Appendix L

Characterization of Meteorology in the VISTAS Region

VISTAS

Characterization of Meteorology and Its Relationships to Fine Particulate Mass and Visibility in the VISTAS Region

Final Report

December 8, 2006

06-046

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Characterization of Meteorology and Its Relationships to Fine Particulate Mass and Visibility in the VISTAS Region

Final Report

December 8, 2006

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Executive Summary

This report summarizes the methods and results of a meteorological characterization study designed to examine the relationships between meteorology, fine particulates, and regional haze at air quality monitoring sites throughout the Southeastern U.S. This study is one of the technical analyses conducted by the Visibility Improvement—State and Tribal Association of the Southeast (VISTAS) to support regulatory planning for regional haze and related air quality issues for the southeastern states.

The results of this study are intended to provide information on the site-specific and regional meteorological and air quality characteristics of the 2000-2004 regional-haze baseline period and, in particular, the representativeness of the meteorological and air quality conditions for 2002, which is the annual simulation period for the VISTAS air quality modeling analysis.

A primary objective of this analysis was to provide the information and tools needed to characterize the relationships between visibility (regional haze), fine particulate matter, and meteorology for Class I and other selected areas within and surrounding the VISTAS region. Classification and Regression Tree (CART) statistical analysis was used to examine these relationships for Interagency Monitoring of Protected Visual Environments (IMPROVE), Speciated Trends Network (STN), and Southeastern Aerosol Research and Characterization (SEARCH) air quality monitoring sites located throughout the Southeast. The CART results provide insight into the relationships between meteorology, fine particulates, and visibility that are important to atmospheric modeling.

Separate CART analyses were conducted for visibility (as defined by the extinction coefficient) and fine particulates (particulate matter with a diameter less than 2.5 microns, $PM_{2.5}$). Visibility analyses were conducted for the IMPROVE and SEARCH sites only; $PM_{2.5}$ analyses were conducted for the IMPROVE, STN, and SEARCH sites. CART was applied for each site and was used to classify days for the period 2000-2004 into groups (or bins) with similar air quality (visibility or $PM_{2.5}$) and meteorological characteristics. Classification accuracy ranged from approximately 72 to 85 percent for visibility and from approximately 75 to 90 percent for $PM_{2.5}$. In applying the CART technique, we found that good classification for most sites was dependent on information about prior day air quality. This indicates that regional buildup and transport of fine particles and related precursor species influences regional visibility and $PM_{2.5}$ concentrations. We also found that moisture is a important meteorological parameter for good classification for both $PM_{2.5}$ and visibility and that the more complex role of moisture in determining light extinction—affecting both particle formation and the contribution of sulfate and nitrate particle species to light extinction—may account for the overall, better classification accuracy for $PM_{2.5}$, compared to extinction coefficient.

The CART results indicate that he most important parameters for determining visibility in the southeastern U.S. include: relative humidity, prior day $PM_{2.5}$ concentrations at potentially upwind monitoring sites, 850 mb temperature, surface temperature (reflecting seasonal differences), and wind speed (both near the surface and aloft). The list of important parameters is similar for $PM_{2.5}$, but relative humidity is less important. Wind directions are not used frequently enough in the CART trees to be considered important parameters to the overall classification, but they are often used near the end of the CART pathways to distinguish poor visibility and high $PM_{2.5}$ days. These results vary by site, although, there are similarities among the sites with similar geographical features.

The CART-derived parameter importance rankings and values were also used to examine potential site groupings. We assumed that similarities in the important parameters between or

among sites indicate similarities in the mechanisms influencing air quality at these sites, and quantified the similarities and differences using a Euclidean distance metric. Although there are some exceptions, the CART-derived groupings, which are based on parameter importance, are also supported by similarities in location and geography. These groupings may provide the basis for assessing model performance and understanding the reasons for model performance problems, as well as accounting for differences in the effectiveness of air quality measures across the monitoring sites and regions.

We also used the CART input data and results to explore the relationships between the meteorological and other input parameters and the air quality metrics, and to examine the specific combinations of parameters (conditions) that lead to impaired air quality. There are often clear distinctions between the average values of the parameters for days in high and low visibility categories and the high and low $PM_{2.5}$ categories.

Insight for atmospheric modeling is gained by considering the characteristics of the bins that contain the 20 percent haziest days or the high $PM_{2.5}$ days for each site. Poor visibility and high $PM_{2.5}$ days are grouped into bins that are characterized by different meteorological and prior-day air quality conditions. One of the more notable differences among the different poor visibility and high $PM_{2.5}$ bins is wind direction, especially surface wind direction. This indicates that different sources (source-receptor relationships) may influence visibility and $PM_{2.5}$ on different days and has implications for emissions control strategy development. In addition, for several sites, large differences in average temperature among the key bins indicate that the regimes vary with season. Other differences involve prior day $PM_{2.5}$ concentration, relative humidity, stability, and degree of persistence (indicating a sea or gulf breeze) for the coastal sites. The differences in the individual parameters combine to represent the different regimes, and there are multiple regimes associated with poor visibility and high $PM_{2.5}$ for all of the areas of interest.

The CART analyses also provide insight into $PM_{2.5}$ composition for different types of poor visibility days and high $PM_{2.5}$ days. In general, analysis of the compositional characteristics for the bins containing the 20 percent haziest days for the IMPROVE sites within the VISTAS region indicates that, on average, ammonium sulfate and organic carbon are the two most important contributors to poor visibility and that their relative contributions vary by site, by bin, and with meteorology. For the inland IMPROVE sites, ammonium sulfate is the dominant contributor. For the coastal IMPROVE sites the contributions from ammonium sulfate and organic carbon on the poor visibility days are more comparable than for the interior sites. As for visibility, the high $PM_{2.5}$ concentration bins are distinguished from the lower concentration bins by higher sulfate and organic matter concentrations.

The STN and SEARCH $PM_{2.5}$ analyses indicate a much larger proportional contribution from organic matter than the IMPROVE sites, especially for the higher $PM_{2.5}$ bins. This is in part due to differences between the measurement techniques for organic carbon. With the higher values for organics, the dominant species varies by bin, much more so than for the IMPROVE sites. These variations are attributable to differences in meteorology as well as regional pollutant transport.

The CART results were used to explore several questions related to modeling episode period representativeness. The key question addressed is: How representative is the year 2002, as selected for VISTAS atmospheric modeling, considering meteorology, fine particulate, and visibility, relative to the full baseline period? The characteristics of the 2000-2004 baseline period and each individual year comprising that period were examined and compared.

The 2002 annual simulation period includes days that capture the general meteorological characteristics associated with a range of visibility at the IMPROVE sites and represents well the typical frequency of occurrence of these conditions. However, somewhat lower than average concentrations and average extinction coefficients characterize 2002 for some sites. $PM_{2.5}$ values for the STN and SEARCH sites are also lower than average compared to other years within the baseline period.

Two subset episode periods from 2002, comprising a total of 71 days, were selected to represent the conditions and concentration levels associated with high $PM_{2.5}$ events in as many areas as possible throughout the VISTAS region. These include a summer episode (1 June – 10 July) and a winter episode (19 November – 19 December 2002). For many of the sites, the summer period includes the peak days for 2002. Considering all sites, between approximately 40 and 100 percent of the most frequently occurring high $PM_{2.5}$ bins are represented by the episode days—this varies by site. As expected, the episodes do not sample the different regimes with the frequency that is typical of the longer periods.

The CART results were also used in the calculation of weighting factors for both regional haze and $PM_{2.5}$ for the annual and episodic modeled days. The weighting factors for regional haze were calculated based on similarities between the modeled days and the regulatory 20% Best and 20% Worst days and the frequency of occurrence of the conditions associated with the modeled days during the 2000-2004 baseline period. The weighting factors for $PM_{2.5}$ were based on the frequency of occurrence of the meteorological conditions. The weighting factors are intended to be applied to the VISTAS atmospheric modeling results so that they can better represent the baseline period for the projection of future air quality related values.

Application of CART has provided an improved understanding of the conditions contributing to high $PM_{2.5}$ and poor visibility in the southeastern states and the basis for the enhanced analysis and interpretation of the VISTAS atmospheric modeling results.

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1. Introduction

This report summarizes the methods and results of the VISTAS meteorological characterization study. This study was designed to examine the relationships between meteorology, fine particulates, and regional haze at air quality monitoring sites throughout the Southeastern U.S., and to provide information on the site-specific and regional meteorological and air quality characteristics of the 2000-2004 baseline and 2002 air quality modeling periods.

1.1. Background

In 1999, the U.S. Environmental Protection Agency (EPA) promulgated regional haze regulations to prevent "any future, and remedy any existing, impairment of visibility" at 156 designated Class I areas (national parks greater than 6000 acres and wilderness areas greater than 5000 acres) (Regional Haze Regulations, 1999). The regional haze rule calls for states to establish "reasonable progress goals" for each Class I area to improve visibility on the 20% haziest days and to prevent visibility degradation on the 20% clearest days. The national goal is to return visibility to natural background levels by 2064. Using the period 2000 to 2004 as the baseline period, states are to evaluate progress in improving visibility by 2018 and every 10 years thereafter. State Implementation Plans (SIPs) for the first phase of the regional haze regulation are due in December 2007.

The National Ambient Air Quality Standard (NAAQS) for particulate matter was revised in 1997 to set annual and 24-hour limits for particles with diameters less than 2.5 microns ($PM_{2.5}$). Based on data for 2001-2003, several counties in the southeastern states were designated in December 2004 as not attaining the annual $PM_{2.5}$ standard. By April 2008, affected states are required to submit a SIP demonstrating control strategies to attain the annual $PM_{2.5}$ standard by April 2010.

The Visibility Improvement – State and Tribal Association of the Southeast (VISTAS) is the Regional Planning Organization (RPO) for ten southeastern states and is conducting the technical analyses to support the States' regulatory planning for regional haze and related air quality issues. As part of this technical support, VISTAS is conducting regional-scale air quality modeling for regional haze and $PM_{2.5}$ using an annual simulation period of 2002. In order to use the simulation results appropriately, VISTAS is also conducting the data analysis study described in this report to identify, describe, and otherwise characterize the meteorological conditions that result in different values of visibility and $PM_{2.5}$, and to relate these metrics to the days that comprise the annual simulation period.

1.2. Objectives and Key Questions

A primary objective of this analysis was to provide the information and tools needed to characterize the relationships between visibility (regional haze), $PM_{2.5}$, and meteorology for Class I and other selected areas within and surrounding the VISTAS region. Classification and Regression Tree (CART) statistical analysis was used to examine these relationships for Interagency Monitoring of Protected Visual Environments (IMPROVE), Speciated Trends Network (STN), and Southeastern Aerosol Research and Characterization (SEARCH) air quality monitoring sites located in the Southeast.

A second objective of the study was to assess the meteorological representativeness of the 2002 modeling period and to guide the use and interpretation of the modeling results for each area of interest and the region. The reliable application of modeling tools for analysis of the effects of future emissions changes on air quality requires that the periods selected for model application represent the type and range of meteorological conditions and pollutant concentration levels that characterize the air quality problem. This applies to discrete multi-day simulation periods and their use in representing expected changes in seasonal and annual

metrics, as well as to annual simulation periods and their ability to reliably represent future-year values of the NAAQS that typically rely on multiple years of data to determine progress and compliance. A key assumption in any modeling exercise is that the results for the modeled periods can be applied to the evaluation of the effects of emissions changes and the determination of attainment or compliance for some future year. Thus, it is important that the modeled periods represent the range and type of frequently occurring meteorological conditions that describe the current (and possible future) air quality.

At first thought, use of an annual simulation period for modeling regional haze and $PM_{2.5}$ seems a reasonable solution to the episode selection problem. However, this is only the case if the year that is selected exhibits the type, range, and relative frequencies of meteorological conditions that characterize an area relative to specific air quality parameters. It follows that the ability to identify, describe, and otherwise characterize the conditions that result in different values of the relevant air quality metrics, and to relate these to the days that comprise the modeling episode periods, is key to the appropriate use of the any simulation results.

To support this type of assessment for VISTAS, the CART input data and results were also used in this study to provide information about the frequency of occurrence of different types of meteorological conditions; differences in PM species concentrations for different ranges of visibility, $PM_{2.5}$ concentrations and meteorological types; and the representativeness of selected annual or multi-day simulation periods. Specifically, key questions that are being considered in this study include, but are not limited to, the following:

1. How representative is the year 2002, as selected for VISTAS atmospheric modeling, considering meteorology, fine particulate, and visibility? This is addressed for each site and for the VISTAS region.
2. How well do subset modeling periods chosen by VISTAS for emission sensitivity analysis capture the range of relationships between meteorology and air quality for each site of interest and for the VISTAS region?

1.3. Overview of the Methodologies

Classification and Regression Tree (CART) statistical analysis was used in this study to classify days for the period 2000–2004 according to visibility (as defined by the extinction coefficient), fine particulates (particulate matter with a diameter less than 2.5 microns, $PM_{2.5}$), and meteorological parameters. The CART input data and results provide information about the relationships between the meteorology and the visibility and $PM_{2.5}$ parameters, the frequency of occurrence of different types of meteorological conditions, the basis for examining differences in PM species concentrations for different ranges of visibility and $PM_{2.5}$ concentrations and different meteorological types, and the basis for examining the representativeness of selected multi-day or annual simulation periods.

The CART results were used to define the role of meteorology in determining visibility and $PM_{2.5}$ concentrations and distinguishing between hazy and clear days for each site. Similarities and differences among the sites were used to develop a regional perspective. The CART results were also used to examine the role of carryover or regional transport of pollutants and the contribution of these mechanisms to visibility degradation.

The CART results for 2000-2004 were incorporated into an interactive analytical tool that, in its characterization mode, allows users to extract information that can be used to answer questions

about how well selected days or groups of days represent the visibility (and optionally $PM_{2.5}$) and meteorological characteristics for a selected site or group of sites. The analytical tool also incorporates an episode selection algorithm (a version of the EPISODES program that was first developed for the Southern Appalachian Mountains Initiative (SAMI) by Deuel and Douglas (1998)). In this alternative, episode selection mode, the analytical tool provides lists of days and multi-day periods that best achieve episode selection criteria that are defined based on user-specified input parameters (for example, specific sites or groups of sites, a maximum number of days, years or periods from which to select days, options for defining key conditions, relative importance of selecting sequential days versus minimizing the error in representing the metrics). In both modes, the ability of the user- or algorithm-selected days to represent key VISTAS regional haze metrics is calculated and presented as an error.

The CART results were also used in the calculation of weighting factors that have enabled VISTAS to make optimum use of the modeled days in representing the best and worst visibility days and annual $PM_{2.5}$ metrics based on the frequency of occurrence of meteorological conditions.

The CART-based episode selection and analysis methodology was previously applied for the SAMI modeling study for the integrated selection of representative episode periods for atmospheric modeling of ozone, particulates, and acid deposition (Deuel and Douglas, 1998). Recent efforts that focus on identifying and understanding the relationships between fine particulates and meteorology include the analysis of high-resolution, speciated $PM_{2.5}$ data collected as part of SEARCH monitoring program (Douglas et al., 2003) and the development of $PM_{2.5}$ forecasting tools for urban areas within the Mid-Atlantic region (Douglas et al., 2004).

Various researchers have employed other statistical techniques in attempting to define the relationships between meteorology and air quality. For example, Cox and Chu (1996) employed regression analysis and Eder et al. (1993) used cluster analysis, which typically relies on principal component analysis, to find similarities in descriptive parameters and then group days with similar conditions. One benefit of CART compared to these techniques is that it allows for the possibility that two days can have similar characteristics but for different reasons (in other words, that there are multiple pathways to that lead to poor visibility or high $PM_{2.5}$ concentrations).

This project has provided (1) an improved understanding of the relationships between meteorology, visibility, and $PM_{2.5}$ throughout the VISTAS region, (2) a turn-key analytical tool that can be used to address a variety of questions regarding meteorological characterization and representativeness as well as the selection of new and/or subset episodes, and (3) weighting factors for use in examining the modeling results.

1.4. Report Contents

The data that were used in the analysis and the data processing and quality assurance procedures are summarized in Section 2 of this report. The CART analysis methods and results are presented in Section 3. Meteorological representativeness of the full and subset modeling periods is addressed in Section 4. The meteorological characterization tool is also described in this section. Key findings and implications for VISTAS are presented in Section 5. Finally, a comparison of the results for Birmingham, Alabama using two different datasets (STN and SEARCH) is provided in the appendix.

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2. Data Acquisition, Processing, and Quality Assurance

In this section of the report, we summarize data that were used in the CART applications for 2000-2004 and in developing the corresponding meteorological characterization tool. The data processing and quality assurance procedures are also described.

2.1. Particulate Matter and Visibility Data

Data from the IMPROVE, STN, and SEARCH air quality monitoring network datasets were used to specify daily and speciated $PM_{2.5}$ mass and to calculate extinction coefficient (visibility).

The data were obtained from the following web sites:

- IMPROVE: http://vista.cira.colostate.edu/views (CIRA, 2005)
- STN: http://www.epa.gov/ttn/airsaqs (EPA, 2005)
- SEARCH: http://www.atmospheric-research.com/public (ARA, 2005)

The VISTAS CART and meteorological classification analyses focused on the IMPROVE and STN data, for selected sites. Under separate funding, we conducted similar work using the SEARCH data/sites and then incorporated this information into the VISTAS meteorological characterization tool and analyses.

2.1.1. Monitoring Sites and Data Availability

The IMPROVE sites within the VISTAS region are listed in Table 2-1a, along with their locations and data availability dates for the 2000-2004 period. IMPROVE measurements are taken every three days. Data completeness for the period 2000-2004 is also provided, and this measure of data completeness accounts for measurement frequency. The IMPROVE sites were used for both the visibility and $PM_{2.5}$ analyses.

Table 2-1a. VISTAS IMPROVE Sites and Summary of Data Availability for the CART Visibility and $PM_{2.5}$ Analyses.

Site Name	State	Elevation (m)	Latitude (deg)	Longitude (deg)	First Date with Data after 1999	Last Date with Data (as of 12/04)	% Complete (for 1/2000-12/2004)
Cadiz	KY	188	36.79	-87.95	3/8/2001	12/31/2004	74
Cape Romain National Wildlife Refuge	SC	3	32.94	-79.66	1/1/2000	12/31/2004	98
Chassahowitzka National Wildlife Refuge	FL	2	28.75	-82.55	1/1/2000	12/31/2004	60
Cohutta	GA	743	34.79	-84.63	6/3/2000	12/31/2004	72
Dolly Sods/Otter Creek Wilderness	WV	1158	39.11	-79.43	1/1/2000	12/31/2004	97
Everglades National Park	FL	3	25.39	-80.68	6/7/2000	12/31/2004	89
Great Smoky Mountains National Park	TN	815	35.63	-83.94	1/1/2000	12/31/2004	99
James River Face	VA	299	37.63	-79.51	6/3/2000	12/31/2004	94
Linville Gorge	NC	986	35.97	-81.93	4/1/2000	12/31/2004	92
Mammoth Cave National Park	KY	248	37.13	-86.15	1/1/2000	12/31/2004	99
Okefenokee National Wildlife Refuge	GA	49	30.74	-82.13	1/1/2000	12/31/2004	99
St. Marks	FL	2	30.09	-84.16	9/3/2000	12/31/2004	69
Shenandoah National Park	VA	1098	38.52	-78.43	1/1/2000	12/31/2004	93
Shining Rock Wilderness	NC	1621	35.39	-82.77	1/1/2000	12/31/2004	79
Sipsey Wilderness	AL	279	34.34	-87.34	1/1/2000	12/31/2004	88
Swanquarter	NC	2	35.45	-76.21	6/10/2000	12/31/2004	62

A total of 15 IMPROVE sites and one CASTNET site (Cadiz) within the VISTAS region were included in the analysis. We will refer to these sites as the VISTAS IMPROVE sites throughout the remainder of this report.

In addition to the IMPROVE sites located within the VISTAS region, we also included five IMPROVE sites that are located in neighboring states. These are listed in Table 2-1b.

Table 2-1b. IMPROVE Sites in Neighboring States and Summary of Data Availability for the VISTAS CART Visibility and $PM_{2.5}$ Analyses.

Site Name	State	Elevation (m)	Latitude (deg)	Longitude (deg)	First Date with Data after 1999	Last Date with Data (as of 12/04)	% Complete
Breton National Wilderness Area	LA	2	29.12	-89.21	8/28/2000	12/31/2004	64
Brigantine National Wildlife Refuge	NJ	5	39.47	-74.45	1/1/2000	12/31/2004	96
Caney Creek	AR	690	34.45	-94.14	6/24/2000	12/31/2004	86
Mingo	MO	112	39.97	-90.14	6/3/2000	12/31/2004	38
Upper Buffalo Wilderness	AR	723	35.83	-93.20	1/5/2000	12/31/2004	96

The analysis also included 16 STN sites located in urban or rural areas throughout the VISTAS region. FRM-based $PM_{2.5}$ data are collected on a daily basis for Birmingham, Charlotte, Greenville-Spartanburg, Louisville, Memphis, Nashville, Raleigh, and Richmond and every three days for the remaining sites. Speciated measurements are collected every three days for Birmingham, Charlotte, Memphis, and Richmond sites and every six days for the remaining sites. The 16 sites are listed in Table 2-4. The period of record refers to the speciated data, since most sites have FRM data for the full period. Data completeness designates the completeness of the FRM data, relative to the full period.

Table 2-2. STN Sites and Summary of Data Availability for the CART Visibility and $PM_{2.5}$ Analyses.

Site Name	State	Elevation (m)	Latitude (deg)	Longitude (deg)	First Date with STN Data after 1999	Last Date with STN Data (as of 12/04)	% Complete FRM (for 1/2000-12/2004)
Birmingham	AL	174	33.55	-86.82	1/13/2001	12/31/2004	97
Charlotte	NC	232	35.24	-80.79	1/13/2001	12/31/2004	94
Chattanooga	TN	200[1]	35.05	-85.30	11/27/2001	12/31/2004	100
Greenville-Spartanburg	SC	300[1]	34.90	-82.31	11/21/2001	12/31/2004	96
Hickory	NC	333	35.73	-81.37	1/2/2002	12/31/2004	99
Huntington-Ashland	WV	200	38.46	-82.64	11/3/2001	12/31/2004	100
Jackson	MS	100[1]	32.10	-90.19	9/22/2001	12/31/2004	95
Kingsport-Bristol	TN	4330	36.54	-82.52	12/3/2001	12/31/2004	100
Louisville	KY	148	38.24	-85.73	11/9/2001	12/31/2004	98
Macon	GA	89	32.78	-83.65	3/3/2002	12/31/2004	90
Memphis	TN	70[1]	35.21	-90.03	9/10/2001	12/31/2004	93
Montgomery	AL	220	32.41	-86.26	2/7/2002	12/31/2004	100
Nashville	TN	160	36.18	-86.74	2/13/2002	12/31/2004	92
Raleigh	NC	100	35.86	-78.57	1/2/2002	12/31/2004	95
Richmond	VA	59	37.51	-77.50	3/2/2001	12/31/2004	88
Savannah	GA	12	32.09	-81.14	3/3/2002	12/31/2004	96

[1]STN site elevation unavailable; value is approximate based on nearby surface met sites.

These sites were selected based on: 1) 2000-2002 $PM_{2.5}$ design value at the STN site, 2) proximity of the STN site to a Class I area, 3) location relative to spatial gaps in the IMPROVE and SEARCH monitoring networks, and 4) period of record for speciated data (a monitoring start date of January 2002 or earlier was preferred). In addition, one site in the Birmingham area was specifically selected to accommodate a comparison of results for multiple sites in an urban area and a direct comparison with the results obtained using the SEARCH data.

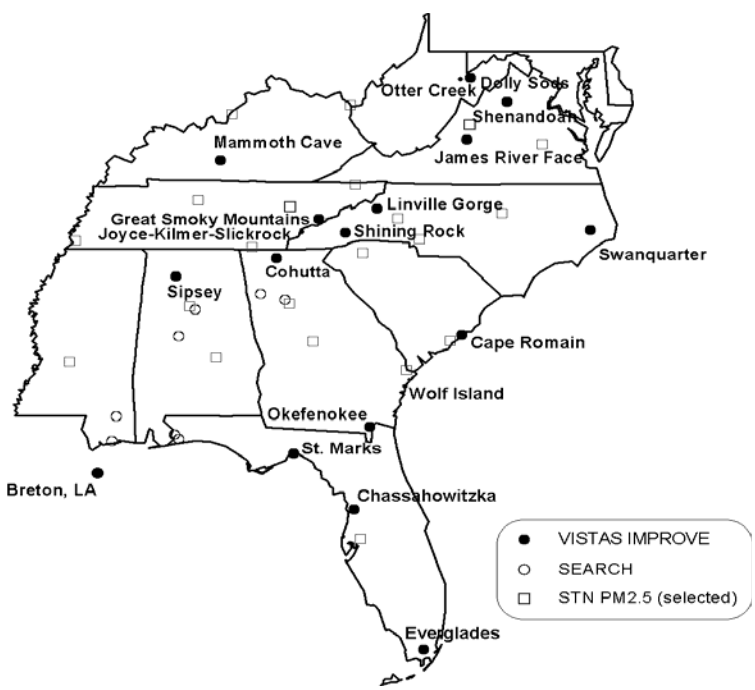
The SEARCH network consists of eight monitoring sites within the VISTAS region. $PM_{2.5}$ mass data are collected on a daily basis, and speciated measurements are collected every three days. These sites are listed in Table 2-3.

Table 2-3. SEARCH Sites and Summary of Data Availability for the VISTAS CART Visibility and $PM_{2.5}$ Analyses.

Site Name	State	Elevation (m)	Latitude (deg)	Longitude (deg)	First Date with Data after 1999	Last Date with Data (as of 12/04)	% Complete
Atlanta (Jefferson St.)	GA	275	33.78	-84.41	1/1/2000	12/31/2004	99
Yorkville	GA	395	33.93	-85.05	1/1/2000	12/31/2004	98
Birmingham	AL	200	33.55	-86.82	1/1/2000	12/31/2004	98
Centreville	AL	135	32.90	-87.25	1/1/2000	12/31/2004	99
Pensacola	FL	27	30.44	-87.26	1/1/2000	12/31/2004	89
Outlying Landing Field (OLF)	FL	45	30.55	-87.38	1/1/2000	12/31/2004	98
Gulfport	MS	5	30.39	-89.05	1/1/2000	12/31/2004	96
Oak Grove	MS	100	30.99	-88.93	1/1/2000	12/31/2004	97

The locations of the IMPROVE, STN, and SEARCH sites are show in Figure 2-1.

Figure 2-1. Locations of the IMPROVE, STN and SEARCH Sites Used for the VISTAS CART Analysis.



Finally, $PM_{2.5}$ data from FRM and STN sites that were not the focus of the CART analysis were used in addition to data from the selected STN sites and the SEARCH sites to represent potential upwind and/or regional values of the air quality parameters.

2.1.2. Parameters of Interest

For the visibility analysis, extinction coefficient is the CART classification variable. The IMPROVE data consist of 24-hour measurements, taken every three days, of the species required for estimating light extinction. The species include ammonium sulfate, ammonium nitrate, organic mass, elemental carbon, soil elements, and coarse mass.

These same species measurements are available from the SEARCH and EPA STN sites, with a couple of exceptions. First, the soil measurement for the SEARCH data is metal oxides. We assumed that this is equivalent to the soil elements measurement from the IMPROVE data. Second, there are no coarse PM measurements for the EPA STN sites and this term was not included in the calculation of extinction coefficient for these sites. For most sites, the contribution from coarse PM is expected to be small. Sea salt may enhance the course PM contribution at coastal sites, but only one of the STN sites included in this analysis is a located in a coastal area.

For the $PM_{2.5}$ analysis we used 24-hour average $PM_{2.5}$ concentration as the CART classification variable. For the IMPROVE sites we used reconstructed fine mass which is intended by IMPROVE for direct comparison to the Federal Reference Method (FRM). FRM mass was used for the STN sites and FRM-equivalent mass was used for the SEARCH sites.

2.1.3. Calculation of Extinction Coefficient

The EPA protocol for the calculation of extinction coefficient was applied and hourly relative humidity values were used in the calculations.

Specifically, the EPA equation for calculating the chemical extinction coefficient (B_{ext}) from the concentrations of particulate species was used as follows:

$$B_{ext} = 10 + 3 \cdot f(RH) \cdot \{[\text{ammonium sulfate}] + [\text{ammonium nitrate}]\}$$
$$+ 4 \cdot [\text{organic carbonaceous material}] + 10 \cdot [\text{black carbon}]$$
$$+ 1 \cdot [\text{soil}] + 0.6 \cdot [\text{coarse matter}]$$

where the square brackets represent concentrations in μgm^{-3} and f(RH) represents the effect of relative humidity on light scattering. The units for B_{ext} are Mm^{-1}.

Hourly relative humidity values were used to determine f(RH). In the EPA methodology, f(RH) consists of a set of monthly-average climatological factors that are unique to each IMPROVE site. For this project, however, we used a site-specific, daily average f(RH) value. For each hour, we determined the value of f(RH) based on measured RH and the values provided in the look up table by EPA (EPA, 2001). We then calculated a daily average f(RH) value, based on the hourly values. The use of hourly RH values means that the best and worst visibility days used in the CART analysis will not necessarily be the same as the best and worst visibility days used in the model-based projections for regional haze. However, use of daily relative humidity data was necessary for the CART analysis since the classification of each day is based on the

relationships between the daily meteorological parameters and visibility (there is no such relationship with monthly relative humidity).

Relative humidity data for the calculation of f(RH) was either for the same site or a nearby meteorological monitoring site. Some of the IMPROVE and STN sites and all of the SEARCH sites have relative humidity data. For sites that lack relative humidity information, we used relative humidity data from the nearest geographically similar site in the calculation of visibility. Geographical similarity was based on elevation, latitude, land-use, and proximity to/location relative to a coastline. The meteorological data and monitoring sites are presented in the next section.

2.1.4. Data Processing and Quality Assurance Procedures

The speciated PM data and calculated extinction coefficients were processed for input to CART and stored in both Excel and database management system (DBMS) format.

Our data quality assurance procedures were designed specifically to ensure that the data being input to CART are reasonable and consistent with our intended use of the software.

Some key actions were undertaken to ensure the reliability of the underlying data from the IMPROVE, STN and SEARCH databases:

- For each monitoring site, site-specific files were created from the larger database and the locations for all sites and units for all data elements were confirmed.
- Randomly selected values in the re-formatted, site-specific files were cross-checked against the original data files for accuracy.
- $PM_{2.5}$ mass and species values and calculated extinction coefficients for each site were extracted and sorted according to magnitude, to check the range of values for reasonableness and the completeness of the dataset (i.e., that missing values were accounted for and properly indicated).

2.2. Meteorological Data

The meteorological data used for this analysis consisted of both surface and upper-air data and were obtained from the National Climatic Data Center (NCDC), primarily via the Internet (NCDC, 2005). Surface meteorological data from the IMPROVE, CASTNET, and SEARCH sites were also used, as indicated in the tables that appear later in this section.

Each $PM_{2.5}$ monitoring site of interest was matched with meteorological data from one or more nearby meteorological monitoring sites. The matching was based on proximity but also considered elevation, latitude, land-use, and location relative to a coastline.

2.2.1. Monitoring Sites and Data Availability

The surface meteorological monitoring sites selected for use with the IMPROVE sites are listed in Table 2-4. The location and elevation of both the IMPROVE and surface meteorological sites are also listed. Four of the IMPROVE sites have hourly surface temperature and relative humidity data that were used directly for those sites. These sites are Great Smoky Mountains National Park, Mammoth Cave, Okefenokee, and Shining Rock. These are not specifically listed in Table 2-4. All other surface meteorological parameters for these four sites were obtained from the site matches listed below. The distance between the IMPROVE and surface meteorological monitoring sites is also given in the table and ranges from approximately 0 to 50 km.

Table 2-4. IMPROVE and Surface Meteorological Monitoring Site Pairs.

IMPROVE Site	State	Elevation (m)	Lat (deg)	Lon (deg)	Surface Met Site	Elevation (m)	Lat (deg)	Lon (deg)	Distance (km)
Breton	LA	2	29.12	-89.21	Boothville	0	29.33	-89.4	30.4
Brigantine National Wildlife Refuge	NJ	5	39.47	-74.45	Atlantic City	18	39.45	-74.57	10.2
Cadiz	KY	188	36.79	-87.85	Cadiz – CASTNET	189	36.78	-87.85	0.2
Caney Creek	AR	690	34.45	-94.14	Mt. Ida	214	34.55	-93.58	52.4
Cape Romain National Wildlife Refuge	SC	3	32.94	-79.66	Charleston Intl Airport	12	32.9	-80.0	32.4
Chassahowitzka National Wildlife Refuge	FL	2	28.75	-82.55	Brooksville-Hernando Co Airport	24	28.47	-82.45	32.6
Cohutta	GA	743	34.79	-84.63	Dalton	244	34.77	-84.88	23.3
Dolly Sods/Otter Creek Wilderness	WV	1158	39.11	-79.43	Parsons – CASTNET	510	39.09	-79.66	20.4
Everglades National Park	FL	3	25.39	-80.68	Everglades – CASTNET	2	25.39	-80.68	0.0
Great Smoky Mountains National Park	TN	815	35.63	-83.94	Look Rock – CASTNET	793	35.63	-83.94	0.1
James River Face	VA	299	37.63	-79.51	Lynchburg Regional Airport	287	37.33	-79.2	43.0
Linville Gorge	NC	986	35.97	-81.93	Hickory Regional Airport	348	35.73	-81.38	56.7
Mammoth Cave National Park	KY	248	37.13	-86.15	Bowling Green-Warren Co Airport	161	36.97	-86.42	30.1
Mingo	MO	112	36.97	-90.14	Polar Bluff Municipal Airport	100	36.77	-90.32	27.2
Okefenokee National Wildlife Refuge	GA	49	30.74	-82.13	Jacksonville Intl Airport	8	30.5	-81.7	49.0
St. Marks	FL	2	30.09	-84.16	Tallahassee Regional Airport	17	30.4	-84.35	38.7
Shenandoah National Park	VA	1098	38.52	-78.43	Big Meadows – CASTNET	1073	38.52	-78.43	0.0
Shining Rock Wilderness	NC	1621	35.39	-82.77	Ashville Regional Airport	652	35.43	-82.53	22.5
Sipsey Wilderness	AL	279	34.34	-87.34	Muscle Shoals	165	34.75	-87.6	51.2
Swanquarter	NC	2	35.45	-76.21	Hatteras Billy Mitchell Airport	3	35.23	-76.62	44.8
Upper Buffalo Wilderness	AR	723	35.83	-93.20	Harrison Boone County Airport	419	32.27	-93.15	49.3

The STN sites selected for this analysis were paired with collocated or nearby sites, as listed in Table 2-5. The distance between the STN and surface meteorological monitoring sites is also given in the table and ranges from 1 to 20 km.

Table 2-5. STN and Surface Meteorological Monitoring Site Pairs.

AIRS Site	State	Elevation (m)	Lat (deg)	Lon (deg)	Surface Met Site	Elevation (m)	Lat (deg)	Lon (deg)	Distance (km)
Birmingham	AL	174	33.55	-86.82	Birmingham Municipal Airport	188	33.57	-86.75	6.3
Montgomery	AL	220	32.41	-86.26	Montgomery Dannelly Field	62	32.3	-86.4	17.7
Macon	GA	89	32.78	-83.65	Macon Middle GA Regional Airport	105	32.68	-83.65	11.1
Savannah	GA	12	32.09	-81.14	Savannah International Airport	14	32.12	-81.2	6.1
Huntington-Ashland	KY	200	38.46	-82.64	Huntington Tri-State Airport	251	38.37	-82.55	12.7
Louisville	KY	148	38.24	-85.73	Louisville Standiford Field	165	38.18	-85.73	6.7
Jackson	MS	100[1]	32.10	-90.19	Jackson International Airport	101	32.32	-90.08	10.5
Hickory	NC	333	35.73	-81.37	Hickory Regional Airport	348	35.73	-81.38	1.3
Charlotte	NC	232	35.24	-80.79	Charlotte-Douglas International Airport	222	35.22	-80.95	15.1
Raleigh	NC	100	35.86	-78.57	Raleigh-Durham International Airport	127	35.87	-78.78	18.6
Greenville-Spartanburg	SC	300[1]	34.90	-82.31	Greenville Downtown Airport	319	34.85	-82.35	6.4
Nashville	TN	160	36.18	-86.74	Nashville International Airport	183	36.13	-86.68	7.4
Chattanooga	TN	200[1]	35.05	-85.30	Chattanooga Lovell Field Airport	205	35.03	-85.2	9.2
Memphis	TN	70[1]	35.21	-90.03	Memphis International Airport	77	35.05	-89.98	17.9
Kingsport-Bristol	TN	4330	36.54	-82.52	Bristol Tri-City Airport	457	36.47	-82.4	13.2
Richmond	VA	59	37.51	-77.50	Richmond International Airport	50	37.5	-77.32	15.8

[1]STN site elevation unavailable; value is approximate based on nearby surface met sites.

All of the SEARCH sites have a full suite of surface meteorological parameters.

The upper-air meteorological monitoring sites selected for use with the IMPROVE sites are listed in Table 2-6. The location and elevation of both the IMPROVE and upper-air meteorological sites are also listed. In several cases, the nearest upper-air site was not significantly closer or (based on geography) more clearly representative of the areas than other surrounding sites and multiple upper-air sites were used to define the airflow and pressure patterns aloft. The distance between the IMPROVE and upper-air meteorological monitoring sites is also given in the table and ranges from 35 to approximately 380 km.

Table 2-6. IMPROVE and Upper-Air Meteorological Monitoring Site Pairs.

IMPROVE Site	State	Elevation (m)	Lat (deg)	Lon (deg)	Upper-Air Met Site(s)	Elevation (m)	Lat (deg)	Lon (deg)	Distance (km)
Breton	LA	2	29.12	-89.21	Slidell	8	30.33	-89.82	147.3
Brigantine National Wildlife Refuge	NJ	5	39.47	-74.45	Brookhaven, NY	20	40.87	-72.87	206.1
					Sterling, VA (Dulles Intl Airport)	85	38.98	-77.47	266.0
Cadiz	KY	188	36.79	-87.85	Nashville	180	36.25	-86.57	129.1
Caney Creek	AR	690	34.45	-94.14	Little Rock	172	34.83	-92.27	176.5
Cape Romain National Wildlife Refuge	SC	3	32.94	-79.66	Charleston	15	32.9	-80.03	35.1
Chassahowitzka National Wildlife Refuge	FL	2	28.75	-82.55	Tampa	13	27.7	-82.4	117.7
Cohutta	GA	743	34.79	-84.63	Atlanta	246	33.35	-84.56	159.8
Dolly Sods/Otter Creek Wilderness	WV	1158	39.11	-79.43	Sterling, VA (Dulles Intl Airport)	85	38.98	-77.47	169.7
					Roanoke	648	37.2	-80.41	229.0
					Wilmington, OH	317	39.42	-83.82	380.2
					Pittsburgh	360	40.53	-80.23	164.8
Everglades National Park	FL	3	25.39	-80.68	Miami	4	25.75	-80.38	50.1
Great Smoky Mountains National Park	TN	815	35.63	-83.94	Nashville	180	36.25	-86.57	246.6
					Greensboro	277	36.08	-79.95	363.5
					Atlanta	246	33.35	-84.56	260.4
James River Face	VA	299	37.63	-79.51	Roanoke	648	37.2	-80.41	92.5
					Sterling, VA (Dulles Intl Airport)	85	38.98	-77.47	233.5
Linville Gorge	NC	986	35.97	-81.93	Greensboro	277	36.08	-79.95	178.9
Mammoth Cave National Park	KY	248	37.13	-86.15	Nashville	180	36.25	-86.57	105.1
Mingo	MO	112	36.97	-90.14	Springfield	394	37.23	-93.4	290.5
					Lincoln-Logan County	178	40.15	-89.33	360.8
					Nashville	180	36.25	-86.57	329.2
					Little Rock	172	34.83	-92.27	305.9
Okefenokee National Wildlife Refuge	GA	49	30.74	-82.13	Tallahassee	25	30.38	-84.37	218.6
					Jacksonville	10	30.43	-81.7	53.6
St. Marks	FL	2	30.09	-84.16	Tallahassee	25	30.38	-84.37	37.8
Shenandoah National Park	VA	1098	38.52	-78.43	Sterling, VA (Dulles Intl Airport)	85	38.98	-77.47	98.0
					Roanoke	648	37.2	-80.41	227.6
Shining Rock Wilderness	NC	1621	35.39	-82.77	Greensboro	277	36.08	-79.95	266.3
Sipsey Wilderness	AL	279	34.34	-87.34	Birmingham	178	33.1	-86.7	150.5
Swanquarter	NC	2	35.45	-76.21	Morehead City/Newport News	11	34.7	-76.8	99.5
Upper Buffalo Wilderness	AR	723	35.83	-93.20	Little Rock	172	34.83	-92.27	139.5

The STN sites selected for this analysis were paired with collocated or nearby sites, as presented in Table 2-7. The distance between the STN and upper-air meteorological monitoring sites is also given in the table and ranges from approximately 10 to 425 km.

Table 2-7. STN and Upper-Air Meteorological Monitoring Site Pairs.

STN Site	State	Elevation (m)	Lat (deg)	Lon (deg)	Upper-Air Met Site	Elevation (m)	Lat (deg)	Lon (deg)	Distance (km)
Birmingham	AL	174	33.55	-86.82	Birmingham	178	33.1	-86.7	51.5
Montgomery	AL	220	32.41	-86.26	Birmingham	178	33.1	-86.7	84.5
Macon	GA	89	32.78	-83.65	Atlanta	246	33.35	-84.56	106.2
Savannah	GA	12	32.09	-81.14	Atlanta	246	33.35	-84.56	349.1
					Charleston	15	32.9	-80.03	137.9
Huntington-Ashland	KY	200	38.46	-82.64	Wilmington, OH	317	39.42	-83.82	147.9
					Nashville	180	36.25	-86.57	425.8
					Roanoke	648	37.2	-80.41	241.0
Louisville	KY	148	38.24	-85.73	Wilmington, OH	317	39.42	-83.82	211.4
					Nashville	180	36.25	-86.57	233.7
					Lincoln-Logan County, IL	178	40.15	-89.33	376.2
Jackson	MS	100[1]	32.301	-90.19	Jackson	91	32.32	-90.07	11.4
Hickory	NC	333	35.73	-81.37	Greensboro	277	36.08	-79.95	133.5
Charlotte	NC	232	35.24	-80.79	Greensboro	277	36.08	-79.95	120.2
Raleigh	NC	100	35.86	-78.57	Greensboro	277	36.08	-79.95	126.4
Greenville-Spartanburg	SC	300[1]	34.90	-82.31	Atlanta	246	33.35	-84.56	269.4
					Greensboro	277	36.08	-79.95	251.3
Nashville	TN	160	36.18	-86.74	Nashville	180	36.25	-86.57	17.2
Chattanooga	TN	200[1]	35.05	-85.30	Nashville	180	36.25	-86.57	176.3
					Atlanta	246	33.35	-84.56	201.0
Memphis	TN	70[1]	35.21	-90.03	Nashville	180	36.25	-86.57	333.2
					Little Rock	172	34.83	-92.27	208.8
Kingsport-Bristol	TN	4330	36.54	-82.52	Nashville	180	36.25	-86.57	364.3
					Roanoke	648	37.2	-80.41	201.7
Richmond	VA	59	37.51	-77.50	Roanoke	648	37.2	-80.41	259.9
					Sterling, VA (Dulles Intl Airport)	85	38.98	-77.47	163.6

[1]STN site elevation unavailable; value is approximate based on nearby surface met sites.

The SEARCH sites were paired with collocated or nearby sites, as presented in Table 2-8. The distance between the SEARCH and upper-air meteorological monitoring sites is also given in the table and ranges from approximately 50 to 300 km.

Table 2-8. SEARCH and Upper-Air Meteorological Monitoring Site Pairs.

SEARCH Site	State	Elevation (m)	Lat (deg)	Lon (deg)	Upper-Air Met Site	Elevation (m)	Lat (deg)	Lon (deg)	Distance (km)
Atlanta (Jefferson St.)	GA	275	33.78	-84.41	Atlanta	246	33.35	-84.56	49.4
Yorkville	GA	395	33.93	-85.05	Atlanta	246	33.35	-84.56	78.8
Birmingham	AL	200	33.55	-86.82	Birmingham	178	33.1	-86.7	51.5
Centreville	AL	135	32.90	-87.25	Birmingham	178	33.1	-86.7	55.9
Pensacola	FL	27	30.44	-87.26	Tallahassee	25	30.38	-84.37	277.1
					Slidell	8	30.33	-89.82	246.5
					Birmingham	178	33.1	-86.7	301.0
Outlying Landing Field (OLF)	FL	45	30.55	-87.38	Tallahassee	25	30.38	-84.37	289.0
					Slidell	8	30.33	-89.82	235.8
					Birmingham	178	33.1	-86.7	290.9
Gulfport	MS	5	30.39	-89.05	Slidell	8	30.33	-89.82	74.3
					Jackson	91	32.32	-90.07	235.6
Oak Grove	MS	100	30.99	-88.93	Slidell	8	30.33	-89.82	112.0
					Jackson	91	32.32	-90.07	183.6

2.2.2. Parameters of Interest

Surface meteorological parameters include hourly values of temperature, relative humidity, wind speed, wind direction, precipitation, and solar radiation.

Upper-air meteorological parameters include twice-daily values of temperature for the 900, 850, and 700 mb levels and dew-point temperature, wind speed, wind direction, and geopotential height for the 850 and 700 mb levels. The levels refer to the altitudes at which the pressure is equal to 900, 850, or 700 mb. Typical altitudes for the 900, 850, and 700 mb pressure levels are 1000, 1500 and 3000 meters.

2.2.3. Data Processing and Quality Assurance Procedures

The surface and upper-air meteorological data were processed for input to CART on a site-by-site basis, and stored in both Excel and database management system (DBMS) format.

The following procedures were followed to ensure that the meteorological data were of sufficient quality and prepared correctly for use in CART.

- All source codes used to collect and reprocess data from the original format to that used by CART were specifically reviewed before application to confirm the suitability of the software for the data type/format. Following this review, the data were formatted into site-specific data files and any data-derived quantities for CART were computed.
- The units for all data elements and for all sites were confirmed.
- The range of time over which the data are available and the timestamp for each data element were reviewed.
- For data elements that are used directly by CART, several (at least ten) random dates and times were selected and the values of the meteorological data elements were spot-checked against the original data files.
- For data elements that are computed from the original values, several (at least 10) random dates and times were selected and the values of the derived quantities were checked for reasonableness. The original data were then used to independently calculate the derived quantity for each of the selected dates and times and the values were compared.
- The values of the meteorological parameters for each site were sorted according to magnitude to check that the values were reasonable and the dataset complete.

2.3. Quality Assurance of the Datasets

The meteorological data and air quality data were merged into a single, CART-ready data file. Several more checks were performed on this merged file, including:

- The first, last, and several intermediate records in the merged file were checked against their values in the corresponding source data files for consistency.
- The format of the merged file was checked for completeness, with respect to dates and variables. Missing data are indicated by “–999.”
- The merged files were then processed using a DBMS tool, which prepares the input database. The outputs of this tool were checked specifically to see if the ranges, minima,

maxima, and number of observations of each variable were reasonable and preserved from the original fields. In this final file, missing data are indicated by a “.”.

Several fields in this merged database were then spot checked against the original values to ensure consistency throughout the process.

As part of the quality assurance of the data, standard statistical analysis techniques were used to summarize and examine the contents of the CART input dataset with respect to completeness, inter-variable (including geographical and meteorological) correlations, spatial and temporal correlations, and distribution of the various elements by site and by year. The results of this task were then used to guide certain aspects of the CART analysis.

3. Examination of Relationships between Meteorological and Air Quality Data Using Classification and Regression Tree (CART) Analysis

Classification and Regression Tree (CART) analysis was used to classify days within the period 2000-2004 according to their meteorological and air quality characteristics. The CART input data and results were used for a variety of different analyses and as input to the meteorological characterization tool. In particular, CART was used to examine the meteorological influences on visibility and $PM_{2.5}$ for each IMPROVE, STN, and SEARCH site. The CART analysis and meteorological characterization are described in this section. CART was applied separately for each IMPROVE, STN, and SEARCH site, and for visibility and $PM_{2.5}$. A comparison of the results for Birmingham using the STN and SEARCH datasets is provided in the appendix.

3.1. Overview of CART

The CART analysis software (Brieman et al., 1984; Steinburg and Colla, 1997) is a statistical analysis tool that partitions a dataset into discrete subgroups based on the value of a user-defined classification parameter (e.g., 24-hour average light extinction coefficient or $PM_{2.5}$ concentration). The remaining parameters in the database are used to segregate the data elements into groups that correspond to different values of the classification parameter. The analysis procedure assumes that there is a causal relationship between the independent input parameters and the classification (or dependent) parameter. Consequently, it is necessary to construct a database of independent parameters such that this relationship can be identified.

For air quality related analyses, the CART technique is used to segregate days with different values of an air quality parameter (the classification parameter) into different groups. The CART technique accomplishes this task through the development of a binary decision tree, comprised of a progression of binary splits on the values of the various independent input parameters. At each split, or node, the days are divided according to the value for one of the independent input parameters, in a way that improves their segregation by the classification parameter. The end of a branch—called a terminal node, or bin—corresponds to a subset of the days with predominantly one value for the classification parameter and characterized by independent input parameter ranges defined along the path to that bin. The tree identifies the conditions associated with each bin, as well as the relative importance of the various air quality and meteorological parameters to the classification. Thus, the CART technique not only segregates the days, but does so in a manner that provides physical insight into the classified days (and, in the case of air quality analysis, information on the meteorological conditions that lead to specific values of the air quality parameters).

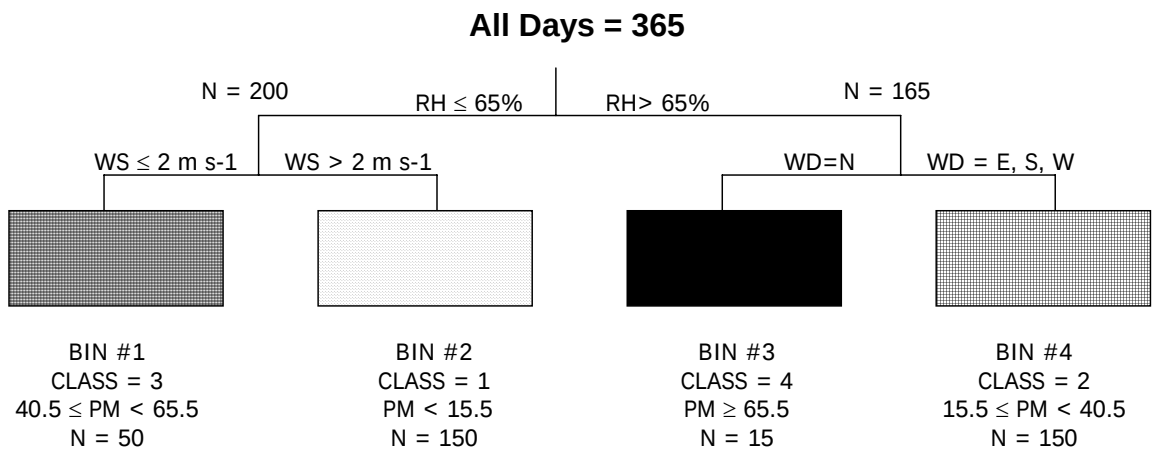
Each value of the classification parameter may be represented by more than one bin, allowing for the possibility that different combinations of the independent input parameters can be associated with a single value of the classification parameter. By segregating the data values into the classification bins, CART also provides information regarding the frequency of occurrence of the conditions associated with each classification bin (or group of days). In this manner, the likely recurrence rate for a particular type of day and the associated prevailing conditions are obtained.

In addition to assembling an input dataset consisting of relevant air quality and meteorological parameters, the user must also define the classification categories, specify the “costs” associated with the misclassification of days into bins corresponding to a different category than indicated by the observed data, and select approximate number of bins to be included in the

classification tree. Thus, the CART results are influenced by some amount of subjectivity. Details of the CART application for this study are presented in the following sections.

A simple example of a CART classification tree diagram is provided in Figure 3-1. In this example, 365 days are grouped into four classification bins that correspond to different levels of $PM_{2.5}$ concentrations. The bins are distinguished by three independent input parameters: relative humidity, wind speed, and wind direction. In this example, Bin #3 includes 15 days that are classified as belonging to the highest $PM_{2.5}$ category (with concentrations greater than or equal to 65 μgm^{-3}). Days with relative humidity values greater than 65 percent and northerly winds are placed in this bin. Bins 1, 2, and 4 are comprised of days with different PM concentrations and different meteorological characteristics.

Figure 3-1. Simple CART Classification Tree Diagram, with Splits on Relative Humidity (RH), Wind Speed (WS), and Wind Direction (WD).



Note that this is a very simple example of a CART tree. For the VISTAS CART analyses, most trees have approximately 25 to 35 bins and include multiple bins for each classification category.

3.2. CART Application Procedures

A first step in the application of CART is the identification of the input parameters. Our list includes available meteorological and air quality parameters that are expected to influence visibility and the formation and distribution of particulates.

3.2.1. Identification of CART Input Parameters

In identifying the input parameters for CART, we began with those used for a recent CART-based $PM_{2.5}$ and visibility analysis using the SEARCH data (Douglas et al., 2003). Additional parameters were added based on data availability at the IMPROVE and STN sites, and input from the VISTAS technical work group.

Surface Meteorological Parameters

Surface meteorological parameters are used to characterize the local meteorological conditions. The surface meteorological inputs for CART are listed below.

- **Temperature**
  - Maximum temperature (ºC)
  - Minimum temperature (ºC)
- **Relative Humidity**
  - 24-hour average relative humidity (%)
- **Wind**
  - 24-hour average wind direction bin; value of 1 through 5, indicating the wind direction corresponding to the 24-hour vector average wind direction: (in degrees) [315, 45), [45, 135), [135, 225), [225, 315), or calm, respectively
  - 24-hour vector wind speed (ms^{-1})
  - Persistence or gulf/sea breeze index (vector wind speed/scalar wind speed). This is an indicator of wind persistence. If the value is 1, this indicates that the vector and scalar wind speeds were the same, which further indicates that the wind was blowing from the same direction during the entire period. A value of 0 indicates that the wind direction was from one direction for half the time and from the opposite direction the other half of the time. Thus a low value indicates the potential for recirculation.
- **Radiation**
  - Solar radiation at noon (limited availability) (Wm^{-2})
- **Precipitation**
  - 24-hour total precipitation (in)
  - Number of hours of measurable precipitation

Upper-Air Meteorological Parameters

Surface meteorological parameters are used to characterize the regional-scale meteorological conditions. The upper-air parameters are as follows:

- **Temperature**
  - ***900 mb***
    - 900 mb—surface temperature gradient, defined here as the difference between the temperature at 900 mb and the surface using the morning temperature sounding data (ºC)
  - ***850 mb***
    - Upper-air 850 mb temperature corresponding to the morning sounding on the current day (ºC)
    - Upper-air 850 mb temperature corresponding to the evening sounding on the current day (ºC)
- **Wind**
  - ***850 mb and 700 mb***

The following two upper-air wind variables were computed using data from yesterday's evening sounding, and the current day's morning and evening soundings for 850 mb and from yesterday's evening sounding for 700 mb for a total of eight input variables for each upper-air monitoring site:

- Wind speed (ms^{-1})
- Wind direction bin; value of 1 through 5, indicating the wind direction: (in degrees) [315, 45), [45, 135), [135, 225), [225, 315), or calm, respectively

- **Recirculation**
  - ***850 mb***
    - Recirculation index (value of 0 or 1) that is based on the difference between the wind direction yesterday and today and/or scalar wind speed. If the difference is +/- 15 degrees of 180 degrees or if average scalar wind speed is < 3 ms^{-1} then the index is set to 1. Otherwise the value is 0.

- **Geopotential Height**
  - ***700 mb***
    - Difference in the daily average geopotential height above sea level of the 700 mb surface (m) using height today minus height yesterday. Note that geopotential height differs from height above mean sea level in that it accounts for the variation of the effects of gravity with altitude and latitude.

- **Clouds**
  - ***850 mb/700 mb***

    The cloud indicator variable combines data from both 850 and 700 mb and was computed using data from the morning and evening soundings.
    - Cloud index. Value based on relative humidity at the 850 mb (rh850) and 700 mb (rh700) levels. Ranges from 1 to 3 are based on the empirical analysis of observed data and are defined as follows:
      - If (rh850 < 80% and rh700 < 65%) then cloud = 1;
      - if (rh850 >= 80% and rh700 < 65%) then cloud = 2;
      - if (rh850 < 80% and rh700 >= 65%) then cloud = 2;
      - if (rh850 >= 80% and rh700 >= 65%) then cloud = 3

Air Quality Parameters

In addition to the meteorological input parameters, several air quality parameters representing $PM_{2.5}$ concentrations for prior days as well as for the region were also used in the CART analysis.

- **Extinction Coefficient**

  Extinction Coefficient—*Classification parameter for the application of CART for visibility.* Assigned a value of 1 through 5, such that each value corresponds to a different range of extinction coefficient. These correspond to the ranges defined by the 20, 50, 80, and 95 percentile values of calculated extinction coefficient for each site.

- **PM2.5**

  24-hour average $PM_{2.5}$—*Classification parameter for the application of CART for $PM_{2.5}$.* Assigned a value of 1 through 4, such that each value corresponds to a different range of $PM_{2.5}$ concentration. These correspond to the ranges defined by the 70, 90, and 97 percentile values of the $PM_{2.5}$ concentrations for each site (μgm^{-3}). The ranges were based on CART performance for previous applications and are somewhat subjective.

- **Regional PM2.5 Indicator Variables**

  Prior-day 24-hour average $PM_{2.5}$ concentration for one or more nearby and thus potentially upwind sites (μgm^{-3}). The specific sites and number of potential upwind sites is different for each IMPROVE, STN, and SEARCH site.

The input parameter lists were refined several times during the course of the CART application. The refinements were primarily guided by the CART results and were applied consistently for all of the sites of interest. The list above represents the final list of parameters.

3.2.2. Display and Analysis of the CART Input Data

To enable the examination of the variations in the input parameters across classification categories, the average value of all input parameters was calculated for each classification category, for each site. The averages were summarized in tabular format and plots of selected parameters were also prepared. The tables are provided later in this section of the report; additional plots are available in electronic format.

3.2.3. CART Application Procedures

CART was applied separately for visibility and $PM_{2.5}$. For visibility, we used extinction coefficient (as described in Section 2) as the characteristic parameter. The bin structure for each site was defined by the 20, 50, 80, and 95 percentile values of the extinction coefficient, resulting in five classification categories. This distribution was adopted, in part, to allow the 20 percent best and worst visibility days to be easily represented by the categories. Category 1 bins contain the 20 percent best visibility days and Category 4 and 5 bins (combined) contain the 20 percent worst visibility days. For $PM_{2.5}$, we used $PM_{2.5}$ mass as the characteristic variable and the bins were assigned a value of 1 through 4, such that each value corresponds to a different range of $PM_{2.5}$ concentration. These were defined by the 70, 90, and 97 percentile values of the $PM_{2.5}$ concentrations for each site (μgm^{-3}).

For this application, we assigned the misclassification costs so that misclassification by two categories was twice as costly as misclassification by one category (the costs are applied on a relative basis). Misclassification can occur due to a number of reasons including: monitoring network limitations (the highest PM concentration in an area may not be observed), use of discrete classification categories (days with PM values near the category boundaries may be misplaced into a lower or higher category, but in this case the concentration difference is only slight), the complexity of the inter-variable relationships, the completeness of the dataset with respect to defining these relationships, and data errors or missing data. The misclassification costs are used in optimizing the trees, considering both classification accuracy and the number of terminal bins.

CART was applied separately for each site using the period of record and temporal resolution appropriate to that site. The application of CART for each site included several applications of CART with varying inputs, in order to accommodate some refinement of the input variables. Specifically, sensitivity tests examined: 1) use of only meteorological input parameters versus both meteorological and air quality parameters, 2) alternative category definitions, 3) various alternative representations of the potential upwind/regional $PM_{2.5}$ concentrations (including one-day ago and two-days ago concentrations, day-to-day differences, and several other variations), 4) average upper-air parameters (where the averages were taken over multiple upper-air sites, 5) different forms of the recirculation parameters, 6) potential problems with the use of certain of the upper-air meteorological parameters for high elevation sites, and 7) alternate forms for the relative humidity parameter (for visibility only).

Key findings from the sensitivity testing include:

- While most of the days can be classified based on meteorological data only, use of prior-day $PM_{2.5}$ data from nearby and potentially upwind sites in addition to the meteorological data improves the classification accuracy for both regional haze and $PM_{2.5}$ (by up to 10 percentage points for some sites).
- The categories defined by the 20, 50, 80, and 95 percentile values of extinction coefficient work as well as or better than other alternatives.
- For areas with multiple nearby upper-air sites, average temperature and moisture parameters and separate wind parameters give the best results.
- Relative humidity is needed for good classification and daily average relative humidity is the most effective form of the parameter.

Following each application, the results were assessed using statistical measures of the goodness of the classification, and then checked for physical reasonableness, as follows:

- The list of input parameters was checked for completeness.
- The CART input parameters were checked to ensure that they were specified reasonably (per the CART user's guide) and as intended.
- The values used to determine the branching of the CART output classification trees were checked to ensure that the values are reasonable and consistent with the input data.
- A matrix representing the statistical goodness of the classification (for the historical days) is created by CART, and the elements of this matrix were examined to ensure a minimum number of misclassifications.
- All splits in the decision tree were checked to ensure that the parameters and values used to develop the classification tree are physically meaningful (i.e., consistent with basic conceptual models of regional haze and $PM_{2.5}$ formation and transport).
- Splits in the decision tree were checked to ensure that CART made decisions (segregating the days) based on values of the input variables that are distinguishable in the data.
- The overall structure of the classification tree and number of classification bins were checked to ensure that the pathways to the different classification bins are distinct and that the bins provide a reasonable segregation of the days based on the daily extinction coefficient values.

- Final bins in the decision tree were checked for uniqueness, such that different bins represent different meteorological characteristics.

One or more bins representing each classification category were selected and the decision pathways leading to those bins were explicitly checked for physically reasonableness.

3.2.4. Display and Analysis of CART Results

The CART results were displayed in a variety of ways, both as part of the quality assurance and to aid the analysis of the results by the VISTAS participants.

Tabular summaries of classification accuracy were prepared and classification accuracy by category and overall were calculated. Overall classification accuracy ranged from approximately 75 to 85 percent for visibility and approximately 80 to 95 percent for $PM_{2.5}$. For any given site, classification accuracy was generally better for $PM_{2.5}$, compared to visibility.

CART trees with approximately 25-35 bins were selected to optimize classification accuracy and physical reasonableness. The majority of the best and worst visibility days and high $PM_{2.5}$ days, however, were grouped into one to four key bins.

The relative importance of the various input parameters to the CART classification tree was examined and plotted for each site, and was used to establish similarities among the sites.

To enable the examination of the variations in the input parameters among the classification bins for each site, and thus the differences among the bins, the average value of all input parameters was calculated for each bin. The averages were summarized in tabular format and plots of selected parameters were also prepared.

Plots of the average compositional characteristics of the days within each bin were also prepared and used to examine the differences among the bins, among the categories and within each category.

3.3. CART Classification Results

Throughout the discussion of the results, the term “classification accuracy” refers to the percentage of days that were assigned to the correct classes (that is, correctly placed into bins with ranges corresponding to their observed values).

3.3.1. Visibility

The classification parameter for visibility is extinction coefficient.

CART was first applied for each site for visibility using only meteorological inputs. The air quality related parameters were omitted from the input datasets, CART was run using only the meteorological inputs, and classification accuracy was assessed for each site. For the IMPROVE sites, approximately 65 to 85 percent of the days were assigned to the correct visibility classes. For the SEARCH sites, the percentages are lower, approximately 60 to 70 percent (primarily due to the greater number of data points).

Next, input parameters accounting for $PM_{2.5}$ mass on the previous day at potentially upwind urban sites were added to the CART input database. This improved the classification accuracy for visibility for all sites, and by as much as 10 percentage points for some sites. This increase

in classification accuracy suggests that transport of fine particles and related precursor species influences visibility at both the IMPROVE and SEARCH sites.

Final classification accuracy is within the range of approximately 74 to 85 percent for the IMPROVE sites and 72 to 83 percent for the SEARCH sites. In calculating classification accuracy, we combine the results for Categories 2 and 3, to emphasize the 20 percent best and worst days. CART classification accuracy for extinction coefficient is summarized in Table 3-1, for the IMPROVE and SEARCH sites.

Table 3-1a. Summary of CART Classification Accuracy for the VISTAS Visibility Analysis: IMPROVE Sites.

Site	CART Classification Accuracy (%)
Breton	76.8
Brigantine	76.4
Cadiz	84.5
Caney Creek	79.8
Cape Romain	77.7
Chassahowitzka	80.5
Cohutta	81.2
Dolly Sods	78.0
Everglades	77.8
Great Smoky Mtns	78.4
James River Face	82.7
Linville Gorge	83.4
Mammoth Cave	81.2
Mingo	84.4
Okefenokee	78.4
Shenandoah	83.0
Shining Rock	81.5
Sipsey	80.5
St. Marks	74.4
Swanquarter	79.7
Upper Buffalo	79.9

Table 3-1b. Summary of CART Classification Accuracy for the VISTAS Visibility Analysis: SEARCH Sites.

Site	CART Classification Accuracy (%)
Atlanta (Jefferson St.)	71.5
Yorkville	82.6
Birmingham	77.1
Centreville	79.1
Pensacola	79.0
Outer Landing Field	79.7
Gulfport	78.0
Oak Grove	76.3

Misclassification can occur due to a number of reasons including monitoring network limitations, length (completeness) of the analysis period, use of discrete classification categories, and data errors or missing data. Our goal for this study was 70 percent classification accuracy for visibility and

this goal was met for all sites. This goal was selected based on prior applications and diagnostic testing.

3.3.2. PM2.5

CART classification accuracy for $PM_{2.5}$ is summarized in Table 3-2, for the IMPROVE, STN, and SEARCH sites.

Table 3-2a. Summary of CART Classification Accuracy for the VISTAS PM2.5 Analysis: IMPROVE Sites.

Site	CART Classification Accuracy (%)
Breton	87.8
Brigantine	86.1
Cadiz	87.2
Caney Creek	83.2
Cape Romain	81.3
Chassahowitzka	84.9
Cohutta	86.6
Dolly Sods	84.9
Everglades	84.8
Great Smoky Mtns	88.1
James River Face	87.9
Linville Gorge	83.7
Mammoth Cave	86.3
Mingo	88.7
Okefenokee	79.3
Shenandoah	81.1
Shining Rock	87.8
Sipsey	82.0
St. Marks	80.5
Swanquarter	88.4
Upper Buffalo	81.4

Table 3-2b. Summary of CART Classification Accuracy for the VISTAS PM2.5 Analysis: STN Sites.

Site	CART Classification Accuracy (%)
Birmingham	78.5
Charlotte	76.9
Chattanooga	84.8
Greenville-Spartanburg	74.5
Hickory	85.3
Huntington-Ashland	85.7
Jackson	79.3
Kingsport-Bristol	87.0
Louisville	78.5
Macon	82.0
Memphis	75.9
Montgomery	85.1
Nashville	79.2
Raleigh	76.3
Richmond	77.8
Savannah	86.1

Table 3-2c. Summary of CART Classification Accuracy for the VISTAS PM2.5 Analysis: SEARCH Sites.

Site	CART Classification Accuracy (%)
Atlanta (Jefferson St.)	71.5
Yorkville	82.6
Birmingham	77.1
Centreville	79.1
Pensacola	79.0
Outer Landing Field	79.7
Gulfport	78.0
Oak Grove	76.3

For $PM_{2.5}$, classification accuracy ranges from approximately 80 to 90 percent for the IMPROVE sites, from 75 to 87 percent for the STN sites, and from 75 to approximately 80 percent for the SEARCH sites. The greater classification accuracy for $PM_{2.5}$, compared to extinction coefficient, especially for the IMPROVE sites, indicates that the relationships between the input parameters and the characteristic parameter are better defined for $PM_{2.5}$ at these sites. This is possibly due to the more complex role of moisture in determining light extinction – affecting both particle formation and the contribution of sulfate and nitrate particle species to light extinction. Sensitivity testing indicates that this increase of approximate 10 percentage points is attributable to the complexities of the extinction coefficient calculation (the IMPROVE equation). When $PM_{2.5}$ was added to the visibility analysis as an input parameter, classification improved dramatically, but only to about 90 percent, on average. We interpret this to mean that the maximum accuracy for visibility is 90 percent and that a 10 percent error is due to the complex way in which extinction coefficient is related to particulate species concentrations. Note, however, that we do not see this same tendency for the SEARCH sites. For these sites, accuracy is about the same for both $PM_{2.5}$ and visibility. This could be due to better relatively humidity measurements at the SEARCH sites, which would tend to improve the visibility analysis or more complex particulate chemistry in and nearby the urban areas (where most of the SEARCH sites are located) which would tend to make the PM analysis more challenging. Our goal for this study was 80 percent classification accuracy for $PM_{2.5}$ and this goal was met or nearly met for most sites. This goal was selected based on prior applications and diagnostic testing.

3.4. Important Classification Parameters

Certain of the input parameters are used more frequently in the construction of the classification trees and an analysis of the important parameters provides some insight into the factors that influence air quality, and how these differ for visibility and $PM_{2.5}$ and among the monitoring sites.

3.4.1. Summary of Important Parameters

Here we summarize the relative importance of each input parameter to the classification for visibility and $PM_{2.5}$, and for specific site groupings. Parameter importance is calculated by CART based on the number of times each parameter is used, either as a split parameter or as a surrogate parameter, to construct the final classification tree. Split parameters are those that explicitly define the branches of the CART tree, and thus separate the days. Surrogate parameters represent the next best splits, and are used in the case of missing data. For example, temperature might be a surrogate for solar radiation since the two parameters tend to be well

correlated, and the 850 mb temperature might be a surrogate for the 900 mb to surface temperature difference since both are indicators of stability. Several surrogates are identified for each split.

Parameter importance is assigned a value ranging from 0 to 100, based on the use of the parameter in defining the CART tree. Specifically, the importance indicates the improvement in classification accuracy that results from using the best split parameter compared to the best surrogate split parameter. The importance values are normalized such that the most important parameter has a value of 100. The values are only meaningful in a relative sense and within the context of the CART analysis. We use parameter importance in this analysis to identify those parameters that are statistically relevant to the classification and assume that these same parameters are also physically relevant to visibility and particulate matter concentrations. That is, we assume that the parameters that are most important in determining the structure of the CART tree are also most important in determining air quality.

Visibility

Considering visibility for all IMPROVE sites, the most important parameters include: relative humidity, prior day $PM_{2.5}$ concentrations at potentially upwind monitoring sites, 850 mb temperature, surface temperature (reflecting seasonal differences), and wind speed (both near the surface and aloft). Of secondary importance are surface pressure, boundary layer stability, wind direction, precipitation, and cloud cover.

We also grouped the sites according to geography as inland, coastal, and mountain and examined the relative importance of the CART parameters for each grouping. For this analysis, the inland sites include (in alphabetical order): Cadiz, Caney Creek, Mammoth Cave, Mingo, Sipsey, and Upper Buffalo. The coastal sites are: Breton, Brigantine, Chassahowitzka, Cape Romain, Everglades, Okefenokee, St. Mark's, and Swanquarter. The mountain sites are Cohutta, Dolly Sods, Great Smoky Mountains, James River, Linville Gorge, Shenandoah, and Shining Rock.

For both the inland and coastal sites the most important parameters for the classification of days for visibility are: prior day $PM_{2.5}$ concentrations at potentially upwind monitoring sites, relative humidity, 850 mb temperature, surface temperature, and wind speed (both near the surface and aloft).

For the mountain sites, temperature both near the surface and aloft are the two most important parameters, emphasizing that visibility varies by season. These are followed in importance by relative humidity, wind speed (near the surface and aloft), and prior day $PM_{2.5}$ concentration. Thus, the important parameters are the same, but their relative importance varies among the three groups. These are displayed in Figure 3-2. Note that in each plot, the prior-day $PM_{2.5}$ concentrations and upper-air parameter importance values may be an average over multiple sites, although each may be represented separately in the CART analysis. This average value is then averaged over all sites in the grouping. In this and subsequent plots of parameter importance, blue is used for air quality parameters, red (maroon) is used for surface meteorological parameters, and yellow is used for upper-air parameters.

Figure 3-2a. Average Parameter Importance for the CART Visibility Analysis: IMPROVE Sites.

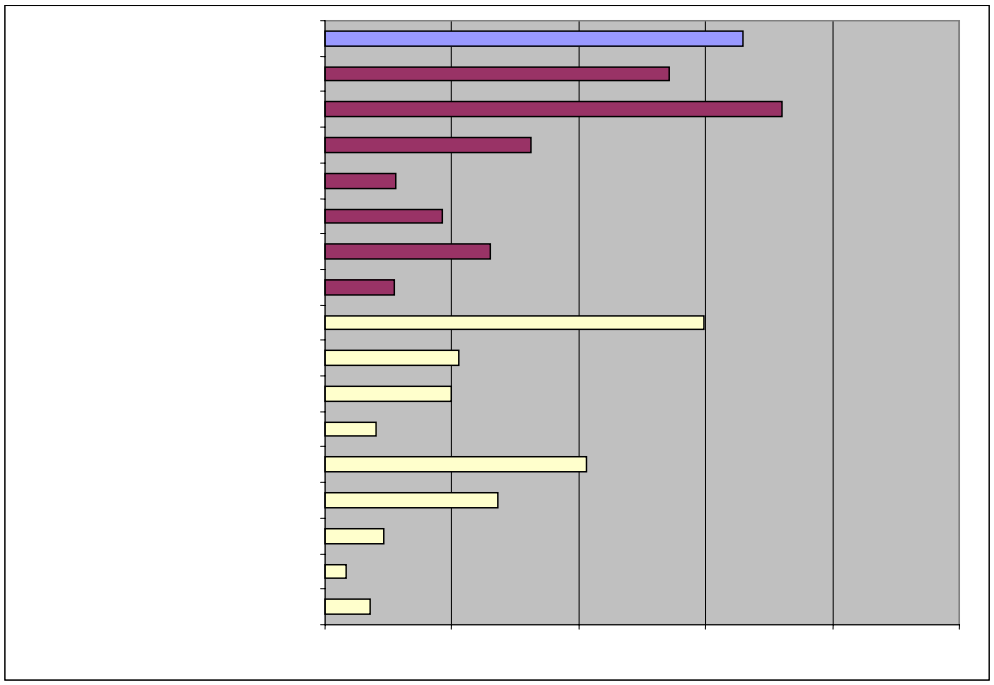


Figure 3-2b. Average Parameter Importance for the CART Visibility Analysis: Inland IMPROVE Sites.

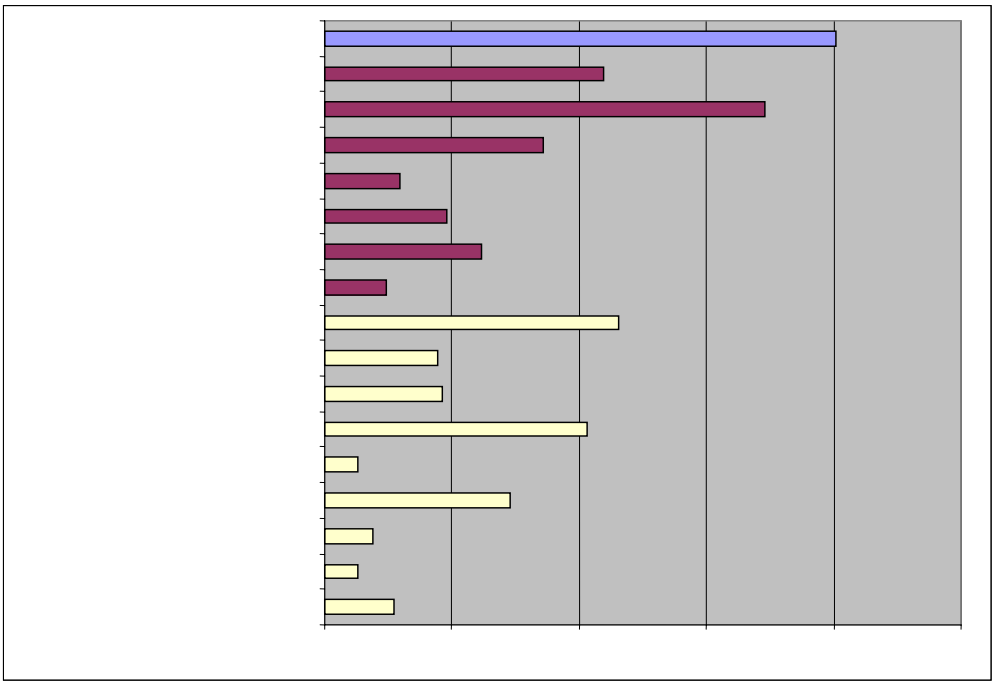


Figure 3-2c. Average Parameter Importance for the CART Visibility Analysis: Coastal IMPROVE Sites.

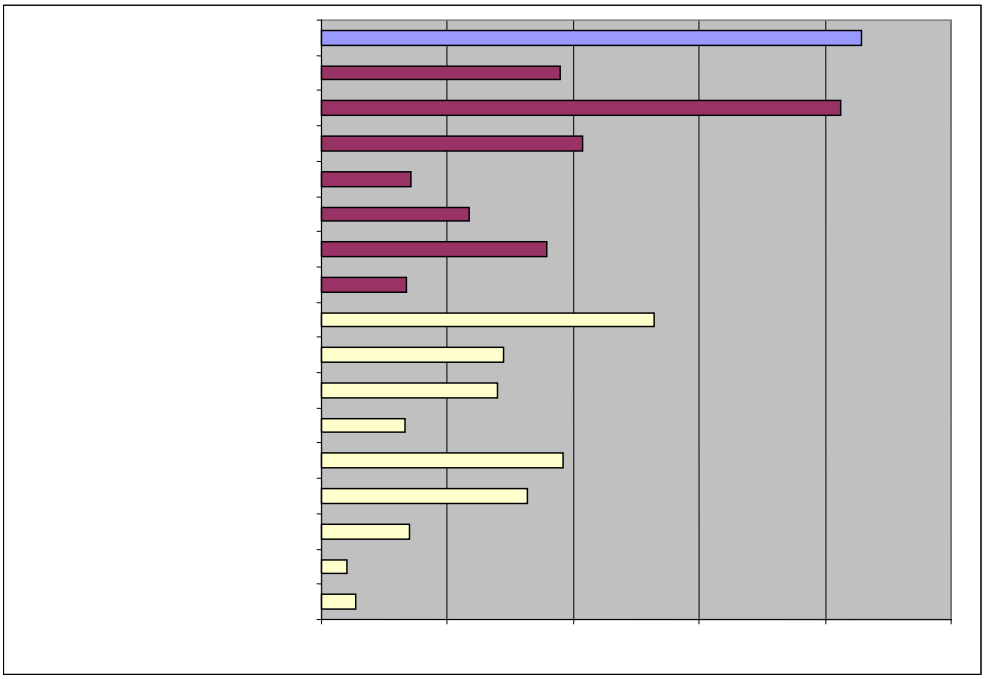
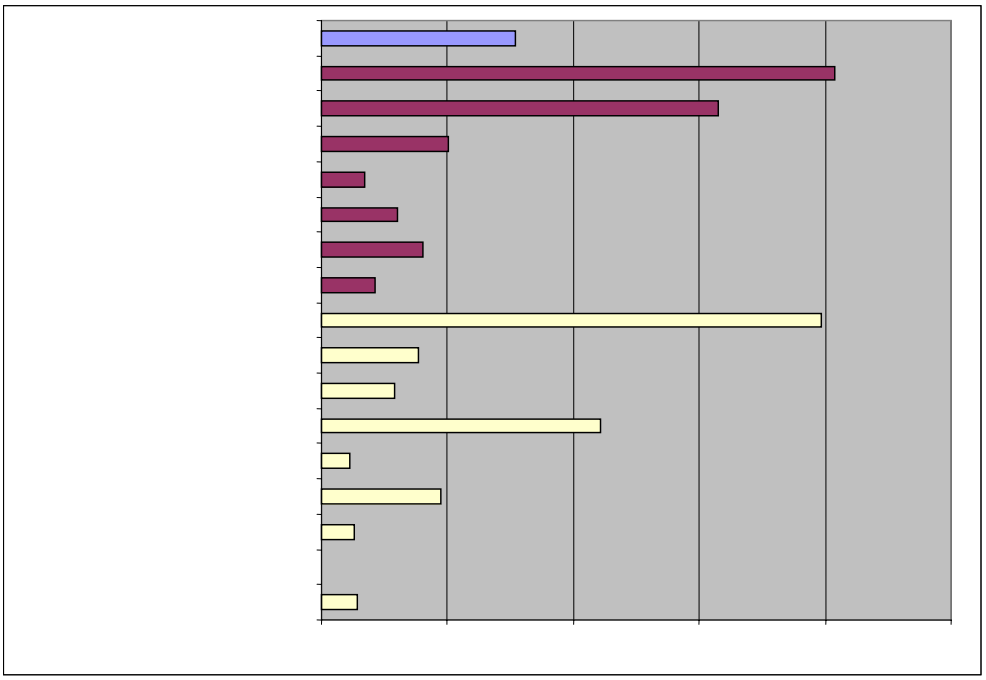


Figure 3-2d. Average Parameter Importance for the CART Visibility Analysis: Mountain IMPROVE Sites.



PM2.5

For $PM_{2.5}$, we consider the IMPROVE, STN, and SEARCH sites separately.

IMPROVE

The most important parameters in the $PM_{2.5}$ analysis for the IMPROVE sites include: prior day $PM_{2.5}$ concentrations at potentially upwind monitoring sites, surface temperature, 850 mb temperature, prior day wind speed aloft, relative humidity, surface pressure, and wind speed (both near the surface and aloft). A key difference when compared to visibility is that relative humidity is less important, but the list of important parameters is similar.

Using the geographical groupings defined above, we looked for differences in parameter importance among the different subsets of the IMPROVE sites. These are displayed in Figure 3-3.

Figure 3-3a. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: IMPROVE Sites.

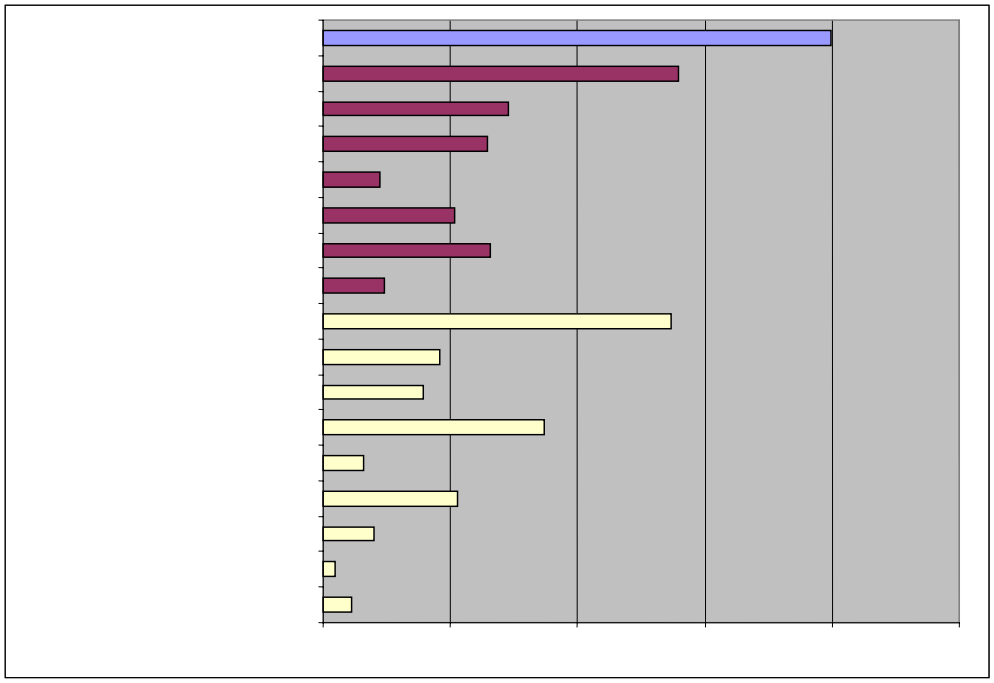


Figure 3-3b. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: Inland IMPROVE Sites.

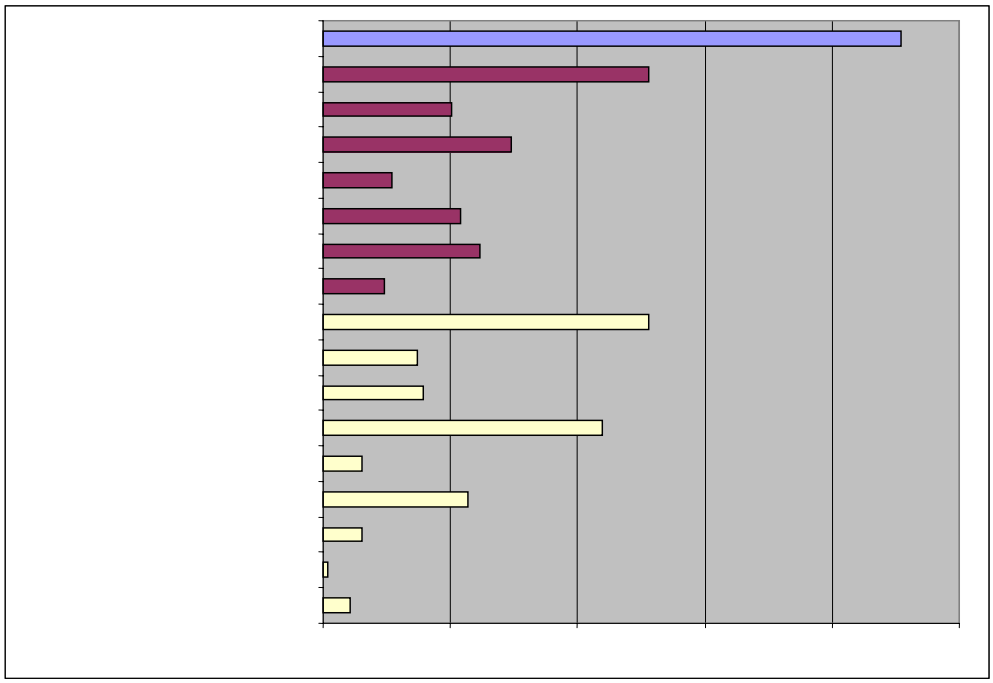


Figure 3-3c. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: Coastal IMPROVE Sites.

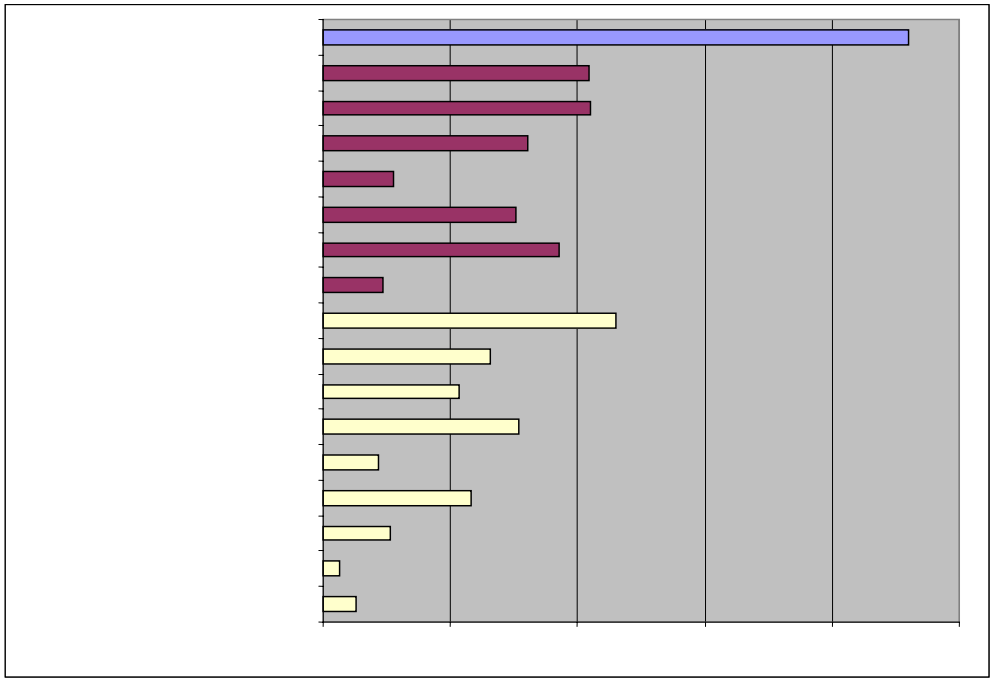
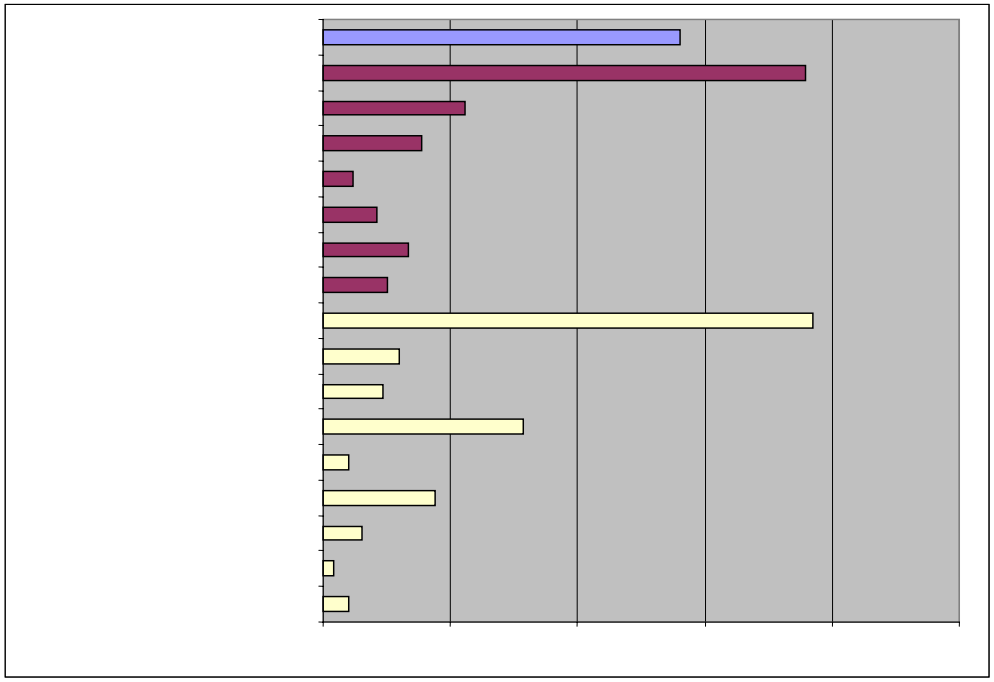


Figure 3-3d. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: Mountain IMPROVE Sites.



One key difference is that relative humidity and persistence (which, for coastal sites, represents a sea or gulf breeze) are more important for the coastal sites, compared to the inland and mountain sites. As for visibility, the temperature parameters are most important for the mountain sites.

STN

For the STN sites, the most important parameters include: prior day $PM_{2.5}$ concentrations at potentially upwind monitoring sites, 850 mb temperature, surface temperature, and wind speed (both near the surface and aloft). Of secondary importance are stability, relative humidity, surface pressure, and wind direction.

Since there are no mountain sites and only one coastal site with this group of sites, we use latitude to divide the STN sites into more northern and more southern sites. The northern site group includes (in alphabetical order): Hickory, Huntington-Ashland, Kingsport-Bristol, Louisville, Nashville, Raleigh, and Richmond. The southern group consists of: Birmingham, Charlotte, Chattanooga, Greenville-Spartanburg, Jackson, Macon, Memphis, Montgomery, and Savannah.

The average variable importance scores for all sites and the two subsets are displayed in Figure 3-4.

Figure 3-4a. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: STN Sites.

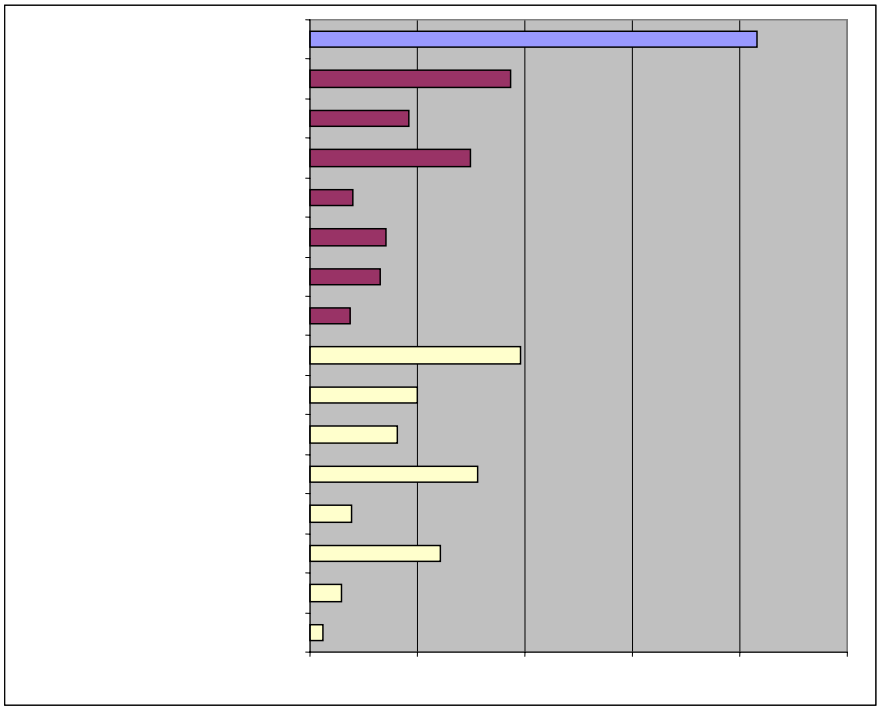


Figure 3-4b. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: More Northern STN Sites.

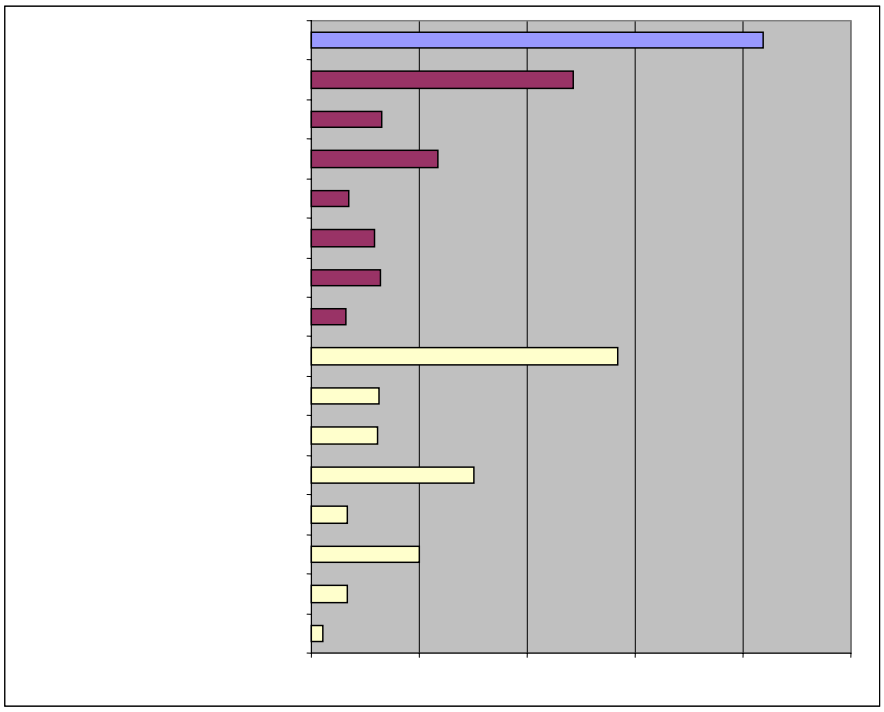
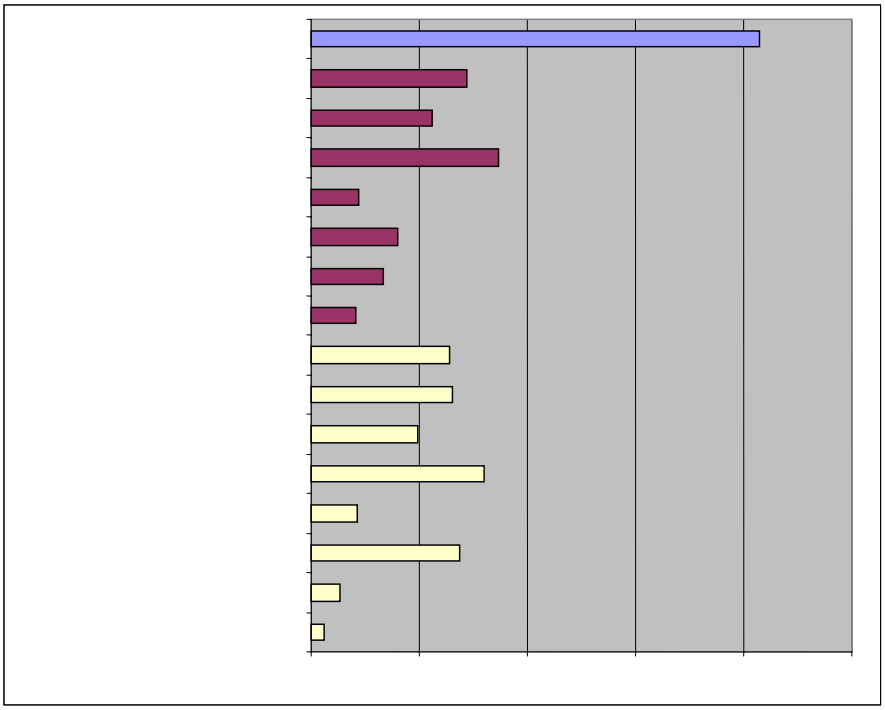


Figure 3-4c. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: More Southern STN Sites.



