APPENDIX A

SUPPLEMENTAL ANALYSIS: 8-HOUR OZONE ATTAINMENT

8-HOUR OZONE ATTAINMENT SUPPLEMENTAL ANALYSIS

Introduction

Under federal law, the South Coast Air Basin (South Coast or Basin) is currently classified as a Severe-17 nonattainment area for the federal 8-hour ozone standard and has a nominal attainment date of June 15, 2021. Given the magnitude of emissions reductions needed to reach attainment, including reductions relying on new or improved control technologies, the South Coast Air Quality Management District (District) does not predict attainment by the 2021 date. Therefore, the District is requesting the Basin be reclassified as Extreme, with required attainment by June 15, 2024. The following sections describe the air quality, emissions, and supplemental analyses, as well as the photochemical modeling that support the overall conclusion that the South Coast will attain the federal 8-hour ozone standard by the 2024 deadline.

U.S. EPA Attainment Demonstration Requirements

The attainment demonstration portion of a State Implementation Plan or SIP consists of the analyses used to determine whether a proposed control strategy provides the reductions necessary to meet the federal standard by the attainment year. This attainment demonstration includes photochemical modeling which predicts that projected controls will result in a high site 8-hour design value for the South Coast of 0.083 parts per million (ppm). Because of the uncertainties inherent in photochemical modeling, U.S. EPA allows states to show that attainment is likely despite modeled results, when the model predicts ozone levels between 0.082 ppm and 0.087 ppm, and the weight of evidence (WOE) evaluated supports an alternative attainment demonstration. The supplemental analyses can include consideration of measured air quality, emissions, and meteorological data, evaluation of other air quality indicators, as well as additional air quality modeling, if appropriate.

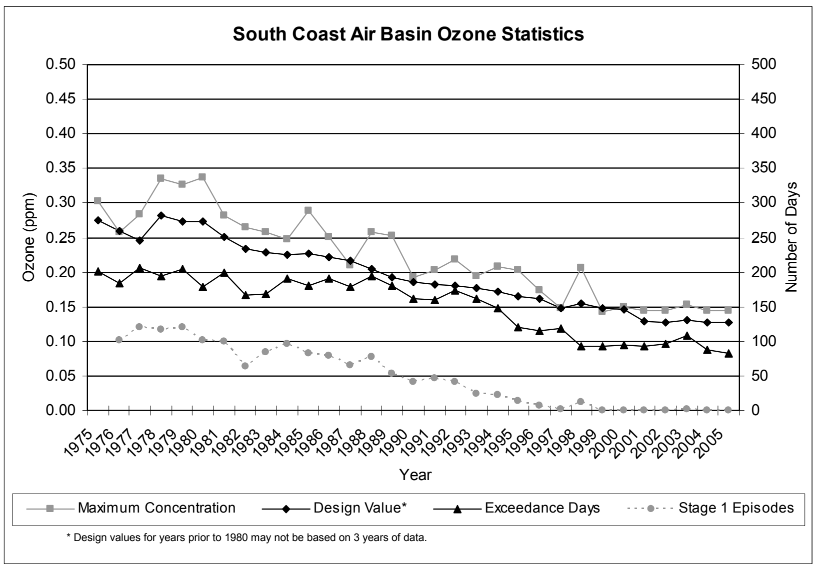
Because all analysis methods have inherent strengths and weaknesses, examining an air quality problem in a variety of ways helps offset the limitations and uncertainties that are inherent in all air quality modeling. This approach also provides a better understanding of the overall problem, as well as insight about the level and mix of emissions controls needed for attainment.

The scope of supplemental analyses 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. This document summarizes the ARB's supplemental assessment of the 8-hour ozone NAAQS attainment demonstration for the South Coast nonattainment area.

Historical Context

Thirty years ago, high ozone concentrations posed a pervasive problem throughout the South Coast. During the mid- to late-1970s, maximum 8-hour concentrations were frequently higher than 0.30 ppm, or nearly four times the level of the federal standard. During this same time period, the standard was exceeded on more than 200 days each year, the federal design value was more than three times the level of the 8-hour standard, and Stage 1 episodes (days with a maximum 1-hour ozone concentration of at least 0.20 ppm) occurred on roughly one-third of the days during each year (refer to Figure A-1).

Figure A-1: South Coast Air Basin Ozone Statistics 1975 to 2005



An emissions control strategy based on reductions of both NOx and ROG was implemented during the 1970s and began to have an impact on resulting ozone air quality. While air quality improvements over the years have been dramatic, progress has not been continuous from one year to the next, nor has the rate of progress been the same during the entire time period. Although there is often a great deal of year-to-year variability, air quality indicators generally showed little progress during the mid- to late-1970s, began improving during the early-1980s, and then were relatively flat again during the mid- to late-1980s. During the last five to six years, there has again been a leveling off in the trends, as shown in Figure A-1, following a period of significant improvement throughout the 1990s. Despite the variable rates of progress, there has been close to a 60 percent overall reduction in both the maximum concentrations and the number of exceedance days since the mid-1970s.

Assessment of Recent Air Quality Trends

General Basinwide Perspective

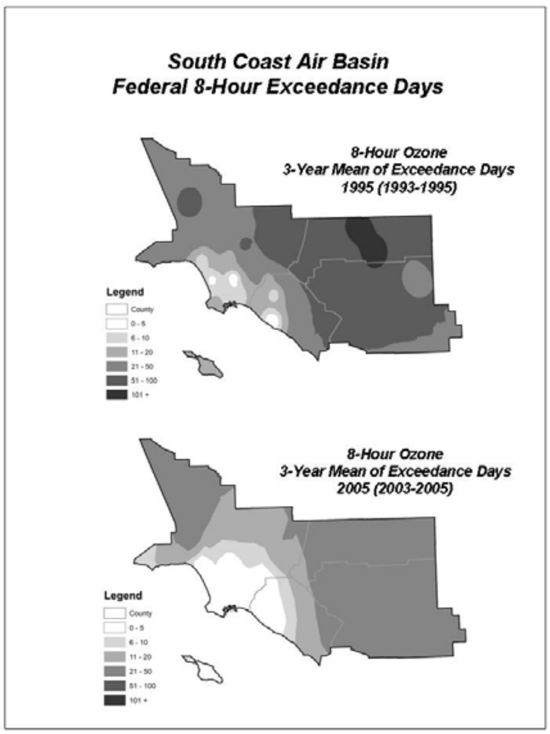
Although there has been significant progress over the last three decades, the South Coast Air Basin still faces one of the biggest ozone air quality challenges in the nation, whether measured by maximum concentration, design value, or number of exceedance days. Furthermore, the South Coast has the distinction of being the only area in the nation originally classified as Severe for the federal 8-hour standard. While air quality has improved over the years, problems still exist in the northwestern portion of Los Angeles County and the South Coast portions of Riverside and San Bernardino counties. While exceedances in these areas occasionally occur outside the ozone season, most are limited to the May through October timeframe. During 2005, the maximum 8-hour ozone concentration was 0.145 ppm, a little less than twice the level of the federal standard. The number of exceedance days totaled 83, equivalent to nearly three months during the year with unhealthful ozone air quality.

Despite the magnitude of the problem, air quality indicators show widespread progress in improving ozone air quality over the last decade, reflecting the impact of continued emissions reductions. Basinwide, maximum concentrations and the number of exceedance days both declined by 30 percent, while the design value declined 25 percent, when comparing 1995 to 2005. Since 1998, Stage 1 Episodes have been eliminated, with the exception of a single episode day during 2003, which was a meteorologically adverse year with respect to ozone.

