Chapter 3: Control Program Effectiveness: Changes in Ozone

To better understand how major control programs affect ozone, EPA looked at overall changes since 1997, and then focused on ozone improvements after 2002 (after implementation of the NO_X SIP Call). These analyses also consider the impact of weather, because variations in weather conditions play an important role in determining ozone levels. This chapter examines the results of these analyses in relation to the original NO_X SIP Call program design by comparing the anticipated changes in emissions and ozone to actual changes.

General Trends: Changes in Ozone Concentrations since 1997

Like NO_X and VOC emissions, ozone concentrations in urban and rural areas have decreased between 1997 and 2004 in response to control programs. Figure 18 shows the percent reductions (adjusted for weather conditions) in seasonal ozone. Seasonal ozone was calculated as the average of daily maximum 8-hour ozone concentrations from May 1 through September 30. Ozone reductions

Ozone Monitoring Networks

For this report, EPA assembled data for 29 urban areas from the Air Quality System (AQS) and 34 rural sites from the Clean Air Status and Trends Network (CASTNET) to provide a more complete picture of the nation's air quality than would be otherwise possible. Sufficient ambient and meteorological data for these sites were available to perform detailed analyses of air quality changes over time.

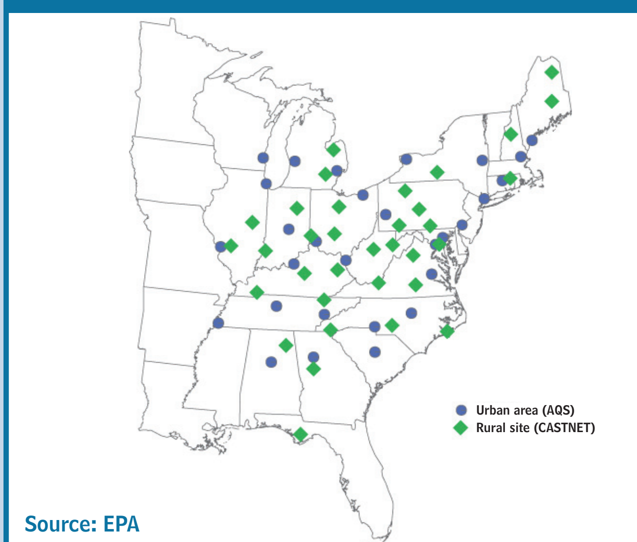
Air Quality System (AQS)

AQS is EPA's repository for state and local data from monitoring networks specifically designed to assess air quality trends and to support regulatory programs, such as nonattainment area designations and development of State Implementation Plans. These networks include the State and Local Air Monitoring Stations (SLAMS) and National Air Monitoring Stations (NAMS). There are more than 700 SLAMS/NAMS monitoring sites in the eastern United States. For more information, see <www.epa.gov/ttn/airs/airsaqs>.

Clean Air Status and Trends Network (CASTNET)

CASTNET is a national network of rural monitoring sites, with more than 50 sites in the eastern United States. EPA established the network primarily to provide data needed to track and evaluate national and regional air pollution control programs. These data provide information necessary to study and investigate the effects of atmospheric pollution on sensitive ecosystems, particularly those effects caused by long-range transport of emissions from regional sources. Data gathered from the network are compiled in a central database and made available on EPA's CASTNET Web site at <www.epa.gov/castnet>.

Urban and Rural Locations



Source: EPA

Note: Urban areas represent multiple monitoring sites. Rural areas represent single monitoring sites.

were greater than 10 percent across a broad geographic region; the average reduction was 14 percent.

Role of Meteorology

Variations in weather conditions play an important role in determining ozone levels. Daily temperature, relative humidity, and wind speed can affect ozone levels. In general, warm dry weather is more conducive to ozone formation than cool wet weather. EPA uses a statistical model to account for the impact of weather on ozone concentrations. Because weather varies over space and time, this adjustment provides a better estimate of the underlying ozone trend and the impact of emission changes (see "Meteorology Matters" on page 17).

To illustrate the overall impact of weather on ozone levels in outdoor air, EPA compared changes in ozone before and after adjusting for weather, as Figures 17 and 18 show. Adjusting for weather made only a small difference (1 percent) in overall ozone change in the eastern United States—an average reduction of 13 percent before adjustment, compared to 14 percent after adjustment. Some states showed notable differences. For example, adjusting for weather at sites in North Carolina, Virginia, and eastern Tennessee resulted in significantly smaller reductions, while adjustments in Ohio, Pennsylvania, and West Virginia showed larger ozone reductions.

