Appendix B
South Coast Air Basin Ozone
Weight of Evidence Analysis

Introduction

The South Coast Air Basin (South Coast) is currently classified as an extreme nonattainment area for the 0.070 parts per million (ppm) federal 8-hour ozone standard (0.070 ppm standard) with a 2037 attainment deadline. Photochemical modeling analyses are a required element of the South Coast State Implementation Plan (SIP) and are used to determine whether existing and planned control strategies provide the reductions needed to meet the 0.070 ppm standard by the attainment deadline. To address the uncertainties inherent to modeling assessments, U.S. Environmental Protection Agency (U.S. EPA) guidance, *Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze,* recommends that supplemental analyses accompany all model attainment demonstrations.

To complement the regional photochemical modeling analyses included in the South Coast SIP, the following Weight of Evidence (WOE) includes detailed analyses of anthropogenic emissions, ambient ozone data, and population exposure trends. Analyses of weekday/weekend differences and meteorological conditions coincident with elevated ozone in South Coast are also presented.

In 2020, data indicate that only 4 out of 25 monitoring sites in the South Coast were in attainment with the 0.070 ppm standard, and design values at the remaining 21 monitoring sites exceeded the 0.070 ppm standard by 9 to 63 percent. Photochemical modeling analyses conducted by the South Coast Air Quality Management District (District) demonstrated that control measures, in addition to those already adopted, are necessary for all sites in the South Coast to meet the 0.070 ppm standard by the 2037 attainment deadline.

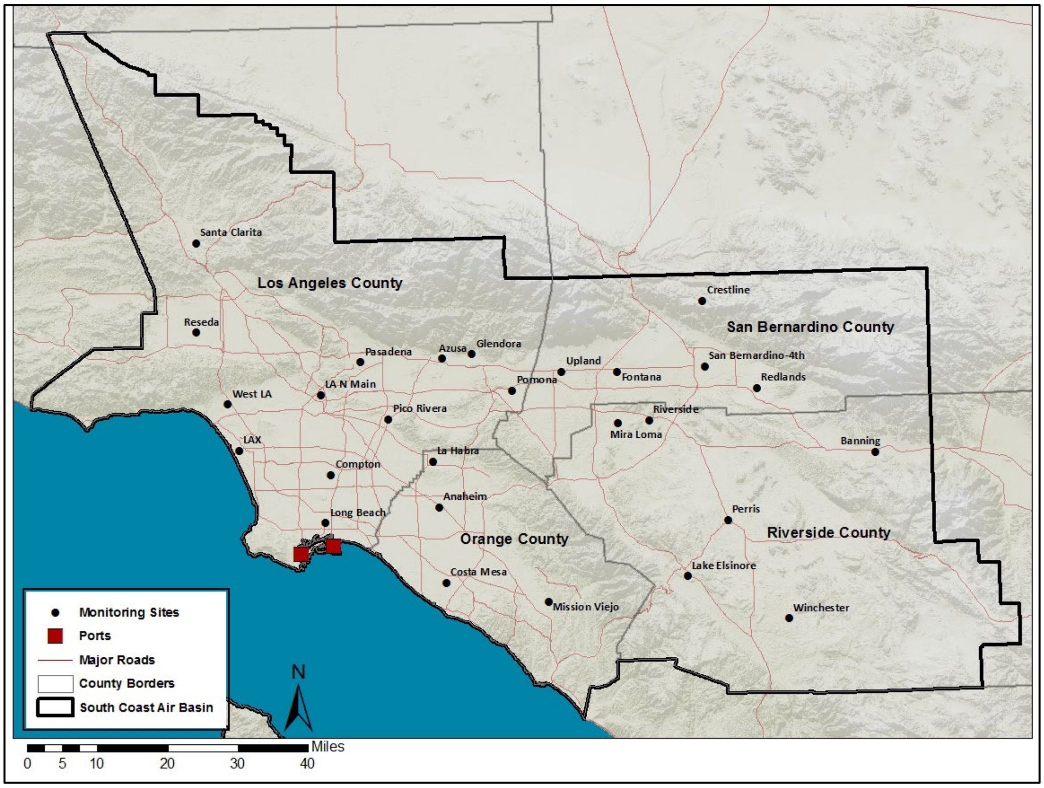
Air quality analyses show that progress is being made at most monitoring sites. However, the extent of progress varies considerably between individual sites and among the many indicators used to evaluate ozone concentrations in an area. The differential progress highlights the complex nature of the ozone challenge in the South Coast and underscores the utility of examining multiple indicators. In addition, the presence of varied topography, a range of climatological areas, and diverse precursor emission sources contribute to a complex path towards attainment.

Area Description

The South Coast encompasses all of Orange County and the non-desert portions of Los Angeles, Riverside, and San Bernardino Counties. Topographically, the South Coast includes a lowland plain, bounded by the Pacific Ocean to the southwest and mountains to the north and east, and several inland valleys. The South Coast encompasses an area of nearly 7000 square miles, including over 100 miles of the Pacific coast.

The South Coast is home to more than 16 million people, including nearly 4 million people in the city of Los Angeles alone. Consequently, the movement of goods and people is a significant source of emissions for the region. As shown in Figure 1, the South Coast hosts an extensive network of freeways to accommodate the operation of over 11 million passenger vehicles. Furthermore, greater than 40 percent of all containerized cargo enters the U.S. via the San Pedro Bay ports of Los Angeles and Long Beach. Most of the population and, consequently, most of the anthropogenic emission sources are concentrated in the southern Los Angeles County portion of the South Coast.

Figure 1: Location of Monitoring Sites in the South Coast Air Basin



Warm and sunny weather persists throughout most of the year due to the presence of a semi-permanent high-pressure system and the associated subsidence of air over the eastern Pacific Ocean and western U.S. These conditions are highly conducive to the accumulation of emissions and subsequent photochemical production of ozone in the summer months. A regional, thermally driven land-sea breeze circulation pattern also promotes a large gradient in ozone concentrations. The lowest concentrations tend to occur at the coastal sites and the highest concentrations are typically measured at the inland valley and elevated mountain sites, particularly those located in the eastern portion of the South Coast, in San Bernardino County. To characterize ozone air quality, the District operates an extensive monitoring network that, in 2020, included 25 monitoring sites in the South Coast, which are shown in Figure 1 and listed in Table 1.

Table 1: Recent Ozone Design Values at Sites in the South Coast Air Basin

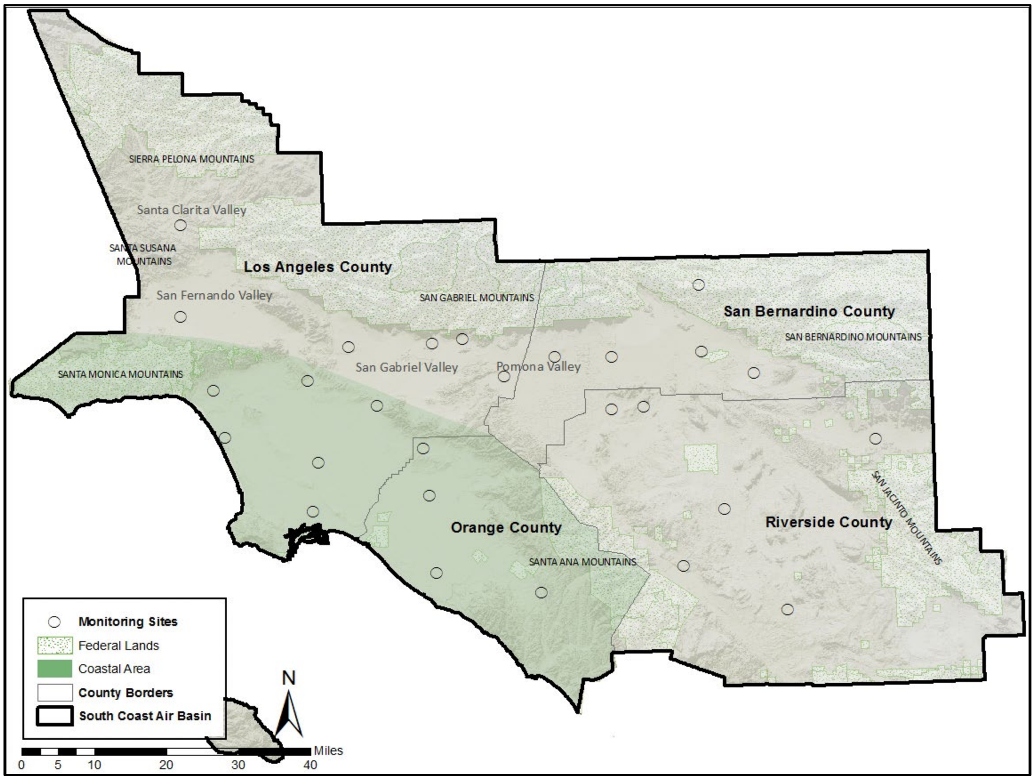
Site Name		AQS ID	County	2019 Design Value (ppm)	2020 Design Value (ppm)	Percent of 0.070 ppm NAAQS in 2020	Meets Standard
Coastal Sites	Anaheim	060590007	ORA	0.067	0.069	99%	Yes
	Mission Viejo	060592022	ORA	0.079	0.082	117%	No
	La Habra	060595001	ORA	0.075	0.077	110%	No
	West Los Angeles	060370113	LA	0.067	0.070	100%	Yes
	Los Angeles-N Main St	060371103	LA	0.072	0.076	109%	No
	Compton	060371302	LA	0.064	0.064	91%	Yes
	Pico Rivera	060371602	LA	0.075	0.078	111%	No
	Los Angeles-LAX	060375005	LA	0.061	0.062	89%	Yes
Inland Sites	Azusa	060370002	LA	0.098	0.097	139%	No
	Glendora	060370016	LA	0.103	0.107	153%	No
	Reseda	060371201	LA	0.091	0.092	131%	No
	Pomona	060371701	LA	0.088	0.088	126%	No
	Pasadena	060372005	LA	0.088	0.093	133%	No
	Santa Clarita	060376012	LA	0.100	0.101	144%	No

	Banning Airport	060650012	RIV	0.098	0.099	141%	No
	Winchester	060650016	RIV	0.079	0.078	111%	No
	Perris	060656001	RIV	0.093	0.094	134%	No
	Riverside-Rubidoux	060658001	RIV	0.096	0.096	137%	No
	Mira Loma	060658005	RIV	0.098	0.098	140%	No
	Lake Elsinore	060659001	RIV	0.087	0.087	124%	No
	Upland	060711004	SBD	0.105	0.106	151%	No
	Fontana	060712002	SBD	0.099	0.102	146%	No
	Redlands	060714003	SBD	0.108	0.114	163%	No
	San Bernardino-4th St	060719004	SBD	0.108	0.110	157%	No
	Crestline	060710005	SBD	0.108	0.109	156%	No

Counties are abbreviated as LA (Los Angeles); ORA (Orange); RIV (Riverside); and SBD (San Bernardino)

The South Coast hosts many distinct topographic, geographic, climatic, and political areas. Past analyses have offered several variations on subdividing the South Coast for presentation and analytical purposes. The South Coast monitoring sites are subdivided into inland and coastal areas based on the proximity to the coast and then further subdivided based on the county in which they are located (Figure 2). The coastal area includes all of Orange County and the southwestern part of Los Angeles County. The coastal area of Los Angeles County includes the area between the Santa Monica Mountains and the border with Orange County. The remainder of the South Coast portion of Los Angeles County is considered inland and includes the Santa Clarita Valley, San Fernando Valley, San Gabriel Valley, and the western Pomona Valley. The inland area also includes the South Coast portions of Riverside and San Bernardino Counties.

Figure 2: Area Map of the South Coast Air Basin



Conceptual Model

Local anthropogenic emissions, complex terrain, prevailing meteorological conditions, and intrabasin transport contribute to the ozone air quality challenges in the South Coast.

Emissions

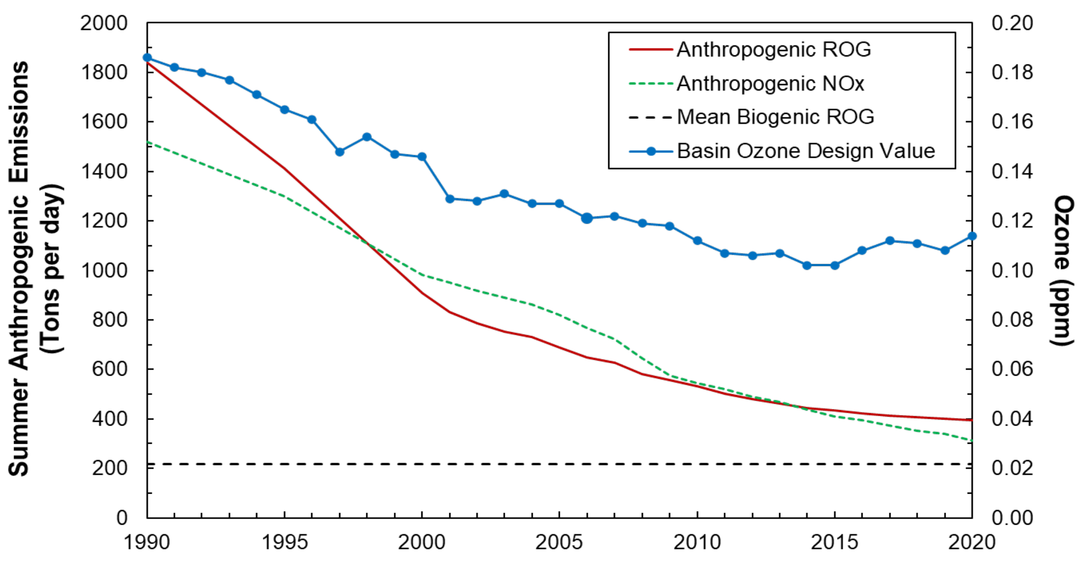
Ozone is a secondary pollutant, photochemically produced through a complex series of reactions involving oxides of nitrogen (NOx) and reactive organic gases (ROG). The large population, wide-range of industries, and varied land use characteristics in the South Coast provide a setting with a diverse suite of NOx and ROG emissions. While NOx emissions in the South Coast are largely from anthropogenic sources, ROG emissions are from a combination of anthropogenic and biogenic sources.

The mix of anthropogenic ozone precursors in the South Coast ranges from mobile source emissions, which include passenger vehicles, heavy-duty diesel trucks, recreational boats, and off-road equipment, to consumer products, which include hair spray, personal care products, and general purpose cleaners. Controlling emissions in the South Coast requires a coordinated, multi-faceted approach at the local, state, and federal levels and the emission control strategies implemented over the years have significantly reduced emissions in the South Coast during the past several decades. As shown in Figure 3, ozone design values have declined in response to reductions in precursor emissions.

While ozone, NOx, and ROG have coincidentally decreased in the South Coast, ozone production regimes are complex, non-linear processes involving many factors across multiple spatial and temporal scales. Given the largely urban setting, which hosts abundant emission sources, ozone production in the South Coast has historically been limited by available ROG. However, as the South Coast has progressed towards attainment, the quantity and composition of precursors has changed along with the associated mechanisms controlling the production and abundance of ozone. The changing chemical composition and production mechanisms can lead to differential benefits for ozone air quality (cf. Finlayson-Pitts and Pitts, 2000 and references therein).

State of the art photochemical modeling assessments, which simulate the outcomes of a wide range of factors acting in concert, are necessary to understand the current and future mechanisms controlling ozone abundance in the South Coast. The most recent modeling indicates that parts of the South Coast are entering a regime where the dominant precursor controlling ozone abundance is shifting from ROG to NOx.

Figure 3: South Coast Precursor Emissions and Ozone Design Values

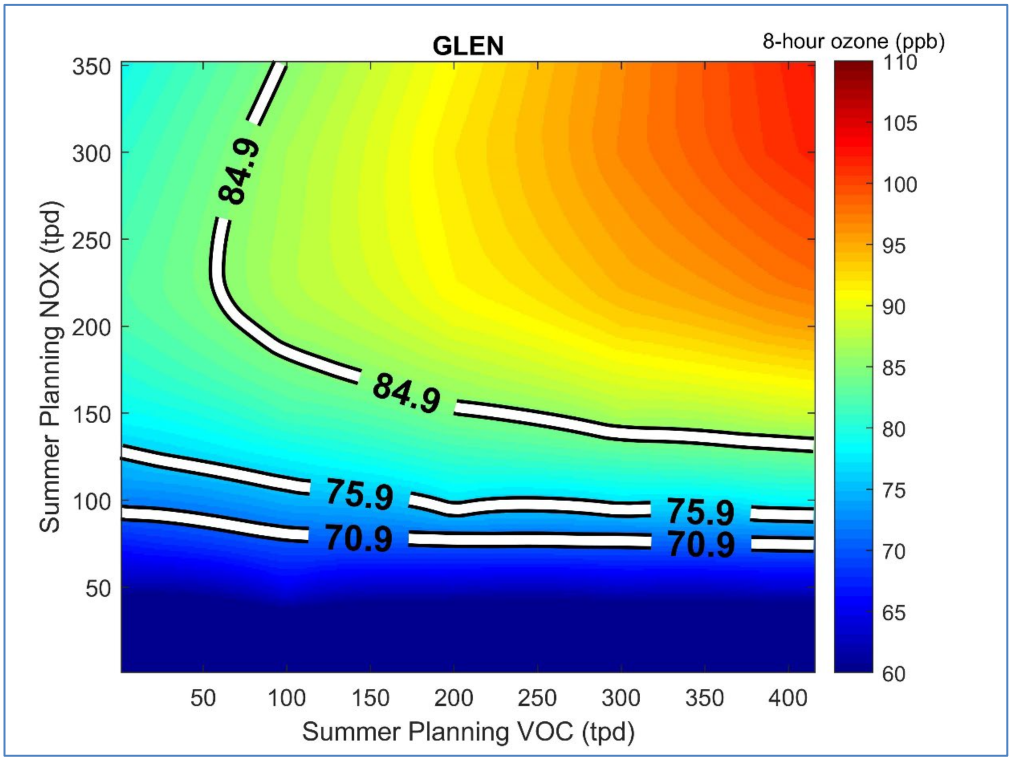


1990-1999 Emissions data from CARB CEPAM Standard Emissions Tool for 2009 Almanac
2000-2020 Emissions data from CARB CEPAM 2022 SIP Planning Tool v1.01 with External Adjustment
Mean Biogenic ROG represents 2018 May-October average of Biogenic Emissions Provided by CARB Air Quality Modeling Group

Figure 4 is a contour plot derived from the District photochemical modeling analyses and illustrates the response of ozone to emission controls. The y-axis represents NOx emissions and the x-axis represents volatile organic compounds (VOC) emissions, which, for the context of this WOE, are treated the same and used interchangeably with ROG emissions. The contours represent the expected site-level ozone design value at a range of NOx and ROG emissions. This contour plot is for Glendora, which is expected to be the design value site in the final years leading up to the 2037 attainment deadline and illustrates the projected transition to a NOx-limited production regime. Contour plots are unique to each site; therefore, it is not intended to be representative of conditions at all sites in the South Coast.

