APPENDIX B

SUPPLEMENTAL ANALYSIS: PM2.5 ATTAINMENT

SOUTH COAST PM2.5 SUPPLEMENTAL ANALYSIS

1. INTRODUCTION

The State Implementation Plan or SIP serves as a demonstration of attainment for the national ambient air quality standards (NAAQS or federal standards). The attainment demonstration comprises analyses used to determine the set of control measures needed to meet the NAAQS by the attainment year. These analyses typically include air quality modeling, which generally guides the selection of the most effective pollutants to control and the magnitude of needed emissions reductions. Because of the uncertainties inherent in photochemical modeling, U.S. Environmental Protection Agency (U.S. EPA) modeling guidance recommends that states perform complementary analyses. These analyses can include consideration of measured air quality, emissions, and meteorological data, evaluation of other air quality indicators, and additional air quality modeling.

A supplemental analysis looks at the entirety of the information at hand to provide a more informed basis for the attainment strategy. Because all methods have inherent strengths and weaknesses, examining an air quality problem in a variety of ways offsets the limitations and uncertainty that are inherent in air quality modeling. This approach also provides a better understanding of the overall problem and the level and mix of emissions controls needed for attainment.

In its modeling guidance, U.S. EPA indicates that the results of supplementary analyses may be used to demonstrate that attainment is likely despite modeled results, when future year modeled annual average design values fall between 14.5 and 15.5 micrograms per cubic meter (ug/m3). This range in modeled design values reflects the uncertainty in predicting absolute PM2.5 concentrations that is inherent in air quality modeling, and therefore recognizes that an improved assessment of attainment can be derived from examining a broader set of analyses.

U.S. EPA recommends that three basic types of analyses be included to supplement the primary modeling analysis:

1) analyses of trends in ambient air quality and emissions,
2) observational models and diagnostic analyses, and
3) additional modeling.

Each analysis is weighted based on its ability to quantitatively assess the ability of the proposed control measures to yield attainment. The scope of the supplemental analysis is different for each nonattainment area. The level of detail appropriate for each area depends upon the complexity of the air quality problem, how far into the future the attainment deadline is, and the amount of data and modeling available. For example, less analysis is needed for an area that is projecting attainment near-term and by a wide margin, and for which recent air quality trends have demonstrated significant progress,

than for areas with more severe air quality challenges. The following sections present the supplemental assessment for PM2.5 in the South Coast Air Basin for each of the areas outlined in the U.S. EPA guidance.

2. ASSESSMENT OF RECENT AIR QUALITY AND EMISSION TRENDS

Current Air Quality

According to U.S. EPA's guidance, even though air quality models are regarded as the most appropriate tool to assess impacts in emission changes, it is also possible to extrapolate future trends in PM2.5 based on measured historical trends of air quality and emissions. Strength of the evidence produced by emissions and air quality trends is increased if an extensive monitoring network exists and if there is a good correlation between past emission reductions and current trends in PM2.5.

The South Coast Air Basin has one of the most severe PM2.5 problems in the nation and represents a considerable challenge in attaining the federal PM2.5 standards. These standards consist of both a 24-hour standard of 65 ug/m3, and an annual average standard of 15 ug/m3. While almost all monitors with complete data in the South Coast still exceeded the annual PM2.5 standard as of 2006, PM2.5 air quality has shown considerable improvement since 1999 when monitoring data for assessing compliance with the federal PM2.5 standard began. When South Coast was first designated nonattainment for the federal PM2.5 standard, the basin exceeded both the annual and 24-hour PM2.5 standards. However, as of 2005, the South Coast now meets the federal 24-hour PM2.5 standard of 65 ug/m3 throughout the basin. Thus, attaining the annual standard is the remaining challenge in this State Implementation Plan (SIP).

Currently, South Coast has an extensive monitoring network with seventeen sites monitoring for PM2.5 in the air basin. Table B-1 provides the federal 3-year annual average values (design values) for each monitoring site for 2006 along with the 2004, 2005, and 2006 annual averages. Table B-2 provides the 2006 federal 3-year 24-hour 98^{th} percentile design value along with the 2004, 2005, and 2006 24-hour 98^{th} percentile values. The design value is a statistic that is used to describe the air quality status of a given area relative to the level of the federal standard. Design values represent the yearly annual average or 98^{th} percentile PM2.5 concentrations averaged over a three year period. Attainment is reached when the design value is at or below the federal standard. As shown in Table B-1, current 2006 design values (reflecting the 2004 through 2006 period) range from 15.0 ug/m3 to 20.8 ug/m3.

Table B-1: PM2.5 Annual Average Values

Monitor	2004 Annual Average (ug/m3)	2005 Annual Average (ug/m3)	2006 Annual Average (ug/m3)	2006 3-year Annual Average Design Value (ug/m3)
Anaheim-Pampas Lane	17.0	14.7	14.0	15.2
Azusa	18.3	17.0	15.4	16.9
Burbank-W Palm Avenue	19.1	17.8	16.5	17.8
Fontana-Arrow Highway	19.9	18.8	18.4	19.4
Long Beach East Pacific Coast Hwy	16.5	14.7	*	*
Los Angeles-North Main Street	18.6	17.8	15.6	17.3
Lynwood	18.5	17.5	16.7	17.5
Mission Viejo 26081 Via Pera	12.0	10.6	*	*
North Long Beach	17.9	15.9	*	*
Ontario-1408 Francis Street	20.9	18.8	18.4	19.4
Pasadena-S Wilson Avenue	16.6	15.1	13.4	15.0
Pico Rivera	20	*	*	*
Reseda	15.7	*	*	*
Riverside-Magnolia	20.8	17.9	16.9	18.6
Riverside-Rubidoux	**22.1**	**21.0**	**19.2**	**20.8**
Riverside-5130 Poinsettia Place	*	*	20.8	*
San Bernardino-4th Street	21.9	17.3	17.7	19

*Incomplete data

The South Coast PM2.5 monitoring sites with the highest air quality levels are located in the eastern part of the air basin including Fontana, Ontario, Riverside and San Bernardino. The eastern part of the basin is most conducive to forming high levels of PM2.5 due to the geography and climate. In the South Coast, air typically flows from the coast to the eastern part of the basin which is the surrounded by mountains. Along with more stagnant conditions, the mountains act as a barrier trapping both emissions and pollutants leading to the build-up of high PM2.5 levels. Monitoring sites located closer to the coast in Los Angeles and Orange Counties have lower PM2.5 air quality levels due to the air flow patterns from the ocean. As shown in bold in the tables, the high site for the region is the Rubidoux-Riverside monitor with 2006 design values of 20.8 ug/m3 for the annual average and 57 ug/m3 for the 24-hour PM2.5 standards.

Table B-2: PM2.5 98th Percentile 24-hour Values

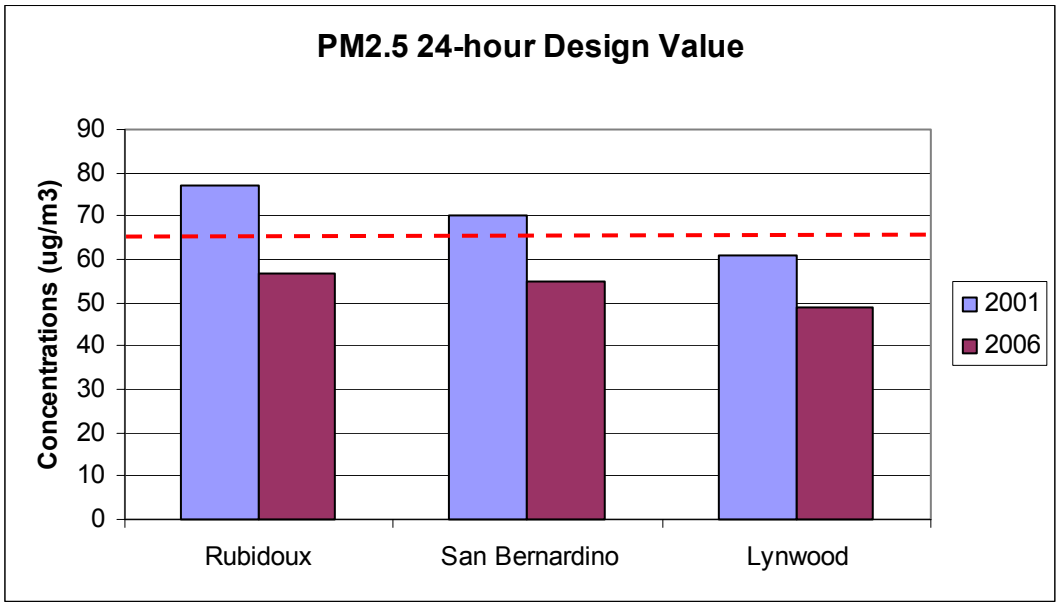
Monitor	2004 24-hour 98th Percentile (ug/m3)	2005 24-hour 98th Percentile (ug/m3)	2006 24-hour 98th Percentile (ug/m3)	2006 3-year 24-hour 98th Percentile Design Value (ug/m3)
Anaheim-Pampas Lane	48.2	41.8	40.5	44
Burbank-W Palm Avenue	49.3	*	43.4	*
Fontana-Arrow Highway	53.6	*	48.2	*
Long Beach East Pacific Coast Hwy	42.0	37.7	*	*
Los Angeles-North Main Street	*	53.3	38.3	*
Lynwood	53.0	48.4	44.4	49
Mission Viejo 26081 Via Pera	38.5	31.4	*	*
Ontario-1408 Francis Street	*	49.5	*	*
Pasadena-S Wilson Avenue	46.5	43.0	32.0	41
Pico Rivera	52.1	*	*	*
Riverside-Magnolia	53.7	*	47.7	*
Riverside-Rubidoux	**59.5**	**58.3**	**53.2**	**57**
Riverside-5130 Poinsettia Place	*	*	52.5	*
San Bernardino-4th Street	72.4	43.4	47.7	55

*Incomplete data

Recent PM2.5 Mass Trends

Despite the magnitude of the problem, considerable progress has occurred in the South Coast over the last seven years due to the ongoing emissions control program. As discussed above, 24-hour concentrations, as shown in Table B-2 and Figure B-1, have decreased approximately 15 percent and based on the 2004 through 2006 data, now attain the federal standard at all sites in the air basin.

Figure B-1: PM2.5 24-hour Design Values



All South Coast monitors with complete PM2.5 data also show a significant decrease in annual average design values (Figure B-2). In 2001, all monitoring sites in the basin had annual design values greater than 20 ug/m3, with the Riverside-Rubidoux site at twice the level of the standard. By 2006, design values decreased throughout the basin, and only one site in the easternmost portion of the basin is still greater than 20 ug/m3. Riverside-Rubidoux remains the high site, with a design value which is 39 percent above the standard. However, the greatest rate of progress has also occurred in the eastern basin. From 2001 through 2006, the Riverside-Rubidoux site design value dropped 30 percent, from 30.1 ug/m3 to 20.8 ug/m3, while the San Bernardino site design value dropped 26 percent, from 25.8 ug/m3 to 19.0 ug/m3. In contrast, the Los Angeles-North Main site design value dropped 23 percent, from 22.6 ug/m3 to 17.3 ug/m3. This trend is further illustrated in Figures B-3 and B-4 which depict maps of the spatial variations in annual average concentrations in 2001 as compared to 2006. A number of sites have annual average concentrations near or below 15 ug/m3 in 2005 or 2006, including Anaheim, Mission Viejo, Pasadena, and Long Beach.

Figure B-2: Three Year Annual Average PM2.5 Design Values

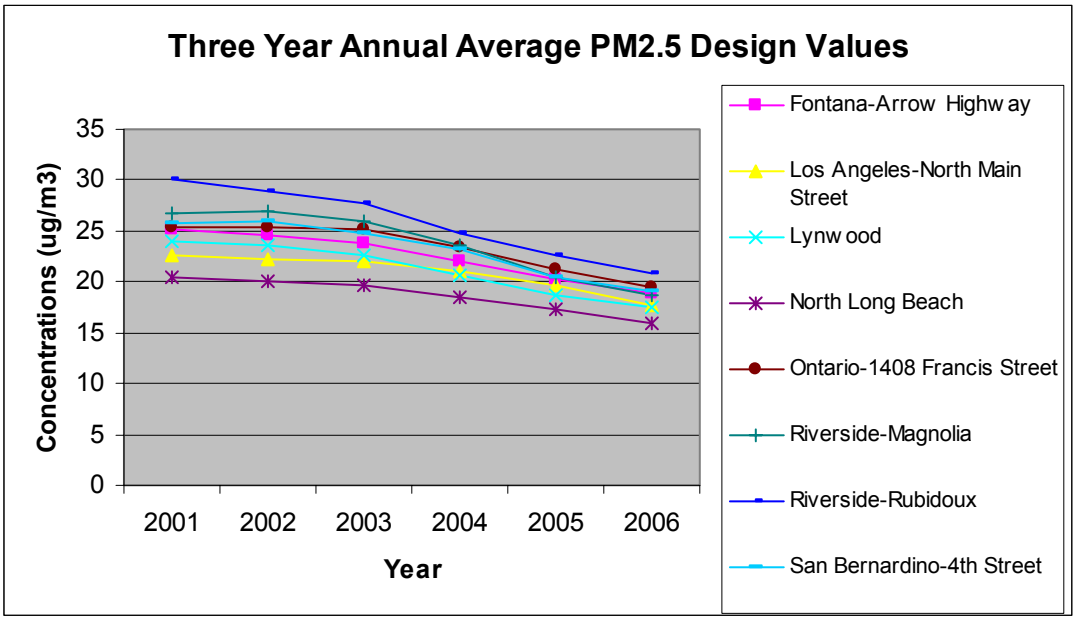


Figure B-3: National PM2.5 Annual Average 2001

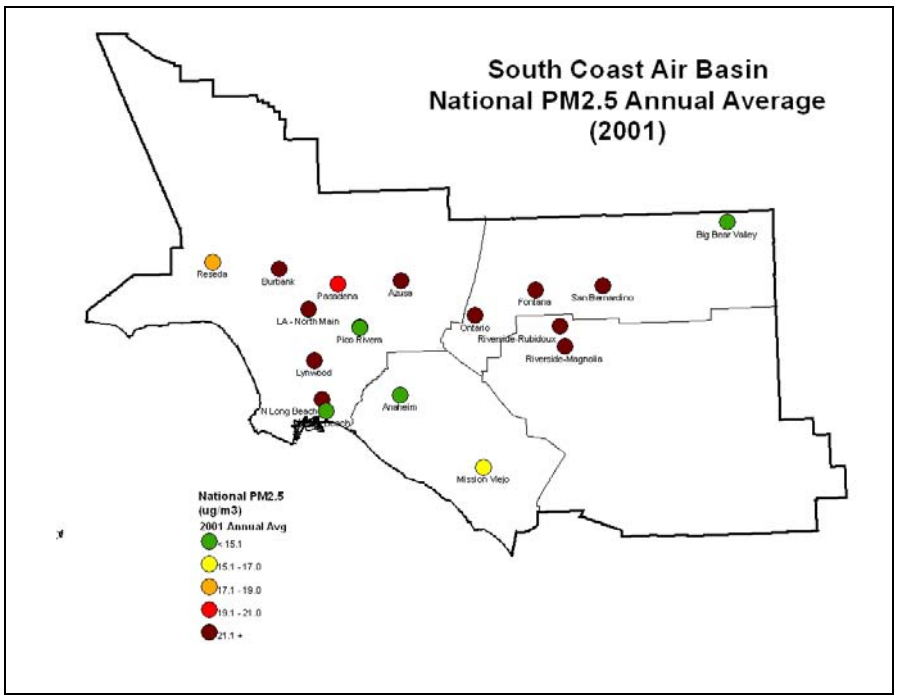
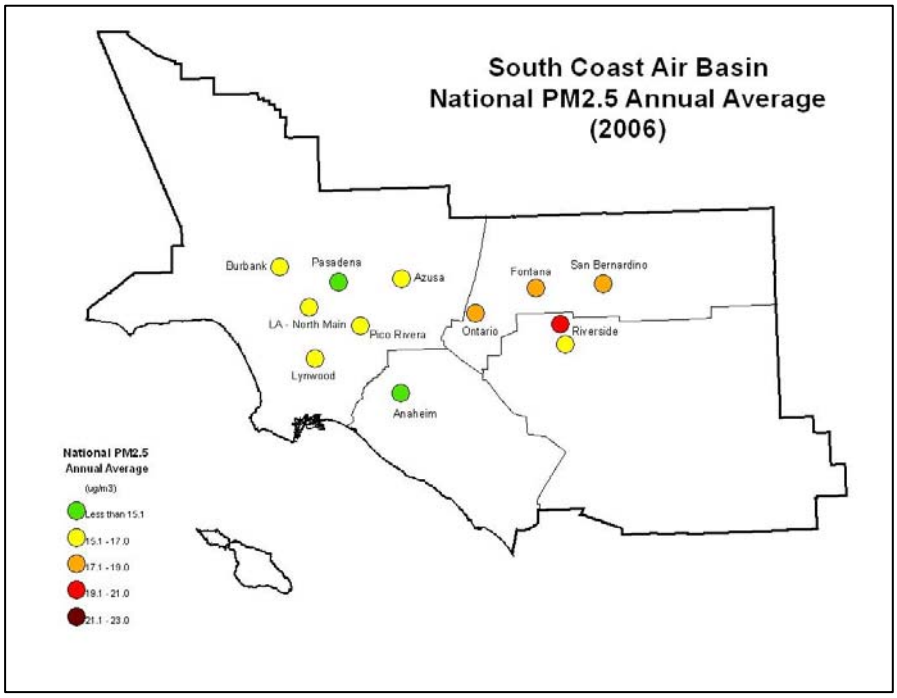


Figure B-4: National PM2.5 Annual Average 2006



The progress observed in both the annual and 24-hour PM2.5 standards reflects the linkage between the two standards. The annual average is comprised of individual 24-hour samples which vary throughout the year. In the South Coast, PM2.5 concentrations do not exhibit a pronounced seasonal variation, with monthly average concentrations above the level of the annual standard occurring in all parts of the year. This relative uniformity results in part from meteorological conditions conducive to the formation of sulfates and nitrates at different times of the year. Sulfate formation is greater in the warmer months while nitrate formation is greater in the cooler weather. Analyses of the changes in the distribution of 24-hour concentrations between 2001-2003 and 2004-2006 indicate that the decrease in both 24-hour and annual average concentrations is the result of a broad downward shift in the distribution of daily PM2.5 concentrations over time. This can be seen in the decrease in monthly average concentrations between 2001 and 2006 at Los Angeles-North Main and Riverside-Rubidoux (Figures B-5 and B-6). Consistent with its greater rate of progress in the annual average, the Riverside-Rubidoux site had seen the largest reduction in monthly average concentrations.

