the MANE-VU region are shown below for both summer 2002 and summer 2004; there are some differences between the two NEAQS study periods in these sites. There were no profilers running in western PA in 2002. The inactive sites for 2004 in the MANE-VU domain are Gray ME, Orange MA, Pinnacle State Park (Addison NY), and Schenectady NY.

Figure II-3: Profilers during summer 2002 NEAQS intensive

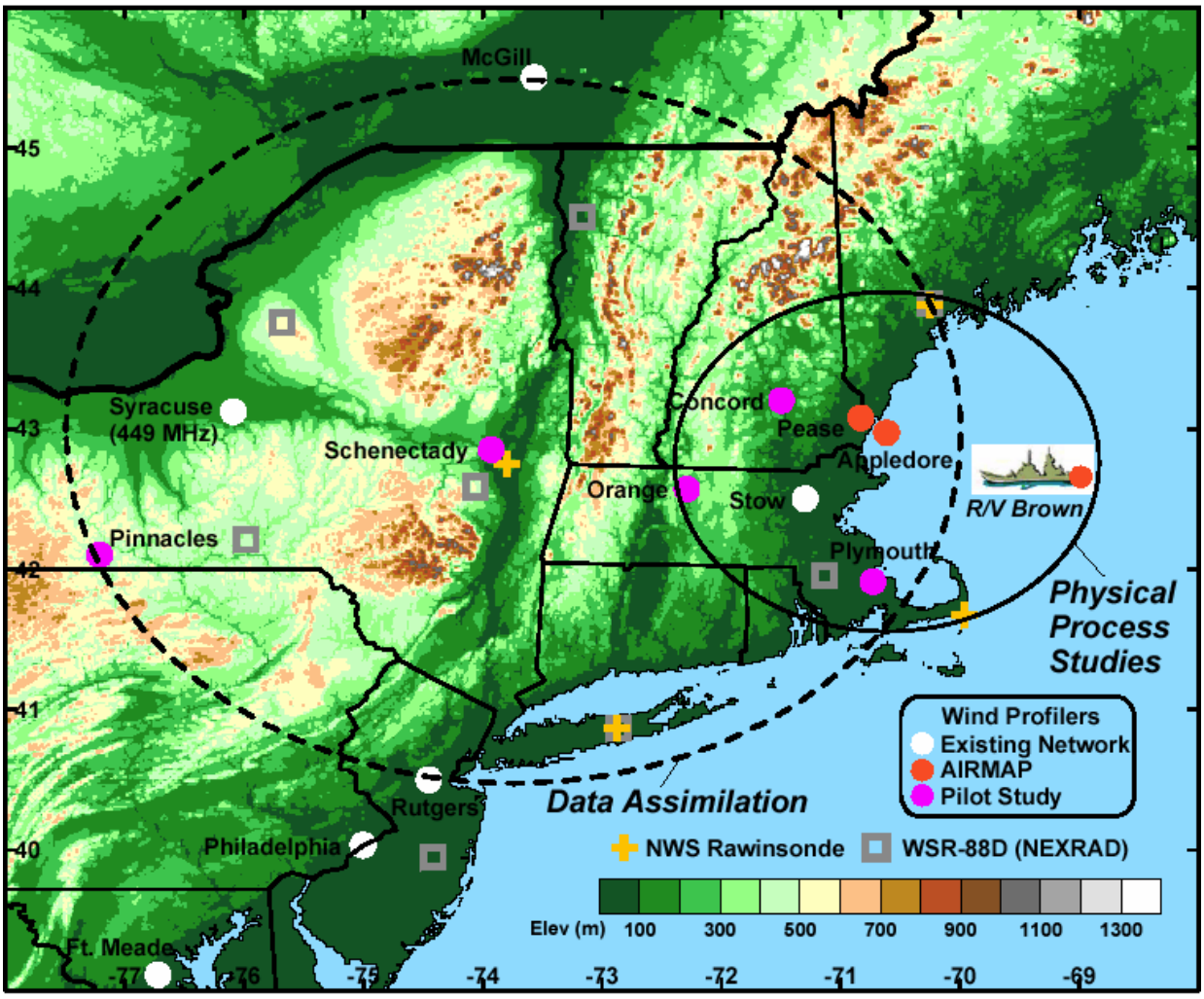
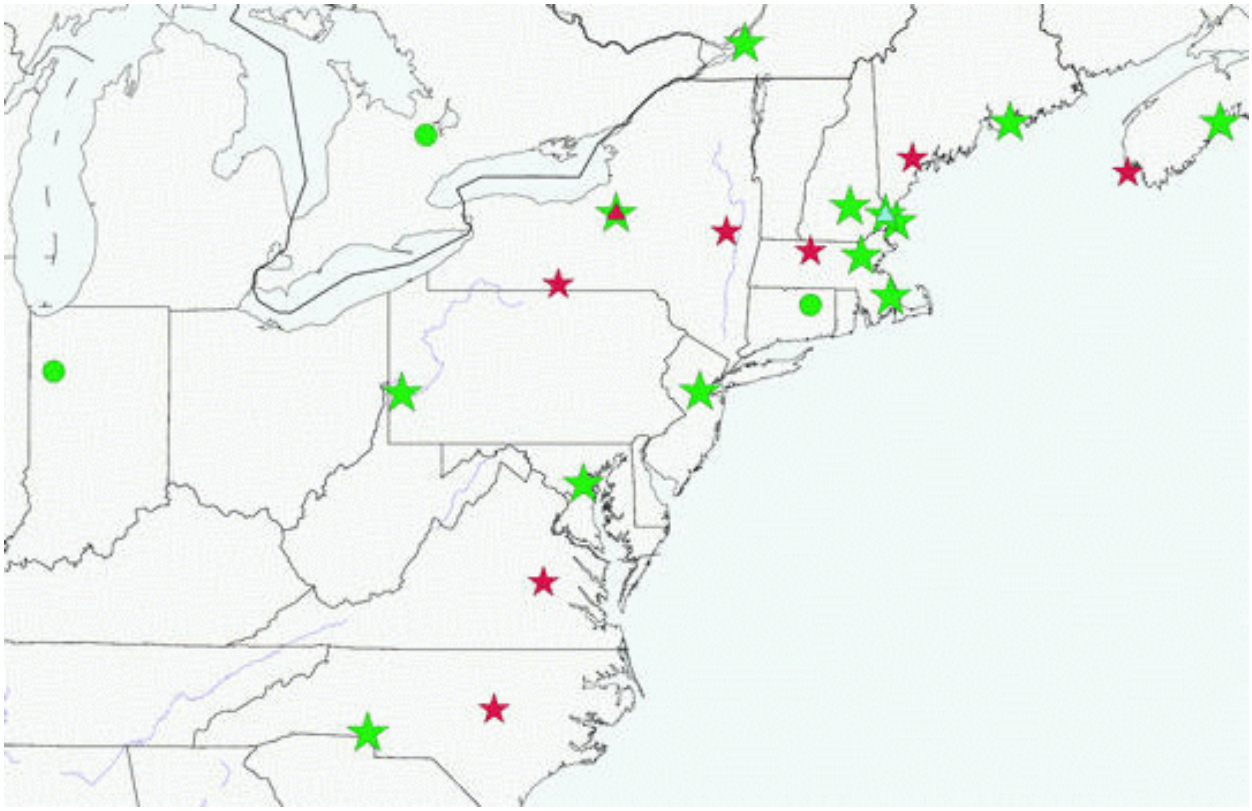


Figure II-4: Profilers during summer 2004 in the MANE-VU domain and surrounding area



Notes: Red indicates inactive sites; star is wind and temp; circle is wind only; triangle is temperature only.

Figure courtesy NOAA FSL

Back Trajectories

Routine archival of observed analyzed wind fields by NOAA's National Center for Environmental Prediction (NCEP) and the availability of the HYSPLIT trajectory model from NOAA's Air Resources Laboratory (ARL) (Draxler and Hess, 1997; Rolph, 2003) provide routine availability of air mass histories in the form of calculated back trajectories. NESCAUM has calculated back trajectories for 17 sites – including Class I areas, potential $PM_{2.5}$ nonattainment areas and STN network monitoring sites – for 1997 through 2002. Eight per day back trajectories were calculated for each site using two different meteorological datasets allowing for the comparison of Eta Data Assimilation System (EDAS) and the Final (FNL) meteorological fields prepared by NCEP.

C. Data Availability

While the various types of data and networks from which they were drawn are described here, the actual data is described in more detail in Appendix A which contains a list of data sets which have been archived by NESCAUM, the parameters measured, sites, as well as the start and stop dates for each dataset.

The Supersite Integrated Relational Database (SIRD) [http://www.supersitesdata.umd.edu], a web-based data query system to make supersite and related program data available to the research community, was funded by the USEPA and originally scheduled to be completed by October 2003. NESCAUM's original plan was to work with SIRD to obtain non-supersite datasets and extend the time frame to be covered by the database to include all of 2002, thus making SIRD into a resource for 2002 MANE-VU analysis. However, a wide range of problems has substantially delayed the completion of SIRD. As of summer 2004, SIRD is only partially operational; most of the data presently available through SIRD queries is from 2001 and is limited to supersites and NOAA profiler data. A list of available SIRD data is at:

http://www.supersitesdata.umd.edu/ShowParameters.aspx

NESCAUM has set up a "data repository" at a non-public but anonymous login FTP site with as much of the relevant 2002 data as could be obtained (see Appendix A for a complete listing as of this writing). This site can be accessed with a browser: ftp://airbeat.org/private/2002ManeVuData/

As additional relevant data become available (2002 Philadelphia NEOPS for example), they will be posted on this site (see the 0_Readme.txt file for a record of changes and updates). While much of this data has been incorporated into the subsequent chapters which analyze the air quality experienced during 2002, many data sets have not been fully explored and some continue to be added. The objective in establishing the archive extends beyond providing source data for this report, but rather to provide easily accessible "one-stop shopping" for modeling and data analysis efforts related to the preparation of SIPs.

References:

Draxler, R.D.; Hess, G.D., "Description of the HYSPLIT-4 Modeling System," *NOAA Technical Memorandum ERL, ARL-224*, Air Resources Laboratory, Silver Springs, Maryland, 24 pgs., **1997**.

Rolph, G.D., Real-time Environmental Applications and Display sYstem (READY) Website (http://www.arl.noaa.gov/ready/hysplit4.html). NOAA Air Resources Laboratory, Silver Spring, MD., **2003**.

III. Overview of 2002

The following three chapters use the data described in Chapter II to explore the air quality during 2002 in various ways. This chapter makes use of routine measurements of aerosol chemistry and physics to provide a general description of the year with respect to air quality and to summarize major events that influenced the MANE-VU region. Routine measurements include: 1) mass-related data from FRM samples (both the "1-in-3" and "everyday" sampling schedules); 2) mass data from continuous (hourly) instruments; 3) mass and chemistry data from USEPA's Speciation Trends Network (STN); 4) mass and chemistry data from the IMPROVE program (cosponsored by USEPA and the National Park Service). In Chapter IV, detailed analysis of the spatial extent and variation of air quality is presented. A major focus is the differentiation between urban and rural locations. Finally, Chapter V contains detailed temporal analysis looking at issues related to averaging times, temporal resolution of the data and detailed episode analysis.

A. State-by-State summaries

An analysis of the range of concentrations observed in each state along with the states' relative position with respect to one another provide context for understanding the extent of fine particle pollution, the spatial distribution of poor air quality within the MANE-VU states, as well as for understanding the "regionality" of specific events.

A.1 Statistics on MANE-VU FRM Mass Sites

Table III-1 provides a summary of basic statistical information on FRM samples collected by MANE-VU monitoring organizations on an urban/rural basis. Because NAAQS attainment is not the focus of this report, and only the single calendar year 2002 is reviewed, those data alone are included in these summary annual statistics. Maximum values throughout the region were impacted by smoke from a series of wildfires burning north of Quebec in early July. Many, but not all, sites reported record high concentrations during that event. Because of the smoke plume's disproportionate impact on some statistics, data from 7/6-7/10 (inclusive) were not used in computing the statistics in Table III-1. Data censored due to this smoke event amounted to 334 observations out of 21,654 from urban sites and 53 observations out of 3,558 from rural sites.

All monitoring organizations in MANE-VU produced sufficient data from FRM sites (both "everyday" and 1-in-3) for statistical analysis in 2002. The basic statistics from the 142 urban and 22 rural sites show that Washington, D.C. had the highest mean and median urban levels of any reporting organization while New Hampshire had the lowest mean and median urban levels.[5] The small number of "rural" FRM sites (D.C., ME, NH, and RI had no such sites) makes meaningful inter-organization comparisons difficult at such sites.

[5] See Chapter II for description of "Urban" versus "Rural" sites.

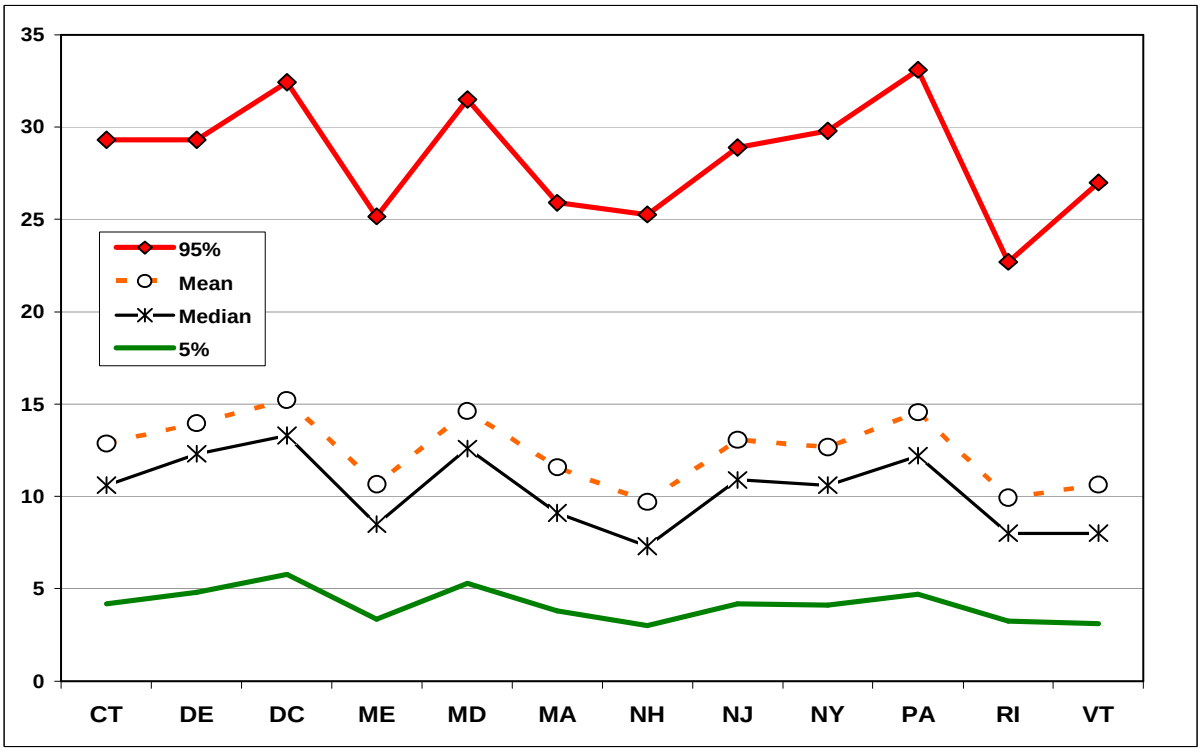
Table III-1: Basic statistics by State and Region for 2002 (excluding 7/6-7/10).

MANE-VU $PM_{2.5}$ Mass - 2002													
Urban													
	CT	***DE***	***DC***	***ME***	***MD***	***MA***	***NH***	***NJ***	***NY***	***PA***	***RI***	***VT***	***MANE-VU***
# Sites	12	5	3	5	12	13	6	15	32	29	6	4	142
# Obs.	1,672	979	798	555	1,981	1,777	664	1,899	4,077	5,343	1,114	461	21,320
Max	54.1	57.8	59.1	41.7	64.2	78.4	35.9	58.9	50.4	89.2	41.2	39.2	89.2
95%	29.3	29.3	32.4	25.2	31.5	25.9	25.3	28.9	29.8	33.1	22.7	27.0	29.8
90%	24.5	23.1	25.1	19.8	25.1	22.3	19.9	24.3	23.4	25.9	18.4	20.9	23.8
75%	16.7	17.0	18.4	13.4	18.0	15.1	12.6	17.0	16.3	18.3	12.7	13.7	16.8
Median	10.6	12.3	13.3	8.5	12.6	9.1	7.3	10.9	10.6	12.2	8.0	8.0	11.0
Mean	12.9	14.0	15.2	10.7	14.6	11.6	9.7	13.1	12.7	14.6	9.9	10.6	13.1
25%	6.9	8.7	9.5	5.8	8.9	6.2	5.0	7.3	6.9	8.2	5.6	5.3	7.2
10%	4.9	6.0	7.1	4.0	6.3	4.7	3.7	5.1	4.9	5.7	4.0	3.7	5.0
5%	4.2	4.8	5.8	3.4	5.3	3.8	3.0	4.2	4.1	4.7	3.3	3.1	4.1
Min	0.3	2.2	0.5	1.9	2.2	0.0	0.2	1.1	1.1	0.0	1.0	1.2	0.0
Rural													
	CT	***DE***	***DC***	***ME***	***MD***	***MA***	***NH***	***NJ***	***NY***	***PA***	***RI***	***VT***	***MANE-VU***
# Sites	1	2	0	0	4	1	0	3	5	5	0	1	22
# Obs.	113	208	na	na	422	107	na	326	971	1,242	na	116	3,505
Max	33.4	52.1	na	na	51.0	33.7	na	46.6	45.9	54.9	na	37.4	54.9
95%	25.4	24.7	na	na	28.4	21.1	na	24.1	25.8	30.1	na	22.9	27.7
90%	22.0	21.1	na	na	22.4	16.9	na	20.4	18.4	24.9	na	14.0	22.1
75%	15.0	15.9	na	na	15.5	10.2	na	13.5	12.3	17.6	na	9.5	14.9
Median	9.5	10.8	na	na	11.1	5.9	na	9.0	7.2	11.7	na	5.1	9.6
Mean	11.4	12.6	na	na	12.8	8.2	na	10.9	9.4	13.8	na	7.6	11.7
25%	5.7	7.8	na	na	7.4	4.4	na	6.1	4.4	7.7	na	3.4	6.0
10%	4.2	5.2	na	na	5.5	2.8	na	4.2	2.9	5.5	na	2.5	3.9
5%	3.7	3.9	na	na	4.5	2.5	na	3.4	2.3	4.2	na	2.1	3.0
Min	2.5	1.5	na	na	2.1	1.3	na	1.5	0.5	1.1	na	0.7	0.5

Comparison of MANE-VU rural and urban sites results shows urban sites to be approximately 1 $\mu g/m^3$ higher than rural ones (for 5^{th} percentile values) and about 2 $\mu g/m^3$ higher at the 95^{th} percentile level.

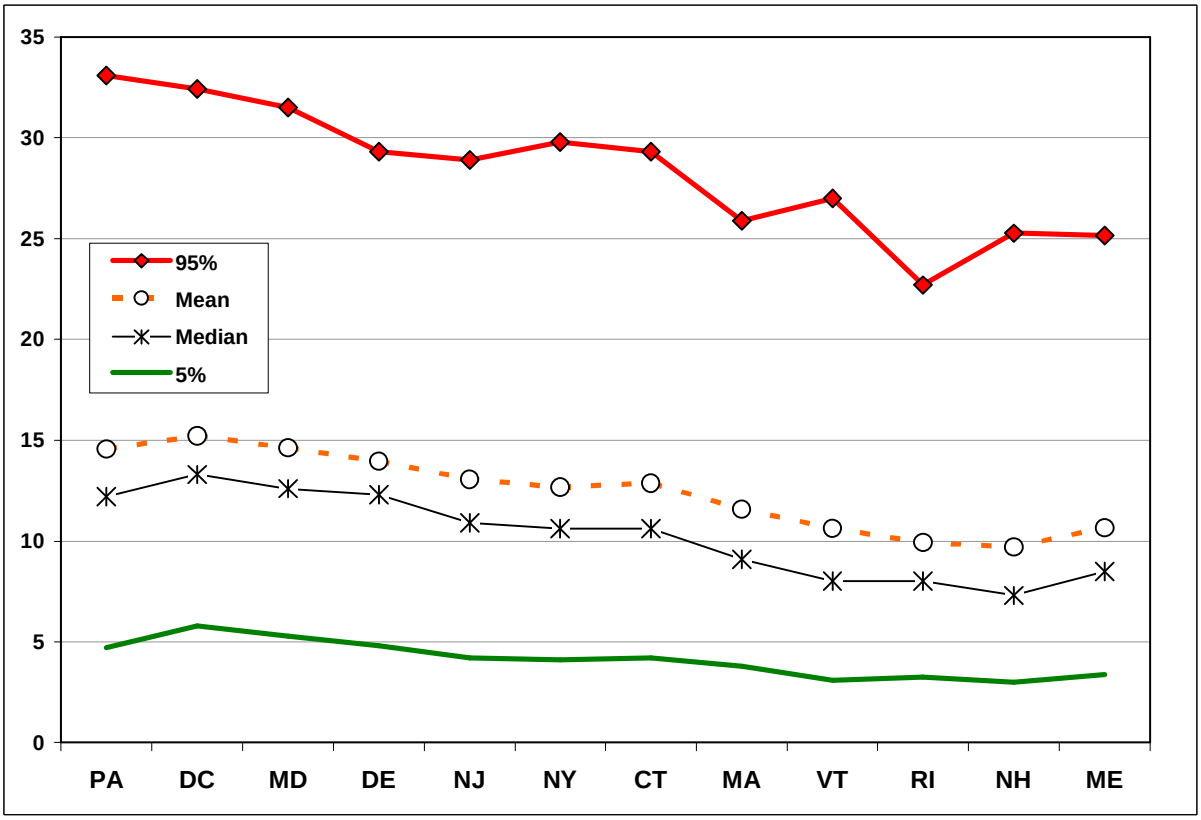
Tabular data is valuable but can be hard to interpret and so selected urban data from Table III-1 are shown graphically in Figure III-1. This approach is helpful in that comparisons between states are more easily made. However, note that slightly rearranging the order of Table III-1 data can give a different perspective. In Figure III-2, MANE-VU monitoring agencies are arranged (approximately) by geographical location along an axis running from Southwest to Northeast.

Figure III-1: Regional Urban $PM_{2.5}$ statistics arranged alphabetically by state.



One interpretation of Figure III-2 is that the impact of fine particle source regions to the west and south of MANE-VU declines, through dispersion the further one travels from those regions. It is also evident that the trend toward lower values does not occur only in the statistical extremes of Table III-1 (i.e., minimum and maximum) but is present throughout the range of concentrations. Because the down-trend in concentrations occurs across a heavily populated portion of the U.S., the decline must be occurring at a faster rate than fresh, primary emissions are being added. Note too that some of the most heavily populated portions of the region (persons/mile^2) occur near the middle portion of the curve in Figure III-2 [http://fedstats.gov/qf/stats/42000.html]. Although the down-trend curve flattens out somewhat in the middle, population density is not the sole driver of this trend. Recall that $PM_{2.5}$ samplers are required in all the most populous areas of each state and there is much overlap in the population densities represented by sites from different organizations.

Figure III-2: Regional Urban $PM_{2.5}$ statistics arranged along a Southwest to Northeast axis



A.2 Time Series of 1-in-3 Day Samples

To further explore the 1-in-3 day data, time series graphs for all sites in MANE-VU were generated. After initially assessing several dozen such graphs from various parts of the region, it became apparent that site-to-site differences were relatively minor. As a result, state-wide time series graphs were developed to give a general sense of the level and distribution of $PM_{2.5}$ concentrations across the region.[6]

Time series graphs from selected states thought to be representative of the northern and southern portions of MANE-VU are displayed in Figures III-3 through III-5. In general, 1-in-3

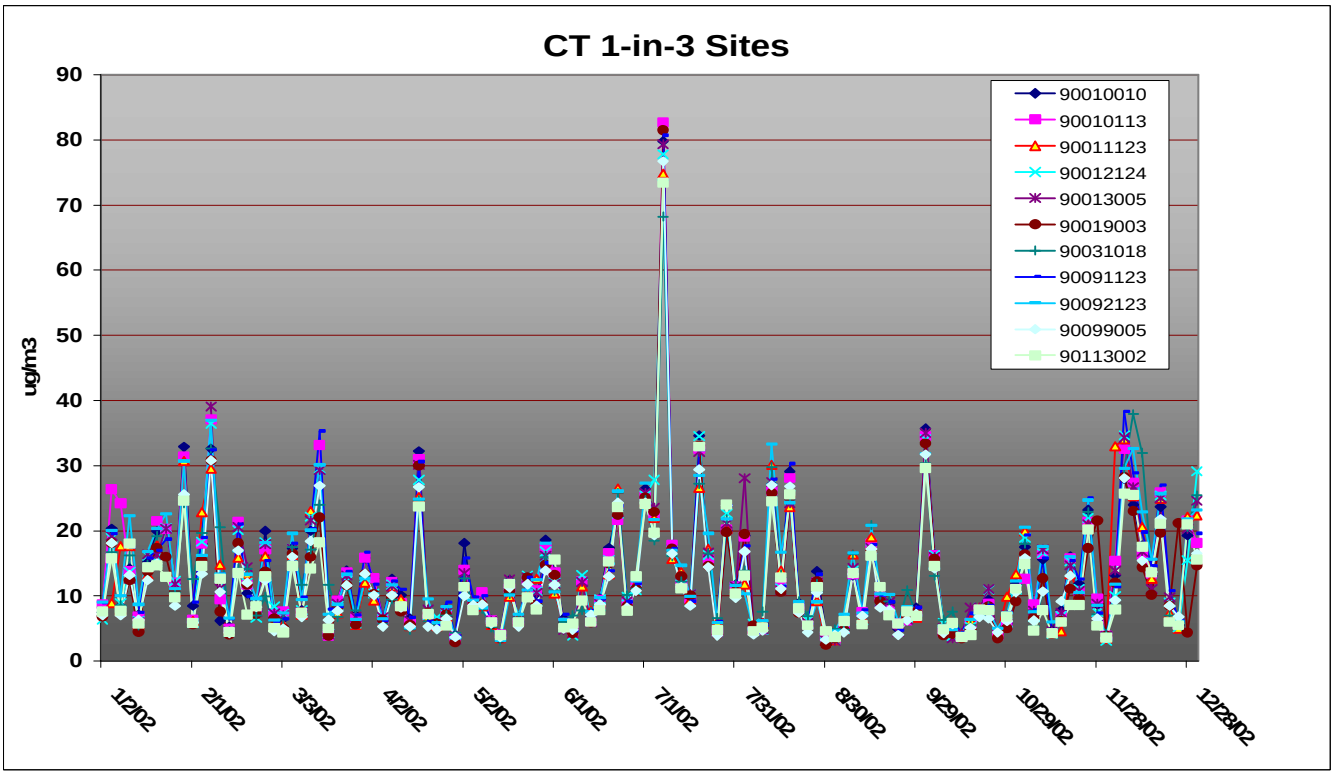
[6] Although sources of regional haze do not arise within nor respect political boundaries, there is some logic in assessing data on a state-by-state basis. Before initiating $PM_{2.5}$ measurements, State monitoring organizations must draft quality assurance project plans (QAPPs) that meet national guidelines issued by USEPA. QAPPs cover all phases of data collection from equipment purchase and operator training through data assessment and reporting. Once approved, QAPPs guide the creation, operation and revision of all PM networks within the State. Monitoring organizations typically minimize operational variables by deploying uniform networks (i.e., equipment from a single manufacturer) and although some sub-State level programs (tribal, county and city) are present within the MANE-VU region, the impact of differences between those organizations and State-operated programs is believed to be minimal. Therefore, it was felt that state-level data sets possessed sufficient uniformity and coherence for these analyses.

day samples from sites throughout MANE-VU show a similar pattern for 2002 but small differences were evident on a seasonal basis and are described in the following examples.

Connecticut

Figure III-3 displays 1-in-3 day FRM data for calendar year (CY) 2002 from Connecticut (CT). Although substantial peaks (>30 µg/m^3) are evident in all seasons, the dominant feature is the spike on 7/7/02 caused by smoke from Canadian wildfires which impinged on many Northeastern and Mid-Atlantic States. Note also that values in CT rarely drop below 5 µg/m^3.

Figure III-3: 2002 $PM_{2.5}$ samples from sites in Connecticut with > 75% data capture.



Concentrations at sites across the state rose and fell in unison from day to day. This spatial pattern, in which relatively large areas exhibit similar concentrations, is a common feature across the MANE-VU region. Note too the "spikiness" in this data set, with large differences in concentration from one sample to the next. Large sample-to-sample variation in 1-in-3 data is often an artifact of the sampling schedule and is discussed in more detail in Section B.1 along with other sample schedule artifacts.

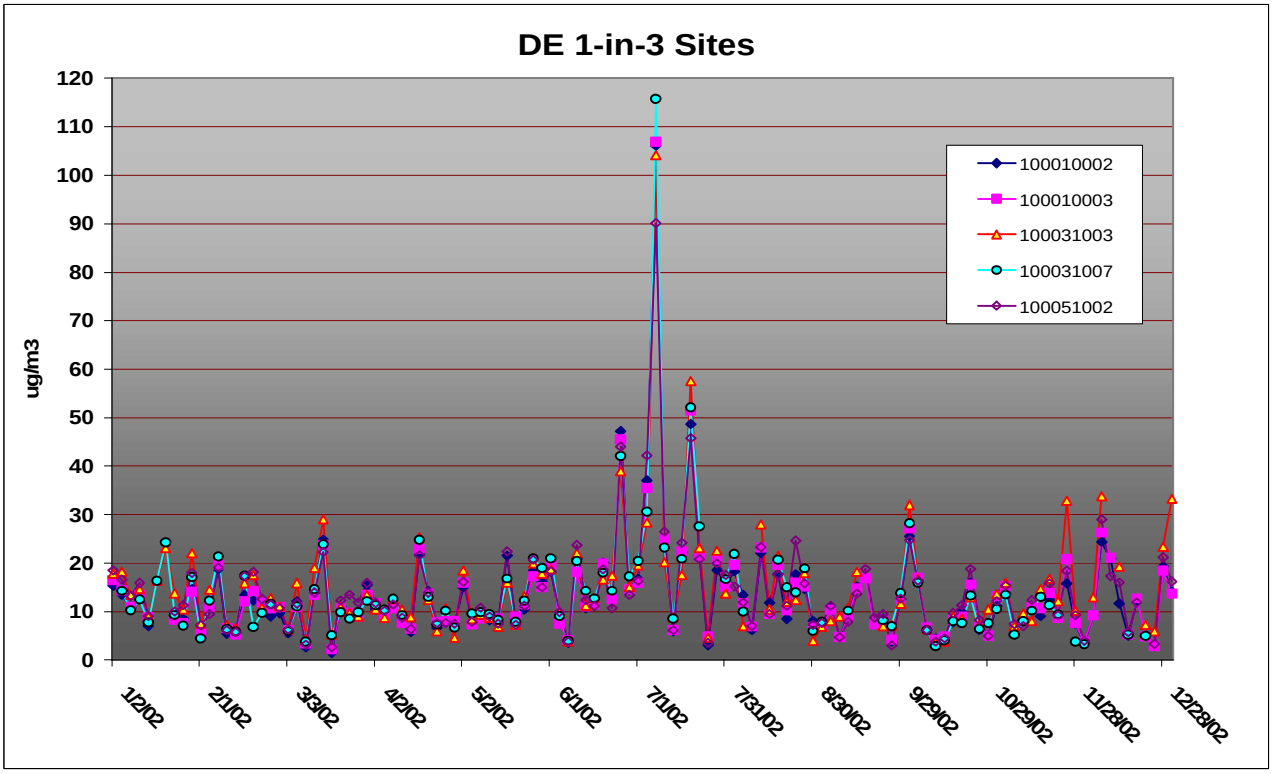
Delaware

Figure III-4 shows 1-in-3 data from Delaware (DE) for 2002. The 7/7/02 wildfire peak is even more prominent in the DE data (115.8 µg/m^3) due to meteorological conditions that controlled the locations and extent of the smoke plume impact. As with many states in the southern portion of the MANE-VU region, DE peak values in the first half of the year do not

exceed the 30 µg/m^3 level nearly as often as more northerly states although concentrations in the fall and winter reach and exceed that level.

Also, note the 40 µg/m^3 (and greater) peaks immediately preceding and following the wildfire spike. Those peaks are associated with stagnant, high pressure air masses rich in photo-chemically derived secondary aerosols which periodically impact portions (or all) of the MANE-VU region. Sites from northern portions of the region show much lower peak values surrounding the wildfire spike.

Figure III-4: 2002 $PM_{2.5}$ samples from sites in Delaware with > 75% data capture.



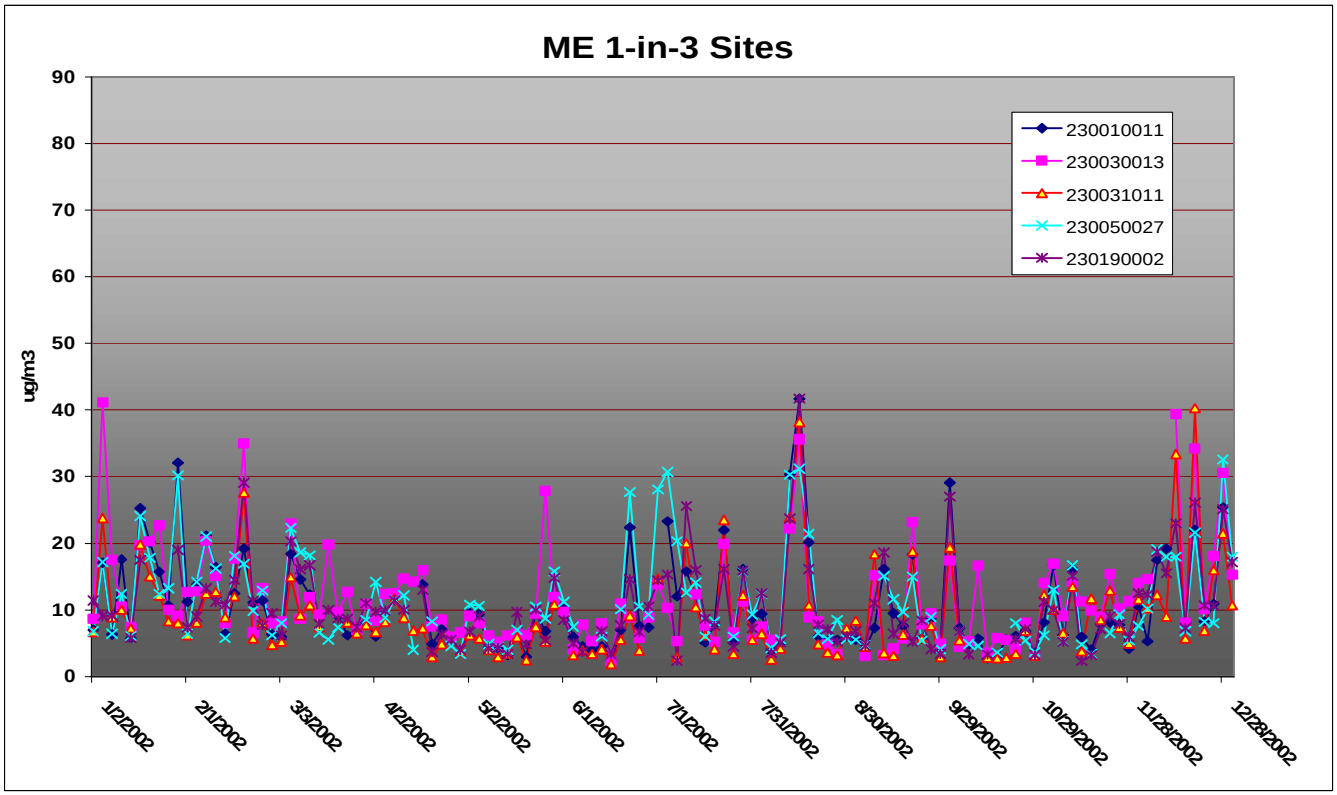
Maine

Figure III-5 shows 1-in-3 data from Maine (ME) for 2002. Although the 2002 data from all other states in MANE-VU can be approximated by a rough "W" shape (high in winter and summer, low in spring and fall) ME is the exception. There is a hint of reduced spring/fall concentrations but ME data is relatively even throughout 2002.

The relative flatness of the ME data is due to the lack of summertime "episodes" during 2002. The early-July Canadian wildfire plume did not heavily impact the state of Maine due to the presence of a slow moving low pressure system that channeled smoke southward to the west of the state. It appears that many stagnant air masses that brought high $PM_{2.5}$ loadings to the MANE-VU region were similarly blocked from reaching Maine. These findings point to the

important role that meteorology plays in the spatial distribution of fine aerosols and regional haze.

Figure III-5: 2002 $PM_{2.5}$ samples from sites in Maine with > 75% data capture.



A.3 Everyday FRM Samples

A total of 31 sites in the MANE-VU region collected "everyday" $PM_{2.5}$ samples and had at least 75% completeness on an annual basis during 2002. There are 10,260 valid observations among these data.

While comparing everyday sample results with 1-in-3 day results it became apparent that the advantage of more frequent sampling at "everyday" sites was offset by the limited number of such sites. For example, a quarter of the MANE-VU States have no "everyday" sites (Maine, New Hampshire and Vermont). Additional information on the impact of sampling schedules is contained in the Section B.1. It should also be noted that USEPA guidance calls for locating everyday samplers in areas expected to have the highest readings (*40 CFR 58, Appendix D, Section 3.7.7.1-4*). Although not shown, a statistical analysis of "everyday" vs. "1-in-3 day" sites does show slightly higher values at everyday sites. The difference was evident on a state-by-state basis as well as on a regional basis throughout MANE-VU.

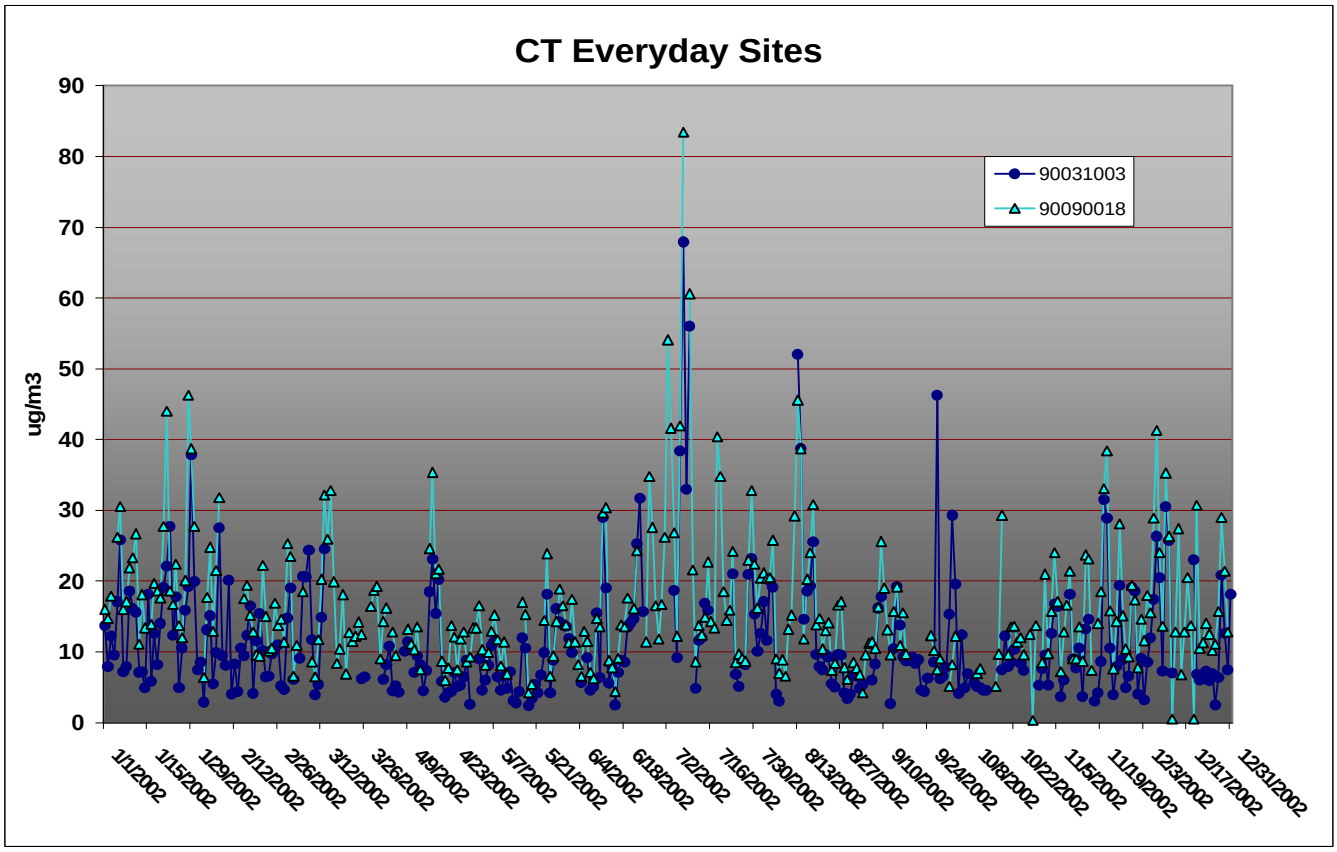
A.4 Time Series of Everyday Samples.