Another way of measuring air quality progress is to estimate the change in the spatial extent of the problem using monitoring data. Over the last decade, the spatial extent of the “clean” coastal areas has increased substantially, with accompanying improvements at sites located inland. Figure A-2 shows contour maps of federal 8-hour exceedance days in the South Coast averaged over two three-year periods, ten years apart -- 1995 and 2005. Ten years ago (1993-1995 average map), the ozone problem was widespread throughout the region. About half of the Basin had more than 50 federal 8-hour exceedance days each year, and nearly all sites had a design value above the level of the federal 8-hour ozone standard. Although the coastal areas were cleaner than the inland areas, only small, isolated portions of the Basin had ten or fewer exceedance days. Today (2003-2005 average map), we see a dramatic expansion of clean areas, especially those in the range of 0 to 5 exceedance days. These clean areas now include about a third of Orange County and a fourth of Los Angeles County. Furthermore, they cover the region where more than half of the Basin population lives. The areas with 6 to 10 and 11 to 20 exceedance days have also grown substantially.

Although we see substantial amounts of basinwide progress from 1995 to 2005, the rate of progress was greatest during the first half of the decade and has leveled off over the last five to six years. This holds for a number of different indicators, including exceedance days, maximum concentration, design value, average concentration on the Top 30 days, and population-weighted exposure. Between 1995 and 1999, there was a 10 percent decrease in design value and a 25 to 30 percent drop in maximum concentration. Comparing this with the 2000 to 2005 timeframe, the design value again decreased about 10 percent, but the drop in maximum concentration was only a tenth and the drop in the number of exceedance days only about half of what it was during the earlier five-year period.

Figure A-2: South Coast Air Basin Change in Federal 8-Hour Exceedance Days 1995 to 2005

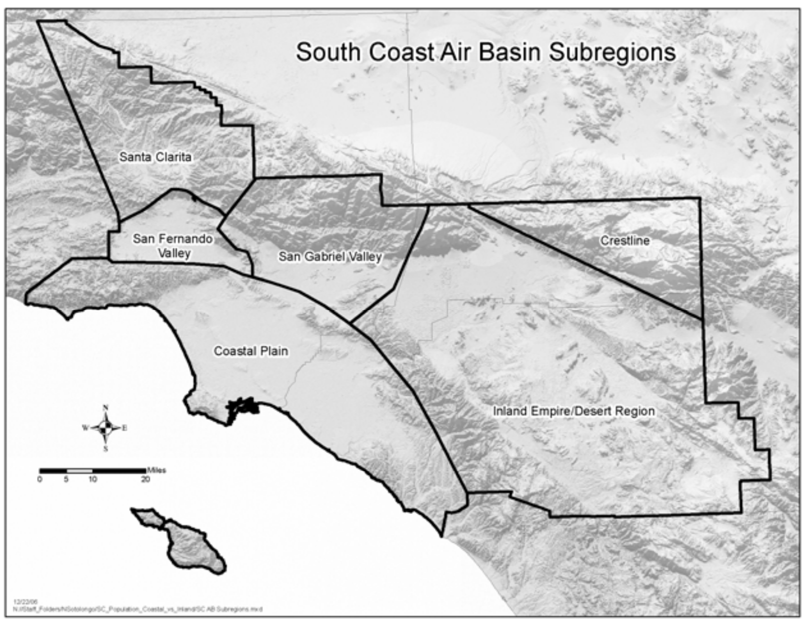


In summary, basinwide measures of maximum concentration, exceedance days, and design value are all down by about 30 percent over the last decade. Although there has been a substantial amount of progress since 1995, most of that progress occurred during the first half of the time period. In contrast, progress for nearly all indicators has been relatively flat since 2000. Despite the slowed progress, the ozone problem is not pervasive throughout the Basin. With continuing emissions reductions, the “problem” areas are shrinking. At the same time, there has been a substantial expansion of the “clean” areas, and a little more than half of the population lives in areas that are now clean.

Regional Analyses

From a basinwide perspective, there has been substantial improvement in ozone over the last decade. However, the basinwide statistics are dominated by the high site(s), which pose the most severe and persistent problems. Dividing the Basin into sub-regions provides a different perspective, showing an even greater magnitude of progress. For the following discussion, the South Coast Air Basin is divided into six broad areas, as shown in Figure A-3: the Coastal Plain, the San Fernando Valley, the Santa Clarita area, the San Gabriel Valley, the Inland Empire/Desert Region, and the Crestline area. These represent six relatively distinct areas, based on geographical, meteorological, and air quality characteristics.

Figure A-3: South Coast Air Basin Sub-regions

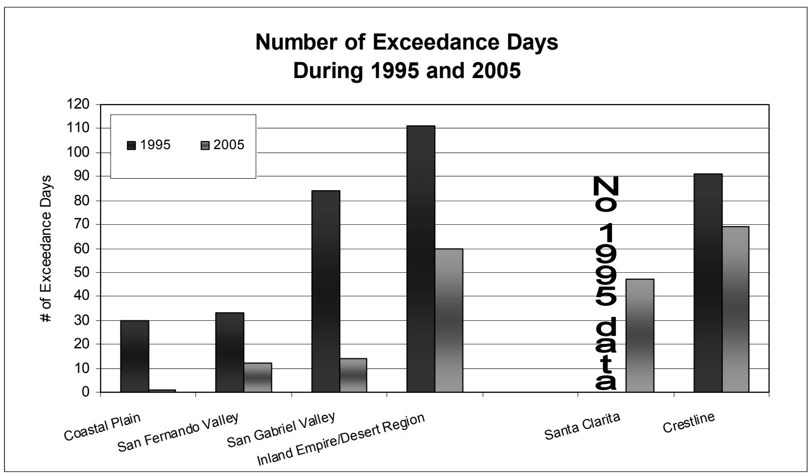


More than half of the Basin population lives in the highly developed Coastal Plain. The bulk of the South Coast emissions are generated in this lowland area which is bordered on one side by the coast and on the other sides by mountains. Because of the marine influence, the Coastal Plain experiences a more temperate climate than the rest of the Basin, and the cooler temperatures and onshore/offshore airflow patterns generally favor good air quality.

As one travels inland, geography and climate pose significant challenges to air quality progress. Similar to the Coastal Plain, the San Fernando and San Gabriel valleys also represent low lying areas, but are generally surrounded by mountains on all sides. These act as barriers to airflow, while also trapping emissions and pollutants. Higher temperatures and more stagnant conditions in these valley areas lead to a build-up of ozone, and overall poorer air quality. The same is true for the Inland Empire/Desert Region, as well as the Santa Clarita and Crestline areas, which are even further from the coast.

Previous analyses have shown that air quality progress within each of the sub-regions tends to be similar, but between the selected regions, the rates of change often differ noticeably. Figure A-4 shows the number of exceedance days during 1995 and 2005 for each of the sub-regions mapped in Figure A-3. While values for the two highest sites in the Basin, Crestline and Santa Clarita, are plotted separately, values for the other sub-regions reflect data from multiple sites within each area.

Figure A-4: South Coast Air Basin Change in Number of Federal 8-Hour Exceedance Days by Sub-region 1995 to 2005



Based on the bar graph, it is striking how clean the air is in the Coastal Plain – Los Angeles County/Orange County – where the bulk of the Basin population lives. During the 2005 May through October ozone season, 90 percent of the days were below the level of even the more health-protective State 8-hour standard, and no site had more than one federal 8-hour exceedance day. Overall, there has been a 95 percent drop in the number of exceedance days in the Coastal Plain over the last decade.

Although all sites in the Coastal Plain either meet or are close to meeting the federal 8-hour standard, dominant weather patterns suggest that the Coastal Plain can be an important emissions source region for areas located inland. However, growth in the inland regions has made them significant sources of ozone precursors, as well. The San Fernando Valley, San Gabriel Valley, and Inland Empire/Desert Region, all of which are located further inland, pose greater air quality challenges. Even so, these areas have shown improvements, including sharp decreases in exceedance days, along with increases in the number of "clean" days with concentrations below the State 8-hour standard. During the 2005 ozone season, 75 to 80 percent of the days in the

San Fernando and San Gabriel valley areas and 40 percent of the days for the Inland Empire/Desert Region met the more health-protective State ozone standard. During this same year, the San Gabriel Valley, once the area with the Basin's worst ozone air quality, had a total of 14 federal exceedance days, down from 84 days in 1995 (an 85 percent decrease). The San Fernando Valley had a 65 percent decrease and the Inland Empire/Desert Region a 45 percent decrease in federal exceedance days between 1995 and 2005.