One key difference is that wind speed is relatively more important for the more southern sites and temperature is relatively more important for the more northern sites. For both sets of sites, prior day $PM_{2.5}$ concentrations are important.

SEARCH

For the SEARCH sites, on average, the most important parameters include: prior day $PM_{2.5}$ concentrations at potentially upwind monitoring sites, wind speed (both near the surface and aloft), surface temperature, relative humidity, and 850 mb temperature. Of secondary importance are persistence, stability, precipitation, surface pressure, and wind direction.

The SEARCH sites were divided into inland and coastal subgroups, and then into urban and rural/suburban subgroups. The average variable importance scores for all sites and the four subsets are displayed in Figure 3-5. The inland grouping includes: Atlanta, Yorkville, Birmingham, and Centreville. The coastal group includes Pensacola, Outlying Landing Field, Gulfport, and Oak Grove. The urban group includes: Atlanta, Birmingham, Pensacola, and Gulfport. The rural/suburban group includes: Yorkville, Centreville, Outlying Landing Field, and Oak Grove.

Figure 3-5a. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: SEARCH Sites.

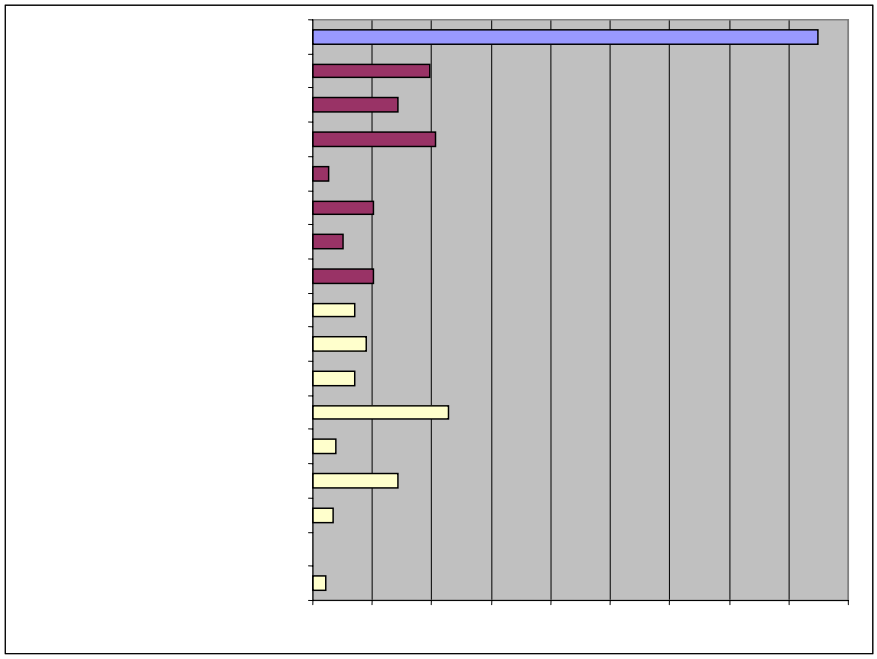


Figure 3-5b. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: Inland SEARCH Sites.

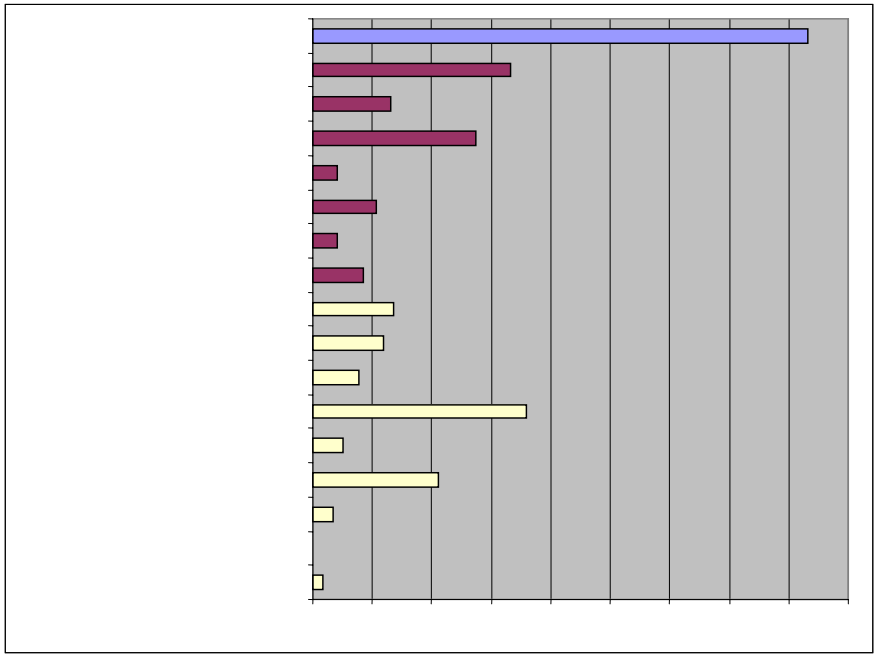


Figure 3-5c. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: Coastal SEARCH Sites.

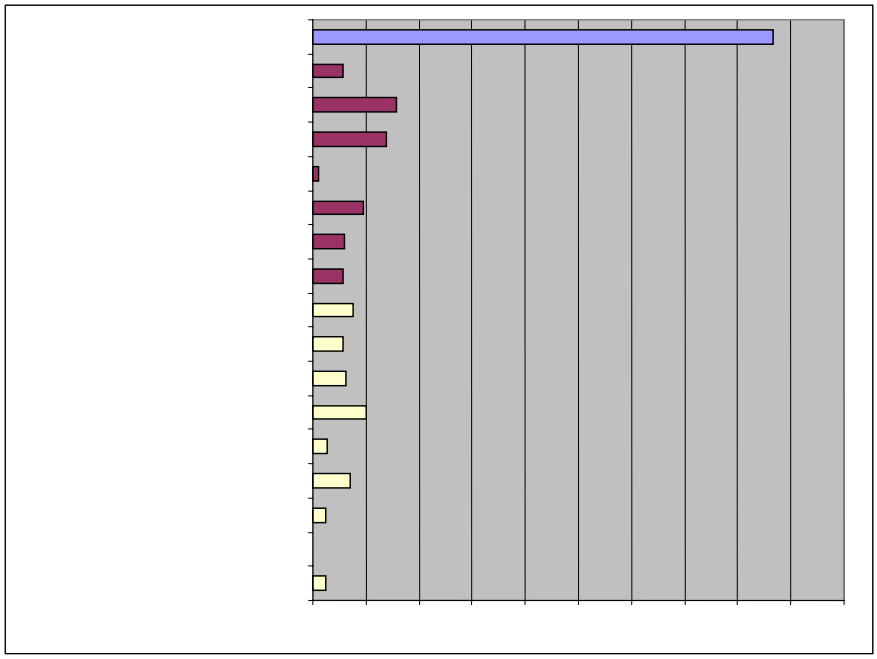


Figure 3-5d. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: Urban SEARCH Sites.

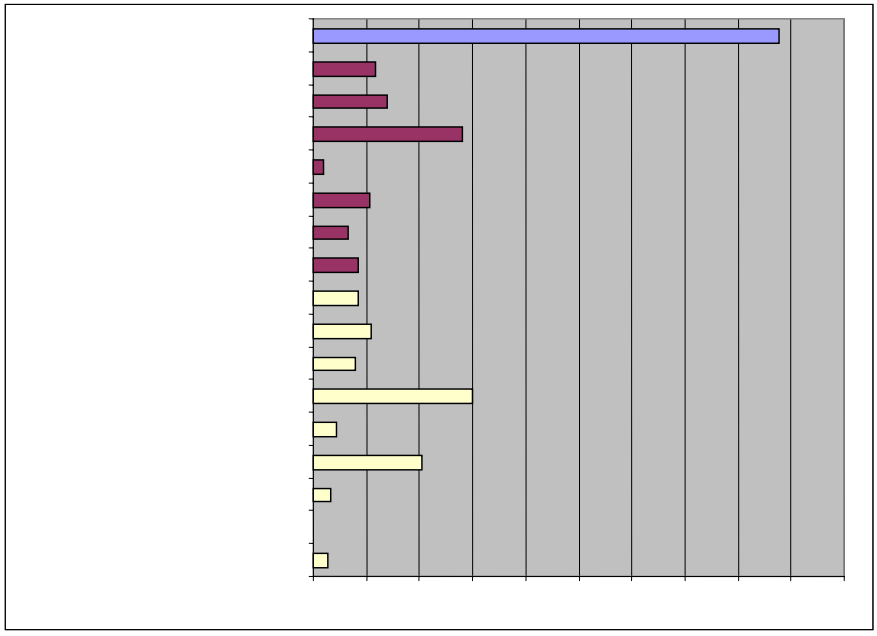
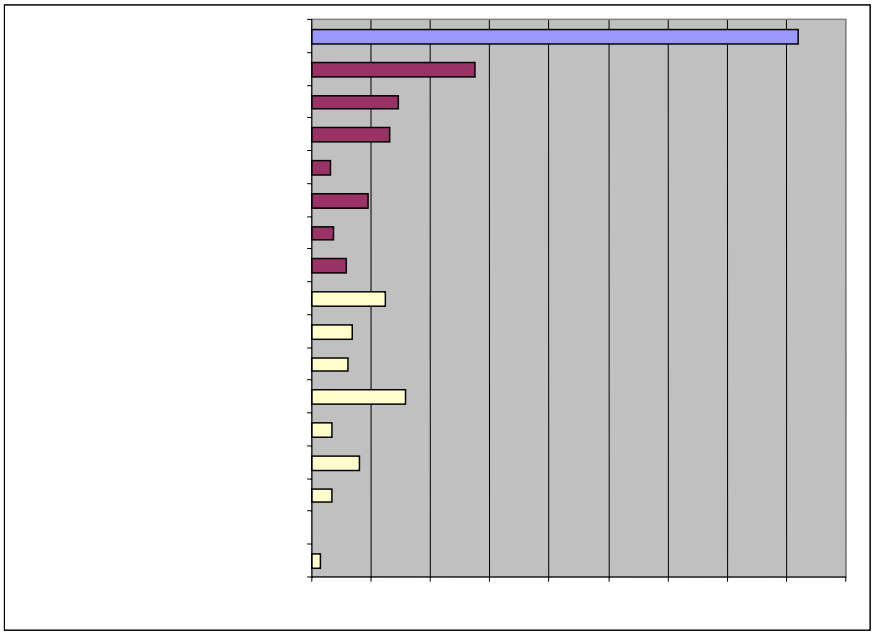


Figure 3-5e. Average Parameter Importance for the CART $PM_{2.5}$ Analysis: Rural/Suburban SEARCH Sites.



Comparing the inland and coastal sites, the classification for both groups depends most heavily on the prior day $PM_{2.5}$ concentrations. For the inland sites, wind speed and temperature parameters are next most important, while for the coastal sites, relative humidity, wind speed, and persistence are among the next most important parameters. The more even values for the coastal sites suggest that a combination of parameters is used in the CART trees. It is possible that the required use of multiple upper-air sites to represent the upper-air parameters also contributed to the lower and more equal values for these parameters (through averaging across multiple sites).

Comparing the urban and rural/suburban sites, wind speed seems to be somewhat more important for the urban sites than for the rural/suburban sites.

3.4.2. CART-Based Site Groupings

The CART-derived parameter importance rankings and values were also used to examine potential site groupings. We assume here that similarities in the important parameters between or among sites indicate similarities in the mechanisms influencing air quality at these sites. Consequently, grouping the sites may provide the basis for assessing model performance or the effectiveness of air quality measures when the drivers of air quality (and thus the mechanisms resulting in poor air quality) are different.

In order to quantify the differences in parameter importance among the sites, we calculated a Euclidean distance for each site pair. The Euclidean distance is defined as follows:

$$DistEuclidean(site1, site2) = \sqrt{\sum_i (X_{site1,i} - X_{site2,i})^2}$$

$\{X_{site1,i}\}$ - Parameter importance score for parameter *i* for site 1

$\{X_{site2,i}\}$ - Parameter importance score for parameter *i* for site 2

Site pairs with the "shortest" Euclidean distance are the most similar with respect to the importance of each parameter, and potentially with respect to the factors that influence air quality. Physical distance between the sites is not considered, only the relative importance of the CART meteorological and air quality parameters.

In calculating the distance values, we considered the IMPROVE, STN, and SEARCH sites separately, and identified potential groupings within each network. In assembling the groups, we required all of the sites within each group to be reasonably paired with all other sites in the group – based on a relatively low value of the Euclidean distance (relative to other site pairs) and reasonable geographical and meteorological similarities. For the IMPROVE sites, we further limited the groupings to the geographical categories of inland, coastal, and mountain sites. Without this restriction, a few of the pairings were not plausible. We included all sites within the VISTAS region. The results are presented in the following sections.

Visibility

For the inland IMPROVE sites, Cadiz, Mammoth Cave, and Sipsey have similar important parameters, as characterized by relatively low Euclidean distance values. The best match is between Cadiz and Mammoth Cave. The results are displayed in Table 3-3.

Table 3-3. Euclidean Distances (unitless) for IMPROVE Sites for Visibility: Inland Sites.

	Cadiz	Mammoth Cave	Sipsey
Cadiz	0.0	67.2	72.1
Mammoth Cave	67.2	0.0	71.3
Sipsey	72.1	71.3	0.0

For the coastal IMPROVE sites, we identified four "groups" consisting of two site pairs and two individual sites. The first group includes Cape Romain and Swanquarter. Okefenokee was a possible site for this grouping, but because it provided the best match for St. Mark's, we included it in the next group. St. Mark's was not well matched with the other two sites in the grouping. The second group includes Okefenokee and St. Mark's. The Euclidean distance results for these site pairs are displayed in Table 3-4. Chassahowitzka and Everglades do not fit well into either group. Both pair reasonably well with Breton (outside of the VISTAS region) with distances of 74.2 and 69.9, respectively, and but do not pair well with one another (distance value is 99.0). Thus these sites are considered separately.

The Euclidean distance is a summary metric of the differences in relative importance over all of the parameters. Thus, many factors contribute to the distance calculations that are used to assess similarities. In some cases it is possible to identify parameters that are important to the calculations. For example, the 850 mb temperature is not as important for Cape Romain and Swanquarter as for Okefenokee and St. Mark's and this influences the pairing. Given the number of parameters that are combined in the summary metric, however, it is not straightforward to single out specific reasons for

the differences and the pairings. The Euclidean is intended to provide a mathematical basis for the parings and we applied some judgment in the use of this information to select the groups.

Table 3-4a. Euclidean Distances (unitless) for IMPROVE Sites for Visibility: Coastal Sites (Group 1).

	Cape Romain	Swanquarter
Cape Romain	0.0	61.8
Swanquarter	61.8	0.0

Table 3-4b. Euclidean Distances (unitless) for IMPROVE Sites for Visibility: Coastal Sites (Group 2).

	Okefenokee	St. Marks
Okefenokee	0.0	74.1
St. Mark's	74.1	0.0

For the mountain IMPROVE sites, we identified two groups. The first group includes Great Smoky Mountains (GSM), James River Face, Linville Gorge, and Shenandoah. The second group includes Cohutta, Dolly Sods, and Shining Rock. The Euclidean distance results for these site pairs are displayed in Table 3-5. The groups do not reflect proximity and are guided by the CART results that local meteorological conditions (for example, relative humidity) are more important in determining visibility at the Group 1 sites than the Group 2 sites.

Table 3-5a. Euclidean Distances (unitless) for IMPROVE Sites for Visibility: Mountain Sites (Group 1).

	GSM	James River	Linville Gorge	Shenandoah
GSM	0.0	60.8	38.7	51.5
James River	60.8	0.0	56.8	77.7
Linville Gorge	38.7	56.8	0.0	40.8
Shenandoah	51.5	77.7	40.8	0.0

Table 3-5b. Euclidean Distances (unitless) for IMPROVE Sites for Visibility: Mountain Sites (Group 2)

	Cohutta	Dolly Sods	Shining Rock
Cohutta	0.0	47.4	33.1
Dolly Sods	47.4	0.0	44.6
Shining Rock	33.1	44.6	0.0

PM2.5

The results for $PM_{2.5}$ are similar, but there are some differences. For the inland IMPROVE sites, Cadiz, Mammoth Cave, and Sipsey have similar important parameters, as characterized by relatively low Euclidean distance values. As for visibility, the best match is between Cadiz and Mammoth Cave. The results are displayed in Table 3-6.

Table 3-6. Euclidean Distances (unitless) for IMPROVE Sites for $PM_{2.5}$: Inland Sites.

	Cadiz	Mammoth Cave	Sipsey
Cadiz	0.0	38.7	43.9
Mammoth Cave	38.7	0.0	44.5
Sipsey	43.9	44.5	0.0

For the coastal IMPROVE sites, we identified two groupings. All sites with the exception of Okefenokee showed similar low Euclidean distances. Okefenokee was not a good match to any of the sites. The Euclidean distance results for the grouped coastal sites are displayed in Table 3-7. Note that the Everglades site is least well matched with all of the other sites and could be excluded from this grouping. In contrast to the values in this table, the lowest value for Okefenokee is 70.5, when matched with Cape Romain.

Table 3-7. Euclidean Distances (unitless) for IMPROVE Sites for $PM_{2.5}$: Coastal Sites (Group 1).

	Cape Romain	Chassahowitzka	Everglades	St. Mark's	Swanquarter
Cape Romain	0.0	47.9	54.6	50.9	37.1
Chassahowitzka	47.9	0.0	58.5	46.5	39.6
Everglades	54.6	58.5	0.0	54.9	48.8
St. Mark's	50.9	46.3	54.9	0.0	40.9
Swanquarter	37.1	39.6	48.8	40.9	0.0

For the mountain IMPROVE sites, we identified two groups. The first group includes Cohutta, Great Smoky Mountains (GSM), James River Face, Linville Gorge, and Shining Rock. The second group includes Dolly Sods and Shenandoah. The Euclidean distance results for these site pairs are displayed in Table 3-8. Cohutta and James River Face (the southernmost and northernmost sites in Group 1) are not as well matched as the rest of the sites in the group, but they are both good matches to the remaining sites. Note the very good match between Dolly Sods and Shenandoah (Group 2).

Table 3-8a. Euclidean Distances (unitless) for IMPROVE Sites for $PM_{2.5}$: Mountain Sites (Group 1).

	Cohutta	GSM	James River	Linville Gorge	Shining Rock
Cohutta	0.0	45.5	70.2	54.3	53.5
GSM	45.5	0.0	44.9	43.4	55.4

James River	70.2	44.9	0.0	51.4	62.6
Linville Gorge	54.3	43.4	51.4	0.0	36.4
Shining Rock	53.5	55.4	62.6	36.4	0.0

Table 3-8b. Euclidean Distances (unitless) for IMPROVE Sites for $PM_{2.5}$: Mountain Sites (Group 2)

	Dolly Sods	Shenandoah
Dolly Sods	0.0	20.2
Shenandoah	20.2	0.0

The STN sites were divided into six groups, in accordance with the Euclidean distances and calculated similarities in parameter importance. The first group includes Charlotte, Greenville-Spartanburg, Nashville, Raleigh, and possibly Kingsport-Bristol (although the fit is less good for this site). The second group includes Huntington-Ashland, Louisville, and Richmond. The third group is Birmingham, Chattanooga, Jackson, and Memphis. The fourth group consists of Macon and Montgomery. Hickory and Savannah are not good matches to any of the other sites. The Euclidean distance results for these site pairs are displayed in Table 3-9.

Table 3-9a. Euclidean Distances (unitless) for STN Sites for $PM_{2.5}$: Group 1.

	Charlotte	Greenville	Kingsport	Nashville	Raleigh
Charlotte	0.0	24.2	55.9	21.5	20.0
Greenville	24.4	0.0	59.4	29.3	19.4
Kingsport	55.9	59.4	0.0	44.1	39.5
Nashville	21.5	29.3	44.1	0.0	31.8
Raleigh	20.0	19.4	39.5	31.8	0.0

Table 3-9b. Euclidean Distances (unitless) for STN Sites for $PM_{2.5}$: Group 2.

	Huntington	Louisville	Richmond
Huntington	0.0	34.1	35.5
Louisville	34.1	0.0	44.1
Richmond	35.3	44.1	0.0

Table 3-9c. Euclidean Distances (unitless) for STN Sites for $PM_{2.5}$: Group 3.

	Birmingham	Chattanooga	Jackson	Memphis
Birmingham	0.0	54.5	53.7	56.2
Chattanooga	54.5	0.0	30.6	44.2

Jackson	53.7	30.6	0.0	29.5
Memphis	56.2	44.2	29.5	0.0

Table 3-9d. Euclidean Distances (unitless) for STN Sites for $PM_{2.5}$: Group 4

	Macon	Montgomery
Macon	0.0	54.5
Montgomery	54.5	0.0

The SEARCH sites were divided into three groups, in accordance with the Euclidean distances and similarities in parameter importance. The first group consists of Atlanta and Birmingham, the two inland, urban sites. The second group consists of Centreville and Yorkville, the two inland, rural sites. Oak Grove was also a good match for Centreville, but not for Yorkville. It is included in the next group because it paired well with all sites in that group. This group includes the coastal sites: Pensacola, Outlying Landing Field (OLF), Gulfport, and Oak Grove. The Euclidean distance results for these site pairs are displayed in Table 3-10.

Table 3-10a. Euclidean Distances (unitless) for SEARCH Sites for $PM_{2.5}$: Group 1

	Atlanta	Birmingham
Atlanta	0.0	38.5
Birmingham	38.5	0.0

Table 3-10b. Euclidean Distances (unitless) for SEARCH Sites for $PM_{2.5}$: Group 2

	Centreville	Yorkville
Centreville	0.0	43.6
Yorkville	43.6	0.0

Table 3-10c. Euclidean Distances (unitless) for SEARCH Sites for $PM_{2.5}$: Group 3.

	Gulfport	Oak Grove	OLF	Pensacola
Gulfport	0.0	22.6	24.1	19.3
Oak Grove	22.6	0.0	10.1	10.5
OLF	24.1	10.1	0.0	16.7
Pensacola	19.3	10.5	16.7	0.0

Although there are some exceptions, the CART-derived groupings, which are based on parameter importance, are, in many cases, also supported by similarities in location and geography. These groupings may provide the basis for assessing model performance and

understanding the reasons for model performance problems, as well as accounting for differences in the effectiveness of air quality measures across the monitoring sites and regions.

3.5. Meteorological Influences on Visibility and Fine Particles

In the previous section, we identified certain parameters that are important to the classification of days with respect to visibility and $PM_{2.5}$ concentration and concluded that these parameters have the potential to influence air quality at the monitoring sites. However, understanding the causes of poor visibility and high $PM_{2.5}$ concentrations also requires an understanding of the relationship between the parameters and the air quality metrics, as well as the specific combinations of parameters (conditions) that lead to impaired air quality. In this section, we further explore those relationships using the CART input data and results.

3.5.1. Categorical Comparisons

In this section we summarize the variations in the input parameters across classification categories for each site and parameter, first for visibility and then for $PM_{2.5}$.

Visibility

To examine these variations, the average value of each input parameter was calculated for each classification category and for each of the IMPROVE sites. Table 3-11 presents the parameter averages for the five categories of visibility. These are bounded by the 20, 50, 80, and 95 percentile values of extinction coefficient, which vary by site, as indicated at the top of each table. The tables for the IMPROVE sites are in alphabetical order, by site name.

Table 3-11a. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Breton.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <50, 50-70, 70-105, 105-135, and ≥135 Mm^{-1}.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	10.1	12.4	14.0	18.0	22.1
Yesterday's FM at Gulfport (μg/m³)	7.9	10.2	11.4	15.4	19.3
Yesterday's FM at Pensacola (μg/m³)	9.4	11.6	13.5	17.5	19.1
Surface Meteorological Parameters					
Max. surface temperature (°C)	21.8	23.8	24.4	25.7	25.3
Min. surface temperature (°C)	16.0	17.5	18.1	18.9	17.7
Relative humidity (%)	73.7	78.4	83.3	82.9	83.5
Surface wind speed (ms^{-1})	3.2	3.2	2.9	2.5	1.8
Surface wind direction (degrees)	52	79	119	106	37
Persistence	0.8	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1022	1020	1019	1019	1019
Rainfall (inches)	0.2	0.1	0.2	0.1	0.0
Rain (# periods)	0.7	0.6	0.8	0.6	0.6
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	11.5	12.7	13.6	13.9	13.4
Temperature PM 850 mb (°C)	12.3	12.7	13.6	14.1	13.9
Stability at Slidell (°C)	0.8	-0.4	0.1	0.0	0.7
Geopotential height difference 700 mb at Slidell (m)	8.3	0.8	-2.6	-0.5	-6.3
Wind speed yesterday 700 mb at Slidell (ms^{-1})	11.8	10.6	9.7	7.5	7.0
Wind direction yesterday 700 mb at Slidell (degrees)	283	262	256	289	311
Wind speed yesterday 850 mb at Slidell (ms^{-1})	8.9	7.7	6.9	6.0	5.7
Wind speed AM 850 mb at Slidell (ms^{-1})	8.1	8.6	7.8	6.3	5.7
Wind speed PM 850 mb at Slidell (ms^{-1})	6.4	8.0	7.5	6.4	6.4
Wind direction yesterday 850 mb at Slidell (degrees)	325	245	255	298	323
Wind direction AM 850 mb at Slidell (degrees)	284	233	217	239	243
Wind direction PM 850 mb at Slidell (degrees)	311	284	227	262	14
Recirculation at Slidell	0.05	0.04	0.04	0.11	0.13
Cloud average	1.6	1.7	1.7	1.6	1.6

Table 3-11b. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Brigantine.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <50, 50-80, 80-135, 135-225, and ≥225 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Wilmington (μg/m^3)	11.2	13.5	17.1	20.1	27.4
Yesterday's FM at New Orleans (μg/m^3)	10.3	13.8	17.1	20.3	24.9
Yesterday's FM at Philadelphia (μg/m^3)	10.6	12.9	16.8	19.7	26.0
Surface Meteorological Parameters					
Max. surface temperature (°C)	13.0	15.8	18.0	22.3	22.2
Min. surface temperature (°C)	3.1	5.5	8.0	12.3	13.8
Relative humidity (%)	61.6	71.8	75.5	79.8	85.3
Surface wind speed (ms^{-1})	4.2	3.3	3.0	2.4	2.2
Surface wind direction (degrees)	306	248	204	212	166
Persistence	0.9	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1023	1022	1020	1019	1018
Rainfall (inches)	0.1	0.1	0.1	0.1	0.1
Rain (# periods)	0.6	0.8	0.8	0.9	1.1
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	0.2	4.6	6.6	9.9	11.4
Temperature PM 850 mb (°C)	1.3	4.5	7.1	10.5	11.9
Stability at Brookhaven (°C)	-3.4	-0.9	0.2	-0.7	-0.8
Geopotential height difference 700 mb at Brookhaven (m)	-2.0	3.0	-5.1	0.3	-9.0
Wind speed yesterday 700 mb at Brookhaven (ms^{-1})	15.3	15.8	13.2	12.7	11.9
Wind speed yesterday 700 mb at Dulles (ms^{-1})	16.2	15.2	12.9	11.7	10.0
Wind direction yesterday 700 mb at Brookhaven (degrees)	275	278	274	278	277
Wind direction yesterday 700 mb at Dulles (degrees)	290	274	276	273	270
Wind speed yesterday 850 mb at Brookhaven (ms^{-1})	12.2	11.5	9.3	9.1	9.0
Wind speed yesterday 850 mb at Dulles (ms^{-1})	12.6	10.8	9.5	7.6	7.9
Wind speed AM 850 mb at Brookhaven (ms^{-1})	12.1	11.7	10.4	9.1	8.6
Wind speed AM 850 mb at Dulles (ms^{-1})	12.8	10.6	10.2	8.7	6.8
Wind speed PM 850 mb at Brookhaven (ms^{-1})	12.1	11.5	11.1	9.8	8.8
Wind speed PM 850 mb at Dulles (ms^{-1})	10.5	10.3	10.6	9.2	8.9
Wind direction yesterday 850 mb at Brookhaven (degrees)	312	283	285	268	281
Wind direction yesterday 850 mb at Dulles (degrees)	312	272	260	261	273
Wind direction AM 850 mb at Brookhaven (degrees)	326	287	277	265	280
Wind direction AM 850 mb at Dulles (degrees)	330	290	281	269	279
Wind direction PM 850 mb at Brookhaven (degrees)	324	292	289	273	299
Wind direction PM 850 mb at Dulles (degrees)	303	271	268	278	297
Cloud average	1.8	1.9	2.0	2.0	2.0

Table 3-11c. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Cadiz.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <55, 55-95, 95-155, 155-230, and ≥230 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Nashville (μg/m^3)	10.0	11.9	16.3	19.6	18.2
Yesterday's FM at St. Louis (μg/m^3)	8.9	13.5	16.9	20.8	23.8
Yesterday's FM at Louisville (μg/m^3)	10.7	14.4	19.9	22.8	24.8
Surface Meteorological Parameters					
Max. surface temperature (°C)	13.1	18.7	21.2	22.5	17.0
Min. surface temperature (°C)	3.4	9.8	12.9	14.1	10.1
Relative humidity (%)	57.3	70.0	79.2	84.8	88.5
Surface wind speed (ms^{-1})	2.6	2.5	2.1	1.6	2.3
Surface wind direction (degrees)	229	188	178	63	0
Persistence	0.8	0.8	0.8	0.8	0.8
Rainfall (inches)	0.0	0.2	0.1	0.2	0.2
Rain (# periods)	0.2	0.6	0.6	0.7	1.0
Solar radiation (W/m^2)	600.3	574.2	579.6	501.2	434.4
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	2.4	8.6	11.3	12.7	9.2
Temperature PM 850 mb (°C)	3.9	9.4	11.9	13.2	9.0
Stability at Nashville (°C)	-0.9	0.2	0.1	-0.2	-0.7
Geopotential height difference 700 mb at Nashville (m)	13.8	3.7	-1.8	-2.7	-9.5
Wind speed yesterday 700 mb at Nashville (ms^{-1})	18.4	13.1	10.1	8.7	11.9
Wind direction yesterday 700 mb at Nashville (degrees)	279	275	263	270	252
Wind speed yesterday 850 mb at Nashville (ms^{-1})	12.1	9.1	7.4	6.4	8.5
Wind speed AM 850 mb at Nashville (ms^{-1})	12.1	11.0	8.2	6.4	7.9
Wind speed PM 850 mb at Nashville (ms^{-1})	9.3	9.6	8.1	6.2	6.1
Wind direction yesterday 850 mb at Nashville (degrees)	289	267	252	270	281
Wind direction AM 850 mb at Nashville (degrees)	306	271	270	276	243
Wind direction PM 850 mb at Nashville (degrees)	274	258	244	235	225
Recirculation at Nashville	0.0	0.0	0.1	0.1	0.1
Cloud average	1.4	1.8	1.8	1.8	2.1

Table 3-11d. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Caney Creek.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <45, 45-75, 75-115, 115-170, and ≥170 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Little Rock (μg/m^3)	9.7	12.1	16.0	19.3	22.4
Yesterday's FM at Dallas (μg/m^3)	9.8	12.3	15.3	17.7	20.1
Surface Meteorological Parameters					
Max. surface temperature (°C)	16.5	19.3	25.1	26.7	27.9
Min. surface temperature (°C)	3.3	7.7	12.8	14.5	15.8
Relative humidity (%)	62.8	71.1	72.9	77.1	77.9
Surface wind speed (ms^{-1})	1.1	1.0	0.9	0.6	0.3
Surface wind direction (degrees)	230	171	139	105	68
Persistence	0.8	0.8	0.9	0.9	0.7
Sea level pressure (mb)	1022	1021	1018	1018	1018
Rainfall (inches)	0.2	0.2	0.1	0.1	0.1
Rain (# periods)	1.0	0.9	0.7	0.7	1.0
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	5.9	8.9	12.9	14.1	14.3
Temperature PM 850 mb (°C)	6.4	9.6	13.7	14.7	15.4
Stability at Little Rock (°C)	0.0	-0.3	-0.5	-0.5	-1.8
Geopotential height difference 700 mb at Little Rock (m)	6.8	3.4	-1.3	0.0	4.4
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	17.8	12.3	10.0	7.8	6.2
Wind direction yesterday 700 mb at Little Rock (degrees)	281	274	289	290	351
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	11.4	9.1	7.3	5.3	5.1
Wind speed AM 850 mb at Little Rock (ms^{-1})	11.7	9.2	8.2	5.8	4.6
Wind speed PM 850 mb at Little Rock (ms^{-1})	10.2	8.9	8.4	6.0	5.7
Wind direction yesterday 850 mb at Little Rock (degrees)	297	261	264	250	0
Wind direction AM 850 mb at Little Rock (degrees)	301	281	268	264	135
Wind direction PM 850 mb at Little Rock (degrees)	285	259	251	238	127
Recirculation at Little Rock	0.0	0.0	0.0	0.2	0.2
Cloud average	1.5	1.7	1.6	1.6	1.9

Table 3-11e. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Cape Romain.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <50, 50-75, 75-110, 110-160, and ≥160 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Charleston (μg/m^3)	9.3	11.3	12.7	16.1	21.5
Surface Meteorological Parameters					
Max. surface temperature (°C)	21.9	22.9	24.8	26.9	28.1
Min. surface temperature (°C)	11.6	11.9	14.4	16.3	18.2
Relative humidity (%)	66.9	70.7	75.8	78.5	81.2
Surface wind speed (ms^{-1})	3.3	3.0	2.7	2.4	1.6
Surface wind direction (degrees)	22	270	206	135	180
Persistence	0.9	0.8	0.8	0.8	0.6
Sea level pressure (mb)	1023	1021	1020	1020	1018
Rainfall (inches)	0.1	0.1	0.1	0.1	0.1
Rain (# periods)	0.6	0.7	0.7	0.7	0.8
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	8.9	10.6	12.4	13.7	14.5
Temperature PM 850 mb (°C)	10.1	11.2	12.6	14.1	15.3
Stability at Charleston (°C)	-1.9	-0.3	0.1	-0.1	-0.5
Geopotential height difference 700 mb at Charleston (m)	5.0	-0.6	3.4	9.8	-9.9
Wind speed yesterday 700 mb at Charleston (ms^{-1})	13.3	12.5	10.0	8.7	8.7
Wind direction yesterday 700 mb at Charleston (degrees)	262	272	282	290	295
Wind speed yesterday 850 mb at Charleston (ms^{-1})	10.4	8.9	7.8	6.2	7.1
Wind speed AM 850 mb at Charleston (ms^{-1})	9.3	10.0	8.0	6.5	7.3
Wind speed PM 850 mb at Charleston (ms^{-1})	8.1	9.2	8.3	6.8	7.2
Wind direction yesterday 850 mb at Charleston (degrees)	241	271	275	314	274
Wind direction AM 850 mb at Charleston (degrees)	249	259	282	284	279
Wind direction PM 850 mb at Charleston (degrees)	287	273	277	295	301
Recirculation at Charleston	0.0	0.1	0.1	0.1	0.1
Cloud average	1.7	1.6	1.7	1.8	1.9

Table 3-11f. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Chassahowitzka.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <60, 60-85, 85-115, 115-165, and ≥165 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Tampa (μg/m^3)	10.1	11.0	13.7	14.7	22.6
Yesterday's FM at Orlando (μg/m^3)	8.4	10.5	11.7	13.0	18.2
Surface Meteorological Parameters					
Max. surface temperature (°C)	24.5	27.5	27.8	27.7	30.9
Min. surface temperature (°C)	13.0	15.0	14.5	14.9	17.2
Relative humidity (%)	71.3	75.9	78.4	79.9	80.0
Surface wind speed (ms^{-1})	3.0	2.2	1.4	1.7	1.1
Surface wind direction (degrees)	18	333	279	17	300
Persistence	0.9	0.8	0.7	0.7	0.6
Sea level pressure (mb)	1021	1020	1020	1021	1018
Rainfall (inches)	0.1	0.1	0.1	0.2	0.0
Rain (# periods)	0.7	0.7	0.6	0.7	0.2
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	12.4	13.6	14.4	14.3	15.8
Temperature PM 850 mb (°C)	12.8	13.9	14.6	14.1	16.3
Stability at Tampa (°C)	-1.9	-1.4	-0.4	-0.7	-1.0
Geopotential height difference 700 mb at Tampa (m)	2.1	-0.8	-0.3	5.2	-1.9
Wind speed yesterday 700 mb at Tampa (ms^{-1})	10.2	8.1	7.2	7.7	5.3
Wind direction yesterday 700 mb at Tampa (degrees)	274	268	254	285	304
Wind speed yesterday 850 mb at Tampa (ms^{-1})	9.0	7.2	6.1	5.4	4.4
Wind speed AM 850 mb at Tampa (ms^{-1})	8.6	7.4	6.3	5.3	3.5
Wind speed PM 850 mb at Tampa (ms^{-1})	7.6	7.3	6.4	5.7	3.7
Wind direction yesterday 850 mb at Tampa (degrees)	243	143	125	0	81
Wind direction AM 850 mb at Tampa (degrees)	294	222	222	209	297
Wind direction PM 850 mb at Tampa (degrees)	127	200	132	45	124
Recirculation at Tampa	0.0	0.1	0.1	0.2	0.1
Cloud average	1.8	1.7	1.7	1.8	1.4

Table 3-11g. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Cohutta.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <50, 50-80, 80-135, 135-220, and ≥220 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Birmingham (μg/m^3)	12.7	15.8	20.6	25.9	33.3
Yesterday's FM at Atlanta (μg/m^3)	13.4	16.5	19.4	24.6	30.2
Yesterday's FM at Nashville (μg/m^3)	10.0	12.2	15.6	20.3	26.4
Yesterday's FM at Knoxville (μg/m^3)	11.3	14.1	18.3	23.3	30.9
Surface Meteorological Parameters					
Max. surface temperature (°C)	12.5	17.4	24.5	29.7	31.7
Min. surface temperature (°C)	2.7	6.4	13.8	18.3	19.1
Relative humidity (%)	67.0	72.8	77.8	76.9	75.1
Surface wind speed (ms^{-1})	2.4	1.8	1.6	1.2	0.9
Surface wind direction (degrees)	354	287	194	231	164
Persistence	0.9	0.8	0.8	0.8	0.7
Rainfall (inches)	0.2	0.1	0.1	0.1	0.0
Rain (# periods)	0.6	0.6	0.6	0.5	0.4
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	6.0	8.9	13.2	15.6	16.3
Temperature PM 850 mb (°C)	5.8	9.2	13.5	15.9	17.4
Stability at Atlanta (°C)	2.1	2.5	2.4	1.7	2.8
Geopotential height difference 700 mb at Atlanta (m)	6.1	1.1	-1.9	-2.8	-3.4
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	18.6	12.8	8.8	6.7	4.5
Wind direction yesterday 700 mb at Atlanta (degrees)	276	268	269	270	74
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	12.2	9.0	6.7	5.1	3.9
Wind speed AM 850 mb at Atlanta (ms^{-1})	13.7	10.2	7.4	5.7	4.5
Wind speed PM 850 mb at Atlanta (ms^{-1})	9.3	8.8	6.9	5.4	4.6
Wind direction yesterday 850 mb at Atlanta (degrees)	294	267	235	291	45
Wind direction AM 850 mb at Atlanta (degrees)	316	267	255	243	270
Wind direction PM 850 mb at Atlanta (degrees)	310	276	249	208	180
Recirculation at Atlanta	0.0	0.0	0.1	0.2	0.2
Cloud average	1.4	1.6	1.8	2.0	2.0

Table 3-11h. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Dolly Sods.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <40, 40-65, 65-125, 125-215, and ≥215 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at DC (μg/m^3)	13.1	13.7	17.3	22.2	25.0
Yesterday's FM at Richmond (μg/m^3)	10.9	12.5	15.5	18.0	21.7
Yesterday's FM at Columbus (μg/m^3)	13.8	14.0	18.3	22.0	29.4
Surface Meteorological Parameters					
Max. surface temperature (°C)	10.2	10.3	17.9	23.3	25.6
Min. surface temperature (°C)	0.2	0.5	7.9	13.6	15.6
Relative humidity (%)	61.7	64.8	69.4	74.6	78.1
Surface wind speed (ms^{-1})	1.9	1.9	1.1	0.7	0.4
Surface wind direction (degrees)	263	273	286	351	300
Persistence	0.7	0.7	0.6	0.5	0.3
Rainfall (inches)	0.1	0.1	0.1	0.2	0.1
Rain (# periods)	0.7	0.5	0.6	0.7	0.5
Solar radiation (W/m^2)	418.5	423.5	523.6	564.9	666.1
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	1.4	0.9	8.1	13.3	14.6
Temperature PM 850 mb (°C)	2.2	1.7	8.9	13.9	15.7
Stability at Pittsburgh (°C)	0.0	-0.9	-0.1	0.9	1.4
Geopotential height difference 700 mb at Pittsburgh (m)	-1.1	2.4	1.1	0.3	-5.7
Wind speed yesterday 700 mb at Dulles (ms^{-1})	17.8	17.3	11.6	8.9	6.7
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	17.8	18.1	11.9	7.7	6.3
Wind speed yesterday 700 mb at Wilmington (ms^{-1})	17.2	17.6	13.0	8.8	6.3
Wind speed yesterday 700 mb at Pittsburgh (ms^{-1})	16.7	16.6	12.8	9.6	7.3
Wind direction yesterday 700 mb at Dulles (degrees)	270	276	284	277	302
Wind direction yesterday 700 mb at Roanoke (degrees)	269	275	282	278	287
Wind direction yesterday 700 mb at Wilmington (degrees)	266	281	285	280	283
Wind direction yesterday 700 mb at Pittsburgh (degrees)	269	276	282	276	295
Wind speed yesterday 850 mb at Dulles (ms^{-1})	12.7	12.3	8.9	6.6	4.7
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	11.5	11.4	8.1	5.6	4.0
Wind speed yesterday 850 mb at Wilmington (ms^{-1})	12.4	12.3	9.4	6.8	4.2
Wind speed yesterday 850 mb at Pittsburgh (ms^{-1})	11.6	12.1	8.5	6.3	5.0
Wind speed AM 850 mb at Dulles (ms^{-1})	13.6	13.3	9.0	6.5	4.6
Wind speed AM 850 mb at Roanoke (ms^{-1})	12.4	12.9	10.1	6.9	6.3
Wind speed AM 850 mb at Wilmington (ms^{-1})	11.8	12.1	9.7	8.7	5.7
Wind speed AM 850 mb at Pittsburgh (ms^{-1})	12.3	12.0	9.8	7.6	5.9
Wind speed PM 850 mb at Dulles (ms^{-1})	12.2	11.9	9.1	7.0	6.3
Wind speed PM 850 mb at Roanoke (ms^{-1})	10.8	10.3	8.1	6.8	4.4
Wind speed PM 850 mb at Wilmington (ms^{-1})	12.6	10.7	9.3	8.3	5.4
Wind speed PM 850 mb at Pittsburgh (ms^{-1})	11.4	10.7	8.6	7.0	6.1
Wind direction yesterday 850 mb at Dulles (degrees)	270	272	279	267	281
Wind direction yesterday 850 mb at Roanoke (degrees)	245	268	269	266	304
Wind direction yesterday 850 mb at Wilmington (degrees)	252	279	272	271	240
Wind direction yesterday 850 mb at Pittsburgh (degrees)	261	269	277	268	286

	Category 1	Category 2	Category 3	Category 4	Category 5
Wind direction AM 850 mb at Dulles (degrees)	279	291	300	279	278
Wind direction AM 850 mb at Roanoke (degrees)	259	285	288	276	257
Wind direction AM 850 mb at Wilmington (degrees)	270	290	291	274	270
Wind direction AM 850 mb at Pittsburgh (degrees)	269	286	282	278	276
Wind direction PM 850 mb at Dulles (degrees)	267	281	288	265	283
Wind direction PM 850 mb at Roanoke (degrees)	264	272	282	258	288
Wind direction PM 850 mb at Wilmington (degrees)	261	265	269	268	288
Wind direction PM 850 mb at Pittsburgh (degrees)	270	270	276	274	264
Cloud average	1.9	1.8	1.9	2.0	2.0

Table 3-11i. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Everglades.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <40, 40-55, 55-80, 80-120, and ≥120 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Palm Beach (μg/m^3)	5.6	6.9	8.4	11.0	13.3
Yesterday's FM at Ft. Lauderdale (μg/m^3)	6.0	7.4	9.2	11.9	13.6
Surface Meteorological Parameters					
Max. surface temperature (°C)	27.9	28.7	27.2	27.7	27.7
Min. surface temperature (°C)	20.5	20.6	18.4	18.2	19.0
Relative humidity (%)	79.1	78.9	78.7	77.0	78.9
Surface wind speed (ms^{-1})	2.1	1.7	1.7	1.4	1.6
Surface wind direction (degrees)	93	85	71	41	58
Persistence	0.8	0.8	0.8	0.7	0.8
Rainfall (inches)	0.3	0.2	0.1	0.1	0.0
Rain (# periods)	0.8	0.8	0.6	0.3	0.3
Solar radiation (W/m^2)	604.6	637.5	598.7	642.3	655.0
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	14.6	15.3	14.4	14.2	14.6
Temperature PM 850 mb (°C)	14.8	15.7	14.5	14.3	14.9
Stability at Miami (°C)	-5.0	-4.6	-3.7	-3.4	-3.3
Geopotential height difference 700 mb at Miami (m)	-3.8	1.0	0.4	0.9	2.8
Wind speed yesterday 700 mb at Miami (ms^{-1})	6.7	6.1	7.6	7.2	8.0
Wind direction yesterday 700 mb at Miami (degrees)	95	172	268	275	286
Wind speed yesterday 850 mb at Miami (ms^{-1})	7.3	6.0	6.3	5.6	6.8
Wind speed AM 850 mb at Miami (ms^{-1})	7.7	6.1	6.2	6.0	6.4
Wind speed PM 850 mb at Miami (ms^{-1})	7.3	5.6	6.6	5.9	5.8
Wind direction yesterday 850 mb at Miami (degrees)	95	85	320	309	308
Wind direction AM 850 mb at Miami (degrees)	125	131	208	258	243
Wind direction PM 850 mb at Miami (degrees)	111	88	0	318	333
Recirculation at Miami	0.0	0.1	0.1	0.1	0.1
Cloud average	1.9	1.7	1.7	1.7	1.5

Table 3-11j. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Great Smoky Mountains.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <45, 45-75, 75-120, 120-180, and ≥180 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Knoxville (μg/m³)	11.7	14.9	18.3	22.2	26.4
Yesterday's FM at Atlanta (μg/m³)	14.6	16.2	20.4	22.6	27.8
Yesterday's FM at Charlotte (μg/m³)	11.4	13.7	17.2	19.2	21.8
Surface Meteorological Parameters					
Max. surface temperature (°C)	9.5	14.7	18.9	20.4	22.6
Min. surface temperature (°C)	2.4	8.3	12.8	14.8	18.0
Relative humidity (%)	57.8	67.7	76.0	79.8	84.6
Surface wind speed (ms^{-1})	2.0	2.0	1.4	1.4	0.9
Surface wind direction (degrees)	300	261	260	270	270
Persistence	0.7	0.7	0.7	0.7	0.6
Rainfall (inches)	0.1	0.1	0.1	0.2	0.2
Rain (# periods)	0.6	0.6	0.7	0.7	0.9
Solar radiation (W/m²)	476.8	542.1	549.1	587.6	491.7
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	4.1	7.7	11.6	13.1	15.5
Temperature PM 850 mb (°C)	5.0	8.4	11.9	13.1	16.1
Stability at Nashville (°C)	0.9	-0.4	-0.2	-0.5	-0.8
Geopotential height difference 700 mb at Nashville (m)	16.5	0.1	-2.2	-1.2	-0.3
Wind speed yesterday 700 mb at Nashville (ms^{-1})	17.4	13.9	11.4	10.1	6.9
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	18.5	13.6	11.1	10.3	7.6
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	16.2	12.1	9.6	8.9	6.4
Wind direction yesterday 700 mb at Nashville (degrees)	279	267	271	281	297
Wind direction yesterday 700 mb at Greensboro (degrees)	276	273	273	286	281
Wind direction yesterday 700 mb at Atlanta (degrees)	278	270	275	273	270
Wind speed yesterday 850 mb at Nashville (ms^{-1})	10.1	9.9	7.8	7.7	5.7
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	12.1	9.4	7.7	7.0	6.0
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	10.5	8.6	6.9	6.3	5.7
Wind speed AM 850 mb at Nashville (ms^{-1})	10.8	11.1	8.3	8.2	6.2
Wind speed AM 850 mb at Greensboro (ms^{-1})	12.6	10.5	8.4	7.1	5.9
Wind speed AM 850 mb at Atlanta (ms^{-1})	11.3	10.1	8.1	7.0	5.4
Wind speed PM 850 mb at Nashville (ms^{-1})	9.5	9.5	7.2	7.6	5.2
Wind speed PM 850 mb at Greensboro (ms^{-1})	10.4	9.8	7.7	6.9	5.0
Wind speed PM 850 mb at Atlanta (ms^{-1})	8.9	8.5	7.1	6.1	5.3
Wind direction yesterday 850 mb at Nashville (degrees)	289	265	258	274	292
Wind direction yesterday 850 mb at Greensboro (degrees)	290	266	264	296	252
Wind direction yesterday 850 mb at Atlanta (degrees)	306	252	253	284	248
Wind direction AM 850 mb at Nashville (degrees)	294	277	278	284	261
Wind direction AM 850 mb at Greensboro (degrees)	293	281	279	298	290
Wind direction AM 850 mb at Atlanta (degrees)	293	266	269	266	256
Wind direction PM 850 mb at Nashville (degrees)	260	252	266	270	259
Wind direction PM 850 mb at Greensboro (degrees)	276	265	267	260	270
Wind direction PM 850 mb at Atlanta (degrees)	306	252	253	284	248
Cloud average	1.4	1.6	1.8	1.9	1.9

Table 3-11k. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site James River Face.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <50, 50-85, 85-155, 155-220, and ≥220 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Richmond (μg/m^3)	10.6	12.5	15.8	18.6	23.8
Yesterday's FM at Greensboro-Winston-Salem (μg/m^3)	10.8	13.2	17.2	21.3	25.3
Yesterday's FM at Knoxville (μg/m^3)	11.3	15.4	18.9	23.2	26.3
Surface Meteorological Parameters					
Max. surface temperature (°C)	12.1	17.1	22.3	25.1	23.0
Min. surface temperature (°C)	0.6	4.3	11.4	14.8	13.7
Relative humidity (%)	51.0	63.8	75.9	79.2	85.4
Surface wind speed (ms^{-1})	2.4	1.8	1.5	1.2	0.8
Surface wind direction (degrees)	266	226	193	180	196
Persistence	0.8	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1023	1022	1021	1019	1022
Rainfall (inches)	0.0	0.1	0.2	0.2	0.1
Rain (# periods)	0.4	0.7	1.1	1.0	1.1
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	-1.7	5.2	10.8	13.0	12.0
Temperature PM 850 mb (°C)	-0.1	5.3	11.3	14.0	12.6
Stability at Roanoke (°C)	0.2	2.7	2.6	1.9	1.3
Geopotential height difference 700 mb at Roanoke (m)	16.3	1.6	-8.9	-7.6	7.6
Wind speed yesterday 700 mb at Dulles (ms^{-1})	19.8	15.6	11.3	9.5	7.8
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	20.7	15.6	10.9	9.2	7.6
Wind direction yesterday 700 mb at Dulles (degrees)	280	279	276	283	273
Wind direction yesterday 700 mb at Roanoke (degrees)	278	274	277	282	266
Wind speed yesterday 850 mb at Dulles (ms^{-1})	14.5	11.4	8.2	6.5	5.0
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	13.4	9.8	7.7	5.8	5.0
Wind speed AM 850 mb at Dulles (ms^{-1})	15.7	11.0	8.9	7.0	5.3
Wind speed AM 850 mb at Roanoke (ms^{-1})	14.3	11.8	9.1	7.9	6.5
Wind speed PM 850 mb at Dulles (ms^{-1})	12.3	11.2	8.9	7.9	6.4
Wind speed PM 850 mb at Roanoke (ms^{-1})	10.9	9.7	8.2	6.4	5.9
Wind direction yesterday 850 mb at Dulles (degrees)	279	276	268	267	270
Wind direction yesterday 850 mb at Roanoke (degrees)	278	270	252	259	264
Wind direction AM 850 mb at Dulles (degrees)	312	293	286	268	266
Wind direction AM 850 mb at Roanoke (degrees)	304	273	274	270	232
Wind direction PM 850 mb at Dulles (degrees)	294	280	272	258	240
Wind direction PM 850 mb at Roanoke (degrees)	288	267	270	260	198
Recirculation at Roanoke	0.0	0.1	0.1	0.0	0.2
Cloud average	1.8	1.8	2.1	2.1	2.1

Table 3-11l. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Linville Gorge.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <35, 35-70, 70-120, 120-180, and ≥180 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Knoxville (μg/m^3)	11.1	14.4	19.0	23.8	29.3
Yesterday's FM at Charlotte (μg/m^3)	11.3	13.7	16.7	20.8	23.1
Yesterday's FM at Greenville (μg/m^3)	10.9	12.8	16.6	20.4	24.8
Surface Meteorological Parameters					
Max. surface temperature (°C)	12.2	17.5	23.6	26.6	26.9
Min. surface temperature (°C)	1.4	6.6	13.5	16.3	17.5
Relative humidity (%)	52.5	65.3	73.8	76.1	79.6
Surface wind speed (ms^{-1})	2.1	1.8	1.5	1.2	0.8
Surface wind direction (degrees)	309	312	194	323	0
Persistence	0.7	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1022	1020	1020	1019	1020
Rainfall (inches)	0.1	0.1	0.1	0.1	0.1
Rain (# periods)	0.5	0.7	0.8	0.8	0.6
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	0.9	7.4	12.3	14.1	14.8
Temperature PM 850 mb (°C)	2.4	7.2	12.9	15.1	15.2
Stability at Greensboro (°C)	-0.7	0.7	0.2	0.4	-0.1
Geopotential height difference 700 mb at Greensboro (m)	11.3	-4.6	1.1	1.6	-0.6
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	20.9	14.4	10.3	7.4	7.3
Wind direction yesterday 700 mb at Greensboro (degrees)	272	273	276	292	301
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	14.0	10.1	7.2	5.6	3.5
Wind speed AM 850 mb at Greensboro (ms^{-1})	14.6	10.9	7.6	6.0	4.3
Wind speed PM 850 mb at Greensboro (ms^{-1})	10.6	9.7	7.9	5.7	4.6
Wind direction yesterday 850 mb at Greensboro (degrees)	278	273	269	263	329
Wind direction AM 850 mb at Greensboro (degrees)	304	281	286	286	300
Wind direction PM 850 mb at Greensboro (degrees)	293	275	248	257	256
Recirculation at Greensboro	0.0	0.0	0.1	0.1	0.2
Cloud average	1.5	1.6	1.9	1.9	2.0

Table 3-11m. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Mammoth Cave.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <55, 55-90, 90-155, 155-250, and ≥250 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Nashville (µg/m^3)	10.2	13.0	15.9	19.4	24.9
Yesterday's FM at Knoxville (µg/m^3)	12.2	16.1	17.6	22.3	27.3
Yesterday's FM at Louisville (µg/m^3)	10.0	14.9	18.4	24.9	29.8
Surface Meteorological Parameters					
Max. surface temperature (°C)	14.2	17.6	21.9	24.9	28.2
Min. surface temperature (°C)	1.9	6.2	11.7	15.1	17.9
Relative humidity (%)	58.7	67.9	76.0	78.8	79.4
Surface wind speed (ms^{-1})	2.6	2.7	2.2	1.7	1.2
Surface wind direction (degrees)	191	218	206	143	202
Persistence	0.9	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1025	1022	1020	1020	1019
Rainfall (inches)	0.0	0.1	0.2	0.2	0.3
Rain (# periods)	0.3	0.8	0.9	0.8	0.9
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	3.1	6.9	10.6	13.5	15.7
Temperature PM 850 mb (°C)	4.5	7.6	11.3	13.5	16.7
Stability at Nashville (°C)	-0.2	0.0	0.0	-0.1	-0.2
Geopotential height difference 700 mb at Nashville (m)	14.7	5.6	-2.8	-5.5	1.2
Wind speed yesterday 700 mb at Nashville (ms^{-1})	18.2	13.8	11.3	8.7	7.8
Wind direction yesterday 700 mb at Nashville (degrees)	285	273	268	266	306
Wind speed yesterday 850 mb at Nashville (ms^{-1})	11.1	9.5	8.3	6.6	4.2
Wind speed AM 850 mb at Nashville (ms^{-1})	11.3	11.2	8.9	6.8	4.9
Wind speed PM 850 mb at Nashville (ms^{-1})	8.4	9.8	8.4	6.4	5.0
Wind direction yesterday 850 mb at Nashville (degrees)	300	267	264	238	315
Wind direction AM 850 mb at Nashville (degrees)	315	272	275	262	291
Wind direction PM 850 mb at Nashville (degrees)	271	255	266	255	238
Recirculation at Nashville	0.0	0.0	0.0	0.1	0.2
Cloud average	1.4	1.7	1.8	1.9	1.9

Table 3-11n. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Mingo.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <55, 55-85, 85-130, 130-190, and ≥190 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at St. Louis (μg/m^3)	10.2	13.7	16.4	22.3	26.4
Surface Meteorological Parameters					
Max. surface temperature (°C)	15.5	17.5	21.6	22.6	20.9
Min. surface temperature (°C)	5.7	6.4	10.6	10.2	9.6
Relative humidity (%)	62.3	68.6	72.0	74.9	77.1
Surface wind speed (ms^{-1})	2.9	2.3	2.1	1.6	1.6
Surface wind direction (degrees)	347	270	210	153	194
Persistence	0.8	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1024	1022	1021	1021	1023
Rainfall (inches)	0.2	0.1	0.3	0.2	0.1
Rain (# periods)	0.8	0.6	0.8	0.6	1.2
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	3.4	6.9	10.6	11.8	10.7
Temperature PM 850 mb (°C)	3.1	7.0	11.2	12.1	11.8
Stability at Little Rock (°C)	-1.3	-0.7	0.2	-0.6	0.9
Geopotential height difference 700 mb at Little Rock (m)	13.4	-1.4	-3.2	-3.5	-5.4
Wind speed yesterday 700 mb at Springfield (ms^{-1})	15.9	14.4	12.2	9.0	11.2
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	16.5	14.1	10.6	8.4	10.0
Wind speed yesterday 700 mb at Lincoln (ms^{-1})	16.9	14.9	13.4	11.8	11.8
Wind speed yesterday 700 mb at Nashville (ms^{-1})	18.1	15.0	11.5	9.9	7.3
Wind direction yesterday 700 mb at Springfield (degrees)	291	286	271	282	270
Wind direction yesterday 700 mb at Little Rock (degrees)	277	291	279	288	270
Wind direction yesterday 700 mb at Lincoln (degrees)	268	279	280	292	270
Wind direction yesterday 700 mb at Nashville (degrees)	270	276	270	279	0
Wind speed yesterday 850 mb at Springfield (ms^{-1})	10.5	10.0	9.1	6.9	9.8
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	10.0	8.9	8.0	6.5	7.0
Wind speed yesterday 850 mb at Lincoln (ms^{-1})	12.2	10.3	9.3	7.2	10.1
Wind speed yesterday 850 mb at Nashville (ms^{-1})	12.2	9.0	8.7	6.5	5.7
Wind speed AM 850 mb at Springfield (ms^{-1})	10.8	9.9	10.2	7.5	5.9
Wind speed AM 850 mb at Little Rock (ms^{-1})	10.1	9.6	8.8	6.6	6.0
Wind speed AM 850 mb at Lincoln (ms^{-1})	11.8	10.0	9.9	8.0	9.2
Wind speed AM 850 mb at Nashville (ms^{-1})	12.8	10.4	9.8	6.5	7.1
Wind speed PM 850 mb at Springfield (ms^{-1})	9.1	9.4	8.4	8.5	6.8
Wind speed PM 850 mb at Little Rock (ms^{-1})	8.7	9.2	8.1	8.9	6.2
Wind speed PM 850 mb at Lincoln (ms^{-1})	10.1	9.4	9.7	8.5	9.6
Wind speed PM 850 mb at Nashville (ms^{-1})	9.3	7.9	8.3	6.9	5.4
Wind direction yesterday 850 mb at Springfield (degrees)	315	286	213	210	203
Wind direction yesterday 850 mb at Little Rock (degrees)	295	292	237	217	191
Wind direction yesterday 850 mb at Lincoln (degrees)	272	272	249	267	211
Wind direction yesterday 850 mb at Nashville (degrees)	268	285	252	262	240
Wind direction AM 850 mb at Springfield (degrees)	330	294	259	261	262
Wind direction AM 850 mb at Little Rock (degrees)	331	289	261	243	233

	Category 1	Category 2	Category 3	Category 4	Category 5
Wind direction AM 850 mb at Lincoln (degrees)	302	277	278	256	279
Wind direction AM 850 mb at Nashville (degrees)	290	286	281	247	288
Wind direction PM 850 mb at Springfield (degrees)	306	279	219	180	239
Wind direction PM 850 mb at Little Rock (degrees)	323	265	253	191	214
Wind direction PM 850 mb at Lincoln (degrees)	292	264	259	225	236
Wind direction PM 850 mb at Nashville (degrees)	283	279	242	225	307
Cloud average	1.7	1.7	1.8	1.8	1.8

Table 3-11o. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Okefenokee.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <55, 55-80, 80-110, 110-170, and ≥170 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Jacksonville (µg/m^3)	8.1	9.5	11.2	14.7	18.8
Surface Meteorological Parameters					
Max. surface temperature (°C)	21.5	26.1	26.7	26.5	28.6
Min. surface temperature (°C)	10.5	15.0	15.3	15.4	18.5
Relative humidity (%)	70.0	75.3	76.8	80.0	80.9
Surface wind speed (ms^{-1})	2.7	2.3	2.1	2.2	1.9
Surface wind direction (degrees)	315	186	110	78	90
Persistence	0.8	0.8	0.7	0.8	0.8
Sea level pressure (mb)	1022	1021	1020	1020	1019
Rainfall (inches)	0.1	0.1	0.2	0.1	0.1
Rain (# periods)	0.7	0.7	0.7	0.6	0.4
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	9.8	13.2	13.3	13.4	15.4
Temperature PM 850 mb (°C)	10.1	13.3	13.7	13.8	15.6
Stability at Jacksonville (°C)	0.1	0.1	0.1	0.4	-0.2
Geopotential height difference 700 mb at Jacksonville (m)	-1.5	0.2	5.2	-1.5	1.3
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	15.3	9.7	9.2	8.4	7.6
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	14.1	9.1	8.5	7.5	7.4
Wind direction yesterday 700 mb at Jacksonville (degrees)	265	256	279	300	297
Wind direction yesterday 700 mb at Tallahassee (degrees)	259	260	268	297	301
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	11.2	7.8	6.8	6.1	5.2
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	10.7	7.5	6.2	4.9	3.9
Wind speed AM 850 mb at Jacksonville (ms^{-1})	10.9	8.6	7.1	6.4	4.6
Wind speed AM 850 mb at Tallahassee (ms^{-1})	10.2	7.7	6.8	5.2	4.5
Wind speed PM 850 mb at Jacksonville (ms^{-1})	8.9	8.1	7.1	6.6	4.7
Wind speed PM 850 mb at Tallahassee (ms^{-1})	8.4	7.2	6.0	5.8	5.3
Wind direction yesterday 850 mb at Jacksonville (degrees)	274	241	265	311	315
Wind direction yesterday 850 mb at Tallahassee (degrees)	280	258	283	335	343
Wind direction AM 850 mb at Jacksonville (degrees)	283	239	247	277	279
Wind direction AM 850 mb at Tallahassee (degrees)	280	245	247	276	230
Wind direction PM 850 mb at Jacksonville (degrees)	284	260	254	286	304
Wind direction PM 850 mb at Tallahassee (degrees)	295	266	287	338	315
Recirculation at Jacksonville	0.0	0.1	0.1	0.0	0.2
Cloud average	1.7	1.8	1.8	1.8	1.8

Table 3-11p. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Shenandoah.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <40, 40-70, 70-145, 145-255, and ≥255 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Richmond (μg/m^3)	10.3	13.6	14.6	20.0	22.1
Yesterday's FM at DC (μg/m^3)	11.7	14.5	18.1	23.1	24.0
Yesterday's FM at Columbus (μg/m^3)	13.4	14.8	19.2	22.2	26.0
Surface Meteorological Parameters					
Max. surface temperature (°C)	4.9	7.2	14.6	19.6	20.5
Min. surface temperature (°C)	-2.2	0.3	7.7	13.6	15.6
Relative humidity (%)	56.6	69.1	78.7	83.4	88.3
Surface wind speed (ms^{-1})	2.6	2.5	1.9	1.4	1.0
Surface wind direction (degrees)	263	276	261	175	189
Persistence	0.9	0.8	0.8	0.8	0.6
Rainfall (inches)	0.1	0.1	0.1	0.1	0.1
Rain (# periods)	0.5	0.6	0.7	0.8	0.9
Solar radiation (W/m^2)	511.2	494.4	542.8	574.9	353.0
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	0.7	2.6	9.5	13.9	15.5
Temperature PM 850 mb (°C)	2.4	3.1	9.9	14.9	15.9
Stability at Dulles (°C)	0.5	-0.4	0.1	-0.4	0.0
Geopotential height difference 700 mb at Dulles (m)	22.7	-10.5	-5.4	0.5	10.8
Wind speed yesterday 700 mb at Dulles (ms^{-1})	18.3	16.2	12.1	8.7	7.1
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	18.6	17.2	11.9	8.4	6.0
Wind direction yesterday 700 mb at Dulles (degrees)	286	275	280	281	284
Wind direction yesterday 700 mb at Roanoke (degrees)	278	274	285	276	270
Wind speed yesterday 850 mb at Dulles (ms^{-1})	12.8	11.7	8.9	6.4	5.3
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	11.3	10.8	8.1	6.0	4.8
Wind speed AM 850 mb at Dulles (ms^{-1})	13.9	12.1	8.6	6.3	5.2
Wind speed AM 850 mb at Roanoke (ms^{-1})	12.4	12.1	10.0	7.4	6.6
Wind speed PM 850 mb at Dulles (ms^{-1})	11.1	11.8	9.4	7.3	6.3
Wind speed PM 850 mb at Roanoke (ms^{-1})	9.7	10.4	8.0	6.8	4.6
Wind direction yesterday 850 mb at Dulles (degrees)	288	275	267	278	278
Wind direction yesterday 850 mb at Roanoke (degrees)	277	263	263	270	262
Wind direction AM 850 mb at Dulles (degrees)	293	290	293	278	270
Wind direction AM 850 mb at Roanoke (degrees)	282	277	279	278	248
Wind direction PM 850 mb at Dulles (degrees)	275	280	285	265	263
Wind direction PM 850 mb at Roanoke (degrees)	267	277	275	267	217
Recirculation at Dulles	0.0	0.0	0.0	0.1	0.2
Cloud average	1.7	1.9	2.0	2.1	2.3

Table 3-11q. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Shining Rock.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <30, 30-60, 60-110, 110-180, and ≥180 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Knoxville (μg/m^3)	12.0	14.7	17.3	23.7	30.8
Yesterday's FM at Charlotte (μg/m^3)	11.4	13.7	16.6	19.6	25.7
Yesterday's FM at Greenville (μg/m^3)	10.9	13.1	16.0	19.9	26.2
Surface Meteorological Parameters					
Max. surface temperature (°C)	11.0	15.4	22.5	26.4	27.2
Min. surface temperature (°C)	0.3	4.7	11.2	14.5	15.4
Relative humidity (%)	62.1	69.3	75.1	75.9	78.5
Surface wind speed (ms^{-1})	3.3	2.8	1.8	1.2	1.0
Surface wind direction (degrees)	2	346	0	175	207
Persistence	0.8	0.8	0.7	0.7	0.7
Sea level pressure (mb)	1022	1022	1021	1020	1021
Rainfall (inches)	0.1	0.1	0.1	0.1	0.1
Rain (# periods)	0.9	0.9	0.9	0.7	0.7
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	2.2	6.0	11.9	14.8	15.4
Temperature PM 850 mb (°C)	2.9	6.5	12.4	15.7	16.3
Stability at Greensboro (°C)	-0.3	0.2	0.3	0.8	0.9
Geopotential height difference 700 mb at Greensboro (m)	5.8	-2.3	1.7	4.8	-6.3
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	19.2	14.6	10.6	8.3	6.0
Wind direction yesterday 700 mb at Greensboro (degrees)	271	267	276	299	336
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	12.5	10.1	7.7	5.6	4.1
Wind speed AM 850 mb at Greensboro (ms^{-1})	13.8	10.4	8.5	6.1	4.5
Wind speed PM 850 mb at Greensboro (ms^{-1})	10.8	9.8	8.0	5.8	5.2
Wind direction yesterday 850 mb at Greensboro (degrees)	280	263	270	293	315
Wind direction AM 850 mb at Greensboro (degrees)	296	280	279	296	305
Wind direction PM 850 mb at Greensboro (degrees)	290	268	256	251	270
Recirculation at Greensboro	0.0	0.0	0.0	0.1	0.2
Cloud average	1.6	1.7	1.8	1.8	1.8

Table 3-11r. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Sipsey.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <60, 60-95, 95-135, 135-200, and ≥200 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Birmingham (µg/m^3)	12.2	17.1	21.0	26.3	32.0
Yesterday's FM at Atlanta (µg/m^3)	14.0	17.0	19.2	25.8	26.3
Yesterday's FM at Nashville (µg/m^3)	9.6	12.5	16.9	20.2	22.3
Yesterday's FM at Memphis (µg/m^3)	9.8	12.1	16.8	17.9	22.9
Surface Meteorological Parameters					
Max. surface temperature (°C)	15.8	21.7	23.8	25.6	26.4
Min. surface temperature (°C)	4.8	10.6	12.5	15.3	16.2
Relative humidity (%)	60.7	72.0	75.7	77.3	79.5
Surface wind speed (ms^{-1})	2.7	2.4	1.8	1.5	0.9
Surface wind direction (degrees)	281	218	152	90	135
Persistence	0.8	0.8	0.7	0.8	0.7
Sea level pressure (mb)	1024	1021	1021	1020	1020
Rainfall (inches)	0.1	0.2	0.1	0.1	0.1
Rain (# periods)	0.5	0.9	0.9	0.8	0.8
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	6.7	11.3	12.8	13.9	14.3
Temperature PM 850 mb (°C)	7.3	11.3	13.0	14.6	15.0
Stability at Birmingham (°C)	0.3	0.6	0.6	0.3	0.4
Geopotential height difference 700 mb at Birmingham (m)	9.2	-0.1	1.3	-5.7	4.1
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	15.9	10.8	9.0	8.1	7.2
Wind direction yesterday 700 mb at Birmingham (degrees)	277	261	278	277	27
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	10.1	8.3	7.0	5.5	4.9
Wind speed AM 850 mb at Birmingham (ms^{-1})	11.7	9.8	7.3	6.9	4.1
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.4	8.7	7.0	6.1	5.0
Wind direction yesterday 850 mb at Birmingham (degrees)	291	246	267	288	72
Wind direction AM 850 mb at Birmingham (degrees)	297	263	250	226	229
Wind direction PM 850 mb at Birmingham (degrees)	292	270	234	239	180
Recirculation at Birmingham	0.0	0.0	0.1	0.1	0.2
Cloud average	1.5	1.7	1.8	2.0	1.6

Table 3-11s. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site St. Marks.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <40, 40-70, 70-100, 100-140, and ≥140 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Orlando (μg/m^3)	9.2	9.0	11.4	11.3	14.9
Yesterday's FM at Pensacola (μg/m^3)	9.6	11.2	14.1	16.9	20.9
Surface Meteorological Parameters					
Max. surface temperature (°C)	23.2	25.7	25.6	27.8	28.2
Min. surface temperature (°C)	12.0	13.6	13.0	15.2	16.7
Relative humidity (%)	65.7	71.8	72.3	74.9	78.5
Surface wind speed (ms^{-1})	2.4	2.0	1.9	1.5	1.2
Surface wind direction (degrees)	42	86	143	174	121
Persistence	0.8	0.7	0.8	0.7	0.6
Sea level pressure (mb)	1022	1021	1020	1020	1021
Rainfall (inches)	0.2	0.2	0.1	0.1	0.1
Rain (# periods)	0.7	0.7	0.6	0.6	0.5
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	11.1	12.8	12.8	14.0	14.9
Temperature PM 850 mb (°C)	11.5	13.0	12.8	14.2	14.8
Stability at Tallahassee (°C)	-0.7	0.0	0.3	0.2	0.3
Geopotential height difference 700 mb at Tallahassee (m)	-1.4	2.0	-0.6	1.0	26.3
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	13.2	9.4	9.5	8.1	7.1
Wind direction yesterday 700 mb at Tallahassee (degrees)	264	264	262	269	307
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	10.4	7.7	7.0	6.0	4.8
Wind speed AM 850 mb at Tallahassee (ms^{-1})	10.0	7.8	7.4	6.3	5.0
Wind speed PM 850 mb at Tallahassee (ms^{-1})	7.8	7.5	6.8	5.7	5.3
Wind direction yesterday 850 mb at Tallahassee (degrees)	278	270	267	288	318
Wind direction AM 850 mb at Tallahassee (degrees)	279	234	246	255	279
Wind direction PM 850 mb at Tallahassee (degrees)	315	302	268	248	342
Recirculation at Tallahassee	0.0	0.1	0.0	0.1	0.2
Cloud average	1.6	1.7	1.7	1.7	1.6

Table 3-11t. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Swanquarter.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <40, 40-70, 70-115, 115-175, and ≥175 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Raleigh (μg/m^3)	11.1	13.3	15.3	18.8	23.4
Yesterday's FM at Norfolk (μg/m^3)	9.1	11.1	13.7	15.8	20.4
Surface Meteorological Parameters					
Max. surface temperature (°C)	19.2	18.9	20.6	24.0	25.7
Min. surface temperature (°C)	12.9	12.8	14.2	17.3	20.4
Relative humidity (%)	68.5	72.0	80.3	84.5	89.2
Surface wind speed (ms^{-1})	3.8	3.8	3.7	3.1	3.2
Surface wind direction (degrees)	318	335	307	255	221
Persistence	0.9	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1023	1022	1020	1019	1016
Rainfall (inches)	0.2	0.1	0.2	0.1	0.0
Rain (# periods)	0.8	0.7	0.9	0.9	0.4
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	7.6	8.5	10.6	13.4	15.5
Temperature PM 850 mb (°C)	8.3	8.8	10.7	13.6	16.0
Stability at Moorhead (°C)	-1.3	-0.7	-0.2	-0.2	-0.6
Geopotential height difference 700 mb at Moorhead (m)	0.9	3.2	-1.0	-7.0	-7.1
Wind speed yesterday 700 mb at Moorhead (ms^{-1})	12.8	13.4	12.5	10.9	9.7
Wind direction yesterday 700 mb at Moorhead (degrees)	260	275	277	282	284
Wind speed yesterday 850 mb at Moorhead (ms^{-1})	9.6	8.8	9.1	7.9	7.7
Wind speed AM 850 mb at Moorhead (ms^{-1})	9.6	9.2	8.4	8.9	7.9
Wind speed PM 850 mb at Moorhead (ms^{-1})	8.8	9.4	8.9	8.6	7.6
Wind direction yesterday 850 mb at Moorhead (degrees)	245	288	271	279	273
Wind direction AM 850 mb at Moorhead (degrees)	268	288	276	281	270
Wind direction PM 850 mb at Moorhead (degrees)	287	284	272	277	282
Recirculation at Moorhead	0.0	0.1	0.0	0.0	0.0
Cloud average	1.7	1.6	1.8	1.6	1.7

Table 3-11u. Summary of Average Input Parameters for Each CART Classification Category: Visibility CART Analysis for the IMPROVE Site Upper Buffalo.

The ranges in extinction coefficient for Categories 1 through 5 are as follows: <40, 40-65, 65-100, 100-150, and ≥150 Mm-1.

	Category 1	Category 2	Category 3	Category 4	Category 5
Visibility Parameters					
Yesterday's FM at Little Rock (μg/m³)	10.3	12.7	15.9	18.9	22.2
Yesterday's FM at Dallas (μg/m³)	10.8	12.7	14.8	16.5	21.5
Surface Meteorological Parameters					
Max. surface temperature (°C)	13.9	19.3	21.4	25.0	23.2
Min. surface temperature (°C)	2.2	8.5	11.4	13.9	13.4
Relative humidity (%)	57.3	66.5	71.5	73.6	81.4
Surface wind speed (ms^{-1})	2.9	2.6	2.8	2.4	1.9
Surface wind direction (degrees)	235	189	180	160	117
Persistence	0.8	0.8	0.8	0.8	0.7
Sea level pressure (mb)	1023	1021	1020	1019	1018
Rainfall (inches)	0.2	0.2	0.1	0.1	0.2
Rain (# periods)	0.5	0.6	0.5	0.3	0.4
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	6.1	10.4	12.4	14.3	13.4
Temperature PM 850 mb (°C)	6.6	10.8	12.7	14.8	14.3
Stability at Little Rock (°C)	0.2	-0.5	-0.8	-1.2	-1.2
Geopotential height difference 700 mb at Little Rock (m)	12.9	-1.7	-3.3	-2.8	1.3
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	17.1	11.9	10.7	8.2	9.7
Wind direction yesterday 700 mb at Little Rock (degrees)	289	276	275	306	288
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	11.2	8.8	8.2	5.6	6.3
Wind speed AM 850 mb at Little Rock (ms^{-1})	10.3	9.3	9.1	6.9	6.7
Wind speed PM 850 mb at Little Rock (ms^{-1})	9.6	8.8	9.1	7.4	7.3
Wind direction yesterday 850 mb at Little Rock (degrees)	303	260	251	287	117
Wind direction AM 850 mb at Little Rock (degrees)	309	270	257	243	293
Wind direction PM 850 mb at Little Rock (degrees)	289	243	253	221	198
Recirculation at Little Rock	0.0	0.0	0.0	0.2	0.2
Cloud average	1.5	1.7	1.7	1.7	1.8

There are often clear distinctions between the average values of these key parameters for days in high and low visibility categories. A summary of the characteristics and categorical variations in selected parameters associated with poor visibility for each site follows:

For Breton, poor visibility is associated with:

- Moderate to high prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures and high relative humidity.
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and northeasterly to easterly winds near the surface.

For Brigantine, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures and high relative humidity.
- Low wind speeds (recirculation).
- Westerly winds aloft and southerly winds near the surface.

For Cadiz, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures (lower for Category 5) and high relative humidity.
- Low to moderate wind speeds near the surface and aloft (higher for Category 5).
- Westerly winds aloft and northerly to northeasterly winds near the surface.

For Caney Creek, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate to high temperatures and relative humidity.
- Very low wind speeds near the surface and low wind speeds aloft.
- Westerly and southeasterly winds aloft and northeasterly to easterly winds near the surface.

For Cape Romain, poor visibility is associated with:

- Moderate to high prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderately high temperatures and high relative humidity.
- Low wind speeds near the surface and moderate wind speeds aloft.
- Westerly winds aloft and southeasterly to southerly winds near the surface.

For Chassahowitzka, poor visibility is associated with:

- Moderate to high prior-day $PM_{2.5}$ (higher for Category 5).
- Moderate to high temperatures and high relative humidity.
- Low wind speeds near the surface and aloft.
- Southwesterly to westerly winds aloft; westerly to northerly winds near the surface.

For Cohutta, poor visibility is associated with:

- Moderate to high prior-day $PM_{2.5}$ (at potentially upwind sites).
- High temperatures and relative humidity.
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and southerly to southwesterly winds near the surface.

For Dolly Sods, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures and moderate to high relative humidity.
- Very low wind speeds near the surface and low wind speeds aloft.
- Westerly winds aloft and northwesterly to northerly winds near the surface.

For Everglades, poor visibility is associated with:

- Moderate prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderately high temperatures and relative humidity (but no increasing tendency).
- Low (slightly) wind speeds near the surface.
- Southwesterly winds aloft and northeasterly winds near the surface.

For the Great Smoky Mountains site, poor visibility is associated with:

- Moderate to high prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures and high relative humidity.
- Low wind speeds near the surface and aloft (especially for Category 5).
- West-southwesterly winds aloft and westerly winds near the surface.

For James River Face, poor visibility is associated with:

- Moderate to high prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures and high relative humidity.
- Low wind speeds near the surface and aloft.
- Southwesterly winds aloft and southerly winds near the surface.

For Linville Gorge, poor visibility is associated with

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- High temperatures and relative humidity.
- Low wind speeds near the surface and aloft.
- Westerly (west-northwesterly) winds aloft; northwesterly to northerly winds near the surface.

For Mammoth Cave, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- High temperatures and relative humidity.
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and southeasterly to southerly winds near the surface.

For Mingo, poor visibility is associated with:

- Moderate to high prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures and high relative humidity.
- Low wind speeds near the surface and aloft.
- Southwesterly winds aloft and southeasterly to southerly winds near the surface.

For Okefenokee, poor visibility is associated with:

- Moderate prior-day $PM_{2.5}$ (at potentially upwind sites).
- High temperatures and relative humidity (slight increasing tendency).
- Low wind speeds near the surface (slightly) and aloft.
- Westerly winds aloft and easterly winds near the surface.

For Shenandoah, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures and high relative humidity.
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and southerly winds near the surface.

For Shining Rock, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate to high temperatures and high relative humidity.
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and southerly to westerly winds near the surface.

For Sipsey, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate temperatures and high relative humidity.
- Low wind speeds near the surface and aloft.
- Southwesterly winds aloft and easterly to southeasterly winds near the surface.

For St. Mark's, poor visibility is associated with:

- Moderate prior-day $PM_{2.5}$ (at potentially upwind sites).
- High temperatures and moderate to high relative humidity (with a slight increasing tendency).
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and southeasterly to easterly winds near the surface.

For Swanquarter, poor visibility is associated with:

- Moderate prior-day $PM_{2.5}$ (there is a jump in concentration between Categories 4 and 5).
- Moderate temperatures and high relative humidity.
- Moderate wind speeds (with a slight decreasing tendency near surface).
- Westerly winds aloft and southwesterly to westerly winds near the surface.

For Upper Buffalo, poor visibility is associated with:

- High prior-day $PM_{2.5}$ (at potentially upwind sites).
- Moderate to high temperatures and relative humidity.
- Low wind speeds near the surface (slight) and aloft.
- Westerly winds aloft and southeasterly winds near the surface.

PM2.5

The average value of each input parameter was also calculated for each $PM_{2.5}$ classification category for each of the STN and SEARCH sites. These are presented in Tables 3-12 and 3-13. The four $PM_{2.5}$ categories are defined by the 70, 90, and 97 percentile values of $PM_{2.5}$ mass, which vary by site, as indicated at the top of each table. Table 3-12 summarizes the data for the STN sites, in alphabetical order, by site name.