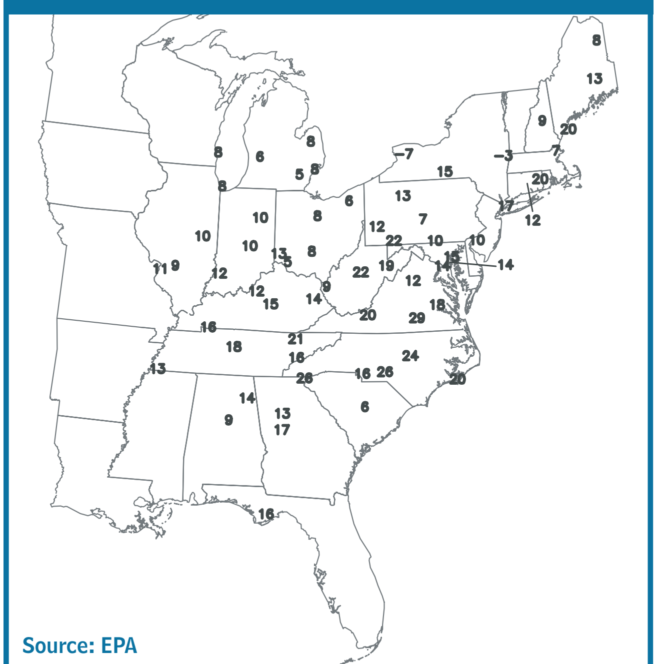
Focus on the NO_X SIP Call: Changes in Ozone

EPA examined geographic patterns and ozone behavior before and after the NO_X SIP Call, and then compared EPA's projections to what actually occurred.

To analyze ozone changes, EPA selected two baseline years—1997 and 2002. These two years were selected to coincide with the period of NO_X reductions attributable to the Acid Rain Program and the OTC NO_X Budget Program (1997 through 2002) and the implementation of the NO_X SIP Call (2002 through 2004).

Ozone improvements were larger after implementation of the NO_X SIP Call. The average reduction in ozone

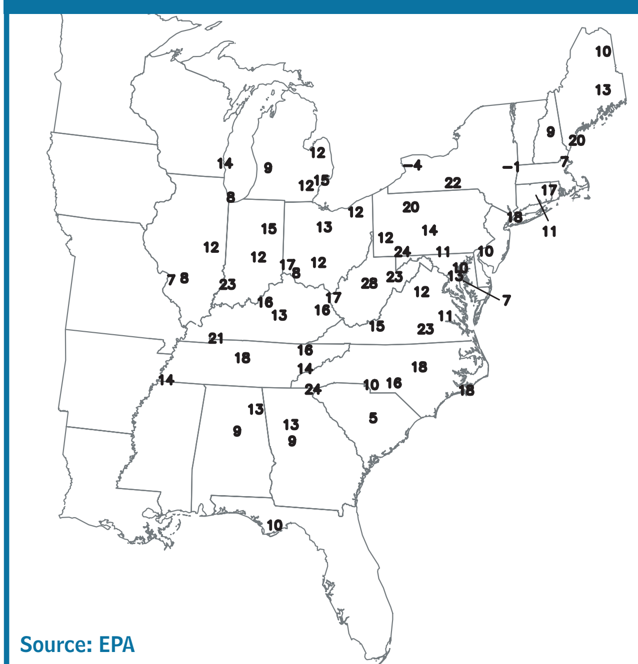
Figure 17: Percent Reduction in Seasonal 8-Hour Ozone, 1997 vs. 2004 (Not Adjusted for Meteorology)



Source: EPA

Note: Margin of error is ± 5 percent.

Figure 18: Percent Reduction in Seasonal 8-Hour Ozone, 1997 vs. 2004 (Adjusted for Meteorology)



Source: EPA

Note: Margin of error is ± 5 percent.

Meteorology Matters

Meteorology plays a major role in both the formation and transport of ozone. For example, the photochemical reactions that transform emissions of NO_X and VOCs into ozone are complex and require warm temperatures and dry conditions. These graphics illustrate how the summers of 1997, 2002, and 2004 compare with historical records (a 30-year average using data from 1971 to 2000) for temperature and precipitation in the eastern United States.