Crestline and Santa Clarita continue to stand out as the sites with the worst ozone air quality, and these sites will likely pose the most difficulty for attaining the federal 8-hour ozone standard. Continuing ROG and NOx emissions reductions have reduced the number of federal exceedance days at both sites. However, the number of days during 2005 was still equal to about one and a half months of the year at Santa Clarita (45 days) and two months of the year at Crestline (67 days). While the number of exceedance days at Crestline and at Santa Clarita is still substantial, especially when compared with other areas of the Basin, there has been improvement over the years. For example, Crestline had a 30 percent reduction in the number of exceedance days from 1995 to 2005. The problem of attainment at Crestline and Santa Clarita is complicated by the distance between the two sites and the fact that less than half of the Santa Clarita exceedances (40 percent) occur on the same days as the Crestline exceedances. Furthermore, as discussed in the following section on the characterization of episodic conditions, the weather conditions favoring high ozone at Crestline are different from those for Santa Clarita.

In summary, there have been changes in the patterns of exceedances on a sub-regional basis in the South Coast. Today, the numbers of exceedance days in all areas are more limited than they were ten years ago. However, there have been different rates of progress in the different areas. The most progress occurred in the Coastal Plain, where the federal standard is exceeded only occasionally now, and all sites are approaching attainment of the more health-protective State 8-hour ozone standard. Other areas have also made great strides – the San Fernando Valley, San Gabriel Valley, and Inland Empire/Desert Region have all seen substantial improvements. As emissions continue to decline, ozone air quality in these areas should continue to improve. Santa Clarita and Crestline still pose major challenges. Although these two sites have shown improvement over the last decade, their rates of progress have been slower than in other areas, and these areas may therefore require the greatest emissions reductions to attain the standard.

Meteorology and Air Quality Trends

Ozone in the ambient air is the result of several factors, two of the most important being emissions and meteorology. The meteorological and photochemical processes leading to ozone formation are complex, involving interactions both at the surface and in the upper air. However, they can be characterized in very general terms: strong sunlight and weak dispersion generate relatively high ozone levels, while weak sunlight and strong dispersion generate relatively low ozone levels. Meteorology, or weather conditions, can vary widely, and these day-to-day conditions strongly influence ambient ozone concentrations.

The previous trends discussion looked at air quality as measured at ambient monitoring sites, without any consideration or adjustment for meteorological variability. The following discussions characterize the general meteorological conditions leading to high ozone concentrations, as well as several different methods of accounting for meteorological variability. These analyses are an effort to better understand the impact of meteorology on air quality and thereby isolate the improvement attributable to emissions reductions. One of the goals of these analyses is to determine the role meteorology has played in the recent leveling off of ozone air quality. Although the analyses indicate that meteorological variability does not account for the flatness of the trends, they do show that it now takes more severe meteorological conditions to produce ozone exceedances.

Characterization and Frequency of Episodic Conditions

In evaluating the meteorological conditions associated with ozone episodes, three well-defined patterns were identified as being associated with the majority of episodes. Collectively, these three patterns are associated with over 90 percent of the 8-hour exceedances that occurred during May through October of 2000 through 2005. The three patterns are characterized by high pressure aloft, generally clear skies, light and variable nighttime and morning winds, strong morning inversions, and deep mixing of pollutants aloft in the afternoon. The patterns are differentiated from one another primarily by small variations in the size of the weather systems influencing each pattern.

The “typical summer weather pattern” usually brings coastal emissions and ozone from the Coastal Plain to the more downwind Inland Empire/Desert Region. It was associated with about a third of the 8-hour ozone exceedances recorded during the analysis period and tended to result in the highest ozone concentrations in the Basin. Under this pattern, high pressure aloft, in combination with calm surface winds during the morning, result in stagnant conditions. Maximum temperatures inland are near 100 degrees, while the Coastal Plain stays relatively cool. In the afternoon, the sea breeze moves onshore, in response to increasing and very hot temperatures inland. Average afternoon wind speeds range between 5 and 10 miles per hour (mph), with only a few hours above 10 mph in the eastern part of the Basin.

The “eddy weather pattern” brings emissions and ozone northward into the Santa Clarita area and San Fernando Valley, as well as eastward into the Crestline area. High ozone concentrations under the eddy pattern typically occur at Crestline, at Santa Clarita (via Newhall Pass), and as far away as Ventura County. This pattern generated the highest number of ozone episodes in the Basin during the study period and is characterized by lower pressure aloft. This promotes more wind flow over the upper levels of the Basin. At the surface, the Coastal Plain is dominated by a stronger onshore flow and a counterclockwise eddy circulation centered off the southern California coast, near Catalina Island. The sea breeze penetrates much deeper into the Basin, causing both temperature and ozone concentrations in the Coastal Plain to be much lower than with the other meteorological patterns.

Finally, the "offshore pattern" typically results in a build-up of ozone near precursor sources or only slightly downwind. Upper and surface level winds along the coast are light and variable, with weak offshore winds. The influence of the marine layer is felt only along the immediate coast, with terrain and slope flows acting as the main transport mechanism into the interior valleys. Surface winds remain offshore until the afternoon, with average afternoon wind speeds ranging between 5 and 10 mph. Maximum temperatures reach near 100 degrees in most eastern areas of the Basin, with coastal areas in the 80s. High ozone concentrations typically occur throughout the metropolitan area, closer to major source regions. In contrast, areas such as Crestline, which are typically dominated by transport, exhibit lower concentrations. This pattern was associated with less than a quarter of the 8-hour ozone exceedances during the analysis period.

High Ozone Forming Potential

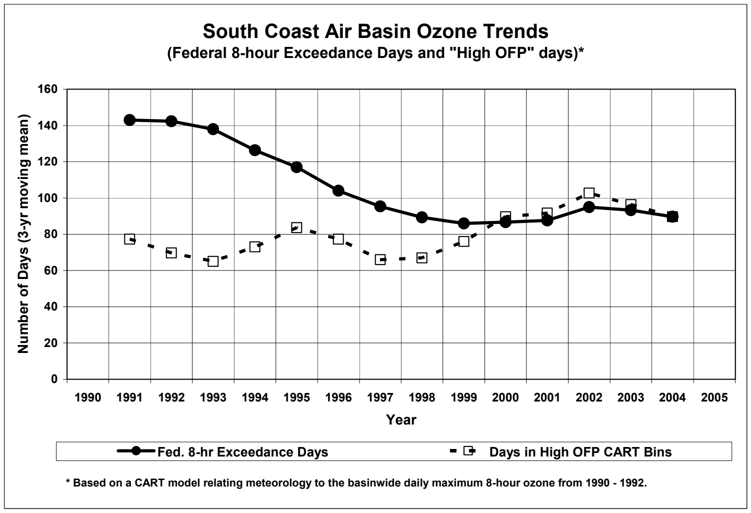
As one approach to help understand the types of meteorological conditions leading to high ozone concentrations, ARB staff completed an analysis of ozone and meteorology using Classification and Regression Tree (CART) techniques. The CART analysis determined rules that separated days into 15 groups based on the degree to which weather conditions favor ozone formation. The CART rules used daily data for surface air temperature, air temperature at 1500 meters[1], wind speed/direction, atmospheric stability, and other factors in relation to daily maximum 8-hour ozone concentrations. From the 15 groups, a subset with high average ozone levels and containing on average about one-third of the ozone season were considered to represent high ozone forming potential (OFP).

The analysis, presented in Figure A-5, shows the number of days with high OFP along with the number of days exceeding the federal 8-hour ozone standard each year (three-year moving means). The changes in exceedance days relative to the changes in high OFP days helps distinguish changes due to meteorology from changes due to emission reductions. Progress is shown when the number of exceedance days decreases in relation to the number of high OFP days.