Table 3-12a. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Birmingham.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <22.5, 22.5-32.5, 32.5-40 and ≥ 40 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	16.8	25.2	29.9	40.5
Yesterday's FM at Atlanta (μg/m³)	16.9	22.1	24.8	31.1
Yesterday's FM at Memphis (μg/m³)	12.9	17.7	19.8	25.1
Yesterday's FM at Nashville (μg/m³)	13.3	18.5	20.9	24.7
Surface Meteorological Parameters				
Max. surface temperature (°C)	20.9	25.9	27.2	29.0
Min. surface temperature (°C)	10.9	14.0	14.4	15.2
Relative humidity (%)	70.4	66.5	63.4	62.3
Surface wind speed (ms^{-1})	2.5	1.5	1.2	0.9
Surface wind direction (degrees)	279	79	87	11
Persistence	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1021	1021	1021	1022
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	1.0	0.6	0.3	0.1
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	10.2	12.9	13.6	14.3
Temperature PM 850 mb (°C)	10.2	13.8	14.3	15.2
Stability at Birmingham (°C)	-0.1	2.1	2.9	4.1
Geopotential height difference 700 mb at Birmingham (m)	-1.2	5.3	0.6	2.8
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	12.7	8.1	7.9	6.0
Wind direction yesterday 700 mb at Birmingham (degrees)	265	302	322	339
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	8.9	5.6	5.0	3.9
Wind speed AM 850 mb at Birmingham (ms^{-1})	10.2	6.3	5.8	4.3
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.9	5.9	5.5	3.7
Wind direction yesterday 850 mb at Birmingham (degrees)	255	345	10	32
Wind direction AM 850 mb at Birmingham (degrees)	264	261	258	284
Wind direction PM 850 mb at Birmingham (degrees)	271	238	90	315
Recirculation at Birmingham	0.0	0.1	0.1	0.3
Cloud average	1.8	1.6	1.6	1.6

Table 3-12b. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Charlotte.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-22.5, 22.5-30 and ≥ 30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Atlanta (μg/m³)	16.6	21.9	25.9	33.6
Yesterday's FM at Charlotte (μg/m³)	13.5	18.2	22.8	29.2
Yesterday's FM at Greensboro (μg/m³)	13.4	18.1	22.0	28.8
Yesterday's FM at Winston-Salem (μg/m³)	13.5	18.1	22.8	28.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	19.8	23.8	26.5	29.0
Min. surface temperature (°C)	9.1	12.0	14.9	17.3
Relative humidity (%)	67.7	69.3	69.7	70.6
Surface wind speed (ms^{-1})	2.2	1.6	1.5	1.3
Surface wind direction (degrees)	251	175	150	198
Persistence	0.8	0.7	0.7	0.7
Sea level pressure (mb)	1021	1021	1021	1019
Rainfall (inches)	0.1	0.1	0.1	0.0
Rain (# periods)	0.8	0.6	0.5	0.5
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	7.7	11.3	13.2	15.5
Temperature PM 850 mb (°C)	8.3	11.9	14.1	16.2
Stability at Greensboro (°C)	-0.1	1.5	1.4	1.2
Geopotential height difference 700 mb at Greensboro (m)	-1.3	2.1	4.1	0.0
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	13.9	10.3	9.4	6.8
Wind direction yesterday 700 mb at Greensboro (degrees)	271	290	296	315
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	9.7	6.7	5.8	5.1
Wind speed AM 850 mb at Greensboro (ms^{-1})	10.6	7.4	6.6	5.3
Wind speed PM 850 mb at Greensboro (ms^{-1})	9.5	7.5	6.6	6.8
Wind direction yesterday 850 mb at Greensboro (degrees)	262	281	280	306
Wind direction AM 850 mb at Greensboro (degrees)	281	288	280	288
Wind direction PM 850 mb at Greensboro (degrees)	269	261	273	274
Recirculation at Greensboro	0.0	0.1	0.1	0.1
Cloud average	1.7	1.7	1.7	1.6

Table 3-12c. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Chattanooga.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-25, 25-32.5 and ≥ 32.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	16	25	30	39
Yesterday's FM at Atlanta (μg/m³)	15.8	22.6	25.7	38.3
Yesterday's FM at Knoxville (μg/m³)	14.0	20.5	27.2	42.0
Surface Meteorological Parameters				
Max. surface temperature (°C)	19.1	25.7	28.5	25.3
Min. surface temperature (°C)	8.5	14.4	16.0	13.1
Relative humidity (%)	66.8	70.6	66.9	74.5
Surface wind speed (ms^{-1})	2.0	1.4	1.0	0.8
Surface wind direction (degrees)	298	225	210	180
Persistence	0.8	0.7	0.7	0.8
Sea level pressure (mb)	1022	1020	1021	1024
Rainfall (inches)	0.2	0.1	0.1	0.0
Rain (# periods)	0.9	0.7	0.4	0.5
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	7.7	12.8	14.5	12.4
Temperature PM 850 mb (°C)	8.2	13.5	14.9	13.0
Stability at Atlanta (°C)	1.8	3.0	4.1	4.1
Geopotential height difference 700 mb at Atlanta (m)	2.2	-2.8	-5.6	-3.0
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	13.5	8.3	6.4	4.4
Wind speed yesterday 700 mb at Nashville (ms^{-1})	15.0	10.4	7.6	5.9
Wind direction yesterday 700 mb at Atlanta (degrees)	272	282	342	117
Wind direction yesterday 700 mb at Nashville (degrees)	273	276	280	135
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	9.5	6.1	4.4	4.7
Wind speed yesterday 850 mb at Nashville (ms^{-1})	10.1	7.5	5.3	5.1
Wind speed AM 850 mb at Atlanta (ms^{-1})	10.9	6.7	5.2	4.9
Wind speed AM 850 mb at Nashville (ms^{-1})	10.6	8.7	6.8	6.3
Wind speed PM 850 mb at Atlanta (ms^{-1})	9.0	6.2	5.2	5.5
Wind speed PM 850 mb at Nashville (ms^{-1})	9.0	7.4	6.7	6.7
Wind direction yesterday 850 mb at Atlanta (degrees)	269	266	56	90
Wind direction yesterday 850 mb at Nashville (degrees)	276	266	248	207
Wind direction AM 850 mb at Atlanta (degrees)	280	253	288	90
Wind direction AM 850 mb at Nashville (degrees)	288	268	270	248
Wind direction PM 850 mb at Atlanta (degrees)	286	221	158	225
Wind direction PM 850 mb at Nashville (degrees)	274	245	231	214
Cloud average	1.8	2.0	1.9	1.9

Table 3-12d. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Greenville-Spartanburg.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-22.5, 22.5-30 and ≥ 30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Atlanta (μg/m³)	16	21	26	34
Yesterday's FM at Columbus (μg/m³)	12.3	15.6	18.3	26.2
Yesterday's FM at Charlotte (μg/m³)	13.4	17.9	21.5	29.0
Yesterday's FM at Greenville-Spartanburg (μg/m³)	13.1	17.9	21.9	29.3
Surface Meteorological Parameters				
Max. surface temperature (°C)	19.8	24.1	25.9	27.2
Min. surface temperature (°C)	9.5	13.1	15.6	17.0
Relative humidity (%)	67.0	68.7	70.6	71.7
Surface wind speed (ms^{-1})	2.3	2.0	1.7	1.7
Surface wind direction (degrees)	299	177	143	79
Persistence	0.7	0.8	0.7	0.8
Sea level pressure (mb)	1021	1021	1020	1021
Rainfall (inches)	0.2	0.1	0.1	0.1
Rain (# periods)	0.8	0.6	0.6	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	8.7	12.2	13.6	14.1
Temperature PM 850 mb (°C)	9.1	12.8	14.3	15.0
Stability at Atlanta (°C)	2.0	3.8	2.8	3.2
Geopotential height difference 700 mb at Atlanta (m)	1.4	-0.3	-4.7	5.6
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	12.8	8.3	7.1	6.3
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	14.2	10.2	8.9	7.2
Wind direction yesterday 700 mb at Atlanta (degrees)	272	280	307	322
Wind direction yesterday 700 mb at Greensboro (degrees)	271	288	303	306
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	8.8	5.6	5.2	4.3
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	9.8	6.6	5.6	5.3
Wind speed AM 850 mb at Atlanta (ms^{-1})	10.1	7.1	6.4	5.5
Wind speed AM 850 mb at Greensboro (ms^{-1})	10.5	7.5	6.8	5.5
Wind speed PM 850 mb at Atlanta (ms^{-1})	8.4	7.0	6.1	5.5
Wind speed PM 850 mb at Greensboro (ms^{-1})	9.4	7.7	6.9	5.8
Wind direction yesterday 850 mb at Atlanta (degrees)	270	252	284	153
Wind direction yesterday 850 mb at Greensboro (degrees)	263	273	286	312
Wind direction AM 850 mb at Atlanta (degrees)	272	250	276	233
Wind direction AM 850 mb at Greensboro (degrees)	283	275	285	300
Wind direction PM 850 mb at Atlanta (degrees)	274	242	240	180
Wind direction PM 850 mb at Greensboro (degrees)	270	258	274	260
Cloud average	1.9	1.8	2.0	1.9

Table 3-12e. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Hickory.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <20, 20-27.5, 27.5-32.5 and ≥ 32.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Charlotte (μg/m³)	14.0	19.0	24.3	26.7
Yesterday's FM at Greensboro (μg/m³)	13.4	18.5	25.6	26.8
Yesterday's FM at Knoxville (μg/m³)	14.7	22.5	27.8	32.4
Yesterday's FM at Winston-Salem (μg/m³)	13.7	19.6	25.5	27.2
Surface Meteorological Parameters				
Max. surface temperature (°C)	18.4	24.1	28.3	27.0
Min. surface temperature (°C)	8.0	13.5	17.4	15.6
Relative humidity (%)	66.5	71.3	71.7	72.7
Surface wind speed (ms^{-1})	1.8	1.2	1.0	1.0
Surface wind direction (degrees)	305	349	34	301
Persistence	0.8	0.7	0.7	0.7
Sea level pressure (mb)	1020	1020	1020	1020
Rainfall (inches)	0.1	0.1	0.1	0.0
Rain (# periods)	0.8	0.6	0.6	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	7.6	12.8	15.2	14.3
Temperature PM 850 mb (°C)	8.0	13.4	16.1	15.3
Stability at Greensboro (°C)	-0.1	1.3	0.8	0.5
Geopotential height difference 700 mb at Greensboro (m)	-0.3	2.2	5.0	3.7
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	14.2	9.3	7.2	7.5
Wind direction yesterday 700 mb at Greensboro (degrees)	271	292	304	315
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	9.9	6.2	5.1	4.5
Wind speed AM 850 mb at Greensboro (ms^{-1})	10.8	6.4	5.9	6.2
Wind speed PM 850 mb at Greensboro (ms^{-1})	9.2	6.8	4.8	5.1
Wind direction yesterday 850 mb at Greensboro (degrees)	270	267	323	309
Wind direction AM 850 mb at Greensboro (degrees)	288	275	333	276
Wind direction PM 850 mb at Greensboro (degrees)	274	255	225	292
Recirculation at Greensboro	0.0	0.1	0.1	0.1
Cloud average	1.7	1.7	1.6	1.8

Table 3-12f. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Huntington-Ashland.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-25, 25-32.5 and ≥ 32.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Louisville (μg/m³)	14.1	22.4	28.1	31.2
Yesterday's FM at Cincinnati (μg/m³)	15.0	21.7	28.0	33.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	15.4	23.2	25.9	29.5
Min. surface temperature (°C)	5.6	12.5	13.9	17.7
Relative humidity (%)	67.7	75.1	75.2	78.0
Surface wind speed (ms^{-1})	2.3	1.4	1.0	0.8
Surface wind direction (degrees)	244	150	180	150
Persistence	0.8	0.7	0.7	0.7
Sea level pressure (mb)	1022	1020	1021	1021
Rainfall (inches)	0.1	0.1	0.1	0.1
Rain (# periods)	1.2	0.9	0.8	0.7
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	5	12	13	16
Temperature PM 850 mb (°C)	5.5	12.7	14.2	16.9
Stability at Wilmington (°C)	-0.8	1.1	1.2	1.4
Geopotential height difference 700 mb at Wilmington (m)	2.2	2.5	-4.2	6.4
Wind speed yesterday 700 mb at Nashville (ms^{-1})	15.2	8.9	6.6	6.3
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	16.1	10.2	6.0	5.3
Wind direction yesterday 700 mb at Nashville (degrees)	274	280	225	90
Wind direction yesterday 700 mb at Roanoke (degrees)	276	279	301	0
Wind speed yesterday 850 mb at Wilmington (ms^{-1})	11.9	7.6	6.0	4.0
Wind speed yesterday 850 mb at Nashville (ms^{-1})	10.3	6.2	5.1	4.2
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	10.6	6.4	4.9	3.9
Wind speed AM 850 mb at Wilmington (ms^{-1})	11.8	8.8	6.2	5.3
Wind speed AM 850 mb at Nashville (ms^{-1})	10.9	7.6	5.6	4.6
Wind speed AM 850 mb at Roanoke (ms^{-1})	12.6	7.8	5.2	5.2
Wind speed PM 850 mb at Wilmington (ms^{-1})	10.7	8.7	7.5	5.9
Wind speed PM 850 mb at Nashville (ms^{-1})	9.1	7.3	5.3	5.1
Wind speed PM 850 mb at Roanoke (ms^{-1})	10.4	6.2	4.7	4.7
Wind direction yesterday 850 mb at Wilmington (degrees)	273	271	255	315
Wind direction yesterday 850 mb at Nashville (degrees)	275	260	210	90
Wind direction yesterday 850 mb at Roanoke (degrees)	266	269	243	326
Wind direction AM 850 mb at Wilmington (degrees)	286	283	262	270
Wind direction AM 850 mb at Nashville (degrees)	288	270	248	146
Wind direction AM 850 mb at Roanoke (degrees)	279	281	263	45
Wind direction PM 850 mb at Wilmington (degrees)	270	266	255	270
Wind direction PM 850 mb at Nashville (degrees)	273	238	233	166
Wind direction PM 850 mb at Roanoke (degrees)	276	257	207	0
Recirculation at Wilmington	0.0	0.1	0.1	0.1
Cloud average	1.8	1.8	1.8	1.8

Table 3-12g. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Jackson.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <15, 15-22.5, 22.5-27.5 and ≥27.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	17.1	22.9	29.1	39.5
Yesterday's FM at Memphis (μg/m³)	12.8	16.9	20.4	25.5
Yesterday's FM at Gulfport (μg/m³)	9.6	13.7	17.8	20.3
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	12.3	16.5	21.1	24.2
Surface Meteorological Parameters				
Max. surface temperature (°C)	22.4	25.7	25.7	29.8
Min. surface temperature (°C)	11.9	12.9	12.5	15.8
Relative humidity (%)	73.0	69.2	67.6	69.0
Surface wind speed (ms^{-1})	2.2	1.5	1.3	1.0
Surface wind direction (degrees)	143	96	108	117
Persistence	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1021	1021	1021	1020
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	0.9	0.5	0.5	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	11.2	12.4	11.9	15.3
Temperature PM 850 mb (°C)	11.3	13.1	12.7	15.8
Stability at Jacksonville (°C)	-0.3	1.5	1.7	2.5
Geopotential height difference 700 mb at Jacksonville (m)	-1.0	3.3	-6.2	4.0
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	12.6	8.4	9.3	6.6
Wind direction yesterday 700 mb at Jacksonville (degrees)	263	302	310	45
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	9.1	6.4	6.2	5.1
Wind speed AM 850 mb at Jacksonville (ms^{-1})	9.9	6.7	7.0	5.2
Wind speed PM 850 mb at Jacksonville (ms^{-1})	8.8	6.4	6.6	4.4
Wind direction yesterday 850 mb at Jacksonville (degrees)	251	319	27	45
Wind direction AM 850 mb at Jacksonville (degrees)	258	286	217	172
Wind direction PM 850 mb at Jacksonville (degrees)	260	210	194	180
Recirculation at Jacksonville	0.0	0.1	0.1	0.2
Cloud average	1.7	1.6	1.5	1.6

Table 3-12h. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Kingsport-Bristol.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-25, 25-32.5 and ≥ 32.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Louisville (μg/m³)	14.6	20.1	27.2	37.5
Yesterday's FM at Knoxville (μg/m³)	14.2	21.1	29.1	37.8
Yesterday's FM at Winston-Salem (μg/m³)	13.3	18.2	24.7	25.1
Yesterday's FM at Richmond (μg/m³)	12.6	16.2	20.9	21.0
Surface Meteorological Parameters				
Max. surface temperature (°C)	16.9	23.4	26.9	27.0
Min. surface temperature (°C)	5.5	10.2	14.2	13.4
Relative humidity (%)	70.0	71.2	73.0	72.7
Surface wind speed (ms^{-1})	1.7	1.0	0.8	0.6
Persistence	0.8	0.7	0.6	0.8
Sea level pressure (mb)	1022	1021	1020	1022
Surface wind direction (degrees)	280	260	255	276
Rainfall (inches)	0.1	0.1	0.0	0.0
Rain (# periods)	1.0	0.5	0.4	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	5.7	11.5	14.5	14.9
Temperature PM 850 mb (°C)	6.7	12.3	15.4	15.9
Stability at Roanoke (°C)	1.3	3.1	3.4	6.5
Geopotential height difference 700 mb at Roanoke (m)	-0.3	5.1	-0.6	-8.8
Wind speed yesterday 700 mb at Nashville (ms^{-1})	14.7	10.7	6.9	5.3
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	15.8	11.5	8.0	5.4
Wind direction yesterday 700 mb at Nashville (degrees)	273	276	278	180
Wind direction yesterday 700 mb at Roanoke (degrees)	272	284	295	349
Wind speed yesterday 850 mb at Nashville (ms^{-1})	9.9	8.0	5.0	4.5
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	10.4	7.1	5.0	4.6
Wind speed AM 850 mb at Nashville (ms^{-1})	10.4	9.3	6.6	6.6
Wind speed AM 850 mb at Roanoke (ms^{-1})	11.7	10.0	6.8	8.4
Wind speed PM 850 mb at Nashville (ms^{-1})	8.8	8.0	6.5	6.3
Wind speed PM 850 mb at Roanoke (ms^{-1})	9.9	7.5	5.6	5.8
Wind direction yesterday 850 mb at Nashville (degrees)	277	264	254	188
Wind direction yesterday 850 mb at Roanoke (degrees)	263	269	267	342
Wind direction AM 850 mb at Nashville (degrees)	288	269	262	220
Wind direction AM 850 mb at Roanoke (degrees)	278	274	280	330
Wind direction PM 850 mb at Nashville (degrees)	266	252	236	234
Wind direction PM 850 mb at Roanoke (degrees)	274	264	252	310
Cloud average	2.0	1.9	2.0	2.1

Table 3-12i. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Louisville.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <20, 20-27.5, 27.5-37.5 and ≥ 37.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Nashville (μg/m³)	13.0	18.2	22.1	26.9
Yesterday's FM at Louisville (μg/m³)	14.0	21.3	27.9	35.4
Yesterday's FM at Cincinnati (μg/m³)	15.1	21.4	26.8	30.9
Yesterday's FM at St. Louis (μg/m³)	13.6	19.9	22.9	29.0
Surface Meteorological Parameters				
Max. surface temperature (°C)	17.0	22.5	26.6	29.3
Min. surface temperature (°C)	7.8	12.6	16.7	18.8
Relative humidity (%)	67.3	69.9	70.1	67.3
Surface wind speed (ms^{-1})	3.1	2.3	1.9	1.5
Surface wind direction (degrees)	244	194	185	198
Persistence	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1021	1020	1020	1020
Rainfall (inches)	0.2	0.1	0.1	0.1
Rain (# periods)	1.0	0.7	0.6	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	5.2	10.2	13.6	15.1
Temperature PM 850 mb (°C)	5.6	10.8	14.5	15.9
Stability at Wilmington (°C)	-0.4	1.1	1.5	2.4
Geopotential height difference 700 mb at Wilmington (m)	-0.3	0.1	1.3	3.1
Wind speed yesterday 700 mb at Wilmington (ms^{-1})	15.9	10.6	8.6	6.5
Wind speed yesterday 700 mb at Nashville (ms^{-1})	14.6	9.3	7.0	5.8
Wind direction yesterday 700 mb at Wilmington (degrees)	278	278	287	301
Wind direction yesterday 700 mb at Nashville (degrees)	276	275	276	14
Wind speed yesterday 850 mb at Wilmington (ms^{-1})	11.5	7.7	6.5	4.4
Wind speed yesterday 850 mb at Nashville (ms^{-1})	9.8	6.6	4.9	4.1
Wind speed AM 850 mb at Wilmington (ms^{-1})	11.7	8.9	7.3	5.6
Wind speed AM 850 mb at Nashville (ms^{-1})	10.8	7.7	5.9	4.8
Wind speed PM 850 mb at Wilmington (ms^{-1})	11.1	9.0	6.8	5.6
Wind speed PM 850 mb at Nashville (ms^{-1})	9.6	7.2	5.7	4.9
Wind direction yesterday 850 mb at Wilmington (degrees)	271	262	255	264
Wind direction yesterday 850 mb at Nashville (degrees)	271	244	233	121
Wind direction AM 850 mb at Wilmington (degrees)	281	271	273	282
Wind direction AM 850 mb at Nashville (degrees)	284	260	253	264
Wind direction PM 850 mb at Wilmington (degrees)	271	260	260	275
Wind direction PM 850 mb at Nashville (degrees)	273	238	239	247
Cloud average	1.7	1.8	1.8	1.8

Table 3-12j. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Macon.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-25, 25-30 and ≥ 30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Atlanta (μg/m³)	16.2	22.3	26.1	32.5
Surface Meteorological Parameters				
Max. surface temperature (°C)	22.4	26.4	27.8	29.4
Min. surface temperature (°C)	11.2	12.7	14.2	14.7
Relative humidity (%)	68.7	68.6	66.4	69.1
Surface wind speed (ms^{-1})	2.3	1.6	1.3	0.9
Surface wind direction (degrees)	273	236	252	261
Persistence	0.8	0.8	0.8	0.6
Sea level pressure (mb)	1021	1021	1021	1020
Rainfall (inches)	0.2	0.1	0.0	0.1
Rain (# periods)	0.8	0.5	0.2	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	9.7	12.4	13.0	14.0
Temperature PM 850 mb (°C)	10.0	13.1	13.9	14.8
Stability at Atlanta (°C)	1.3	4.0	4.3	5.1
Geopotential height difference 700 mb at Atlanta (m)	0.0	2.4	-5.8	5.5
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	13.1	9.7	7.2	7.2
Wind direction yesterday 700 mb at Atlanta (degrees)	264	281	337	340
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	9.4	6.4	5.5	4.7
Wind speed AM 850 mb at Atlanta (ms^{-1})	10.7	7.5	5.6	5.3
Wind speed PM 850 mb at Atlanta (ms^{-1})	8.8	7.2	4.9	4.4
Wind direction yesterday 850 mb at Atlanta (degrees)	263	273	355	342
Wind direction AM 850 mb at Atlanta (degrees)	270	270	261	309
Wind direction PM 850 mb at Atlanta (degrees)	273	256	259	315
Recirculation at Atlanta	0.0	0.1	0.2	0.1
Cloud average	1.7	1.6	1.7	1.7

Table 3-12k. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Memphis.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-22.5, 22.5-30 and ≥ 30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	17.8	24.1	28.6	32.5
Yesterday's FM at Memphis (μg/m³)	12.5	17.7	21.9	29.4
Yesterday's FM at Nashville (μg/m³)	13.3	18.2	21.5	27.1
Yesterday's FM at St. Louis (μg/m³)	13.8	18.7	22.0	28.2
Yesterday's FM at Little Rock (μg/m³)	12.5	17.8	21.8	25.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	20.8	23.8	25.4	27.6
Min. surface temperature (°C)	11.5	13.8	15.0	17.6
Relative humidity (%)	66.1	65.3	64.0	64.2
Surface wind speed (ms^{-1})	3.2	2.5	2.3	2.2
Surface wind direction (degrees)	179	158	135	135
Persistence	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1021	1021	1021	1020
Rainfall (inches)	0.2	0.1	0.1	0.0
Rain (# periods)	0.9	0.6	0.5	0.2
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	8.8	11.1	12.0	13.7
Temperature PM 850 mb (°C)	9.2	11.7	12.7	14.3
Stability at Nashville (°C)	-0.5	1.1	1.5	1.3
Geopotential height difference 700 mb at Nashville (m)	-0.6	0.8	3.3	-6.7
Wind speed yesterday 700 mb at Nashville (ms^{-1})	14.1	9.8	8.4	7.6
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	13.2	9.5	7.6	8.2
Wind direction yesterday 700 mb at Nashville (degrees)	272	288	299	12
Wind direction yesterday 700 mb at Little Rock (degrees)	277	284	293	18
Wind speed yesterday 850 mb at Nashville (ms^{-1})	9.7	6.5	5.6	5.1
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	9.5	7.2	5.5	5.5
Wind speed AM 850 mb at Nashville (ms^{-1})	10.6	7.8	6.4	5.5
Wind speed AM 850 mb at Little Rock (ms^{-1})	10.2	7.4	6.0	5.8
Wind speed PM 850 mb at Nashville (ms^{-1})	9.5	7.1	5.9	5.8
Wind speed PM 850 mb at Little Rock (ms^{-1})	9.3	7.6	5.9	6.0
Wind direction yesterday 850 mb at Nashville (degrees)	260	282	278	336
Wind direction yesterday 850 mb at Little Rock (degrees)	265	260	228	131
Wind direction AM 850 mb at Nashville (degrees)	276	281	279	287
Wind direction AM 850 mb at Little Rock (degrees)	277	271	240	240
Wind direction PM 850 mb at Nashville (degrees)	264	271	240	290
Wind direction PM 850 mb at Little Rock (degrees)	268	255	225	169
Cloud average	1.9	1.8	1.8	1.9

Table 3-12l. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Montgomery.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-25, 25-30 and ≥30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	16.3	24.6	33.2	41.5
Yesterday's FM at Atlanta (μg/m³)	16.4	22.1	28.2	33.5
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	12.4	16.4	20.4	23.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	23.2	27.3	30.0	30.0
Min. surface temperature (°C)	11.9	14.1	17.0	17.6
Relative humidity (%)	71.5	68.9	69.2	68.4
Surface wind speed (ms^{-1})	2.3	1.6	1.4	0.9
Surface wind direction (degrees)	180	106	117	135
Persistence	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1021	1020	1020	1020
Rainfall (inches)	0.1	0.1	0.1	0.0
Rain (# periods)	0.8	0.5	0.3	0.6
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	10.3	12.6	14.7	14.9
Temperature PM 850 mb (°C)	10.5	12.9	15.8	15.7
Stability at Birmingham (°C)	0.1	1.5	2.0	2.4
Geopotential height difference 700 mb at Birmingham (m)	1.9	-1.2	1.1	-0.6
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	12.3	8.9	6.9	6.7
Wind direction yesterday 700 mb at Birmingham (degrees)	264	293	293	338
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	8.8	6.2	5.2	4.3
Wind speed AM 850 mb at Birmingham (ms^{-1})	10.0	7.1	5.0	5.0
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.5	6.4	4.8	4.1
Wind direction yesterday 850 mb at Birmingham (degrees)	253	285	0	329
Wind direction AM 850 mb at Birmingham (degrees)	265	267	219	276
Wind direction PM 850 mb at Birmingham (degrees)	274	264	180	307
Recirculation at Birmingham	0.0	0.1	0.1	0.3
Cloud average	1.7	1.6	1.6	1.9

Table 3-12m. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Nashville.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-25, 25-32.5 and ≥ 32.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	17.4	25.1	29.3	32.9
Yesterday's FM at Memphis (μg/m³)	12.5	17.3	23.1	26.3
Yesterday's FM at Nashville (μg/m³)	12.9	18.0	25.0	28.5
Yesterday's FM at Louisville (μg/m³)	14.8	20.2	25.8	32.4
Yesterday's FM at Cincinnati (μg/m³)	15.7	20.0	26.0	31.3
Yesterday's FM at Knoxville (μg/m³)	15.4	20.1	24.7	30.1
Surface Meteorological Parameters				
Max. surface temperature (°C)	19.3	23.5	26.6	29.2
Min. surface temperature (°C)	9.3	12.6	15.8	17.3
Relative humidity (%)	67.4	69.2	68.9	66.6
Surface wind speed (ms^{-1})	2.7	2.0	1.7	1.5
Surface wind direction (degrees)	211	175	147	153
Persistence	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1021	1021	1020	1021
Rainfall (inches)	0.2	0.1	0.1	0.0
Rain (# periods)	0.9	0.6	0.5	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	7.7	11.3	13.4	15.4
Temperature PM 850 mb (°C)	8.2	11.9	14.3	15.9
Stability at Nashville (°C)	-0.4	1.0	1.1	1.0
Geopotential height difference 700 mb at Nashville (m)	-1.4	2.6	2.1	2.0
Wind speed yesterday 700 mb at Nashville (ms^{-1})	14.3	9.1	7.4	7.0
Wind direction yesterday 700 mb at Nashville (degrees)	273	285	304	45
Wind speed yesterday 850 mb at Nashville (ms^{-1})	9.7	6.5	4.6	4.9
Wind speed AM 850 mb at Nashville (ms^{-1})	10.7	7.6	5.7	5.8
Wind speed PM 850 mb at Nashville (ms^{-1})	9.4	7.1	5.6	5.1
Wind direction yesterday 850 mb at Nashville (degrees)	264	262	291	333
Wind direction AM 850 mb at Nashville (degrees)	278	270	278	278
Wind direction PM 850 mb at Nashville (degrees)	267	256	254	263
Recirculation at Nashville	0.0	0.1	0.1	0.2
Cloud average	1.8	1.7	1.7	1.8

Table 3-12n. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Raleigh.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-22.5, 22.5-30 and ≥ 30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Charlotte (μg/m³)	13.8	18.6	22.1	28.6
Yesterday's FM at Richmond (μg/m³)	12.5	16.8	19.9	27.2
Yesterday's FM at Raleigh (μg/m³)	13.0	18.2	21.8	29.4
Yesterday's FM at Winston-Salem (μg/m³)	13.8	18.5	22.7	28.1
Surface Meteorological Parameters				
Max. surface temperature (°C)	19.6	24.9	27.5	30.9
Min. surface temperature (°C)	8.9	12.3	15.0	17.9
Relative humidity (%)	68.9	69.6	70.4	69.7
Surface wind speed (ms^{-1})	2.4	2.1	1.8	1.9
Surface wind direction (degrees)	274	208	221	231
Persistence	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1022	1021	1020	1018
Rainfall (inches)	0.1	0.1	0.1	0.0
Rain (# periods)	0.8	0.6	0.4	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	7.6	11.9	13.7	16.0
Temperature PM 850 mb (°C)	8.1	12.6	14.5	16.6
Stability at Greensboro (°C)	-0.2	1.9	1.3	1.2
Geopotential height difference 700 mb at Greensboro (m)	-1.3	3.5	0.7	0.2
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	13.8	10.7	9.2	7.5
Wind direction yesterday 700 mb at Greensboro (degrees)	272	282	302	298
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	9.5	7.2	5.8	5.2
Wind speed AM 850 mb at Greensboro (ms^{-1})	10.3	8.0	7.0	6.0
Wind speed PM 850 mb at Greensboro (ms^{-1})	9.3	7.9	6.9	6.1
Wind direction yesterday 850 mb at Greensboro (degrees)	263	269	278	298
Wind direction AM 850 mb at Greensboro (degrees)	281	283	277	296
Wind direction PM 850 mb at Greensboro (degrees)	269	262	263	277
Recirculation at Greensboro	0.0	0.1	0.1	0.1
Cloud average	1.8	1.6	1.7	1.6

Table 3-12o. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Richmond.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-25, 25-30 and ≥30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Richmond (μg/m³)	12.2	17.9	21.7	27.7
Yesterday's FM at Winston-Salem (μg/m³)	13.5	19.6	22.7	28.1
Yesterday's FM at Washington, D.C. (μg/m³)	14.1	20.5	24.7	34.0
Surface Meteorological Parameters				
Max. surface temperature (°C)	18.7	23.9	25.0	29.9
Min. surface temperature (°C)	8.3	12.2	14.6	18.5
Relative humidity (%)	69.1	72.3	74.9	73.2
Surface wind speed (ms^{-1})	2.9	2.3	2.0	2.0
Surface wind direction (degrees)	289	179	149	183
Persistence	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1022	1021	1020	1019
Rainfall (inches)	0.1	0.1	0.1	0.1
Rain (# periods)	0.9	0.6	0.7	0.5
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	5.1	10.6	11.8	15.4
Temperature PM 850 mb (°C)	6.1	11.3	12.9	16.3
Stability at Dulles (°C)	-0.3	2.0	1.0	1.9
Geopotential height difference 700 mb at Dulles (m)	-3.1	5.2	9.4	-3.8
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	15.0	11.1	9.5	6.7
Wind speed yesterday 700 mb at Dulles (ms^{-1})	15.0	11.7	10.7	8.8
Wind direction yesterday 700 mb at Roanoke (degrees)	276	283	281	297
Wind direction yesterday 700 mb at Dulles (degrees)	276	283	288	300
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	9.8	7.1	6.1	4.8
Wind speed yesterday 850 mb at Dulles (ms^{-1})	10.8	8.3	7.2	6.6
Wind speed AM 850 mb at Roanoke (ms^{-1})	11.4	9.8	7.7	7.4
Wind speed AM 850 mb at Dulles (ms^{-1})	11.1	8.4	7.0	7.0
Wind speed PM 850 mb at Roanoke (ms^{-1})	9.4	7.9	6.5	6.5
Wind speed PM 850 mb at Dulles (ms^{-1})	10.6	9.1	7.3	7.6
Wind direction yesterday 850 mb at Roanoke (degrees)	264	263	282	284
Wind direction yesterday 850 mb at Dulles (degrees)	272	274	285	297
Wind direction AM 850 mb at Roanoke (degrees)	272	276	277	270
Wind direction AM 850 mb at Dulles (degrees)	285	276	291	283
Wind direction PM 850 mb at Roanoke (degrees)	270	257	255	264
Wind direction PM 850 mb at Dulles (degrees)	277	265	281	264
Cloud average	2.0	1.9	2.0	1.8

Table 3-12p. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the STN Site Savannah.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <17.5, 17.5-22.5, 22.5-27.5 and ≥27.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Atlanta (μg/m³)	17.4	22.1	26.1	26.8
Yesterday's FM at Charleston (μg/m³)	11.0	15.2	19.2	21.8
Surface Meteorological Parameters				
Max. surface temperature (°C)	24.4	25.5	27.1	26.1
Min. surface temperature (°C)	13.9	12.4	14.1	13.1
Relative humidity (%)	74.1	72.3	72.9	70.2
Surface wind speed (ms^{-1})	2.3	1.7	1.3	1.4
Surface wind direction (degrees)	193	305	270	180
Persistence	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1021	1021	1020	1020
Rainfall (inches)	0.1	0.0	0.1	0.1
Rain (# periods)	0.7	0.4	0.4	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	10.8	11.4	12.5	12.6
Temperature PM 850 mb (°C)	11.3	12.2	13.3	12.7
Stability at Charleston (°C)	-1.2	1.2	1.3	0.6
Geopotential height difference 700 mb at Charleston (m)	1.6	14.8	1.1	5.2
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	11.7	10.4	8.3	11.8
Wind speed yesterday 700 mb at Charleston (ms^{-1})	11.5	10.2	9.2	10.5
Wind direction yesterday 700 mb at Atlanta (degrees)	267	294	305	315
Wind direction yesterday 700 mb at Charleston (degrees)	268	300	308	321
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	8.5	6.7	5.9	7.1
Wind speed yesterday 850 mb at Charleston (ms^{-1})	8.8	7.7	6.2	7.6
Wind speed AM 850 mb at Atlanta (ms^{-1})	9.4	8.0	7.0	8.5
Wind speed AM 850 mb at Charleston (ms^{-1})	9.1	8.0	6.3	8.0
Wind speed PM 850 mb at Atlanta (ms^{-1})	7.8	7.5	5.9	6.0
Wind speed PM 850 mb at Charleston (ms^{-1})	8.6	7.5	7.1	7.1
Wind direction yesterday 850 mb at Atlanta (degrees)	259	302	299	307
Wind direction yesterday 850 mb at Charleston (degrees)	257	302	310	306
Wind direction AM 850 mb at Atlanta (degrees)	267	285	281	319
Wind direction AM 850 mb at Charleston (degrees)	261	292	295	304
Wind direction PM 850 mb at Atlanta (degrees)	267	276	279	302
Wind direction PM 850 mb at Charleston (degrees)	273	310	318	319
Cloud	1.9	1.7	1.9	1.8

A summary of the characteristics and categorical variations in selected parameters associated with poor visibility for each site follows:

For Birmingham, high $PM_{2.5}$ is associated with

- High temperatures.
- High $PM_{2.5}$ on previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and northerly winds near the surface.
- Stable lapse rates.

For Charlotte, high $PM_{2.5}$ for is associated with

- High temperatures.
- High $PM_{2.5}$ on previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and southerly winds near the surface.

For Chattanooga, high $PM_{2.5}$ is associated with

- Moderate temperatures.
- Very high $PM_{2.5}$ on previous day (potentially upwind sites).
- Low wind speeds near the surface and aloft.
- Easterly winds aloft and southerly winds near the surface.
- Stable conditions.
- Slightly higher RH (compared to lower $PM_{2.5}$ bins).

For Greenville-Spartanburg, high $PM_{2.5}$ is associated with

- Moderate to high temperatures.
- High $PM_{2.5}$ on previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft (slight tendency for lower wind speeds compared to lower $PM_{2.5}$ bins).
- Southwesterly winds aloft and easterly winds near the surface.

For Hickory, high $PM_{2.5}$ is associated with

- Moderate to high temperatures.
- High $PM_{2.5}$ on previous day (potentially upwind sites).
- Very low wind speeds near the surface.
- Westerly winds aloft and near the surface.

High $PM_{2.5}$ for Huntington-Ashland is associated with

- Moderate to high temperatures.
- High relative humidity.
- High $PM_{2.5}$ on previous day (potentially upwind sites).
- Very low wind speeds near the surface and low wind speeds aloft.
- Westerly winds aloft and southeasterly winds near the surface.
- Stable conditions.

For Jackson, high $PM_{2.5}$ is associated with

- High temperatures.
- High $PM_{2.5}$ on previous day (potentially upwind sites).
- Low wind speeds, especially near the surface.
- Southerly winds aloft and easterly winds near the surface (easterly surface winds appear for all categories).
- Stable lapse rates.

For Kingsport-Bristol, high $PM_{2.5}$ is associated with

- Moderate temperatures.
- High $PM_{2.5}$ on previous day (potential upwind sites).
- Very low wind speeds near the surface; moderate wind speeds aloft.
- Northwesterly winds aloft and westerly winds near the surface.
- Stable conditions.

For Louisville, high $PM_{2.5}$ is associated with

- Moderate temperatures.
- High $PM_{2.5}$ on previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and southerly winds near the surface.
- Stable conditions.

High $PM_{2.5}$ for Macon is associated with

- Moderate temperatures.
- High $PM_{2.5}$ on previous day (potentially upwind sites).
- Very low wind speeds near the surface and low wind speeds aloft.

- West-northwesterly winds aloft and westerly winds near the surface.
- Stable conditions.

High $PM_{2.5}$ for Memphis is associated with

- Moderate to high temperatures.
- High $PM_{2.5}$ on previous day (local & potentially upwind sites).
- Moderate wind speeds near the surface and low wind speeds aloft.
- Westerly winds aloft and southeasterly winds near the surface.

For Montgomery, high $PM_{2.5}$ is associated with

- Moderate temperatures.
- High $PM_{2.5}$ on previous day (potentially upwind sites).
- Low wind speeds, especially near the surface.
- Westerly winds aloft and southeasterly winds near the surface.
- Stable conditions.

For Nashville, high $PM_{2.5}$ is associated with

- High temperatures.
- High $PM_{2.5}$ on previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and south-southeasterly winds near the surface.

For Raleigh, high $PM_{2.5}$ is associated with

- High temperatures.
- High $PM_{2.5}$ on previous day (local & potentially upwind sites).
- Low to moderate wind speeds near the surface and aloft.
- Westerly winds aloft and southwesterly winds near the surface.

For Richmond, high $PM_{2.5}$ is associated with

- High temperatures.
- High $PM_{2.5}$ on previous day (local & potentially upwind sites).
- Low to moderate wind speeds.
- Westerly winds aloft and southerly winds near the surface.
- Stable conditions.

For Savannah, high $PM_{2.5}$ is associated with

- Moderate to high temperatures.
- Relatively high $PM_{2.5}$ on previous day (potentially upwind).
- Low to moderate wind speeds near the surface and aloft (high bins are not distinguished by wind speed).
- Westerly winds aloft and southerly winds near the surface.

Table 3-13 summarizes the data for the SEARCH sites, for the inland sites and then the coastal sites.

Table 3-13a. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the SEARCH Site Atlanta (Jefferson St.).

The ranges in PM2.5 for Categories 1 through 4 are as follows: <20, 20-27.5, 27.5-35 and ≥ 35 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Atlanta (μg/m³)	16.3	22.9	27.2	33.8
Yesterday's FM at Birmingham (μg/m³)	16.8	25.4	30.5	37.1
Surface Meteorological Parameters				
Max. surface temperature (°C)	20.9	25.6	26.7	27.4
Min. surface temperature (°C)	11.4	15.0	15.7	15.7
Relative humidity (%)	68.4	68.1	67.1	67.0
Surface wind speed (ms^{-1})	1.8	1.2	1.0	0.9
Surface wind direction (degrees)	275	227	241	275
Persistence	0.8	0.8	0.7	0.8
Station pressure (mb)	989	989	989	989
Rainfall (inches)	0.2	0.1	0.1	0.0
Rain (# periods)	0.8	0.5	0.6	0.1
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	10.1	13.0	13.3	14.2
Temperature PM 850 mb (°C)	10.2	13.8	14.0	15.0
Stability at Atlanta (°C)	1.8	4.0	4.3	5.8
Geopotential height difference 700 mb at Atlanta (m)	-0.2	3.2	-1.1	8.0
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	12.7	8.5	7.1	6.4
Wind direction yesterday 700 mb at Atlanta (degrees)	268	299	305	346
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	8.8	5.5	5.0	4.1
Wind speed AM 850 mb at Atlanta (ms^{-1})	10.3	6.3	6.0	4.6
Wind speed PM 850 mb at Atlanta (ms^{-1})	8.7	5.9	5.8	4.6
Wind direction yesterday 850 mb at Atlanta (degrees)	260	291	322	324
Wind direction AM 850 mb at Atlanta (degrees)	265	273	287	278
Wind direction PM 850 mb at Atlanta (degrees)	271	249	244	276
Recirculation at Atlanta	0.0	0.1	0.2	0.3
Cloud average	1.7	1.7	1.7	1.5

Table 3-13b. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the SEARCH Site Yorkville.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <15, 15-22.5, 22.5-30 and ≥ 30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Atlanta (μg/m³)	16.1	21.5	27.1	33.7
Yesterday's FM at Birmingham (μg/m³)	16.1	24.5	29.8	40.2
Yesterday's FM at Yorkville (μg/m³)	10.6	16.7	21.8	29.6
Surface Meteorological Parameters				
Max. surface temperature (°C)	18.5	25.0	27.2	28.6
Min. surface temperature (°C)	9.1	15.2	17.3	18.6
Relative humidity (%)	73.3	72.5	72.1	73.6
Surface wind speed (ms^{-1})	2.8	2.2	2.0	1.5
Surface wind direction (degrees)	271	117	79	79
Persistence	0.8	0.8	0.8	0.7
Station pressure (mb)	975	975	974	975
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	1.0	0.7	0.7	0.5
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	9.5	13.2	14.5	15.2
Temperature PM 850 mb (°C)	9.5	14.0	15.1	16.4
Stability at Atlanta (°C)	2.1	3.0	3.0	3.4
Geopotential height difference 700 mb at Atlanta (m)	-0.3	2.5	-0.1	4.2
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	13.4	8.0	6.5	5.7
Wind direction yesterday 700 mb at Atlanta (degrees)	268	291	317	17
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	9.2	5.4	4.8	4.0
Wind speed AM 850 mb at Atlanta (ms^{-1})	10.6	6.5	5.8	4.0
Wind speed PM 850 mb at Atlanta (ms^{-1})	8.9	6.3	5.3	4.3
Wind direction yesterday 850 mb at Atlanta (degrees)	261	293	0	21
Wind direction AM 850 mb at Atlanta (degrees)	269	257	289	45
Wind direction PM 850 mb at Atlanta (degrees)	274	218	257	58
Recirculation at Atlanta	0.0	0.1	0.2	0.3
Cloud average	1.7	1.7	1.7	1.7

Table 3-13c. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the SEARCH Site Birmingham.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <20, 20-30, 30-37.5 and ≥ 37.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	16.5	24.1	29.5	38.2
Yesterday's FM at Atlanta (μg/m³)	16.7	21.6	23.7	30.8
Yesterday's FM at Memphis (μg/m³)	12.7	17.0	19.9	23.3
Yesterday's FM at Nashville (μg/m³)	13.2	17.5	20.6	23.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	21.6	26.0	27.5	28.4
Min. surface temperature (°C)	11.5	14.3	13.9	14.7
Relative humidity (%)	70.9	66.4	63.0	62.3
Surface wind speed (ms^{-1})	1.8	1.3	1.0	0.8
Surface wind direction (degrees)	247	73	18	345
Persistence	0.8	0.8	0.7	0.7
Station pressure (mb)	998	998	998	1000
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	1.0	0.6	0.4	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	10.2	12.5	13.0	13.9
Temperature PM 850 mb (°C)	10.3	13.2	13.9	14.7
Stability at Birmingham (°C)	-0.3	2.1	3.1	3.5
Geopotential height difference 700 mb at Birmingham (m)	-1.7	5.2	2.3	5.1
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	12.8	8.7	7.7	6.9
Wind direction yesterday 700 mb at Birmingham (degrees)	265	298	307	329
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	9.1	5.9	4.6	4.5
Wind speed AM 850 mb at Birmingham (ms^{-1})	10.3	6.6	5.6	5.0
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.9	6.3	5.5	4.3
Wind direction yesterday 850 mb at Birmingham (degrees)	252	345	349	14
Wind direction AM 850 mb at Birmingham (degrees)	264	251	283	243
Wind direction PM 850 mb at Birmingham (degrees)	273	219	321	270
Recirculation at Birmingham	0.02	0.08	0.13	0.28
Cloud average	1.8	1.6	1.6	1.5

Table 3-13d. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the SEARCH Site Centreville.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <15, 15-22.5, 22.5-30 and ≥ 30 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	16.6	25.4	31.4	35.8
Yesterday's FM at Atlanta (μg/m³)	16.7	22.1	26.7	28.9
Yesterday's FM at Centreville (μg/m³)	10.2	16.8	22.4	26.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	21.4	27.4	30.4	29.7
Min. surface temperature (°C)	11.1	16.0	18.8	17.9
Relative humidity (%)	73.8	71.3	70.7	67.5
Surface wind speed (ms^{-1})	2.1	1.7	1.3	1.2
Surface wind direction (degrees)	207	80	40	341
Persistence	0.8	0.8	0.7	0.7
Station pressure (mb)	1005	1004	1004	1005
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	0.8	0.5	0.3	0.2
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	9.9	13.4	14.8	14.1
Temperature PM 850 mb (°C)	10.1	14.0	15.8	14.9
Stability at Birmingham (°C)	0.1	1.6	1.6	2.6
Geopotential height difference 700 mb at Birmingham (m)	-0.1	1.7	0.3	4.9
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	12.7	7.9	6.9	7.5
Wind direction yesterday 700 mb at Birmingham (degrees)	265	287	337	335
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	268	224	27	344
Wind speed AM 850 mb at Birmingham (ms^{-1})	10.0	6.7	5.2	5.5
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.7	6.5	4.9	4.5
Wind direction yesterday 850 mb at Birmingham (degrees)	256	289	0	6
Wind direction AM 850 mb at Birmingham (degrees)	266	241	254	304
Wind direction PM 850 mb at Birmingham (degrees)	268	224	27	344
Recirculation at Birmingham	0.0	0.1	0.2	0.2
Cloud average	1.8	1.6	1.7	1.7

Table 3-13e. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the SEARCH Site Pensacola.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <15, 15-22.5, 22.5-27.5 and ≥27.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Gulfport (μg/m³)	9.4	13.9	17.0	20.8
Yesterday's FM at Pensacola (μg/m³)	10.7	16.1	21.0	24.8
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	12.1	16.8	19.5	21.8
Surface Meteorological Parameters				
Max. surface temperature (°C)	24.0	24.2	24.7	26.8
Min. surface temperature (°C)	16.1	14.4	14.3	17.2
Relative humidity (%)	79.7	75.4	74.8	73.8
Surface wind speed (ms^{-1})	1.6	1.2	1.0	0.8
Surface wind direction (degrees)	110	69	37	225
Persistence	0.8	0.7	0.7	0.6
Station pressure (mb)	1019	1020	1021	1019
Rainfall (inches)	0.2	0.1	0.0	0.1
Rain (# periods)	1.0	0.5	0.3	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	12.8	12.4	12.3	13.5
Temperature PM 850 mb (°C)	12.8	12.9	12.7	14.0
Stability at Tallahassee (°C)	-0.4	1.1	1.7	1.7
Geopotential height difference 700 mb at Tallahassee (m)	-3.2	7.3	8.3	3.0
Wind speed yesterday 700 mb at Slidell (ms^{-1})	10.6	8.9	7.9	6.2
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	10.1	9.2	9.1	7.9
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	12.1	10.6	9.7	7.5
Wind direction yesterday 700 mb at Slidell (degrees)	259	294	295	312
Wind direction yesterday 700 mb at Tallahassee (degrees)	256	296	309	305
Wind direction yesterday 700 mb at Birmingham (degrees)	261	291	305	299
Wind speed yesterday 850 mb at Slidell (ms^{-1})	8.1	6.2	6.3	4.5
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	7.5	6.2	5.9	5.6
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	8.6	6.8	6.3	4.9
Wind speed AM 850 mb at Slidell (ms^{-1})	8.8	6.3	5.8	4.7
Wind speed AM 850 mb at Tallahassee (ms^{-1})	8.4	6.4	6.0	5.2
Wind speed AM 850 mb at Birmingham (ms^{-1})	9.9	7.6	6.9	5.0
Wind speed PM 850 mb at Slidell (ms^{-1})	8.1	6.4	6.1	4.9
Wind speed PM 850 mb at Tallahassee (ms^{-1})	7.7	5.9	5.5	5.3
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.6	6.9	6.7	4.9
Wind direction yesterday 850 mb at Slidell (degrees)	250	330	345	349
Wind direction yesterday 850 mb at Tallahassee (degrees)	245	330	340	334
Wind direction yesterday 850 mb at Birmingham (degrees)	242	316	315	337
Wind direction AM 850 mb at Slidell (degrees)	235	260	207	270
Wind direction AM 850 mb at Tallahassee (degrees)	236	277	302	286
Wind direction AM 850 mb at Birmingham (degrees)	253	277	291	294
Wind direction PM 850 mb at Slidell (degrees)	271	279	304	0
Wind direction PM 850 mb at Tallahassee (degrees)	258	312	353	326
Wind direction PM 850 mb at Birmingham (degrees)	265	259	305	302
Cloud average	1.9	1.7	1.5	1.7

Table 3-13f. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the SEARCH Site Outlying Landing Field (OLF).

The ranges in PM2.5 for Categories 1 through 4 are as follows: <12.5, 12.5-20, 20-27.5 and ≥27.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Gulfport (μg/m³)	9.3	14.0	18.1	23.9
Yesterday's FM at Pensacola (μg/m³)	10.6	16.0	21.7	26.0
Yesterday's FM at Outer Landing Field (μg/m³)	9.3	14.2	19.4	29.8
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	12.0	16.6	20.4	23.7
Surface Meteorological Parameters				
Max. surface temperature (°C)	23.4	25.4	28.1	29.4
Min. surface temperature (°C)	14.1	14.8	16.6	17.9
Relative humidity (%)	78.8	75.0	71.3	72.9
Surface wind speed (ms^{-1})	2.2	1.7	1.5	1.4
Surface wind direction (degrees)	126	72	330	292
Persistence	0.8	0.7	0.7	0.7
Station pressure (mb)	1014	1015	1014	1013
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	1.0	0.6	0.4	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	12.6	13.1	14.3	15.3
Temperature PM 850 mb (°C)	12.7	13.4	14.8	15.6
Stability at Tallahassee (°C)	-0.3	0.8	0.7	-0.1
Geopotential height difference 700 mb at Tallahassee (m)	-2.2	5.7	2.3	1.0
Wind speed yesterday 700 mb at Slidell (ms^{-1})	10.9	8.1	6.2	5.8
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	10.4	8.1	8.2	8.0
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	12.4	9.6	8.0	7.1
Wind direction yesterday 700 mb at Slidell (degrees)	259	293	313	326
Wind direction yesterday 700 mb at Tallahassee (degrees)	257	298	318	300
Wind direction yesterday 700 mb at Birmingham (degrees)	261	293	310	310
Wind speed yesterday 850 mb at Slidell (ms^{-1})	8.2	6.0	5.3	4.7
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	7.7	5.9	5.6	5.2
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	8.8	6.3	5.6	4.0
Wind speed AM 850 mb at Slidell (ms^{-1})	8.8	6.2	5.5	4.8
Wind speed AM 850 mb at Tallahassee (ms^{-1})	8.5	6.2	5.5	6.2
Wind speed AM 850 mb at Birmingham (ms^{-1})	10.1	7.1	6.2	5.1
Wind speed PM 850 mb at Slidell (ms^{-1})	8.0	6.4	5.7	4.5
Wind speed PM 850 mb at Tallahassee (ms^{-1})	7.7	5.9	5.3	5.8
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.7	6.6	5.8	4.5
Wind direction yesterday 850 mb at Slidell (degrees)	257	330	9	6
Wind direction yesterday 850 mb at Tallahassee (degrees)	248	339	346	324
Wind direction yesterday 850 mb at Birmingham (degrees)	247	307	336	325
Wind direction AM 850 mb at Slidell (degrees)	239	234	201	214
Wind direction AM 850 mb at Tallahassee (degrees)	240	264	294	253
Wind direction AM 850 mb at Birmingham (degrees)	257	270	285	285
Wind direction PM 850 mb at Slidell (degrees)	269	291	32	18
Wind direction PM 850 mb at Tallahassee (degrees)	262	322	6	330
Wind direction PM 850 mb at Birmingham (degrees)	266	259	326	278
Cloud average	1.9	1.7	1.7	1.8

Table 3-13g. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the SEARCH Site Gulfport.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <12.5, 12.5-20, 20-25 and ≥25 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Gulfport (μg/m³)	9.1	13.9	19.2	23.7
Yesterday's FM at Pensacola (μg/m³)	11.1	16.0	20.8	25.1
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	11.8	16.4	21.9	25.2
Surface Meteorological Parameters				
Max. surface temperature (°C)	23.5	26.1	27.0	28.8
Min. surface temperature (°C)	15.1	16.4	16.3	18.3
Relative humidity (%)	78.3	76.0	74.1	72.6
Surface wind speed (ms^{-1})	2.0	1.5	1.2	1.0
Surface wind direction (degrees)	170	176	195	259
Persistence	0.8	0.7	0.6	0.6
Station pressure (mb)	1017	1017	1018	1017
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	0.9	0.4	0.3	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	11.9	13.2	13.1	13.6
Temperature PM 850 mb (°C)	12.0	13.5	13.5	14.5
Stability at Slidell (°C)	-0.2	1.1	2.2	1.5
Geopotential height difference 700 mb at Slidell (m)	-0.4	1.7	2.9	0.6
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	12.5	9.3	8.1	6.5
Wind speed yesterday 700 mb at Slidell (ms^{-1})	11.0	8.1	6.7	6.2
Wind direction yesterday 700 mb at Jacksonville (degrees)	262	292	297	325
Wind direction yesterday 700 mb at Slidell (degrees)	257	295	320	340
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	9.1	6.4	5.5	5.0
Wind speed yesterday 850 mb at Slidell (ms^{-1})	8.3	6.0	5.7	5.3
Wind speed AM 850 mb at Jacksonville (ms^{-1})	10.0	7.2	5.8	4.9
Wind speed AM 850 mb at Slidell (ms^{-1})	8.9	6.3	5.5	4.6
Wind speed PM 850 mb at Jacksonville (ms^{-1})	8.9	6.9	5.9	5.0
Wind speed PM 850 mb at Slidell (ms^{-1})	8.1	6.5	5.6	4.8
Wind direction yesterday 850 mb at Jacksonville (degrees)	244	289	319	0
Wind direction yesterday 850 mb at Slidell (degrees)	248	346	14	7
Wind direction AM 850 mb at Jacksonville (degrees)	254	268	266	294
Wind direction AM 850 mb at Slidell (degrees)	237	245	186	342
Wind direction PM 850 mb at Jacksonville (degrees)	259	244	208	0
Wind direction PM 850 mb at Slidell (degrees)	264	331	342	6
Recirculation at Slidell	0.0	0.1	0.2	0.2
Cloud average	1.9	1.7	1.6	1.7

Table 3-13h. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the SEARCH Site Oak Grove.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <12.5, 12.5-20, 20-27.5 and ≥27.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Gulfport (μg/m³)	9.1	14.2	19.3	21.4
Yesterday's FM at Oak Grove (μg/m³)	9.3	14.2	19.7	25.1
Yesterday's FM at Pensacola (μg/m³)	11.1	16.6	21.3	22.9
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	11.7	16.5	21.6	24.2
Surface Meteorological Parameters				
Max. surface temperature (°C)	22.6	26.6	28.4	27.3
Min. surface temperature (°C)	12.4	15.1	16.0	16.6
Relative humidity (%)	75.2	72.9	68.0	66.1
Surface wind speed (ms^{-1})	1.8	1.6	1.2	1.2
Surface wind direction (degrees)	120	111	62	356
Persistence	0.8	0.8	0.7	0.7
Station pressure (mb)	1010	1010	1011	1010
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	0.8	0.5	0.3	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	11.7	13.8	14.2	13.1
Temperature PM 850 mb (°C)	11.8	14.1	14.8	13.9
Stability at Slidell (°C)	0.1	0.6	1.2	1.1
Geopotential height difference 700 mb at Slidell (m)	-0.2	1.3	1.7	4.3
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	12.5	8.7	7.6	8.5
Wind speed yesterday 700 mb at Slidell (ms^{-1})	11.0	7.4	6.4	7.6
Wind direction yesterday 700 mb at Jacksonville (degrees)	265	287	301	293
Wind direction yesterday 700 mb at Slidell (degrees)	259	292	333	324
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	9.1	6.2	5.3	5.6
Wind speed yesterday 850 mb at Slidell (ms^{-1})	8.2	5.9	5.3	5.8
Wind speed AM 850 mb at Jacksonville (ms^{-1})	9.8	7.1	5.4	6.3
Wind speed AM 850 mb at Slidell (ms^{-1})	8.8	6.2	5.0	5.5
Wind speed PM 850 mb at Jacksonville (ms^{-1})	8.8	6.8	5.4	5.5
Wind speed PM 850 mb at Slidell (ms^{-1})	8.0	6.4	5.3	5.2
Wind direction yesterday 850 mb at Jacksonville (degrees)	250	261	337	315
Wind direction yesterday 850 mb at Slidell (degrees)	256	352	17	357
Wind direction AM 850 mb at Jacksonville (degrees)	258	254	254	291
Wind direction AM 850 mb at Slidell (degrees)	242	215	204	263
Wind direction PM 850 mb at Jacksonville (degrees)	261	231	204	306
Wind direction PM 850 mb at Slidell (degrees)	271	276	50	3
Recirculation at Slidell	0.0	0.1	0.2	0.2
Cloud average	1.9	1.8	1.7	1.8

A summary of the characteristics and categorical variations in selected parameters associated with poor visibility for each site follows:

For Atlanta, high $PM_{2.5}$ is associated with

- High $PM_{2.5}$ on the previous day (local & potentially upwind sites).
- Moderate temperatures.
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and near the surface.
- Stable conditions.

For Yorkville, high $PM_{2.5}$ is associated with

- Moderate to high temperatures.
- High $PM_{2.5}$ on the previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft.
- Northeasterly winds aloft and easterly winds near the surface.
- Stable conditions.

High $PM_{2.5}$ for Birmingham is associated with

- Moderate to high temperatures.
- High $PM_{2.5}$ on the previous day (local & potentially upwind sites).
- Very low wind speeds near the surface and low winds speeds aloft.
- Southwesterly winds aloft and northwesterly winds near the surface.
- Stable conditions.

For Centreville, high $PM_{2.5}$ is associated with

- High temperatures.
- High $PM_{2.5}$ on the previous day (local & potentially upwind sites).
- Low wind speeds near the surface and moderate wind speeds aloft.
- West-northwesterly winds aloft and northwesterly winds near the surface.
- Stable conditions.

For Pensacola, high $PM_{2.5}$ is associated with

- Moderate temperatures.
- High $PM_{2.5}$ on the previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft.
- Westerly winds aloft and southwesterly winds near the surface.
- Stable conditions.

For the Outlying Landing Field, high $PM_{2.5}$ is associated with

- High temperatures.
- High $PM_{2.5}$ on the previous day (local & potentially upwind sites).
- Low wind speeds near the surface and moderate wind speeds aloft.
- Southwesterly winds aloft and westerly winds near the surface.

High $PM_{2.5}$ for Gulfport is associated with

- Moderate to high temperatures.
- High $PM_{2.5}$ on the previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft.
- Northwesterly winds aloft and westerly winds near the surface.
- Stable conditions.

For Oak Grove, high $PM_{2.5}$ is associated with

- Moderate to high temperatures.
- Moderate to high $PM_{2.5}$ on the previous day (local & potentially upwind sites).
- Low wind speeds near the surface and aloft (but only a slight tendency for lower wind speeds for the highest $PM_{2.5}$ categories).
- Westerly winds aloft and northerly winds near the surface.

The data characteristics and tendencies associated with high $PM_{2.5}$ for the IMPROVE sites (not shown) are similar to those associated with poor visibility. However, there is less of an apparent relationship between $PM_{2.5}$ and relative humidity.

3.5.2. Analysis of Key Bins

Greater insight, particularly for atmospheric modeling, is gained by considering the characteristics of the key bins that represent the 20 percent haziest days or the high $PM_{2.5}$ days for each site. Key bins are those containing the greatest number of correctly classified days. Approximately three key bins were identified for each classification category for each site.

Visibility

Table 3-14 summarizes the characteristics for key Category 4 and 5 bins for visibility for the IMPROVE monitoring sites. Recall that the Category 4 and 5 bins contain the majority of the 20 percent worst visibility days, accounting for some misclassification.

Table 3-14a. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Breton.

The ranges in extinction coefficient for Categories 4 and 5 are 105-135 and ≥135 Mm-1.

	Class 4	Class 5
	Bin 31	Bin 33
Visibility Parameters		
Yesterday's FM at New Orleans/Baton Rouge (μg/m^3)	16.7	31.9
Yesterday's FM at Gulfport (μg/m^3)	16.7	26.5
Yesterday's FM at Pensacola (μg/m^3)	19.5	25.8
Surface Meteorological Parameters		
Max. surface temperature (°C)	24.2	21.8
Min. surface temperature (°C)	17.0	12.5
Relative humidity (%)	80.9	86.2
Surface wind speed (ms^{-1})	3.4	1.8
Surface wind direction (degrees)	101	360
Persistence	1.0	0.8
Sea level pressure (mb)	1020	1022
Rainfall (inches)	0.0	0.0
Rain (# periods)	0.3	0.8
Upper-Air Meteorological Parameters		
Temperature AM 850 mb (°C)	12.4	9.1
Temperature PM 850 mb (°C)	13.1	9.8
Stability at Slidell (°C)	1.4	3.0
Geopotential height difference 700 mb at Slidell (m)	11.7	-2.8
Wind speed yesterday 700 mb at Slidell (ms^{-1})	7.6	8.0
Wind direction yesterday 700 mb at Slidell (degrees)	304	288
Wind speed yesterday 850 mb at Slidell (ms^{-1})	6.7	6.7
Wind speed AM 850 mb at Slidell (ms^{-1})	6.7	6.2
Wind speed PM 850 mb at Slidell (ms^{-1})	6.1	7.1
Wind direction yesterday 850 mb at Slidell (degrees)	315	270
Wind direction AM 850 mb at Slidell (degrees)	288	315
Wind direction PM 850 mb at Slidell (degrees)	243	45
Recirculation at Slidell	0.1	0.0
Cloud average	1.5	1.7

Table 3-14b. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Brigantine.

The ranges in extinction coefficient for Categories 4 and 5 are 135-225 and ≥225 Mm-1.

	Class 4			Class 5		
	Bin 24	Bin 25	Bin 16	Bin 26	Bin 27	Bin 22
Visibility Parameters						
Yesterday's FM at Wilmington (µg/m^3)	20.4	20.9	22.3	39.7	33.3	19.3
Yesterday's FM at New Orleans (µg/m^3)	21.5	15.7	21.3	29.3	31.4	20.8
Yesterday's FM at Philadelphia (µg/m^3)	19.2	19.7	21.2	37.7	32.8	17.8
Surface Meteorological Parameters						
Max. surface temperature (°C)	20.8	9.3	29.3	23.9	16.9	13.9
Min. surface temperature (°C)	11.4	0.3	18.0	14.6	9.4	10.0
Relative humidity (%)	82.8	87.2	67.8	78.9	87.3	96.5
Surface wind speed (ms^{-1})	0.8	0.7	0.8	0.7	0.7	0.9
Surface wind direction (degrees)	1022	1023	1018	1020	1016	1015
Persistence	2.2	2.2	2.7	2.2	2.8	2.4
Sea level pressure (mb)	162	27	252	180	n/a	108
Rainfall (inches)	0.1	0.1	0.0	0.0	0.6	0.1
Rain (# periods)	0.9	1.1	0.6	1.0	2.0	1.5
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	9.1	0.5	14.0	11.5	9.5	8.6
Temperature PM 850 mb (°C)	10.5	-0.1	14.0	12.1	6.9	7.7
Stability at Brookhaven (°C)	-0.1	-1.5	-0.6	-1.6	0.9	-2.0
Geopotential height difference 700 mb at Brookhaven (m)	10.7	3.1	-7.3	10.1	-34.5	-6.4
Wind speed yesterday 700 mb at Brookhaven (ms^{-1})	10.2	21.8	10.2	13.4	14.9	14.3
Wind speed yesterday 700 mb at Dulles (ms^{-1})	9.5	18.6	9.0	12.1	21.1	12.2
Wind direction yesterday 700 mb at Brookhaven (degrees)	285	270	270	270	270	297
Wind direction yesterday 700 mb at Dulles (degrees)	270	270	281	270	270	270
Wind speed yesterday 850 mb at Brookhaven (ms^{-1})	7.2	11.7	8.4	10.8	13.8	9.6
Wind speed yesterday 850 mb at Dulles (ms^{-1})	5.6	11.1	6.6	8.1	13.4	8.8
Wind speed AM 850 mb at Brookhaven (ms^{-1})	7.5	11.6	8.2	8.0	18.3	9.4
Wind speed AM 850 mb at Dulles (ms^{-1})	8.1	12.1	6.9	5.8	16.5	8.7
Wind speed PM 850 mb at Brookhaven (ms^{-1})	9.1	11.0	9.4	8.1	7.2	8.7
Wind speed PM 850 mb at Dulles (ms^{-1})	9.2	13.3	7.4	6.3	15.9	13.9
Wind direction yesterday 850 mb at Brookhaven (degrees)	287	261	262	277	270	281
Wind direction yesterday 850 mb at Dulles (degrees)	255	270	236	270	270	281
Wind direction AM 850 mb at Brookhaven (degrees)	255	270	270	297	270	288
Wind direction AM 850 mb at Dulles (degrees)	243	270	293	292	270	281
Wind direction PM 850 mb at Brookhaven (degrees)	265	297	278	297	270	270
Wind direction PM 850 mb at Dulles (degrees)	253	262	307	270	270	297
Cloud average	2.0	1.9	1.7	2.1	2.0	2.2

Table 3-14c. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Cadiz.

The ranges in extinction coefficient for Categories 4 and 5 are 155-230 and ≥230 Mm-1.

	Class 4				Class 5	
	Bin 18	Bin 25	Bin 22	Bin 31	Bin 32	Bin 29
Visibility Parameters						
Yesterday's FM at Nashville (μg/m^3)	19.6	21.8	14.4	18.2	22.9	7.9
Yesterday's FM at St. Louis (μg/m^3)	14.3	26.3	13.5	22.5	28.8	22.1
Yesterday's FM at Louisville (μg/m^3)	22.6	27.8	15.3	19.1	33.0	16.0
Surface Meteorological Parameters						
Max. surface temperature (°C)	27.1	26.5	15.0	16.2	23.3	9.5
Min. surface temperature (°C)	18.4	17.3	8.3	9.1	15.5	4.0
Relative humidity (%)	83.3	86.0	96.8	83.5	88.1	90.8
Surface wind speed (ms^{-1})	1.2	1.5	1.8	1.8	1.5	1.7
Surface wind direction (degrees)	315	146	135	0	180	346
Persistence	0.7	0.8	0.8	0.8	0.7	0.8
Rainfall (inches)	0.2	0.2	0.2	0.0	0.1	0.1
Rain (# periods)	0.7	0.6	1.5	0.4	0.6	0.8
Solar radiation (W/m^2)	537	511	351	457	558	352
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	15.8	15.1	8.4	8.5	14.5	1.8
Temperature PM 850 mb (°C)	16.5	16.0	7.9	8.3	13.5	4.6
Stability at Nashville (°C)	-0.3	0.4	-2.0	-1.3	0.3	-3.5
Geopotential height difference 700 mb at Nashville (m)	-16.0	6.7	-22.8	-2.3	-0.5	9.5
Wind speed yesterday 700 mb at Nashville (ms^{-1})	7.1	4.4	12.9	14.6	12.0	17.4
Wind direction yesterday 700 mb at Nashville (degrees)	297	198	243	256	270	236
Wind speed yesterday 850 mb at Nashville (ms^{-1})	5.8	4.6	7.6	8.5	6.0	14.1
Wind speed AM 850 mb at Nashville (ms^{-1})	5.3	6.4	10.2	6.6	8.2	10.4
Wind speed PM 850 mb at Nashville (ms^{-1})	4.9	6.9	9.0	6.1	6.6	6.0
Wind direction yesterday 850 mb at Nashville (degrees)	321	169	252	315	256	256
Wind direction AM 850 mb at Nashville (degrees)	321	180	225	307	236	304
Wind direction PM 850 mb at Nashville (degrees)	315	172	259	333	243	270
Recirculation at Nashville	0.1	0.1	0.1	0.0	0.0	0.0
Cloud average	1.8	2.1	2.1	1.7	2.1	1.8

Table 3-14d. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Caney Creek.

The ranges in extinction coefficient for Categories 4 and 5 are 115-170 and ≥170 Mm-1.

	Class 4			Class 5	
	Bin 18	Bin 25	Bin 24	Bin 19	Bin 16
Visibility Parameters					
Yesterday's FM at Little Rock (µg/m^3)	25.8	18.0	21.5	28.1	19.8
Yesterday's FM at Dallas (µg/m^3)	20.3	15.7	26.2	24.0	18.2
Surface Meteorological Parameters					
Max. surface temperature (°C)	29.6	26.5	29.8	29.8	29.2
Min. surface temperature (°C)	17.1	13.7	16.3	17.8	18.0
Relative humidity (%)	76.8	75.7	76.0	79.1	79.3
Surface wind speed (ms^{-1})	0.4	0.1	0.4	0.2	0.2
Surface wind direction (degrees)	95	90	117	56	45
Persistence	0.9	0.4	1.0	0.8	0.8
Sea level pressure (mb)	1017	1018	1016	1017	1017
Rainfall (inches)	0.1	0.2	0.0	0.0	0.2
Rain (# periods)	0.7	0.8	0.6	1.0	1.4
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	15.6	13.9	17.1	16.1	15.5
Temperature PM 850 mb (°C)	16.0	14.5	17.7	16.7	16.2
Stability at Little Rock (°C)	-1.0	-0.2	-0.7	-0.6	-3.9
Geopotential height difference 700 mb at Little Rock (m)	-1.0	-22.8	10.6	0.8	-2.6
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	6.2	10.4	7.0	4.2	5.4
Wind direction yesterday 700 mb at Little Rock (degrees)	304	256	360	333	180
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	3.7	7.3	5.5	4.3	4.5
Wind speed AM 850 mb at Little Rock (ms^{-1})	3.7	10.3	3.2	3.7	4.6
Wind speed PM 850 mb at Little Rock (ms^{-1})	2.7	8.6	10.7	4.8	5.4
Wind direction yesterday 850 mb at Little Rock (degrees)	360	259	180	207	90
Wind direction AM 850 mb at Little Rock (degrees)	277	243	180	153	180
Wind direction PM 850 mb at Little Rock (degrees)	180	259	180	153	153
Recirculation at Little Rock	0.4	0.0	0.0	0.1	0.1
Cloud average	1.7	2.0	1.2	1.9	2.0

Table 3-14e. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Cape Romain.

The ranges in extinction coefficient for Categories 4 and 5 are 110-160 and ≥160 Mm-1.

	Class 4				Class 5
	Bin 33	Bin 21	Bin 17	Bin 27	Bin 32
Visibility Parameters					
Yesterday's FM at Charleston (μg/m^3)	24.1	12.8	14.3	15.9	23.7
Surface Meteorological Parameters					
Max. surface temperature (°C)	30.8	25.7	24.6	24.0	27.6
Min. surface temperature (°C)	21.6	14.8	14.3	12.7	18.2
Relative humidity (%)	76.6	83.1	80.2	77.7	81.8
Surface wind speed (ms^{-1})	3.0	2.2	1.9	3.1	1.4
Surface wind direction (degrees)	198	0	76	121	158
Persistence	0.9	0.8	0.7	0.9	0.5
Sea level pressure (mb)	1018	1021	1022	1023	1018
Rainfall (inches)	0.0	0.0	0.1	0.0	0.2
Rain (# periods)	0.4	0.9	0.9	0.3	0.9
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	16.5	12.5	12.4	11.6	14.5
Temperature PM 850 mb (°C)	16.8	14.3	13.4	12.4	15.2
Stability at Charleston (°C)	-2.0	0.6	0.1	0.5	-0.9
Geopotential height difference 700 mb at Charleston (m)	-3.7	3.6	45.6	28.2	-4.3
Wind speed yesterday 700 mb at Charleston (ms^{-1})	7.2	7.7	7.9	6.9	9.2
Wind direction yesterday 700 mb at Charleston (degrees)	323	279	301	315	301
Wind speed yesterday 850 mb at Charleston (ms^{-1})	6.4	3.7	4.2	4.5	7.6
Wind speed AM 850 mb at Charleston (ms^{-1})	6.6	6.9	2.0	4.7	8.0
Wind speed PM 850 mb at Charleston (ms^{-1})	7.7	5.7	4.0	3.7	7.6
Wind direction yesterday 850 mb at Charleston (degrees)	338	270	11	0	285
Wind direction AM 850 mb at Charleston (degrees)	315	292	309	143	279
Wind direction PM 850 mb at Charleston (degrees)	315	323	342	180	297
Recirculation at Charleston	0.0	0.1	0.3	0.3	0.1
Cloud average	1.8	1.6	1.8	1.9	2.0

Table 3-14f. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Chassahowitzka.

The ranges in extinction coefficient for Categories 4 and 5 are 115-165 and ≥165 Mm-1.

	Class 4		Class 5	
	Bin 30	Bin 17	Bin 36	Bin 29
Visibility Parameters				
Yesterday's FM at Tampa (µg/m^3)	17.3	9.1	31.4	18.8
Yesterday's FM at Orlando (µg/m^3)	15.2	12.1	23.9	17.9
Surface Meteorological Parameters				
Max. surface temperature (°C)	28.1	28.9	31.9	31.1
Min. surface temperature (°C)	14.6	17.9	17.4	18.6
Relative humidity (%)	79.6	85.0	77.0	80.1
Surface wind speed (ms^{-1})	1.5	2.5	0.9	1.8
Surface wind direction (degrees)	45.0	56.0	292.0	297.0
Persistence	0.7	0.8	0.6	0.9
Sea level pressure (mb)	0.2	0.1	0.0	0.0
Rainfall (inches)	1022	1020	1018	1019
Rain (# periods)	0.4	0.6	0.1	0.0
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	14.7	15.7	16.0	16.4
Temperature PM 850 mb (°C)	14.2	15.8	16.4	17.8
Stability at Tampa (°C)	-1.0	-1.1	-0.3	-1.4
Geopotential height difference 700 mb at Tampa (m)	16.3	4.7	-1.1	-10.6
Wind speed yesterday 700 mb at Tampa (ms^{-1})	6.7	8.1	5.4	4.3
Wind direction yesterday 700 mb at Tampa (degrees)	304	256	180	14
Wind speed yesterday 850 mb at Tampa (ms^{-1})	3.2	3.8	3.8	5.4
Wind speed AM 850 mb at Tampa (ms^{-1})	2.2	4.2	3.2	4.5
Wind speed PM 850 mb at Tampa (ms^{-1})	4.6	4.1	4.6	3.7
Wind direction yesterday 850 mb at Tampa (degrees)	45	270	81	90
Wind direction AM 850 mb at Tampa (degrees)	191	207	63	270
Wind direction PM 850 mb at Tampa (degrees)	135	270	76	135
Recirculation at Tampa	0.5	0.4	0.0	0.0
Cloud average	1.9	1.6	1.4	1.2

Table 3-14g. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Cohutta.

The ranges in extinction coefficient for Categories 4 and 5 are 135-220 and ≥220 Mm-1.

	Class 4			Class 5
	Bin 27	Bin 19	Bin 22	Bin 28
Visibility Parameters				
Yesterday's FM at Birmingham (µg/m^3)	29.6	35.4	18.4	32.4
Yesterday's FM at Atlanta (µg/m^3)	22.3	39.3	18.3	33.2
Yesterday's FM at Nashville (µg/m^3)	23.2	19.3	13.8	27.8
Yesterday's FM at Knoxville (µg/m^3)	21.9	27.2	18.8	37.9
Surface Meteorological Parameters				
Max. surface temperature (°C)	31.6	28.1	31.0	32.9
Min. surface temperature (°C)	20.3	8.1	21.9	20.3
Relative humidity (%)	73.2	71.7	72.3	76.7
Surface wind speed (ms^{-1})	1.5	1.3	0.5	0.5
Surface wind direction (degrees)	360	360	180	180
Persistence	1.0	0.7	0.4	0.6
Rainfall (inches)	0.2	0.0	0.2	0.0
Rain (# periods)	0.7	0.2	1.0	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	17.1	13.6	16.3	17.6
Temperature PM 850 mb (°C)	17.9	13.8	17.2	18.6
Stability at Atlanta (°C)	1.0	5.0	-0.9	1.7
Geopotential height difference 700 mb at Atlanta (m)	10.7	-6.5	24.9	-1.8
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	4.8	6.6	7.4	4.3
Wind direction yesterday 700 mb at Atlanta (degrees)	323	281	256	101
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	4.1	4.2	4.9	3.3
Wind speed AM 850 mb at Atlanta (ms^{-1})	4.5	5.4	4.1	4.1
Wind speed PM 850 mb at Atlanta (ms^{-1})	5.4	6.0	3.3	4.4
Wind direction yesterday 850 mb at Atlanta (degrees)	292	281	243	63
Wind direction AM 850 mb at Atlanta (degrees)	256	297	236	270
Wind direction PM 850 mb at Atlanta (degrees)	360	259	214	135
Recirculation at Atlanta	0.2	0.2	0.6	0.3
Cloud average	2.0	1.5	2.2	1.7

Table 3-14h. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Dolly Sods.

The ranges in extinction coefficient for Categories 4 and 5 are 125-215 and ≥215 Mm-1.

	Class 4			Class 5	
	Bin 15	Bin 25	Bin 22	Bin 13	Bin 19
Visibility Parameters					
Yesterday's FM at DC (μg/m^3)	24.4	21.5	28.9	19.2	29.9
Yesterday's FM at Richmond (μg/m^3)	19.2	21.1	19.1	17.9	25.5
Yesterday's FM at Columbus (μg/m^3)	21.0	25.6	22.4	19.5	41.3
Surface Meteorological Parameters					
Max. surface temperature (°C)	24.6	22.4	26.6	24.8	27.0
Min. surface temperature (°C)	15.0	14.5	14.5	15.3	16.6
Relative humidity (%)	75.5	73.9	64.5	78.9	77.3
Surface wind speed (ms^{-1})	0.3	1.4	0.8	0.3	0.3
Surface wind direction (degrees)	90	90	18	307	259
Persistence	0.3	0.9	0.5	0.3	0.2
Rainfall (inches)	0.1	0.2	0.0	0.0	0.2
Rain (# periods)	0.5	0.9	0.3	0.2	0.6
Solar radiation (W/m^2)	652	494	748	679	708
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	14.4	12.6	14.6	14.1	15.9
Temperature PM 850 mb (°C)	15.1	12.7	15.8	14.6	17.0
Stability at Pittsburgh (°C)	1.6	-1.2	1.5	1.3	1.1
Geopotential height difference 700 mb at Pittsburgh (m)	6.3	-6.1	-0.7	6.3	-27.6
Wind speed yesterday 700 mb at Dulles (ms^{-1})	7.5	4.3	7.2	8.1	5.4
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	6.5	4.6	6.0	7.1	4.6
Wind speed yesterday 700 mb at Wilmington (ms^{-1})	7.4	6.3	5.4	6.2	6.5
Wind speed yesterday 700 mb at Pittsburgh (ms^{-1})	10.2	6.2	8.7	6.7	7.0
Wind direction yesterday 700 mb at Dulles (degrees)	297	297	270	284	315
Wind direction yesterday 700 mb at Roanoke (degrees)	270	297	259	256	326
Wind direction yesterday 700 mb at Wilmington (degrees)	276	243	278	304	288
Wind direction yesterday 700 mb at Pittsburgh (degrees)	276	270	284	279	321
Wind speed yesterday 850 mb at Dulles (ms^{-1})	6.0	4.9	5.0	4.1	5.0
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	4.9	4.6	5.3	4.2	3.5
Wind speed yesterday 850 mb at Wilmington (ms^{-1})	7.5	6.4	5.7	2.6	4.8
Wind speed yesterday 850 mb at Pittsburgh (ms^{-1})	5.7	6.0	5.9	4.5	5.7
Wind speed AM 850 mb at Dulles (ms^{-1})	5.4	4.9	5.2	4.7	4.5
Wind speed AM 850 mb at Roanoke (ms^{-1})	5.8	5.2	5.6	4.5	7.3
Wind speed AM 850 mb at Wilmington (ms^{-1})	8.3	8.0	7.0	3.5	6.7
Wind speed AM 850 mb at Pittsburgh (ms^{-1})	7.6	5.4	6.0	5.3	6.0
Wind speed PM 850 mb at Dulles (ms^{-1})	6.3	5.8	5.9	5.7	5.9
Wind speed PM 850 mb at Roanoke (ms^{-1})	5.3	5.8	5.7	3.5	4.2
Wind speed PM 850 mb at Wilmington (ms^{-1})	7.6	8.6	9.4	5.0	5.7
Wind speed PM 850 mb at Pittsburgh (ms^{-1})	6.4	6.1	7.2	5.5	6.2
Wind direction yesterday 850 mb at Dulles (degrees)	277	180	261	284	297

	Class 4			Class 5	
	Bin 15	Bin 25	Bin 22	Bin 13	Bin 19
Wind direction yesterday 850 mb at Roanoke (degrees)	292	207	207	243	342
Wind direction yesterday 850 mb at Wilmington (degrees)	264	225	252	180	252
Wind direction yesterday 850 mb at Pittsburgh (degrees)	277	270	278	0	279
Wind direction AM 850 mb at Dulles (degrees)	239	90	270	256	286
Wind direction AM 850 mb at Roanoke (degrees)	259	135	225	180	278
Wind direction AM 850 mb at Wilmington (degrees)	260	297	270	252	291
Wind direction AM 850 mb at Pittsburgh (degrees)	270	270	293	270	291
Wind direction PM 850 mb at Dulles (degrees)	256	117	214	270	293
Wind direction PM 850 mb at Roanoke (degrees)	247	90	180	117	323
Wind direction PM 850 mb at Wilmington (degrees)	241	315	243	180	304
Wind direction PM 850 mb at Pittsburgh (degrees)	249	207	243	207	288
Cloud average	2.0	2.0	1.8	2.0	2.0

Table 3-14i. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Everglades.

The ranges in extinction coefficient for Categories 4 and 5 are 80-120 and ≥120 Mm-1.

	Class 4		Class 5
	Bin 22	Bin 24	Bin 36
Visibility Parameters			
Yesterday's FM at Palm Beach (μg/m^3)	11.9	10.8	16.2
Yesterday's FM at Ft. Lauderdale (μg/m^3)	12.2	9.5	16.2
Surface Meteorological Parameters			
Max. surface temperature (°C)	25.0	28.6	28.1
Min. surface temperature (°C)	13.8	18.8	19.5
Relative humidity (%)	71.4	79.9	80.8
Surface wind speed (ms^{-1})	1.5	1.6	1.4
Surface wind direction (degrees)	15	63	59
Persistence	0.8	0.8	0.7
Rainfall (inches)	0.0	0.0	0.0
Rain (# periods)	0.2	0.4	0.3
Solar radiation (W/m^2)	704	633	635
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	11.0	14.4	14.8
Temperature PM 850 mb (°C)	11.0	14.6	15.3
Stability at Miami (°C)	-2.4	-3.4	-3.4
Geopotential height difference 700 mb at Miami (m)	2.3	-6.4	-0.1
Wind speed yesterday 700 mb at Miami (ms^{-1})	8.8	3.4	7.6
Wind direction yesterday 700 mb at Miami (degrees)	295	270	302
Wind speed yesterday 850 mb at Miami (ms^{-1})	6.0	4.8	6.1
Wind speed AM 850 mb at Miami (ms^{-1})	6.5	5.4	5.3
Wind speed PM 850 mb at Miami (ms^{-1})	5.8	6.3	5.4
Wind direction yesterday 850 mb at Miami (degrees)	350	292	320
Wind direction AM 850 mb at Miami (degrees)	349	259	225
Wind direction PM 850 mb at Miami (degrees)	31	297	338
Recirculation at Miami	0.1	0.3	0.1
Cloud average	1.6	1.6	1.5

Table 3-14j. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Great Smoky Mountains.

The ranges in extinction coefficient for Categories 4 and 5 are 120-180 and ≥180 Mm-1.

	Class 4			Class 5		
	Bin 27	Bin 29	Bin 18	Bin 35	Bin 32	Bin 15
Visibility Parameters						
Yesterday's FM at Knoxville (μg/m³)	34.7	20.0	25.3	34.9	15.7	25.6
Yesterday's FM at Atlanta (μg/m³)	25.1	20.9	28.8	31.6	16.8	38.3
Yesterday's FM at Charlotte (μg/m³)	23.4	16.9	23.7	24.3	17.8	23.8
Surface Meteorological Parameters						
Max. surface temperature (°C)	26.2	24.1	13.5	24.0	23.4	16.8
Min. surface temperature (°C)	20.2	18.6	7.7	19.3	18.9	12.9
Relative humidity (%)	66.1	87.6	88.5	82.1	86.6	90.7
Surface wind speed (ms^{-1})	1.0	1.0	1.9	0.8	1.0	0.7
Surface wind direction (degrees)	297	202	225	252	342	63
Persistence	0.6	0.6	0.8	0.5	0.6	0.5
Rainfall (inches)	0.1	0.5	0.2	0.1	0.3	0.0
Rain (# periods)	0.2	1.1	1.1	0.8	1.0	0.3
Solar radiation (W/m²)	696	638	328	556	538	326
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	17.1	16.0	7.7	16.6	16.2	11.0
Temperature PM 850 mb (°C)	17.7	17.0	7.6	17.1	16.7	11.5
Stability at Nashville (°C)	1.4	-1.7	-1.3	-0.8	-1.8	0.3
Geopotential height difference 700 mb at Nashville (m)	-5.6	-6.0	-4.1	1.3	0.9	-6.0
Wind speed yesterday 700 mb at Nashville (ms^{-1})	5.9	12.8	13.6	6.3	5.8	9.6
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	6.8	8.8	12.8	6.9	8.7	8.4
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	5.2	7.2	10.6	4.6	6.8	6.0
Wind direction yesterday 700 mb at Nashville (degrees)	342	270	264	342	270	180
Wind direction yesterday 700 mb at Greensboro (degrees)	18	277	263	292	261	243
Wind direction yesterday 700 mb at Atlanta (degrees)	79	262	256	n/a	252	180
Wind speed yesterday 850 mb at Nashville (ms^{-1})	4.5	9.4	9.4	5.4	4.9	8.2
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	4.4	6.0	9.3	5.5	7.5	6.9
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	4.3	5.0	6.8	4.2	7.2	5.5
Wind speed AM 850 mb at Nashville (ms^{-1})	5.9	12.8	9.8	4.4	5.1	8.9
Wind speed AM 850 mb at Greensboro (ms^{-1})	5.8	7.5	7.7	6.4	6.2	7.2
Wind speed AM 850 mb at Atlanta (ms^{-1})	5.4	6.5	7.2	5.0	5.4	4.0
Wind speed PM 850 mb at Nashville (ms^{-1})	6.1	9.2	11.1	4.9	3.5	7.7
Wind speed PM 850 mb at Greensboro (ms^{-1})	4.7	7.4	8.9	5.5	5.7	2.3
Wind speed PM 850 mb at Atlanta (ms^{-1})	4.3	6.2	7.7	4.9	4.7	5.8
Wind direction yesterday 850 mb at Nashville (degrees)	180	241	270	297	333	207
Wind direction yesterday 850 mb at Greensboro (degrees)	34	270	270	248	243	243
Wind direction yesterday 850 mb at Atlanta (degrees)	99	262	261	162	270	207
Wind direction AM 850 mb at Nashville (degrees)	297	265	270	243	n/a	90
Wind direction AM 850 mb at Greensboro (degrees)	338	276	259	270	315	270
Wind direction AM 850 mb at Atlanta (degrees)	22	256	262	135	256	270
Wind direction PM 850 mb at Nashville (degrees)	270	270	315	180	0	180
Wind direction PM 850 mb at Greensboro (degrees)	180	252	278	243	270	0
Wind direction PM 850 mb at Atlanta (degrees)	90	225	259	45	252	243
Cloud average	1.8	2.1	1.8	1.7	2.1	2.0

Table 3-14k. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site James River Face.

The ranges in extinction coefficient for Categories 4 and 5 are 155-220 and ≥220 Mm-1.

	Class 4			Class 5
	Bin 34	Bin 35	Bin 18	Bin 37
Visibility Parameters				
Yesterday's FM at Richmond (μg/m^3)	22.8	21.3	17.5	24.6
Yesterday's FM at Greensboro-Winston-Salem (μg/m^3)	26.5	28.1	16.8	29.1
Yesterday's FM at Knoxville (μg/m^3)	28.8	23.5	17.7	30.3
Surface Meteorological Parameters				
Max. surface temperature (°C)	30.2	23.4	24.0	25.1
Min. surface temperature (°C)	16.7	14.8	16.6	14.3
Relative humidity (%)	72.6	85.3	81.8	84.1
Surface wind speed (ms^{-1})	1.2	1.2	0.5	0.8
Surface wind direction (degrees)	201	45	45	180
Persistence	0.8	0.9	0.6	0.8
Sea level pressure (mb)	1019	1019	1016	1023
Rainfall (inches)	0.1	0.3	0.2	0.1
Rain (# periods)	0.5	1.4	1.4	0.9
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	15.7	12.3	13.1	13.4
Temperature PM 850 mb (°C)	17.0	12.7	14.1	13.5
Stability at Roanoke (°C)	3.3	1.1	-0.3	2.0
Geopotential height difference 700 mb at Roanoke (m)	20.3	-38.3	-9.0	12.8
Wind speed yesterday 700 mb at Dulles (ms^{-1})	10.2	11.4	12.6	7.9
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	9.9	9.6	13.7	7.2
Wind direction yesterday 700 mb at Dulles (degrees)	294	262	278	270
Wind direction yesterday 700 mb at Roanoke (degrees)	284	259	284	259
Wind speed yesterday 850 mb at Dulles (ms^{-1})	6.9	6.5	8.7	4.5
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	5.0	5.9	8.3	4.2
Wind speed AM 850 mb at Dulles (ms^{-1})	7.2	6.3	6.8	5.0
Wind speed AM 850 mb at Roanoke (ms^{-1})	6.9	8.2	6.6	6.2
Wind speed PM 850 mb at Dulles (ms^{-1})	7.5	7.9	5.3	6.5
Wind speed PM 850 mb at Roanoke (ms^{-1})	5.1	10.2	5.1	4.9
Wind direction yesterday 850 mb at Dulles (degrees)	265	259	315	262
Wind direction yesterday 850 mb at Roanoke (degrees)	270	225	276	256
Wind direction AM 850 mb at Dulles (degrees)	280	194	338	270
Wind direction AM 850 mb at Roanoke (degrees)	291	239	321	241
Wind direction PM 850 mb at Dulles (degrees)	270	248	342	233
Wind direction PM 850 mb at Roanoke (degrees)	256	261	304	194
Recirculation at Roanoke	0.0	0.0	0.0	0.2
Cloud average	1.8	2.4	2.4	2.1

Table 3-14l. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Linville Gorge.

The ranges in extinction coefficient for Categories 4 and 5 are 120-180 and ≥180 Mm-1.

	Class 4		Class 5
	Bin 20	Bin 23	Bin 28
Visibility Parameters			
Yesterday's FM at Knoxville (μg/m^3)	24.8	24.1	39.5
Yesterday's FM at Charlotte (μg/m^3)	20.8	21.4	28.8
Yesterday's FM at Greenville (μg/m^3)	18.9	21.1	33.4
Surface Meteorological Parameters			
Max. surface temperature (°C)	28.9	28.1	27.3
Min. surface temperature (°C)	17.4	18.5	16.4
Relative humidity (%)	72.4	83.6	77.5
Surface wind speed (ms^{-1})	1.1	0.6	0.8
Surface wind direction (degrees)	310	252	315
Persistence	0.7	0.6	0.7
Sea level pressure (mb)	1019	1019	1021
Rainfall (inches)	0.6	1.1	0.6
Rain (# periods)	0.0	0.3	0.0
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	15.4	15.9	15.1
Temperature PM 850 mb (°C)	16.3	16.8	15.7
Stability at Greensboro (°C)	0.5	0.7	0.6
Geopotential height difference 700 mb at Greensboro (m)	0.7	8.5	0.1
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	6.5	6.1	7.2
Wind direction yesterday 700 mb at Greensboro (degrees)	297	262	315
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	4.9	4.5	4.2
Wind speed AM 850 mb at Greensboro (ms^{-1})	5.0	5.4	5.5
Wind speed PM 850 mb at Greensboro (ms^{-1})	4.7	4.2	5.3
Wind direction yesterday 850 mb at Greensboro (degrees)	297	217	270
Wind direction AM 850 mb at Greensboro (degrees)	329	217	286
Wind direction PM 850 mb at Greensboro (degrees)	297	210	281
Recirculation at Greensboro	0.0	0.1	0.1
Cloud average	1.9	1.9	1.8

Table 3-14m. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Mammoth Cave.

The ranges in extinction coefficient for Categories 4 and 5 are 155-250 and ≥250 Mm-1.

	Class 4		Class 5
	Bin 29	Bin 8	Bin 34
Visibility Parameters			
Yesterday's FM at Nashville (µg/m^3)	18.1	25.5	27.7
Yesterday's FM at Knoxville (µg/m^3)	23.7	31.0	28.6
Yesterday's FM at Louisville (µg/m^3)	23.1	31.2	31.7
Surface Meteorological Parameters			
Max. surface temperature (°C)	29.0	33.0	28.3
Min. surface temperature (°C)	18.8	18.1	16.8
Relative humidity (%)	77.0	64.0	77.9
Surface wind speed (ms^{-1})	2.4	1.0	1.2
Surface wind direction (degrees)	189	360	194
Persistence	0.8	0.7	0.8
Sea level pressure (mb)	1018	1021	1018
Rainfall (inches)	0.1	0.0	0.0
Rain (# periods)	1.1	0.3	0.5
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	15.0	16.9	15.6
Temperature PM 850 mb (°C)	16.7	17.6	17.0
Stability at Nashville (°C)	0.6	2.3	0.9
Geopotential height difference 700 mb at Nashville (m)	-8.6	2.6	-1.6
Wind speed yesterday 700 mb at Nashville (ms^{-1})	6.9	4.4	6.1
Wind direction yesterday 700 mb at Nashville (degrees)	233	45	349
Wind speed yesterday 850 mb at Nashville (ms^{-1})	6.5	4.3	4.1
Wind speed AM 850 mb at Nashville (ms^{-1})	8.7	5.2	3.2
Wind speed PM 850 mb at Nashville (ms^{-1})	8.4	5.5	4.6
Wind direction yesterday 850 mb at Nashville (degrees)	202	252	0
Wind direction AM 850 mb at Nashville (degrees)	259	0	338
Wind direction PM 850 mb at Nashville (degrees)	233	45	180
Recirculation at Nashville	0.0	0.1	0.3
Cloud average	1.9	1.9	1.8

Table 3-14n. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Mingo.

The ranges in extinction coefficient for Categories 4 and 5 are 130-190 and ≥190 Mm-1.

	Class 4		Class 5
	Bin 28	Bin 21	Bin 31
Visibility Parameters			
Yesterday's FM at St. Louis (µg/m^3)	27.2	14.6	29.2
Surface Meteorological Parameters			
Max. surface temperature (°C)	22.5	26.1	18.9
Min. surface temperature (°C)	10.7	10.2	7.0
Relative humidity (%)	74.3	70.3	74.7
Surface wind speed (ms^{-1})	1.4	1.8	1.8
Surface wind direction (degrees)	108	225	225
Persistence	0.7	0.8	0.8
Sea level pressure (mb)	1022	1020	1024
Rainfall (inches)	0.1	0.0	0.2
Rain (# periods)	0.7	0.3	1.1
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	11.7	12.8	9.0
Temperature PM 850 mb (°C)	11.8	13.4	9.6
Stability at Little Rock (°C)	-1.0	0.8	1.5
Geopotential height difference 700 mb at Little Rock (m)	-2.6	-3.4	-10.8
Wind speed yesterday 700 mb at Springfield (ms^{-1})	7.8	7.8	11.1
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	7.8	4.8	11.3
Wind speed yesterday 700 mb at Lincoln (ms^{-1})	10.1	10.9	13.2
Wind speed yesterday 700 mb at Nashville (ms^{-1})	9.2	8.4	7.1
Wind direction yesterday 700 mb at Springfield (degrees)	270	270	261
Wind direction yesterday 700 mb at Little Rock (degrees)	307	284	236
Wind direction yesterday 700 mb at Lincoln (degrees)	307	270	270
Wind direction yesterday 700 mb at Nashville (degrees)	304	252	n/a
Wind speed yesterday 850 mb at Springfield (ms^{-1})	5.3	7.4	9.8
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	5.5	6.5	8.4
Wind speed yesterday 850 mb at Lincoln (ms^{-1})	5.2	7.8	12.1
Wind speed yesterday 850 mb at Nashville (ms^{-1})	5.3	5.9	6.7
Wind speed AM 850 mb at Springfield (ms^{-1})	7.4	6.8	5.4
Wind speed AM 850 mb at Little Rock (ms^{-1})	6.6	6.2	6.8
Wind speed AM 850 mb at Lincoln (ms^{-1})	7.5	7.4	10.0
Wind speed AM 850 mb at Nashville (ms^{-1})	5.2	8.1	7.4
Wind speed PM 850 mb at Springfield (ms^{-1})	7.6	9.8	6.3
Wind speed PM 850 mb at Little Rock (ms^{-1})	8.4	5.9	5.9
Wind speed PM 850 mb at Lincoln (ms^{-1})	7.4	7.6	7.9
Wind speed PM 850 mb at Nashville (ms^{-1})	6.7	5.6	5.8
Wind direction yesterday 850 mb at Springfield (degrees)	198	207	217
Wind direction yesterday 850 mb at Little Rock (degrees)	225	180	202
Wind direction yesterday 850 mb at Lincoln (degrees)	270	243	217

	Class 4		Class 5
	Bin 28	Bin 21	Bin 31
Wind direction yesterday 850 mb at Nashville (degrees)	270	180	239
Wind direction AM 850 mb at Springfield (degrees)	254	270	256
Wind direction AM 850 mb at Little Rock (degrees)	236	256	236
Wind direction AM 850 mb at Lincoln (degrees)	263	252	297
Wind direction AM 850 mb at Nashville (degrees)	191	270	284
Wind direction PM 850 mb at Springfield (degrees)	166	180	214
Wind direction PM 850 mb at Little Rock (degrees)	169	198	217
Wind direction PM 850 mb at Lincoln (degrees)	262	146	270
Wind direction PM 850 mb at Nashville (degrees)	207	207	315
Cloud average	1.8	1.7	1.9

Table 3-14o. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Okefenokee.

The ranges in extinction coefficient for Categories 4 and 5 are 110-170 and ≥170 Mm-1.

	Class 4			Class 5
	Bin 34	Bin 16	Bin 22	Bin 30
Visibility Parameters				
Yesterday's FM at Jacksonville (μg/m³)	20.5	10.0	10.9	23.9
Surface Meteorological Parameters				
Max. surface temperature (°C)	25.3	26.7	22.9	31.1
Min. surface temperature (°C)	12.6	14.6	13.6	20.6
Relative humidity (%)	76.3	76.7	88.9	78.1
Surface wind speed (ms^{-1})	2.4	2.1	1.8	1.7
Surface wind direction (degrees)	70	90	90	117
Persistence	0.9	0.8	0.8	0.7
Sea level pressure (mb)	1022	1021	1021	1016
Rainfall (inches)	0.0	0.0	0.0	0.1
Rain (# periods)	0.4	0.5	0.4	0.7
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	11.6	13.5	12.6	16.6
Temperature PM 850 mb (°C)	12.2	14.0	13.0	16.9
Stability at Jacksonville (°C)	1.2	1.2	0.7	-0.3
Geopotential height difference 700 mb at Jacksonville (m)	4.6	-6.5	-1.9	-3.0
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	7.8	7.4	9.3	7.3
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	7.0	5.3	10.0	6.4
Wind direction yesterday 700 mb at Jacksonville (degrees)	326	0	270	301
Wind direction yesterday 700 mb at Tallahassee (degrees)	339	315	263	309
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	4.9	4.6	7.6	4.9
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	3.7	3.3	6.5	3.8
Wind speed AM 850 mb at Jacksonville (ms^{-1})	5.7	6.9	6.7	4.3
Wind speed AM 850 mb at Tallahassee (ms^{-1})	4.4	3.3	5.4	4.6
Wind speed PM 850 mb at Jacksonville (ms^{-1})	6.6	6.6	6.2	3.6
Wind speed PM 850 mb at Tallahassee (ms^{-1})	5.5	4.8	5.7	5.3
Wind direction yesterday 850 mb at Jacksonville (degrees)	360	18	270	315
Wind direction yesterday 850 mb at Tallahassee (degrees)	50	45	256	351
Wind direction AM 850 mb at Jacksonville (degrees)	117	18	248	281
Wind direction AM 850 mb at Tallahassee (degrees)	101	360	270	233
Wind direction PM 850 mb at Jacksonville (degrees)	117	315	236	304
Wind direction PM 850 mb at Tallahassee (degrees)	68	11	214	326
Recirculation at Jacksonville	0.1	0.0	0.0	0.3
Cloud average	1.6	1.5	1.9	1.8

Table 3-14p. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Shenandoah.

The ranges in extinction coefficient for Categories 4 and 5 are 145-255 and ≥255 Mm-1.

	Class 4		Class 5	
	Bin 26	Bin 38	Bin 34	Bin 28
Visibility Parameters				
Yesterday's FM at Richmond (μg/m^3)	9.4	20.5	12.7	23.4
Yesterday's FM at DC (μg/m^3)	11.8	23.1	14.2	27.3
Yesterday's FM at Columbus (μg/m^3)	18.7	26.2	18.4	22.8
Surface Meteorological Parameters				
Max. surface temperature (°C)	16.9	21.4	22.1	19.6
Min. surface temperature (°C)	15.6	15.6	16.3	15.7
Relative humidity (%)	97.9	81.0	86.1	92.5
Surface wind speed (ms^{-1})	1.4	1.4	1.3	1.0
Surface wind direction (degrees)	180	90	180	180
Persistence	0.9	0.9	0.8	0.6
Rainfall (inches)	2.5	0.6	0.8	1.3
Rain (# periods)	0.6	0.1	0.1	0.2
Solar radiation (W/m^2)	123	690	620	226
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	13.6	15.2	15.9	15.9
Temperature PM 850 mb (°C)	14.1	16.5	17.0	15.6
Stability at Dulles (°C)	-3.4	-1.1	0.0	0.4
Geopotential height difference 700 mb at Dulles (m)	-16.5	5.3	-14.8	20.7
Wind speed yesterday 700 mb at Dulles (ms^{-1})	11.6	8.4	5.5	5.9
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	11.3	7.5	5.7	5.9
Wind direction yesterday 700 mb at Dulles (degrees)	270	310	315	277
Wind direction yesterday 700 mb at Roanoke (degrees)	270	281	270	254
Wind speed yesterday 850 mb at Dulles (ms^{-1})	6.2	5.4	4.9	4.7
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	6.1	5.7	3.5	4.8
Wind speed AM 850 mb at Dulles (ms^{-1})	9.3	5.8	5.8	4.3
Wind speed AM 850 mb at Roanoke (ms^{-1})	4.3	5.5	5.0	6.7
Wind speed PM 850 mb at Dulles (ms^{-1})	6.2	5.6	6.9	6.2
Wind speed PM 850 mb at Roanoke (ms^{-1})	3.9	5.1	5.1	5.0
Wind direction yesterday 850 mb at Dulles (degrees)	225	270	315	270
Wind direction yesterday 850 mb at Roanoke (degrees)	n/a	315	270	248
Wind direction AM 850 mb at Dulles (degrees)	270	0	270	243
Wind direction AM 850 mb at Roanoke (degrees)	180	0	297	217
Wind direction PM 850 mb at Dulles (degrees)	180	180	225	198
Wind direction PM 850 mb at Roanoke (degrees)	n/a	68	270	169
Recirculation at Dulles	0.5	0.3	0.4	0.3
Cloud average	3.0	2.0	2.5	2.5

Table 3-14q. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Shining Rock.

The ranges in extinction coefficient for Categories 4 and 5 are 110-180 and ≥180 Mm-1.

	Class 4			Class 5
	Bin 11	Bin 31	Bin 25	Bin 28
Visibility Parameters				
Yesterday's FM at Knoxville (μg/m^3)	18.1	31.4	30.3	40.4
Yesterday's FM at Charlotte (μg/m^3)	16.7	25.8	21.7	29.2
Yesterday's FM at Greenville (μg/m^3)	16.3	27.7	25.3	32.2
Surface Meteorological Parameters				
Max. surface temperature (°C)	26.0	27.7	24.8	28.2
Min. surface temperature (°C)	14.8	16.8	13.3	16.7
Relative humidity (%)	75.0	82.1	75.1	76.2
Surface wind speed (ms^{-1})	0.9	1.1	1.1	1.1
Surface wind direction (degrees)	27	297	180	315
Persistence	0.6	0.6	0.7	0.7
Sea level pressure (mb)	1021	1018	1021	1021
Rainfall (inches)	0.0	0.2	0.0	0.0
Rain (# periods)	0.5	1.7	0.4	0.2
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	14.6	16.6	12.5	16.4
Temperature PM 850 mb (°C)	15.7	16.6	13.4	17.8
Stability at Greensboro (°C)	1.7	0.0	1.0	-0.2
Geopotential height difference 700 mb at Greensboro (m)	4.1	-8.2	14.7	-4.2
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	7.7	8.6	9.4	5.8
Wind direction yesterday 700 mb at Greensboro (degrees)	324	279	284	323
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	4.8	7.2	4.9	3.4
Wind speed AM 850 mb at Greensboro (ms^{-1})	5.8	6.2	4.0	4.9
Wind speed PM 850 mb at Greensboro (ms^{-1})	5.2	6.8	2.4	6.1
Wind direction yesterday 850 mb at Greensboro (degrees)	321	270	360	286
Wind direction AM 850 mb at Greensboro (degrees)	339	292	270	277
Wind direction PM 850 mb at Greensboro (degrees)	252	256	153	263
Recirculation at Greensboro	0.1	0.1	0.2	0.0
Cloud average	1.7	1.7	1.6	1.8

Table 3-14r. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Sipsey.

