

Chapter 2: The Scope and Magnitude of the PM_{2.5} Air Quality Problem

Chapter Overview

This chapter characterizes PM air quality in current and future year emissions scenarios in terms of aerosol composition, concentration and spatial and temporal patterns across the nation based largely on ambient data and analyses contained in EPA's The Particle Pollution Report¹ and Particulate Matter Staff Paper.² This chapter also discusses regional and local source contributions to urban PM_{2.5}. EPA national and regional PM_{2.5} air quality modeling utilizing EPA's Community Multiscale Air Quality (CMAQ) modeling system is used to illustrate the areas likely to be in nonattainment under alternative standard options and the expected composition of the PM_{2.5} in selected urban areas.³ In addition, source apportionment studies are presented to demonstrate the impacts of regional and local sources on ambient PM_{2.5} levels.

Composition of PM_{2.5}

Particulate matter (PM) is a highly complex mixture of solid particles and liquid droplets distributed among numerous atmospheric gases which interact with solid and liquid phases. Particles range in size from those smaller than 1 nanometer (10⁻⁹ meter) to over 100 microns (1 micron is 10⁻⁶ meter) in diameter (for reference, a typical strand of human hair is 70 microns and particles less than about 20 microns generally are not detectable by the human eye.) Particle visual perception more often is based on their ability to scatter (and to a lesser extent, absorb) visible light resulting in impaired visibility associated with haze. For regulatory purposes, particles are classified as PM_{2.5} and PM_{10-2.5}, corresponding to their size (diameter) range in micrometers and referring to total particle mass under 2.5 and between 2.5 and 10 micrometers, respectively.

Particles span many sizes and shapes and consist of hundreds of different chemicals. Particles are emitted directly from sources and also are formed through atmospheric chemical reactions and often are referred to as primary and secondary particles, respectively. Particle pollution also varies by time of year and location and is affected by several aspects of weather, such as temperature, clouds, humidity, and wind. Further complicating particles is the shifting between solid/liquid and gaseous phases influenced by concentration and meteorology, especially temperature.

Particles are made up of different chemical components. The major components, or species, are carbon, sulfate and nitrate compounds, and crustal materials such as soil and ash (Figure 2-1). The different components that make up particle pollution come from specific sources and are

¹ The Particle Pollution Report: Current Understanding of Air Quality and Emissions through 2003. http://www.epa.gov/airtrends/aqtrnd04/pmreport03/pmcover_2405.pdf#page=1.

² Particulate Matter Staff Paper: Current Review. http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_cr_sp.html.

³ Multi-pollutant legislation – Multi-pollutant analyses and technical support documents. <http://www.epa.gov/airmarkets/mp/>.

often formed in the atmosphere. Particulate matter includes both “primary” PM, which is directly emitted into the air, and “secondary” PM, which forms indirectly from fuel combustion and other sources. Primary PM consists of carbon (soot)—emitted from cars, trucks, heavy equipment, forest fires, and burning waste—and crustal material from unpaved roads, stone crushing, construction sites, and metallurgical operations. Secondary PM forms in the atmosphere from gases. Some of these reactions require sunlight and/or water vapor. Secondary PM includes:

- Sulfates formed from sulfur dioxide emissions from power plants and industrial facilities
- Nitrates formed from nitrogen oxide emissions from cars, trucks, industrial facilities, and power plants
- Organic carbon formed from reactive organic gas emissions from cars, trucks, industrial facilities, forest fires, and biogenic sources such as trees.

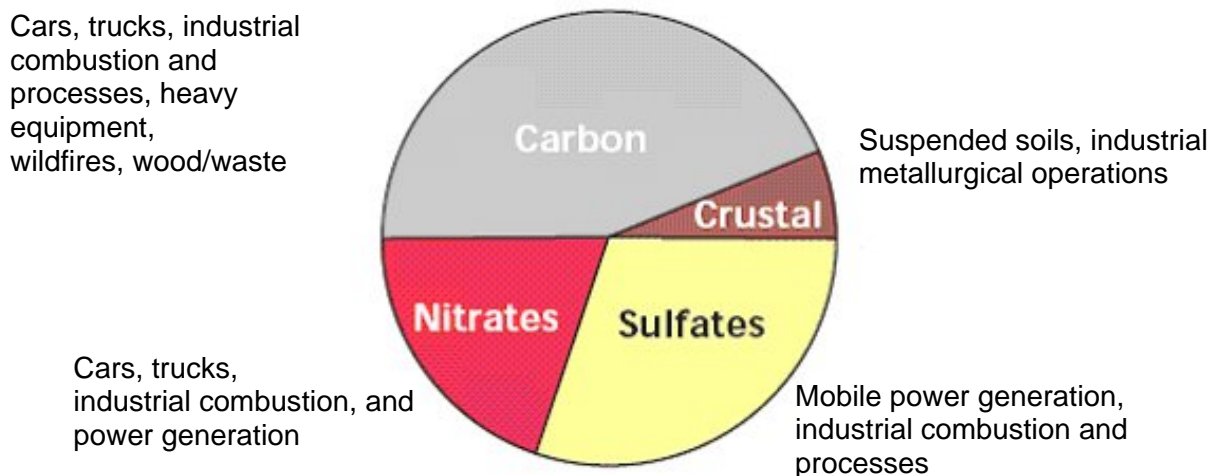


Figure 2-1. National Average of Source Contribution to Fine Particle Levels.⁴

In addition, ammonia from sources such as fertilizer and animal feed operations contributes to the formation of sulfates and nitrates that exist in the atmosphere as ammonium sulfate and ammonium nitrate. Note that fine particles can be transported long distances by wind and weather and can be found in the air thousands of miles from where they were formed.

⁴ Source: The Particulate Matter Report, USEPA 454-R-04-002, Fall 2004. Carbon reflects both organic carbon and elemental carbon. Organic carbon accounts for automobiles, biogenics, gas-powered off-road, and wildfires. Elemental carbon is mainly from diesel powered sources.

The chemical makeup of particles varies across the United States (as shown in Figure 2-2). For example, fine particles in the eastern half of the United States contain more sulfates than those in the West, while fine particles in southern California contain more nitrates than other areas of the country. Carbon is a substantial component of fine particles everywhere.

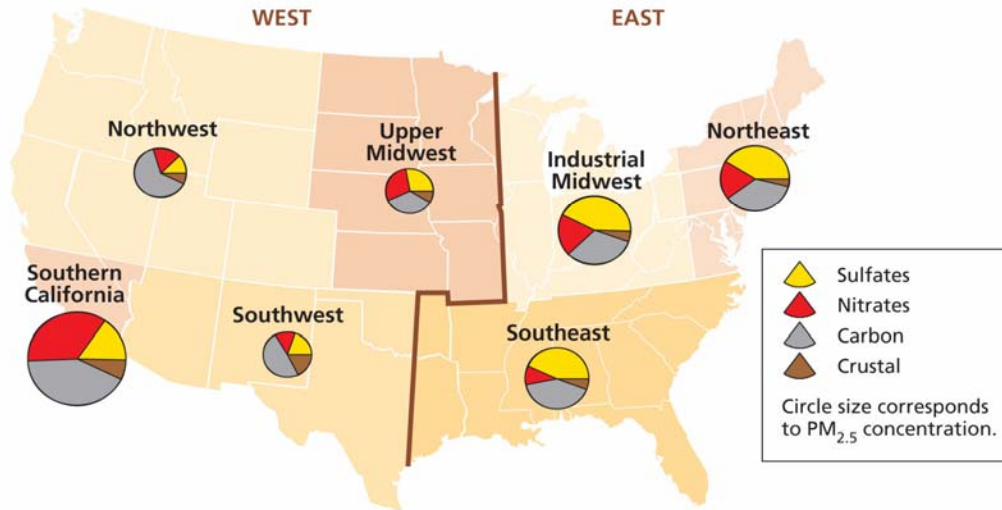


Figure 2-2. Average PM_{2.5} composition in urban areas by region, 2003.

Seasonal and Daily Patterns of PM_{2.5}

Fine particles often have a seasonal pattern. As shown in Figure 2-3, PM_{2.5} values in the eastern half of the United States are typically higher in the third calendar quarter (July-September) when sulfates are more readily formed from sulfur dioxide (SO₂) emissions from power plants in that region. Fine particle concentrations tend to be higher in the fourth calendar quarter (October through December) in many areas of the West, in part because fine particle nitrates and carbonaceous particles are more readily formed in cooler weather, and wood stove and fireplace use produces more carbon.

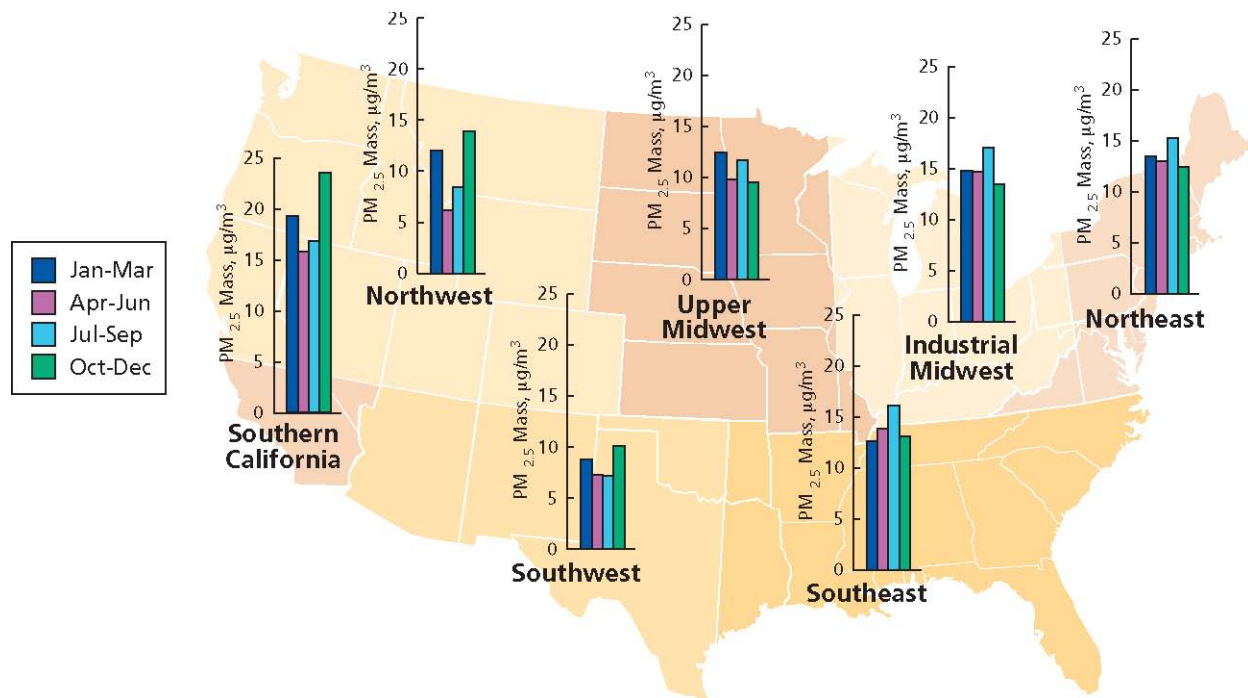


Figure 2-3. Seasonal averages of PM_{2.5} concentration by region, 1999-2003.

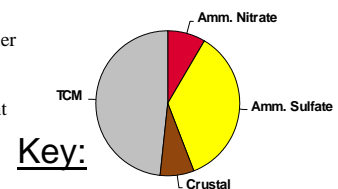
In addition, daily values of PM_{2.5} also reveal patterns based on the time of year. Unlike daily ozone levels, which are usually elevated in the summer, daily PM_{2.5} values at some locations can be high at any time of the year. Table 2-1 provides 2003 data on daily PM_{2.5} values and their composition on high mass days for various sites within large metropolitan areas (in the east: Birmingham, AL; Atlanta, GA; New York City, NY; Cleveland, OH; Chicago, IL; and St. Louis, MO; in the west: Salt Lake City, UT; and Fresno, CA). Mass is proportioned into four categories: sulfates, nitrates, crustal, and total carbonaceous mass (TCM, the sum of EC and OCM). For each site, the table shows the 2003 annual average speciation pattern, the profile for the five highest PM_{2.5} mass days in that year—both individually and averaged together—and corresponding FRM mass values (annual average, five highest days, and average of five highest). The table shows some notable differences in the percentage contribution of each of the species to total mass when looking at the high end of the distribution versus the annual average. In all of the eastern city sites, the percentage of sulfates is somewhat higher on the five high days as compared to the annual averages. In the two western cities, the percentage of nitrates is higher on the five high days as compared to the annual averages. TCM appears somewhat lower percentage on the five high days compared to the annual averages in most cities.

Table 2-1. PM_{2.5} composition on high mass days in select urban areas, 2003.