Looking at the trend lines from 1990 through 1999 provides an illustration of how to interpret Figure A-5. From 1990 to 1999, observed exceedance days decreased by 57 days, from 143 to 86, while high OFP days increased by 1 day, from 76 to 77. Therefore, relative to high OFP, the "real" decrease in exceedance days was about 58 days (the decrease in exceedance days plus the increase in high OFP days).

[1] Above sea level

Figure A-5: South Coast Air Basin Federal 8-Hour Exceedance Days and High OFP Days 1990 to 2005



The overall analysis suggests that ozone improvements in the South Coast are primarily attributable to substantial emissions reductions. The decline in the number of exceedance days between 1990 and 1999 was not a result of favorable weather, because the number of days with adverse weather conditions did not change substantially during this time period, while the number of exceedance days showed a steady decrease. Furthermore, even though ozone levels have been relatively flat during the last five to six years, the analysis suggests that more adverse weather conditions are now required to produce an exceedance of the federal standard.

Meteorologically Adjusted Trends

As discussed above, meteorological parameters such as temperature, pressure, and wind speed are systematically correlated with sunlight and dispersion and can be used in formulas that predict daily ozone levels. As a second method to address the role of meteorology, a statistical model that predicts daily maximum ozone on the basis of daily meteorological data was used to adjust daily ozone observations.

First, days from the May through October ozone season for the years 1990 to 2005 were assigned to separate groups based on pressure and temperature gradients, along with selected wind speeds and directions. Together, two groups accounted for the vast majority of exceedance days during the ozone season in the South Coast. For each of these groups, data from 1990 through 1992 were used to calibrate a within-group model to predict daily maximum 8-hour ozone from daily weather data. The limited span of years was used for calibration so that when it was applied for all the years (1990 through 2005), it would provide a level playing field for meteorological effects apart from the influence of changes in emissions.

Met-adjusted trends are presented in the following two figures. Both figures are based on data for basinwide daily maximum ozone concentrations, after these have been reconciled to long-term meteorological norms regarding group frequencies and concentrations within each group. The three lines on each graph represent the mean of the Top 10, Top 20, and Top 30 met-adjusted concentrations. Each line was smoothed using a three-year moving mean, because the process of met-adjustment does not remove meteorological influences perfectly, and other factors also affect year-to-year changes.

In Figure A-6, all three trend lines track together and show significant improvement over the time period. Since 2000, the trend has been rather "flat." A similar period of relative flatness is seen from 1996 to 1999, followed by a period of more pronounced progress.

Figure A-6: South Coast Air Basin Ozone Trends 1990 to 2005 Adjusted for Meteorology

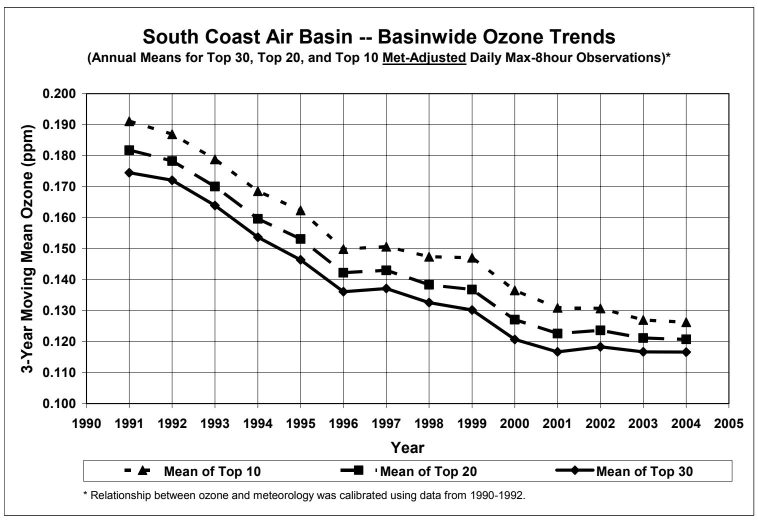


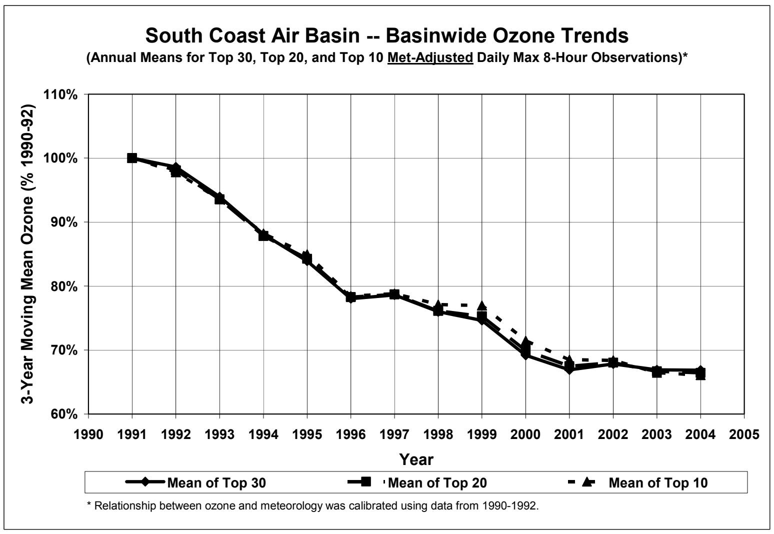
Figure A-7 emphasizes the similarity between the trend lines for all three indicators: the means of the Top 10, Top 20, and Top 30 basinwide daily maximum 8-hour ozone concentrations. When expressed in terms of percent with respect to their values in 1990, the trends for all three indicators are almost identical. Because of this similarity, it is apparent that the top 16 percent[2] of summer ozone concentrations in the South Coast Air Basin have responded very similarly to emissions reductions since 1990.

In summary, a critical question concerning ozone in the South Coast Air Basin is whether ozone levels since 2000 have been improving, deteriorating, or unchanged. Over short periods, such as 2000 to 2005, it is important to consider the weather

[2] Of the 184 days from May through October, 30 represents 16%.

conditions when studying trends. As described in the above sections, the effects of weather on ambient ozone concentrations were considered in two ways:
(1) OFP/CART trends for exceedance days and (2) met-adjusted trends for average ozone on high concentration days. While both analyses confirm that ozone trends have been flat, they also suggest that more adverse meteorological conditions are now required to produce an exceedance of the federal 8-hour ozone standard.

Figure A-7: South Coast Air Basin Ozone Trends 1990 to 2005 Adjusted for Meteorology and Expressed as a Percentage of the Base Year



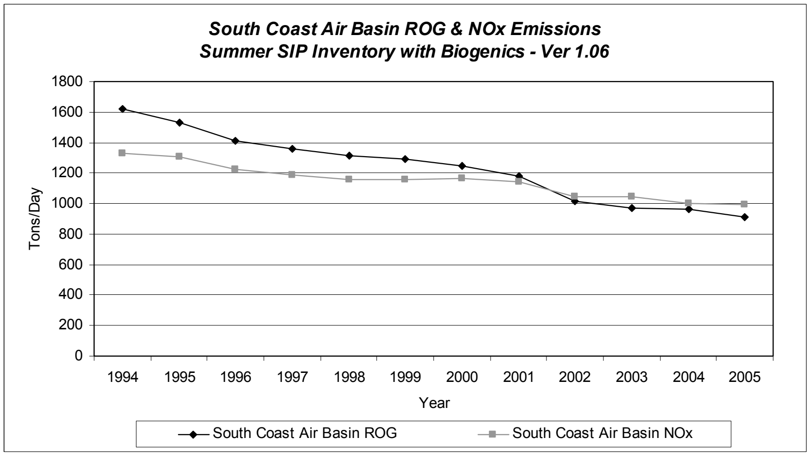
Emissions and Precursor Trends

Oxides of nitrogen (NOx) and reactive organic gases (ROG) are precursors to ozone. Emissions controls have significantly reduced the amounts of these precursors in the ambient air, resulting in improved air quality. However, similar to ozone, the rate of reduction for each precursor has varied over time. This has resulted in a different “mix” of precursors over the years. Both the rates of reduction and the mix of precursors can impact ozone improvement. The following sections describe the NOx and ROG emissions trends since 1994, as well as the amounts of these precursors measured in the ambient air.