Everyday sampling fills the gaps evident in 1-in-3 schedule and smoothes out some of the "spikiness" shown in Figures III-3 and III-4. Times series graphs of everyday data are presented for CT and DE to allow comparison with the corresponding 1-in-3 day time series.

Connecticut

Everyday samples from CT (Figure III-6) show the same general pattern as the 1-in-3 samples. Everyday peak values are somewhat higher (which may be related to the siting requirements noted above) and a few new "spikes", not apparent in the 1-in-3 data, are evident near mid-August and mid/late-November.

Figure III-6: 2002 daily $PM_{2.5}$ data from CT sites with >75% data capture.

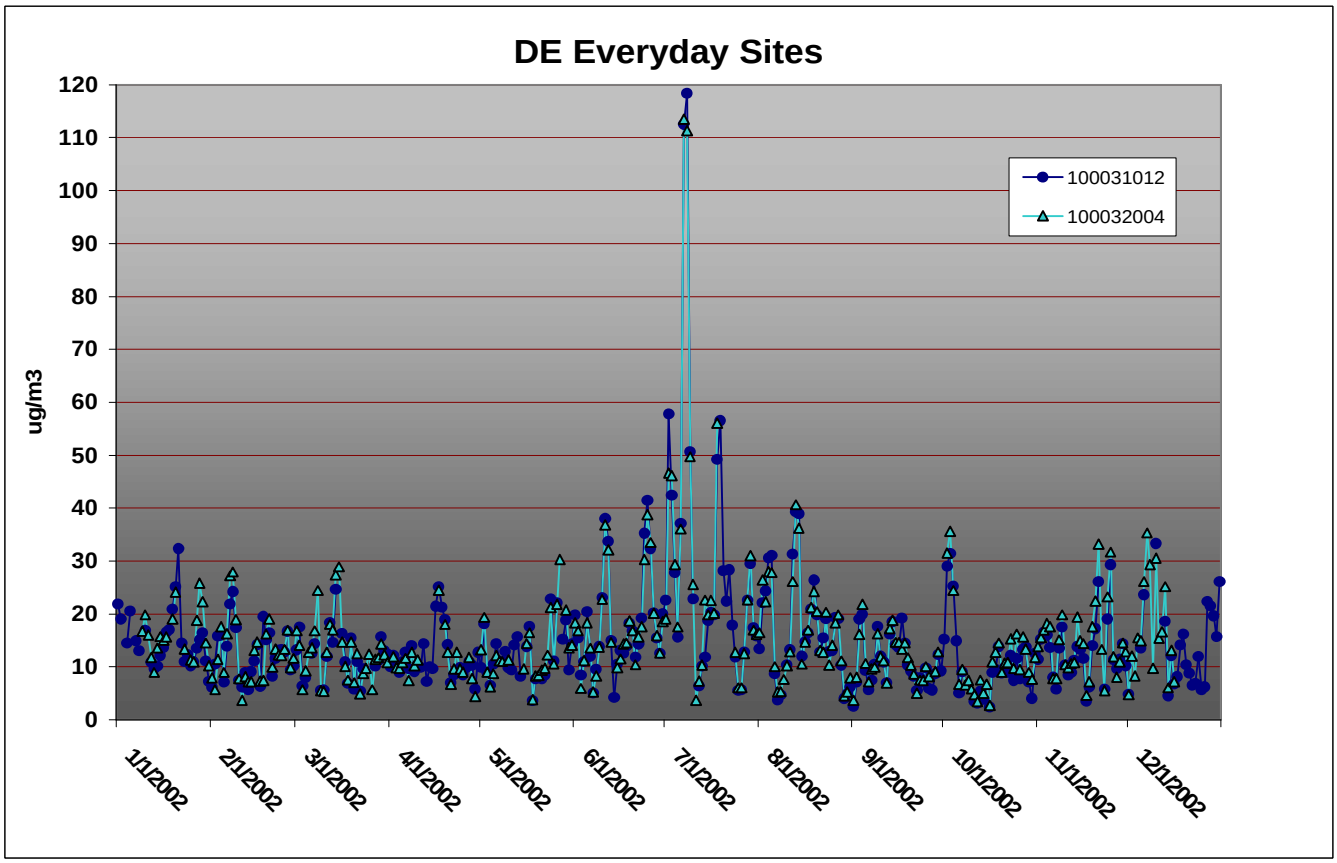


Delaware

Everyday samples from DE (Figure III-7) are very similar to 1-in-3 samples from that state and, as with the CT data, everyday sampling revealed two noteworthy episodes not caught by the less frequent schedule. The mid-August episode is significant (exceeding 40 µg/m^3) while the mid-November episode peaks at just under 30 µg/m^3 (average of both sites).

The DE sites are typical of the southern portion of MANE-VU during 2002 with few peaks above 30 µg/m^3 in the first half of the year, several mid-year episodes that exceed those in the north and multiple episodes above 30 µg/m^3 in the latter portion of the year.

Figure III-7: 2002 daily $PM_{2.5}$ data from DE sites with >75% data capture.

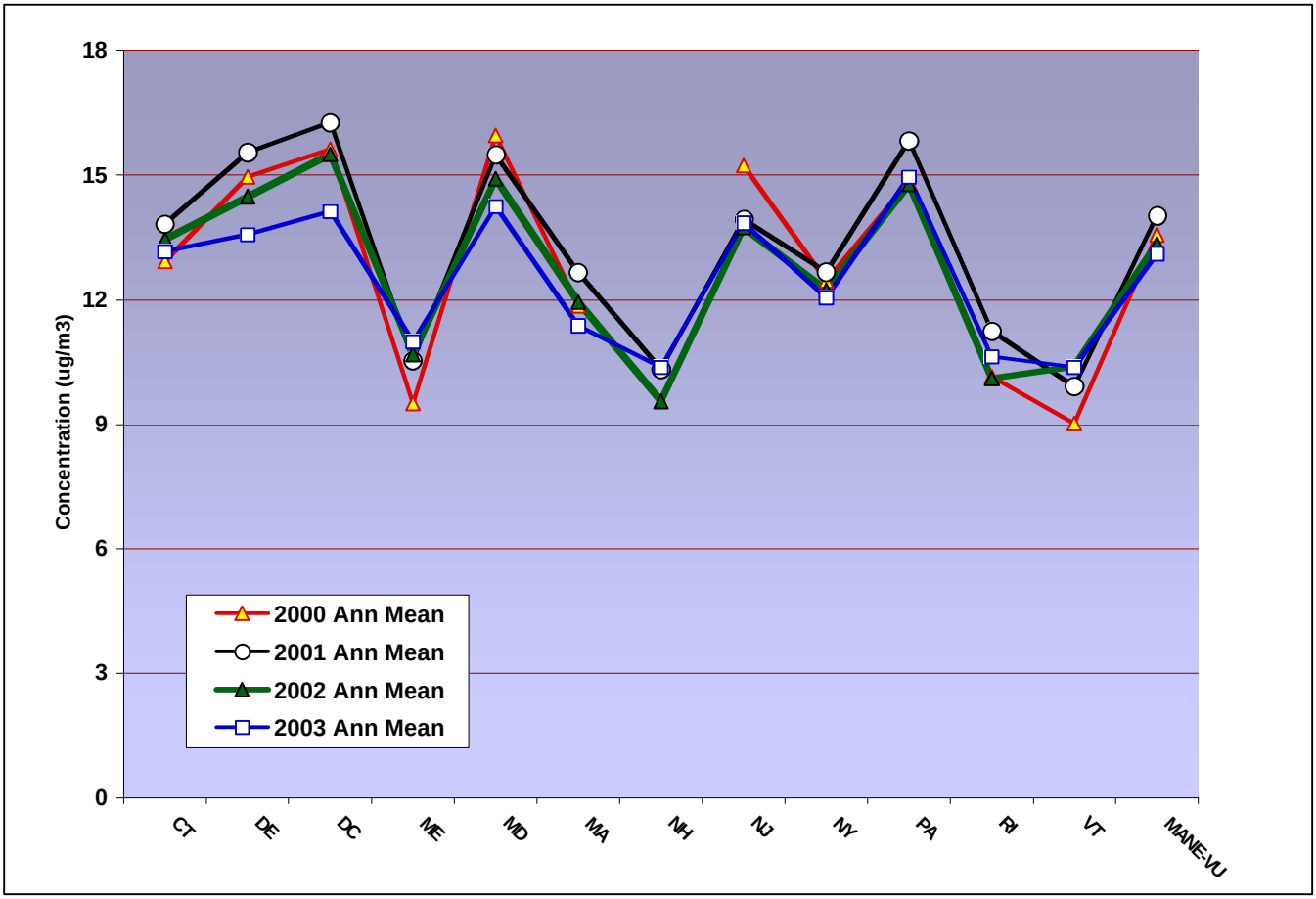


B. Temporal Patterns of PM Mass Distribution

Knowledge of "where" high fine aerosol concentrations occur is important with respect to human exposure considerations and for determining source-receptor relationships. Equally important, however, is the understanding of "when" fine aerosol concentrations are high (or low). Understanding temporal distributions can help differentiate between locally generated and transported fine particulate matter and aid in both the development and evaluation of strategies aimed at controlling the sources of fine particles. This section explores the timescales associated with changes in ambient concentration of fine particles.

B.1 Inter-annual variability

Figure III-8: Average mass from 1-in-3 FRM samplers 2000-2003.



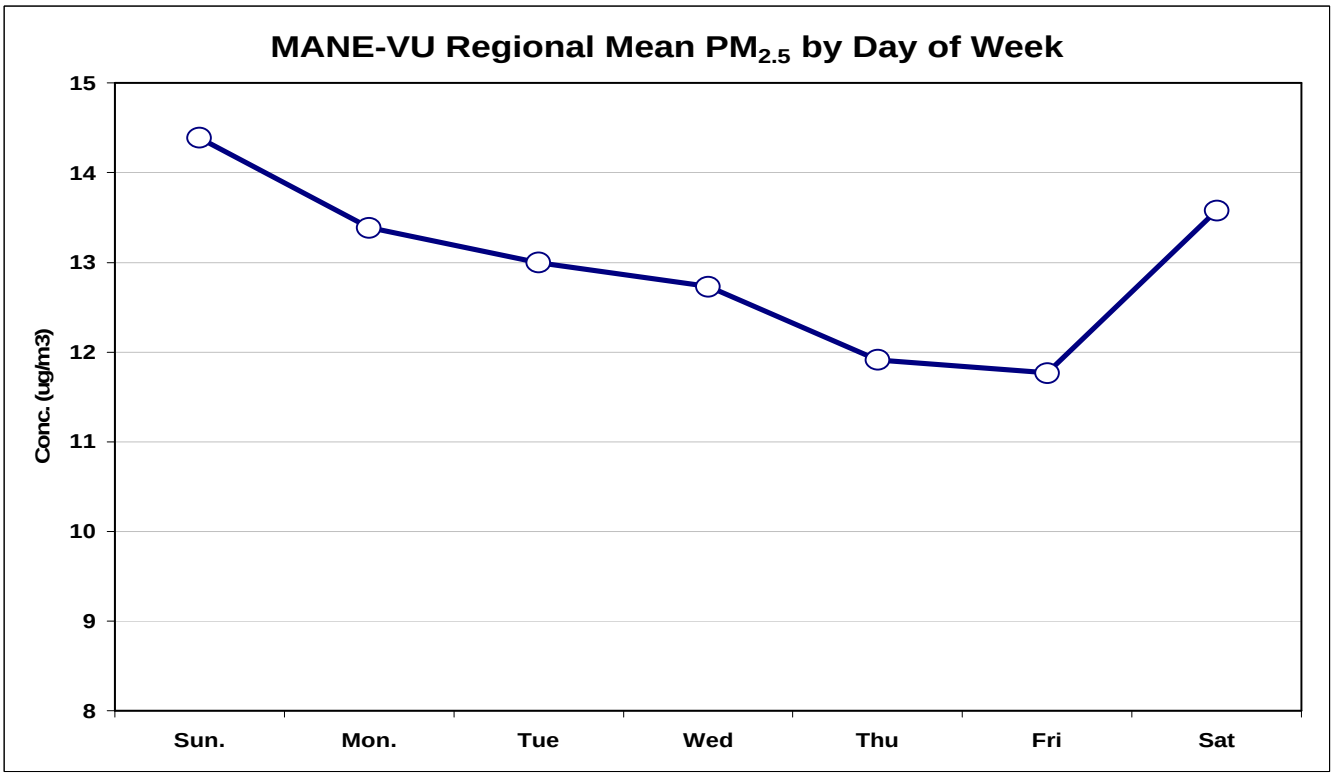
In order to assess whether the data presented for 2002 represent extreme values or whether they are typical of annual pattern of fine particle pollution, mean $PM_{2.5}$ values have been calculated by state and compared to state mean values from other years in the baseline period for the regional haze program.[7] Figure III-8 shows that, in most states, the mean $PM_{2.5}$ concentration was below the mean from other years, leading to a MANE-VU-wide mean that was slightly below the mean for other years in the baseline period (see last column). All years lie within one microgram (7.5 percent) of each other (13.01 $\mu g/m^3$ – 14.02 $\mu g/m^3$) suggesting that despite 2002 having the lowest mean across the MANE-VU domain, it is not anomalous and can be considered representative of the baseline period.

[7] Baseline visibility conditions for the regional haze program are to be calculated for data from the calendar years 2000 through 2004. Data for calendar year 2004 are not yet available.

B.2 Weekday vs. Weekend Mass Distribution (1-in-3 and Everyday)

Because the majority of fine particulate is believed to arise from anthropogenic sources (at least in populated regions of the Eastern U.S.), it is possible that one might discern differences in $PM_{2.5}$ distributions in response to both short duration and long duration human activities. One regularly occurring short-term pattern of interest is the Monday through Friday five-day "work week" followed by a two-day weekend. In most areas of the MANE-VU region the weekdays are characterized by higher emissions from both stationary and mobile sources due to workers commuting to classic "40 hour per week" jobs. Weekends are typically lower in both stationary and mobile emissions because of reductions in commuting as well as industrial/commercial emissions.

Figure III-9: Average mass from 1-in-3 FRM samplers during 2002.

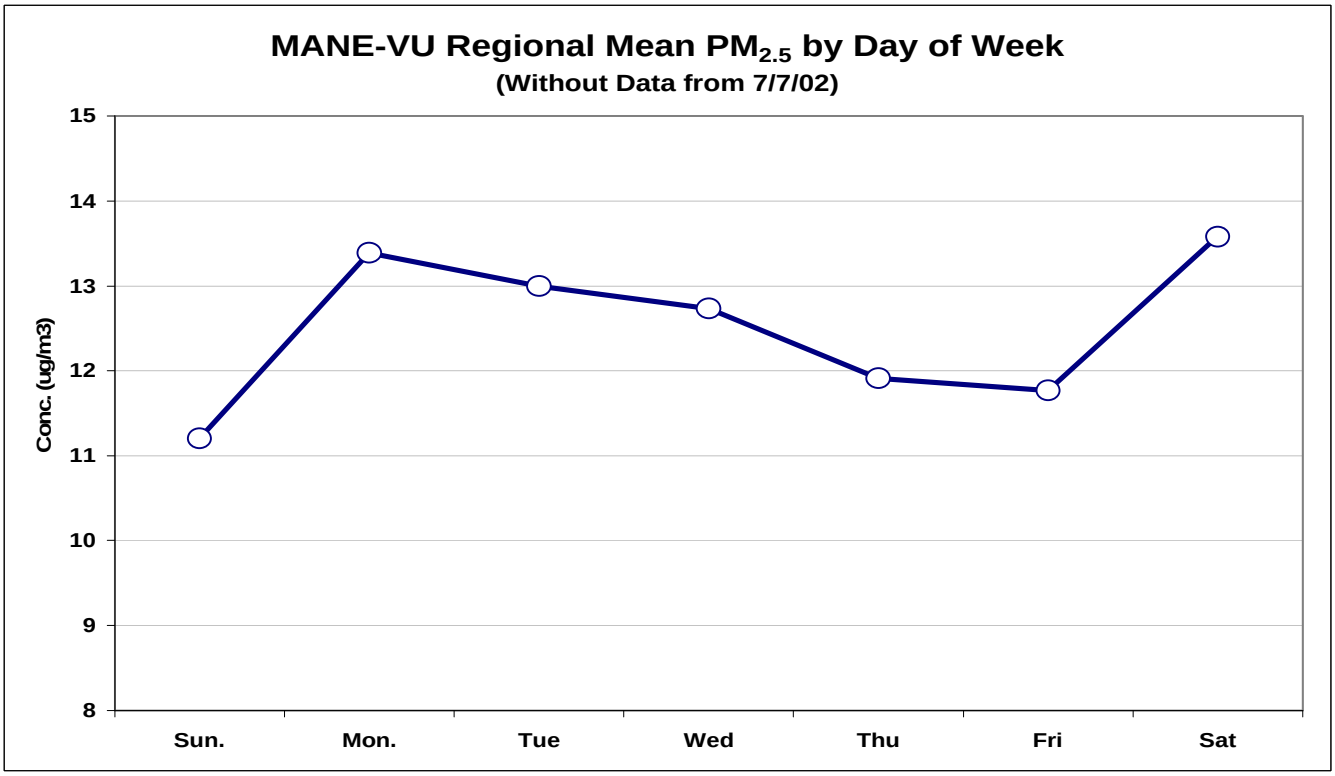


In-depth analysis of day-of-week (DoW) patterns is not practical for the 1-in-3 day sample data because of the limited number of data points available (i.e., a maximum of 17 points per day per year assuming 100% data collection). The mean regional 2002, 1-in-3 FRM mass distribution by day of week is plotted in Figure III-9 to illustrate the point. The mean regional values are the daily averages of the 133 FRM samplers running on the 1-in-3 day schedule.

Although derived from an extremely robust data set (14,950 observations) Figure III-9 is biased by a small number of high concentrations. One example is the Canadian wildfire event

which was captured near its peak by the 1-in-3 day sampling network on 7/7/02 (a Sunday). Figure III-10 shows the same data as in Figure III-9 except that observations from 7/7 have been removed. Censoring this single sample day (out of 17 Sundays) lowers the average Sunday value from 14.4 µg/m^3 to 11.2 µg/m^3 - a reduction of over 22%.

Figure III-10: Average mass from 1-in-3 FRM samplers during 2002 without wildfire data.



Large-scale photochemical and stagnation events in 2002 also impacted days other than Sundays. As was seen above, incomplete sampling (less than everyday) can bias DoW (and other) analyses. Therefore, a closer look at the impact of FRM sample scheduling is in order.

Table III-2 shows data from the first 30 days of 2002 along with four columns of data for each day. Daily mean data for the MANE-VU region is shown in the first column. These mean values were derived by averaging results from the 31 everyday FRM sites (both urban and rural) in MANE-VU that reported at least 75% data capture for 2002. Data from January 31 is excluded in order to have exactly 10 data triplets. The three schemes shown in the table refer to possible 1-in-3 day sampling schedules that could be used. In 2002, "Scheme B" coincides with the USEPA-mandated 1-in-3 day sampling schedule since the first sample day was Jan. 2.

Table III-2: The three possible 1-in-3 day sampling schemes for 2002.

Impact of Sampling Schedule on $PM_{2.5}$ Concentrations				
	Mean Reg. $PM_{2.5}$	Scheme "A"	Scheme "B"	Scheme "C"
1/1/02	13.4	13.4		
1/2/02	12.3		12.3	
1/3/02	13.1			13.1
1/4/02	10.7	10.7		
1/5/02	17.8		17.8	
1/6/02	25.7			25.7
1/7/02	9.6	9.6		
1/8/02	11.4		11.4	
1/9/02	17.5			17.5
1/10/02	19.5	19.5		
1/11/02	14.1		14.1	
1/12/02	11.9			11.9
1/13/02	7.7	7.7		
1/14/02	10.5		10.5	
1/15/02	12.8			12.8
1/16/02	9.2	9.2		
1/17/02	14.5		14.5	
1/18/02	11.9			11.9
1/19/02	17.5	17.5		
1/20/02	19.7		19.7	
1/21/02	27.2			27.2
1/22/02	14.3	14.3		
1/23/02	11.9		11.9	
1/24/02	16.5			16.5
1/25/02	7.6	7.6		
1/26/02	10.9		10.9	
1/27/02	18.9			18.9
1/28/02	23.8	23.8		
1/29/02	23.2		23.2	
1/30/02	13.5			13.5
Mean =	***15.0 ug/m^3***	***13.3 ug/m^3***	***14.6 ug/m^3***	***16.9 ug/m^3***

If the mean of the everyday schedule is used as a base value, the sampling schemes will vary from the base by -1.7 µg/m^3 (-11.3%) for scheme "A" and 1.9 µg/m^3 (+12.6%) for scheme "C". USEPA acknowledges the possibility of such sample schedule artifacts and, in order to minimize them, requires three complete years of data when calculating design values.

When attempting to use data from relatively short time periods (e.g., CY 2002) it can be instructive to compare data from various sampling schedules to ascertain the presence of undue sampling schedule bias. Figure III-11, although similar to Figure III-9, is derived exclusively from everyday data (urban and rural sites). In Figure III-10 the "Scheme B" data is simply the MANE-VU mean regional everyday data set that has been censored (non-sample day data was removed) to mimic the actual 1-in-3 day schedule employed during 2002. Fine particle mass

Figure III-11: Regional $PM_{2.5}$ data from 31 everyday FRM samplers in MANE-VU.

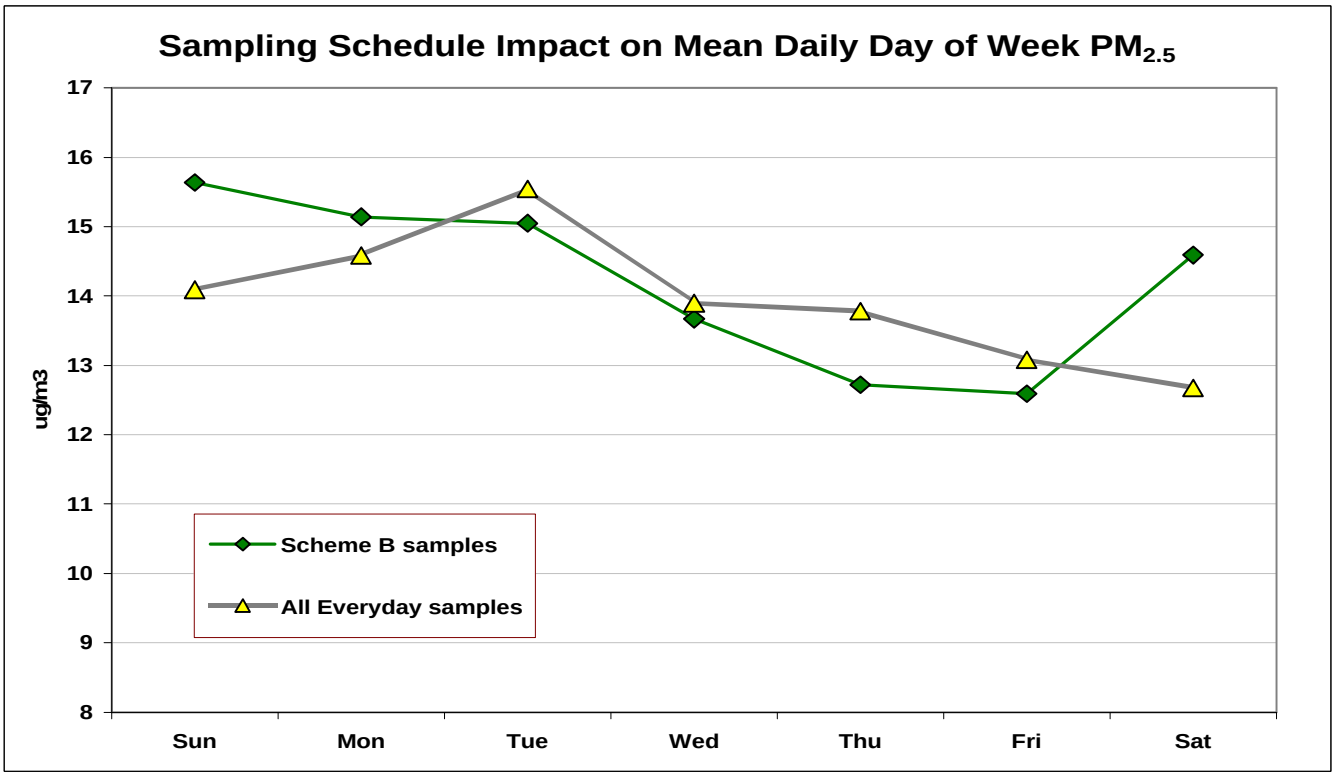
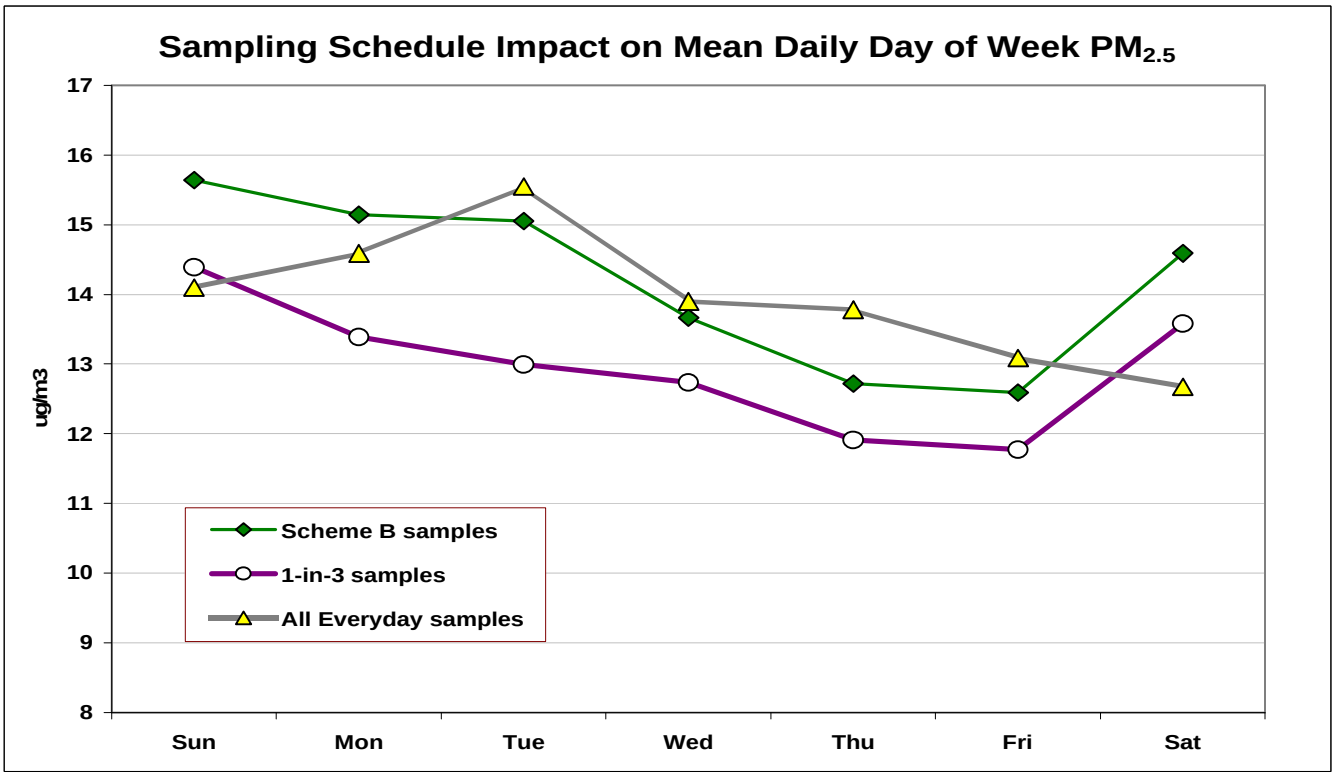


Figure III-12: Mean regional $PM_{2.5}$ data as derived from both 31 everyday FRM samplers and 133 1-in-3 day samplers in MANE-VU.

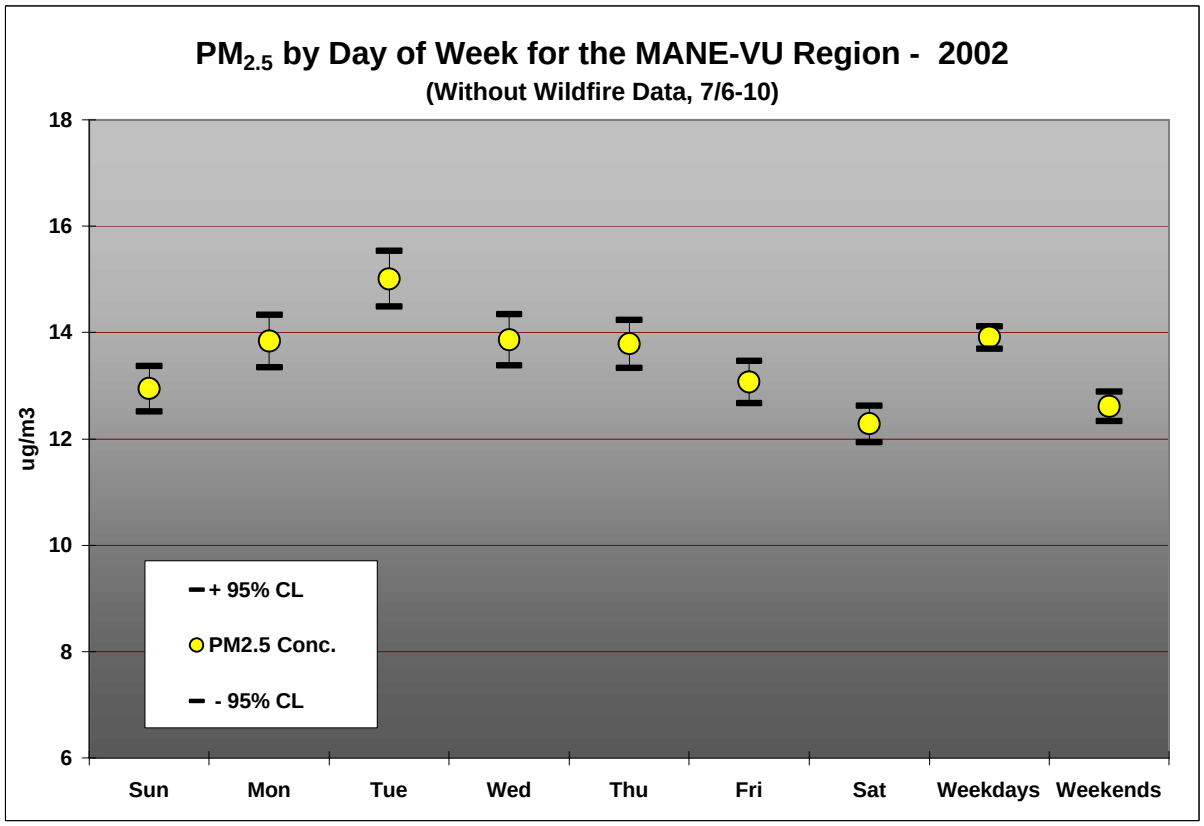


concentrations appear greatly over-reported by the Scheme B schedule. As previously noted, USEPA guidance calls for locating everyday samplers in areas expected to yield higher concentrations. Those siting requirements could play a role in the weekend bias observed here.

Note, in Figure III-12, the effect of comparing 1-in-3 day data (from sites expected to have lower concentrations) to everyday data. As expected, the 1-in-3 data show lower concentrations across the board compared to Scheme B (by 1-2 $\mu g/m^3$). Both the 1-in-3 and Scheme B data over-report weekend values because they do not include all the lower weekend values captured by the everyday schedule. Data from everyday sites display the expected higher concentrations (due to siting considerations) but there does not appear to be an undue bias in the 1-in-3 day site data, other than that noted above from non-sample days.

The "everyday" FRM data set is more robust for DoW analysis than the 1-in-3 data even though it comprises only 31 sites as opposed to 133. Figure III-13 shows mean $PM_{2.5}$ mass data for the MANE-VU region from the 31 "everyday" sampling stations. Because of the highly variable impact on analysis, data from the early July wildfires (July 6th through 10th - inclusive) were not included. In addition to showing the mean mass distribution by day-of-week, Figure III-12 shows categories for "Weekdays" (Monday through Friday) and "Weekends" (Saturday and Sunday) as well as 95 percent confidence levels (CLs) for all data points.

Figure III-13: $PM_{2.5}$ mean mass data from 31 sites with at least 75% data for 2002.



The day-of-week mass distribution in Figure III-13 is not similar to either Figures III-9 or III-10, but it is more in line with classical understanding of weekly fine particle distributions in urban areas. Although there is overlap in the confidence levels for several days, Saturday confidence limits are lower than all weekday confidence limits except Friday. Tuesday confidence limits are higher than all but Monday confidence limits. This pattern, or a variant of it, has been often noted in other regions. It is driven both by generally higher stationary source emissions on weekdays and by mobile source use which tends to peak near mid-week – typically Tuesdays or Wednesdays.

However, the CLs for "Weekdays" and "Weekends" do not overlap indicating that, during 2002, at least, weekdays in the MANE-VU region were statistically more likely to experience high $PM_{2.5}$ concentrations than weekends consistent with the stationary and mobile source activity patterns noted above.

B.3 Creating "FRM-like" Hourly Data

Although there have been many calls for approval of a continuous mass measurement method, USEPA does not recognize any continuous fine aerosol measurement technique as being equivalent to the current FRM $PM_{2.5}$ measurement technique. USEPA's reluctance to approve a continuous method is, in part, grounded on comparison studies which have demonstrated that continuous monitors do not accurately reproduce FRM results on a national basis (*R. Scheffe, USEPA, personal communication*).

The inaccuracies are generally linked to the above-ambient temperatures employed by most continuous monitors to prevent collection or formation of liquid water within the monitor. Because the sample filter in the FRM sampler is maintained at no more than 5^oC above ambient temperature, some percentage of the volatile and semi-volatile materials that collect on the filter remain there. However, raising the collection filter temperature to 30^oC or 50^oC (typical internal temperatures in continuous monitors) drives off a considerable portion of the volatile and semi-volatile mass. The farther that ambient temperature departs from the operating temperature of the continuous monitor, the larger the loss of mass. Thus, in the MANE-VU region where the vast majority of PM monitors operate at elevated internal temperature, continuous fine particle mass data needs the largest correction during the winter season.

In order to develop a comprehensive set of continuous PM data for the MANE-VU region, a consistent approach was used to present all raw continuous data on a single FRM like scale.[8] Appendix B has a detailed description on how MANE-VU continuous PM data was converted to FRM-like data for purposes of the following analyses.

[8] The approach selected for use here, focusing on the Julian Day of the year, was developed by Dirk Felton of the NY DEC. The Julian Day (JD) acts as a surrogate for ambient temperature and, when properly correlated and regressed with respect to FRM data the method produces FRM-like data that meets the USEPA-required correlation coefficient (R^2) of 0.82 or greater.

B.4 Statistics on FRM-like Hourly Data

A total of 20 sites in the MANE-VU region hosting continuous monitors collected at least 75% of all possible hours (8,760) in 2002 and also collected at least 75% of the data from the collocated FRM sampler. As noted earlier, two of the 20 sites are in rural/remote areas and are not included in all analyses discussed in this section although they are included in Table III-3 which summarizes basic statistical data from the continuous monitors. The data in Table III-3 have been adjusted to be FRM-like.

Table III-3: Summary of FRM-like continuous fine particle measurements for 2002.

FRM-like Hourly Data (ug/m ^{3}) - 2002								
	CT	DE	ME	NJ	NY	PA	VT	MANE-VU
# Sites	3	1	3	4	4	3	2	20
# Obs.	25,991	8,300	25,656	33,637	34,080	25,650	17,436	170,750
Max	146	237	119	165	211	198	117	237
0.95%	33.8	40.8	27.9	35.2	33.2	44.6	30.4	34.7
0.90%	26.3	30.6	21.7	26.8	24.8	33.2	23.7	26.3
75%	17.3	20.3	14.3	17.2	15.1	19.7	15.0	16.7
Median	10.5	13.0	8.7	11.0	9.1	11.9	8.1	10.1
Mean	13.2	15.9	10.9	13.9	12.0	16.2	10.8	13.1
25%	5.8	7.2	4.9	6.9	5.1	7.2	3.9	5.7
10%	2.6	3.1	2.1	4.0	2.5	3.9	1.5	2.7
5%	1.1	0.8	0.9	2.6	1.4	2.2	-0.9	1.3
Min	-1.7	-6.1	-7.0	-4.3	-12.4	-2.1	-6.6	-12.4

Although not accepted by USEPA for NAAQS attainment-related issues, continuous (hourly) fine aerosol data has great value. Hourly fine particle data is used exclusively in generating daily air quality index (AQI) data and is used extensively by epidemiologists and other health effects researchers.

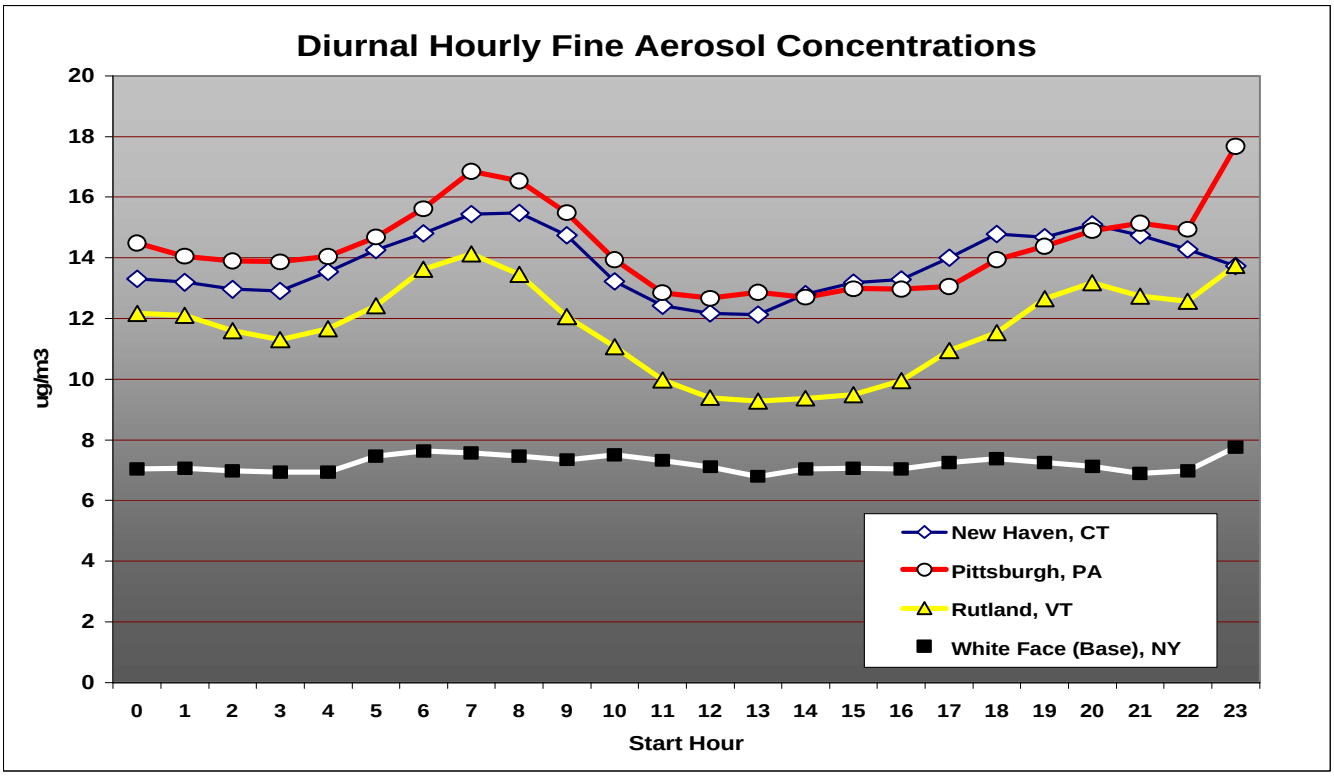
One advantage of hourly data is that it retains extreme peak values that are averaged out by daily sampling. By comparing the maximum hourly values shown here with maximum 1-in-3 day and everyday FRM values in Tables III-1 we can see that the hourly data displays peak values twice those of the FRM samples. It is this type of information that makes hourly data invaluable for health effects related work where short-term, extreme exposures may have importance.

