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Task 1

Conceptual Model
Ozone Analysis of the San Antonio Region
Updates through Year 2010

Technical Report

July 15th, 2011

Prepared by:

Alamo Area Council of Governments

Prepared in Cooperation with the
Texas Commission on Environmental Quality

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Abstract: Photochemical models allow analysts to predict the impact of control strategies on ambient ozone concentrations. To predict whether control strategies will enable regions to meet federal ozone standards, photochemical models simulate the effects of control measures under meteorological and atmospheric conditions that are conducive to elevated ozone concentrations, as characterized by a region's conceptual model. Meteorological characteristics associated with high ozone in the San Antonio region include stagnant air over Texas, limited frontal movement, lack of precipitation, clear skies, morning wind directions from the northwest to northeast, back trajectories from the northeast to southeast, and a low early morning mixing height followed by a rapid rise in mixing height during the afternoon. Aircraft sampling, back trajectory analysis, and upwind monitor readings indicate ozone plumes can impact cities such as San Antonio hundreds of miles from their origin. While ozone readings at upwind monitors have declined in recent years, indicating a decrease in background ozone, the design value at all upwind monitors still exceed 60 ppb. Since transport accounts for the majority of ozone recorded at local monitors and new point sources are planned in Texas, it will be difficult for the region to demonstrate attainment of federal ozone standards with only local emission controls. San Antonio experiences two seasonal peaks in the frequency of high ozone days. The first seasonal peak is in May and June, and the second covers a period from August through October. Significant differences in meteorological conditions during high ozone events exist between the seasonal peaks. A combination of greater tropospheric-stratospheric air exchange combined with higher North American upper troposphere/stratospheric ozone levels during the early months of the ozone season can be partially responsible for the higher ground level ozone observed in San Antonio during the spring ozone season peak. Likewise, the reduction of this phenomenon and chemical loss of upper NO_X pollutants can decrease ground level ozone in July, which occurs before air mass stagnation, and northeasterly transport contributes to an increase in ground level ozone measurements during the fall ozone season peak. When high ozone events were analyzed, the Aug. 17 – Oct. 9, 2006 period demonstrated the greatest suitability for future photochemical modeling.

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EXECUTIVE SUMMARY

Many challenges face the fast growing region of San Antonio, one of which is to ensure attainment of the proposed revision to the 8-hour average ozone National Ambient Air Quality Standard (NAAQS). To meet this challenge, control strategies designed to reduce ozone precursor pollutants are analyzed in photochemical models. An effective photochemical model simulates ozone and meteorological conditions typically observed on high ozone days. A Conceptual Model is used to determine air quality trends, meteorological patterns, precursor emissions, and ozone transport during high ozone events. These analyses help identify appropriate high ozone events for evaluating the effects of ozone control measures during the photochemical modeling process.

Extensive data sets were analyzed to develop an updated conceptual model for the San Antonio region including meteorology, emissions, ozone, and spatial observations. Chapter 1 defines the elements and usage of a conceptual model. This chapter outlines the determining criteria desirable for modeling high ozone events as outlined in EPA's modeling guidelines.[1] Chapter 2 contains the analysis of air quality trends in San Antonio. The 2008-2010 design values are 75 ppb at both C23 and C58, indicating that the San Antonio region ended 2010 with two regulatory monitors exceeding 70 ppb – the upper end of the proposed revision to the ozone standard, which is slated to be in the 60 - 70 ppb range. Although the 2008 – 2010 design values at all regulatory-sited monitors are above this range, there was a significant reduction in the number of high ozone days from 2006 through 2010.