Note: Meteorology can vary significantly from one site to the next.

1997

(normal ozone-forming potential)

Temperature – In general below normal, except Florida and New England (near normal)

Precipitation – Mixed (slightly above normal in some places and slightly below normal in others)

2002

(above normal ozone-forming potential)

Temperature – Mostly above normal, except South (near normal to slightly below normal)

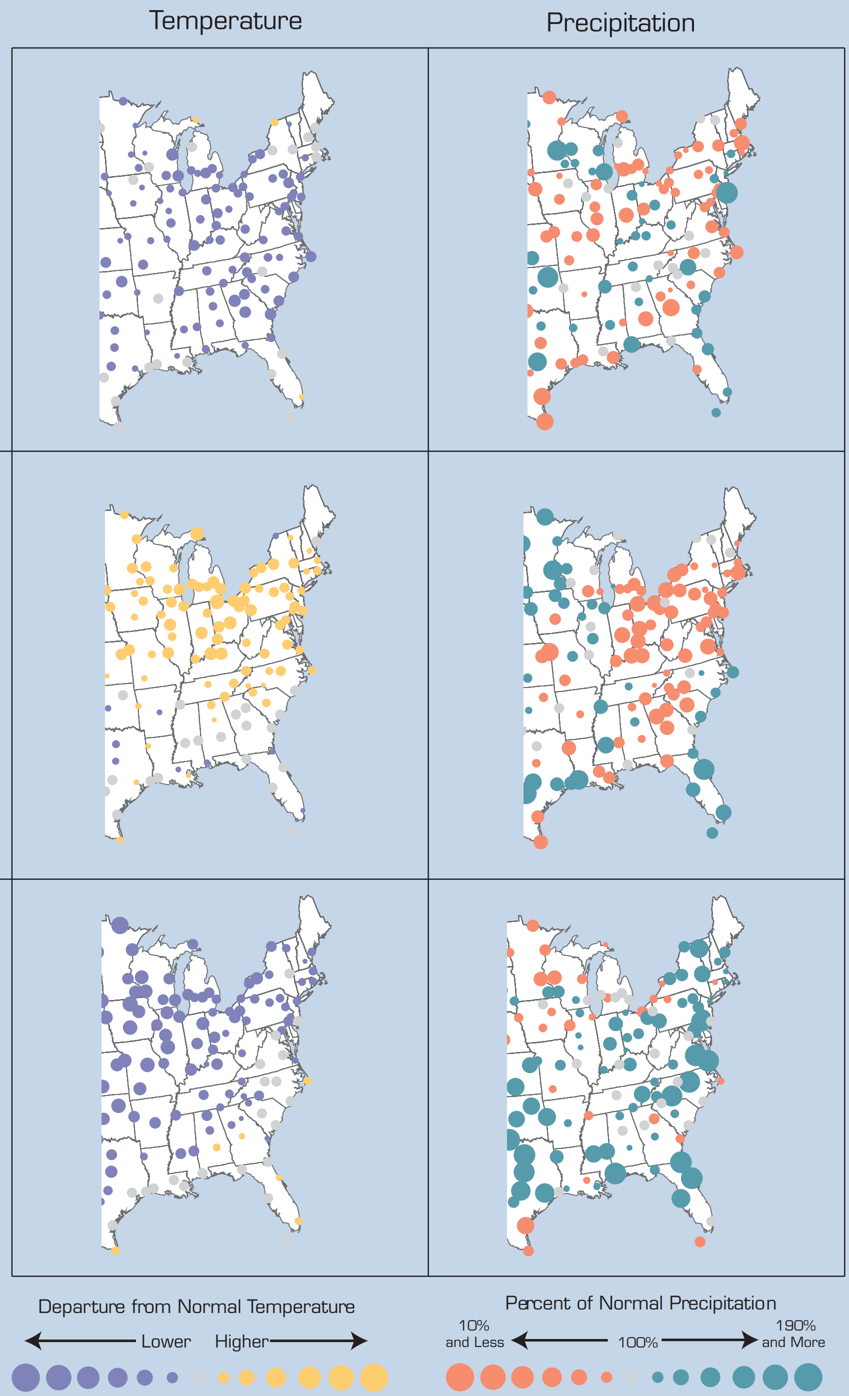
Precipitation – Mostly below normal except South and Midwest (above normal)