As shown in Figure 4, when ROG emissions are reduced to ~300 tons/day, NOx emissions would have to be reduced to ~60-70 tons/day to meet the 0.070 ppm standard at the Glendora monitoring site. On the other hand, a strategy that called for ROG-only emission reductions could not bring Glendora into attainment. Rather, substantial NOx emission reductions would be necessary to initiate a reduction in ozone concentrations. This pattern indicates that, while reduction in ROG is beneficial for progress, the path towards attainment of the 0.070 ppm standard is with NOx-focused control strategies.

Figure 4: Ozone Isopleth for 2037 at Glendora



Contour plot from Appendix V of the District 2022 Draft Air Quality Management Plan

The wide spacing between the ozone contour lines at the top of the y-axis in Figure 4 suggests that as sites transition from a ROG-limited ozone production regime to a NOx-limited ozone production regime, progress will initially slow before accelerating (indicated by the more narrowly spaced contour lines) with entry into a NOx-limited regime. A temporarily slowed rate of progress in measured ozone concentrations could be indicative of entry into a transitional regime. Thus, analyses intended to project attainment dates or rates of future progress must recognize non-linear changes in progress rates that are expected with a transition to a NOx-limited ozone production regime. As a result, linear regression is not suitable for predicting future progress for an area such as the South Coast and is not used in this WOE.

An additional factor, not evident in the contour plot, is that weekday and weekend emission patterns are different. Past analyses have revealed weekday/weekend differences in ozone concentrations. However, concentrations above the 0.070 ppm standard routinely occur on both weekend days and weekdays, which adds to the complexity of developing an effective emission control program in the South Coast.

Meteorology and Complex Terrain

The most dominant low-level weather feature in the South Coast is a prevailing sea breeze circulation pattern, which is driven by differential heating between the coastal and inland areas and provides a persistent mechanism by which coastal emissions can be routinely transported to inland areas. During the daytime hours, as the land surface heats faster than the ocean water, air flows from the coastal areas toward the inland areas. The daytime near-surface flow of air follows the South Coast's terrain, transporting emissions from the urban coastal area into the valleys and mountains. During nighttime hours, the land surface cools faster than the water surface and the flow reverses, moving air from the inland areas toward the coast. This pattern promotes the recirculation of emissions near the ground and often allows emissions to build for multiple days in a row.

The sea breeze pattern is at its peak when coastal temperatures are mild, due to a morning marine layer during the summer months, while inland, skies are clear, and temperatures are warm to hot. These conditions are conducive to the photochemical production of ozone and frequently lead to exceedances in the inland areas. However, during periods when the coastal areas are sunny all day and warm, often in the late spring or early fall, emissions remain localized and are more likely to lead to high ozone concentrations in the coastal areas.

Vertical movement of air parcels also plays a role in the recirculation of pollutants in the South Coast. Daytime surface heating and the presence of complex terrain, particularly in the inland areas, promotes lofting of pollutants derived from surface emissions. In the absence of winds strong enough to disperse the lofted pollution outside of the South Coast, pollutants can accumulate aloft and become re-entrained in the layer of air near the surface as the land surface heats up and rises and the aloft air descends. Recirculation of emissions that accumulate aloft can contribute to multi-day exceedance events in the South Coast.

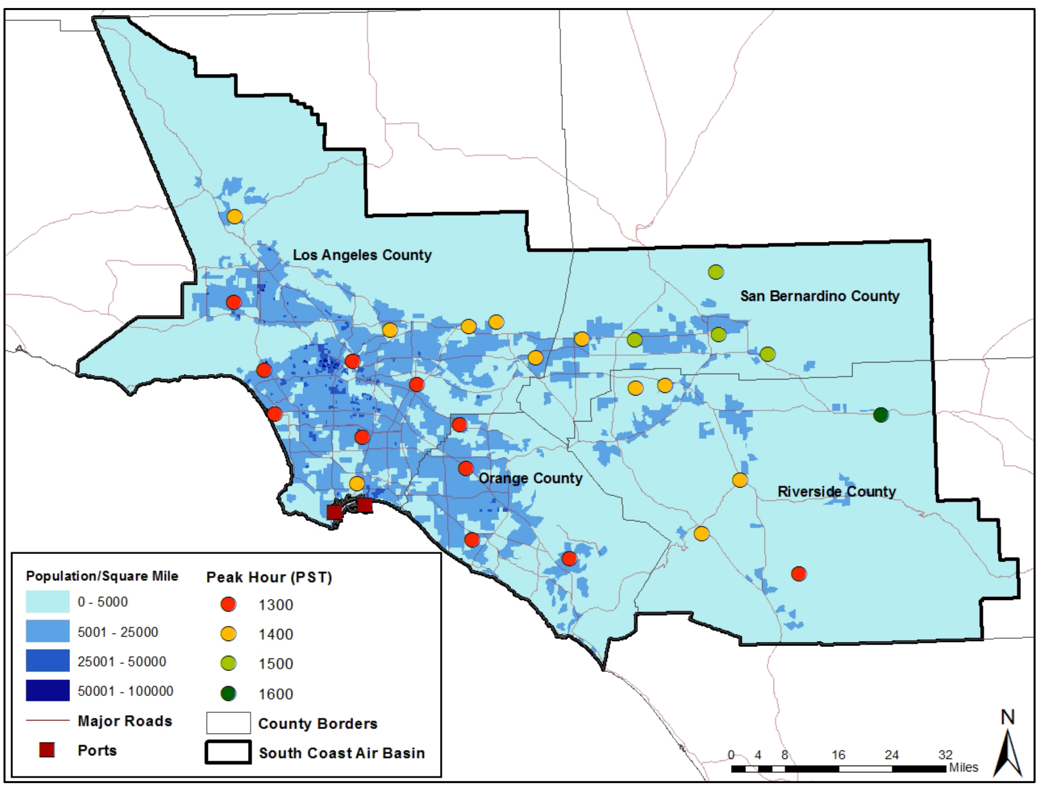
The complex terrain throughout the South Coast acts as a physical constraint on movement of air parcels, limiting dispersion of pollutants and facilitating daytime transport of emissions from coastal to inland areas. Most exceedance days are characterized by the presence of high pressure aloft and mostly clear skies with light, variable winds overnight and throughout the morning hours. The light winds coupled with the confining terrain prevent the ventilation and dispersion of pollutants derived from regional emission sources and lead to exceedances of air quality standards. Detailed analyses for the meteorological conditions conducive to high ozone concentrations in each of the various sub-regions of the South Coast are discussed later in this WOE.

Intrabasin Transport

Terrain and meteorology coupled with the broad distribution of emission sources throughout the South Coast are conducive to intrabasin transport. Several lines of evidence, including the timing of peak concentrations, site-level diurnal patterns, and targeted analyses of back trajectory patterns and meteorology on exceedance days, highlight the role of intrabasin transport in driving peak concentrations throughout the region.

As shown in Figure 5, the earliest peaks in ozone concentration are generally at the sites in the most densely populated areas. Specifically, in the coastal area, peak concentrations typically occur around 1300 PST, shortly after midday and coincident with maximum solar insolation. Northeast of the coastal area, the timing of peak ozone concentrations is delayed by about an hour. Farther northeast, in the inland valleys and mountains, peaks are delayed by about 2 hours relative to the coastal area. Ozone at the eastern mountain passes reach peak concentrations by an average of 3 hours after the coastal areas peaked. This pattern indicates that the daytime transport of South Coast emissions largely contributes to peak ozone concentrations and understanding transport mechanisms is critical for addressing ozone in the South Coast.

Figure 5: Average Hour of Peak Ozone Concentration at South Coast Monitoring Sites for April-October 2016-2020



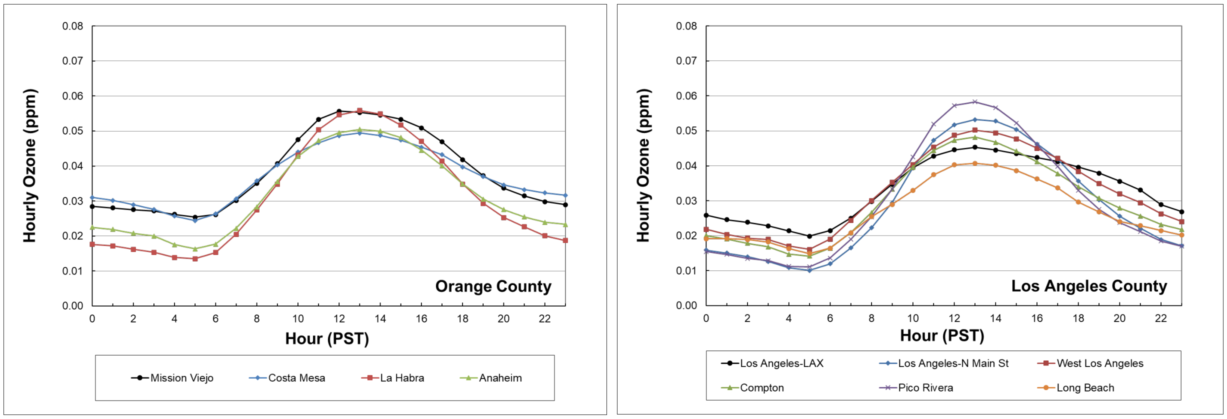
The typical diurnal (24-hour) pattern in ozone concentrations measured at individual locations provides insight into general processes that contribute to regional air quality. Diurnal patterns at monitoring sites in urban core areas, which are densely populated, are often characterized by narrow periods of peak concentrations coincident with peak solar insolation. Nighttime/early morning minimum concentrations are typically at, or near, zero due to availability of NOx for titration of ozone, thereby suppressing ozone concentrations. In suburban and rural locations, peak concentrations are typically higher and persist for an extended period resulting in a broader ozone concentration peak. The nighttime/early morning minimum concentrations are dependent on each monitoring site's distance from the urban core and other site characteristics, but does not typically reach zero in suburban/rural areas.

To focus analyses on periods when exceedance days typically occurred, the hourly ozone data shown in the following figures were limited to the months of April through October. To represent the current state of air quality dynamics in the South Coast, as well as maintain a large sample size to compensate for interannual variability, the period considered was 2016 through 2020.

In Orange County, the average diurnal profiles were consistent among sites and were characterized by broad ozone peaks between 1200 and 1400 PST that included maxima ranging from 0.051 to 0.056 ppm (Figure 6). Among monitoring sites, the average nighttime minima decreased with distance from the coast, but remained above zero at all sites. Although Orange County is largely urbanized, the overall profile of the ozone peak is somewhat broader than might be expected for an urban area and highlights the role of meteorology in the ozone cycle. Due to Orange County's proximity to the coast, a persistent marine layer limits solar insolation and suppresses peak temperatures, which limit ozone photochemistry in Orange County. At La Habra, which is the furthest inland, the profile, with its somewhat narrower peak and low minimum concentration, is more consistent with a site in an urban source area.

For monitoring sites in the coastal area of Los Angeles County (Figure 6), diurnal ozone profile maxima ranged from 0.041 to 0.058 ppm. As was seen in Orange County, the lowest minimum concentrations occurred at sites furthest from the coast. The Los Angeles-LAX, West Los Angeles, Compton, and Long Beach profiles were also similar to sites in Orange County, with a broad ozone peak between 1200 and 1400 PST. The magnitude of the Long Beach peak was markedly lower than all other coastal sites, suggesting that it is uniquely impacted by conditions that typically suppress daytime ozone concentrations. The proximity to emissions sources as well as coastal meteorology may contribute to suppressed daytime ozone concentrations. In contrast, the highest peak ozone concentrations were at Pico Rivera and Los Angeles-N Main St, which also had slightly narrower profiles and lower minima relative to other sites in the area, consistent with an urban source area.

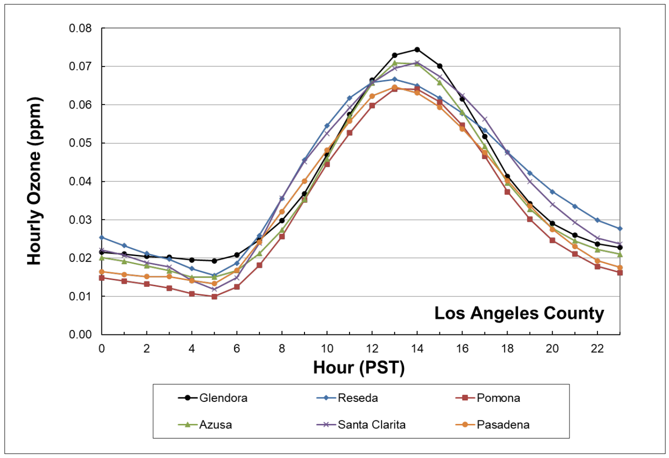
Figure 6: Average Diurnal Profiles for Ozone Concentrations at Coastal Area Sites April-October (2016-2020)



At sites in the inland area of Los Angeles County, average maximum concentrations ranged from 0.064 to 0.074 ppm (Figure 7). The variable distance from the urban core was evident in the diurnal profiles of ozone. The earliest peak ozone concentrations were at Reseda and Pasadena. The coincident timing of the ozone peak at these two sites highlights the importance of terrain-forced flow in the South Coast as these two sites are downwind of the most densely populated portion of Los Angeles, albeit in different directions. Reseda is located to the northwest and Pasadena to the northeast of the highly urbanized portion of Los Angeles. During the daytime, terrain channels the sea-breeze in divergent directions funneling air through the highly urbanized portion of Los Angeles to the northwest into the San Fernando Valley as well as to the east into the San Gabriel Valley.

The Pasadena diurnal ozone profile was similar in shape and magnitude to the coastal Pico Rivera site, suggesting that these two sites may represent the spatial bounds for where urban emission sources in South Coast are concentrated. This seems feasible given that prevailing winds are generally from the southwest during the time of year considered and the most densely populated area of Los Angeles County is directly southwest of Pasadena and Pico Rivera. Glendora and Santa Clarita had the highest average peak ozone concentrations in Los Angeles County, which is consistent with their suburban, downwind valley locations. Santa Clarita and Reseda had the broadest peak ozone profiles and among the highest average minima, which is consistent with being located furthest from the urban core.

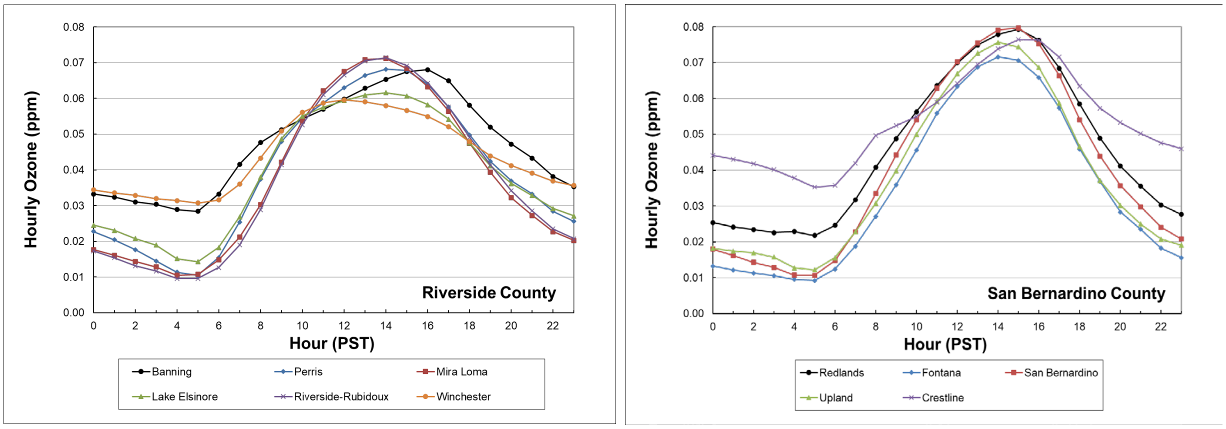
Figure 7: Average Diurnal Profiles for Ozone Concentrations at Inland Los Angeles County Sites April-October (2016-2020)



The diurnal ozone profiles at sites in Riverside County varied more than those in Los Angeles and Orange Counties, with maxima ranging from 0.059 to 0.072 ppm (Figure 8). The shape and magnitude of the profiles at Mira Loma and Riverside-Rubidoux, which are closest to the South Coast urban core, were the narrowest and had the highest average peak concentrations and the lowest minima in Riverside County. The Perris and Lake Elsinore profiles were similar to Mira Loma and Riverside-Rubidoux, but with lower peak ozone concentrations. The Winchester and Banning profiles were broad and had relatively elevated minima. The Winchester profile peaked early, suggesting that it is removed from the South Coast urban core impacts, whereas, the Banning profile peak was delayed by several hours, highlighting the role of transport within the South Coast on ozone air quality at this site.

The diurnal ozone profiles among sites in San Bernardino County were consistent with each other and had maxima ranging from 0.072 to 0.079 ppm (Figure 8). The profiles were like profiles at Mira Loma and Riverside-Rubidoux in Riverside County. Peak ozone concentrations centered around 1400 PST at Fontana and Upland, and around 1500 PST at Redlands and San Bernardino. At Crestline, the ozone peak was delayed by an hour at 1600 PST. The range of minima was large but increased relative to distance from the South Coast urban core. The highest minimum concentrations in the San Bernardino County were at Redlands and Crestline. At Crestline the average minimum ozone concentration was 0.035 ppm, amounting to 50 percent of the 0.070 ppm threshold. Consequently, the highest peak ozone concentrations were at Redlands and Crestline, highlighting the role of transported urban emissions on air quality in San Bernardino County.

Figure 8: Average Diurnal Profiles for Ozone Concentrations at Riverside County and San Bernardino County Sites April-October (2016-2020)



Furthermore, examination of the timing of peak ozone concentrations and diurnal profiles highlighted the significant role of intrabasin transport in the South Coast. Ozone at sites located in the coastal areas tends to peak earlier and at a lower magnitude than at sites in the inland areas. Sites furthest from the coastal areas also have significantly higher minimum concentrations, which presents an added challenge for attainment.

To complement our conceptual understanding of the nature of ozone production and transport in the South Coast, California Air Resources Board (CARB) staff used the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to calculate the 36-hour back trajectories. This analysis was applied to the 2020 high ozone days at high ozone sites in each county of the South Coast.

The back trajectory analyses indicated that most regionally isolated ozone exceedance days were characterized by weak sea breeze and relatively shallow marine layer in the coastal areas during the early morning hours. Given that the sea breeze circulation promotes dispersion and ventilation of pollution in the South Coast, stagnant conditions in the coastal areas could contribute to the build-up of emissions. Weak pressure gradients between the coastal and inland regions generally occurred on days when ozone exceedances were isolated to the coastal area and valley sites in inland Los Angeles County, suggesting that local emissions from coastal and urban core areas contributed to elevated ozone at these sites. Strong pressure gradients between the coastal and inland regions generally occurred on days when ozone exceedances were isolated to sites in San Bernardino and Riverside Counties, which indicates that transport of emissions contributed to elevated ozone concentrations measured in these counties.