| Urban Area | Statistic* | Composition Percents (%) | | | | PM _{2.5} mass** (µg/m ³) | Annual average | Average of 5 highest days |
|--------------------|--|--------------------------|--------------|---------|------|---|----------------|---------------------------|
| | | Amm. Nitrate | Amm. Sulfate | Crustal | TCM | | | |
| Birmingham, AL | • Annual average | 8.5 | 35.6 | 7.6 | 48.3 | 17.9 | | |
| | • Average of 5 highest PM _{2.5} mass days | 3.8 | 40.0 | 7.8 | 48.3 | 40.7 | | |
| | • Highest PM _{2.5} mass day | 1.9 | 55.1 | 5.5 | 37.4 | 46.6 | | |
| | • 2 nd highest PM _{2.5} mass day | 4.2 | 26.9 | 11.0 | 57.9 | 40.4 | | |
| | • 3 rd highest PM _{2.5} mass day | 15.3 | 15.7 | 10.7 | 58.4 | 39.2 | | |
| | • 4 th Highest PM _{2.5} mass day | 2.7 | 51.1 | 7.4 | 38.7 | 39.1 | | |
| | • 5 th Highest PM _{2.5} mass day | 2.6 | 34.6 | 6.4 | 56.3 | 38.3 | | |
| Atlanta, GA | • Annual average | 8.1 | 42.8 | 4.0 | 45.0 | 15.2 | | |
| | • Average of 5 highest PM _{2.5} mass days | 2.6 | 60.1 | 2.3 | 34.3 | 35.2 | | |
| | • Highest PM _{2.5} mass day | 2.0 | 70.5 | 1.9 | 25.6 | 37.8 | | |
| | • 2 nd highest PM _{2.5} mass day | 2.0 | 47.8 | 2.5 | 47.8 | 37.1 | | |
| | • 3 rd highest PM _{2.5} mass day | 2.4 | 67.6 | 2.1 | 27.9 | 36.8 | | |
| | • 4 th Highest PM _{2.5} mass day | 3.2 | 50.8 | 2.9 | 43.1 | 35.0 | | |
| | • 5 th Highest PM _{2.5} mass day | 3.6 | 67.5 | 1.9 | 27.0 | 29.3 | | |
| New York City, NY | • Annual average | 20.2 | 38.3 | 5.1 | 36.4 | 13.1 | | |
| | • Average of 5 highest PM _{2.5} mass days | 11.6 | 57.9 | 3.0 | 27.4 | 40.5 | | |
| | • Highest PM _{2.5} mass day | 3.6 | 58.3 | 5.5 | 32.6 | 45.9 | | |
| | • 2 nd highest PM _{2.5} mass day | 5.0 | 69.0 | 1.4 | 24.6 | 45.8 | | |
| | • 3 rd highest PM _{2.5} mass day | 27.8 | 42.1 | 3.1 | 27.0 | 38.2 | | |
| | • 4 th Highest PM _{2.5} mass day | 5.1 | 59.4 | 4.6 | 30.9 | 36.4 | | |
| | • 5 th Highest PM _{2.5} mass day | 9.7 | 62.2 | 2.0 | 26.1 | 36.0 | | |
| Cleveland, OH | • Annual average | 22.3 | 38.3 | 7.4 | 32.1 | 17.6 | | |
| | • Average of 5 highest PM _{2.5} mass days | 21.4 | 42.5 | 6.3 | 30.0 | 44.1 | | |
| | • Highest PM _{2.5} mass day | 32.7 | 43.2 | 2.3 | 21.7 | 57.9 | | |
| | • 2 nd highest PM _{2.5} mass day | 25.1 | 41.5 | 4.0 | 29.3 | 46.4 | | |
| | • 3 rd highest PM _{2.5} mass day | 4.8 | 64.4 | 8.7 | 22.1 | 45.5 | | |
| | • 4 th Highest PM _{2.5} mass day | 8.8 | 37.5 | 14.7 | 39.0 | 35.7 | | |
| | • 5 th Highest PM _{2.5} mass day | 31.4 | 20.5 | 4.0 | 44.0 | 35.0 | | |
| Chicago, IL | • Annual average | 28.0 | 31.8 | 4.6 | 35.6 | 15.2 | | |
| | • Average of 5 highest PM _{2.5} mass days | 41.2 | 34.0 | 2.3 | 22.4 | 34.4 | | |
| | • Highest PM _{2.5} mass day | 46.0 | 30.7 | 1.2 | 22.1 | 38.3 | | |
| | • 2 nd highest PM _{2.5} mass day | 49.2 | 36.4 | 0.8 | 13.6 | 35.3 | | |
| | • 3 rd highest PM _{2.5} mass day | 51.8 | 27.7 | 1.2 | 19.3 | 35.1 | | |
| | • 4 th Highest PM _{2.5} mass day | 5.6 | 61.7 | 3.8 | 28.9 | 32.5 | | |
| | • 5 th Highest PM _{2.5} mass day | 47.8 | 16.1 | 5.3 | 30.8 | 30.7 | | |
| St. Louis, MO | • Annual average | 20.0 | 36.0 | 5.6 | 38.4 | 14.5 | | |
| | • Average of 5 highest PM _{2.5} mass days | 12.2 | 61.9 | 3.9 | 22.0 | 35.9 | | |
| | • Highest PM _{2.5} mass day | 6.2 | 69.1 | 3.6 | 21.0 | 50.6 | | |
| | • 2 nd highest PM _{2.5} mass day | 5.0 | 67.0 | 2.0 | 26.0 | 36.0 | | |
| | • 3 rd highest PM _{2.5} mass day | 6.4 | 69.2 | 3.2 | 21.3 | 33.1 | | |
| | • 4 th Highest PM _{2.5} mass day | 5.0 | 58.9 | 8.2 | 28.1 | 30.8 | | |
| | • 5 th Highest PM _{2.5} mass day | 40.2 | 42.3 | 2.7 | 14.7 | 28.9 | | |
| Salt Lake City, UT | • Annual average | 28.3 | 12.2 | 8.5 | 51.1 | 10.0 | | |
| | • Average of 5 highest PM _{2.5} mass days | 46.3 | 10.8 | 2.9 | 40.0 | 40.6 | | |
| | • Highest PM _{2.5} mass day | 50.6 | 6.3 | 2.5 | 40.5 | 59.5 | | |
| | • 2 nd highest PM _{2.5} mass day | 43.5 | 11.9 | 2.6 | 42.0 | 52.1 | | |
| | • 3 rd highest PM _{2.5} mass day | 42.4 | 13.5 | 3.7 | 40.4 | 34.2 | | |
| | • 4 th Highest PM _{2.5} mass day | 48.2 | 5.9 | 4.7 | 41.3 | 28.7 | | |
| | • 5 th Highest PM _{2.5} mass day | 45.4 | 20.2 | 1.5 | 32.8 | 28.4 | | |
| Fresno, CA | • Annual average | 35.5 | 10.2 | 3.6 | 50.7 | 18.0 | | |
| | • Average of 5 highest PM _{2.5} mass days | 42.4 | 4.7 | 1.3 | 51.6 | 54.2 | | |
| | • Highest PM _{2.5} mass day | 55.2 | 4.6 | 2.1 | 38.2 | 59.0 | | |
| | • 2 nd highest PM _{2.5} mass day | 58.4 | 8.5 | 0.9 | 32.2 | 56.3 | | |
| | • 3 rd highest PM _{2.5} mass day | 17.5 | 1.5 | 1.3 | 79.7 | 54.4 | | |
| | • 4 th Highest PM _{2.5} mass day | 35.1 | 5.3 | 1.0 | 58.6 | 52.6 | | |
| | • 5 th Highest PM _{2.5} mass day | 44.6 | 3.7 | 1.3 | 50.3 | 50.0 | | |

* The 5 highest days shown (and aggregated) for each site actually represent the 5 highest days (based on collocated FRM mass; see next bullet) that the speciation monitor sampled. FRM monitors at different locations in the metropolitan area and/or collocated FRM measurements on days that the speciation sampler did not record valid data may have had higher values than some or all of the 5 high values shown. Event-flagged data were omitted from this analyses.

** 'PM_{2.5} mass' concentration represents the collocated (w/ speciation monitor) same-day FRM measurement unless not available, in which case the speciation monitor gravimetric mass was substituted.



Future-year Predictions of PM_{2.5} Levels and Composition

EPA recently conducted a comprehensive analysis of the combination of the Clean Air Interstate Rule (CAIR), the Clean Air Mercury Rule (CAMR), and the Clean Air Visibility Rule (CAVR) rules promulgated by EPA in 2005.⁵ The analysis also included the emissions reductions expected from a number of national rules that affect light- and heavy-duty vehicles and non-road mobile sources. EPA modeled this combined control scenario for 2010, 2015, and 2020 using the Community Multi-Scale Air Quality (CMAQ) model. The 2015 control scenario was used as the *regulatory base case* for the PM NAAQS analysis. None of the scenarios included projections of what actions states might take in their State Implementation Plans (SIPs) to meet the current ozone or current PM standards

Predicted PM_{2.5} Levels

As shown in Table 2-2, the above described EPA modeling provides current design values and future year projections for 2010, 2015, and 2020 that can be used to determine which counties are projected to attain the standard and those that will be in nonattainment under various standard options being considered here. This is not a forecast of the air quality EPA would expect to occur in these years, because the baseline analyzed contains only current programs, and not the additional reductions that states might take in SIPs designed to meet the current PM NAAQS. Nevertheless, this baseline scenario analysis does show that EPA's recently promulgated CAIR-CAVR-CAMR program, mobile source regulations, and current state and local programs would make significantly reduce projected PM_{2.5} nonattainment in the eastern US under any of the standard alternatives analyzed, as compared to current air quality levels.

The current design value (DV) for any area is based on a 5-year weighted average, 1999-2003, of ambient data.⁶ Note that certain counties may have complete data for purposes of calculating annual 5-year weighted design values, but incomplete data for calculating 24-hour design values, and vice versa. Therefore, the analysis for some counties may be based on only one form of the standard. Due to this, the number of nonattainment counties will possibly be understated. Increases in nonattainment counts between years may reflect growth in uncontrolled sectors. Appendix A contains complete state and county annual and daily design value data used in the determination of annual and daily attainment/nonattainment for projected 2010, 2015, and 2020 years.

⁵ Clean Air Interstate Rule Emissions Inventory Technical Support Document (EPA Docket #: OAR-2003-0053-2047).

⁶ Procedures for Estimating Future PM_{2.5} Values for the CAIR Final Rule by Applications of the Speciated Modeling Attainment Test (SMAT), Updated November 8, 2004 (EPA Docket #: OAR-2003-0053-1907).

Table 2-2. Summary of Projected County Attainment and Nonattainment Counts: Projected 2010, 2015, and 2020*

| <i>Standard Alternatives (annual/daily in $\mu\text{g}/\text{m}^3$)</i> | | <i>Projected with Regulatory Base Case</i> | | | | | | | | |
|--|----------------|--|------|------|----------|------|------|----------|------|------|
| | | 2010 | | | 2015 | | | 2020 | | |
| | | National | East | West | National | East | West | National | East | West |
| 15/65— current standard | Attain ** | 77 | 75 | 2 | 84 | 84 | 0 | 82 | 83 | 0 |
| | Non- Attain | 39 | 27 | 12 | 32 | 18 | 14 | 34 | 19 | 15 |
| 15/40 | Attain ** | 81 | 75 | 6 | 90 | 84 | 6 | 86 | 83 | 3 |
| | Non- Attain | 57 | 27 | 30 | 48 | 18 | 30 | 52 | 19 | 33 |
| 15/35— Proposed | Attain ** | 102 | 98 | 4 | 115 | 111 | 4 | 110 | 108 | 2 |
| | Non- Attain | 89 | 43 | 46 | 76 | 30 | 46 | 81 | 33 | 48 |
| 14/35 | Attain ** | 125 | 121 | 4 | 139 | 135 | 4 | 132 | 130 | 2 |
| | Non- Attain | 110 | 64 | 46 | 96 | 50 | 46 | 103 | 55 | 48 |
| 15/30 | Attain ** | 129 | 129 | 0 | 148 | 148 | 0 | 147 | 148 | 0 |
| | Non- Attain | 197 | 135 | 62 | 178 | 116 | 62 | 179 | 116 | 63 |

*See Appendix E for details on projection method used here (i.e., Speciated Modeled Attainment Test--SMAT).

**These are counties with monitors that reported concentrations above the respective NAAQS alternative levels based on 2002-2004 data that are projected to attain the alternative in the forecast years noted.

The series of maps which follows provides further detail on the preceding tables (Figures 2-4 through 2-13). The first map in each pair graphically depicts the counties which attain and those that do not attain the various standard levels in 2015 assuming a regulatory baseline of the CAIR/CAVR/CAMR rules, the national mobile rules for light and heavy-duty vehicles and non-road mobile sources, and current state programs that address these and other source categories that were on the books as of early 2005 (i.e., *regulatory base case*). For example, in Figure 2-4, red counties cannot attain the annual $15 \mu\text{g}/\text{m}^3$ or the 24 hour $65 \mu\text{g}/\text{m}^3$ standards. Yellow counties do not attain the 24 hour standard but do attain the annual. Orange counties do not attain the annual standard but do attain the 24 hour standard. Grey counties are those that attain both standards in 2015 after the regulatory base case rules take effect when compared to current air quality levels. The second map (e.g. Figure 2-5) in each pair shows the increment by which each county is exceeding each standard. This permits an evaluation of which areas are relatively close to attaining the NAAQS, and which may need more significant reductions. It is reasonable to expect that most areas relatively close to the standard levels are likely to be able to reach attainment with the addition of only local controls. As the increment above the standard increases, the likelihood increases that more extensive local, or, where possible, additional

regional controls might be needed for an area to reach attainment. These results suggest the following generalizations about the alternatives:

- As compared to the current standards, the proposed tighter daily standard of $35 \mu\text{g}/\text{m}^3$ appears to have a bigger impact in the West than in the East, particularly after the forecast regulatory base case controls are more fully implemented by 2015. Most of the eastern counties that would not attain the $35 \mu\text{g}/\text{m}^3$ standard in 2015 are part of nonattainment areas that are required to adopt further controls under the current standards. However, the increment above the daily standard is generally below $5 \mu\text{g}/\text{m}^3$.
- Most of the counties that would not attain the proposed daily standard in the northwestern quadrant of the US currently attain the annual and 24-hour NAAQS. These areas have lower annual averages, but can have high daily peaks during the winter months with more inversions as well as emissions from heating. The increment above the daily standard varies from 3 to $7 \mu\text{g}/\text{m}^3$ in this region.
- Southern and central California, which have a number of counties that violate the current daily standard, have increments in the range of 20 to $48 \mu\text{g}/\text{m}^3$ above the proposed daily standard.
- The analysis of an annual standard of $14 \mu\text{g}/\text{m}^3$ showed 235 counties out of attainment for both 24 hour and annual, 139 in attainment with both in 2015. The major effect of adopting a tighter annual standard of $14 \mu\text{g}/\text{m}^3$ would yield 20 additional non-attainment counties in the East in 2015. This alternative increases by $1 \mu\text{g}/\text{m}^3$ the increment above the annual NAAQS in all 32 counties forecast not to attain the current NAAQS.
- The adoption of a tighter 24 hour standard of $30 \mu\text{g}/\text{m}^3$ produces a substantially larger number of nonattainment counties nationwide. At this level, the daily standard is projected to be controlling for most areas.