Emissions Trends

Emissions controls have significantly reduced the amounts of both ROG and NOx emitted by various sources throughout the South Coast. Figure A-8 shows the estimated basinwide trend in precursor emissions from 1994 to 2005. The totals reflect estimates for the summer season in tons per day and include emissions from natural biogenic sources.

Figure A-8: South Coast Air Basin ROG and NOx Emissions 1994 to 2005



Basinwide, ROG emissions show a relatively steady decline over the entire time period. In comparison, NOx emissions also declined, although at a slower overall rate. NOx emissions declined between 1994 and 1998, were fairly stable between 1998 and 2001, but then showed a small decline again between 2001 and 2005. In terms of total reduction, ROG emissions decreased about 45 percent between 1994 and 2005. The reduction in NOx emissions was less -- a 25 percent reduction between 1994 and 2005. Because the majority of the basinwide emissions (ROG and NOx) occur in the Los Angeles County portion of the Basin, most of the emissions reductions have occurred in this area (refer to Figure A-9). By comparison, the level of emissions reductions in the remaining three counties have been much smaller (refer to Figure A-10).

Figure A-9: Los Angeles County ROG and NOx Emissions 1994 to 2005

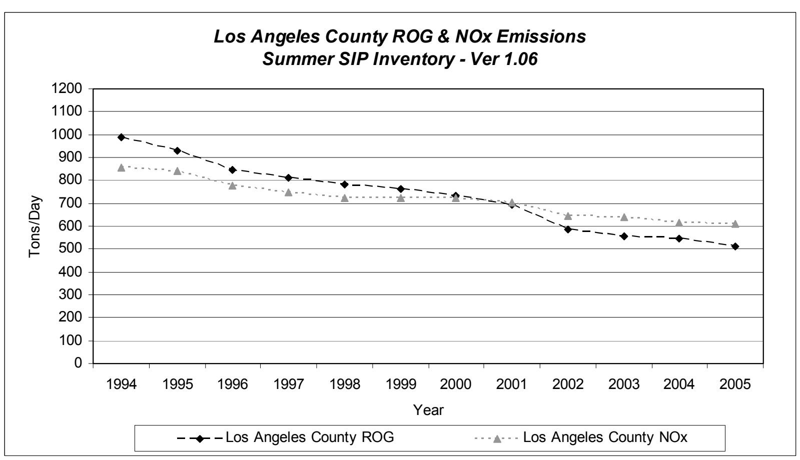
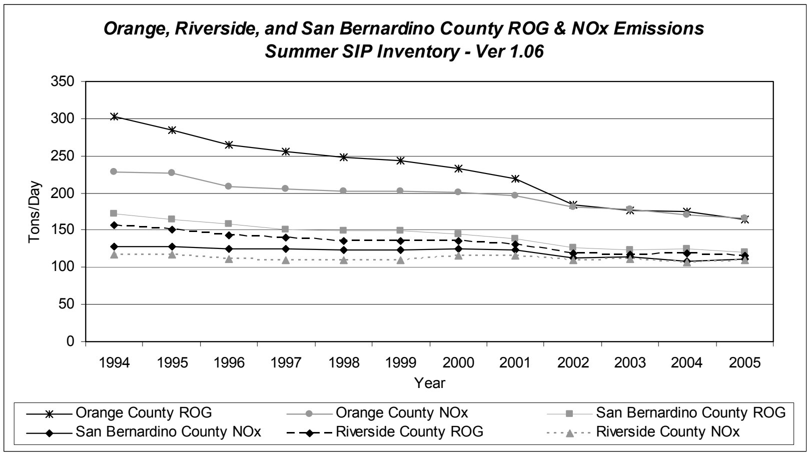


Figure A-10: Orange, Riverside, and San Bernardino County ROG and NOx Emissions 1994 to 2005

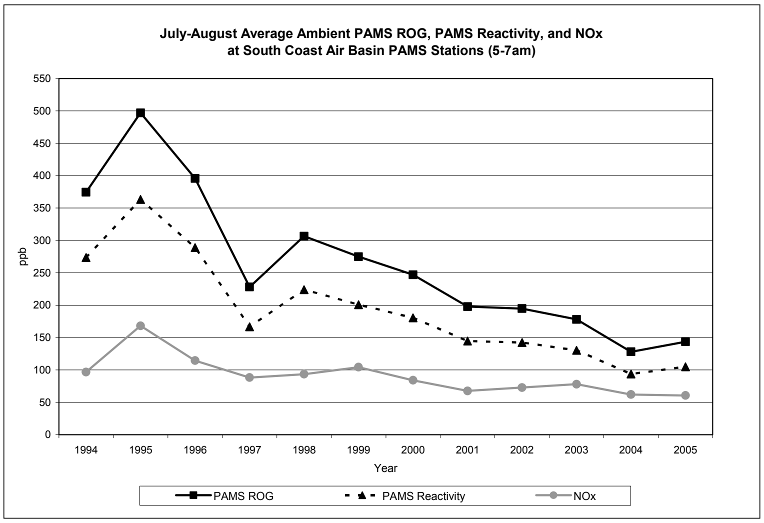


The differing rates of reduction for basinwide ROG and NOx emissions has led to a change in the relative amounts of ROG and NOx. Before about 2000, the estimated amount of ROG emissions was higher than the estimated amount of NOx emissions. However, the levels were about equal in 2000, and the pattern reverses in the following years. It is interesting to note that this reversal in the relationship between ROG and NOx occurred at about the same time that basinwide ambient ozone concentrations leveled off. This provides support for the idea that both NOx and ROG emissions reductions are needed to reduce ambient ozone concentrations. Previous emissions controls have primarily targeted ROG. However, in the future, there needs to be a long-term focus on achieving significant NOx reductions, as well.

Precursor Trends

In addition to the reduction in overall emissions as estimated by the emissions inventory, ozone precursor monitoring data confirm the reduction of both ROG and NOx in the ambient air. As shown in Figure A-11, there has been an overall reduction in both the amount of ROG, as well as the reactivity of the ROG mix measured at the Photochemical Assessment Monitoring Stations (PAMS) network in the South Coast. Since 1999, both ROG from the PAMS network and NOx from co-located monitors show reduction patterns similar to those for the estimated emissions, in that ROG is coming down at a faster rate than NOx (about a 60 percent reduction in ROG versus a 40 percent reduction in NOx). This confirms the effectiveness of the emissions control programs, which historically, have focused more heavily on ROG reductions.

Figure A-11: South Coast Air Basin Ambient Summer ROG and NOx Trends at PAMS Stations (5-7 am) 1994 to 2005

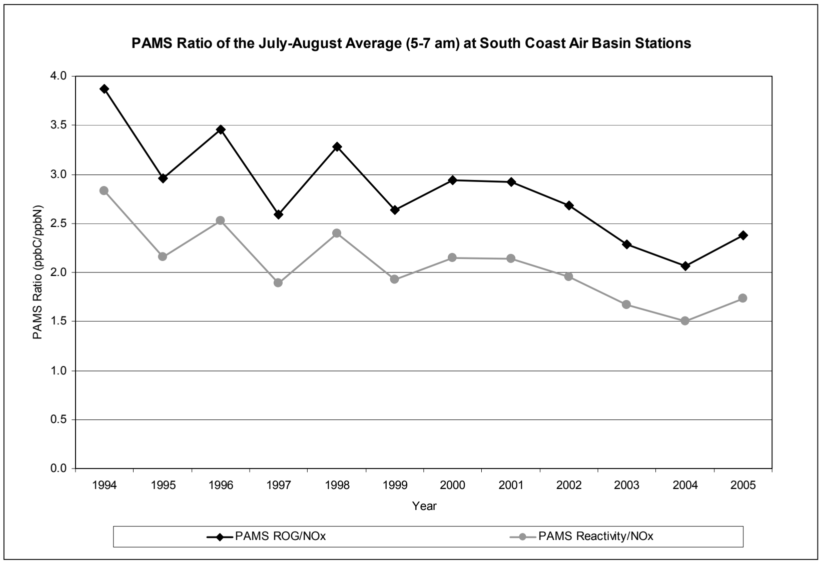


While the PAMS precursor data show a lower overall decline in NOx, as compared with ROG, there have been spatial differences in NOx reductions, as well. Over the 12-year time period (1994 to 2005), the average 5 am to 7 am July-August NOx decreased about 35 percent at sites located west of Upland. During this same time period, sites located east of Upland saw only about a 3 percent reduction in average 5 am to 7 am July-August NOx. The slower decline in NOx levels in the eastern part of the Basin is consistent with faster growth rates in these downwind portions of the South Coast. This growth has partially offset the benefits of emissions control programs in the eastern portion of the Basin.