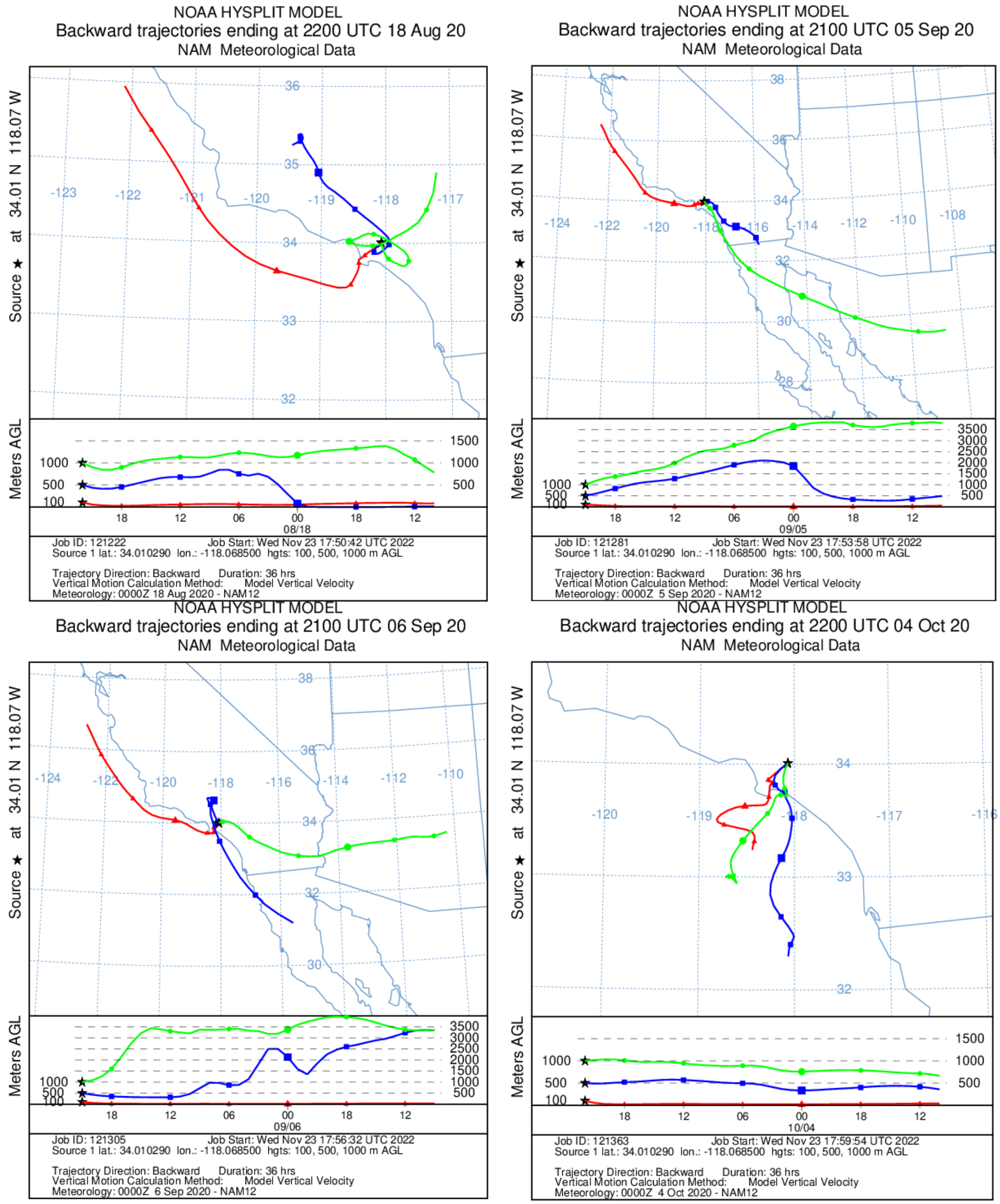
The back trajectories, which were initiated from 100, 500 and 1000 meters (m) above ground level (agl) on 2020 exceedance days, provided the opportunity to gain further insight into the potential source areas and specific transport corridors that may contribute to ozone on exceedance days in the South Coast. In general, the maps of the back trajectories initiated from 100 m to 500 m agl indicate well-defined transport corridors for each site, which are consistent with surface wind flow patterns that follow the terrain. The divergent patterns in the trajectories initiated from 500 m to 1000 m agl highlight the complex transport dynamics that can contribute to elevated ozone at sites that drive attainment in the South Coast.

To illustrate these patterns, maps of the trajectories constructed for 2020 high ozone exceedance days at high ozone sites in the South Coast are shown in Figure 9.

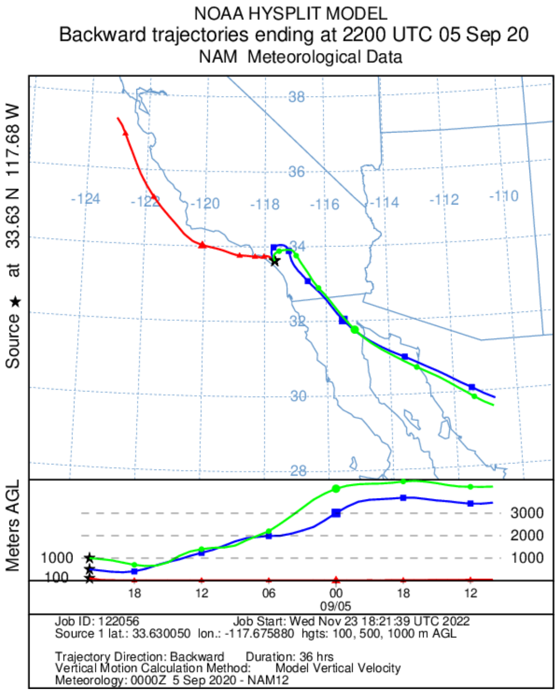
Meeting the 0.070 ppm ozone standard is a complex challenge in the South Coast. A diverse suite of precursor emissions results from a large and densely populated urban core. The area is characterized by complex terrain, which limits dispersion and effectively traps emissions in the South Coast. Meteorological conditions are dominated by a semi-permanent high-pressure system, which exacerbates the trapping effect of the local terrain, and a thermally driven sea breeze circulation serves to routinely transport emissions from the coastal areas to inland areas as well as recirculate emissions in the South Coast. State of the art photochemical modeling, supported by extensive monitoring and research efforts, indicates that the path towards attainment of the 0.070 ppm ozone standard is with a NOx-focused control strategy.

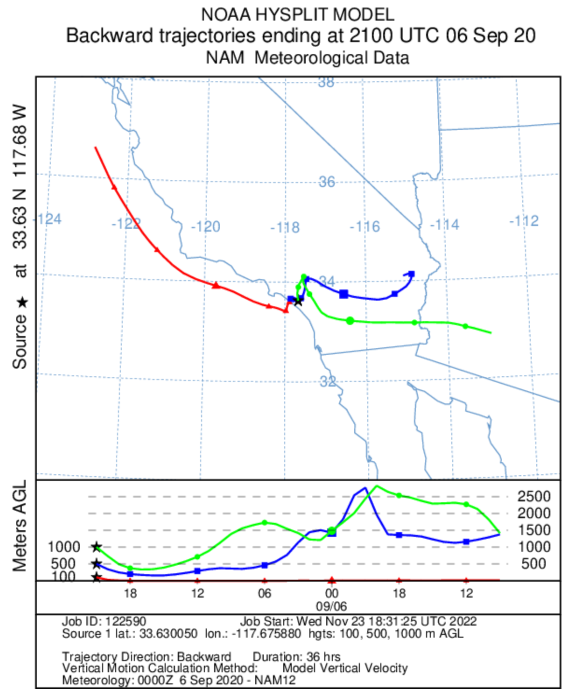
Figure 9. 36-hour Back Trajectories at Time of Peak Ozone Concentration on 2020 High Ozone Days at High Ozone Sites in each County of South Coast

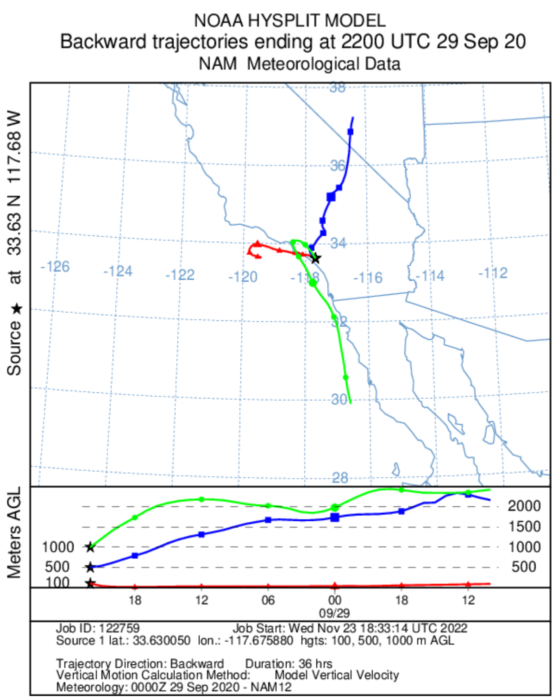
1) Pico Rivera

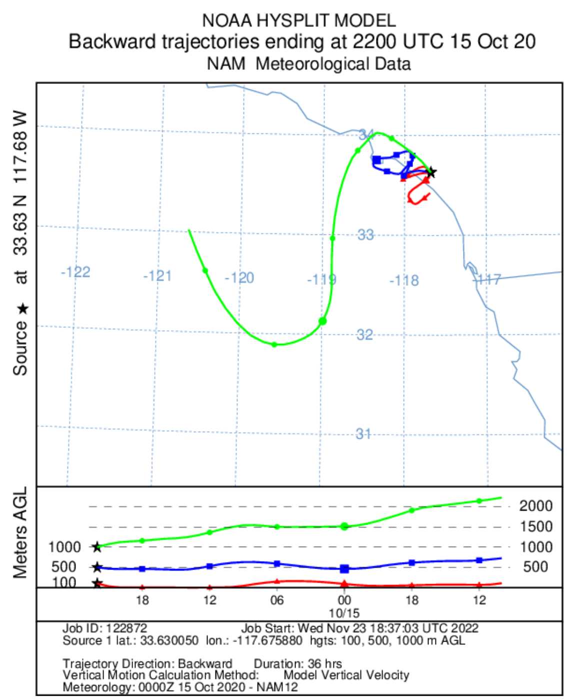


2) Mission Viejo

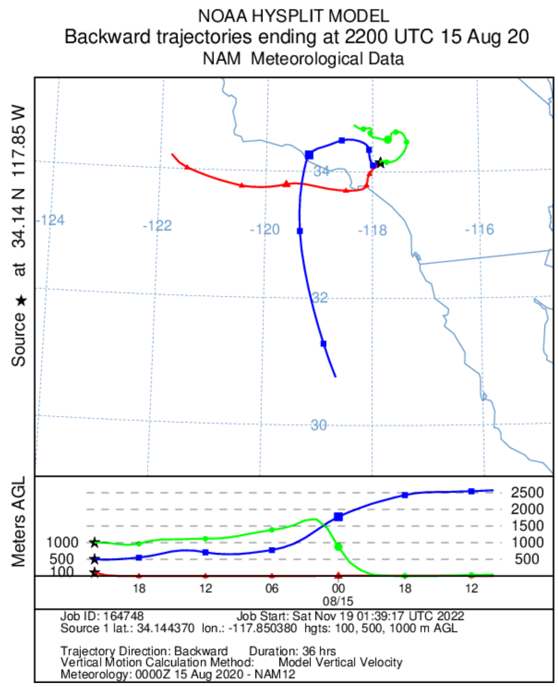




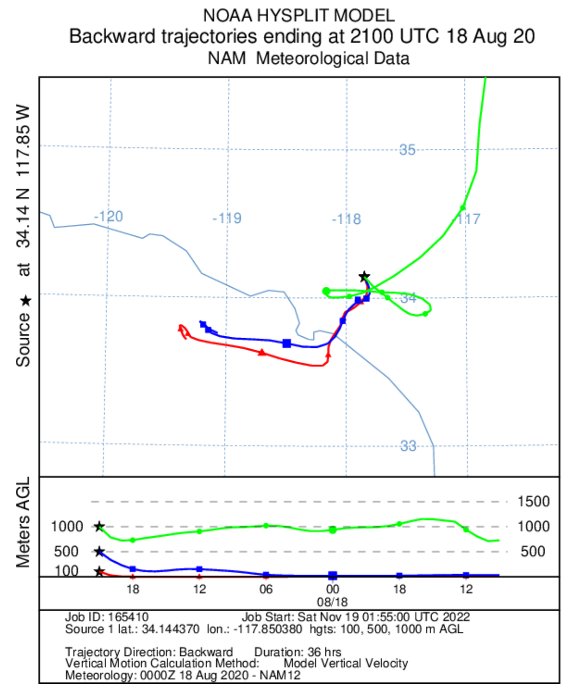




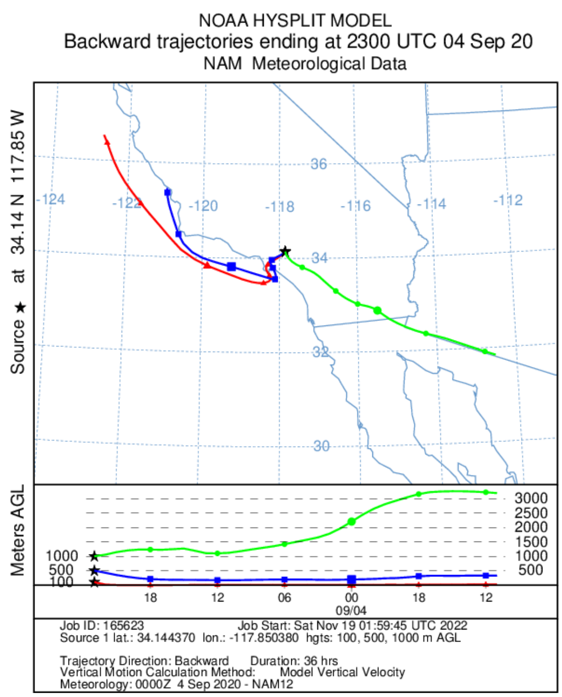
3) Glendora



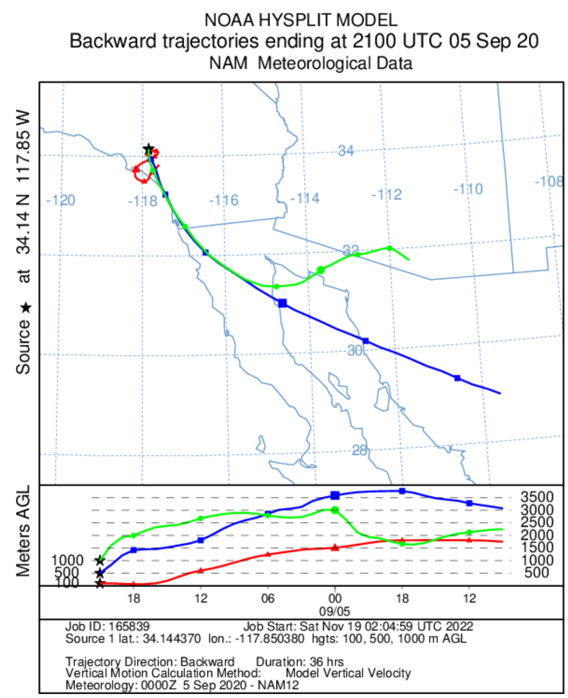
NOAA HYSPLIT MODEL
Backward trajectories ending at 2200 UTC 15 Aug 20
NAM Meteorological Data
Source ★ at 34.14 N 117.85 W
Meters AGL
08/15
Job ID: 164748 Job Start: Sat Nov 19 01:39:17 UTC 2022
Source 1 lat.: 34.144370 lon.: -117.850380 hgts: 100, 500, 1000 m AGL
Trajectory Direction: Backward Duration: 36 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 15 Aug 2020 - NAM12



NOAA HYSPLIT MODEL
Backward trajectories ending at 2100 UTC 18 Aug 20
NAM Meteorological Data
Source ★ at 34.14 N 117.85 W
Meters AGL
08/18
Job ID: 165410 Job Start: Sat Nov 19 01:55:00 UTC 2022
Source 1 lat.: 34.144370 lon.: -117.850380 hgts: 100, 500, 1000 m AGL
Trajectory Direction: Backward Duration: 36 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 18 Aug 2020 - NAM12

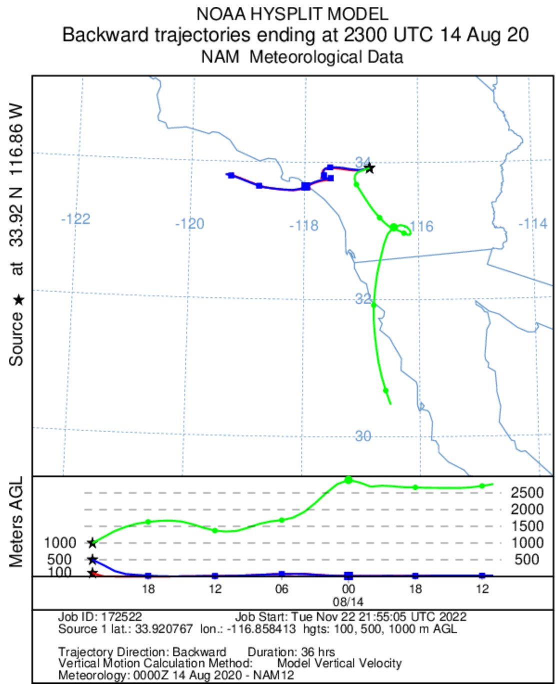


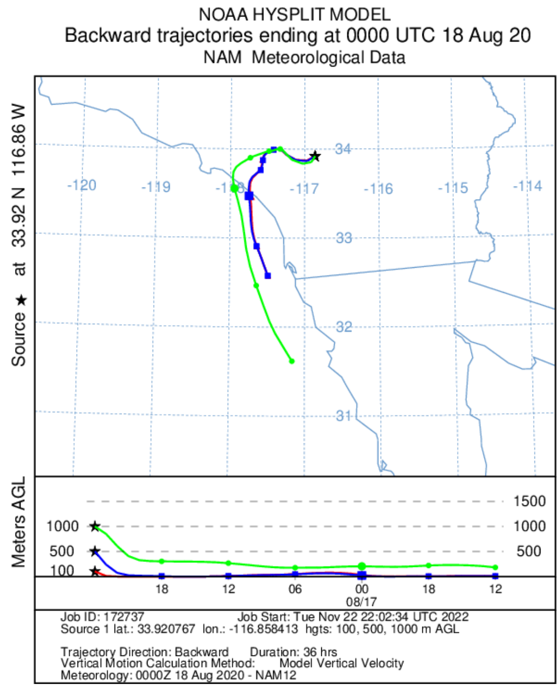
NOAA HYSPLIT MODEL
Backward trajectories ending at 2300 UTC 04 Sep 20
NAM Meteorological Data
Source ★ at 34.14 N 117.85 W
Meters AGL
09/04
Job ID: 165623 Job Start: Sat Nov 19 01:59:45 UTC 2022
Source 1 lat.: 34.144370 lon.: -117.850380 hgts: 100, 500, 1000 m AGL
Trajectory Direction: Backward Duration: 36 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 4 Sep 2020 - NAM12