2004

(below normal ozone-forming potential)

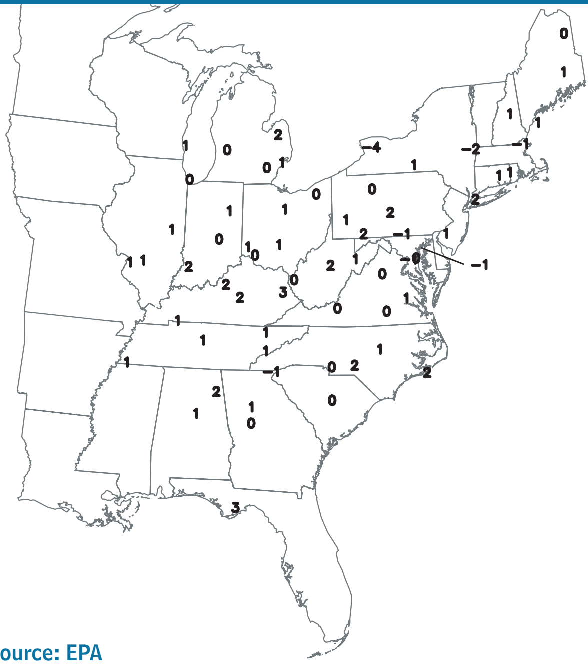
Temperature – Mostly cooler to much cooler except Southeast (normal to slightly above normal)

Precipitation – Mostly above normal except upper Midwest (below normal)



Sources: National Oceanic and Atmospheric Administration (NOAA), EPA

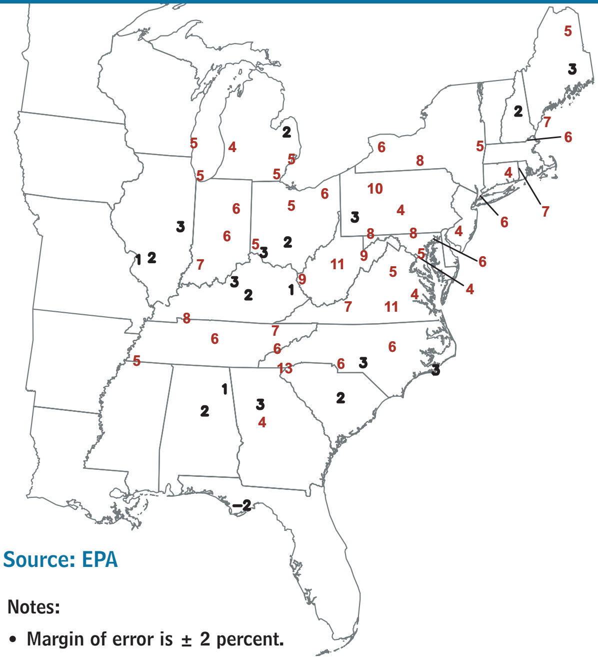
Figure 19: Percent Reduction in Seasonal 8-Hour Ozone Per Year, 1997-2002 (Adjusted for Meteorology)



Source: EPA

Note: Margin of error is ± 1 percent.

Figure 20: Percent Reduction in Seasonal 8-Hour Ozone Per Year, 2002-2004 (Adjusted for Meteorology)



Source: EPA

Notes:

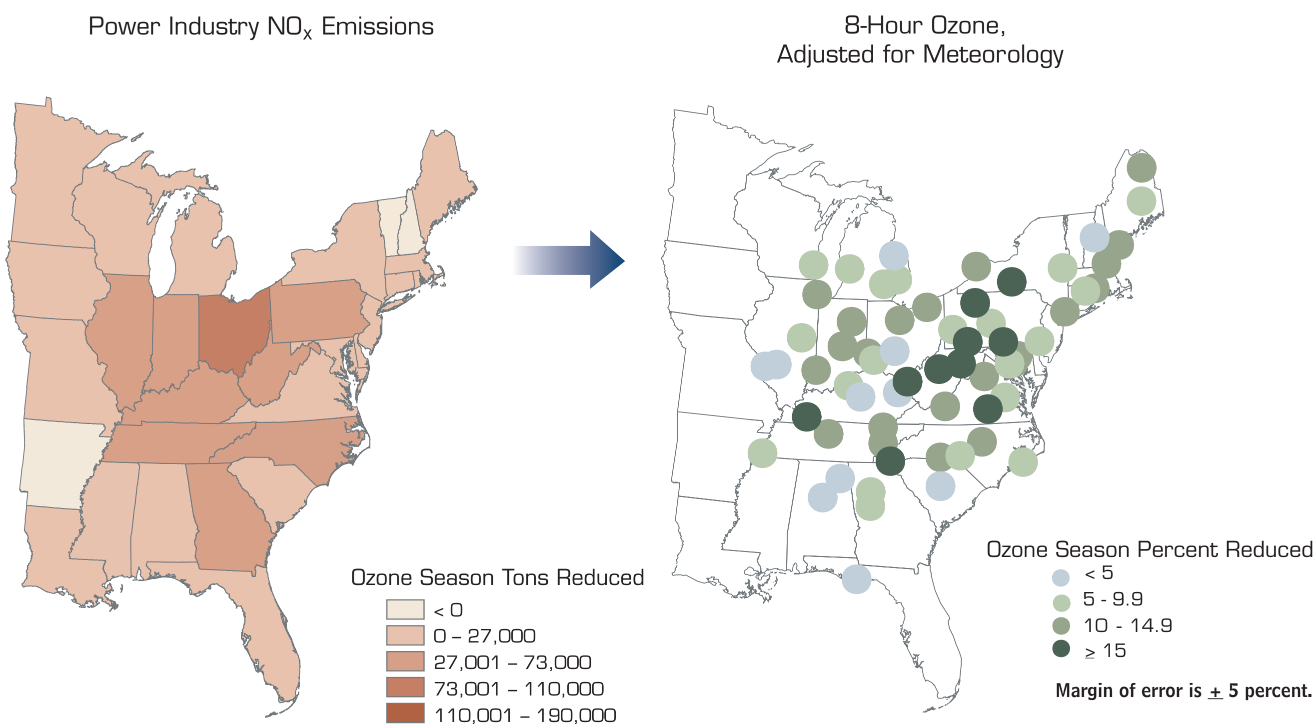
- Margin of error is ± 2 percent.
- Locations with ozone changes greater than 3 percent per ozone season are highlighted in red.

between 1997 and 2002 was about 4 percent (adjusted for weather), compared with more than 10 percent between 2002 and 2004. Meteorological adjustment was especially important for this analysis because of the significant difference in the ozone-forming potential between 2002 and 2004. The difference in ozone levels between 2002 and 2004 was about 17 percent before adjusting for weather, compared with about 10 percent after adjustment.

Figures 19 and 20 illustrate how reductions in ozone levels changed before and after the NO_X SIP Call (after adjusting for weather). These figures show average percent changes per ozone season between two time periods: 1997 through 2002 (the five-year period before the NO_X SIP Call) and 2002 through 2004 (the two-year period after the NOx SIP Call). This analysis of emissions and ozone shows that the NO_X SIP Call achieved an additional 4 percent reduction per ozone season. Before the NO_X SIP Call was in place, ozone declined about 1 percent per ozone season in most areas in the East, although some states (Kentucky and Florida) realized average reductions as large as 3 percent per ozone season (see Figure 19). After implementation of the NO_X SIP Call (see Figure 20), the ozone reduction was larger—5 percent per ozone season on average—with many areas exceeding 5 percent.

EPA expects that NO_X and VOC emissions will continue to decrease in 2005. Despite these improvements, ozone levels in 2005 could be higher than in 2004, depending on weather conditions. (Weather conditions in 2004 were not conducive to ozone formation.) To accurately estimate trends in ozone air quality, meteorological effects must be taken into account.

Figure 21: Reductions in Ozone Season Power Industry NO_X Emissions and 8-Hour Ozone, 2002 vs. 2004



Source: EPA

Notes:

- **Darker states show larger NO_X reductions.**
- **Arkansas (268 tons), New Hampshire (611 tons), and Vermont (16 tons) show small increases in ozone season emissions from 2002 to 2004.**

Comparison of Power Industry NO_X Emission Reductions and Ozone Changes

Figure 21 shows the relationship between reductions in power industry NO_X emissions and reductions in ozone after implementation of the NO_X SIP Call. Generally, there is a strong association between areas with the greatest NO_X emission reductions (such as the Midwest) and downwind sites exhibiting the greatest improvement in ozone. This suggests that the effect of NO_X transport has been reduced in the eastern United States. While this report does not attribute all ozone reductions after 2002 to the NO_X SIP Call, it does show that the NO_X SIP Call played a major role in reducing ozone concentrations.

