Explaining the Trends

$PM_{2.5}$ Trends in Three Regions (1999–2003)

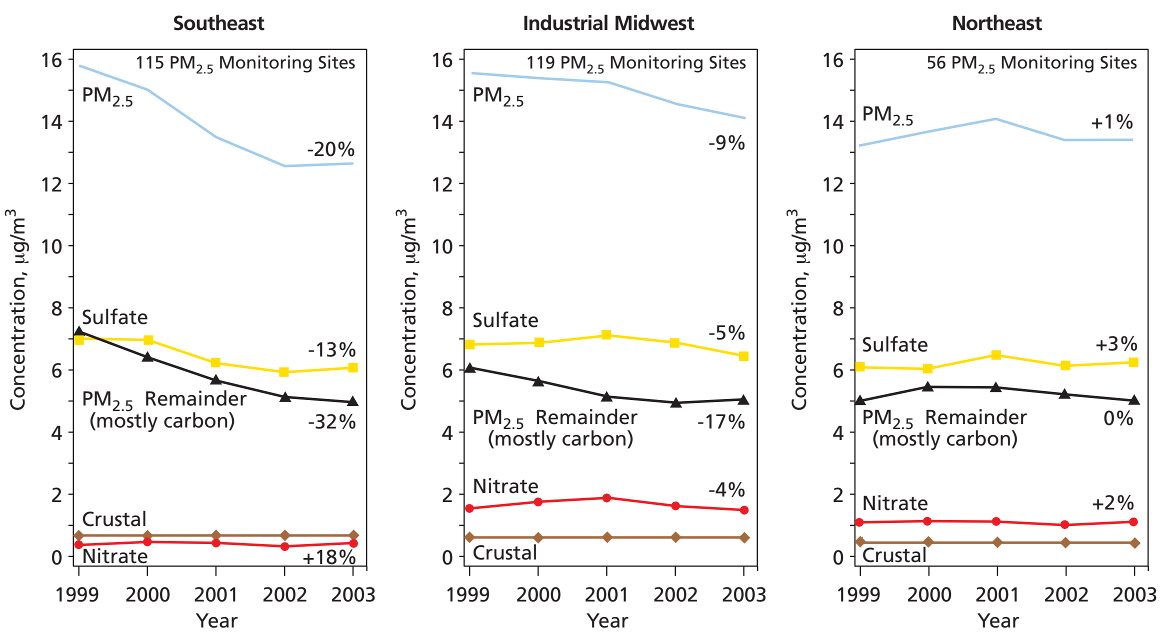
To better understand ambient air quality, it is helpful to examine trends and the factors that contribute to those trends in specific regions. This section explores, in detail, trends in three regions in the eastern half of the country from 1999 to 2003.

Figure 16 shows the 5-year regional trends in urban $PM_{2.5}$ and its major chemical constituents. In the Southeast, $PM_{2.5}$ declined sharply from 1999 to 2002, with little further change to 2003. Overall, the Southeast shows a 20% decrease in $PM_{2.5}$ from 1999 to 2003. In the Industrial Midwest, there is a gradual downward $PM_{2.5}$ trend from 1999 to 2001 and a more pronounced decrease from 2001 to 2003. Overall, $PM_{2.5}$ decreased 9% over the 5-year period. In the Northeast, $PM_{2.5}$ increased slightly from 1999 through 2001, then decreased through 2003, for an overall increase of 1%. Trends in PM components indicate that reductions in sulfates appear to be responsible for approximately one-third of the reductions in $PM_{2.5}$ in the Industrial Midwest and the Southeast. Trends in sulfate concentrations in the eastern United States match well with trends in SO_2 emissions from power plants over the past 14 years (based on analyses discussed in the previous section; see Figure 15).

Figure 17 shows that, on smaller subregional scales, the relationship between sulfate concentrations and power plant SO_2 emissions can vary among the subregions. Although trends in sulfate concentrations and SO_2 emissions match best overall in the Southeast (SO_2 emissions down 15%, sulfate concentrations down 13%, from 1999 to 2003), the year-to-year comparisons for the Industrial Midwest and the Northeast do not show such a close match. Sulfur dioxide emissions in the Industrial Midwest declined 19%, while sulfate concentrations declined 5%. In the Northeast, sulfur dioxide emissions were down 6%, and sulfate concentrations were up 3%.