B.5 Diurnal Mass Distribution

In addition to its utility in health effects work, hourly data can be useful in identifying the impact of some sources of pollution. Data from continuous monitors at rural sites have been separated from urban/suburban data in order to preserve their inherent differences. Figure III-14 shows the fine aerosol diurnal pattern at three urban and one rural site. The most obvious difference between these site types is the "flatness" of the rural trace. Because there are so few

sources nearby, the diurnal trace from the White Face Mt. site in upper New York State only varies from its mean daily value by about 0.4 µg/m^3 at any time of the day. This is in sharp contrast to the nearly 2 µg/m^3 (or greater) variations at the urban sites.

Figure III-14: differences in annual diurnal patterns between urban and rural sites.



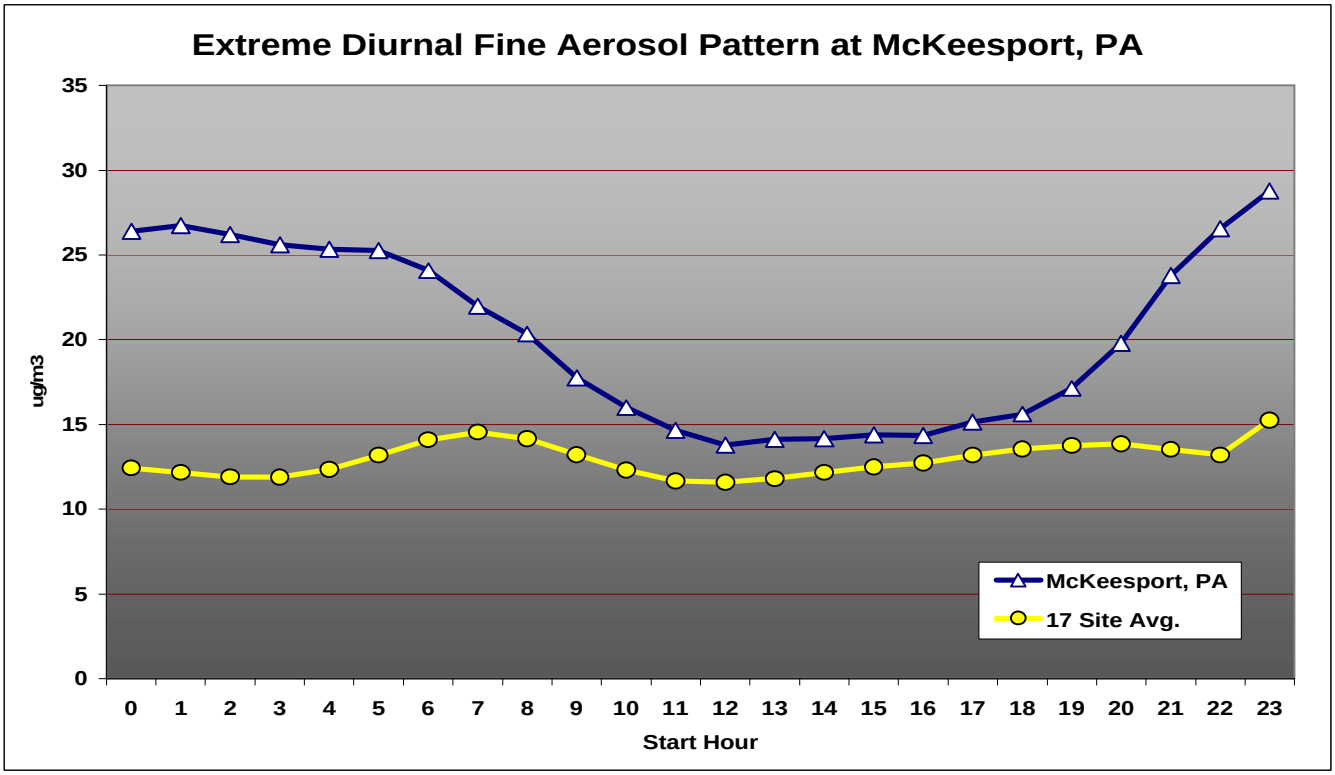
An extreme example of urban fine aerosol is evident in the data from McKeesport, PA (a suburb of Pittsburgh). Figure III-15 compares the McKeesport diurnal data with that from the other 17 continuous urban monitors in the MANE-VU region. Although McKeesport shows afternoon concentrations about equal to those throughout the region, the nighttime and morning concentrations are about twice as high as the average of all other sites in the region. The extended nighttime peak is due to the impact of a nearby source whose overnight emissions are concentrated near the surface by poor atmospheric ventilation.

Referring back to Figure III-14, note the prominent hump in the diurnal urban curves between 5 and 9 AM. These higher values are a result of both the morning commute emissions (predominantly mobile sources) and the effects of meteorology. Morning emissions in the winter (except those from tall stacks), tend to be trapped near the earth's surface until solar energy can warm the air at ground level sufficiently so that it rises and promotes good mixing. This effect traps not only mobile source emissions but also those from home heating (especially in the winter) and commercial/industrial establishments as they gear up for the day ahead.

Improved ventilation dilutes the morning "slug" of mobile source emissions as the atmosphere heats up (~10 AM – 4 PM). Subsequent emissions of all kinds occur in a relatively

well ventilated, mixed layer such that concentrations decline and remain relatively low. As the evening rush hour begins, concentrations once more begin to rise due both to the influx of fresh mobile source emissions and the reduced mixing ability of the atmosphere due to declining solar radiation. During nighttime hours concentrations remain high due to poor mixing even though fresh emissions are perhaps at their daily minimum level.

Figure III-15: 2002 atypical diurnal pattern from near Pittsburgh.



Seasonal variations in diurnal concentrations are shown in Figures III-16 through III-18. Winter diurnal patterns clearly show the impact of morning inversions on ground level fine aerosol concentrations (Figure III-16) as a prominent peak. The much smaller evening rush-hour peak is evident to some extent at all sites.

Summer measurements show a totally different pattern (Figure III-17). Although the morning rush can be discerned at some sites little else is evident. The impact of individual source types on the summertime diurnal fine aerosol pattern is highly variable (by site) and very difficult to determine.

The combination spring/fall season is, in some respects, the most clearly defined of all. The AM rush hour is clearly evident as is the PM evening commute in Figure III-18.

Figure III-16: Hourly fine aerosol concentrations during the winter season at urban/suburban sites.

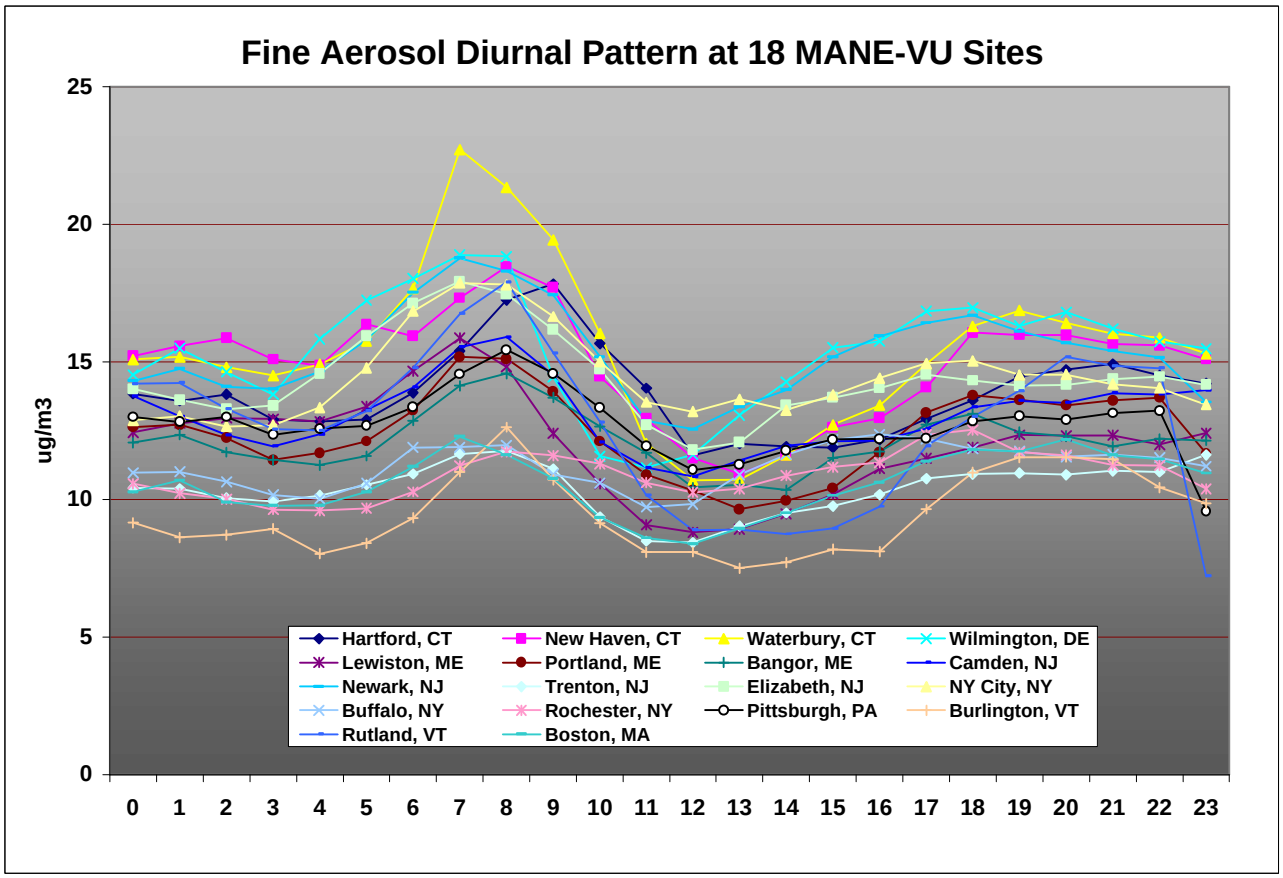


Figure III-17: Hourly fine aerosol concentrations during the summer season at urban/suburban sites.

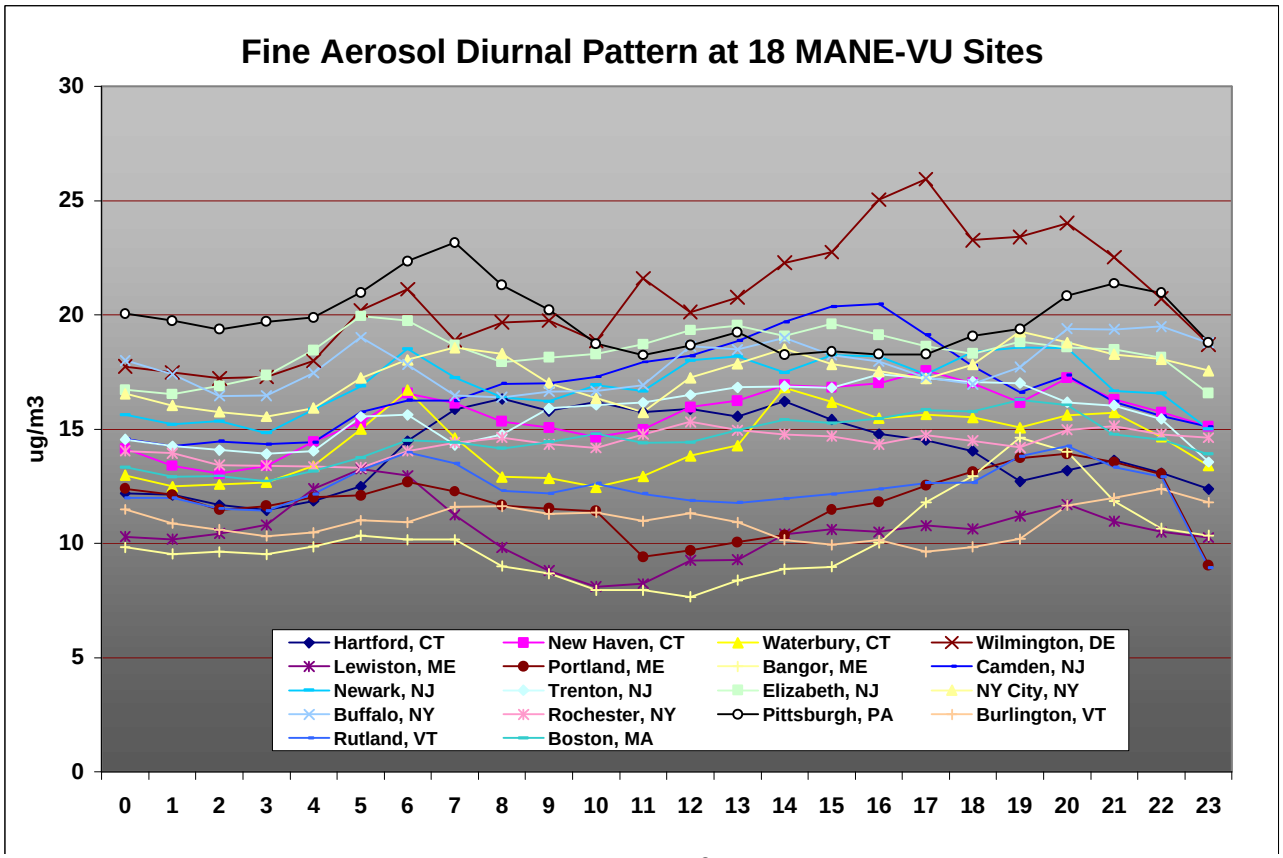
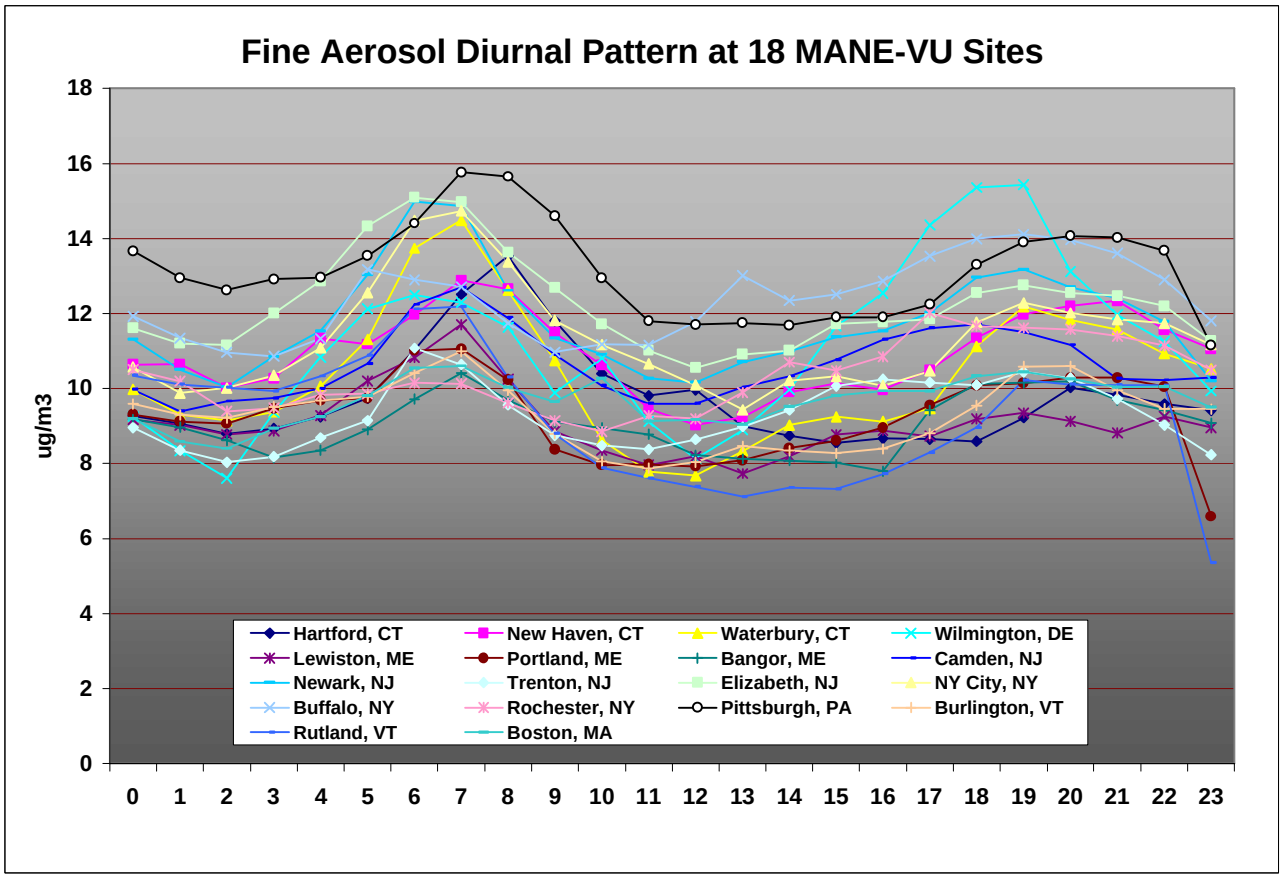


Figure III-18: Hourly fine aerosols during the combined spring/fall season at urban/suburban sites.

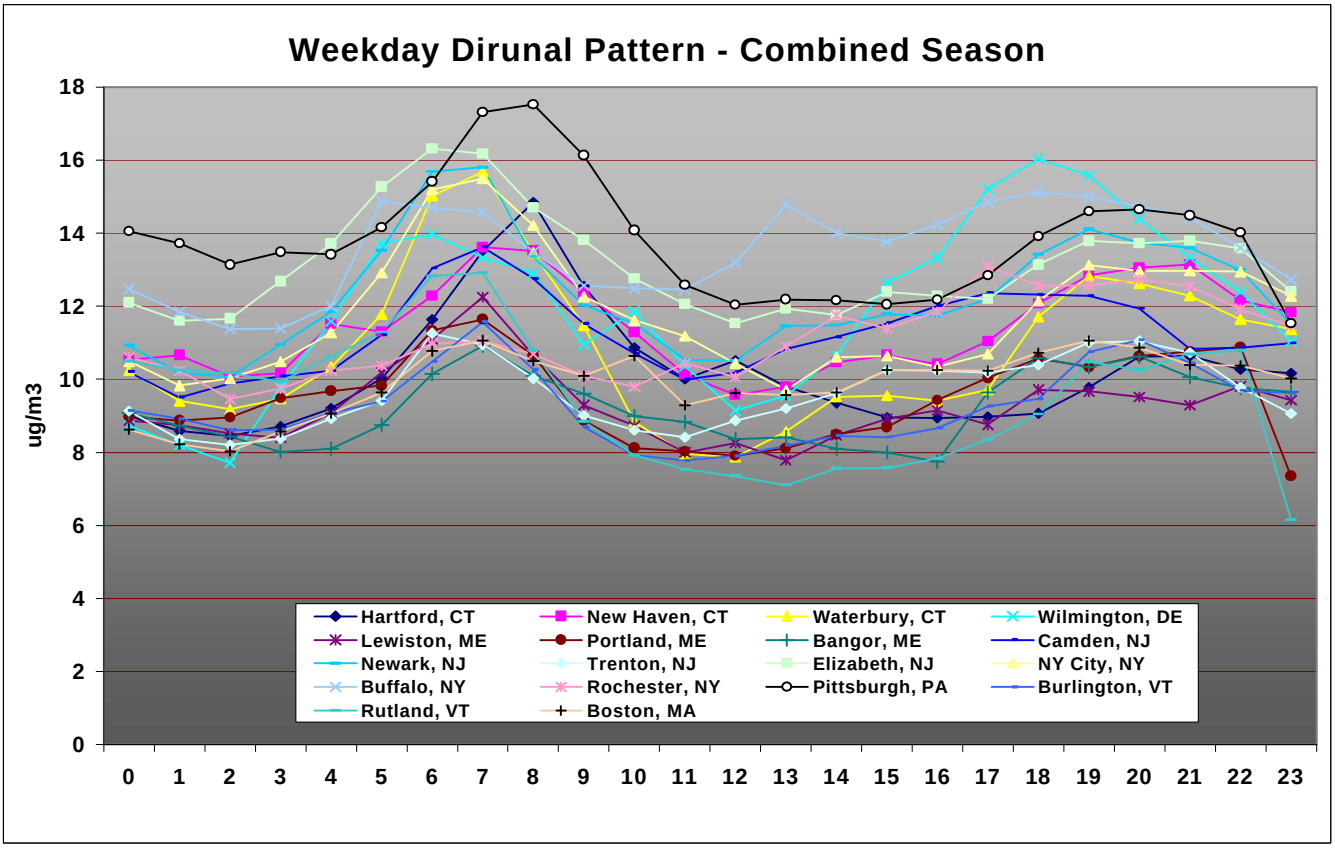


The generally higher wind speeds during the spring and fall periods leads to improved atmospheric ventilation. During those same periods, the lack of extreme temperatures reduces the possibility of both strong morning inversions and concomitant sharp increases in stationary source emissions due to increased heating or cooling demands. Therefore, the spring/fall period, without large quantities of transported material or sharp swings in stationary source emissions may be the best time to extract information on the impact of local mobile sources.

By further parsing the spring/fall hourly fine aerosol data into weekday/weekend categories we can gain some insight into the fine aerosol contribution of morning rush hour traffic. Figures III-19 and III-20 show weekday and weekend fine aerosol concentrations during the combined spring/fall season.

Note that in Figure III-19, morning rush hour peak concentrations range from about 11-17 µg/m^3 but the weekend values for the same period (Figure III-20) are reduced to 8-13 µg/m^3. If our assumptions about the impacts of meteorology and reduced heating/cooling demand are correct, then we can estimate the contribution from local mobile sources across the MANE-VU region to be slightly over 3 µg/m^3 on a typical weekday during the Spring or Fall. Although mobile source emissions are reduced on weekends, they do not go to zero so this estimate must be assumed to be a lower bound.

Figure III-19: Hourly fine aerosol weekday concentrations during the combined spring/fall season at 17 urban/suburban sites.



C. Speciated data

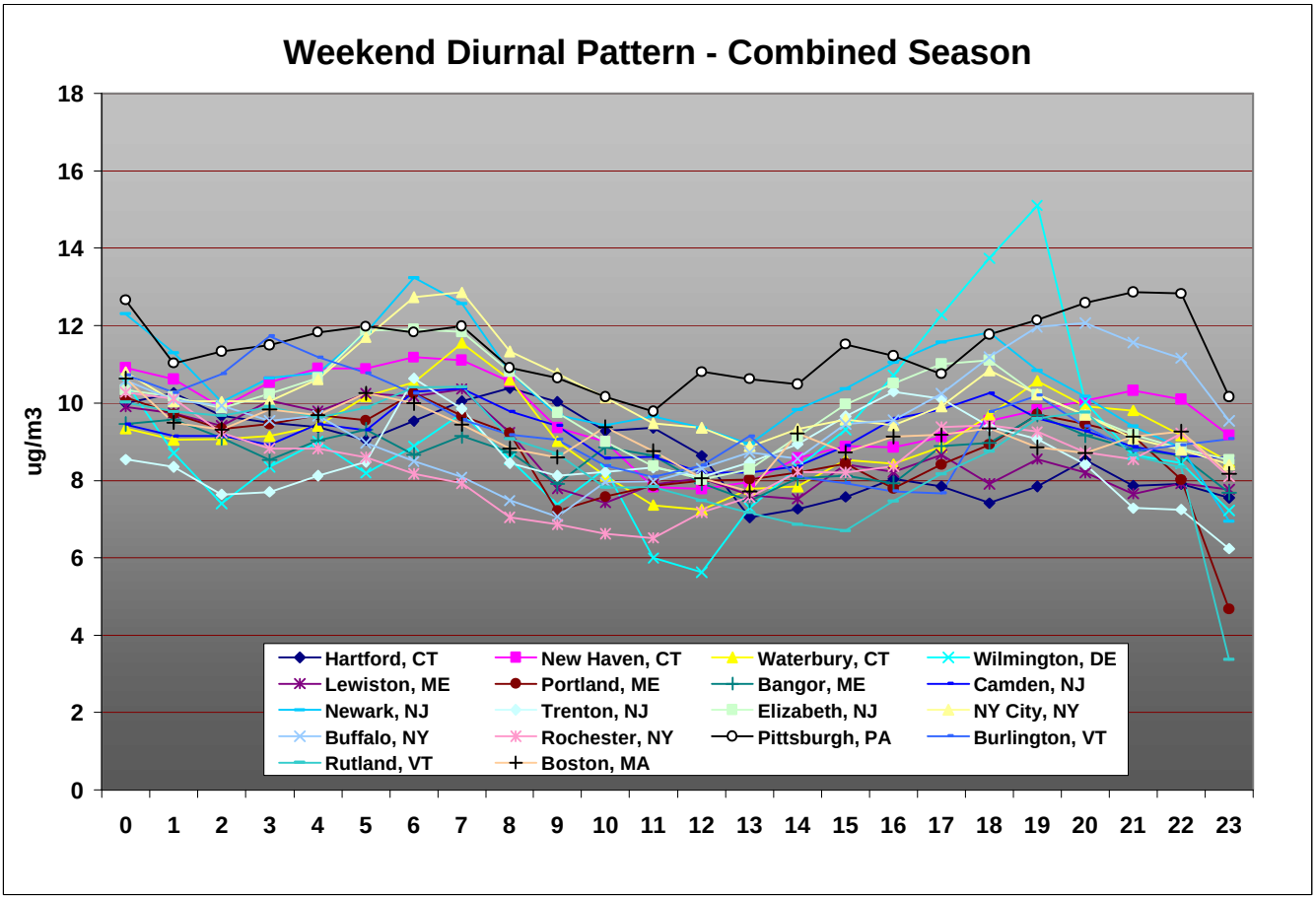
In 2002, two networks operated in MANE-VU to collect speciated fine particle data, the Interagency Monitoring of Protected Visual Environments (IMPROVE) network and the Speciation Trends Network (STN). Both networks measure fine particle mass and chemical speciation (composition - inorganic ions, metals, and carbon) using different manual filter-based methods for 24-hour intervals every third-day. IMPROVE was designed to explore the current status and potential causes of visibility impairment in National Parks and other Class I areas in the 1980's and underwent a significant expansion in 2001 as a result of the Regional Haze program (http://vista.cira.colostate.edu/improve/). The sites are sponsored by the states, tribes, and various Federal agencies (USEPA, FWS, NPS, USFS). Simultaneous with the IMPROVE expansion, USEPA developed STN, a state-run network which assists states in understanding urban area fine particle composition.

The speciation networks operating in MANE-VU during 2002 consisted of seventeen IMPROVE monitors and forty-two STN sites. An additional three non-MANE-VU IMPROVE sites were incorporated into the analysis in this report given their proximity: Shenandoah, Dolly Sods and James River Face. Many of the STN sites began running during the course of 2002,

with only twenty-six sites operational for the entire twelve months. All but one IMPROVE site operated for the entire year.

Taken together, these data sources can help illuminate rural/urban differences in fine particulate composition. However, some care is warranted in combining data from the networks due to different sampling and analytical methods used. These differences are discussed in further detail in the technical report developed for MANE-VU, Technical Memorandum #7: Review of Speciation Trends Network and IMPROVE Chemically Speciated Data.[9] In this document, the measured data have been combined to show the spatial and temporal behavior of fine particle mass, sulfate, nitrate, and total carbon.[10]

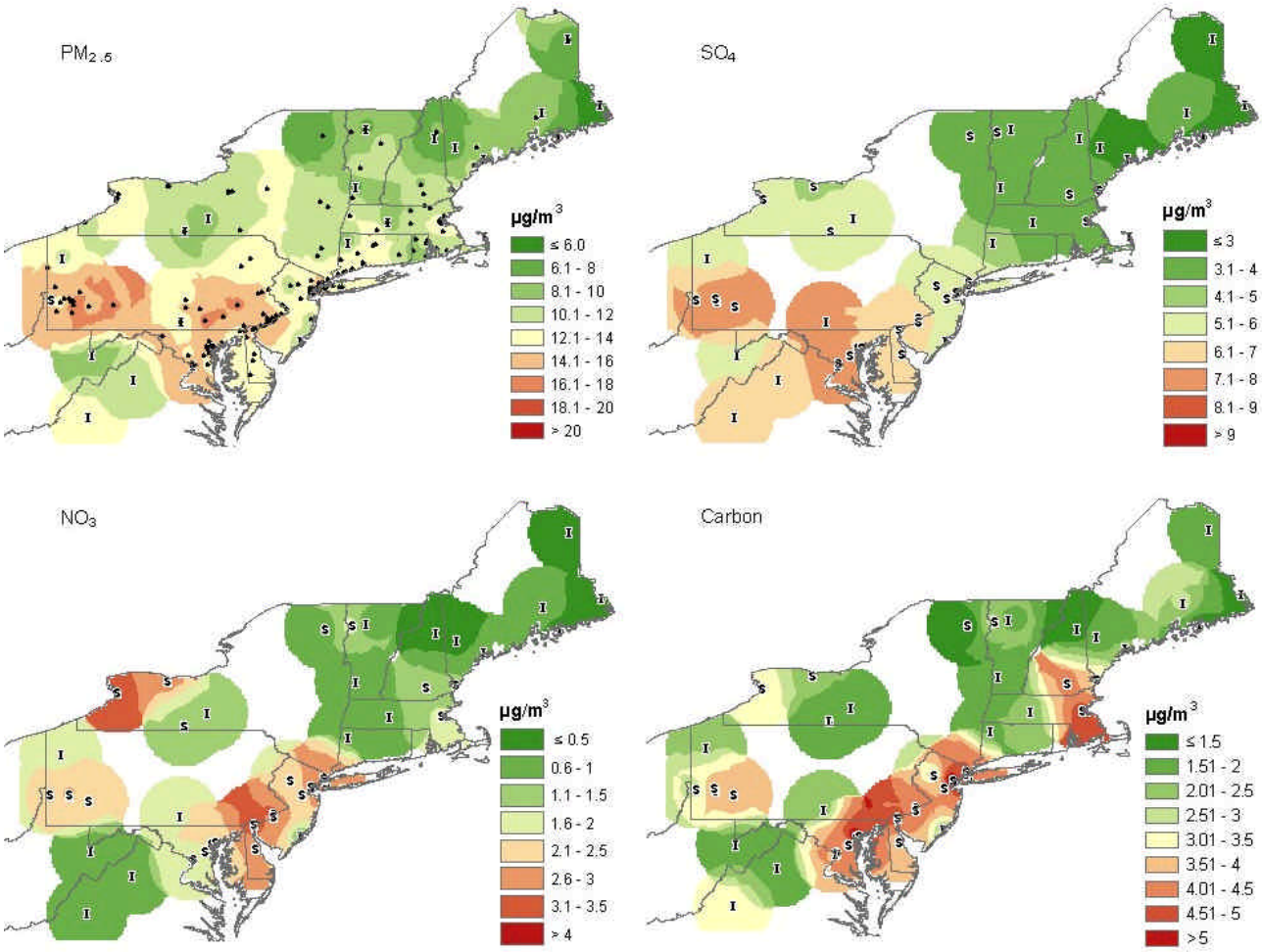
Figure III-20: Hourly fine aerosol weekend concentrations during the combined spring/fall season at 17 urban/suburban sites.



[9] Available at http://bronze.nescaum.org/regionalhaze/memoranda/Memo7-IMPROVE_STN.pdf

[10] Sulfate is assumed to be fully ammoniated. Nitrate data are used as reported. Total carbon (TC) is defined as the sum of reported elemental (EC) and organic (OC) carbon. Given the inter-network inconsistencies in the definition of EC/OC, the simplest comparison is given for TC, avoiding the allocation issue between the two forms of carbon and the multiplicative factor assumed for organic carbon. No attempt is made to account for other elements (O,N, etc.) that are incorporated into organic carbon particulates. It should be noted that STN carbon is blank corrected as reported in USEPA's AQS system as of January 2004.

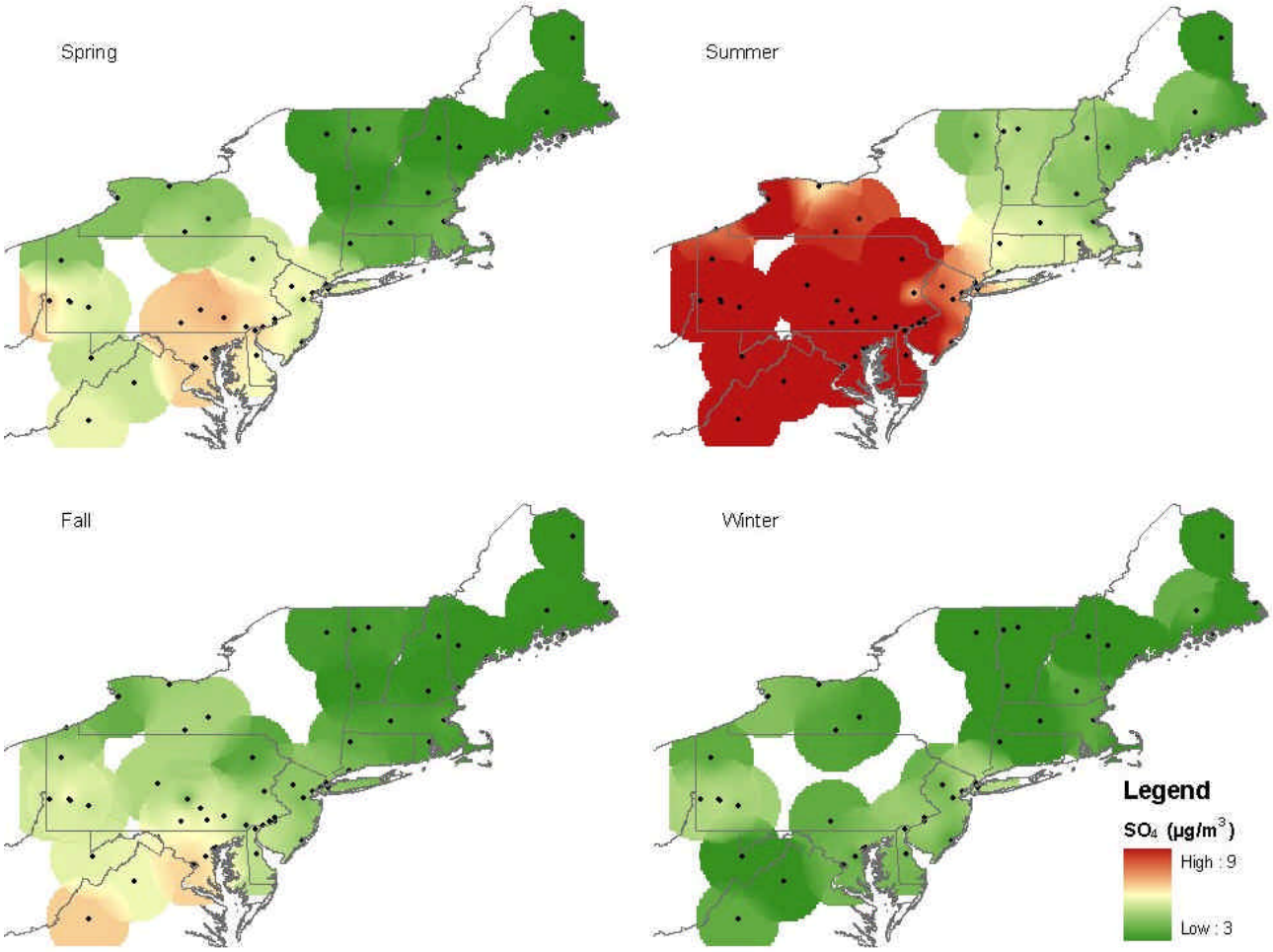
Figure III-21 2002 Annual Average $PM_{2.5}$, Sulfate, Nitrate and Total Carbon for MANE-VU based on IMPROVE and STN data. Mass data are supplemented by the FRM network



Four four-paneled figures were developed based on the available data. The first, Figure III-21, shows 2002 annual average $PM_{2.5}$, sulfate, nitrate and total carbon maps with associated mass scales The fine mass map combines the FRM mass data with the two speciated networks to provide substantially greater coverage than available through any network alone. Subtle network density differences exist between the annual average maps and the seasonal maps displayed in figures III-22, III-23, and III-24. Annual average values were only calculated if sufficient data were available from all four seasons. As defined here, the seasons are meteorological (Spring = March, April, May; Summer = June, July, August; Fall = September, October, November; and Winter = January, February, December).

The maps reveal that urban areas have higher fine particle concentrations than the surrounding rural areas. Those areas to the west and south appear to be impacted the most. From a seasonal view, the summer PM levels are substantially higher than the other seasons, with

Figure III-22: 2002 Seasonal Average SO_4 based on IMPROVE and STN data.



winter a distant second. The summer shows the greatest southwest to northeast particle gradient, whereas winter displays a more obvious local urban source contribution.

The strong summer gradients appear to be driven by gradients in sulfate. The wintertime urban excess is derived from a combination of factors, with carbon and nitrogen dominating the higher levels observed. The urban carbon excess appears in all seasons, though is most pronounced in summer, followed by winter. Nitrate on the other hand shows the opposite with winter urban excess being greatest and summer urban-rural differences minimal. In general, the plots loosely confirm the current understanding for emissions sources of particulate and its precursors: sulfur sources tend to be more prevalent south and west of MANE-VU, with carbon and nitrogen sources more reflective of population density.

Figure III-23: 2002 Seasonal Average NO_3, based on IMPROVE and STN data.