Figure B-5: Changes in Seasonal Pattern from 2001 to 2006 at Los Angeles-North Main Monitoring Site

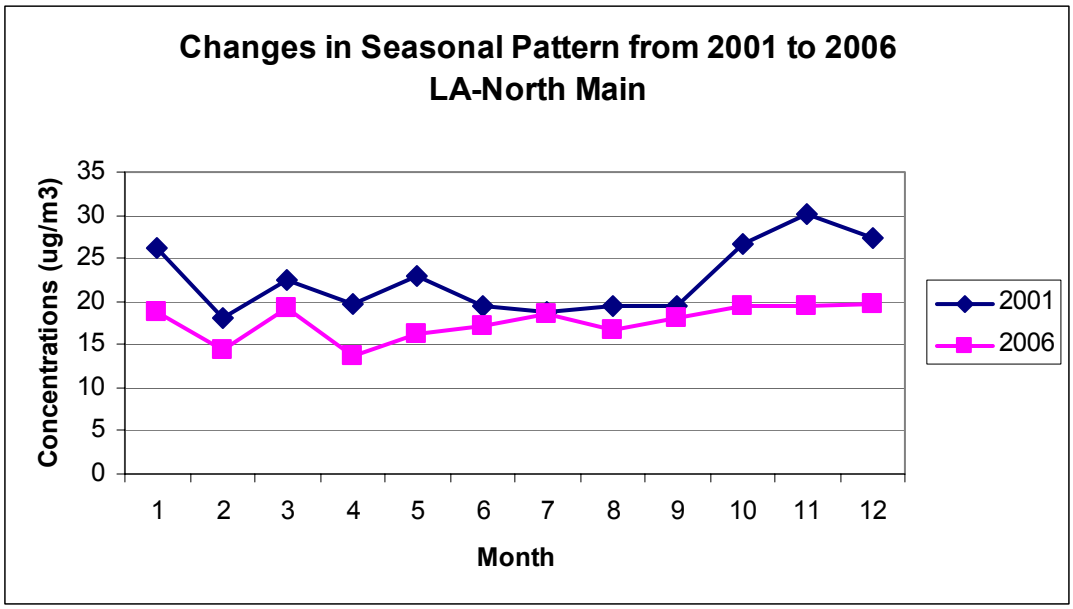
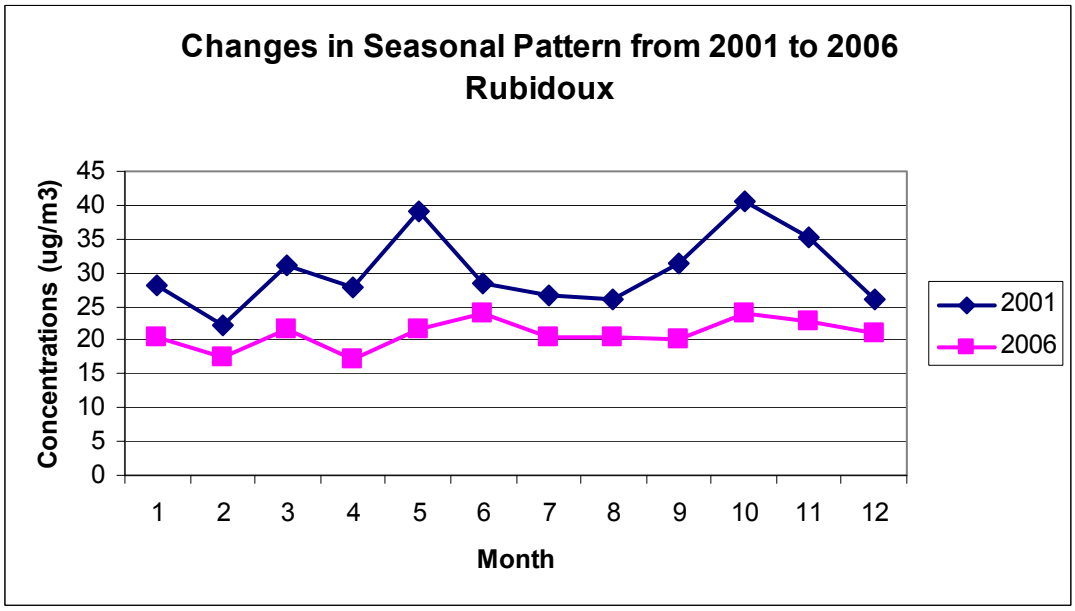


Figure B-6: Changes in Seasonal Pattern From 2001 to 2006 at Riverside-Rubidoux Monitoring Site



A comparison of the changes in the frequency distribution of 24-hour concentrations over the last few years provides another means of understanding progress. Data collected from 24-hour samples during the 1999–2001 period at the Los Angeles-North Main site indicate that 8.2 percent of the samples had concentrations greater than

40 ug/m3 (Figure B-7). In comparison, during the 2004-2006 period the number of samples with PM2.5 concentrations greater than 40 ug/m3 fell to 4.2 percent. At the Riverside-Rubidoux monitoring site, data collected during the 1999–2001 period indicate that 23.3 percent of the samples had concentrations greater than 40 ug/m3 (Figure B-8), while during the 2004-2006 period, only 8.5 percent of the samples had concentrations greater than 40 ug/m3. Significant reductions in the percent of samples greater than 20 ug/m3 were also observed at both sites. These analyses illustrate that progress in the annual average is linked not just to reductions in peak concentrations at certain times of the year, but to decreases across a broad range of conditions.

Figure B-7: PM2.5 Concentrations at Los Angeles-North Main 1999-2001 versus 2004-2006

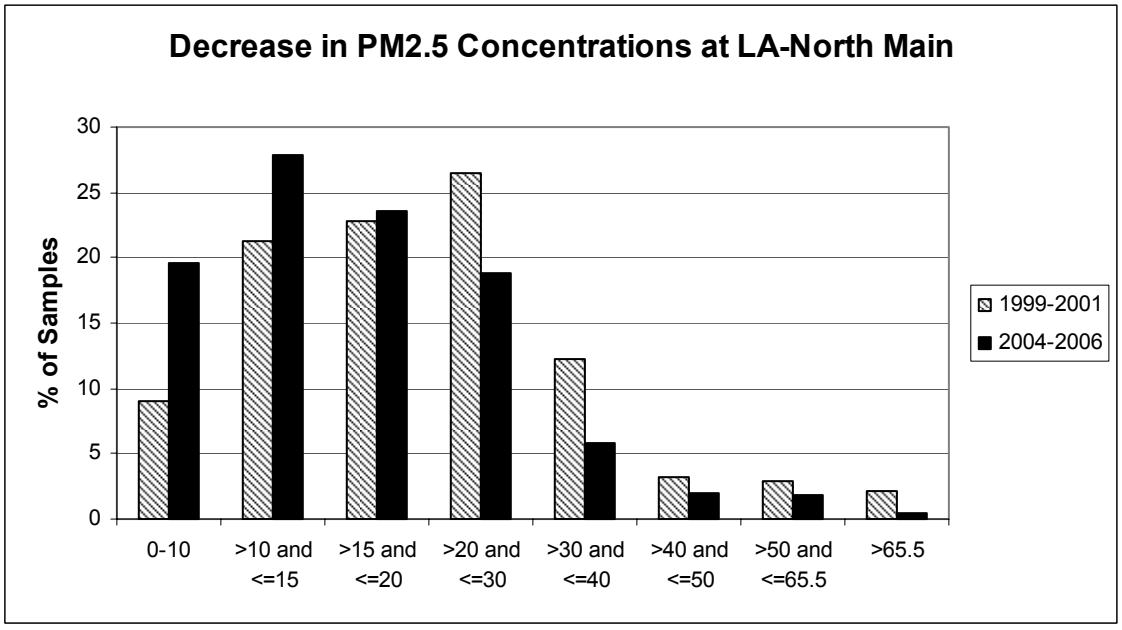
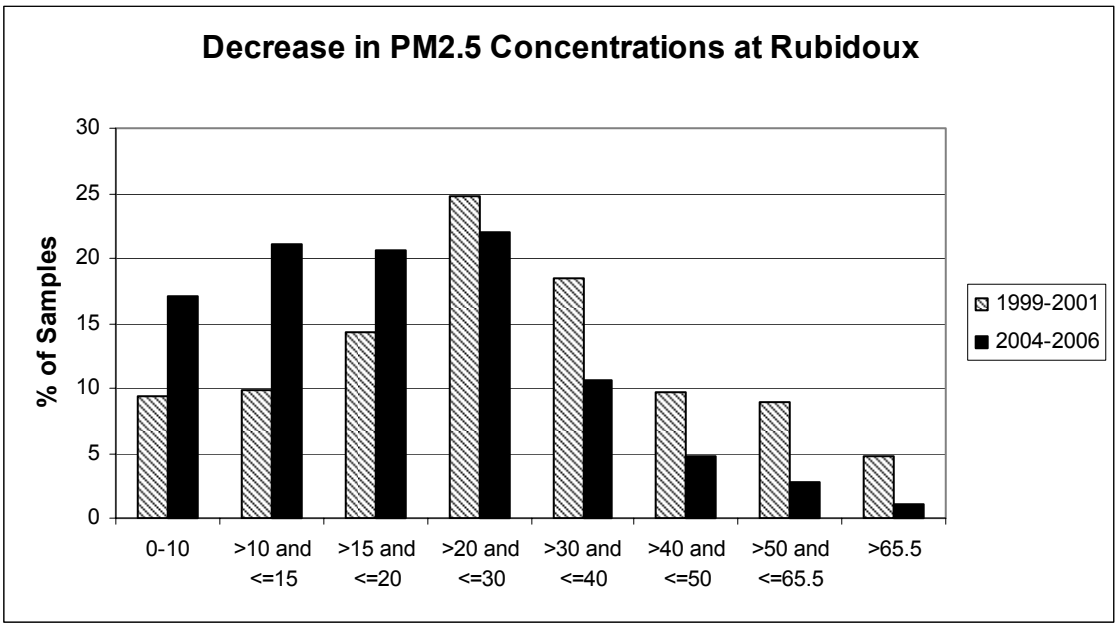


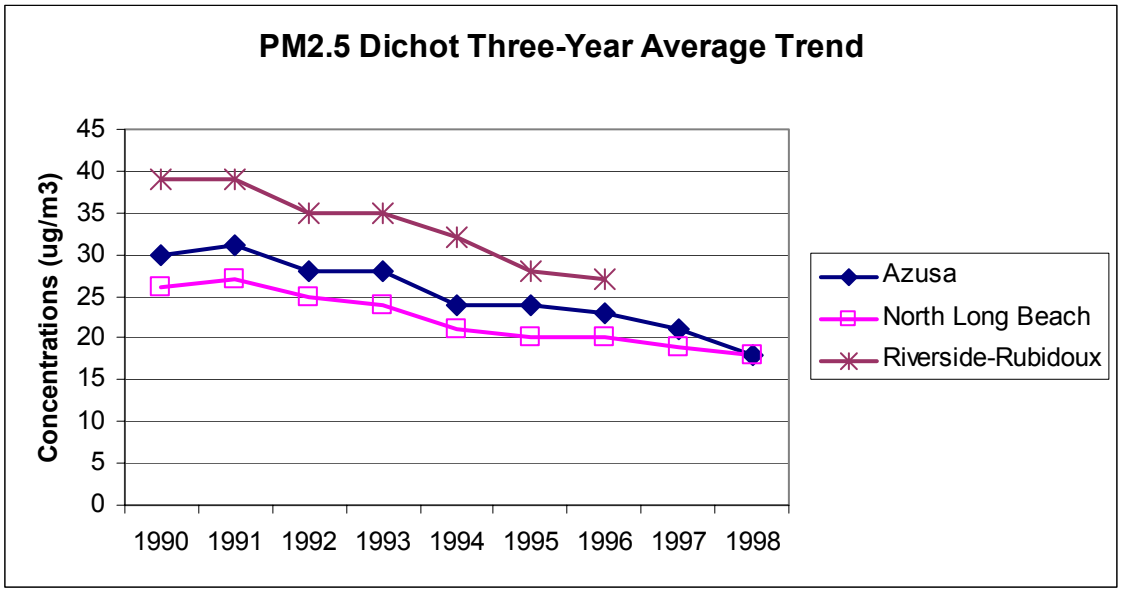
Figure B-8: PM2.5 Concentrations at Riverside – Rubidoux 1999-2001 versus 2004-2006



Historical PM2.5 Mass Trends

The PM2.5 Federal Reference Method (FRM) network that is used for comparison to the federal standard was first deployed in 1998 and 1999. However, PM2.5 data have been routinely collected in the South Coast Air Basin since the late 1980s using dichotomous samplers that were operated for research purposes. The PM2.5 dichotomous data correlate very well with the FRM data (r=0.98), but are biased lower than the FRM by approximately 12 percent, therefore an absolute comparison to the FRM can not be made. This bias is due to the loss of semi-volatile species on the dichotomous sampler which are better captured with the FRM due to improved filter handling and temperature controls (Motallebi 2003). However, the relative changes in the dichotomous data are still useful by providing a longer-term context for assessing trends. Figure B-9 depicts PM2.5 concentrations at three sites. At the highest site, Riverside-Rubidoux, the 3-year average concentrations decreased about 30 percent from 1990 to 1996. The other two sites shown in the graph, Los Angeles-North Main and Azusa, have a longer dichotomous data record, from 1990 to 1998. Between 1990 and 1998, PM2.5 concentrations decreased 30 percent at Azusa and 40 percent at Los Angeles North Main. Therefore, looking at dichotomous data and FRM data trends together illustrate a continued long-term improvement in PM2.5 concentrations.

Figure B-9: PM2.5 Dichotomous Three-Year Average Trend



Meteorology and Air Quality Trends

Although the weather plays a role in the atmospheric formation of PM2.5, the downward trends in the South Coast Air Basin do not appear to be an artifact of good meteorological conditions, especially given the long-term consistency of the trends. Unlike ozone, meteorologically adjusted PM2.5 concentrations have not been developed. However, a number of factors which may influence PM2.5 concentrations were assessed. Since PM2.5 concentrations in the South Coast Air Basin are high throughout the year, we evaluated both annual precipitation and summer ozone forming potential to assess the effect of weather on PM2.5 concentrations (Table B-3). Years with high precipitation would tend to reduce PM2.5 concentrations during the rainy period, while years with high ozone forming potential would tend to be conducive to greater secondary particulate matter formation and thus higher PM2.5 concentrations.

Although there was a range of weather conditions between 2001 and 2005, the yearly percent decrease in annual average PM2.5 concentrations remained fairly constant, suggesting that weather was not the primary cause of the observed downward trend. For example, 2002 was a very dry year, and ozone forming potential was above average, suggesting conditions conducive to higher PM2.5 concentrations. However, PM2.5 concentrations declined 11 percent in 2002 compared to the previous year. The same rate of decline continued in 2003 and 2004, despite the variations in weather.

Table B-3: Impact of Precipitation and Ozone Forming Potential on Annual Average PM2.5 Concentrations at Riverside-Rubidoux

Year	Precipitation % of Average	Ozone Forming Potential	Annual Average PM2.5 Concentration (ug/m3)	Change in Annual Average PM2.5 (%)
2001	132%	Average	30.95	9%
2002	49%	Above Average	27.44	-11%
2003	89%	Above Average	24.83	-10%
2004	135%	Below Average	22.14	-11%
2005	183%	Average	21.04	-5%

On a seasonal basis, Figures B-10 and B-11 show that both the summer and winter seasons show improvement since 1999. Between 1999 and 2006, Los Angeles-North Main summer and winter season averages decreased by 22 and 40 percent, respectively. Between 1999 and 2006, Riverside-Rubidoux summer and winter season averages decreased by 35 and 44 percent, respectively.