The ranges in extinction coefficient for Categories 4 and 5 are 135-200 and ≥200 Mm-1.

	Class 4			Class 5
	Bin 23	Bin 26	Bin 15	Bin 25
Visibility Parameters				
Yesterday's FM at Birmingham (μg/m^3)	36.2	36.7	19.6	33.2
Yesterday's FM at Atlanta (μg/m^3)	34.0	40.6	17.1	24.8
Yesterday's FM at Nashville (μg/m^3)	23.5	27.9	17.2	22.3
Yesterday's FM at Memphis (μg/m^3)	24.0	22.2	12.7	21.0
Surface Meteorological Parameters				
Max. surface temperature (°C)	29.8	30.5	28.6	27.8
Min. surface temperature (°C)	16.1	18.9	16.7	17.8
Relative humidity (%)	58.1	74.3	74.8	79.1
Surface wind speed (ms^{-1})	2.0	1.3	0.9	1.0
Surface wind direction (degrees)	117	225	34	180
Persistence	0.8	0.8	0.8	0.7
Sea level pressure (mb)	1023	1019	1020	1020
Rainfall (inches)	0.0	0.0	0.1	0.0
Rain (# periods)	0.0	0.4	0.7	0.9
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	15.2	16.3	15.8	15.0
Temperature PM 850 mb (°C)	16.1	17.1	16.2	15.9
Stability at Birmingham (°C)	2.6	1.4	1.3	0.5
Geopotential height difference 700 mb at Birmingham (m)	2.8	0.9	-0.6	4.8
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	6.1	5.1	6.3	7.1
Wind direction yesterday 700 mb at Birmingham (degrees)	180	14	326	315
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	4.6	2.8	5.4	4.2
Wind speed AM 850 mb at Birmingham (ms^{-1})	2.5	3.1	4.1	3.4
Wind speed PM 850 mb at Birmingham (ms^{-1})	5.4	3.9	3.2	4.2
Wind direction yesterday 850 mb at Birmingham (degrees)	270	56	360	90
Wind direction AM 850 mb at Birmingham (degrees)	243	225	n/a	202
Wind direction PM 850 mb at Birmingham (degrees)	63	180	18	180
Recirculation at Birmingham	0.2	0.4	0.1	0.1
Cloud average	1.4	1.8	1.7	1.5

Table 3-14s. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site St. Marks.

The ranges in extinction coefficient for Categories 4 and 5 are 100-140 and ≥140 Mm-1.

	Class 4		Class 5
	Bin 21	Bin 19	Bin 27
Visibility Parameters			
Yesterday's FM at Orlando (μg/m^3)	13.3	6.9	28.2
Yesterday's FM at Pensacola (μg/m^3)	18.0	18.6	25.9
Surface Meteorological Parameters			
Max. surface temperature (°C)	28.8	24.7	26.8
Min. surface temperature (°C)	14.5	15.1	12.2
Relative humidity (%)	72.8	85.6	69.2
Surface wind speed (ms^{-1})	1.3	2.2	0.7
Surface wind direction (degrees)	146	45	45
Persistence	0.7	0.8	0.7
Sea level pressure (mb)	1020	1024	1021
Rainfall (inches)	0.0	0.3	0.0
Rain (# periods)	0.3	1.3	0.0
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	13.8	14.5	11.8
Temperature PM 850 mb (°C)	14.1	14.1	11.6
Stability at Tallahassee (°C)	1.8	2.1	3.2
Geopotential height difference 700 mb at Tallahassee (m)	5.8	12.8	-4.8
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	7.1	9.1	6.1
Wind direction yesterday 700 mb at Tallahassee (degrees)	270	225	315
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	3.6	7.3	2.6
Wind speed AM 850 mb at Tallahassee (ms^{-1})	4.9	3.3	4.9
Wind speed PM 850 mb at Tallahassee (ms^{-1})	5.1	5.9	6.8
Wind direction yesterday 850 mb at Tallahassee (degrees)	315	315	342
Wind direction AM 850 mb at Tallahassee (degrees)	225	297	315
Wind direction PM 850 mb at Tallahassee (degrees)	207	n/a	18
Recirculation at Tallahassee	0.1	0.3	0.3
Cloud average	1.5	1.5	1.8

Table 3-14t. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Swanquarter.

The ranges in extinction coefficient for Categories 4 and 5 are 115-175 and ≥175 Mm-1.

	Class 4		Class 5	
	Bin 28	Bin 30	Bin 23	Bin 27
Visibility Parameters				
Yesterday's FM at Raleigh (µg/m^3)	21.9	17.8	20.3	22.6
Yesterday's FM at Norfolk (µg/m^3)	16.9	20.0	14.1	18.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	20.9	24.0	19.9	25.1
Min. surface temperature (°C)	14.9	15.4	13.1	20.0
Relative humidity (%)	88.3	87.0	82.3	91.6
Surface wind speed (ms^{-1})	2.6	1.5	3.0	3.2
Surface wind direction (degrees)	180	225	281	212
Persistence	0.7	0.7	0.7	0.8
Sea level pressure (mb)	1022	1018	1019	1016
Rainfall (inches)	0.0	0.3	0.1	0.1
Rain (# periods)	0.5	1.2	1.2	0.7
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	12.7	13.0	9.7	15.9
Temperature PM 850 mb (°C)	13.0	13.9	8.8	16.2
Stability at Moorhead (°C)	-0.2	2.0	-1.4	0.1
Geopotential height difference 700 mb at Moorhead (m)	2.7	-19.8	-32.6	-9.6
Wind speed yesterday 700 mb at Moorhead (ms^{-1})	10.4	6.3	20.4	9.8
Wind direction yesterday 700 mb at Moorhead (degrees)	270	281	243	280
Wind speed yesterday 850 mb at Moorhead (ms^{-1})	9.2	5.0	13.1	7.5
Wind speed AM 850 mb at Moorhead (ms^{-1})	11.3	8.8	9.4	8.4
Wind speed PM 850 mb at Moorhead (ms^{-1})	6.7	7.0	12.7	8.3
Wind direction yesterday 850 mb at Moorhead (degrees)	252	270	259	265
Wind direction AM 850 mb at Moorhead (degrees)	270	180	270	270
Wind direction PM 850 mb at Moorhead (degrees)	259	342	281	276
Recirculation at Moorhead	0.0	0.2	0.0	0.1
Cloud average	1.7	1.5	1.5	1.7

Table 3-14u. Summary of Average Input Parameters for Key Bins for CART Classification Categories 4 and 5: Visibility CART Analysis for the IMPROVE Site Upper Buffalo.

The ranges in extinction coefficient for Categories 4 and 5 are 100-150 and ≥150 Mm-1.

	Class 4			Class 5	
	Bin 28	Bin 33	Bin 29	Bin 38	Bin 34
Visibility Parameters					
Yesterday's FM at Little Rock (μg/m³)	18.8	29.6	15.0	22.7	28.4
Yesterday's FM at Dallas (μg/m³)	18.3	21.8	17.5	25.5	28.9
Surface Meteorological Parameters					
Max. surface temperature (°C)	28.2	28.5	21.0	25.6	30.4
Min. surface temperature (°C)	16.6	17.2	10.2	17.7	17.2
Relative humidity (%)	1.8	2.5	3.0	2.4	2.0
Surface wind speed (ms^{-1})	159	191	180	162	135
Surface wind direction (degrees)	0.7	0.8	0.9	0.8	0.8
Persistence	73.3	69.6	74.0	87.4	71.3
Sea level pressure (mb)	1020	1017	1018	1016	1017
Rainfall (inches)	0.0	0.0	0.0	0.1	0.0
Rain (# periods)	0.1	0.0	0.6	0.4	0.0
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	15.5	16.2	12.4	16.5	16.7
Temperature PM 850 mb (°C)	16.6	17.1	11.5	17.2	17.5
Stability at Little Rock (°C)	-1.9	-1.5	-2.0	-2.3	0.2
Geopotential height difference 700 mb at Little Rock (m)	1.7	-14.5	-38.0	7.2	-2.8
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	4.9	6.7	9.8	9.9	5.3
Wind direction yesterday 700 mb at Little Rock (degrees)	323	360	256	256	90
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	2.8	4.4	8.9	6.2	4.3
Wind speed AM 850 mb at Little Rock (ms^{-1})	4.0	5.3	10.5	5.8	3.9
Wind speed PM 850 mb at Little Rock (ms^{-1})	3.2	5.1	12.4	7.9	3.7
Wind direction yesterday 850 mb at Little Rock (degrees)	22	239	180	194	45
Wind direction AM 850 mb at Little Rock (degrees)	220	252	270	248	315
Wind direction PM 850 mb at Little Rock (degrees)	180	236	360	207	135
Recirculation at Little Rock	0.5	0.3	0.0	0.4	0.2
Cloud average	1.8	1.4	1.9	1.6	1.7

While there are many similarities in the conditions that describe the key bins, there are also some important differences (that relate directly to source-receptor relationships and potentially to control strategy effectiveness). For discussion purposes, we examine the results for the Cape Romain, Great Smoky Mountains, and Mammoth Cave IMPROVE sites.

For Cape Romain, the extinction coefficients for Categories 4 and 5 are in the range 100 to 160 and greater than or equal to 160 Mm^{-1}, respectively. We note that all the key bins of the 20 percent haziest days at Cape Romain are characterized by high temperatures, low surface wind speeds, and moderate to high relative humidity, but the values vary among the bins. Prior day $PM_{2.5}$ values for Charleston are in the range of 12 to 24 μgm^{-3}, and vary more considerably among the key bins. One possible reason for this is that transport from Charleston is potentially more important for two of the bins, Bins 33 and 32, compared to the remaining bins. Average

surface wind direction is more variable across the key bins, and is northerly to northeasterly for two of the key bins, southeasterly for two of the bins, and south-southwesterly for the remaining key bin, indicating differences in the transport patterns and or source-receptor relationships between the days that comprise the bins. Recirculation by the sea breeze (as indicated by persistence) is important for Bin 32, the key Category 5 bin. Upper-air wind speeds and directions vary among the bins. Wind speeds are higher aloft for Bins 33 and 32, compared to the other key bins. Morning and evening 850 mb wind directions are northwesterly for all but Bin 27, which has southeasterly to southerly winds. Bins 33 and 32, which are in close proximity in the CART tree, have, as expected, similar average characteristics. However, Bin 33 is a Category 4 bin and Bin 32 is a Category 5 bin. An important difference in the characteristics between the bins is surface wind speed. This is also the parameter that splits the two bins in the CART tree. The higher extinction coefficient days in Bin 32 appear to be driven by lower wind speeds and a greater potential for recirculation by the sea breeze.

For GSM, the extinction coefficients for Categories 4 and 5 are in the range 120 to 180 and greater than or equal to 180 Mm^{-1}, respectively. The key bins of the 20 percent haziest days at GSM are characterized by low surface wind speeds. Four of the six key bins have high temperatures (summer regimes) and two have lower temperatures (characteristic of fall or spring regimes). All but one of the key bins is characterized by greater than 80 percent relative humidity. Prior day $PM_{2.5}$ values for Knoxville, Atlanta, and Charlotte vary among the bins in a consistent manner, but the range in value is different for the three areas (with generally lower values for Charlotte). As for Cape Romain, this indicates that transport from the surrounding areas is potentially more important for some of the bins, compared to others. Average surface wind direction is southwesterly for four of the key bins, northwesterly for one bin, and northeasterly for one bin. Upper-air wind speeds and directions vary among the monitoring sites. The closest and most directly relevant site is Nashville. Wind speeds aloft are lower for the Category 5 bins, compared to the Category 4 bins. The 850 mb wind directions for Nashville are westerly to northwesterly for the Category 4 bins, and westerly then southerly for two of the three Category 5 bins, and northerly for the remaining Category 5 bin. Thus wind direction both near the surface and aloft appears to distinguish the Category 4 bins from the higher bins, and the Category 5 bins from one another. Northerly wind components for Bin 32 seem to drive the poor visibility, since the regional $PM_{2.5}$ concentrations are relatively low, on average, for this bin. In addition to the summer regimes being distinguished by different wind directions, the two cooler bins (Bins 18 and 15) are also characterized by different wind directions (from one another).

For Mammoth Cave, the extinction coefficients for Categories 4 and 5 are in the range 155 to 250 and greater than or equal to 250 Mm^{-1}, respectively. All three key bins of the 20 percent haziest days at Mammoth Cave are characterized by high temperatures, low surface wind speeds, and moderate relative humidity, but these vary among the bins. Prior day $PM_{2.5}$ values for Nashville, Knoxville, and Louisville vary among the bins in a consistent manner, with generally lower values for Nashville. Prior day $PM_{2.5}$ values are higher for Bins 8 and 34, than for Bin 29. Average surface wind direction is southerly for Bins 29 and 34 and northerly for Bin 8. The difference in wind speed between Bins 29 and 34 (lower wind speeds for Bin 34) may account for the higher extinction coefficients for Bin 34, although there are also some differences in wind directions aloft. Upper-air wind speeds are highest for Bin 29. Morning and evening 850 mb wind directions vary considerably among the key bins.

CART analyses also provide insight into $PM_{2.5}$ composition for key bins of poor visibility days at the IMPROVE sites. In general, analysis of the compositional characteristics for the key bins for the 20 percent haziest days for the Southern Appalachian IMPROVE sites indicates a predominance of ammonium sulfate and a contribution from organic carbon. Figure 3-6 shows the average composition for all key visibility bins for each of the IMPROVE sites. Note that the scale may be different for each site.

Figure 3-6a. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Breton.

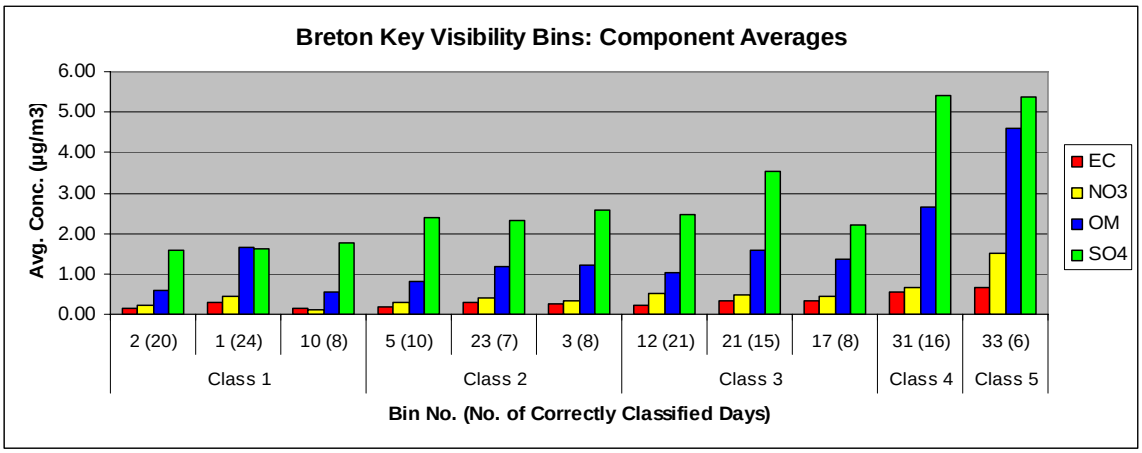


Figure 3-6b. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Brigantine.

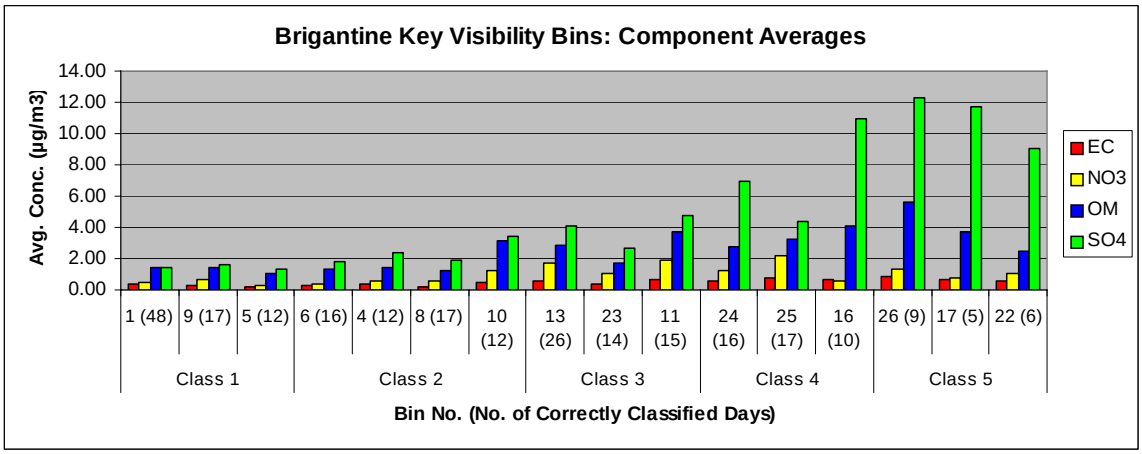


Figure 3-6c. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Cadiz.

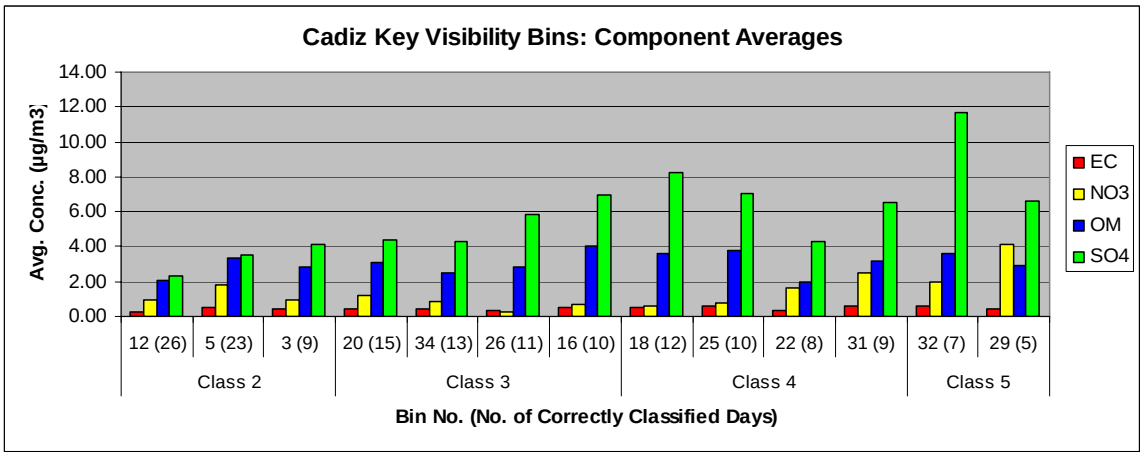


Figure 3-6d. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Caney Creek.

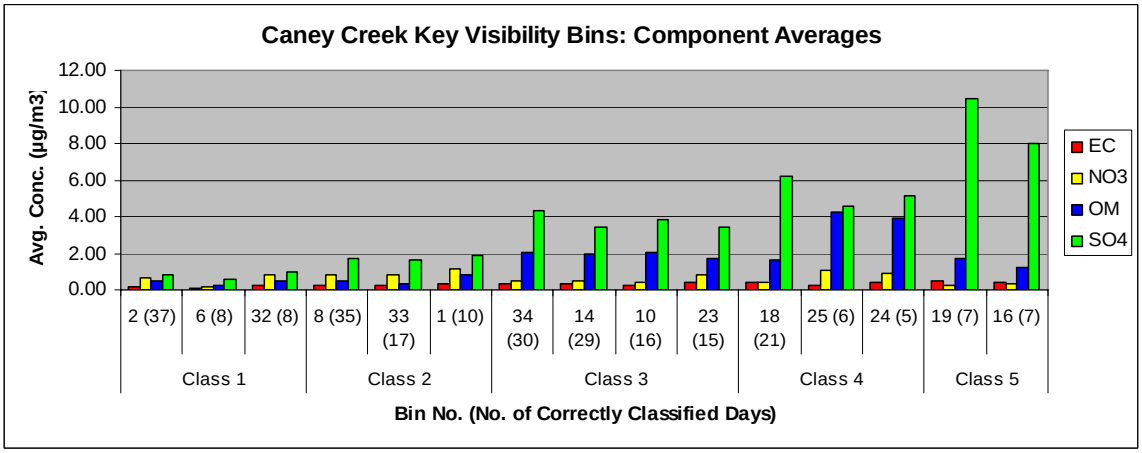


Figure 3-6e. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Cape Romain.

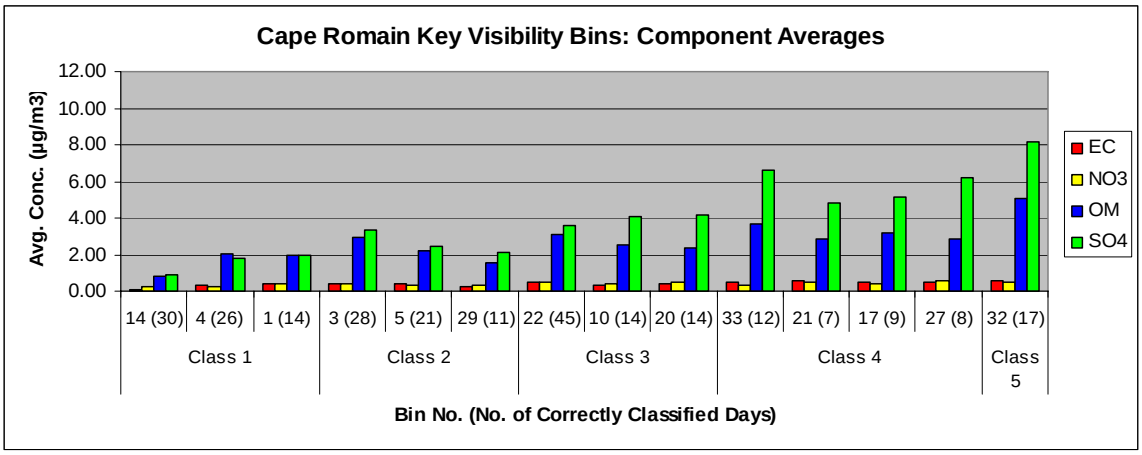


Figure 3-6f. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Chassahowitzka.

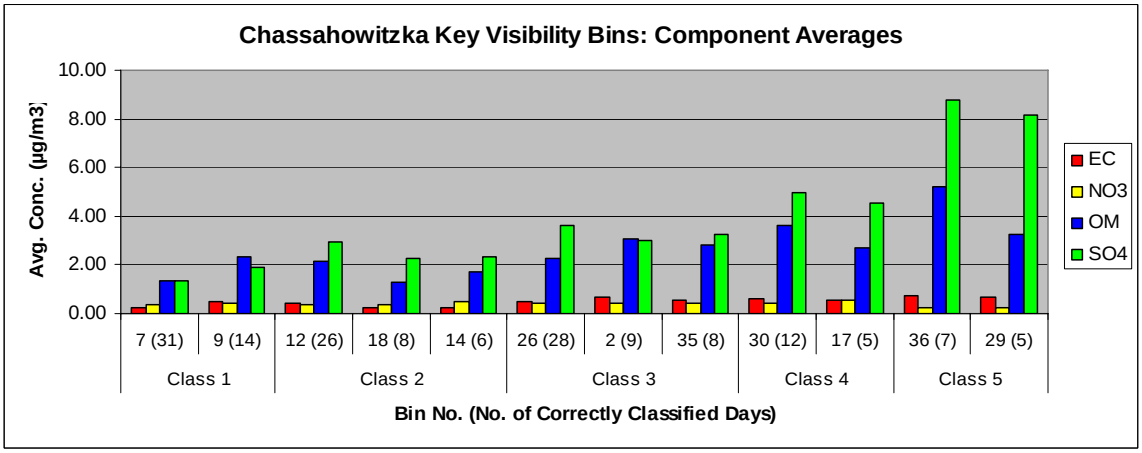


Figure 3-6g. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Cohutta.

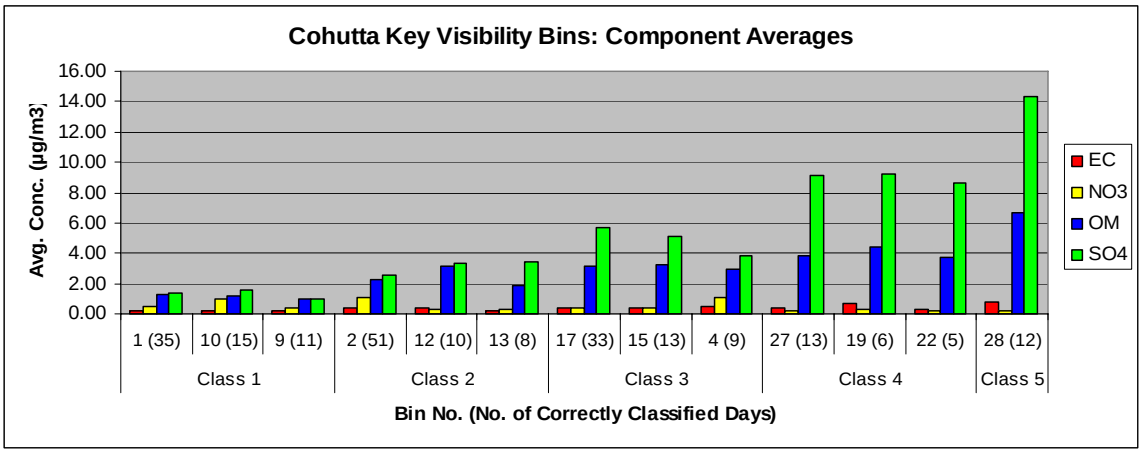


Figure 3-6h. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Dolly Sods.

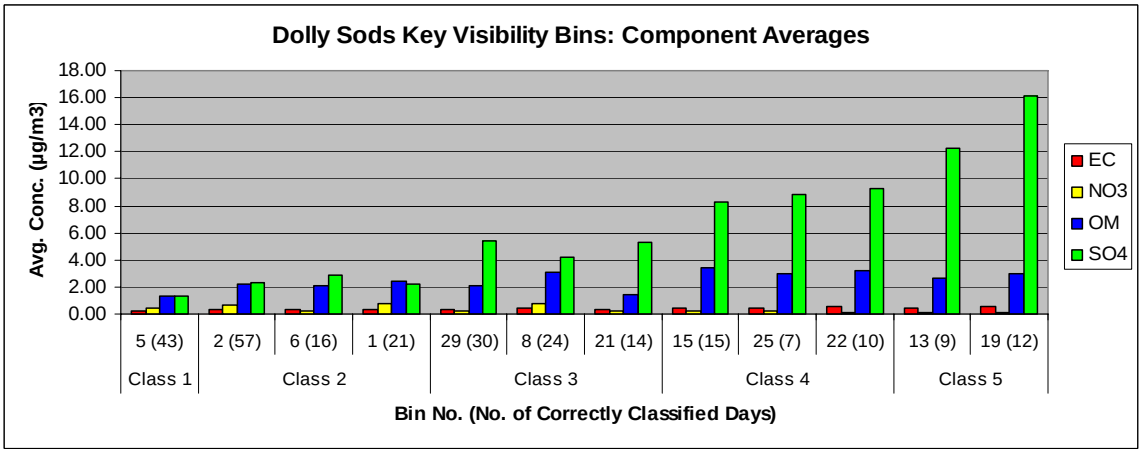


Figure 3-6i. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Everglades.

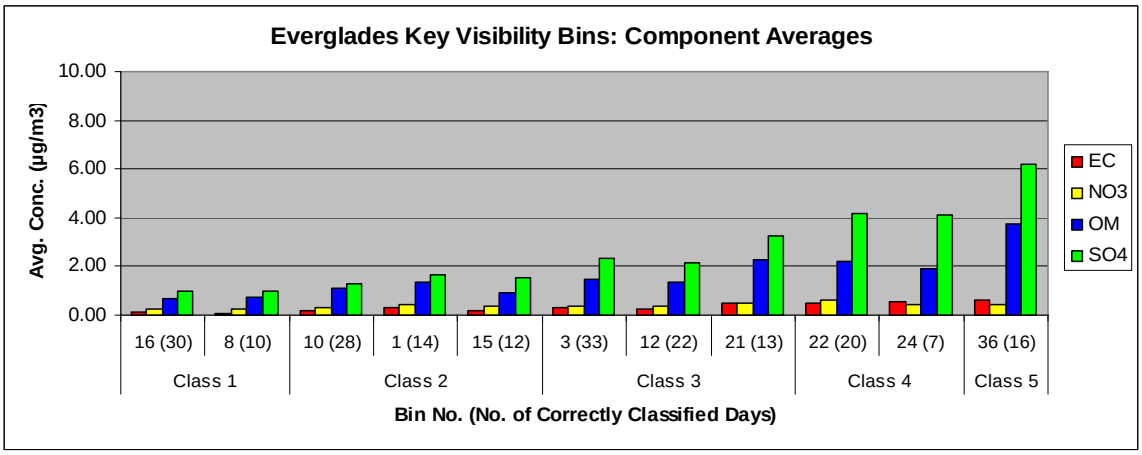


Figure 3-6j. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Great Smoky Mountains.

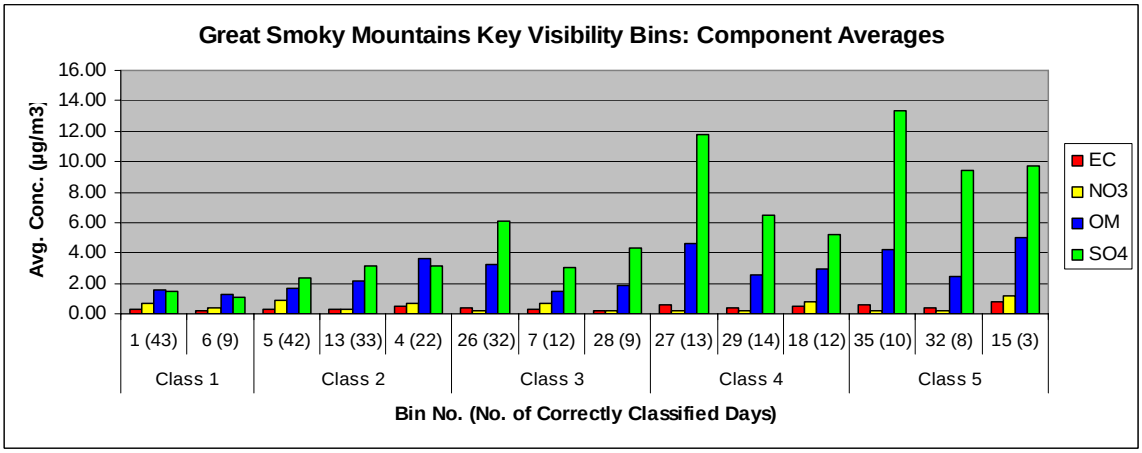


Figure 3-6k. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site James River Face.

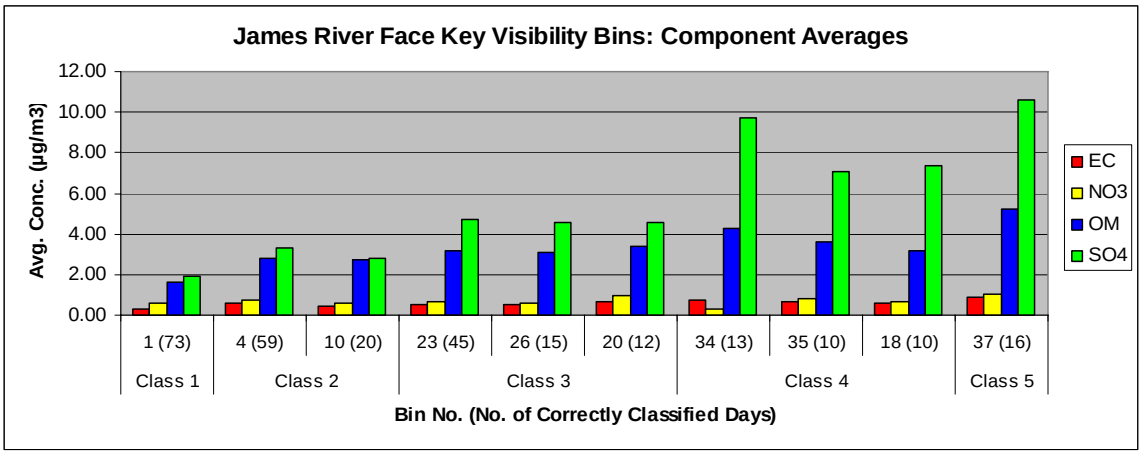


Figure 3-6l. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Linville Gorge.

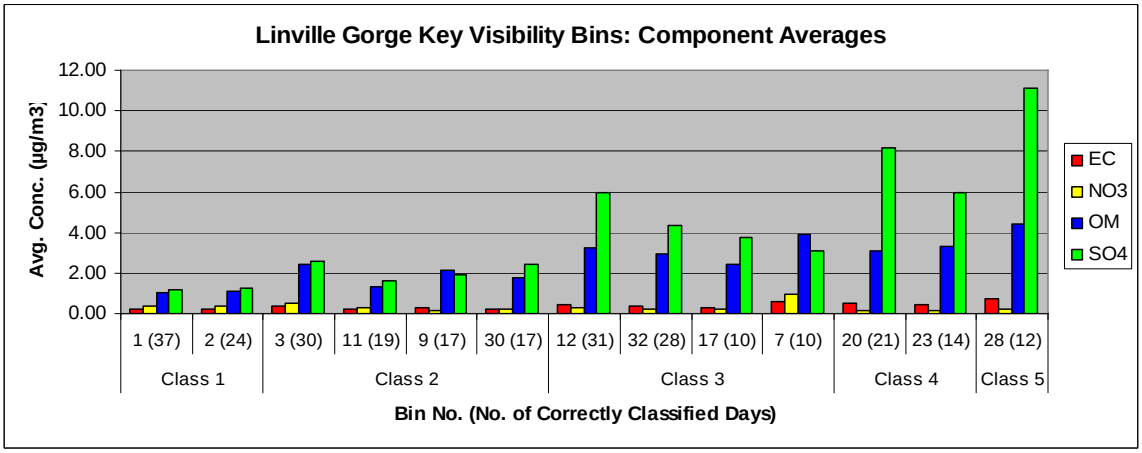


Figure 3-6m. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Mammoth Cave.

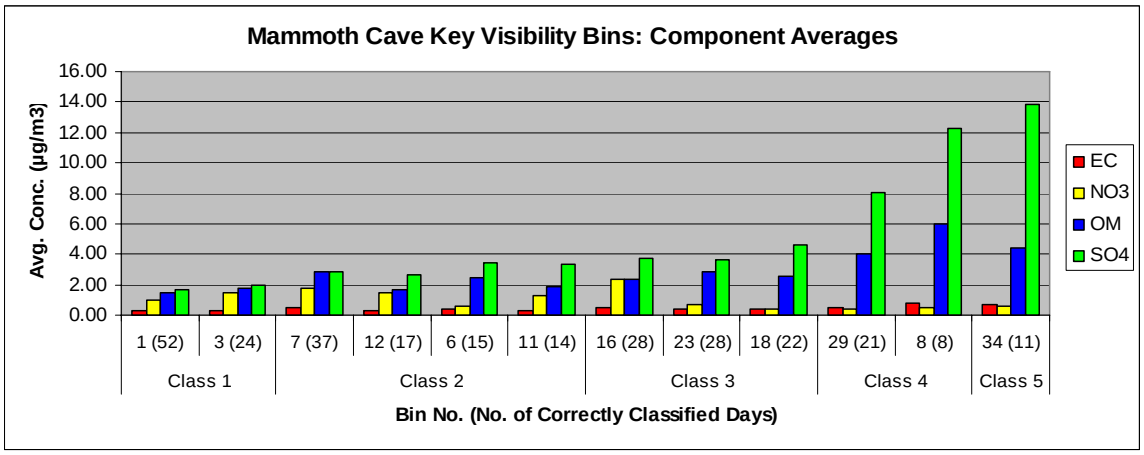


Figure 3-6n. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Mingo.

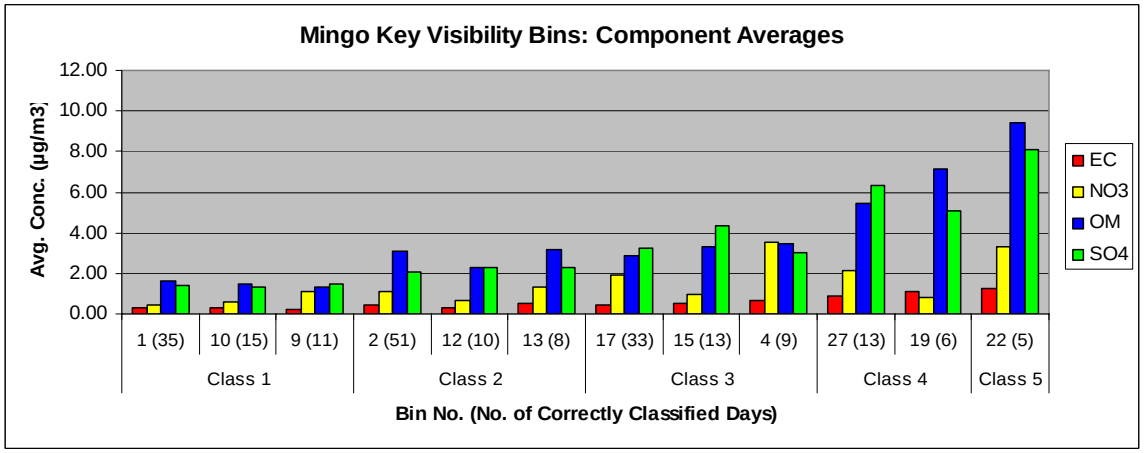


Figure 3-6o. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Okefenokee.

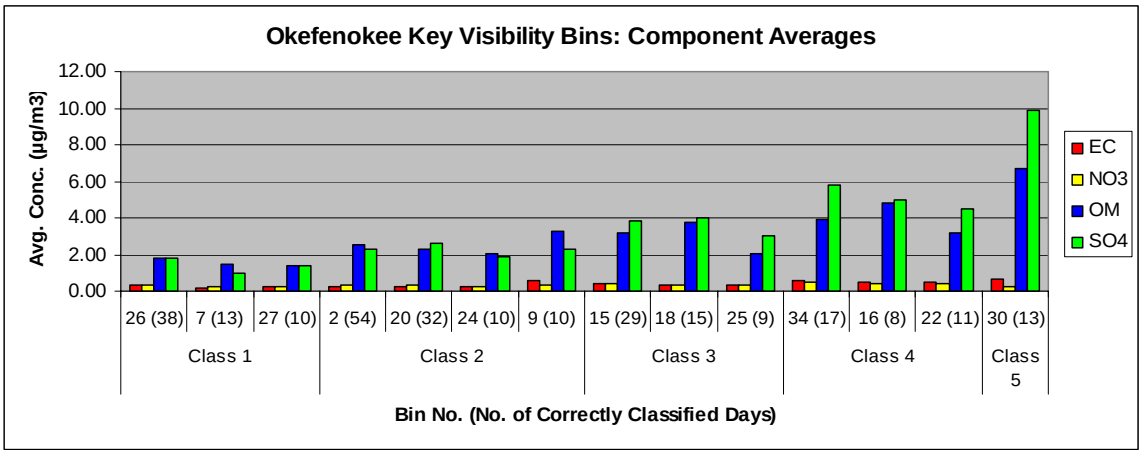


Figure 3-6p. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Shenandoah.

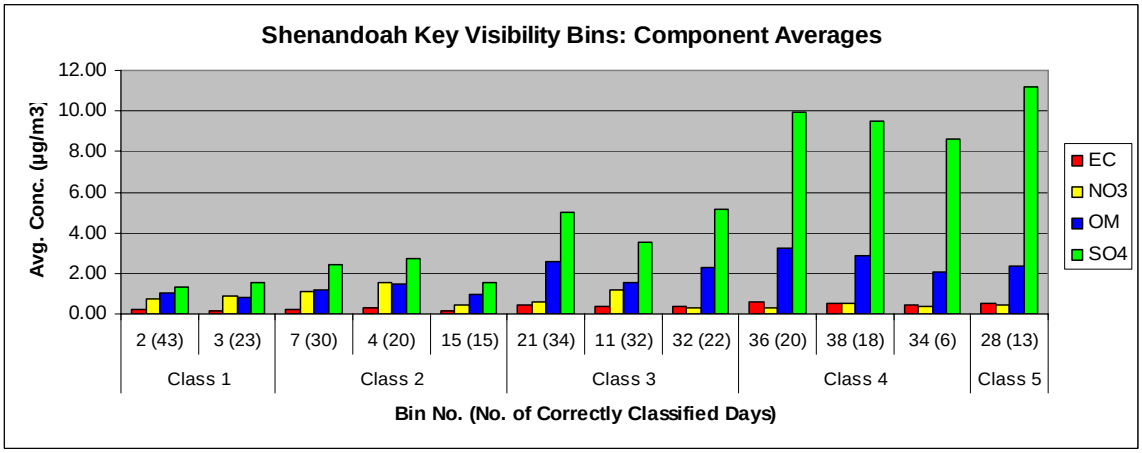


Figure 3-6q. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Shining Rock.

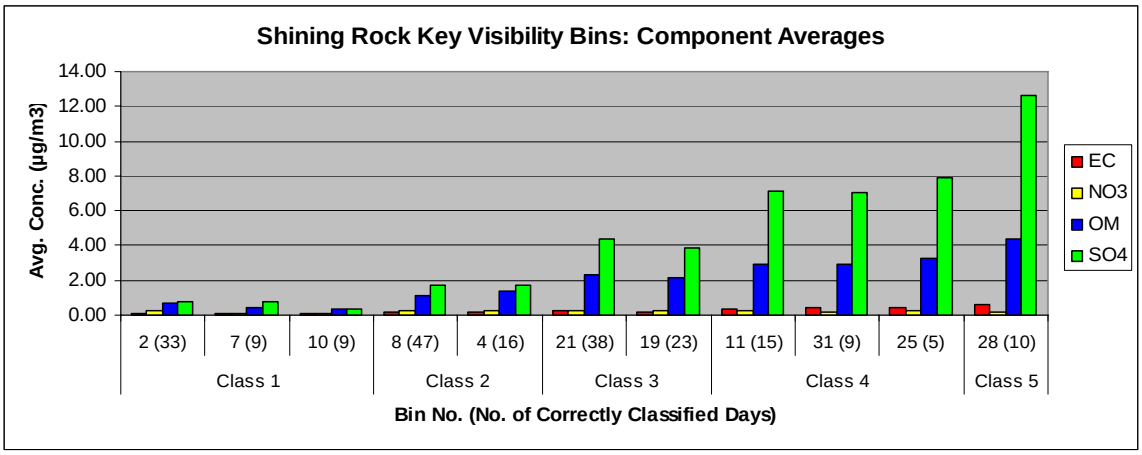


Figure 3-6r. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Sipsey.

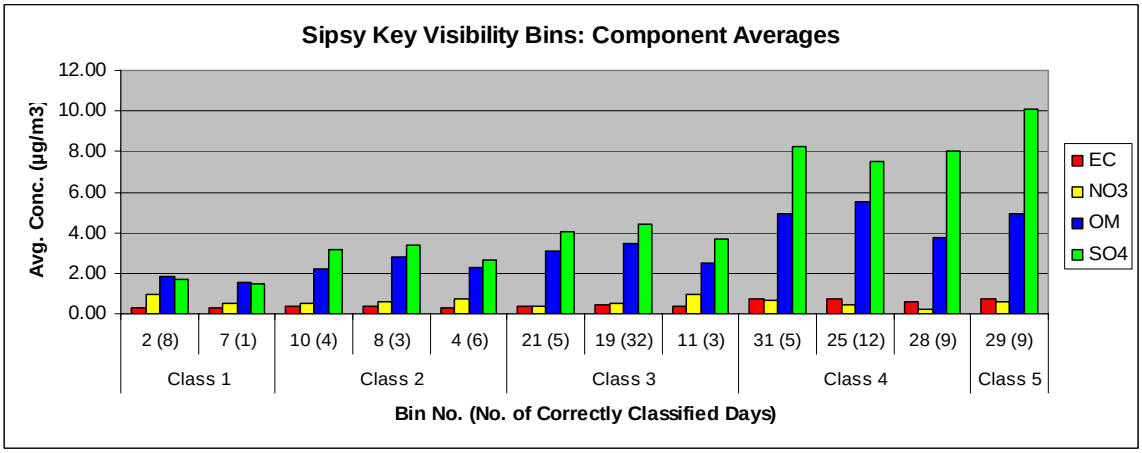


Figure 3-6s. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site St Mark's.

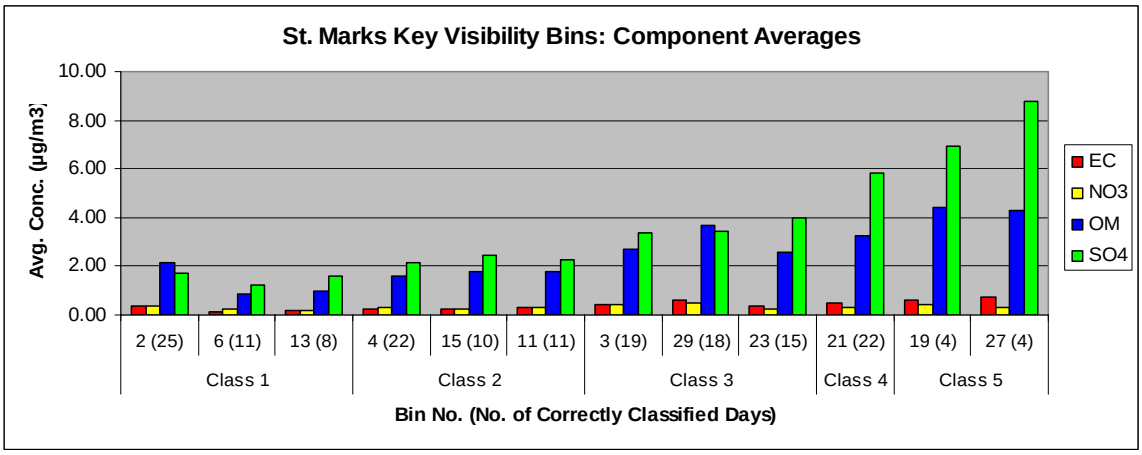


Figure 3-6t. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Swanquarter.

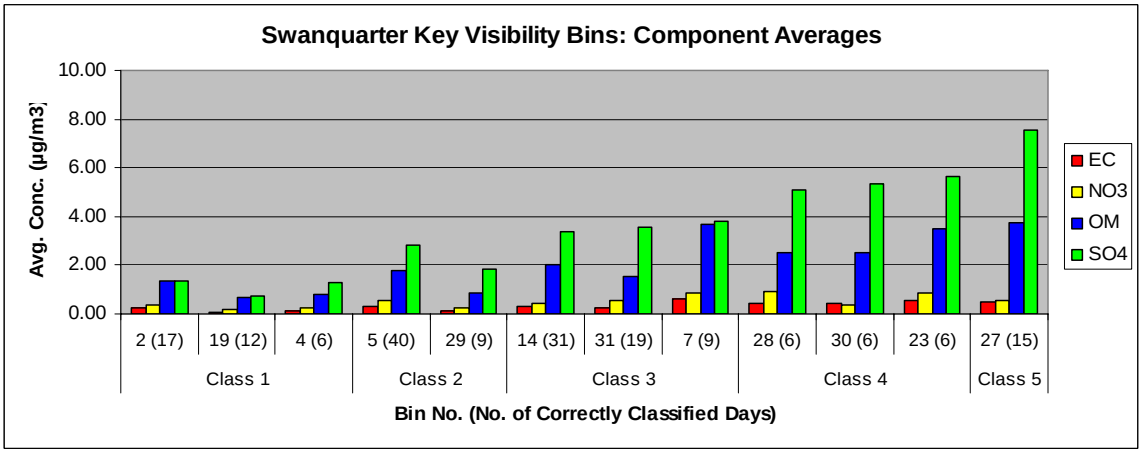
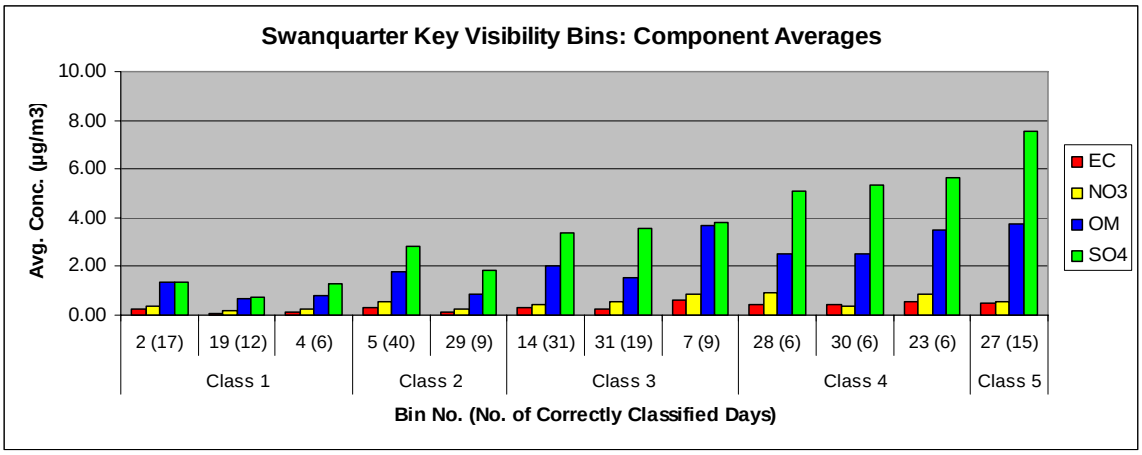


Figure 3-6u. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key Visibility Bins for All CART Classification Categories: IMPROVE Site Upper Buffalo.



The compositional charts clearly illustrate that the relative contributions of various $PM_{2.5}$ components vary by bin for each of the sites. The high $PM_{2.5}$ concentration bins are distinguished from the lower concentration bins by higher sulfate and organic matter concentrations, and, in many cases, lower nitrate concentrations. Within each category, there are variations among the bins that are due to differences in meteorology as well as regional pollutant transport.

For example, consider the three poor visibility bins for Mammoth Cave (Bins 29, 8 and 34). Earlier in this section, we noted that days within Bin 34 are characterized by lower surface wind speeds and higher regional (potential upwind) concentrations than those within Bin 29. In the compositional chart (Figure 3-6m), these differences are manifested as higher sulfate, with little difference in the other components. Bin 8 days have, on average, comparable surface wind speeds and regional concentrations compared to days in Bin 34. Lower relative humidity for Bin 8 may contribute to the lower sulfate concentrations. Winds from the north-northeast (compared to the south) may explain the higher organic matter component, with possible transport of particulates and precursors from Midwestern urban areas such as Louisville, Lexington, and Cincinnati.

In general, the CART-based compositional analysis results indicate that, for the interior and mountain IMPROVE sites in the VISTAS states, ammonium sulfate is the dominant contributor to $PM_{2.5}$ concentration and organic carbon is an important component of $PM_{2.5}$ on poor visibility days. For the coastal IMPROVE sites the contributions from ammonium sulfate and organic carbon to $PM_{2.5}$ on the poor visibility days are more comparable than at the interior sites.

PM2.5

Tables 3-15 through 3-17 summarize the characteristics for key Category 3 and 4 bins for $PM_{2.5}$ for the IMPROVE, STN and SEARCH monitoring sites, respectively. The Category 3 and 4 bins represent the 10 percent highest $PM_{2.5}$ days.

Table 3-15a. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Breton.

The ranges in PM2.5 for Categories 3 and 4 are 12.5-17.5 and ≥17.5 μgm-3.

	Class 3		Class 4
	Bin 19	Bin 27	Bin 21
Visibility Parameters			
Yesterday's FM at New Orleans/Baton Rouge (μg/m^3)	18.1	30.5	21.0
Yesterday's FM at Gulfport (μg/m^3)	16.1	27.7	21.5
Yesterday's FM at Pensacola (μg/m^3)	16.4	30.2	26.4
Surface Meteorological Parameters			
Max. surface temperature (°C)	23.6	22.0	30.4
Min. surface temperature (°C)	17.6	13.7	23.3
Relative humidity (%)	78.6	86.0	73.3
Surface wind speed (ms^{-1})	3.3	1.6	1.9
Surface wind direction (degrees)	34	22	79
Persistence	0.9	0.8	0.7
Sea level pressure (mb)	1022	1021	1016
Rainfall (inches)	0.0	0.0	0.0
Rain (# periods)	0.2	1.1	0.3
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	12.2	10.1	15.8
Temperature PM 850 mb (°C)	12.8	10.7	16.6
Stability at Slidell (°C)	1.0	1.4	0.1
Geopotential height difference 700 mb at Slidell (m)	4.3	-6.7	-0.6
Wind speed yesterday 700 mb at Slidell (ms^{-1})	9.4	7.4	4.9
Wind direction yesterday 700 mb at Slidell (degrees)	307	360	342
Wind speed yesterday 850 mb at Slidell (ms^{-1})	7.0	7.6	5.1
Wind speed AM 850 mb at Slidell (ms^{-1})	6.6	6.1	4.2
Wind speed PM 850 mb at Slidell (ms^{-1})	6.7	6.5	4.6
Wind direction yesterday 850 mb at Slidell (degrees)	323	360	360
Wind direction AM 850 mb at Slidell (degrees)	323	63	252
Wind direction PM 850 mb at Slidell (degrees)	360	63	18
Recirculation at Slidell	0.0	0.1	0.1
Cloud average	1.4	1.7	1.7

Table 3-15b. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis IMPROVE Site Brigantine.

The ranges in PM2.5 for Categories 3 and 4 are 17.5-22.5 and ≥22.5 μgm-3.

	Class 3		Class 4
	Bin 23	Bin 29	Bin 31
Visibility Parameters			
Yesterday's FM at Wilmington (μg/m³)	15.1	29.7	33.2
Yesterday's FM at New Orleans (μg/m³)	18.1	24.6	26.8
Yesterday's FM at Philadelphia (μg/m³)	14.1	26.5	32.8
Surface Meteorological Parameters			
Max. surface temperature (°C)	29.6	30.3	31.8
Min. surface temperature (°C)	18.7	18.1	21.1
Relative humidity (%)	73.9	64.5	67.2
Surface wind speed (ms^{-1})	2.9	3.1	2.8
Surface wind direction (degrees)	209	225	207
Persistence	0.9	0.8	0.8
Sea level pressure (mb)	1018	1020	1016
Rainfall (inches)	0.0	0.0	0.0
Rain (# periods)	0.4	0.3	0.5
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	14.3	14.2	16.1
Temperature PM 850 mb (°C)	15.0	14.4	17.5
Stability at Brookhaven (°C)	-0.7	0.0	-0.1
Geopotential height difference 700 mb at Brookhaven (m)	6.2	-4.8	1.0
Wind speed yesterday 700 mb at Brookhaven (ms^{-1})	8.1	13.1	9.2
Wind speed yesterday 700 mb at Dulles (ms^{-1})	8.7	12.5	6.7
Wind direction yesterday 700 mb at Brookhaven (degrees)	288	252	306
Wind direction yesterday 700 mb at Dulles (degrees)	292	252	288
Wind speed yesterday 850 mb at Brookhaven (ms^{-1})	6.3	11.7	9.0
Wind speed yesterday 850 mb at Dulles (ms^{-1})	6.8	12.1	5.9
Wind speed AM 850 mb at Brookhaven (ms^{-1})	10.0	11.4	8.6
Wind speed AM 850 mb at Dulles (ms^{-1})	8.4	10.5	6.6
Wind speed PM 850 mb at Brookhaven (ms^{-1})	10.1	9.2	9.7
Wind speed PM 850 mb at Dulles (ms^{-1})	8.3	7.7	8.0
Wind direction yesterday 850 mb at Brookhaven (degrees)	281	252	304
Wind direction yesterday 850 mb at Dulles (degrees)	270	225	270
Wind direction AM 850 mb at Brookhaven (degrees)	275	270	284
Wind direction AM 850 mb at Dulles (degrees)	270	252	293
Wind direction PM 850 mb at Brookhaven (degrees)	270	270	275
Wind direction PM 850 mb at Dulles (degrees)	257	288	304
Cloud average	1.9	1.8	2.0

Table 3-15c. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Cadiz.

The ranges in PM2.5 for Categories 3 and 4 are 17.5-22.5 and ≥22.5 μgm-3.

	Class 3		Class 4
	Bin 23	Bin 6	Bin 30
Visibility Parameters			
Yesterday's FM at Nashville (μg/m³)	21.7	11.9	28.7
Yesterday's FM at St. Louis (μg/m³)	20.6	23.9	28.4
Yesterday's FM at Louisville (μg/m³)	21.7	18.0	39.7
Surface Meteorological Parameters			
Max. surface temperature (°C)	28.2	19.6	26.7
Min. surface temperature (°C)	17.5	10.9	17.3
Relative humidity (%)	72.4	78.5	76.2
Surface wind speed (ms^{-1})	1.4	1.8	1.3
Surface wind direction (degrees)	360	360	n/a
Persistence	0.9	0.8	0.8
Rainfall (inches)	0.0	0.0	0.1
Rain (# periods)	0.0	0.2	0.4
Solar radiation (W/m²)	822	431	554
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	16.8	9.0	15.5
Temperature PM 850 mb (°C)	17.1	11.1	15.8
Stability at Nashville (°C)	1.8	-0.4	1.5
Geopotential height difference 700 mb at Nashville (m)	7.9	18.9	2.2
Wind speed yesterday 700 mb at Nashville (ms^{-1})	7.9	11.6	7.7
Wind direction yesterday 700 mb at Nashville (degrees)	342	252	27
Wind speed yesterday 850 mb at Nashville (ms^{-1})	4.2	9.0	4.3
Wind speed AM 850 mb at Nashville (ms^{-1})	4.0	4.8	5.5
Wind speed PM 850 mb at Nashville (ms^{-1})	4.3	2.8	5.1
Wind direction yesterday 850 mb at Nashville (degrees)	45	270	360
Wind direction AM 850 mb at Nashville (degrees)	45	297	270
Wind direction PM 850 mb at Nashville (degrees)	n/a	180	153
Recirculation at Nashville	0.3	0.0	0.2
Cloud average	1.4	1.8	1.8

Table 3-15d. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Caney Creek.

The ranges in PM2.5 for Categories 3 and 4 are 15-20 and ≥ 20 μgm-3.

	Class 3			Class 4
	Bin 13	Bin 32	Bin 27	Bin 31
Visibility Parameters				
Yesterday's FM at Little Rock (μg/m³)	19.5	21.8	22.9	18.6
Yesterday's FM at Dallas (μg/m³)	25.5	20.6	18.2	19.0
Surface Meteorological Parameters				
Max. surface temperature (°C)	26.9	33.6	33.4	32.8
Min. surface temperature (°C)	14.3	20.6	20.7	17.1
Relative humidity (%)	72.7	74.8	74.3	64.3
Surface wind speed (ms^{-1})	0.7	0.1	0.5	0.7
Surface wind direction (degrees)	157.3	148.3	108.3	190.3
Persistence	0.9	1.0	0.9	0.9
Sea level pressure (mb)	1018	1016	1015	1016
Rainfall (inches)	0.0	0.0	0.1	0.0
Rain (# periods)	0.4	0.5	0.6	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	14.1	19.4	18.6	19.0
Temperature PM 850 mb (°C)	14.7	20.2	19.9	18.9
Stability at Little Rock (°C)	-0.7	-2.4	-1.5	-0.5
Geopotential height difference 700 mb at Little Rock (m)	0.7	-9.6	14.6	-3.7
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	5.9	6.6	5.8	8.8
Wind direction yesterday 700 mb at Little Rock (degrees)	304	117	315	14
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	4.8	5.5	3.5	6.9
Wind speed AM 850 mb at Little Rock (ms^{-1})	8.5	4.4	2.8	9.0
Wind speed PM 850 mb at Little Rock (ms^{-1})	5.8	7.4	2.8	9.8
Wind direction yesterday 850 mb at Little Rock (degrees)	180	270	270	243
Wind direction AM 850 mb at Little Rock (degrees)	233	270	243	248
Wind direction PM 850 mb at Little Rock (degrees)	207	360	360	214
Recirculation at Little Rock	0.0	0.0	0.4	0.0
Cloud average	1.6	1.3	1.8	1.3

Table 3-15e. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Cape Romain.

The ranges in PM2.5 for Categories 3 and 4 are 15-17.5 and ≥17.5 μgm-3.

	Class 3		Class 4	
	Bin 15	Bin 31	Bin 22	Bin 33
Visibility Parameters				
Yesterday's FM at Charleston (μg/m^3)	13.0	21.5	24.5	29.7
Surface Meteorological Parameters				
Max. surface temperature (°C)	17.9	34.6	28.2	31.0
Min. surface temperature (°C)	7.8	23.6	18.0	19.1
Relative humidity (%)	67.9	73.8	77.5	68.9
Surface wind speed (ms^{-1})	3.3	2.7	1.5	2.9
Surface wind direction (degrees)	225	225	153	214
Persistence	0.9	0.9	0.5	0.9
Sea level pressure (mb)	1020	1014	1018	1017
Rainfall (inches)	0.0	0.0	0.0	0.0
Rain (# periods)	0.8	0.3	0.6	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	7.9	19.2	14.5	14.7
Temperature PM 850 mb (°C)	9.7	20.2	14.7	16.4
Stability at Charleston (°C)	2.3	-1.3	-0.6	-1.1
Geopotential height difference 700 mb at Charleston (m)	5.0	-13.3	-3.5	-13.2
Wind speed yesterday 700 mb at Charleston (ms^{-1})	19.9	8.4	7.7	8.3
Wind direction yesterday 700 mb at Charleston (degrees)	270	342	300	326
Wind speed yesterday 850 mb at Charleston (ms^{-1})	14.1	5.0	7.3	5.2
Wind speed AM 850 mb at Charleston (ms^{-1})	8.5	6.2	8.0	6.8
Wind speed PM 850 mb at Charleston (ms^{-1})	15.4	7.0	6.4	7.3
Wind direction yesterday 850 mb at Charleston (degrees)	270	360	291	333
Wind direction AM 850 mb at Charleston (degrees)	270	360	291	304
Wind direction PM 850 mb at Charleston (degrees)	270	342	329	307
Recirculation at Charleston	0.0	0.3	0.1	0.0
Cloud average	1.7	1.8	1.8	1.4

Table 3-15f. Summary of Average Input Parameters for Each Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Chassahowitzka.

The ranges in PM2.5 for Categories 3 and 4 are 12.5-17.5 and ≥17.5 μgm-3.

	Class 3		Class 4
	Bin 13	Bin 8	Bin 27
Visibility Parameters			
Yesterday's FM at Tampa (μg/m³)	15.4	15.6	25.8
Yesterday's FM at Orlando (μg/m³)	13.4	11.6	20.3
Surface Meteorological Parameters			
Max. surface temperature (°C)	29.1	28.0	30.9
Min. surface temperature (°C)	17.7	13.1	17.0
Relative humidity (%)	80.9	78.8	79.9
Surface wind speed (ms^{-1})	1.8	1.1	1.5
Surface wind direction (degrees)	360	288	270
Persistence	0.8	0.6	0.6
Sea level pressure (mb)	1019	1020	1018
Rainfall (inches)	0.2	0.0	0.0
Rain (# periods)	0.7	0.0	0.2
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	15.2	13.7	15.3
Temperature PM 850 mb (°C)	15.4	13.4	16.0
Stability at Tampa (°C)	-2.2	-0.9	-0.9
Geopotential height difference 700 mb at Tampa (m)	-2.0	-3.3	-0.3
Wind speed yesterday 700 mb at Tampa (ms^{-1})	5.6	5.9	5.5
Wind direction yesterday 700 mb at Tampa (degrees)	23	270	297
Wind speed yesterday 850 mb at Tampa (ms^{-1})	5.1	3.7	4.6
Wind speed AM 850 mb at Tampa (ms^{-1})	2.9	3.9	4.9
Wind speed PM 850 mb at Tampa (ms^{-1})	5.3	4.6	5.0
Wind direction yesterday 850 mb at Tampa (degrees)	53	72	104
Wind direction AM 850 mb at Tampa (degrees)	90	225	180
Wind direction PM 850 mb at Tampa (degrees)	108	117	90
Recirculation at Tampa	0.1	0.3	0.0
Cloud average	2.2	1.6	1.2

Table 3-15g. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Cohutta.

The ranges in PM2.5 for Categories 3 and 4 are 20-25 and ≥25 μgm-3.

	Class 3	Class 4
	Bin 21	Bin 29
Visibility Parameters		
Yesterday's FM at Birmingham (μg/m³)	36.4	34.1
Yesterday's FM at Atlanta (μg/m³)	30.2	35.5
Yesterday's FM at Nashville (μg/m³)	21.0	31.1
Yesterday's FM at Knoxville (μg/m³)	27.4	38.8
Surface Meteorological Parameters		
Max. surface temperature (°C)	32.3	32.3
Min. surface temperature (°C)	20.0	19.1
Relative humidity (%)	71.4	76.8
Surface wind speed (ms^{-1})	0.9	0.6
Surface wind direction (degrees)	198	180
Persistence	0.9	0.6
Rainfall (inches)	0.1	0.0
Rain (# periods)	0.4	0.2
Upper-Air Meteorological Parameters		
Temperature AM 850 mb (°C)	16.9	16.7
Temperature PM 850 mb (°C)	17.6	17.8
Stability at Atlanta (°C)	2.4	2.3
Geopotential height difference 700 mb at Atlanta (m)	-6.8	-7.0
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	4.3	5.1
Wind direction yesterday 700 mb at Atlanta (degrees)	360	98
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	3.6	3.7
Wind speed AM 850 mb at Atlanta (ms^{-1})	2.9	4.8
Wind speed PM 850 mb at Atlanta (ms^{-1})	5.0	4.7
Wind direction yesterday 850 mb at Atlanta (degrees)	8	117
Wind direction AM 850 mb at Atlanta (degrees)	333	117
Wind direction PM 850 mb at Atlanta (degrees)	135	90
Recirculation at Atlanta	0.3	0.2
Cloud average	1.9	1.7

Table 3-15h. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Dolly Sods.

The ranges in PM2.5 for Categories 3 and 4 are 17.5-22.5 and ≥22.5 μgm-3.

	Class 3		Class 4	
	Bin 21	Bin 18	Bin 23	Bin 27
Visibility Parameters				
Yesterday's FM at DC (μg/m³)	18.0	14.1	36.3	28.1
Yesterday's FM at Richmond (μg/m³)	18.9	14.7	26.7	23.1
Yesterday's FM at Columbus (μg/m³)	30.1	15.4	33.9	28.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	27.6	26.3	26.5	26.9
Min. surface temperature (°C)	15.4	14.6	16.9	15.9
Relative humidity (%)	75.0	68.4	73.9	70.8
Surface wind speed (ms^{-1})	0.4	0.4	0.4	0.6
Surface wind direction (degrees)	76	252	284	360
Persistence	0.3	0.3	0.3	0.4
Rainfall (inches)	0.1	0.0	0.1	0.0
Rain (# periods)	0.4	0.5	0.6	0.0
Solar radiation (W/m²)	732	692	695	735
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	15.9	16.1	16.1	14.2
Temperature PM 850 mb (°C)	17.0	16.9	17.1	15.4
Stability at Pittsburgh (°C)	2.1	1.9	2.5	-1.0
Geopotential height difference 700 mb at Pittsburgh (m)	-2.9	4.8	-27.5	30.3
Wind speed yesterday 700 mb at Dulles (ms^{-1})	7.5	7.2	6.9	6.5
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	6.3	4.9	6.3	4.6
Wind speed yesterday 700 mb at Wilmington (ms^{-1})	7.7	11.4	6.0	4.9
Wind speed yesterday 700 mb at Pittsburgh (ms^{-1})	10.4	10.4	8.5	6.0
Wind direction yesterday 700 mb at Dulles (degrees)	315	288	297	315
Wind direction yesterday 700 mb at Roanoke (degrees)	346	288	309	270
Wind direction yesterday 700 mb at Wilmington (degrees)	270	288	284	270
Wind direction yesterday 700 mb at Pittsburgh (degrees)	277	288	297	315
Wind speed yesterday 850 mb at Dulles (ms^{-1})	4.6	5.1	6.5	2.4
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	3.0	4.4	3.9	2.7
Wind speed yesterday 850 mb at Wilmington (ms^{-1})	6.5	8.0	5.7	4.9
Wind speed yesterday 850 mb at Pittsburgh (ms^{-1})	5.8	5.5	5.5	3.5
Wind speed AM 850 mb at Dulles (ms^{-1})	5.6	6.9	5.0	5.5
Wind speed AM 850 mb at Roanoke (ms^{-1})	5.2	7.9	6.5	3.4
Wind speed AM 850 mb at Wilmington (ms^{-1})	8.6	13.4	6.7	6.5
Wind speed AM 850 mb at Pittsburgh (ms^{-1})	7.2	9.9	6.9	7.2
Wind speed PM 850 mb at Dulles (ms^{-1})	6.1	9.4	5.8	7.7
Wind speed PM 850 mb at Roanoke (ms^{-1})	4.3	5.1	4.1	4.3
Wind speed PM 850 mb at Wilmington (ms^{-1})	9.1	8.5	6.5	8.8
Wind speed PM 850 mb at Pittsburgh (ms^{-1})	6.2	9.3	6.5	8.1
Wind direction yesterday 850 mb at Dulles (degrees)	256	270	291	162

	Class 3		Class 4	
	Bin 21	Bin 18	Bin 23	Bin 27
Wind direction yesterday 850 mb at Roanoke (degrees)	243	225	279	135
Wind direction yesterday 850 mb at Wilmington (degrees)	248	270	248	180
Wind direction yesterday 850 mb at Pittsburgh (degrees)	256	225	297	225
Wind direction AM 850 mb at Dulles (degrees)	243	225	300	270
Wind direction AM 850 mb at Roanoke (degrees)	284	225	300	207
Wind direction AM 850 mb at Wilmington (degrees)	254	288	278	225
Wind direction AM 850 mb at Pittsburgh (degrees)	284	270	284	243
Wind direction PM 850 mb at Dulles (degrees)	225	270	291	180
Wind direction PM 850 mb at Roanoke (degrees)	180	225	277	153
Wind direction PM 850 mb at Wilmington (degrees)	233	288	293	207
Wind direction PM 850 mb at Pittsburgh (degrees)	233	270	288	207
Cloud average	2.0	2.0	2.0	1.7

Table 3-15i. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Everglades.

The ranges in PM2.5 for Categories 3 and 4 are 12.5-15 and ≥ 15 μgm-3.

	Class 3	Class 4	
	Bin 21	Bin 27	Bin 2
Visibility Parameters			
Yesterday's FM at Palm Beach (μg/m³)	11.4	11.8	6.6
Yesterday's FM at Ft. Lauderdale (μg/m³)	12.6	13.8	7.7
Surface Meteorological Parameters			
Max. surface temperature (°C)	28.6	29.0	29.2
Min. surface temperature (°C)	20.2	19.3	20.6
Relative humidity (%)	78.2	74.3	72.1
Surface wind speed (ms^{-1})	2.0	1.9	2.2
Surface wind direction (degrees)	90	90	108
Persistence	0.9	0.9	0.8
Rainfall (inches)	0.0	0.0	0.1
Rain (# periods)	0.2	0.0	0.5
Solar radiation (W/m^2)	731	759	713
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	15.0	15.9	14.5
Temperature PM 850 mb (°C)	15.7	15.5	14.7
Stability at Miami (°C)	-5.1	-3.4	-6.5
Geopotential height difference 700 mb at Miami (m)	-1.8	22.3	-1.5
Wind speed yesterday 700 mb at Miami (ms^{-1})	11.7	9.5	3.5
Wind direction yesterday 700 mb at Miami (degrees)	270	236	108
Wind speed yesterday 850 mb at Miami (ms^{-1})	8.9	8.8	5.5
Wind speed AM 850 mb at Miami (ms^{-1})	7.3	8.5	6.7
Wind speed PM 850 mb at Miami (ms^{-1})	5.8	6.7	7.0
Wind direction yesterday 850 mb at Miami (degrees)	270	243	90
Wind direction AM 850 mb at Miami (degrees)	270	90	45
Wind direction PM 850 mb at Miami (degrees)	297	360	90
Recirculation at Miami	0.0	0.0	0.0
Cloud average	1.2	1.4	1.8

Table 3-15j. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Great Smoky Mountains.

The ranges in PM2.5 for Categories 3 and 4 are 17.5-25 and ≥ 25 μgm-3.

	Class 3			Class 4
	Bin 11	Bin 13	Bin 26	Bin 24
Visibility Parameters				
Yesterday's FM at Knoxville (μg/m³)	20.9	18.5	38.1	39.8
Yesterday's FM at Atlanta (μg/m³)	23.8	24.9	26.1	38.8
Yesterday's FM at Charlotte (μg/m³)	22.0	17.3	26.4	27.8
Surface Meteorological Parameters				
Max. surface temperature (°C)	24.6	24.5	25.1	24.4
Min. surface temperature (°C)	19.7	19.3	19.5	19.3
Relative humidity (%)	72.9	66.8	71.7	71.3
Surface wind speed (ms^{-1})	1.1	0.8	0.8	0.9
Surface wind direction (degrees)	45	243	180	270
Persistence	0.6	0.6	0.5	0.6
Rainfall (inches)	0.0	0.0	0.1	0.0
Rain (# periods)	0.2	0.4	0.4	0.1
Solar radiation (W/m²)	731	715	679	558
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	16.0	15.6	16.1	15.6
Temperature PM 850 mb (°C)	16.9	15.1	16.8	16.4
Stability at Nashville (°C)	0.5	2.5	0.1	1.2
Geopotential height difference 700 mb at Nashville (m)	-3.0	-5.1	-3.0	-6.0
Wind speed yesterday 700 mb at Nashville (ms^{-1})	5.7	4.3	7.0	5.0
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	5.3	6.3	5.1	6.6
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	4.0	4.5	4.5	5.4
Wind direction yesterday 700 mb at Nashville (degrees)	281	297	260	59
Wind direction yesterday 700 mb at Greensboro (degrees)	307	315	45	344
Wind direction yesterday 700 mb at Atlanta (degrees)	297	333	135	82
Wind speed yesterday 850 mb at Nashville (ms^{-1})	2.8	3.6	4.4	4.4
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	3.8	5.0	3.7	4.7
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	4.0	4.8	4.4	4.7
Wind speed AM 850 mb at Nashville (ms^{-1})	3.8	5.7	4.3	5.4
Wind speed AM 850 mb at Greensboro (ms^{-1})	4.3	5.1	3.5	6.0
Wind speed AM 850 mb at Atlanta (ms^{-1})	4.4	6.3	4.8	4.3
Wind speed PM 850 mb at Nashville (ms^{-1})	4.6	4.9	5.4	6.0
Wind speed PM 850 mb at Greensboro (ms^{-1})	4.4	5.0	3.4	5.4
Wind speed PM 850 mb at Atlanta (ms^{-1})	4.6	4.3	5.6	4.2
Wind direction yesterday 850 mb at Nashville (degrees)	360	207	135	270
Wind direction yesterday 850 mb at Greensboro (degrees)	360	360	180	297
Wind direction yesterday 850 mb at Atlanta (degrees)	37	360	127	98
Wind direction AM 850 mb at Nashville (degrees)	270	256	180	259
Wind direction AM 850 mb at Greensboro (degrees)	270	360	270	301
Wind direction AM 850 mb at Atlanta (degrees)	135	315	72	108
Wind direction PM 850 mb at Nashville (degrees)	243	284	180	207
Wind direction PM 850 mb at Greensboro (degrees)	315	315	143	291
Wind direction PM 850 mb at Atlanta (degrees)	108	117	108	124
Cloud average	2.0	1.4	2.0	1.5

Table 3-15k. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site James River Face.

The ranges in PM2.5 for Categories 3 and 4 are 20-25 and ≥25 μgm-3.

	Class 3		Class 4
	Bin 23	Bin 14	Bin 16
Visibility Parameters			
Yesterday's FM at Richmond (μg/m³)	27.9	21.7	22.6
Yesterday's FM at Greensboro-Winston-Salem (μg/m³)	27.7	19.8	25.2
Yesterday's FM at Knoxville (μg/m³)	26.8	23.7	33.3
Surface Meteorological Parameters			
Max. surface temperature (°C)	30.8	26.7	29.0
Min. surface temperature (°C)	17.6	18.9	13.2
Relative humidity (%)	72.8	83.8	69.4
Surface wind speed (ms^{-1})	2.0	0.6	0.8
Surface wind direction (degrees)	211	n/a	211
Persistence	0.9	0.8	0.9
Sea level pressure (mb)	1020	1023	1022
Rainfall (inches)	0.1	0.1	0.0
Rain (# periods)	0.8	1.0	0.0
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	16.3	14.3	13.9
Temperature PM 850 mb (°C)	16.6	16.0	15.4
Stability at Roanoke (°C)	3.8	0.1	4.9
Geopotential height difference 700 mb at Roanoke (m)	-22.4	25.4	-1.8
Wind speed yesterday 700 mb at Dulles (ms^{-1})	7.9	6.3	4.9
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	5.6	6.2	4.9
Wind direction yesterday 700 mb at Dulles (degrees)	278	270	352
Wind direction yesterday 700 mb at Roanoke (degrees)	307	225	315
Wind speed yesterday 850 mb at Dulles (ms^{-1})	5.3	3.3	4.2
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	3.1	4.4	2.7
Wind speed AM 850 mb at Dulles (ms^{-1})	6.7	4.0	3.9
Wind speed AM 850 mb at Roanoke (ms^{-1})	9.5	4.9	5.7
Wind speed PM 850 mb at Dulles (ms^{-1})	9.0	4.9	5.1
Wind speed PM 850 mb at Roanoke (ms^{-1})	9.1	6.2	3.5
Wind direction yesterday 850 mb at Dulles (degrees)	278	252	259
Wind direction yesterday 850 mb at Roanoke (degrees)	239	45	315
Wind direction AM 850 mb at Dulles (degrees)	262	180	292
Wind direction AM 850 mb at Roanoke (degrees)	262	180	284
Wind direction PM 850 mb at Dulles (degrees)	243	198	270
Wind direction PM 850 mb at Roanoke (degrees)	225	135	304
Recirculation at Roanoke	0.0	0.3	0.3
Cloud average	1.9	2.3	2.0

Table 3-15l. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Linville Gorge.

The ranges in PM2.5 for Categories 3 and 4 are 17.5-20 and ≥ 20 μgm-3.

	Class 3		Class 4
	Bin 30	Bin 19	Bin 25
Visibility Parameters			
Yesterday's FM at Knoxville (μg/m³)	30.2	32.1	35.9
Yesterday's FM at Charlotte (μg/m³)	26.4	15.7	30.0
Yesterday's FM at Greensboro-Winston-Salem (μg/m³)	29.9	17.0	28.0
Surface Meteorological Parameters			
Max. surface temperature (°C)	18.4	18.8	23.3
Min. surface temperature (°C)	29.0	29.3	28.3
Relative humidity (%)	19.6	16.9	16.4
Surface wind speed (ms^{-1})	77.2	65.5	68.8
Surface wind direction (degrees)	0.8	1.4	0.8
Persistence	326	297	284
Sea level pressure (mb)	0.6	0.7	0.7
Rainfall (inches)	1018	1017	1021
Rain (# periods)	0.1	0.0	0.0
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	16.6	15.8	14.7
Temperature PM 850 mb (°C)	17.2	17.3	15.9
Stability at Greensboro (°C)	-0.2	2.9	1.1
Geopotential height difference 700 mb at Greensboro (m)	-12.3	-0.1	4.3
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	6	6	6
Wind direction yesterday 700 mb at Greensboro (degrees)	270	326	342
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	4	6	5
Wind speed AM 850 mb at Greensboro (ms^{-1})	5.8	6.4	5.0
Wind speed PM 850 mb at Greensboro (ms^{-1})	5.8	4.7	5.1
Wind direction yesterday 850 mb at Greensboro (degrees)	225	0	338
Wind direction AM 850 mb at Greensboro (degrees)	342	288	315
Wind direction PM 850 mb at Greensboro (degrees)	270	270	297
Recirculation at Greensboro	0.0	0.2	0.1
Cloud average	1.8	1.2	1.9

Table 3-15m. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Mammoth Cave.

The ranges in PM2.5 for Categories 3 and 4 are 20-25 and ≥25 μgm-3.

	Class 3			Class 4
	Bin 30	Bin 5	Bin 24	Bin 21
Visibility Parameters				
Yesterday's FM at Nashville (μg/m³)	26.2	10.0	22.1	30.4
Yesterday's FM at Knoxville (μg/m³)	30.4	16.1	36.4	30.9
Yesterday's FM at Louisville (μg/m³)	33.1	18.5	28.2	34.8
Surface Meteorological Parameters				
Max. surface temperature (°C)	31.3	28.8	28.9	30.8
Min. surface temperature (°C)	21.2	19.0	19.2	17.2
Relative humidity (%)	72.8	77.7	81.6	69.7
Surface wind speed (ms^{-1})	2.7	0.8	0.8	1.0
Surface wind direction (degrees)	236	n/a	108	252
Persistence	0.8	0.6	0.6	0.7
Sea level pressure (mb)	1018	1018	1016	1021
Rainfall (inches)	0.4	0.0	0.5	0.0
Rain (# periods)	1.4	0.0	0.8	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	17.2	14.7	16.4	15.9
Temperature PM 850 mb (°C)	18.5	17.7	17.3	16.8
Stability at Nashville (°C)	-0.3	-1.0	0.2	1.7
Geopotential height difference 700 mb at Nashville (m)	-10.5	22.7	1.3	-0.7
Wind speed yesterday 700 mb at Nashville (ms^{-1})	7.2	8.9	8.3	4.2
Wind direction yesterday 700 mb at Nashville (degrees)	297	315	315	90
Wind speed yesterday 850 mb at Nashville (ms^{-1})	4.7	6.3	2.8	3.5
Wind speed AM 850 mb at Nashville (ms^{-1})	8.0	4.9	3.8	4.6
Wind speed PM 850 mb at Nashville (ms^{-1})	6.6	3.5	4.6	4.5
Wind direction yesterday 850 mb at Nashville (degrees)	239	288	135	297
Wind direction AM 850 mb at Nashville (degrees)	270	315	225	297
Wind direction PM 850 mb at Nashville (degrees)	225	270	315	180
Recirculation at Nashville	0.0	0.3	0.5	0.3
Cloud average	1.8	1.8	2.0	1.8

Table 3-15n. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Mingo.

The ranges in PM2.5 for Categories 3 and 4 are 20-25 and ≥25 μgm-3.

	Class 3	Class 4	
	Bin 21	Bin 18	Bin 8
Visibility Parameters			
Yesterday's FM at St. Louis (μg/m³)	33.2	25.8	17.5
Surface Meteorological Parameters			
Max. surface temperature (°C)	24.7	26.6	27.4
Min. surface temperature (°C)	9.6	14.8	10.8
Relative humidity (%)	69.6	73.6	64.6
Surface wind speed (ms^{-1})	0.8	1.3	2.1
Surface wind direction (degrees)	256	162	214
Persistence	0.8	0.8	0.9
Sea level pressure (mb)	1025	1018	1022
Rainfall (inches)	0.2	0.8	0.0
Rain (# periods)	0.0	0.1	0.0
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	10.9	14.0	14.2
Temperature PM 850 mb (°C)	11.1	15.1	15.3
Stability at Little Rock (°C)	-1.2	-1.9	0.7
Geopotential height difference 700 mb at Little Rock (m)	-7.4	-0.8	-6.4
Wind speed yesterday 700 mb at Springfield (ms^{-1})	7.4	11.6	7.0
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	5.3	9.9	3.4
Wind speed yesterday 700 mb at Lincoln (ms^{-1})	9.7	10.0	10.1
Wind speed yesterday 700 mb at Nashville (ms^{-1})	3.4	6.8	6.7
Wind direction yesterday 700 mb at Springfield (degrees)	236	243	256
Wind direction yesterday 700 mb at Little Rock (degrees)	214	297	270
Wind direction yesterday 700 mb at Lincoln (degrees)	256	301	256
Wind direction yesterday 700 mb at Nashville (degrees)	90	252	270
Wind speed yesterday 850 mb at Springfield (ms^{-1})	6.7	9.0	8.2
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	3.4	6.8	4.3
Wind speed yesterday 850 mb at Lincoln (ms^{-1})	7.7	8.5	7.1
Wind speed yesterday 850 mb at Nashville (ms^{-1})	4.7	4.6	5.1
Wind speed AM 850 mb at Springfield (ms^{-1})	5.4	5.5	8.6
Wind speed AM 850 mb at Little Rock (ms^{-1})	6.7	6.9	4.9
Wind speed AM 850 mb at Lincoln (ms^{-1})	8.0	7.7	7.8
Wind speed AM 850 mb at Nashville (ms^{-1})	5.8	7.1	6.7
Wind speed PM 850 mb at Springfield (ms^{-1})	6.3	4.6	15.1
Wind speed PM 850 mb at Little Rock (ms^{-1})	5.2	5.9	8.8
Wind speed PM 850 mb at Lincoln (ms^{-1})	8.1	4.9	14.2
Wind speed PM 850 mb at Nashville (ms^{-1})	5.9	5.1	6.5
Wind direction yesterday 850 mb at Springfield (degrees)	194	202	180
Wind direction yesterday 850 mb at Little Rock (degrees)	194	207	166
Wind direction yesterday 850 mb at Lincoln (degrees)	236	252	270

	Class 3	Class 4	
	Bin 21	Bin 18	Bin 8
Wind direction yesterday 850 mb at Nashville (degrees)	207	225	180
Wind direction AM 850 mb at Springfield (degrees)	225	279	236
Wind direction AM 850 mb at Little Rock (degrees)	225	236	214
Wind direction AM 850 mb at Lincoln (degrees)	256	281	236
Wind direction AM 850 mb at Nashville (degrees)	225	252	297
Wind direction PM 850 mb at Springfield (degrees)	194	153	194
Wind direction PM 850 mb at Little Rock (degrees)	214	191	194
Wind direction PM 850 mb at Lincoln (degrees)	225	270	225
Wind direction PM 850 mb at Nashville (degrees)	243	360	194
Cloud average	2.0	1.6	1.4

Table 3-15o. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for Okefenokee.

The ranges in PM2.5 for Categories 3 and 4 are 15-20 and ≥20 μgm-3.

	Class 3		Class 4	
	Bin 28	Bin 31	Bin 3	Bin 30
Visibility Parameters				
Yesterday's FM at Jacksonville (μg/m³)	18.3	30.2	9.5	30.2
Surface Meteorological Parameters				
Max. surface temperature (°C)	31.0	27.1	30.8	32.7
Min. surface temperature (°C)	19.3	15.6	17.5	21.6
Relative humidity (%)	71.9	75.9	71.4	74.1
Surface wind speed (ms^{-1})	2.0	2.6	2.1	1.5
Surface wind direction (degrees)	n/a	117	108	153
Persistence	0.7	0.8	0.8	0.6
Sea level pressure (mb)	1016	1022	1020	1016
Rainfall (inches)	0.1	0.0	0.0	0.0
Rain (# periods)	0.6	0.4	0.3	0.1
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	15.9	12.7	15.1	17.5
Temperature PM 850 mb (°C)	16.6	13.0	16.1	18.1
Stability at Jacksonville (°C)	0.3	-0.5	1.5	-0.4
Geopotential height difference 700 mb at Jacksonville (m)	-3.9	-4.8	2.5	-1.8
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	8.5	7.5	5.9	8.6
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	6.9	6.2	6.2	6.7
Wind direction yesterday 700 mb at Jacksonville (degrees)	304	270	315	342
Wind direction yesterday 700 mb at Tallahassee (degrees)	315	360	315	346
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	6.2	5.6	3.5	4.3
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	4.8	2.5	2.7	3.8
Wind speed AM 850 mb at Jacksonville (ms^{-1})	6.7	7.6	4.7	5.2
Wind speed AM 850 mb at Tallahassee (ms^{-1})	5.7	4.1	5.0	3.5
Wind speed PM 850 mb at Jacksonville (ms^{-1})	5.4	7.6	3.3	4.8
Wind speed PM 850 mb at Tallahassee (ms^{-1})	4.9	5.2	2.2	4.3
Wind direction yesterday 850 mb at Jacksonville (degrees)	315	360	315	326
Wind direction yesterday 850 mb at Tallahassee (degrees)	360	326	90	14
Wind direction AM 850 mb at Jacksonville (degrees)	270	27	45	326
Wind direction AM 850 mb at Tallahassee (degrees)	297	333	135	270
Wind direction PM 850 mb at Jacksonville (degrees)	270	27	315	326
Wind direction PM 850 mb at Tallahassee (degrees)	342	27	315	333
Recirculation at Jacksonville	0.1	0.0	0.0	0.1
Cloud average	1.6	1.4	1.8	1.9

Table 3-15p. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Shenandoah.

The ranges in PM2.5 for Categories 3 and 4 are 17.5-22.5 and ≥22.5 μgm-3.

	Class 3		Class 4	
	Bin 13	Bin 25	Bin 28	Bin 16
Visibility Parameters				
Yesterday's FM at Richmond (μg/m³)	18.5	28.2	27.6	18.6
Yesterday's FM at DC (μg/m³)	22.5	29.7	32.6	24.5
Yesterday's FM at Columbus (μg/m³)	17.5	28.5	34.4	34.2
Surface Meteorological Parameters				
Max. surface temperature (°C)	21.2	21.6	24.1	22.9
Min. surface temperature (°C)	14.8	13.2	18.4	15.7
Relative humidity (%)	83.4	76.8	76.5	71.7
Surface wind speed (ms^{-1})	1.1	2.3	1.5	0.7
Surface wind direction (degrees)	180	315	207	117
Persistence	0.7	0.9	0.8	0.5
Rainfall (inches)	0.5	0.8	0.4	0.4
Rain (# periods)	0.1	0.1	0.0	0.1
Solar radiation (W/m²)	568	698	690	568
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	15.0	15.4	18.5	15.6
Temperature PM 850 mb (°C)	16.6	15.3	18.9	17.3
Stability at Dulles (°C)	-0.8	0.6	1.6	2.8
Geopotential height difference 700 mb at Dulles (m)	23.4	-25.8	6.0	5.7
Wind speed yesterday 700 mb at Dulles (ms^{-1})	8.0	12.2	6.9	5.1
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	7.5	9.7	5.8	5.4
Wind direction yesterday 700 mb at Dulles (degrees)	293	270	311	342
Wind direction yesterday 700 mb at Roanoke (degrees)	278	236	360	304
Wind speed yesterday 850 mb at Dulles (ms^{-1})	5.1	7.0	6.5	3.7
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	3.6	7.3	4.0	2.2
Wind speed AM 850 mb at Dulles (ms^{-1})	4.5	10.7	6.1	3.2
Wind speed AM 850 mb at Roanoke (ms^{-1})	4.2	12.1	7.3	3.7
Wind speed PM 850 mb at Dulles (ms^{-1})	4.3	11.8	7.8	3.6
Wind speed PM 850 mb at Roanoke (ms^{-1})	4.1	12.2	5.9	3.2
Wind direction yesterday 850 mb at Dulles (degrees)	288	236	291	252
Wind direction yesterday 850 mb at Roanoke (degrees)	315	270	309	270
Wind direction AM 850 mb at Dulles (degrees)	259	252	297	315
Wind direction AM 850 mb at Roanoke (degrees)	259	284	288	304
Wind direction PM 850 mb at Dulles (degrees)	256	270	278	315
Wind direction PM 850 mb at Roanoke (degrees)	211	284	281	180
Recirculation at Dulles	0.2	0.0	0.1	0.5
Cloud average	2.2	1.6	1.7	1.8

Table 3-15q. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Shining Rock.

The ranges in PM2.5 for Categories 3 and 4 are 15-20 and ≥ 20 μgm-3.

	Class 3			Class 4
	Bin 10	Bin 27	Bin 21	Bin 23
Visibility Parameters				
Yesterday's FM at Knoxville (μg/m^3)	19.6	30.6	31.0	35.8
Yesterday's FM at Charlotte (μg/m^3)	16.6	23.9	22.7	27.8
Yesterday's FM at Greenville (μg/m^3)	16.0	27.2	28.7	28.8
Surface Meteorological Parameters				
Max. surface temperature (°C)	26.4	28.1	26.3	28.1
Min. surface temperature (°C)	13.1	17.9	16.2	15.8
Relative humidity (%)	74.5	81.3	74.6	73.7
Surface wind speed (ms^{-1})	1.2	1.1	1.1	1.5
Surface wind direction (degrees)	180	351	297	360
Persistence	0.7	0.6	0.7	0.7
Sea level pressure (mb)	1024	1018	1018	1020
Rainfall (inches)	0.0	0.1	0.0	0.0
Rain (# periods)	26.4	28.1	26.3	28.1
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	14.0	17.0	15.0	16.0
Temperature PM 850 mb (°C)	15.2	17.6	15.1	17.3
Stability at Greensboro (°C)	0.5	-0.4	0.4	0.7
Geopotential height difference 700 mb at Greensboro (m)	13.2	-16.4	17.8	-3.2
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	8.7	7.4	9.2	6.9
Wind direction yesterday 700 mb at Greensboro (degrees)	304	297	284	342
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	5.3	6.1	5.1	4.8
Wind speed AM 850 mb at Greensboro (ms^{-1})	5.7	5.7	4.1	5.1
Wind speed PM 850 mb at Greensboro (ms^{-1})	5.7	5.1	2.7	7.1
Wind direction yesterday 850 mb at Greensboro (degrees)	270	281	315	284
Wind direction AM 850 mb at Greensboro (degrees)	297	292	270	293
Wind direction PM 850 mb at Greensboro (degrees)	198	256	360	278
Recirculation at Greensboro	0.1	0.0	0.0	0.0
Cloud average	2.1	1.9	1.6	1.6

Table 3-15r. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Sipsey.

The ranges in PM2.5 for Categories 3 and 4 are 17.5-22.5 and ≥22.5 μgm-3.

	Class 3		Class 4
	Bin 29	Bin 22	Bin 30
Visibility Parameters			
Yesterday's FM at Birmingham (μg/m³)	33.1	43.3	45.6
Yesterday's FM at Atlanta (μg/m³)	28.6	26.4	35.3
Yesterday's FM at Nashville (μg/m³)	18.9	17.9	33.0
Yesterday's FM at Memphis (μg/m³)	20.1	24.0	29.4
Surface Meteorological Parameters			
Max. surface temperature (°C)	31.3	24.3	30.8
Min. surface temperature (°C)	18.5	9.6	16.8
Relative humidity (%)	70.4	69.8	66.7
Surface wind speed (ms^{-1})	1.3	1.2	1.1
Surface wind direction (degrees)	63	270	270
Persistence	0.8	0.6	0.7
Sea level pressure (mb)	1018	1022	1021
Rainfall (inches)	0.1	0.0	0.0
Rain (# periods)	0.3	0.0	0.5
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	17.0	9.6	15.0
Temperature PM 850 mb (°C)	17.9	12.5	16.0
Stability at Birmingham (°C)	1.5	1.4	2.5
Geopotential height difference 700 mb at Birmingham (m)	-2.0	24.0	-0.5
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	5.4	11.2	5.7
Wind direction yesterday 700 mb at Birmingham (degrees)	45	207	60
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	5.5	6.7	4.3
Wind speed AM 850 mb at Birmingham (ms^{-1})	4.5	9.0	4.9
Wind speed PM 850 mb at Birmingham (ms^{-1})	4.6	7.0	4.9
Wind direction yesterday 850 mb at Birmingham (degrees)	27	207	74
Wind direction AM 850 mb at Birmingham (degrees)	180	225	108
Wind direction PM 850 mb at Birmingham (degrees)	360	243	90
Recirculation at Birmingham	0.1	0.0	0.2
Cloud average	1.4	2.0	1.5

Table 3-15s. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site St. Marks.

The ranges in PM2.5 for Categories 3 and 4 are 15-17.5 and ≥17.5 μgm-3.

	Class 3		Class 4
	Bin 22	Bin 30	Bin 19
Visibility Parameters			
Yesterday's FM at Orlando (μg/m³)	16.4	17.6	11.3
Yesterday's FM at Pensacola (μg/m³)	20.3	16.5	24.8
Surface Meteorological Parameters			
Max. surface temperature (°C)	22.6	35.7	26.2
Min. surface temperature (°C)	4.9	23.6	14.9
Relative humidity (%)	68.4	70.6	73.6
Surface wind speed (ms^{-1})	0.6	0.9	1.5
Surface wind direction (degrees)	360	315	360
Persistence	0.5	0.4	0.6
Sea level pressure (mb)	1022	1016	1023
Rainfall (inches)	0.0	0.0	0.1
Rain (# periods)	0.5	0.5	0.7
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	11.8	19.2	14.3
Temperature PM 850 mb (°C)	11.6	19.5	13.0
Stability at Tallahassee (°C)	7.9	-0.1	-0.8
Geopotential height difference 700 mb at Tallahassee (m)	13.6	-13.0	12.7
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	8.3	4.4	8.7
Wind direction yesterday 700 mb at Tallahassee (degrees)	270	0	315
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	7.9	4.6	5.6
Wind speed AM 850 mb at Tallahassee (ms^{-1})	6.5	3.3	5.6
Wind speed PM 850 mb at Tallahassee (ms^{-1})	4.8	4.2	4.2
Wind direction yesterday 850 mb at Tallahassee (degrees)	342	18	315
Wind direction AM 850 mb at Tallahassee (degrees)	315	270	284
Wind direction PM 850 mb at Tallahassee (degrees)	342	n/a	360
Recirculation at Tallahassee	0.0	0.3	0.2
Cloud average	1.5	1.8	1.3

Table 3-15t. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Swanquarter.