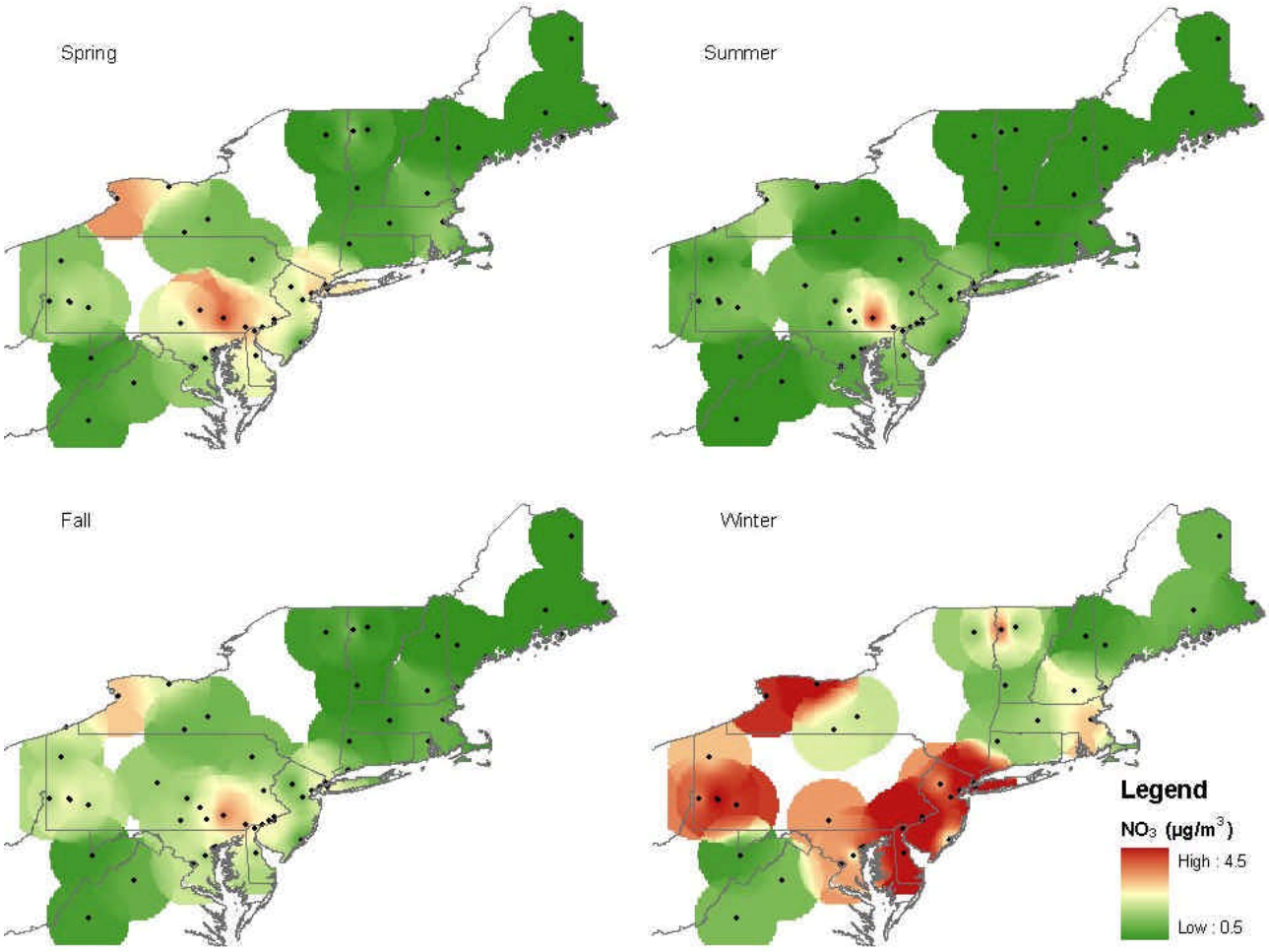
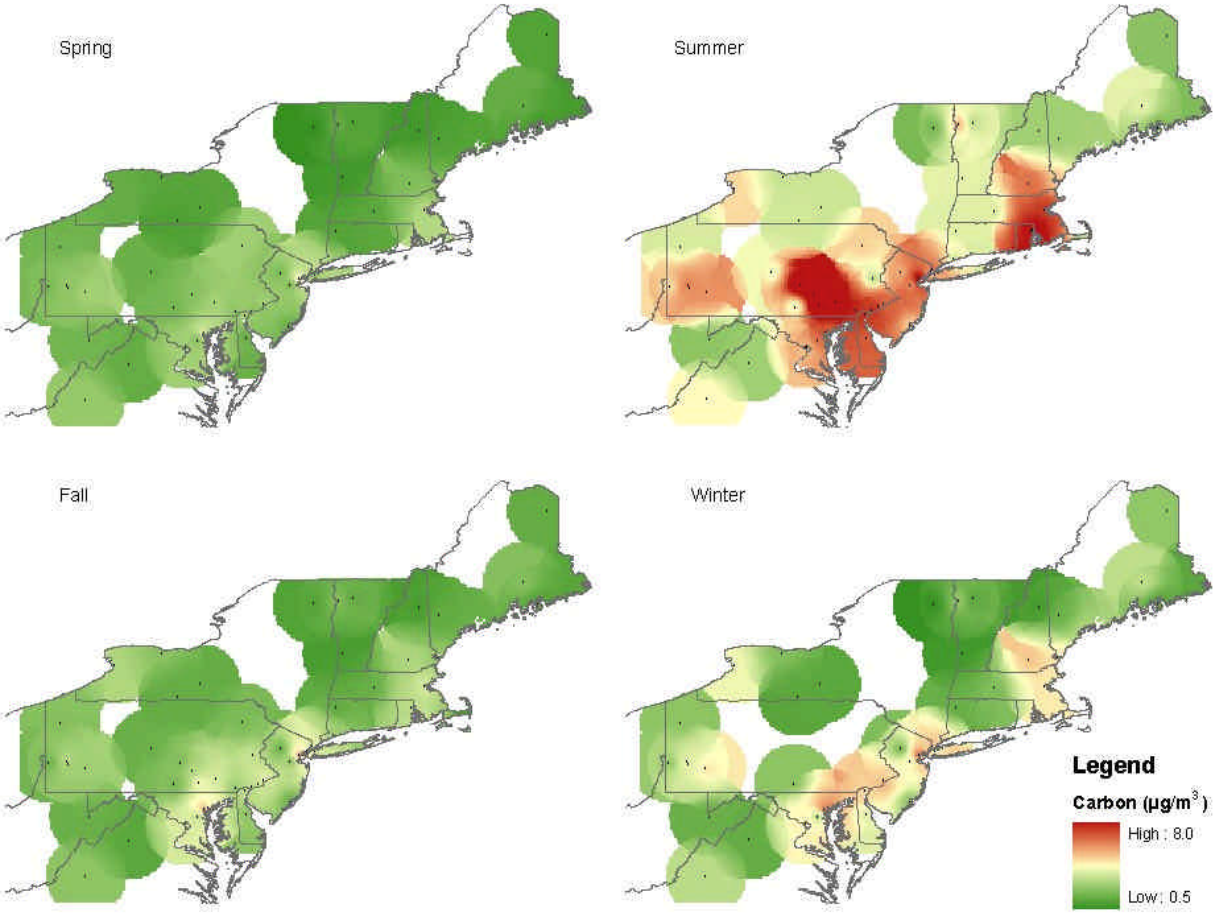


Figure III-24: 2002 Seasonal Average Total Carbon based IMPROVE and STN data.



D. Chapter Summary

During 2002, annual average concentrations of $PM_{2.5}$ ranged from 7.6 to 15.2 µg/m^3 across the MANE-VU domain with concentrations declining at a fairly even rate along an axis from southwest to northeast indicating that the MANE-VU region is impacted by source regions to its south and west. Mean $PM_{2.5}$ concentrations in the southwest (PA) are about 4 µg/m^3 higher than mean values in the extreme northeast (ME).

The domain wide mean for 2002 was within 1 µg/m^3 of means for other years within the baseline period suggesting that while 2002 saw somewhat lower concentrations of ambient fine particles, it was not anomalously low. On an annual basis, $PM_{2.5}$ urban concentrations exceed rural concentrations by about 1 µg/m^3 at the 5th percentile level and by about 2 µg/m^3 at the 95th percentile.

Time series plots of 1-in-3 day $PM_{2.5}$ samples throughout the region display a bimodal annual distribution with maximum values in the winter and summer. A major high concentration "event" occurred in early July when smoke from a series of wildfires north of Quebec impinged on most of the MANE-VU region which strongly influence the shape and character these time series with some areas seeing readings of over 100 $\mu g/m^3$. Areas in the southern portion of MANE-VU experienced higher peak concentrations than the north from photochemical-haze events both before and after the July event.

Mean values from "everyday" sampling sites tend to be somewhat higher than means from "1-in-3 day" sites on both a state-by-state and regional basis. The difference is likely due to high concentration events missed by the 1-in-3 day schedule and may be related to siting considerations since everyday sites tend to be located in areas which experience the highest concentrations. Time series plots of the everyday FRM data demonstrate the utility of more frequent sampling (i.e., more extreme values are captured) relative to the 1-in-3 day plots.

An analysis of the everyday data demonstrates that mean regional concentrations measured by 1-in-3 day samples could vary in 2002 by plus or minus ~2 $\mu g/m^3$ depending on the "start" day chosen. Day of week analysis indicates that weekends (Saturday and Sunday) have significantly lower regional mean concentrations (at the 95 percent confidence level) than weekdays with highest concentrations occurring on Tuesdays and lowest on Saturdays. Finally, although everyday FRM samplers are sited to capture the highest expected concentrations, those sites show the same weekly pattern as 1-in-3 day sites.

Analysis of continuous fine particle monitoring data (adjusted to be "FRM-like" by the Julian Day method) peak hourly concentrations during 2002 were numerically about two times higher than peak daily values. The separation of hourly data into rural and urban components clearly demonstrates that rural/remote sites display a mean diurnal pattern that, as with ozone, is much flatter than the pattern at urban sites.

The spatial and seasonal behavior of fine particle chemical constituents in MANE-VU is presented geographically for 2002. A spatial gradient of sulfate with highest levels in the southwest and lowest concentrations in the northeast is observed based on IMPROVE and STN data, and is most pronounced in the summer. Nitrate is more predominant in urban areas in the wintertime. Carbon appears to be higher at urban monitoring sites than rural sites near the same metropolitan areas and the effect is more pronounced during the warmer months.

In Chapter IV we turn our attention to a more detailed look at spatial patterns of air quality. We focus in particular on what the data can tell us about rural/urban differences and the adequacy of the monitoring network from a spatial perspective.

IV. Detailed Spatial Analysis

Although the analysis of routine fine particle mass and chemistry measurements provides valuable information, the addition of more highly focused data regarding the physical and chemical processes in the atmosphere is more instructive. This chapter provides analyses that are either more in-depth (with respect to routine measurements) or more wide-ranging in scope than the material presented in Chapter III.

A. Rural vs. Urban $PM_{2.5}$ Mass

Comparison of $PM_{2.5}$ concentrations from rural areas with those from urban/suburban areas can add significantly to our understanding of the impact on air quality of both urban sources and of medium to long-range fine aerosol transport. To assist with this approach, data from ten pairs of rural and urban/suburban FRM sites throughout the MANE-VU region were selected and analyzed.

Table IV-1 shows basic site description information including the approximate, straight-line distance between the site pairs.

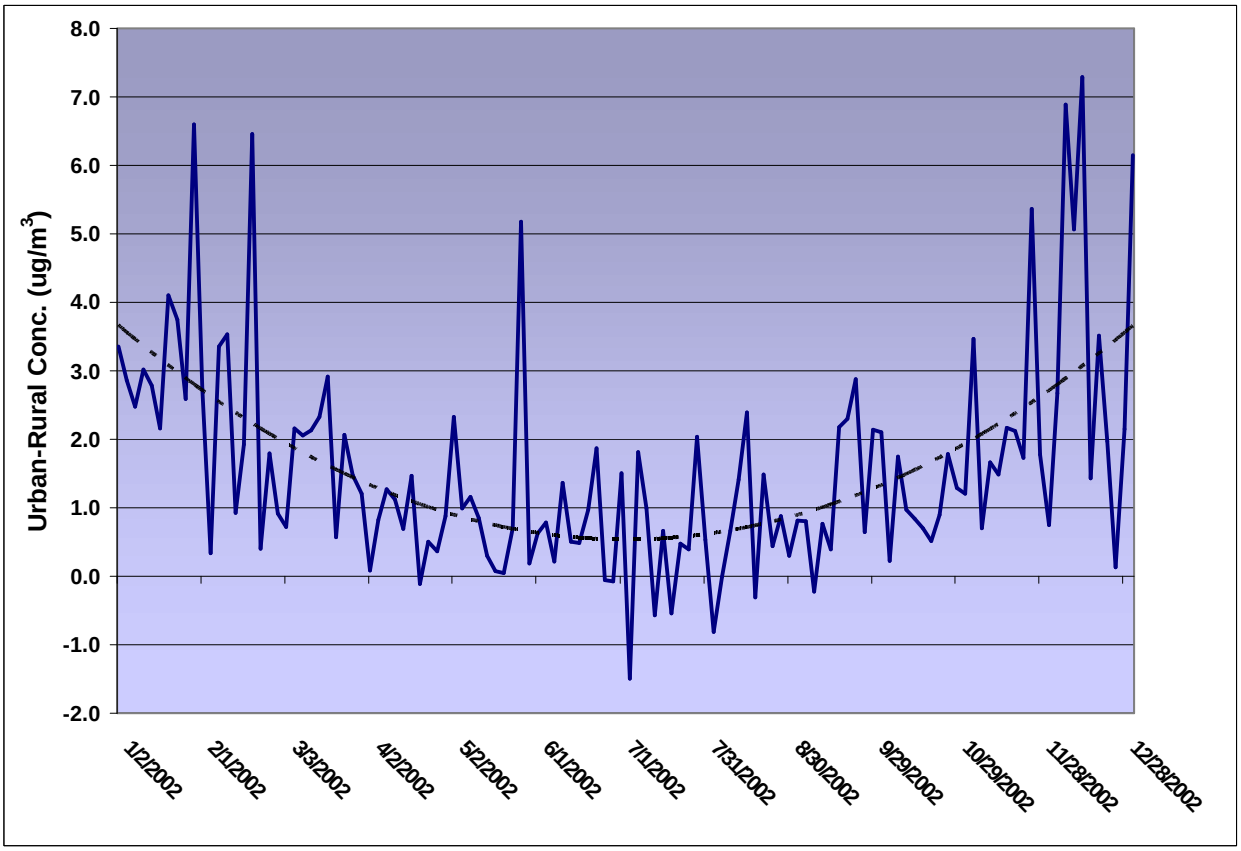
Table IV-1: MANE-VU Rural/Urban site pair information.

State	Site No	City	Land use	Location type	Longitude	Latitude	Inter-site Distance (mi)
DE	100051002		Agricultural	Rural	-75.55560	38.98470	
DE	100010002	Seaford	Residential	Suburban	-75.61310	38.64440	24.0
MA	250154002	Ware	Forest	Rural	-72.33472	42.29833	
MA	250130016	Springfield	Commercial	Urban & Center City	-72.59140	42.10890	17.6
MD	240030014		Agricultural	Rural	-76.65310	38.90250	
MD	245100049	Baltimore	Residential	Urban & Center City	-76.63750	39.26170	25.2
ME	230052003	Cape Elizabeth	Residential	Rural	-70.20778	43.56083	
ME	230010011	Lewiston	Commercial	Urban & Center City	-70.21500	44.08940	37.0
NJ	340218001		Agricultural	Rural	-74.85470	40.31500	
NJ	340210008	Trenton	Residential	Urban & Center City	-74.76360	40.22220	7.7
NY	360010012	Albany	Agricultural	Rural	-73.75690	42.68070	
NY	360930003	Schenectady	Residential	Suburban	-73.94020	42.79960	11.7
NY	361030001	Babylon	Commercial	Rural	-73.42030	40.74580	
NY	360590013	Bethpage	Residential	Suburban	-73.49060	40.76080	3.3
NY	360130011	Westfield	Agricultural	Rural	-79.60250	42.29080	
PA	420490003	Erie	Commercial	Suburban	-80.03860	42.14180	22.2
PA	420030093		Residential	Rural	-80.02080	40.60720	
PA	420030021	Pittsburgh	Residential	Suburban	-79.94140	40.41360	14.0
PA	420290100		Commercial	Rural	-75.76860	39.83440	
DE	100031012	Newark	Residential	Suburban	-75.76170	39.69190	10.0

Due to the difficulty in finding a significant number of rural/urban site pairs which operated on the same sampling schedule, sites with a mixture of schedules were used to insure samples representative of the entire MANE-VU region. As a result, three of the 20 sites employed an everyday schedule while two sites sampled every sixth day (the remainder sampled every third day). Data from the three everyday sites were edited so as to include data from the 1-in-3 schedule only. In all, a total of 1098 data points were possible from the ten site pairs for 2002. Of the 1098 possible point-pairs, 951 (87%) were valid and were used in this analysis.

As expected, urban/suburban areas, with their rich supply of emission sources, almost always reported higher concentrations than their nearby sister sites in rural areas. Of the 951 valid data pairs 660 showed higher urban/suburban levels while 291 cases showed higher rural levels.

Figure IV-1: Difference in FRM data between ten urban/rural site pairs for 2002.



One interesting aspect of the 2002 rural/urban data concerns the pattern in seasonal differences between such site pairs. Figure IV-1 shows the difference (urban-rural) between the ten site pairs as a time series. Although some rural-to-urban seasonal differences are to be expected, the variation in the magnitude of this difference is surprising. In the warm/hot months, the mean rural/urban difference amounts to no more than ~0.7 µg/m^3 (based on a best-fit 2nd order polynomial curve) which is a relatively small differential. However, during the cool/cold months that difference climbs to almost 4 µg/m^3 demonstrating a total annual seasonal variation

of at least 3 $\mu g/m^3$. Since the mean annual concentration of all sites is 12.6 $\mu g/m^3$, an annual variation of 3 $\mu g/m^3$ becomes significant.

One explanation for the observed seasonal variation concerns the temporal distribution of local and transported emissions. In the summertime, MANE-VU sites repeatedly experience sulfate events due to transport from regions to the south and west. During such events both rural and urban sites throughout MANE-VU record high (i.e., >15 $\mu g/m^3$) daily average $PM_{2.5}$ concentrations. During summer stagnation events, atmospheric ventilation is poor and local emissions are added to the transported burden with the result that concentrations throughout the region (both rural and urban) are relatively uniform. There are enough of these events to drive the urban/rural difference down to less than 1 $\mu g/m^3$ during warm/hot months.

During the wintertime, strong local inversions frequently trap local emissions during the overnight and early morning periods resulting in elevated urban concentrations. Rural areas experience those same inversions but have relatively fewer local sources so that wintertime concentrations in rural locations tend to be lower than those in nearby urban areas. Medium and long range fine aerosol transport events do occur during the winter but at a much reduced rate compared to summertime. So, it is the interplay between local and distant sources as well as meteorological conditions that drive the observed seasonal rural/urban difference in FRM concentrations.

B. Rural versus Urban Chemistry

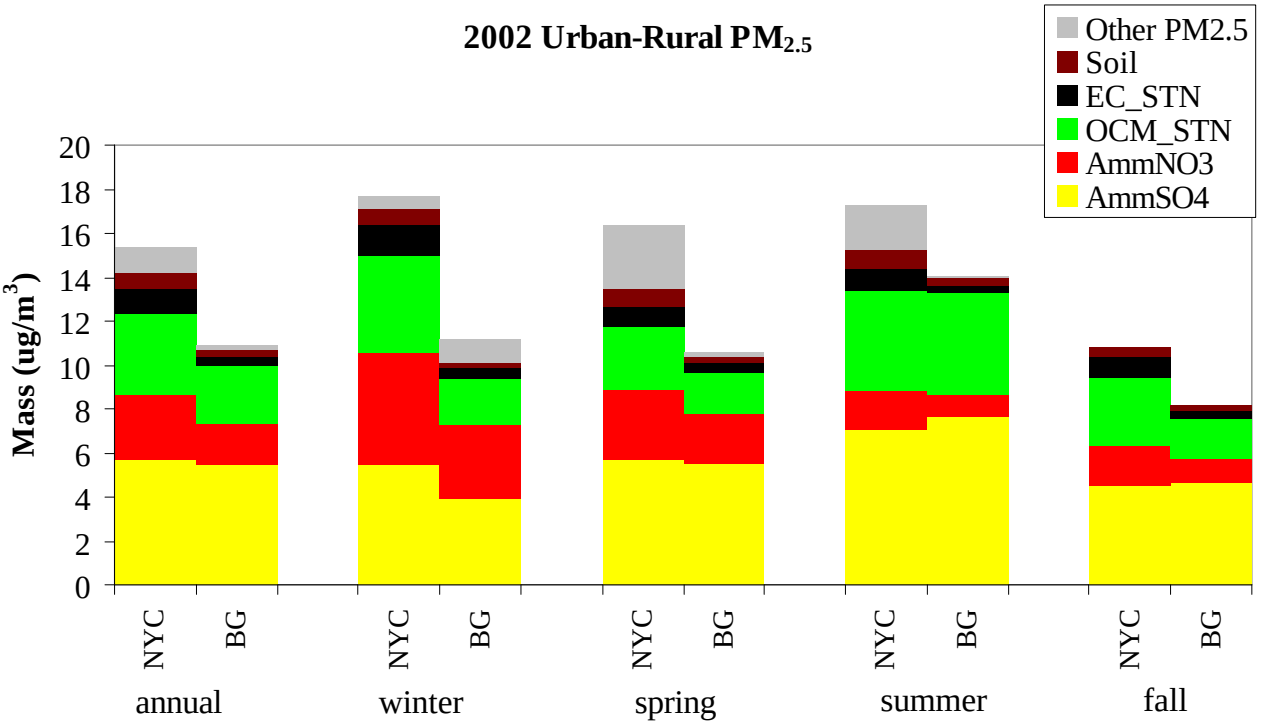
It is important to note that the above analysis looks at rural/urban differences across a number of sites, and is thus a much more robust result than a typical "urban excess" type analyses. It is difficult to discern any significant meaning about the cause of "excess" mass from a single pair of sites. There are many factors that influence the concentrations at a particular site and it is likely that for every pair of sites which shows an urban excess, one could find some pair of locations that might show something similar to an urban "deficit." While paired sites from an urban and a rural location will *typically* show greater concentrations in the urban location and lower levels of pollution in rural areas, great care must be exercised in the interpretation of any two-site analysis such as the comparisons of speciated components of PM presented here.

Here two Urban-Rural pairs of speciation monitors are compared: New York City and Chester, New Jersey; Boston and Quabbin Reservoir, Massachusetts. (see Figure IV-2 and IV-3). The first three sites are Speciation Trends locations, while the Reservoir site is part of the IMPROVE protocol network.

To provide a more direct comparison of the differences between the urban and rural sites, only those days for which both monitors in a pair had data were used. Four seasonal averages were computed for 2002, with seasons defined as winter (January, February, December), spring (March, April, May), Summer (June, July, August) and Fall (September, October, November). July 7 was excluded from the analysis since the Quebec forest fires impacting the region on that day would have dominated the summertime averages. The major fine particle species categories

were considered, including ammonium sulfate, ammonium nitrate, organic carbon, elemental carbon and soil mass. Traditional assumptions about these constituents were made; all sulfate was fully neutralized and a multiplier of 1.4 was used to account for mass of organic carbon[11]. An "other $PM_{2.5}$ mass" category was created to delineate the difference between gravimetric mass determined from the Teflon filter and the reconstructed mass sum of the individual mass constituents. Where no "other" mass is graphed, the sum of the species either equaled or exceeded the directly measured mass.

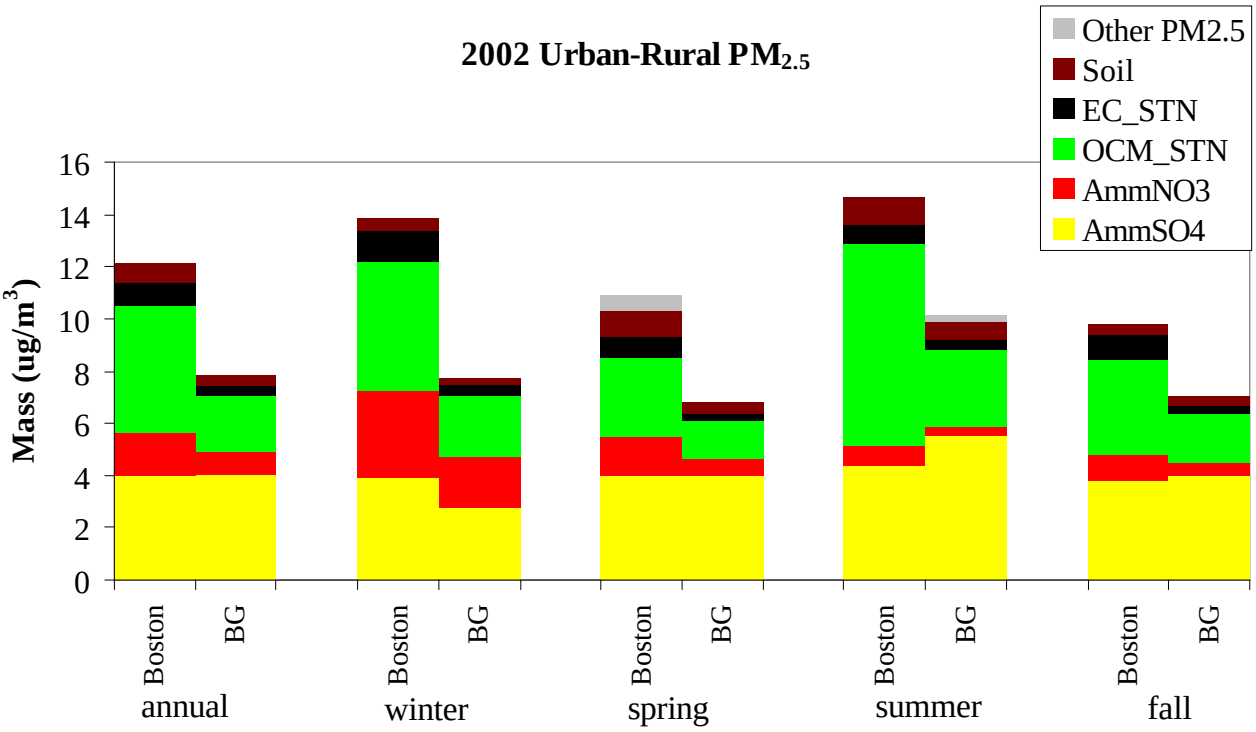
Figure IV-2: New York City Urban area Compared to an upwind Background Site.



The Urban-Rural differences show consistency for both New York City and Boston. On an annual scale, the sulfate levels are comparable, with increased mass loading at these urban sites driven primarily by differences in nitrates and carbon with smaller differences in "soil" levels. One interesting aspect of this comparison is the seasonal differences in the urban-rural sulfate split. On an annual basis, sulfate appears to be similar at urban and rural locations (based on these two pair of sites); however, during the colder months, the urban sulfate levels are elevated relative to the rural levels. This behavior is opposite during the summer. During the

[11] No adjustments were made to account for the different operationally defined definitions of carbon between the IMPROVE and STN networks. In the case of NYC, both rural and urban monitors were STN. The Boston pair reflects not only inter-site differences, but also differences in definition of organic and elemental carbon. However, the general interpretation of the data differences remains consistent. Based on current understanding, the rural elemental carbon would be even lower than what is shown on the graph if it were made consistent with the STN definition of EC. Likewise, the organic carbon value would increase slightly for the rural value, as the EC would be allocated to OC. The urban OC levels are so much greater than those in the rural area that a slight increase in rural OC makes little difference.

Figure IV-3: Boston Urban area Compared to an upwind Background Site.



wintertime, the northeast urban corridor itself is a substantial source of sulfur. These local emissions can be trapped near the surface during the winter and have a corresponding higher impact on the urban area relative to the rural area.

For both urban and rural areas, the summertime OC levels are significantly greater than wintertime concentrations. Although the oxidation chemistry slows in winter, the cooler temperatures change the phase dynamics, driving more mass into the condensed over the gas phase. This along with more frequent temperature inversions, which limit atmospheric ventilation of the urban boundary layer can lead to the observed increases in both organic and nitrate levels during winter months (relative to spring and fall). EC, OC and nitrate all are observed to have higher measured levels in the urban area, driven by local sources of these constituents.

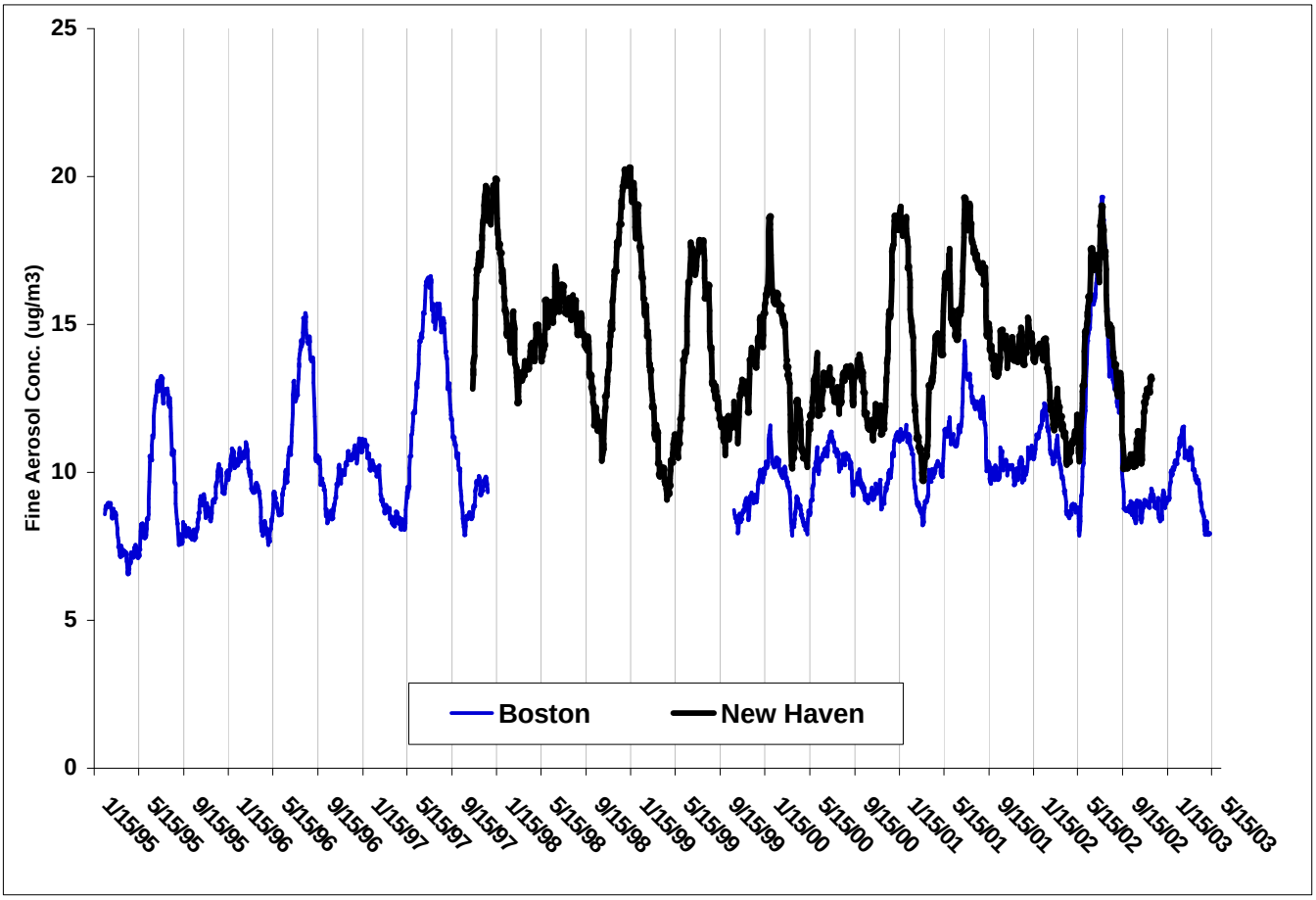
C. Regional scales of influence

In the previous sections of this chapter, we have explored the relationship between local urban emissions and the regional influence of transported air pollution across much broader spatial scales. In order to understand the scale of influence for regional events we turn to hourly data to explore how well data from nearby sites (initially Boston, MA and New Haven, CT) track together. Although a substantial gap exists in the Boston data, overlaying data from the two sites (Figure IV-4) shows some remarkable similarities (but note that data from the Canadian wildfires of 7/5-7/11 are excluded in Figure IV-4). In spite of the fact that New Haven displays

persistently higher fine particle concentrations, the two sites track each other very well. For example, note the high degree of similarity in the data "structure" surrounding 7/15/01. A 60-day filter, by intention, smoothes out many small fluctuations but the correlation between sites separated by more than 100 miles is somewhat surprising.

Figure IV-5 shows a closer look at the Boston/New Haven site inter-relationship. In this figure, 24-hour average daily concentrations (calendar day values) from Boston (x-axis) are compared to the same day values from New Haven. Although the correlation coefficient (R^2) is not robust enough to make predictions for one city based on the other city's data, concentrations are strongly linked between these two widely separated cities.

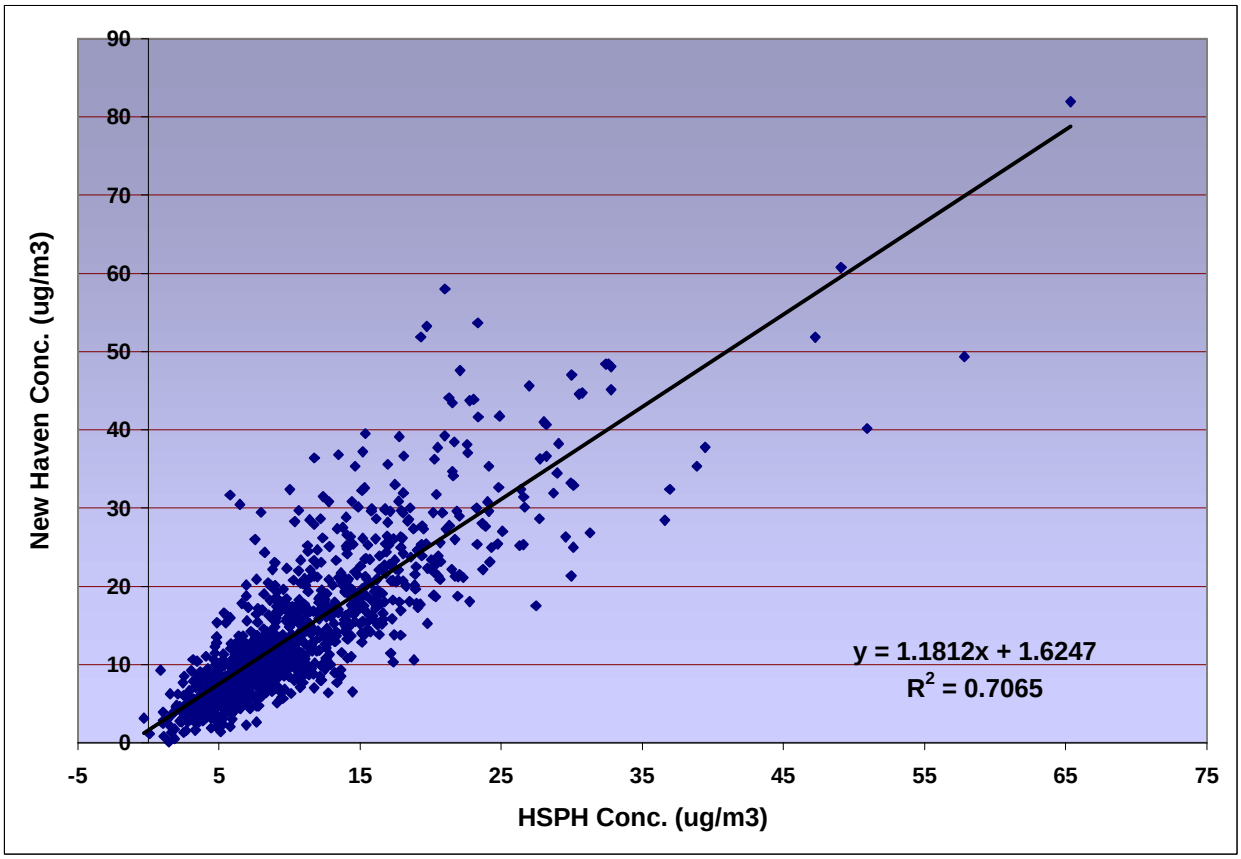
Figure IV-4: TEOM 60-day running average values for Boston, MA and New Haven, CT.



It is certain that a portion of this linkage is due to shared atmospheric physics. Both cities experience strong morning inversions, during cold months, that tend to break up nearly at the same time. Because less than two degrees of longitude separate the two cities, the sun reaches a given angle from the horizon at New Haven less than eight minutes after reaching the same angle in Boston. Although cloud cover can impede atmospheric solar heating (and can vary widely between the two cities), tropospheric mixing should proceed along similar schedules in both cites. That means that morning concentrations (from local sources) can be expected to rise and fall in unison in both cities which, in turn, should lead to a increased correlation in winter time

concentrations (the same can be said of any two reasonably nearby cities that are not separated by significant geographical barriers).

Figure IV-5: Daily average fine aerosol concentrations at HSPH (Boston, MA) versus State St. (New Haven, CT).



Given the predominance of prevailing westerly winds in the Northeast (especially in the summer), similar concentrations, due to transport (especially in the afternoon hours) can be expected in both cities during warmer months too. This occurs because transported material aloft begins to mix downward during the late morning to early afternoon period in both Boston and New Haven resulting in increased correlation of summer time concentrations.

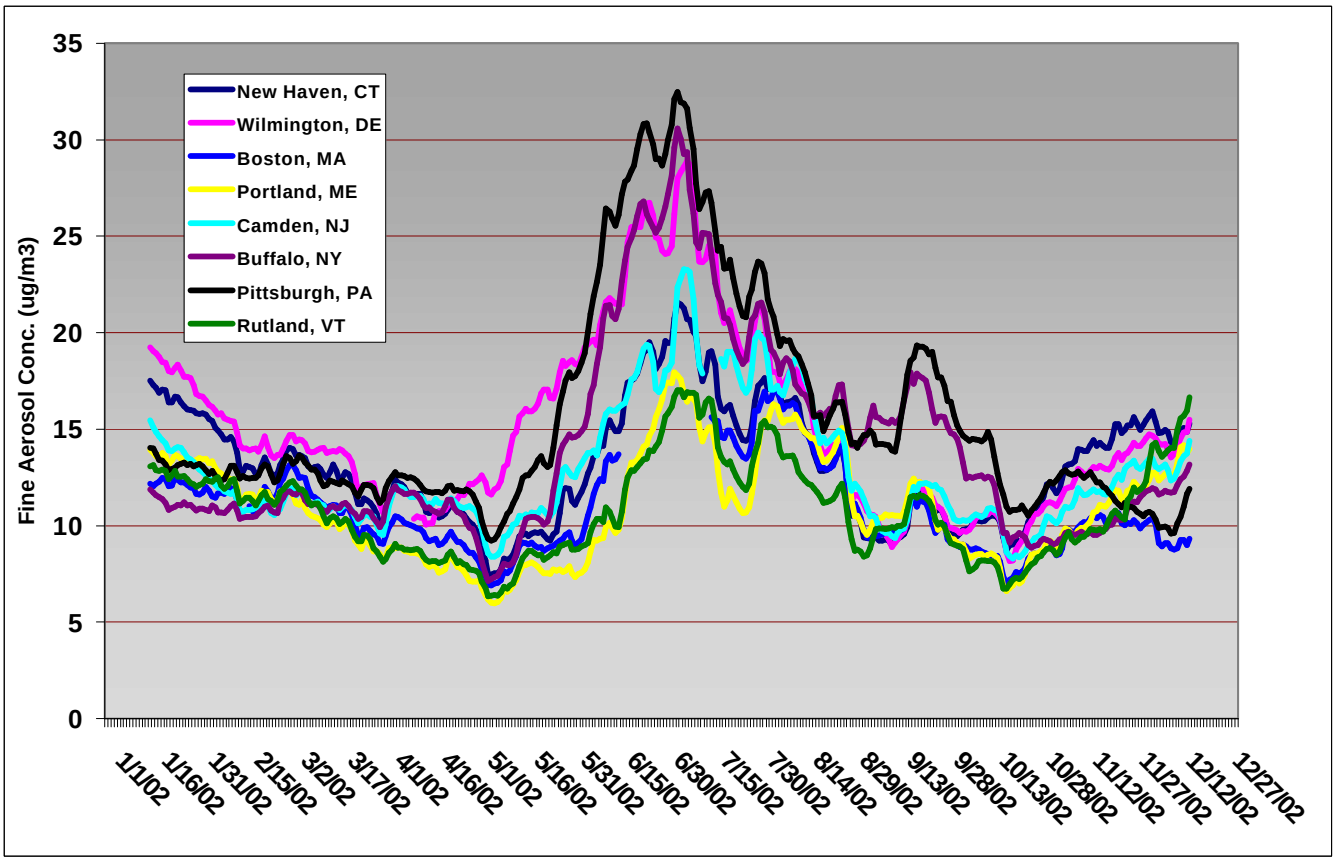
Due to proximity, similar atmospheric regimes and the lack of geographic obstructions, both cities might be considered to be within the same regional "air shed". Therefore it is not unreasonable to expect a high degree of correlation in fine aerosol concentrations between the two cities.

Given the degree of correspondence in fine particle concentrations between these two Northeastern cities, an examination of more widely separated sites in MANE-VU is in order. Figure IV-6 shows running 30-day average values from hourly fine particle monitors at eight locations throughout the MANE-VU region for CY 2002. Sites were chosen to be as widely separated as possible while being representative of significant urban areas in the region. Rather than using a 60-day filter, as with the Boston/New Haven data, a 30-day filter was applied to the

smaller (single year) data set in order to reduce the amount of data "lost" while still producing a relatively noise-free signal (note that data from the Canadian Smoke event is excluded from Figure IV-6 since not all portions of MANE-VU were impacted by that event). Only days with more than 17 valid hours were used in averaging.

Although the range of concentrations varies significantly by season, there appears to be a noticeable correlation between sites across the region. During the spring and late fall of 2002,

Figure IV-6: 30 Day Running Average Concentrations from Eight Representative MANE-VU Sites (Data from 7/5/02 through 7/11/02 is excluded).



the range of concentrations across MANE-VU was rather narrow (i.e., less than 7 µg/m^3) but that range increased to nearly 17 µg/m^3 in mid-summer. In spite of the varying range, some remarkable "structure" is evident in the data. Note for example the sudden drop in concentrations across the region during early May and the broad spike at all sites during the mid- to late-September period. Although these sites are separated by distances of up to nearly 500 miles, they trend up and down together and can exhibit remarkably similar changes in concentration when under the influence of certain meteorological regimes.

Although there is not sufficient data from New Hampshire for 2002 to definitively make the case, it appears that the northern tier states in the MANE-VU region (Vermont, New Hampshire and Maine) did not experience the extreme transport-driven concentrations evident in the central and southern portions of the area.