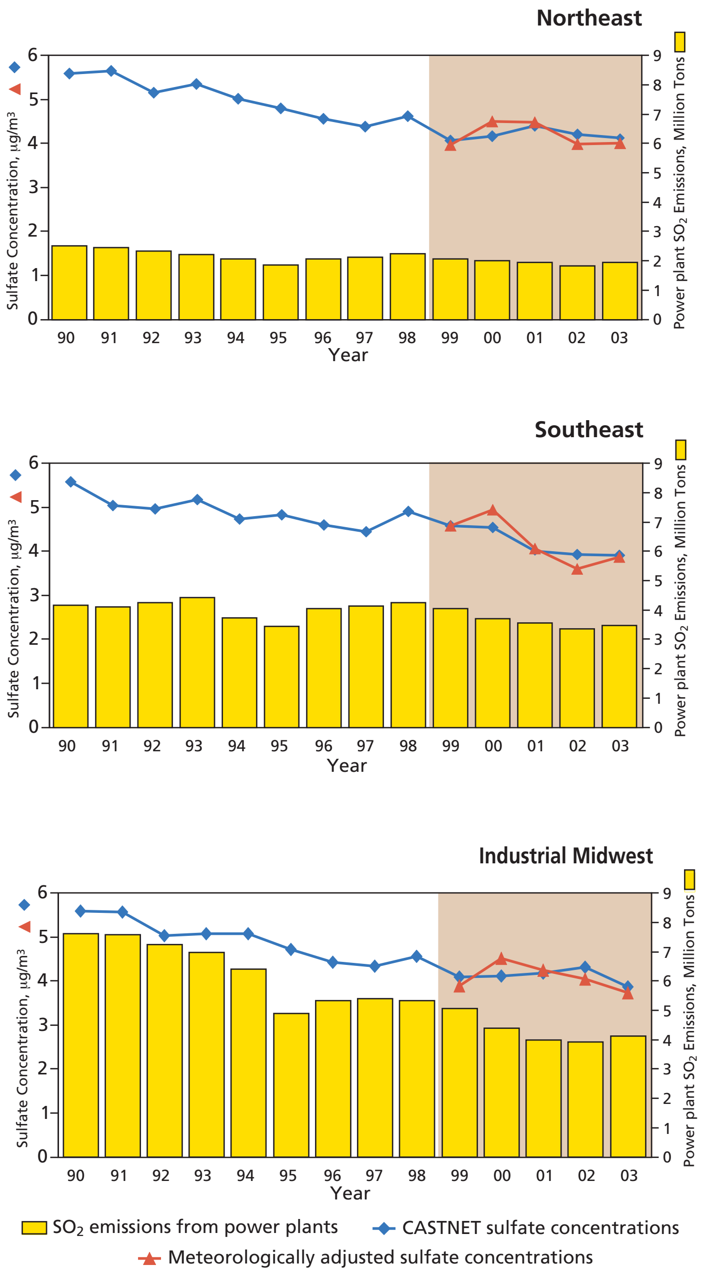
These subregional differences may be caused by several factors, the most important of which is likely to be transport. As Figure 17 shows, the ratio of sulfate concentrations to SO_2 emissions is higher in the Northeast than in the other regions. This suggests that transport of emissions

Figure 16. Trends in $PM_{2.5}$ and its chemical constituents, 1999–2003.



Note: Sulfate and nitrate concentrations from the CASTNET monitoring network were adjusted to represent mass in $PM_{2.5}$ and include ammonium as well as water. Trends for crustal were not available so constant values based on 2002–2003 data for each region were used. See www.epa.gov/airtrends/pm.html for further details.

Figure 17. Meteorologically adjusted sulfate concentrations, 1999–2003.



from other regions contributes to sulfate formation in the Northeast. Other factors that may contribute to the subregional differences in these trends include variations in meteorological conditions that are important to sulfate formation and transport, contributions to the Northeast from Canada, and subregional differences in the contributions of sources other than power plants.

Effect of Meteorology

Weather plays a role both in the atmospheric formation of $PM_{2.5}$ and in the quantity of emissions that contribute to this pollution. For this report, we examined the effect of meteorology on sulfates, which are a major component of $PM_{2.5}$, especially in the eastern half of the United States. To assess the effect of meteorology on annual average sulfate concentrations, EPA has conducted a preliminary analysis, adjusting sulfate levels based on weather conditions. (The blue line in Figure 17 represents measured sulfate concentrations; the red line represents the meteorologically adjusted sulfate concentrations.) One of the main parameters driving these preliminary adjustments is temperature. In the eastern half of the United States, 1999, 2001, and 2003 were near-normal meteorological years, so only minimal adjustments to sulfate concentrations were needed. In 2000, however, a cool summer may well have caused sulfur dioxide emissions to be lower than average, resulting in lower amounts of sulfates in the air. Adjusting for weather in 2000 raised estimated sulfate levels in all three regions to the level expected during a year with average weather conditions.