The ranges in PM2.5 for Categories 3 and 4 are 12.5-17.5 and ≥17.5 μgm-3.

	Class 3			Class
	Bin 21	Bin 17	Bin 13	Bin 28
Visibility Parameters				
Yesterday's FM at Raleigh (μg/m³)	21.7	22.4	21.6	34.9
Yesterday's FM at Norfolk (μg/m³)	19.2	15.2	19.7	35.8
Surface Meteorological Parameters				
Max. surface temperature (°C)	26.5	25.4	15.7	29.7
Min. surface temperature (°C)	20.7	17.9	7.2	24.0
Relative humidity (%)	90.8	82.1	77.5	81.5
Surface wind speed (ms^{-1})	3.5	3.0	1.6	4.2
Surface wind direction (degrees)	210	243	349	270
Persistence	0.8	0.7	0.6	0.9
Sea level pressure (mb)	1017	1020	1025	1016
Rainfall (inches)	0.0	0.1	0.0	0.1
Rain (# periods)	0.5	0.8	0.2	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	16.6	14.7	8.8	17.7
Temperature PM 850 mb (°C)	17.3	14.6	9.9	18.9
Stability at Moorhead (°C)	-0.1	-1.7	6.9	-1.5
Geopotential height difference 700 mb at Moorhead (m)	-6.2	4.8	11.2	-11.0
Wind speed yesterday 700 mb at Moorhead (ms^{-1})	8	12	10	7
Wind direction yesterday 700 mb at Moorhead (degrees)	276	270	304	342
Wind speed yesterday 850 mb at Moorhead (ms^{-1})	6	9	7	4
Wind speed AM 850 mb at Moorhead (ms^{-1})	7.3	9.1	6.7	7.7
Wind speed PM 850 mb at Moorhead (ms^{-1})	6.3	7.3	7.0	7.2
Wind direction yesterday 850 mb at Moorhead (degrees)	270	270	326	315
Wind direction AM 850 mb at Moorhead (degrees)	275	270	304	288
Wind direction PM 850 mb at Moorhead (degrees)	270	270	315	270
Recirculation at Moorhead	0.1	0.2	0.0	0.0
Cloud average	1.6	1.8	1.0	1.8

Table 3-15u. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for IMPROVE Site Upper Buffalo.

The ranges in PM2.5 for Categories 3 and 4 are 15-17.5 and ≥17.5 μgm-3.

	Class 3			Class 4
	Bin 23	Bin 28	Bin 30	Bin 32
Visibility Parameters				
Yesterday's FM at Little Rock (μg/m³)	17.6	25.8	23.4	30.0
Yesterday's FM at Dallas (μg/m³)	17.5	21.1	16.6	24.8
Surface Meteorological Parameters				
Max. surface temperature (°C)	29.3	23.9	33.6	32.2
Min. surface temperature (°C)	17.4	14.0	21.0	20.4
Relative humidity (%)	73.0	78.4	68.9	69.4
Surface wind speed (ms^{-1})	2.4	2.2	1.7	1.7
Surface wind direction (degrees)	166	135	90	194
Persistence	0.8	0.8	0.8	0.7
Sea level pressure (mb)	1020	1020	1018	1018
Rainfall (inches)	0.0	0.2	0.0	0.0
Rain (# periods)	0.0	0.5	0.0	0.2
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	16.4	13.5	19.2	18.2
Temperature PM 850 mb (°C)	17.7	13.5	19.3	19.5
Stability at Little Rock (°C)	-2.9	-1.4	-2.7	-1.1
Geopotential height difference 700 mb at Little Rock (m)	25.5	-9.4	6.8	0.4
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	4.9	2.7	8.1	5.2
Wind direction yesterday 700 mb at Little Rock (degrees)	360	225	45	45
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	4.4	2.2	3.9	3.8
Wind speed AM 850 mb at Little Rock (ms^{-1})	5.3	4.5	4.1	3.7
Wind speed PM 850 mb at Little Rock (ms^{-1})	4.2	4.9	4.5	3.3
Wind direction yesterday 850 mb at Little Rock (degrees)	117	162	45	270
Wind direction AM 850 mb at Little Rock (degrees)	243	252	90	259
Wind direction PM 850 mb at Little Rock (degrees)	194	180	90	236
Recirculation at Little Rock	0.4	0.3	0.8	0.4
Cloud average	1.8	1.5	1.5	1.6

We discuss the findings for Cape Romain, Great Smoky Mountains, and Mammoth Cave below.

For Cape Romain, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 15 to 17.5 and greater than or equal to 17.5 μgm^{-3}, respectively. There are two Category 3 and two Category 4 bins that meet the criteria for key bins. One of the Category 3 bins represents a fall, winter, or early spring regime, and is characterized by a relatively low average maximum temperature. The remaining three bins are characterized by high temperatures, low to moderate surface wind speeds, and moderate relative humidity, and these vary relative to one another among the bins. Prior day $PM_{2.5}$ values for Charleston are in the range of 13 to 29 μgm^{-3}, and are highest for the Category 4 bins. Average surface wind direction is southwesterly for three of the key bins, and southeasterly for the remaining key bin. Recirculation by the sea breeze (as indicated by persistence) appears to be important for Bin 22, which is a Category 5 bin. Stability is greatest, on average, for the cooler days in Bin 15. Upper-air wind speeds and directions vary slightly

among the bins. Wind speeds are highest for the cooler regime (Bin 15). Morning and evening 850 mb wind directions are northwesterly for all bins. A comparison of the two Category 4 bins shows that Bin 22 has lower temperatures, higher humidity, lower surface wind speeds, southeasterly surface winds, and greater cloud cover. Bin 33 has higher temperatures, lower humidity, higher surface wind speeds, southwesterly surface winds, and less cloud cover. Clearly, different combinations of local parameters can result in high $PM_{2.5}$ concentrations.

For GSM, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 17.5 to 25 and greater than or equal to 25 μgm^{-3}, respectively. All four key bins are characterized by very low surface wind speeds and relatively high temperatures. All but one of the key bins is characterized by greater than 80 percent relative humidity. The Category 4 bin has the highest prior-day $PM_{2.5}$ concentrations at the three potential upwind areas (Knoxville, Atlanta, and Charlotte). The greatest differences among the bins are the wind directions. An anticyclonic circulation aloft (a high pressure system) over the GSM region is indicated by the upper-level wind directions (southwesterly winds over Nashville, northwesterly winds over Greensboro, and southeasterly winds over Atlanta) for Bin 24 (the Category 4 bin).

For Mammoth Cave, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 20 to 25 and greater than or equal to 25 μgm^{-3}, respectively. All four key bins are characterized by high temperatures. Relative humidity varies among the bins and is lowest for Bin 21 (the Category 4 bin). Average surface wind speed is very low for three of the bins, and somewhat higher (moderate) for Bin 30 (one of the Category 3 bins). Prior day $PM_{2.5}$ values for Nashville, Knoxville, and Louisville vary among the bins, and the variation is not consistent among the three sites. Bin 5 is distinguished by low prior-day $PM_{2.5}$ values for all three potential upwind areas. Average surface wind direction is southwesterly for Bins 30 and 21, southeasterly for Bin 24, and not available (unable to be calculated) for Bin 5. Morning and evening 850 mb wind directions vary considerably among the key bins. Bin 21, the Category 4 bin, is distinguished from the Category 3 bins by higher prior-day $PM_{2.5}$ concentrations at all three potential upwind sites, lower relative humidity, and a shift from northwesterly to southerly winds aloft during the daytime hours.

Figure 3-7 shows the average composition for all key $PM_{2.5}$ bins for each of the IMPROVE sites.

Figure 3-7a. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Breton.

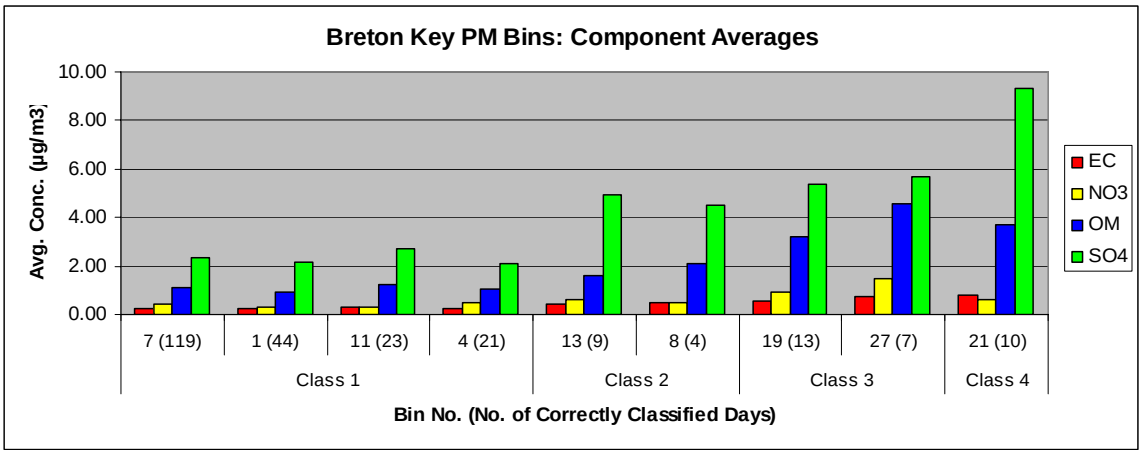


Figure 3-7b. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Brigantine.

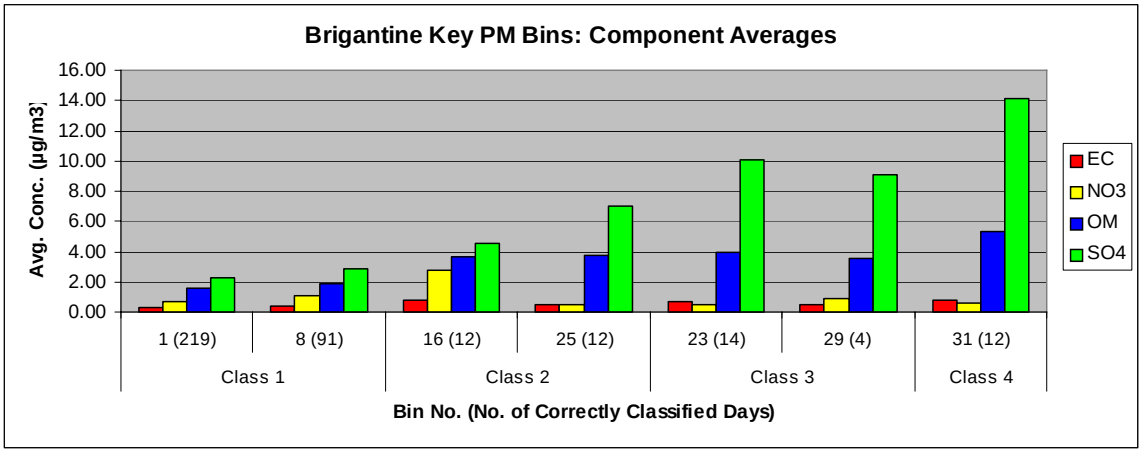


Figure 3-7c. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Cadiz.

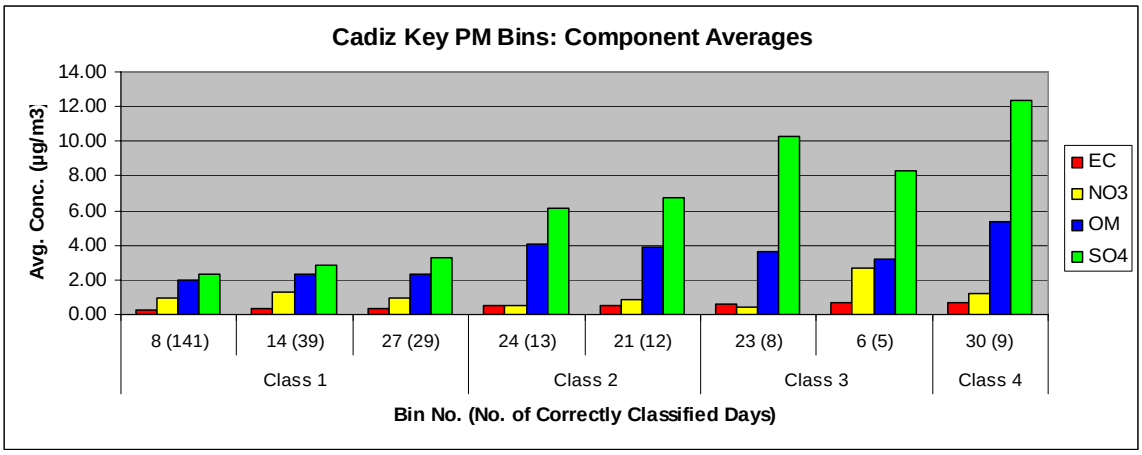


Figure 3-7d. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Caney Creek.

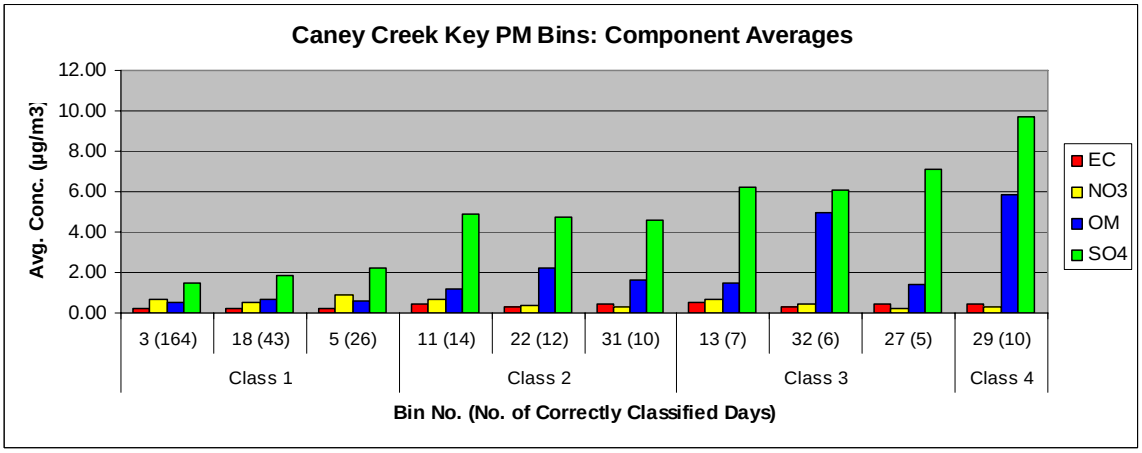


Figure 3-7e. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Cape Romain.

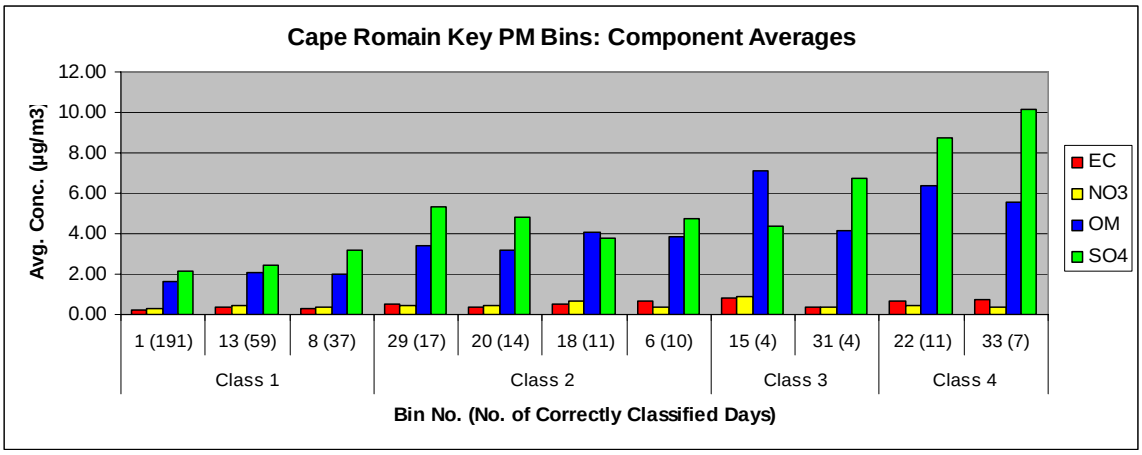


Figure 3-7f. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Chassahowitzka.

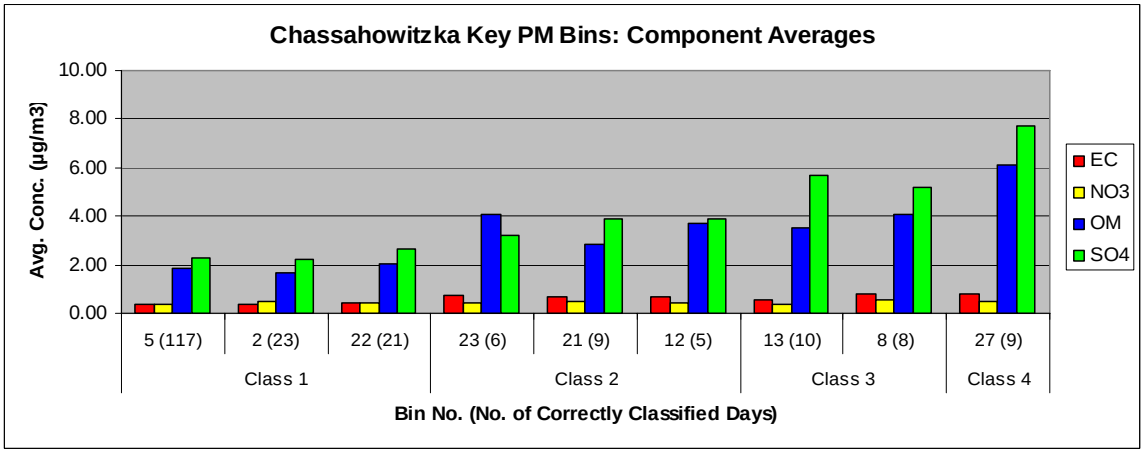


Figure 3-7g. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Cohutta.

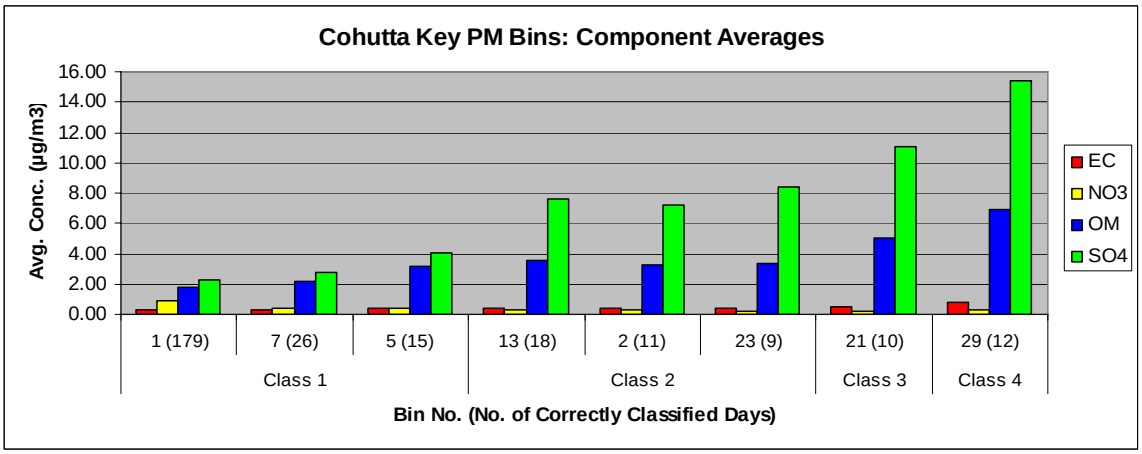


Figure 3-7h. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Dolly Sods.

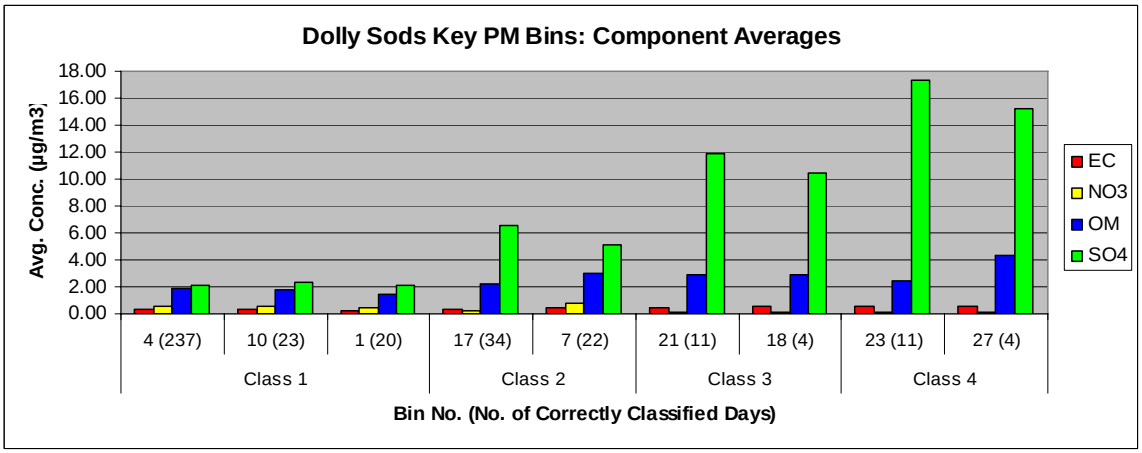


Figure 3-7i. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Everglades.

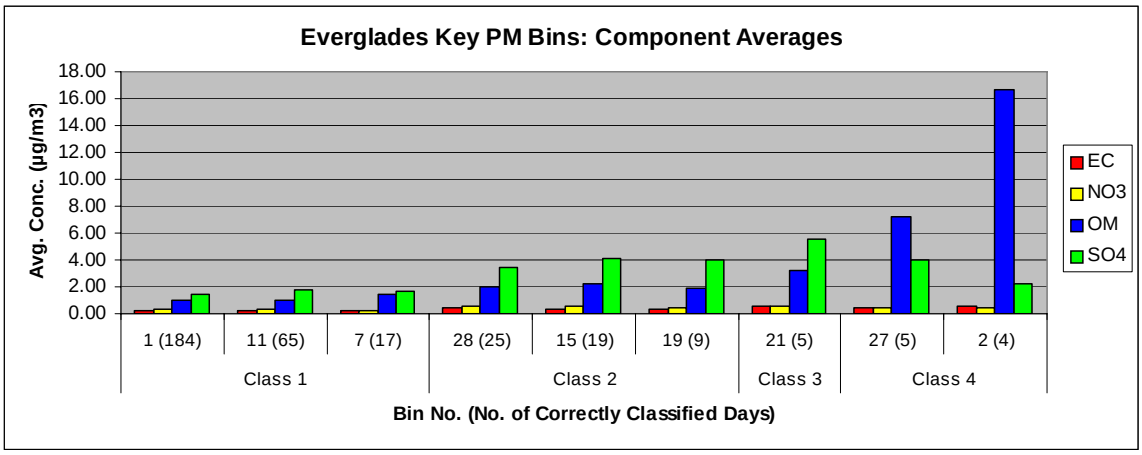


Figure 3-7j. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Great Smoky Mountains.

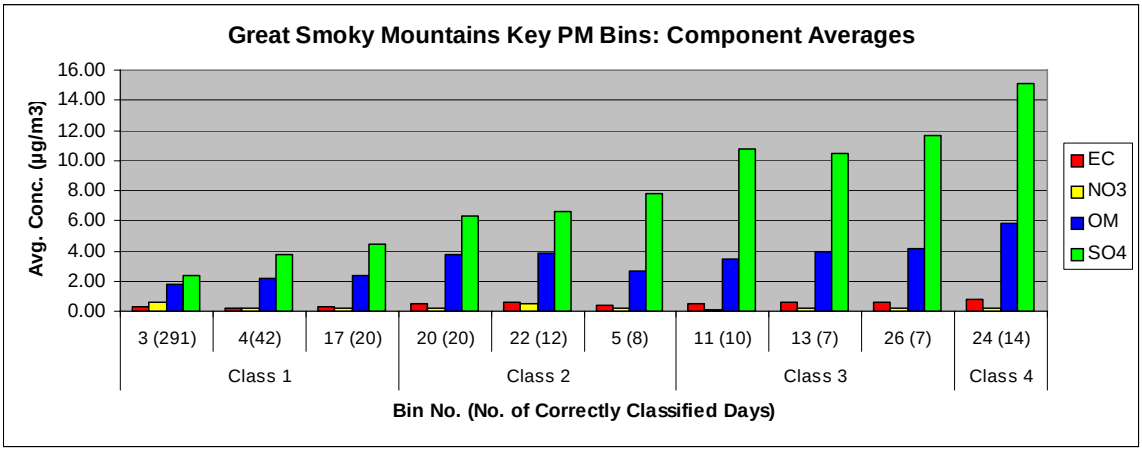


Figure 3-7k. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site James River Face.

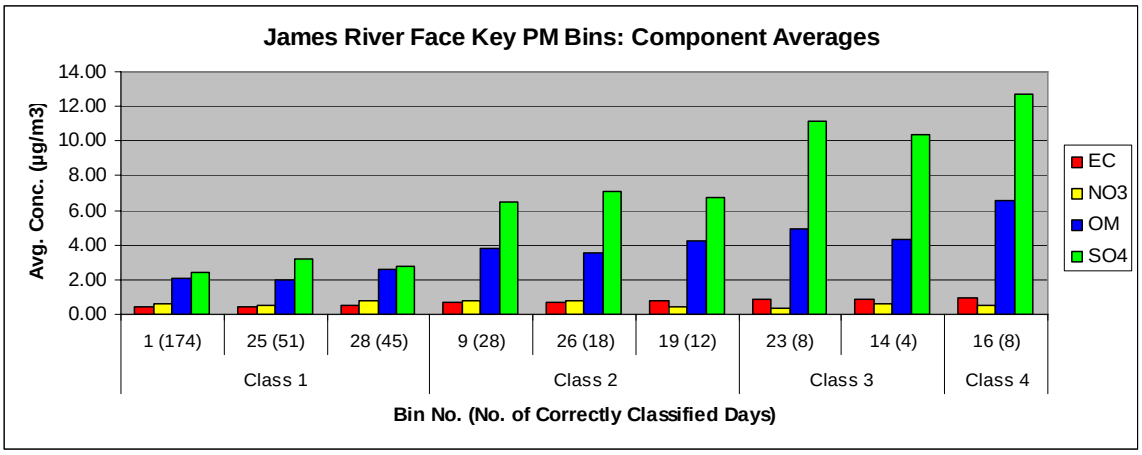


Figure 3-7l. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Linville Gorge.

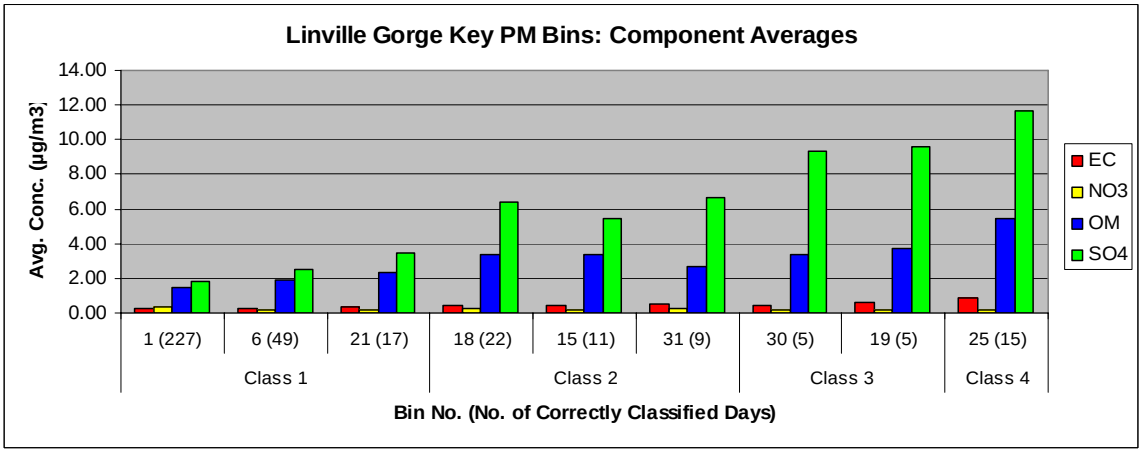


Figure 3-7m. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Mammoth Cave.

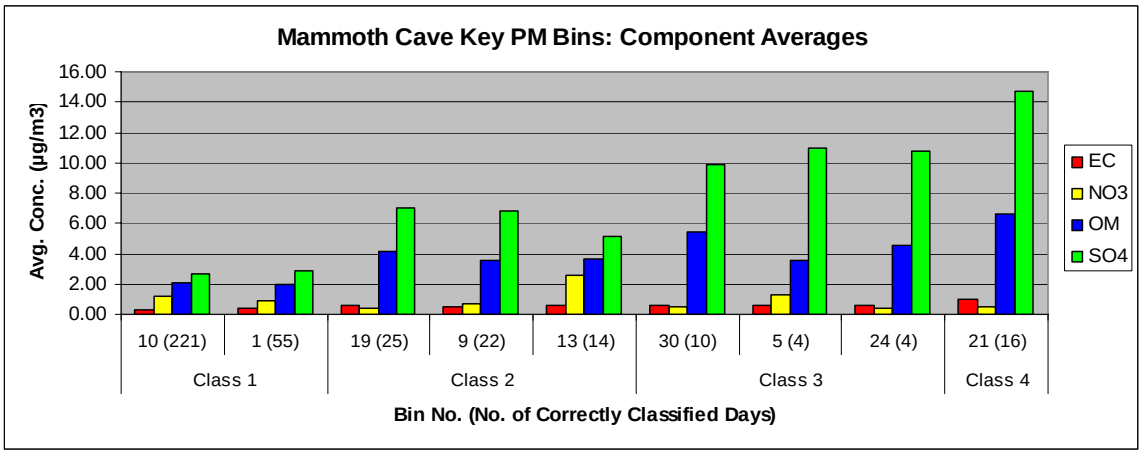


Figure 3-7n. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Mingo.

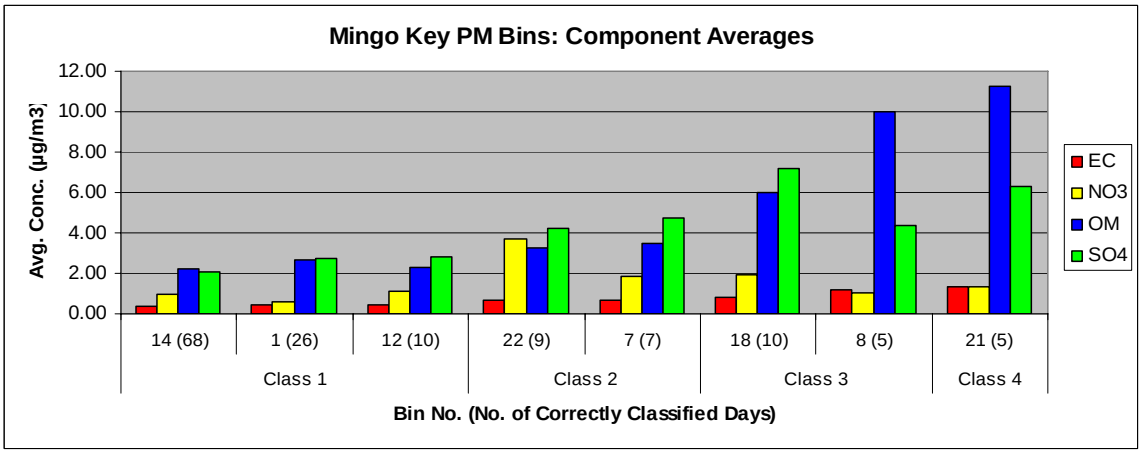


Figure 3-7o. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Okefenokee.

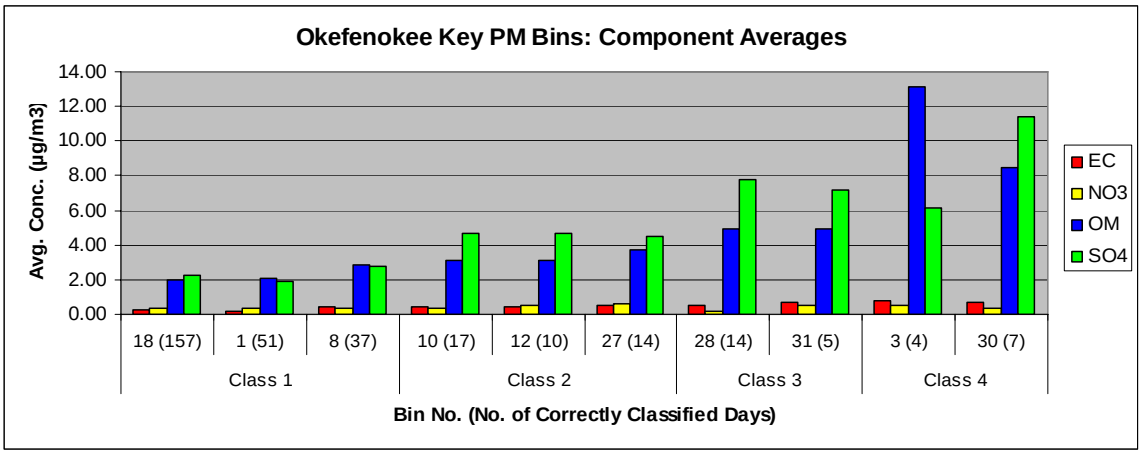


Figure 3-7p. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Shenandoah.

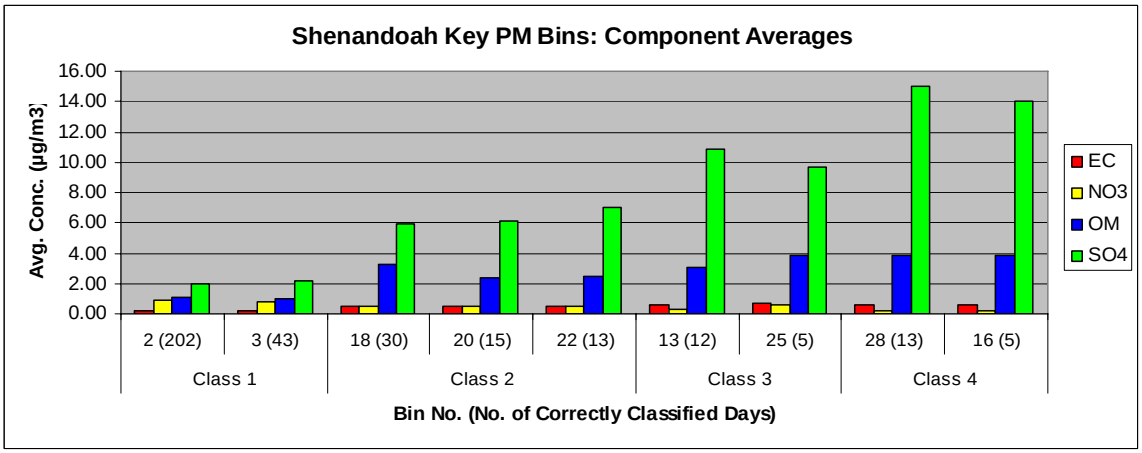


Figure 3-7q. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Shining Rock.

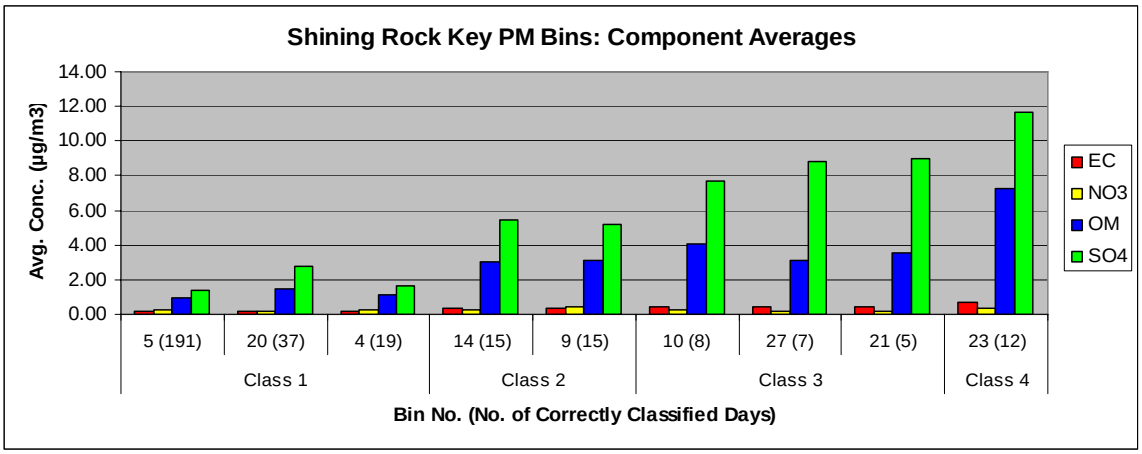


Figure 3-7r. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Sipsey.

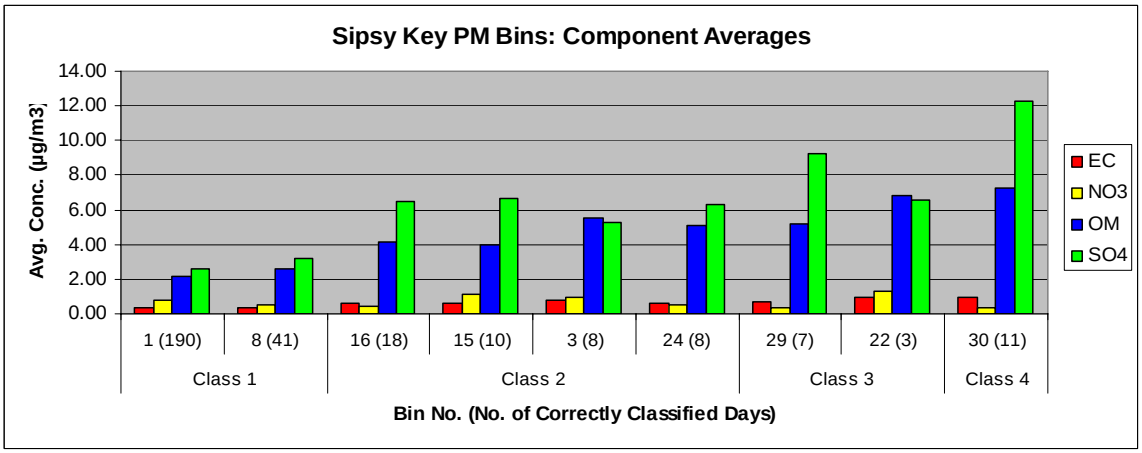


Figure 3-7s. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site St Mark's.

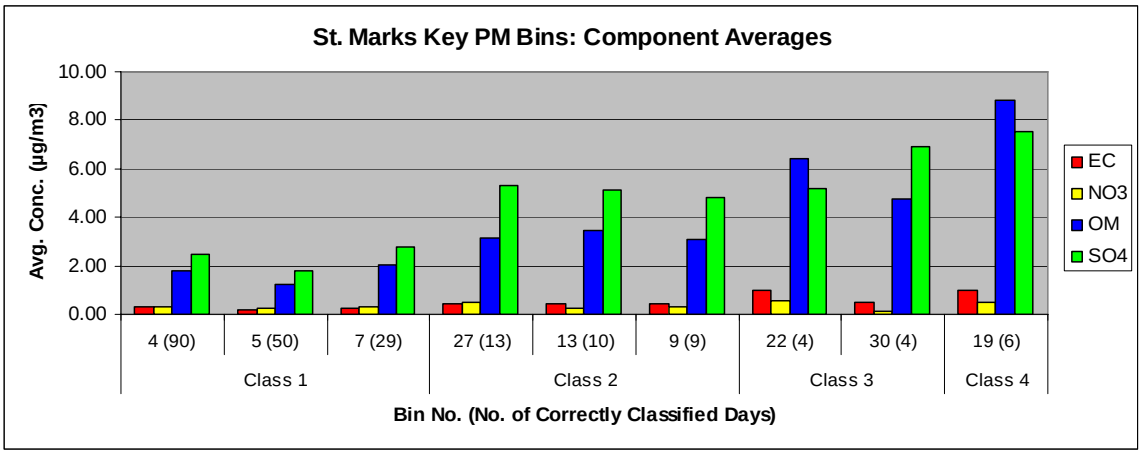


Figure 3-7t. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Swanquarter.

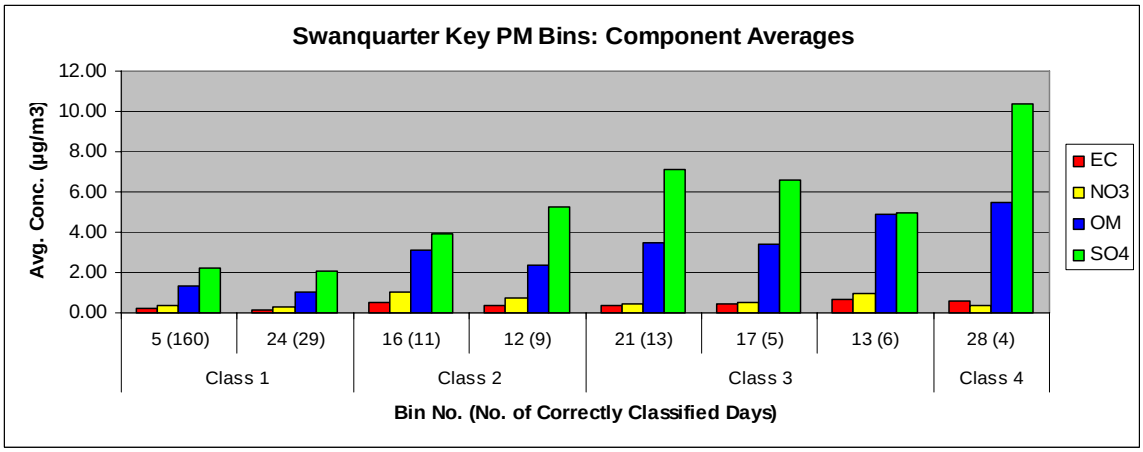
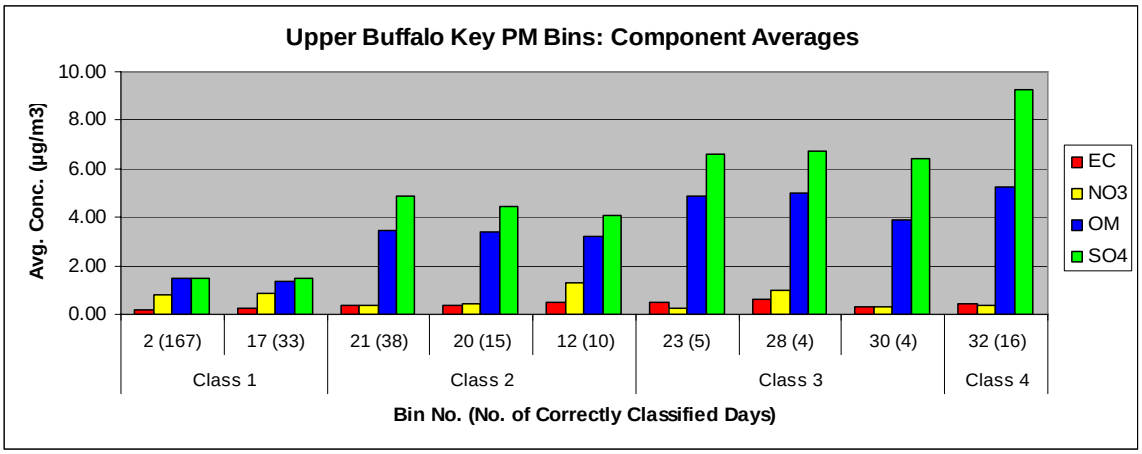


Figure 3-7u. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: IMPROVE Site Upper Buffalo.



The compositional charts for $PM_{2.5}$ also clearly illustrate that the relative contributions of various $PM_{2.5}$ components vary by bin for each of the sites. As for visibility, the high $PM_{2.5}$ concentration bins are distinguished from the lower concentration bins by higher sulfate and organic matter concentrations, and, in many cases, lower nitrate concentrations. Within each category, the variations among the bins are due to differences in meteorology as well as regional pollutant transport.

Table 3-16 summarizes the characteristics for key Category 3 and 4 bins for the STN monitoring sites.

Table 3-16a. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Birmingham.

The ranges in PM2.5 for Categories 3 and 4 are 32.5-40 and ≥ 40 μgm-3.

	Class 3		Class 4	
	Bin 11	Bin 26	Bin 19	Bin 10
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	30.5	32.6	50.7	32.4
Yesterday's FM at Atlanta (μg/m³)	23.2	24.1	37.6	25.6
Yesterday's FM at Memphis (μg/m³)	21.5	27.9	28.3	22.2
Yesterday's FM at Nashville (μg/m³)	22.0	31.3	27.7	19.5
Surface Meteorological Parameters				
Max. surface temperature (°C)	27.9	34.0	28.3	29.6
Min. surface temperature (°C)	14.8	22.7	14.5	14.6
Relative humidity (%)	61.3	61.2	63.1	61.6
Surface wind speed (ms^{-1})	1.0	2.2	0.7	0.3
Surface wind direction (degrees)	90	81	342	112
Persistence	0.7	0.9	0.8	0.5
Sea level pressure (mb)	1021	1017	1022	1023
Rainfall (inches)	0.0	0.0	0.0	0.0
Rain (# periods)	0.3	0.3	0.1	0.2
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	13.8	18.2	13.6	14.6
Temperature PM 850 mb (°C)	15.0	19.3	14.4	15.9
Stability at Birmingham (°C)	3.6	0.8	4.5	4.0
Geopotential height difference 700 mb at Birmingham (m)	-3.2	6.7	1.3	5.9
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	6.9	9.2	5.8	6.0
Wind direction yesterday 700 mb at Birmingham (degrees)	24	22	34	22
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	4.6	6.5	3.6	4.5
Wind speed AM 850 mb at Birmingham (ms^{-1})	5.5	4.6	3.7	4.0
Wind speed PM 850 mb at Birmingham (ms^{-1})	5.1	6.9	2.9	3.2
Wind direction yesterday 850 mb at Birmingham (degrees)	24	22	34	22
Wind direction AM 850 mb at Birmingham (degrees)	243	56	270	45
Wind direction PM 850 mb at Birmingham (degrees)	60	68	270	180
Recirculation at Birmingham	0.1	0.0	0.4	0.2
Cloud average	1.6	1.7	1.5	1.5

Table 3-16b. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Charlotte.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-30 and ≥ 30 μgm-3.

	Class 3				Class 4
	Bin 31	Bin 15	Bin 12	Bin 18	Bin 26
$PM_{2.5}$ Parameters					
Yesterday's FM at Atlanta (μg/m³)	28.2	33.4	20.6	23.2	35.2
Yesterday's FM at Charlotte (μg/m³)	28.6	20.1	19.3	18.8	32.2
Yesterday's FM at Greenville-Spartanburg (μg/m³)	27.2	19.0	18.3	18.3	30.4
Yesterday's FM at Winston-Salem (μg/m³)	29.2	19.7	20.8	22.4	31.7
Surface Meteorological Parameters					
Max. surface temperature (°C)	31.2	23.6	26.0	33.7	29.2
Min. surface temperature (°C)	19.7	10.6	16.5	20.3	16.7
Relative humidity (%)	70.2	66.8	71.0	62.2	69.1
Surface wind speed (ms^{-1})	1.8	1.3	1.6	1.1	1.2
Surface wind direction (degrees)	207	194	102	209	185
Persistence	0.7	0.8	0.6	0.7	0.7
Sea level pressure (mb)	1019	1022	1021	1018	1020
Rainfall (inches)	0.2	0.0	0.4	0.0	0.0
Rain (# periods)	0.6	0.2	0.6	0.3	0.3
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	17.1	10.3	12.1	18.2	15.2
Temperature PM 850 mb (°C)	17.6	12.2	12.7	19.5	15.7
Stability at Greensboro (°C)	0.5	3.6	-0.4	1.7	1.4
Geopotential height difference 700 mb at Greensboro (m)	-6.6	6.6	25.5	2.3	-1.5
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	9.1	9.2	10.0	7.0	6.5
Wind direction yesterday 700 mb at Greensboro (degrees)	286	288	306	319	326
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	5.8	5.4	5.5	4.1	5.0
Wind speed AM 850 mb at Greensboro (ms^{-1})	8.6	6.1	4.7	5.1	3.9
Wind speed PM 850 mb at Greensboro (ms^{-1})	7.0	7.5	4.1	5.2	5.2
Wind direction yesterday 850 mb at Greensboro (degrees)	259	247	301	301	309
Wind direction AM 850 mb at Greensboro (degrees)	278	246	307	323	302
Wind direction PM 850 mb at Greensboro (degrees)	273	270	n/a	270	278
Recirculation at Greensboro	0	0.1	0.3	0.1	0.2
Cloud average	1.8	1.4	2	1.7	1.5

Table 3-16c. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Chattanooga.

The ranges in PM2.5 for Categories 3 and 4 are 25-32.5 and ≥ 32.5 μgm-3.

	Class 3			Class 4
	Bin 22	Bin 19	Bin 21	Bin 28
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	34.5	30.2	36.9	44.8
Yesterday's FM at Atlanta (μg/m³)	24.4	23.3	27.1	45.4
Yesterday's FM at Knoxville (μg/m³)	25.9	26.4	26.5	44.7
Surface Meteorological Parameters				
Max. surface temperature (°C)	30.0	29.8	34.3	26.1
Min. surface temperature (°C)	16.7	18.7	21.1	13.9
Relative humidity (%)	69.6	73.3	61.2	73.2
Surface wind speed (ms^{-1})	0.8	0.8	1.7	0.7
Surface wind direction (degrees)	225	194	243	180
Persistence	0.8	0.6	0.7	0.8
Sea level pressure (mb)	1022	1021	1017	1024
Rainfall (inches)	0.1	0.1	0.1	0.0
Rain (# periods)	0.3	0.9	0.6	0.5
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	15.8	14.7	18.6	12.5
Temperature PM 850 mb (°C)	16.3	16.0	19.1	12.9
Stability at Atlanta (°C)	4.5	3.2	5.3	4.9
Geopotential height difference 700 mb at Atlanta (m)	-7.4	-3.4	-4.5	-9.1
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	6.1	5.3	5.6	3.9
Wind speed yesterday 700 mb at Nashville (ms^{-1})	7.6	7.5	6.4	5.6
Wind direction yesterday 700 mb at Atlanta (degrees)	34	108	27	117
Wind direction yesterday 700 mb at Nashville (degrees)	270	243	326	90
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	4.4	4.2	3.8	4.3
Wind speed yesterday 850 mb at Nashville (ms^{-1})	4.4	5.5	4.6	4.6
Wind speed AM 850 mb at Atlanta (ms^{-1})	4.6	4.5	4.9	4.3
Wind speed AM 850 mb at Nashville (ms^{-1})	7.7	7.3	6.7	6.9
Wind speed PM 850 mb at Atlanta (ms^{-1})	5.3	4.1	6.0	6.0
Wind speed PM 850 mb at Nashville (ms^{-1})	6.2	6.3	6.2	6.5
Wind direction yesterday 850 mb at Atlanta (degrees)	90	90	360	90
Wind direction yesterday 850 mb at Nashville (degrees)	180	281	326	207
Wind direction AM 850 mb at Atlanta (degrees)	270	90	360	90
Wind direction AM 850 mb at Nashville (degrees)	236	248	307	236
Wind direction PM 850 mb at Atlanta (degrees)	127	90	27	225
Wind direction PM 850 mb at Nashville (degrees)	214	217	297	225
Cloud average	1.9	2.1	1.9	1.9

Table 3-16d. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Greenville-Spartanburg.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-30 and ≥ 30 μgm-3.

	Class 3			Class 4		
	Bin 20	Bin 25	Bin 22	Bin32	Bin 21	Bin30
$PM_{2.5}$ Parameters						
Yesterday's FM at Atlanta (μg/m³)	27.1	36.1	24.9	40.2	26.0	30.1
Yesterday's FM at Columbus (μg/m³)	17.7	28.4	16.6	29.3	17.9	25.4
Yesterday's FM at Charlotte (μg/m³)	23.9	30.1	24.8	32.9	26.3	25.5
Yesterday's FM at Greensboro (μg/m³)	25.2	32.8	24.6	34.1	26.7	23.3
Surface Meteorological Parameters						
Max. surface temperature (°C)	28.0	28.9	29.5	28.5	26.8	29.6
Min. surface temperature (°C)	17.3	18.9	19.2	18.0	13.4	20.1
Relative humidity (%)	67.8	75.7	70.2	71.9	69.6	70.6
Surface wind speed (ms^{-1})	2.2	1.4	2.1	1.8	1.9	1.4
Surface wind direction (degrees)	195	236	63	236	112	90
Persistence	0.8	0.7	0.8	0.8	0.8	0.8
Sea level pressure (mb)	1019	1018	1021	1020	1022	1020
Rainfall (inches)	0.0	0.2	0.0	0.1	0.0	0.0
Rain (# periods)	0.6	0.9	0.5	0.4	0.0	0.0
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	14.3	15.8	15.8	14.8	13.1	15.5
Temperature PM 850 mb (°C)	16.1	16.2	16.5	15.5	14.1	16.8
Stability at Atlanta (°C)	2.4	2.1	0.0	3.0	2.7	2.5
Geopotential height difference 700 mb at Atlanta (m)	-6.5	-20.5	9.2	9.8	-10.3	14.1
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	6.0	5.6	4.82	5.5	6.5	6.6
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	8.4	6.2	4.4	7.3	5.9	5.1
Wind direction yesterday 700 mb at Atlanta (degrees)	278	14	108	310	45	34
Wind direction yesterday 700 mb at Greensboro (degrees)	283	326	270	287	9	346
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	5.0	4.9	4.4	4.2	4.8	3.5
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	5.9	5.9	6.2	5.4	4.0	3.7
Wind speed AM 850 mb at Atlanta (ms^{-1})	6.8	5.0	5.0	5.3	4.2	4.0
Wind speed AM 850 mb at Greensboro (ms^{-1})	7.6	5.2	6.5	6.1	3.5	3.7
Wind speed PM 850 mb at Atlanta (ms^{-1})	6.4	4.9	5.3	5.1	4.2	4.1
Wind speed PM 850 mb at Greensboro (ms^{-1})	7.0	5.9	5.1	6.6	3.9	4.6
Wind direction yesterday 850 mb at Atlanta (degrees)	140	284	79	171	90	360
Wind direction yesterday 850 mb at Greensboro (degrees)	270	270	56	270	27	31
Wind direction AM 850 mb at Atlanta (degrees)	239	360	59	234	227	34
Wind direction AM 850 mb at Greensboro (degrees)	257	307	74	266	27	34
Wind direction PM 850 mb at Atlanta (degrees)	250	207	74	211	146	90
Wind direction PM 850 mb at Greensboro (degrees)	249	270	90	274	225	90
Cloud average	2.0	2.2	2.4	1.9	2.0	1.8

Table 3-16e. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Hickory.

The ranges in PM2.5 for Categories 3 and 4 are 27.5-32.5 and ≥ 32.5 μgm-3.

	Class 3		Class 4	
	Bin 29	Bin 27	Bin 22	Bin 17
$PM_{2.5}$ Parameters				
Yesterday's FM at Charlotte (μg/m³)	27.7	29.3	30.4	21.5
Yesterday's FM at Greensboro (μg/m³)	25.6	33.9	30.3	21.6
Yesterday's FM at Knoxville (μg/m³)	29.0	34.2	36.5	23.5
Yesterday's FM at Winston-Salem (μg/m³)	31.3	29.4	31.9	19.1
Surface Meteorological Parameters				
Max. surface temperature (°C)	28.5	25.8	29.5	23.5
Min. surface temperature (°C)	17.5	14.7	18.0	12.0
Relative humidity (%)	70.2	71.9	71.5	71.2
Surface wind speed (ms^{-1})	1.9	0.8	0.8	1.4
Surface wind direction (degrees)	315	45	270	14
Persistence	0.8	0.8	0.7	0.8
Sea level pressure (mb)	1020	1019	1020	1023
Rainfall (inches)	0.0	0.0	0.0	0.0
Rain (# periods)	0.5	0.8	0.5	0.4
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	15.3	14.9	16.2	10.2
Temperature PM 850 mb (°C)	15.6	16.2	16.6	12.1
Stability at Greensboro (°C)	0.3	1.3	-0.9	2.6
Geopotential height difference 700 mb at Greensboro (m)	-5.5	2.1	7.7	-4.0
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	7.9	9.3	6.7	8.9
Wind direction yesterday 700 mb at Greensboro (degrees)	288	315	333	284
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	3.6	9.2	3.3	5.9
Wind speed AM 850 mb at Greensboro (ms^{-1})	6.5	7.6	5.8	6.9
Wind speed PM 850 mb at Greensboro (ms^{-1})	6.2	5.0	5.2	5.2
Wind direction yesterday 850 mb at Greensboro (degrees)	288	342	292	360
Wind direction AM 850 mb at Greensboro (degrees)	360	n/a	277	270
Wind direction PM 850 mb at Greensboro (degrees)	225	270	281	45
Recirculation at Greensboro	0.0	0.0	0.2	0.0
Cloud average	1.6	1.5	1.9	1.8

Table 3-16f. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Huntington-Ashland.

The ranges in PM2.5 for Categories 3 and 4 are 25-32.5 and ≥ 32.5 μgm-3.

	Class 3		Class 4
	Bin 14	Bin 12	Bin 23
$PM_{2.5}$ Parameters			
Yesterday's FM at Louisville (μg/m³)	27.9	28.7	40.2
Yesterday's FM at Cincinnati (μg/m³)	26.8	24.2	44.7
Surface Meteorological Parameters			
Max. surface temperature (°C)	27.8	29.4	29.1
Min. surface temperature (°C)	15.8	17.6	17.4
Relative humidity (%)	74.8	77.6	75.0
Surface wind speed (ms^{-1})	1.2	0.8	0.9
Surface wind direction (degrees)	162	135	214
Persistence	0.7	0.6	0.8
Sea level pressure (mb)	1020	1020	1023
Rainfall (inches)	0.0	0.0	0.0
Rain (# periods)	0.8	0.5	0.8
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	14.1	15.8	14.7
Temperature PM 850 mb (°C)	15.3	16.7	16.0
Stability at Wilmington (°C)	1.5	2.4	1.3
Geopotential height difference 700 mb at Wilmington (m)	-6.6	-7.0	-16.3
Wind speed yesterday 700 mb at Nashville (ms^{-1})	7.6	5.1	4.4
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	4.3	5.9	4.7
Wind direction yesterday 700 mb at Nashville (degrees)	198	360	117
Wind direction yesterday 700 mb at Roanoke (degrees)	297	315	22
Wind speed yesterday 850 mb at Wilmington (ms^{-1})	5.8	5.7	3.5
Wind speed yesterday 850 mb at Nashville (ms^{-1})	5.5	4.2	3.6
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	4.3	5.2	3.8
Wind speed AM 850 mb at Wilmington (ms^{-1})	6.8	4.2	6.4
Wind speed AM 850 mb at Nashville (ms^{-1})	6.9	2.5	3.8
Wind speed AM 850 mb at Roanoke (ms^{-1})	4.2	6.8	6.6
Wind speed PM 850 mb at Wilmington (ms^{-1})	9.4	5.6	6.1
Wind speed PM 850 mb at Nashville (ms^{-1})	6.2	4.0	5.1
Wind speed PM 850 mb at Roanoke (ms^{-1})	4.9	4.9	5.6
Wind direction yesterday 850 mb at Wilmington (degrees)	207	288	236
Wind direction yesterday 850 mb at Nashville (degrees)	194	315	207
Wind direction yesterday 850 mb at Roanoke (degrees)	135	315	14
Wind direction AM 850 mb at Wilmington (degrees)	252	270	281
Wind direction AM 850 mb at Nashville (degrees)	270	225	207
Wind direction AM 850 mb at Roanoke (degrees)	214	288	342
Wind direction PM 850 mb at Wilmington (degrees)	233	270	270
Wind direction PM 850 mb at Nashville (degrees)	207	270	207
Wind direction PM 850 mb at Roanoke (degrees)	169	270	342
Recirculation at Wilmington	0	0.3	0.1
Cloud average	1.8	2.0	1.8

Table 3-16g. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Jackson.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-27.5 and ≥27.5 μgm-3.

	Class 3	Class 4	
	Bin 30	Bin 34	Bin 22
$PM_{2.5}$ Parameters			
Yesterday's FM at Birmingham (μg/m^3)	38.7	42.8	41.3
Yesterday's FM at Memphis (μg/m^3)	24.8	23.8	28.0
Yesterday's FM at Gulfport (μg/m^3)	24.0	21.2	23.2
Yesterday's FM at New Orleans/Baton Rouge (μg/m^3)	26.5	25.1	25.7
Surface Meteorological Parameters			
Max. surface temperature (°C)	29.0	29.7	30.4
Min. surface temperature (°C)	17.3	14.0	17.6
Relative humidity (%)	70.1	67.6	69.9
Surface wind speed (ms^{-1})	1.2	1.4	0.8
Surface wind direction (degrees)	63	90	146
Persistence	0.7	0.9	0.8
Sea level pressure (mb)	1018	1021	1019
Rainfall (inches)	0.1	0.0	0.0
Rain (# periods)	0.7	0.3	0.2
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	14	16.2	15.1
Temperature PM 850 mb (°C)	16.2	15.3	16.6
Stability at Jacksonville (°C)	-0.3	4.7	1.8
Geopotential height difference 700 mb at Jacksonville (m)	-3.8	2.3	1.3
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	5.8	5.8	5.9
Wind direction yesterday 700 mb at Jacksonville (degrees)	270	45	76
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	4.0	5.4	4.4
Wind speed AM 850 mb at Jacksonville (ms^{-1})	6.7	7.4	3.0
Wind speed PM 850 mb at Jacksonville (ms^{-1})	6.0	6.9	1.7
Wind direction yesterday 850 mb at Jacksonville (degrees)	117	n/a	76
Wind direction AM 850 mb at Jacksonville (degrees)	191	n/a	171
Wind direction PM 850 mb at Jacksonville (degrees)	180	n/a	180
Recirculation at Jacksonville	0.1	0.0	0.4
Cloud average	2	1.6	1.6

Table 3-16h. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Kingsport-Bristol.

The ranges in PM2.5 for Categories 3 and 4 are 25-32.5 and ≥ 32.5 μgm-3.

	Class 3			Class 4
$PM_{2.5}$ Parameters	Bin 27	Bin 3	Bin 24	Bin 32
Yesterday's FM at Louisville (μg/m³)	28.6	17.1	28.8	41.4
Yesterday's FM at Knoxville (μg/m³)	39.1	24.9	20.5	38.7
Yesterday's FM at Winston-Salem (μg/m³)	28.9	21.1	21.9	26.2
Yesterday's FM at Richmond (μg/m³)	23.3	12.7	19.4	22.1
Surface Meteorological Parameters				
Max. surface temperature (°C)	30.4	25.9	28.7	27.2
Min. surface temperature (°C)	18.0	12.4	15.7	14.7
Relative humidity (%)	73.0	72.3	75.5	77.4
Surface wind speed (ms^{-1})	0.8	0.6	0.9	0.7
Persistence	0.7	0.7	0.7	0.8
Sea level pressure (mb)	1019	1022	1019	1022
Surface wind direction (degrees)	198	256	236	270
Rainfall (inches)	0.1	0.0	0.1	0.0
Rain (# periods)	0.6	0.0	0.6	0.6
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	17.2	13.1	15.9	15.3
Temperature PM 850 mb (°C)	18.3	14.3	16.8	16.3
Stability at Roanoke (°C)	2.6	3.9	4.2	5.3
Geopotential height difference 700 mb at Roanoke (m)	2.6	-0.2	3.9	-11.6
Wind speed yesterday 700 mb at Nashville (ms^{-1})	6.2	7.7	6.3	4.6
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	7.9	7.0	6.5	5.2
Wind direction yesterday 700 mb at Nashville (degrees)	270	270	297	360
Wind direction yesterday 700 mb at Roanoke (degrees)	284	286	292	360
Wind speed yesterday 850 mb at Nashville (ms^{-1})	4.9	4.2	5.4	3.6
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	4.6	4.5	5.0	4.3
Wind speed AM 850 mb at Nashville (ms^{-1})	6.7	5.6	8.3	6.1
Wind speed AM 850 mb at Roanoke (ms^{-1})	5.4	5.7	8.8	8.3
Wind speed PM 850 mb at Nashville (ms^{-1})	7.5	5.0	5.7	6.1
Wind speed PM 850 mb at Roanoke (ms^{-1})	5.4	3.5	7.6	6.4
Wind direction yesterday 850 mb at Nashville (degrees)	217	27.	248	194
Wind direction yesterday 850 mb at Roanoke (degrees)	288	214	256	351
Wind direction AM 850 mb at Nashville (degrees)	247	297	270	239
Wind direction AM 850 mb at Roanoke (degrees)	281	315	270	329
Wind direction PM 850 mb at Nashville (degrees)	236	217	256	243
Wind direction PM 850 mb at Roanoke (degrees)	236	.270	236	301
Cloud average	1.9	1.8	2.1	2.0

Table 3-16i. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Louisville.

The ranges in PM2.5 for Categories 3 and 4 are 27.5-37.5 and ≥ 37.5 μgm-3.

	Class 3			Class 4		
	Bin 15	Bin 30	Bin 17	Bin 24	Bin 25	Bin 29
$PM_{2.5}$ Parameters						
Yesterday's FM at Nashville (μg/m³)	16.7	28.5	29.0	29.4	29.1	25.9
Yesterday's FM at Louisville (μg/m³)	29.5	37.0	31.1	35.7	38.5	33.3
Yesterday's FM at Cincinnati (μg/m³)	25.7	37.6	31.9	32.5	32.2	32.6
Yesterday's FM at St. Louis (μg/m³)	15.9	29.9	17.9	32.0	27.4	28.6
Surface Meteorological Parameters						
Max. surface temperature (°C)	32.4	26.3	32.8	28.9	34.1	22.6
Min. surface temperature (°C)	22.4	16.2	22.3	18.1	22.2	12.5
Relative humidity (%)	67.3	69.4	65.6	68.9	55.4	78.1
Surface wind speed (ms^{-1})	1.7	2.8	2.8	1.6	1.1	1.0
Surface wind direction (degrees)	243	202	221	225	9.	135
Persistence	0.7	0.8	0.8	0.7	0.7	0.6
Sea level pressure (mb)	1017	1020	1018	1019	1023	1023
Rainfall (inches)	0.1	0.1	0.2	0.1	0.0	0.1
Rain (# periods)	0.6	0.5	0.7	0.6	0.0	0.5
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	17.1	13.8	17.2	14.8	17.2	11.6
Temperature PM 850 mb (°C)	17.8	14.0	17.8	15.4	18.6	11.8
Stability at Wilmington (°C)	1.4	2.5	0.3	2.8	2.9	1.7
Geopotential height difference 700 mb at Wilmington (m)	-11.0	-2.4	-12.5	-7.8	14.3	16.5
Wind speed yesterday 700 mb at Wilmington (ms^{-1})	5.8	9.6	11.1	5.6	4.2	10.0
Wind speed yesterday 700 mb at Nashville (ms^{-1})	5.3	7.4	5.3	5.9	5.5	7.7
Wind direction yesterday 700 mb at Wilmington (degrees)	284	286	270	299	243	297
Wind direction yesterday 700 mb at Nashville (degrees)	288	207	180	351	117	45
Wind speed yesterday 850 mb at Wilmington (ms^{-1})	5.0	7.6	8.8	3.1	2.2	8.5
Wind speed yesterday 850 mb at Nashville (ms^{-1})	3.9	3.9	5.0	3.5	2.8	6.1
Wind speed AM 850 mb at Wilmington (ms^{-1})	4.9	10.1	9.8	5.9	3.0	5.8
Wind speed AM 850 mb at Nashville (ms^{-1})	3.9	6.8	6.9	5.2	4.2	5.6
Wind speed PM 850 mb at Wilmington (ms^{-1})	6.4	9.4	9.4	6.7	2.7	5.0
Wind speed PM 850 mb at Nashville (ms^{-1})	4.6	6.5	6.4	5.2	3.2	4.8
Wind direction yesterday 850 mb at Wilmington (degrees)	315	254	266	225	117	315
Wind direction yesterday 850 mb at Nashville (degrees)	297	270	197	117	108	315
Wind direction AM 850 mb at Wilmington (degrees)	270	277	266	273	315	360
Wind direction AM 850 mb at Nashville (degrees)	243	254	250	259	45	45
Wind direction PM 850 mb at Wilmington (degrees)	262	279	264	275	117	360
Wind direction PM 850 mb at Nashville (degrees)	270	236	229	261	76	135
Cloud average	2.0	1.7	1.8	1.9	1.7	1.7

Table 3-16j. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Macon.

The ranges in PM2.5 for Categories 3 and 4 are 25-30 and ≥ 30 μgm-3.

	Class 3	Class 4
	Bin 19	Bin 14
$PM_{2.5}$ Parameters		
Yesterday's FM at Atlanta (μg/m^3)	30.0	31.1
Surface Meteorological Parameters		
Max. surface temperature (°C)	33.8	27.1
Min. surface temperature (°C)	20.9	10.4
Relative humidity (%)	68.2	67.2
Surface wind speed (ms^{-1})	0.6	0.7
Surface wind direction (degrees)	153	225
Persistence	0.4	0.7
Sea level pressure (mb)	1017	1021
Rainfall (inches)	0.0	0.0
Rain (# periods)	0.2	0.4
Upper-Air Meteorological Parameters		
Temperature AM 850 mb (°C)	17.7	12.1
Temperature PM 850 mb (°C)	18.0	12.9
Stability at Atlanta (°C)	3.2	7.4
Geopotential height difference 700 mb at Atlanta (m)	7.4	12.0
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	0.6	0.7
Wind direction yesterday 700 mb at Atlanta (degrees)	27	326
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	3.3	4.5
Wind speed AM 850 mb at Atlanta (ms^{-1})	2.8	5.7
Wind speed PM 850 mb at Atlanta (ms^{-1})	4.9	4.7
Wind direction yesterday 850 mb at Atlanta (degrees)	34	342
Wind direction AM 850 mb at Atlanta (degrees)	225	333
Wind direction PM 850 mb at Atlanta (degrees)	207	326
Recirculation at Atlanta	0.2	0.1
Cloud average	1.6	1.5

Table 3-16k. Summary of Average Input Parameters for Each Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Memphis.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-30 and ≥ 30 μgm-3.

	Class 4			Class 5		
	Bin 14	Bin 5	Bin 25	Bin 15	Bin 32	Bin 22
$PM_{2.5}$ Parameters						
Yesterday's FM at Birmingham (μg/m³)	34.6	30.7	29.6	32.2	34.7	27.5
Yesterday's FM at Memphis (μg/m³)	21.8	15.3	21.4	23.0	35.0	23.1
Yesterday's FM at Nashville (μg/m³)	22.1	18.7	19.4	23.0	30.1	25.3
Yesterday's FM at St. Louis (μg/m³)	21.2	18.4	19.7	19.0	31.5	24.7
Yesterday's FM at Little Rock (μg/m³)	21.9	16.6	19.0	26.5	29.0	19.5
Surface Meteorological Parameters						
Max. surface temperature (°C)	31.0	28.3	23.4	33.4	28.8	24.5
Min. surface temperature (°C)	20.2	17.4	11.2	23.8	18.8	16.6
Relative humidity (%)	59.4	57.4	62.1	63.9	64/3	68.8
Surface wind speed (ms^{-1})	2.4	2.3	2.8	2.0	2.0	2.0
Surface wind direction (degrees)	157	117	180	180	174	360
Persistence	0.8	0.9	0.9	0.8	0.8	0.8
Sea level pressure (mb)	1020	1021	1022	1019	1019	1019
Rainfall (inches)	0.0	0.0	0.1	0.0	0.0	0.0
Rain (# periods)	0.2	0.4	0.4	0.7	0.2	0.3
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	15.4	12.5	11.2	17.9	14.8	13.1
Temperature PM 850 mb (°C)	16.2	13.7	11.8	18.7	15.4	13.7
Stability at Nashville (°C)	2.3	1.5	5.6	-0.3	1.9	0.3
Geopotential height difference 700 mb at Nashville (m)	5.0	8.0	-3.9	-78.3	-5.9	2.9
Wind speed yesterday 700 mb at Nashville (ms^{-1})	4.2	4.9	6.8	11.0	7.4	6.5
Wind speed yesterday 700 mb at Little Rock (ms^{-1})	5.7	5.1	6.1	5.8	7.6	7.0
Wind direction yesterday 700 mb at Nashville (degrees)	319	90	326	326	24	63
Wind direction yesterday 700 mb at Little Rock (degrees)	135	90	270	315	90	360
Wind speed yesterday 850 mb at Nashville (ms^{-1})	3.8	5.3	3.1	3.9	4.6	5.1
Wind speed yesterday 850 mb at Little Rock (ms^{-1})	4.6	5.4	4.7	2.9	5.3	4.4
Wind speed AM 850 mb at Nashville (ms^{-1})	4.8	3.7	8.0	4.9	4.6	4.8
Wind speed AM 850 mb at Little Rock (ms^{-1})	5.8	3.8	7.4	3.9	5.7	4.2
Wind speed PM 850 mb at Nashville (ms^{-1})	4.3	3.7	12.7	4.5	5.1	5.2
Wind speed PM 850 mb at Little Rock (ms^{-1})	5.2	4.2	7.7	2.2	6.1	5.2
Wind direction yesterday 850 mb at Nashville (degrees)	221	162	360	360	330	27
Wind direction yesterday 850 mb at Little Rock (degrees)	170	108	221	207	135	360
Wind direction AM 850 mb at Nashville (degrees)	262	270	243	292	292	117
Wind direction AM 850 mb at Little Rock (degrees)	196	153	233	270	204	326
Wind direction PM 850 mb at Nashville (degrees)	193	135	236	284	304	360
Wind direction PM 850 mb at Little Rock (degrees)	187	135	225	270	173	90
Cloud average	1.8	1.9	1.5	1.9	1.9	2.3

Table 3-16l. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Montgomery.

The ranges in PM2.5 for Categories 3 and 4 are 25-30 and ≥ 30 μgm-3.

	Class 3		Class 4	
	Bin 19	Bin 31	Bin 26	Bin 14
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	31.8	34.8	47.1	30.9
Yesterday's FM at Atlanta (μg/m³)	25.4	33.6	35.7	32.9
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	19.3	22.7	23.0	22.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	32.9	31.7	31.8	30.4
Min. surface temperature (°C)	21.0	20.3	18.4	21.0
Relative humidity (%)	71.3	66.2	65.3	75.6
Surface wind speed (ms^{-1})	0.9	2.7	0.8	1.0
Surface wind direction (degrees)	270	90	270	90
Persistence	0.6	0.9	0.7	0.6
Sea level pressure (mb)	1019	1020	1020	1017
Rainfall (inches)	0.2	0.0	0.0	0.1
Rain (# periods)	0.9	0.2	0.4	1.0
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	32.9	31.7	31.8	30.4
Temperature PM 850 mb (°C)	18.7	16.6	16.6	16.3
Stability at Birmingham (°C)	1.0	0.9	2.8	0.2
Geopotential height difference 700 mb at Birmingham (m)	0.2	6.1	-4.9	-5.3
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	6.8	5.3	5.1	7.6
Wind direction yesterday 700 mb at Birmingham (degrees)	270	180	326	45
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	7.1	5.8	3.6	4.7
Wind speed AM 850 mb at Birmingham (ms^{-1})	4.6	5.7	4.7	4.3
Wind speed PM 850 mb at Birmingham (ms^{-1})	6.4	4.3	4.0	2.2
Wind direction yesterday 850 mb at Birmingham (degrees)	360	270	333	326
Wind direction AM 850 mb at Birmingham (degrees)	256	180	284	284
Wind direction PM 850 mb at Birmingham (degrees)	27	207	346	270
Recirculation at Birmingham	0.0	0.2	0.2	0.6
Cloud average	1.6	1.8	1.8	2.2

Table 3-16m. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Nashville.

The ranges in PM2.5 for Categories 3 and 4 are 25-32.5 and ≥ 32.5 μgm-3.

	Class 3			Class 4	
	Bin 19	Bin 16	Bin 27	Bin 25	Bin 20
$PM_{2.5}$ Parameters					
Yesterday's FM at Birmingham (μg/m³)	29.4	30.8	28.6	40.1	24.2
Yesterday's FM at Memphis (μg/m³)	24.5	20.3	28.1	29.5	24.4
Yesterday's FM at Nashville (μg/m³)	27.9	21.0	30.1	32.0	29.0
Yesterday's FM at Louisville (μg/m³)	26.4	23.5	32.2	31.5	42.1
Yesterday's FM at Cincinnati (μg/m³)	24.3	23.3	31.6	33.5	29.1
Yesterday's FM at Knoxville (μg/m³)	21.5	23.3	24.5	36.3	20.6
Surface Meteorological Parameters					
Max. surface temperature (°C)	23.2	32.2	31.2	30.3	33.2
Min. surface temperature (°C)	12.2	20.4	20.8	18.1	21.4
Relative humidity (%)	69.5	66.1	61.6	64.8	67.0
Surface wind speed (ms^{-1})	1.5	1.7	2.8	1.3	1.4
Surface wind direction (degrees)	194	180	315	180	360
Persistence	0.7	0.7	0.9	0.7	0.7
Sea level pressure (mb)	1021	1020	1018	1022	1017
Rainfall (inches)	0.0	0.0	0.0	0.0	0.0
Rain (# periods)	0.3	0.4	0.1	0.2	0.2
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	10.5	16.7	16.8	15.8	19.8
Temperature PM 850 mb (°C)	11.8	17.9	16.8	16.4	20.8
Stability at Nashville (°C)	1.4	1.0	0.5	1.6	0.2
Geopotential height difference 700 mb at Nashville (m)	9.9	15.3	-9.8	-0.6	10.2
Wind speed yesterday 700 mb at Nashville (ms^{-1})	7.9	4.4	6.6	5.2	7.4
Wind direction yesterday 700 mb at Nashville (degrees)	328	315	333	90	27
Wind speed yesterday 850 mb at Nashville (ms^{-1})	4.9	3.9	4.8	4.3	4.6
Wind speed AM 850 mb at Nashville (ms^{-1})	5.4	6.1	6.6	5.6	6.0
Wind speed PM 850 mb at Nashville (ms^{-1})	5.1	5.3	5.9	5.0	4.5
Wind direction yesterday 850 mb at Nashville (degrees)	281	214	315	225	27
Wind direction AM 850 mb at Nashville (degrees)	301	261	329	243	360
Wind direction PM 850 mb at Nashville (degrees)	236	211	315	180	360
Recirculation at Nashville	0.1	0.1	0.1	0.2	0.2
Cloud average	1.6	1.8	1.5	1.9	1.6

Table 3-16n. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Raleigh.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-30 and ≥ 30 μgm-3.

	Class 3			Class 4		
	Bin 22	Bin 23	Bin 9	Bin 28	Bin 30	Bin 26
$PM_{2.5}$ Parameters						
Yesterday's FM at Charlotte (μg/m³)	19.7	23.6	20.3	31.0	29.3	32.4
Yesterday's FM at Richmond (μg/m³)	18.7	16.7	19.0	31.0	27.0	26.6
Yesterday's FM at Raleigh (μg/m³)	18.9	26.3	18.6	31.8	31.4	30.7
Yesterday's FM at Winston-Salem (μg/m³)	20.7	25.4	22.4	31.2	30.6	27.2
Surface Meteorological Parameters						
Max. surface temperature (°C)	32.4	23.1	24.8	33.0	34.2	25.1
Min. surface temperature (°C)	18.9	11.8	13.9	20.5	21.6	12.0
Relative humidity (%)	67.8	76.1	73.7	69.9	71.6	71.4
Surface wind speed (ms^{-1})	1.3	1.9	1.3	1.7	2.2	2.0
Surface wind direction (degrees)	211	243	124	239	211	27
Persistence	0.7	0.8	0.8	0.8	0.7	0.8
Sea level pressure (mb)	1019	1020	1022	1018	1017	1022
Rainfall (inches)	0.2	0.1	0.1	0.0	0.0	0.0
Rain (# periods)	0.4	0.7	0.5	0.2	0.7	0.2
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	16.5	11.7	11.8	17.1	18.6	12.3
Temperature PM 850 mb (°C)	18.1	10.9	13.3	18.0	19.0	12.4
Stability at Greensboro (°C)	1.0	1.3	-0.3	0.4	0.9	2.1
Geopotential height difference 700 mb at Greensboro (m)	2.1	-23.6	28.4	-1.6	-8.1	6.0
Wind speed yesterday 700 mb at Greensboro (ms^{-1})	7.9	11.1	10.4	6.4	8.7	9.4
Wind direction yesterday 700 mb at Greensboro (degrees)	7	276	309	306	270	346
Wind speed yesterday 850 mb at Greensboro (ms^{-1})	4.3	6.9	6.3	5.0	5.0	5.5
Wind speed AM 850 mb at Greensboro (ms^{-1})	3.8	9.9	6.1	3.9	9.8	6.7
Wind speed PM 850 mb at Greensboro (ms^{-1})	3.6	7.3	5.6	4.3	9.1	6.0
Wind direction yesterday 850 mb at Greensboro (degrees)	339	236	297	294	261	360
Wind direction AM 850 mb at Greensboro (degrees)	342	256	270	302	286	14
Wind direction PM 850 mb at Greensboro (degrees)	270	259	270	277	262	326
Recirculation at Greensboro	0.2	0.1	0.2	0.1	0.0	0.2
Cloud average	1.7	1.8	1.8	1.5	1.7	1.4

Table 3-16o. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Richmond.

The ranges in PM2.5 for Categories 3 and 4 are 25-30 and ≥ 30 μgm-3.

	Class 3			Class 4		
	Bin 8	Bin 12	Bin 16	Bin 24	Bin 33	Bin 32
$PM_{2.5}$ Parameters						
Yesterday's FM at Richmond (μg/m³)	13.1	21.7	21.9	26.6	37.2	22.7
Yesterday's FM at Winston-Salem (μg/m³)	16.0	21.9	22.6	16.3	33.5	25.7
Yesterday's FM at Washington, D.C. (μg/m³)	15.5	20.8	21.7	37.9	42.2	28.0
Surface Meteorological Parameters						
Max. surface temperature (°C)	30.3	26.3	22.3	25.3	34.8	33.6
Min. surface temperature (°C)	19.0	16.7	10.9	14.5	22.6	20.6
Relative humidity (%)	70.4	80.2	72.3	78.6	68.8	68.1
Surface wind speed (ms^{-1})	1.6	2.2	1.2	1.9	2.3	1.9
Surface wind direction (degrees)	326	146	104	144	216	198
Persistence	0.7	0.8	0.6	0.8	0.7	0.8
Sea level pressure (mb)	1018	1020	1020	1020	1018	1020
Rainfall (inches)	0.2	0.0	0.1	0.0	0.1	0.0
Rain (# periods)	0.9	0.5	0.9	0.7	0.7	0.2
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	14.9	12.5	9.1	12.5	18.3	18.1
Temperature PM 850 mb (°C)	16.4	13.8	10.4	13.6	19.3	18.1
Stability at Dulles (°C)	1.4	0.8	1.6	2.3	1.1	3.9
Geopotential height difference 700 mb at Dulles (m)	13.3	3.1	13.8	-4.8	12.0	5.6
Wind speed yesterday 700 mb at Roanoke (ms^{-1})	10.2	8.0	11.5	7.4	6.0	6.3
Wind speed yesterday 700 mb at Dulles (ms^{-1})	9.7	8.1	13.7	9.9	8.2	8.0
Wind direction yesterday 700 mb at Roanoke (degrees)	307	270	270	288	315	360
Wind direction yesterday 700 mb at Dulles (degrees)	292	309	270	275	300	6
Wind speed yesterday 850 mb at Roanoke (ms^{-1})	5.0	4.6	6.7	5.0	4.9	3.7
Wind speed yesterday 850 mb at Dulles (ms^{-1})	7.5	3.9	10.2	6.2	6.7	6.1
Wind speed AM 850 mb at Roanoke (ms^{-1})	6.0	6.8	7.3	6.9	8.2	7.7
Wind speed AM 850 mb at Dulles (ms^{-1})	8.9	5.5	8.6	7.4	7.0	6.4
Wind speed PM 850 mb at Roanoke (ms^{-1})	5.3	4.9	7.5	7.4	5.9	6.5
Wind speed PM 850 mb at Dulles (ms^{-1})	7.7	7.0	8.0	8.2	7.7	8.2
Wind direction yesterday 850 mb at Roanoke (degrees)	323	270	270	262	276	301
Wind direction yesterday 850 mb at Dulles (degrees)	323	270	270	275	291	326
Wind direction AM 850 mb at Roanoke (degrees)	360	259	270	270	275	225
Wind direction AM 850 mb at Dulles (degrees)	351	309	278	270	290	278
Wind direction PM 850 mb at Roanoke (degrees)	346	198	214	254	270	252
Wind direction PM 850 mb at Dulles (degrees)	338	217	270	259	270	270
Cloud average	1.9	1.9	2.0	1.9	1.8	1.7

Table 3-16p. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for STN Site Savannah.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-27.5 and ≥27.5 μgm-3.

	Class 3		Class 4
	Bin 17	Bin 5	Bin 25
$PM_{2.5}$ Parameters			
Yesterday's FM at Atlanta (μg/m³)	23.8	30.4	31.5
Yesterday's FM at Charleston (μg/m³)	18.4	11.2	26.1
Surface Meteorological Parameters			
Max. surface temperature (°C)	25.9	29.6	30.9
Min. surface temperature (°C)	12.7	6.0	19.3
Relative humidity (%)	71.7	67.2	71.3
Surface wind speed (ms^{-1})	0.9	0.8	1.3
Surface wind direction (degrees)	45	236	207
Persistence	0.7	0.4	0.7
Sea level pressure (mb)	1022	1017	1019
Rainfall (inches)	0.0	0.0	0.0
Rain (# periods)	0.1	0.4	0.0
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	11.0	12.9	15.8
Temperature PM 850 mb (°C)	12.0	14.4	16.4
Stability at Charleston (°C)	1.8	1.1	-1.4
Geopotential height difference 700 mb at Charleston (m)	5.8	17.1	-0.9
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	8.6	9.1	8.6
Wind speed yesterday 700 mb at Charleston (ms^{-1})	7.3	13.3	7.6
Wind direction yesterday 700 mb at Atlanta (degrees)	315	360	338
Wind direction yesterday 700 mb at Charleston (degrees)	315	315	342
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	5.1	7.4	3.8
Wind speed yesterday 850 mb at Charleston (ms^{-1})	5.8	8.6	5.8
Wind speed AM 850 mb at Atlanta (ms^{-1})	4.8	6.7	7.1
Wind speed AM 850 mb at Charleston (ms^{-1})	4.7	8.0	6.9
Wind speed PM 850 mb at Atlanta (ms^{-1})	5.6	5.8	5.3
Wind speed PM 850 mb at Charleston (ms^{-1})	6.2	6.1	6.0
Wind direction yesterday 850 mb at Atlanta (degrees)	288	333	304
Wind direction yesterday 850 mb at Charleston (degrees)	346	288	321
Wind direction AM 850 mb at Atlanta (degrees)	288	304	18
Wind direction AM 850 mb at Charleston (degrees)	342	284	326
Wind direction PM 850 mb at Atlanta (degrees)	284	326	304
Wind direction PM 850 mb at Charleston (degrees)	333	304	349
Cloud	1.9	2.0	1.8

For Charlotte, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 22.5 to 30 and greater than or equal to 30 μgm^{-3}, respectively. There are four Category 3 and one Category 4 key bins. All of the key high $PM_{2.5}$ bins are characterized by low surface wind speeds, and moderate relative humidity. Average temperatures and, to some extent, humidity vary relative among the bins. Bins 15 and 12 (two of the Category 3 bins) have lower temperatures, typical of spring or

fall. Prior day $PM_{2.5}$ values at the potential upwind sites are consistently highest for Bin 26, the Category 4 bin. With the exception of Atlanta, the regional concentrations vary consistently among the bins. Average surface wind direction is southwesterly for four of the five key bins, and southeasterly for the remaining key bin (Bin 12). Stability is greatest, on average, for the cooler days in Bin 15. Upper-air wind speeds and directions vary only slightly among the bins. Morning and evening 850 mb wind directions are northwesterly for all bins. The higher regional concentrations are the most distinguishing feature of the Category 4 bin. Thus, regional build-up/transport appears to drive high $PM_{2.5}$ in Charlotte.

For Chattanooga, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 25 to 32.5 and greater than or equal to 32.5 μgm^{-3}, respectively. There are three Category 3 and one Category 4 bins that meet the criteria for key bins. All of the key high $PM_{2.5}$ bins are characterized by very low surface wind speeds and moderate relative humidity. Average temperature ranges from moderate to high and varies among the bins. Bins 28 (the Category 4 bin) has the lowest temperatures, both near the surface and aloft. Prior day $PM_{2.5}$ values for at the potential upwind sites are consistently highest for Bin 28, the Category 4 bin. Average surface wind direction is southwesterly for the three key Category 3 bins, and southerly for the Category 4 bin. Upper-air wind directions vary considerably among the bins. Southwesterly winds over Nashville and easterly followed by southwesterly winds aloft over Atlanta characterize the Bin 28 (Category 4). Average conditions for days within Bin 28 are similar in many respects to those for Bin 19, cooler temperatures and much higher regional concentrations appear to influence the higher $PM_{2.5}$ concentrations for Bin 28.

For Louisville, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 27.5 to 37.5 and greater than or equal to 37.5 μgm^{-3}, respectively. There are three Category 3 and three Category 4 bins that meet the criteria for key bins. The Category 4 bins have lower average wind speeds and a greater tendency for easterly wind components. The Category 4 bins are characterized by a range of temperature, humidity, and wind direction. All are associated with low wind speeds and high prior-day $PM_{2.5}$ concentrations at potential upwind sites. Bin 29 has the lowest average temperature and the highest average relative humidity value. This bin is also characterized by southeasterly surface winds and northerly to easterly winds aloft. Bin 24 is distinguished by southwesterly to westerly winds both near the surface and aloft. Bin 25 is characterized by very high average temperatures and low relative humidity. Winds are from the northeast near the surface and from the northwest to the southeast aloft. Winds speeds aloft are low, compared to other bins. For Louisville, CART appears to have identified three distinct high $PM_{2.5}$ concentration regimes.

For Macon, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 25 to 30 and greater than or equal to 30 μgm^{-3}, respectively. There is one key bin for each category. Both are characterized, on average, by very low surface wind speeds, moderate relative humidity, and prior-day $PM_{2.5}$ concentrations of about 30 μgm^{-3} in the Atlanta area. Bin 19 (Category 3) has higher temperatures and lower wind speeds aloft. Surface wind directions are from the southeast, and upper air wind directions are from the southwest. Bin 14 (Category 4) has cooler temperatures and greater stability. Surface wind directions are from the southwest, and upper air wind directions are from the northwest. Local conditions combined with a greater potential for pollutant transport from Atlanta appear to drive the higher $PM_{2.5}$ concentrations for Bin 14.

Figure 3-8 shows the average composition for all key $PM_{2.5}$ bins for each of the STN sites. Note that for some sites and bins, there were insufficient speciated data to compute the bin averages. These are marked with an asterisk.

Figure 3-8a. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Birmingham.

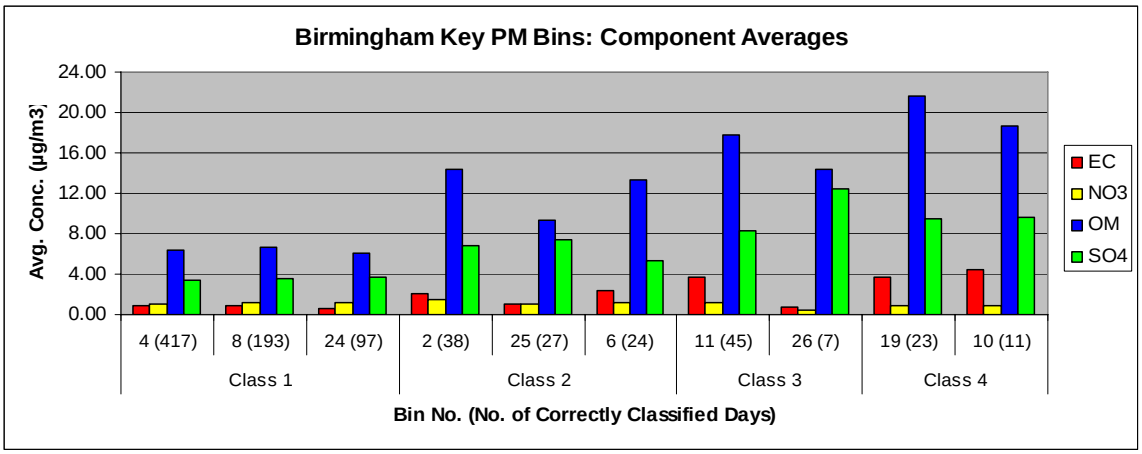


Figure 3-8b. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Charlotte.

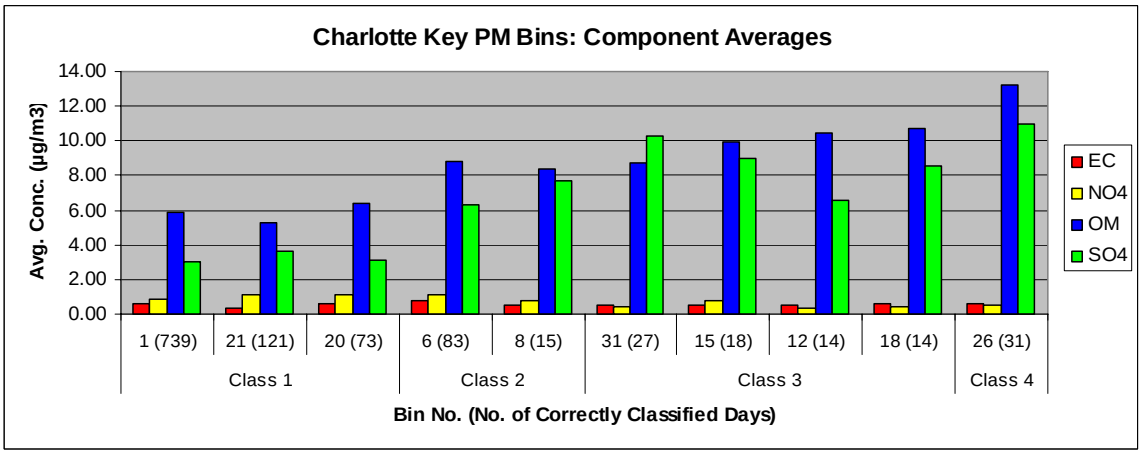


Figure 3-8c. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Chattanooga.