NOAA HYSPLIT MODEL
Backward trajectories ending at 2100 UTC 05 Sep 20
NAM Meteorological Data
Source ★ at 34.14 N 117.85 W
Meters AGL
09/05
Job ID: 165839 Job Start: Sat Nov 19 02:04:59 UTC 2022
Source 1 lat.: 34.144370 lon.: -117.850380 hgts: 100, 500, 1000 m AGL
Trajectory Direction: Backward Duration: 36 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 5 Sep 2020 - NAM12

4) Banning


NOAA HYSPLIT MODEL
Backward trajectories ending at 2300 UTC 14 Aug 20
NAM Meteorological Data
Source ★ at 33.92 N 116.86 W
Meters AGL
Job ID: 172522 Job Start: Tue Nov 22 21:55:05 UTC 2022
Source 1 lat.: 33.920767 lon.: -116.858413 hgts: 100, 500, 1000 m AGL
Trajectory Direction: Backward Duration: 36 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 14 Aug 2020 - NAM12


NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 18 Aug 20
NAM Meteorological Data
Source ★ at 33.92 N 116.86 W
Meters AGL
Job ID: 172737 Job Start: Tue Nov 22 22:02:34 UTC 2022
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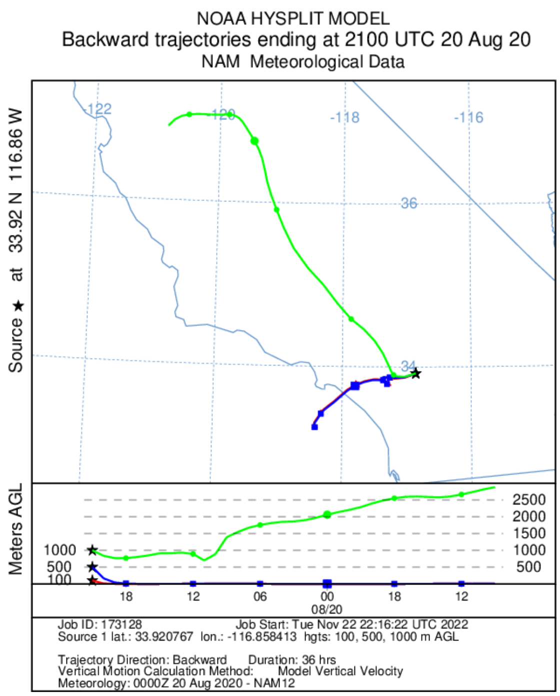
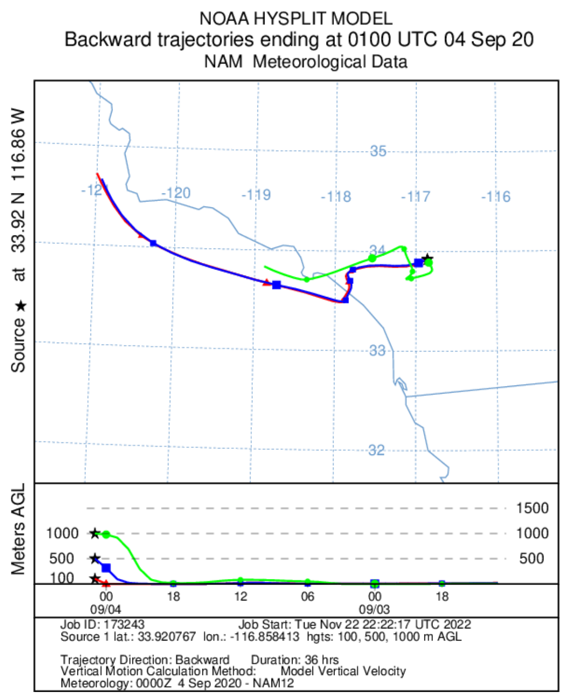
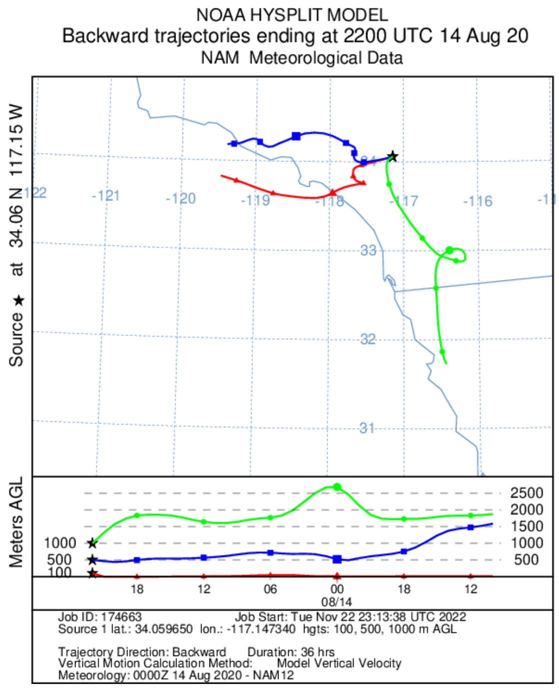
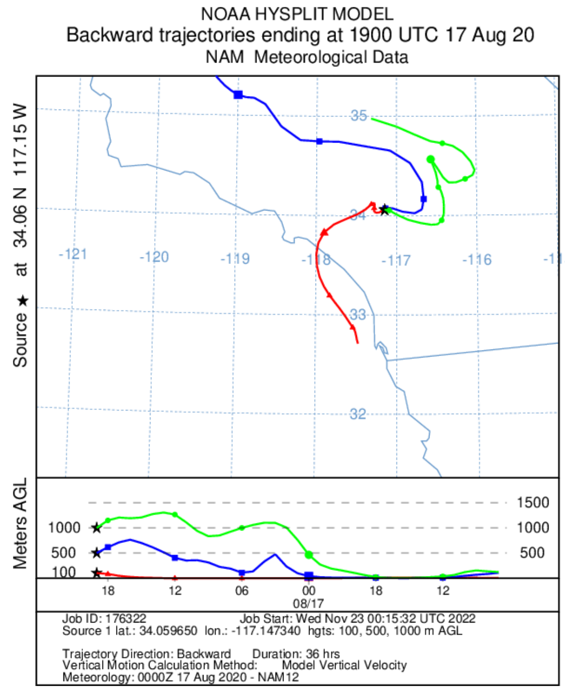
Trajectory Direction: Backward Duration: 36 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 18 Aug 2020 - NAM12

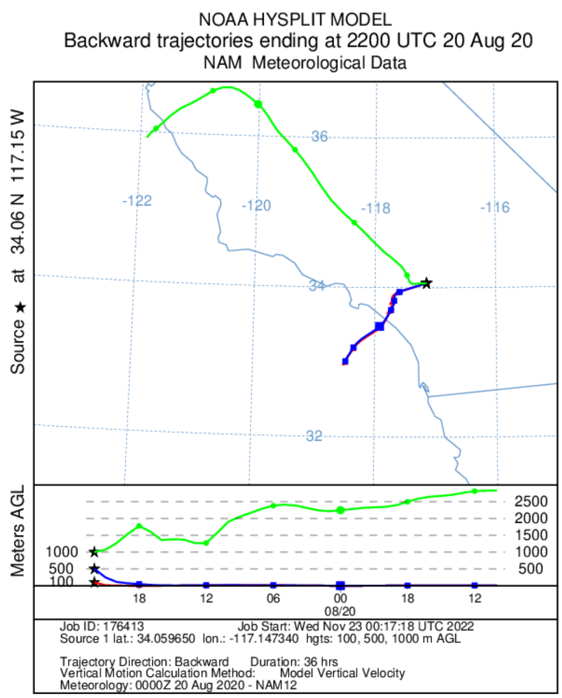

NOAA HYSPLIT MODEL
Backward trajectories ending at 2100 UTC 20 Aug 20
NAM Meteorological Data
Source ★ at 33.92 N 116.86 W
Meters AGL
Job ID: 173128 Job Start: Tue Nov 22 22:16:22 UTC 2022
Source 1 lat.: 33.920767 lon.: -116.858413 hgts: 100, 500, 1000 m AGL
Trajectory Direction: Backward Duration: 36 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 20 Aug 2020 - NAM12

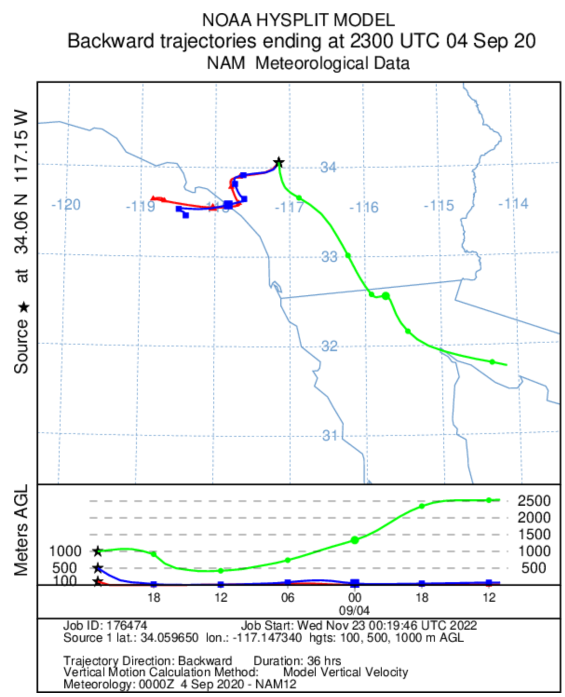

NOAA HYSPLIT MODEL
Backward trajectories ending at 0100 UTC 04 Sep 20
NAM Meteorological Data
Source ★ at 33.92 N 116.86 W
Meters AGL
Job ID: 173243 Job Start: Tue Nov 22 22:22:17 UTC 2022
Source 1 lat.: 33.920767 lon.: -116.858413 hgts: 100, 500, 1000 m AGL
Trajectory Direction: Backward Duration: 36 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 4 Sep 2020 - NAM12

5) Redlands







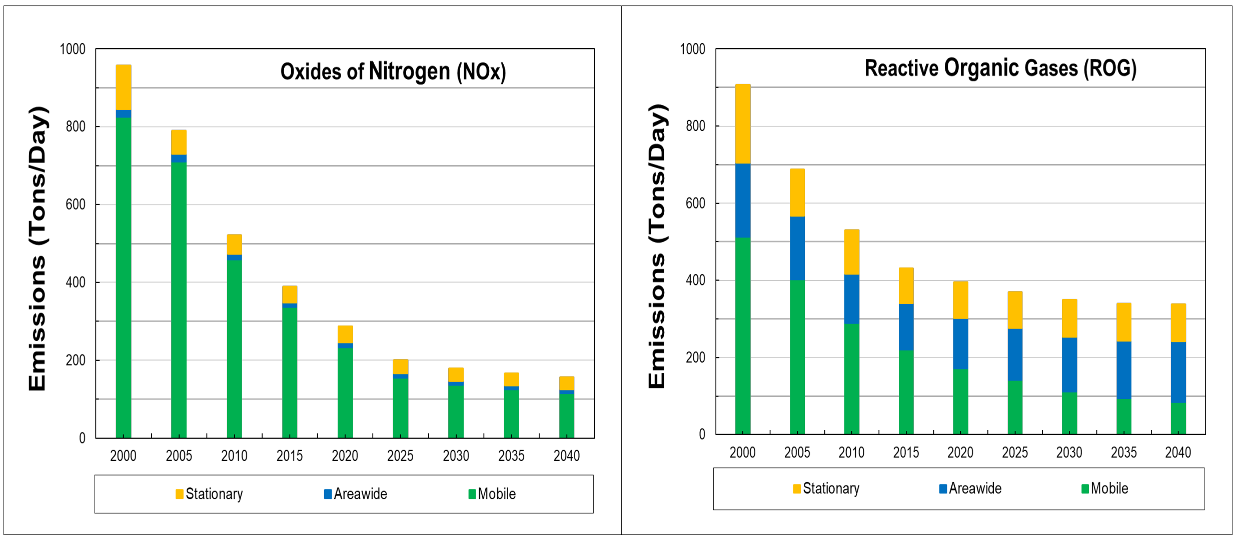


Anthropogenic Emissions

Data from the CARB 2022 Ozone SIP Inventory for Summer were used to evaluate trends in anthropogenic emissions of ozone precursors, NOx and ROG. Federal, State, and local programs have yielded significant overall reductions in emissions of ozone precursors in the South Coast. Most recently, between 2000 and 2020, the South Coast achieved substantial reductions in ozone precursor emissions (Figure 10), namely:

- Total NOx emissions declined by 70 percent; and
- Total ROG emissions declined by 56 percent.

Figure 10: Summer Emissions in the South Coast



Data Source: CARB 2022 Ozone SIP Planning Tool v1.01 with External Adjustment

Between 2000 and 2020, the top three NOx emission inventory subcategories were light-duty automobiles, heavy heavy-duty diesel trucks, and off-road equipment, whereas the top three ROG emission inventory subcategories during this period were light-duty automobiles, consumer products, and off-road equipment. The range of emission sources, for the top ROG subcategories, highlights the complexity of emission sources in the South Coast. However, consistent with the dense population and extensive network of roads, mobile sources dominate the emission inventories of ozone precursors. The emissions inventory indicates that mobile sources accounted for 81 percent of NOx emissions and 43 percent of ROG emissions in 2020.

In 2000, the largest mobile source subcategories for NOx emissions in South Coast were light-duty automobiles, heavy heavy-duty diesel trucks, off-road equipment, and light-duty trucks (Figure 11). Between 2000 and 2020, NOx emissions from light-duty automobiles declined by 90 percent, whereas NOx emissions from heavy heavy-duty diesel trucks, off-road equipment, and light-duty trucks declined by 68 percent, 70 percent, and 87 percent, respectively.

Going forward from 2020, current control programs will further reduce emissions by 2037, namely:

- Total NOx emissions will decline an additional 44 percent; and

- Total ROG emissions will decline an additional 14 percent.

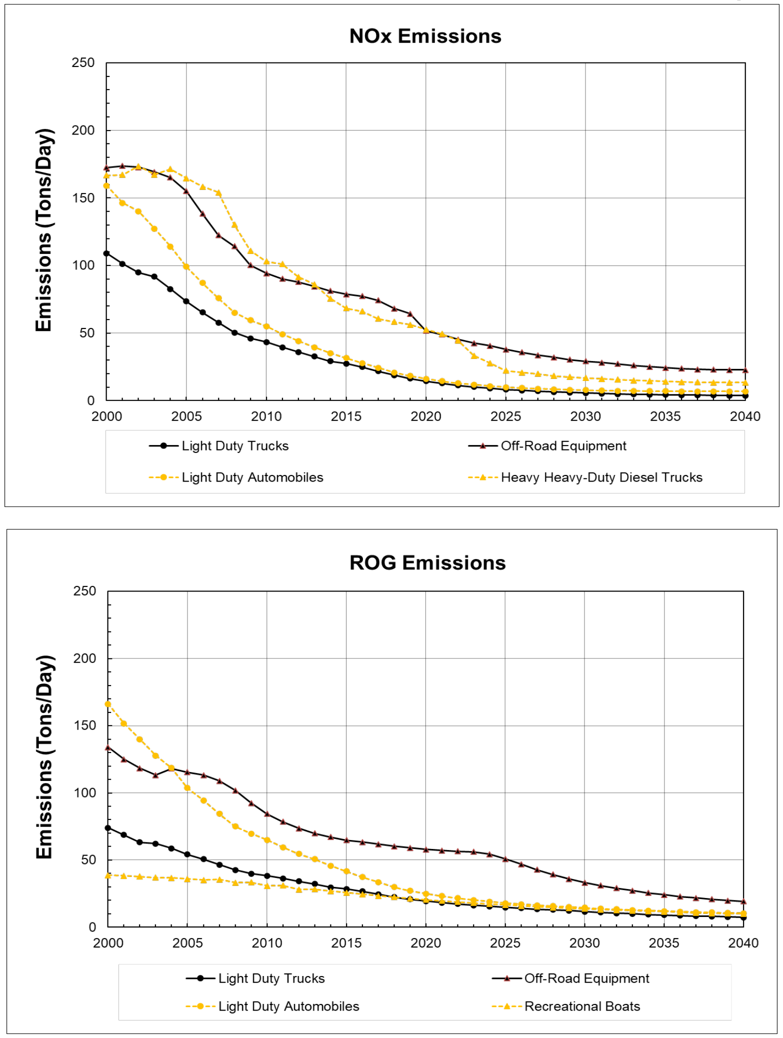
Comparing these future reductions to those obtained between 2000 and 2020, both NOx and ROG reduction rates are slowing, but the NOx reductions will be much greater than those for ROG. This supports the concept that the South Coast is expected to transition to a NOx-limited ozone production regime and that NOx control strategies will be the most effective at reducing ambient ozone concentrations.

On a sector basis, due to the implementation of adopted control measures, by 2037, projections indicate that NOx emissions from light-duty automobiles, heavy heavy-duty diesel trucks, off-road equipment, and light-duty trucks will decline from 2020 levels by an additional 57 percent, 74 percent, 55 percent, and 72 percent, respectively.

Most of the declines projected between 2020 and 2037 will occur prior to 2025. With the implementation of the final increment of the truck and bus rule, a sharp decline in heavy heavy-duty truck emissions is expected between 2022 and 2025. However, following 2025, projections indicate that the rate of decline for these mobile source sectors will slow without additional control programs. Furthermore, projections indicate that by 2025, heavy heavy-duty diesel trucks and off-road equipment will represent the top two mobile source categories, and in 2037, will collectively account for more than 60 percent of the 60 tons/day NOx carrying capacity estimated by the District as necessary to meet a 0.070 ppm standard in the South Coast.

Within the ROG mobile source category, light-duty passenger automobiles, light-duty trucks, off-road equipment, and recreational boats account for the largest quantities of ROG emissions. As shown in Figure 11, between 2000 and 2020, ROG emissions declined across these categories with reductions amounting to 85 percent for light-duty automobiles, 74 percent for light-duty trucks, 57 percent for off-road equipment, and 47 percent for recreational boats. Between 2020 and 2037, ROG emissions are projected to continue to decline. In 2037, projections indicate that ROG emissions will be 55 percent, 57 percent, 62 percent, and 48 percent lower than 2020 levels for light-duty automobiles, light-duty trucks, off-road equipment, and recreational boats, respectively.