Trends in Ambient NO_X Concentrations

Ambient concentrations of NO_X gases have fallen as NO_X emissions have declined. EPA examined data from both urban and rural monitoring sites, looking at NO_X from air quality monitors in the AQS network and total nitrate measurements from CASTNET sites. The results indicate that ambient concentrations of ozone-forming gases and total particulate nitrates have decreased over the past seven years, further evidence that NO_X emissions have been reduced.

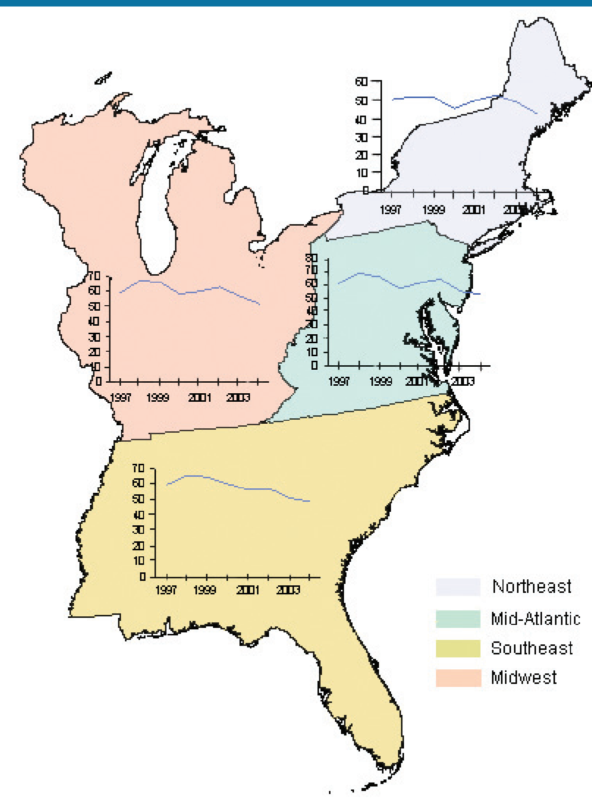
Ozone Reduction in Rural Areas Shows Regional Improvements

The primary goal of the NO_X SIP Call is to reduce regional transport of ozone across state boundaries by reducing NO_X. EPA's Clean Air Status and Trends Network (CASTNET) provides long-term data on ozone air quality at more than 50 monitoring sites in rural areas across the eastern United States. The monitoring information collected at rural sites is a good indicator of background ozone concentrations, because rural areas are not as influenced by local emissions sources. The rural network is particularly relevant to assessing progress under the NO_X SIP Call, because it represents levels of ozone and precursor gases that are being transported from one area to another.

Due to changing weather conditions, air quality trends often show high year to year variability over time. Some of this variability can be overcome through the use of consistent and continuous long-term monitoring data. The results presented here show the variability over time in actual observed ozone concentrations at rural sites on a regional level.

The figure below shows a gradual decline in seasonal average 8-hour daily maximum ozone levels from 1997 to 2004 for all four eastern regions. The largest improvements occurred after 1998 and again after 2002. The downward trend is especially evident in the Southeast, which has experienced a steady decline in ozone in rural areas since 1998. These results have not been adjusted for weather; however, the overall downward trend is consistent with trends that have been adjusted for the influences of weather.