Figure B-10: PM2.5 Seasonal Trends at LA-North Main

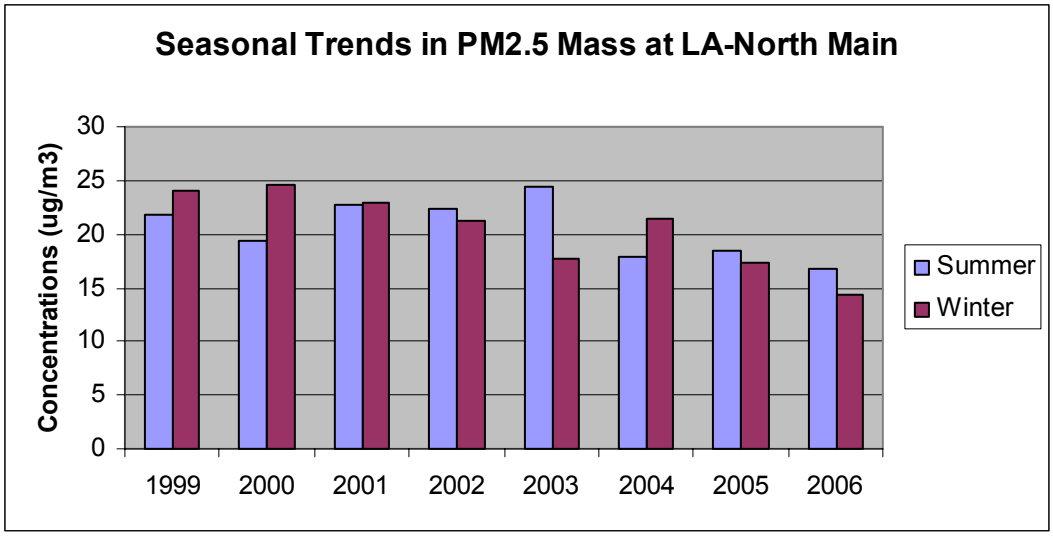
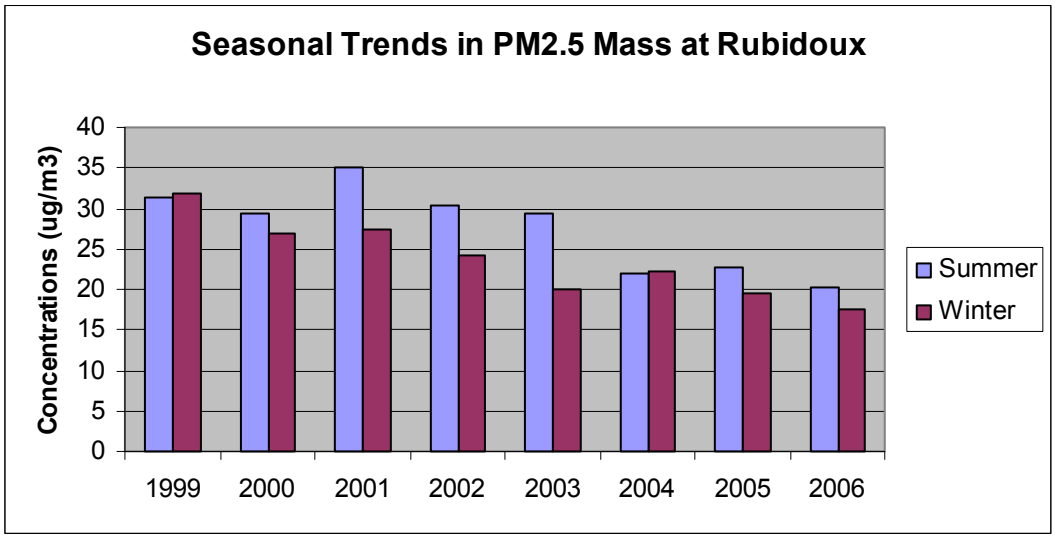


Figure B-11: PM2.5 Seasonal Trends at Riverside-Rubidoux



Chemical Composition and Emissions Trends

Current Chemical Composition

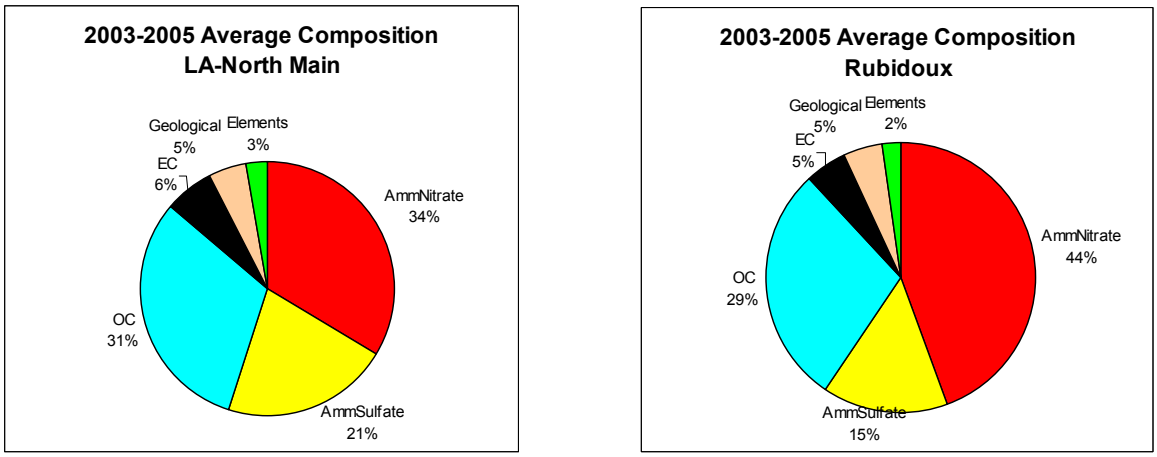
Unlike ozone, particulate matter (PM) is not a single chemical, but instead consists of many different chemical components. Investigating these different components and how they vary by site and season provides us with a better understanding of their complexity and responses to the emission control program. This mix of chemical components consists of both directly emitted PM such as geological material and elemental carbon (soot), known as primary PM, as well as PM formed in the atmosphere from the reactions of precursor gases, known as secondary PM. These precursor pollutants include nitrogen oxides (NOx), sulfur oxides (SOx), reactive organic gases (ROG), and ammonia. NOx, SOx, and ammonia combine to form secondary ammonium nitrate and sulfate. ROG can form secondary organic carbon, as well as participate in the production of secondary ammonium nitrate.

Chemical components are routinely measured at only two Speciated Trends Network sites, Los Angeles-North Main, and Riverside-Rubidoux. These two sites are representative of the highly populated western basin (Los Angeles), and the highest PM2.5 concentration area in the eastern basin (Riverside). The chemical composition of PM2.5, seasonal variability, and trends in these components are discussed below to provide further insight into the linkage between observed progress and ongoing emission reductions.

The annual average PM2.5 chemical composition for Riverside-Rubidoux and Los Angeles-North Main is shown in Figure B-12. Although ammonium nitrate, ammonium sulfate, and organic carbon are the major constituents at both sites, there are important differences between the two sites as well. For example, Los Angeles-North Main has a greater contribution from ammonium sulfate and elemental

carbon than Riverside-Rubidoux, likely reflecting the greater impact from shipping and goods movement related activities in this region. In contrast, Riverside has a greater contribution from ammonium nitrate due to its location further downwind in the basin and the longer time available for the secondary formation of this constituent. It can be important for the attainment strategy to recognize these regional differences. However, even though there are regional differences in the composition, the PM2.5 problem is widespread throughout the basin and many of the emission sources contributing to the problem are regional in nature.

Figure B-12: 2003 – 2005 Average Composition Los Angeles-North Main Site and Riverside-Rubidoux Site



Figures B-13 and B-14 illustrate the seasonal variability in chemical components that make up the annual average for the Los Angeles-North Main and the Riverside-Rubidoux sites averaged over 2003 through 2005. At the Los Angeles-North Main site (Figure B-13), ammonium nitrate is lowest during the spring months, and increases through fall and winter. Sulfate has a photochemical aspect so concentrations are greatest in the summer. At the Los Angeles-North Main site, ammonium sulfate increases sharply from April to July, and then slowly begins to descend to its lowest concentration in December. The Riverside-Rubidoux site follows the same trend, with the exception that ammonium sulfate concentrations at the Los Angeles-North Main site increase more rapidly and to a higher level than Riverside-Rubidoux. At the Riverside-Rubidoux site (Figure B-14), ammonium nitrate is highest in the summer months from June through October, then decreases sharply from October to December. In both locations, organic carbon and the geological components remain fairly constant throughout the year.

Figure B-13: PM2.5 Seasonal Pattern in Chemical Components Los Angeles-North Main Site 2003-2005 Average

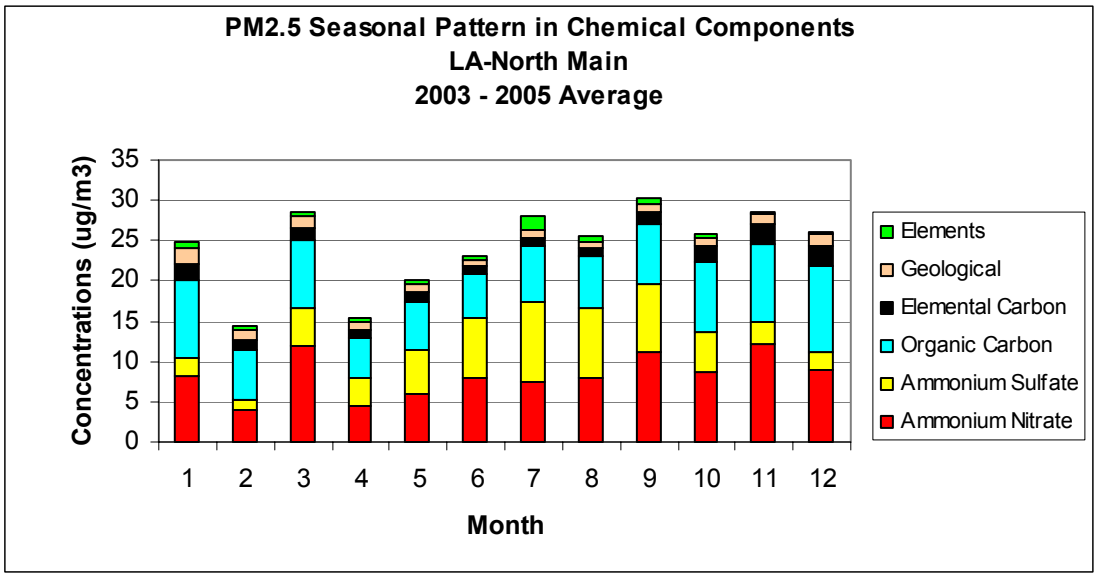
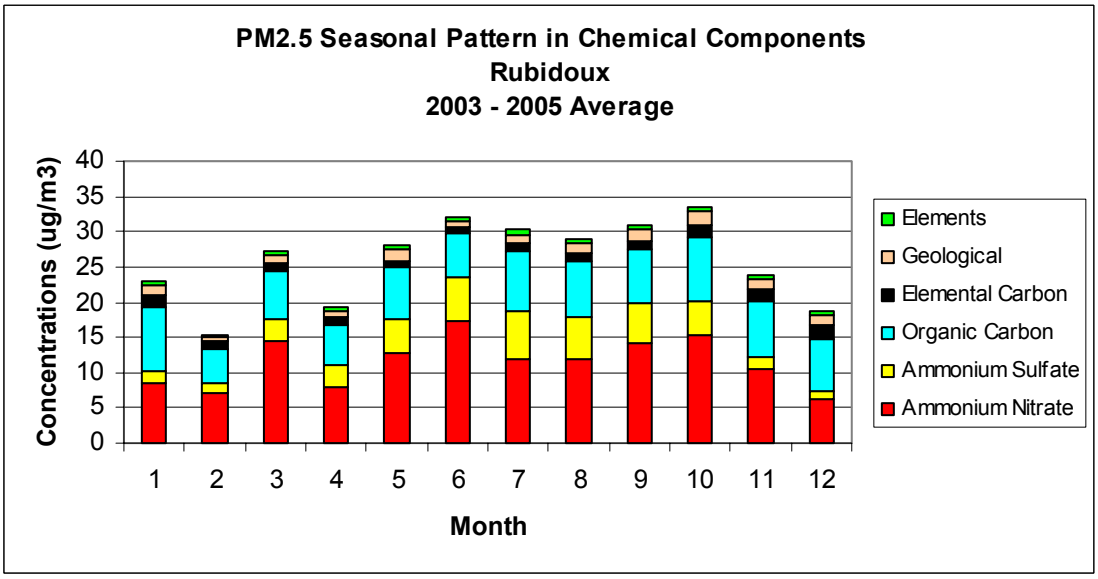


Figure B-14: PM2.5 Seasonal Pattern in Chemical Components Riverside-Rubidoux Site 2003-2005 Average



Chemical Composition Trends

As discussed previously, all monitoring sites have shown decreasing PM2.5 concentrations from 2001 to 2006. Trends in individual chemical components and precursor concentrations, as well as emissions inventory trends were evaluated to

understand the primary chemical components responsible for this progress and to evaluate the response to ongoing control programs. Riverside-Rubidoux has shown the greatest decline in concentrations, with the most significant reductions occurring in ammonium nitrate and carbonaceous aerosols components (Figure B-15). Ammonium nitrate concentrations have dropped 40 percent, and carbonaceous aerosols have dropped 19 percent. Approximately two-thirds of the PM2.5 improvement observed in the South Coast can therefore be attributed to reduced ammonium nitrate; a much smaller portion of the remaining PM2.5 improvement is due to reductions in carbonaceous compounds (19 percent) and ammonium sulfate (~17 percent). Trends for Los Angeles-North Main are shown in Figure B-16.

Figure B-15: Trends in PM2.5 Mass and Chemical Components Riverside-Rubidoux

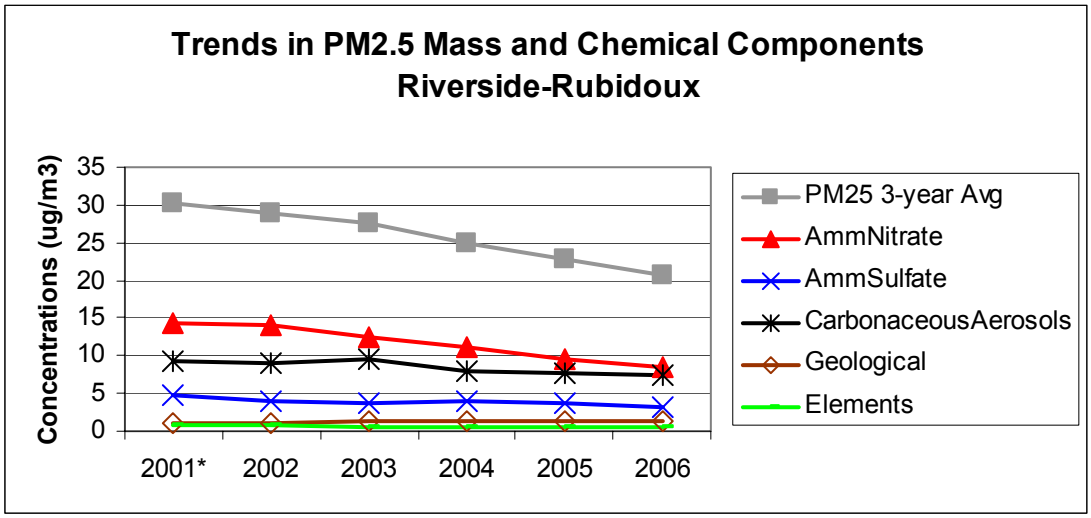
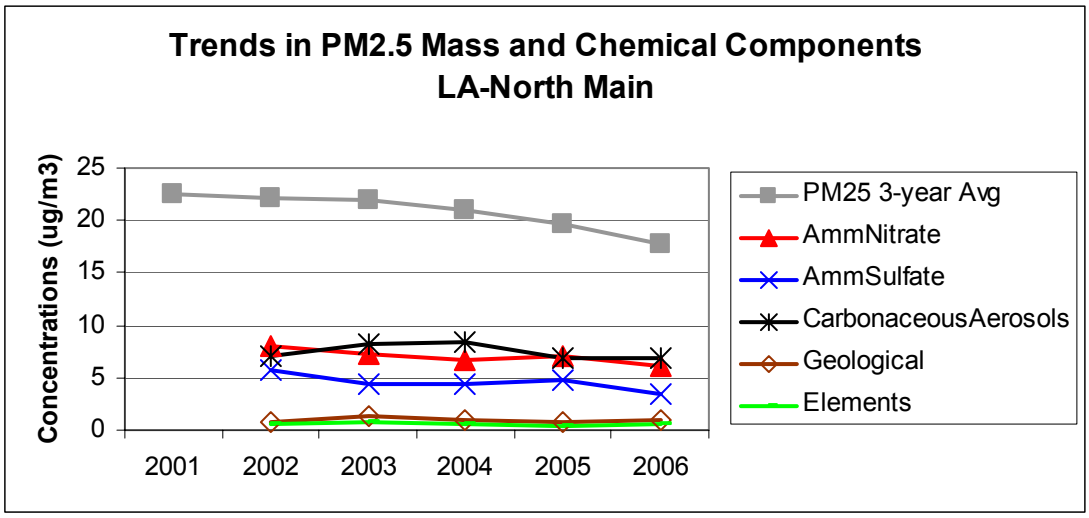
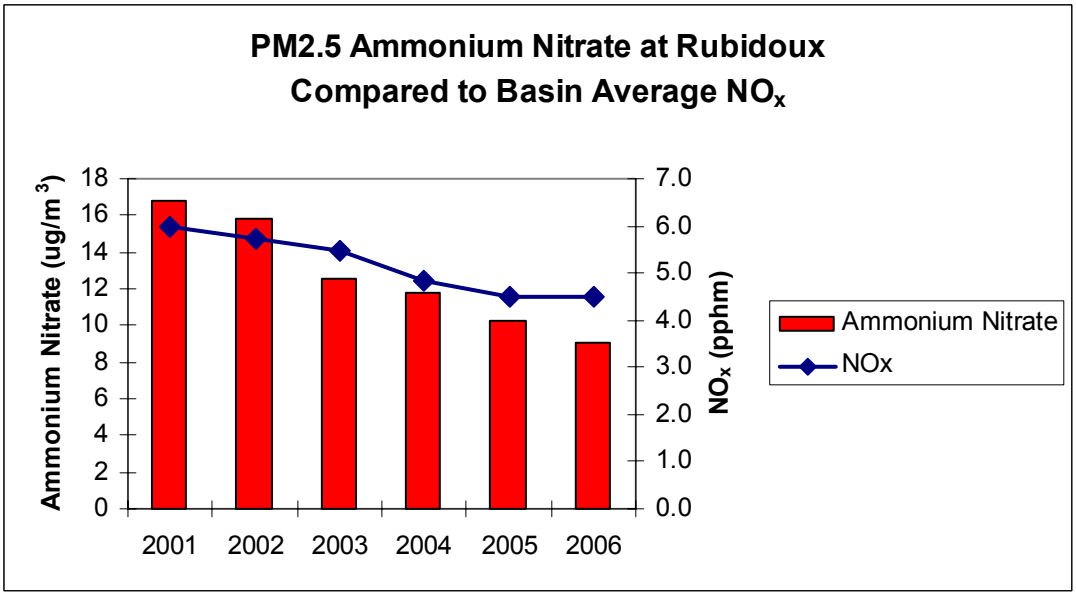


Figure B-16: Trends in PM2.5 Mass and Chemical Components Los Angeles-North Main



Trends in ammonium nitrate concentrations also correlate well with recent trends in basin average NOx, a precursor to ammonium nitrate. Since 2001, basin average NOx has decreased by 25 percent while ammonium nitrate concentrations decreased 40 percent. As our emission control program has reduced the amount of these precursors, we have seen a corresponding improvement in air quality. Figure B-17 illustrates the downward trend of ammonium nitrate concentrations compared with similar declines in basin average NOx concentrations at Riverside-Rubidoux.