Conversely, the summer of 2002 in the eastern United States was one of the hottest in recent years. Sulfur dioxide emissions were higher that year, likely due (at least in part) to increased demand for electricity for cooling. The meteorological adjustment for 2002 reduces the amount of sulfates in all three regions to levels expected during a normal meteorological year.

In two of the three regions, the variations in power plant SO_2 emissions (illustrated by the yellow bars in Figure 17) generally correlate more closely with the meteorologically adjusted sulfates (the red line) than the unadjusted sulfates (the blue line). In the Industrial Midwest, however, adjusting for weather causes the sulfate trend to move farther away from the sulfur dioxide emission trend in 2002-2003. More refined meteorological analyses and emission inventories are necessary to fully understand these results.

The $PM_{2.5}$ Remainder

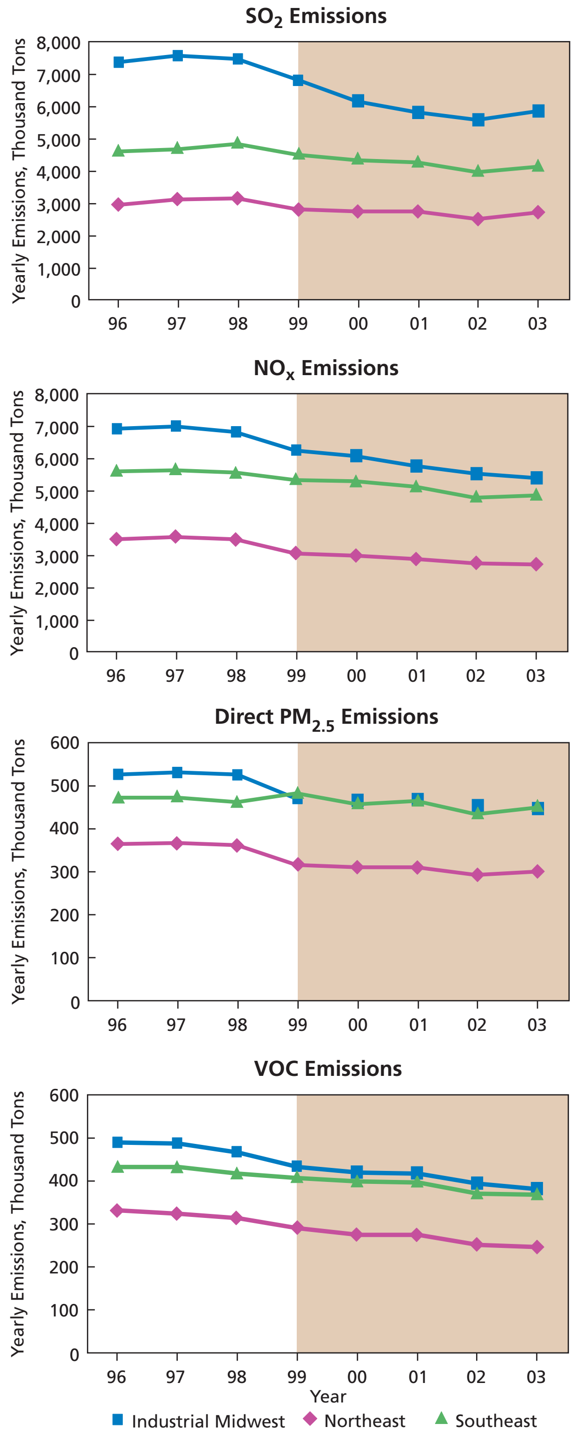
Figure 16 (page 20) also shows the estimated trend in the "$PM_{2.5}$ remainder" for each of the three regions. The remainder is estimated by subtracting all known $PM_{2.5}$ components from the total $PM_{2.5}$ mass. Some uncertainties exist in our interpretations of these data; however, the $PM_{2.5}$ remainder appears to consist mostly of carbon-containing particles. Some small contributions to the $PM_{2.5}$ remainder trend shown in Figure 16 include

- Trends in crustal material
- Local contributions for nitrates and sulfates (see the discussion on pages 8 and 9)
- Any changes in data quality or the operation of EPA's $PM_{2.5}$ Federal Reference Method monitoring network during its first few years of operation.