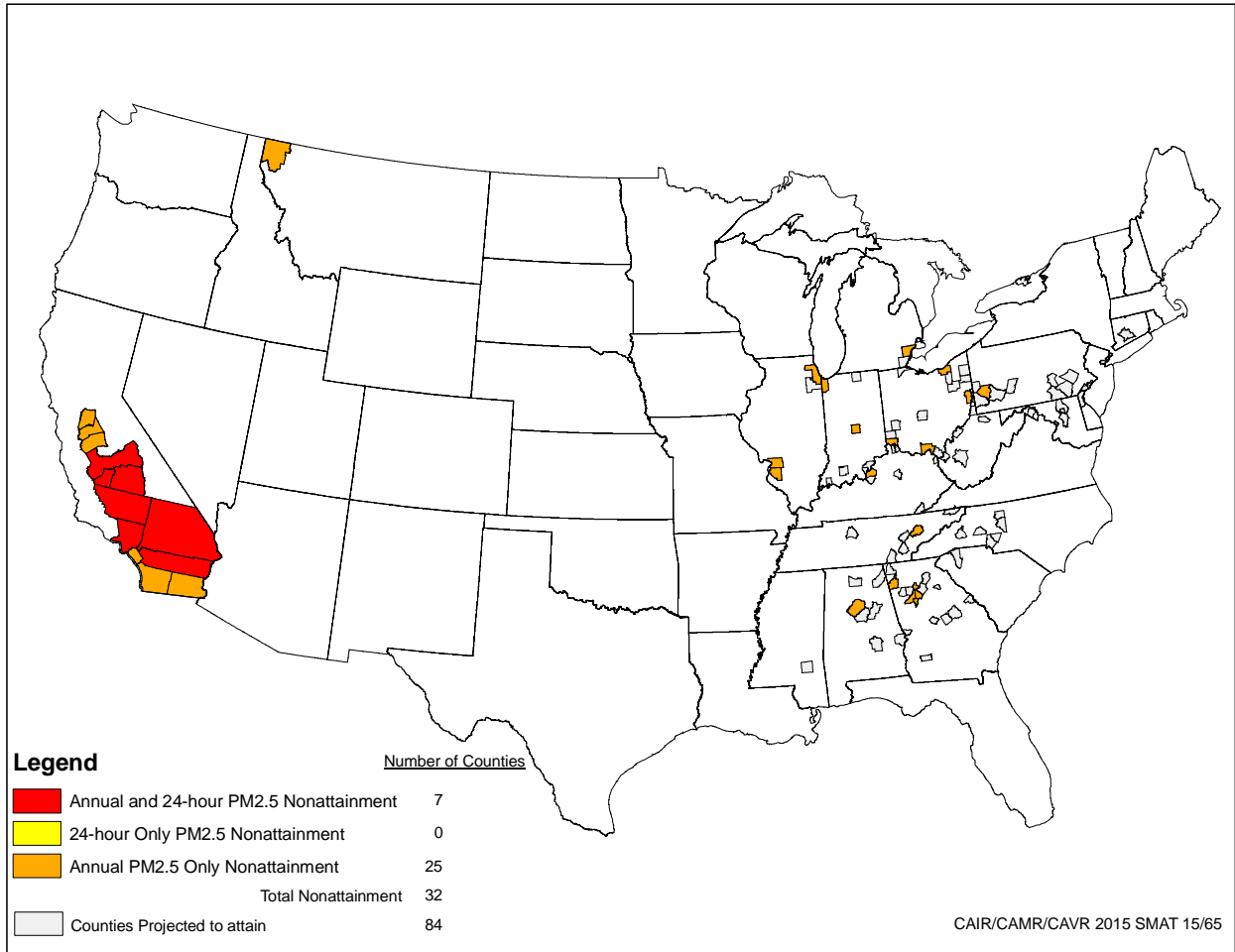


Figure 2-4. Counties Projected to Exceed the PM_{2.5} NAAQS with 2015 Base Case Scenario Controls - Annual 15 µg/m³ and 24-Hour 65 µg/m³ (Current Standard).

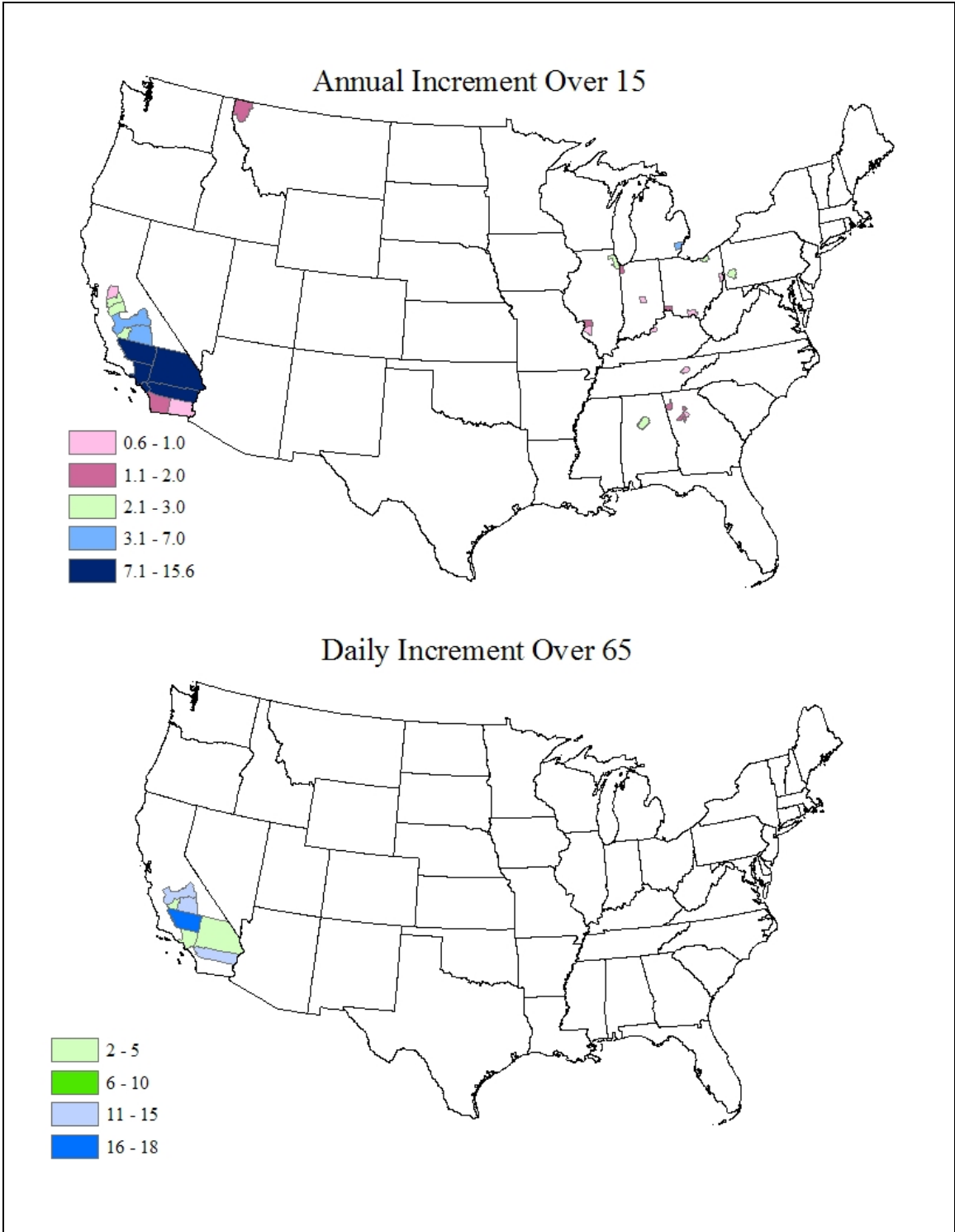


Figure 2-5. Increment (in $\mu\text{g}/\text{m}^3$) by which Projected Nonattainment Counties in 2015 would exceed the $\text{PM}_{2.5}$ NAAQS - Annual $15 \mu\text{g}/\text{m}^3$ and 24-Hour $65 \mu\text{g}/\text{m}^3$ (Current Standard).

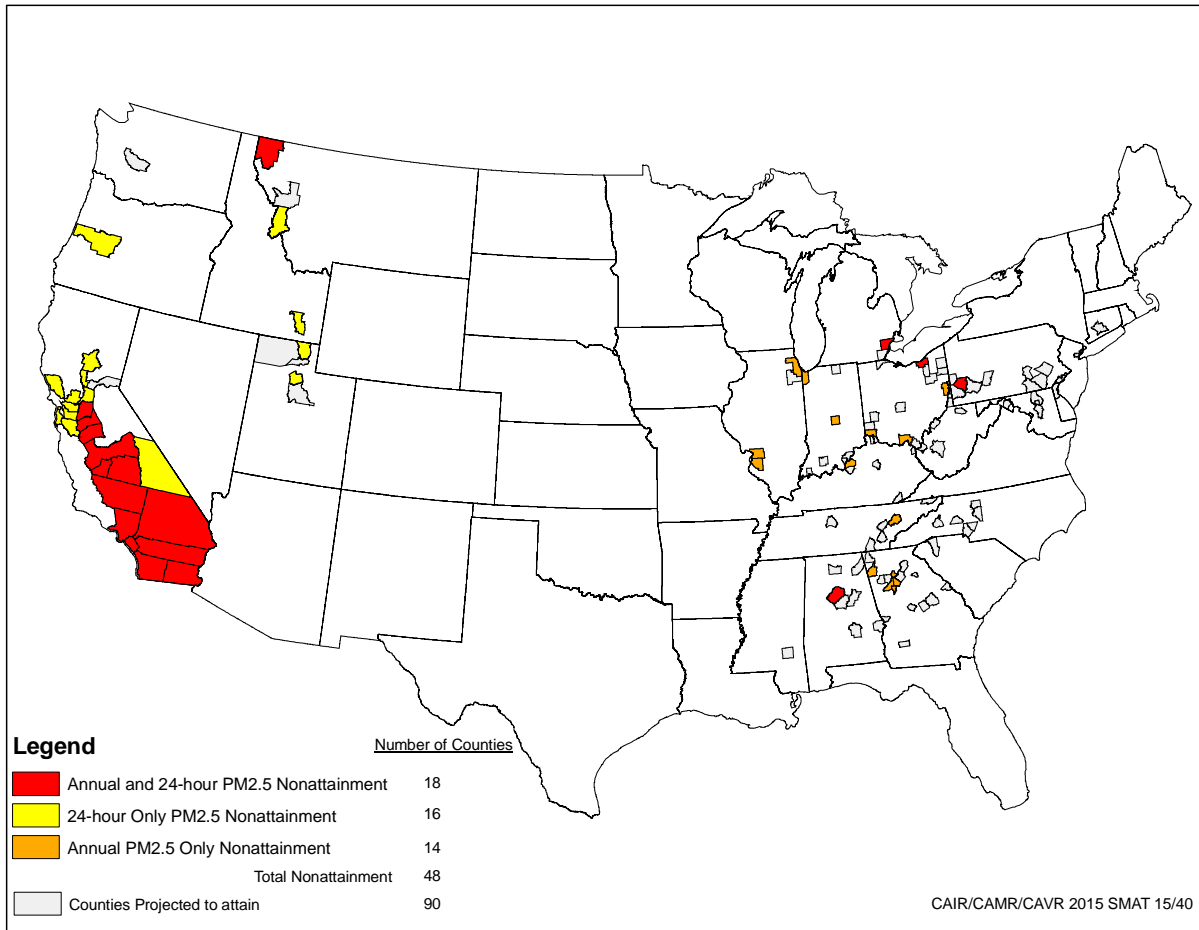


Figure 2-6. Counties Projected to Exceed the PM_{2.5} NAAQS with 2015 Base Case Scenario Controls - Annual 15 µg/m³ and 24-Hour 40 µg/m³ alternative.

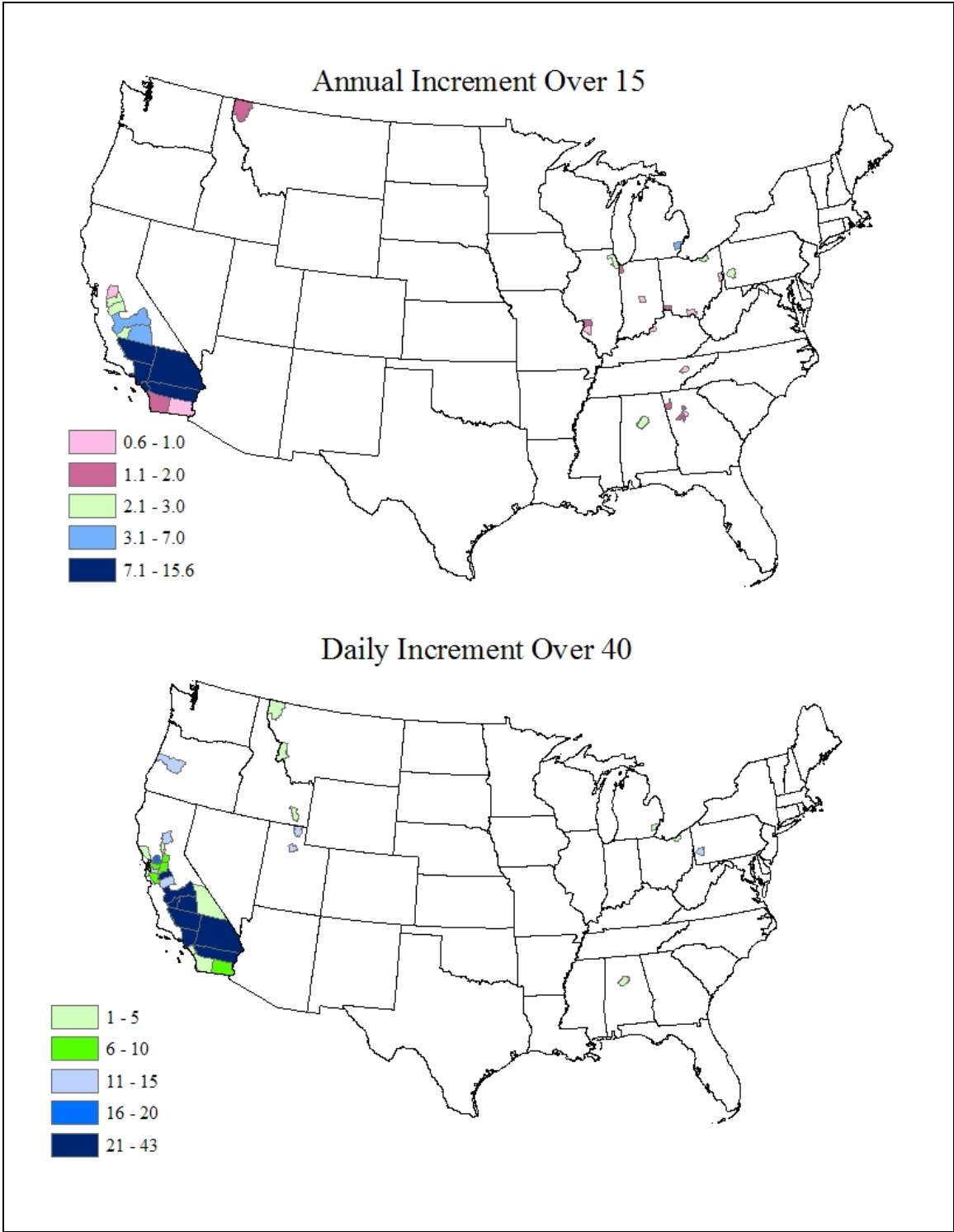


Figure 2-7. Increment (in $\mu\text{g}/\text{m}^3$) by which Projected Nonattainment Counties in 2015 would exceed the $\text{PM}_{2.5}$ NAAQS - Annual $15 \mu\text{g}/\text{m}^3$ and 24-Hour $40 \mu\text{g}/\text{m}^3$ NAAQS alternative.