Figure B-17: PM2.5 Ammonium Nitrate Compared to NOx Riverside-Rubidoux



Similar relationships between both ammonium nitrate and sulfate and ambient precursor concentrations can be seen in the longer-term record. Figures B-18 and B-19 show trends in basin average ambient NOx and SO2 concentrations along with corresponding ambient nitrate and sulfate measurements from the PM10 network extending back to the late 1980s. Both nitrate and sulfate have experienced significant decreases, with nitrate decreasing 43 percent, and sulfate 40 percent. During the same period, there were concurrent declines in ambient NOx and SO2 concentrations.

Figure B-18: Three-Year Average Concentrations of PM10 Nitrate and NOx in South Coast Air Basin

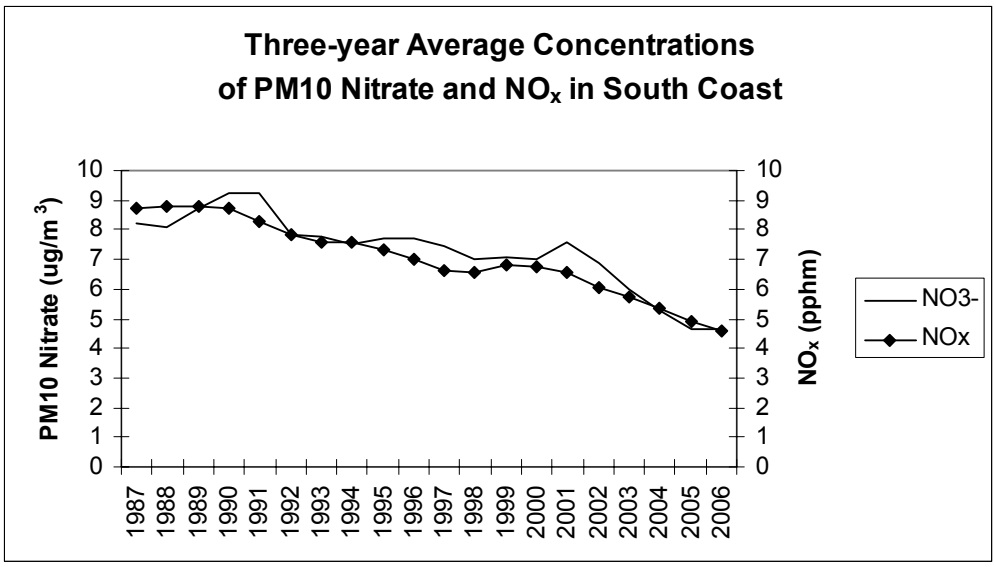
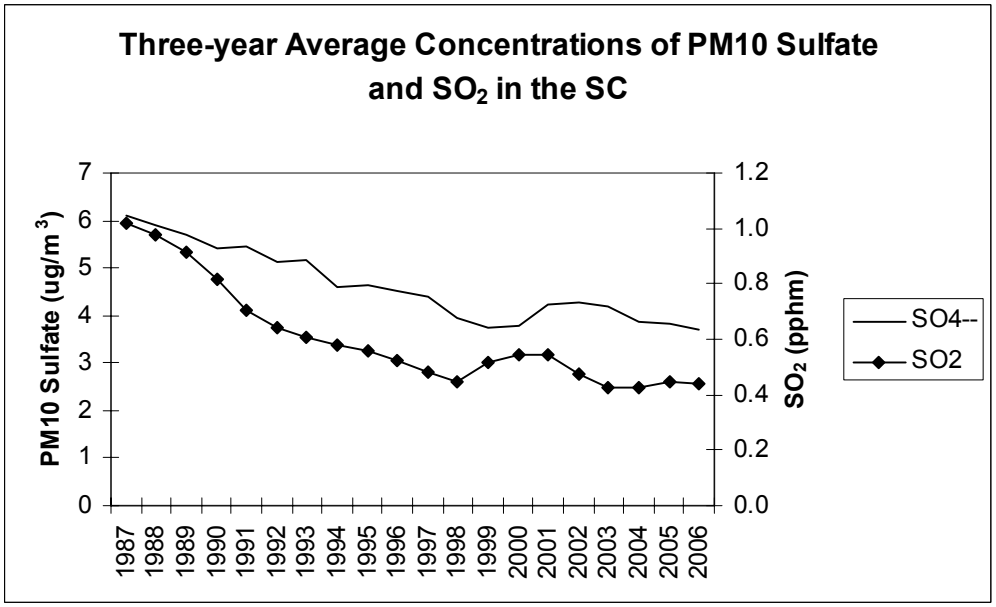


Figure B-19: Three-Year Average Concentrations of PM10 Sulfate and SO2 in the South Coast Air Basin



In addition, Figure B-20 compares the PM10 and PM2.5 nitrate at the Riverside-Rubidoux monitor. Even though PM2.5 monitoring recently began, the data shows that the PM2.5 and PM10 nitrate levels track very well. Furthermore, the emission reduction strategy in place that reduced PM10 nitrate levels will also reduce PM2.5 nitrate levels. As shown in the figure, the PM2.5 nitrate levels are higher than the PM10 nitrate levels. This is due to the loss of semi-volatile nitrates with the PM10 monitor configuration, which are better captured on the PM2.5 monitor.

Figure B-20: Three-Year Average Concentrations of PM10 and PM2.5 Nitrate at Riverside-Rubidoux

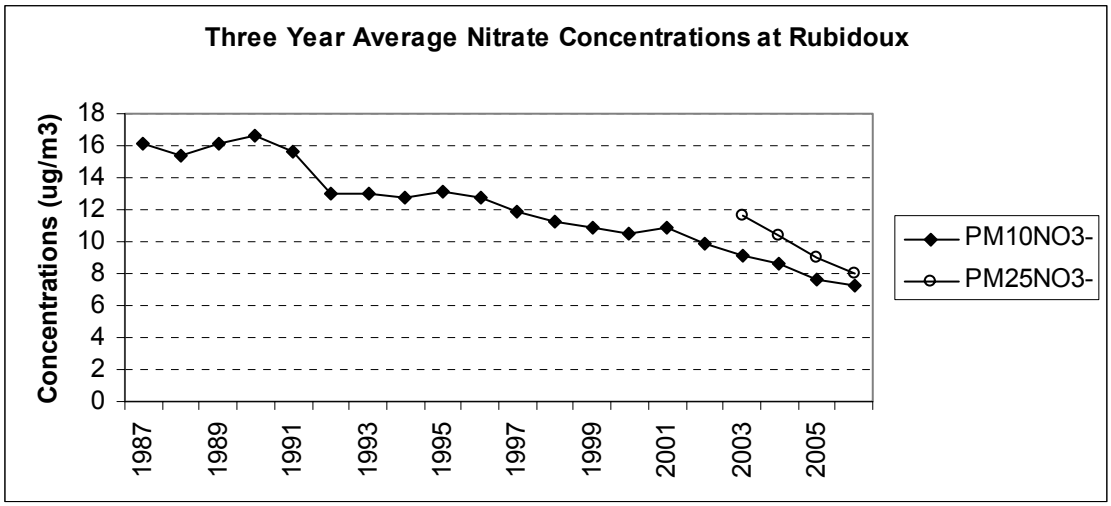


Figure B-21: Three-Year Average Concentrations of PM10 and PM2.5 Sulfate at Riverside-Rubidoux

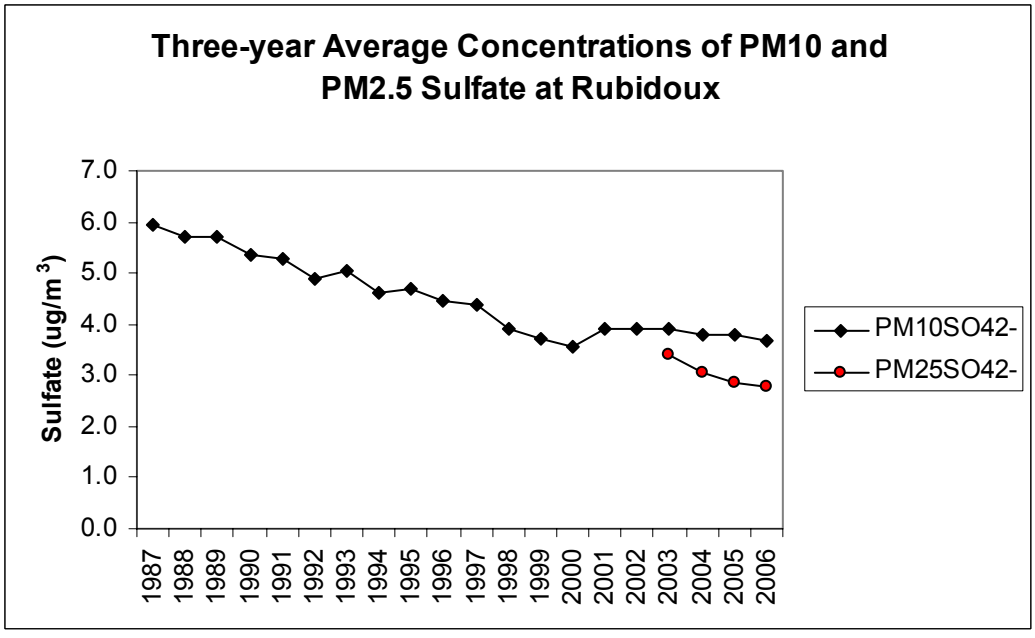


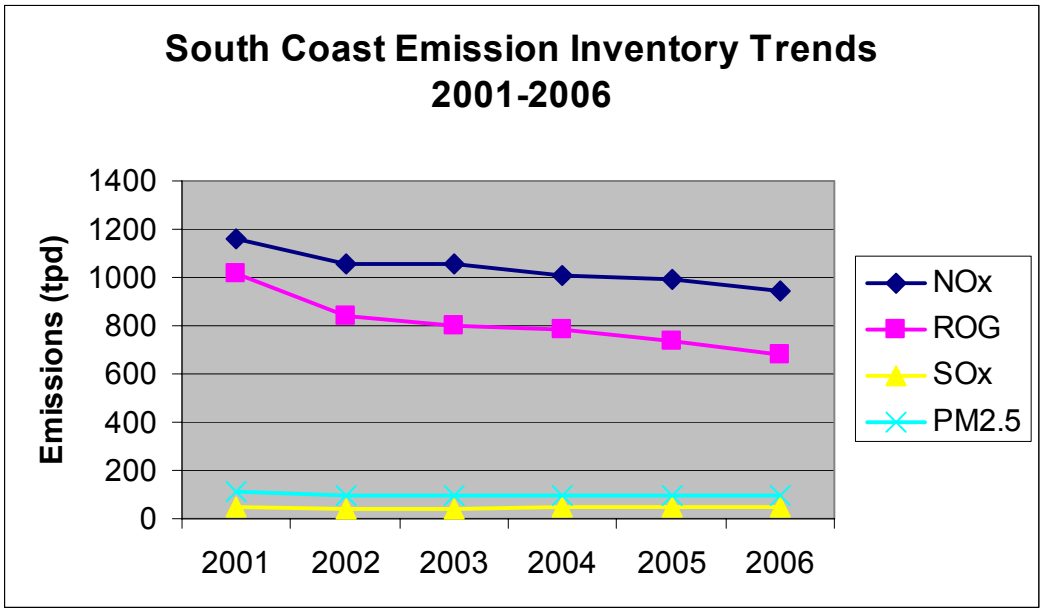
Figure B-21 compares the PM10 and PM2.5 sulfate at the Riverside-Rubidoux monitor. As with nitrate, the data shows that the PM2.5 and PM10 sulfate levels track very well. In contrast with nitrate, the PM10 sulfate is higher than the PM2.5 sulfate. Because sulfate is nonvolatile and is retained well by filters, the PM10 monitor is not subject to the same sampling artifacts for sulfate as it is for nitrate. Therefore, the difference between PM10 and PM2.5 represents sulfate in the coarse particle range.

Emission Trends

At the same time that ambient concentrations have been declining, the emissions of pollutants that contribute to the different components of PM2.5 have also been decreasing. Figure B-22 illustrates the recent emission trends in the South Coast air basin from 2001 through 2006. The greatest decrease in emissions occurred in ROG with a decrease of 33 percent, or 339 tpd. NOx also decreased, experiencing a decline of 213 tpd, or 18 percent. These reductions reflect the benefits of control programs which have provided continuing reductions despite increasing population growth. PM2.5 emissions showed a much smaller decrease of 11 tpd, while SOx emissions increased slightly by 5 tpd. Much of the increase in SOx emissions can be attributed to growth in the goods movement sector. However, over the longer-term period, both SOx and NOx emissions have also dropped substantially as documented by the decrease in ambient NOx and SO2 concentrations reflected in Figures B-20 and B-21 above.

The combined downward trends in PM2.5 components, precursor concentrations, and emissions all indicate that over both the long-term and short-term, the ongoing control program has had substantial benefits in improving air quality and that similar emission reductions in the future should provide continuing progress towards attaining the federal PM2.5 standards.

Figure B-22: South Coast Air Basin Emission Inventory Trends 2001-2006



3. OBSERVATIONAL MODELS AND DIAGNOSTIC ANALYSES

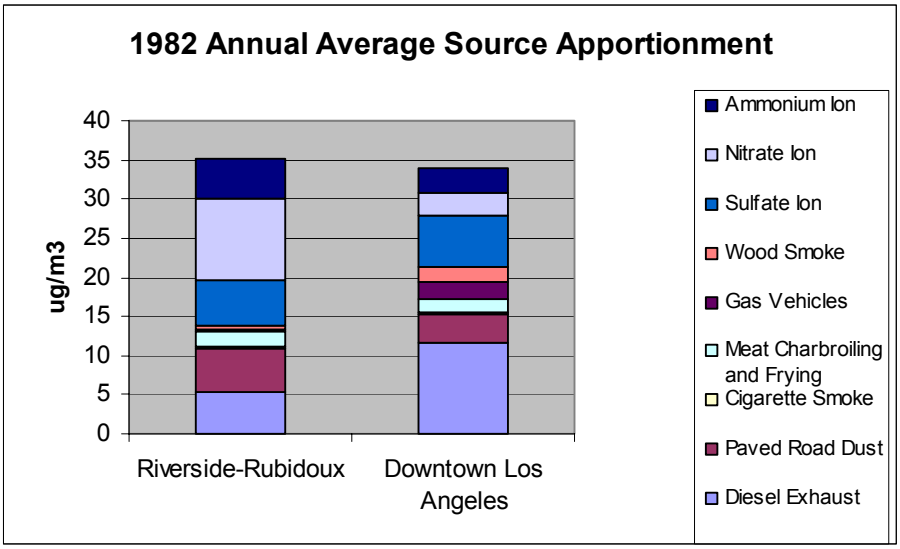
Observational models take advantage of monitored data to draw conclusions about the relative importance of different types of emissions and precursors as factors contributing to observed PM2.5 concentrations. According to U.S. EPA guidance, observational models can be used to corroborate the effects of prior control strategies, as well as identify the potential effectiveness of proposed control approaches. U.S. EPA recommends using both source apportionment (receptor models) and indicator species approaches. The two most widely applied receptor modeling approaches are multi-variate statistical models such as positive matrix factorization (PMF) and the chemical mass balance model (CMB). Receptor models are particularly useful in identifying the source contributions to directly emitted PM. This supplemental analysis summarizes results from prior receptor modeling studies as well as new results from both PMF and CMB applied to more recent data. In addition, previous work using an indicator species approach to assess the limiting precursor in secondary nitrate formation in the South Coast Air Basin is discussed.

Observational Models

Prior Source Apportionment Studies

Numerous source apportionment studies have been conducted in the South Coast reflecting snapshots of different sites and times using various receptor models. While the precise contributions vary, these studies have all identified diesel and gasoline vehicle exhaust, smoke from wood burning and cooking, and fugitive dust as important contributors to directly emitted PM2.5. In 1982, Caltech conducted an annual average source apportionment study at four sites in the air basin: West Los Angeles, Downtown Los Angeles, Pasadena, and Riverside-Rubidoux (Schauer 1996). This study found that directly emitted exhaust from mobile sources (gasoline and diesel) contributed an average of 26 percent, dust an average of 13 percent, and wood smoke and cooking an average of 7 percent each to annual average PM2.5 concentrations. Figure B-23 compares the source apportionment results for Downtown Los Angeles and Riverside-Rubidoux. For example, the largest source in Downtown Los Angeles was diesel exhaust, while at Riverside-Rubidoux it was nitrate. Wood smoke and sulfate were more predominant at Downtown Los Angeles, while paved road dust was higher at Riverside-Rubidoux.

Figure B-23: 1982 Annual Average Source Apportionment of Fine Particulate Matter



In a report for ARB, Watson (1993) characterized primary organic carbon sources and compared them with PM concentrations in the Los Angeles area during the 1987 Southern California Air Quality Study. The analysis identified motor vehicles, meat cooking, road dust, and wood smoke as contributing to fine particle organic compounds in the region. In another study in 1993, annual composite samples from four sites in the South Coast found that mobile sources contributed 14 percent of organic carbon, dust 10 percent, wood smoke 9 percent, and cooking 26 percent (Hannigan 2005). In the most recent study conducted in the region, analysis of primary PM10 conducted through the Children's Health Study in 1995 by the University of Wisconsin-Madison and Cal Tech (Manchester-Neesvig 2003) demonstrated both a strong spatial and seasonal variability in contributions. For example, as shown in Table B-4, in Riverside wood smoke contributed an average of 1.83 ug/m3 during November through December (25 percent of primary PM), dropping to 0.51 ug/m3 during January through April (14 percent of primary PM). Within the winter season, wood smoke contributions ranged from 1.2 ug/m3 at Long Beach (14 percent of primary PM10), up to 3.72 ug/m3 at Mira Loma (28 percent of primary PM10).