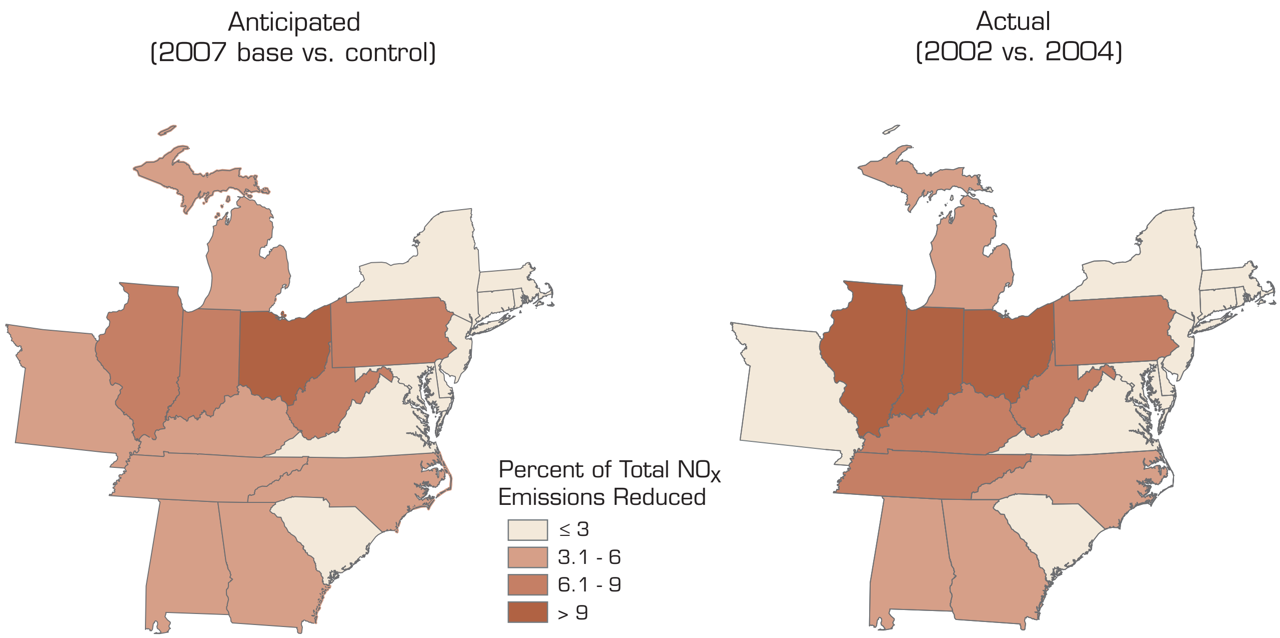
Rural Seasonal Average 8-hour Daily Maximum Ozone by Region, 1997-2004



Source: EPA

Note: Ozone concentrations are in parts per billion (ppb)

Figure 22: Ozone Season Power Industry NO_X Emissions Reduced, Anticipated and Actual



Source: EPA

Notes:

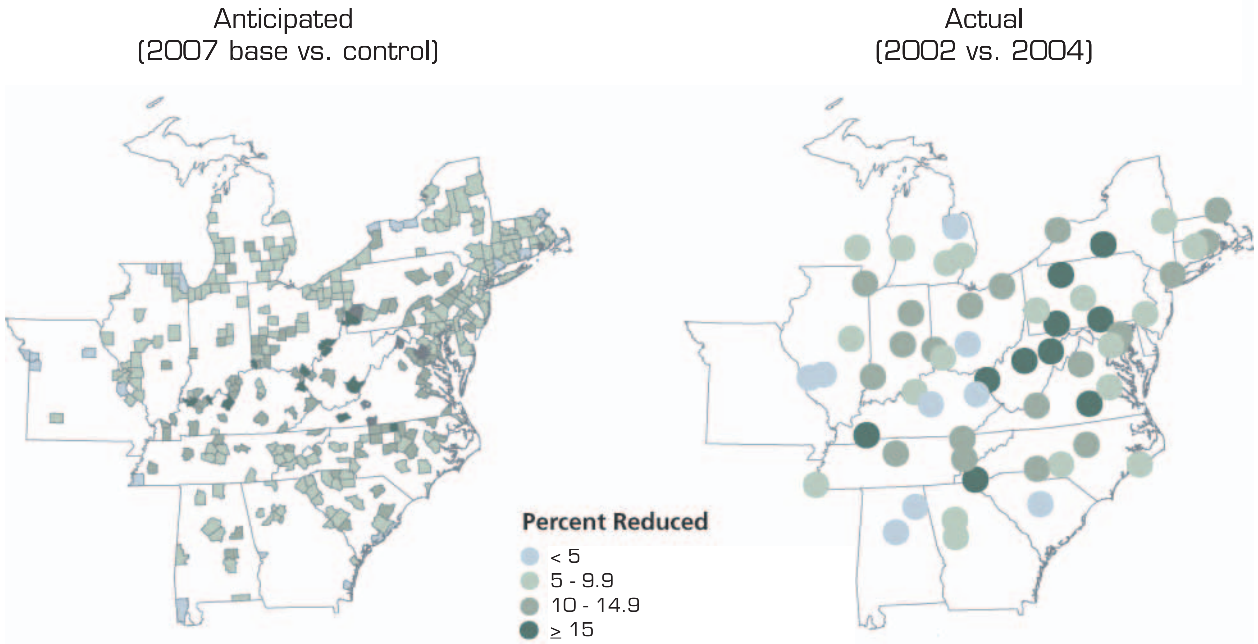
- Darker states show larger NO_X reductions.
- Percent of total NO_X emissions reduced is an individual state's emissions reduced, divided by total reductions across all states (in tons).
- Anticipated results are the estimated difference in power industry emissions between the 2007 base case and 2007 with the NOx SIP Call for the days modeled, which represent the ozone season.
- Actual results are the difference in state total ozone season power industry emissions between 2002 and 2004, as reported to EPA.