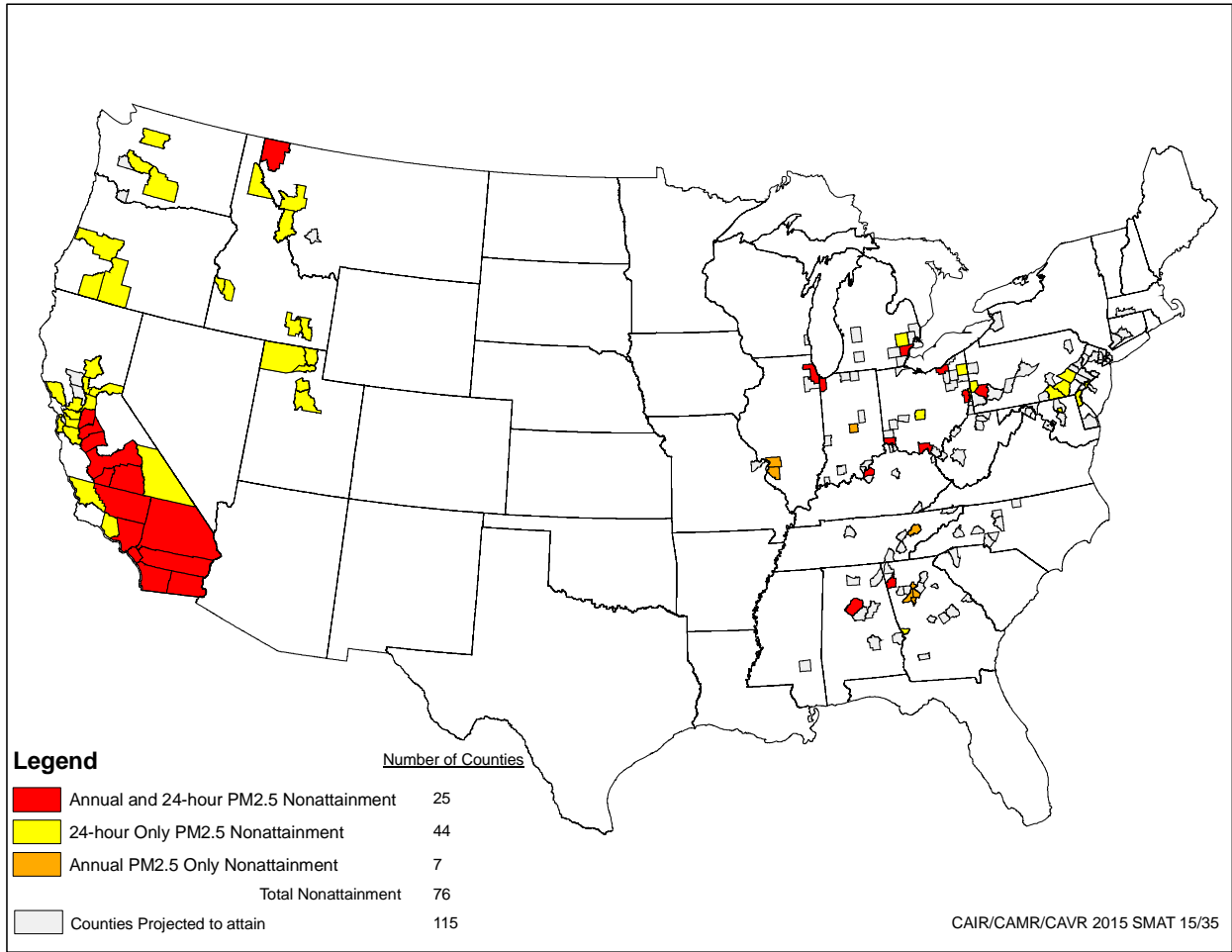


Figure 2-8. Counties Projected to Exceed the PM_{2.5} NAAQS with 2015 Base Case Scenario Controls - Annual 15 µg/m³ and 24-Hour 35 µg/m³ (Proposed Revised NAAQS)

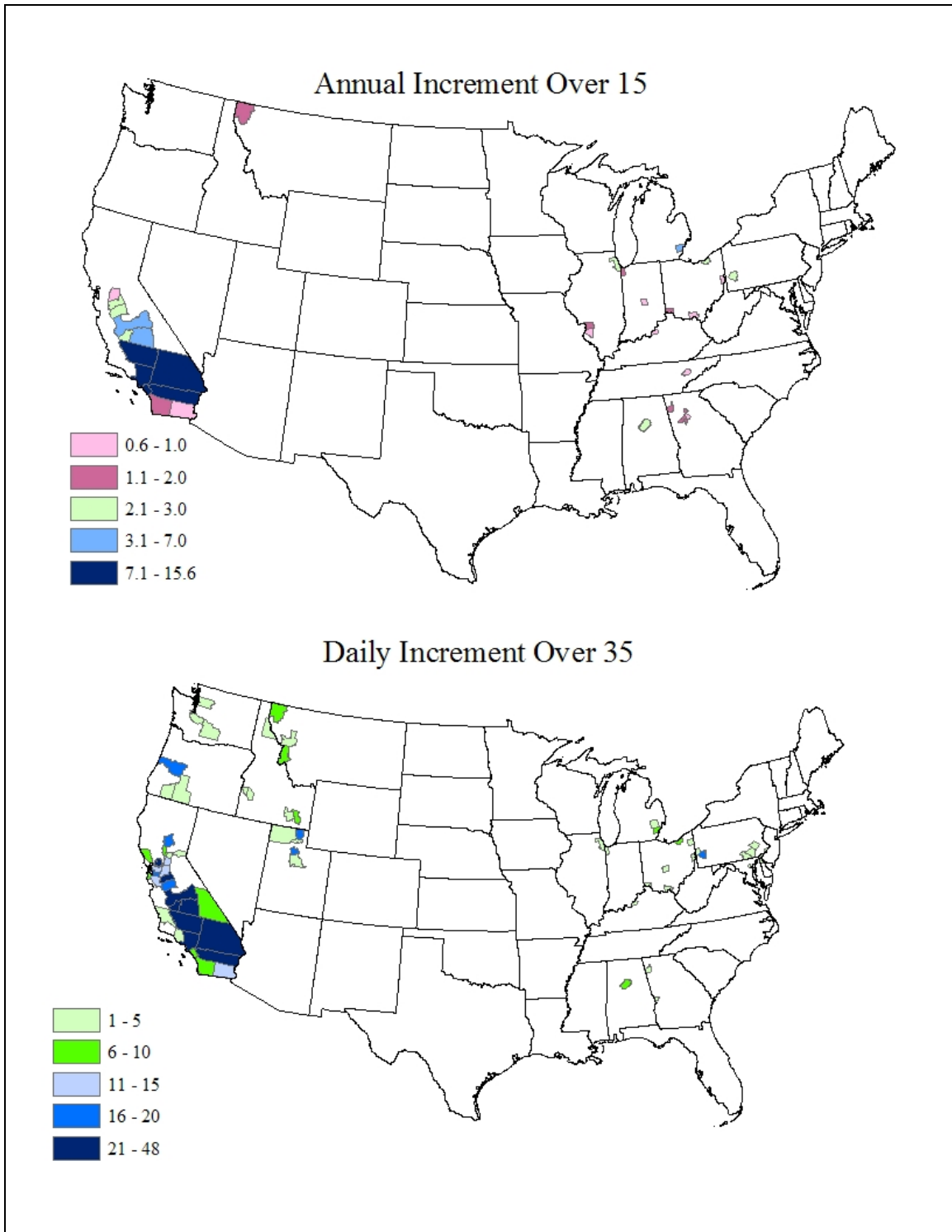


Figure 2-9. Increment (in $\mu\text{g}/\text{m}^3$) by which Projected Nonattainment Counties in 2015 would exceed the $\text{PM}_{2.5}$ NAAQS - Annual $15 \mu\text{g}/\text{m}^3$ and 24-Hour $35 \mu\text{g}/\text{m}^3$ (Proposed Revised NAAQS)..

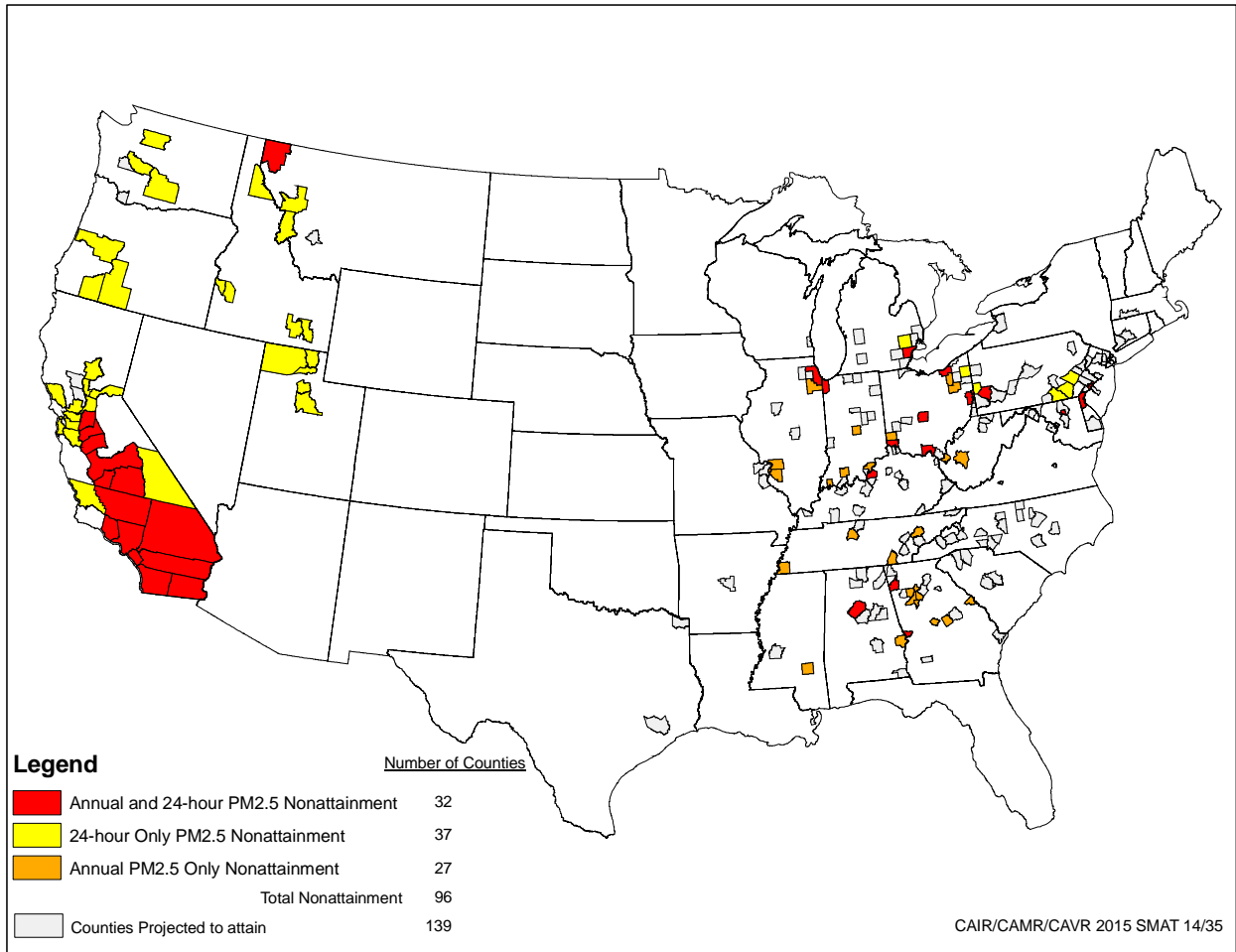


Figure 2-10. Counties Projected to Exceed the PM_{2.5} NAAQS with 2015 Base Case Scenario Controls - Annual 14 µg/m³ and 24-Hour 35 µg/m³ alternative.

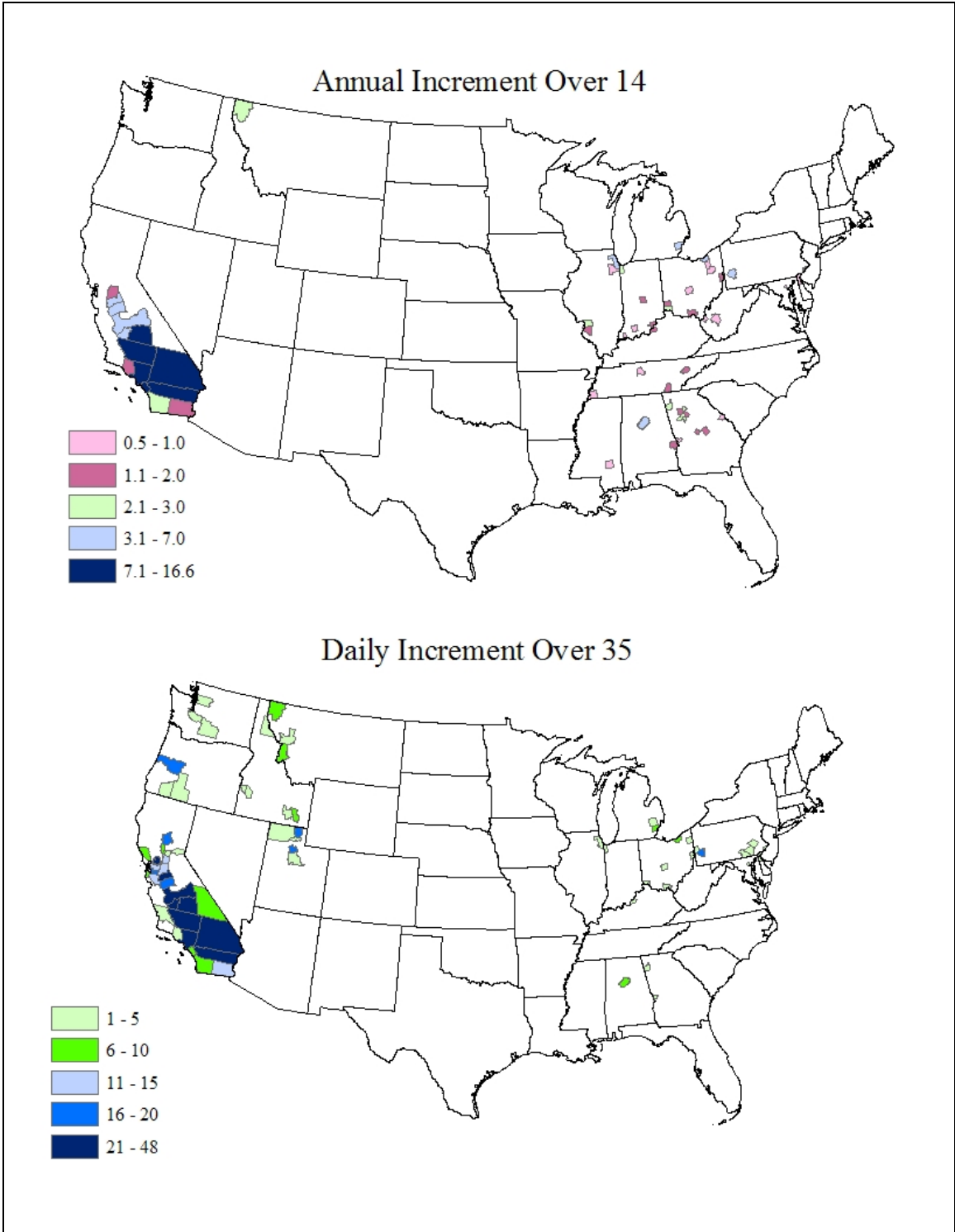


Figure 2-11. Increment (in $\mu\text{g}/\text{m}^3$) by which Projected Nonattainment Counties in 2015 would exceed the $\text{PM}_{2.5}$ NAAQS - Annual $14 \mu\text{g}/\text{m}^3$ and 24-Hour $35 \mu\text{g}/\text{m}^3$ NAAQS alternative