Figure IV-7: 2002 Annual Average $PM_{2.5}$ maps comparing different measurement spatial density

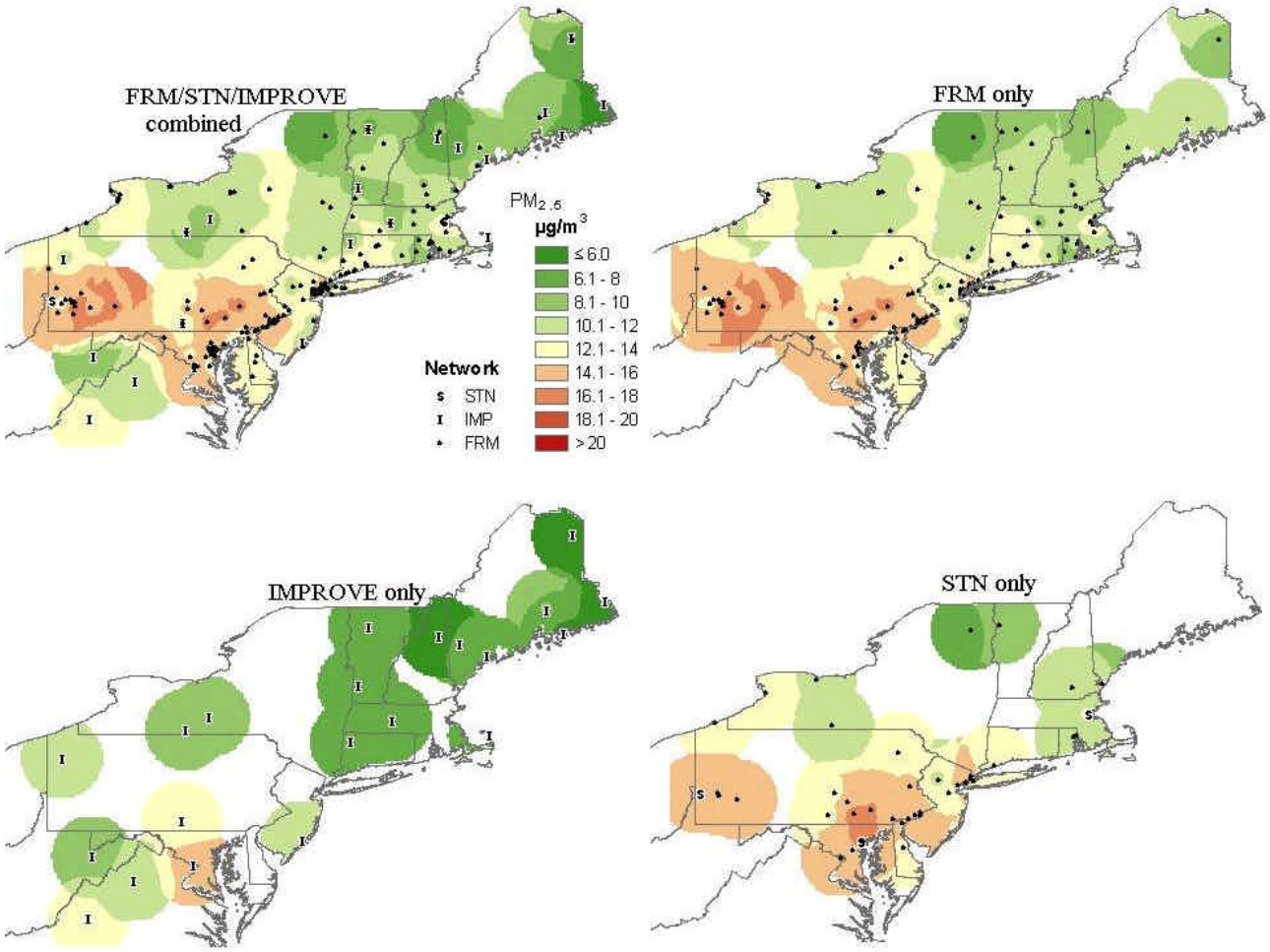
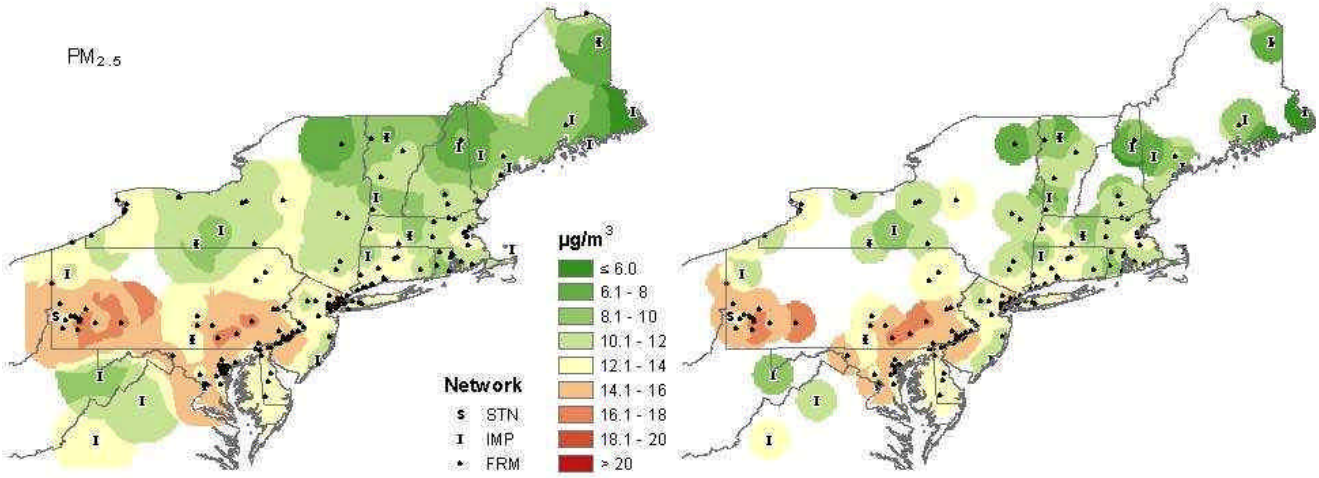


Figure IV-7 shows how spatial density of monitors influences concentration maps derived from the measurements. Four maps are shown depicting annual average fine particle levels within MANE-VU. These maps show considerable differences depending on the network of monitors chosen for mapping. The range of influence for each monitor was set to one degree latitude/longitude, or roughly 80-100 km radius around the plotted point. Inverse weighting of up to the nearest six monitors was used to create the interpolations. In general, the denser the network of points, the better the interpolated map represents the spatial variations in concentrations. One drawback of this approach is that the "representative range" of each monitor is unlikely to be constant. Rather, it is likely that each monitor has a distinct region over which its observations are representative, depending on the distribution of sources impacting the area and topography.

Figure IV-8 demonstrates the effect of cutting the radius of influence in half to one-half a degree. The new map may better represent the urban areas and their surrounds; however, given the low density of monitors in rural areas, considerable white space exists on the "tighter" radius of influence map.

The maps in Figures IV-7 and IV-8 illustrate the impact that network monitor density and data display choices have on the graphic representation of pollutant data. In an ideal situation, a highly dense data collection network would be available, as that would provide the most accurate spatial information. The reality of air pollution monitoring forces the end user to make assumptions regarding the spatial extent to which a monitor's data are accurate. These figures show that the assumptions can significantly influence the spatial gradients. Thus, end users are reminded that the maps are visualization tools which are most accurate near monitored points and should be considered rough estimates only for levels between monitors.

Figure IV-8: 2002 Annual Average $PM_{2.5}$ maps comparing different radii of influence



D. Chapter Summary

Perhaps not surprisingly, ambient concentrations of $PM_{2.5}$ tend to be higher in urban areas relative to rural locations throughout the MANE-VU domain. However, this effect appears to have an annual cycle with an average urban/rural difference of 4 µg/m^3 during the winter months and less than 1 µg/m^3 in the summer. Explanations include the higher rate of occurrence of "regional" PM events during summer months that affect large geographic regions uniformly and reduced atmospheric ventilation of the boundary layer in the winter months which allow for the accumulation of local SO_2 emissions and carbonaceous aerosol.

This is consistent with a comparison of speciated concentrations at two MANE-VU urban/rural pairs which show that sulfate, OC and nitrate, are all elevated (at these two urban sites) relative to concentrations measured at rural upwind sites during winter months. Higher levels of OC and nitrate are present at the two urban locations in summer as well.

Smoothed, long-term data sets from different sites show a high degree of correspondence between relatively nearby cities such as Boston, MA and New Haven, CT. Smoothed data from across the MANE-VU domain suggests that the entire Northeast U.S. tracks fairly well together

with respect to synoptic timescales with some occasional differences between coastal and inland sites or extreme northern and southern ends of the domain.

Finally, comparison from multiple networks demonstrates that a fairly dense network of monitors is required to achieve truly complete spatially representative estimates of fine particle concentrations across the region. Care must be exercised when assessing the spatial representativeness of individual monitors.

V. Detailed Temporal Analysis

A. 2002 in context

Perhaps the longest continuous record of $PM_{2.5}$ levels in the MANE-VU region come from two sites in the northern portion of the region with hourly TEOM data sets covering five or more years. The Connecticut DEP has operated a TEOM at the State Street site in New Haven since November of 1997. The Massachusetts DEP operated a TEOM at its South Boston site between January of 1995 and January of 1998. In September of 1999 MA DEP moved the TEOM to the roof of the Countway Building at the Harvard School of Public Health. Given the relatively short distance between the South Boston and HSPH sites, the Boston data set comprises both sites.

Highly time resolved data of most pollutants possesses a large dynamic range due to both changes in source strength and variations in meteorology. In order to reduce the "noise level" of the TEOM data, a 60-day running average filter was applied. Once filtered it is easier to visually discern medium-to long-term patterns in the data. Figure IV-4 in the preceding chapter shows the "filtered" multi-year TEOM data from New Haven and Boston. Both sites display a strong bimodal annual distribution with peaks near January 1 and July 1. In addition to demonstrating that these sites track together over large distances, the figure shows that the calendar year 2002 is not remarkable with respect to previous years. The fact that the January 2002 peak at New Haven and Boston seem less dramatic than in previous years may partly explain why annual average PM was lower in 2002 (see Figure III-8). Without the exaggerated peak during the 2002 Quebec Wildfire event, the July peak is not distinct from conditions in previous years. The year 2002 would seem to be a fairly typical year with respect to month to month variation and magnitude of ambient fine particulate mass concentrations.

As noted in Chapter IV, there is a fair degree of correlation in long term (i.e., 30- and 60-day averages) fine particle concentrations throughout the MANE-VU region. In some cases there is a high degree of correlation, although such cases are limited to short time periods (i.e., days or weeks).

Also note that the South Boston site (early Boston trace) displays a different inter-annual pattern than the nearby HSPH site. At South Boston, both winter and summer maxima are pronounced but summer peaks clearly exceed winter peaks. There appears to be a much smaller difference between winter and summer peaks at the HSPH site with the exception of the summer of 2002. Even with the Canadian wildfire data removed, the 2002 summer peak at Boston clearly does not fit the normal pattern for that site. That discrepancy may be due to transport events which heavily impacted the central and southern portions of MANE-VU during 2002.

Fine particle concentrations during the summer of 2000 are anomalously low at both New Haven and Boston probably due to a larger than usual number of rainy days during that period. Ozone concentrations were also markedly reduced during the summer of 2000 throughout most of the northeast and mid-Atlantic region.

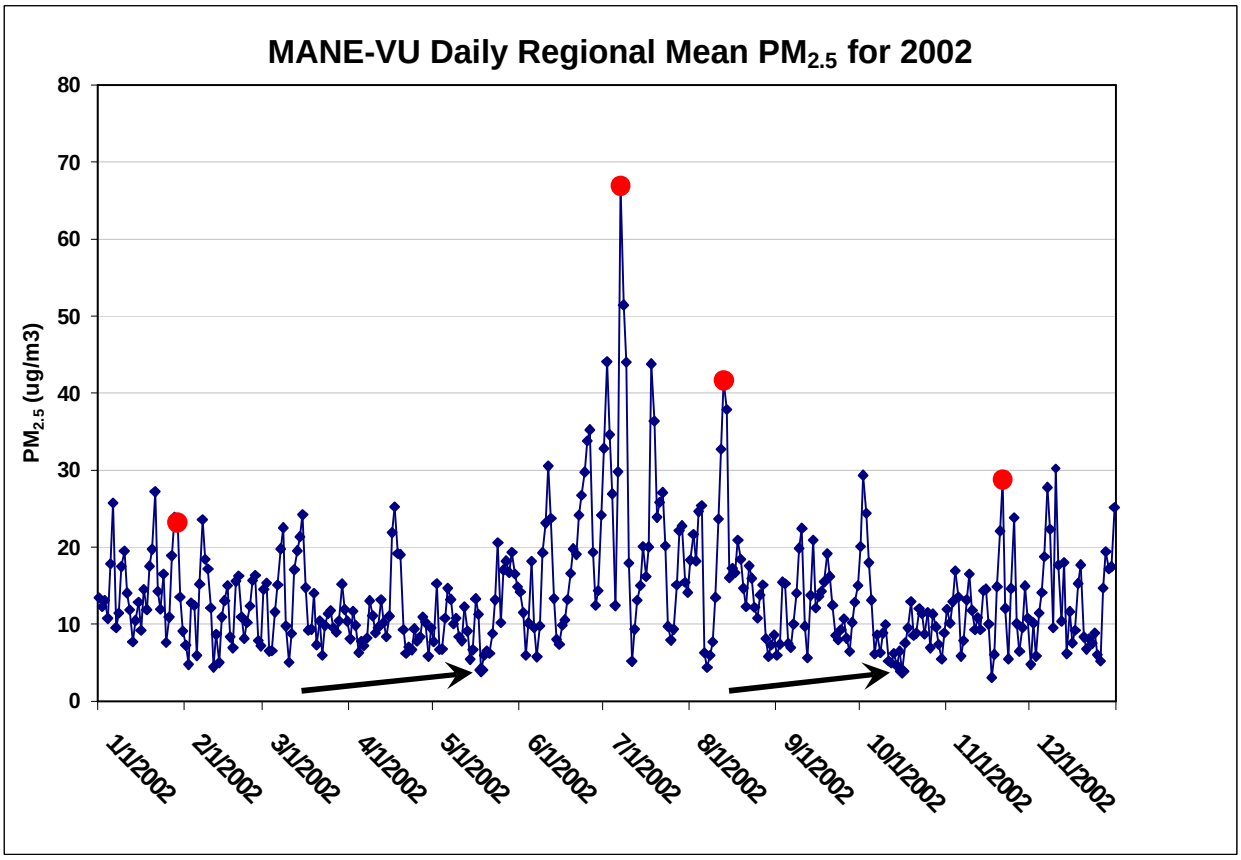
B. 2002 Episodes of interest

In order to understand typical fine particulate concentrations in a broader regional context for the year 2002 specifically, Figure V-1 was produced which shows regional daily average $PM_{2.5}$ values for MANE-VU. Each daily value is the average of all FRM samples for that date from FRM samplers in MANE-VU that were scheduled to sample everyday during 2002 (the number of reporting sites on a given date varies between 25 and 31).

Four data points, denoting periods of possible interest, have been highlighted by large, red circles. Those periods are centered on 1/28/02, 7/7/02, 7/18/02, 8/13/02 and 11/21/02. The highest daily average value in the region during 2002, occurred on 7/7/02 when the smoke plume from a series of wildfires, burning north of Quebec, impinged on the northeastern and central Atlantic states. Due to the widespread nature and intensity of this episode it deserves more analysis.

Another warm-weather episode centers on 8/13/02 when after four days of extremely low $PM_{2.5}$ concentrations, levels slowly rose (over 4 days) to an average regional value greater than 40 $\mu g/m^3$. Concentrations then quickly fell (over 2 days) to more typical levels. This event is representative of typical regional haze episodes that affect the MANE-VU region, is has been highlighted with more detailed analyses presented in Section D.

Figure V-1: PM2.5 episodes of regional interest in 2002.



A cold-weather episode of interest occurred in late January of 2002 when mean regional $PM_{2.5}$ concentrations exceeded 20 µg/m^3 while regional NO_x levels (see section C) spiked to the third highest value of the year with the mean from the six locations exceeding 127 ppb.

A late fall period of interest occurred around 11/21/02 when regional $PM_{2.5}$ levels rose from an extremely low regional value (3.1 µg/m^3) over four days to a high of 28.5 µg/m^3. At the height of this episode, regional NO_x exceeded 137 ppb – a value tied for the highest daily mean of 2002.

In addition to periods of high concentration, extended periods of low concentrations are also important to the MANE-VU regional haze program since they may indicate the presence of clean air "corridors" which bring relatively clean air to the region. Two periods of clean air evident in Figure V-1 (centered on 5/18/02 and 10/16/02) are denoted by arrows.

C. Seasonal relationship between PM and NOx

Because nitrogen oxides (NO_x) can be a good indicator of regional as well as local emissions, NO_x data for the MANE-VU region was downloaded from USEPA's AQS. Ultimately, data from six widely separated MANE-VU NO_x sites were selected (one site each in CT, DC, MA, NH, PA and VT). Sites were selected both for high data capture rates and geographic location. The NO_x data was then aggregated into regional averages on a daily basis and compared to $PM_{2.5}$ FRM data from 34 "everyday" sampling sites (which were also averaged on a regional basis).

Figure V-2: Regional $PM_{2.5}$ and NO_x in 2002.

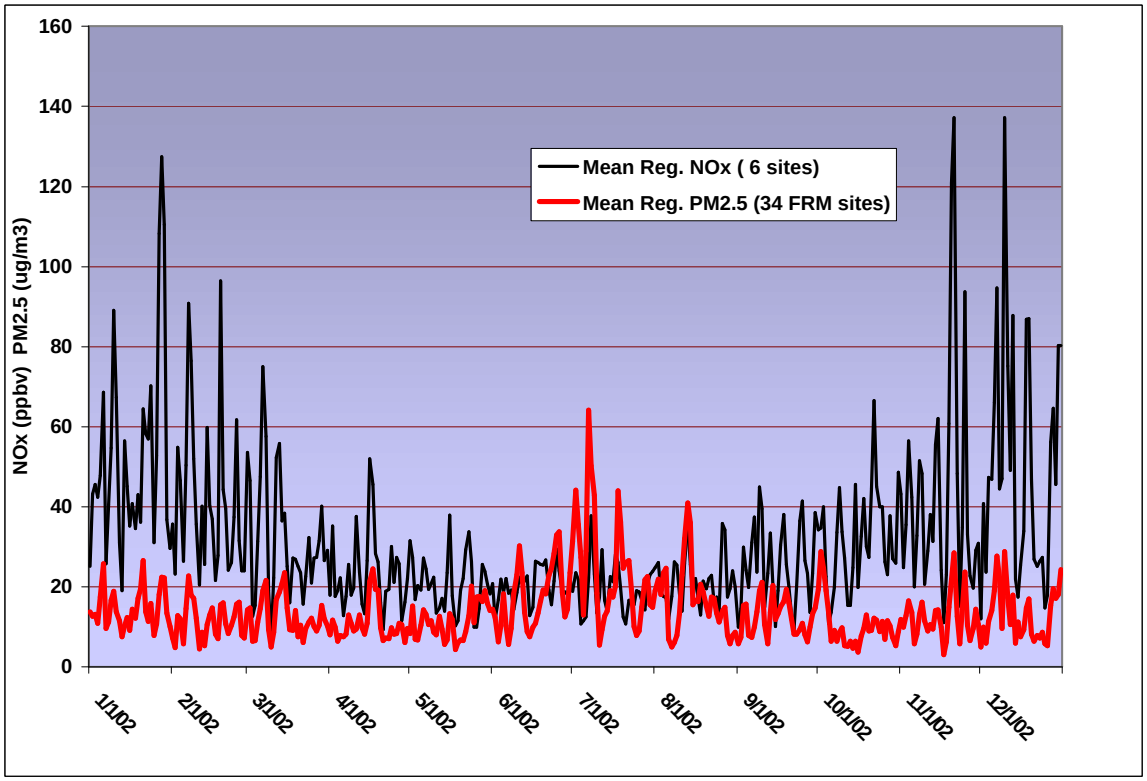
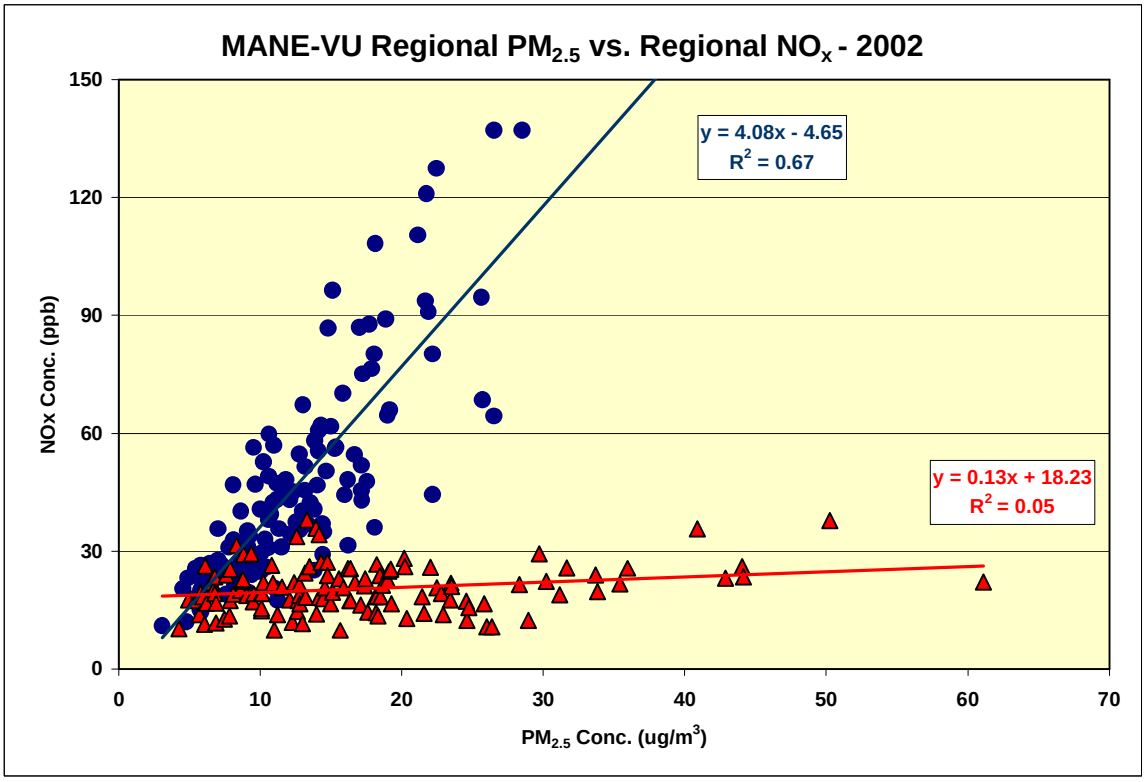


Figure V-3: $PM_{2.5}$ vs. NO_x correlation by season.



During 2002 there were virtually no periods when regional mean $PM_{2.5}$ concentrations rose above 20 µg/m^3 and were not accompanied by rising (or already high) NO_x concentrations. However, as seen in Figure V-2, NO_x concentrations vary widely on an annual basis and tend to occur out-of-sync with fine particle concentrations.

Although the min/max extremes of these two pollutants are offset in time, they are highly correlated during some parts of the year. For example, Figure V-3 shows the regional $PM_{2.5}$ and NO_x data for the coldest (Jan., Feb., Nov., and Dec,) and hottest (May, June, July and Aug.) seasons of 2002. Wintertime NO_x and $PM_{2.5}$ concentrations are rather well correlated (r^2=0.67) while summertime concentrations are not at all linked. This dichotomy can be explained by several coincident effects including: 1) reduced UV radiation during cold months (which minimizes photolysis of NO_2 to NO, the classical pathway for creation of O_3); 2) the increase in space heating requirements from stationary sources (which preferentially increases morning NO_x emissions; increased NO_x emissions due to "cold-start" mobile source engines and 3) decreased mixing height depths due to reduced solar input (which allows morning concentrations to build quickly). Note that the Spring/Fall $PM_{2.5}$ vs. NO_x correlation (not shown) lies about mid-way between the winter/summer values shown in Figure V-3).

D. Episode Analysis

Although the analysis of routine fine particle mass and chemistry measurements provides valuable information, the addition of more highly focused data regarding the physical and chemical processes in the atmosphere can be more instructive. This section provides a more in-depth analysis than is possible based on the routine measurements presented in Chapter III alone.

D.1 Meteorological and pollution overview of August 8-16

We begin our analysis of the high PM and regional haze episode of August 2002 by reviewing surface maps from the period to provide a synoptic overview of major weather systems that were influencing air quality across the Northeast U.S. during that time. Figures V-4 through V-7, respectively, show an eight-panel display of surface weather maps, back trajectories, fine particle and ozone concentrations from 12Z (8 AM EDT) each day. The following chronology of events combines the meteorological insights with PM concentration information to provide a basic storyline for analysis.

A slow-moving high pressure system centered over the Great Lakes set up northerly flow over the MANE-VU region on 8/8. The High drifted southeast-ward and became extended over several days bringing high temperatures to the region. Calm conditions east of MANE-VU on August 10 were pivotal in the formation of fine aerosol concentrations, which began building in the Ohio River valley. Over the next four days concentrations in the MANE-VU region climbed into the 60-90 $\mu g/m^3$ range over a wide area before being swept out to sea by a series of frontal passages beginning on 8/15.

8/8 – A high pressure system over the Great Lakes produces NW-N prevailing surface winds (~4-8 mph) throughout the region. Maximum daily temperatures approach or exceed 80^0F.

8/9 – Wind speeds fall off but direction remains NW-N as the High moves into the central portion of MANE-VU. Temperatures rise as cloud cover declines.

8/10 – The High reaches the east coast and stalls. Temperatures (except in northern-most areas) reach 90^0 F while surface-level winds turn to more southerly directions. Calm conditions through the morning hours in the lower Ohio River valley promote creation of haze noted in surface observations.

8/11 – Circulation around the High (now near Cape Hatteras) becomes well established. Peak temperatures are in the low to mid-90's. Morning winds are low-to-calm in the area east of the Mississippi – the area of haze now reaches from Michigan to northern Texas and eastward to West Virginia and eastern Tennessee. A surface-level trough descends from north of the Great Lakes during the day, passes eastward through the Ohio valley and stalls over the Alleghenies and southward.

8/12 – Temperatures exceed 90^0 F throughout MANE-VU except in coastal ME. The area of concentrated haze has pushed eastward and now extends from central ME to central PA.

Haze builds throughout the day MANE-VU as circulation forces it to channel NE between the stalled trough and a cold front approaching from the mid-west.

8/13 – Calm conditions prevail as the trough reaches coastal NJ by 8 AM. Generally clear skies allow temperatures to reach the mid-90's everywhere except in coastal ME. Dew points, which had been rising since 8/8, reach the upper 60's. Peak hourly fine aerosol concentrations are greater than 40 $\mu g/m^3$ everywhere in MANE-VU and exceed 90 $\mu g/m^3$ in some locations. By 8 PM, showers associated with the approaching cold front have reached into Ohio.

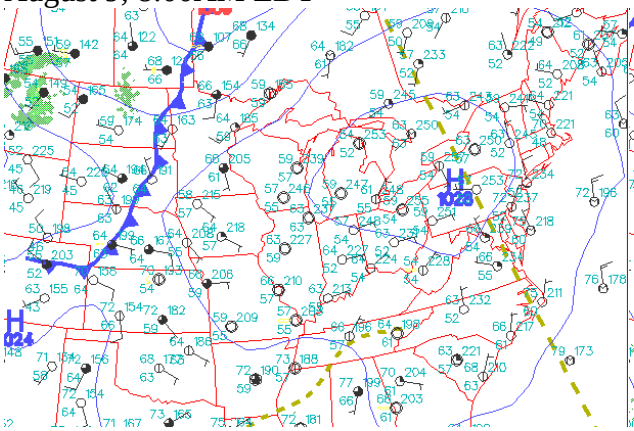
8/14 – By 8 AM the trough has dissipated and the High is moving offshore. Dew points remain in the upper 60's and peak temperatures reach into the 90's everywhere and top 100 in several locations. Increased ventilation causes aerosol concentrations to drop throughout the day everywhere except ME where some locations peak above 60 $\mu g/m^3$ after midnight.

8/15 – The approaching cold front and associated showers fall apart during the morning hours. By 8 PM a new batch of moderate rain has intruded deeply into the region from the SW and has virtually pushed the haze out of MANE-VU.

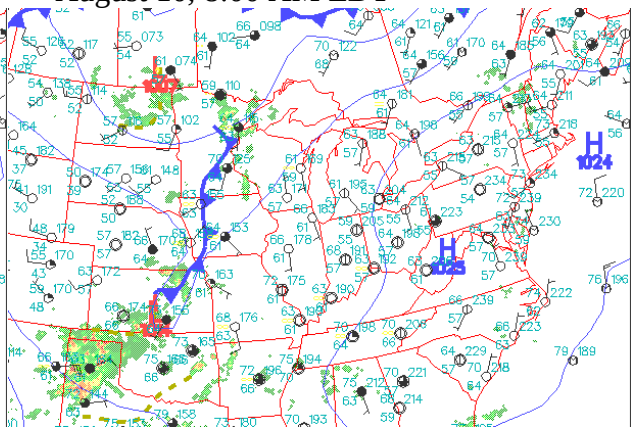
8/16 – A new High building in over the upper Midwest pushes the remains of the showers out of the Northeast.

Figure V-4: Surface weather maps for August 9-16, 2002

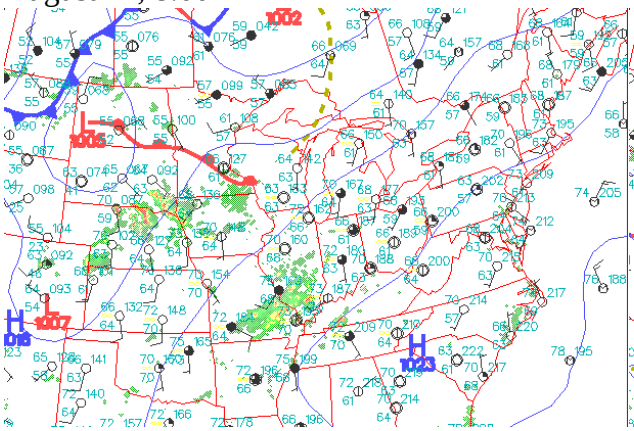
August 9, 8:00AM EDT



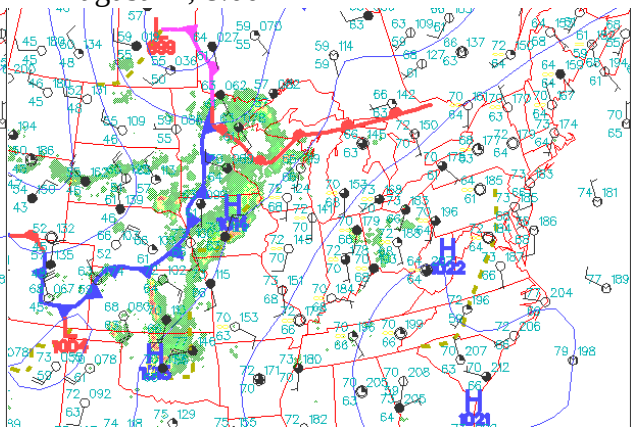
August 10, 8:00 AM EDT



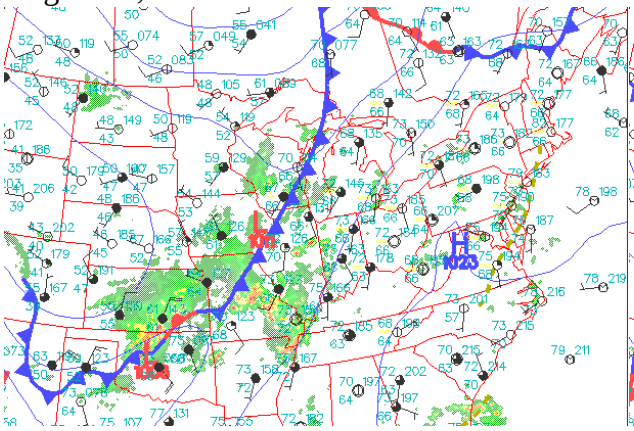
August 11, 8:00 AM EDT



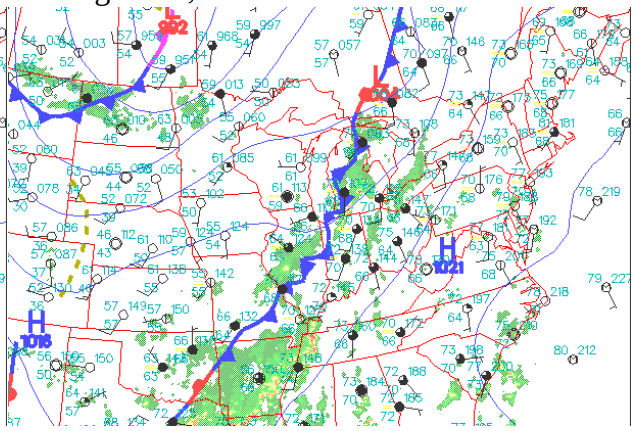
August 12, 8:00 AM EDT



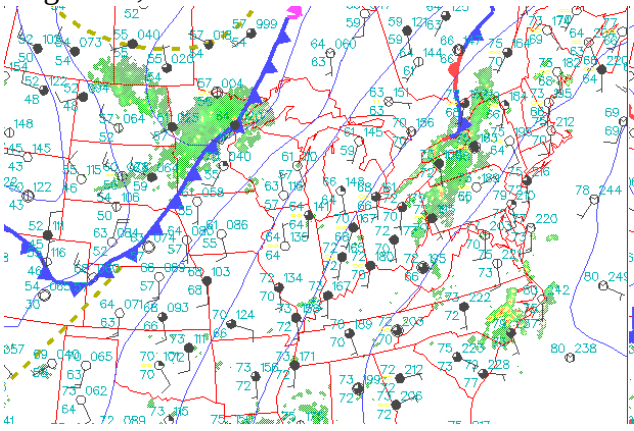
August 13, 8:00 AM EDT



August 14, 8:00 AM EDT



August 15, 8:00 AM EDT



August 16, 8:00 AM EDT

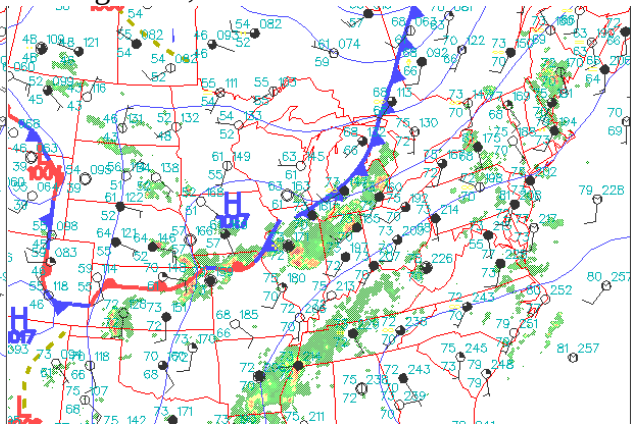


Figure V-5: HYSPLIT 72-hour back trajectories for August 9-16, 2002

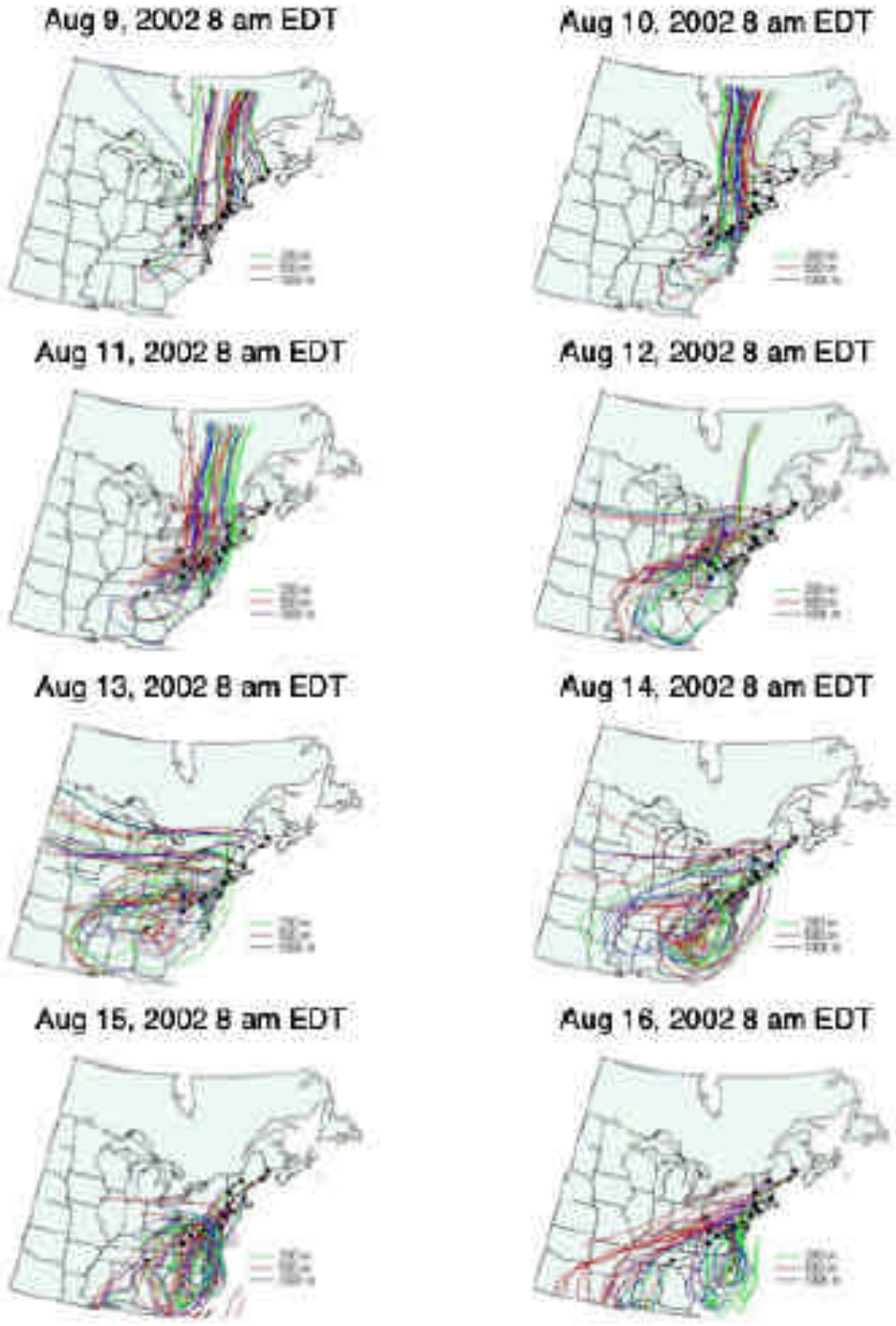


Figure V-6: Spatially interpolated maps of fine particle concentrations August 9 – 16, 2002