Table B-4: 1995 Children's Health Study CMB analysis of wood smoke contribution to PM10 (ug/m3)

	Riverside	Mira Loma	Long Beach	Upland
Nov – Dec	1.81	3.72	1.19	2.38
Jan-April	0.51	0.29	0.68	0.99
May-Oct	0.30	0.21	0.29	0.40

Recent Studies

To evaluate the major PM2.5 sources and their contributions in the South Coast Air Basin using more recent data, two different source apportionment techniques were applied to data collected in 2003 through 2005. The CMB model uses measured source profiles and chemical speciation data in combination to determine source contributions. A fundamental underlying assumption is that the source profiles used as input are appropriate and representative for the region. In contrast, PMF analysis does not require the input of source profiles, but rather evaluates the covariance of the chemical species to determine a set of factors, which are typically interpreted as source types. Source contributions are then calculated for each of the factors. Because the factors reflect species which vary in time in a similar manner, the factors may reflect the impacts of primary sources, as well the secondary species that have condensed on these primary particles. Since each technique has strengths and weaknesses, combined the two source apportionment techniques provide complementary results.

Positive Matrix Factorization

PMF analysis was conducted for the Los Angeles-North Main and the Riverside-Rubidoux site data collected between 2003 and 2005. After testing different numbers of sources and different modeling parameters, eight and nine major source factors were identified at the Los Angeles-North Main and the Riverside-Rubidoux sites, respectively.

The average source contributions of each source to the PM2.5 mass concentrations are provided in Figure B-24. Secondary nitrate particles that accompany secondary carbonaceous materials contributed the most at both sites accounting for 30 percent of the PM2.5 concentrations at the Los Angeles-North Main site and 49 percent at the Riverside-Rubidoux site. In contrast, secondary sulfate particles contributed more at the Los Angeles-North Main site (23 percent) than at the Riverside-Rubidoux site (9 percent). The possible source directions for the secondary particles and airborne soil were estimated by conditional probability functions and are shown as probabilities in Figure B-25. Figure B-25 shows that most of the secondary nitrate particles as well as the secondary sulfate particles at the Riverside-Rubidoux site were associated with westerly winds indicating strong contributions from the western basin. As major sources, gasoline vehicles and diesel emissions account for 7 percent and 11 percent, respectively, of the PM2.5 concentration at the Los Angeles-North Main site and 10 percent and 6 percent at the Riverside-Rubidoux site. There appear to be greater impacts from diesel emission sources at the Los Angeles-North Main site, potentially reflecting the proximity to shipping and goods-movement-related activities.

Biomass smoke contributed 10 percent of the PM2.5 concentrations at the Los Angeles-North Main site and 6 percent at the Riverside-Rubidoux site. The biomass smoke category reflects contributions from residential wood burning as well as managed and wildland fires; smoke from commercial cooking is also in this category. Aged aerosol with sea salt 1 and 2 contributed 9 percent of the PM2.5 concentrations at the Los Angeles-North Main site and 11 percent at the Riverside-Rubidoux site. Aged

aerosol with sea salt 1 and 2 reflect particles in which chloride in the fresh sea salt is displaced by acidic gases during transport across the air basin. Therefore, aged aerosol with sea salt includes other particles such as organic carbon, elemental carbon, sulfate, and nitrate in addition to sodium and chloride. Due to transport across the basin, there is more aged aerosol with sea salt in Riverside-Rubidoux compared to Los Angeles-North Main. Airborne soil contributed 10 percent of the PM2.5 concentrations at the Los Angeles-North Main site and 7 percent at the Riverside-Rubidoux site. Airborne soil profile contains organic and elemental carbon indicating it also includes re-suspended soil by road traffic in addition to wind blown soil dust. Airborne soil identified at the Los Angeles-North Main site did not show clear directionality. However, as shown in Figure B-24, airborne soil identified at the Riverside-Rubidoux site was strongly associated with winds from the northeast. An additional factor contributing 2 percent of the PM2.5 concentrations was separated at the Riverside-Rubidoux site. This source profile includes organic and elemental carbon, zinc, calcium, iron, and lead suggesting an industrial emissions source. At the Los Angeles-North Main site, a similar signal was not likely strong enough to be separated.

Figure B-24: 2003 – 2005 Average Source Contributions (PMF): Los Angeles-North Main Site and Riverside-Rubidoux Site

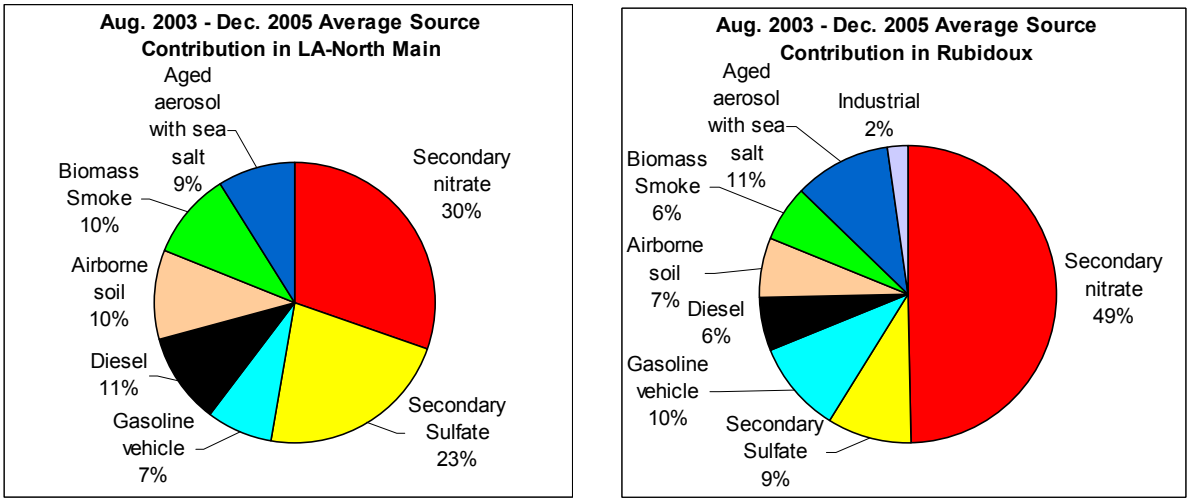
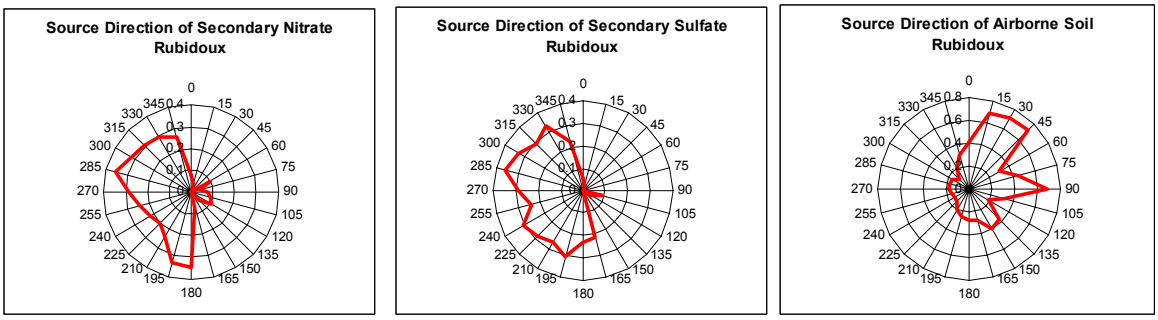


Figure B-25: Possible Source Directions at the Riverside-Rubidoux Site



The monthly patterns in source contributions are shown in Figures B-26 and B-27. Secondary nitrate particles have winter high monthly variations and similar March and October/November high patterns at both sites. Secondary sulfate particles show monthly variation with higher concentrations in summer at both sites when the photochemical activity is highest. At both sites, biomass smoke shows the highest contributions during the winter (Figures B-26 and B-27) and on weekends, indicating this source is mostly from residential wood burning smoke. Also, slightly elevated contributions in July at both sites indicate possible smoke contributions from managed burning/wildfires in the summer. Airborne soil has September/October high patterns at both sites when the winds from the northeast are most predominant.

Figure B-26: 2003 – 2005 Monthly Average Source Contributions (PMF): Los Angeles-North Main Site

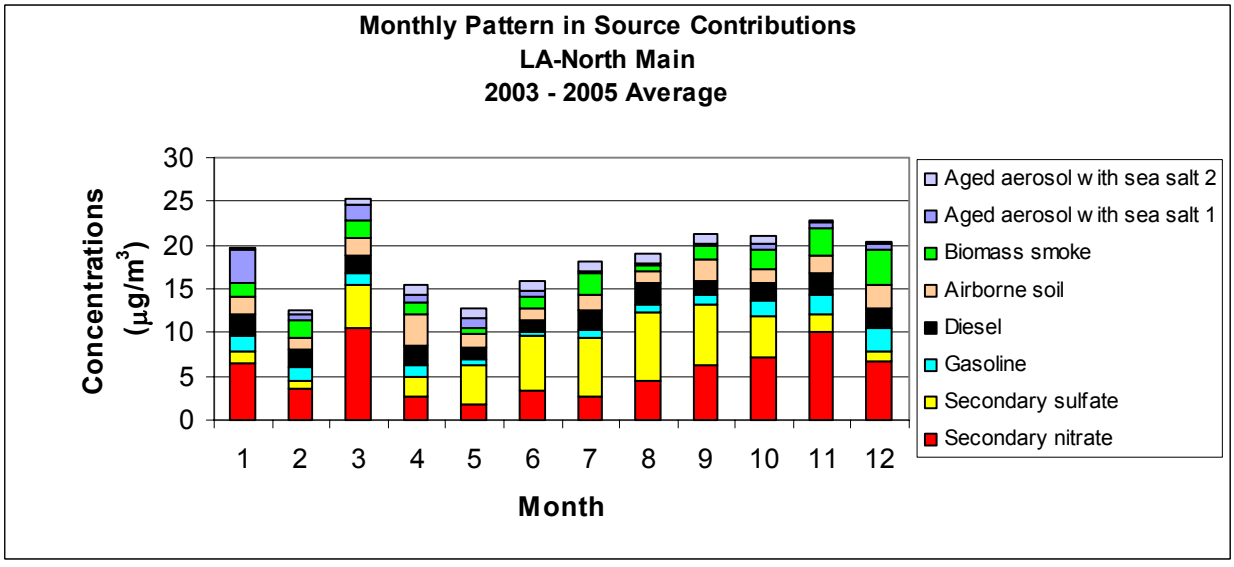
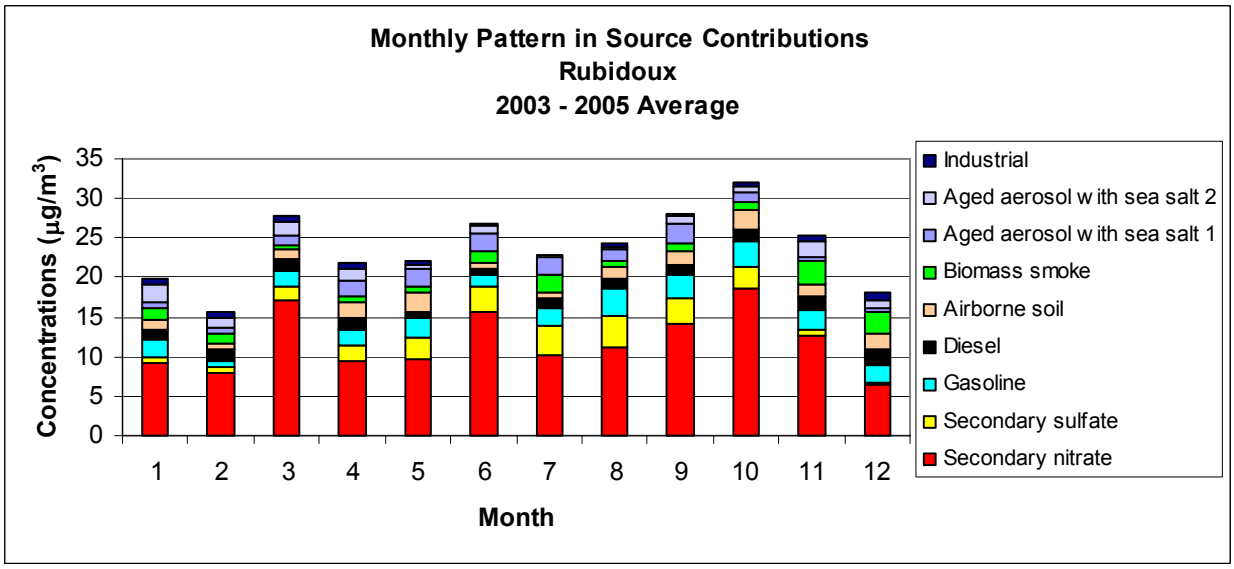


Figure B-27: 2003 – 2005 Monthly Average Source Contributions (PMF): Riverside-Rubidoux Site



Chemical Mass Balance Modeling

Additional source apportionment analysis was conducted for the Los Angeles-North Main and the Riverside-Rubidoux site data collected between 2003 and 2005 using the Chemical Mass Balance (CMB 8.2) model. The annual average source contributions at Rubidoux and Los-Angeles-North Main Street were estimated by applying the CMB model to 195 and 101, respectively, individual PM2.5 sample concentrations collected between 1/1/2004 and 12/31/2005 at Riverside-Rubidoux and Los Angeles-North Main. Source profiles for PM2.5 developed during previous studies were applied to the measurements to calculate source contributions to the PM2.5 mass. Source contribution estimates were calculated based on the 2004-2005 average for the individual samples that had acceptable results for the performance measures

Figure B-28 illustrates the 2004-2005 average source contributions for Riverside-Rubidoux. Ammonium nitrate was the most significant source contributing 47 percent and 34 percent of the PM2.5 mass at Riverside Rubidoux and Los Angeles North Main, respectively. Ammonium sulfate accounted for 14 percent at Riverside-Rubidoux and 20 percent at Los Angeles North Main. Motor vehicle exhaust (diesel and gasoline combined) contribution was similar at both sites ranging from 11 percent at Riverside-Rubidoux to 12 percent at Los Angeles North Main. Vegetative burning, which included residential wood combustion and wildfires, contributed 7 percent and 8 percent, respectively, of the PM2.5 mass. Sea salt contributed about 1 percent of the PM2.5 mass at both sites. The sea salt contribution was estimated using a pure sea salt profile for Los Angeles North Main and reacted profile for Riverside-Rubidoux, where 25 percent of chlorine was replaced by nitrate on a molar basis (Chow et al., 1996a).

Figure B-28. Estimated 2004-2005 Average PM2.5 Source Contributions at Riverside-Rubidoux and Los Angeles North Main

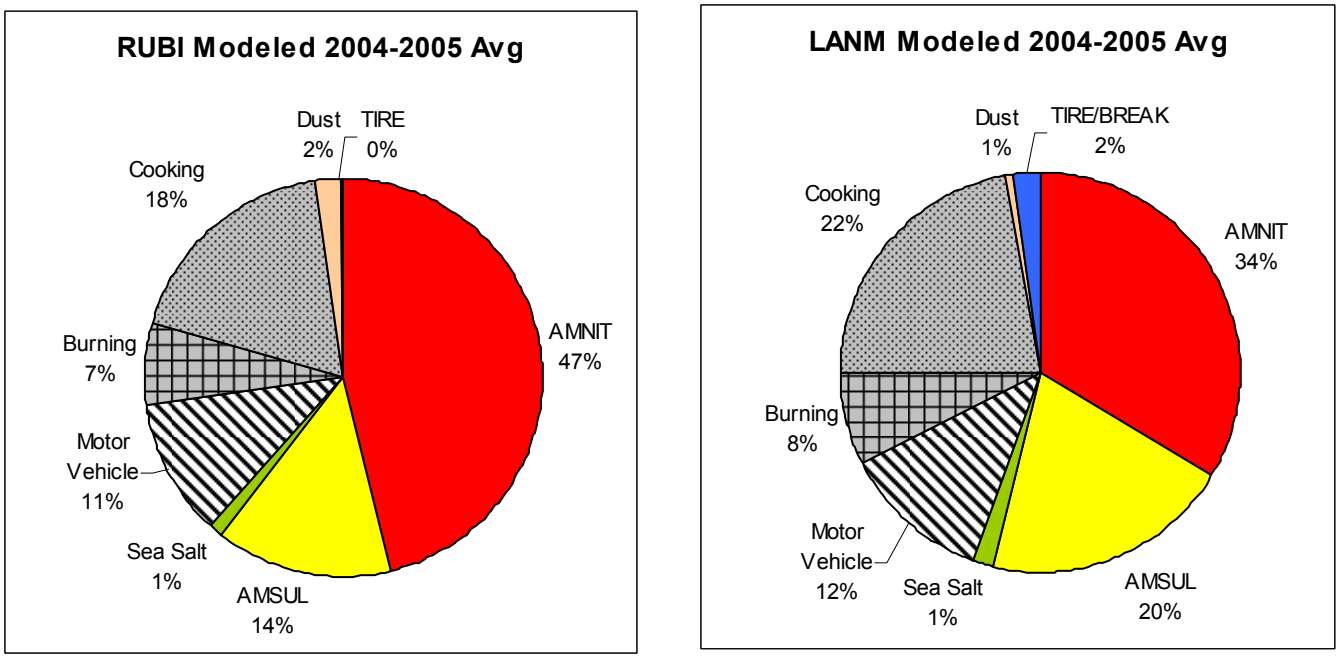


Figure B-28 shows that the initial cooking contribution ranged from 19 percent to 22 percent; however that likely included positive organic carbon sampling artifacts, secondary organic aerosols, as well as other combustion sources. In order to test this theory, we ran two sets of data; one with organic carbon (OC) as reported in the speciation trends network data and another one in which positive sampling artifacts, estimated to be 2.77 ug/m3 at Riverside-Rubidoux and 3.17 ug/m3 at Los Angeles North Main, were subtracted from the measured OC. The motor vehicle and burning contribution were almost the same in both data sets, but the cooking contribution was lower for the corrected data set, dropping to approximately 6 percent, which was more consistent with estimates of cooking contributions from prior studies (Table B-5).