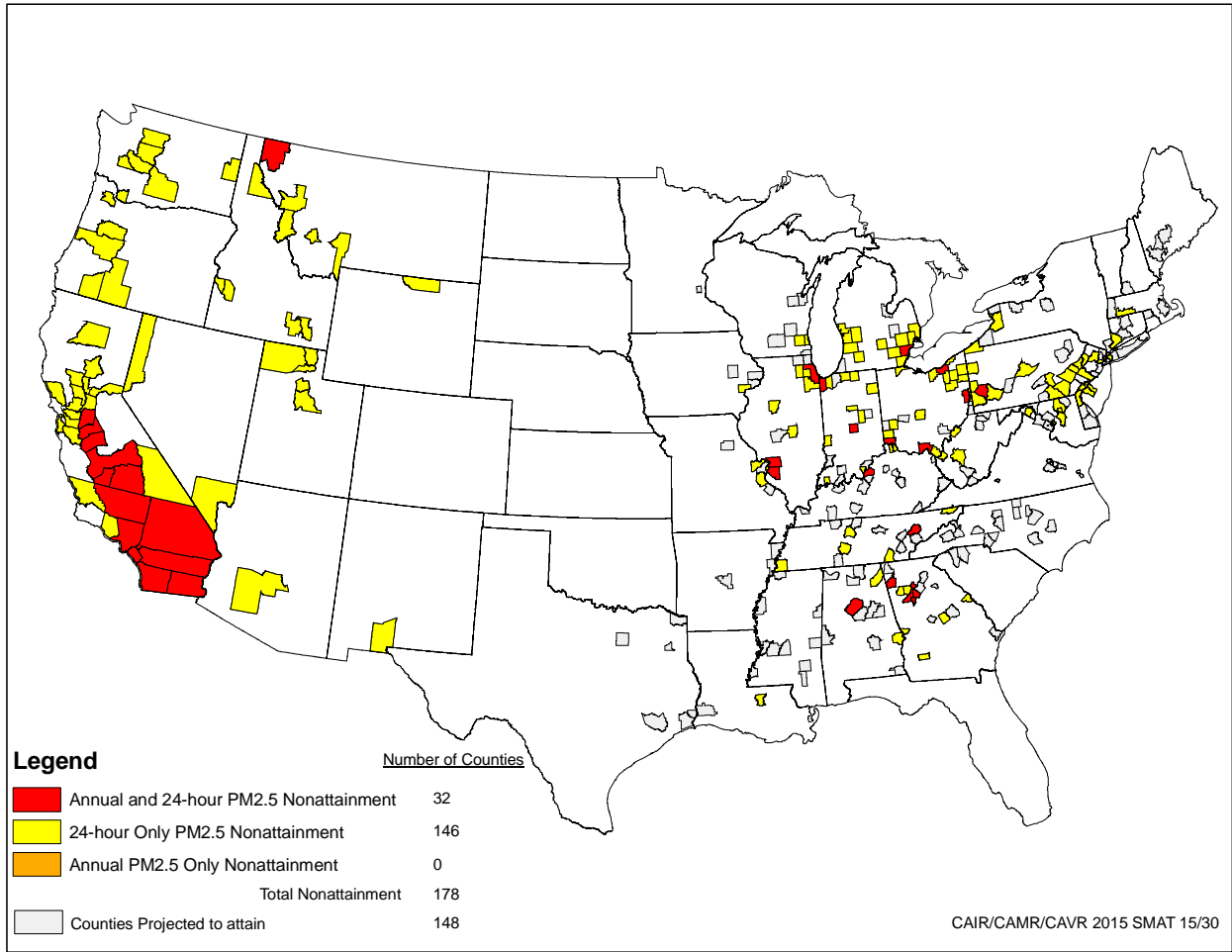


Figure 2-12. Counties Projected to Exceed the PM_{2.5} NAAQS with 2015 Base Case Scenario Controls - Annual 15 µg/m³ and 24-Hour 30 µg/m³ alternative.

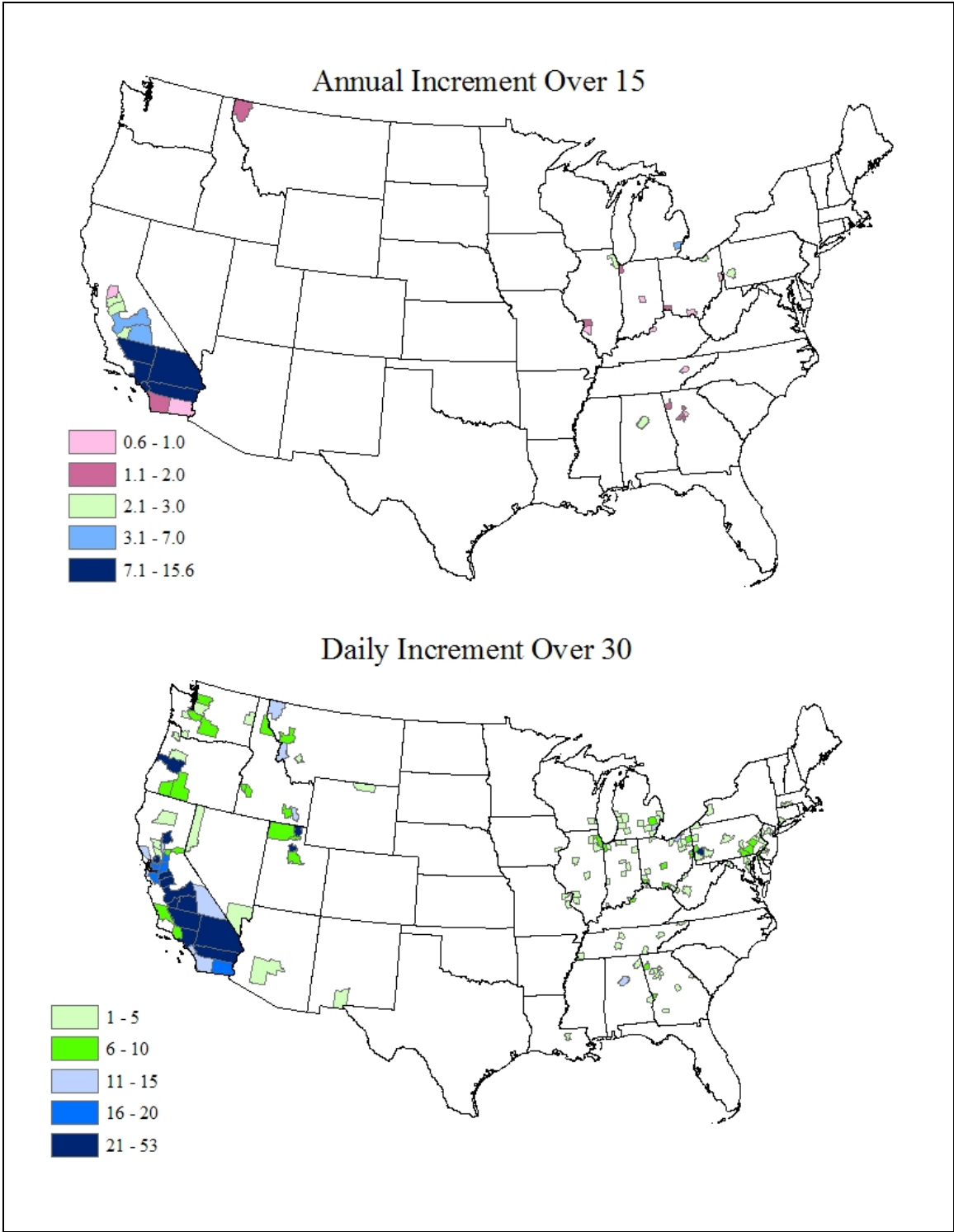


Figure 2-13. Increment (in $\mu\text{g}/\text{m}^3$) by which Projected Nonattainment Counties in 2015 would exceed the $\text{PM}_{2.5}$ NAAQS - Annual $15 \mu\text{g}/\text{m}^3$ and 24-Hour $30 \mu\text{g}/\text{m}^3$ NAAQS alternative

Predicted PM_{2.5} Component Species for Selected Areas

Based on our CMAQ modeling, a local perspective of PM_{2.5} levels and composition is provided in this section in order to further elaborate the nature of the PM_{2.5} air quality problem after implementation of the CAIR/CAMR/CAVR rules, the national mobile rules for light and heavy-duty vehicles and non-road mobile sources, and current state programs that were on the books as of early 2005.⁷ As an illustrative example, a localized analysis of current ambient and future-year speciation is provided for two cities, one in the East and one in the West.

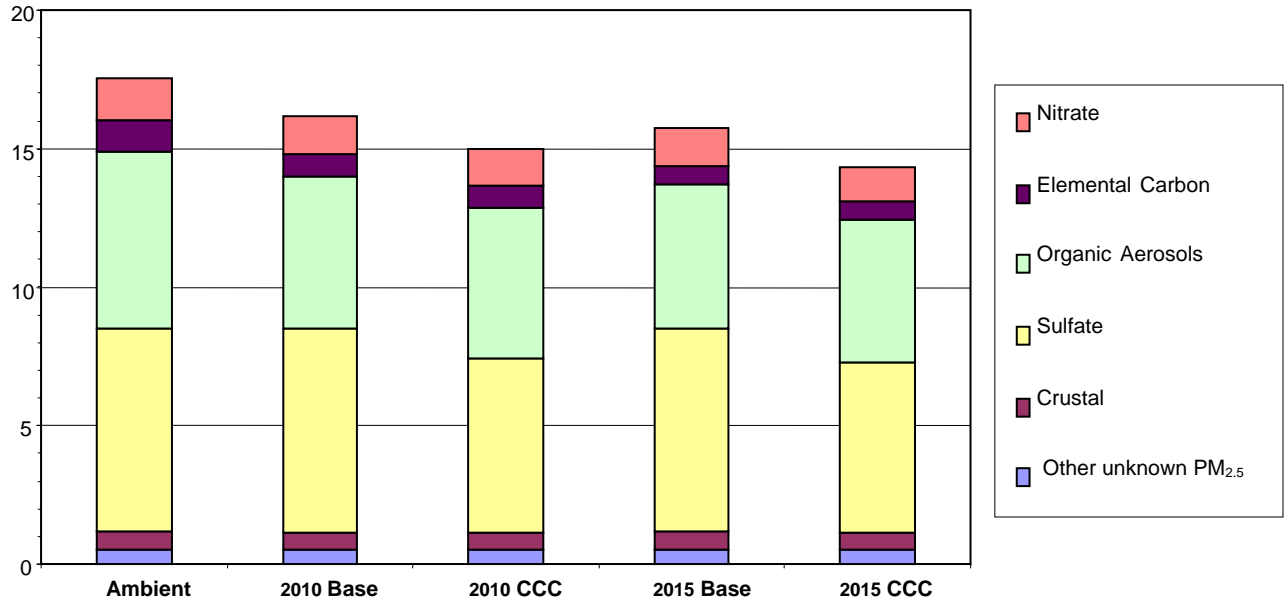
Figure 2-14 shows projected PM_{2.5} component species concentrations (i.e., sulfate, nitrate, elemental carbon, organic aerosols, crustal, and uncontrollable PM_{2.5}) for current ambient data (5 year weighted average, 1999-2003), 2010 and 2015 base case (no controls), and 2010 and 2015 regulatory base case with the addition of the controls mentioned in the previous paragraph. Please note that organic aerosols include directly emitted organic carbon and organic carbon particles formed in the atmosphere from anthropogenic sources and biogenic sources. Uncontrollable PM_{2.5} is based upon a 0.5 µg/m³ PM_{2.5} blank mass correction used in the Speciated Modeled Attainment Test (SMAT) approach where a number of adjustments and additions were made to the measured species data to provide for consistency with the chemical components retained on the FRM Teflon filter.⁸ The analysis provided here specifically looks at areas within the East (New York City), and the West (Salt Lake City).

Notably, organic aerosols are a large fraction of the overall remaining PM_{2.5} mass in New York and Salt Lake City. Sulfate is a considerable part of the total PM_{2.5} mass in both cities and is the largest contributor to PM_{2.5} mass in New York City. Nitrate is a relatively small source of PM_{2.5} for New York City but nitrate is the second largest contributor to the remaining PM_{2.5} problem in Salt Lake City. The relatively large contribution of sulfate to PM_{2.5} mass in New York City is characteristic of the urban air pollution mixture in the East, while the nitrate contribution to PM_{2.5} mass in Salt Lake City is characteristic of that found in the West.

⁷ Multi-pollutant legislation modeling. (Multi-pollutant analyses and technical support documents. [http://www.epa.gov/airmarkets/mp/.](http://www.epa.gov/airmarkets/mp/))

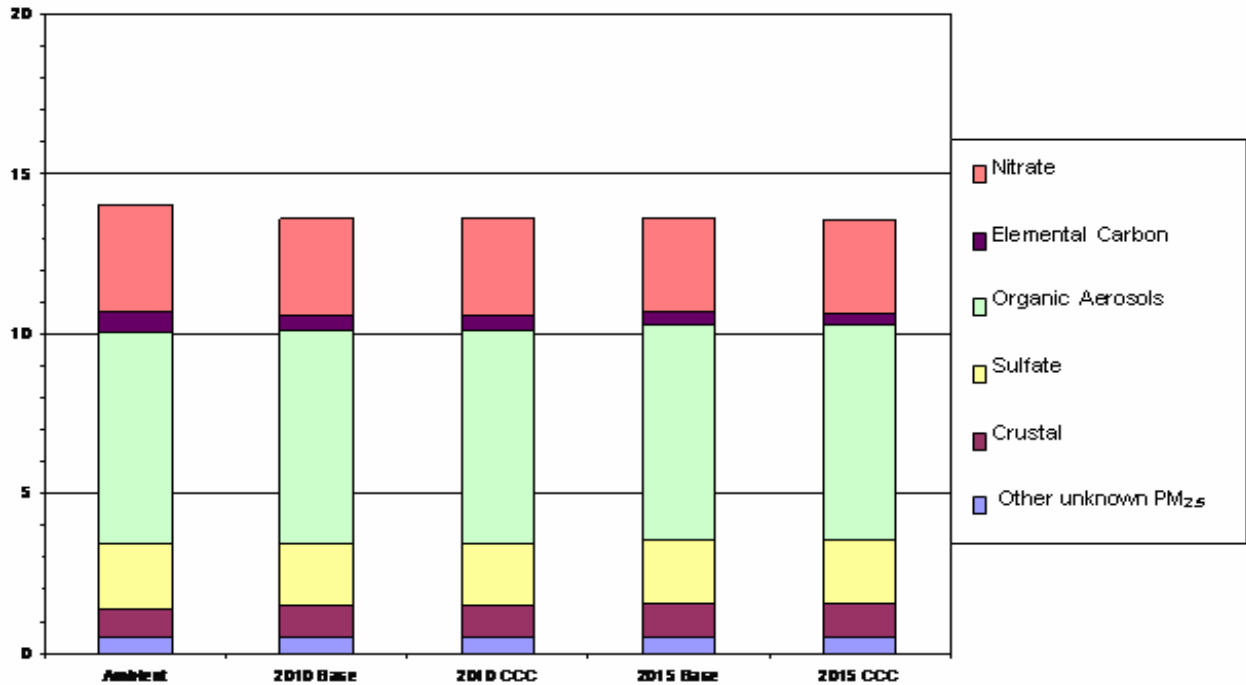
⁸ Procedures for Estimating Future PM_{2.5} Values for the CAIR Final Rule by Applications of the Speciated Modeling Attainment Test (SMAT), Updated November 8, 2004 (EPA Docket #: OAR-2003-0053-1907).