Comparison of NO_X SIP Call Results to Program Design

EPA uses air quality models to help predict the impacts of new or proposed programs (see "Estimating the Impact of Proposed Control Programs" on page 22). For the NO_X SIP Call, EPA used models to estimate changes in NO_X emissions and their effects on ozone levels. Figure 22 shows the state-by-state percentage of total NO_X emission reductions anticipated from the NO_X SIP Call and the actual reductions achieved by the power industry between 2002 and 2004. Because the majority of the states subject to the NO_X SIP Call were required to meet their emission caps by 2004, EPA expects few additional reductions after 2004 as the compliance supplement pool is used up, and in response to growth in fossil fuel generation to meet increasing electric demand.

Figure 22 shows that actual NO_X emission reductions occurred where anticipated. The largest reductions took place in states along the Ohio River Valley. States are color-coded based on the percent of total emissions reduced, which is calculated as an individual state's emission reductions, divided by total reductions across all states (in tons). Anticipated reductions are based on tons reduced across days modeled, which represent the ozone season. Actual reductions are based on tons reduced across ozone season days.

Figure 23:
Percent Reductions in Seasonal 8-Hour Ozone, Anticipated and Actual



Source: EPA

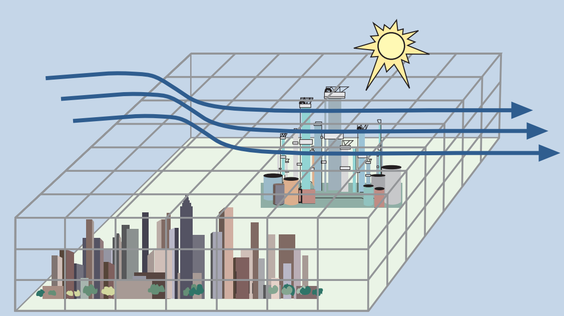
Notes:

- **EPA used projections of 2007 emissions—both with and without the NO_X SIP Call—to evaluate the rule's impact on ozone concentrations. Although EPA's modeling used 2007 as a base year, the regulation required the majority of these reductions to be implemented prior to May 31, 2004 (in all affected states, except portions of Missouri and Georgia).**
- **For this report, EPA compared model-predicted changes in seasonal average 8-hour ozone to actual ambient changes, before and after the NO_X SIP Call.**

Similarly, Figure 23 illustrates where ozone reductions were anticipated and where actual ozone reductions were achieved. Both maps use average daily maximum 8-hour ozone concentrations. Anticipated improvements are based on model predictions, and actual improvements are based on measurements taken during the ozone season. As with NO_X emissions, the anticipated and actual changes in ozone generally are similar (e.g., both show largest reductions along the Ohio River Valley), indicating that the NO_X SIP Call appears to have achieved its goal of reducing ozone in the eastern United States.

Estimating the Impact of Proposed Control Programs

EPA uses air quality models to predict how emissions from a specific source or combination of sources will contribute to ozone concentrations at downwind sites. Using estimates of hourly emissions and meteorology, these models simulate the physical and chemical processes that contribute to ozone formation and transport. These models allow EPA to test hypotheses about how ozone levels will respond to reductions in VOC and NO_X emissions resulting from an individual control program or combination of control programs.



Photochemical grid models simulate atmospheric chemistry and transport throughout the geographic area of interest.