Dust and tire contribution were estimated using different profiles at each site. In case of Rubidoux, dust was represented by a resuspended road dust profile. A separate tire profile was also included in the model, but the estimated concentrations were lower than the uncertainty. At LA-North Main, the brake and tire wear were combined into a single profile and a separate dust profile was used.

Table B-5. Impact of Adjusting Carbon Data on Source Contribution
(Average of 106 days)

Source Category	Contribution (ug/m3)	
	Original Data	Blank Corrected Data
Riverside Rubidoux		
Motor Vehicle	2.8	2.8
Burning	1.8	1.6
Cooking	5.5	1.6
Los Angles North Main		
Motor Vehicle	2.8	3.4
Burning	1.8	1.9
Cooking	5.0	-1

Diagnostic Analyses

Indicator Species Approach

As discussed in prior sections, trends in ammonium nitrate concentrations have tracked well with concurrent reductions in NOx, suggesting that NOx control is an effective approach for ensuring further reductions in ammonium nitrate. An indicator species approach provides an additional method to investigate which chemical precursor a secondary species such as ammonium nitrate is most responsive to control of. Blanchard (2000) used a thermodynamic equilibrium model, SCAPE2, to calculate indicator species ratios for several locations in California, including the South Coast Air Basin. The study looked at nitrate concentration changes in response to the changes in nitric acid, ammonia, and sulfuric acid based on the excess of ammonium plus ammonia over the sum of nitric acid, nitrate, and sulfate. This approach was applied to the field study data measured in the South Coast during the California Acid Deposition Monitoring Program and the 1987 Southern California Air Quality Study. The results indicated that that nitrate formation was not limited by the availability of ammonia for most samples, therefore suggesting that NOx controls are more effective in reducing ammonium nitrate concentrations.

4. AIR QUALITY MODELING

Rollback Modeling

In addition to the evaluation of air quality trends and the observational and diagnostic analyses, a rollback modeling analysis was conducted by ARB to estimate the impacts of future emission reductions on resulting air quality. Rollback modeling was conducted for the two sites with routine speciation data – Riverside-Rubidoux, and Los Angeles-North Main. Reductions or increases in emissions are assumed to have a linear corresponding effect in the ambient PM2.5 concentrations at the monitor, taking into

account background concentrations. The ammonium nitrate component however, was assumed to have a non-linear response to reductions in NOx, with a ratio of 1.3:1 (i.e. a 50% reduction in NOx would provide only a 38% reduction in ammonium nitrate). Table B-6 lists the associated emission category and background concentration used for each PM2.5 component in the rollback analysis.

Table B-6: PM2.5 Components, Background Concentrations, and Emission Categories use in Rollback Analysis

PM2.5 Component	**Background Concentration**	**Emission Category**
Ammonium Nitrate	0.2 ug/m3	Basin wide NOx
Ammonium Sulfate	0.6 ug/m3	Basin wide SOx
Secondary Organic Carbon (OC)	0.2 ug/m3	Basin wide ROG
Primary Organic Carbon (OC)	1.8 ug/m3	Basin wide PM2.5
Elemental Carbon (EC)	0.0 ug/m3	Basin wide PM2.5 diesel
Other	0.5 ug/m3	Basin wide PM2.5

Rollback modeling of two future emissions scenarios was conducted. In the first scenario, the relative reduction or increase of the baseline emission inventories between 2005 and 2014 of each PM2.5 component was applied to determine a future value for each PM2.5 component. The future PM2.5 design value was determined by summing the PM2.5 components and their corresponding background concentration. The same technique was then used to evaluate the impact of the April 24, 2007 ARB staff proposed State Strategy for California's 2007 State Implementation Plan together with local South Coast measures (an additional reduction of 142 tpd of NOx, 23 tpd of SOx, 56 tpd of ROG, and 11 tpd of directly emitted PM2.5). The results of this modeling are shown in Tables B-7 and B-8. The rollback technique estimated that the substantial additional emission reductions contained in the ARB State Strategy as proposed in the April 24, 2007 document would be sufficient to provide for attainment at Riverside-Rubidoux as well Los Angeles-North Main.

Table B-7: Rollback Modeling Predicted PM2.5 Concentrations at Riverside-Rubidoux

	PM2.5 (ug/m3)	Ammonium Nitrate (ug/m3)	Ammonium Sulfate (ug/m3)	Secondary OC (ug/m3)	Primary OC (ug/m3)	EC (ug/m3)	Other (ug/m3)
2005	22.7	10.1	3.4	1.9	4.5	1.1	1.6
2014 baseline	18.1	7.3	2.7	1.4	4.4	0.6	1.6
2014 control	14.8	6.3	1.6	1.3	4.2	0.2	1.5

*Numbers may not add due to rounding

Table B-8: Rollback Modeling Predicted PM2.5 Concentrations at Los Angeles-North Main

	PM2.5 (ug/m3)	Ammonium Nitrate (ug/m3)	Ammonium Sulfate (ug/m3)	Secondary OC (ug/m3)	Primary OC (ug/m3)	EC (ug/m3)	Other (ug/m3)
2005	19.6	6.6	4.2	1.8	4.3	1.2	1.5
2014 baseline	15.3	4.9	3.3	1.4	4.2	0.7	0.9
2014 control	13.0	4.2	2.1	1.3	3.9	0.2	1.3

*Numbers may not add due to rounding

Grid-Based Modeling

Annual average grid-based aerosol modeling was conducted by the South Coast District. The PM modeling for the South Coast Air Basin was based on the 1997 Southern California Ozone Study domain which covers San Luis Obispo, Santa Barbara, Kern, Ventura, San Bernardino, Los Angeles, Orange, Riverside, San Diego, and Imperial Counties and extends into Northwestern Mexico. During 2005, the MATES III field study was conducted in the South Coast Air Basin during which speciated PM2.5 concentrations were measured at 9 monitoring sites throughout the year. The year 2005 was selected for the annual PM2.5 simulation since the resulting MATES III data set was robust and useful for model evaluation. The PM modeling was run using the Comprehensive Air Quality Model with extensions (CAMx) air quality model. The model was run for emissions inventories representing the year 2005 and the year 2014.

To demonstrate attainment of the federal PM2.5 standard, U.S. EPA guidelines recommend using a model-based relative reduction or response factor (RRF) approach for projecting future design values. The RRF approach projects design values from a specific baseline year (in this case 2005) to a future year (2014). For PM2.5, this is done on a species basis (known as the Speciated Model Attainment Test), which are

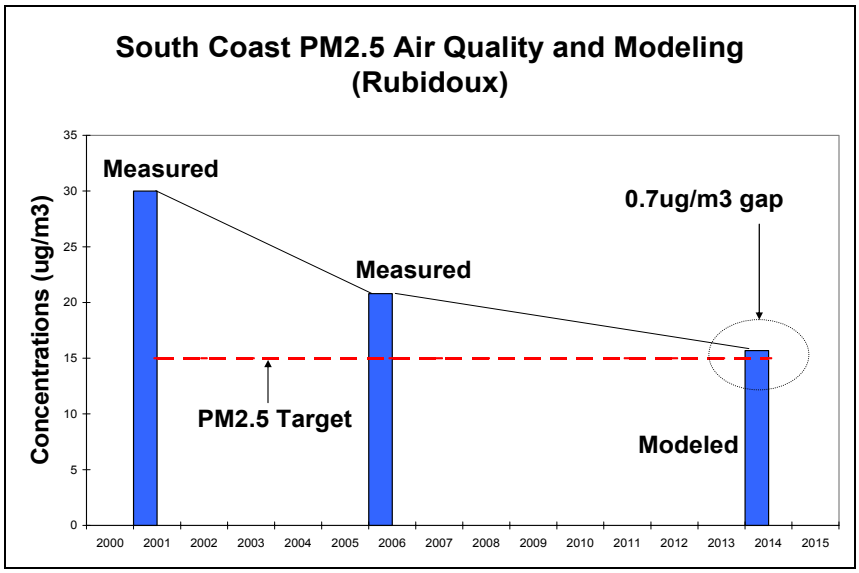
then summed to determine the future year PM2.5 concentrations. The modeled future year design values representing ARB's control strategy along with local South Coast District measures are listed in Table B-9. As shown in the table, the proposed control strategy significantly reduces PM2.5 concentrations in the South Coast Air Basin regionwide. However, a few areas are near, but do not meet the 15.0 ug/m3 federal PM2.5 standard, including the high site at Riverside-Rubidoux, with a predicted 2014 concentration of 15.7 ug/m3.

Table B-9: South Coast 2014 Grid-Based Modeling Predicted PM2.5 Concentrations with ARB Control Measures

	PM2.5 Mass (ug/m3)	Ammonium (ug/m3)	Nitrate (ug/m3)	Sulfate (ug/m3)	OC (ug/m3)	EC (ug/m3)	Others/ Metals (ug/m3)	Water (ug/m3)	Blank (ug/m3)
Anaheim	12.6	1.2	2.9	2	1.7	1.2	1.9	1.3	0.5
Burbank	15.5	1.6	3.7	1.9	2.9	1.6	2	1.4	0.5
Compton	14.7	1.5	3.4	2.3	2.2	1.5	1.9	1.5	0.5
Fontana	15.2	1.6	4	2	1.4	1.8	2.5	1.4	0.5
Los Angeles	15.4	1.8	4.4	2.3	0.9	1.7	2.1	1.8	0.5
Long Beach	12.9	1.4	3.1	2.3	1.3	1.2	1.7	1.4	0.5
Rubidoux	15.7	1.7	4.5	1.9	1.9	1.6	2.1	1.5	0.5
Wilmington	12.1	1.2	2.5	2.2	1.4	1.4	1.7	1.3	0.5

The grid-based modeling indicates that PM2.5 progress will slow down and be less responsive to controls than has been previously observed. For example, between 2001 and 2006 observed ammonium nitrate concentrations dropped by 40 percent. The grid-based modeling predicts a similar decline will occur between 2006 and 2014. However, emissions, specifically NOx emissions, are projected to drop by about 6 percent per year from 2006 to 2014 – approximately twice as fast as they fell between 2001 and 2006. Figure B-29 below illustrates the actual progress from 2001 to 2006 as compared to the progress predicted by the grid-based modeling from 2006 through 2014. Therefore the grid-based model appears to be somewhat "stiff" or less responsive to NOx controls than expected.

Figure B-29: Comparison of Measured Progress in PM2.5 Annual Average Design Values Compared to Predicted Progress



Retrospective Modeling

While chemical transport models may represent the best tool to assess and address a region's PM problem, these models are not without uncertainties. Uncertainties can be introduced at any step of the model formulation and application and lie primarily in (1) the simplifications needed to efficiently simulate complex atmospheric processes and (2) the model's meteorological and emissions inputs. In order to test the ability of a model to effectively capture observed phenomena, model performance tests are necessary. Diagnostic tests to determine how well a model simulates concentration changes due to changes in emissions are particularly useful, because this is how chemical transport models are applied in the U.S. EPA recommended attainment demonstration. A "retrospective analysis" is one such diagnostic test to determine how well a model responds to historical emissions changes. In a retrospective analysis the model is run for a number of prior years so that observed and modeled trends can be compared.

ARB ran the CAMx model using 2005 meteorology and (1) 1995, (2) 1999, and (3) 2005 emissions for two domains over the South Coast Air Basin (SCAB). The predicted species concentrations were then compared to particulate observations at western (e.g., Los Angeles) and eastern (e.g., Rubidoux) sites in the SCAB in order to evaluate how well the modeled concentration trends track those observed.

It is important to note here that the meteorology was held constant while emissions were backcasted for 1995 and 1999. This was due to a lack of resources to exercise the prognostic meteorology model for those two years. Since the meteorology was not identical for all three years, the modeled trend is only an approximation to the more

appropriate modeled trend that would have been obtained using actual meteorology for 1995 and 1999. Thus, the comparison of the modeled and observed trends presented here is not expected to be quantitative, as the model only captures the trend due to emissions changes. In reality the trends are due to both emissions changes and meteorological variability.

A description of the model and simulation configuration is given below and is followed by a graphical comparison of modeled and observed annual PM concentrations at sites throughout the South Coast Air Basin.

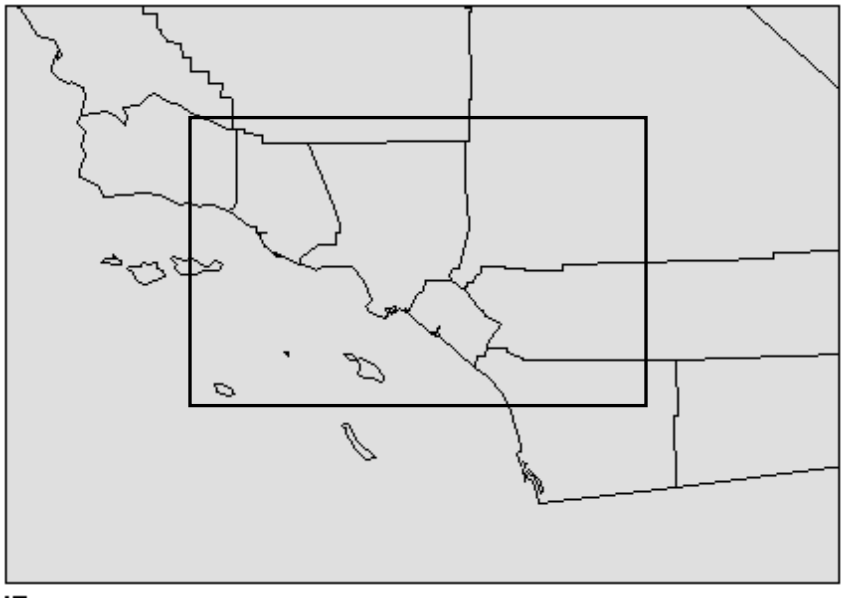
Model Inputs and Domain Specifications

In order to capture the long-term spatiotemporal variation of PM2.5 and its response to emissions changes for the South Coast Air Basin, the CAMx model was run for 1995, 1999, and 2005 over two domains (Figure B-30) using a Lambert Conformal coordinate system. The first domain is a 65x40 5-km^2 cell domain including Orange, Los Angeles, Riverside, San Bernardino and Ventura counties (SCAQS). The second domain referenced here is the 116x80 5-km^2 cell "SCOS" domain which covers San Luis Obispo, Santa Barbara, Kern, Ventura, San Bernardino, Los Angeles, Orange, Riverside, San Diego, and Imperial Counties and extends into Northwestern Mexico. The larger domain, which is nearly 4 times larger than the smaller domain, was originally employed to reduce the impact of the shipping lanes on the western and southern boundaries.

Both domains have a similar vertical structure, extending to approximately 5 kilometers above ground level and divided into 8 vertical layers, with the CAMx layer structure largely dependent upon the layer structure of the meteorological model. Meteorological inputs were generated with the fifth generation Penn State/NCAR Mesoscale Model (MM5). MM5 was run for 2005 in 5-day segments without Four Dimensional Data Assimilation (FDDA).

CAMx has been set up to run in a two-section fine-coarse PM configuration with gas-phase chemistry represented by the Carbon Bond IV chemical mechanism. Some changes to the default partitioning of secondary particulates were made in accordance with the AERO-LT model developed by the South Coast Air Quality Management District (SCAQMD).

Figure B-30: SCOS Modeling Domain with SCAQS Modeling Domain Inset



Emissions were prepared for 1995, 1999, and 2005 using CEFS version 1.06. CAMx was run for those years over both domains, while keeping boundary concentrations and meteorology constant.

Results

Figures B-31 and B-32 show modeled and observed PM2.5 total carbon, ammonium, nitrate, and sulfate concentrations at Los Angeles and Rubidoux. The modeled results that follow are for the simulations with the larger SCOS domain. However, the modeled trends for the two domains are remarkably similar (Figures B-33 and B-34). While the remaining figures show results for the "SCOS" simulations, it should be understood that the same conclusions can be drawn for simulations over both the large and small domains.

In Figures B-31 through B-34, the modeled concentrations are compared with PM2.5 data collected during the 1995 and 1999 PTEP/TEP studies and, during later years, with data collected at the Speciated Trends Network (STN) monitors at Los Angeles and Rubidoux. The main goal of a retrospective analysis such as this one is to show that the model behaves "predictably". This is, therefore, a somewhat qualitative test of predicted and observed trends. Due to the fact that meteorology is not changed between years, the model results can only capture the concentration changes due to emissions variations. Observed concentrations vary from year to year and reflect concentration fluctuations that are a result of emissions changes and meteorological variability.

For both Los Angeles and Rubidoux, the predicted trends for total PM2.5 carbon concentrations match the observed trends very well. This may be due to the mostly primary nature of the elemental and organic carbon and their relative insensitivity to meteorological changes. For ease of comparison of the trends, modeled and observed concentrations are "normalized" by the 2005 concentrations. For the largely secondary species of nitrate, ammonium, and sulfate, however, the observed and modeled trends do not agree as well, and further analysis is required to determine whether the model behaves as is "expected". It is expected that meteorological changes would play a significant role in the formation of secondary compounds such as nitrate and sulfate. However, constructing prognostic meteorology fields for the entire years of 1995 and 1999 is a major undertaking that is beyond the scope of this initial study.