New York City



Note: "CCC" refers to the regulatory base case.

Salt Lake City



Note: "CCC" refers to the regulatory base case.

Figure 2-14. Projected PM_{2.5} Component Species Concentrations in New York City and Salt Lake City Regional and Local Sources of PM_{2.5}

Both local and regional sources contribute to particle pollution. Figure 2-15 shows how much of the PM_{2.5} mass can be attributed to local versus regional sources for 13 selected urban areas. In each of these urban areas, monitoring sites were paired with nearby rural sites. When the average rural concentration is subtracted from the measured urban concentration, the estimated local and regional contributions become apparent. Urban and nearby rural PM_{2.5} concentrations suggest substantial regional contributions to fine particles in the East. The measured PM_{2.5} concentration is not necessarily the maximum for each urban area. Regional concentrations are derived from the rural IMPROVE monitoring network.⁹

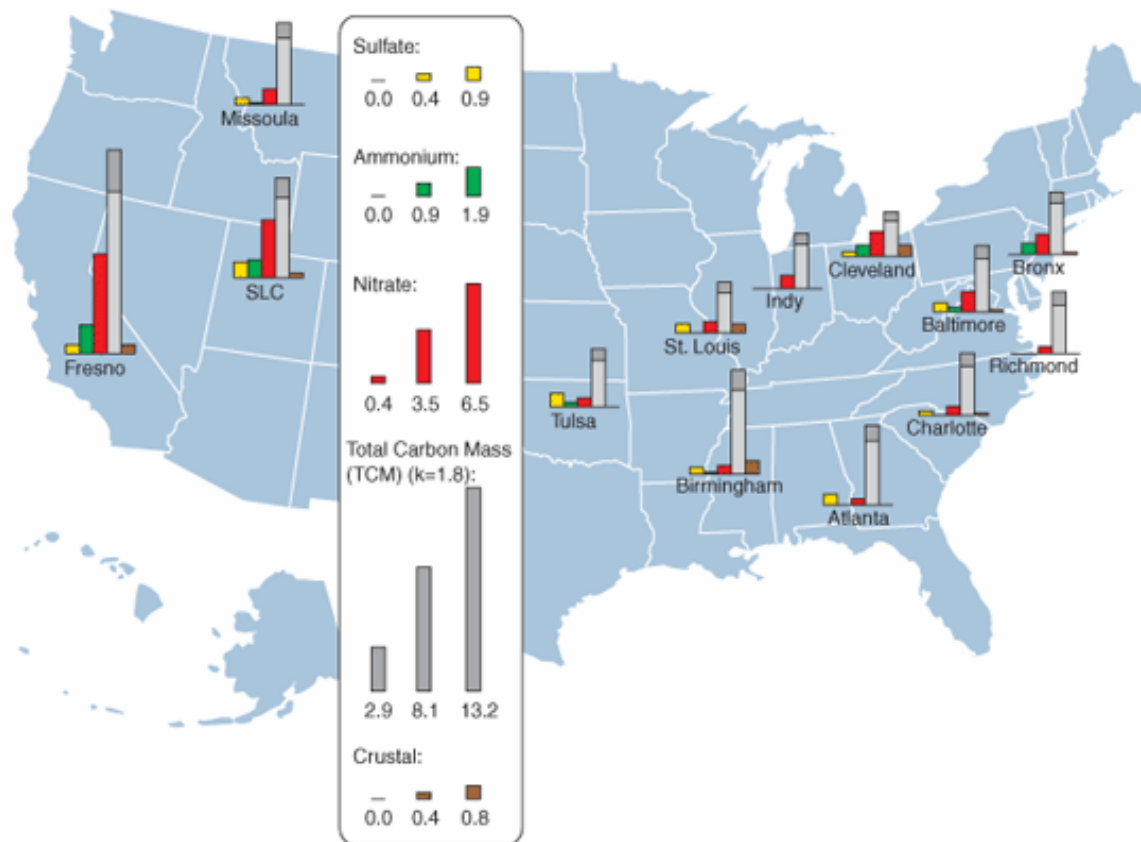


Figure 2-15. Estimated ‘urban excess’ of 13 urban areas by PM_{2.5} species component. The urban excess is estimated by subtracting the measured PM_{2.5} species at a regional monitor location (assumed to be representative of regional background) from those measured at an urban location.¹⁰

⁹Interagency Monitoring of Protected Visual Environments (IMPROVE) <http://vista.cira.colostate.edu/improve>

¹⁰ Note: In Total Carbon Mass (TCM) is the sum of Organic Carbon (OC) and Elemental Carbon (EC) In this graph, the light grey is OC and the dark grey is EC. See: Turpin, B. and H-J, Lim, 2001: Species contributions to PM_{2.5} mass concentrations: Revisiting common assumptions for estimating organic mass, Atmospheric Environment, 35, 602-610.

As shown in Figure 2-15, we observe a large urban excess across the US for most PM_{2.5} species but especially for total carbon mass. All of these locations have consistently high urban excess for total carbon mass with Fresno, CA and Birmingham, AL having the largest observed measures. Larger urban excess of nitrates is seen in the western US with Fresno, CA and Salt Lake City, UT being significantly higher than all other areas across the nation. These results indicate that local sources of these pollutants are indeed contributing to the PM_{2.5} air quality problem in these areas. As expected for a predominately regional pollutant, only a modest urban excess is observed for sulfates.

In the East, regional pollution contributes more than half of total PM_{2.5} concentrations. Rural background PM_{2.5} concentrations are high in the East and are somewhat uniform over large geographic areas. These regional concentrations come from emission sources such as power plants, natural sources, and urban pollution and can be transported hundreds of miles. The local and regional contributions for the major chemical components that make up urban PM_{2.5}: sulfates, carbon, and nitrates. Implementation of the promulgated CAIR-CAVR-CAMR program, mobile source regulations, and current state and local programs national rules will address regional contribution of PM_{2.5} associated with NO_x and SO₂, however states will need to examine local emission control measures to address the local PM_{2.5} contribution.

Source Apportionment Studies of PM_{2.5}

Fine particulate matter is a unique pollutant in that concentrations are influenced by both primary emissions and secondary atmospheric reactions. As described earlier, when attempting to characterize the sources affecting PM_{2.5} concentrations, it is important to note that both regional and local sources impact ambient levels. Regional sources are usually characterized as secondary particulate such as sulfates and nitrates. These are particles which form through atmospheric reactions and then are transported over long distances. Conversely, local influence usually involves directly emitted particulate matter from sources such as industrial facilities (i.e., iron and steel manufacturing, coke ovens, and pulp mills among others), residential wood and waste burning, and gasoline and diesel vehicles.¹¹

Development of effective and efficient emission control strategies to lower PM_{2.5} ambient concentrations can be aided by determining the relationship between the various types of emissions sources and elevated levels of PM_{2.5} at ambient monitoring sites. Source apportionment analyses such as receptor modeling are useful in this regard by both qualifying and quantifying potential fine particulate regional and local source impacts on a receptor's ambient concentrations. The goal is to apportion the mass concentrations into components attributable to the most significant sources. Receptor modeling techniques utilize measured ambient concentrations of PM_{2.5} species to quantify the contribution that regional and local sources have at a given receptor which, in this case, is an ambient monitoring location.¹² These

¹¹ Note that while we believe that the mobile source sector is a substantial contributor to total PM_{2.5} mass; our current mobile source inventory and control measures are limited in completeness. For this reason, we believe there are more mobile source reductions available than those that we model in our controls analysis.

¹² Currently, two established receptor models are widely used for source apportionment studies: the Chemical Mass Balance (CMB) model and Positive Matrix Factorization (PMF). The CMB receptor model relies on measured

techniques are very useful in characterizing fine particulate source contributions to ambient PM_{2.5} levels; however, there are inherent limitations including but not limited to the adequacy (e.g., vintage and representativeness) of existing source profiles in identifying source groups or specific sources, availability and completeness of ambient datasets to fully inform these techniques, and current scientific understanding and measured data to relate tracer elements to specific sources, production processes, or activities.

A literature compilation summarizing 27 source apportionment studies was conducted as part of a research and preparation program for CAIR (rule based on PM_{2.5} transport).¹³ Literature selected in this compilation represented key source apportionment research, focusing primarily on recent source apportionment studies in the eastern U.S. Table 2-4 provides a detailed matrix that presents an overview of the sources found in the studies by location. The sources identified are grouped into seven categories: sulfate/coal, mobile, nitrate, biomass burning, industrial, crustal and salt, and other/not identified. It is important to note that some of these studies are based on older ambient databases and that more recent ambient data have shown improvement and reduced levels of ambient PM_{2.5} concentrations across the US, especially in the east, which affects the quantitative conclusions one may draw from these studies. In particular, the relative importance of sulfates and nitrates from power generation is declining as the result of recent reductions in precursor emissions from these sources as part of regulations like the acid rain program. In addition, many of the models used here include secondary organic carbon aerosols (SOC) within the “sulfate” or “coal” categories (Lee et al, 2003, is an exception), although emissions of carbonaceous species from coal plants is negligible. The inclusion of SOC in these categories is likely because similar atmospheric chemistry creates both types of secondary aerosols, which together are the largest components of regional air masses common in summer in the Eastern U.S. Sources of the organic gases which form SOC include: vegetation, vehicles, and industrial VOC and SVOC emissions.

While more recent information (e.g. Figure 2-2) shows that secondarily formed PM_{2.5} associated with precursor emissions from combustion sources (SO₂ and NO_x) remain important components of the problem faced across many U.S. cities, in recent years other common significant local contributors such as industrial facilities, wood combustion and mobile sources are relatively more important than in the past. The mixture of the industrial source contribution varies across the nation with heavy manufacturing such as metal processing (i.e., steel production, coke ovens, and foundries), petroleum refining, and cement manufacturing among others. The extent of these industrial source contributions to local PM_{2.5} problems vary across the U.S. and can even vary within an urban area. Therefore, the key for each area is to understand the nature of their problem (i.e., determining the relationship between the various types of emissions sources and elevated levels of PM_{2.5} at ambient monitoring sites) in order to develop effective and efficient emission control strategies to reduce PM_{2.5} ambient concentrations.

source profiles as well as ambient species measurements to produce a source contribution estimate at the receptor location, while the PMF technique decomposes the ambient measurement data matrix into source profiles and contributions by utilizing the underlying relationship (i.e., correlations) between the individually measured species.

¹³ Second Draft Technical Report (Revision 1), Compilation of Existing Studies on Source Apportionment for PM_{2.5}, August 22, 2003 (Contract No. 68-D-02-061; Work Assignment 1-05).

<http://www.epa.gov/oar/oaqps/pm25/docs/compsareports.pdf>

Table 2-3. Source matrix from published apportionment studies by approximate geography.

| Location or Nearest City | Reference | Total Mass ($\mu\text{g}/\text{m}^3$) | Sulfate/Coal | | Nitrate | Mobile | | | Biomass burning | | | Industrial | | | Crustal and Salt | | | Miscellaneous | | | |
|------------------------------------|----------------------------|---|--------------------|-----------|---------|--------|---------|----------------------|-----------------|----------|------------|--------------------|---------|------------|-----------------------|---------------|-------------------|---------------|----------|----------------|-------|
| | | | Regional transport | secondary | | Local | General | Secondary OC/general | Diesel | Gasoline | Wood smoke | Vegetative burning | Smelter | Inclinator | Oil/diesel combustion | Other/general | Crustal/dirt/soil | Road salt | Sea salt | Not identified | Other |
| NORTHEAST & MIDATLANTIC | | | | | | | | | | | | | | | | | | | | | |
| Acadia Natl Pk, ME | Coutant et al. 2002 | 7.5 | 2.3 | | | | | | | | | | | | | | | | | | |
| Lye Brook, VT | Coutant et al. 2002 | 7.6 | 3.8 | | | | | | | | | | | | | | | | | | |
| Underhill, VT | Poirot et al. 2001 (PMF) | 7.9 | 4.8 | | | | | | | | | | | | | | | | | | |
| Underhill, VT | Poirot et al. 2001 (UNMDX) | 8.4 | 5.8 | | | | | | | | | | | | | | | | | | |
| Underhill, VT | Polissar et al. 2001 | 6.4 | 3.7 | | | | | | | | | | | | | | | | | | |
| Underhill, VT | Song et al. 2001 | 8.0 | 4.9 | | | | | | | | | | | | | | | | | | |
| Bronx, NY | Coutant et al. 2003 | 16.1 | 5.3 | | | 4.1 | 2.5 | | | | | | | 1.2 | 1.8 | 1.0 | | | | | |
| Connecticut Hill, NY | Coutant et al. 2002 | 19.0 | 5.5 | | | | 1.5 | | | | | | | | | 0.1 | | | | | 11.8 |
| Brigantine, NJ | Coutant et al. 2002 | 11.6 | 5.7 | | | | 3.5 | | | | | | | 1.3 | 0.3 | 0.1 | | | | | 0.7 |
| Brigantine, NJ | Lee, JH et al. 2003a | 11.4 | 7.9 | | | | 1.8 | | | | | | | 0.2 | 0.3 | 0.2 | | | | | |
| Brigantine, NJ | Song et al. 2001 | 11.4 | 7.1 | | | 0.9 | 0.6 | | | | | | | 0.5 | 0.2 | 0.1 | | | | | 0.9 |
| Aiendtsville, PA | Coutant et al. 2002 | 22.5 | 6.2 | | | | 2.0 | | | | | | | 0.0 | 0.1 | 0.0 | | | | | 14.0 |
| M.K.Goddard, PA | Coutant et al. 2002 | 19.5 | 5.8 | | | | 4.2 | | | | | | | 0.4 | 0.3 | | | | | | 0.0 |
| Baltimore-Wash. corridor | Chen et al. 2002 | 13. | 5.3 | 0.9 | 2.0 | 1.8 | | | | | | | | | | | | | | | |
| Washington, DC | Coutant et al. 2002 | 17.9 | 7.5 | | | | 6.8 | | | | | | | 1.8 | | 1.4 | | | | | 0.3 |
| Washington, DC | Coutant et al. 2003 | 16.7 | 7.7 | | | 1.2 | 4.7 | | | | | | | | | 1.5 | | | | | 0.5 |
| Washington, DC | Song et al. 2001 | 17.5 | 10.0 | | | 3.5 | 1.6 | | | | | | | 0.9 | 0.6 | 0.5 | | | | | 0.6 |
| Washington, DC | Kim and Hooke 2003 | 17.9 | 10.7 | | | 1.6 | | 0.4 | 3.8 | | | | | 0.7 | 0.4 | 0.4 | | | | | 0.4 |
| Jeff.James River, VA | Coutant et al. 2002 | 14.7 | 7.2 | | | | 3.7 | | | | | | | 0.3 | 0.4 | 0.5 | | | | | |
| Shenandoah, VA | Coutant et al. 2002 | 11.8 | 4.5 | | | | 3.2 | | | | | | | | | 0.2 | | | | | 0.3 |
| Dolly Sods, WV | Coutant et al. 2002 | 12.7 | 5.0 | | | | 4.5 | | | | | | | 0.2 | 0.2 | 0.8 | | | | | 1.2 |
| MIDWEST | | | | | | | | | | | | | | | | | | | | | |
| Toronto, ON | Lee, PKH et al. 2003b | 12.7 | 3.3 | | | 4.6 | 1.9 | | | | | | | 0.1 | | 0.1 | 0.0 | 1.3 | 1.0 | | |
| Quaker City, OH | Coutant et al. 2002 | 20.5 | 6.3 | | | | 2.0 | | | | | | | | | | | | | | 3.4 |
| Livonia, IN | Coutant et al. 2002 | 20.1 | 6.3 | | | | 3.9 | | | | | | | | | | | | | | |
| Mammoth Cave, KY | Coutant et al. 2002 | 16.0 | 4.9 | | | | 6.1 | | | | | | | | | 0.7 | 0.1 | 0.8 | 0.3 | | |
| Great Smoky, TN | Coutant et al. 2002 | 13.4 | 4.8 | | | | 6.8 | | | | | | | | | 0.6 | | | | | 0.2 |
| Indianapolis, IN | Coutant et al. 2003 | 17.3 | 6.7 | | | 3.6 | 3.2 | | | | | | | | | 0.5 | | | | | 0.5 |
| Bondville, IL | Coutant et al. 2002 | 18.7 | 5.4 | | | | 0.3 | | | | | | | | | 0.8 | | | | | 0.1 |
| St. Louis, MO | Coutant et al. 2003 | 17.2 | 5.7 | | | 5.0 | 2.9 | | | | | | | | | 2.2 | | | | | 1.4 |
| Milwaukee, WI | Coutant et al. 2003 | 14.5 | 4.5 | | | 4.1 | 2.5 | | | | | | | | | 2.7 | 0.3 | | | | 0.4 |
| Boundary Waters, MN | Coutant et al. 2002 | 5.4 | 2.4 | | | | 2.2 | | | | | | | | | 0.2 | 0.2 | 0.1 | | | |
| SOUTHEAST & SOUTH | | | | | | | | | | | | | | | | | | | | | |
| Charlotte, NC | Coutant et al. 2003 | 16.2 | 5.7 | | | 1.2 | 3.9 | | | | | | | | | 0.7 | | 1.9 | | | |