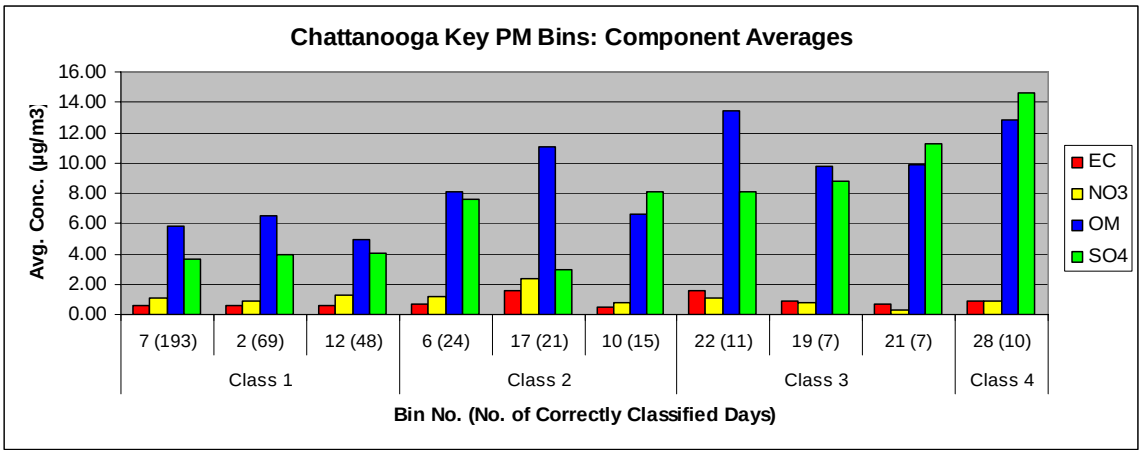
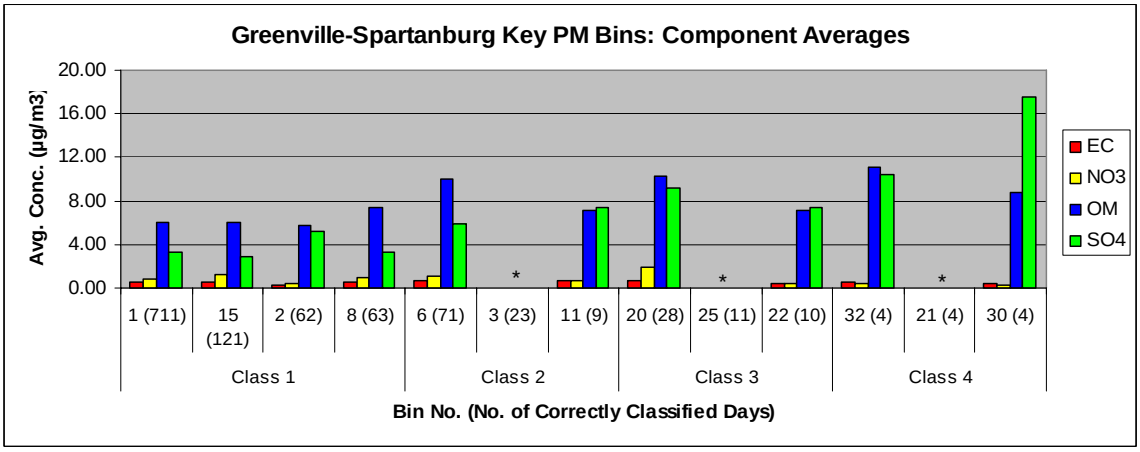
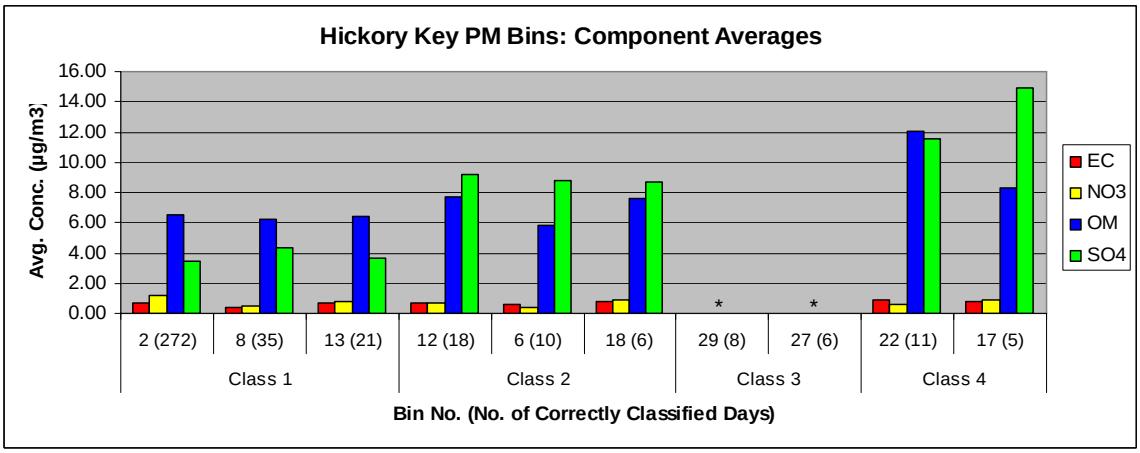


Figure 3-8d. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Greenville-Spartanburg.



** No speciated data for this bin*

Figure 3-8e. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Hickory.



** No speciated data for this bin*

Figure 3-8f. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Huntington-Ashland.

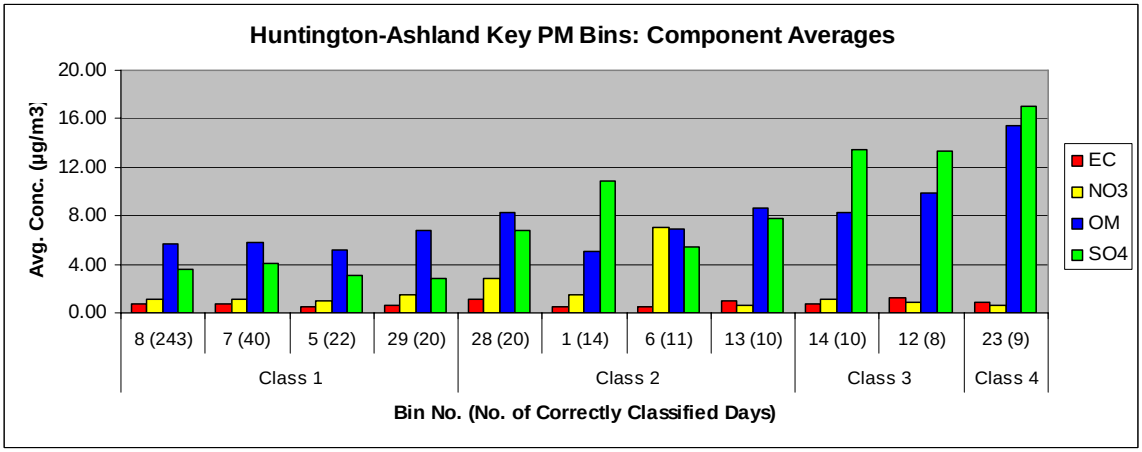
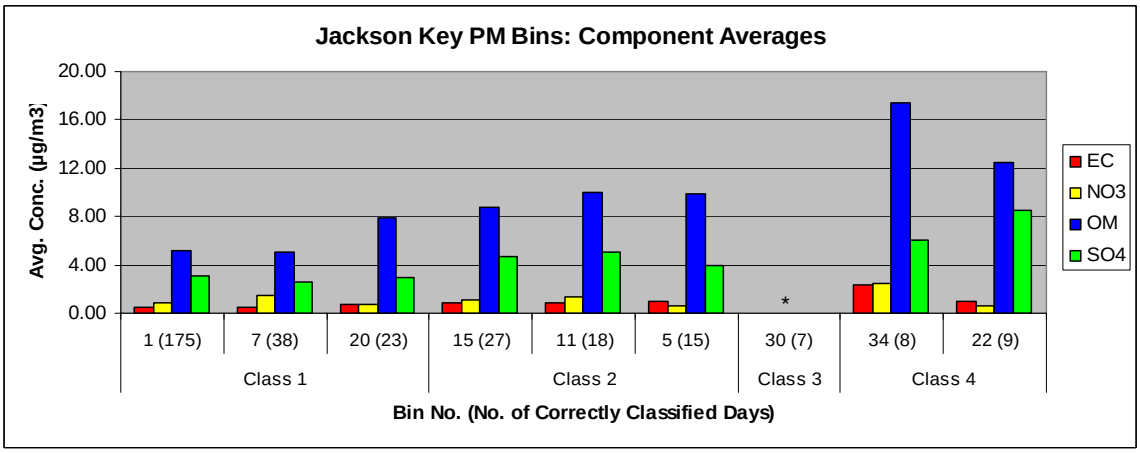


Figure 3-8g. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Jackson.



** No speciated data for this bin*

Figure 3-8h. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Kingsport-Bristol.

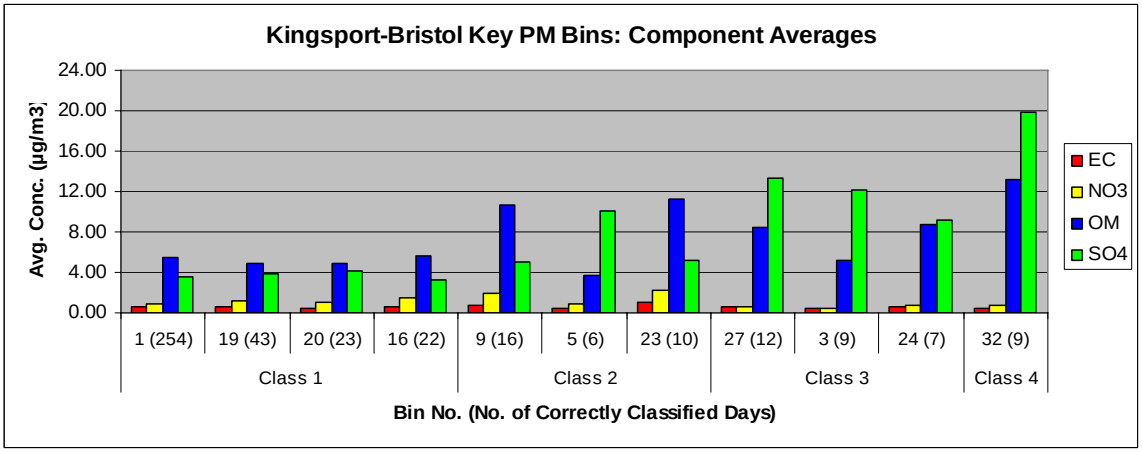
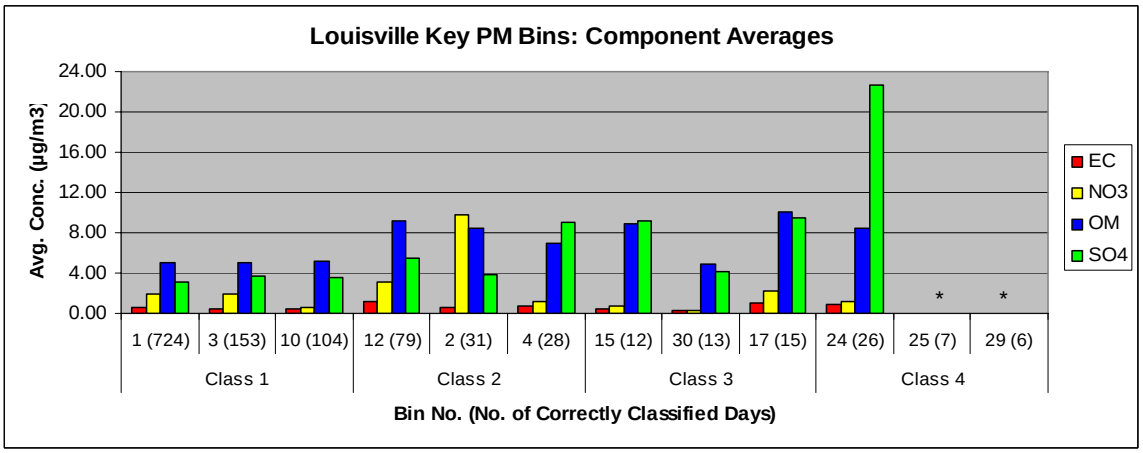


Figure 3-8i. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Louisville.



** No speciated data for this bin*

Figure 3-8j. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Macon.

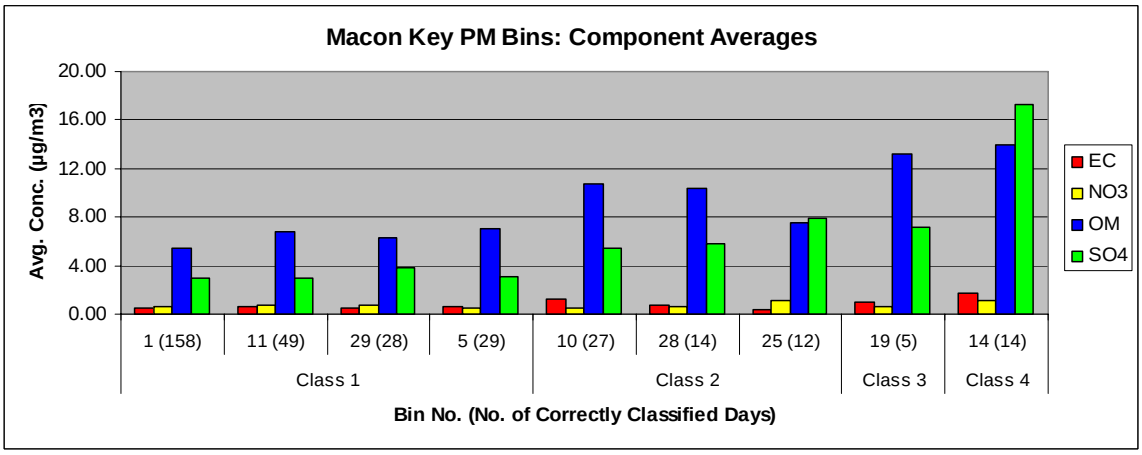
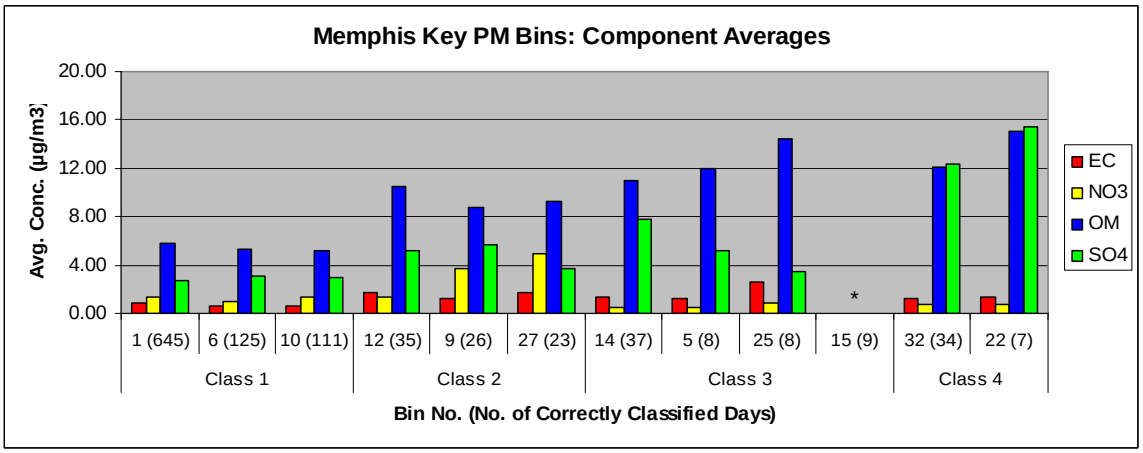


Figure 3-8k. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Memphis.



** No speciated data for this bin*

Figure 3-8l. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Montgomery.

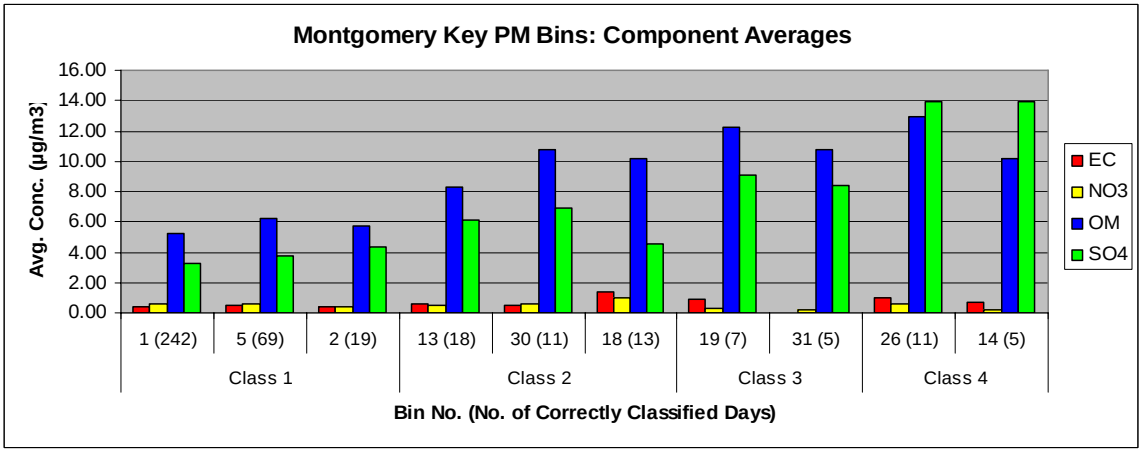
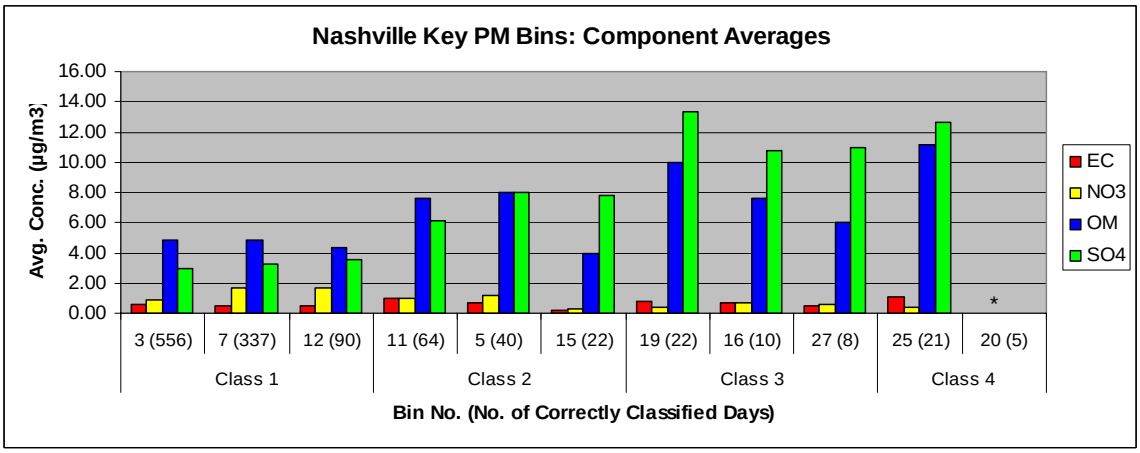
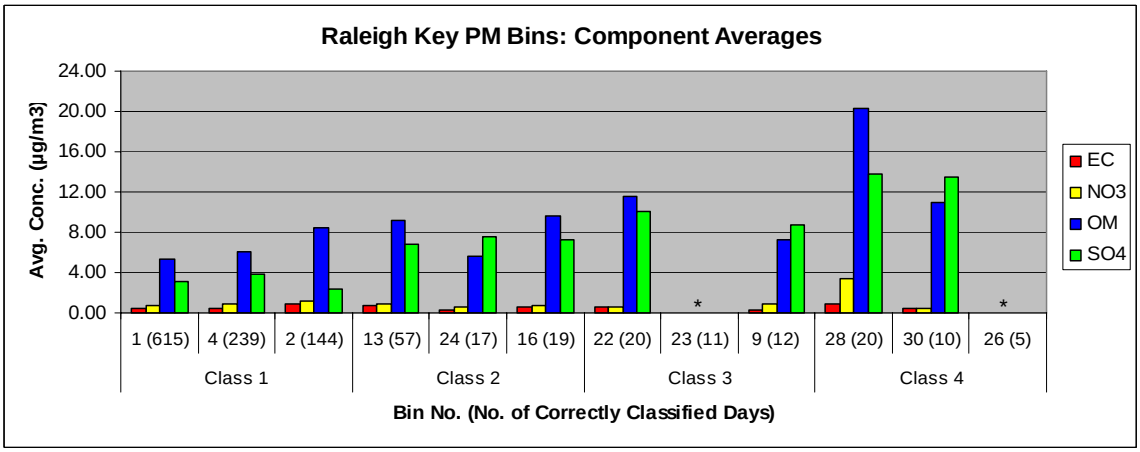


Figure 3-8m. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Nashville.



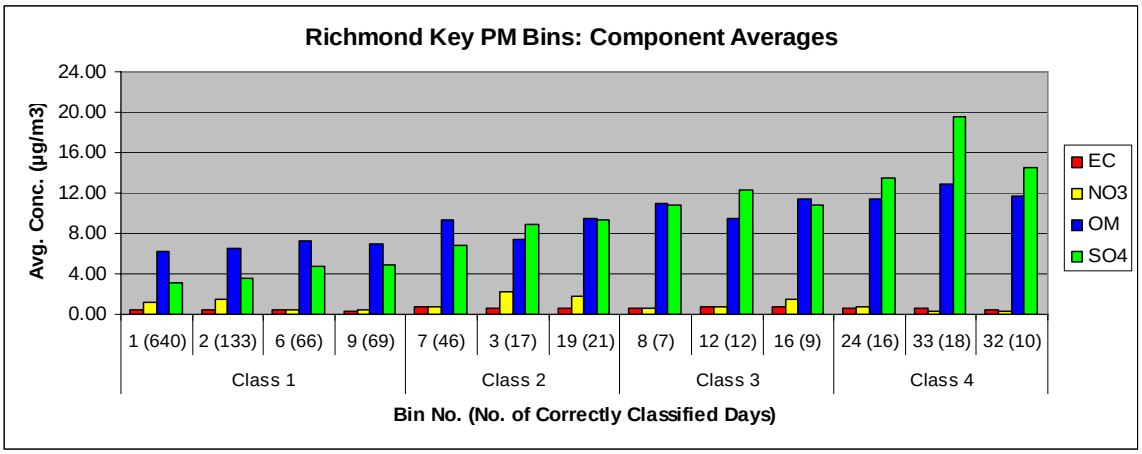
** No speciated data for this bin*

Figure 3-8n. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Raleigh.



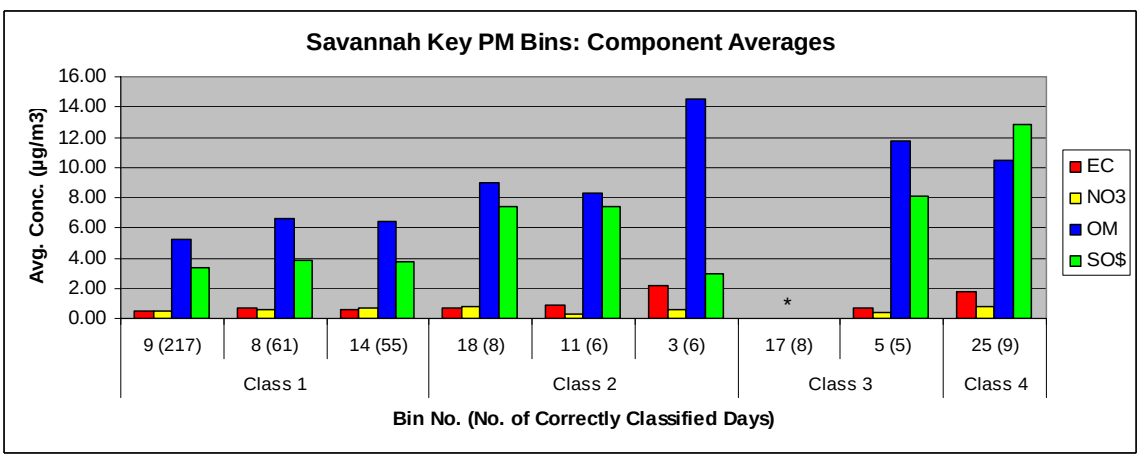
** No speciated data for this bin*

Figure 3-8o. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Richmond.



** No speciated data for this bin*

Figure 3-8p. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: STN Site Savannah.



** No speciated data for this bin*

The STN compositional charts show a much larger proportional contribution from organic matter compared to those for the IMPROVE sites, especially for the higher $PM_{2.5}$ bins. This is in part due to differences between the IMPROVE and STN measurement techniques for organic carbon. Studies (e.g., EPA, 2004) have estimated the STN measurements to be as much as 30 percent higher. Another reason for the higher organic contribution is that the STN sites are located in urban areas, which have higher organic carbon emissions.

The relative contributions of the $PM_{2.5}$ components vary by bin for each of the sites. The high $PM_{2.5}$ concentration bins are distinguished from the lower concentration bins by higher sulfate and organic matter concentrations. With the higher values for organics, the dominant species

varies by bin, much more so than for the IMPROVE sites. Again, these variations are attributable to differences in meteorology as well as regional pollutant transport.

Consider the two key high $PM_{2.5}$ bins for Macon (Bins 19 and 14). We noted earlier, that more stable conditions and a greater potential for pollutant transport from Atlanta appear to drive the higher $PM_{2.5}$ concentrations for Bin 14. This is manifested (Figure 3-8j) by higher average sulfate concentrations for this bin, compared to Bin 19. On average, Bin 19 is dominated by organic matter, while Bin 14 has a greater proportion of sulfate.

Table 3-17 summarizes the characteristics for key Category 3 and 4 bins for the SEARCH monitoring sites.

Table 3-17a. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for SEARCH Site Atlanta (Jefferson St.).

The ranges in PM2.5 for Categories 3 and 4 are 27.5-35 and ≥ 35 μgm-3.

	Class 3			Class 4		
	Bin 28	Bin 31	Bin 21	Bin 19	Bin 23	Bin 26
$PM_{2.5}$ Parameters						
Yesterday's FM at Atlanta (μg/m³)	31.3	30.9	33.4	37.7	34.9	43.4
Yesterday's FM at Birmingham (μg/m³)	34.1	35.9	35.5	39.2	34.3	44.0
Surface Meteorological Parameters						
Max. surface temperature (°C)	31.7	26.2	27.9	29.8	27.23	28.5
Min. surface temperature (°C)	21.4	18.0	16.1	18.6	14.5	15.0
Relative humidity (%)	74.2	70.7	66.0	69.9	61.8	65.1
Surface wind speed (ms^{-1})	0.7	1.9	0.6	0.8	0.6	0.5
Surface wind direction (degrees)	248	117	207	254	304	63
Persistence	0.6	0.9	0.6	0.8	0.6	0.6
Station pressure (mb)	987	990	990	988	989	991
Rainfall (inches)	0.3	0.1	0	0.0	0.0	0
Rain (# periods)	1.7	0.7	0	0.1	0.1	0
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	17.1	14.7	13.5	15.4	13.6	14.1
Temperature PM 850 mb (°C)	17.6	13.8	14.9	16.3	15.7	14.8
Stability at Atlanta (°C)	2.7	2.7	6.1	4.6	6.4	6.8
Geopotential height difference 700 mb at Atlanta (m)	-4.6	27.5	-10.8	6.4	-3.3	37.3
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	6.4	5.5	5.4	5.6	9.9	3.6
Wind direction yesterday 700 mb at Atlanta (degrees)	326	259	31	9	326	0
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	3.6	5.2	5.2	2.4	6.8	4.9
Wind speed AM 850 mb at Atlanta (ms^{-1})	5.3	6.8	3.4	3.5	7.1	3.5
Wind speed PM 850 mb at Atlanta (ms^{-1})	4.7	6.6	3.4	6.7	4.8	3.7
Wind direction yesterday 850 mb at Atlanta (degrees)	281	180	n/a	307	326	315
Wind direction AM 850 mb at Atlanta (degrees)	306	166	90	288	315	45
Wind direction PM 850 mb at Atlanta (degrees)	225	146	135	225	307	76
Recirculation at Atlanta	0.1	0.1	0.2	0.4	0	0.2
Cloud average	2.1	2.1	1.5	1.6	1.6	1.2

Table 3-17b. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for SEARCH Site Yorkville.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-30 and ≥ 30 μgm-3.

	Class 3			Class 4		
	Bin 18	Bin 28	Bin 16	Bin 22	Bin 29	Bin 15
$PM_{2.5}$ Parameters						
Yesterday's FM at Atlanta (μg/m³)	25.5	35.5	26.3	38.0	39.9	27.1
Yesterday's FM at Birmingham (μg/m³)	28.3	38.3	29.9	43.9	35.3	30.7
Yesterday's FM at Yorkville (μg/m³)	22.2	28.7	22.7	35.4	31.8	21.5
Surface Meteorological Parameters						
Max. surface temperature (°C)	28.5	28.2	23.2	28.6	26.6	28.6
Min. surface temperature (°C)	18.1	17.6	18.1	18.4	17.2	18.6
Relative humidity (%)	71.7	66.7	92.6	72.8	75.0	71.3
Surface wind speed (ms^{-1})	2.0	2.7	1.7	1.2	2.6	1.8
Surface wind direction (degrees)	99	243	180	243	90	108
Persistence	0.8	0.9	0.6	0.7	1.0	0.7
Station pressure (mb)	975	972	972	974	978	974
Rainfall (inches)	0.1	0.1	0.1	0.0	0.1	0.1
Rain (# periods)	0.6	0.5	2.0	0.1	0.9	1.2
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	15.0	15.2	13.9	15.3	13.4	15.3
Temperature PM 850 mb (°C)	14.3	16.4	15.3	16.5	13.0	16.6
Stability at Atlanta (°C)	2.5	6.6	-1.0	4.0	4.0	2.2
Geopotential height difference 700 mb at Atlanta (m)	-6.9	-6	-0.9	4.8	5.4	-1.6
Wind speed yesterday 700 mb at Atlanta (ms^{-1})	5.1	4.9	7.4	5.7	4.5	6.0
Wind direction yesterday 700 mb at Atlanta (degrees)	48	292	360	23	333	27
Wind speed yesterday 850 mb at Atlanta (ms^{-1})	4.2	3.4	4.3	3.9	4.5	3.8
Wind speed AM 850 mb at Atlanta (ms^{-1})	6.1	5.9	5.3	4.0	5.9	4.2
Wind speed PM 850 mb at Atlanta (ms^{-1})	4.4	7.6	5.2	4.0	5.9	4.2
Wind direction yesterday 850 mb at Atlanta (degrees)	98	249	315	22	117	297
Wind direction AM 850 mb at Atlanta (degrees)	90	277	225	342	124	90
Wind direction PM 850 mb at Atlanta (degrees)	112	254	0	56	124	135
Recirculation at Atlanta	0.2	0.2	0.3	0.4	0	0.2
Cloud average	1.7	1.7	2.5	1.7	2.0	1.8

Table 3-17c. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for SEARCH Site Birmingham.

The ranges in PM2.5 for Categories 3 and 4 are 30-37.5 and ≥ 37.5 μgm-3.

	Class 3		Class 4		
	Bin 10	Bin 14	Bin 25	Bin 20	Bin 24
$PM_{2.5}$ Parameters					
Yesterday's FM at Birmingham (μg/m³)	24.7	35.6	51.1	33.1	35.8
Yesterday's FM at Atlanta (μg/m³)	21.1	27.8	39.3	23.5	25.5
Yesterday's FM at Memphis (μg/m³)	18.8	21.9	27.8	18.2	20.8
Yesterday's FM at Nashville (μg/m³)	16.8	21.2	28.9	18.7	17.9
Surface Meteorological Parameters					
Max. surface temperature (°C)	28.6	28.5	28.7	23.7	30.4
Min. surface temperature (°C)	12.8	15.8	14.0	10.2	15.9
Relative humidity (%)	60.1	66.5	58.6	64.8	58.4
Surface wind speed (ms^{-1})	0.6	0.5	0.5	0.5	0.7
Surface wind direction (degrees)	360	342	344	27	180
Persistence	0.6	0.5	0.7	0.6	0.7
Station pressure (mb)	998	998	1000	1002	1000
Rainfall (inches)	0.0	0.1	0.0	0.0	0.0
Rain (# periods)	0.3	0.6	0.0	0.2	0.1
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	12.9	13.1	13.5	11.3	15.0
Temperature PM 850 mb (°C)	13.7	14.5	14.1	12.3	15.9
Stability at Birmingham (°C)	4.0	3.1	4.6	2.9	4.3
Geopotential height difference 700 mb at Birmingham (m)	6.6	-2.9	0.8	-14.7	30.1
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	6.5	5.2	4.7	9.0	6.8
Wind direction yesterday 700 mb at Birmingham (degrees)	310	292	354	63	338
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	4.2	2.7	2.9	7.0	2.8
Wind speed AM 850 mb at Birmingham (ms^{-1})	5.1	4.9	3.7	6.1	4.2
Wind speed PM 850 mb at Birmingham (ms^{-1})	4.3	4.8	2.9	4.9	3.7
Wind direction yesterday 850 mb at Birmingham (degrees)	360	254	37	27	90
Wind direction AM 850 mb at Birmingham (degrees)	270	243	270	180	270
Wind direction PM 850 mb at Birmingham (degrees)	34	220	360	207	243
Recirculation at Birmingham	0.2	0.3	0.5	0.0	0.4
Cloud average	1.3	1.7	1.4	1.6	1.6

Table 3-17d. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for SEARCH Site Centreville.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-30 and ≥ 30 μgm-3.

	Class 3			Class 4		
	Bin 16	Bin 20	Bin 19	Bin 28	Bin 18	Bin 21
$PM_{2.5}$ Parameters						
Yesterday's FM at Birmingham (μg/m³)	34.6	33.6	32.8	51.5	25.3	38.6
Yesterday's FM at Atlanta (μg/m³)	28.1	33.1	31.1	38.1	18.5	30.0
Yesterday's FM at Centreville (μg/m³)	24.7	24.6	26.7	38.3	24.3	27.9
Surface Meteorological Parameters						
Max. surface temperature (°C)	31.2	31.7	32.9	31.0	25.4	35.4
Min. surface temperature (°C)	20.4	20.3	22.8	19.8	13.5	23.7
Relative humidity (%)	70.8	21.9	70.0	67.6	68.0	71.6
Surface wind speed (ms^{-1})	1.4	0.9	3.0	1.0	1.2	1.0
Surface wind direction (degrees)	330	110	304	349	329	153
Persistence	0.7	0.6	1.0	0.7	0.6	0.6
Station pressure (mb)	1003	1004	997	1005	1003	1005
Rainfall (inches)	0.0	0.0	0.0	0.1	0.1	0.0
Rain (# periods)	0.3	0.4	0.2	0.1	0.6	0.2
Upper-Air Meteorological Parameters						
Temperature AM 850 mb (°C)	15.5	15.8	18.2	15.2	12.4	18.0
Temperature PM 850 mb (°C)	16.2	17.1	17.9	15.9	11.3	20.1
Stability at Birmingham (°C)	1.6	2	-1.4	2.6	1.7	3.4
Geopotential height difference 700 mb at Birmingham (m)	-4.1	-0.2	-19.8	-0.3	15.1	10.3
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	5.9	5.6	9.3	4.9	12.3	5.2
Wind direction yesterday 700 mb at Birmingham (degrees)	342	56	27	6	297	360
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	4.6	3.6	5.6	3.7	6.1	2.6
Wind speed AM 850 mb at Birmingham (ms^{-1})	5.0	3.3	11.0	3.5	8.2	4.6
Wind speed PM 850 mb at Birmingham (ms^{-1})	4.5	2.6	7.1	2.9	4.7	2.7
Wind direction yesterday 850 mb at Birmingham (degrees)	360	27	14	23	11	n/a
Wind direction AM 850 mb at Birmingham (degrees)	309	202	360	243	270	315
Wind direction PM 850 mb at Birmingham (degrees)	356	117	346	45	360	270
Recirculation at Birmingham	0.3	0.4	0	0.4	0	0.3
Cloud average	1.8	1.6	1.6	1.9	1.8	1.7

Table 3-17e. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for SEARCH Site Pensacola.

The ranges in PM2.5 for Categories 3 and 4 are 22.5-27.5 and ≥27.5 μgm-3.

	Class 3		Class 4		
	Bin 22	Bin 31	Bin 19	Bin 27	Bin 18
$PM_{2.5}$ Parameters					
Yesterday's FM at Gulfport (μg/m³)	19.4	24.2	18.2	25.0	16.9
Yesterday's FM at Pensacola (μg/m³)	22.7	30.8	19.5	30.7	20.1
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	21.3	26.7	18.7	25.3	19.1
Surface Meteorological Parameters					
Max. surface temperature (°C)	25.2	24.9	25.3	28.0	24.2
Min. surface temperature (°C)	13.1	16.1	14.6	18.7	10.6
Relative humidity (%)	70.4	85.8	73.5	74.1	64.1
Surface wind speed (ms^{-1})	1.6	0.6	0.5	0.7	0.6
Surface wind direction (degrees)	90	72	153	169	360
Persistence	0.9	0.7	0.4	0.6	0.7
Station pressure (mb)	1019	1019	1022	1018	1024
Rainfall (inches)	0.0	0.1	0.0	0.0	0.0
Rain (# periods)	0.0	0.7	0.1	0.2	0.0
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	11.8	14.0	12.5	14.3	10.4
Temperature PM 850 mb (°C)	12.0	14.0	13.0	14.8	11.3
Stability at Tallahassee (°C)	2.3	1.9	2.4	1.5	6.2
Geopotential height difference 700 mb at Tallahassee (m)	-7.5	11	23.1	0.6	-2.8
Wind speed yesterday 700 mb at Slidell (ms^{-1})	8.0	6.4	5.7	4.7	7.5
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	7.8	6.7	9.1	7.2	7.5
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	8.9	9.8	9.9	6.8	10.2
Wind direction yesterday 700 mb at Slidell (degrees)	90	270	297	328	315
Wind direction yesterday 700 mb at Tallahassee (degrees)	315	90	338	309	288
Wind direction yesterday 700 mb at Birmingham (degrees)	284	292	323	310	288
Wind speed yesterday 850 mb at Slidell (ms^{-1})	7.7	5.8	5.1	3.9	4.6
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	5.0	5.4	3.0	4.6	5.7
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	6.4	6.0	5.3	4.2	6.1
Wind speed AM 850 mb at Slidell (ms^{-1})	8.1	5.9	3.5	4.3	4.8
Wind speed AM 850 mb at Tallahassee (ms^{-1})	7.0	5.6	4.2	4.8	4.3
Wind speed AM 850 mb at Birmingham (ms^{-1})	8.5	7.1	5.9	4.1	6.1
Wind speed PM 850 mb at Slidell (ms^{-1})	8.1	4.9	4.0	4.3	5.1
Wind speed PM 850 mb at Tallahassee (ms^{-1})	7.2	6.1	4.0	5.6	4.5
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.4	8.0	5.4	4.6	5.0
Wind direction yesterday 850 mb at Slidell (degrees)	360	180	346	360	333
Wind direction yesterday 850 mb at Tallahassee (degrees)	360	360	360	339	360
Wind direction yesterday 850 mb at Birmingham (degrees)	270	207	304	342	315
Wind direction AM 850 mb at Slidell (degrees)	207	194	207	214	342
Wind direction AM 850 mb at Tallahassee (degrees)	270	207	333	270	288
Wind direction AM 850 mb at Birmingham (degrees)	284	214	315	282	360
Wind direction PM 850 mb at Slidell (degrees)	297	198	360	22	360
Wind direction PM 850 mb at Tallahassee (degrees)	45	270	63	328	342
Wind direction PM 850 mb at Birmingham (degrees)	270	225	315	270	333
Cloud average	1.4	1.9	1.3	1.8	1.5

Table 3-17f. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for SEARCH Site Outlying Landing Field (OLF).

The ranges in PM2.5 for Categories 3 and 4 are 20-27.5 and ≥27.5 μgm-3.

	Class 3		Class 4
	Bin 25	Bin 13	Bin 28
$PM_{2.5}$ Parameters			
Yesterday's FM at Gulfport (μg/m³)	19.9	17.2	28.3
Yesterday's FM at Pensacola (μg/m³)	23.9	21.4	31.5
Yesterday's FM at Outer Landing Field (μg/m³)	21.1	16.2	33.8
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	21.9	20.3	27.0
Surface Meteorological Parameters			
Max. surface temperature (°C)	31.0	25.3	30.6
Min. surface temperature (°C)	18.5	11.0	18.9
Relative humidity (%)	67.5	59.1	73.3
Surface wind speed (ms^{-1})	1.6	1.1	1.0
Surface wind direction (degrees)	270	342	286
Persistence	0.7	0.6	0.6
Station pressure (mb)	1014	1016	1013
Rainfall (inches)	0.0	0.0	0.0
Rain (# periods)	0.2	0.1	0.4
Upper-Air Meteorological Parameters			
Temperature AM 850 mb (°C)	15.4	11.7	15.6
Temperature PM 850 mb (°C)	16.3	12.0	16.0
Stability at Tallahassee (°C)	1.2	3.9	-0.4
Geopotential height difference 700 mb at Tallahassee (m)	3.1	1.6	5.3
Wind speed yesterday 700 mb at Slidell (ms^{-1})	4.8	6.1	4.9
Wind speed yesterday 700 mb at Tallahassee (ms^{-1})	7.5	8.4	6.9
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	7.8	7.5	5.8
Wind direction yesterday 700 mb at Slidell (degrees)	4	360	330
Wind direction yesterday 700 mb at Tallahassee (degrees)	336	342	311
Wind direction yesterday 700 mb at Birmingham (degrees)	315	352	319
Wind speed yesterday 850 mb at Slidell (ms^{-1})	4.8	7.0	4.0
Wind speed yesterday 850 mb at Tallahassee (ms^{-1})	5.5	4.1	4.6
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	6.0	5.4	5.6
Wind speed AM 850 mb at Slidell (ms^{-1})	4.7	5.8	3.9
Wind speed AM 850 mb at Tallahassee (ms^{-1})	5.3	6.0	5.2
Wind speed AM 850 mb at Birmingham (ms^{-1})	6.7	6.2	3.4
Wind speed PM 850 mb at Slidell (ms^{-1})	5.7	5.9	3.6
Wind speed PM 850 mb at Tallahassee (ms^{-1})	5.4	5.8	5.3
Wind speed PM 850 mb at Birmingham (ms^{-1})	6.0	5.1	3.0
Wind direction yesterday 850 mb at Slidell (degrees)	25	11	22
Wind direction yesterday 850 mb at Tallahassee (degrees)	352	360	325
Wind direction yesterday 850 mb at Birmingham (degrees)	320	352	333
Wind direction AM 850 mb at Slidell (degrees)	180	90	135
Wind direction AM 850 mb at Tallahassee (degrees)	319	346	243
Wind direction AM 850 mb at Birmingham (degrees)	270	326	279
Wind direction PM 850 mb at Slidell (degrees)	8	63	48
Wind direction PM 850 mb at Tallahassee (degrees)	347	34	352
Wind direction PM 850 mb at Birmingham (degrees)	320	360	225
Cloud average	1.6	1.1	1.8

Table 3-17g. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for SEARCH Site Gulfport.

The ranges in PM2.5 for Categories 3 and 4 are 20-25 and ≥25 μgm-3.

	Class 3			Class 4	
	Bin 29	Bin 12	Bin 10	Bin 30	Bin 16
$PM_{2.5}$ Parameters					
Yesterday's FM at Gulfport (μg/m³)	24.3	25.5	17.7	28.1	16.7
Yesterday's FM at Pensacola (μg/m³)	20.0	18.0	21.7	29.9	16.9
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	26.1	18.3	18.1	28.4	22.1
Surface Meteorological Parameters					
Max. surface temperature (°C)	26.1	23.4	31.7	29.4	27.4
Min. surface temperature (°C)	6.1	9.6	21.3	19.4	16.7
Relative humidity (%)	77.9	69.7	73.9	73.3	67.9
Surface wind speed (ms^{-1})	1.4	1.0	1.2	1.0	0.7
Surface wind direction (degrees)	158	191	194	220	225
Persistence	0.7	0.5	0.6	0.5	0.4
Station pressure (mb)	1018	1019	1017	1017	1018
Rainfall (inches)	0.1	0.0	0.0	0.0	0.0
Rain (# periods)	0.5	0.1	0.3	0.3	0.1
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	12.5	11.1	16.2	14.2	13.2
Temperature PM 850 mb (°C)	12.5	11.5	16.7	14.9	14.0
Stability at Slidell (°C)	1.7	7.0	-0.1	0.7	2.3
Geopotential height difference 700 mb at Slidell (m)	-1.2	9.3	5.0	1.6	-6.7
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	7.6	8.1	6.8	6.0	9.0
Wind speed yesterday 700 mb at Slidell (ms^{-1})	4.6	6.2	5.7	5.5	8.8
Wind direction yesterday 700 mb at Jacksonville (degrees)	279	320	281	330	297
Wind direction yesterday 700 mb at Slidell (degrees)	297	342	360	353	297
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	6.3	6.4	3.6	4.2	5.9
Wind speed yesterday 850 mb at Slidell (ms^{-1})	4.6	6.2	5.7	4.4	8.0
Wind speed AM 850 mb at Jacksonville (ms^{-1})	6.7	4.9	5.8	4.4	7.3
Wind speed AM 850 mb at Slidell (ms^{-1})	5.2	5.0	5.0	4.0	6.1
Wind speed PM 850 mb at Jacksonville (ms^{-1})	6.3	6.4	3.6	4.7	5.1
Wind speed PM 850 mb at Slidell (ms^{-1})	5.2	5.6	4.8	4.3	5.1
Wind direction yesterday 850 mb at Jacksonville (degrees)	270	360	n/a	9	342
Wind direction yesterday 850 mb at Slidell (degrees)	351	6	90	21	360
Wind direction AM 850 mb at Jacksonville (degrees)	262	262	169	243	304
Wind direction AM 850 mb at Slidell (degrees)	180	243	121	149	360
Wind direction PM 850 mb at Jacksonville (degrees)	217	211	166	225	297
Wind direction PM 850 mb at Slidell (degrees)	270	236	90	29	360
Recirculation at Slidell	0.3	0.2	360	0.2	0.0
Cloud average	1.7	1.2	1.7	1.6	1.6

Table 3-17h. Summary of Average Input Parameters for Key Bins for CART Classification Categories 3 and 4: $PM_{2.5}$ CART Analysis for SEARCH Site Oak Grove.

The ranges in PM2.5 for Categories 3 and 4 are 20-27.5 and ≥27.5 μgm-3.

	Class 3			Class 4	
	Bin 19	Bin 29	Bin 14	Bin 31	Bin 26
$PM_{2.5}$ Parameters					
Yesterday's FM at Gulfport (μg/m³)	19.4	23.8	14.7	26.0	22.3
Yesterday's FM at Oak Grove (μg/m³)	19.7	22.9	17.1	35.0	22.8
Yesterday's FM at Pensacola (μg/m³)	18.6	28.6	17.1	24.6	30.73
Yesterday's FM at New Orleans/Baton Rouge (μg/m³)	23.8	22.9	16.8	29.3	26.4
Surface Meteorological Parameters					
Max. surface temperature (°C)	28.6	33.0	29.3	28.7	25.5
Min. surface temperature (°C)	16.2	20.1	14.4	17.2	14.3
Relative humidity (%)	65.2	71.2	62.4	67.6	65.8
Surface wind speed (ms^{-1})	1.0	1.2	1.4	1.1	1.2
Surface wind direction (degrees)	75	180	360	321	76
Persistence	0.7	0.8	0.8	0.7	0.8
Station pressure (mb)	1012	1010	1011	1010	1011
Rainfall (inches)	0.0	0.0	0.0	0.0	0.0
Rain (# periods)	0.2	0.12	0.1	0.2	0.5
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	14.0	17.0	14.6	13.7	11.7
Temperature PM 850 mb (°C)	13.6	18.0	15.4	14.7	12.3
Stability at Slidell (°C)	1.1	0.0	2.7	1.6	0.9
Geopotential height difference 700 mb at Slidell (m)	-0.1	4.0	3.7	5.6	6.4
Wind speed yesterday 700 mb at Jacksonville (ms^{-1})	6.3	5.2	7.9	9.0	5.1
Wind speed yesterday 700 mb at Slidell (ms^{-1})	5.9	4.9	7.1	7	6.4
Wind direction yesterday 700 mb at Jacksonville (degrees)	323	8	315	297	270
Wind direction yesterday 700 mb at Slidell (degrees)	329	27	329	328	309
Wind speed yesterday 850 mb at Jacksonville (ms^{-1})	4.8	4.4	4.2	4.7	3.9
Wind speed yesterday 850 mb at Slidell (ms^{-1})	5.4	4.4	6.3	4.8	4.5
Wind speed AM 850 mb at Jacksonville (ms^{-1})	5.1	4.7	4.0	6.5	4.5
Wind speed AM 850 mb at Slidell (ms^{-1})	4.6	3.9	4.3	4.5	5.4
Wind speed PM 850 mb at Jacksonville (ms^{-1})	4.8	4.4	5.5	5.0	6.6
Wind speed PM 850 mb at Slidell (ms^{-1})	5.7	4.3	5.0	4.5	5.7
Wind direction yesterday 850 mb at Jacksonville (degrees)	90	342	315	307	270
Wind direction yesterday 850 mb at Slidell (degrees)	48	23	14	0	333
Wind direction AM 850 mb at Jacksonville (degrees)	194	270	326	275	207
Wind direction AM 850 mb at Slidell (degrees)	243	90	45	278	198
Wind direction PM 850 mb at Jacksonville (degrees)	149	284	146	304	153
Wind direction PM 850 mb at Slidell (degrees)	52	63	56	10	27
Recirculation at Slidell	0.2	0.3	0	0.4	0.2
Cloud average	1.7	1.7	1.6	1.7	1.8

For Atlanta, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 30 to 37.5 and greater than or equal to 37.5 μgm^{-3}, respectively. There are three Category 3 and three Category 4 bins that meet the criteria for key bins. The Category 4 bins tend to have lower average relative humidity, greater stability, and higher prior-day $PM_{2.5}$ concentrations, than the Category 3 bins, but many of the characteristics are similar between the two groups of bins. The Category 4 bins are characterized by very low surface wind speeds. Surface wind directions are from the southwest (Bin 19), northwest (Bin 23), and northeast (Bin 26). Two of the Category 4 bins have cooler minimum temperatures than the other key bins and greater stability. This same tendency is reflected in the wind directions aloft. In contrast, southeasterly wind components are associated with the two of the Category 3 bins. CART appears to have identified three distinct high $PM_{2.5}$ concentration regimes.

For Birmingham, the $PM_{2.5}$ concentration ranges for Categories 3 and 4 are 30 to 37.5 and greater than or equal to 37.5 μgm^{-3}, respectively. There are two Category 3 and three Category 4 bins that meet the criteria for key bins. All of the key bins are characterized by very low surface wind speeds. Two of the three Category 4 bins are distinguished from the Category 3 bins by lower average relative humidity. The third bin is distinguished from the Category 3 bins and all other key bins by lower temperatures. Bin 25 (Category 4) is very similar to Bin 10 (Category 3), in terms of the average parameter values, with the exception of the prior-day PM concentration for Birmingham. A much higher prior-day value for Bin 25 likely contributes to the higher $PM_{2.5}$ values and higher category designation. Bins 20 and 24 are differentiated by wind directions. Surface winds are northeasterly for Bin 20 and southerly for Bin 24, compared to northwesterly for Bin 25 and the key Category 3 bins. Upper-level winds are southerly to southwesterly for Bin 20 and (more typically) westerly to southwesterly for Bin 24.

Figure 3-9 shows the average composition for all key $PM_{2.5}$ bins for each of the SEARCH sites.

Figure 3-9a. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: SEARCH Site Atlanta.

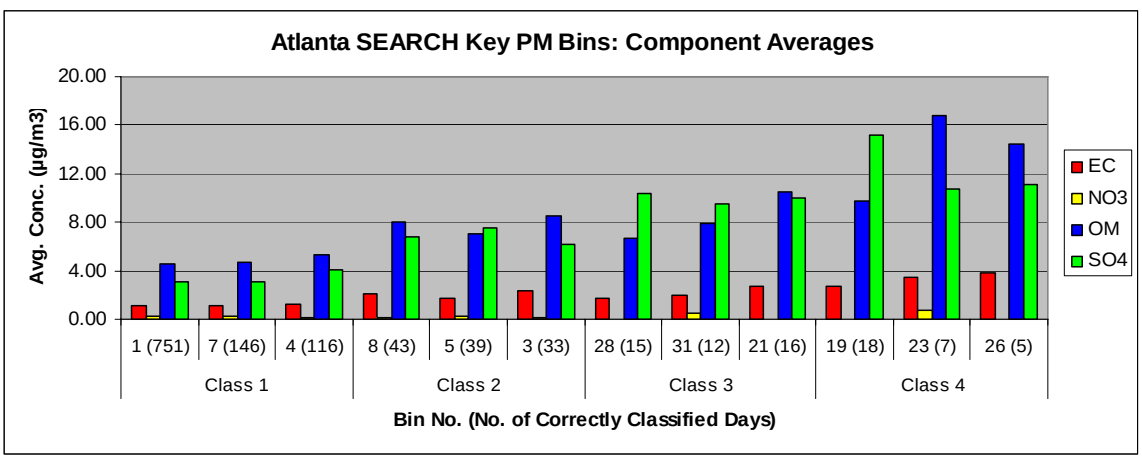


Figure 3-9b. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: SEARCH Site Yorkville.

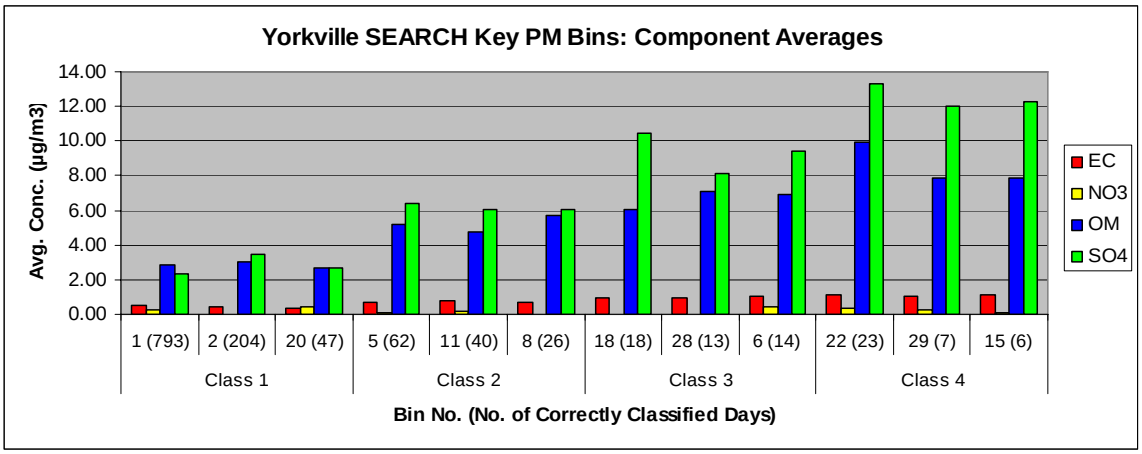


Figure 3-9c. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: SEARCH Site Birmingham.

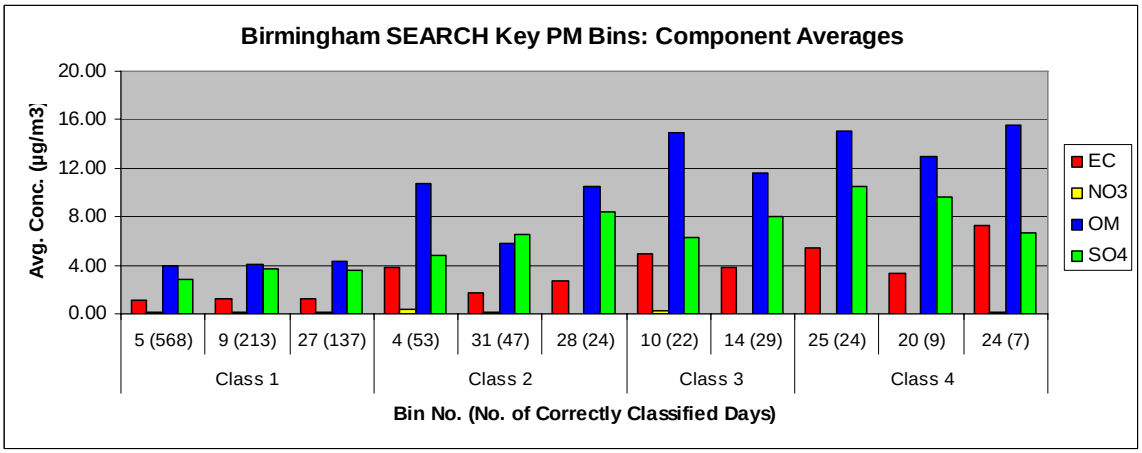


Figure 3-9d. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: SEARCH Site Centreville.

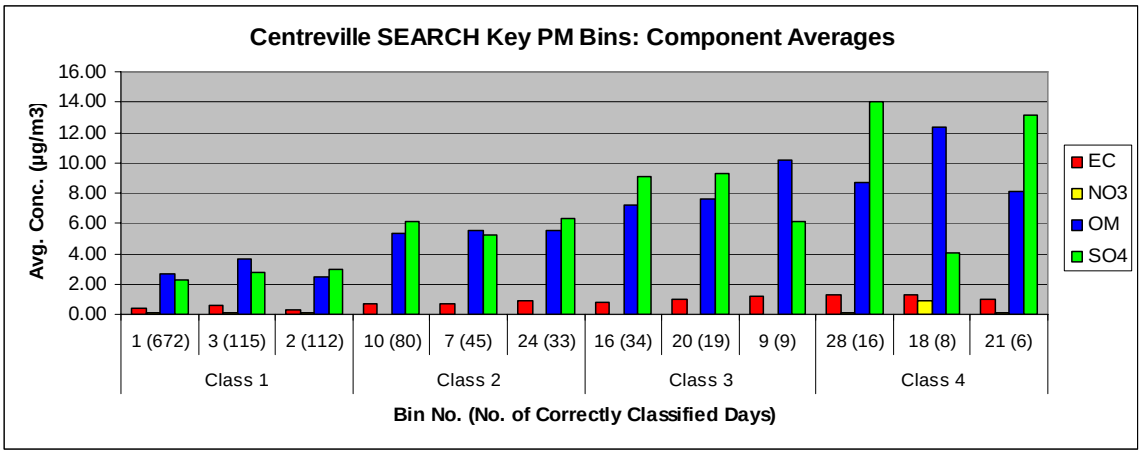


Figure 3-9e. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: SEARCH Site Pensacola.

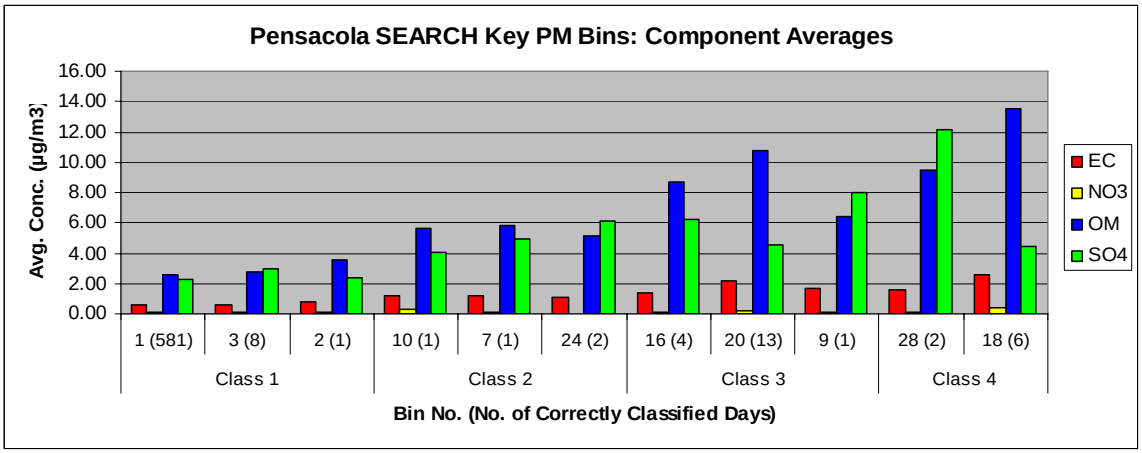


Figure 3-9f. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: SEARCH Site Outlying Landing Field.

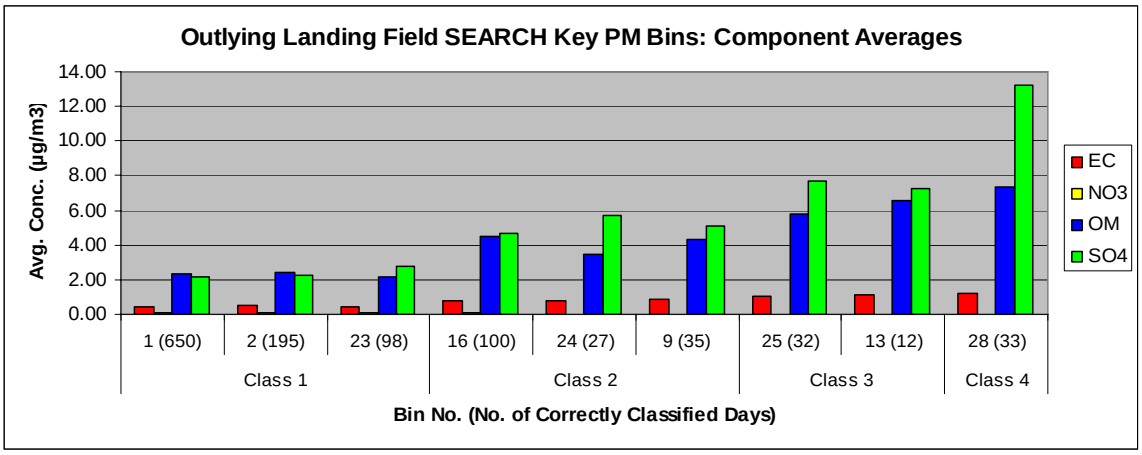


Figure 3-9g. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: SEARCH Site Gulfport.

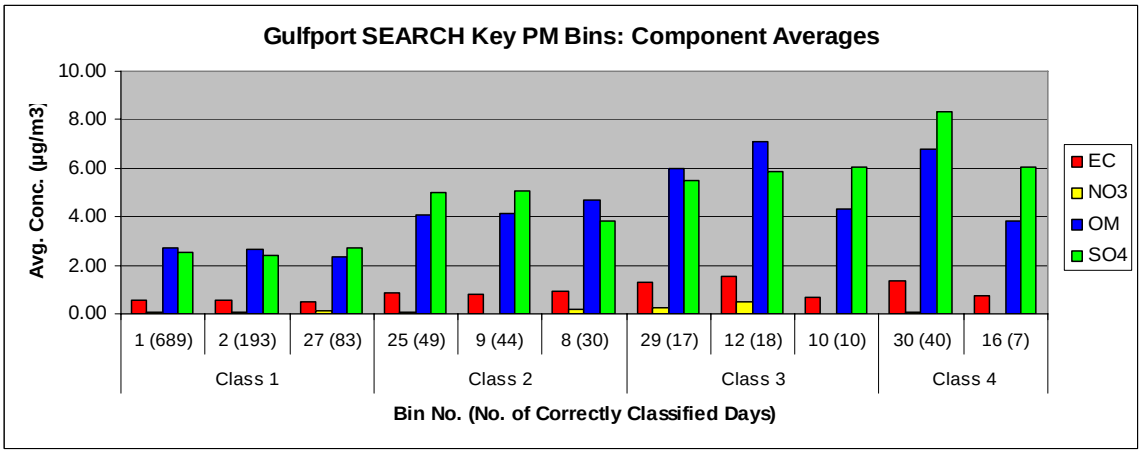
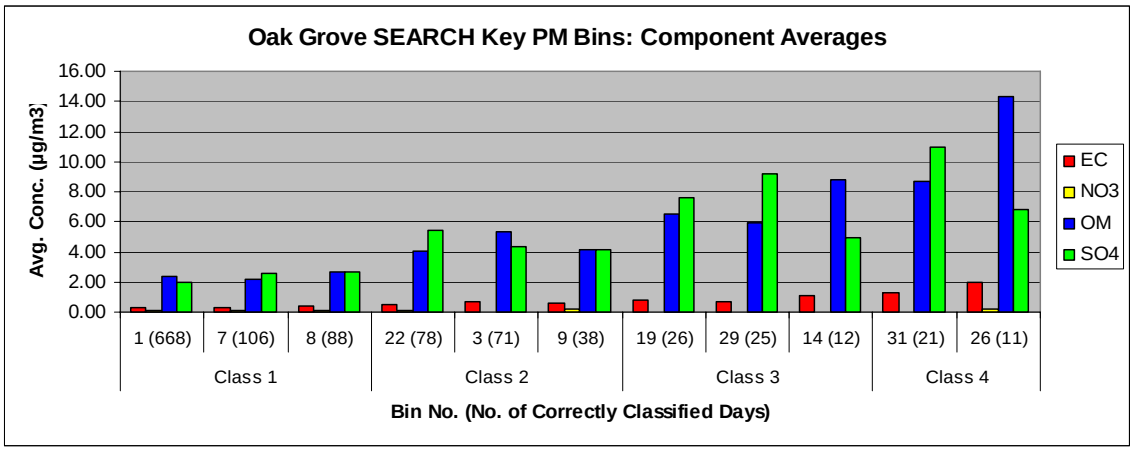


Figure 3-9h. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: SEARCH Site Oak Grove.



The compositional charts for the $PM_{2.5}$ for the SEARCH sites also show a much larger proportional contribution from organics than the IMPROVE charts, especially for the higher $PM_{2.5}$ bins. The relative ranking of the species contributions is similar to that for the STN sites. A comparison of the compositional averages for Birmingham using the STN (Figure 3-8a) and SEARCH (Figure 3-9c) data, shows that the organic matter and overall $PM_{2.5}$ values are higher in the STN data, but that the tendency for organic matter to be the dominant species appears in both sets of results.

The compositional analysis results for Birmingham (Figure 3-9c) also show a higher contribution of elemental carbon than for most other sites, and this may be related to emissions from the steel industry facilities that are located in Birmingham.

For all three of the key Category 4 $PM_{2.5}$ bins for Birmingham (Bins 25, 20, and 24), organic matter is the dominant species. However, the relative proportion of the species concentrations is different for each bin. This may be due to the differences in the average wind directions. All of the key bins are characterized by very low surface wind speeds, but, on average, the days within the bins have different wind directions. Surface winds are northwesterly for Bin 24, northeasterly for Bin 20, and southerly for Bin 24. We noted earlier that Bin 25 (Category 4) is very similar to Bin 10 (Category 3), in terms of the average parameter values, with the exception of the prior-day PM concentration for Birmingham. The two bins have similar species distributions, and the higher values for Bin 24 are due to slight increases in sulfate and organic matter and a greater increase in elemental carbon.

4. Meteorological Representativeness and Episode Selection Exercises

The CART results and a meteorological characterization and episode selection tool, based on these results, were used to provide information related to the representativeness of the model year 2002 and the periods selected by VISTAS for model performance evaluation and preliminary sensitivity testing, relative to the five-year regional haze baseline period. The CART results and tool were also used in selecting subset periods of 2002 for $PM_{2.5}$ modeling and sensitivity analysis, and in the calculation of weighting factors related to regional haze and $PM_{2.5}$ for the modeled days. These exercises are described in this section. A comparison of the results for Birmingham using the STN and SEARCH datasets is provided in the appendix.

4.1. Meteorological Characterization and Episode Selection Tool

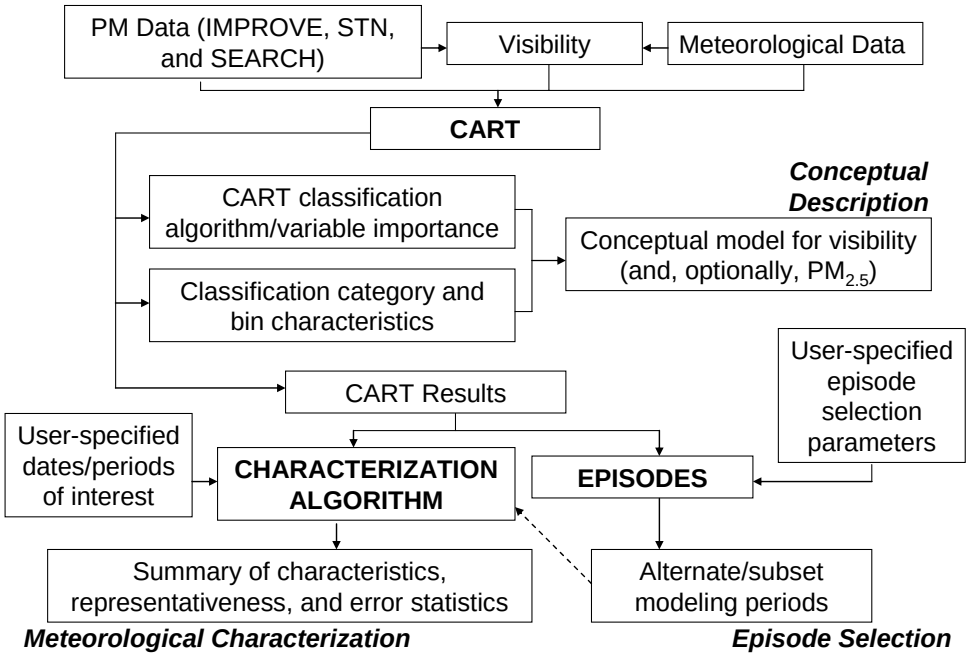
In this study, the CART results served as the basis for developing a tool capable of addressing questions regarding the representativeness of selected episodic and annual simulation periods as well as the selection of discrete multi-day periods for refined modeling or control-strategy evaluation. The CART results (groupings of days with similar characteristics) were coupled with characterization and episode selection algorithms in order to provide this information. The VISTAS meteorological characterization tool is available in electronic format.

For any input set of days, the characterization algorithm assesses and summarizes the range, type, and frequency of sampling of the CART bins; the degree to which key characteristics (CART bins) are represented; mean values for all parameters, including chemical speciation; representation of the days comprising the regional metrics, and ability to represent the regional haze metrics or $PM_{2.5}$ annual average or design values (estimated using error statistics) for one or more sites selected by the user. A summary of the meteorological parameters for the selected days is also optionally provided, together with an assessment of whether or not the conditions are typical of the full analysis period.

The episode selection algorithm, based on the EPISODES program that we originally developed for SAMI, identifies episodes characterized by typical (frequently occurring) meteorological conditions and representative of the multi-year visibility and $PM_{2.5}$ metrics. The selection of days is guided by user-input episode selection criteria pertaining to the number of days, contiguousness and length of episode periods, and error tolerance in representing the regional haze metrics. The days identified by the episode selection algorithm can then be summarized using the characterization algorithm.

Figure 4-1 diagrams the VISTAS meteorological characterization and episode selection tool.

Figure 4-1. Schematic Diagram of the VISTAS Meteorological Characterization and Episode Selection Tool.



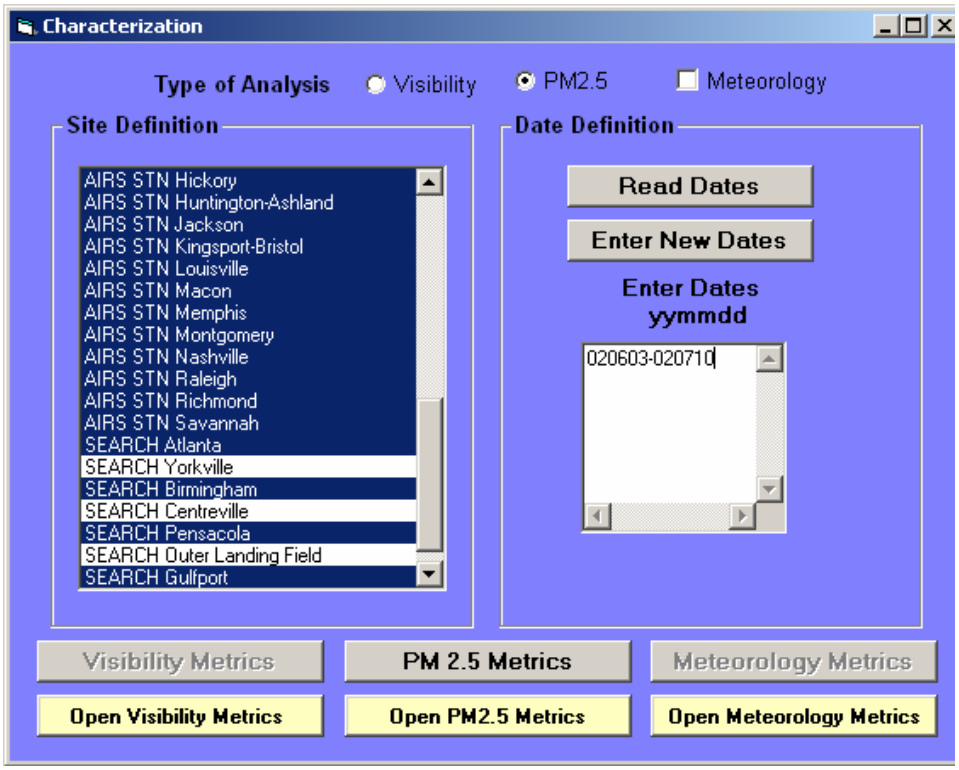
Together the CART results and the meteorological characterization and episode selection tool were used to provide information related to the representativeness of the model year 2002 and the periods selected by VISTAS for model performance evaluation and preliminary sensitivity testing.

4.1.1. Meteorological Characterization Component

In the characterization mode, the user inputs a date or series of dates and the tool provides information about those dates.

The user must select the type of analysis (visibility or $PM_{2.5}$) by selecting the appropriate button. He/she may also select the meteorology option by checking that box. He/she must also select the desired site(s) and either enter the dates manually or read them in from an external file by clicking on the "Read Dates" button. The tool will accept any dates included in the analysis period, which currently includes the years 2000-2004. The dates must be in *yymmdd* format. The initial input screen for an example application for $PM_{2.5}$ for the STN sites and the Atlanta, Birmingham, Gulfport, and Pensacola SEARCH sites for 3 June – 10 July 2002 is displayed in Figure 4-2.

Figure 4-2. Initial Input Screen for the Characterization Portion of the VISTAS Meteorological Characterization Tool: Example for PM2.5 for all STN Sites Plus the Atlanta, Birmingham, Gulfport, and Pensacola SEARCH Sites, for 6/3/02-7/10/02.



Once the dates are entered, the user must select from among the *Visibility Metrics*, *PM2.5 Metrics*, or *Meteorological Metrics* buttons to obtain the results. For both visibility and PM, key metrics summarize how well the days represent:

- Frequently occurring meteorological conditions, as identified by CART
  - Number and type of key[1] bins represented.
  - Percent of key bins represented within each classification category.
  - Distribution of days within the key bins, relative to the full analysis period.
  - Distribution of days within all bins, relative to the full analysis period.

For visibility, the output also includes the following regional haze metrics, where the 20 percent worst and best days are defined, respectively, as the 20 percent haziest and 20 percent clearest days in the 2000-2004 baseline period:

- Mean extinction coefficient, calculated using a CART-based frequency weighting of the days. The average is calculated in this manner so that it can be compared with annual mean

[1] Key bins for each category are those containing the greatest number of correctly classified days. Approximately three key bins were selected for each classification category for each site.

extinction coefficient values and to determine whether the extinction coefficients for the selected subset of days are representative of a selected or typical annual period.

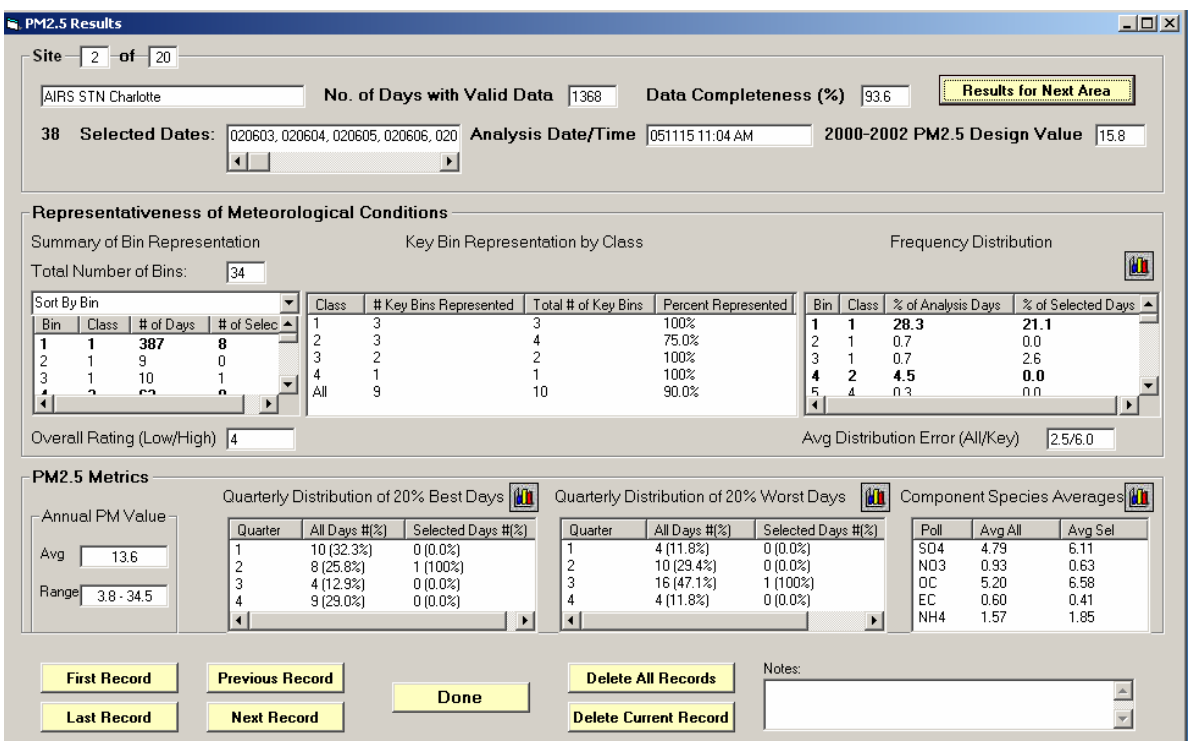
- Range of extinction coefficient.
- Quarterly distribution relative to the 20 percent best and worst days.
- Dates of the selected days that are also among the 20 percent best and worst days.
- Chemical composition and ranking of contributors to extinction coefficient and $PM_{2.5}$.

For PM, the output also includes the following $PM_{2.5}$ metrics:

- $PM_{2.5}$ design value
- Range of $PM_{2.5}$ concentrations.
- Annual average $PM_{2.5}$ concentration, calculated using a CART-based frequency weighting of the days. The average is calculated in this manner so that it can be compared with annual average concentrations, including those that comprise the design value. The objective is to determine whether the concentrations for the selected subset of days are representative of a selected or typical annual period.
- Quarterly distribution relative to the 20 percent best and worst days.
- Chemical composition and ranking of contributors to $PM_{2.5}$.

An example result for $PM_{2.5}$ is given in Figure 4-3.

Figure 4-3. Example Characterization Result Screen for PM2.5.



For meteorology, the output includes the bin and CART category into which each date falls as well as the maximum temperature, relative humidity, wind speed and direction, and precipitation on that date. It also includes the number and percent of the selected days that have atypical meteorological conditions.

There are also several options for graphical display of the results (these are obtained by clicking on the miniature bar charts next to the metric descriptors).

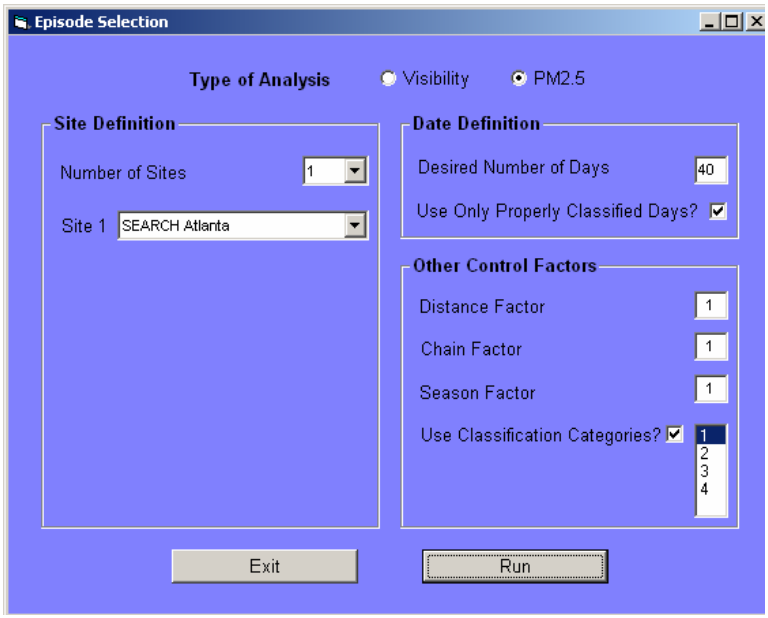
The characterization tool was used during the course of the project to examine the representativeness of the two episode periods selected for air quality model performance evaluation, and to refine the selection of the two episode periods that were used for model sensitivity analysis.

4.1.2. Episode Selection Component

In the episode selection mode, the user specifies criteria for episode selection (such as total number of days, sites to optimize over, relative importance of various control factors, etc.) and the analytic tool provides a list of episode dates. These dates can subsequently be input to the characterization scheme to obtain information about the episodes.

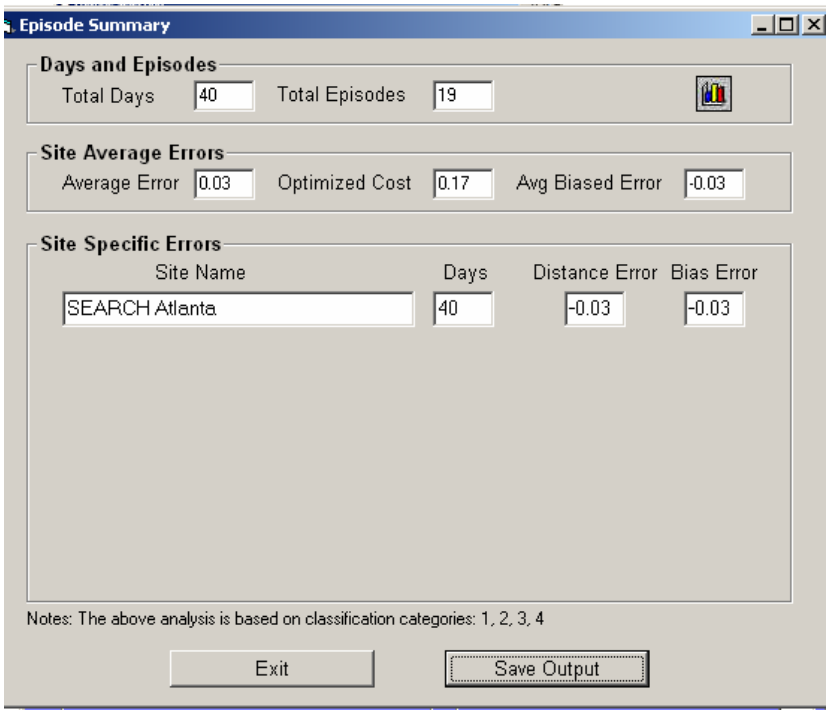
The user must select the type of analysis (visibility or $PM_{2.5}$), by selecting the appropriate button, and select the number (up to 8) and name(s) of the sites from two drop-down menus. He/she may enter the desired number of days (the default is 40), and check a box if he/she wishes to use only properly classified days. The user may also enter values for other control factors, including a distance factor, chain factor, and season factor. The relative values of these factors (and not the absolute values) guide the episode selection and specify the relative importance of 1) representing annual average values of visibility (or $PM_{2.5}$), 2) including consecutive days, and 3) representing all seasons in the episode selection results. The distance factor determines the relative emphasis on selecting days (combined) that represent the weighted annual average value of extinction coefficient or $PM_{2.5}$ (whichever is selected) and thus the key bins. The chain factor determines the degree to which consecutive days are sought. The season factor weights the degree to which the different seasons are represented by the selected dates. Finally, the user may check a box if he/she wishes to consider only days from particular classification categories. If so, he/she then has the opportunity to select those categories from a menu. The initial input screen for an example application for $PM_{2.5}$ for the Atlanta SEARCH site is displayed in Figure 4-4.

Figure 4-4. Initial Input Screen for the Episode Selection Portion of the VISTAS Meteorological Characterization Tool: Example for PM2.5 for Atlanta.



Once the inputs are entered, the *Run* button is selected and the results screen appears. This summarizes the total number of episodes (defined by contiguous days), combined error summary for all selected sites, and site-specific errors. The errors summarize how well the selected episodes represent annual average values. The combined-site errors include an average error (the average difference in extinction coefficient or concentration), optimized cost (a relative measure of how well the distance, chain and season criteria are met), and average biased error (biased or signed error, averaged over all sites). The site-specific errors include the distance error (which quantifies the representation of the annual average value of the parameter, scaled to compensate for bins that are not represented) and the biased error (same as the distance error but not scaled to account for missing bins). By clicking on the *Save Output* button, the user can save and open/view a file containing the episode dates. An example results screen is shown in Figure 4-5.

Figure 4-5. Example Episode Selection Result Screen for PM2.5.



There is also an option for graphical display of the results (obtained by clicking on the miniature bar chart).

The episode selection component of the tool was used to guide the selection of the two episode periods that were used by VISTAS for model sensitivity analysis.

4.2. Analysis of the Representativeness of the 2002 Simulation Period

The CART results and meteorological characterization tool were used to explore several questions related to modeling episode period representativeness. As noted earlier, the key question is: How representative is the year 2002, as selected for VISTAS atmospheric modeling, considering meteorology, fine particulate, and visibility, relative to the full baseline period. The characteristics of the 2000-2004 baseline period and each individual year comprising that period are examined and compared in this section.

4.2.1. IMPROVE Sites

Table 4-1 summarizes and compares 2000-2004, and each individual year within this period for the IMPROVE sites. The summary metrics included in this table are the weighted average extinction coefficient, weighted average $PM_{2.5}$ concentration, range in $PM_{2.5}$ concentration, percentage of key visibility bins represented (considering all classes), the relative distribution of days among the key visibility bins for all categories (distribution error), percentage of key $PM_{2.5}$ bins represented (considering all classes), and the relative distribution of days among the key $PM_{2.5}$ bins for all categories (distribution error). These terms are explained in more detail, in the discussion following Table 4-1.

Table 4-1. Summary of Visibility, $PM_{2.5}$, and Meteorological Characteristics for the 2000-2004 Analysis Period: IMPROVE Sites.

(a) Breton

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	78.5	7.6	1.2 – 21.5	100			
2000	92.5	9.4	4.3 – 17.2	100	1.9	100	2.9
2001	78.3	7.7	2.2 – 20.3	100	1.3	100	1.4
2002	71.2	6.7	1.8 – 16.4	100	1.6	100	0.7
2003	79.5	7.6	1.7 – 19.7	100	0.9	100	0.9
2004	80.5	7.9	1.2 – 21.5	100	1.3	100	1.3

(b) Brigantine

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	95.6	9.7	1.4 – 39.2				
2000	100.2	10.1	1.5 – 27.3	100	0.9	100	0.8
2001	86.1	9.3	2.6 – 30.1	100	1.3	100	2.1
2002	93.6	9.6	1.4 – 36.5	100	0.9	100	1.7
2003	96.7	9.8	1.8 – 39.2	100	1.7	100	1.1
2004	92.5	9.6	3.0 – 28.6	100	1.3	100	1.6

(c) Cadiz

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	107.4	11.0	0.6 – 31.3				
2000	NA	NA	NA	NA	NA	NA	NA
2001	100.4	10.9	0.6 – 27.1	100	1.7	100	1.6
2002	107.4	11.1	4.1 – 30.2	100	1.1	100	1.0
2003	111.4	11.1	3.0 – 31.1	100	1.3	100	0.5
2004	105.3	11.1	2.2 – 26.5	100	1.1	100	1.5

(d) Caney Creek

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	83.0	9.0	0.3 – 28.3				
2000	85.8	9.0	0.3 – 22.4	100	1.6	100	1.7
2001	79.1	9.3	0.9 – 21.6	100	1.0	100	1.4
2002	92.1	8.9	0.5 – 28.3	100	0.9	100	1.0
2003	87.5	8.8	1.5 – 25.1	100	1.0	100	1.2
2004	80.9	8.6	0.4 – 19.0	100	1.2	100	1.3

(e) Cape Romain

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	82.0	8.6	1.1 – 30.1				
2000	90.5	9.4	2.7 – 24.9	100	1.2	100	2.2
2001	77.2	8.6	2.0 – 21.9	100	0.5	100	1.0
2002	79.8	8.0	1.1 – 22.6	100	1.3	100	1.1
2003	74.0	8.0	1.5 – 18.5	100	1.0	100	1.1
2004	88.7	8.7	1.3 – 30.1	100	0.8	100	1.1

(f) Chassahowitzka

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	89.5	8.7	2.1 – 24.7				
2000	96.2	8.8	3.3 – 24.7	100	1.7	100	1.9
2001	88.9	8.8	2.1 – 20.7	100	0.7	100	0.6
2002	86.5	8.2	2.5 – 17.7	100	1.1	100	1.6
2003	69.6	7.8	3.4 – 13.4	100	1.7	100	2.2
2004	NA	NA	NA	NA	NA	NA	NA

(g) Cohutta

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	95.6	10.7	1.2 – 44.4				
2000	128.2	12.8	3.9 – 32.7	100	1.7	100	1.4
2001	87.3	9.8	1.8 – 29.6	100	1.0	100	1.0
2002	95.4	10.6	2.2 – 44.4	100	1.2	100	1.3
2003	92.9	10.4	1.2 – 34.3	100	1.2	100	1.5
2004	98.4	10.1	1.9 – 32.4	100	1.5	100	1.3

(h) Dolly Sods

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	86.0	9.4	0.4 – 37.2				
2000	89.3	10.4	1.3 – 26.1	100	1.1	100	1.7
2001	82.0	8.9	2.0 – 35.7	100	0.7	100	1.5
2002	79.1	8.7	1.3 – 37.2	100	1.0	100	0.9
2003	91.5	9.8	0.4 – 29.8	100	1.0	100	1.3
2004	80.8	9.9	0.9 – 31.2	100	1.5	100	1.3

(i) Everglades

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	63.4	6.5	1.1 – 34.4				
2000	70.5	6.2	1.1 – 24.9	100	2.3	100	2.5
2001	63.1	6.0	1.8 – 17.5	100	1.1	100	1.3
2002	61.8	6.3	1.4 – 23.4	100	1.0	100	1.3
2003	67.6	7.2	1.7 – 24.1	100	1.3	100	1.3
2004	62.0	6.6	2.1 – 34.4	100	1.5	100	1.1

(j) Great Smoky Mountains

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	85.7	10.1	0.5 – 35.6				
2000	92.3	10.5	2.3 – 35.6	100	1.8	100	1.7
2001	82.2	9.8	1.8 – 29.9	100	1.0	100	1.3
2002	78.6	9.8	1.7 – 27.9	100	1.1	100	0.7
2003	86.7	9.9	0.5 – 32.1	100	1.1	100	1.5
2004	86.0	10.3	1.5 – 23.9	100	1.1	100	1.2

(k) James River Face

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	102.1	10.9	0.5 – 31.5				
2000	128.5	12.9	4.5 – 26.9	100	1.3	100	1.4
2001	97.1	10.1	2.8 – 28.9	100	1.4	100	0.9
2002	101.0	11.7	3.5 – 31.5	100	1.3	100	1.1
2003	99.6	10.3	0.5 – 29.2	100	1.3	100	1.4
2004	94	10.0	2.4 – 25.9	100	1.0	100	1.0

(l) Linville Gorge

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	80	8.9	0.3 – 29.2				
2000	94.2	10.4	1.3 – 29.2	100	1.5	100	1.7
2001	78.1	8.3	15 – 23.8	100	1.1	100	0.9
2002	72.4	8.8	1.6 – 27.1	92.3	1.7	100	1.0
2003	78.8	8.3	0.3 – 27.6	100	1.5	100	1.1
2004	77.0	8.6	1.5 – 21.6	100	1.0	100	0.9

(m) Mammoth Cave

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	110.0	11.7	2.0 – 44.6				
2000	116.5	12.7	4.0 – 44.6	100	1.6	100	2.1
2001	105.7	11.3	2.0 – 28.4	100	1.7	100	1.3
2002	104.1	11.5	3.8 – 34.0	100	0.8	100	1.4
2003	106.2	11.5	3.9 – 32.4	100	1.1	100	1.1
2004	109.5	11.5	2.5 – 27.6	100	1.5	100	2.0

(n) Mingo

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	94.7	11.5	2.4 – 50.0				
2000	101.5	12.9	2.6 – 34.5	100	1.8	100	1.2
2001	90.4	11.3	2.4 – 50.0	100	1.1	100	1.2
2002	80.9	9.1	3.1 – 15.4	100	1.2	100	2.4
2003	NA	NA	NA	NA	NA	NA	NA
2004	NA	NA	NA	NA	NA	NA	NA

(o) Okefenokee

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	86.7	9.1	2.2 – 42.9				
2000	94.3	9.5	3.5 – 24.8	100	1.5	100	1.9
2001	85.3	9.5	3.0 – 24.9	100	1.3	100	1.1
2002	88.9	9.5	2.9 – 30.1	100	1.0	100	0.7
2003	81.5	8.5	2.2 – 20.4	100	1.0	80	1.2
2004	85.4	9.0	2.8 – 42.9	100	1.2	100	0.9

(p) Shenandoah

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	95.2	9.3	0.1 – 33.9				
2000	96.9	9.3	0.7 – 22.7	100	1.6	100	0.9
2001	99.4	9.5	1.7 – 33.9	100	1.1	100	1.0
2002	99.0	9.6	0.8 – 29.8	100	2.2	100	1.8
2003	95.0	9.3	0.1 – 29.3	100	1.2	100	1.3
2004	89.9	8.7	0.5 – 26.1	100	1.6	100	0.4

(q) Shining Rock

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	75.1	7.8	0.2 – 57.6				
2000	85.4	8.3	1.6 – 57.6	100	1.3	100	0.9
2001	74.5	7.8	1.1 – 24.1	100	1.1	100	0.9
2002	65.0	8.1	0.4 – 23.2	100	1.3	100	1.2
2003	84.2	8.4	0.2 – 34.8	100	1.6	100	1.4
2004	65.3	7.0	0.9 – 17.8	100	1.1	100	0.9

(r) Sipsey

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	100.8	11.1	1.6 – 36.3				
2000	104.9	11.6	3.9 – 36.3	100	2.0	100	3.1
2001	100.8	10.7	1.6 – 23.0	100	1.1	100	1.5
2002	95.9	10.8	4.4 – 29.0	100	1.2	100	1.2
2003	104.1	11.7	4.0 – 28.6	100	1.0	100	1.0
2004	95.6	10.8	31 – 26.0	100	1.2	100	1.7

(s) St. Marks

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	77.9	8.5	1.5 – 31.9				
2000	88.5	9.0	3.4 – 20.1	100	1.5	100	1.9
2001	78.9	8.2	2.0 – 18.4	100	0.9	100	1.0
2002	79.2	8.1	2.3 – 21.4	100	1.0	100	1.7
2003	81.1	8.3	1.5 – 23.8	91.7	1.0	100	1.9
2004	73.9	9.4	2.8 – 31.9	100	1.4	100	1.3

(t) Swanquarter

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	81.8	7.9	0.6 – 27.0				
2000	89.7	8.3	2.2 – 17.6	100	0.6	100	2.4
2001	79.0	7.7	1.8 – 24.9	100	1.3	100	1.9
2002	79.3	8.1	1.8 – 22.2	100	1.3	100	1.9
2003	78.8	7.1	0.6 – 27.0	100	1.1	100	0.9
2004	NA	NA	NA	NA	NA	NA	NA

(u) Upper Buffalo

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	73.4	8.6	0.1 – 30.0				
2000	81.0	9.3	1.1 – 30.0	100	1.1	100	1.4
2001	64.8	7.9	0.7 – 20.7	100	0.8	100	1.4
2002	79.2	9.2	1.7 – 27.1	100	1.0	100	1.6
2003	77.8	9.1	0.1 – 25.1	100	1.7	100	1.5
2004	67.0	8.6	0.7 – 23.5	100	1.3	100	1.3

The weighted average is the average of the daily values that are weighted according to the frequency of occurrence of similar conditions for the full period. The weights are based on the CART results, and frequency of occurrence of conditions is based on the number of days in

each CART bin. Days that have conditions that occur more frequently are given greater weights, while those that occur less frequently are given lesser weights. In this manner, the frequency of occurrence of meteorological conditions is normalized for each year and the average extinction coefficient and $PM_{2.5}$ values are more likely to reflect other factors such as emissions. Unusually high or low concentrations/extinction for a certain type of conditions (severity) will also affect the average. For many of the sites, the highest extinction and $PM_{2.5}$ values occur in 2000. Otherwise the values are fairly similar for all years. The range in $PM_{2.5}$, which is not normalized for meteorology, is also similar for each of the five years.

For all sites, the key bins for both visibility and $PM_{2.5}$ are represented for all of the years, although there are a few exceptions. This is expected since we are considering full year periods, each of which represents one fifth of the multi-year period that is used to determine the key bins. As we will see later in this report, this metric is more informative when we consider shorter, episodic periods.