Domainwide NOx emissions decrease on the order of 25% between 1995 and 2005, and while this is not a uniform decrease throughout the entire domain, most inland cells see a decrease in NOx emissions. This ~25% decrease in domainwide emissions is large enough that the model should clearly predict a downward trend in nitrate concentrations. Indeed, the model does predict a downward trend. Between 1995 and 2005 predicted PM2.5 nitrate concentrations decrease by 10% and 16% at Los Angeles and Rubidoux, respectively. For PM2.5 sulfate, the emissions changes are more complex, and the modeled trends are expected to be less distinct. While domainwide SO_2 emissions are expected to increase (due mainly to increased shipping activity), inland SO_2 emissions are expected to decrease. In some areas, however, primary particulate sulfate emissions are expected to increase. In Figures B-35 and B-36, a spatial plot of the absolute difference of SO_2 emissions between 1995 and 2005 and primary PM2.5 SO_4 emissions between 1995 and 2005 are shown for a randomly selected day (February 25th). While SO_2 emissions are decreasing in the immediate vicinity of Los Angeles and Rubidoux, primary PM2.5 sulfate emissions look to be increasing near Rubidoux. This is reflected in the predicted sulfate concentrations where there is a 12% decrease in PM2.5 sulfate at Los Angeles and a 3% increase at Rubidoux from 1995 to 2005. The model behaves predictably given the emissions changes, but the relation of modeled and observed trends is not as clear.

Due to the limited number of speciated PM2.5 data and the possible disconnect between data taken from the PTEP (PM_{10} Technical Enhancement Program) and STN samplers, it is difficult to make a stronger statement about the model's retrospective performance in comparison to observed trends. While there is a relative scarcity of PM2.5 data for previous years in the SCAB, PM10 nitrate and sulfate measurements have been taken at various sites for many years. Contrary to the PM2.5 PTEP and STN data where differences in sampling protocols may skew the observed trends, the available PM10 measurements present an opportunity to examine the observed nitrate and sufate trends without uncertainties associated with varying measurement techniques. Figures B-37 and B-38 show the measured and modeled trends for PM10 nitrate and sulfate at 5 sites, Burbank, Fontana, Los Angeles, North Long Beach, and Rubidoux. This larger dataset indicates a pronounced variability in annual average nitrate and sulfate concentrations that was not clear with the PM2.5 observations. For sulfate (Figure B-38), the modeled and observed trends compare very well for most

sites. The observed flattening of the sulfate trends in later years is also predicted by the model. While PM10 nitrate predictions fall in line with the observed trends at Burbank, at the other sites, the predicted trends are less steep than those observed. Since the simulation is only capturing emissions changes while the observations include meteorological and background variability as well, it is difficult to determine if the agreement for nitrate is unsatisfactory.

Conclusion

CAMx was run for three years (1995, 1999, and 2005) with 2005 meteorology and boundary conditions held constant for all simulations in an effort to compare model and observed response to historical emissions changes. While the three years were not modeled as rigorously as possible (meteorology was held constant), the model responds as expected, predicting lower 2005 concentrations for species that see a decrease in emissions over the 10-year period. Comparisons with PM10 and PM2.5 species data at multiple sites throughout the South Coast Air Basin allow a qualitative comparison between the model and observations. Observed and total PM2.5 carbon trends correspond well for eastern and western sites, as do PM_{10} sulfate concentrations. While predicted and observed PM10 nitrate concentrations both show a downward trend over the ten-year period, modeled trends are less steep than those observed. Since the observed concentrations include meteorological and background concentration variability while the model does not, it is difficult to determine if the agreement between the observed and predicted trends, especially for nitrate, is unsatisfactory.

Figure B-31: Observed and Predicted PM2.5 Total Carbon, Ammonium, Nitrate, and Sulfate at Los Angeles (SCOS Domain)

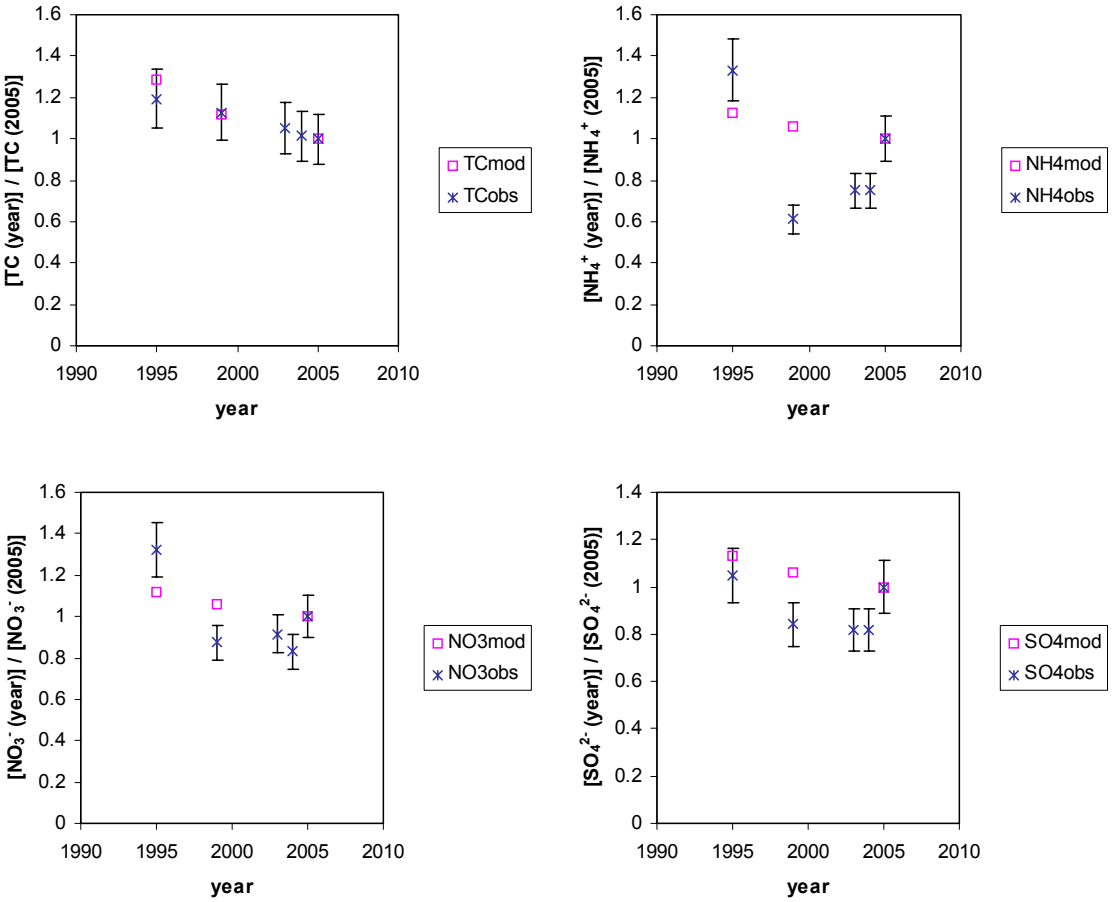


Figure B-32: Observed and Predicted PM2.5 Total Carbon, Ammonium, Nitrate, and Sulfate at Rubidoux (SCOS Domain)

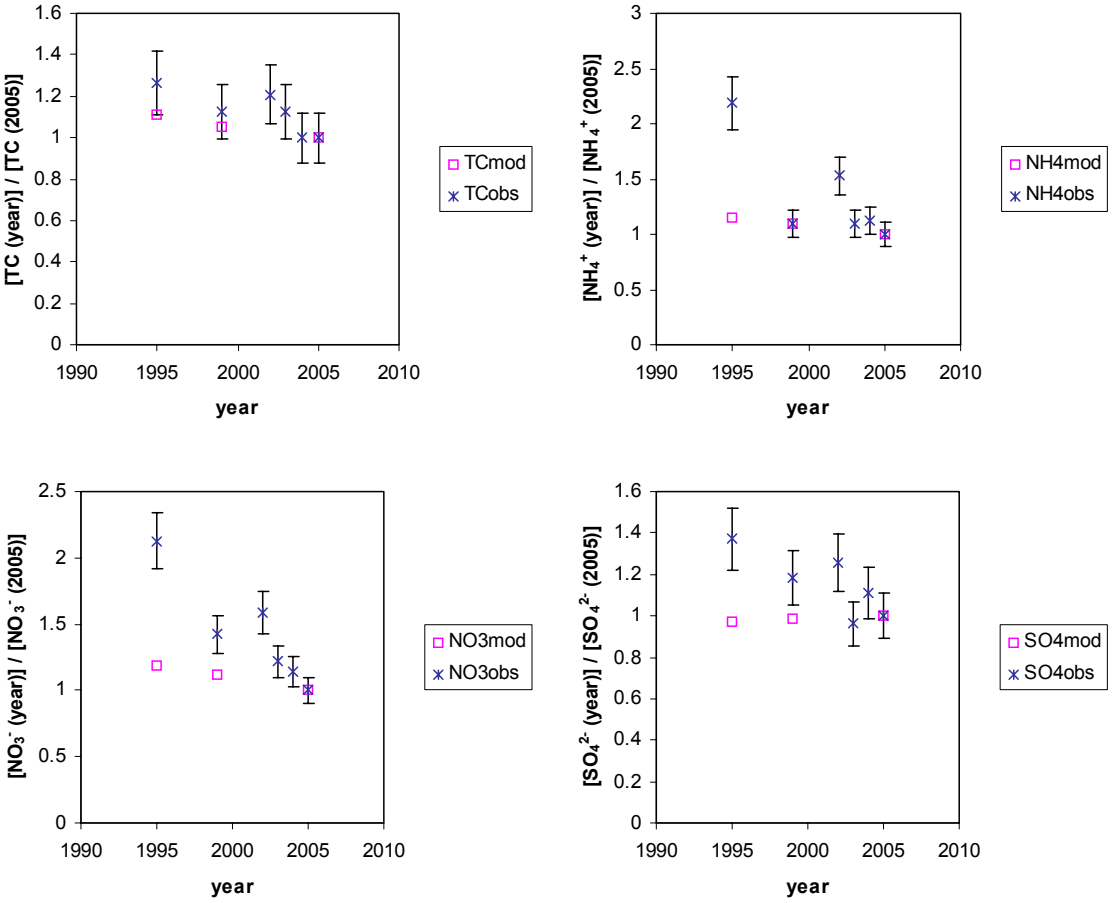


Figure B-33: Observed and Predicted PM2.5 Total Carbon, Ammonium, Nitrate, and Sulfate at Los Angeles (SCAQS Domain)

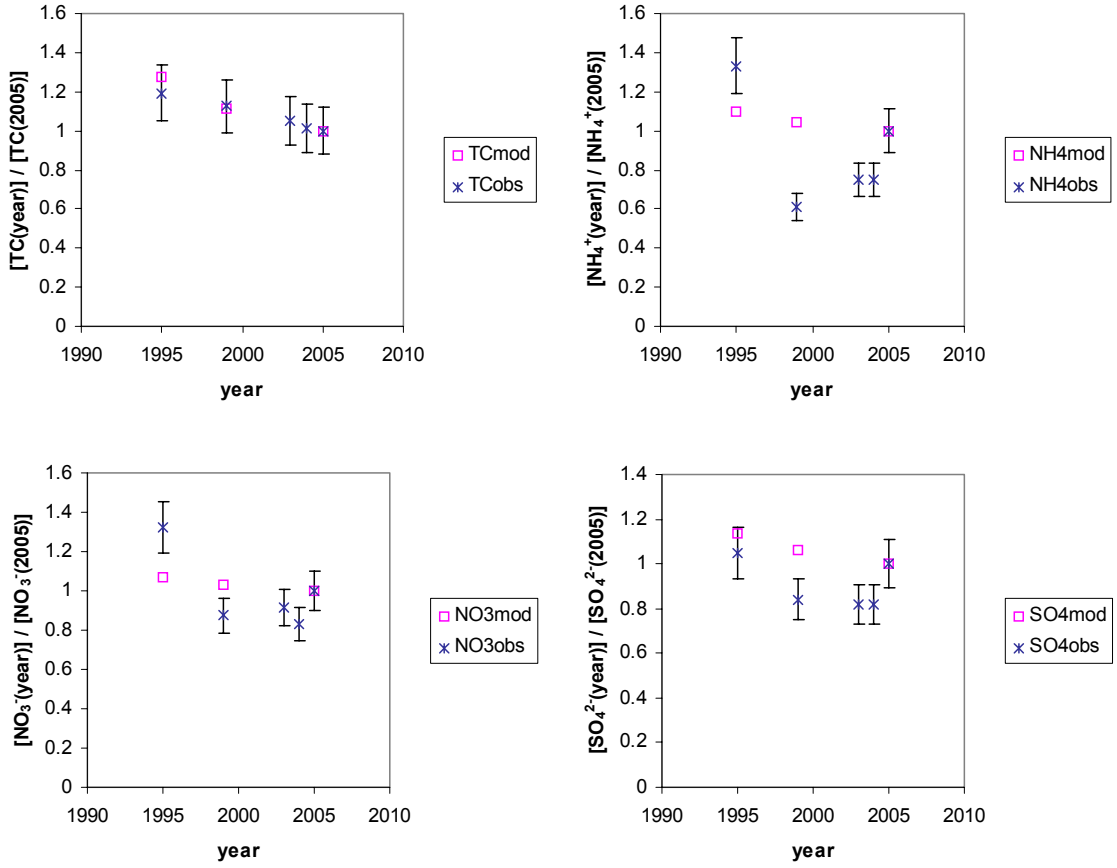


Figure B-34: Observed and Predicted PM2.5 Total Carbon, Ammonium, Nitrate, and Sulfate at Rubidoux (SCAQS Domain)

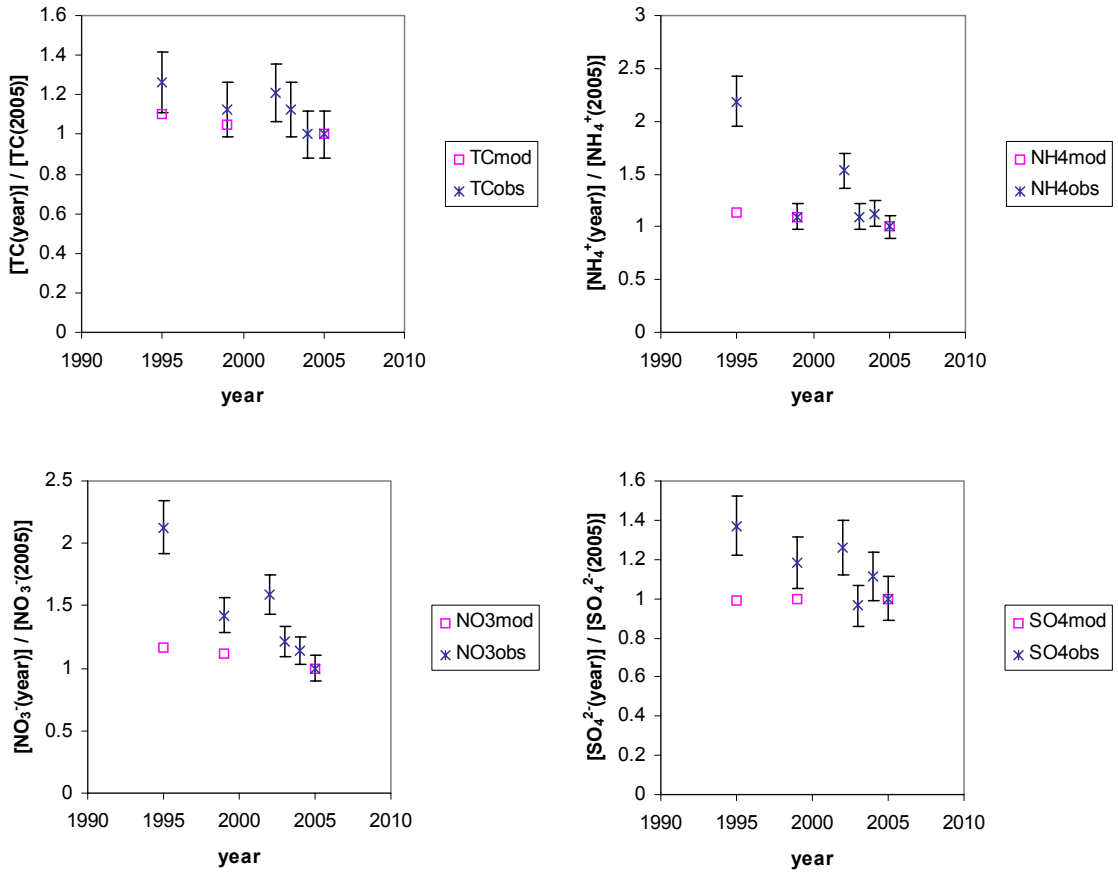


Figure B-35: Absolute SO_2 Emissions Change Between 1995 and 2005 at Noon for a Day in February (February 25th). A negative value indicates an increase in emissions between 1995 and 2005. Los Angeles (west) and Rubidoux (east) are marked by stars.