The ratio of ROG to NOx in the ambient air is an important factor in ozone formation. Figure A-12 shows the ambient ROG to NOx ratios for both the total measured ROG and the reactive portion of the total measured ROG. Both ratios are quite variable during the earlier years, although they track well over the entire timeframe. Over the 12-year period, the ratios for both have been reduced. The ratio for total ROG to NOx was 3.9 in 1994 compared with 2.4 in 2005. Similarly, the ratio for reactive ROG to NOx was reduced from 2.8 in 1994 to 1.7 in 2005. This reduction in the ROG to NOx ratio reflects the historical emphasis on ROG controls.

In summary, emissions estimates show a steady decline in ROG over the last 12 years. Estimates show a smaller overall decrease in NOx emissions. Prior to 1999, the level of estimated NOx emissions was lower than the level of ROG emissions. Both were about equal in 2000, and NOx emissions are higher since then.

Figure A-12: South Coast Air Basin Summer Morning PAMS Ratios and Morning ROG and NOx Emissions 1994 to 2005



Similar to the estimated emissions, measured ROG from the PAMS network, as well as NOx from co-located samplers also show a relatively steady decline in measurements over time. While the measured data show a fairly continuous decrease in ambient ROG, ambient NOx concentrations showed the greatest decrease between 1994 and 2001. Since 2001, there has been little change. This period of relatively stable ambient NOx concentrations generally coincides with a leveling off of ambient ozone concentrations. In addition to a reduction in the total amounts of precursors, data from the PAMS network show a reduction in the overall reactivity of the ROG mix. The ratios of ROG to NOx and ROG reactivity to NOx track well over the 12 years, with both averaging about 2 or higher during the entire period.

The ozone control strategy has been effective in reducing precursor emissions, especially hydrocarbon emissions and the reactivity of the hydrocarbon mix. However, despite these reductions, almost all measures of ozone air quality in the South Coast have been relatively flat since 2000. Photochemical modeling suggests that because of where the area currently lies with respect to ROG to NOx ratios, slow rates of improvement are not unexpected. Furthermore, the decrease in the reactivity of the ROG mix means that it now takes longer for photochemical reactions to occur, and this is reflected in an eastward movement of the basinwide peak ozone concentrations over time.

Despite the slow rate of basinwide improvement, ROG emissions reductions over the last several years have resulted in improved ozone in the coastal urban areas of the South Coast. However, the NOx reductions have not been sufficient to lower ozone concentrations in the eastern (downwind) portions of the Basin. Over the long-term, emissions controls must focus on NOx reductions. Modeling results support this, showing that substantial reductions in NOx emissions (a 75 percent reduction), coupled with a lesser reduction in ROG emissions (a 20 percent reduction) are needed to reach attainment throughout the Basin, including downwind, transport-impacted areas. As additional controls are implemented, ozone should once again begin to improve at a more rapid rate.

Modeling Results

The ozone modeling domain for the South Coast was based on the domain defined for the 1997 Southern California Ozone Study (SCOS) and includes not only the South Coast Air Basin, but the surrounding coastal, desert, and mountain areas, as well. The domain horizontal grid is 116 by 80 cells, with a resolution of five kilometers. The ozone episode periods selected for modeling comprised a combination of five episodes from the years 2004 and 2005, chosen to reflect recent ozone design values, along with a 1997 episode to maintain continuity with the 2003 South Coast Air Quality Management District (District) SIP.

The required meteorological fields were generated using the MM5 prognostic meteorological model, and the required emissions inventories were developed by District staff. The ozone air quality modeling utilized the Comprehensive Air Quality Model with Extensions (CAMx) model, with initial and boundary conditions based on estimates of clean-air concentrations. Analysis of the model outputs included the estimation of 1-hour and 8-hour ozone concentrations for each ozone monitoring site within the domain, as well as statistical measures comparing observed and simulated ozone concentrations. These analyses were used to evaluate model performance by sub-region within the domain.

As required by U.S. EPA guidance, a relative reduction factor (RRF) approach was used in projecting future design values. The RRF reflects the ratio between the future year model prediction (in this case the end of 2023) and the reference year model prediction (in this case 2002). A reference or base year design value is then multiplied by the RRF to project a future year design value. The District's modeling satisfies the minimum five episode requirement for use in developing a site-specific RRF for most sites, as recommended by the U.S. EPA's guidance for modeling 8-hour ozone design values.

Results of the modeling analyses show that all sites in the South Coast Air Basin will attain the federal 8-hour ozone standard by June 15, 2024, as required for Extreme ozone nonattainment areas. The amounts of emissions reductions needed to reach attainment vary throughout the Basin, because the magnitude of the ozone problem varies from place to place. Sites located in the eastern portions of the Basin, in particular Crestline, Fontana, and Redlands, are projected to have the highest future year design values, at 0.083 ppm, 0.081 ppm, and 0.081 ppm, respectively. These future year values are just below the level of a federal 8-hour exceedance. The future year ozone projection for Santa Clarita, another high site in the Basin, is 0.074 ppm, which is a little more than 10 percent below the level of a federal 8-hour exceedance.

In addition to projecting attainment by 2024, results of the modeling analyses confirm the recent flatness of the ozone trends in the South Coast Air Basin. As described previously, maximum concentrations measured at the Crestline site showed little progress between 2002 and 2005. Given the emissions reductions that occurred during this timeframe, the modeling analyses indicate that little progress should have been expected. However, despite the recent plateau, the modeling analyses show that in future years, a dual pollutant control strategy will be effective in reducing ambient ozone concentrations, eventually bringing the South Coast Air Basin into attainment for the federal 8-hour ozone standard. However, because of where the Basin is, with respect to the current mix of ROG and NOx emissions, it may be several years before substantial progress occurs. Therefore, it is important to recognize that progress must be evaluated in the long-term, and that short-term plateaus are not unexpected.

Modeled Versus Ambient Changes in Ozone on Meteorologically Similar Days

As part of the supplemental analysis, ARB staff compared changes in modeled ozone to changes in measured ambient ozone from 1996 to 2005. The purpose of this analysis was to corroborate the modeled results and to assess the model's response to a particular pattern of emissions reductions. The analysis is intended to help in interpreting the modeling results.

Methods

The key step in comparing changes in modeled versus ambient ozone was selecting days in each year for which meteorological conditions were similar to conditions that prevailed on the modeled days. For the South Coast, a total of six 2004 and 2005 episode days with satisfactory model performance were available for comparison. Each selected day was part of a multi-day episode that was successfully modeled as a "base case," using day-specific inventories. Each multi-day episode was subsequently re-run using summer planning inventories for 1996 and 2005. The six episode days that were modeled and selected for comparison were August 6-8, 2004, and July 17-19, 2005.

ARB staff compared the relative (percent) change in modeled ozone from 1996 to 2005 for the modeled days to the relative change in ambient ozone on days with similar meteorological conditions for the same period. Meteorological similarity was determined using surface temperature, surface wind speed and direction, temperature aloft (about 5000 feet above sea level), atmospheric stability, and integrated wind speed and direction aloft (surface to about 5000 feet). The similarity scale for each meteorological factor was standardized before determining a composite similarity for meteorology. Composite similarity was a weighted sum reflecting the relative importance of each meteorological characteristic: surface temperature (weight = 1), surface winds (weight = 0.25), temperature aloft (weight = 1), atmospheric stability (weight = 0.25), and winds aloft (weight = 0.5). For this analysis, the sum of the weights did not need to equal 1.