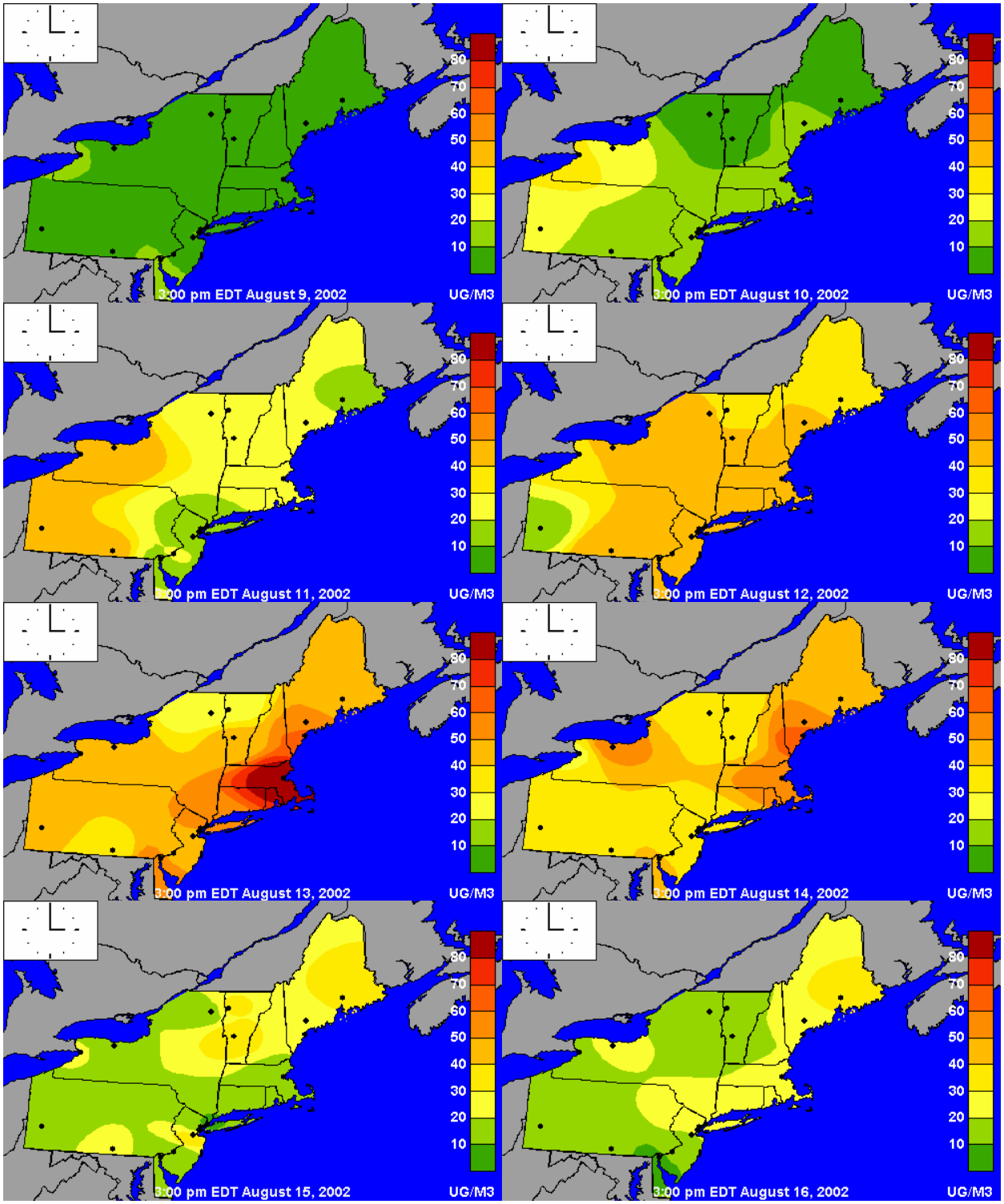
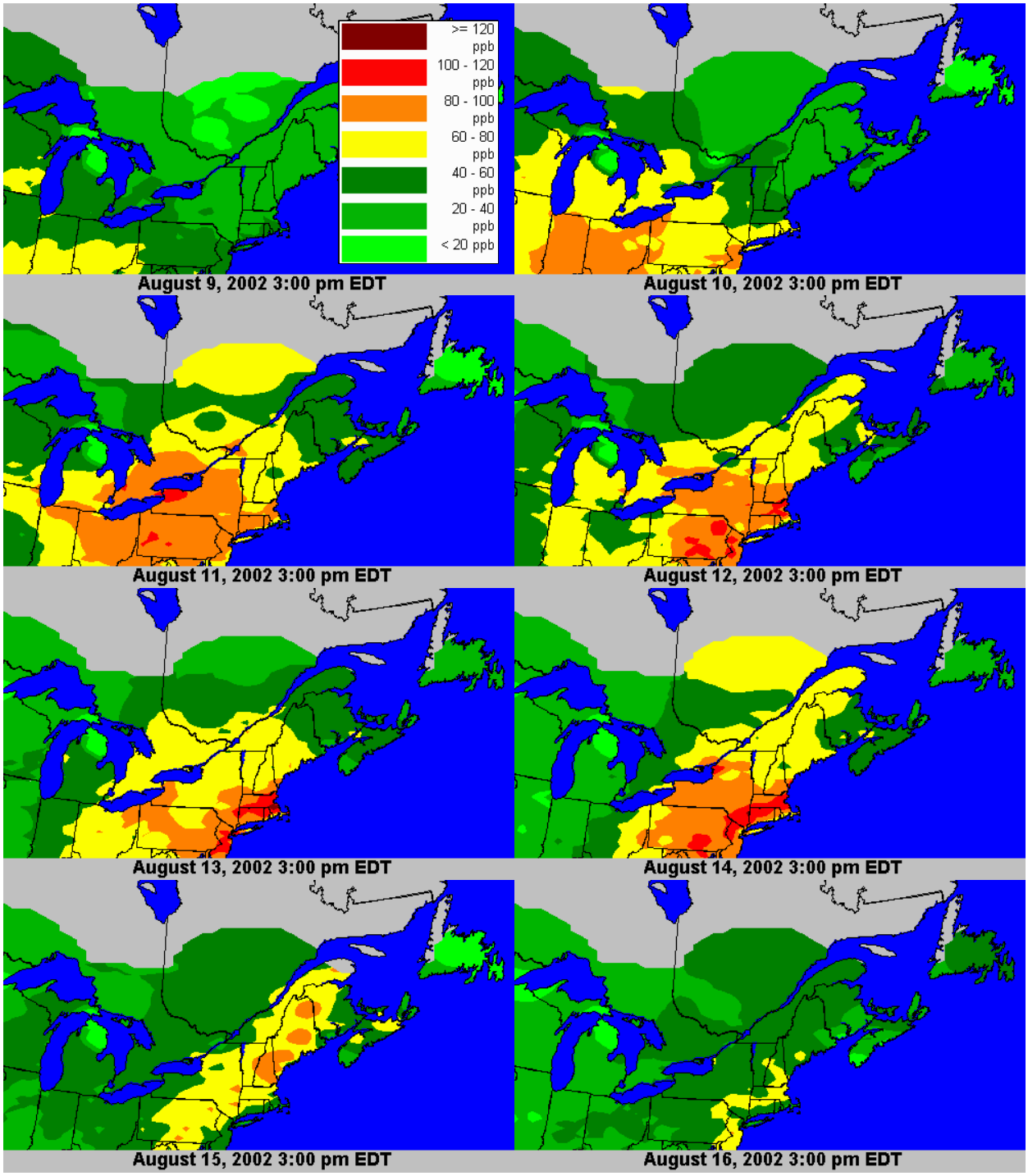


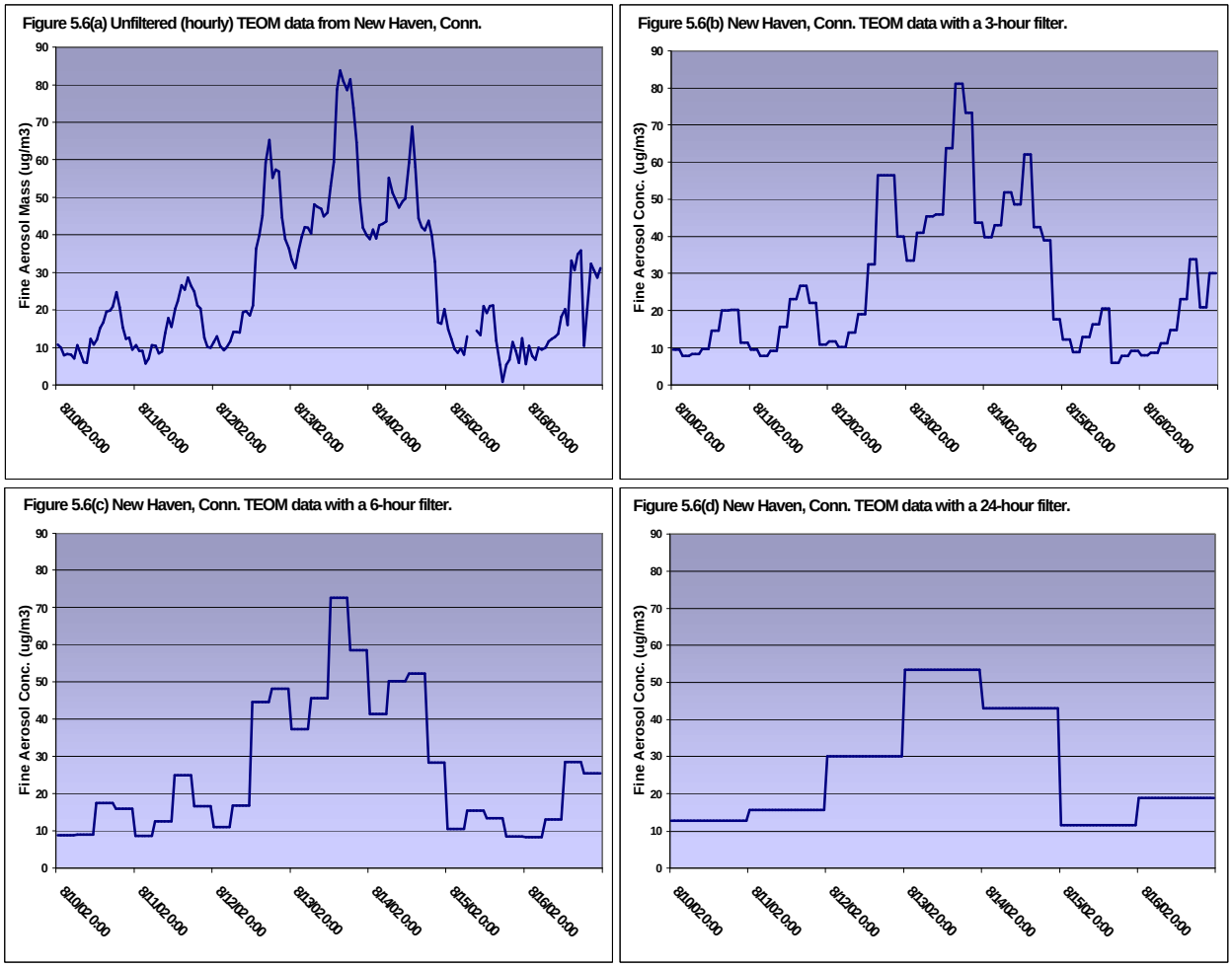
Figure V-7: Spatially interpolated maps of ozone concentrations August 9 – 16, 2002



D.2 Temporal Resolution of the Data

In analyzing the available chemical data available for interpreting the air quality event of August 2002, it is important to point out that the use of different averaging times can have a profound effect on our understanding of the progression of any specific episode. Many subtleties of synoptic-scale meteorology and atmospheric chemistry are "aliased out" of data sets with temporal resolution greater than 3-6 hours. These effects are demonstrated in Figure V-8 which show fine aerosol TEOM data from New Haven for the "episode" period August 10-16, 2002. In these figures, the hourly TEOM values have been aggregated into 3-, 6- and 24-hour mean values. Average concentrations are inversely proportional to the length of the averaging period and the ratio of peak hourly concentration within a daily average ranges from about 1.5 to 1.75 for this episode.

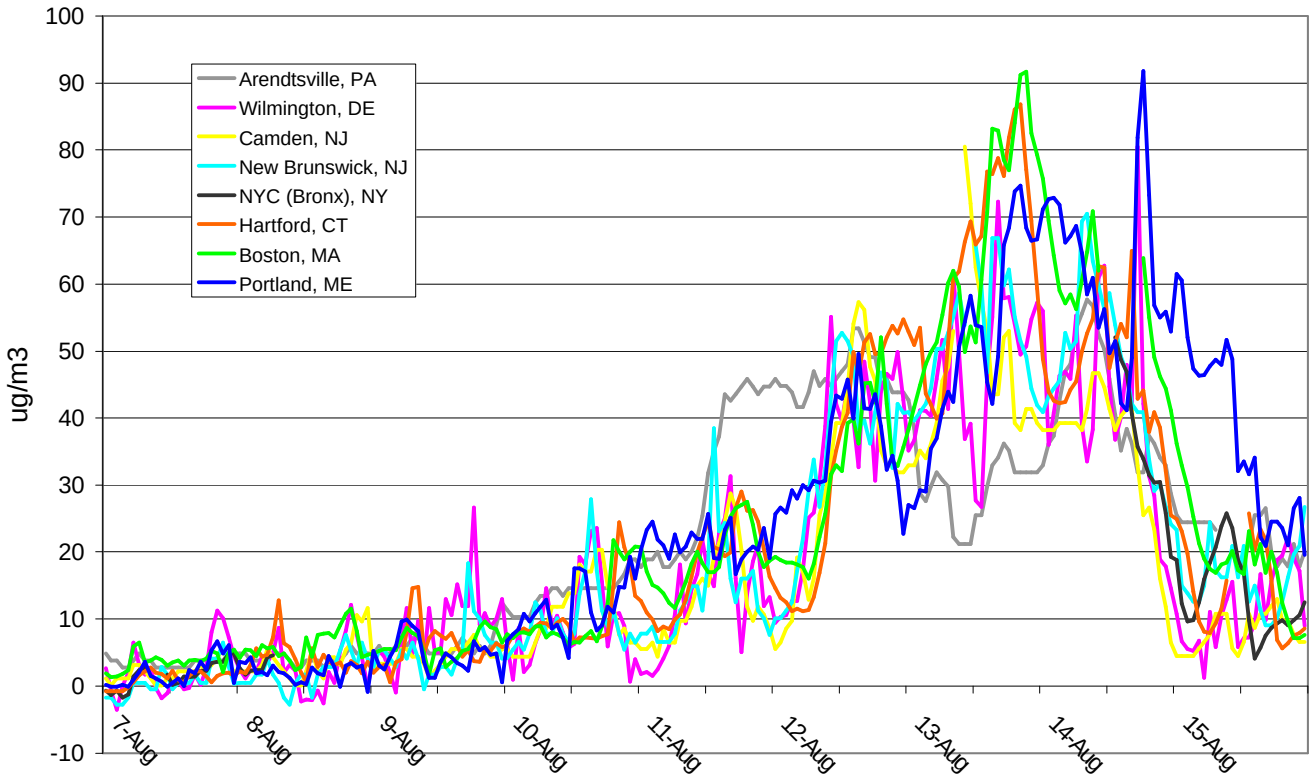
Figure V-8: Effects of averaging times (or temporal resolution) on time series information.



D.3 Semi-continuous sulfate

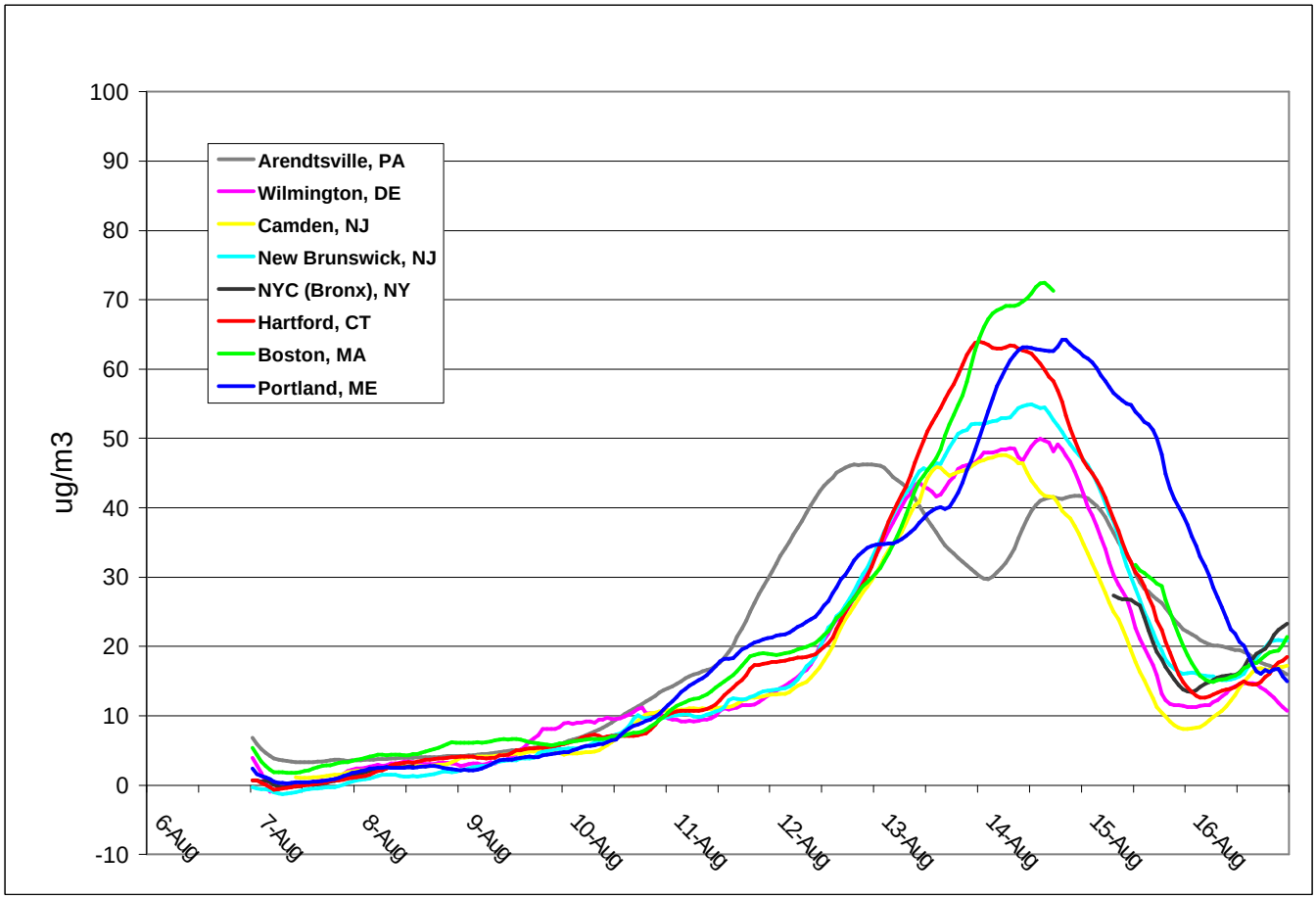
Higher temporal resolution data provide insight into how the events played out in much more detail than can be captured by 8 frames on a page; however the most complete picture is obtained when these high *temporal* resolution data can be presented in the context of the relatively greater *spatial* detail provided by maps such as we have seen in Figures V-4 through V-7. In Figure V-9 and V-10 we show the same continuous PM data presented in Figure IV-6 but we have limited the dataset to cover just the August 8-16, 2002 time period. We have also presented the data with hourly average data and with a 24-hour rolling average filter to smooth the data.

Figure V-9: Hourly average fine aerosol at 8 MANE-VU sites during the August, 2002 episode.



Looking at these figures in the context of the maps presented in the earlier figures, it is interesting to note the rapid increase, first, in Arendtsville, PA at noon on the 11th, followed by a rise in concentrations along the East Coast around noon on the 12th. This is consistent with Figure V-7 which shows high PM levels covering Western Pennsylvania by 3pm on the 11th and that high PM area has moved over to cover the East coast by 3pm the next day. This also makes sense with respect to Figure V-5 and 6 which show the high pressure system established on the East Coast by the 11th with surface level back trajectories having shifted from northerly flow to slow southwesterly flow in the western portion of the domain by the morning of the 11th and the Coastal sites having switched by the morning of the 12th.

Figure V-10: 24-Hour rolling average fine aerosol at 8 MANE-VU sites during the August, 2002 episode.

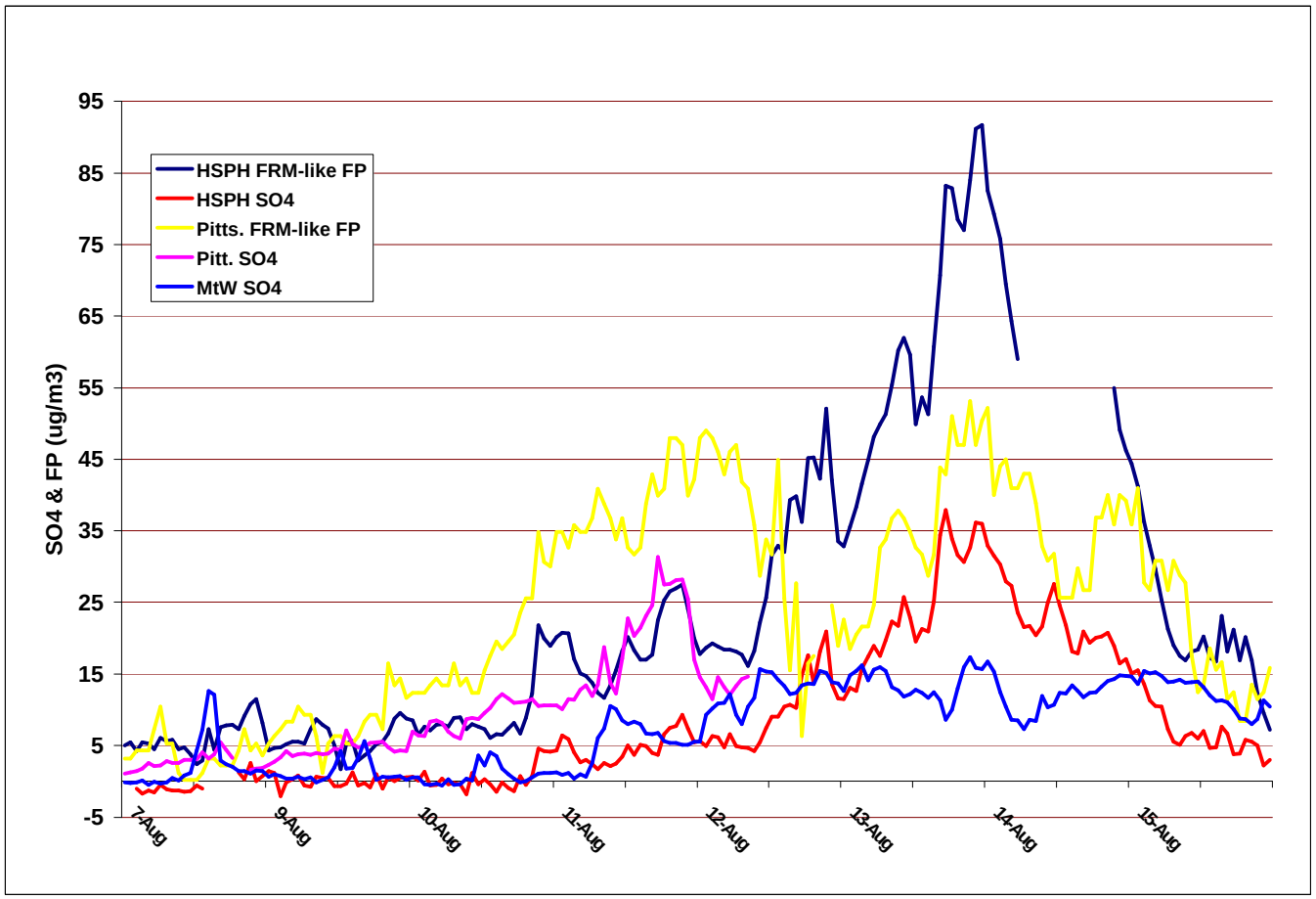


Also note the very high levels observed close to mid-day on the 13th at sites between New York City and Portland, Maine. This is consistent with the strong gradients shown for 3pm on the 13th in Figure V-4. These rapid increases in concentration are easily explained by the back trajectories which show the advancing front (at this point over Lake Michigan) beginning to push, at upper levels of the atmosphere, an airmass from the Upper Midwest due east across the Northern half of the MANE-VU domain. At lower levels (see 200 meter trajectories) it can be seen that at the surface, this airmass had spent the previous 3-4 days winding around the Tennesee and Ohio River Valleys which then were driven into the Northern reaches of MANE-VU at the peak of the pollution event.

Not all questions are answered by highly time resolved data, however. Figure V-11 shows continuous fine particle and sulfate data from three sites in MANE-VU: Pittsburgh, PA, Boston, MA, and the summit of Mt. Washington, NH. In this figure, we see that while all sites appear to be rising in a uniform fashion up until midnight of the 11th, the Pittsburgh site then experiences a rapid drop in sulfate levels while overall $PM_{2.5}$ continue to rise for an additional 12-15 hours. Unfortunately, the sulfate instrument in Pittsburgh went down shortly after that, so we do not know when sulfate levels rebounded, but we do see a subsequent rise in $PM_{2.5}$ in Pittsburgh on the 13th and into the 14th, tracking the rising levels of PM and sulfate at the HSPH site in Boston and on the summit of Mt. Washington. Note that sulfate levels on the summit of

Mt. Washington, a very rural location, reached over 15 µg/m^3 of sulfate during the height of the episode!

Figure V-11: Continuous fine particle and sulfate concentrations at three MANE-VU sites during the August, 2002 episode.



E. Chapter Summary

Fine aerosol concentrations in the MANE-VU region, especially in urbanized areas, display a strong bimodal annual distribution with peaks near January1 and July 1. Both local and transported aerosol mass drive this distribution with local sources predominating during the colder months and more distant sources contributing heavily during the warmer months. Unusual, synoptic-scale meteorological conditions can perturb this distribution and although CY 2002 was a reasonably "typical" year, the impact of Canadian wildfires in early July strongly influenced summer "peak" values. Note too, that data from monitoring stations within a given metropolitan area may show differences in relative height of peak concentrations.

Although co-pollutants sometimes display strong correlations with fine aerosol concentrations, the correlations tend to be seasonal. For example, whenever regional fine aerosol concentrations in MANE-VU exceeded 20 ug/m^3, they were always accompanied by high (or rising) regional NO_x levels – especially during the colder months.

A strong association between fine aerosols and continuous sulfate levels across MANE-VU was also noted during the summer of 2002 highlighting the impact of transport on the region from sources to the South and West. Continuous sulfate measurements also demonstrate the utility inherent in highly time-resolved chemistry data. This utility is also demonstrated by continuous aerosol data which showed that the ratio of peak hourly concentrations to daily average concentration during "episode" conditions in MANE-VU are in the 1.5 to 1.75 range.

VI. Conclusion

Monitoring data collected by routine monitoring networks located throughout the MANE-VU region have been analyzed and presented in order to provide context for interpretation of air quality conditions that existed during calendar year 2002. This year is unique because it represents the mid-point of the "baseline" period for establishing benchmark visibility conditions against which future visibility improvement will be gauged. In addition, 2002 has been selected by consensus of the RPOs as the year for which SIP-related modeling and data analysis activities will be focused.

Given this unique status, a collection of data sets ranging from continuous and FRM $PM_{2.5}$ mass to speciated chemical measurements of various kinds, have been collected, archived and assessed. The archived datasets are available for MANE-VU analysts to access for future model evaluation as well as data analysis activities. The data archive is not static, but will be complemented with additional datasets as they become available.

The current collection of data, and thus the primary data analyzed in this report, is mostly a product of the state-based routine monitoring networks mandated by USEPA, however many special studies that were in place during 2002 have new data becoming available every day (e.g. NEAQS). It is anticipated that this new data will continue to add insights to the more general observations presented in this report, as well as to highlight aspects of the data that have yet to be explored.

As MANE-VU prepares to develop control strategies in order to achieve national visibility goals for individual sites in the Northeast and Mid-Atlantic U.S., it is crucial that available monitoring data provide consistent evidence to support recommended options toward that goal. The collection and presentation of the data sets contained in this report is the first step in ensuring that this objective is achieved.

Analysis to date suggests the following generalized findings:

- Fine particulates in the Northeast and Mid-Atlantic U.S. consist of approximately half sulfate, with the balance consisting of a mix of organic material, nitrates, elemental carbon, soil, and other trace components.

- Fine particle concentrations tend to peak during summer months and winter months with relatively few high PM episodes occurring during the spring or fall.

- During the summer, sulfates are highest in concentration over the southern and western portion of the MANE-VU region, closer to source regions associated with high SO_2 emissions.

- Limited atmospheric mixing during the winter months, changes in thermodynamic stability of secondary organic aerosol and particulate nitrate, as well as potential increases of local emission sources during winter months all contribute to PM episodes during winter which, though usually less severe, tend to be more

localized in urban locations where the greatest potential for human exposure exists. Winter PM tends to contain higher levels of secondary organic aerosol and nitrate relative to summer PM.

- In general, sites tend to track together across very broad geographic scales suggesting the regional influence on ambient fine particulate concentrations. The most significant differences are observed between coastal and inland sites and those in the far southern portions of the MANE-VU domain relative to the Northeast portions.

Appendix A
2002 MANE-VU Data Archive

A.1 Conventions

All data cited in the report "2002 Year in Review" are available at: ftp://airbeat.org/private/2002ManeVuData/. In addition, other data described but not used in that report are also available at that site.

This catalog is a guide to assist in understanding what is available and how it is structured. The following conventions are used in the catalog:

1) The first column (with the heading "**Directory**" in green font) shows the names of directories in the order they exists on the airbeat site,
2) Directories contain either sub-directories or files. The second column shows either the name of the subdirectory within a directory (green font) OR the name of the file (with the appropriate file extension).
3) The column labeled "**Notes**" describes the nature of the data in the sub-directory/file and, in the case of zipped files, shows the name of the file which will appear when the file is unzipped.
4) The column "**File Type**" describes the native application or format of the data.
5) Although an attempt was made to list all measured species within each file (column five "**Parameter(s)**", some files contain data from monitoring programs that are so large that listing all species was not possible (e.g., IMPROVE).
6) Similarly, not all sites could be listed in column six "**Site(s)**", (e.g., FRM data from 160+ sites or aircraft data).
7) The "Start" and "End" date columns are self-explanatory except where files contain data from multiple sites that start/end and different dates. In such cases a tilde (~) or the word "variable" is used.

Data users should also note the caveats/requests in the "0_Readme.txt" and "0_Terms of Use.txt" files in the main directory at the airbeat site.

A.2 Data Tables

Table A-1 contains the listing of archived datasets as described in section A.1.

Directory	Sub-Directory/File Name	Notes	File Type	Parameter(s)	Site(s)	Start Date	End Date
2002-03 STI profiler data	***Mane-Vu-STI 2002 profiler data -- Access database.zip***	Contains file "NESCAUM.mdb" - includes data for both sites.	Zipped MS Access DB	All UA	Stow MA / East Brunswick NJ	6/13/2002	10/31/2002
2002 STN-Improve-FRM_JG	***2002 data - JG.zip***	5 Excel files with both raw and summarized data.	Zipped Excel	IMPROVE, STN, FRM mass	20 IMP (incl. 3 non-MANE-VU), 42 STN, 133 1-in-3 FRM, 31 "everyday" FRM	1/1/2002	12/31/2002
Airmap	***Mount Washington AIRMAP bulk aerosol_GAllen.xls***	Contains ~24hr data - Mt Wash only.	Excel sprdsht	SO_4, NO_3, NA, NH_4, K, Mg, Ca, Cl.	Mt. Washington	6/1/2001	12/31/2002
Airmap	***airmap bulk aerosol.zip***	5 txt files w ~24hr data from each site and a site desc file. Incl DL, uncert & lat/lon info.	Zipped txt	SO_4, NO_3, NA, NH_4, K, Mg, Ca, Cl.	Castle Springs, Ft. Constitution, Mt. Washington, Thompson Farm.	6/1/2001	12/31/2002
Airmap	***airmap_hourly_data.zip***	Contains "airmap_data.csv" with hourly data from each site, DL, uncert & lat/lon info.	Zipped Excel	CNC, CO, CO_2, NO, NO_Y, O_3, PM_{25}, PSAP, SCA-NGN, SCA-RR, SO_2.	Appledore Is., Castle Springs, Mt. Washington, Thompson Farm.	6/1/2001	12/31/2002
Airmap	***NEAQS2002 1min airmap gas.txt.zip***	Contains "UNHNEAQS2t.txt" with minute data from each site, DL, uncert & lat/lon info.	Zipped txt	NO, NO_Y, O_3, PM_{25}, PSAP, SCA-NGN, SCA-RR, SO_2, TMP, BP, WS,WD,	Appledore Is., Castle Springs, Mt. Washington, Thompson Farm.	7/12/2002	8/10/2002
Al Lestons frm-teom data	***All FRM 4 NESC_Rev5april2004.xls***	$PM_{2.5}$ FRM data from 164 sites in MANE-VU (also Harvard Impactor data from 1 Boston site) for 2002.	Excel sprdsht	$PM_{2.5}$	Multiple	1/1/2002	12/31/2002

Al Lestons frm-teom data	***Mane-Vu julian day continuous pm 2002 correction result summary table.xls***	Summary of Julian Day correction factors developed for 21 MANE-VU sites for 2002.	Excel sprdsht	$PM_{2.6}$	Multiple	1/1/2002	12/31/2002
Al Lestons frm-teom data	***FRM-like TEOM 4 NESC.xls Rev_5April2004.zip***	FRM-like hourly data from 20 MANE-VU sites (1 site heavily impacted by local sources is omitted).	Excel sprdsht	$PM_{2.7}$	Multiple	1/1/2002	12/31/2002
AQS_data2002 from SIRD	***DO_350WF_ST_08_09_10_11.zip***	Text file contains all data (incl met) reported to EPA's AQS for 2002 by the states of CO, CT, DE and DC.	Zipped txt	Multiple	Multiple	1/1/2002	12/31/2002
AQS_data2002 from SIRD	***DO_350WF_ST_23_24_25.zip***	Text file contains all data (incl met) reported to EPA's AQS for 2002 by the states of ME, MD and MA.	Zipped txt	Multiple	Multiple	1/1/2002	12/31/2002
AQS_data2002 from SIRD	***DO_350WF_ST_30_31_32_33.zip***	Text file contains all data (incl met) reported to EPA's AQS for 2002 by the states of MT, NE, NV and NH.	Zipped txt	Multiple	Multiple	1/1/2002	12/31/2002
AQS_data2002 from SIRD	***DO_350WF_ST_34_35_36.zip***	Text file contains all data (incl met) reported to EPA's AQS for 2002 by the states of NJ, NM and NY.	Zipped txt	Multiple	Multiple	1/1/2002	12/31/2002
AQS_data2002 from SIRD	***DO_350WF_ST_40_41_42_44_45.zip***	Text file contains all data (incl met) reported to EPA's AQS for 2002 by the states of OK, OR, PA, RI and SC.	Zipped txt	Multiple	Multiple	1/1/2002	12/31/2002
AQS_data2002 from SIRD	***DO_350WF_ST_46_47_48_49_50.zip***	Text file contains all data (incl met) reported to EPA's AQS for 2002 by the states of SD, TN, TX, UT and VT.	Zipped txt	Multiple	Multiple	1/1/2002	12/31/2002
Boston	***2002 Boston BC.xls***	Hourly "black carbon" concs from Roxbury & Harvard Sch Pub Health (HSPH) sites for CY 2002.	Excel sprdsht	Black Carbon	2 Boston sites - Roxbury & HSPH	1/1/2002	12/31/2002

Boston	***Boston2002ecoc_daily.xl***	Daily avg (24hr) concs of elemental and organic carbon (EC/OC) from HSPH site.	Excel sprdsht	Elemental carbon, organic carbon	HSPH	1/1/2002	12/31/2002
Boston	***HSPH-Boston-2002daily_sulfate_filter data.xls***	Daily avg (24hr) concs of SO_4 from HSPH site.	Excel sprdsht	SO_4	HSPH	1/1/2002	12/31/2002
Boston	**HSPH-Boston-2002PM2.5filter data.xls**	Daily avg (24hr) concs of fine aerosol (via Harvard Impactor) from HSPH site.	Excel sprdsht	Fine aerosol (~2.5u).	HSPH	1/1/2002	12/31/2002
Canadian data	***Hourly PM and gases***	Contains the file "2002_hourly eastern Canada Data.zip" which contains 10 txt files for the pollutants noted. Data is for 2002 from multiple eastern Canadian sites.	Zipped txt	CO, NO, NO_2, NOx, O_3, PM_{fine}(BAM), PM_{fine}(dryer)?, SO_2, PM_{10}(TEOM), PM_{fine}(TEOM)	Multiple	1/1/2002	12/31/2002
Canadian data	***NAPS daily PM***	Consists of 14 files containing fine/coarse & total mass and chemistry data from the 4 sites listed. Samplers used were dichots and Partisols.	Excel sprdsht, ASCII text, MS Word	Multiple	New Brunswick, Nova Scotia, Ontario, Quebec	~1/3/2002	variable

DOE PNL and BNL NEAQS2002 flights	***DOE_G1 data.zip***	18 files - 1 for each day the G-1 flew during NEAQS/NAOPEX 2002 (data is 10 sec avg). Also contains txt & Excel files describing data formats & link to BNL site.	Zipped txt	Lat, Long, Alt, Static P, P alt, T amb, Theta, DP, RH, H_2O MR, WS, WD, UV sky, UV gnd, Blue bscat, Green bscat, Blue totscat, Red totscat, PCASP tot, FSSP tot, BAP, O_3, CO, SO_2, NO NO_2, NOy.	Aircraft data	7/9/2002	8/11/2002
DOE PNL and BNL NEAQS2002 flights	***BinnedPart***	Contains the file "binned_particle_data.zip" which contains 10 sec data (multiple bins) from the PCASP PMS and FSSP instruments for each flight during NEAQS/NAOPEX 2002. CAUTION: file names in this zip file are identical to those in "DOE_G1 data.zip" file.	Zipped txt	15 size bins plus "sum", "area" & "volume" data for PCASP PMS and FSSP instruments.	Aircraft data	7/9/2002	8/11/2002
Hopke 2002 Rochester	***rochester.zip***	Contains the file "rochesteralldata_H.xls" which holds 1 min SO_4, 30 min TEOM, 1 hr BC and 1 hr EC/OC data.	Excel sprdsht	SO_4, $PM_{2.5}$(TEOM), BC, EC, OC.	Rochester, NY	~6/1/02	6/19/2002

NOAA Ron Brown NEAQS2002 data	***All NEAQS2002_PMEL Tim_Bates data in acf format.zip***	15 acf files contain pollutant and met data from the summer of 2002. Timestamp varies by parameter (15 min - 1Hr). Metadata contained in front end of each file, followed by raw data.	acf (use NotePad, EditPad, etc to open)	Multiple	Various offshore East coast locations.	~7/12/02	~8/10/02
NOAA Ron Brown NEAQS2002 data	***NEAQS2002-Eric_Williams.zip***	15 minute NO, NO_2, NOy, O_3 and SO_2 data in the file "NEAQS2002-Eric_Williams.dat"	DAT	NO, NO_2, NOy, O_3 and SO_2	Various offshore East coast locations.	~7/12/02	~8/10/02
NY Supersite/ WhiteFace	***WFM_8400S_10min_data_send.xls***	10-minute SO_4 data	Excel sprdsht	SO_4	Whiteface Mt., NY	7/9/2002	8/7/2002
Phila NEOPS2002	***Millersville Balloon July smoke event***	5 Excel files containing fine aerosol data from balloon-borne Dust Trak monitor during Canadian wildfire event on 7/7/02.	Excel sprdsht	Fine aerosol (~2.5u).	Philadelphia, PA	7/7/2002	7/7/2002
Phila NEOPS2003	***Millersville_Balloon_NarstoData***	Zipped files of surface gas & part data and tethersonde data from NEOPS for the years 2002 (data back thru 1999 also available). Note: tethersonde file would not "load completely" in Excel - too many lines!	Zipped csv	multiple	Philadelphia, PA	6/29/2002	8/6/2002
Phila NEOPS2004	***Philly2002NEOPS_Hopke_rev25may04.zip***	2 zipped Excel files of NEOPS data for July 2002.	Zipped Excel	2.5TEOM(SES), BC, EC, OC, OptEC, SO4, Bscat	Philadelphia, PA	~7/1/02	~7/31/02
Pittsburgh Supersite	***PAQS_CONT_VOC_V1.zip***	2 zipped Excel files of Pitts Air Quality Study (PAQS) hourly VOC data (auto GC/MS) for July 2002 (and Jan 2002).	Zipped csv	Multiple VOCs	Pittsburgh, PA	7/9/2002	8/10/2002

Pittsburgh Supersite	***PAQS_NEPH_SCHP_V1.zip***	Zipped file contains ~1 yr of hourly Bscat (Neph) from PAQS.	Zipped csv	Bscat	Pittsburgh, PA	7/16/2001	7/1/2002
Pittsburgh Supersite	***PAQS_PEROX_V1.zip***	Contains 2 zipped files intended for peroxide data but data is not evident (much meta-data is listed).	Zipped xls				
Pittsburgh Supersite	***PAQS_STEAM_IC_V1.zip***	3 zipped files with 2-hour data on water soluble gases & aerosols.		SO_4, NO_2, NO_3, Cl, NH_4, NH_3, Na, HNO_3, HNO_2, HCl,	Pittsburgh, PA	10/1/2001	9/28/2002
Pittsburgh Supersite	***PAQS_SURF-CONT-SO4-NO3_SCHP_V1.zip***	10-min avg sulfate & nitrate from PAQS in 8 monthly zipped files.	Zipped csv	SO_4, NO_3	Pittsburgh, PA	1/1/2002	9/1/2002
Pittsburgh Supersite	***PAQS_SURF-GAS-TEOM_SCHP_V1.zip***	10-min avg of 5 gases and fine aerosol (TEOM) from PAQS in 8 monthly zipped files.	Zipped csv	O3, NO, NOx, SO2, CO, Fine Aero(TEOM)	Pittsburgh, PA	1/1/2002	9/1/2002
Pittsburgh Supersite	***PAQS_SURF-MET-DATA_SCHP_V1.zip***	10-min avg of 8 met parameters from PAQS in 10 monthly zipped files.	Zipped csv	WS, WD, Precip, Temp, RH, BP, Sol Rad, UV Rad.	Pittsburgh, PA	1/2/2002	10/10/2002
Pittsburgh Supersite	***PAQS_CONT_OCEC_20010701_20020814_V1.csv***	Variable timestamp (1-4 hr) EC/OC data from $PM_{2.5}$ samples. (Thermo-optical, NIOSH)	Zipped csv	EC/OC	Pittsburgh, PA	7/1/2002	8/14/2002
Pittsburgh Supersite	***PAQS_DENUDED_ORGANIC_SCHP-20010701-20020529_V1.csv***	Daily (24-hr) filter-based OC/EC via TOR analysis from PAQS.	Zipped csv	OC, EC, Temp, BP	Pittsburgh, PA	7/1/2001	5/28/2002
Pittsburgh Supersite	***PAQS_DICHOT_20010523_20020630_V1.csv***	Daily (24-hr) fine and coarse particle fractions via Dichot sampler from PAQS.	Zipped csv	Fpmass, CPmass	Pittsburgh, PA	6/19/2001	7/1/2002

Pittsburgh Supersite	***PAQS_FILTER_INORGANIC_20020101_20020721_V1.csv***	Daily (24-hr) measure of 5 gases from PAQS.	Zipped csv	NH_3, NH_4, SO_4, NO_3, HNO_3	Pittsburgh, PA	1/1/2002	7/20/2002
Pittsburgh Supersite	***PAQS_FILTER_OCEC_SCHP-20010630-20020731_V1.csv***	Daily (24-hr) measure of OC/EC from PAQS.	Zipped csv	OC, EC	Pittsburgh, PA	6/29/2001	7/30/2002
Pittsburgh Supersite	***PAQS_FOG_20020101_20020513_V1.csv***	Fog chemistry data for discrete events between 1/1/02 and 5/31/02.	Zipped csv	Na, NH_4, K, Mg, Ca, Cl, NO_2, NO_3, SO_4, TOC, DOC, pH	Pittsburgh, PA	1/1/2002	5/31/2002
Pittsburgh Supersite	***PAQS_FRM_20010523_20020630_V1.csv***	Daily (24-hr) $PM_{2.5}$ mass (FRM) from PAQS.	Zipped csv	$PM_{2.5}$ mass	Pittsburgh, PA	5/23/2001	6/30/2002
Pittsburgh Supersite summer 2002	***PAQS_MOUDI_MASS_20010611_20020630_V1.csv***	Daily (~24-hr) particle size data (9-stage MOUDI) from PAQS.	Zipped csv	Mean particle dia and mass for 9 fractions.	Pittsburgh, PA	6/12/2001	7/1/2002
MTW hourly so4	***2002_AMC_PM-SO4.xls***	24-hr filter-based SO_4 data from 2 sites.	Excel	SO_4	Camp Dodge & "Lakes" site.	~6/5/02	9/13/2002
summer 2002 MTW hourly so5	***Nescaum Mt Washington hourly sulfate data June-Sept 2002.xls***	Hourly SO4 from Mt. Wash - incl discussion of results when hrly data was compared to daily filter data at same site.	Excel	SO_5	Mt. Washington	6/4/2002	9/16/2002
Surface Met	***Data***	Contains (massive) zip files of all NWS surface met parameters from all NWS stations in the US.	Zipped "gz"	Multiple met.	Multiple	1/1/2002	12/31/2002
UMD flights	***2002 UMD Aircraft ManeVu Flights - Final data.zip***	18 zipped Excel files- 1 for each UMD flight made on behalf of MANE-VU in '02. Also, see "0_Fair Data-use Notice.txt"	Zipped xls	Multiple gas & particle.	18 flights over MANE-VU	7/2/2002	8/14/2002
UMD flights	***2002-all-flights_finaldata_viaMDE.zip***	54 zipped Excel files - 1 for each UMD flight during '02. Also, see "0_Fair Data-use Notice.txt"	Zipped xls	Multiple gas & particle.	54 flights over the mid-Atlantic, New England area.	5/23/2002	10/3/2002

Winter2004_B
alloonData ***Data*** "Data" Folder is empty.