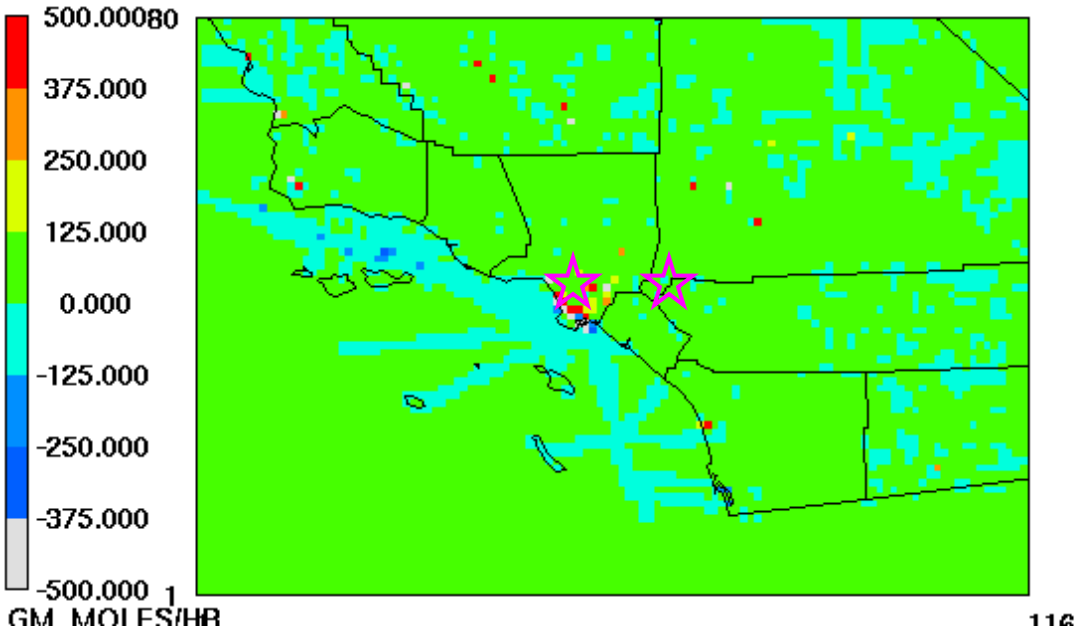


Figure B-36: Absolute PM2.5 Sulfate Emissions Change Between 1995 and 2005 at Noon for a Day in February (February 25th). A negative value indicates an increase in emissions between 1995 and 2005.

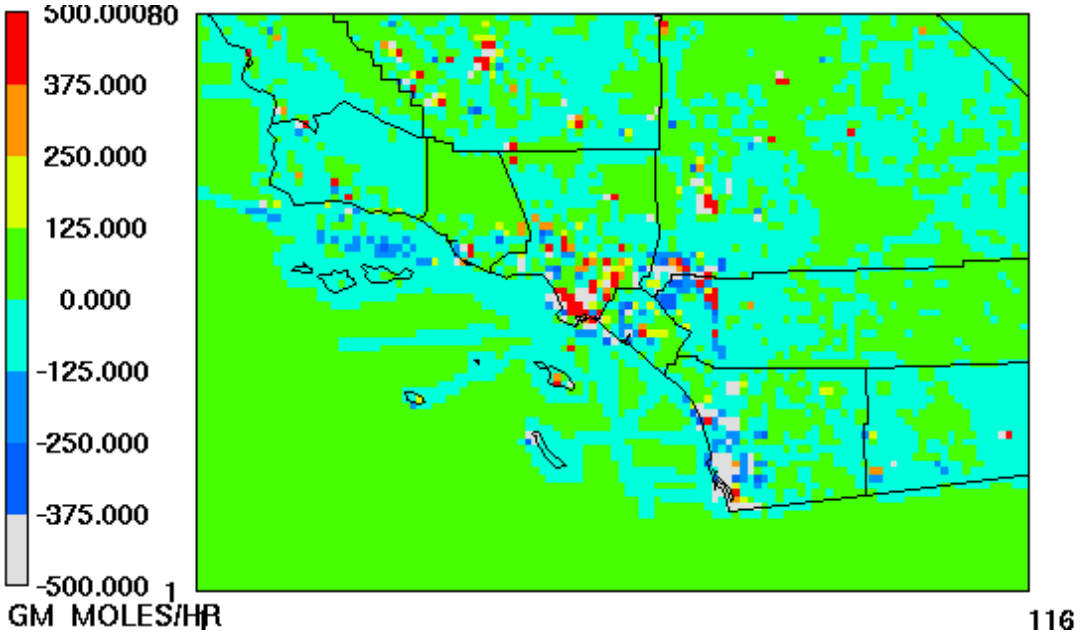


Figure B-37: Observed and Modeled Trends for PM10 NO_3 at Burbank, Fontana, Los Angeles, North Long Beach, and Rubidoux

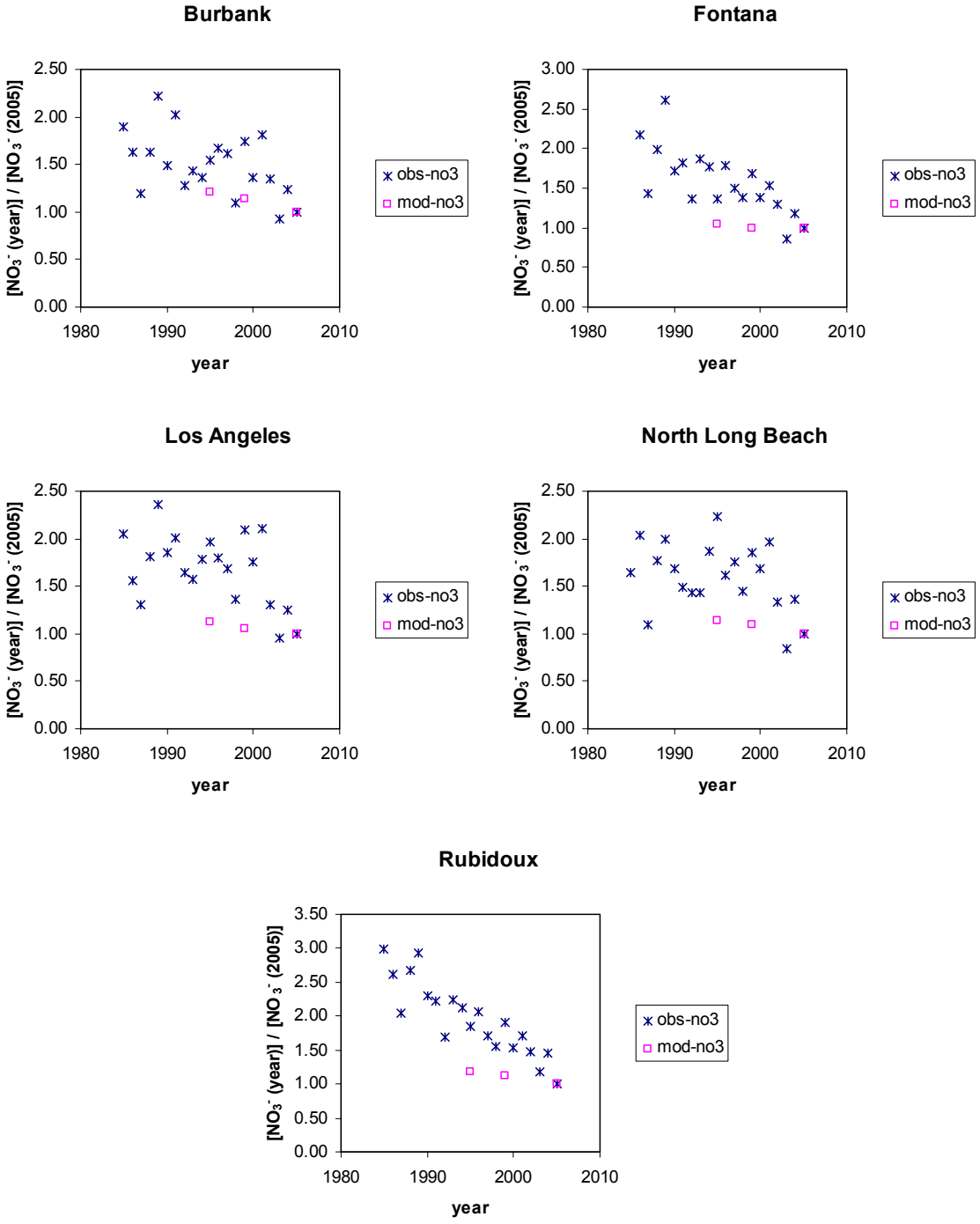
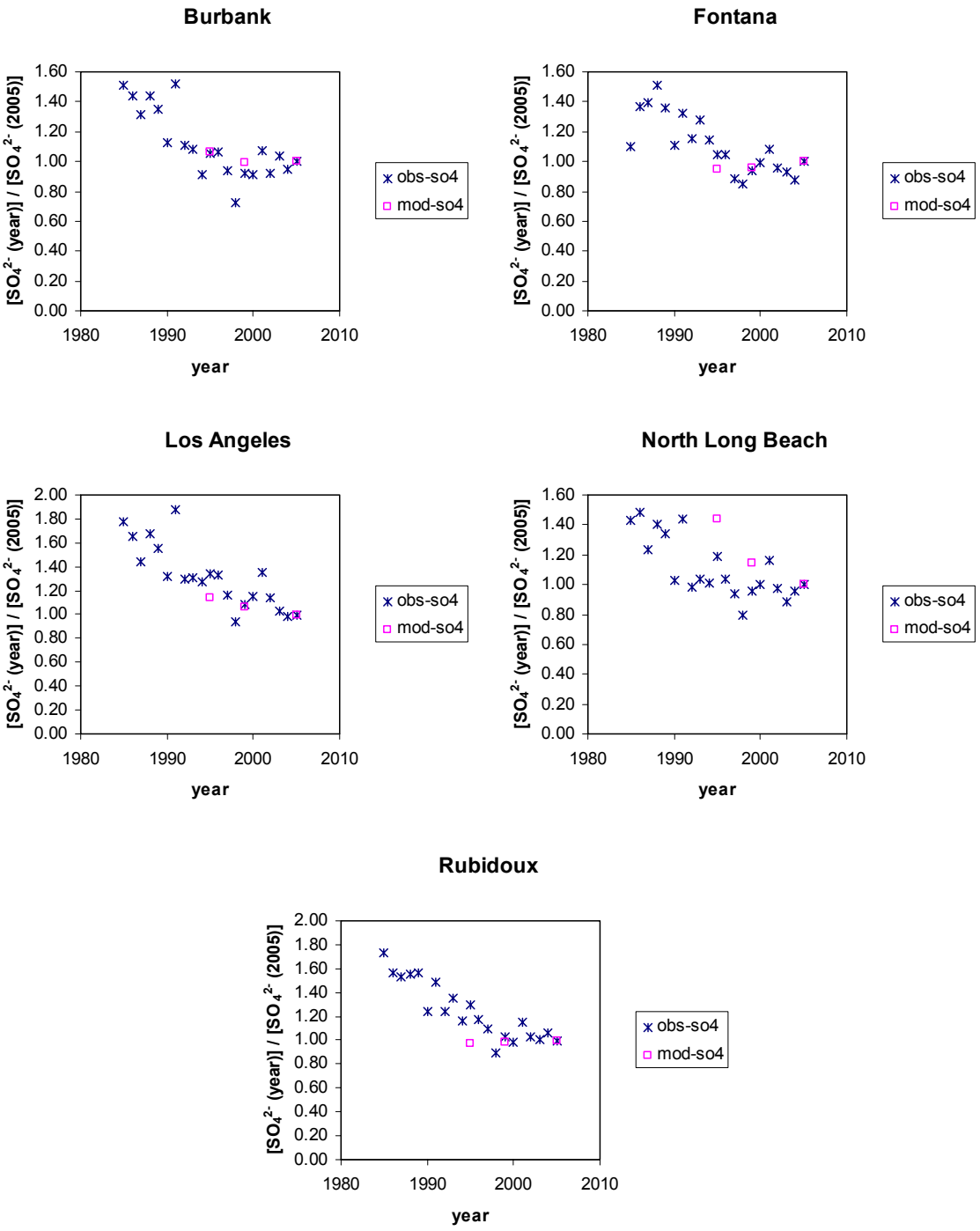


Figure B-38: Observed and Modeled Trends for PM10 SO_4 at Burbank, Fontana, Los Angeles, North Long Beach, and Rubidoux



Assessment of Alternative Attainment Scenarios

Sensitivity testing conducted by the South Coast District indicated that reductions in SOx have the biggest impact on PM2.5 concentrations, followed by directly emitted PM2.5 and then NOx. Reductions in VOCs had the least impact on PM2.5 concentrations. The relative effectiveness of emission reductions in terms of micrograms of PM2.5 reduced per ton of emissions reduction for each PM precursor is shown in Table B-10.

Table B-10: Relative Effectiveness of PM2.5 Emission Reductions

Emissions Category	Relative Effectiveness in Reducing PM2.5
SOx	Factor of 10
PM2.5	Factor of 5
NOx	Factor of 3
ROG	Factor of 1

Given the relatively greater effectiveness of reductions in directly emitted PM2.5 as compared to NOx, ARB staff conducted a grid-based modeling sensitivity analysis to determine the potential impact of further residential wood combustion and cooking controls, categories that contribute significantly to the primary PM levels in the South Coast as indicated by source apportionment studies. ARB staff evaluated two scenarios; a 100 percent reduction in residential wood combustion emissions for November through February, and a 50 percent reduction in residential wood combustion emissions for November through February, both coupled with a 20 percent reduction in cooking emissions for the entire year. In addition, the South Coast District evaluated the impact of curtailing wood burning on days when PM2.5 exceeds 35 ug/m3, coupled with control of cooking emissions. The results of these three scenarios at the Riverside-Rubidoux site are shown in Table B-11. This grid-based modeling analysis indicates that further controls on these sources of directly emitted PM2.5 can have significant benefits in further reducing PM2.5 concentrations.

Table B-11: Predicted Reduction in Annual Average 2014 PM2.5 Concentrations for Residential Wood Burning and Cooking Control Scenarios

	Scenario Description	**Annual Average PM2.5 Reduction (ug/m3)**
Scenario 1	100% reduction in woodsmoke from November – February + 20% reduction in cooking year-round	0.89
Scenario 2	50% reduction in woodsmoke from November-February + 20% reduction in cooking year-round	0.45
Scenario 3	Curtailment of woodsmoke on days where PM2.5 > 35 ug/m3 and control of cooking	0.10

Based upon this analysis, the South Coast District added an additional control measure that reflects scenario 3 in Table B-11, reducing the predicted annual average design value at Riverside-Rubidoux to 15.6 ug/m3. Analysis by ARB staff also identified an additional 14 tons of mobile source NOx reductions. Taken together, the attainment demonstration design value drops to just below 15.5 ug/m3 at the high site of Riverside Rubidoux, and therefore a predicted design value within the uncertainty bounds identified by U.S. EPA as qualifying for a weight of evidence attainment demonstration.

5. SUMMARY

In summary, the South Coast has experienced tremendous progress in reducing PM2.5 concentrations since initial monitoring began in 1990. Between 1990 and 1998, PM2.5 annual average concentrations dropped by 30 to 40 percent throughout the basin. Since 1999, when the official regulatory monitoring program for comparison to the federal PM2.5 standard began, PM2.5 annual average concentrations have dropped a further 23 to 30 percent. While the peak annual average design value in the basin was 30 ug/m3 in 2000, twice the level of the standard, it dropped to 22.7 ug/m3 in 2005, with a continued decline in 2006 to 20.8 ug/m3. In addition, the South Coast now attains the federal 24-hour standard of 65 ug/m3. Although concentrations remain the highest in the eastern basin, the rate of decrease in PM2.5 and the response to ongoing control programs has also been the greatest in this region.

Unlike ozone, PM2.5 consists of many different components. Analysis of the trends in different components of PM2.5 has shown that over the last six years, decreases in ammonium nitrate have had the greatest contribution to declining PM2.5 mass trends, with ammonium nitrate concentrations at Riverside-Rubidoux dropping by 40 percent. During this same time period, ambient NOx concentrations, a precursor to ammonium nitrate, as well as NOx emissions have also decreased by 25 and 18 percent respectively. Looking back to the late 1980s, both ammonium nitrate and ammonium sulfate have declined significantly, along with concurrent declines in ambient NOx and SO2 concentrations and NOx and SOx emissions. These significant trends in declining PM2.5 concentrations, ambient precursor concentrations, and associated emissions all

suggest that continuing reductions of both NOx and SOx emissions of the same order of magnitude as seen in the past will provide significant further progress in attaining the annual PM2.5 standard.

In order to estimate the impact of further emission reductions on future PM2.5 concentrations, both linear rollback and grid-based aerosol modeling were conducted. PM2.5 annual average concentrations in 2014 based on emission reductions achieved from both the ongoing control program, as well as the new measures specified in the Statewide Strategy, were estimated with both methods. Substantial further emission reductions of approximately 40 to 50 percent for all key pollutants will occur between 2005 and 2014.

Based on the linear rollback modeling approach, all sites in the basin would be expected to attain the annual standard by 2014, including the high site at Riverside-Rubidoux. Although the linear rollback approach does not incorporate the potentially non-linear and inter-pollutant interactions of controls that can be addressed through grid-based modeling, the predicted future year concentrations from the rollback modeling are consistent with observed air quality trends and the response to past emission reductions. In contrast, the grid-based modeling shows a significantly lower response to emission controls, with higher predicted concentrations in 2014 as compared to the rollback modeling. This modeling suggests that a much greater rate of emission reductions will be needed over the next ten years in order to sustain the same amount of progress observed in recent years. As a result, while the grid-based modeling indicates that the coastal sites would still attain the annual standard, portions of the western and eastern basin are predicted to remain above the standard in 2014, with a maximum predicted concentration design value of just below 15.5 ug/m3 at Riverside-Rubidoux. This is within the range for which a weight-of-evidence attainment demonstration is appropriate.

Considering all of the information available, on balance, ARB staff believes that the evidence provided by the supplemental analysis suggests that the South Coast will attain the annual average PM2.5 standard throughout the basin by 2014. This is due to the following considerations:

- The significant progress that has already occurred, a 9.2 ug/m3 drop in annual average design value between 2001 and 2006, which represents two-thirds of the progress needed to attain the annual standard by 2014;

- Attainment of the 24-hour standard has already occurred;

- The positive response of ammonium nitrate and ammonium sulfate concentrations to past reductions in NOx and SOx emissions;

- The pace of future emission reductions for NOx and SOx, reflecting a 50 percent decrease in NOx and a 45 percent decrease in SOx, which is significantly greater than during the 2001-2006 period;

- Speciated rollback modeling which indicates attainment in 2014; and,

- The small degree by which the attainment demonstration modeling design value is above the annual standard, which is within the range of the uncertainty of this type of modeling. This, coupled with the relatively conservative response of the model to NOx reductions, would suggest that attainment is likely.

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