Chapter 3 provides typical local meteorological conditions that are conducive to ozone formation including days with stagnant air, limited frontal movements, no precipitation, low atmospheric moisture content in the afternoon, and clear skies. Mixing heights are typically lower in the early morning hours and experience a rapid rise in the late morning through early afternoon on high ozone days. Timing, location, and intensity of ozone events are influenced by the interaction between local and regional wind patterns. Wind vectors on high ozone days were more stagnated and originated from the east and northeast. At C23, winds slowly change direction at the monitor from the north to the east in a clockwise fashion during the day. The directions of the wind vectors indicate that transported emissions from the north and northeast on high ozone days combine with local emissions to produce elevated ozone conditions. C58 wind vectors show there is a flow reversal of winds arriving at the monitors from the northwest in the morning before 7 am. These winds can re-circulate local ozone precursor emissions and ozone from the previous day that combine with local and transported emissions resulting in elevated ozone levels.

Multivariate correlation analyses were used to determine the impact of multiple meteorological factors on ozone formation. The strongest multivariate correlation for the 60 ppb proposed standard was back trajectory direction - diurnal temperature change and humidity - back trajectory distance. Humidity – back trajectory distance had the strongest multivariate correlation for days over 65 ppb and 70 ppb. Wind Speed – humidity and humidity – back trajectory direction also had a very strong correlation with high ozone days. The lowest correlation with high ozone days was wind speed - afternoon wind direction, temperature - wind speed, and temperature - afternoon wind direction.

There are currently five NO_X monitors in San Antonio, all of which typically indicate low NO_X levels with the exception of C27, which often records moderate NO_X concentrations. Although C27 has the highest recorded NO_X in the region, NO_X emissions at this monitor have significantly decreased

[1] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze", Research Triangle Park, North Carolina. EPA -454/B-07-002. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

since 2000. Decreases in recorded NO_X are attributed to controls put on major NO_X sources including power plants and cement kilns, and significant reductions of NO_X emissions from on-road and off-road vehicles. Local NO_X emissions should continue a downward trend, in large part due to improvements in vehicle emission standards, while local VOC emissions are expected to remain steady. C59 is an upwind monitor site on most high ozone days and NO_X measurements from 2000 to 2010 were minimal at the monitor indicating there was not a significant amount of NO_X being transported into San Antonio from the southeast.

The impact of background ozone and ozone-precursor transport is considered in Chapter 4. While ozone readings at upwind monitors have declined in recent years, indicating a decrease in background ozone, ozone readings at upwind monitor sites still exceed the range of the proposed revision to the standard on some days. Since the majority of ozone recorded at local monitors is the result of transport from other areas, it is difficult for the San Antonio region to demonstrate attainment with only local emission controls. Easterly to northeasterly winds bring high levels of background ozone into San Antonio from the Midwest U.S, Dallas, Houston and other regions. Sampling of industrial point sources and urban ozone plumes by aircraft increases the knowledge of regional ozone development.

Variations in both local ozone levels and transported ozone throughout the ozone season are addressed in Chapter 5, as it has become more apparent that seasonal meteorological trends have an important role in monitored ozone readings in San Antonio. In May and June, there is a seasonal peak in the frequency of high ozone days in most Texas cities. This period represents the first high ozone seasonal peak that San Antonio typically experiences, and corresponds to the yearly beginning of intermittent high pressure systems which result in the light winds, clear skies, and high solar radiation that drive high ozone production. However, by early July the frequency of high ozone days declines. The second seasonal peak covers a period from August through October. Resulting wind vectors during the May – June ozone season peak tend to be from the east and southeast on high ozone days, while the August and September ozone season peak wind vectors are dominated by winds from the northeast. Regulatory monitors in northwest San Antonio are impacted by transport from the northeast on most high ozone days during the fall ozone seasonal peak.

A significant amount of transport occurs during the spring ozone season peak. A combination of greater tropospheric-stratospheric air exchange combined with higher North American upper troposphere/stratospheric ozone levels during the early months of the ozone season are contributing factors. Likewise, the reduction of this phenomenon and chemical loss of upper NO_X pollutants could explain the decrease in ground level ozone in July, which occurs before the air mass stagnation and northeasterly transport that contribute to an increase in ground level ozone measurements during the fall ozone season peak.