For each modeled day, ARB staff identified the four most similar days in each year. If each selected day was similar to only one of the modeled days, a total of 24 days in each year would have been selected. However, because some of the modeled days were similar to each other, the number of days selected to reflect ambient conditions ranged from 11 to 19 for the years 1996 to 2005. The average number of days selected per year was slightly more than 15.

In the South Coast, comparisons were based on the average of model results at selected sites in the Riverside and San Bernardino County portions of the Basin, which comprise the Inland Empire/Desert Region. Also included in the analysis area was Crestline, the current design site for the federal 8-hour ozone standard. Crestline routinely shows the highest ozone concentrations in the Basin, both on a daily and an annual basis. Long-term sites in the analysis area include Crestline, Riverside, San Bernardino, Banning, and Perris. In addition to a regional comparison, model and ambient results were compared at the first three sites. Banning and Perris were not considered individually because of problematic model performance in these areas.

The San Fernando Valley/Santa Clarita sub-regions were not considered because of problems with the ambient data. Specifically, Santa Clarita, the key monitoring site, was relocated from a fire station, where diesel fire engines produced NOx that scavenged ozone locally, to a more representative location with lower NOx emissions. Ozone readings at the new location were systematically higher, and an appropriate adjustment of the ambient trend was problematic.

The Coastal Plain sub-region also was not considered because of spotty model performance. While model performance was satisfactory at some locations, it was not at others. In addition, the Coastal Plain generally has relatively low ozone concentrations, making comparisons for the Inland Empire/Desert Region and Crestline area relatively more important.

Results

The comparisons of modeled ozone to ambient ozone do not constitute proof that the model results are either good or bad, since assumptions implicit in the methodology could lead to differences. For example, the criteria used to identify days with similar meteorology could not ensure that the selected days were identical to the modeled episodes. Also, the day-specific inventories used to validate the models' base cases differ to some degree from the summer planning inventories used to represent 1996 and 2005. Nevertheless, this analysis is a reasonable approach for examining model behavior and real-world behavior under similar atmospheric conditions. The key conclusions of the ARB analysis include the following:

- Model performance was strongest in the Inland Empire/Desert Region and Crestline area which comprise the Riverside and San Bernardino County portions of the Basin. Sites in these areas regularly record the highest 8-hour ozone concentrations in the Basin.

- For the Inland Empire/Desert Region and Crestline area, the modeled improvement in daily maximum 8-hour ozone from 1996 to 2005 was 17 percent, while the ambient improvement was 14 percent.
- Modeled and ambient improvements at multiple sites in the Inland Empire/Desert Region and Crestline area were reasonably consistent.

As shown in Table A-1, the agreement between the ambient and modeled trends was quite good for the Inland Empire/Desert Region and Crestline area as a whole and for the Crestline and San Bernardino sites specifically. This provides some indication that the modeling system as a whole is able to reasonably reproduce the ambient trends on a relative basis. That is, while the model may not be able to replicate the exact air quality measurements that occurred in 1996 and 2005, it is able to reasonably capture the relative change in ozone. This performance is consistent with the use of relative reduction factors in the application of air quality models for federal 8-hour ozone SIPs.

Results for the Riverside site were not as good as for the other two sites. Nevertheless, the modeled and ambient trends still compare relatively well. Additional analysis is needed to better understand the cause or causes of the larger difference at Riverside.

Table A-1: Modeled versus Ambient Ozone Progress from 1996 to 2005 in the South Coast Air Basin.

Basin	***Sub-region or Site***	***Modeled Progress***	***Ambient Progress***
South Coast	Inland Empire / Desert Region / Crestline area	17 percent	14 percent
	Crestline	16 percent	15 percent
	San Bernardino	18 percent	18 percent
	Riverside	18 percent	12 percent

Figures A-13 through A-16 give a graphical representation of the results in Table A-1. The graphs show the modeled values for 1996 and 2005. In contrast, the ambient trends are shown as annual values from 1996 through 2005.

In Figures 13, 14, and 16, the ambient ozone level for 1998 is notable. This analysis emphasized meteorological similarity among the days selected for the ambient trend. Accordingly, most of the weather effects related to ozone formation and accumulation should have little impact on the trend. The persistence of anomalous values in 1998 is consistent with other analyses conducted by ARB staff. Efforts to remove the effects of meteorology from the ozone trends in the Inland Empire/Desert Region, and at Crestline in particular, have been unsuccessful in coaxing the 1998 data into reasonable agreement with the rest of the trend. Several alternative explanations are under investigation: (1) perhaps some unusual meteorological pattern affected the study area in 1998, and this pattern is not reflected in the factors used to adjust the ozone data, or (2) it is possible that a factor unrelated to meteorology, such as a temporary effect of monitor recalibration or unusual local activity, may have strongly affected the ozone data for 1998. The trend for the Inland Empire/Desert Region and Crestline area reflects the regional daily maximum 8-hour ozone data, which often is dominated by the Crestline site. Therefore, the Inland Empire/Desert Region trend is interconnected with the Crestline trend. Furthermore, Crestline is located high in the mountains, in contrast to San Bernardino and Riverside, which are not elevated sites and represent large suburban populations.

Figure 13: Modeled versus Ambient Trends from 1996 to 2005 in the Inland Empire / Desert Region / Crestline Area