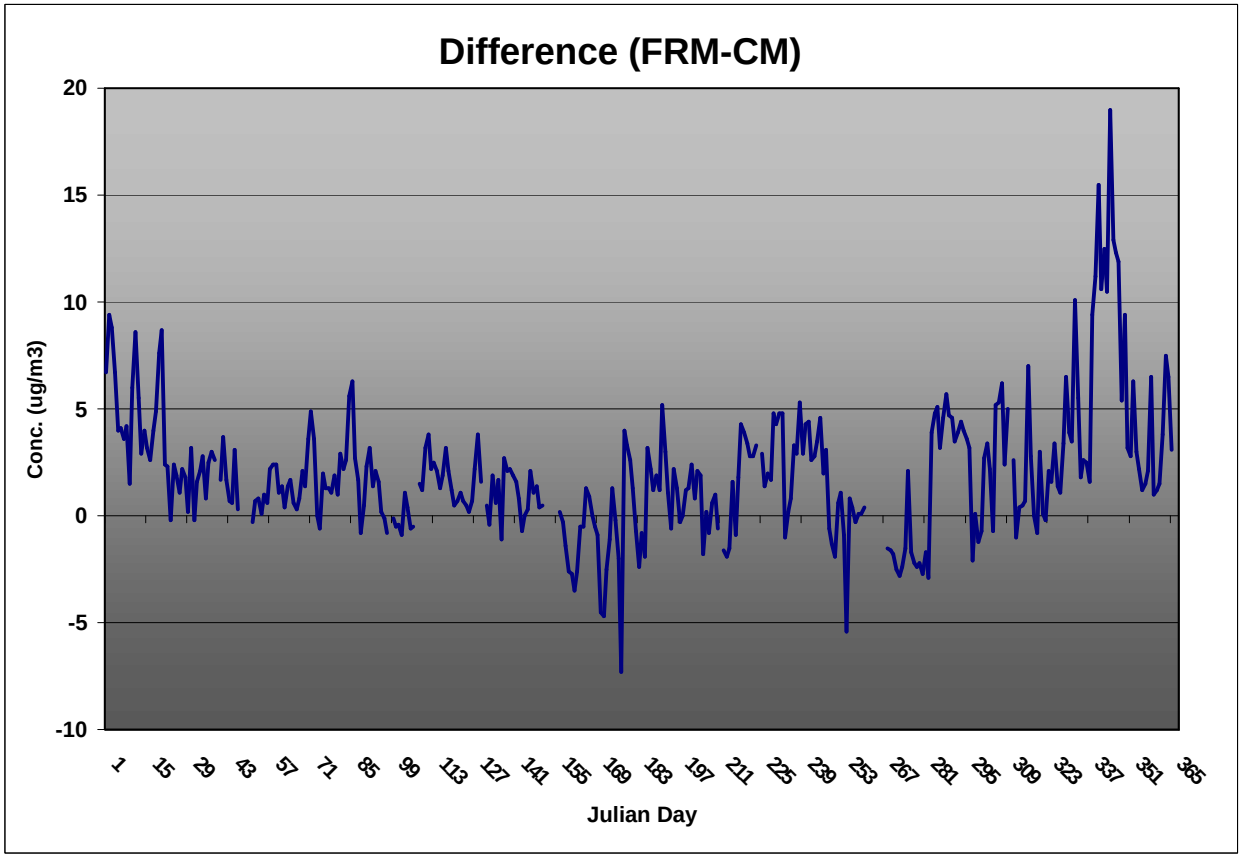
Appendix B
Julian Day Correction of TEOM Monitor Data

B.1 Explanation

The following material describes an approach for adjusting continuous (hourly) fine aerosol data so that it closely resembles data collected by the USEPA's Federal Reference Method (FRM) for $PM_{2.5}$. This approach relies on the "Julian Day" (JD) of the year which is simply the rank order of a given day. For example, Jan.19 is JD 19 and July 19 is JD 200 (in a non-leap year). This approach was developed using hourly data from Tapered Element Oscillating Microbalance (TEOM) monitors and its suitability for use with monitors relying on other operating principals has not been tested. Detailed procedures follow this explanation.

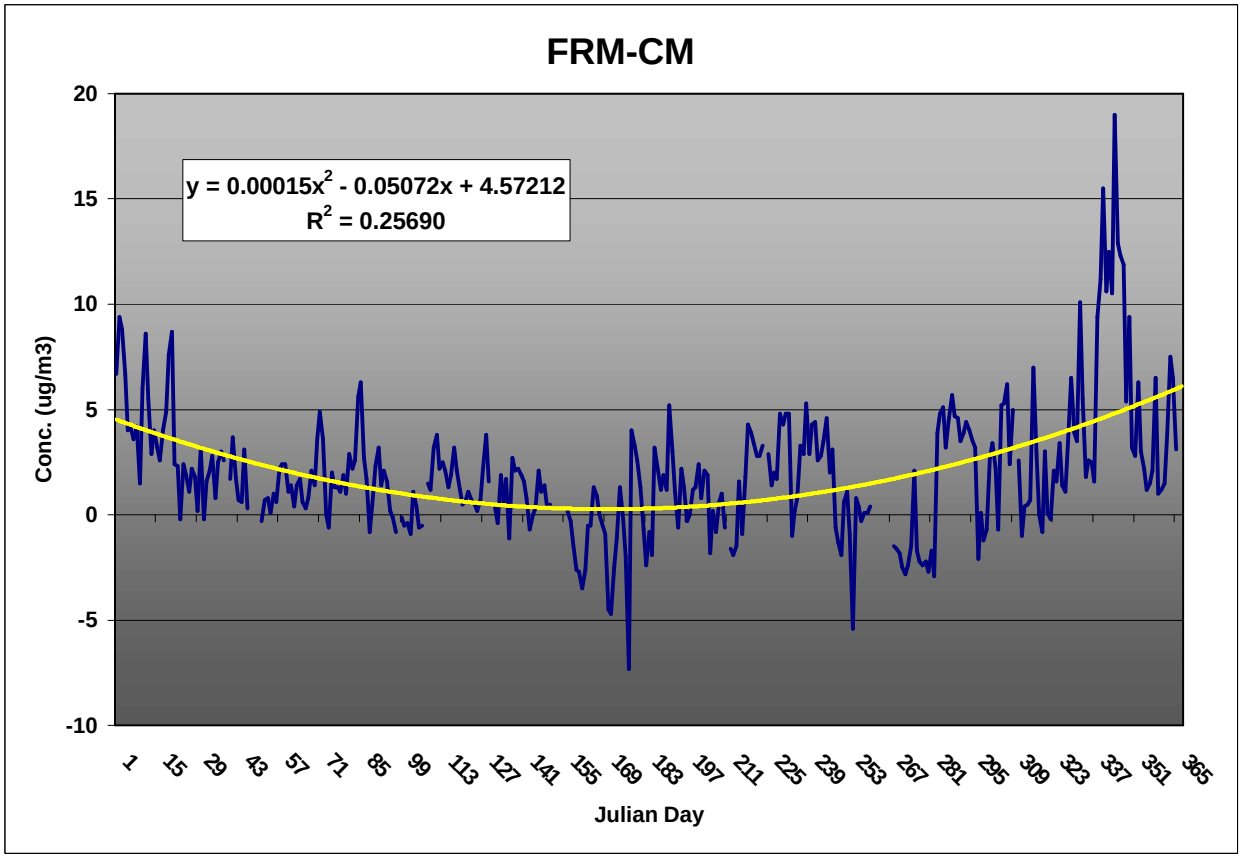
If the differences between FRM samples and the equivalent continuous monitor (CM) data are graphed on an annual basis the results will look something like this:

Figure B-1: Annual difference between FRM and CM values.



By generating a "best fit" 2nd order polynomial curve to the "difference" data, an equation is determined, in terms of Julian day, which can remove seasonal variation. The curve and equation for the Figure B-1 data are shown in Figure B-2.

Figure B-2: FRM-CM difference data with 2nd order polynomial best fit line and equation.

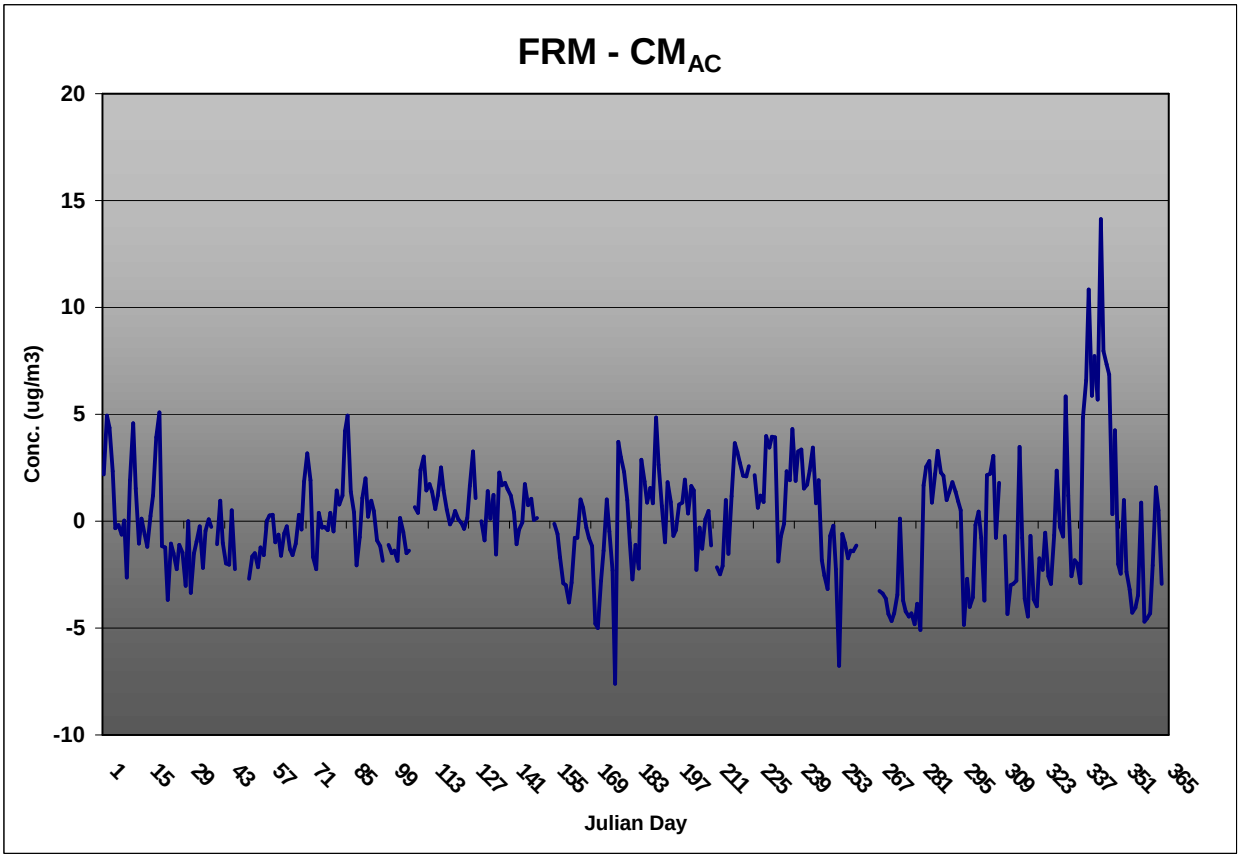


The polynomial equation is employed to create a Julian day-base additive term (JD_A) that, combined with the CM data, creates an "annually corrected" term (CM_{AC}) and removes the seasonal variation. A difference still exists but it is now linear.

A simple least squares linear regression can then be performed on the FRM/CM_{AC} pairs. The resulting equation is examined to determine the goodness of fit, which according to USEPA, must have a correlation coefficient (R^2) greater than 0.81. The equation is then "inverted" in order to create "FRM-like" CM data (CM_{FRM}) on an hourly basis.

The foregoing discussion was based on the assumption that FRM samples were collected every day of the year. However, many sites operate on a "1-in-3 day" schedule and additional steps are required to process data from those sites. Also, asymmetric annual PM distributions should be accounted for during creation of "FRM-like" data. Both of these topics are covered in the detailed procedures that follow.

Figure B-3: Seasonally adjusted difference.



B.2 Procedure - "Everyday" FRM samples

1. Aggregate the raw continuous monitor data (CM) into 24-hour daily averages.

2. Inspect both the CM and FRM data sets for seasonal completeness. This example uses three seasons of four months each. To be complete, each (approx.) 121 day season must have at least 75% data capture or 121 x 0.75 = 91 samples. Seasons in the example spread sheet (Excel) are delineated by different font colors of the sample date.

3. Arrange seasonally complete CM and FRM data in a spreadsheet in order by sample date (all scheduled dates must be included even if no data is available) and include a column for the Julian Day (JD).

4. Calculate the difference between data pairs as: Difference = (FRM - CM). Delete any zero values created by missing data ("real" zeros resulting from equal FRM/CM values are fine).

5. Create a line graph using JD as "X" and FRM-CM as "Y" (Chart **1** in the "Everyday Data" example).

6. Click on the graph to highlight it and on under "*Chart*" options select "*Add Trendline*". Choose "*2nd order polynomial*" and under the "*Options*" menu select both "*Display equation on chart*." and "*Display R-squared value on chart*." Specify at least 5 decimal places in the equation.

7. Calculate the "JD Adder" (JD_A) using the 2nd order polynomial and the JD value for each day of the year. If the difference in JD_A between the first and last day of the year exceeds 0.5 µg/m^3 go to the next step. Otherwise, go to step 13.

8. Average the JD_A values for the first and last days of the year and enter the value on lines 2 and 366 of the column labeled "Start/End Corr"

9. Find the minimum JD_A value for the year and enter it on line 183 of the "Start/End Corr" column.

10. Create a line graph using JD as "X" values and "Start/End Corr." as "Y" values (Chart **2** in the "Everyday Data" example).

11. Create a 2nd order polynomial equation and R^2 value for this new graph as in step 6.

12. Calculate the "JD Start/End" Adder" ($JD_{S/E}$) using the polynomial equation found in step 11.

13. Calculate "Annually Corrected" continuous monitor values (CM_{AC}) for each day. These are the sums of continuous monitor values (CM) and the JD adder from either step 7 or step 12.

14. Create a scatter graph of FRM vs. CM_{AC} including regression equation and R^2 values (Chart **3** in the "Everyday Data" example).

15. If the R^2 value in Chart 3 is greater than 0.81 the FRM/CM correlation meets USEPA criteria - proceed to the next step.

16. To create hourly FRM-like concentrations (CM_{FRM}) in terms of CM data, rearrange the linear equation to the form:

$$CM_{FRM} = [(CM_{AC}) \times (1/slope)]-(intercept/slope)$$

This completes the preparations needed to transform hourly PM values into "FRM-like" data. To calculate CM_{FRM} values perform the following steps.

A.) Employ the non-linear transform (based on either J_{DA} or JD_{SE}) that generates "annually" corrected continuous monitor values (CM_{AC}) on all CM hourly data points. In the attached example this is:

$$\mathbf{CM_{AC} = CM + (0.00015 \times JD^2) - (0.053351 \times JD) + 5.3351}$$

Then,

B.) Perform the linear correction of the just created CM_{AC} hourly data, which in the attached example is:

$$\mathbf{CM_{FRM} = (CM_{AC} \times 1.017) - 0.160}$$

B.3 Procedure - "1-in-3 Day" FRM samples

1. Aggregate the raw continuous monitor data (CM) into 24-hour daily averages.

2. Inspect both the CM and FRM data sets for seasonal completeness. This example uses three seasons of four months each. To be complete, each (approx.) 40-sample season must have at least 75% data capture or 40 x 0.75 = 30 samples (90 samples for the year). Seasons in the example spread sheet (Excel) are delineated by different font colors of the sample date.

3. Arrange seasonally complete CM and FRM data in a spreadsheet in order by sample date (all scheduled dates must be included even if no data is available). Include a column for the Julian Day (JD) and a "counter" column associated with the sample date.

4. Calculate the difference between data pairs as: Difference = (FRM - CM). Delete any zero values created by missing data ("real" zeros resulting from equal FRM/CM values are fine).

5. Create a line graph using the "counter" as "X" and FRM-CM as "Y" (Chart 1 in the "1-in-3 Data" example).

6. Click on the graph to highlight it and on under "*Chart*" options select "*Add Trendline*". Choose "*2nd order polynomial*" and under the "*Options*" menu select both "*Display equation on chart*." and "*Display R-squared value on chart*." Specify at least 5 decimal places in the equation.

7. Calculate the "JD Adder" (JD_A) using the 2nd order polynomial and the counter value for each sample day.

8. Average the JD_A values for the first and last days of the year and enter the value on lines 2 and 366 of the column labeled "Start/End Corr"

9. Find the minimum JD_A value for the year and enter it on line 183 of the "Start/End Corr" column.

10. Create a line graph using JD as "X" values and "Start/End Corr." as "Y" values (Chart **2** in the "1-in-3 Data" example).

11. Create a 2nd order polynomial equation and R^2 value for this new graph as in step 6.

12. Calculate the "JD Start/End" adder ($JD_{S/E}$) using the polynomial equation found in step 11.

13. Calculate "Annually Corrected" continuous monitor values (CM_{AC}) for each day. These are the sums of continuous monitor values (CM) and the JD adder from step 12.

14. Create a scatter graph of FRM vs. CM_{AC} including regression equation and R^2 values (Chart **3** in the "1-in-3 Data" example).

15. If the R^2 value in Chart 3 is greater than 0.81 the FRM/CM correlation meets USEPA criteria - proceed to the next step.

16. To create hourly FRM-like concentrations (CM_{FRM}) in terms of CM data, rearrange the linear equation to the form:

$$CM_{FRM} = [(CM_{AC}) \times (1/slope)]-(intercept/slope)$$

This completes the preparations needed to transform hourly PM values into "FRM-like" data. To calculate CM_{FRM} values perform the following steps.

A.) Employ the non-linear transform (based on either J_{DA} or JD_{SE}) that generates "annually" corrected continuous monitor values (CM_{AC}) on all CM hourly data points. In the attached example the seasonal transform is:

$$\mathbf{CM_{AC} = CM + (0.00016 \times JD^2) - (0.05989 \times JD) + 3.43973}$$

Then,

B.) Perform the linear correction of the just created CM_{AC} hourly data and truncate calculated values after one decimal place. In the attached example the linear correction is:

$$\mathbf{CM_{FRM} = (CM_{AC} \times 1.080) - 0.792}$$

B.4 Tables, Charts and Factors used

Several example tables, explanatory charts and specific factors used in the preceding list of procedures are provided on the following pages.

Table B-1: Example Spreadsheet for Sites with Everyday Data (AQS Site = 42 003 008)

JD	Everyday Sample Date	FRM	Contin. Monitor (CM)	Difference (FRM-CM)	JD_A (from 2nd Order Poly)	Start/End Correction	$JD_{S/E}$ (from Col. G)	CM_{AC} (CM + JD_A Or $JD_{S/E}$)
1	1/1/02	15.5	8.8	6.7	4.52155	5.28	5.2	14.0
2	1/2/02	20.6	11.2	9.4	4.47128		5.2	16.4
3	1/3/02	21.7	12.9	8.8	4.42131		5.1	18.0
4	1/4/02	14.1	7.4	6.7	4.37164		5.1	12.5
5	1/5/02	14.6	10.6	4.0	4.32227		5	15.6
6	1/6/02	16.5	12.4	4.1	4.27320		5	17.4
7	1/7/02	8.6	5	3.6	4.22443		4.9	9.9
8	1/8/02	10.4	6.2	4.2	4.17596		4.9	11.1
9	1/9/02	11.2	9.7	1.5	4.12779		4.8	14.5
10	1/10/02	19.6	13.6	6.0	4.07992		4.7	18.3
11	1/11/02	14.6	6	8.6	4.03235		4.7	10.7
12	1/12/02	10.7	5.2	5.5	3.98508		4.6	9.8
13	1/13/02	6.1	3.2	2.9	3.93811		4.6	7.8
14	1/14/02	11.7	7.7	4.0	3.89144		4.5	12.2
15	1/15/02	11.0	7.8	3.2	3.84507		4.5	12.3
16	1/16/02	13.0	10.4	2.6	3.79900		4.4	14.8
17	1/17/02	13.0	9	4.0	3.75323		4.4	13.4
18	1/18/02	13.3	8.4	4.9	3.70776		4.3	12.7
19	1/19/02	20.6	13	7.6	3.66259		4.3	17.3
20	1/20/02	21.4	12.7	8.7	3.61772		4.2	16.9
21	1/21/02	17.9	15.5	2.4	3.57315		4.2	19.7
22	1/22/02	15.4	13.1	2.3	3.52888		4.1	17.2
23	1/23/02	8.2	8.4	-0.2	3.48491		4.1	12.5
24	1/24/02	12.6	10.2	2.4	3.44124		4	14.2
25	1/25/02	8.9	7	1.9	3.39787		4	11.0
26	1/26/02	6.7	5.6	1.1	3.35480		4	9.6
27	1/27/02	13.0	10.8	2.2	3.31203		3.9	14.7
28	1/28/02	17.3	15.5	1.8	3.26956		3.9	19.4
29	1/29/02	17.7	17.5	0.2	3.22739		3.8	21.3
30	1/30/02	8.4	5.2	3.2	3.18552		3.8	9.0
31	1/31/02	9.3	9.5	-0.2	3.14395		3.7	13.2
32	2/1/02	6.3	4.7	1.6	3.10268		3.7	8.4
33	2/2/02	6.7	4.6	2.1	3.06171		3.6	8.2
34	2/3/02	10.5	7.7	2.8	3.02104		3.6	11.3
35	2/4/02	6.7	5.9	0.8	2.98067		3.5	9.4
36	2/5/02	7.5	5	2.5	2.94060		3.5	8.5
37	2/6/02	12.0	9	3.0	2.90083		3.4	12.4
38	2/7/02	12.4	9.8	2.6	2.86136		3.4	13.2
39	2/8/02				2.82219		3.4	3.4
40	2/9/02	18.7	17	1.7	2.78332		3.3	20.3
41	2/10/02	12.5	8.8	3.7	2.74475		3.3	12.1
42	2/11/02	5.0	3.3	1.7	2.70648		3.2	6.5
43	2/12/02	7.3	6.6	0.7	2.66851		3.2	9.8
44	2/13/02	5.6	5	0.6	2.63084		3.1	8.1
45	2/14/02	13.4	10.3	3.1	2.59347		3.1	13.4
46	2/15/02	14.4	14.1	0.3	2.55640		3.1	17.2
47	2/16/02				2.51963		3	3.0
48	2/17/02				2.48316		3	3.0
49	2/18/02				2.44699		2.9	2.9
50	2/19/02				2.41112		2.9	2.9

51	**2/20/02**	8.7	9	-0.3	2.37555		2.9	11.9
52	**2/21/02**	10.7	10	0.7	2.34028		2.8	12.8
53	**2/22/02**	8.3	7.5	0.8	2.30531		2.8	10.3
54	**2/23/02**	13.2	13.1	0.1	2.27064		2.7	15.8
55	**2/24/02**	19.5	18.5	1.0	2.23627		2.7	21.2
56	**2/25/02**	18.0	17.4	0.6	2.20220		2.7	20.1
57	**2/26/02**	14.2	12	2.2	2.16843		2.6	14.6
58	**2/27/02**	9.2	6.8	2.4	2.13496		2.6	9.4
59	**2/28/02**	11.5	9.1	2.4	2.10179		2.5	11.6
60	**3/1/02**	11.1	10	1.1	2.06892		2.5	12.5
61	**3/2/02**	9.8	8.4	1.4	2.03635		2.5	10.9
62	**3/3/02**	5.6	5.2	0.4	2.00408		2.4	7.6
63	**3/4/02**	7.6	6.2	1.4	1.97211		2.4	8.6
64	**3/5/02**	11.0	9.3	1.7	1.94044		2.4	11.7
65	**3/6/02**	10.7	10.1	0.6	1.90907		2.3	12.4
66	**3/7/02**	17.1	16.8	0.3	1.87800		2.3	19.1
67	**3/8/02**	16.9	16.1	0.8	1.84723		2.3	18.4
68	**3/9/02**	10.5	8.4	2.1	1.81676		2.2	10.6
69	**3/10/02**	4.7	3.3	1.4	1.78659		2.2	5.5
70	**3/11/02**	10.0	6.4	3.6	1.75672		2.2	8.6
71	**3/12/02**	17.4	12.5	4.9	1.72715		2.1	14.6
72	**3/13/02**	17.6	14	3.6	1.69788		2.1	16.1
73	**3/14/02**	23.2	23.2	0.0	1.66891		2.1	25.3
74	**3/15/02**	18.1	18.7	-0.6	1.64024		2	20.7
75	**3/16/02**	10.3	8.3	2.0	1.61187		2	10.3
76	**3/17/02**	7.0	5.7	1.3	1.58380		2	7.7
77	**3/18/02**	13.8	12.5	1.3	1.55603		1.9	14.4
78	**3/19/02**	13.9	12.8	1.1	1.52856		1.9	14.7
79	**3/20/02**	8.9	7	1.9	1.50139		1.9	8.9
80	**3/21/02**	12.7	11.7	1.0	1.47452		1.8	13.5
81	**3/22/02**	7.5	4.6	2.9	1.44795		1.8	6.4
82	**3/23/02**	7.4	5.2	2.2	1.42168		1.8	7.0
83	**3/24/02**	11.6	9	2.6	1.39571		1.7	10.7
84	**3/25/02**	14.2	8.6	5.6	1.37004		1.7	10.3
85	**3/26/02**	14.6	8.3	6.3	1.34467		1.7	10.0
86	**3/27/02**	12.6	9.9	2.7	1.31960		1.6	11.5
87	**3/28/02**	16.2	14.5	1.7	1.29483		1.6	16.1
88	**3/29/02**	14.0	14.8	-0.8	1.27036		1.6	16.4
89	**3/30/02**	8.0	7.5	0.5	1.24619		1.6	9.1
90	**3/31/02**	11.5	9.2	2.3	1.22232		1.5	10.7
91	**4/1/02**	10.8	7.6	3.2	1.19875		1.5	9.1
92	**4/2/02**	13.0	11.6	1.4	1.17548		1.5	13.1
93	**4/3/02**	6.8	4.7	2.1	1.15251		1.4	6.1
94	**4/4/02**	9.0	7.4	1.6	1.12984		1.4	8.8
95	**4/5/02**	8.5	8.3	0.2	1.10747		1.4	9.7
96	**4/6/02**	6.8	6.9	-0.1	1.08540		1.4	8.3
97	**4/7/02**	11.2	12	-0.8	1.06363		1.3	13.3
98	**4/8/02**				1.04216		1.3	1.3
99	**4/9/02**	10.8	10.9	-0.1	1.02099		1.3	12.2
100	**4/10/02**	6.7	7.2	-0.5	1.00012		1.3	8.5
101	**4/11/02**	11.3	11.7	-0.4	0.97955		1.2	12.9
102	**4/12/02**	10.2	11.1	-0.9	0.95928		1.2	12.3
103	**4/13/02**	11.4	10.3	1.1	0.93930		1.2	11.5
104	**4/14/02**	11.2	10.8	0.4	0.91963		1.2	12.0
105	**4/15/02**	14.6	15.2	-0.6	0.90026		1.1	16.3
106	**4/16/02**	23.4	23.9	-0.5	0.88120		1.1	25.0
107	**4/17/02**				0.86243		1.1	1.1
108	**4/18/02**	22.4	20.9	1.5	0.84396		1.1	22.0
109	**4/19/02**	15.7	14.5	1.2	0.82579		1	15.5

110	**4/20/02**	11.1	7.9	3.2	0.80792		1	8.9
111	**4/21/02**	8.4	4.6	3.8	0.79034		1	5.6
112	**4/22/02**	8.1	5.9	2.2	0.77307		1	6.9
113	**4/23/02**	8.7	6.2	2.5	0.75611		1	7.2
114	**4/24/02**	13.0	10.9	2.1	0.73943		0.9	11.8
115	**4/25/02**	8.2	6.9	1.3	0.72307		0.9	7.8
116	**4/26/02**	8.9	7	1.9	0.70700		0.9	7.9
117	**4/27/02**	12.4	9.2	3.2	0.69123		0.9	10.1
118	**4/28/02**	10.1	8	2.1	0.67576		0.9	8.9
119	**4/29/02**	6.4	5.2	1.2	0.66059		0.8	6.0
120	**4/30/02**	10.0	9.5	0.5	0.64571		0.8	10.3
121	**5/1/02**	8.2	7.5	0.7	0.63114		0.8	8.3
122	**5/2/02**	13.7	12.6	1.1	0.61687		0.8	13.4
123	**5/3/02**	6.0	5.3	0.7	0.60290		0.8	6.1
124	**5/4/02**	7.3	6.8	0.5	0.58924		0.7	7.5
125	**5/5/02**	12.9	12.7	0.2	0.57587		0.7	13.4
126	**5/6/02**	15.2	14.5	0.7	0.56279		0.7	15.2
127	**5/7/02**	15.5	13.3	2.2	0.55003		0.7	14.0
128	**5/8/02**	17.0	13.2	3.8	0.53755		0.7	13.9
129	**5/9/02**	14.4	12.8	1.6	0.52539		0.7	13.5
130	**5/10/02**				0.51352		0.6	0.6
131	**5/11/02**	11.8	11.3	0.5	0.50194		0.6	11.9
132	**5/12/02**	14.7	15.1	-0.4	0.49067		0.6	15.7
133	**5/13/02**	9.5	7.6	1.9	0.47971		0.6	8.2
134	**5/14/02**	7.2	6.6	0.6	0.46904		0.6	7.2
135	**5/15/02**	7.2	5.5	1.7	0.45867		0.6	6.1
136	**5/16/02**	13.4	14.5	-1.1	0.44860		0.5	15.0
137	**5/17/02**	6.9	4.2	2.7	0.43882		0.5	4.7
138	**5/18/02**	4.9	2.8	2.1	0.42935		0.5	3.3
139	**5/19/02**	8.4	6.2	2.2	0.42019		0.5	6.7
140	**5/20/02**	7.2	5.3	1.9	0.41132		0.5	5.8
141	**5/21/02**	8.5	6.9	1.6	0.40274		0.5	7.4
142	**5/22/02**	13.8	13	0.8	0.39448		0.5	13.5
143	**5/23/02**	17.9	18.6	-0.7	0.38650		0.5	19.1
144	**5/24/02**	20.5	20.5	0.0	0.37884		0.4	20.9
145	**5/25/02**	19.0	18.7	0.3	0.37147		0.4	19.1
146	**5/26/02**	13.9	11.8	2.1	0.36440		0.4	12.2
147	**5/27/02**	22.5	21.4	1.1	0.35762		0.4	21.8
148	**5/28/02**	19.0	17.6	1.4	0.35115		0.4	18.0
149	**5/29/02**	18.6	18.2	0.4	0.34498		0.4	18.6
150	**5/30/02**	27.4	26.9	0.5	0.33911		0.4	27.3
151	**5/31/02**				0.33355		0.4	0.4
152	**6/1/02**				0.32827		0.4	0.4
153	**6/2/02**				0.32330		0.3	0.3
154	**6/3/02**				0.31864		0.3	0.3
155	**6/4/02**				0.31427		0.3	0.3
156	**6/5/02**	20.3	20.1	0.2	0.31020		0.3	20.4
157	**6/6/02**	4.2	4.5	-0.3	0.30642		0.3	4.8
158	**6/7/02**	7.0	8.4	-1.4	0.30296		0.3	8.7
159	**6/8/02**	13.4	16	-2.6	0.29979		0.3	16.3
160	**6/9/02**	26.9	29.6	-2.7	0.29692		0.3	29.9
161	**6/10/02**	37.5	41	-3.5	0.29435		0.3	41.3
162	**6/11/02**	41.4	44	-2.6	0.29207		0.3	44.3
163	**6/12/02**	24.4	24.9	-0.5	0.29010		0.3	25.2
164	**6/13/02**	20.9	21.4	-0.5	0.28844		0.3	21.7
165	**6/14/02**	17.7	16.4	1.3	0.28706		0.3	16.7
166	**6/15/02**	8.2	7.3	0.9	0.28600		0.2	7.5
167	**6/16/02**	6.6	6.6	0.0	0.28522		0.2	6.8
168	**6/17/02**	9.9	10.4	-0.5	0.28475		0.2	10.6
169	**6/18/02**	16.3	17.2	-0.9	0.28458		0.2	17.4

170	6/19/02	13.9	18.4	-4.5	0.28471		0.2	18.6
171	6/20/02	30.6	35.3	-4.7	0.28514		0.2	35.5
172	6/21/02	34.4	36.9	-2.5	0.28587		0.2	37.1
173	6/22/02	41.3	42.4	-1.1	0.28690		0.2	42.6
174	6/23/02	41.0	39.7	1.3	0.28824		0.2	39.9
175	6/24/02	41.4	41.6	-0.2	0.28987		0.2	41.8
176	6/25/02	51.7	53.7	-2.0	0.29180		0.2	53.9
177	6/26/02	45.1	52.4	-7.3	0.29403		0.2	52.6
178	6/27/02	17.5	13.5	4.0	0.29655		0.2	13.7
179	6/28/02	12.5	9.2	3.3	0.29939		0.2	9.4
180	6/29/02	20.3	17.7	2.6	0.30251		0.2	17.9
181	6/30/02	40.8	39.5	1.3	0.30594		0.2	39.7
182	7/1/02	54.4	55.1	-0.7	0.30967	0.28	0.2	55.3
183	7/2/02	43.6	46	-2.4	0.31370		0.2	46.2
184	7/3/02	29.1	29.9	-0.8	0.31803		0.2	30.1
185	7/4/02	33.7	35.6	-1.9	0.32266		0.2	35.8
186	7/5/02	6.8	3.6	3.2	0.32759		0.2	3.8
187	7/6/02	9.9	7.7	2.2	0.33282		0.2	7.9
188	7/7/02	19.9	18.7	1.2	0.33835		0.2	18.9
189	7/8/02	35.6	33.7	1.9	0.34418		0.2	33.9
190	7/9/02	34.4	33.2	1.2	0.35031		0.2	33.4
191	7/10/02	16.6	11.4	5.2	0.35674		0.2	11.6
192	7/11/02	6.1	3.1	3.0	0.36347		0.2	3.3
193	7/12/02	8.7	7.6	1.1	0.37051		0.2	7.8
194	7/13/02	21.5	22.1	-0.6	0.37784		0.2	22.3
195	7/14/02	10.7	8.5	2.2	0.38547		0.2	8.7
196	7/15/02	21.8	20.5	1.3	0.39340		0.2	20.7
197	7/16/02	23.0	23.3	-0.3	0.40163		0.2	23.5
198	7/17/02	28.4	28.4	0.0	0.41015		0.2	28.6
199	7/18/02	48.4	47.2	1.2	0.41898		0.2	47.4
200	7/19/02	27.6	26.3	1.3	0.42811		0.2	26.5
201	7/20/02	25.7	23.3	2.4	0.43754		0.2	23.5
202	7/21/02	36.4	35.6	0.8	0.44727		0.2	35.8
203	7/22/02	38.0	35.9	2.1	0.45730		0.3	36.2
204	7/23/02	19.6	17.7	1.9	0.46763		0.3	18.0
205	7/24/02	14.9	16.7	-1.8	0.47826		0.3	17.0
206	7/25/02	12.5	12.3	0.2	0.48919		0.3	12.6
207	7/26/02	23.9	24.7	-0.8	0.50042		0.3	25.0
208	7/27/02	22.6	22	0.6	0.51195		0.3	22.3
209	7/28/02	21.8	20.8	1.0	0.52378		0.3	21.1
210	7/29/02	18.0	18.6	-0.6	0.53591		0.3	18.9
211	7/30/02				0.54835		0.3	0.3
212	7/31/02	21.9	23.5	-1.6	0.56108		0.3	23.8
213	8/1/02	21.9	23.8	-1.9	0.57411		0.3	24.1
214	8/2/02	32.6	34.1	-1.5	0.58744		0.3	34.4
215	8/3/02	12.2	10.6	1.6	0.60106		0.3	10.9
216	8/4/02	23.3	24.2	-0.9	0.61499		0.3	24.5
217	8/5/02	34.3	32.5	1.8	0.62923		0.4	32.9
218	8/6/02	4.5	0.2	4.3	0.64375		0.4	0.6
219	8/7/02	5.5	1.6	3.9	0.65858		0.4	2.0
220	8/8/02	6.9	3.5	3.4	0.67371		0.4	3.9
221	8/9/02	10.7	7.9	2.8	0.68914		0.4	8.3
222	8/10/02	20.8	18	2.8	0.70487		0.4	18.4
223	8/11/02	40.7	37.4	3.3	0.72090		0.4	37.8
224	8/12/02				0.73723		0.4	0.4
225	8/13/02	37.5	34.6	2.9	0.75386		0.4	35.0
226	8/14/02	36.9	35.5	1.4	0.77079		0.5	36.0
227	8/15/02	22.0	20	2.0	0.78802		0.5	20.5
228	8/16/02	15.4	13.7	1.7	0.80555		0.5	14.2
229	8/17/02	13.3	8.5	4.8	0.82339		0.5	9.0