Figure 11: Summer Emissions in the South Coast Air Basin, 2000-2040

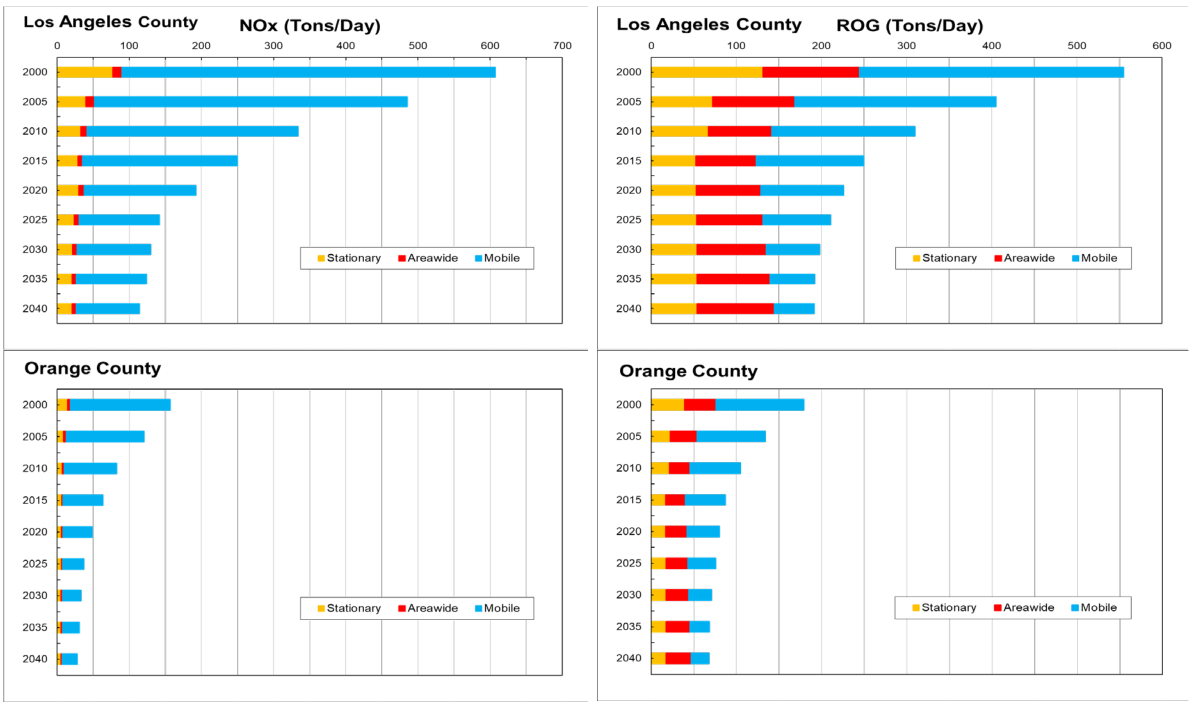


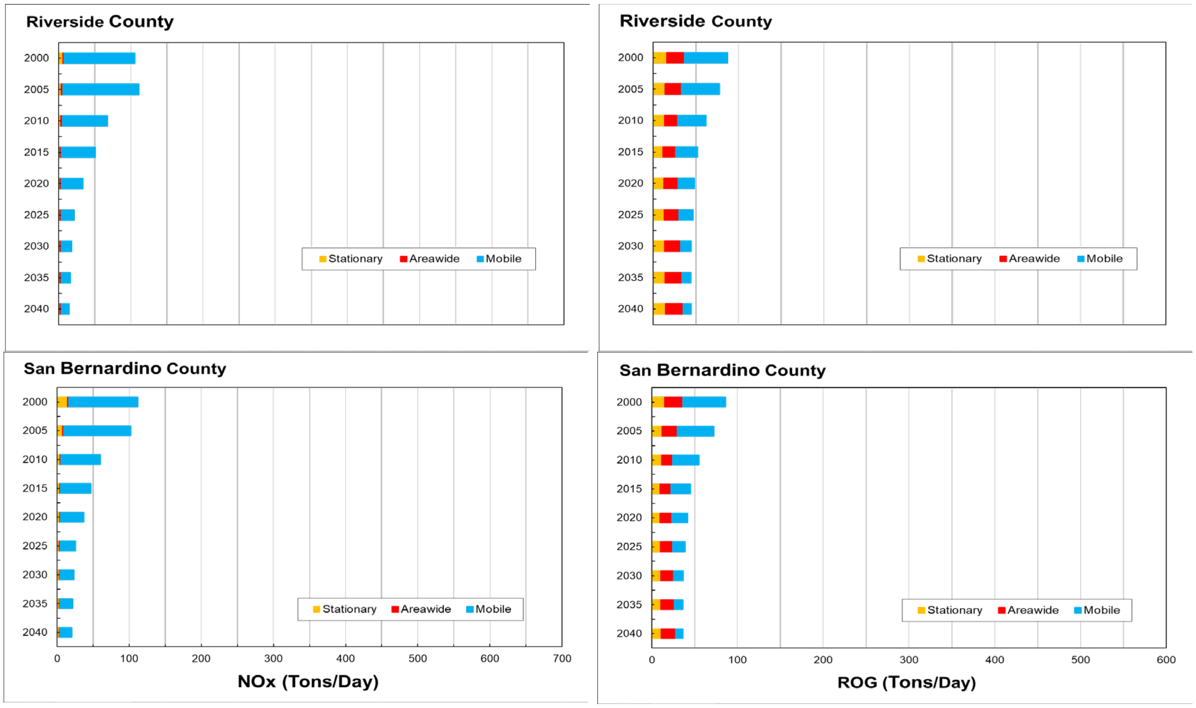
Data Source: CARB 2022 Ozone SIP Planning Tool v1.01 with External Adjustment

On a sub-Basin scale, the Los Angeles County portion of South Coast accounts for the largest portion of NOx and ROG emissions, followed by Orange County, and the South Coast portions of Riverside and San Bernardino Counties (Figure 12). From 2000 to 2040, Los Angeles County NOx emissions were more than three times greater than emissions in other counties in South Coast, whereas ROG emissions in Los Angeles County were more than double those in other South Coast counties. Besides, NOx and ROG emissions declined in all counties between 2000 and 2040; and the magnitude of decline was largest in the Los Angeles County portion of South Coast. Like the Basin-wide emissions inventory, mobile sources dominate the county-level inventories of NOx and ROG emissions. Projections through 2037, shown in Figure 12, indicate that mobile sources will continue to dominate the NOx inventory, whereas stationary, areawide, and mobile sources will make nearly equal contributions to the ROG inventory in all counties.

The county-level differences in emissions in Figure 12 are consistent with the spatial distribution of emissions derived from satellite observations and regional chemical transport modeling. Regional modeling shown in Figure 13 highlights the dominance of Los Angeles County emissions in the South Coast emissions inventory and indicates that peak emission areas for NOx and ROG are closely aligned with the major freeways throughout coastal Los Angeles County and western Orange County. As discussed earlier, prevailing westerly winds provide a persistent mechanism by which emissions from these areas are routinely transported inland, disproportionately promoting elevated ozone at sites downwind of these peak emission areas.

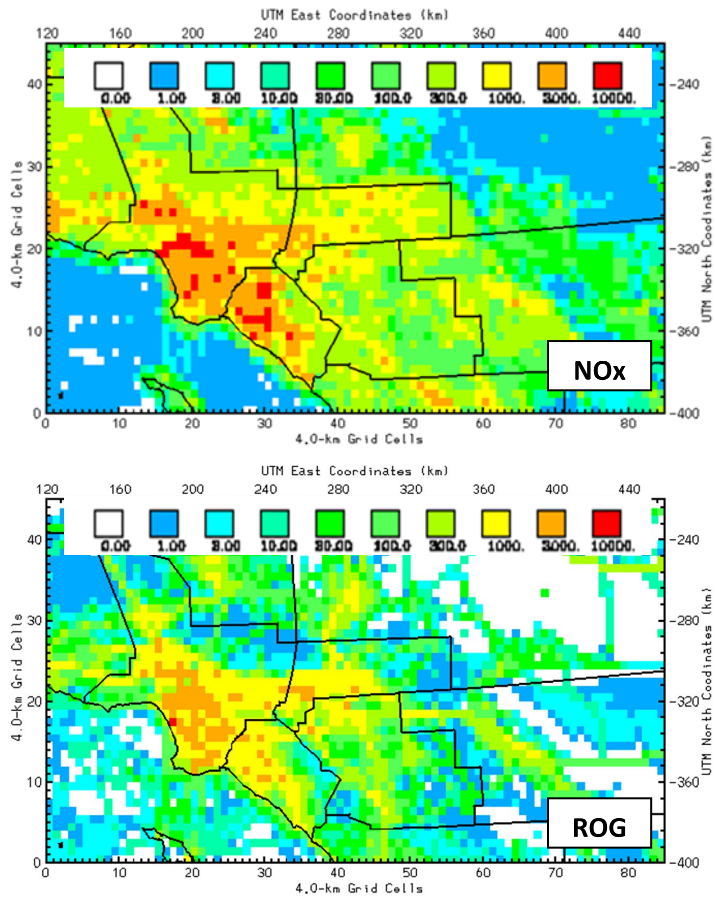
Figure 12: County-Level Summer Emissions in the South Coast Air Basin





Data Source: CARB 2022 Ozone SIP Planning Tool v1.01 with External Adjustment

Figure 13: Spatial Distribution of the Rate of NOx (top) and ROG (bottom) Emissions on a Summer Weekday in the South Coast Air Basin

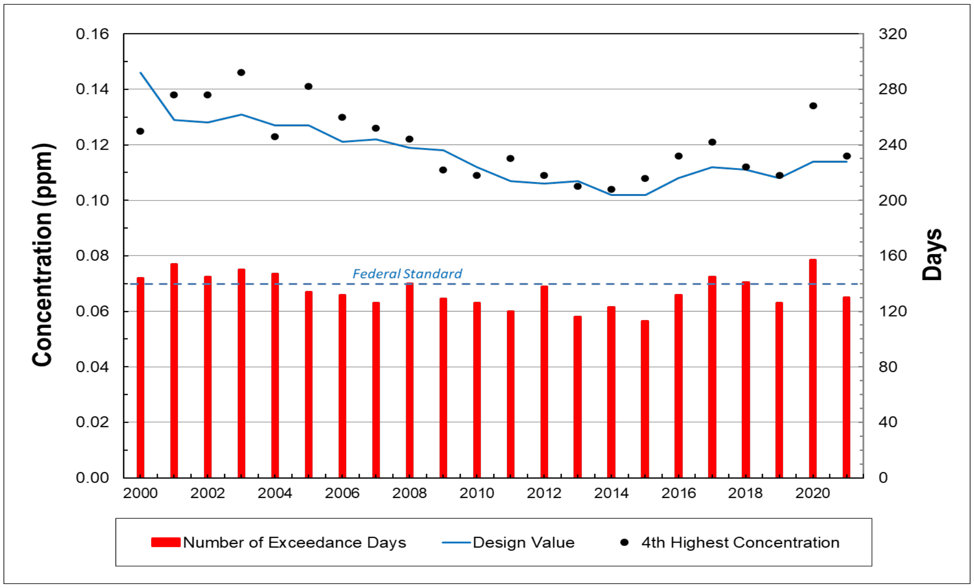


Data source: CMAQ Modeling by ARB staff for July 25, 2012, at 1300. Emissions rate is in g-mole/sec.

Ozone Air Quality

Ozone air quality has improved slightly in the South Coast over the last 20 years, as shown in Figure 14. Between 2001 and 2020, the South Coast's 8-hour ozone design value decreased by 12 percent, from 0.129 ppm to 0.114 ppm. During this same period, the annual fourth highest daily maximum average 8-hour ozone concentration decreased by only 3 percent, from a high of 0.138 ppm in 2001, to 0.134 ppm in 2020. Whereas, in 2020, the 0.070 ppm standard was exceeded in South Coast on 157 days, a 3 days increase from 2001 when the standard was exceeded on 154 days.

Figure 14: Basinwide Ozone Air Quality in the South Coast Air Basin



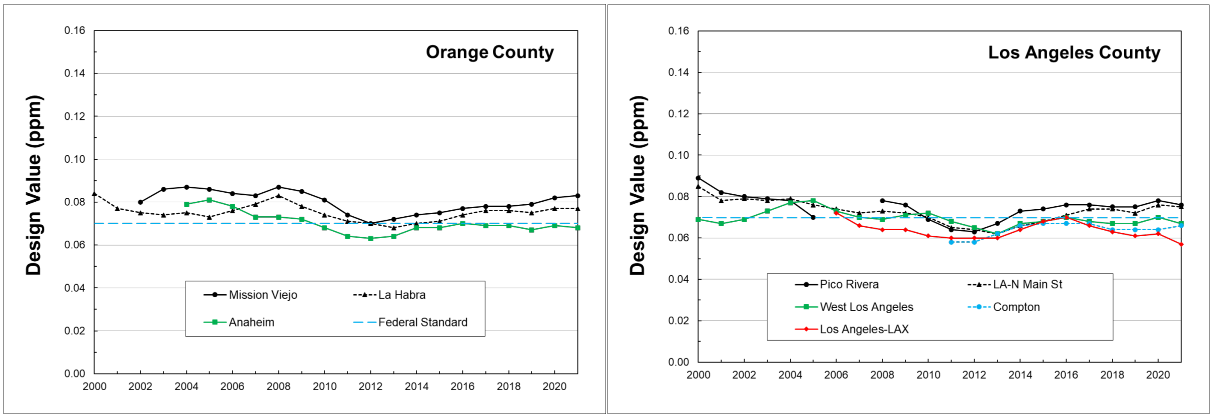
Ozone Design Values

The design value is the metric that can be directly compared to the federal ozone standard for the purposes of determining attainment status. The following section will focus on long-term trends in ozone design value concentrations throughout the South Coast. In addition, the spatial variability of air quality and population exposure is examined to provide insight on the extent of progress and challenges towards attainment.

As previously discussed, ozone air quality in the South Coast varies between the coastal and inland areas. In the coastal area, 2020 design values met the 0.070 ppm standard at four of eight sites, and exceeded the federal standard at other four sites with values ranginging from 0.062 to 0.082 ppm. In the inland area, 2020 design values at all sites exceeded the 0.070 ppm standard with values ranging from 0.088 to 0.107 ppm in the inland area of Los Angeles County, 0.078 to 0.099 ppm in Riverside County, and 0.102 to 0.114 ppm in San Bernardino County. Between 2001 and 2020, ozone design values generally followed a decreasing trend at most sites in the South Coast from 2000 to the period around 2012 - 2014, then slightly increased until recent years.

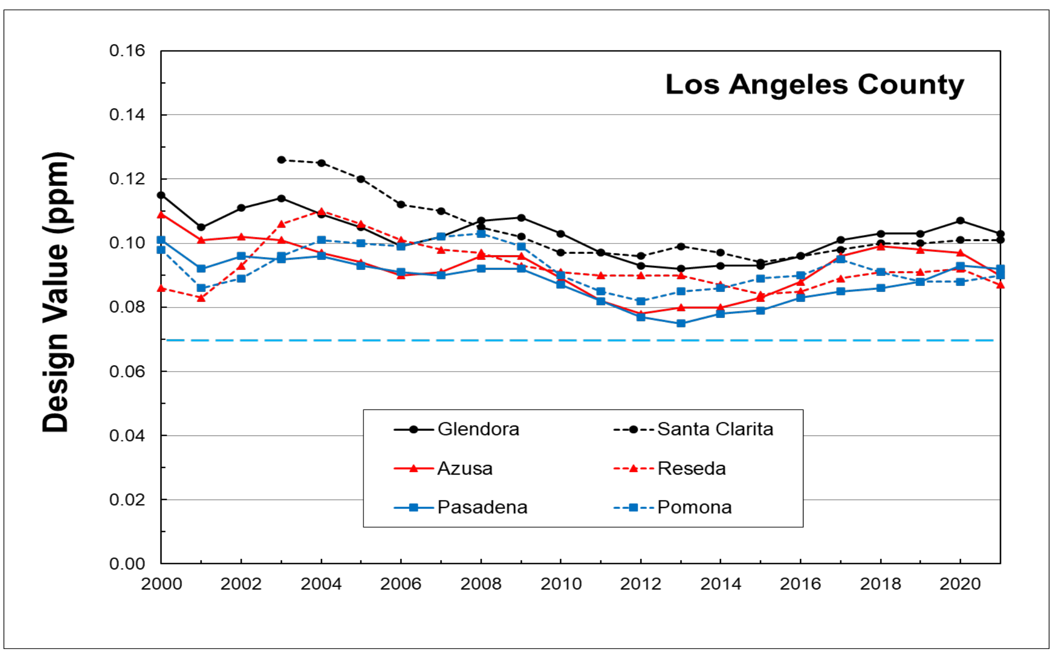
In the coastal area, there was not a significant change in ozone design values at most sites between 2000 and 2021 (Figure 15). At two sites, Pico Rivera and Los Angeles-N Main St, design values decreased significantly during this period, at a rate of 0.0006 and 0.0005 ppm per year, respectively.

Figure 15: 2000-2021 Design Values at Sites in the South Coast Coastal Area



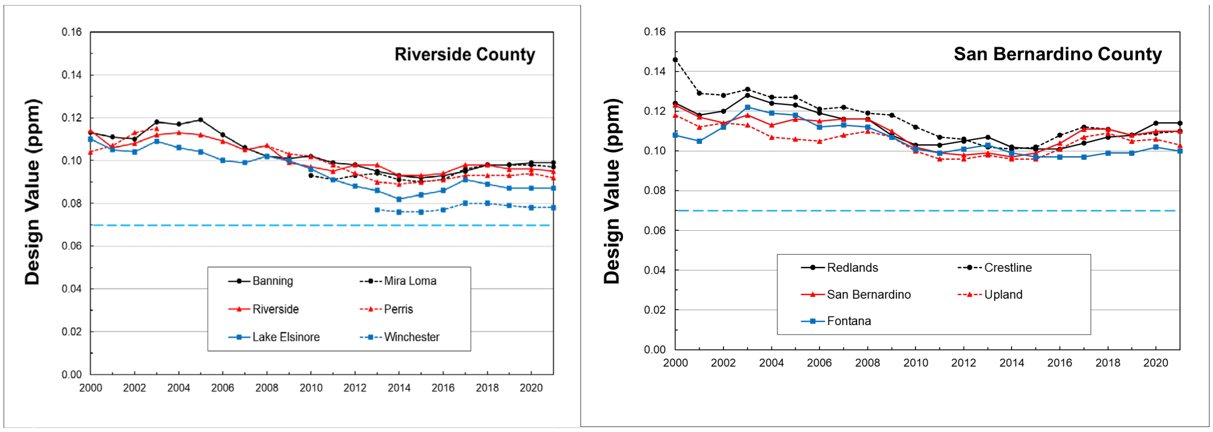
In the inland areas, ozone design values showed an overall decrease at most sites between 2000 and 2020 (Figure 16). At Pasadena, Glendora, Azusa, and Pomona, inland sites in Los Angeles County, the decrease in design values ranged from an average of 0.0004 ppm per year at Glendora to 0.0006 ppm per year at Azusa. Whereas the ozone design value at Reseda increased from 0.086 ppm in 2000 to 0.092 ppm in 2020. Ozone design value at Glendora showed a moderate decline from 0.115 ppm in 2000 to 0.107 ppm in 2020. Photochemical modeling analyses conducted by the District indicate that Glendora will be the design site in the year leading up to the attainment deadline, suggesting that attainment will be most challenging at Glendora.