Despite the uncertainties, the reductions in the $PM_{2.5}$ remainder for the Industrial Midwest and Southeast appear to be due, in large part, to reductions in emissions that contribute to the formation of carbon-containing particles. The relative importance of various man-made emissions sources to these trends is uncertain and may vary by region and urban area. Important sources of carbon-containing particles in urban air include direct emissions from sources such as motor vehicles, fuel combustion, and fires and atmospheric transformation of certain organic gases, including both regional biogenic emissions and some components of man-made VOCs.

It is interesting to note that, in Figure 18, the decrease in the estimated $PM_{2.5}$ remainder corresponds either to reductions in directly emitted fine particles or reductions in man-made VOC emissions. The Northeast region, however, shows virtually no net change in $PM_{2.5}$ or in any of its estimated components. Yet both direct $PM_{2.5}$ emissions and VOC emissions decreased from 1999 to 2003. EPA is continuing to conduct research and analysis to better identify and quantify key direct emission sources in addition to the relative contribution of man-made VOC emissions to atmospheric formation of carbon-containing particles.

Figure 18. $PM_{2.5}$ emission trends.



Percent Change in Emissions from 1999 to 2003

	Industrial Midwest	Northeast	Southeast
SO_2	-15	-3	-9
NO_x	-14	-10	-9
$PM_{2.5}$	-5	-5	-7
VOC	-12	-15	-9

For more details on the $PM_{2.5}$ remainder, see www.epa.gov/airtrends/pm.html. For information on EPA's monitoring networks, see www.epa.gov/ttn/amtic/.

Control Programs

Many programs have been put in place to reduce levels of particulate matter. Table 1 lists the major emission control programs that have contributed to reductions in PM since 1995 and will continue to reduce PM in the future. These programs control direct PM emissions and/or the emissions that contribute to PM formation, such as SO_2, NO_x, and VOCs. The control programs consist of a series of regulations that reduce emissions from many stationary and mobile source sectors. For example, beginning in 2008, states will be required to attain the National Ambient Air Quality Standards for fine particles. EPA's proposed Clean Air Interstate Rule (proposed in December 2003) will help states meet those requirements by reducing SO_2 and NO_x emissions in the eastern United States thus reducing particle pollution transported across state boundaries. Another regulation, the Best Available Retrofit Technology (BART) program, will require the older, existing power plants to control PM emissions with retrofit pollution control equipment. Also, national mobile source rules are in place to strengthen the emission requirements for virtually all types of mobile sources. Many localities also have pollution reduction requirements for diesel engine retrofits as well as sulfur limits in diesel and gasoline engines.

Table 1. A Selection of Emission Control Programs Contributing to PM Emission Reductions, 1995–2015

Program	Sector	Direct PM[a] Reductions	PM Precursors SO_2 Reductions	PM Precursors NO_x Reductions	PM Precursors VOC Reductions	Implementation Date
Clean Air Nonroad Diesel Rule	Mobile sources	X	X	X		2004-2015
Clean Air Interstate Rule (proposed December 2003)	Electric Utilities	X	X	X		2010-2015
Acid Rain Program	Electric Utilities		X	X		1995-2010
NO_x SIP Call	Electric Utilities		X	X		2004
Regional Haze Rule/ Best Available Retrofit Technology	Electric Utilities[b]	X	X	X		2013-2015
$PM_{2.5}$ Implementation[c]	Stationary/Area/ Mobile sources	X	X	X	X	2008-2015
PM_{10} SIPs (e.g., San Joaquin Valley)	Stationary/Area/ Mobile sources	X	X	X	X	Ongoing
Maximum Achievable Control Technology (MACT) Standards[d]	Stationary/Area	X			X	1996-2003
Various Mobile Source Programs[e]		X	X	X	X	Ongoing

[a] Includes elemental and organic carbon, metals, and other direct emissions of PM.

[b] Also applies to industrial boiler and the other source categories also covered under Prevention of Significant Deterioration (PSD).

[c] Includes Reasonably Available Control Technology (RACT) and Reasonably Available Control Measures (RACM).

[d] Includes a variety of source categories such as Boilers and Process heaters, Pulp and Paper, Petroleum Refineries, various minerals and ores, and others. While these standards are for hazardous air pollutants (HAPs) such as metals, measures to reduce HAPs in many cases also reduce PM emissions.

[e] Includes such programs as onroad diesel and gasoline engines, nonroad gasoline engines, Low Sulfur Diesel and Gasoline Fuel Limits for onroad and offroad engines, Motorcycles, Land-based recreational vehicles, and Marine diesel engines.