| Location or Nearest City | Reference | Total Mass ($\mu\text{g}/\text{m}^3$) | Sulfate/Coal | | Nitrate | Mobile | | | Biomass burning | | | Industrial | | | Crustal and Salt | | | Miscellaneous | | | |
|--------------------------|----------------------------|---|--------------------|-----------|---------|--------|---------|----------------------|-----------------|----------|------------|--------------------|---------|------------|-----------------------|---------------|-------------------|---------------|----------|----------------|-------|
| | | | Regional transport | secondary | | Local | General | Secondary OC/general | Diesel | Gasoline | Wood smoke | Vegetative burning | Smelter | Inclinator | Oil/diesel combustion | Other/general | Crustal/dirt/soil | Road salt | Sea salt | Not identified | Other |
| Atlanta, GA | Kim et al. 2003a | 16.3 | 10.2 | | | 1.6 | | 2.0 | 1.1 | 1.3 | | | | | | 0.7 | 0.5 | | | | 0.5 |
| Atlanta, GA | Kim et al. 2003b | 16.0 | 10.1 | | | 1.6 | | 2.0 | 2.7 | 0.5 | | | | | | 0.2 | 0.4 | | | | |
| Atlanta, GA | Kim et al. 2002a | 16.0 | 10.1 | | | 1.3 | 4.0 | | | | | | | | | 0.4 | 0.2 | | | | |
| Birmingham, AL | Coutant et al. 2003 | 19.5 | 7.3 | | | 1.6 | 6.5 | | | | | | | | | 1.5 | 1.3 | | | | 1.2 |
| Houston, TX | Coutant et al. 2003 | 14.2 | 5.5 | | | | 6.2 | | | | | | | | | 0.9 | 0.8 | | | | 0.3 |
| WEST | | | | | | | | | | | | | | | | | | | | | |
| Phoenix, AZ | Lewis et al. 2002 | 12.6 | 2.4 | | | | | 2.0 | 4.2 | | | | | | | | | | | | 2.6 |
| Spokane, WA | Kim et al. 2002c | 12.1 | 2.3 | | | 1.1 | 1.3 | | | | | | | | | | | | | | 1.1 |
| Seattle, WA | Maykut et al. 2003 (CMB) | 8.9 | 1.5 | | | 0.4 | 3.9 | | | | | | | | | 0.8 | 0.4 | | | | 0.6 |
| Seattle, WA | Maykut et al. 2003 (UNMDX) | 8.9 | | | | | | 1.7 | 0.8 | | | | | | | 1.3 | 0.5 | | | | 1.1 |
| Seattle, WA | Maykut et al. 2003 (PMF) | 8.9 | 1.6 | | | | | 1.6 | 0.4 | | | | | | | 0.9 | 1.2 | | | | 0.3 |

Notes: All values are in $\mu\text{g}/\text{m}^3$. Sources greater than 20 percent but less than 40 percent of the total mass are shaded yellow; sources greater than 40 percent are shaded pink.

In order to present a concise overview, some sources were renamed and/or combined in some studies. Some values were calculated based on reported percentages. Sum of sources may not equal the total due to rounding and/or modeling limitations. Refer to descriptions in Table A-3 for exact source names, number of sources, and values.

Studies not included: Bistye (2002) presented back trajectory analysis only with no sources identified. Wishinski and Poirot (1986) measured visibility and did not report concentrations or mass. Long (2002) focused on 3 one-week "event" studies (e.g., forest fires, Olympic Games) and did not present overall results. Zheng et al. (2002) presented concentration data for four one-month sampling periods for 8 sites but no annual average by site and source. Lowenthal & Rahn (1989) and Rahn & Lowenthal (1984) are early studies that identified sources as regional areas. Kim et al. (2002b), Liu et al. (2003b), Liu et al. (2003c), Ramadan et al. (2000), Ramadan et al. (2003) did not provide sufficient concentration and/or percent mass values to complete this table. Chow and Watson (2002) was a summary of other studies.

(Source: Compilation of Existing Studies on Source Apportionment for $\text{PM}_{2.5}$, August 22, 2003 (Contract No. 68-D-02-061; Work Assignment I-05).

Note that the underlying data in some of these studies reflect regional or local compositions and levels that may not be reflective of current conditions. The "Sulfate/Coal" category includes two major categories of $\text{PM}_{2.5}$. One is secondary sulfate, from oxidation of SO_2 emissions; the other is secondary organic carbon aerosol, largely from oxidation of VOCs and SVOCs from sources such as vegetation, vehicles, and industrial emissions of these gases.

Local-Scale Assessment of Primary PM_{2.5} for Three Urban Areas

In addition to the regional-scale analyses discussed above, a local scale modeling assessment was performed for selected urban areas. Local-scale air dispersion analyses require detailed local-scale emissions inventories. The emissions inventory used in this local-scale analysis is based on the national level emissions inventory for the regional-scale modeling. This national level inventory does not include all the information required by the local scale model such as building dimensions and exact stack locations and is a source of uncertainty in the results.

Local-scale air quality modeling was used to examine the spatial variability of direct PM_{2.5} concentrations associated with emissions of primary PM_{2.5} within each urban area, and to estimate the contribution of primary PM_{2.5} emissions from local sources in the urban area to ambient PM_{2.5} concentrations at Federal Reference Method (FRM) monitoring sites. In addition, attribution of the modeled concentrations to specific emission source groups in the urban area such as electric generating facilities, industrial facilities, residential wood burning, commercial cooking, mobile sources and others (see the Technical Support Document for the AERMOD Analyses¹⁴ for a complete list) allowed for an investigation the potential role of controls of primary PM_{2.5} emissions from local sources on attainment. This assessment complements the regional-scale modeling analyses through its ability to provide concentrations at a higher spatial resolution and an estimate of the impact of local sources of primary PM_{2.5}. We focused this assessment on three urban areas: Birmingham, Seattle, and Detroit. Each of these areas has different characteristics in terms of the mixture of emissions sources, meteorology, and associated PM_{2.5} air quality issues. This assessment had a future focus on the incremental impacts of direct PM_{2.5} sources within these areas after implementation of the regulatory base case

Based on 2001 meteorology data and the 2015 regulatory base case emissions inventory used in the CMAQ analysis, the AERMOD modeling system was applied to each urban area to provide concentration estimates of directly emitted PM_{2.5} by species across a specified network of receptors within each urban area. AERMOD provides a more refined geographic view of local PM_{2.5} concentrations compared to the coarse view provided by the 36 kilometer resolution of the CMAQ model. Appendix B provides summary results for each urban area for both annual and daily concentrations. These results indicate high annual concentration gradients for primary PM_{2.5} over distances much less than the 36 or 12 kilometer resolution typically used in photochemical grid modeling for the study area. Furthermore, local sources of primary PM_{2.5} are significant contributors to these concentration gradients. These sources vary in their importance by monitor location and include industrial sources (iron and steel manufacturing, coke ovens, pulp and paper mills), human activities like residential wood/waste burning, and onroad and nonroad sources. Complete details of the AERMOD modeling system and results for each urban area are provided in the Technical Support Document (TSD).

¹⁴ Technical Support Document for the Local-Scale Assessment for the PM NAAQS Proposal, February, 2006

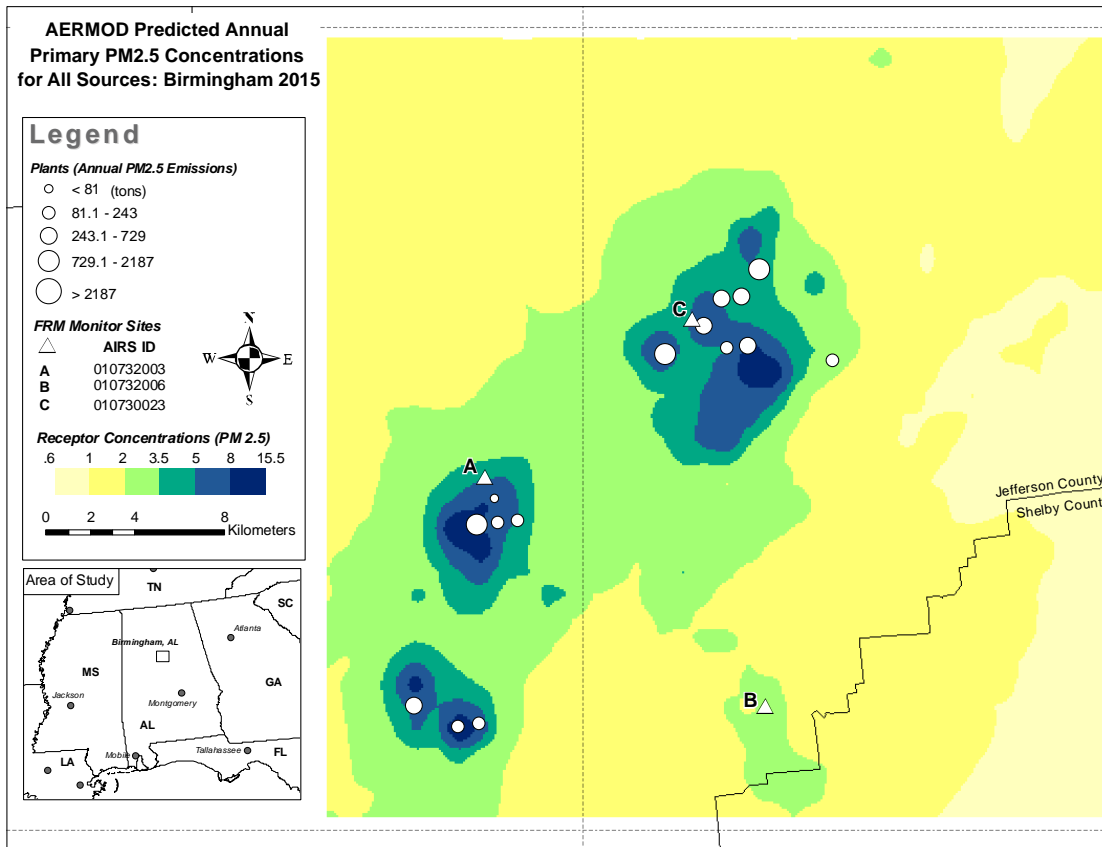


Figure 2-16. Spatial Gradient in Birmingham, AL of AERMOD Predicted Annual Primary PM_{2.5} Concentrations (ug/m³) for All Sources: 2015

Note: Dashed lines reflect the 36km grid cells from regional-scale modeling with CMAQ model.

Figure 2-16 shows the spatial distribution of PM_{2.5} for Birmingham resulting from modeling the primary PM_{2.5} emissions from local sources. Consistent with urban excess estimates for this area (see Figure 2-23), the modeling results indicate high annual concentration gradients for primary PM_{2.5} over distances much less than the 36 or 12 kilometer resolution typically used in photochemical grid modeling for the study area. Depending upon monitor location, the most significant contributors to the predicted spatial gradient shown in Figure 2-18 include metal manufacturing and processing, mineral/rock wool manufacturing, and other industrial sources. In Birmingham, these local sources contribute roughly 30 percent of the measured concentrations at the projected 2015 non-attainment monitors A and C. Applying available controls¹⁵ from AirControlNet and recently completed studies¹⁶ to reduce primary PM_{2.5} emissions from these

¹⁵ See Table 11 from Appendix B: Local-Scale Assessment of Primary PM_{2.5} for Three Urban Areas,

¹⁶ E.H. Pechan and Associates and Research Triangle Institute. Evaluation of Potential PM_{2.5} Reductions by Improving Performance of Control Devices: PM_{2.5} Emission Estimates. Prepared for the U.S. Environmental Protection Agency. September 30, 2005. Final Report, U.S. Environmental Protection Agency. AirControlNET Control Measures Documentation Report, Version 4.1. Prepared by E.H. Pechan and Associates. September 2005.

local sources are helpful but are not projected to bring each of the monitors fully into attainment by 2015. The assessment shows that reductions of primary PM_{2.5} at local sources using available controls in Birmingham account for between 20 and 30 percent of the incremental concentrations of PM_{2.5} required to meet an annual standard of 15 µg/m³ and between 20 to 35 percent of the incremental concentrations of PM_{2.5} required to meet a daily standard of 35 µg/m³. Note that controls were not identified for all local sources within each area because of limited data on baseline control and/or a limited understanding of controls available for specific sources.