Figure 16: 2000-2021 Design Values at Sites in Inland Los Angeles County



In Riverside County, design values decreased between 0.0005 and 0.0012 ppm per year, at Banning, Riverside-Rubidoux, Perris, and Lake Elsinore (Figure 17). There was not a significant trend in ozone design values at the Mira Loma and Winchester sites. Design values decreased significantly at all five sites in San Bernardino County, ranging from an average of 0.0003 ppm per year at Fontana to 0.0019 ppm per year at Crestline.

Figure 17: 2000-2021 Design Values at Sites in Riverside and San Bernardino Counties



As shown in Figures 15-17, ozone design values significantly decreased at many South Coast sites between 2000 and 2015. However, this decreasing trend slowed down or even reversed since middle 2010's at almost all sites in the South Coast. As shown in Table 2, the ozone design values decreased from 2000 to 2020 at all sites except Reseda and West Los Angeles. But from 2016 to 2020, the ozone design values increased at most sites, especially at inland sites.

This recent slowing of progress at many monitoring sites may be indicative of a shift to a transitional ozone production regime across a broad spatial scale. Given the non-linear nature of this transition, past trends are not a good indicator for projecting the pace of future progress due to the continuing implementation of new rules and regulations to reduce emissions.

Table 2: Average Change in Design Values at Sites in the South Coast

Site Name	County	2000 Design Value (ppm)	2016 Design Value (ppm)	2017 Design Value (ppm)	2018 Design Value (ppm)	2019 Design Value (ppm)	2020 Design Value (ppm)	2016-2020 Average Change (ppm/year)	2000-2020 Average Change (ppm/year)
Anaheim	ORA	0.072	0.070	0.069	0.069	0.067	0.069	-0.0003	-0.0001
Mission Viejo	ORA	No data	0.077	0.078	0.078	0.079	0.082	0.0013	-
La Habra	ORA	0.084	0.074	0.076	0.076	0.075	0.077	0.0008	-0.0004

West Los Angeles	LA	0.069	0.070	0.068	0.067	0.067	0.070	0.0000	0.0001
LA-N Main St	LA	0.085	0.071	0.074	0.074	0.072	0.076	0.0013	-0.0005
Compton	LA	No data	0.067	0.067	0.064	0.064	0.064	-0.0008	-
Pico Rivera	LA	0.089	0.076	0.076	0.075	0.075	0.078	0.0005	-0.0006
Long Beach	LA	No data	0.057	0.057	0.056	0.056	No data	-	-
Los Angeles-LAX	LA	No data	0.070	0.066	0.063	0.061	0.062	-0.0020	-
Azusa	LA	0.109	0.088	0.096	0.099	0.098	0.097	0.0023	-0.0006
Glendora	LA	0.115	0.096	0.101	0.103	0.103	0.107	0.0028	-0.0004
Reseda	LA	0.086	0.085	0.089	0.091	0.091	0.092	0.0018	0.0003
Pomona	LA	0.098	0.090	0.095	0.091	0.088	0.088	-0.0005	-0.0005
Pasadena	LA	0.101	0.083	0.085	0.086	0.088	0.093	0.0025	-0.0004
Santa Clarita	LA	No data	0.096	0.098	0.100	0.100	0.101	0.0013	-
Banning Airport	RIV	0.113	0.093	0.095	0.098	0.098	0.099	0.0015	-0.0007
Winchester	RIV	No data	0.077	0.080	0.080	0.079	0.078	0.0003	-
Perris	RIV	0.104	0.091	0.093	0.093	0.093	0.094	0.0008	-0.0005
Riverside-Rubidoux	RIV	0.114	0.094	0.098	0.098	0.096	0.096	0.0005	-0.0009
Mira Loma	RIV	No data	0.091	0.096	0.098	0.098	0.098	0.0018	-

Lake Elsinore	RIV	0.110	0.086	0.091	0.089	0.087	0.087	0.0003	-0.0012
Upland	SBD	0.118	0.101	0.107	0.109	0.105	0.106	0.0013	-0.0006
Fontana	SBD	0.108	0.097	0.097	0.099	0.099	0.102	0.0013	-0.0003
Redlands	SBD	0.124	0.101	0.104	0.107	0.108	0.114	0.0033	-0.0005
San Bernardino	SBD	0.123	0.104	0.111	0.111	0.108	0.110	0.0015	-0.0007
Crestline	SBD	0.146	0.108	0.112	0.111	0.108	0.109	0.0003	-0.0019

Yellow cells indicate decrease or no change in design value

Population Exposure

To provide a visual representation of ozone air quality throughout the South Coast, inverse distance weighting (IDW) was used to spatially interpolate design values. In 2000, the areas in the South Coast where design values were at or below the 0.070 ppm threshold were limited to a stretch of communities within 20 miles of the coast (Figure 18). However, ozone design values throughout the majority of the South Coast were well above the 0.070 ppm threshold, with most areas exceeding 0.084 ppm.

The improvement in ozone air quality in the South Coast between 2000 and 2020 is evident by the increase in the geographic area below the 0.070 ppm threshold shown in Figure 18, which extends throughout the coastal areas of Los Angeles County and most of Orange County. Areas where the design value was greater than 0.084 ppm were limited to pockets in the northeastern portion of Los Angeles County, northern Riverside County, and the South Coast portion of San Bernardino County.

Figure 18: Contour Maps of Design Values in the South Coast Air Basin

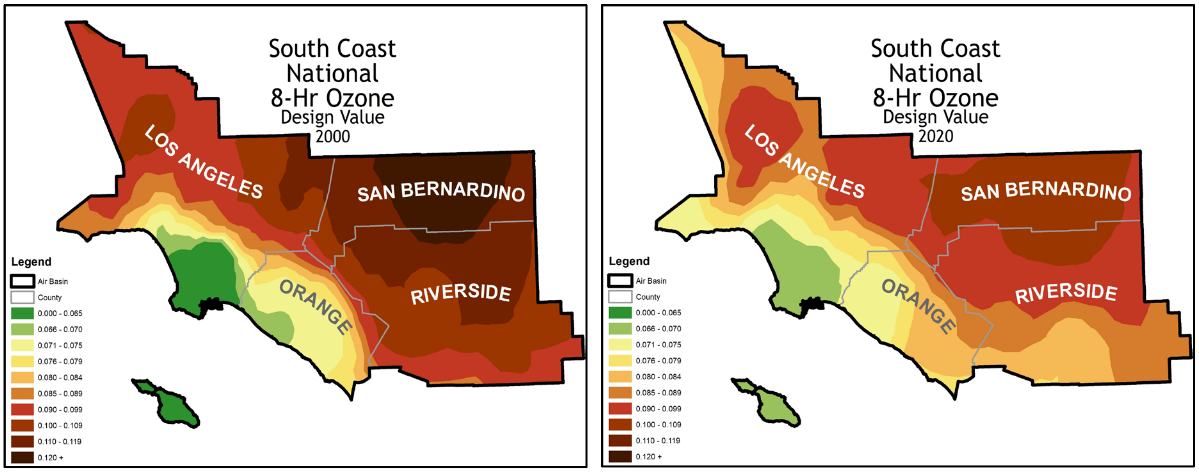
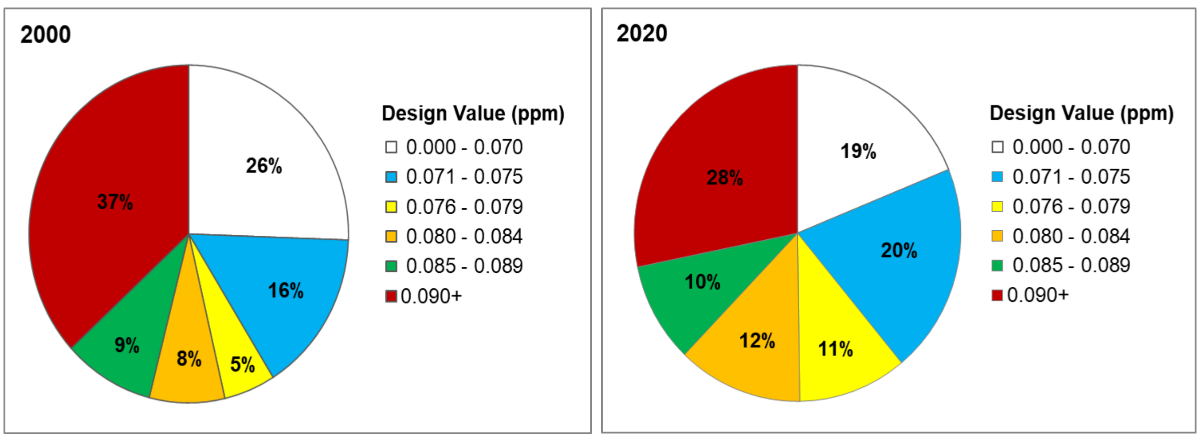


Figure 19: Population Exposure to Ozone in the South Coast Air Basin



Interpolated design values derived using IDW were overlaid with population census data to provide the quantitative estimates of population exposure in the South Coast shown in Figure 19. Though the percentage of the South Coast population who lived in areas where the ozone design values at or below the 0.070 ppm threshold decreased from 26 percent in 2000 to 19 percent in 2020, the percentage of population who lived in heavy polluted areas with ozone design values above 0.090 ppm also greatly reduced from 37 percent in 2000 to 28 percent in 2020. Besides, the percentage of population who lived in moderate polluted areas with ozone design values between 0.070 ppm and 0.085 ppm increased from 29 percent in 2000 to 43 percent in 2020.

Analysis of ozone design values provides a good deal of insight as to the status of compliance with the federal ozone standard. However, the design values offer a limited perspective of air quality progress in an area like the South Coast where the meteorological dynamics and emission regimes contributing to measured ozone are complex, and multiple sites experience dozens of exceedance days during a single year. Thus, looking beyond the design values provides a more thorough evaluation of the nature of progress and the factors that contribute to exceedances of air quality standards in an area.

Additional Indicators to Assess Progress

Top 25 Analysis

The relatively high frequency and large spatial extent of exceedance days in the South Coast add a key challenge to attainment compared to other areas in California. To complement the design value analysis, which indicated a widespread but moderate improvement in air quality from 2000 to 2020, the Top 25 daily maximum 8-hour average ozone concentrations averaged over a 5-year period of 2016 to 2020 were compared to those averaged during the 5-year period of 2001 to 2005.

The comparison of ranked values provides insight as to the extent to which the highest ozone concentrations are responding to control measures over time without relying on any assumptions regarding the distribution of the data. In Figures 20 through 24, markers below the zero-grid line indicate that 2016-2020 ranked concentrations were lower than 2001-2005 ranked concentrations. Conversely, markers above the zero-grid line indicate 2016-2020 concentrations were higher than 2001-2005 concentrations with the same rank. Markers on the zero-grid line indicate the same ozone concentrations in 2001-2005 and 2016-2020. In general, analyses indicate that concentrations on days in the upper end of the Top 25 improved more than the concentrations on days in the lower end of the Top 25.

In Orange County, ozone concentrations on the Top 25 days in 2016-2020 were slightly lower than in 2001-2005, at Anaheim, Costa Mesa, and Mission Viejo (Figure 20), indicating a slight improvement in ozone air quality. In contrast, at La Habra, ozone concentrations on the Top 25 days in 2016-2020 were generally higher than in 2001-2005, indicating a setback in ozone air quality at this site. Since most of the markers are close to the zero line, the changes in ozone air quality were generally small in this region.

In the coastal area of Los Angeles County, ozone concentrations on the Top 25 days in 2016-2020 were lower than in 2001-2005 at all three sites (Figure 21), indicating an improvement in ozone air quality in this coastal region. The improvement was larger at Los Angeles-LAX and West Los Angeles than at LA-N Main Street, as indicated by the distances from the corresponding markers to the zero line.

In inland Los Angeles County, ozone concentrations on the Top 25 days in 2016-2020 were lower than in 2001-2005 at all sites except Azusa (Figure 22), indicating the ozone air quality is improving at most sites of this region. The improvement was largest at Santa Clarita, followed by Reseda, then by Glendora, Pasadena, and Pomona with only moderate progress at these three sites, also indicated by the distances from the corresponding markers to the zero line.

At all monitoring sites in Riverside County, ozone concentrations on the Top 25 days in 2016-2020 were lower than in 2001-2005 (Figure 23). The improvement at Perris was moderate since its corresponding markers are below but near the zero line. The largest and most persistent improvements were at Banning, Lake Elsinore, and Rubidoux, which are among the eastern-most sites in the South Coast portion of the County.

In San Bernardino County, ozone concentrations on all Top 25 days at Crestline, Fontana, and Redlands were much lower in 2016-2020 than in 2001-2005 (Figure 24), indicating a large improvement at these sites. These three sites are also among the eastern-most sites in the South Coast. At the Upland and San Bernardino sites, the ozone air quality remained relatively unchanged since their corresponding markers were near the zero line.

Figure 20: Comparison of Top 25 days in 2001-2005 and 2016-2020 at Orange County Sites

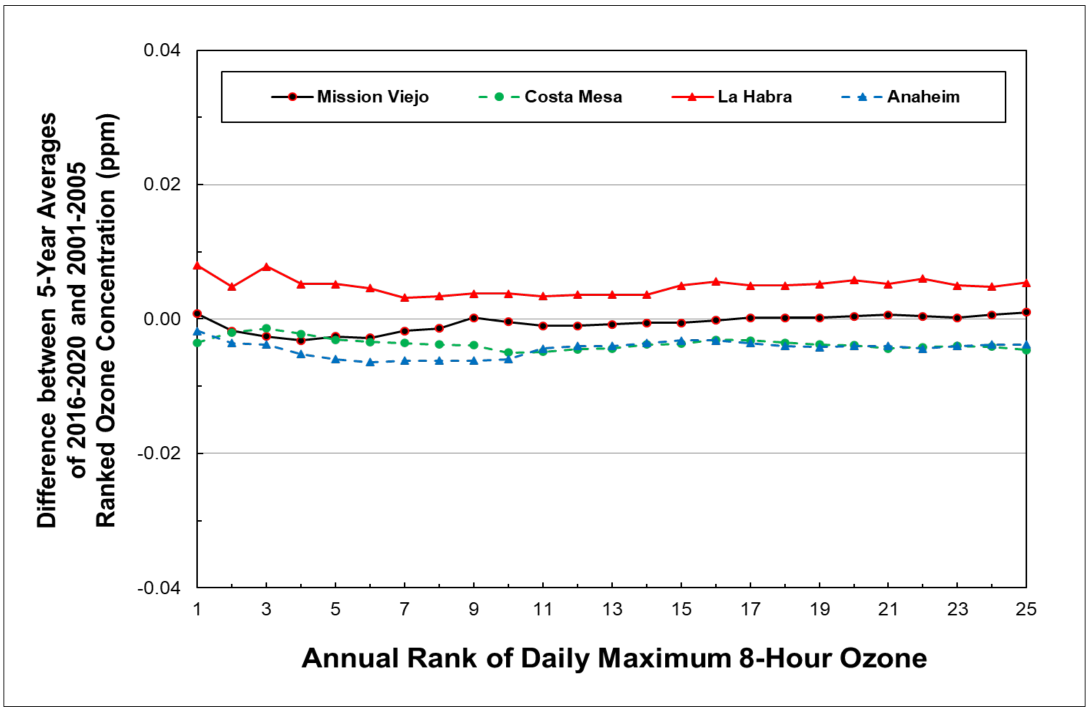


Figure 21: Comparison of Top 25 days in 2001-2005 and 2016-2020 at Coastal Los Angeles County Sites

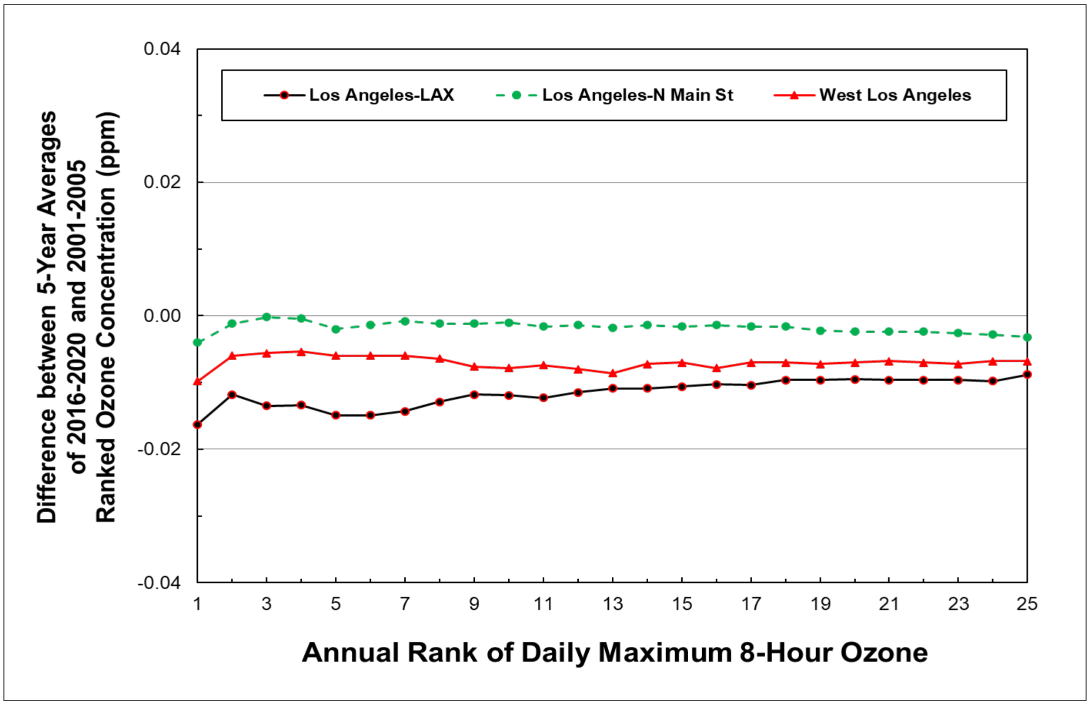


Figure 22: Comparison of Top 25 days in 2001-2005 and 2016-2020 at Inland Los Angeles County Sites