The distribution error ranges quantifies how well the frequency distribution of days among the bins matches that for the full baseline period. It has the units of percent since it is the average difference of two percentage values. For all sites, this value ranges from approximately 0.5 to 3 percent. A smaller error indicates a better match. Considering this metric, 2002 does not stand out as being significantly more or less representative than the other years that comprise the baseline period. No one year stands out as being most typical of the period for a majority of the sites. The distribution error over all key visibility bins is lowest for 2002 for Brigantine, Cadiz, Caney Creek, Everglades, Mammoth Cave, and Okefenokee. The results vary by site.

For example, for Cape Romain (Table 4-1e), the weighted extinction and $PM_{2.5}$ values for 2002 are lower than on average for the full baseline period. The range in $PM_{2.5}$ is typical of the other baseline years. The distribution error for visibility is slightly larger than for the other years in the period, and that for $PM_{2.5}$ is about the same as the other years (except for 2000, which is quite a bit higher).

For the GSM site (Table 4-1j), the weighted average extinction coefficient for 2002 is lower than on average for the full baseline period, but the average $PM_{2.5}$ value is typical of the period. The range in $PM_{2.5}$ is also typical of the other baseline years. The distribution error for visibility is about the same as the other years (except for 2000, which is quite a bit higher), that for $PM_{2.5}$ is the lowest among the five years.

For Mammoth Cave (Table 4-1m), the weighted extinction and $PM_{2.5}$ values for 2002 are representative of the full baseline period, but slightly below the average values for the full period. The year 2000 has some high values, which tend to increase the five-period average. The range in $PM_{2.5}$ is typical of the other baseline years, with the exception of 2000. The distribution error for visibility is the lowest among all of the years, while that for PM is in the middle.

Considering the entire VISTAS region, it is not expected that any single year will be typical or representative for all areas of the Class I areas of interest. The year 2000 seems to be the least representative year, and 2002 is as good as or better than most of the others for most sites. Knowing how well the 2002 simulation period represents each area may aid the analysis and interpretation of the VISTAS air quality modeling results.

4.2.2. STN Sites

Table 4-2 summarizes and compares 2000-2004, and each individual year within this period for the STN sites. The summary metrics included in this table are the weighted average $PM_{2.5}$

concentration, range in $PM_{2.5}$ concentration, percentage of key $PM_{2.5}$ bins represented (considering all classes), and the relative distribution of days among the key $PM_{2.5}$ bins for all categories (distribution error).

Table 4-2. Summary of $PM_{2.5}$ and Meteorological Characteristics for the 2000-2004 Analysis Period: STN Sites.

(a) Birmingham

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	18.8	0.4 - 71.3		
2000	20.1	0.4 - 71.3	100	2.7
2001	18.4	1.0 - 51.5	100	0.8
2002	17.8	4.2 - 47.8	100	1.1
2003	18.0	2.9 - 46.4	90	1.4
2004	18.4	3.6 – 53.3	80	1.6

(b) Charlotte

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.7	2.3 – 45.2		
2000	15.4	2.9 – 43.5	100	1.8
2001	14.5	3.8 – 40.3	100	0.9
2002	14.4	3.2 – 45.2	100	1.6
2003	14.2	2.3 – 40.4	90	1.4
2004	14.6	2.6 – 39.8	100	1.3

(c) Chattanooga

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	15.6	2.5 – 48.6		
2000	16.0	4.8 – 48.6	100	2.3
2001	15.8	2.5 – 47.5	100	1.6
2002	14.5	4.2 – 31.3	100	1.1
2003	15.4	3.0 – 41.4	90	1.6
2004	14.8	3.1 – 31.3	100	1.1

(d) Greenville-Spartanburg

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.8	0.5 – 51.5		
2000	15.5	3.5 – 51.5	100	1.7
2001	14.8	2.4 – 40.7	92.3	0.8
2002	14.9	1.5 – 49.8	100	1.2
2003	14.6	0.5 – 40.1	100	0.9
2004	14.5	3.1 – 38.0	100	0.7

(e) Hickory

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	15.8	2.6 – 40.7		
2000	16.7	4.7 – 38.0	100	1.1
2001	15.6	3.8 – 40.0	100	0.9
2002	15.5	4.5 – 40.7	100	0.9
2003	16.1	2.6 – 39.8	100	1.2
2004	15.7	3.2 – 37.4	100	1.0

(f) Huntington-Ashland

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.7	0.6 – 54.5		
2000	15.7	0.6 – 37.2	100	1.8
2001	14.1	3.1 – 54.5	100	1.3
2002	14.9	3.0 – 46.8	100	1.0
2003	15.5	5.2 – 37.7	100	1.1
2004	13.2	3.2 – 30.7	100	0.8

(g) Jackson

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	13.7	1.8 – 45.3		
2000	14.0	3.2 – 41.4	100	1.1
2001	13.3	1.8 – 40.3	100	1.5
2002	13.0	1.8 – 45.3	100	2.0
2003	13.5	4.5 – 31.5	100	0.7
2004	13.6	2.3 – 33.6	100	2.0

(h) Kingsport-Bristol

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.8	1.9 – 49.2		
2000	15.8	4.3 – 43.0	100	1.8
2001	14.6	3.2 – 45.7	100	1.4
2002	14.0	2.6 – 37.5	100	0.8
2003	14.3	1.9 – 49.2	100	1.5
2004	14.2	3.8 – 37.7	100	1.5

(i) Louisville

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	17.1	3.3 – 100.6		
2000	17.4	3.5 – 54.7	100	1.5
2001	17.3	3.5 – 53.2	100	0.9
2002	17.7	4.1 – 100.6	100	1.0
2003	16.4	3.5 – 55.7	91.7	0.9
2004	15.9	3.3 – 45.8	75	1.2

(j) Macon

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	16.1	1.6 – 56.2		
2000	16.8	3.8 – 56.2	100	2.1
2001	15.9	1.6 – 39.7	100	1.4
2002	15.2	4.3 – 41.0	100	1.2
2003	15.2	3.5 – 36.3	100	1.6
2004	16.2	4.0 – 43.8	100	1.7

(k) Memphis

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.2	1.1 – 50.0		
2000	15.2	1.1 – 50.0	100	1.6
2001	13.8	2.7 – 41.3	100	0.9
2002	13.8	3.6 – 49.4	91.7	0.8
2003	14.0	3.2 – 38.0	100	0.7
2004	13.8	3.1 – 38.2	91.7	1.6

(l) Montgomery

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.7	0.4 – 52.1		
2000	16.1	0.4 – 52.1	100	2.4
2001	13.7	0.6 – 38.8	100	1.4
2002	14.9	3.5 – 39.4	100	0.7
2003	14.2	5.1 – 42.8	90	1.3
2004	14.4	5.3 – 45.0	100	1.8

(m) Nashville

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.9	0.2 – 42.3		
2000	15.6	0.5 – 42.3	100	2.0
2001	14.8	0.2 – 38.2	90.9	0.8
2002	14.6	2.6 – 39.8	100	1.1
2003	14.9	4.2 – 42.3	100	0.7
2004	13.8	2.2 – 36.6	100	1.4

(n) Raleigh

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.1	2.3 – 52.8		
2000	15.0	3.0 – 52.8	100	1.4
2001	13.9	3.7 – 48.7	91.7	1.0
2002	13.3	2.3 – 43.8	91.7	1.6
2003	14.2	2.8 – 45.3	100	0.9
2004	13.5	2.8 – 41.7	100	1.1

(o) Richmond

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.2	0.0 – 50.5		
2000	14.9	2.2 – 38.9	100	1.0
2001	14.3	2.0 – 49.1	100	0.5
2002	13.0	1.2 – 50.5	100	1.0
2003	14.0	2.8 – 43.5	100	1.1
2004	13.5	0.0 – 38.2	92.3	0.7

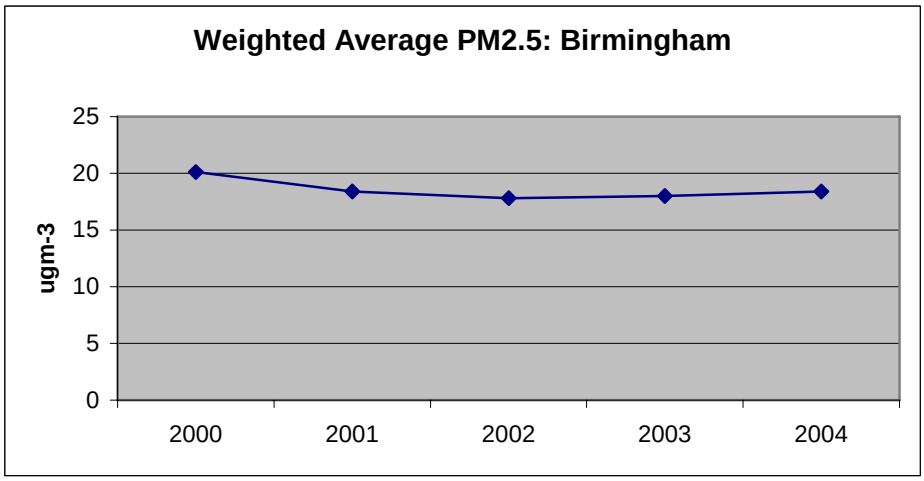
(p) Savannah

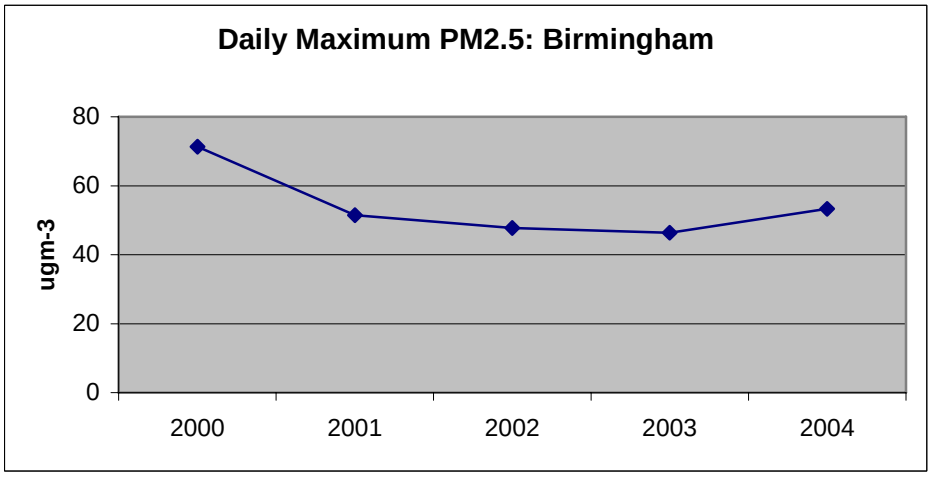
Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.0	3.2 – 55.3		
2000	14.7	4.7 – 44.5	100	2.3
2001	14.9	3.2 – 55.3	100	1.4
2002	12.8	3.9 – 30.1	100	1.5
2003	13.5	4.1 – 49.6	88.9	0.6
2004	13.4	4.7 – 40.2	100	2.1

The weighted average $PM_{2.5}$ values tend to be highest for 2000. Otherwise the values are fairly similar for all years, with some variations. The range in $PM_{2.5}$, which is not normalized for meteorology, is also similar for each of the five years. Figure 4-6 shows the year by year tendencies in weighted average $PM_{2.5}$ and daily maximum 24-hour average $PM_{2.5}$, for each of the STN sites. For most sites, there is no apparent trend, especially for the meteorologically adjusted (weighted average) values. This indicates that $PM_{2.5}$ concentrations in the urban areas have neither increased nor decreased during the five-year period.

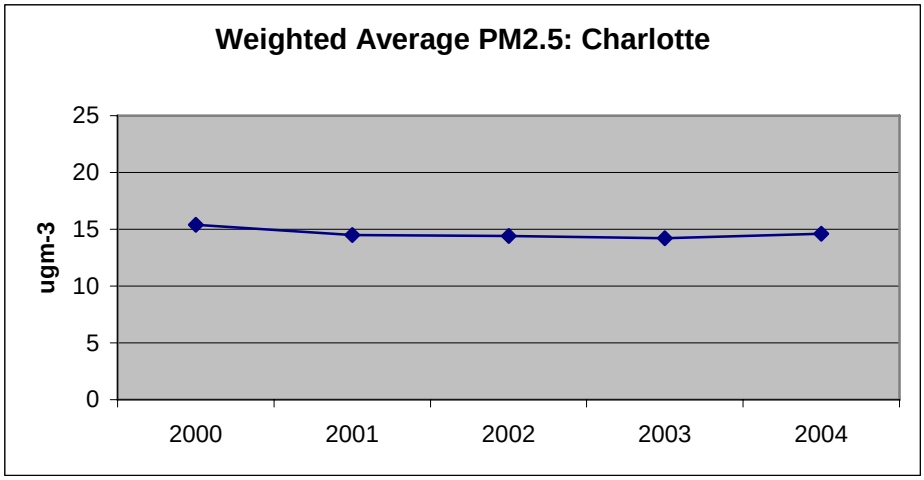
Figure 4-6. Year-by-Year Tendencies in Weighted Average $PM_{2.5}$ and Daily Maximum 24-hour Average $PM_{2.5}$

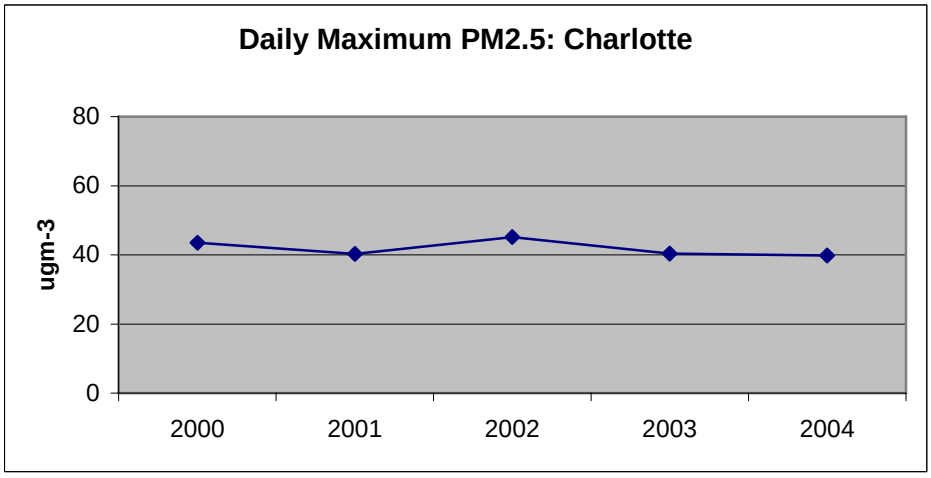
(a) Birmingham



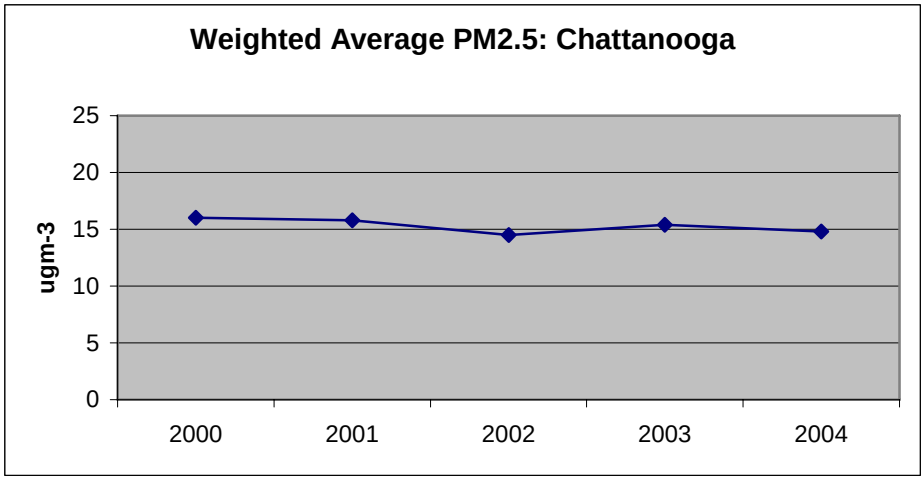


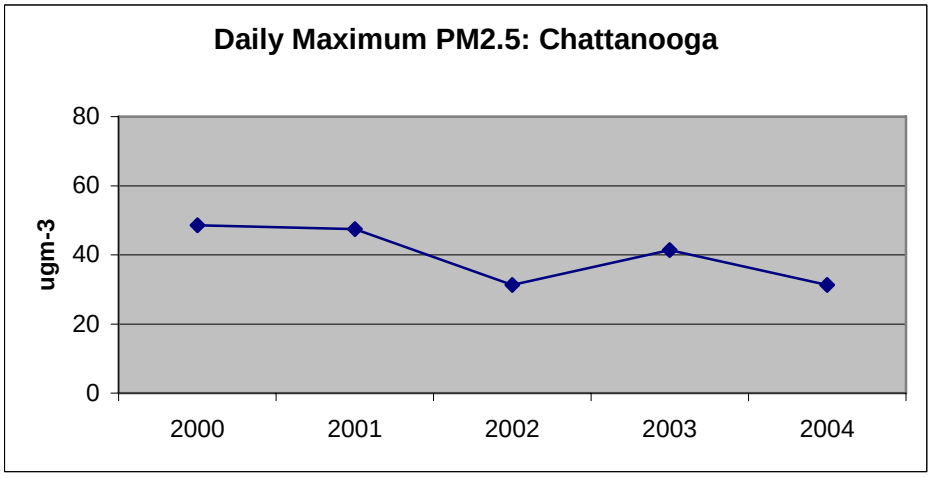
(b) Charlotte


Weighted Average PM2.5: Charlotte
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

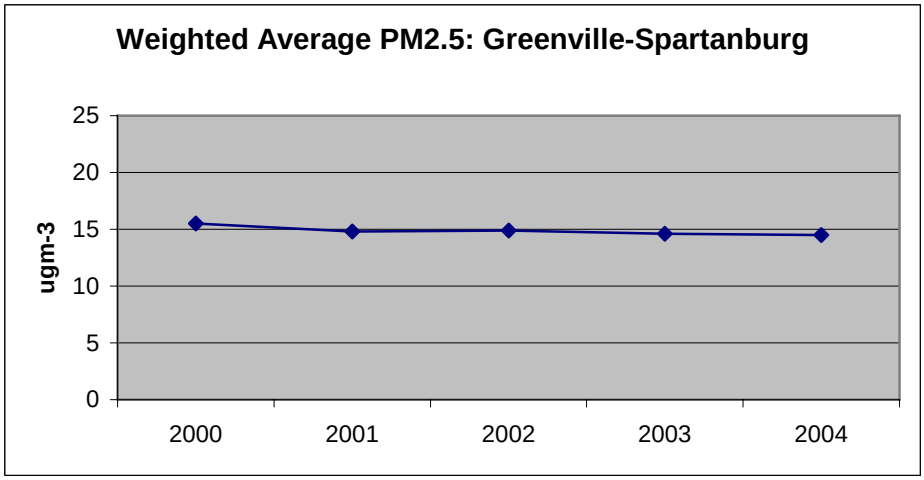

Daily Maximum PM2.5: Charlotte
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

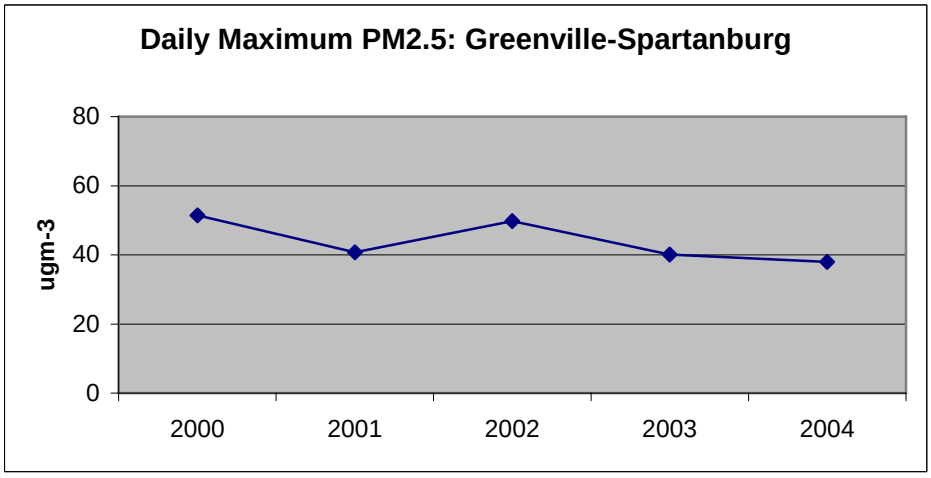
(c) Chattanooga



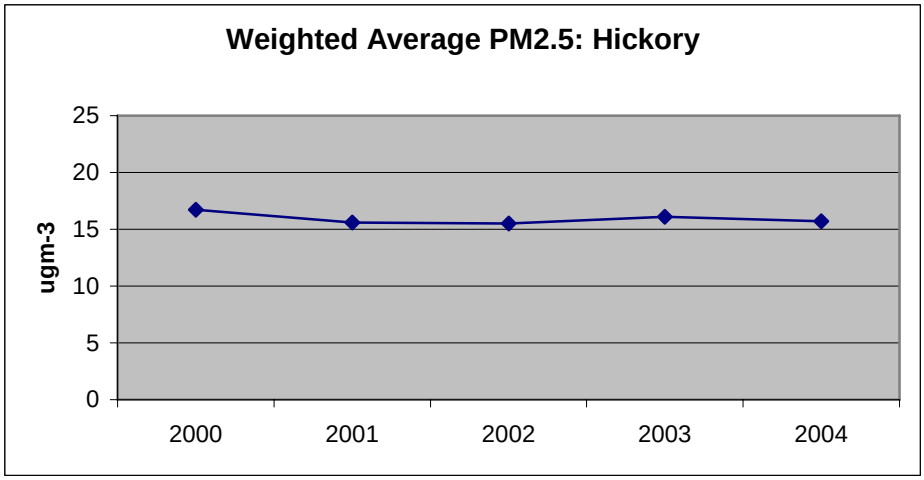


(d) Greenville-Spartanburg





(e) Hickory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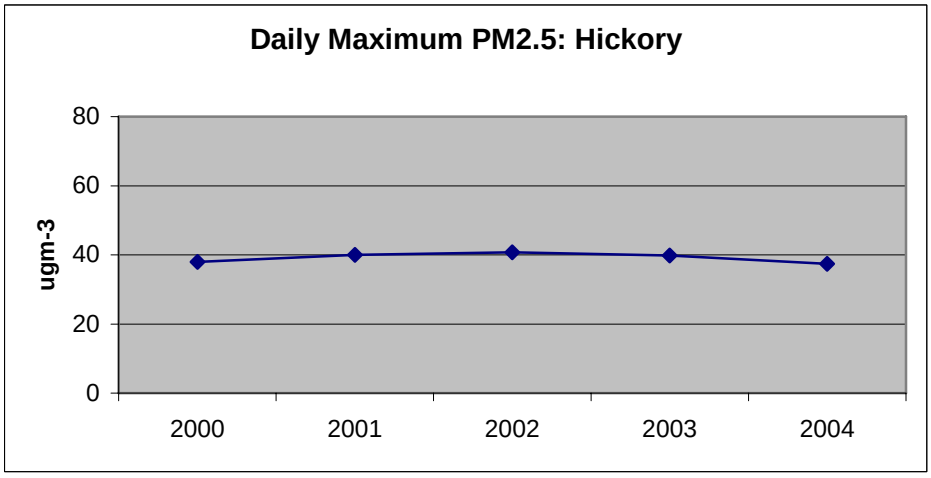
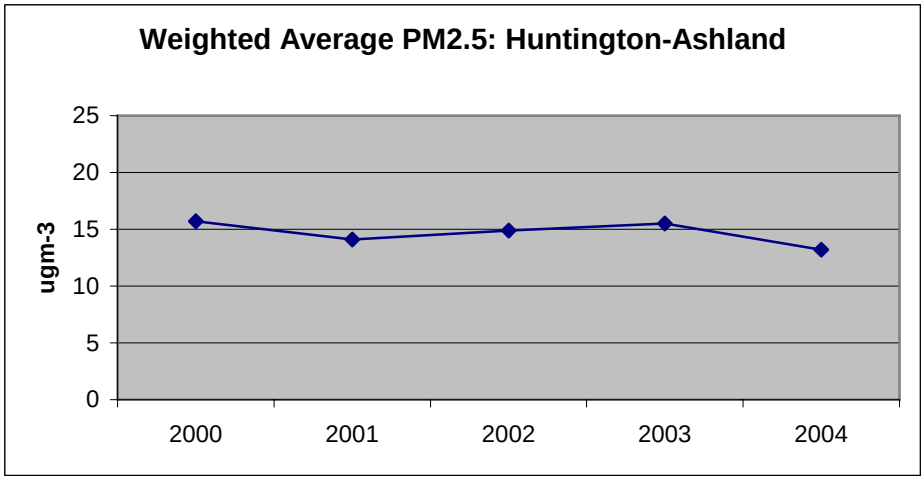
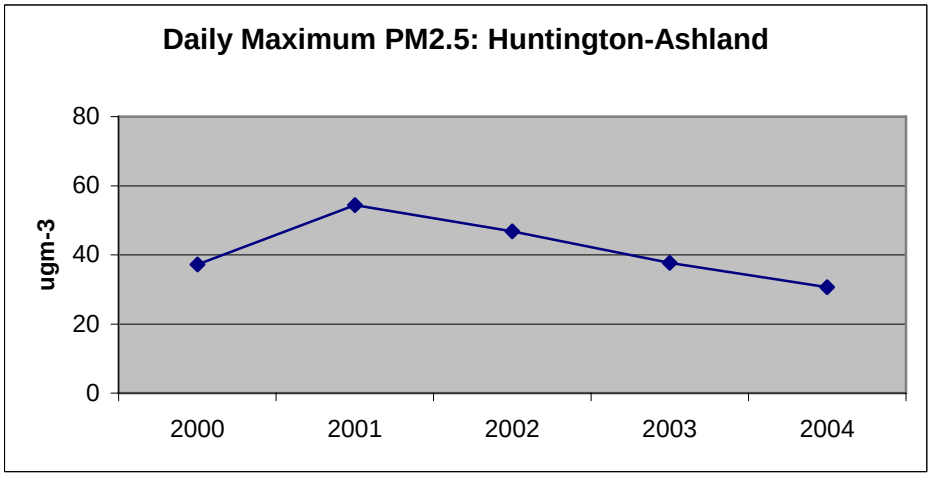
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

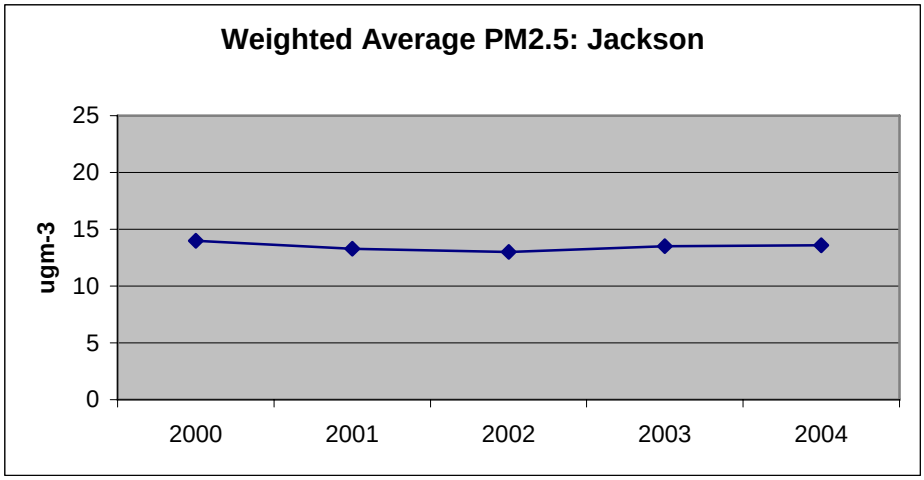

Daily Maximum PM2.5: Hickory
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

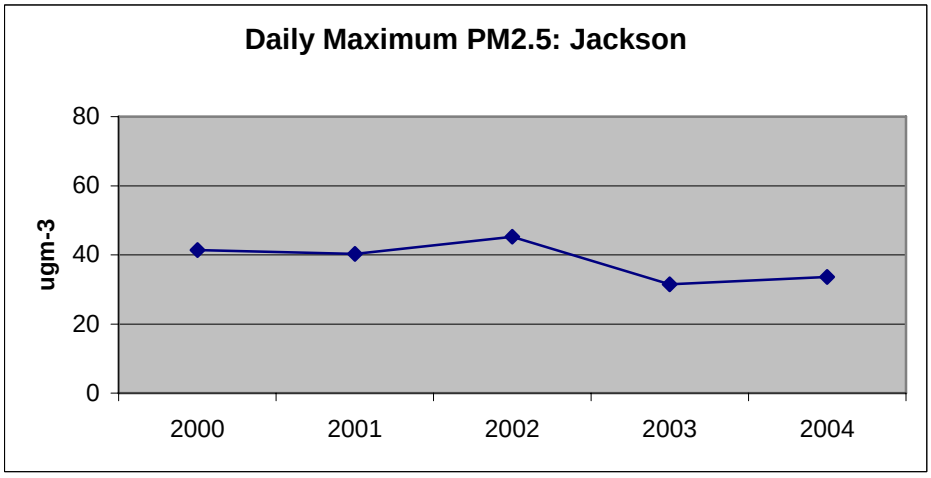
(f) Huntington-Ashland



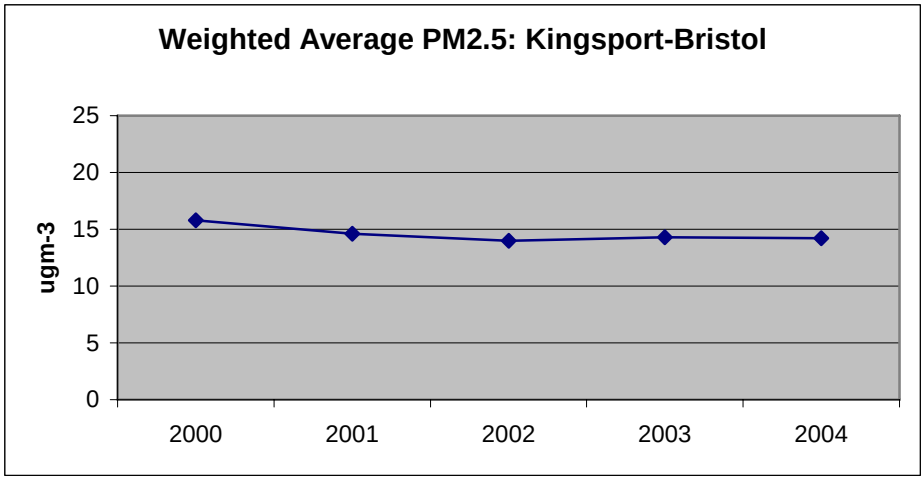


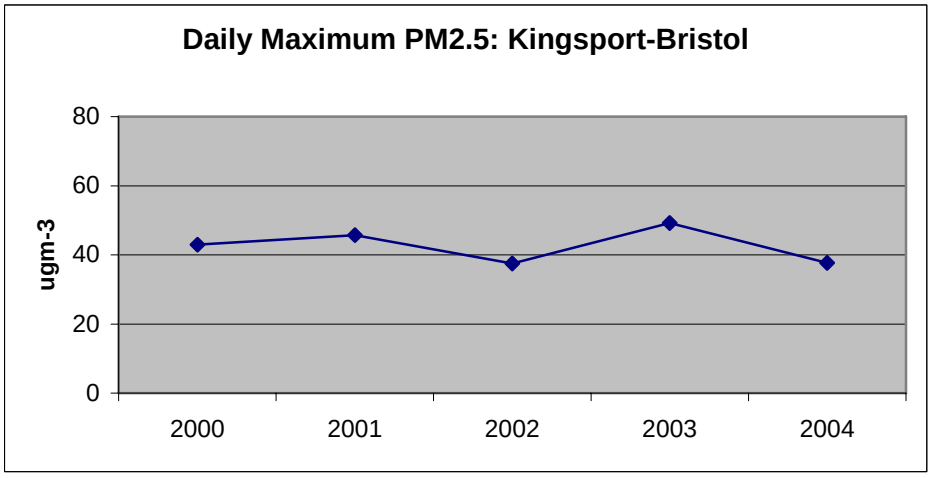
(g) Jackson


Weighted Average PM2.5: Jackson
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

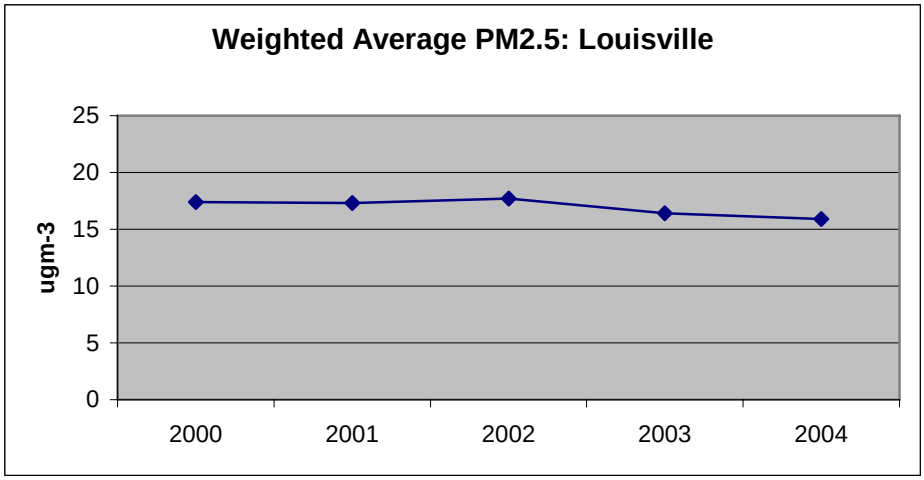

Daily Maximum PM2.5: Jackson
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

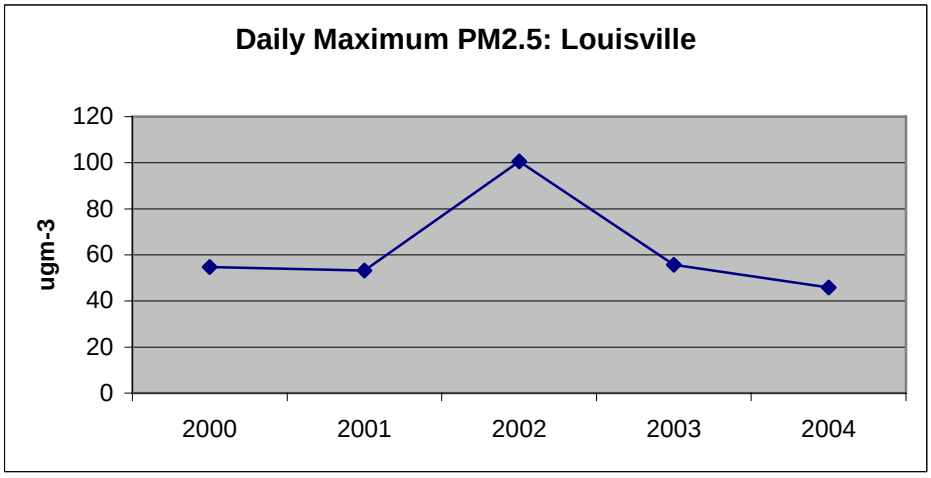
(h) Kingsport


Weighted Average PM2.5: Kingsport-Bristol
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

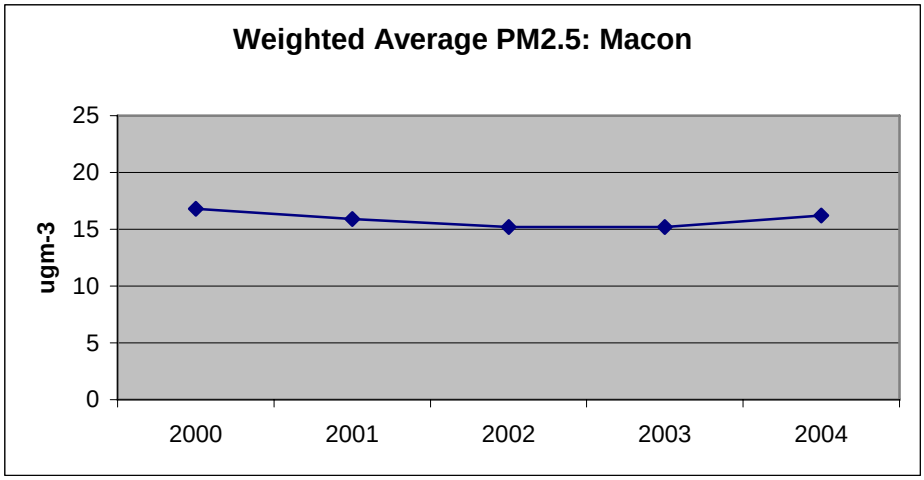

Daily Maximum PM2.5: Kingsport-Bristol
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

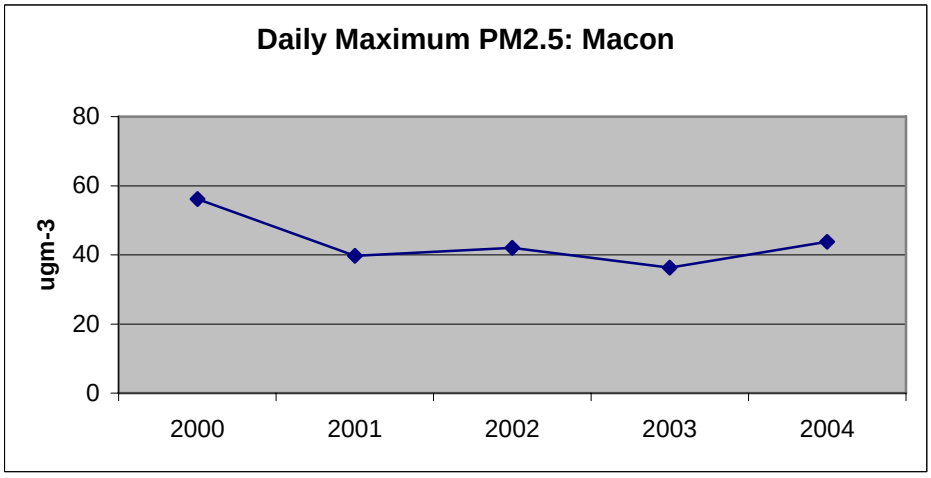
(i) Louisville



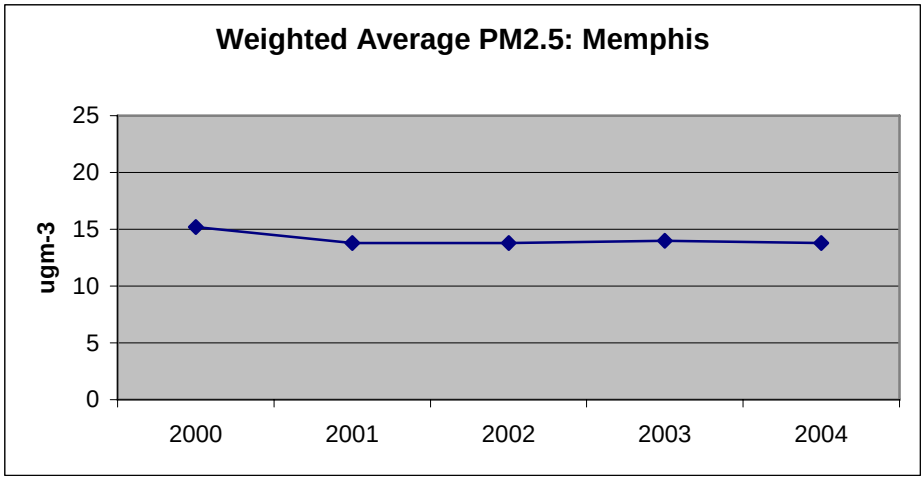


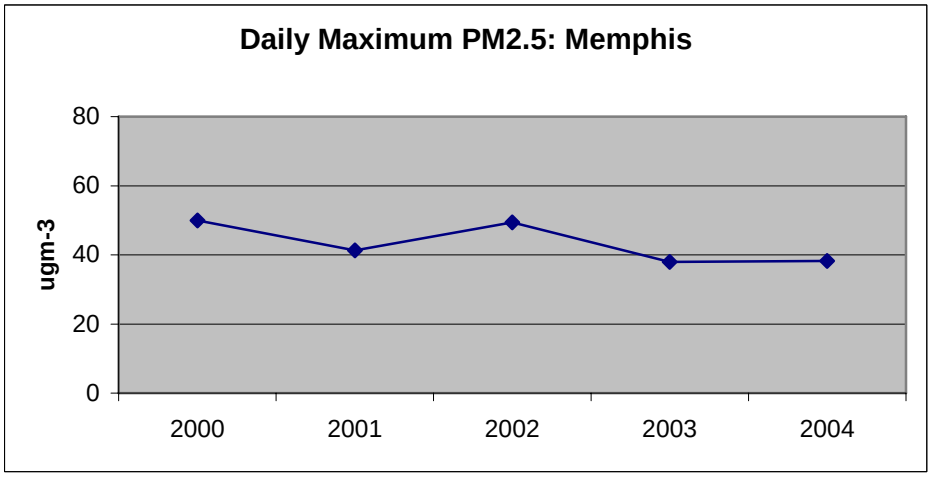
(j) Macon


Weighted Average PM2.5: Macon
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

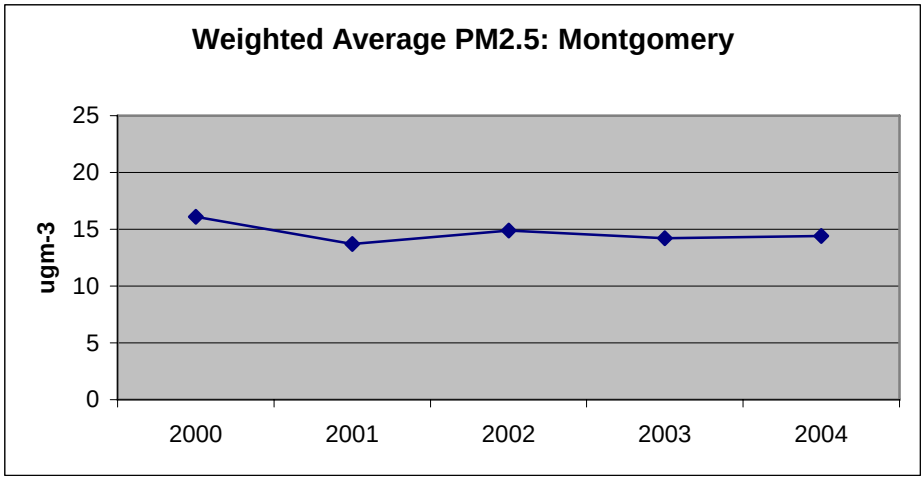

Daily Maximum PM2.5: Macon
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

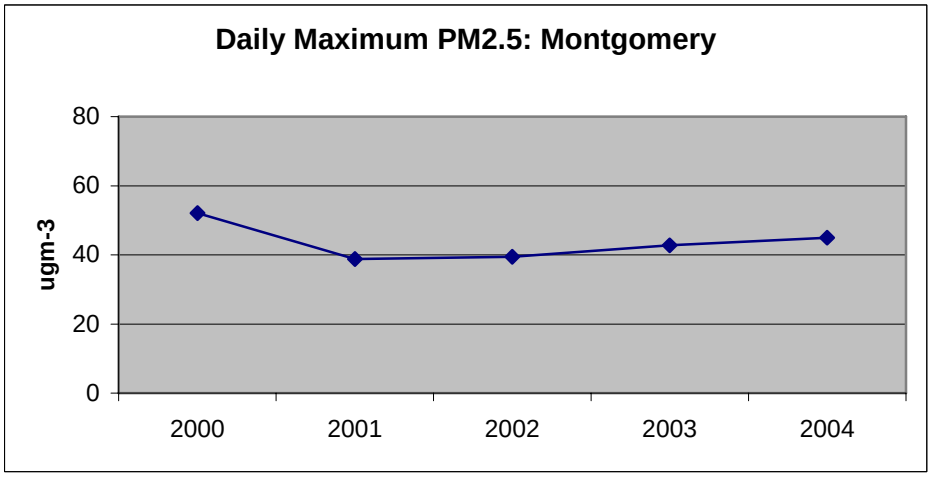
(k) Memphis


Weighted Average PM2.5: Memphis
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

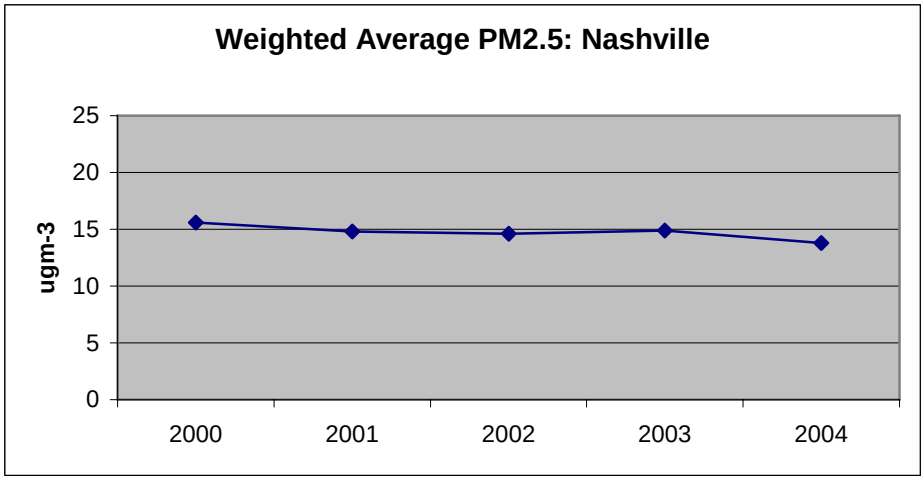

Daily Maximum PM2.5: Memphis
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

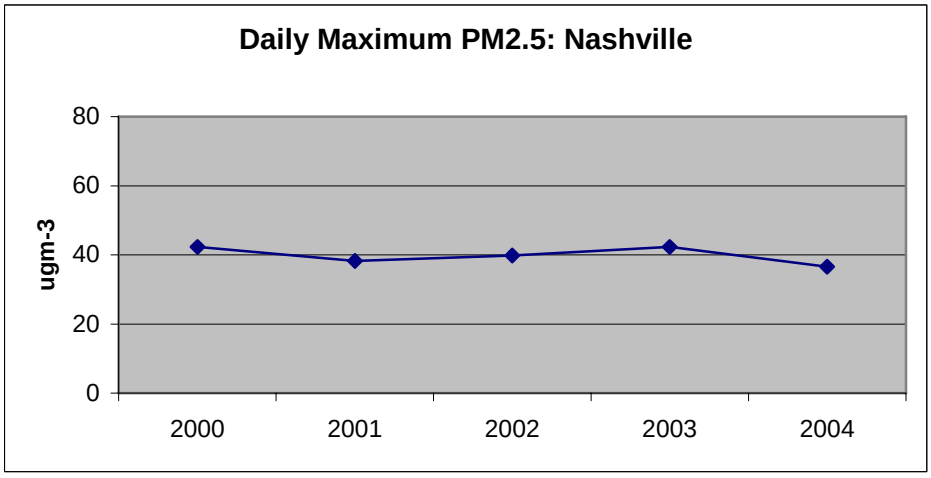
(l) Montgomery



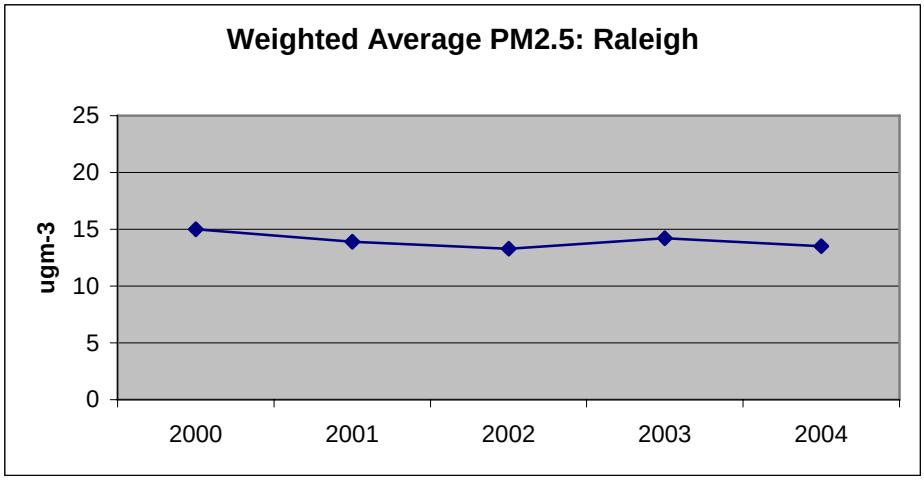


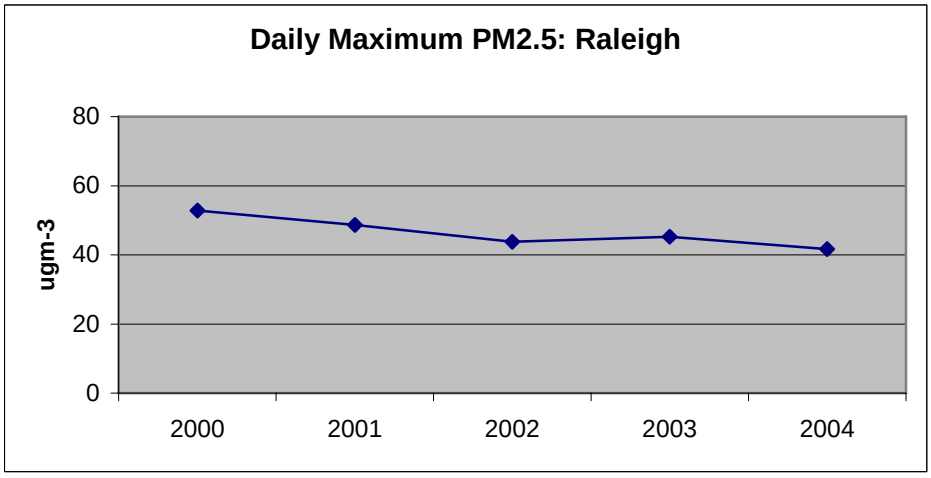
(m) Nashville


Weighted Average PM2.5: Nashville
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

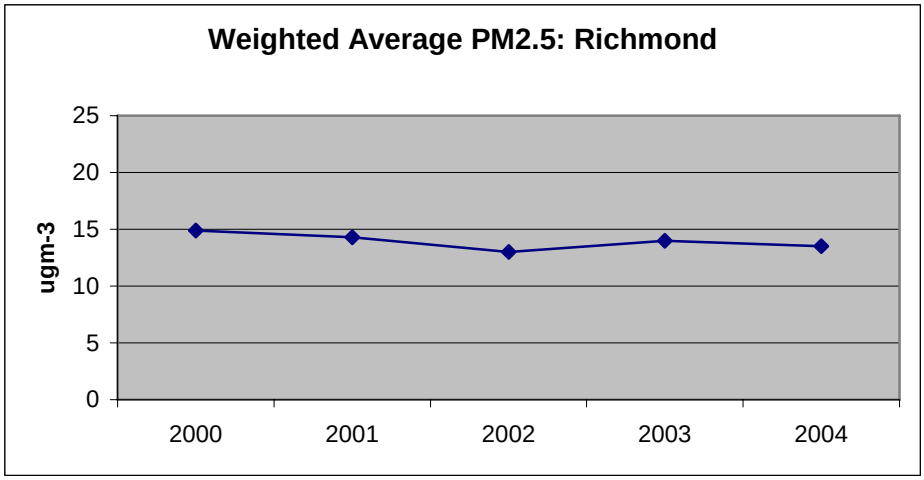

Daily Maximum PM2.5: Nashville
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

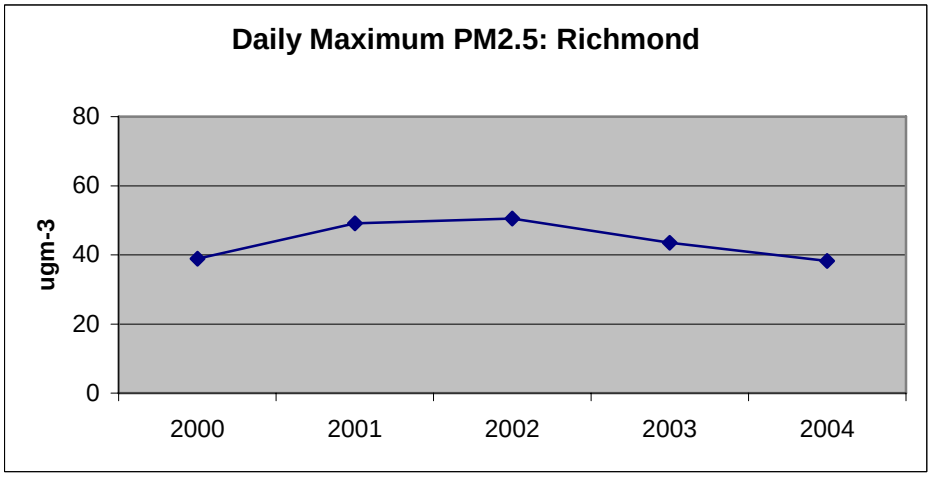
(n) Raleigh


Weighted Average PM2.5: Raleigh
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

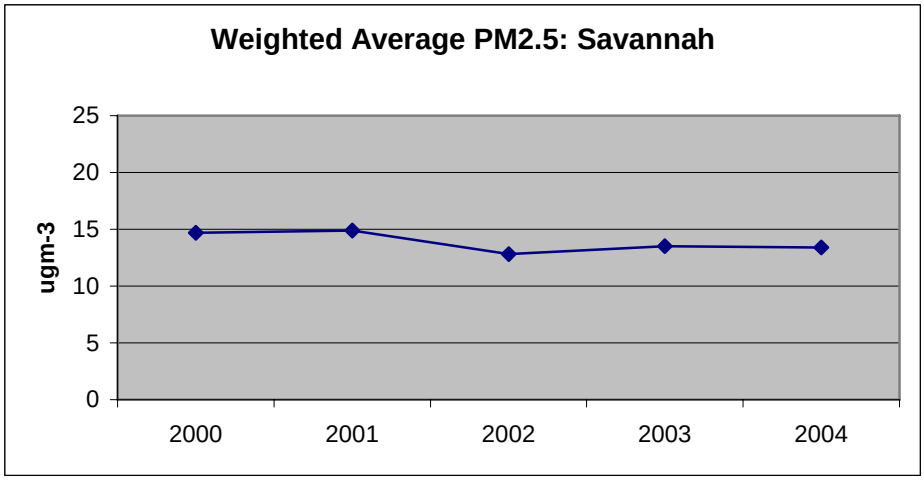

Daily Maximum PM2.5: Raleigh
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

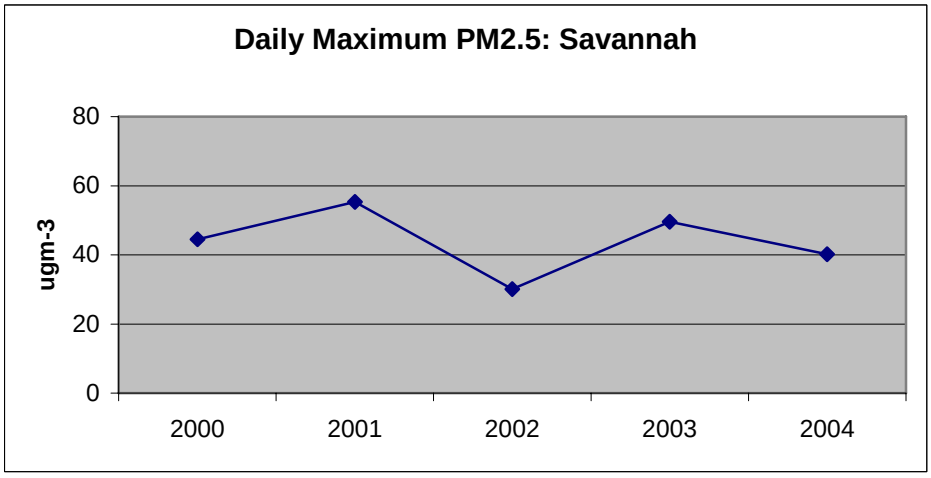
(o) Richmond


Weighted Average PM2.5: Richmond
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004


Daily Maximum PM2.5: Richmond
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

(p) Savannah





With few exceptions, the key bins for $PM_{2.5}$ are represented for all of the years. Again, this is expected since we are considering full year periods, each of which represents one fifth of the multi-year period that is used to determine the key bins.

The distribution error ranges from approximately 0.5 to 2.5 and quantifies how well the frequency distribution of days among the bins matches that for the full baseline period. No one year stands out as being most typical of the period for a majority of the sites. The distribution error over all key bins is lowest for 2002 for Chattanooga, Hickory, Kingsport-Bristol, Macon, and Montgomery, and close to the lowest for several other sites. Overall, 2000 is the year with the least representative distribution. As for the IMPROVE sites, the results vary by site.

For example, for Charlotte (Table 4-2b), the weighted $PM_{2.5}$ value for 2002 is close to the average for the full baseline period. The maximum concentration occurred during this year, but the range in $PM_{2.5}$ is typical of the other baseline years. The distribution error is slightly larger than for the other years in the period, except for 2000. The year 2001 appears to be the most typical year.

For Chattanooga (Table 4-2c), the weighted average $PM_{2.5}$ value for 2002 is lower than the average for the full baseline period and the lower values are also reflected in the range. Nevertheless, the frequency of conditions was normal and the distribution error is the lowest overall (along with that for 2004).

For Louisville (Table 4-2i), the weighted average $PM_{2.5}$ value for 2002 is slightly higher than the average for the full baseline period and the range indicates that there was at least one very high daily value (greater than 100 μgm^{-3}) recorded during 2002. The distribution error is among the lowest, indicating a typical frequency of meteorological scenarios.

For Macon (Table 4-2j), the weighted average $PM_{2.5}$ value for 2002 is lower than the average for the full baseline period and the range is similar to that for the other years with the exception of 2002. The distribution error is the lowest, over all the years considered.

For the urban areas, the year 2000 seems to be the least representative year, and 2002 is as good as or better than most of the others for most sites. Consequently, 2002 is a representative year for most sites, but the specific implications of using 2002 as the model baseline year vary by site.

4.2.3. SEARCH Sites

Table 4-3 summarizes and compares 2000–2004, and each individual year within this period for the SEARCH sites. The summary metrics included in this table are the weighted average $PM_{2.5}$ concentration, range in $PM_{2.5}$ concentration, percentage of key $PM_{2.5}$ bins represented (considering all classes), and the relative distribution of days among the key $PM_{2.5}$ bins for all categories (distribution error).

Table 4-3. Summary of $PM_{2.5}$ and Meteorological Characteristics for the 2000-2004 Analysis Period: SEARCH Sites.

(a) Atlanta (Jefferson St.)

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	16.6	1.1 – 66.1		
2000	16.9	3.7 – 62.6	100	1.8
2001	16.4	2.2 – 66.1	100	0.9
2002	16.3	3.7 – 40.2	91.7	0.8
2003	16.2	1.5 – 47.0	100	1.0
2004	16.8	1.1 – 49.5	100	1.7

(b) Yorkville

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	13.6	0.7 – 65.2		
2000	14.5	2.3 – 65.2	100	1.5
2001	13.2	2.5 – 54.4	100	0.7
2002	13.2	2.6 – 34.8	100	0.6
2003	12.0	2.2 – 43.0	91.7	1.0
2004	13.4	0.7 – 39.5	91.7	0.4

(c) Birmingham

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	17.9	2.8 – 75.2		
2000	18.3	3.8 – 66.4	100	2.3
2001	17.2	3.3 – 48.9	100	1.1
2002	17.5	3.9 – 45.3	100	0.9
2003	16.8	2.8 – 45.0	90.9	1.4
2004	18.0	3.2 – 75.2	100	1.4

(d) Centreville

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	12.9	1.2 – 54.4		
2000	13.3	3.0 – 54.4	100	2.1
2001	12.4	1.2 – 34.9	100	0.9
2002	13.1	2.9 – 48.6	91.7	1.4
2003	12.3	1.8 – 39.5	91.7	0.6
2004	12.8	2.6 – 40.8	91.7	0.8

(e) Pensacola

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	12.8	1.2 – 52.5		
2000	12.6	3.4 – 45.5	100	2.0
2001	13.1	2.6 – 52.5	100	0.9
2002	13.2	3.3 – 40.7	100	1.4
2003	12.5	1.6 – 41.7	90.9	1.1
2004	12.4	1.2 – 40.7	100	0.9

(f) Outlying Landing Field

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	11.8	0.7 – 130.9		
2000	12.4	0.7 – 130.9	100	2.6
2001	11.1	2.4 – 32.9	100	1.1
2002	11.3	2.3 – 38.3	100	1.8
2003	11.5	2.2 – 32.6	100	1.7
2004	11.7	2.3 – 44.8	100	1.6

(g) Gulfport

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	11.4	0.3 – 44.0		
2000	11.0	0.3 – 44.0	100	1.4
2001	11.4	2.3 – 41.4	100	1.2
2002	11.4	2.8 – 31.9	100	1.3
2003	11.6	2.7 – 30.1	100	0.6
2004	11.5	1.6 – 43.5	100	1.6

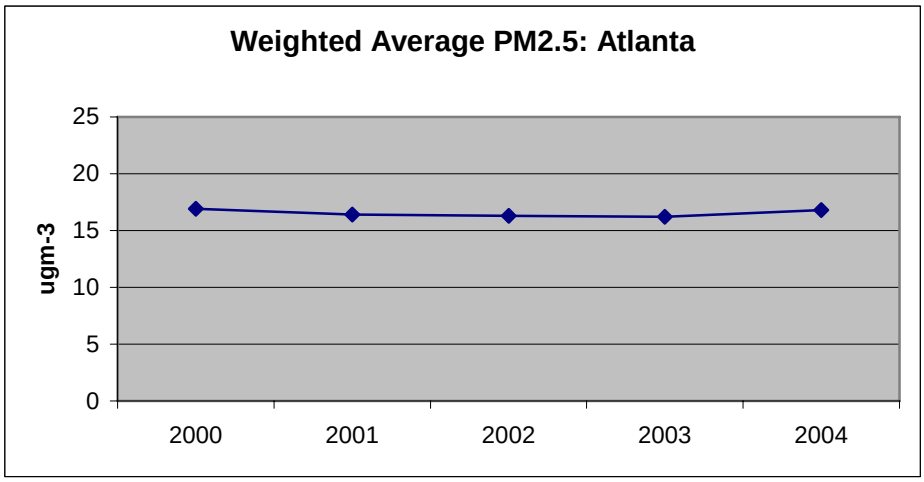
(h) Oak Grove

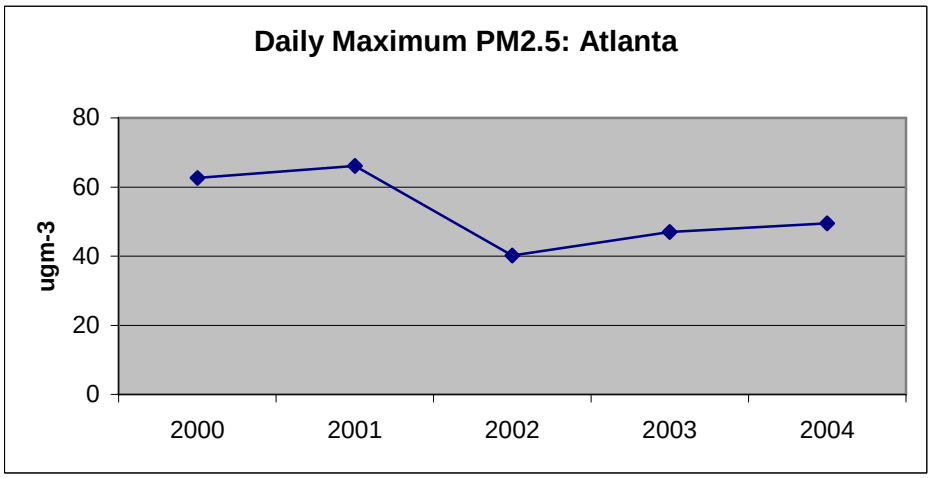
Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	11.8	1.5 – 90.1		
2000	11.9	2.5 – 41.4	100	2.2
2001	11.8	2.3 – 90.1	100	0.7
2002	11.4	2.2 – 67.1	100	1.3
2003	11.5	1.5 – 43.9	100	0.8
2004	11.6	2.2 – 37.2	100	0.6

For the inland sites the weighted average $PM_{2.5}$ values tend to be highest for 2000, lower for 2001-2003, and then high again for 2004. For the coastal sites, the values are fairly similar for all years, with some variations. The range in $PM_{2.5}$ indicates that the highest values were recorded early during the five-year period. Figure 4-7 shows the year by year tendencies in weighted average $PM_{2.5}$ and daily maximum 24-hour average $PM_{2.5}$ for each of the SEARCH sites. For most sites, there is no apparent trend in the meteorologically adjusted (weighted average) values. The maximum values follow the tendency described above.

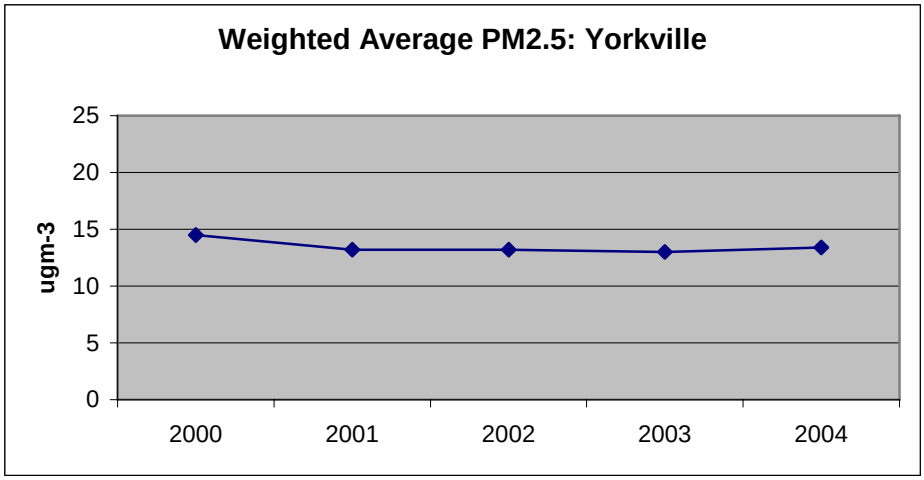
Figure 4-7. Year-by-Year Tendencies in Weighted Average $PM_{2.5}$ and Daily Maximum 24-hour Average $PM_{2.5}$ for Each of the SEARCH Sites.

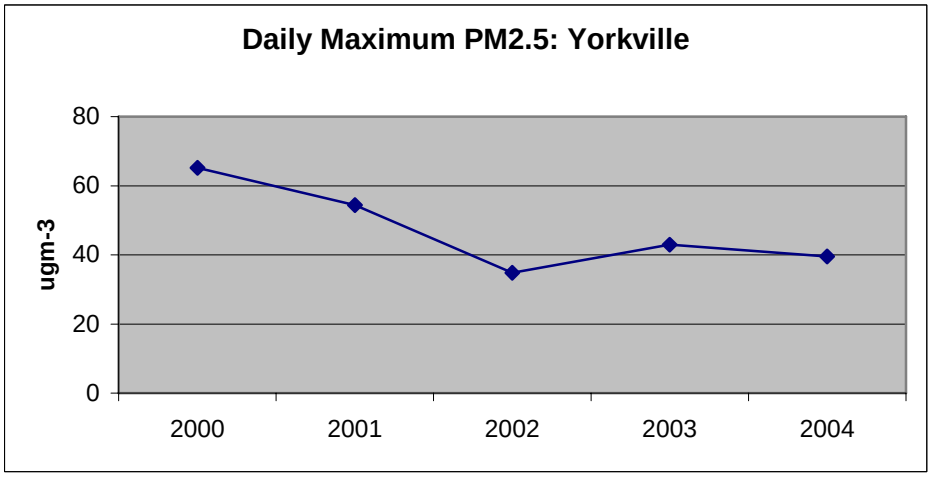
(a) Atlanta



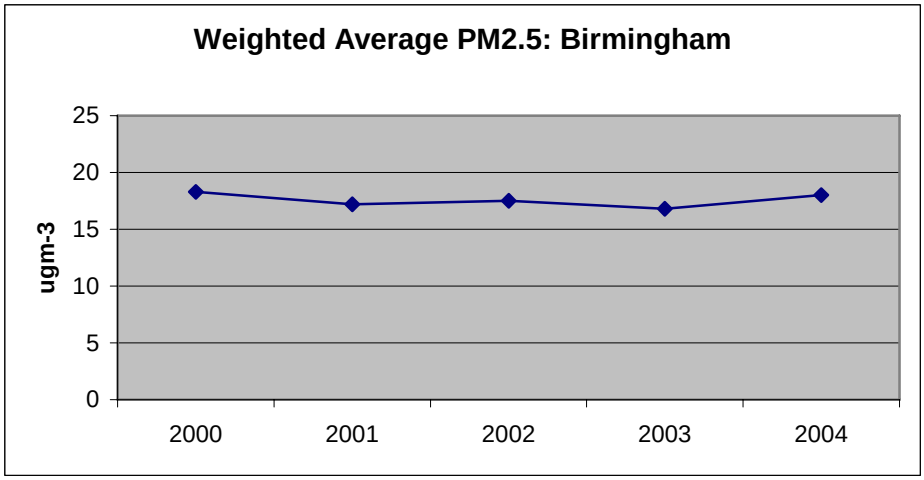


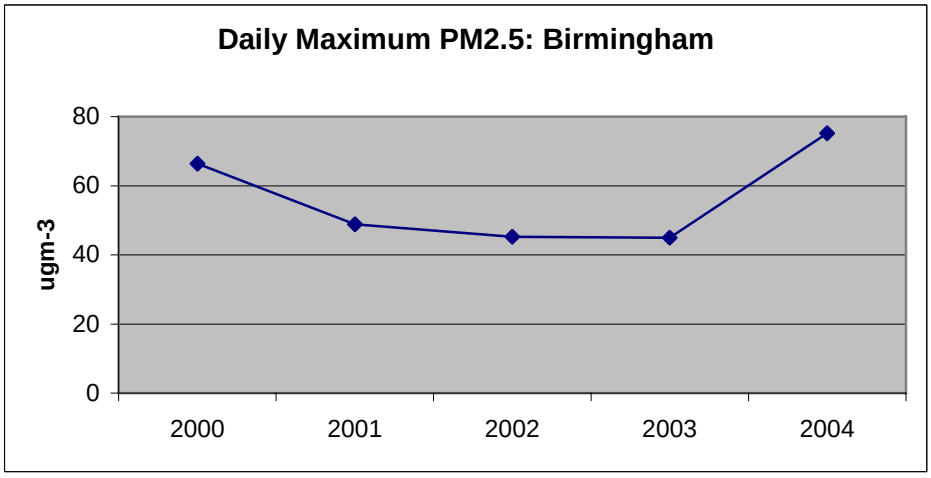
(b) Yorkville


Weighted Average PM2.5: Yorkville
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

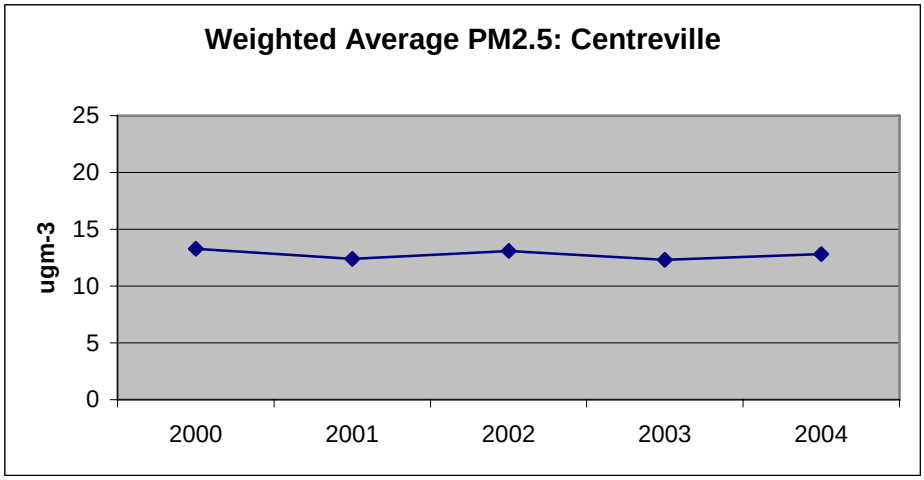

Daily Maximum PM2.5: Yorkville
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

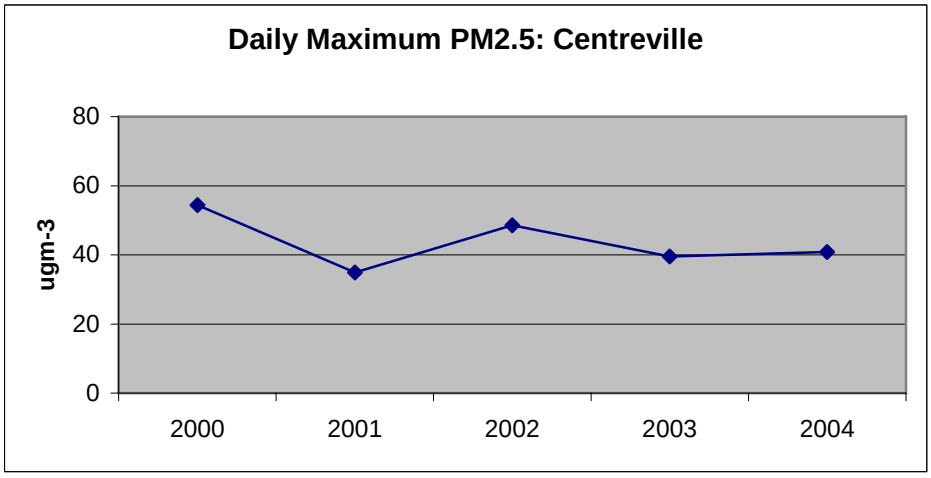
(c) Birmingham



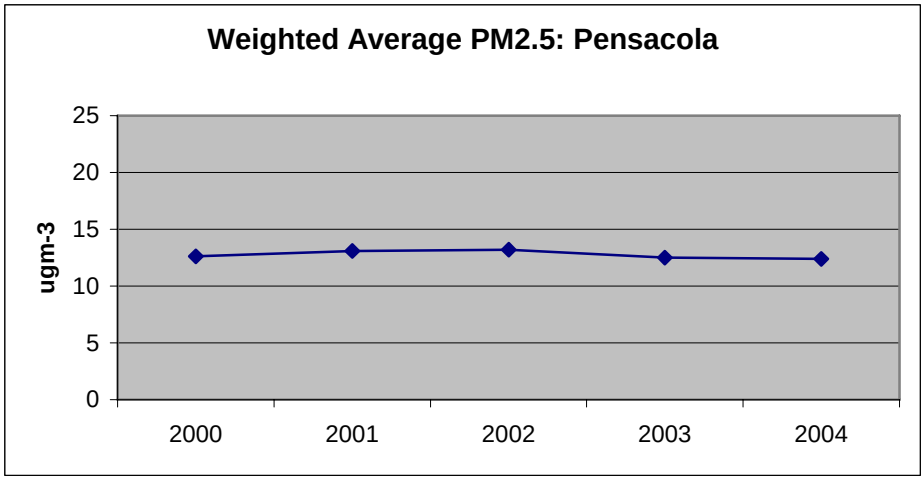


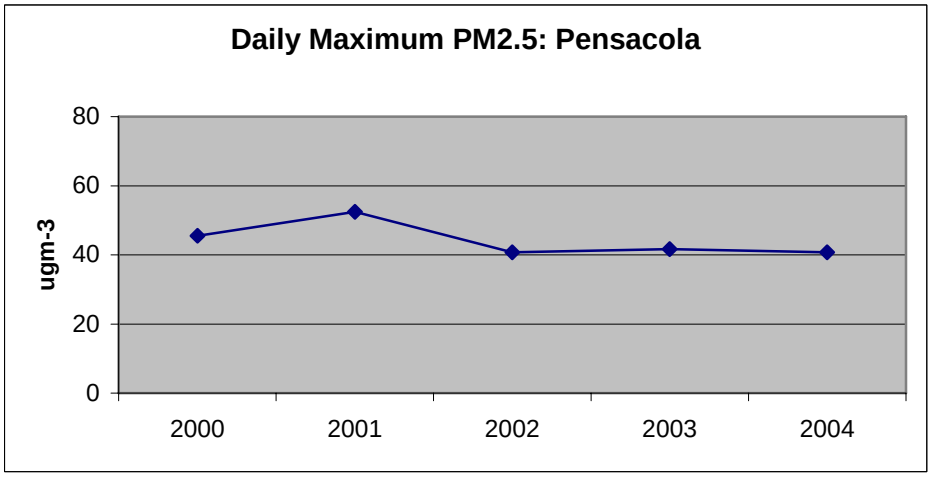
(d) Centreville



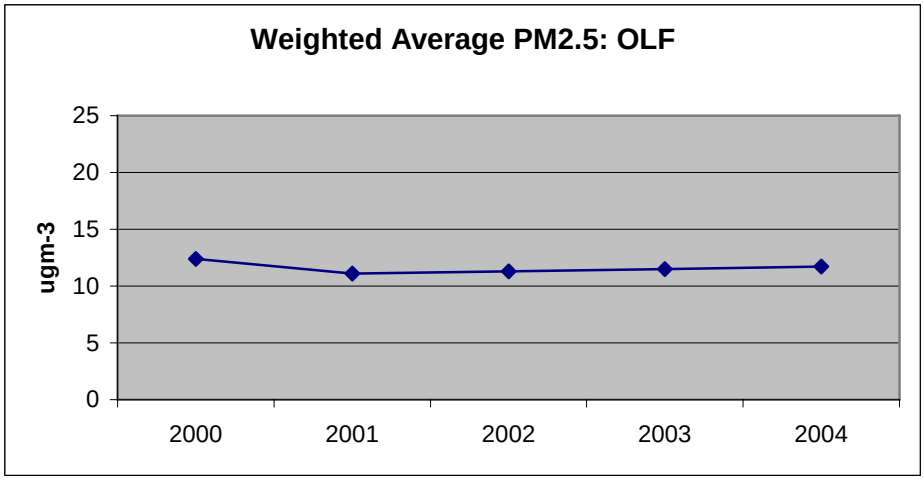


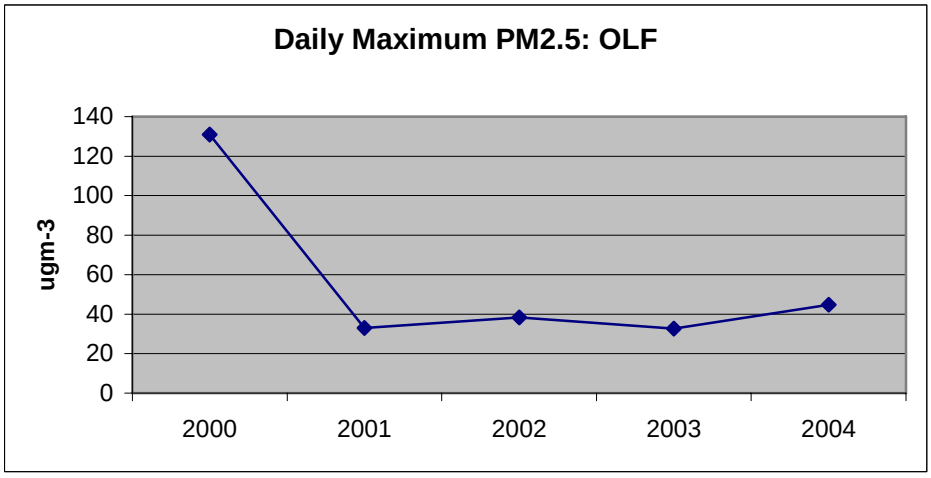
(e) Pensacola


Weighted Average PM2.5: Pensacola
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

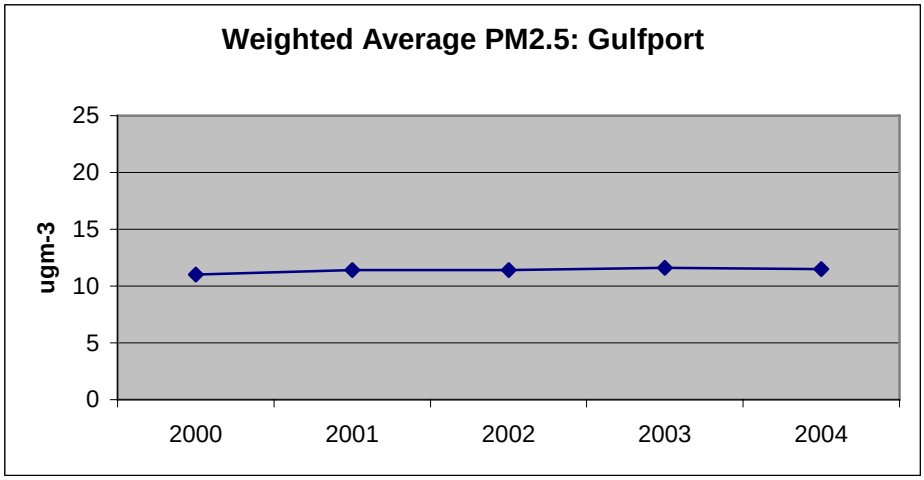

Daily Maximum PM2.5: Pensacola
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

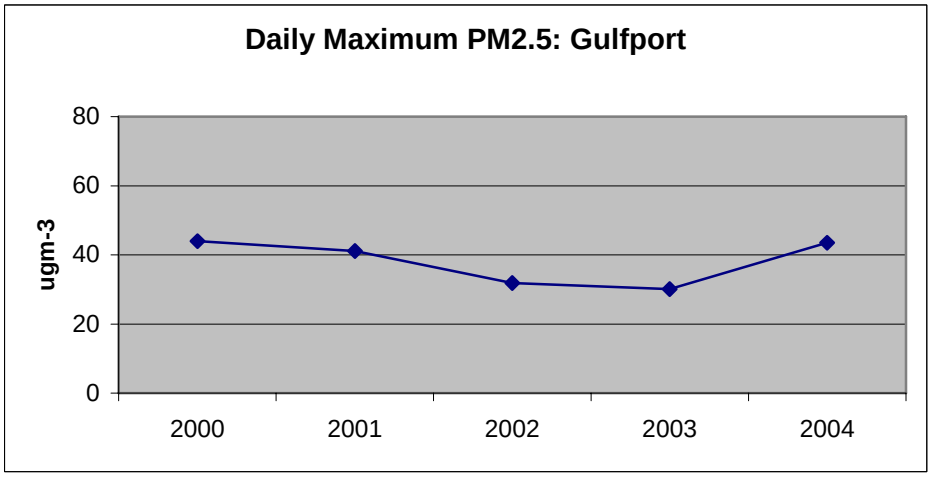
(f) OLF


Weighted Average PM2.5: OLF
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004

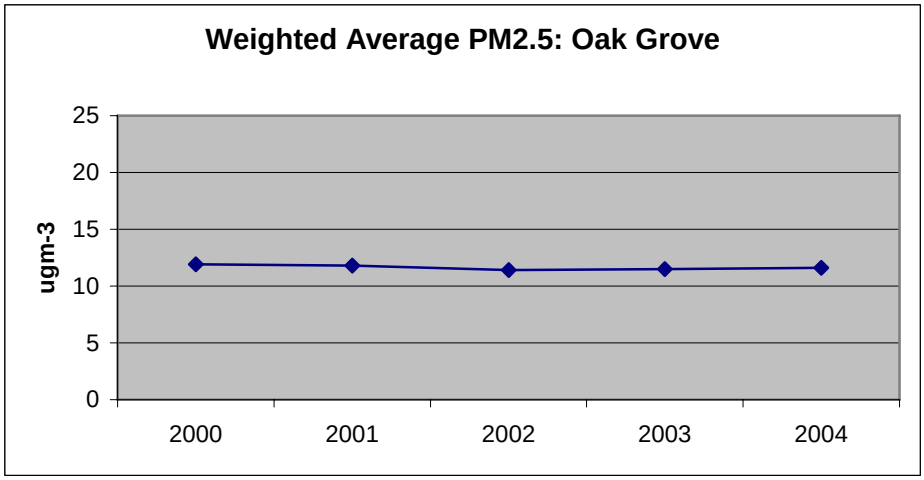

Daily Maximum PM2.5: OLF
ugm-3
140
120
100
80
60
40
20
0
2000
2001
2002
2003
2004

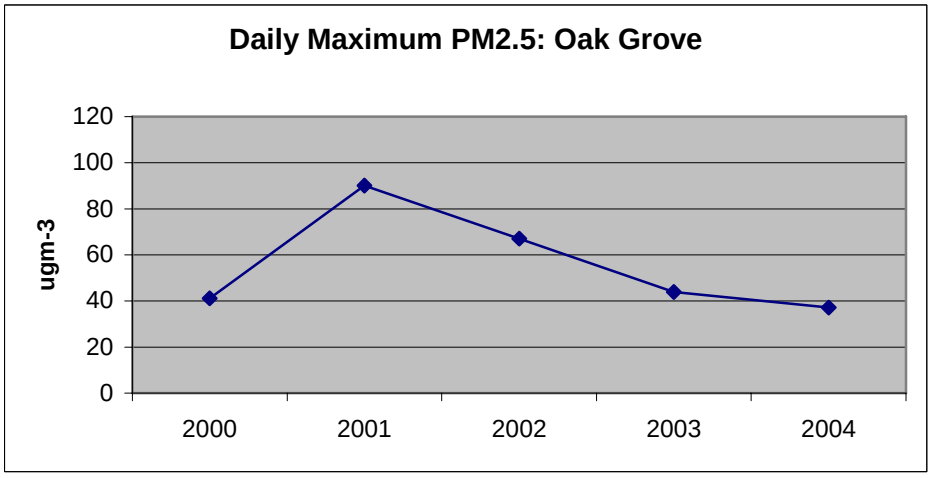
(g) Gulfport


Weighted Average PM2.5: Gulfport
ugm-3
25
20
15
10
5
0
2000
2001
2002
2003
2004


Daily Maximum PM2.5: Gulfport
ugm-3
80
60
40
20
0
2000
2001
2002
2003
2004

(h) Oak Grove





With few exceptions, the key bins for $PM_{2.5}$ are represented for all of the years. The distribution error ranges from approximately 0.5 to 2.5 and quantifies how well the frequency distribution of days among the bins matches that for the full baseline period. The distribution error over all key bins is lowest for 2002 for Atlanta, Yorkville, and Birmingham. Overall, 2000 is the year with the least representative distribution.

For Atlanta (Table 4-3a), the weighted $PM_{2.5}$ value for 2002 is close to the average for the full baseline period. The range reflects a lower maximum value than for the other years and not all key bins are represented. Nevertheless, the distribution error is the lowest among all years considered.

For Birmingham (Table 4-3c), the weighted average $PM_{2.5}$ value for 2002 is also close to the average for the full baseline period, and the range is typical for the middle years. The distribution error is the lowest overall.

For the SEARCH sites, 2002 does not include some of the higher values of the other years but other indicators suggest that this is a representative year for the SEARCH sites.

4.3. Selection Subset Episodes for Model-Based Sensitivity Analysis

The CART results were also used in selecting subset periods of 2002 for $PM_{2.5}$ modeling and sensitivity analysis. The episode selection methods are presented in this section and the key question of "How well do subset modeling periods chosen by VISTAS for emission sensitivity analysis capture the range of relationships between meteorology and air quality for each site of interest and for the VISTAS region?" is examined.

4.3.1. Episode Selection

The goal of this exercise was to identify two approximate month-long subset periods of 2002 to represent the conditions and concentration levels associated with high $PM_{2.5}$ events in as many areas as possible throughout the VISTAS region. The two periods were also to represent both winter and summer types of regimes. The primary focus of this exercise was $PM_{2.5}$; however, information about ozone was also included in the final stages of the analysis. Because the selected episode periods were potentially to be used for $PM_{2.5}$ modeling of urban areas, we considered only the results for the STN and SEARCH sites. The episode selection methodology is outlined below.

First we prepared color-coded charts of daily $PM_{2.5}$ concentrations for each STN and SEARCH site and identified (primarily visually) winter and summer periods with a range of high and low concentrations for as many sites as possible. We also used the episode selection tool to identify periods that sample a range of key conditions for selected groups of areas.

We then input these dates into the CART-based meteorological characterization tool and used the summaries provided by the tool to assess and compare the representativeness of the periods with respect to frequent (key) meteorological conditions, annual average $PM_{2.5}$ (and ozone) concentrations, and speciation. We considered all of the VISTAS STN and SEARCH areas, but gave more attention to those with the higher $PM_{2.5}$ design values.

The analysis components included several characterization metrics that focused on how well the weighted annual average and range of $PM_{2.5}$ concentrations represent these same metrics for the full baseline period, and the degree to which the key $PM_{2.5}$ bins are represented by the identified periods. We also compared the compositional averages for the identified days with those for the baseline periods. Finally, we examined the range and frequency of occurrence of wind directions at the surface and 850 mb levels relative to a longer period of record.

The winter period was selected first. From three candidate winter periods, the period 19 November–20 December 2002 was selected to best capture the $PM_{2.5}$ concentrations (especially for the sites with the higher $PM_{2.5}$ design values) and the key high $PM_{2.5}$ CART bins. The wind directions for this period also represented the average wintertime distribution slightly better than the other two candidates, for several locations.

Seven candidate summertime periods were then reviewed with respect to representing the summer conditions for the baseline period and complementing the selected wintertime period in representing the annual range of conditions of the baseline period. The summertime period 3 June–10 July 2002 was selected. When this period is combined with the wintertime period, optimum representation of the key bins (for all categories) and the distribution of days among the key bins are achieved. The distribution of wind directions for high PM days is also representative of the longer period. Finally, the period includes high ozone days for the areas

with the higher design values. This exercise demonstrates the use of the episode selection and meteorological characterization tool to identify episodic periods for air quality modeling.

4.3.2. Episode Representativeness

The characteristics, attributes, and limitations of the episode periods are examined and compared in this section. Although the episode selection only considered the STN and SEARCH sites, we examine the representativeness of the selected episodes for the IMPROVE, STN and SEARCH sites.

IMPROVE Sites

Table 4-4 summarizes and compares 2000-2004, 2002, and the combined episode periods for the IMPROVE sites. The summary metrics are the same as those for Table 4-1. The weighted extinction coefficients and average concentrations provide information on how well 2002 represents average conditions for the baseline period (as discussed earlier in this section) and then how well the subset episodes represent the 2002 annual period, when the days are weighted to best represent the expected frequency of occurrence of the different types of conditions. For many of the sites, good to very good agreement is achieved between the 2002 and episode values. The range in $PM_{2.5}$ concentration for the episode days indicates that, for many of the sites, the episode days include the peak days for 2002 (that is, the upper end of the range is the same as for 2002). The episodes contain 71 days, and as expected, do not always include days from all of the key bins. However, considering all sites, between 70 and 100 percent of the key bins are captured for both visibility and PM by the episode days – this varies by site. As expected, the distribution errors are larger for the episode periods, indicating that the episodes do not necessarily sample the various types of days with the frequency that is typical of the longer periods. For several of the coastal sites, including Cape Romain, Chassahowitzka, Everglades, and Swanquarter, the distribution error for the episode periods is not that much greater than that for 2002. Further inland, where more variable meteorology may lead to larger differences between the conditions described by the CART bins, the difference in the errors tends to be greater.

Table 4-4. Summary of Visibility, $PM_{2.5}$ and Meteorological Characteristics for 2000-2004, 2002, and the 2002 VISTAS Episodic Analysis Periods: IMPROVE Sites.

(a) Breton

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	78.5	7.6	1.2 – 21.5	100			
2002	71.2	6.7	1.8 – 16.4	100	1.6	100	0.7
Episodes	69.1	6.1	3.8 – 8.5	81.8	3.3	77.8	3.4

(b) Brigantine

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	95.6	9.7	1.4 – 39.2				
2002	93.6	9.6	1.4 – 36.5	100	0.9	100	1.7
Episodes	101.1	9.5	3.6 – 36.5	81.3	2.3	100	5.4

(c) Cadiz

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	107.4	11.0	0.6 – 31.3				
2002	107.4	11.1	4.1 – 30.2	100	1.1	100	1.0
Episodes	107.5	10.3	4.1 – 30.2	85.7	4.3	100	4.1

(d) Caney Creek

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	83.0	9.0	0.3 – 28.3				
2002	92.1	8.9	0.5 – 28.3	100	0.9	100	1.0
Episodes	93.4	7.9	0.5 – 26.2	86.7	1.6	90	2.8

(e) Cape Romain

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	82.0	8.6	1.1 – 30.1				
2002	79.8	8.0	1.1 – 22.6	100	1.3	100	1.1
Episodes	79.1	7.3	1.4 – 16.4	85.7	2.4	90.9	2.2

(f) Chassahowitzka

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	89.5	8.7	2.1 – 24.7				
2002	86.5	8.2	2.5 – 17.7	100	1.1	100	1.6
Episodes	87.3	7.7	3.1 – 12.6	91.7	2.7	100	1.8

(g) Cohutta

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	95.6	10.7	1.2 – 44.4				
2002	95.4	10.6	2.2 – 44.4	100	1.2	100	1.3
Episodes	90.8	10.6	3.9 – 44.4	100	2.4	87.5	2.6

(h) Dolly Sods

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	86.0	9.4	0.4 – 37.2				
2002	79.1	8.7	1.3 – 37.2	100	1.0	100	0.9
Episodes	81.6	8.2	2.1 – 37.2	100	3.3	100	4.9

(i) Everglades

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	63.4	6.5	1.1 – 34.4				
2002	61.8	6.3	1.4 – 23.4	100	1.0	100	1.3
Episodes	69.1	6.6	1.4 – 23.4	81.8	2.5	88.9	1.9

(j) Great Smoky Mountains

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	85.7	10.1	0.5 – 35.6				
2002	78.6	9.8	1.7 – 27.9	100	1.1	100	0.7
Episodes	72.1	9.2	2.0 – 25.4	71.4	2.3	100	2.5

(k) James River Face

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	102.1	10.9	0.5 – 31.5				
2002	101.0	11.7	3.5 – 31.5	100	1.3	100	1.1
Episodes	92.1	11.2	4.5 – 31.5	70.0	2.4	88.9	2.5

(l) Linville Gorge

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	80	8.9	0.3 – 29.2				
2002	72.4	8.8	1.6 – 27.1	92.3	1.7	100	1.0
Episodes	55.8	8.3	3.1 – 21.6	76.9	4.2	88.9	2.3

(m) Mammoth Cave

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	110.0	11.7	2.0 – 44.6				
2002	104.1	11.5	3.8 – 34.0	100	0.8	100	1.4
Episodes	100.8	10.9	6.1 – 25.3	91.7	3.2	88.9	4.4

(n) Mingo

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	94.7	11.5	2.4 – 50.0				
2002	80.9	9.1	3.1 – 15.4	100	1.2	100	2.4
Episodes	NA	NA	NA	NA	NA	NA	NA

(o) Okefenokee

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	86.7	9.1	2.2 – 42.9				
2002	88.9	9.5	2.9 – 30.1	100	1.0	100	0.7
Episodes	80.2	8.3	2.9 – 28.3	100	2.3	90	2.6

(p) Shenandoah

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	95.2	9.3	0.1 – 33.9				
2002	99.0	9.6	0.8 – 29.8	100	2.2	100	1.8
Episodes	88.0	8.3	2.7 – 26.1	100	3.9	88.9	3.5

(q) Shining Rock

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	75.1	7.8	0.2 – 57.6				
2002	65.0	8.1	0.4 – 23.2	100	1.3	100	1.2
Episodes	47.8	10.8	2.8 – 21.0	81.8	3.6	77.8	1.9

(r) Sipsey

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	100.8	11.1	1.6 – 36.3				
2002	95.9	10.8	4.4 – 29.0	100	1.2	100	1.2
Episodes	87.6	10.5	5.5 – 20.8	91.7	2.5	100	4.1

(s) St. Marks

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	77.9	8.5	1.5 – 31.9				
2002	79.2	8.1	2.3 – 21.4	100	1.0	100	1.7
Episodes	64.5	6.8	2.4 – 15.7	91.7	3.2	77.8	3.8

(t) Swanquarter

Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	81.8	7.9	0.6 – 27.0				
2002	79.3	8.1	1.8 – 22.2	100	1.3	100	1.9
Episodes	65.8	7.0	2.2 – 22.2	83.3	2.3	75	2.4

(u) Upper Buffalo

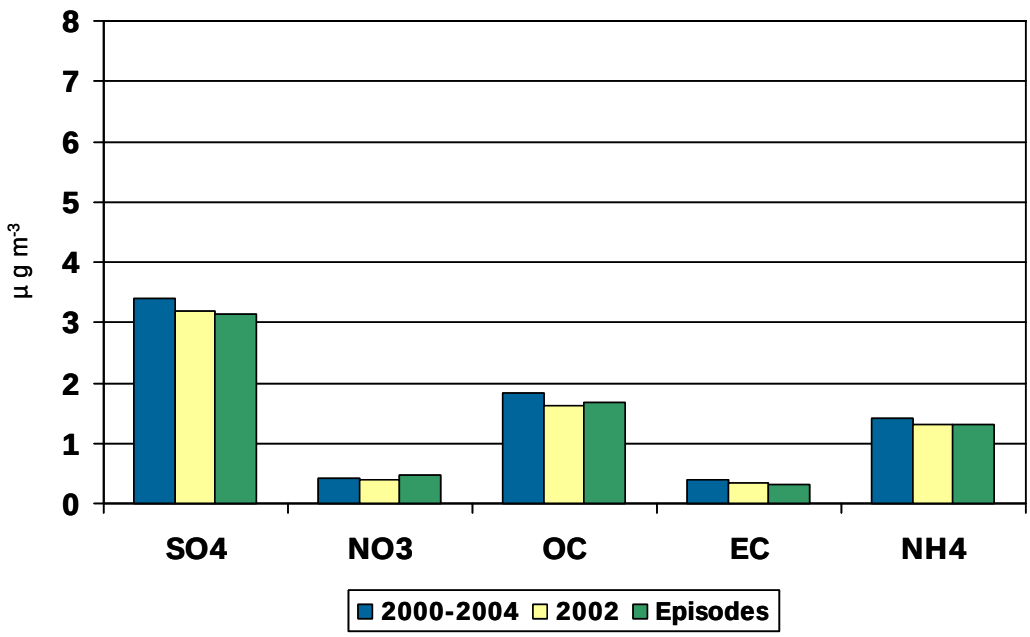
Period	Weighted Average Extinction Coefficient (Mm^{-1})	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key Visibility Bins Represented (%)	Distribution Error Over All Key Visibility Bins (%)	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	73.4	8.6	0.1 – 30.0				
2002	79.2	9.2	1.7 – 27.1	100	1.0	100	1.6
Episodes	78.2	8.3	3.5 – 26.0	92.3	2.8	88.9	3.2

Some additional plots are provided to characterize the overall representativeness of the urban-$PM_{2.5}$-based episode periods for selected example sites, namely Cape Romain, Great Smoky

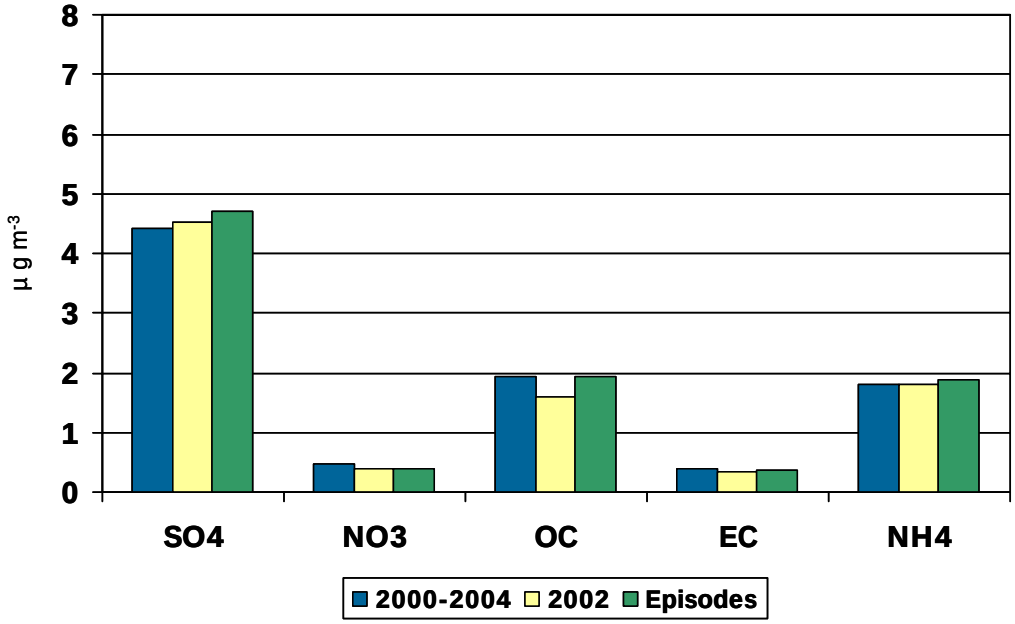
Mountains, and Mammoth Cave. Figure 4-8 compares the average concentration of the PM species for the three time periods, 2000-2004, 2002, and 1 June – 10 July and 19 November – 19 December, 2002 (the combined subset episode periods). Figure 4-9 examines and compares the distribution of surface wind direction, by wind direction quadrant, for the three sets of dates.