230	**8/18/02**	14.1	9.8	4.3	0.84152		0.5	10.3
231	**8/19/02**	19.0	14.2	4.8	0.85995		0.5	14.7
232	**8/20/02**	12.8	8	4.8	0.87867		0.5	8.5
233	**8/21/02**	17.9	18.9	-1.0	0.89771		0.6	19.5
234	**8/22/02**	28.4	28.2	0.2	0.91704		0.6	28.8
235	**8/23/02**	13.7	12.9	0.8	0.93666		0.6	13.5
236	**8/24/02**	16.3	13	3.3	0.95660		0.6	13.6
237	**8/25/02**	15.9	13	2.9	0.97683		0.6	13.6
238	**8/26/02**	19.9	14.6	5.3	0.99735		0.6	15.2
239	**8/27/02**	18.6	15.7	2.9	1.01819		0.6	16.3
240	**8/28/02**	11.6	7.3	4.3	1.03932		0.7	8.0
241	**8/29/02**	9.0	4.6	4.4	1.06075		0.7	5.3
242	**8/30/02**	7.9	5.3	2.6	1.08248		0.7	6.0
243	**8/31/02**	8.6	5.8	2.8	1.10451		0.7	6.5
244	**9/1/02**	6.2	2.7	3.5	1.12684		0.7	3.4
245	**9/2/02**	14.5	9.9	4.6	1.14947		0.8	10.7
246	**9/3/02**	27.1	25.1	2.0	1.17240		0.8	25.9
247	**9/4/02**	10.2	7.1	3.1	1.19563		0.8	7.9
248	**9/5/02**	11.3	11.9	-0.6	1.21916		0.8	12.7
249	**9/6/02**	12.2	13.5	-1.3	1.24299		0.8	14.3
250	**9/7/02**	10.9	12.8	-1.9	1.26712		0.8	13.6
251	**9/8/02**	18.2	17.6	0.6	1.29155		0.9	18.5
252	**9/9/02**	18.4	17.3	1.1	1.31628		0.9	18.2
253	**9/10/02**	36.7	37.6	-0.9	1.34131		0.9	38.5
254	**9/11/02**	7.4	12.8	-5.4	1.36664		0.9	13.7
255	**9/12/02**	7.4	6.6	0.8	1.39227		1	7.6
256	**9/13/02**	17.6	17.2	0.4	1.41820		1	18.2
257	**9/14/02**	21.4	21.7	-0.3	1.44443		1	22.7
258	**9/15/02**	6.0	5.9	0.1	1.47096		1	6.9
259	**9/16/02**	19.3	19.2	0.1	1.49779		1	20.2
260	**9/17/02**	17.2	16.8	0.4	1.52492		1.1	17.9
261	**9/18/02**				1.55235		1.1	1.1
262	**9/19/02**				1.58008		1.1	1.1
263	**9/20/02**				1.60811		1.1	1.1
264	**9/21/02**				1.63644		1.2	1.2
265	**9/22/02**				1.66507		1.2	1.2
266	**9/23/02**				1.69400		1.2	1.2
267	**9/24/02**				1.72323		1.2	1.2
268	**9/25/02**	11.7	13.2	-1.5	1.75276		1.3	14.5
269	**9/26/02**	7.2	8.8	-1.6	1.78259		1.3	10.1
270	**9/27/02**	3.1	4.9	-1.8	1.81272		1.3	6.2
271	**9/28/02**	17.7	20.2	-2.5	1.84315		1.3	21.5
272	**9/29/02**	27.4	30.2	-2.8	1.87388		1.4	31.6
273	**9/30/02**	25.6	28	-2.4	1.90491		1.4	29.4
274	**10/1/02**	29.7	31.2	-1.5	1.93624		1.4	32.6
275	**10/2/02**	28.9	26.8	2.1	1.96787		1.4	28.2
276	**10/3/02**	26.9	28.6	-1.7	1.99980		1.5	30.1
277	**10/4/02**	18.7	20.9	-2.2	2.03203		1.5	22.4
278	**10/5/02**	7.3	9.7	-2.4	2.06456		1.5	11.2
279	**10/6/02**	10.5	12.7	-2.2	2.09739		1.5	14.2
280	**10/7/02**	7.3	10	-2.7	2.13052		1.6	11.6
281	**10/8/02**	8.0	9.7	-1.7	2.16395		1.6	11.3
282	**10/9/02**	17.0	19.9	-2.9	2.19768		1.6	21.5
283	**10/10/02**	20.7	16.8	3.9	2.23171		1.7	18.5
284	**10/11/02**	5.5	0.7	4.8	2.26604		1.7	2.4
285	**10/12/02**	11.0	5.9	5.1	2.30067		1.7	7.6
286	**10/13/02**	9.4	6.2	3.2	2.33560		1.8	8.0
287	**10/14/02**	7.2	2.6	4.6	2.37083		1.8	4.4
288	**10/15/02**	9.6	3.9	5.7	2.40636		1.8	5.7
289	**10/16/02**	7.1	2.4	4.7	2.44219		1.8	4.2

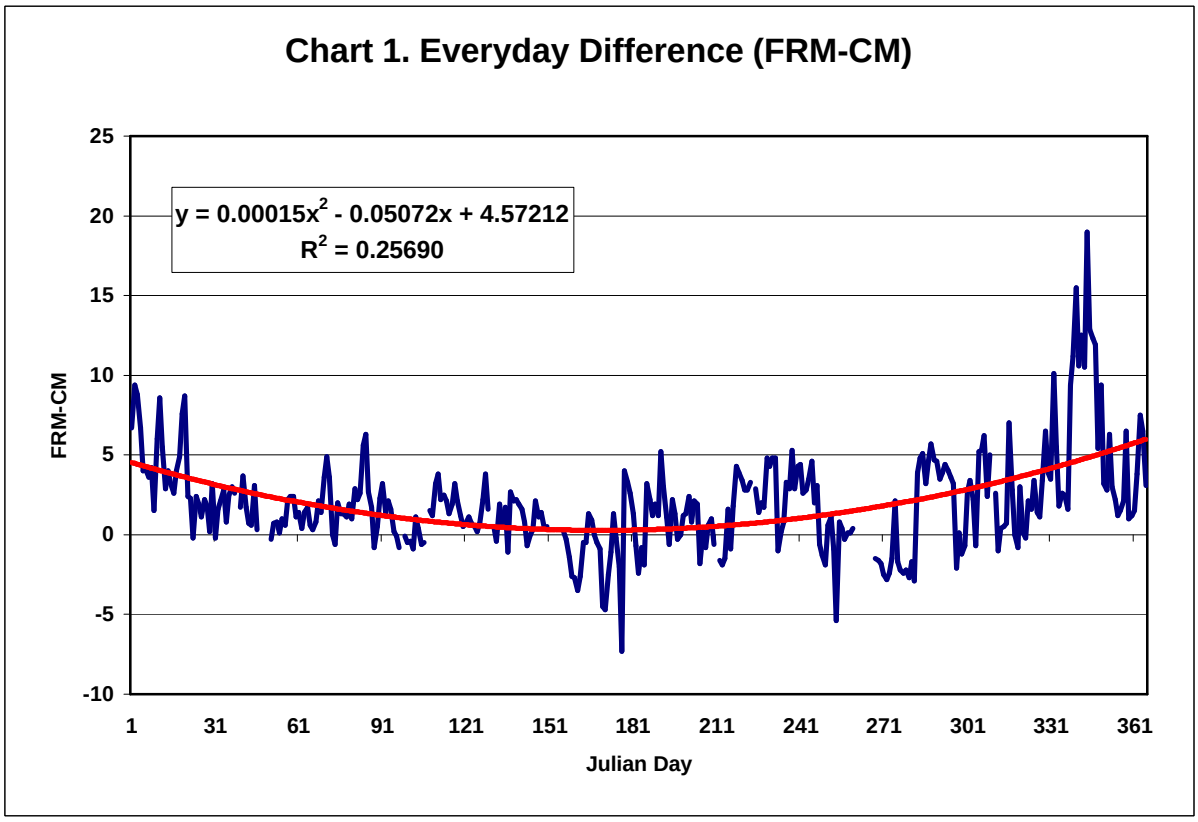
290	**10/17/02**	7.9	3.3	4.6	2.47832		1.9	5.2
291	**10/18/02**	10.4	6.9	3.5	2.51475		1.9	8.8
292	**10/19/02**	10.2	6.3	3.9	2.55148		1.9	8.2
293	**10/20/02**	13.3	8.9	4.4	2.58851		2	10.9
294	**10/21/02**	13.3	9.3	4.0	2.62584		2	11.3
295	**10/22/02**	18.7	15.1	3.6	2.66347		2	17.1
296	**10/23/02**	14.4	11.2	3.2	2.70140		2.1	13.3
297	**10/24/02**	7.6	9.7	-2.1	2.73963		2.1	11.8
298	**10/25/02**	10.6	10.5	0.1	2.77816		2.1	12.6
299	**10/26/02**	10.4	11.6	-1.2	2.81699		2.2	13.8
300	**10/27/02**	14.3	15	-0.7	2.85612		2.2	17.2
301	**10/28/02**	10.7	8	2.7	2.89555		2.2	10.2
302	**10/29/02**	6.2	2.8	3.4	2.93528		2.3	5.1
303	**10/30/02**	3.8	1.6	2.2	2.97531		2.3	3.9
304	**10/31/02**	11.6	12.3	-0.7	3.01564		2.4	14.7
305	**11/1/02**	16.5	11.3	5.2	3.05627		2.4	13.7
306	**11/2/02**	14.0	8.7	5.3	3.09720		2.4	11.1
307	**11/3/02**	19.0	12.8	6.2	3.13843		2.5	15.3
308	**11/4/02**	14.0	11.6	2.4	3.17996		2.5	14.1
309	**11/5/02**	16.6	11.6	5.0	3.22179		2.5	14.1
310	**11/6/02**				3.26392		2.6	2.6
311	**11/7/02**	16.9	14.3	2.6	3.30635		2.6	16.9
312	**11/8/02**	10.1	11.1	-1.0	3.34908		2.6	13.7
313	**11/9/02**	9.1	8.7	0.4	3.39211		2.7	11.4
314	**11/10/02**	7.7	7.2	0.5	3.43544		2.7	9.9
315	**11/11/02**	11.6	10.9	0.7	3.47907		2.8	13.7
316	**11/12/02**	18.3	11.3	7.0	3.52300		2.8	14.1
317	**11/13/02**	11.3	8.5	2.8	3.56723		2.8	11.3
318	**11/14/02**	10.6	10.6	0.0	3.61176		2.9	13.5
319	**11/15/02**	10.7	11.5	-0.8	3.65659		2.9	14.4
320	**11/16/02**	11.4	8.4	3.0	3.70172		3	11.4
321	**11/17/02**	4.1	4	0.1	3.74715		3	7.0
322	**11/18/02**	8.8	9	-0.2	3.79288		3	12.0
323	**11/19/02**	16.7	14.6	2.1	3.83891		3.1	17.7
324	**11/20/02**	16.2	14.6	1.6	3.88524		3.1	17.7
325	**11/21/02**	20.5	17.1	3.4	3.93187		3.2	20.3
326	**11/22/02**	6.9	5.5	1.4	3.97880		3.2	8.7
327	**11/23/02**	6.9	5.8	1.1	4.02603		3.3	9.1
328	**11/24/02**	13.6	10.2	3.4	4.07356		3.3	13.5
329	**11/25/02**	21.6	15.1	6.5	4.12139		3.3	18.4
330	**11/26/02**	11.3	7.4	3.9	4.16952		3.4	10.8
331	**11/27/02**	6.7	3.2	3.5	4.21795		3.4	6.6
332	**11/28/02**	16.1	6	10.1	4.26668		3.5	9.5
333	**11/29/02**	10.9	5.4	5.5	4.31571		3.5	8.9
334	**11/30/02**	4.5	2.7	1.8	4.36504		3.6	6.3
335	**12/1/02**	4.7	2.1	2.6	4.41467		3.6	5.7
336	**12/2/02**	10.2	7.7	2.5	4.46460		3.7	11.4
337	**12/3/02**	6.6	5	1.6	4.51483		3.7	8.7
338	**12/4/02**	17.7	8.3	9.4	4.56536		3.7	12.0
339	**12/5/02**	14.2	3	11.2	4.61619		3.8	6.8
340	**12/6/02**	20.2	4.7	15.5	4.66732		3.8	8.5
341	**12/7/02**	15.2	4.6	10.6	4.71875		3.9	8.5
342	**12/8/02**	17.5	5	12.5	4.77048		3.9	8.9
343	**12/9/02**	13.2	2.7	10.5	4.82251		4	6.7
344	**12/10/02**	31.5	12.5	19.0	4.87484		4	16.5
345	**12/11/02**	16.8	3.9	12.9	4.92747		4.1	8.0
346	**12/12/02**	22.4	10.1	12.3	4.98040		4.1	14.2
347	**12/13/02**	17.6	5.7	11.9	5.03363		4.2	9.9
348	**12/14/02**	8.8	3.4	5.4	5.08716		4.2	7.6
349	**12/15/02**	16.5	7.1	9.4	5.14099		4.3	11.4

350	**12/16/02**	6.7	3.5	3.2	5.19512		4.3	7.8
351	**12/17/02**	10.0	7.2	2.8	5.24955		4.4	11.6
352	**12/18/02**	15.5	9.2	6.3	5.30428		4.4	13.6
353	**12/19/02**	13.2	10.2	3.0	5.35931		4.5	14.7
354	**12/20/02**	7.0	4.8	2.2	5.41464		4.5	9.3
355	**12/21/02**	4.3	3.1	1.2	5.47027		4.6	7.7
356	**12/22/02**	6.4	4.9	1.5	5.52620		4.6	9.5
357	**12/23/02**	8.1	6	2.1	5.58243		4.7	10.7
358	**12/24/02**	12.8	6.3	6.5	5.63896		4.7	11.0
359	**12/25/02**	6.0	5	1.0	5.69579		4.8	9.8
360	**12/26/02**	8.5	7.3	1.2	5.75292		4.8	12.1
361	**12/27/02**	17.0	15.5	1.5	5.81035		4.9	20.4
362	**12/28/02**	19.2	15.4	3.8	5.86808		4.9	20.3
363	**12/29/02**	26.7	19.2	7.5	5.92611		5	24.2
364	**12/30/02**	27.5	21	6.5	5.98444		5	26.0
365	**12/31/02**	11.3	8.2	3.1	6.04306	5.28	5.1	13.3

Correction Factors for everyday datasets

Corrections needed to get to FRM-like data
Nonlinear Transform: $CM_{AC} = CM + (.00015*JD^2) - (.05525*JD) + 5.3351$
Linear Transform: $CM_{FRM} = (CM_{AC}*1.017) - 0.160$

Charts for everyday datasets



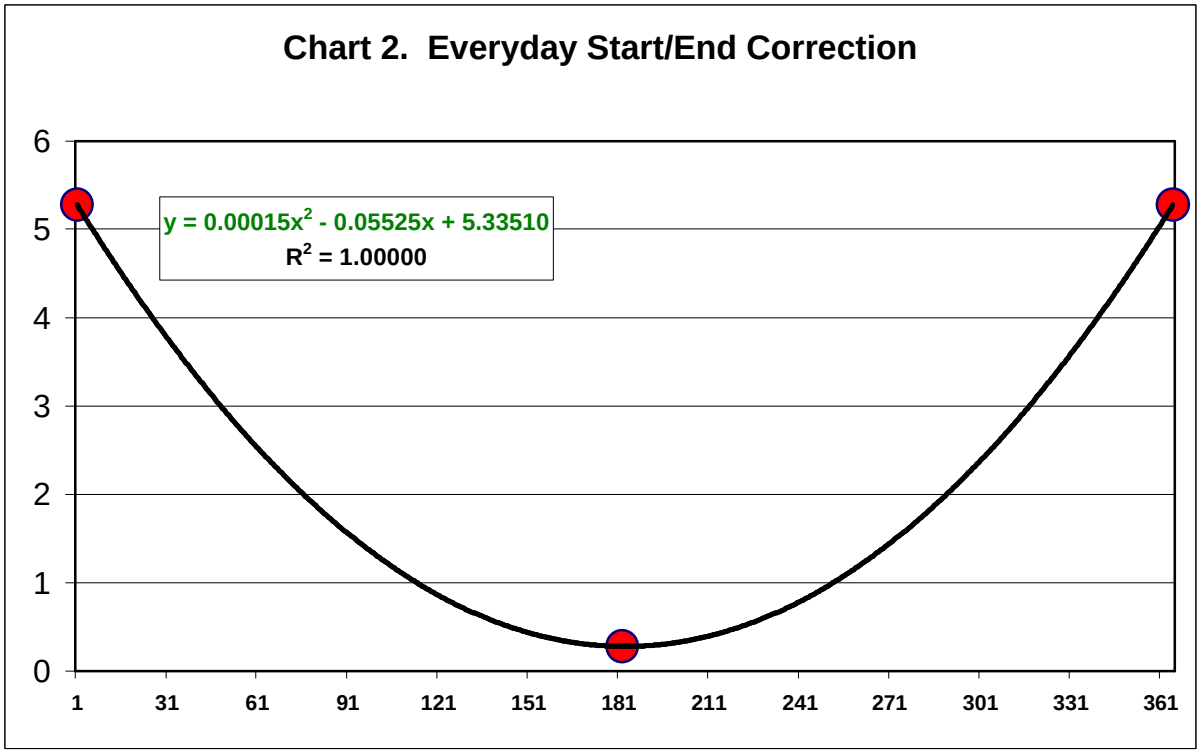


Chart 2. Everyday Start/End Correction
y = 0.00015x² - 0.05525x + 5.33510
R² = 1.00000
6
5
4
3
2
1
0
1
31
61
91
121
151
181
211
241
271
301
331
361

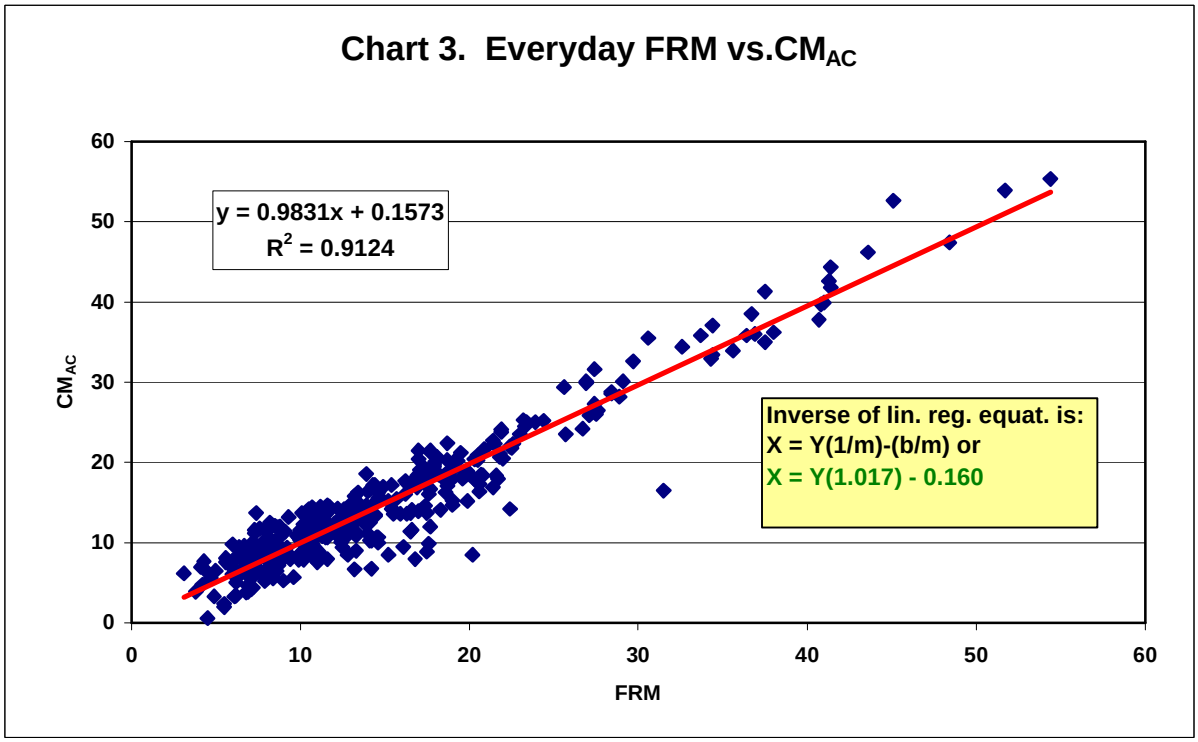


Chart 3. Everyday FRM vs.CMAC
y = 0.9831x + 0.1573
R² = 0.9124
Inverse of lin. reg. equat. is:
X = Y(1/m)-(b/m) or
X = Y(1.017) - 0.160
CMAC
FRM
60
50
40
30
20
10
0
0
10
20
30
40
50
60

Table B-2: Example Spreadsheet for Sites with 1-in-3 Data (AQS Site = 36 029 005)

JD	Counter	1-in-3 Sample Date	JD of Sample Date	FRM	Continuous Monitor (CM)	Difference (FRM-CM)	JD_A (from 2nd Order Poly)	Start/End Correction	$JD_{S/E}$ (from Column I)	CM_{AC} (CM + $JD_{S/E}$)
1								3.38		
2	1	1/2/02	2	6.7	6.8	-0.1	4.43206		3.32059	10.1
3	2	1/5/02	5	16.7	11.5	5.2	4.23838		3.14428	14.6
4	3	1/8/02	8	9.2	7.3	1.9	4.04764		2.97085	10.2
5	4	1/11/02	11	10.4	6.8	3.6	3.85984		2.8003	9.6
6	5	1/14/02	14	11	9.5	1.5	3.67498		2.63263	12.1
7	6	1/17/02	17	8.1	7.9	0.2	3.49306		2.46784	10.3
8	7	1/20/02	20	15	9.6	5.4	3.31408		2.30593	11.9
9	8	1/23/02	23	8.7	7.7	1.0	3.13804		2.1469	9.8
10	9	1/26/02	26	8.3	7.3	1.0	2.96494		1.99075	9.2
11	10	1/29/02	29	28.5	18.3	10.2	2.79478		1.83748	20.1
12	11	2/1/02	32	4.3	5.5	-1.2	2.62756		1.68709	7.1
13	12	2/4/02	35	9.7	7.6	2.1	2.46328		1.53958	9.1
14	13	2/7/02	38	17.5	10.9	6.6	2.30194		1.39495	12.2
15	14	2/10/02	41	18.3	12.9	5.4	2.14354		1.2532	14.1
16	15	2/13/02	44	3.8	5.7	-1.9	1.98808		1.11433	6.8
17	16	2/16/02	47	16.5	9.2	7.3	1.83556		0.97834	10.1
18	17	2/19/02	50	19.8	19.1	0.7	1.68598		0.84523	19.9
19	18	2/22/02	53	8.5	9	-0.5	1.53934		0.715	9.7
20	19	2/25/02	56	11.5	14	-2.5	1.39564		0.58765	14.5
21	20	2/28/02	59	6	6.8	-0.8	1.25488		0.46318	7.2
22	21	3/3/02	62	5.1	6.1	-1.0	1.11706		0.34159	6.4
23	22	3/6/02	65	23.6	13.1	10.5	0.98218		0.22288	13.3
24	23	3/9/02	68	11	13.4	-2.4	0.85024		0.10705	13.5
25	24	3/12/02	71	16.4	13.6	2.8	0.72124		-0.0059	13.5
26	25	3/15/02	74	15.2	15.1	0.1	0.59518		-0.11597	14.9
27	26	3/18/02	77	10.9	9.6	1.3	0.47206		-0.22316	9.3
28	27	3/21/02	80	8.6	9.3	-0.7	0.35188		-0.32747	8.9
29	28	3/24/02	83	8	9	-1.0	0.23464		-0.4289	8.5
30	29	3/27/02	86	14.8	11.3	3.5	0.12034		-0.52745	10.7
31	30	3/30/02	89	13.8	9.7	4.1	0.00898		-0.62312	9
32	31	4/2/02	92	18.1	13.1	5.0	-0.09944		-0.71591	12.3
33	32	4/5/02	95	8.5	7.1	1.4	-0.20492		-0.80582	6.2
34	33	4/8/02	98	17.3	17.6	-0.3	-0.30746		-0.89285	16.7
35	34	4/11/02	101	10.3	12.7	-2.4	-0.40706		-0.977	11.7
36	35	4/14/02	104	8.5	8.5	0.0	-0.50372		-1.05827	7.4
37	36	4/17/02	107	22	23.9	-1.9	-0.59744		-1.13666	22.7
38	37	4/20/02	110	4	5.1	-1.1	-0.68822		-1.21217	3.8
39	38	4/23/02	113	10.5	10.3	0.2	-0.77606		-1.2848	9
40	39	4/26/02	116	7.8	8.6	-0.8	-0.86096		-1.35455	7.2
41	40	4/29/02	119	7.2	7	0.2	-0.94292		-1.42142	5.5
42	41	5/2/02	122	16.5	12.1	4.4	-1.02194		-1.48541	10.6
43	42	5/5/02	125	17.1	17.3	-0.2	-1.09802		-1.54652	15.7
44	43	5/8/02	128	5.2	5.9	-0.7	-1.17116		-1.60475	4.2
45	44	5/11/02	131	7.5	8.6	-1.1	-1.24136		-1.6601	6.9
46	45	5/14/02	134	5	7	-2.0	-1.30862		-1.71257	5.2
47	46	5/17/02	137	6.2	6.8	-0.6	-1.37294		-1.76216	5
48	47	5/20/02	140	7.1	8.5	-1.4	-1.43432		-1.80887	6.6
49	48	5/23/02	143	17.4	20.3	-2.9	-1.49276		-1.8527	18.4
50	49	5/26/02	146	8	9	-1.0	-1.54826		-1.89365	7.1

51	50	**5/29/02**	149	26.3	31.1	-4.8	-1.60082		-1.93172	29.1
52	51	**6/1/02**	152	13.6	14	-0.4	-1.65044		-1.96691	12
53	52	**6/4/02**	155	15.4	16.2	-0.8	-1.69712		-1.99922	14.2
54	53	**6/7/02**	158				-1.74086		-2.02865	-2
55	54	**6/10/02**	161				-1.78166		-2.0552	-2
56	55	**6/13/02**	164	11.6	12.9	-1.3	-1.81952		-2.07887	10.8
57	56	**6/16/02**	167	5.9	7.7	-1.8	-1.85444		-2.09966	5.6
58	57	**6/19/02**	170	11.2	15.2	-4.0	-1.88642		-2.11757	13
59	58	**6/22/02**	173	30.7	33.1	-2.4	-1.91546		-2.1326	30.9
60	59	**6/25/02**	176	46.8	50.6	-3.8	-1.94156		-2.14475	48.4
61	60	**6/28/02**	179	13.1	16.1	-3.0	-1.96472		-2.15402	13.9
62	61	**7/1/02**	182	49.6	53	-3.4	-1.98494		-2.16041	50.8
63	62	**7/4/02**	185	20.3	29.6	-9.3	-2.00222		-2.16392	27.4
64	63	**7/7/02**	188	39.5	38.4	1.1	-2.01656		-2.16455	36.2
65	64	**7/10/02**	191	5.3	7.8	-2.5	-2.02796		-2.1623	5.6
66	65	**7/13/02**	194	15.5	18.6	-3.1	-2.03642		-2.15717	16.4
67	66	**7/16/02**	197				-2.04194		-2.14916	-2.1
68	67	**7/19/02**	200	32	36.3	-4.3	-2.04452		-2.13827	34.1
69	68	**7/22/02**	203	32	35	-3.0	-2.04416		-2.1245	32.8
70	69	**7/25/02**	206	15.1	18.5	-3.4	-2.04086		-2.10785	16.3
71	70	**7/28/02**	209	14.3	15.5	-1.2	-2.03462		-2.08832	13.4
72	71	**7/31/02**	212	19.3	21.7	-2.4	-2.02544		-2.06591	19.6
73	72	**8/3/02**	215	10.4	11.6	-1.2	-2.01332		-2.04062	9.5
74	73	**8/6/02**	218	2.5	4.1	-1.6	-1.99826		-2.01245	2
75	74	**8/9/02**	221	9.6	11.7	-2.1	-1.98026		-1.9814	9.7
76	75	**8/12/02**	224	43.1	42.2	0.9	-1.95932		-1.94747	40.2
77	76	**8/15/02**	227	22.4	22.6	-0.2	-1.93544		-1.91066	20.6
78	77	**8/18/02**	230	10.9	11.2	-0.3	-1.90862		-1.87097	9.3
79	78	**8/21/02**	233	12	15.1	-3.1	-1.87886		-1.8284	13.2
80	79	**8/24/02**	236	11.7	13.2	-1.5	-1.84616		-1.78295	11.4
81	80	**8/27/02**	239	6.1	8.6	-2.5	-1.81052		-1.73462	6.8
82	81	**8/30/02**	242	10.4	13	-2.6	-1.77194		-1.68341	11.3
83	82	**9/2/02**	245	14.3	14.6	-0.3	-1.73042		-1.62932	12.9
84	83	**9/5/02**	248	6.8	8.6	-1.8	-1.68596		-1.57235	7
85	84	**9/8/02**	251	27.1	28.6	-1.5	-1.63856		-1.5125	27
86	85	**9/11/02**	254	4.9	6.6	-1.7	-1.58822		-1.44977	5.1
87	86	**9/14/02**	257	18	21.3	-3.3	-1.53494		-1.38416	19.9
88	87	**9/17/02**	260	13.1	15.9	-2.8	-1.47872		-1.31567	14.5
89	88	**9/20/02**	263	29.6	31.8	-2.2	-1.41956		-1.2443	30.5
90	89	**9/23/02**	266	6.5	7.6	-1.1	-1.35746		-1.17005	6.4
91	90	**9/26/02**	269	11.5	13.1	-1.6	-1.29242		-1.09292	12
92	91	**9/29/02**	272	18.5	20.6	-2.1	-1.22444		-1.01291	19.5
93	92	**10/2/02**	275	33.5	34.2	-0.7	-1.15352		-0.93002	33.2
94	93	**10/5/02**	278				-1.07966		-0.84425	-0.8
95	94	**10/8/02**	281				-1.00286		-0.7556	-0.7
96	95	**10/11/02**	284	11.7	14.3	-2.6	-0.92312		-0.66407	13.6
97	96	**10/14/02**	287	4.3	6.7	-2.4	-0.84044		-0.56966	6.1
98	97	**10/17/02**	290	5.6	7.7	-2.1	-0.75482		-0.47237	7.2
99	98	**10/20/02**	293	5.6	7.6	-2.0	-0.66626		-0.3722	7.2
100	99	**10/23/02**	296	6.3	7.9	-1.6	-0.57476		-0.26915	7.6
101	100	**10/26/02**	299	7.3	7.7	-0.4	-0.48032		-0.16322	7.5
102	101	**10/29/02**	302	8.1	9.4	-1.3	-0.38294		-0.05441	9.3
103	102	**11/1/02**	305	3.8	6.6	-2.8	-0.28262		0.05728	6.6
104	103	**11/4/02**	308	14.2	11.3	2.9	-0.17936		0.17185	11.4
105	104	**11/7/02**	311	6.5	6.7	-0.2	-0.07316		0.2893	6.9
106	105	**11/10/02**	314	7.7	10	-2.3	0.03598		0.40963	10.4
107	106	**11/13/02**	317	17.4	12.5	4.9	0.14806		0.53284	13
108	107	**11/16/02**	320	4.8	4.5	0.3	0.26308		0.65893	5.1
109	108	**11/19/02**	323	12.4	11.3	1.1	0.38104		0.7879	12

110	109	**11/22/02**	326	11.1	8.8	2.3	0.50194		0.91975	9.7
111	110	**11/25/02**	329	8.3	8.5	-0.2	0.62578		1.05448	9.5
112	111	**11/28/02**	332	11.1	7.9	3.2	0.75256		1.19209	9
113	112	**12/1/02**	335	3.1	5.1	-2.0	0.88228		1.33258	6.4
114	113	**12/4/02**	338	15.6	11.4	4.2	1.01494		1.47595	12.8
115	114	**12/7/02**	341	20.3	13.1	7.2	1.15054		1.6222	14.7
116	115	**12/10/02**	344	18.3	14.4	3.9	1.28908		1.77133	16.1
117	116	**12/13/02**	347	22.6	14.5	8.1	1.43056		1.92334	16.4
118	117	**12/16/02**	350	6.7	7.3	-0.6	1.57498		2.07823	9.3
119	118	**12/19/02**	353	13.7	12.7	1.0	1.72234		2.236	14.9
120	119	**12/22/02**	356	7.9	8.7	-0.8	1.87264		2.39665	11
121	120	**12/25/02**	359	5	6.3	-1.3	2.02588		2.56018	8.8
122	121	**12/28/02**	362	16.6	14.9	1.7	2.18206		2.72659	17.6
123	122	**12/31/02**	365	13.7	13.1	0.6	2.34118		2.89588	15.9
124										
125										
126										

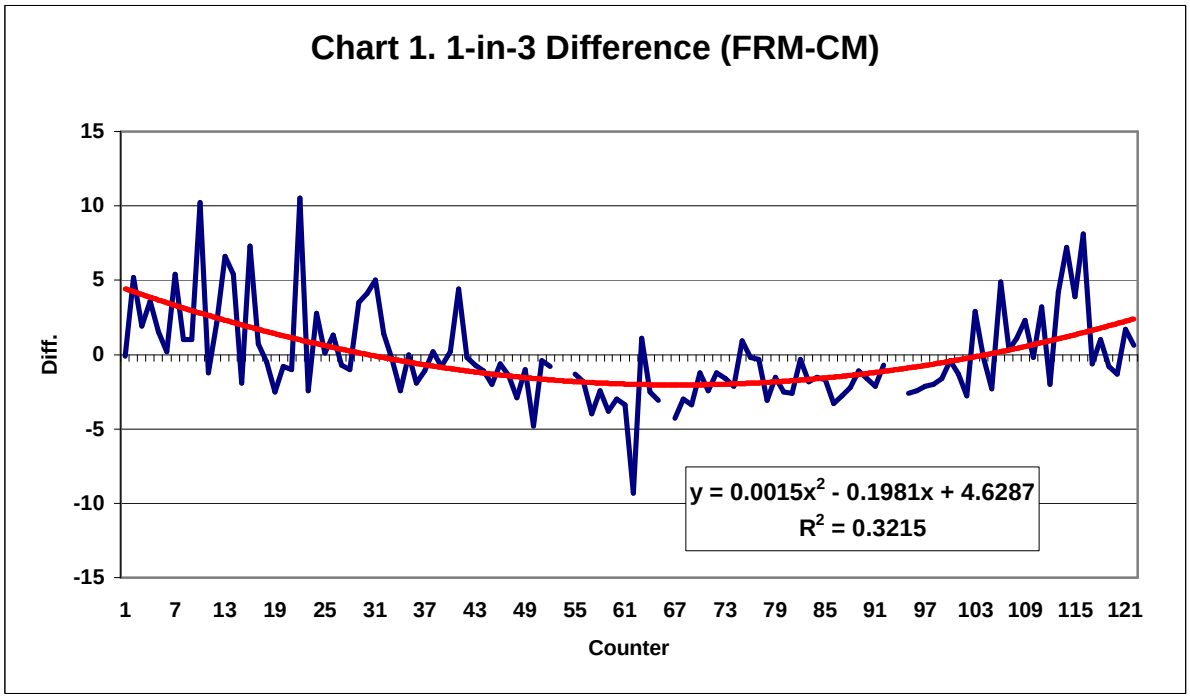
180										
181										
182								-2.04		
183										
184										

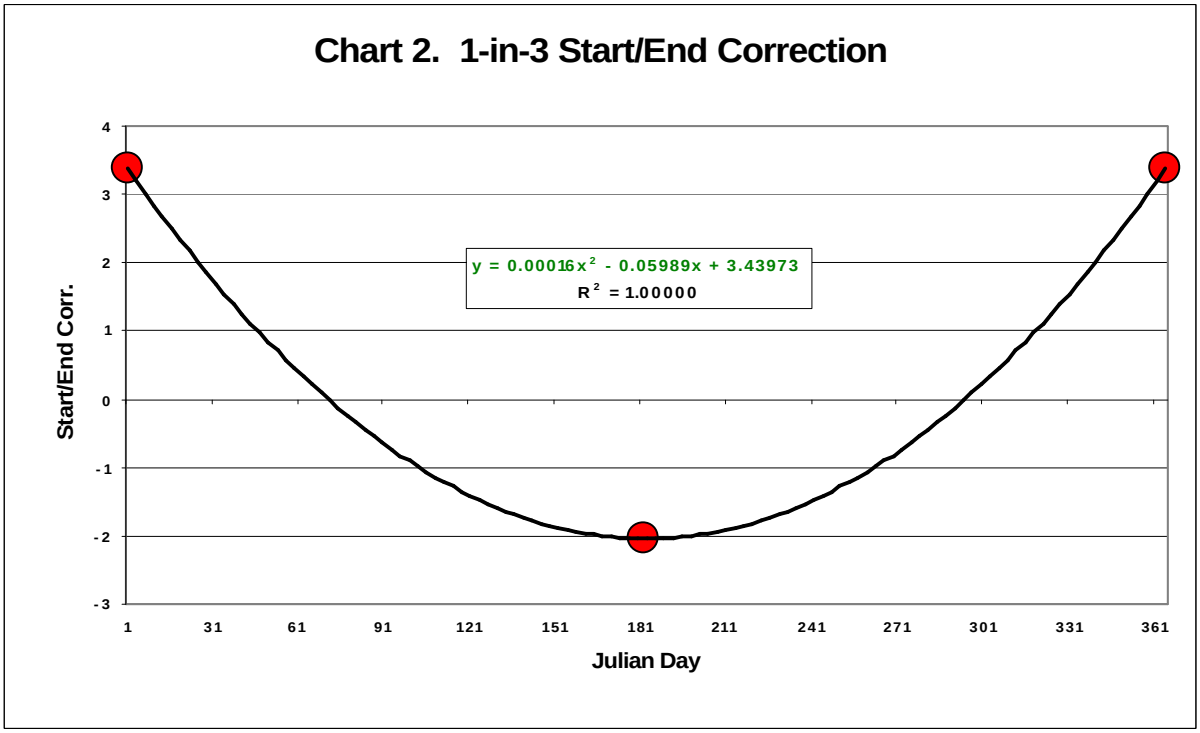
363										
364										
365								3.38		

Correction Factors for 1-in-3-day datasets

Corrections needed to get to FRM-like data
Nonlinear Transform: CM_{AC} = CM + (0.00016*JD^2) -(.05989*JD) + 3.43973
Linear Transform: CM_{FRM} = (CM_{AC}*1.080) - 0.792

Charts for 1-in-3 day datasets





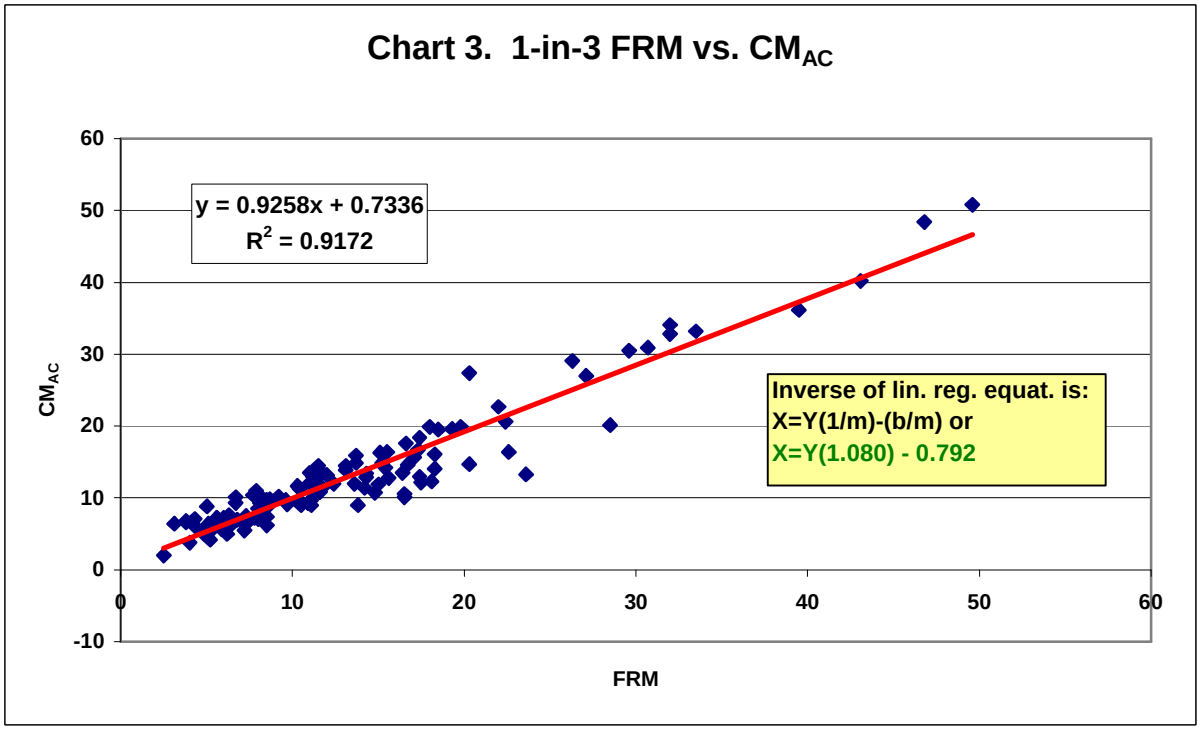


Chart 3. 1-in-3 FRM vs. CM$_{AC}$
y = 0.9258x + 0.7336
R^2 = 0.9172
Inverse of lin. reg. equat. is:
X=Y(1/m)-(b/m) or
X=Y(1.080) - 0.792
CM$_{AC}$
FRM
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60