The suitability of high ozone events for photochemical modeling is analyzed in Chapter 6. The Aug. 17 – Oct. 9, 2006 high ozone event ranked the highest in suitability, having typical ozone readings, typical wind directions on high ozone days, typical back trajectories on high ozone days, and extensive meteorological and ozone data sets available for modeling. Three other high ozone events also exhibited typical ozone and meteorological conditions on high ozone days: Aug. 22 – Sept. 9, 2005, Sept. 17 – Oct. 3, 2008, and May 18 – June 6, 2009. The remaining six high ozone events had poor rankings in several categories, most notably having atypical back trajectories and winds, and these episodes would not be ideal candidates for modeling. When choosing a new episode for photochemical modeling in the San Antonio region, the information provided in this conceptual model, in addition to any new information, should be considered, as well as cost and whether or not multiple regions could benefit from the development of a modeling episode.

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1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is charged with the maintenance of air quality across the United States through a series of standards, the National Ambient Air Quality Standards (NAAQS). When regions fail to comply with these standards, the Clean Air Act requires that the state, in consultation with local political subdivisions, develop a state implementation plan (SIP) to address the violation. "A State Implementation Plan (SIP) is an enforceable plan developed at the state level that explains how the state will comply with air quality standards according to the federal Clean Air Act. A SIP must be submitted by the state government of any state that has areas that are designated in nonattainment of federal air quality standards."[2]

Forecasting future air quality and modeling of air quality control strategies are among the basic elements of a SIP. Since control strategy modeling requires extensive technical analyses of control strategy impacts under a variety of typical meteorological conditions that produce high ozone, it is important that each photochemical modeling episode be based on a time period characterized by such meteorological conditions. Careful selection of photochemical episodes for use in the SIP is critical.

A conceptual model is one of the main tools used when selecting photochemical modeling episodes that are representative of high ozone events. Results from the conceptual model are used to assess and evaluate photochemical modeling results. Air quality trends, meteorology patterns, precursor emissions, and ozone transport are evaluated for the San Antonio region in the conceptual model.

1.1. *Conceptual Description*

Elevated ozone episodes occurring in the San Antonio area during 2010 are described in chapter 6. Factors that contributed to elevated ozone concentrations in the San Antonio area were identified, and cumulatively, formed the *conceptual description* for the region. The conceptual description includes ozone formation trends, local meteorological analysis, ozone transport, and seasonal ozone variations, as described in the following chapters.

Chapter 2: Air Quality Trends in the San Antonio Area
- Surface measurements of ozone concentrations
- Changes in ozone readings from year to year
- Frequency and location of monitored ozone violations
- Correlation between 8-hour and 1-hour ozone readings

Chapter 3: Meteorological and Ozone Precursor Emissions in the San Antonio Area
- Regional meteorological patterns
- Local ground level meteorological patterns including precipitation, relative humidity, solar radiation, temperature, atmospheric pressure, wind speed, and wind direction.
- Correlation of monitored ozone readings with other pollutants including NO_X, SO_X, $PM_{2.5}$, and canister sampling of surface non-methane hydrocarbon measurements
- Elevated meteorological patterns including mixing height
- Trends in local emissions

Chapter 4: Background Ozone and Ozone Transport into the San Antonio Area
- Back trajectories analysis
- Upwind monitor readings
- Aircraft sampling of urban and industrial plumes

[2] TCEQ, September 24, 2009. "SIP: Introduction to the Texas State Implementation Plan (SIP)". Available online: http://www.tceq.state.tx.us/implementation/air/sip/sipintro.html. Accessed: 05/12/10.

- Transport analysis in the photochemical model
- Regional point sources contributions

Chapter 5: Seasonal Ozone Variations

- Seasonal and daily variation in high ozone
- Meteorological Impact on Ozone Season Variations
- Impact of Upper Troposphere Ozone

EPA recommends a conceptual description of the ozone problem be developed to aid the selection of modeling episodes. “A conceptual description is useful for helping a State/Tribe identify priorities and allocate resources in performing a modeled demonstration.”[3] Thus, a successful conceptual model characterizes the nature of the ozone problem and helps identify suitable time periods for photochemical model development used for control strategies evaluation.