Figure 4-8. Comparison of Species Concentrations (μgm^{-3}) for Sulfate (SO4), Nitrate (NO3), Organic Carbon (OC), Elemental Carbon (EC) and Ammonium (NH4) for 2000-2004, 2002, and 2002 VISTAS Episode Periods: IMPROVE Sites.

(a) Cape Romain



(b) Great Smoky Mountains



(c) Mammoth Cave

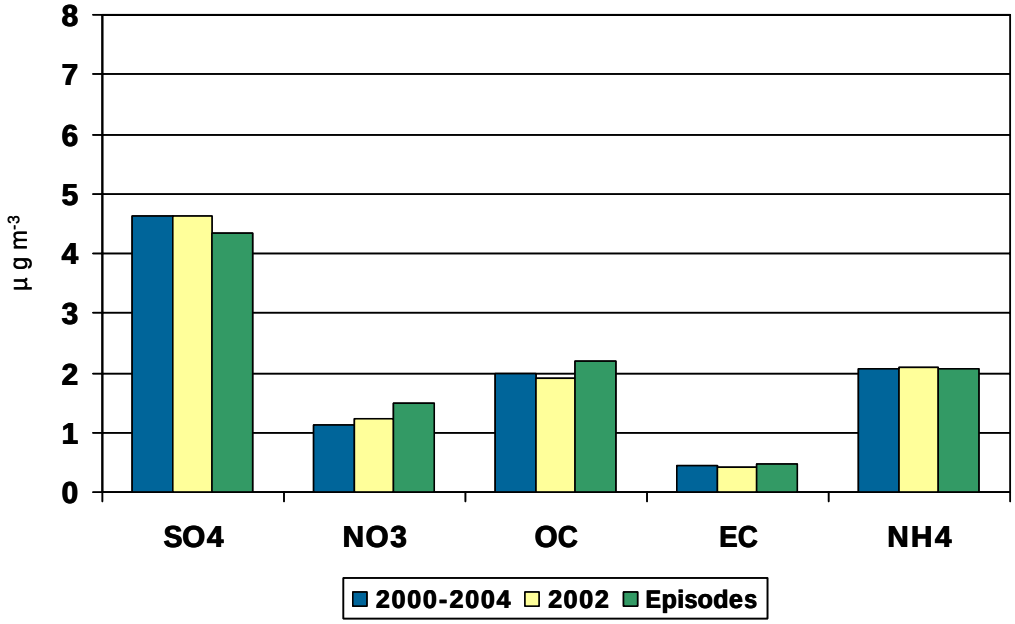
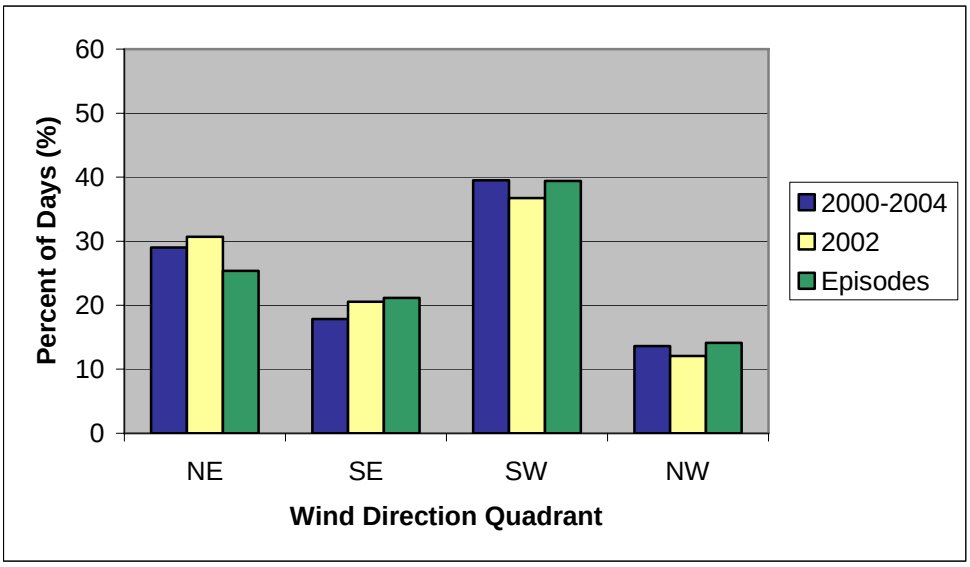
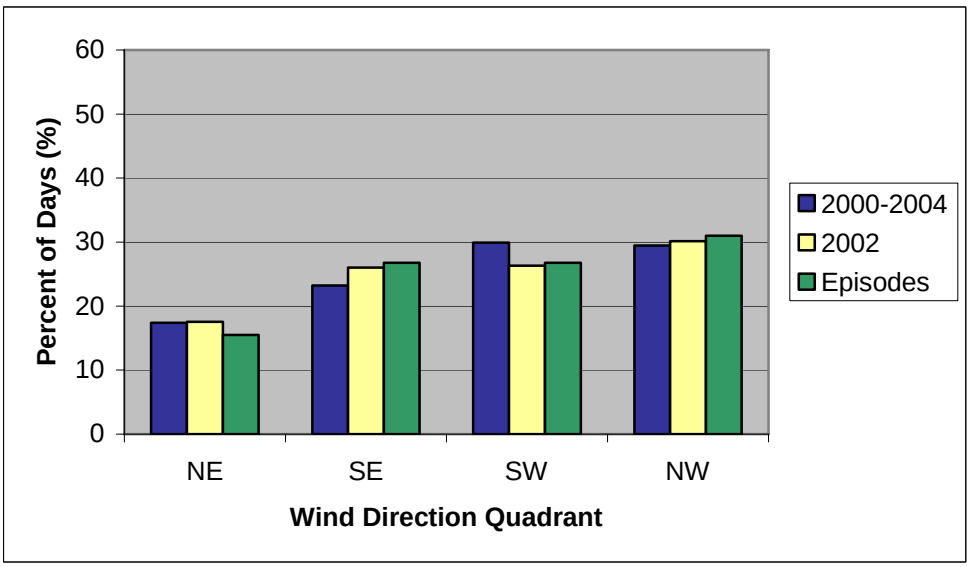


Figure 4-9. Distribution of Surface Wind Directions by Quadrant for 2000-2004, 2002, and 2002 VISTAS Episode Periods: IMPROVE Sites.

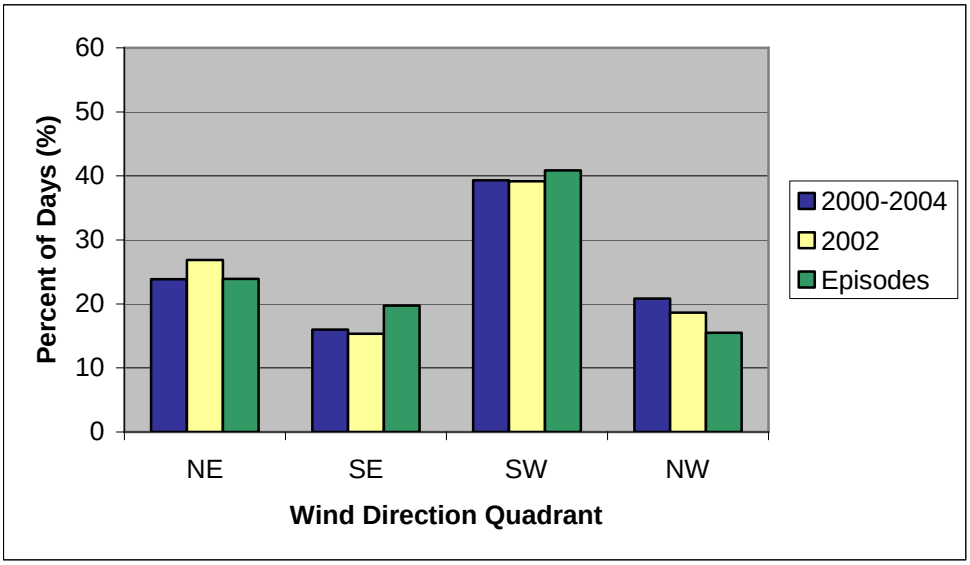
(a) Cape Romain



(b) Great Smoky Mountains



(c) Mammoth Cave



For Cape Romain (Figure 4-8a), the average concentrations for all species are very similar for all three periods. The subset periods match the averages for 2002 very closely. The distributions of wind directions (Figure 4-9a) for the three periods also agree very well, with fewer occurrences of northeasterly winds for the episodes, than the longer periods.

For GSM (Figure 4-8b), both 2002 and the episodes have slightly higher sulfate concentrations than the full baseline period, and 2002, on average, has slightly lower organic carbon. The distributions of wind directions (Figure 4-9b) for the three periods agree quite well. 2002 has a higher percentage of days with southeasterly winds and a lower percentage of days with southwesterly winds than the full period. The distribution for the episode periods follows that for 2002 fairly closely.

For Mammoth Cave (Figure 4-8c), the episode days have, on average, slightly lower sulfate and slightly higher nitrate and organic carbon concentrations than both 2002 and the full baseline period, which are very well matched in terms of average concentrations. The episodes also have a greater percentage of days with southeasterly winds and a lesser percentage of days with northwesterly winds than the longer periods (Figure 4-9c).

STN Sites

Table 4-5 summarizes and compares 2000-2004, 2002, and the combined episode periods for the STN sites. The summary metrics are the same as those for Table 4-2. The weighted average $PM_{2.5}$ concentrations provide information on how well 2002 represents average conditions for the baseline period (as discussed earlier in this section) and then how well the subset episodes represent the 2002 annual period, when the days are weighted to best represent expected frequency of occurrence of the different types of conditions.

Table 4-5. Summary of $PM_{2.5}$ and Meteorological Characteristics for 2000-2004, 2002, and the 2002 VISTAS Episodic Analysis Periods: STN Sites.

(a) Birmingham

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	18.8	0.4 - 71.3		
2002	17.8	4.2 - 47.8	100	1.1
Episodes	18.8	7.1 – 41.5	100	3.5

(b) Charlotte

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.7	2.3 – 45.2		
2002	14.4	3.2 – 45.2	100	1.6
Episodes	14.7	3.8 – 34.5	100	3.2

(c) Chattanooga

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	15.6	2.5 – 48.6		
2002	14.5	4.2 – 31.3	100	1.1
Episodes	13.5	4.3 – 31.3	90	3.9

(d) Greenville-Spartanburg

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.8	0.5 – 51.5		
2002	14.9	1.5 – 49.8	100	1.2
Episodes	15.7	4.5 – 37.3	42.3	1.9

(e) Hickory

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	15.8	2.6 – 40.7		
2002	15.5	4.5 – 40.7	100	0.9
Episodes	15.3	5.8 – 33.5	100	4.2

(f) Huntington-Ashland

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.7	0.6 – 54.5		
2002	14.9	3.0 – 46.8	100	1.0
Episodes	13.7	3.0 – 46.8	100	3.7

(g) Jackson

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	13.7	1.8 – 45.3		
2002	13.0	1.8 – 45.3	100	2.0
Episodes	11.9	4.8 – 24.8	77.8	2.9

(h) Kingsport-Bristol

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.8	1.9 – 49.2		
2002	14.0	2.6 – 37.5	100	0.8
Episodes	13.8	4.9 – 34.4	90.9	3.4

(i) Louisville

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	17.1	3.3 – 100.6		
2002	17.7	4.1 – 100.6	100	1.0
Episodes	18.2	7.1 – 100.6	91.7	3.9

(j) Macon

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	16.1			
2002	15.2	4.3 – 41.0	100	1.2
Episodes	13.6	5.2 – 29.3	88.9	3.0

(k) Memphis

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.2	1.1 – 50.0		
2002	13.8	3.6 – 49.4	91.7	0.8
Episodes	14.5	3.9 – 36.4	75	3.0

(l) Montgomery

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.7	0.4 – 52.1		
2002	14.9	3.5 – 39.4	100	0.7
Episodes	13.9	6.5 – 28.9	90	2.4

(m) Nashville

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.9	0.2 – 42.3		
2002	14.6	2.6 – 39.8	100	1.1
Episodes	15.1	6.6 – 39.8	81.8	3.1

(n) Raleigh

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.1	2.3 – 52.8		
2002	13.3	2.3 – 43.8	91.7	1.6
Episodes	13.5	4.3 – 43.8	91.7	2.2

(o) Richmond

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.2	0.0 – 50.5		
2002	13.0	1.2 – 50.5	100	1.0
Episodes	13.9	2.8 – 50.5	92.3	3.7

(p) Savannah

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	14.0	3.2 – 55.3		
2002	12.8	3.9 – 30.1	100	1.5
Episodes	11.9	5.7 – 20.3	88.9	2.0

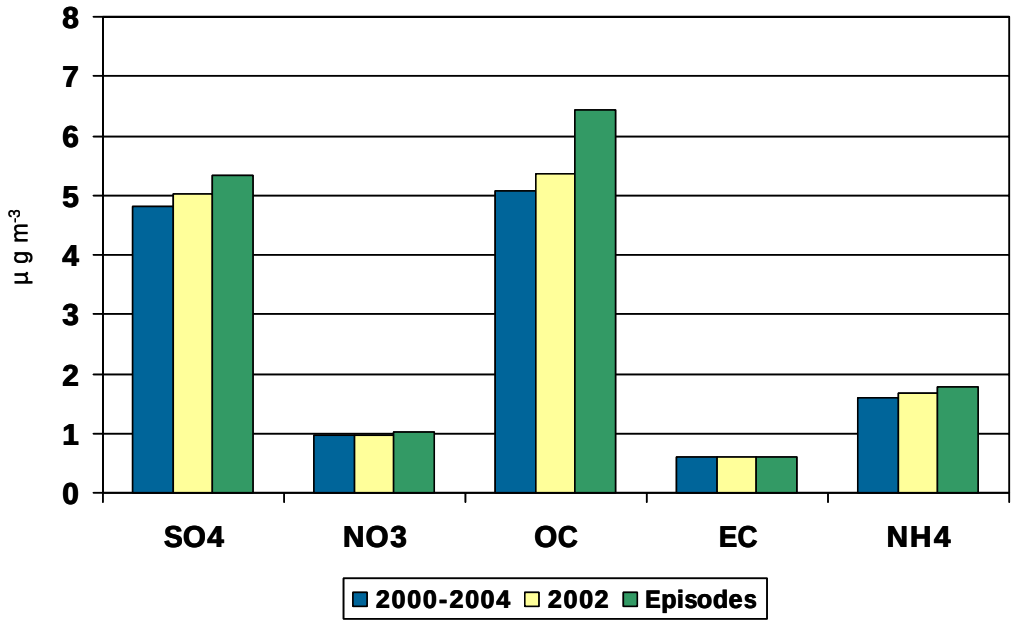
Overall good to very good agreement is achieved between the 2002 and episode values, and the weighted average concentration for the episode days is within approximately 1 μgm^{-3} of the 2002 average value for many of the sites. For several sites, the episode days include the peak

days for 2002 (the upper end of the range is the same as for 2002). Considering all sites, between 42 and 100 percent of the key bins are captured by the episode days. The distribution errors are larger for the episode periods, as the episodes do not necessarily sample the various types of days with the frequency that is typical of the longer periods.

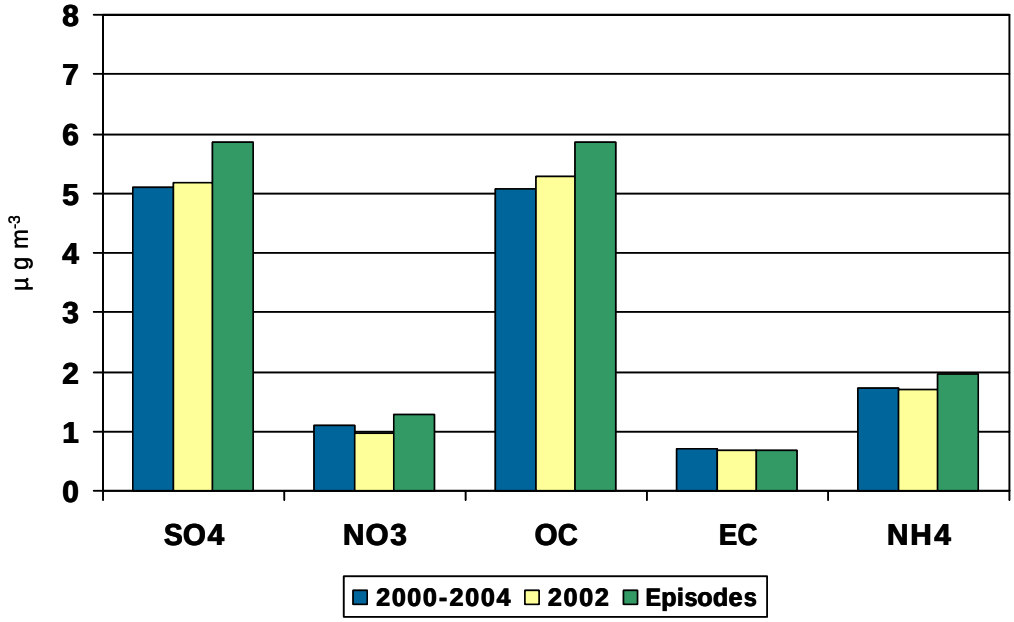
Figure 4-10 compares the average concentration of the PM species for 2000-2004, 2002, and the combined episode periods for four example sites: Charlotte, Chattanooga, Louisville, and Macon. Figure 4-11 examines and compares the distribution of surface wind direction, by wind direction quadrant, for the three sets of dates, for these same sites.

Figure 4-10. Comparison of Species Concentrations (μgm^{-3}) for Sulfate (SO4), Nitrate (NO3), Organic Carbon (OC), Elemental Carbon (EC) and Ammonium (NH4) for 2000-2004, 2002, and 2002 VISTAS Episode Periods: STN Sites.

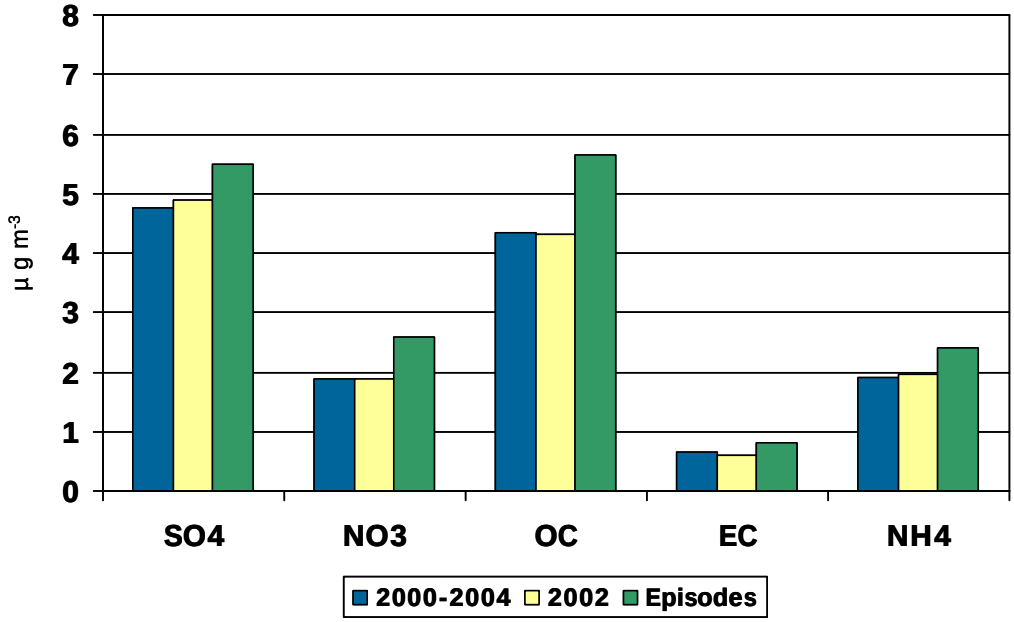
(a) Charlotte



(b) Chattanooga



(c) Louisville



(d) Macon

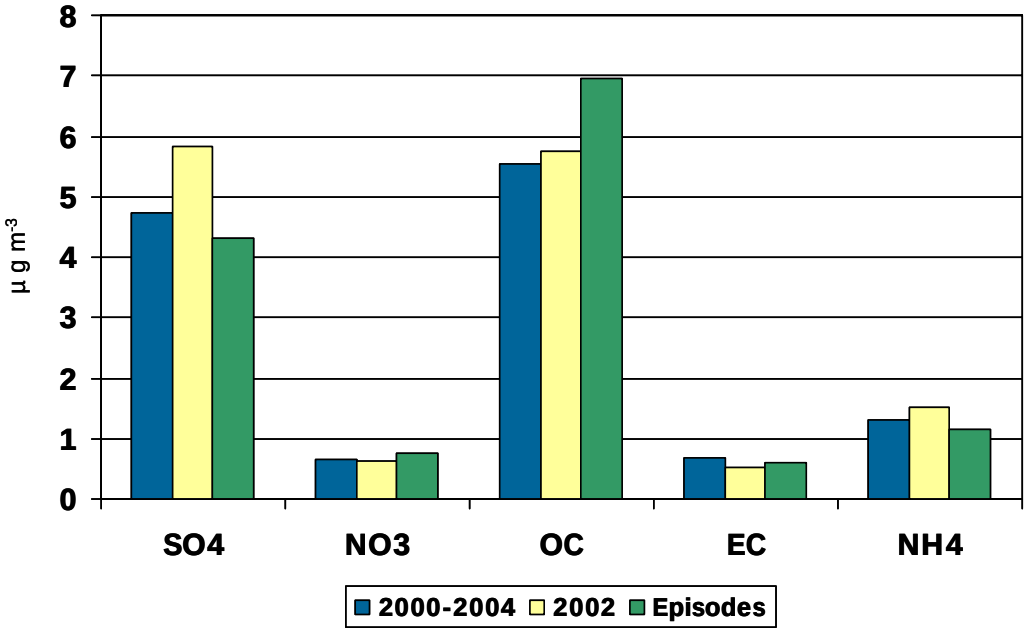
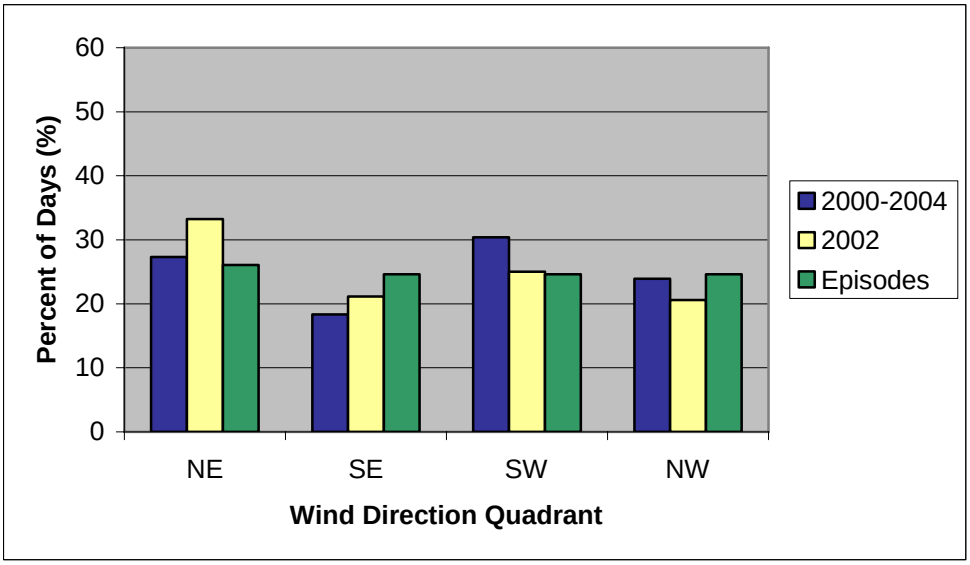
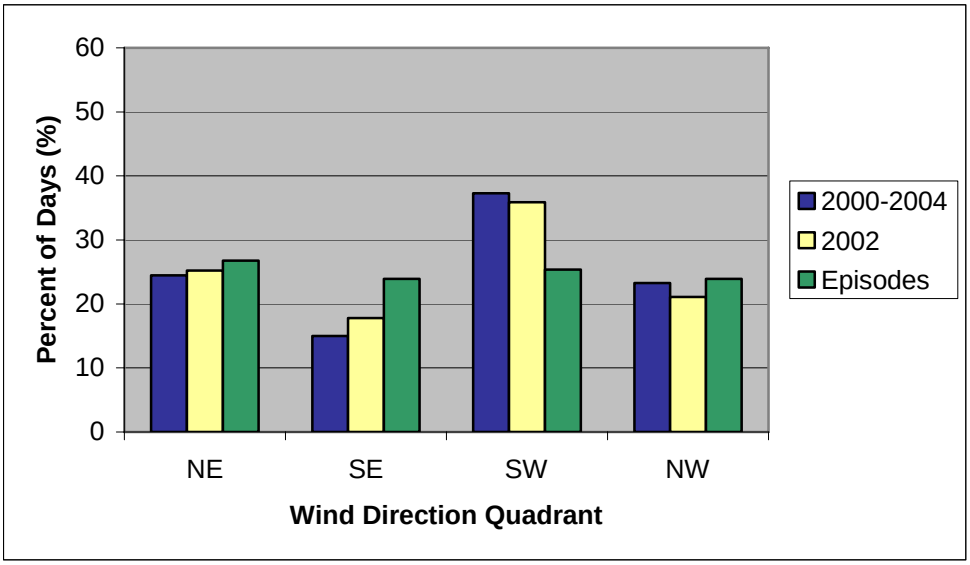


Figure 4-11. Distribution of Surface Wind Directions by Quadrant for 2000-2004, 2002, and 2002 VISTAS Episode Periods: STN Sites.

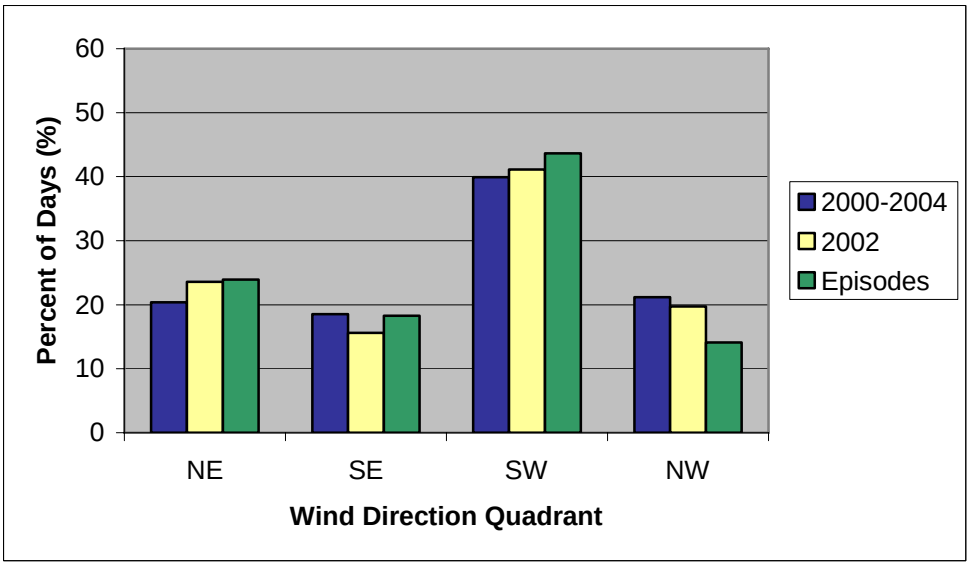
(a) Charlotte



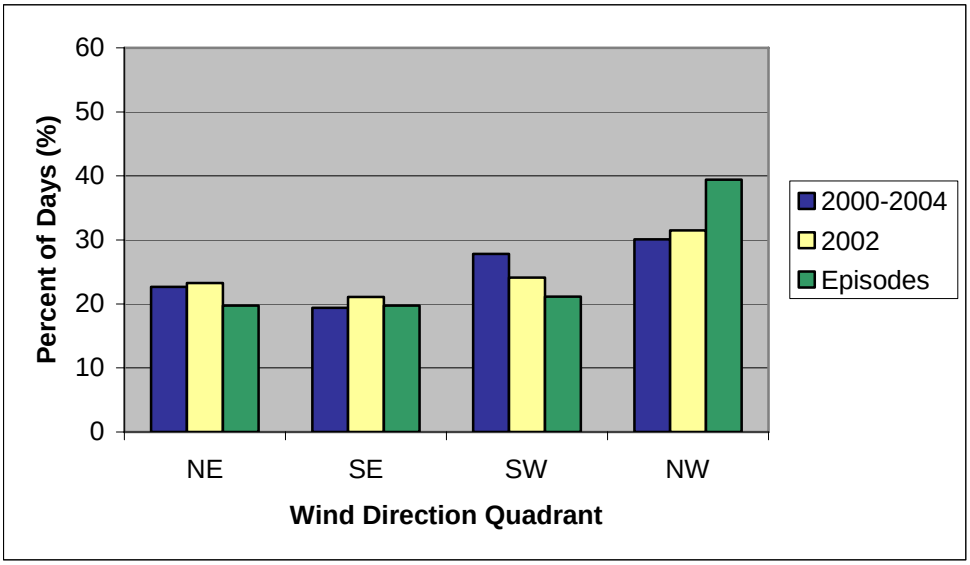
(b) Chattanooga



(c) Louisville



(d) Macon



Average concentrations for sulfate and organic carbon are higher for 2002, compared to the baseline period, and even higher for the episode periods for Charlotte (Figure 4-10a). There area also differences in the distribution of wind directions among the three periods (Figure 4-11a). Both 2002 and the episode periods show a lesser proportion of southwesterly winds than the baseline period. The 2002 annual period makes up for this with winds from the northeast, and the episodes make up for this with winds from the southeast.

For Chattanooga (Figure 4-10b), the episode periods have higher average species concentrations for sulfate, organic carbon, and, to some extent, nitrate and ammonium, than the longer periods. They are also characterized by a greater proportion of southeasterly and a less proportion of southwesterly winds than the longer periods (Figure 4-11b).

Similarly, for Louisville (Figure 4-10c), the episode periods have higher average species concentrations for all species than the longer periods. In this case, a lower fraction of the days have northwesterly winds (Figure 4-11c).

For Macon (Figure 4-10d), 2002 is characterized by higher average sulfate than the baseline period and the episode days have higher organic carbon concentrations than both 2002 and the full baseline period. The episode days have a greater percentage of days with northwesterly winds compared to the longer periods (Figure 4-11d). Differences in the wind direction distributions between 2002 and the full baseline period are relatively small.

SEARCH Sites

Table 4-6 summarizes and compares 2000-2004, 2002, and the combined episode periods for the STN sites. The summary metrics are the same as those for Table 4-2.

Table 4-6. Summary of $PM_{2.5}$ and Meteorological Characteristics for 2000-2004, 2002, and the 2002 VISTAS Episodic Analysis Periods: SEARCH Sites.

(a) Atlanta (Jefferson St.)

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	16.6	1.1 – 66.1		
2002	16.3	3.7 – 40.2	91.7	0.8
Episodes	17.2	5.0 – 40.2	91.7	3.0

(b) Yorkville

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	13.6	0.7 – 65.2		
2002	13.2	2.6 – 34.8	100	0.6
Episodes	13.6	3.8 – 34.8	91.7	1.9

(c) Birmingham

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	17.9	2.8 – 75.2		
2002	17.5	3.9 – 45.3	100	0.9
Episodes	18.5	5.5 – 41.2	90.9	3.0

(d) Centreville

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	12.9	1.2 – 54.4		
2002	13.1	2.9 – 48.6	91.7	1.4
Episodes	11.8	4.1 – 39.7	75	2.7

(e) Pensacola

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	12.8	1.2 – 52.5		
2002	13.2	3.3 – 40.7	100	1.4
Episodes	12.1	3.4 – 31.5	90.9	4.2

(f) Outlying Landing Field

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	11.8	0.7 – 130.9		
2002	11.3	2.3 – 38.3	100	1.8
Episodes	10.4	3.6 – 21.0	77.8	3.7

(g) Gulfport

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	11.4	0.3 – 44.0		
2002	11.4	2.8 – 31.9	100	1.3
Episodes	10.0	3.3 – 18.9	72.7	2.9

(h) Oak Grove

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	11.8	1.5 – 90.1		
2002	11.4	2.2 – 67.1	100	1.3
Episodes	10.1	3.0 – 27.5	63.6	2.3

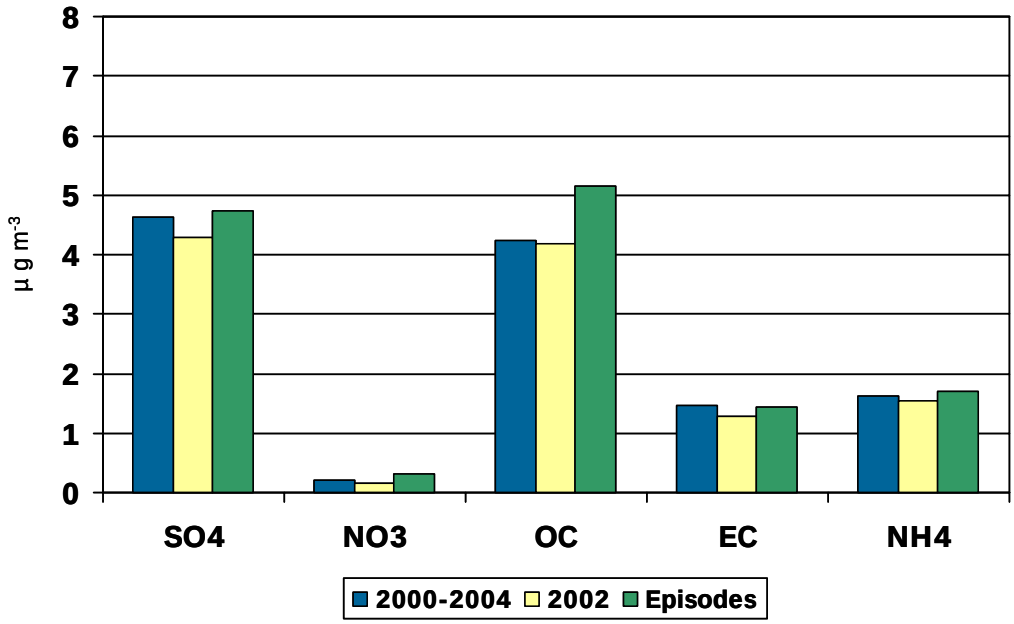
The weighted average $PM_{2.5}$ concentrations are quite similar for all three sets of dates, and the weighted average concentration for the episode days is within approximately 1 μgm^{-3} of the 2002 average value for all of the sites. The range in $PM_{2.5}$ concentration is similar for 2002 and

the episode days for the inland sites, but not for the coastal sites. Considering all sites, between 64 and 100 percent of the key bins are captured by the episode days. The distribution errors are larger for the episode periods, as the episodes do not necessarily sample the various types of days with the frequency that is typical of the longer periods.

Figure 4-12 compares the average concentration of the PM species for 2000-2004, 2002, and the combined episode periods for two of the SEARCH sites: Atlanta and Birmingham. Figure 4-13 examines and compares the distribution of surface wind direction, by wind direction quadrant, for the three sets of dates, for these same sites.

Figure 4-12. Comparison of Species Concentrations (μgm^{-3}) for Sulfate (SO4), Nitrate (NO3), Organic Carbon (OC), Elemental Carbon (EC) and Ammonium (NH4) for 2000-2004, 2002, and 2002 VISTAS Episode Periods: SEARCH Sites.

(a) Atlanta



(b) Birmingham

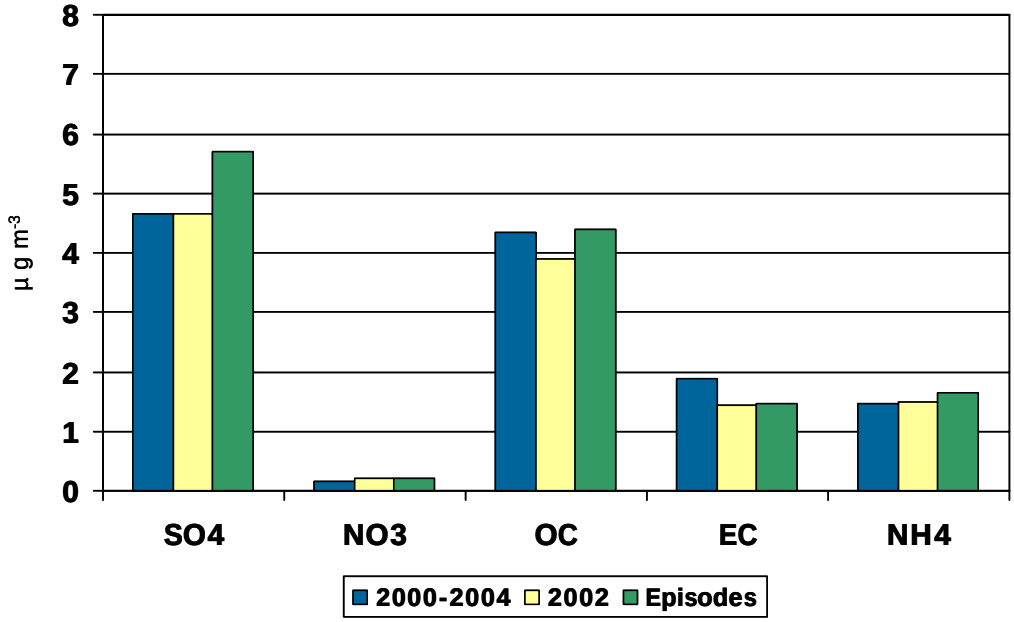
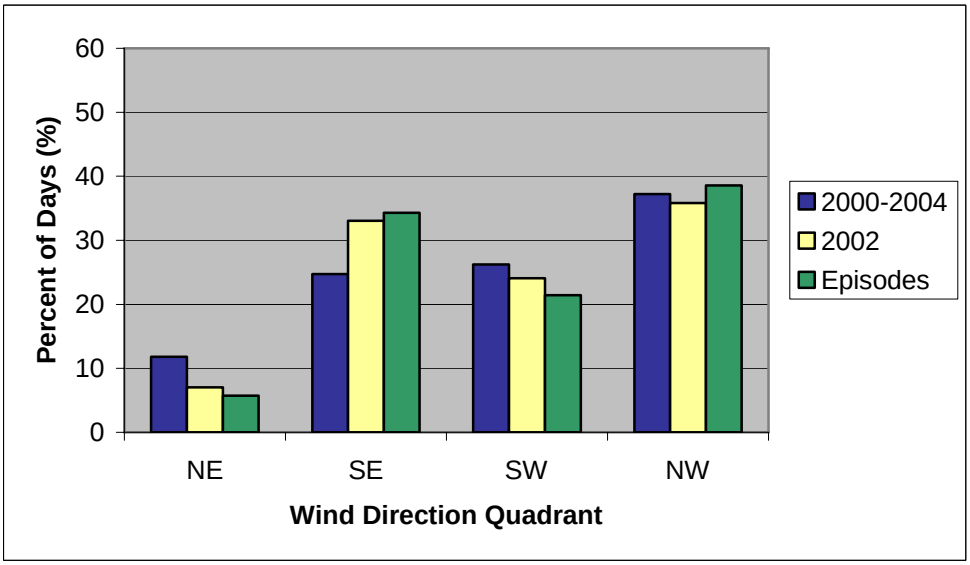
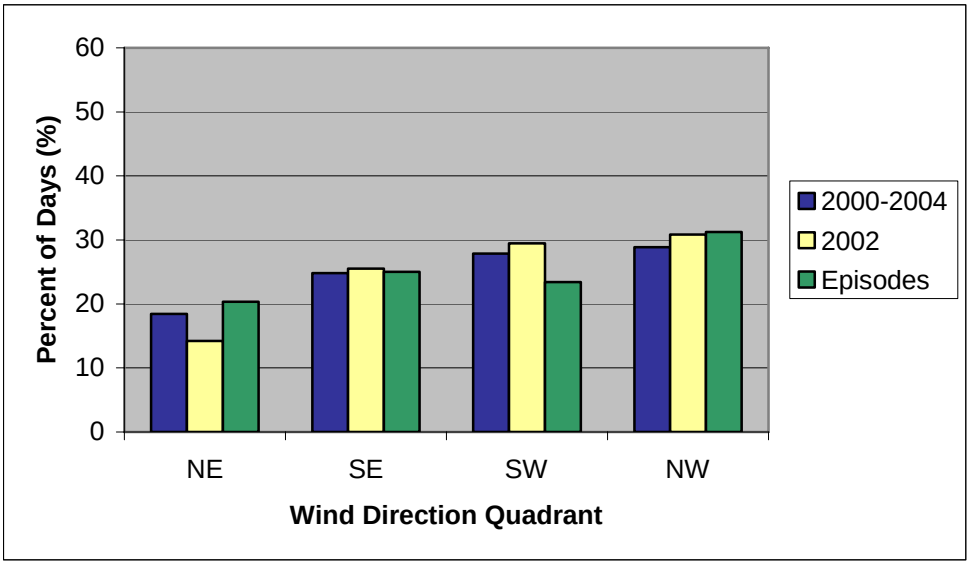


Figure 4-13. Distribution of Surface Wind Directions by Quadrant for 2000-2004, 2002, and 2002 VISTAS Episode Periods: SEARCH Sites.

(a) Atlanta



(b) Birmingham



For Atlanta (Figure 4-12a), the average concentrations for all species are very similar for 2002 and the full baseline period. The episode days are characterized by higher sulfate and organics than 2002. The plot of the distribution of wind directions (Figure 4-13a) shows that all three periods are similar with regard to the predominantly northwesterly winds, the distribution among the other three quadrants differs.

For Birmingham (Figure 4-12b), episodes have higher sulfate concentrations than both 2002 and the full baseline period. Organic carbon is lower than the baseline for 2002 and higher than the baseline for the episodes. The distribution of wind directions (Figure 4-13b) for 2002 and the full baseline period are fairly similar. The episode days have a higher percentage of days with northeasterly winds and a lower percentage of days with southwesterly winds than the longer periods.

4.4. Calculation of Meteorologically-Based Weighting Factors

The CART results and tool were also used in the calculation of weighting factors related to regional haze and $PM_{2.5}$ for the modeled days. The weighting factors are intended to be applied to the VISTAS atmospheric modeling results so that they can better represent the baseline period for the projection of future air quality related values. Weights were calculated for each site based on 1) similarities between the modeled days and the regulatory Best and Worst days (for regional haze) and 2) the frequency of occurrence of the conditions associated with the modeled days during the 2000-2004 baseline period (for regional haze and $PM_{2.5}$). Additional detail on the calculation of the weighting factors is provided below.

The weighting factors for the modeled days can be used to weight each day's contribution to the average relative reduction factor that is used to estimate future year air quality. There are a number of different ways in which the weighting factors can be used. For illustrative purposes, we provide a simple example. Consider the quarterly relative reduction factor (RRF) for a species, which is defined as the ratio of the quarterly average future-year to base-year

simulated species concentration. Assume that the quarterly average value is based on two modeled days.

The unweighted RRF is equal to $(C1_f + C2_f)/(C1_b + C2_b)$ where C1 and C2 are the simulated concentrations for days 1 and 2, and the subscripts f and b refer to the future and base scenarios.

If the days are assigned weighting factors of w1 and w2, the weighted RRF becomes $(w1 \cdot C1_f + w2 \cdot C2_f)/(w1 \cdot C1_b + w2 \cdot C2_b)$.

The weighting factors are available in Excel format.

4.4.1. Annual Weighting Factors for Regional Haze

Two approaches were used to calculate the weighting factors for regional haze. Both relied on the identification of the 20 percent "Best" and "Worst" visibility days for the period 2000-2004, using the IMPROVE methodology in which extinction coefficient is calculated as discussed in Section 2 of this report but using a monthly average f(rh) rather than a daily f(rh), as applied in this study. Only days with data were considered eligible for weighting. Days with data that are similar to one or more of the IMPROVE-method Best or Worst days (also referred to as the regulatory Best and Worst days) were assigned weighting factors. A day was considered to be similar to a Best or Worst day if it was assigned to the same CART bin as a Best or Worst day. Weighting factors were calculated separately for Best days and Worst days, and the set of days representing Best days is mutually exclusive from the set of days representing Worst days.

In the first approach, a weighting factor was assigned to each similar day based on both the overall frequency of occurrence of meteorological conditions (the total number of days in the CART bin) as well as the number of regulatory Best or Worst days in each bin.

In the second approach, the weighting factors were based only on the number of Best or Worst days in each bin.

Meteorological Frequency and Best/Worst Based Weighting Factors

We calculated weighting factors for each of the 21 IMPROVE sites for all 2002 dates for which there were valid visibility data for the site in question. Weighting factors for use in the Best days and Worst days assessments were calculated separately.

In calculating the weighting factors, we relied on the CART analysis results and used the bins and the number of days within each bin to define the meteorological and air quality conditions and their frequency of occurrence. Weights were assigned to each bin based on the total number of days in the bin and the number of Best (or Worst) days in the bin from a list of the 20% Best (B) (or 20% Worst (W)) days provided by VISTAS. The process consists of seven steps, as follows:

1) Each CART bin containing one or more B (or W) days is identified and the number of B (or W) days in the bin is counted (#B (or #W)).

2) Each CART bin is assigned a weight equal to the total number of days in the bin divided by the total number of days included in the CART analysis (T/TT).

3) Each CART bin containing one or more B (or W) day is assigned a second weighting factor equal to #B (or #W) divided by the total number of B (or W) days included in the analysis (B/TB (or W/TW)).

4) Each bin containing one or more of the selected days is identified and a bin weight (binwt) is calculated as the product of the two weighting factors above, T/TT and B/TB (or W/TW), divided by the sum of each term over all bins represented by one or more selected days.

5) Binwt is then normalized to account for unrepresented bins, giving an adjusted bin weight (adjbinwt). For all bins containing at least one B (or W) day and at least one selected day, adjbinwt sums to 1.

6) Adjbinwt is divided by the number of selected days within each bin to give the final weighting factor for that bin (Day Wt).

7) Day Wt is assigned to the relevant dates based on each date's bin classification.

Days were only assigned weights if the extinction coefficients were within the ranges appropriate to the Best or Worst classification categories. For the Best days, these are Categories 1 and 2 (Category 1 represents the 20 percent best days using daily extinction and f(rh) values; Category 2 was also considered). For the Worst days, these are Categories 3, 4, and 5 (Categories 4 and 5 combined represent the 20 percent worst days using daily extinction and f(rh) values and Category 3 is the neighboring category). For bins containing both B and W days, certain days were assigned factors to represent Best days and other days were assigned factors to represent Worst days.

The weighting factors accommodate the use of more than just the Best and Worst days in the future projection of regional haze by including similar days to the Best and Worst days in the calculations. The weighting factors for the Best and Worst days only provide an improved representation of the frequency of occurrence of the conditions associated with the Best and Worst days, considering the full baseline period.

Best/Worst Only Based Weighting Factors

This is a simplified version of the approach described in the previous section. It considers only the number of Best or Worst days in a bin. Again, we calculated weighting factors for each of the 21 IMPROVE sites for all 2002 dates for which there were valid visibility data for the site in question. Weighting factors for use in the Best days and Worst days assessments were calculated separately

In calculating the weighting factors, we relied on the CART analysis results to identify days with similar conditions to the regulatory Best and Worst days. Weights were assigned to each bin based on the number of B (or W) days in the bin from a list of the 20% Best (B) (or 20% Worst (W)) days provided by VISTAS. The process consists of five steps, as follows:

1) Each CART bin containing one or more B (or W) days is identified and the number of B (or W) days in the bin is counted (#B (or #W)).

2) Each CART bin containing one or more B (or W) day and one or more of the selected days is assigned a weight (binwt) equal to #B (or #W) divided by the total number of B (or W) days included in the analysis (B/TB (or W/TW)).

3) Binwt is then normalized to account for unrepresented bins, giving an adjusted bin weight (adjbinwt). For all bins containing at least one B (or W) day and at least one selected day, adjbinwt sums to 1.

4) Adjbinwt is divided by the number of selected days within each bin to give the final weighting factor for that bin (Day Wt).

5) Day Wt is assigned to the relevant dates based on each date's bin classification.

As for the first approach, days were only assigned weights if the extinction coefficients were within the ranges appropriate to the Best or Worst classification categories.

The weighting factors accommodate the use of more than just the Best and Worst days in the future projection of regional haze by including similar days to the Best and Worst days in the calculations. These weighting factors take into account the number of Best and Worst days in a bin, however, they do not account for the overall frequency of occurrence of the conditions associated with the Best and Worst days, considering the full baseline period.

4.4.2. Episodic Weighting Factors for PM2.5

For $PM_{2.5}$, weighting factors were calculated for each day of the two subset episode periods 1 June – 10 July and 19 November – 19 December, 2002, and for each STN and SEARCH site. These factors were based on the frequency of occurrence of the air quality/meteorological conditions represented by the episode day (based on the total number of days in the CART bin to which the day is assigned). All episode days with data were considered eligible for weighting.

In calculating the weighting factors, we relied on the CART analysis results and used the bins and the number of days within each bin to define the meteorological and air quality conditions and their frequency of occurrence. Weights were assigned to each bin based on the total number of days in the bin. The process consists of four steps, as follows:

1) Each CART bin containing one or more of the episode days is assigned a weight (binwt) equal to the total number of days in the bin divided by the total number of days included in the CART analysis (T/TT).

2) Binwt is normalized to account for unrepresented bins, giving an adjusted bin weight (adjbinwt). For all bins containing at least one episode day, adjbinwt sums to 1.

3) Adjbinwt for each bin is divided by the number of episode days within the bin to give the final weighting factor for that bin (Day Wt).

4) Day Wt is assigned to the episode dates based on each date's bin classification.

The weighting factors are expected to provide an improved representation of the frequency of occurrence of the conditions associated with the full baseline period.

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5. Key Findings and Implications for VISTAS Air Quality Modeling

The CART results provide insight into the relationships between meteorology, $PM_{2.5}$, and visibility that are important to atmospheric modeling. Some key findings are summarized in this section.

CART Application

The application of CART included several sensitivity tests involving variations to the input dataset. Comparison of the results from the application of CART with and without $PM_{2.5}$ input data demonstrates that including $PM_{2.5}$ is important to classification accuracy. This result indicates that regional buildup and transport of fine particles and related precursor species influences regional visibility and $PM_{2.5}$ concentrations. Overall, better classification accuracy for $PM_{2.5}$, compared to extinction coefficient, especially for the IMPROVE sites, indicates that the relationships between the input parameters and the characteristic parameter are better defined for $PM_{2.5}$ at these sites. This is possibly due the more complex role of moisture in determining light extinction – affecting both particle formation and the contribution of sulfate and nitrate particle species to light extinction. For both visibility and $PM_{2.5}$, moisture is an important input to CART, and some information about moisture is needed in order to achieve good classification. We found daily average relative humidity to be the most effective form of the moisture parameter.

Parameter Importance

The CART results indicate that temperature, wind speed, and relative humidity are key meteorological parameters that distinguish days with different fine particle mass and visibility values in the southeastern U.S. Considering visibility for the IMPROVE sites, the most important parameters include: relative humidity, prior day $PM_{2.5}$ concentrations at potential upwind monitoring sites, 850 mb temperature, surface temperature (reflecting seasonal differences), and wind speed (both near the surface and aloft). For $PM_{2.5}$ relative humidity is less important, but the list of important parameters is similar. One key difference when comparing parameter importance for the inland, coastal, and mountain sites is that relative humidity and persistence (which, for coastal sites, represents a sea or gulf breeze) are more important for the coastal sites, compared to the inland and mountain sites. The temperature parameters are most important for the mountain sites. Wind directions are not used frequently enough in the CART trees to be considered important parameters to the overall classification, but they are often used near the end of the CART pathways to distinguish poor visibility and high $PM_{2.5}$ days.

For $PM_{2.5}$ for the STN and SEARCH sites, the most important parameters include: prior day $PM_{2.5}$ concentrations, 850 mb temperature, surface temperature, and wind speed (both near the surface and aloft). Relative humidity is also important for the coastal SEARCH sites.

These results vary by site, although, there are similarities among the sites within similar geographical features. An assessment of the meteorological inputs for air quality modeling should emphasize good representation of these key parameters.

Site Groupings

The CART-derived parameter importance results were used to examine potential site groupings. We identified similarities in the important parameters for the analysis sites and attributed these to similarities in the mechanisms influencing air quality at these sites. In general, the CART-derived groupings, which are based on parameter importance, are also supported by similarities in location and geography. The groupings for the IMPROVE sites are different for visibility versus $PM_{2.5}$. These groupings may provide the basis for assessing model performance and

understanding the reasons for model performance problems. The grouping may also aid the interpretation of differences in the effectiveness of air quality measures across the monitoring sites and regions.

CART Classification Results

CART also provides insight into the types of conditions that, based on their frequency of occurrence over a multi-year period, should be represented in an assessment of air quality responses to emissions changes. Poor visibility and high $PM_{2.5}$ days are grouped into bins that are characterized by different meteorological and prior-day air quality conditions. While there are similarities in the conditions that describe the key (most populated) bins, there are also some important differences that relate directly to source-receptor relationships and potentially control strategy effectiveness.

One of the more notable differences among the key poor visibility and high $PM_{2.5}$ bins is wind direction, especially surface wind direction. Wind direction, however, does not have a high parameter importance ranking. For many of the cases we examined, this is primarily because wind direction was used in the outermost (lowest) branches of the CART tree, such that days with similar features in many respects were separated into different bins (characterized by different extinction or $PM_{2.5}$ values) according to wind direction. Thus, wind direction can be important, but only in differentiating a small number of days. For several sites, large differences in average temperature among the key bins indicate that the regimes vary with season. Other differences include prior day $PM_{2.5}$ concentration, relative humidity, stability, and degree of persistence (indicating a sea or gulf breeze) for the coastal sites. The differences in the individual parameters combine to represent the different regimes, and there are multiple regimes associated with poor visibility and high $PM_{2.5}$ for all of the areas of interest. The differences among the key bins emphasize the need to include days that represent the different types of meteorological conditions that accompany poor visibility and high PM events in any model-based air quality planning exercise.

The CART analyses also provide insight into $PM_{2.5}$ composition for different (key) types of poor visibility days and high $PM_{2.5}$ days. In general, analysis of the compositional characteristics for the key bins for the 20 percent haziest days for the IMPROVE sites within the VISTAS region indicates that, on average, ammonium sulfate and organic carbon are the two most important contributors to poor visibility and that their relative contributions vary by site, by bin, and with meteorology. For the inland IMPROVE sites, ammonium sulfate is the dominant contributor. For the coastal IMPROVE sites the contributions from ammonium sulfate and organic carbon on the poor visibility days are more comparable than at the interior sites. As for visibility, the high $PM_{2.5}$ concentration bins are distinguished from the lower concentration bins by higher sulfate and organic matter concentrations.

The STN compositional charts show a much larger proportional contribution from organic matter compared to those for the IMPROVE sites, especially for the higher $PM_{2.5}$ bins. This is in part due to differences between the IMPROVE and STN measurement techniques for organic carbon. With the higher values for organics, the dominant species varies by bin, much more so than for the IMPROVE sites. These variations are attributable to differences in meteorology as well as regional pollutant transport.

The compositional charts for the $PM_{2.5}$ for the SEARCH sites also show a much larger proportional contribution from organics than the IMPROVE charts, especially for the higher

$PM_{2.5}$ bins. The relative ranking of the species contributions is similar to that for the STN sites. A comparison of the compositional averages for Birmingham using the STN and SEARCH data, shows that the organic matter and overall $PM_{2.5}$ values are higher in the STN data, but that the tendency for organic matter to be the dominant species appears in both sets of results for the more urban sites.

Simulation Period Representativeness

The 2002 annual simulation period includes days that capture the general meteorological characteristics associated with a range of visibility at the IMPROVE sites and represents well the typical frequency of occurrence of these conditions. However, somewhat lower than average concentrations and average extinction coefficients characterize 2002 for some sites. $PM_{2.5}$ values for the STN and SEARCH sites are also lower than average compared to other years within the baseline period. There is no apparent trend in the meteorologically adjusted (weighted average) annual average values of $PM_{2.5}$ for the STN and SEARCH sites.

While it is not expected that any single year will be typical or representative for all areas of the Class I and urban areas of interest, the CART results enhance the understanding of how well the 2002 simulation period represents each area and this will allow VISTAS to use and interpret their air quality modeling results appropriately.

Two subset episode periods from 2002, comprising a total of 71 days, were selected to represent the conditions and concentration levels associated with high $PM_{2.5}$ events in as many areas as possible throughout the VISTAS region. These include a summer episode (1 June – 10 July) and a winter episode (19 November – 19 December, 2002). For many of the sites, the summer period includes the peak days for 2002. As expected, the episode periods, do not include days from all of the key bins for all sites. Considering all sites, between approximately 40 and 100 percent of the key bins are included by the episode days – this varies by site. The distribution errors are larger for the episode periods, compared to the annual periods, indicating that the episodes do not sample the different regimes with the frequency that is typical of the longer periods.

Weighting Factors

The CART results and tool were also used in the calculation of weighting factors for both regional haze and $PM_{2.5}$ for the annual and episodic modeled days. The weighting factors were intended to improve the ability of the modeling results for 2002 and the subset periods to represent the full baseline period. The weighting factors for regional haze were calculated based on similarities between the modeled days and the regulatory 20% Best and 20% Worst days and the frequency of occurrence of the conditions associated with the modeled days during the 2000-2004 baseline period. The weighting factors for $PM_{2.5}$ were based on the frequency of occurrence of the meteorological conditions.

The weighting factors are intended to be applied to the VISTAS atmospheric modeling results so that they can better represent the baseline period for the projection of future air quality related values. In this manner, application of CART has improved the understanding of the conditions contributing to elevated $PM_{2.5}$ and poor visibility in the southeastern states and has provided the basis for the enhanced analysis and interpretation of atmospheric modeling results.

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Appendix: Comparison of Results for the STN and SEARCH Birmingham Sites

Two CART analyses were conducted for Birmingham. Both analyses used $PM_{2.5}$ data for the North Birmingham monitoring site. For the first analysis, the $PM_{2.5}$ data were based on STN measurements and the surface meteorological inputs were based on data from the nearby NWS monitoring site. For the second analysis, the SEARCH data were used to prescribe both the $PM_{2.5}$ and surface meteorological inputs. In both cases, upper-air meteorological data from the nearby NWS measurement site were used. $PM_{2.5}$ data are available for both sites for the entire 2000-2004 period. The analysis using the SEARCH data includes one additional year of speciated data (for the year 2000). In this appendix, we compare the results and inferences for the two Birmingham analyses for $PM_{2.5}$.

Comparative Analysis

CART classification accuracy for $PM_{2.5}$ is very similar for the two analyses—78.5 percent for the STN analysis and 77.1 percent for the SEARCH analysis. The relative importance of the input parameters in constructing the CART classification tree is also very similar for the two analyses, as displayed in Figures A-1 and A-2. Prior-day PM concentrations, surface wind speed, prior-day 700 mb wind speed, relative humidity, and stability are, in order, the five most important parameters for the STN analysis. These same five parameters along with 850 mb wind speed are most important for the SEARCH analysis. The order of importance is roughly the same, with 850 mb wind speed surpassing relative humidity in relative importance for the SEARCH analysis.

Figure A-1. Parameter Importance for the CART $PM_{2.5}$ Analysis: Birmingham STN Site.

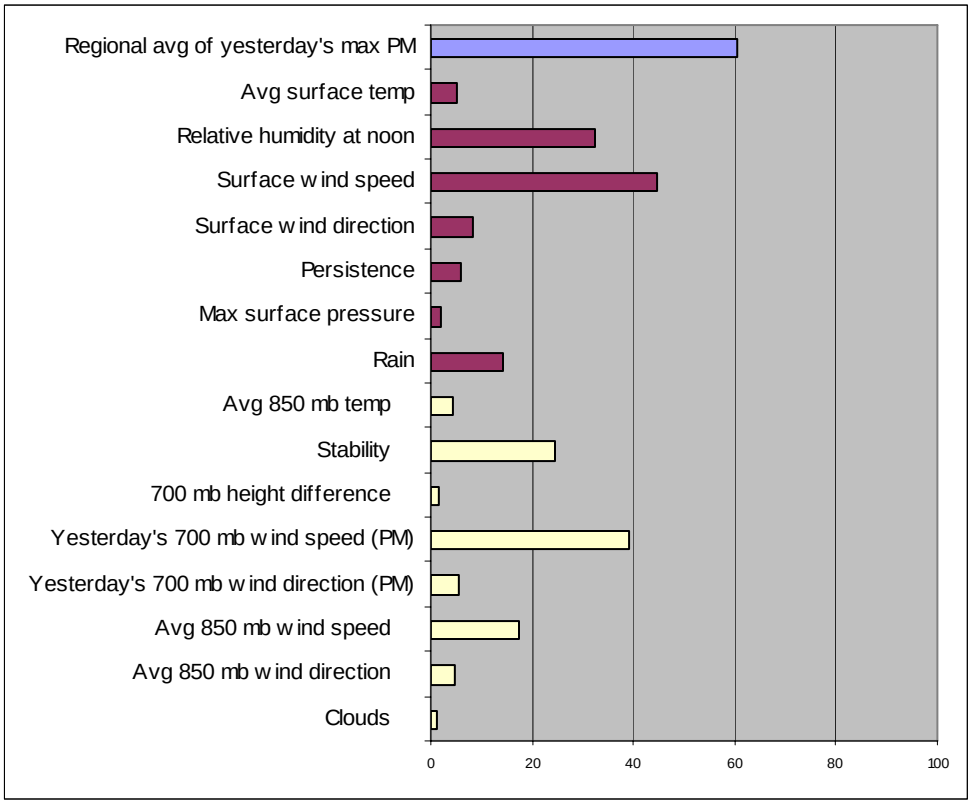
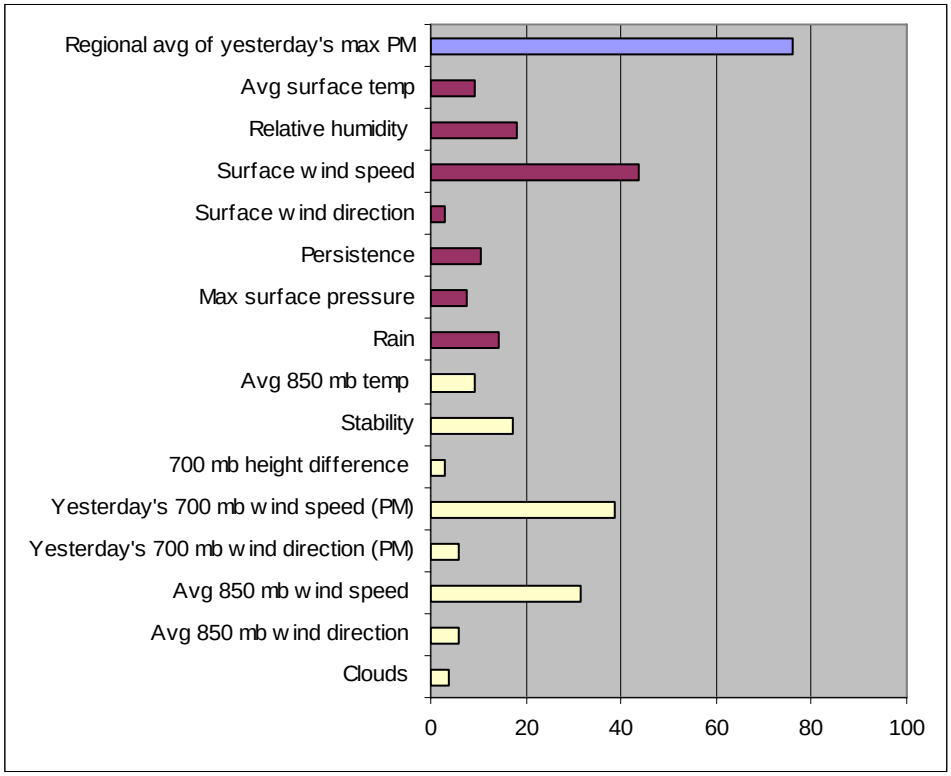


Figure A-2. Parameter Importance for the CART $PM_{2.5}$ Analysis: Birmingham SEARCH Site.



A more detailed look at the CART classification trees confirms that analysis results are similar, with respect to the conditions leading to high $PM_{2.5}$ and, in CART terms, the high $PM_{2.5}$ classification bins. However, the CART tree developed using the SEARCH data has more bins than that developed using the STN data (32 versus 26).

The CART input data for the two analyses are summarized in Tables A-1 and A-2. These tables present the average value of each input parameter for each $PM_{2.5}$ classification category for the Birmingham STN and SEARCH datasets. The four $PM_{2.5}$ categories are defined by the 70, 90, and 97 percentile values of $PM_{2.5}$ mass, which are slightly different for the two sites. For the STN site, the ranges for Categories 1 through 4 are <22.5, 22.5-32.5, 32.5-40 and $\geq$ 40 μgm^{-3}. For the SEARCH site, the ranges are <20, 20-30, 30-37.5 and $\geq$ 37.5 μgm^{-3}.

Table A-1. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the Birmingham STN Site.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <22.5, 22.5-32.5, 32.5-40 and ≥ 40 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	16.8	25.2	29.9	40.5
Yesterday's FM at Atlanta (μg/m³)	16.9	22.1	24.8	31.1
Yesterday's FM at Memphis (μg/m³)	12.9	17.7	19.8	25.1
Yesterday's FM at Nashville (μg/m³)	13.3	18.5	20.9	24.7
Surface Meteorological Parameters				
Max. surface temperature (°C)	20.9	25.9	27.2	29.0
Min. surface temperature (°C)	10.9	14.0	14.4	15.2
Relative humidity (%)	70.4	66.5	63.4	62.3
Surface wind speed (ms^{-1})	2.5	1.5	1.2	0.9
Surface wind direction (degrees)	279	79	87	11
Persistence	0.8	0.8	0.7	0.7
Sea level pressure (mb)	1021	1021	1021	1022
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	1.0	0.6	0.3	0.1
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	10.2	12.9	13.6	14.3
Temperature PM 850 mb (°C)	10.2	13.8	14.3	15.2
Stability at Birmingham (°C)	-0.1	2.1	2.9	4.1
Geopotential height difference 700 mb at Birmingham (m)	-1.2	5.3	0.6	2.8
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	12.7	8.1	7.9	6.0
Wind direction yesterday 700 mb at Birmingham (degrees)	265	302	322	339
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	8.9	5.6	5.0	3.9
Wind speed AM 850 mb at Birmingham (ms^{-1})	10.2	6.3	5.8	4.3
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.9	5.9	5.5	3.7
Wind direction yesterday 850 mb at Birmingham (degrees)	255	345	10	32
Wind direction AM 850 mb at Birmingham (degrees)	264	261	258	284
Wind direction PM 850 mb at Birmingham (degrees)	271	238	90	315
Recirculation at Birmingham	0.0	0.1	0.1	0.3
Cloud average	1.8	1.6	1.6	1.6

Table A-2. Summary of Average Input Parameters for Each CART Classification Category: $PM_{2.5}$ CART Analysis for the Birmingham SEARCH Site.

The ranges in PM2.5 for Categories 1 through 4 are as follows: <20, 20-30, 30-37.5 and ≥ 37.5 μgm-3.

	Category 1	Category 2	Category 3	Category 4
$PM_{2.5}$ Parameters				
Yesterday's FM at Birmingham (μg/m³)	16.5	24.1	29.5	38.2
Yesterday's FM at Atlanta (μg/m³)	16.7	21.6	23.7	30.8
Yesterday's FM at Memphis (μg/m³)	12.7	17.0	19.9	23.3
Yesterday's FM at Nashville (μg/m³)	13.2	17.5	20.6	23.4
Surface Meteorological Parameters				
Max. surface temperature (°C)	21.6	26.0	27.5	28.4
Min. surface temperature (°C)	11.5	14.3	13.9	14.7
Relative humidity (%)	70.9	66.4	63.0	62.3
Surface wind speed (ms^{-1})	1.8	1.3	1.0	0.8
Surface wind direction (degrees)	247	73	18	345
Persistence	0.8	0.8	0.7	0.7
Station pressure (mb)	998	998	998	1000
Rainfall (inches)	0.2	0.1	0.0	0.0
Rain (# periods)	1.0	0.6	0.4	0.3
Upper-Air Meteorological Parameters				
Temperature AM 850 mb (°C)	10.2	12.5	13.0	13.9
Temperature PM 850 mb (°C)	10.3	13.2	13.9	14.7
Stability at Birmingham (°C)	-0.3	2.1	3.1	3.5
Geopotential height difference 700 mb at Birmingham (m)	-1.7	5.2	2.3	5.1
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	12.8	8.7	7.7	6.9
Wind direction yesterday 700 mb at Birmingham (degrees)	265	298	307	329
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	9.1	5.9	4.6	4.5
Wind speed AM 850 mb at Birmingham (ms^{-1})	10.3	6.6	5.6	5.0
Wind speed PM 850 mb at Birmingham (ms^{-1})	8.9	6.3	5.5	4.3
Wind direction yesterday 850 mb at Birmingham (degrees)	252	345	349	14
Wind direction AM 850 mb at Birmingham (degrees)	264	251	283	243
Wind direction PM 850 mb at Birmingham (degrees)	273	219	321	270
Recirculation at Birmingham	0.02	0.08	0.13	0.28
Cloud average	1.8	1.6	1.6	1.5

The values and variations in the $PM_{2.5}$ related parameters among the classification categories are very similar for the two datasets.

The surface meteorological parameters are also very similar, with some exceptions for the surface wind directions. For the STN analysis, the Category 3 surface wind directions are easterly, on average. For the SEARCH analysis, they are north-northeasterly. For the STN analysis, the Category 4 surface wind directions are north-northeasterly, on average. For the SEARCH analysis, they are north-northwesterly. In both cases, the surface winds have a northerly component on the highest $PM_{2.5}$ days. The westerly component is more pronounced in the SEARCH data summary.

The average values and tendencies for the upper-air parameters are also very similar, with the exception of the 850 mb wind directions for the two highest categories. Again the SEARCH data summary shows a more pronounce westerly component at higher concentrations, especially at the

time of the evening sounding. The greater differences for wind direction compared to other parameters may be due, in part, to the uncertainties inherent in calculating an average wind direction (if the wind directions included in the averaging vary considerably, the average may not be very meaningful).

From both analyses, we can summarize that high $PM_{2.5}$ for Birmingham is associated with high temperatures, high $PM_{2.5}$ on the previous day (local & potentially upwind sites), very low wind speeds near the surface and low wind speeds aloft, westerly wind components aloft and northerly wind components near the surface, and stable lapse rates.

Table A-3 compares the characteristics of key high $PM_{2.5}$ bins (Category 4) for the Birmingham STN and SEARCH analyses. Key bins are those containing the greatest number of correctly classified days. For ease of comparison, we focused on the key Category 4 bins (which contain subsets of the days with the highest concentrations). There are two key bins for the STN analysis, and three key bins for the SEARCH analysis. Due to different units between the two analyses, the row containing surface pressure was omitted from the combined table.

Table A-3. Summary of Average Input Parameters for Key Bins for CART Classification Category 4: $PM_{2.5}$ CART Analysis for Birmingham.

The ranges in PM2.5 for Category 4 are ≥37.5 and ≥40 μgm-3 for the STN and SEARCH analyses, respectively.

	STN		SEARCH		
	Bin 19	Bin 10	Bin 25	Bin 20	Bin 24
$PM_{2.5}$ Parameters					
Yesterday's FM at Birmingham (μg/m³)	50.7	32.4	51.1	33.1	35.8
Yesterday's FM at Atlanta (μg/m³)	37.6	25.6	39.3	23.5	25.5
Yesterday's FM at Memphis (μg/m³)	28.3	22.2	27.8	18.2	20.8
Yesterday's FM at Nashville (μg/m³)	27.7	19.5	28.9	18.7	17.9
Surface Meteorological Parameters					
Max. surface temperature (°C)	28.3	29.6	28.7	23.7	30.4
Min. surface temperature (°C)	14.5	14.6	14.0	10.2	15.9
Relative humidity (%)	63.1	61.6	58.6	64.8	58.4
Surface wind speed (ms^{-1})	0.7	0.3	0.5	0.5	0.7
Surface wind direction (degrees)	342	112	344	27	180
Persistence	0.8	0.5	0.7	0.6	0.7
Rainfall (inches)	0.0	0.0	0.0	0.0	0.0
Rain (# periods)	0.1	0.2	0.0	0.2	0.1
Upper-Air Meteorological Parameters					
Temperature AM 850 mb (°C)	13.6	14.6	13.5	11.3	15.0
Temperature PM 850 mb (°C)	14.4	15.9	14.1	12.3	15.9
Stability at Birmingham (°C)	4.5	4.0	4.6	2.9	4.3
Geopotential height difference 700 mb at Birmingham (m)	1.3	5.9	0.8	-14.7	30.1
Wind speed yesterday 700 mb at Birmingham (ms^{-1})	5.8	6.0	4.7	9.0	6.8
Wind direction yesterday 700 mb at Birmingham (degrees)	34	22	354	63	338
Wind speed yesterday 850 mb at Birmingham (ms^{-1})	3.6	4.5	2.9	7.0	2.8
Wind speed AM 850 mb at Birmingham (ms^{-1})	3.7	4.0	3.7	6.1	4.2
Wind speed PM 850 mb at Birmingham (ms^{-1})	2.9	3.2	2.9	4.9	3.7
Wind direction yesterday 850 mb at Birmingham (degrees)	34	22	37	27	90
Wind direction AM 850 mb at Birmingham (degrees)	270	45	270	180	270
Wind direction PM 850 mb at Birmingham (degrees)	270	180	360	207	243
Recirculation at Birmingham	0.4	0.2	0.5	0.0	0.4
Cloud average	1.5	1.5	1.4	1.6	1.6

For the STN analysis, the $PM_{2.5}$ concentration for Category 4 is greater than or equal to 40 μgm^{-3}. Bin 19 is distinguished by a much higher prior-day value $PM_{2.5}$ concentration than Bin 10. The temperature and humidity characteristics of the two bins are similar. Both key bins are characterized by very low surface wind speeds, but different surface wind directions. Surface winds are southeasterly for Bin 10 and northwesterly for Bin 19. Upper-level wind speeds are lower (slightly) for Bin 19. Upper-level wind directions are northeasterly to southerly for Bin 10, and primarily westerly (on the current day) for Bin 19.

For the SEARCH analysis, the $PM_{2.5}$ concentration for Category 4 is greater than or equal to 37.5 μgm^{-3}. Bin 25 is distinguished by a much higher prior-day value $PM_{2.5}$ concentration, and in this regard is similar to Bin 19 from the STN analysis. Bin 20 is distinguished by lower temperatures and slightly higher relative humidity than the other two SEARCH Category 4 bins. All three key bins are characterized by very low surface wind speeds, but surface wind directions differ among the three bins. Surface winds are northeasterly for Bin 20, southerly for Bin 24, and northwesterly for Bin 25. Upper-level wind speeds are lowest (in general) for Bin 25 and highest for Bin 20. Upper-level winds (current day) are southerly to southwesterly for Bin 20, westerly to southwesterly for Bin 24 and westerly to northerly for Bin 25.

If we compare the STN and SEARCH results, we find that Bin 19 from the STN analysis is similar in many respects to Bin 25 from the SEARCH analysis. Key similarities (that also distinguish these bins from other Category 4 bins within their respective analyses) include very high $PM_{2.5}$ concentration on the prior day, northwesterly surface winds, low wind speeds aloft, and a transition from northeasterly to westerly winds aloft from the prior day to the morning of the current day. Bin 10 from the STN analysis has some features in common with Bin 20 of the SEARCH analysis and some features in common with Bin 24 of the SEARCH analysis. For example, Bins 10 (STN) and 24 (SEARCH) both have, on average, southerly wind components aloft during the afternoon hours of the current day. In some cases, the combined characteristics of SEARCH Bins 20 and 24 seem to represent Bin 10 (STN). For example, the surface wind directions for SEARCH Bins 20 and 24 (northeasterly and southerly) when combined give a resultant wind direction similar to that for STN Bin 10 (southeasterly). It is interesting that for all of the Category 4 bins for both analyses, the prior-day 850 mb winds are from the northeast.

In summary, both CART analyses separate the days with very high prior-day concentrations and northwesterly to northerly winds from the remaining Category 4 days. The analysis using the SEARCH data appears to further divide the remaining days into two groups that are distinguished by temperature, relative humidity, surface and upper-air wind directions, and upper-air wind speeds. We have not explored the reasons for this additional and apparently meaningful segregation, but possible reasons include use of collocated surface meteorological data (for the SEARCH analysis) or that differences between the measurement techniques lead to the identification of different relationships between the $PM_{2.5}$ values and the other input parameters.

As part of our analysis, we also examined $PM_{2.5}$ composition for key bins corresponding to each Birmingham analysis. Figures A-3 and A-4 show the average composition for all key $PM_{2.5}$ bins for the STN and SEARCH analysis, respectively. Note that the scales are different.

Figure A-3. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: Birmingham STN Site.

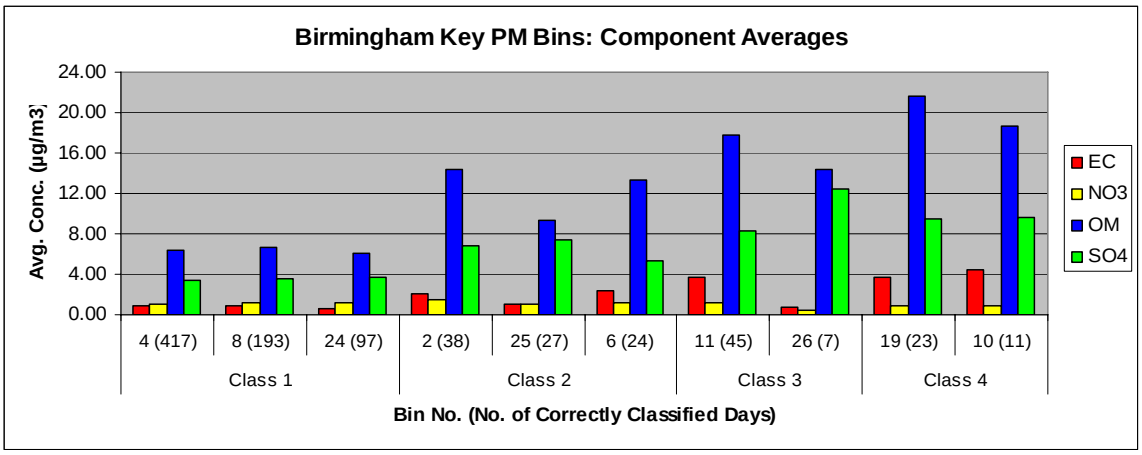
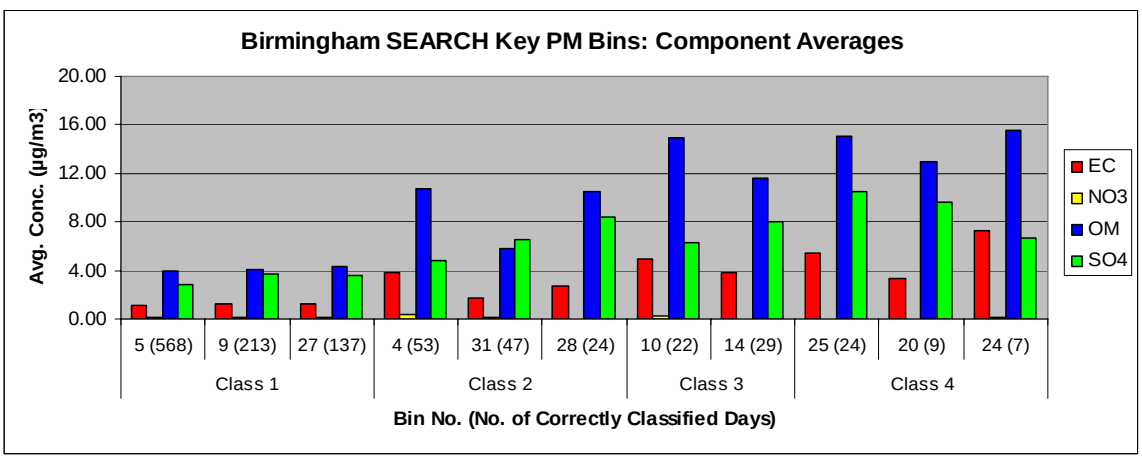


Figure A-4. Average Elemental Carbon (EC), Nitrate (NO3), Organic Matter (OM), and Sulfate (SO4) Concentrations (μgm^{-3}) for Key $PM_{2.5}$ Bins for All CART Classification Categories: Birmingham SEARCH Site.



A comparison of the compositional averages for Birmingham using the STN (Figure A-3) and SEARCH (Figure A-4) data shows that the organic matter and overall $PM_{2.5}$ values are higher in the STN data, but that the tendency for organic matter to be the dominant species appears in both sets of results. For all key Category 4 $PM_{2.5}$ bins (for both the STN and SEARCH analysis), organic matter is the dominant species. However, the relative proportion of the species concentrations is different for each bin. This may be due to the differences in the average wind directions. As noted earlier, we found that all of the key bins are characterized by very low surface wind speeds, but, on average, the days within the bins have different wind directions. The similarities in the average parameter values noted earlier for Bins 19 (STN) and 25 (SEARCH) are not apparent in the relative values of the average species concentrations.

The compositional analysis results for Birmingham (especially for the SEARCH data) show a higher contribution of elemental carbon than for most other sites, and this may be related to emissions from the steel industry facilities that are located in Birmingham.

The CART results and meteorological characterization tool were used to explore several questions related to modeling episode period representativeness. The characteristics of the 2000-2004 baseline period and each individual year comprising that period are examined for Birmingham using both the STN and SEARCH data in Tables A-4 and A-5. The summary metrics included in this table are the weighted average $PM_{2.5}$ concentration, range in $PM_{2.5}$ concentration, percentage of key $PM_{2.5}$ bins represented (considering all classes), and the relative distribution of days among the key $PM_{2.5}$ bins for all categories (distribution error). These terms are explained in more detail in the main report.

Table A-4. Summary of $PM_{2.5}$ and Meteorological Characteristics for the 2000-2004 Analysis Period: Birmingham STN Site.

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	18.8	0.4 – 71.3		
2000	20.1	0.4 – 71.3	100	2.7
2001	18.4	1.0 – 51.5	100	0.8
2002	17.8	4.2 – 47.8	100	1.1
2003	18.0	2.9 – 46.4	90	1.4
2004	18.4	3.6 – 53.3	80	1.6

Table A-5. Summary of $PM_{2.5}$ and Meteorological Characteristics for the 2000-2004 Analysis Period: Birmingham SEARCH Site.

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	17.9	2.8 – 75.2		
2000	18.3	3.8 – 66.4	100	2.3
2001	17.2	3.3 – 48.9	100	1.1
2002	17.5	3.9 – 45.3	100	0.9
2003	16.8	2.8 – 45.0	90.9	1.4
2004	18.0	3.2 – 75.2	100	1.4

The differences in the ranges and the weighted average concentrations between the STN and SEARCH summaries are attributable to differences in the measured data. The distribution

errors, however, vary similarly among the years for the two datasets. This indicates that in both CART analyses, the days are similarly distributed among the key bins. The results for both analyses suggest that 2002 is one of the more representative years for Birmingham.

The characteristics, attributes, and limitations of the combined VISTAS episode periods (1 June – 10 July and 19 November – 19 December, 2002) for $PM_{2.5}$ for Birmingham are examined and compared in Table A-6 and A-7 for the STN and SEARCH analyses, respectively. The summary metrics are the same as those for Tables A-4 and A-5.

Table A-6. Summary of $PM_{2.5}$ and Meteorological Characteristics for 2000-2004, 2002, and the 2002 VISTAS Episodic Analysis Periods: Birmingham STN Site.

Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	18.8	0.4 – 71.3		
2002	17.8	4.2 – 47.8	100	1.1
Episodes	18.8	7.1 – 41.5	100	3.5

Table A-7. Summary of $PM_{2.5}$ and Meteorological Characteristics for 2000-2004, 2002, and the 2002 VISTAS Episodic Analysis Periods: Birmingham SEARCH Site.

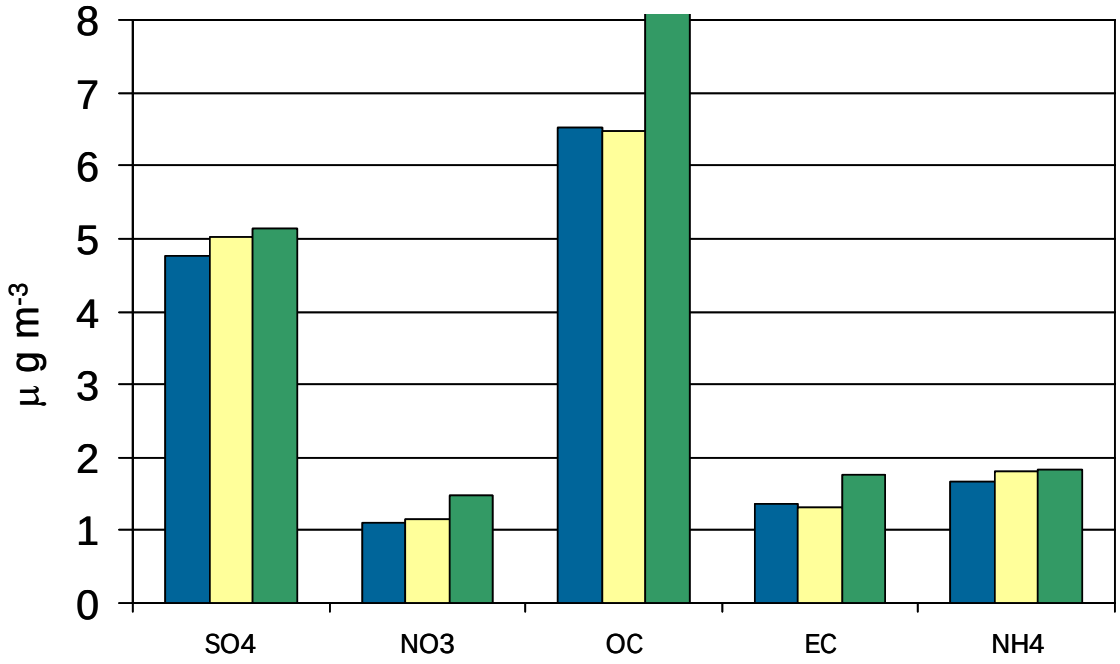
Period	Weighted Average PM2.5 Concentration (μgm^{-3})	Range in $PM_{2.5}$ Concentration (μgm^{-3})	Percentage of Key PM2.5 Bins Represented (%)	Distribution Error Over All Key PM2.5 Bins (%)
2000–2004	17.9	2.8 – 75.2		
2002	17.5	3.9 – 45.3	100	0.9
Episodes	18.5	5.5 – 41.2	90.9	3.0

In both cases, the weighted average concentration for the episode days is 1 μgm^{-3} higher than the 2002 average value and the episode days include at least one high $PM_{2.5}$ day but not the peak day for 2002. The distribution errors are similar for the two analyses and the larger errors for the episode periods indicate that the episodes do not sample the various types of days with the frequency that is typical of 2002 and multi-year periods.

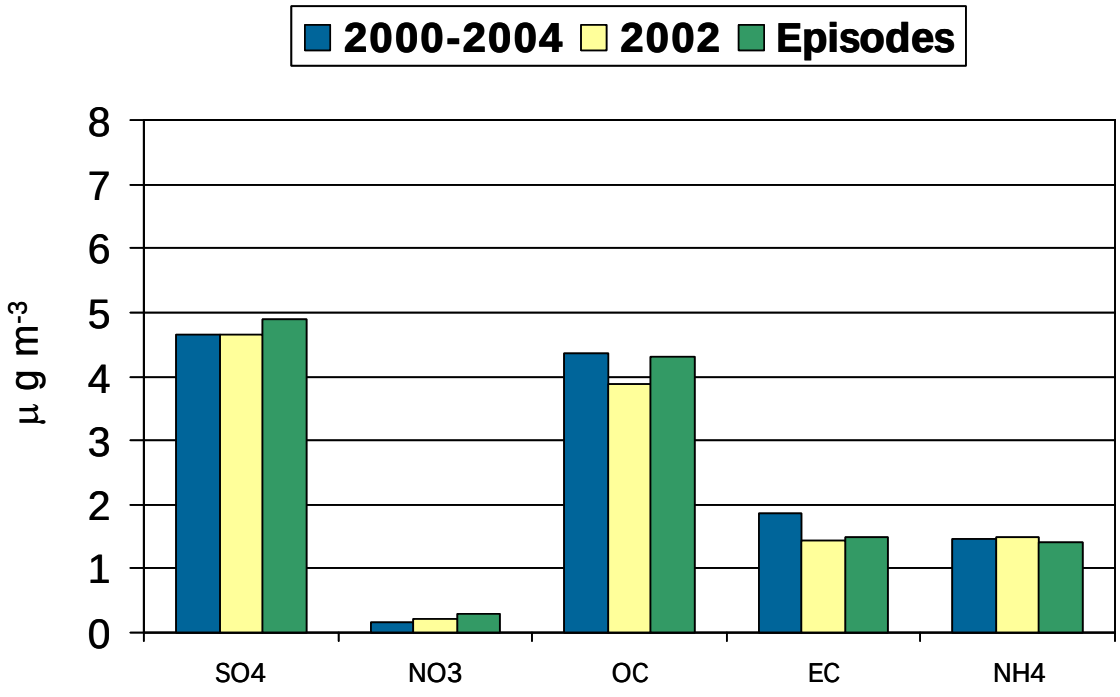
Finally, to characterize the overall representativeness of the urban-$PM_{2.5}$-based episode periods, Figure A-5 compares the average concentration of the PM species for 2000-2004, 2002, and the combined subset episode periods.

Figure A-5. Comparison of Species Concentrations (μgm^{-3}) for Sulfate (SO4), Nitrate (NO3), Organic Carbon (OC), Elemental Carbon (EC) and Ammonium (NH4) for 2000-2004, 2002, and 2002 VISTAS Episode Periods: Birmingham.

(a) STN



(b) SEARCH



For both datasets, the average concentrations for all species for 2002 are similar to those for the full period. Using the STN data (Figure A-5a), the episodes have higher organic carbon and slightly higher sulfate, nitrate and elemental carbon concentrations than both 2002 and the full period. Using the SEARCH data, (Figure A-5b), the episodes have slightly higher sulfate concentrations than both 2002 and the full baseline period. Note that we used two methods for the calculation of the average species concentrations for the episodes, first we used all data and then we recalculated using only data for those days with both STN and SEARCH data. Results for the second method are shown in the plots, but the conclusions are the same for both methods. The representativeness of the concentration characteristics of the episode days differs between the two datasets.

Summary of Findings

In summary, there are differences in the measured $PM_{2.5}$ and species concentrations between the STN and SEARCH datasets for Birmingham. Despite the differences in the $PM_{2.5}$ concentrations, the variation in the average characteristics of the days within percentage-based $PM_{2.5}$ classification categories is similar between the two datasets. Consequently, the STN and SEARCH CART analyses for Birmingham are similar with respect to classification accuracy, relative importance of the input parameters, and the overall conditions leading to the high $PM_{2.5}$ classification bins.

Both CART analyses separate the days with very high prior-day concentrations and northwesterly to northerly winds from the remaining high $PM_{2.5}$ days. The analysis using the SEARCH data provides some additional detail and further divides the remaining days into two groups with different physical characteristics. Use of collocated surface meteorological data in the SEARCH analysis may allow CART to better detect the relationships between the $PM_{2.5}$ values and the meteorological parameters, or the SEARCH $PM_{2.5}$ measurement techniques may be better in tune with the effects of meteorology.

The concentration characteristics of the key bins for the STN and SEARCH analysis are consistent in that organic matter tends to be the dominant species in both sets of results. The relative species concentrations, however, vary among the key bins and between the two analyses.

For both analyses, the 2002 and subset episode days are similarly distributed among the key bins and the results for both analyses suggest that 2002 is one of the more meteorologically representative years for Birmingham, considering the period 2000-2004. The representativeness of the concentration characteristics of the episode days differs between the two datasets.

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