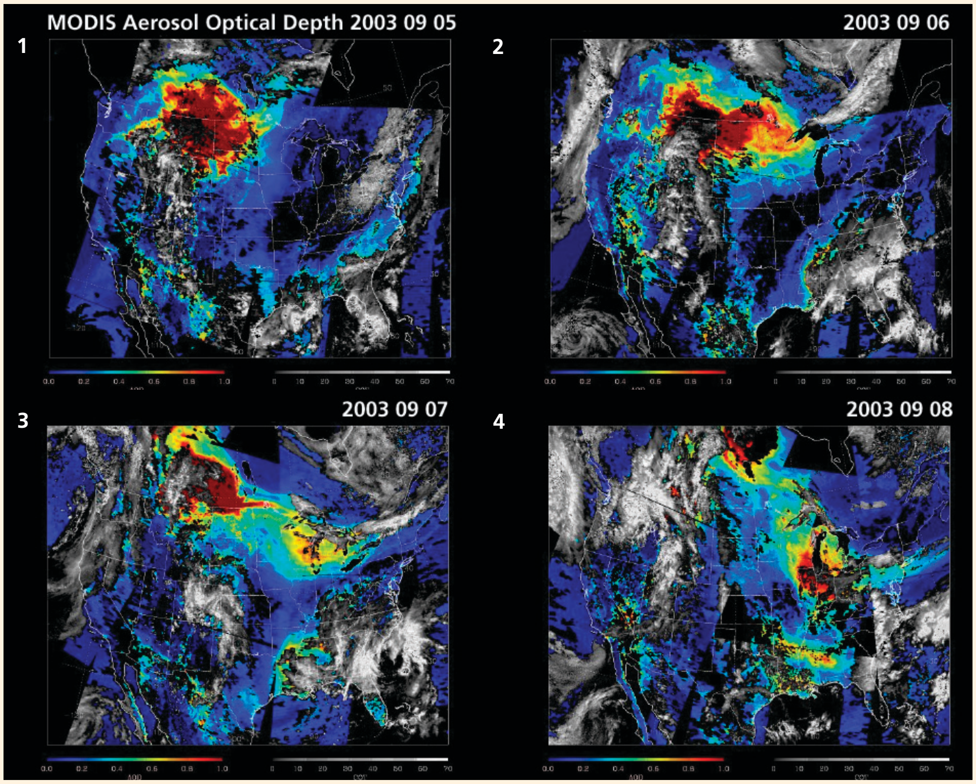
Using Satellites to Track Particulate Matter

The most direct way to obtain surface concentration data for particles is from the routine measurements made at surface monitoring stations across the United States. This approach has some limitations, however, because large regions of the country do not have surface monitors, and coastal regions are often influenced by polluted air approaching over water. In addition, pollution may be transported aloft, undetected by surface monitors, and then descend to influence air at the ground. New work being done through a collaborative partnership between EPA, the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA) uses satellite observations to augment the surface network monitoring data with satellite data.

The NASA MODIS (Moderate Resolution Imaging Spectroradiometer) instruments on board the EOS (Earth Observing System) satellites EOS-Terra and EOS-Aqua provide twice-daily measurements of aerosol optical depth (AOD), a measure of how much light airborne particles prevent from passing through a column of atmosphere. Scientists use these measurements to estimate the relative amount of aerosols suspended in the atmosphere.

IDEA (Infusing satellite Data into Environmental Applications) is a partnership between EPA, NASA, and NOAA. These agencies are working to improve air quality assessment, management, and prediction by infusing satellite measurements from NASA into EPA and NOAA analyses for public benefit.

Initial research shows that MODIS-derived data are suitable for tracking air quality events on a regional scale and may be a good surrogate for estimating the intensity of surface $PM_{2.5}$ concentrations. More research and data are needed to help show how aerosol loads are distributed vertically in the atmosphere so that MODIS-derived AOD can be put into the proper context. For more information on the MODIS-derived AOD and $PM_{2.5}$ pollution events, go to the Cooperative Institute for Meteorological Satellite Studies/Space Science and Engineering Center at the University of Wisconsin-Madison website: http://idea.ssec.wisc.edu.



Composites of MODIS-derived AOD (color) and cloud optical thickness (black-white) from September 5 to 8, 2003. The majority of the high AOD seen in the images (yellow-red) was the result of several very large wildfires in western North America from British Columbia to Oregon. MODIS-derived AOD tracked the movement of the plume, which eventually affected surface $PM_{2.5}$ concentrations throughout the midwestern United States.