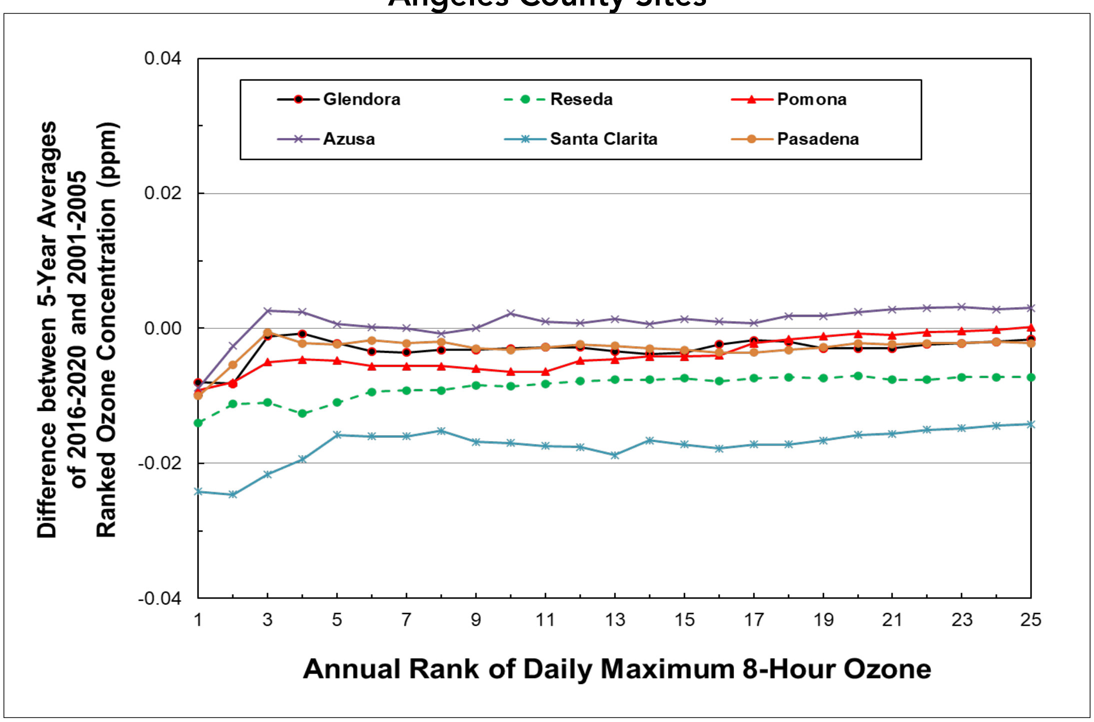


Figure 23: Comparison of Top 25 days in 2001-2005 and 2016-2020 at Riverside County Sites

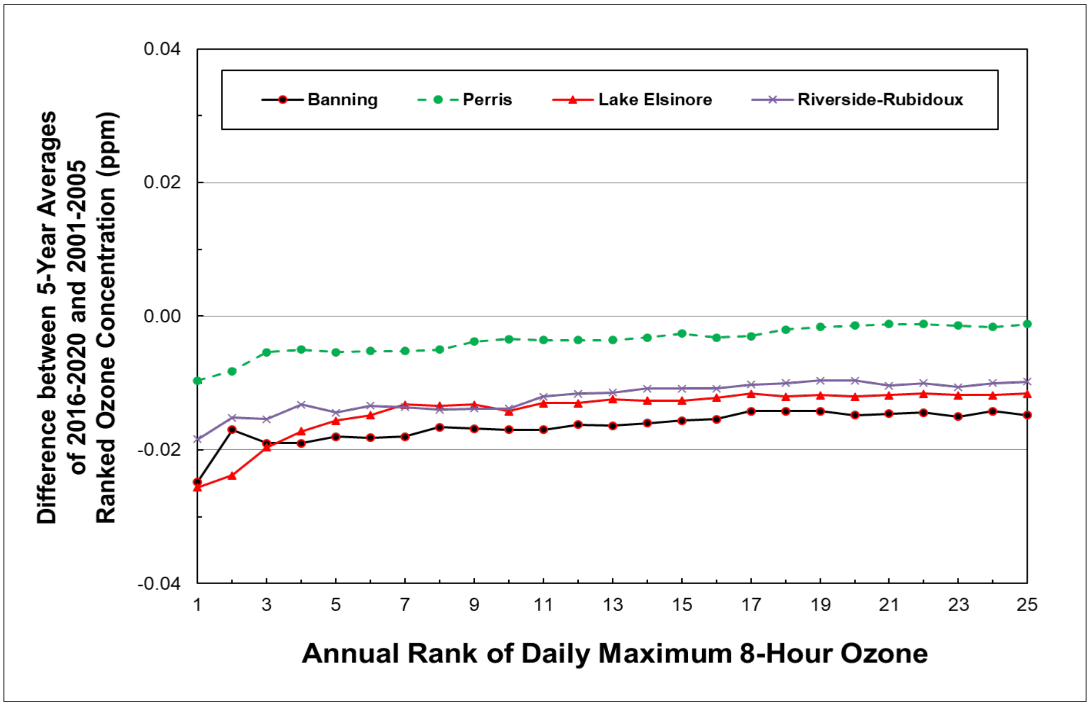
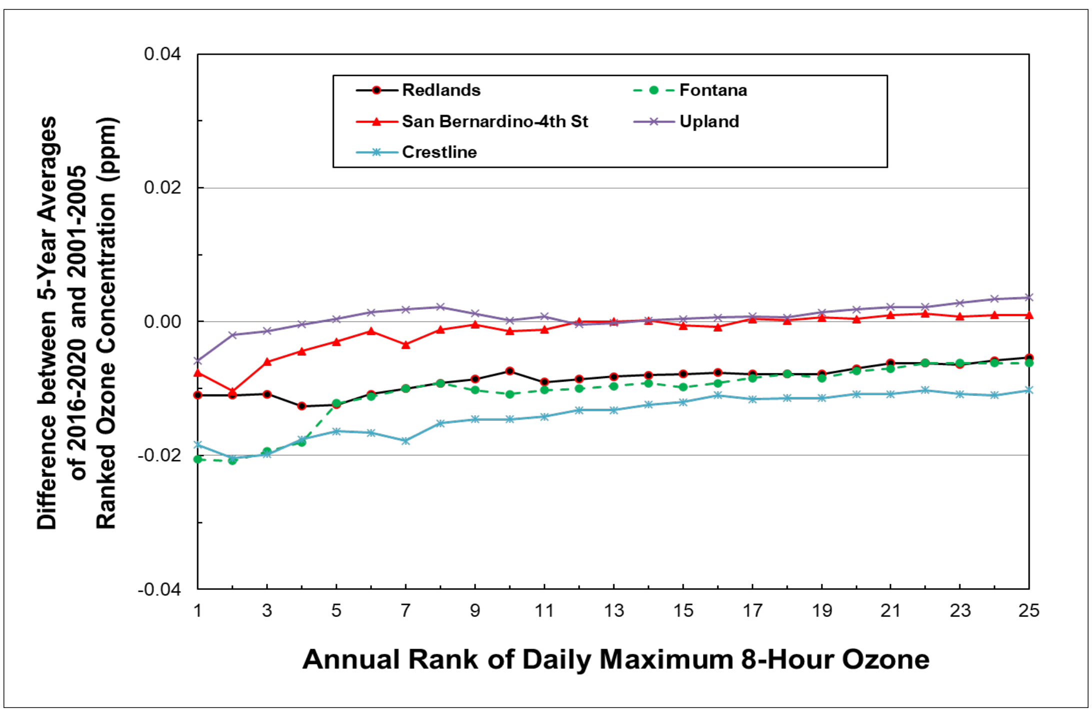


Figure 24: Comparison of Top 25 days in 2001-2005 and 2016-2020 at San Bernardino County Sites



Exceedance Days

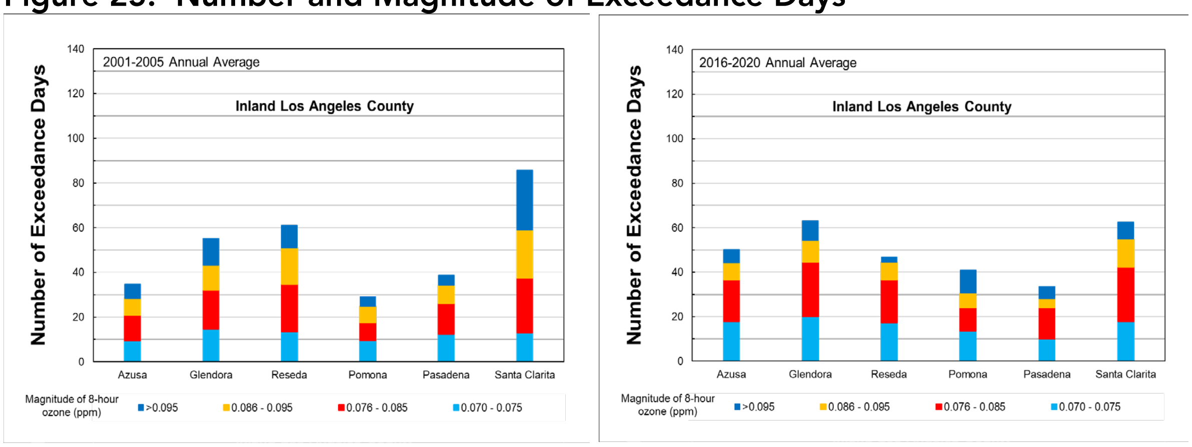
The extent of progress in the inland areas of the South Coast, in terms of reducing the number of exceedance days over the last 20 years, has varied among sites. Figure 25 presents the five-year averages of the number of exceedance days above the 0.070 ppm standard for different ozone concentration ranges at sites in the inland area. The sites in the coastal area are not included in Figure 25 due to the relatively low number of exceedance days; rather the sites shown are limited to those in the inland area of the South Coast.

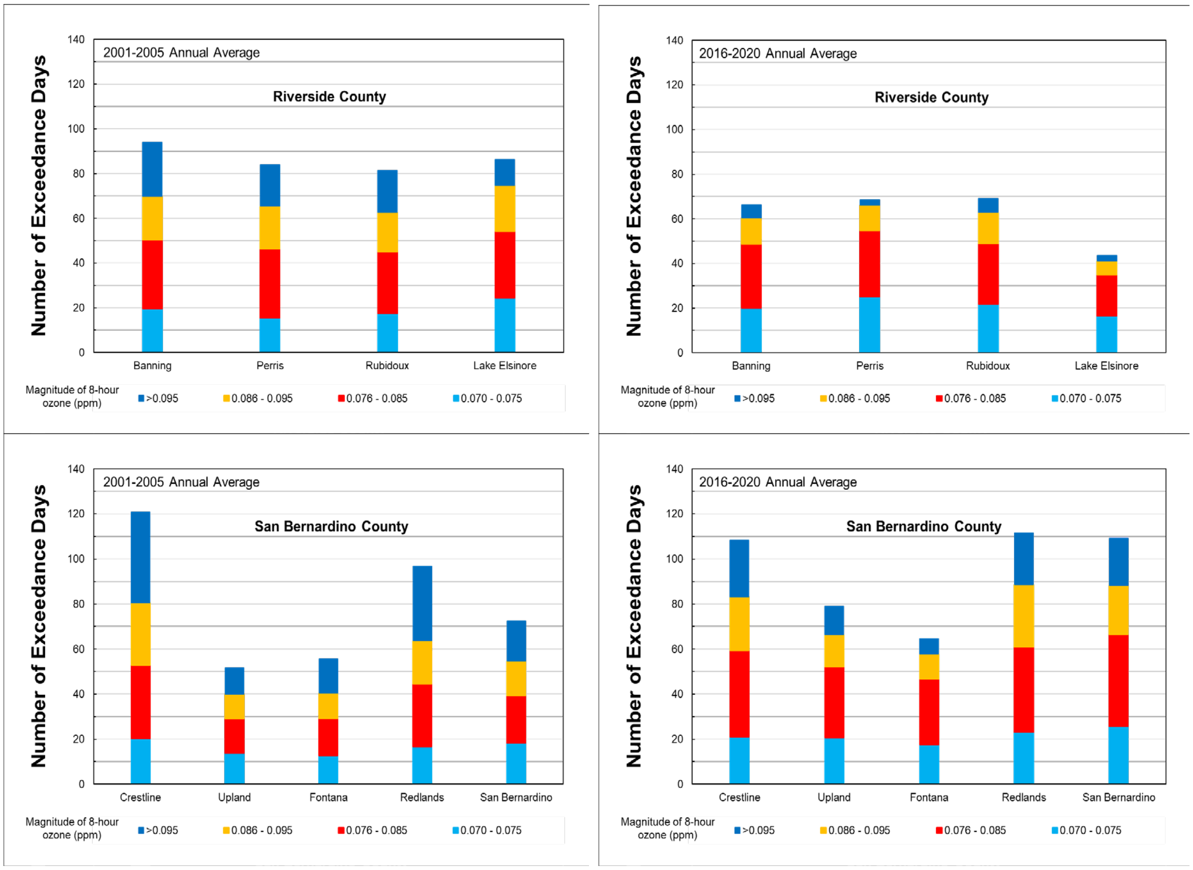
In the inland area of Los Angeles County, the number of exceedance days in 2016-2020 at Pasadena, Reseda, and Santa Clarita was 14 percent, 23 percent, and 27 percent lower than in 2001-2005, respectively. In contrast, the number of exceedance days in 2016-2020 at Glendora, Pomona, and Azusa was 14 percent, 40 percent, and 44 percent higher in 2016-2020 than in 2001-2005, respectively.

In the South Coast portion of Riverside County, the number of exceedance days declined between 2001-2005 and 2016-2020 at all sites in the County. The largest decreases in the number of exceedance days occurred at Lake Elsinore (50 percent) and Banning (30 percent).

In the South Coast portion of San Bernardino County, the number of exceedance days increased from 2001-2005 to 2016-2020 at all sites except Crestline, with 53 percent at Upland, 51 percent at San Bernardino, 16 percent at Fontana, and 15 percent at Redlands, respectively. In contrast, a 10 percent decrease in the number of exceedance days in 2016-2020 was observed at Crestline.

Figure 25: Number and Magnitude of Exceedance Days





Summary of additional indicators

The assessment of long-term ozone design value trends between 2000 and 2020 indicated a generally widespread improvement in air quality. However, patterns in near-term design values suggest that the rate of progress has slowed or even reversed at many sites in the South Coast. Given the relatively large extent and frequency of ozone concentrations in the South Coast that exceed the 0.070 ppm threshold, the consideration of indicators beyond design values can provide additional insight into ozone air quality in the region. An increase in the Top 25 annual concentrations or an increase in the frequency of exceedance days at several sites including Pomona, Fontana, Upland, Redlands, Glendora, Azusa, and San Bernardino, were in contrast to the ozone design value analyses. Collectively, these indicators highlight the complexity of the ozone challenge in the South Coast and provide further evidence of the region shifting to a transitional ozone production regime.

Weekday/Weekend Differences

The occurrence of higher ozone concentrations on weekends than on weekdays, has been documented in the South Coast as well as many other urban areas and has been studied and discussed in the scientific literature. Recent analyses using ground-based data from the 2010 CalNex field campaign in the South Coast, indicated that NOx emissions were 34±4 percent higher on weekdays than weekends (Pollack et al., 2012). Pollack et al. (2012) also noted that ozone production efficiency was 51±14 percent higher on the weekends, which indicates that the difference in weekend emissions leads to more efficient production of ozone from available precursors. Using data from the CalNex field campaign, as well as surface monitoring data from 1996 to 2014, Baidar et al. (2015) found that the magnitude and spatial extent of the weekend/weekday differences were diminishing in the South Coast. Moreover, the authors noted that the occurrence of lower ozone concentrations on weekends relative to weekdays was increasing, particularly on weekends with high temperatures. Similar to the findings from many earlier studies, the authors attributed the higher weekend concentrations in the South Coast largely to reduced NOx emissions and the associated chemical feedback.

Past work has used several different classification schemes and metrics to evaluate the magnitude and extent of the weekday/weekend differences. In this WOE, CARB staff considered the day of the week on which exceedance days occur.

Day of the Week Exceedances

To shift the focus of the analyses to exceedance days and the areas that potentially drive attainment in the South Coast, CARB staff next considered the distribution of the day of the week on which exceedance days occurred. The period considered was limited to 2016 to 2020 because previous studies (Baidar et al., 2015; Cai et al., 2019; Schroeder et al., 2022) indicated that the weekday/weekend differences were diminishing in the South Coast, particularly in recent years. Coastal sites were not considered in this analysis because the number of exceedance days in recent years was very low.

At the sites in inland Los Angeles County, exceedance days occurred more frequently on weekend days than weekdays at Pomona, Glendora, Azusa, and Pasadena (Figure 26), which are the sites closest to South Coast's urban core area in inland Los Angeles County. However, the similar sharp weekend/weekday difference was not observed at Reseda and Santa Clarita, which are sites far away from the urban core area.

In Riverside County, a weekend/weekday difference in the occurrence of exceedance days was not observed at all sites during the period of 2016-2020 (Figure 27).

In San Bernardino County, the sharp weekend/weekday difference is not observed at all sites, though the exceedance days were somewhat more frequent on weekends at Upland and Fontana, which are also the sites closest to South Coast's urban core area in the San Bernardino County.

This weekend/weekday difference analysis indicates that, during 2016-2020, exceedance days occurred more frequently on weekend days than weekdays in areas closest to South Coast's urban core area. While in areas far away from the South Coast's urban core area, the sharp weekend/weekday difference was not observed during the period of 2016 to 2020.

Weekday vs. Weekend Concentration

To further investigate the weekday/weekend difference, CARB staff compared the annually averaged weekend and weekday daily maximum 8-hour ozone concentrations. The analysis used all daily maximum 8-hour ozone concentrations on exceedance days (above 0.070 ppm) and calculated the annual averages for all weekends (Saturday and Sunday) and all weekdays (Monday-Friday), respectively. A ratio of weekend to weekday concentration is calculated for each year from 2000 to 2021 at every site in the inland areas. As shown in Figure 29, although there is some year-to-year variability which is likely due to inter-annual variability in meteorological conditions and its impact on the regional transport patterns, the weekend to weekday ratio of the daily maximum 8-hr ozone concentrations has been decreasing over the last 20 years. Most of the sites in the downwind inland areas now have weekend to weekday ratio close to or below one, suggesting that lower NOx emissions in the weekend are resulting in lower ozone. This is consistent with the modeling results discussed early that the South Coast is entering a regime where the dominant precursor controlling ozone abundance is shifting from ROG to NOx.