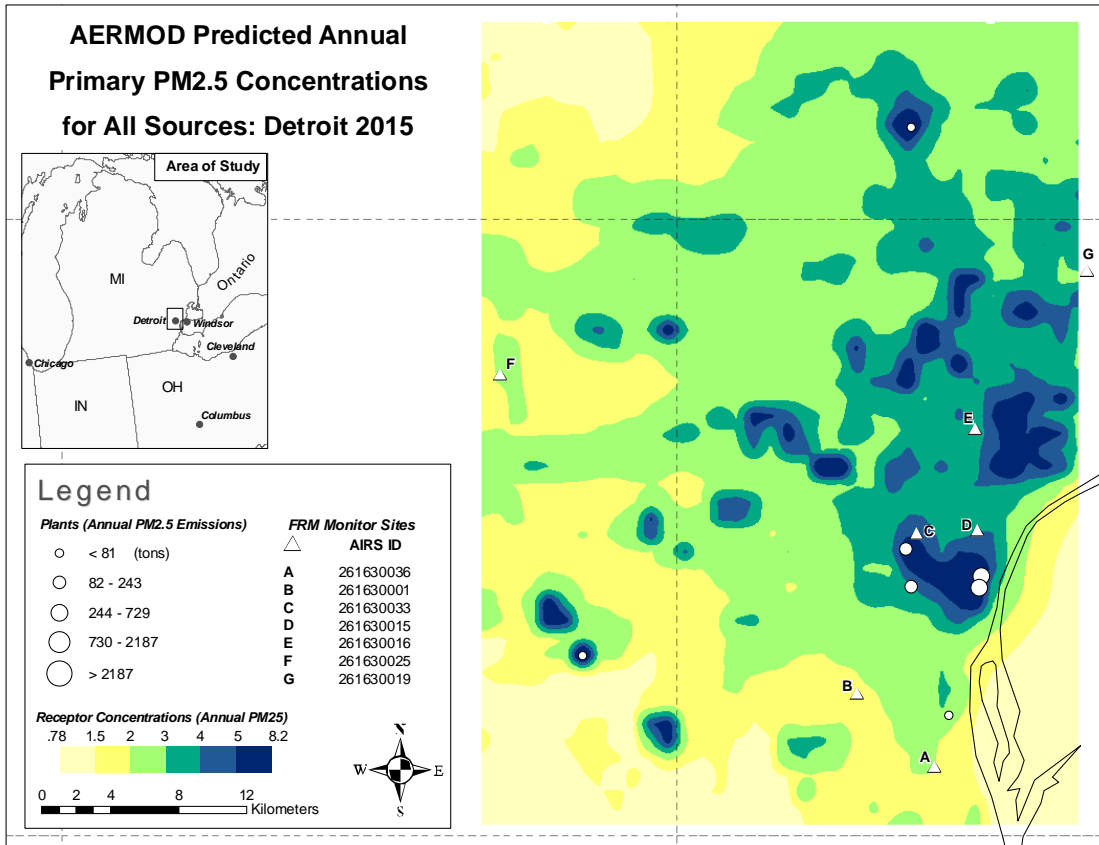


Figure 2-17. Spatial Gradient in Detroit, MI of AERMOD Predicted Annual Primary PM_{2.5} Concentrations (ug/m³) for All Sources: 2015

Note: Dashed lines reflect the 36km grid cells from regional-scale modeling with CMAQ model.

Figure 2-17 shows the spatial distribution of PM_{2.5} for Detroit resulting from AERMOD modeling of the primary PM_{2.5} emissions from local sources. Similar to Birmingham, modeling results here also indicate high annual concentration gradients of primary PM_{2.5} within typical photochemical modeling grid resolutions. Thus, spatial gradients exist within the study area for primary PM_{2.5} with a variety of local sources such as metal manufacturing, commercial cooking, and onroad and nonroad vehicles being significant contributors depending upon the location of the monitor. The local sources contribute about 25 percent of the measured concentrations at the

projected 2015 non-attainment monitors A, C and D. Applying available controls¹⁷ from AirControlNet and recently completed studies¹⁸ on these local sources are helpful but are not projected to fully bring each of the monitors into attainment. The assessment shows that reductions of primary PM_{2.5} at local sources using available controls account for between 17 and 50 percent of the incremental concentrations of PM_{2.5} required to meet an annual standard of 15 µg/m³ and between 7 to 34 percent of the incremental concentrations of PM_{2.5} required to meet a daily standard of 35 µg/m³. Note that controls were not identified for all local sources within each area because of limited data on baseline control and/or a limited understanding of controls available for specific sources.

¹⁷ See Table 11 from Appendix B: Local-Scale Assessment of Primary PM_{2.5} for Three Urban Areas,

¹⁸ E.H. Pechan and Associates and Research Triangle Institute. Evaluation of Potential PM_{2.5} Reductions by Improving Performance of Control Devices: PM_{2.5} Emission Estimates. Prepared for the U.S. Environmental Protection Agency. September 30, 2005. Final Report, U.S. Environmental Protection Agency. AirControlNET Control Measures Documentation Report, Version 4.1. Prepared by E.H. Pechan and Associates. September 2005.

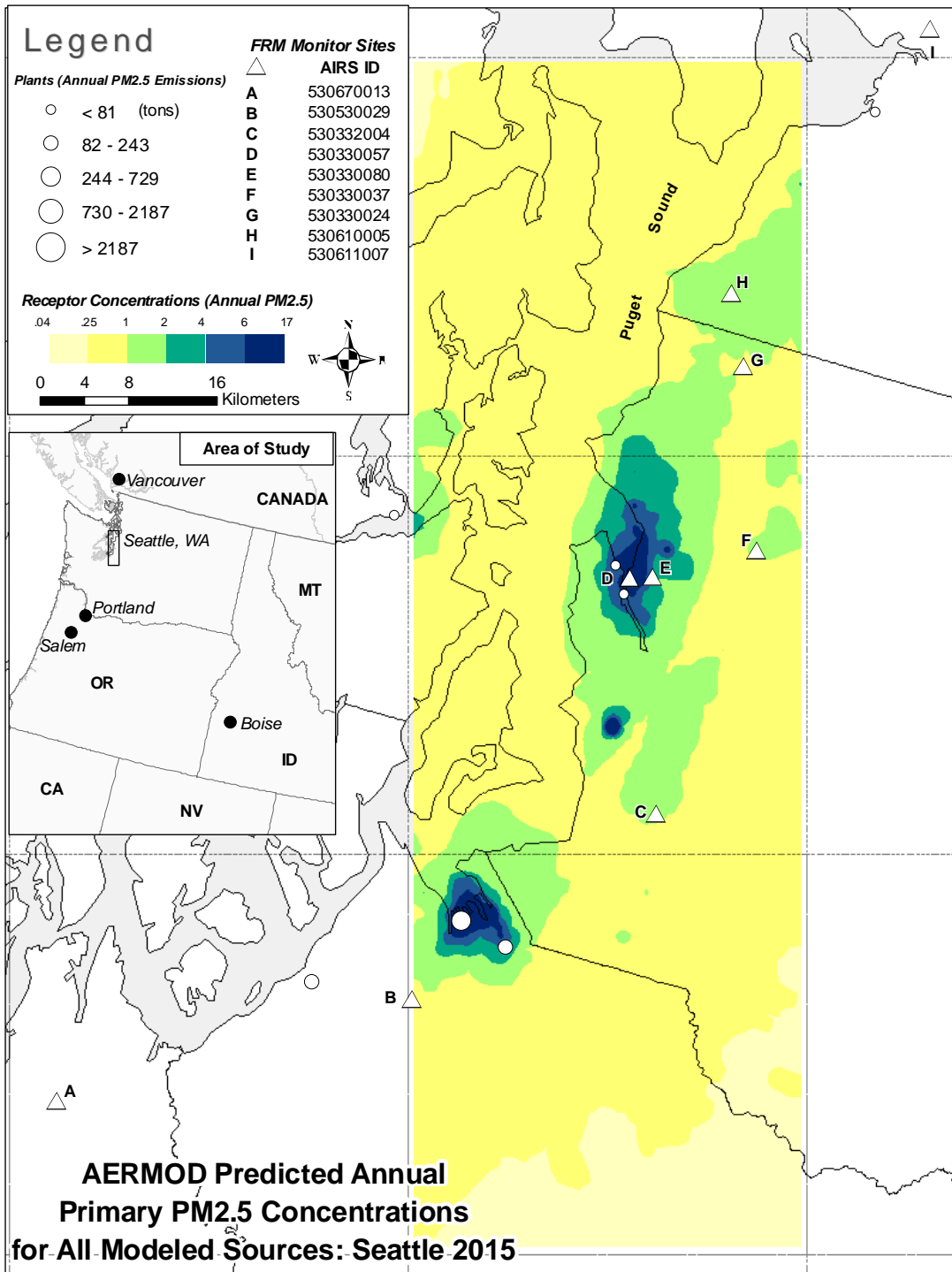


Figure 2-18. Spatial Gradient in Seattle, WA of AERMOD Predicted Annual Primary PM_{2.5} Concentrations (ug/m³) for All Modeled Sources: 2015
 Note: Dashed lines reflect the 36km grid cells from regional-scale modeling with CMAQ model.

Figure 2-18 shows the spatial distribution of PM_{2.5} for Seattle resulting from AERMOD modeling of the primary PM_{2.5} emissions from local sources. Modeling results here also indicate high concentration gradients of primary PM_{2.5} within the urban area and typical photochemical modeling grid resolutions. Furthermore, the nature of the problem in Seattle is daily rather than annual exceedences, which adds to the variability in source contributions at specific monitor locations. Significantly contributing local sources include paper and forest products plants, commercial and marine vessels, residential wood burning, and commercial cooking. Those local sources that were modeled contribute about 10 percent of the measured concentrations at the projected 2015 non-attainment monitors B and I. Applying available controls¹⁹ from AirControlNet and recently completed studies²⁰ on these local sources are helpful but are not projected to fully bring each of the monitors into attainment with the daily standard. The assessment shows that reductions of primary PM_{2.5} at local sources using available controls account for between 5 and 50 percent of the incremental concentrations of PM_{2.5} required to meet a daily standard of 35 µg/m³. Note that controls were not identified for all local sources within each area because of limited data on baseline control and/or a limited understanding of controls available for specific sources.

As detailed in Appendix A, the Seattle urban area was also evaluated using photochemical grid modeling through application of the Response Surface Model (RSM). There are important differences across these modeling approaches that limit the direct comparability of these modeling results. A major difference is that the RSM includes background and/or transported concentrations of direct PM_{2.5} within the urban area but focused only on organic components of primary PM_{2.5}, whereas the AERMOD modeling was limited to only those emissions sources in the city and surrounding counties but included other directly emitted species of PM_{2.5} like crustal materials. Despite these differences a comparison of results from these assessments provides insights of use here. For comparison purposes, in Snohomish county, the RSM suggests that direct PM_{2.5} emissions of carbon contribute around 2.2 µg/m³ to the daily design value in 2015 whereas the AERMOD estimate for modeled sources here is 3.4 µg/m³. This comparison suggests that there is an additional 50 percent contribution of direct PM_{2.5} attributable to a combination of direct PM_{2.5} emissions of crustal materials (which were not evaluated with the RSM approach) and the effect of "local" modeling that provides a more resolved spatial gradient within this urban area. Furthermore, both AERMOD and RSM predict that residential wood burning, which is an area source, is the major contributor at this monitor location. In King County, the RSM suggests that direct PM_{2.5} emissions of carbon contribute around 2.5 µg/m³ to the daily design value which is comparable to the AERMOD prediction of 2.4 µg/m³ from all modeled sources of direct PM_{2.5} emissions. This indicates that background or transported concentrations of primary PM_{2.5} may be more important at this monitor location.

¹⁹ See Table 11 from Appendix B: Local-Scale Assessment of Primary PM_{2.5} for Three Urban Areas,

²⁰ E.H. Pechan and Associates and Research Triangle Institute. Evaluation of Potential PM_{2.5} Reductions by Improving Performance of Control Devices: PM_{2.5} Emission Estimates. Prepared for the U.S. Environmental Protection Agency. September 30, 2005. Final Report, U.S. Environmental Protection Agency. AirControlNET Control Measures Documentation Report, Version 4.1. Prepared by E.H. Pechan and Associates. September 2005.

Insights from Local-Scale Assessment

The local-scale modeling assessment provides the following insights:

- Local-scale dispersion modeling shows high spatial concentration gradients of primary PM_{2.5} within the nonattainment areas, which are not predicted by the regional-scale, photochemical grid modeling (i.e., CMAQ) and therefore provides important complementary information in evaluating the ability of areas to attain future PM_{2.5} standards.
- For monitors projected to show non-attainment in 2015 within each urban area, the local-scale modeling indicates that primary PM_{2.5} emissions from local sources in the emission inventory such as electric generating utilities, industrial facilities, residential wood burning, commercial cooking, and mobile and nonroad sources are a significant contributor. The most influential sources vary by monitor location depending on proximity.
- Local-scale modeling results are consistent with urban excess estimates (as shown earlier in Figure 2-15) and indicate that directly emitted PM_{2.5} from local sources are key contributors to the measured PM_{2.5} concentrations at projected 2015 nonattainment monitors. In the urban areas studied, the modeled concentrations of primary PM_{2.5} ranged from 10% to as high as 35% of the total measured concentrations at the projected 2015 non-attainment monitors.²¹ The remaining percentage of measured PM_{2.5} concentrations is attributed to secondary formation of PM_{2.5} from local and regional sources and the transport of primary PM_{2.5} from the regional sources. Thus, local-scale modeling is not sufficient to describe the total concentrations in these urban areas. As such, to better understand the nature of the concentrations PM_{2.5}, this modeling is a complement to the regional-scale photochemical modeling which accounts for sources outside of the local area and the secondarily-formed components of PM_{2.5}.
- Local-scale modeling indicates that controls on primary PM_{2.5} emissions from local sources will play an important role in attaining the PM_{2.5} standards. In the three urban areas studied, it was determined that available controls deemed applicable to local sources can provide between 20 to 50 percent of the incremental concentrations of PM_{2.5} required to meet an annual standard of 15 µg/m³ and between 5 to 50 percent of the incremental concentrations of PM_{2.5} required to meet a daily standard of 35 µg/m³. The TSD provides tabular results showing the impact of these identified controls for each of the urban areas. Note that controls were not identified for all local sources within each area because of limited understanding of the baseline controls and/or available controls at specific sources.

²¹ Table 12 from Appendix B: Local-Scale Assessment of Primary PM_{2.5} for Three Urban Areas, EPA expects that this contribution may be understating the contribution at particular monitors due to use of national level inventories for directly emitted PM_{2.5} that may not fully reflect these emissions from local sources, e.g. mobile source organic carbon emission are known to be understated here.

not include all the information required by the local scale model such as building dimensions and exact stack locations and is a source of uncertainty in the results.

- Local-scale modeling results identified important contributing sectors for each area but were not always consistent with source apportionment analysis based on ambient data (as discussed earlier in this Chapter). Specifically, the contribution of mobile sources is deemed to be understated in these modeling results compared to source apportionment results. This inconsistency indicates the need to improve the emissions inventory's absolute levels of primary $PM_{2.5}$ and its speciation into the $PM_{2.5}$ components.