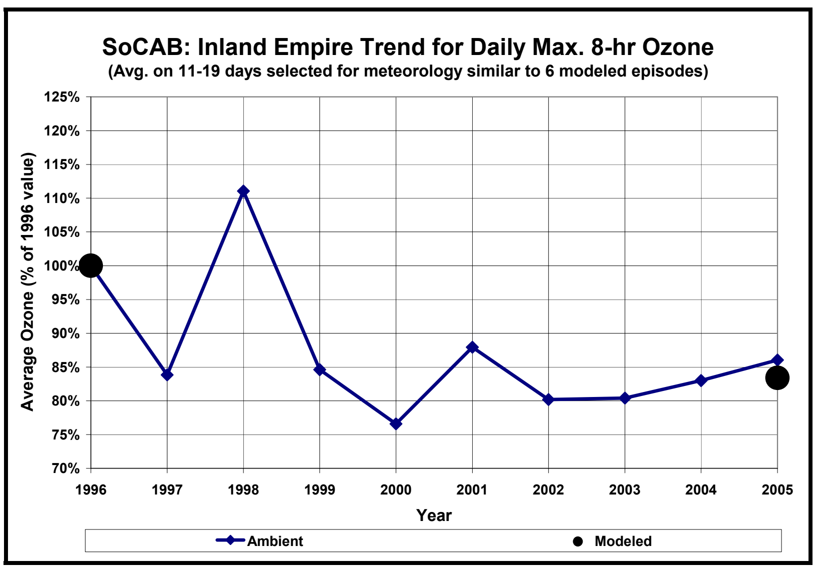


Figure 14: Modeled versus Ambient Trends from 1996 to 2005 at Crestline

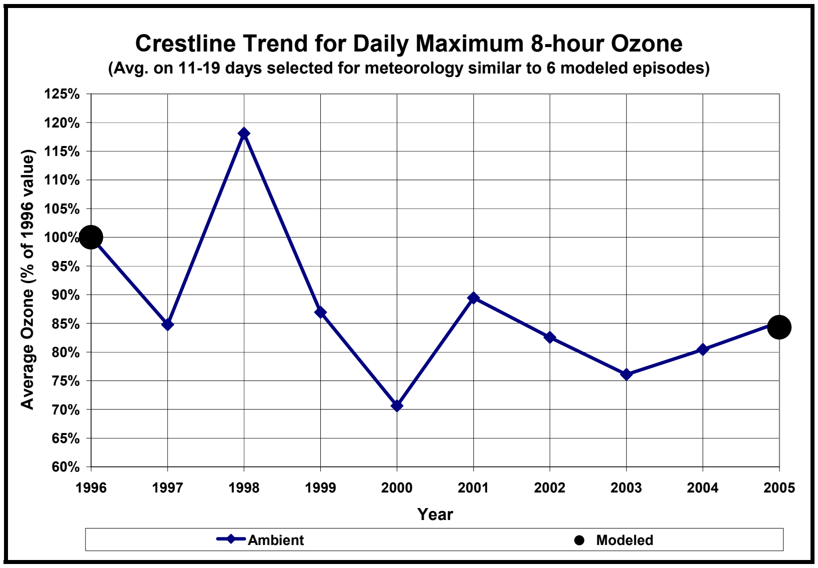


Figure 15: Modeled versus Ambient Trends from 1996 to 2005 at San Bernardino

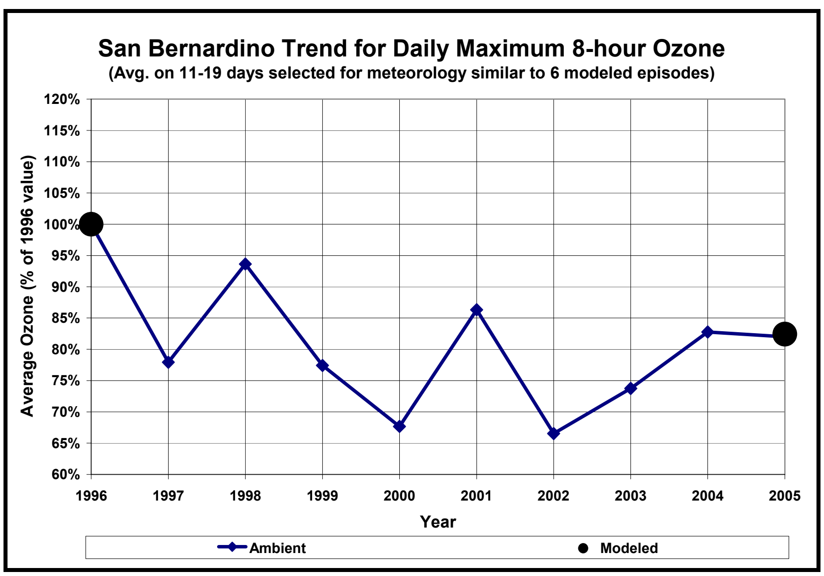
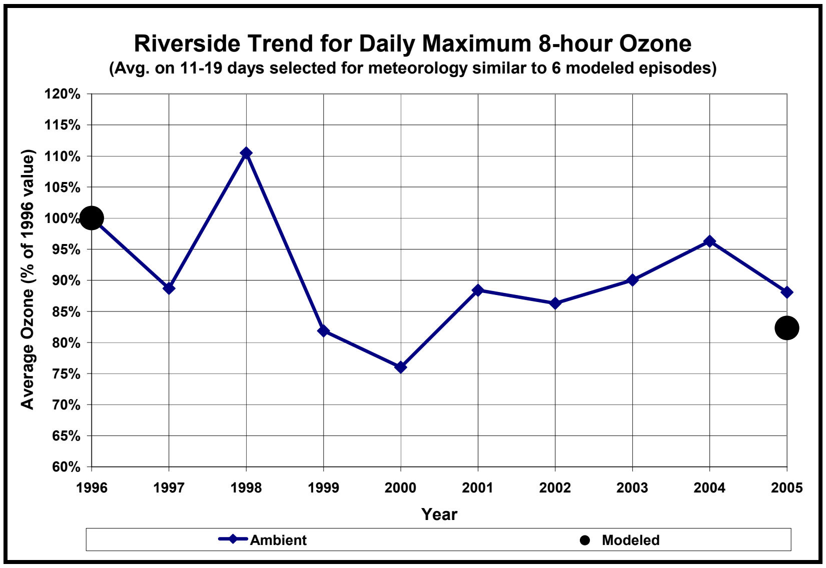


Figure 16: Modeled versus Ambient Trends from 1996 to 2005 at Riverside



Summary

The supplemental analysis supports the modeled attainment demonstration. Currently, the South Coast is classified as Severe-17 with respect to the federal 8-hour ozone standard, with attainment required by 2021. Because of the magnitude of emissions reductions required, the District is requesting reclassification as Extreme, with a June 15, 2024 attainment deadline. The Extreme classification allows the attainment demonstration to rely on emissions reductions from measures that anticipate the development of new technologies or improvement of existing technologies. These measures are often referred to as “black box” measures and go beyond the short-term measures that are based on known and demonstrated technologies.

Photochemical modeling completed by the District indicates that all sites in the South Coast Air Basin will reach attainment by the 2024 deadline with a 76 percent reduction in NOx emissions and a 22 percent reduction in ROG emissions. Based on these reductions, Crestline, the high site, will have a future year design value of 0.083 ppm, which is below the level of a federal 8-hour ozone exceedance. Based on the modeling results and supplemental analyses, attainment by 2024 can be projected because of the following factors:

- Over the last decade, basinwide measures of maximum concentration, design value, and number of exceedance days all declined by about 30 percent. Because these are basinwide numbers, they reflect the “worst case” sites. On a sub-regional basis, the amount of improvement during the last ten years is even greater.

- During the mid-1990s, the ozone problem was widespread throughout the South Coast Air Basin. Today, the spatial extent of the relatively clean areas has expanded substantially. Furthermore, more than half of the Basin population now lives in areas with design values that meet the federal 8-hour ozone standard.

- Progress has occurred at different rates in different parts of the Basin. The greatest amount of progress occurred in the Coastal Plain, where all sites are approaching attainment of the more health-protective State 8-hour ozone standard. Other areas have also improved significantly. Even the two high sites, Crestline and Santa Clarita, have made substantial gains, although at slower overall rates.

- Emissions estimates and ambient precursor data show that both ROG and NOx have declined, although ROG has declined at the faster rate. Prior to 2000, the level of estimated NOx emissions was greater than ROG emissions. However, beginning in 2000, NOx emissions have been about equal to or higher than ROG emissions. This crossover in the emissions trend lines occurred at about the same time that the ozone trends began to level off, lending support to the idea than both ROG and NOx reductions are important for ozone improvement.

- Emissions estimates indicate a continuing decline in emissions for both precursors, as the State and District continue to pursue an aggressive dual pollutant emissions control program. However, based on the magnitude of emissions reductions needed for ozone attainment, as well as the readiness of NOx control technologies, a NOx-heavy strategy is being proposed as providing the most efficient path to attainment.

- Because emissions from the South Coast can be transported to areas outside the Basin, emissions reductions in the South Coast area should result in ozone improvements not only there, but also in other downwind, transport-impacted areas such as Ventura County, the Coachella Valley, and the Mojave Desert Air Basin.

- Analyses suggest that the ozone improvements that have been achieved are primarily attributable to substantial emission reductions. The decline in the number of exceedance days between 1990 and 2000 was not a result of favorable weather, because the number of days with adverse weather conditions actually increased or remained level during this time period, while the number of exceedance days decreased. Furthermore, even though ozone levels have been relatively flat during the last five to six years, analyses suggest that more adverse weather conditions are now required to produce an exceedance of the federal standard.

- Photochemical modeling shows a design value of 0.083 ppm at Crestline by the end of 2023. The design values at other sites in the Basin are predicted at or below 0.081 ppm. All of these values are below the level of a federal 8-hour ozone exceedance.

- A comparison of modeled to measured changes on meteorologically similar days showed model performance was strongest in the Inland Empire/Desert Region and Crestline area, where the highest 8-hour ozone concentrations regularly occur. Results showed a 17 percent improvement from 1996 to 2005 based on modeling, compared with a 14 percent improvement based on changes in the measured data.

Taken together, the results of these analyses indicate that all sites in the South Coast can expect to attain the federal 8-hour ozone standard by June 15, 2024, the attainment deadline for an Extreme ozone nonattainment area.