Figure 26: Distribution of 2016-2020 Exceedance Days by Day of the Week at Sites in Inland Los Angeles County

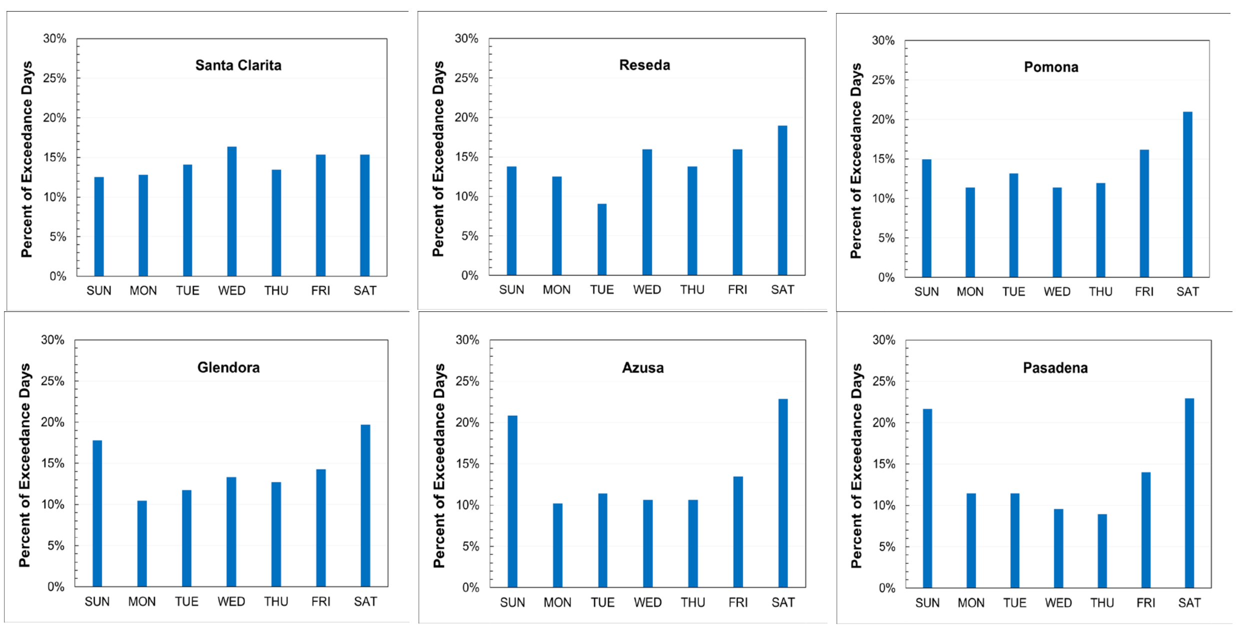


Figure 27: Distribution of 2016-2020 Exceedance Days by Day of the Week at Sites in Riverside County

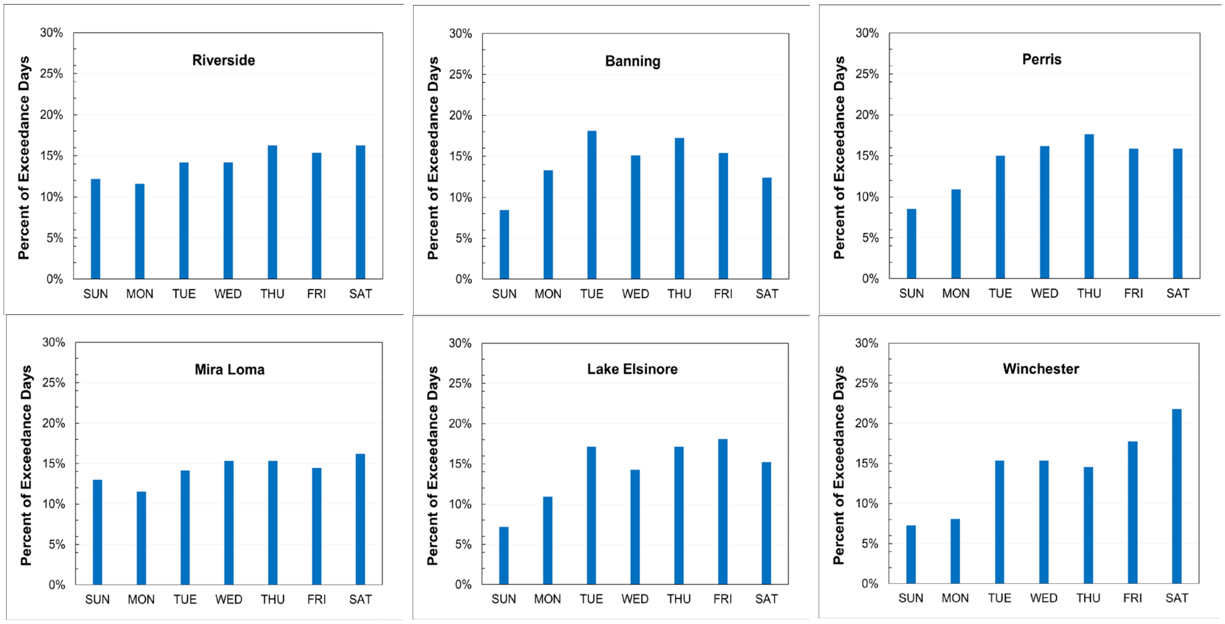


Figure 28: Distribution of 2016-2020 Exceedance Days by Day of the Week at Sites in San Bernardino County

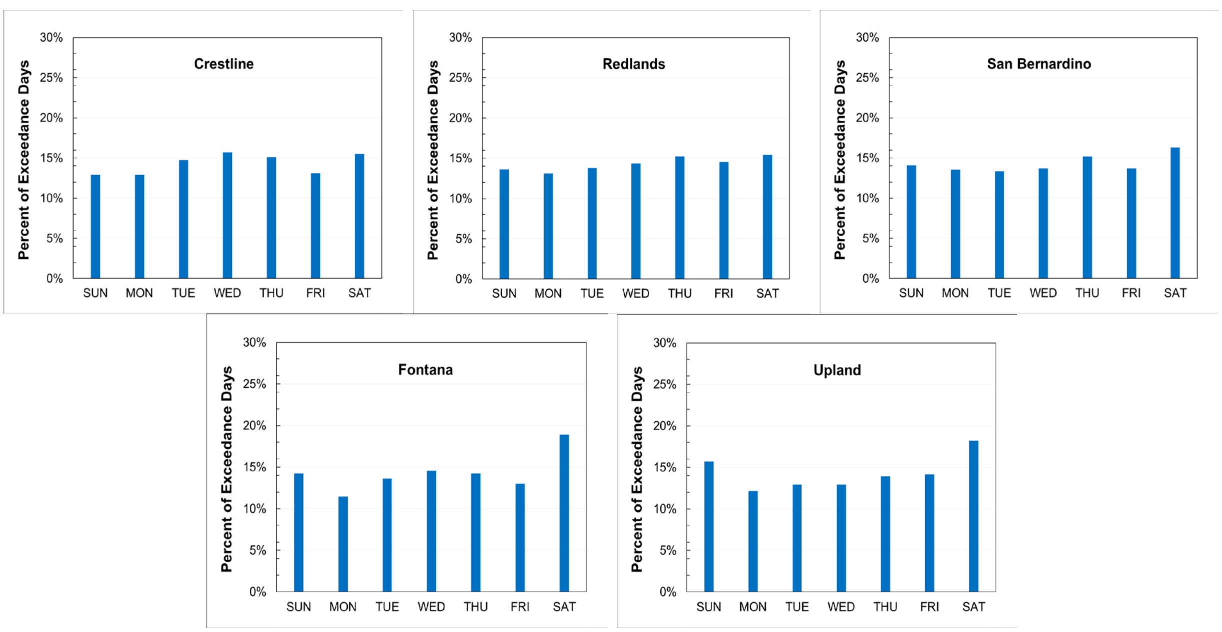
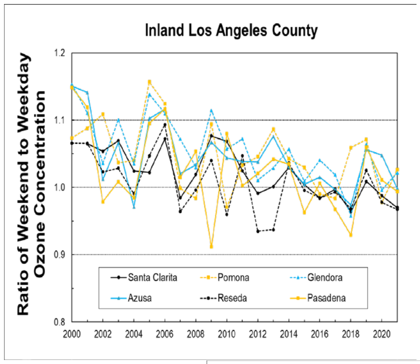
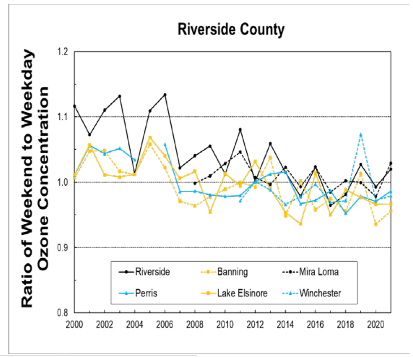
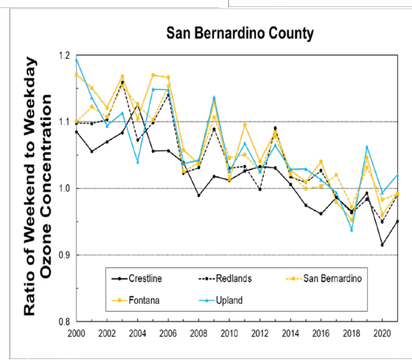


Figure 29: Ratio of Annually Averaged Weekend to Weekday Daily Maximum 8-hr Ozone Concentrations







Attainment Projections

With the implementation of controls and improvements in ozone air quality over the past several decades (as shown in the discussion of historical ozone air quality trends), photochemical modeling demonstrates that the path to attainment is a NOx-focused control strategy. As a result, the rate of NOx and ROG reductions is expected to shift in the post-2020 timeframe. NOx and ROG reductions will both continue, albeit the rate of ROG reductions will be increasingly modest compared to NOx reductions.

District Attainment Modeling

Results of the regional photochemical modeling analyses performed by the District are shown in Table 3. None of the sites shown in Table 3 met the 0.070 ppm standard in 2018 (modeling base year) or in 2020. The ozone design values at eight of the sites were higher in 2020 than in 2018. The District modeling indicates that scenarios where control measures are limited to those that have already been adopted (baseline) do not lead to the Basin-wide attainment by 2037. As discussed earlier in this WOE, reductions in NOx emissions from the heavy-duty sector are expected to level off after 2023. Additional controls beyond those already adopted are necessary for the South Coast to meet the 0.070 ppm standard by the 2037 attainment deadline.

Table 3: Recent Measured Design Values and 2022 District Attainment Modeling Design Values Projections

County	Site Name	2018 Design Value (ppm)	2019 Design Value (ppm)	2020 Design Value (ppm)	2037 Baseline Projection (ppm)	2037 Projection w/Controls (ppm)
LA	Azusa	0.099	0.098	0.097	0.0903	0.0688
LA	Glendora	0.103	0.103	0.107	0.0933	**0.0703**
LA	Reseda	0.091	0.091	0.092	0.0818	0.0645
LA	Pomona	0.091	0.088	0.088	0.0806	0.0593
LA	Pasadena	0.086	0.088	0.093	0.0818	0.0646
LA	Santa Clarita	0.100	0.100	0.101	0.0850	0.0638
RIV	Banning	0.098	0.098	0.099	0.0797	0.0606
RIV	Perris	0.093	0.093	0.094	0.0760	0.0577
RIV	Riverside	0.098	0.096	0.096	0.0837	0.0636
RIV	Mira Loma	0.098	0.098	0.098	0.0840	0.0638
RIV	Lake Elsinore	0.089	0.087	0.087	0.0724	0.0552
SBD	Crestline	0.111	0.108	0.109	0.0934	0.0670
SBD	Upland	0.109	0.105	0.106	0.0929	0.0681
SBD	Fontana	0.099	0.099	0.102	0.0850	0.0619
SBD	Redlands	0.107	0.108	0.114	0.0892	0.0653
SBD	San Bernardino	0.111	0.108	0.110	0.0932	0.0673

The District modeling scenarios that include proposed control measures indicate that, for the sites with projections included in the final draft of the Air Quality Management Plan, none of the sites will meet the 0.070 ppm standard by 2037. Longer-term projections of scenarios with proposed control measures indicate that all sites in South Coast will meet the 0.070 ppm standard by 2037.

In the scenarios with proposed control measures, Crestline, Glendora, Upland, Azusa, and San Bernardino are projected to meet the 0.070 ppm standard in 2037 by less than a six percent margin, indicating that the largest attainment challenge will be at these sites. Redlands and Crestline have historically been the 8-hour ozone design sites for the South Coast and ozone concentrations and are strongly influenced by daytime transport of urban emissions. Glendora, Upland, and Azusa are in closer proximity to the urban core and prevailing daytime winds and local terrain typically move air from the urban core to these sites. District modeling indicates that in future years, the highest ozone design values will be in the Glendora area.

Summary

As discussed throughout this WOE, ozone production is a non-linear process and the drivers of production can vary over relatively short spatial and temporal scales. The rate of historical ozone air quality improvements has varied over time, in response to the change in composition and quantity of NOx and ROG emissions. Therefore, the rate of at which ozone air quality improvements are accomplished leading up to attainment will be expected to vary as controls are implemented and sites transition from largely ROG-limited to predominantly NOx-limited ozone production regimes. As a result, some sites may be able to meet the 0.070 ppm standard by an early date, while sites with the greatest challenge, including Glendora, will not be able to meet this standard until the 2037 attainment date.

2021 Ozone Data

With extended periods of high temperatures and minimal precipitation, conditions in 2020 have been particularly favorable for ozone production in the South Coast. Extensive wildfires across the California State, including the South Coast, are also negatively impacting the local ozone air quality. Data indicate that the 2021 design value for the South Coast will be 0.114 ppm, same as in 2020 (Table 4).

As shown in Table 4, from 2000 to 2021, the ozone design value decreased at most sites across the South Coast, the amount of decrease is very small, especially at historically high sites. The slow progress in 2021 ozone design values highlights the role of interannual variability as well as the need for routine assessment of control strategies.

Table 4: Comparison of 2020 and 2021 Design Values in the South Coast

	Site Name	County	2020 Design Value (ppm)	2021 Design Value (ppm)	2020 to 2021 Change (ppm)
Coastal Sites	Anaheim	ORA	**0.069**	**0.068**	-0.001
	Mission Viejo	ORA	0.082	0.083	0.001
	La Habra	ORA	0.077	0.077	0.000

	West Los Angeles	LA	**0.070**	**0.067**	-0.003
	Los Angeles-N Main St	LA	0.076	0.075	-0.001
	Compton	LA	**0.064**	**0.066**	0.002
	Pico Rivera	LA	0.078	0.076	-0.002
	Los Angeles-LAX	LA	**0.062**	**0.057**	-0.005
Inland Sites	Azusa	LA	0.097	0.090	-0.007
	Glendora	LA	0.107	0.103	-0.004
	Reseda	LA	0.092	0.087	-0.005
	Pomona	LA	0.088	0.090	0.002
	Pasadena	LA	0.093	0.092	-0.001
	Santa Clarita	LA	0.101	0.101	0.000
	Banning Airport	RIV	0.099	0.099	0.000
	Winchester	RIV	0.078	0.078	0.000
	Perris	RIV	0.094	0.092	-0.002
	Riverside-Rubidoux	RIV	0.096	0.095	-0.001
	Mira Loma	RIV	0.098	0.097	-0.001
	Lake Elsinore	RIV	0.087	0.087	0.000
	Upland	SBD	0.106	0.103	-0.003
	Fontana	SBD	0.102	0.100	-0.002
	Redlands	SBD	0.114	0.114	0.000
	San Bernardino-4th St	SBD	0.110	0.110	0.000
	Crestline	SBD	0.109	0.110	0.001

Yellow cells indicate decrease or no change in design value

Conclusions

The South Coast is currently classified as an extreme ozone nonattainment area with a 2037 attainment date for the 0.070 ppm 8-hour ozone standard. This WOE evaluated ambient air quality and emission trends to complement the regional photochemical modeling analyses conducted to assess South Coast's progress toward meeting the 2037 attainment date for the 0.070 ppm standard. Photochemical modeling analyses indicate that the South Coast will not meet the attainment deadline with the currently adopted control measures alone; therefore, adoption of additional control measures is necessary for the South Coast to reach attainment by the 2037 deadline. Modeling analyses suggest that the most efficient path to attainment is through implementation of a NOx-focused control strategy, which would transition the region from a predominantly ROG-limited ozone production regime to a NOx-limited ozone production regime.

Control measures implemented in the South Coast through federal, State, and local programs have led to a substantial decline in emissions of ozone precursors and a substantial improvement in ozone air quality between 2000 and 2020.

- Total NOx emissions in South Coast declined by 70 percent and total ROG emissions declined by 56 percent. Moreover, the South Coast design value decreased by 12 percent, from 0.129 ppm in 2001 to 0.114 ppm in 2020.

- Complex terrain, meteorology, and the distribution of emissions promote a substantial gradient in ozone concentration. In 2020, ozone design values at four sites in the South Coast met the 0.070 ppm standard. Design values in the inland areas ranged from 0.078 to 0.099 ppm in Riverside County, 0.088 to 0.107 ppm in the inland portion of Los Angeles County, and 0.102 to 0.114 ppm in San Bernardino County.

- In recent years, the rate of progress has slowed or reversed at several sites. The decrease in ozone design values between 2011 and 2020 was lower at most sites compared to the rate of decrease in design values between 2000 and 2020. This widespread slowing of progress is indicative of a non-linear regional transition from a predominantly ROG-limited ozone production regime to a predominantly NOx-limited ozone production regime, which is predicted by photochemical modeling analyses.

- Meteorological conditions may play a significant role in the slow down or reversal of the declining trend in recent years.

- Comparison of the Top 25 days in 2001-2005 and 2016-2020, indicated consistency in progress across the South Coast with some minor variability. The most persistent progress has occurred at sites in Riverside County, sites adjacent to the San Gabriel Mountains in Los Angeles County, and sites adjacent to the San Bernardino Mountains in San Bernardino County.

- Since 2000, weekday/weekend differences have diminished in the South Coast. As the South Coast continues to move toward a NOx-limited regime, the weekday/weekend differences are expected to continue to diminish. Consideration of these differences will continue to be a factor in designing effective control strategies for attainment of air quality standards in the South Coast.

- Interannual variability plays a substantial role in measured ozone concentrations throughout the South Coast. Interannual variability coupled with a transitioning ozone regime, likely contributed to the widespread increases observed in the South Coast.

- Analysis discussed in the District's Final Draft AQMP indicates that NOx emissions will decrease to 220 tons per day in 2037, based on already adopted control measures. While this will provide for ongoing progress, air quality modeling indicates that further NOx reductions from new control measures are needed, with NOx levels of approximately 60 tons per day needed to reach attainment.

Collectively, the air quality analyses included in this WOE indicate that, while substantial progress has been accomplished in the South Coast, additional measures are necessary to meet the 0.070 ppm standard at all sites by the attainment deadline. These findings are consistent with the photochemical modeling results included in the final draft of the District Air Quality Management Plan.

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