1.2. *Air Quality Trends*

San Antonio is currently in attainment of the NAAQS for all pollutants. However, “on January 6, 2010, EPA proposed to strengthen the national ambient air quality standards (NAAQS) for ground-level ozone, the main component of smog. The proposed revisions are based on scientific evidence about ozone and its effects on people and the environment. EPA is proposing to strengthen the 8-hour “primary” ozone standard, designed to protect public health, to a level within the range of 0.060-0.070 parts per million (ppm). EPA is also proposing to establish a distinct cumulative, seasonal “secondary” standard, designed to protect sensitive vegetation and ecosystems, including forests, parks, wildlife refuges and wilderness areas. EPA is proposing to set the level of the secondary standard within the range of 7-15 ppm-hours.”[4] According to the EPA, “the health effects associated with ozone exposure include respiratory health problems ranging from decreased lung function and aggravated asthma to increased emergency department visits, hospital admissions and premature death. The environmental effects associated with seasonal exposure to ground-level ozone include adverse effects on sensitive vegetation, forests, and ecosystems.”[5]

From 2008 through 2010, San Antonio registered ozone concentrations at several Continuous Ambient Monitoring Stations (CAMS) that could cause the region to violate the proposed revision to the 8-hour primary ozone standard. In 2008, the San Antonio region experienced 13 days in which ozone concentrations exceeded 70 ppb, while in 2009 there were 8 days, and in 2010 there were 11 days. The fourth highest 8-hour averages and design values for the three most recent complete years, 2008-2010, at regulatory sited monitors in the San Antonio region are listed in Table 1-1. The 2008-2010 design value (truncated average) is 75 ppb at C23 and 75 ppb at C58, indicating that the San Antonio region had two monitors exceeding 70 ppb – the upper end of the range proposed for the

[3] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. “Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze”, Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 126. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

[4] EPA, January 6, 2010. “Fact Sheet: Proposal to Revise the National Ambient Air Quality Standards for Ozone”., p. 1. Available online: http://www.epa.gov/air/ozonepollution/pdfs/fs20100106std.pdf. Accessed 06/28/10.

[5] EPA, September 16, 2009. “Fact Sheet: EPA to Reconsider Ozone Pollution Standards”., p. 1. Available online: http://www.epa.gov/air/ozonepollution/pdfs/O3_Reconsideration_FACT%20SHEET_091609.pdf. Accessed 06/28/10.

revised standard. The design values at all regulatory-sited monitors exceeded the lower and mid range (60 and 65 ppb) of the proposed revision to the ozone standard.

Table 1-1: Design Values and 4th Highest 8-hour Ozone Concentrations[6], 2008-2010

Monitor	2008 (ppb)	2009 (ppb)	20010 (ppb)	2008-2010 Design Value
San Antonio Northwest C23	78	75	72	75
Camp Bullis C58	74	73	78	75
CPS Pecan Valley C678	75	68	65	69
Calaveras Lake C59	73	62	64	66
Heritage Mid. School C622	72	63	64	66

1.3. *Meteorological and Ozone Pre-Cursor Emissions*

Preliminary analysis of the San Antonio region indicates a number of factors that are associated with elevated ozone concentrations, forming a specific conceptual description. This model includes regional as well as local factors, which in aggregate contribute to ozone elevation in the San Antonio region. Areas of stagnated air over Texas, few frontal movements, no precipitation, and clear skies characterize high ozone events. Local meteorological conditions during high ozone events include no precipitation, low atmosphere moisture content present in the afternoon, clear skies, and morning wind direction from the northwest or north. Mixing heights on high ozone days are typically lower in the early morning hours followed by a rapid rise in the late morning through early afternoon.

Significant amounts of volatile organic compound (VOC) and nitrogen oxide (NO_X) emissions are emitted in the San Antonio region from mobile sources, power plants, industrial facilities, coating operations, petroleum products, and biogenic sources. Mobile sources include cars, trucks, heavy construction equipment, land and garden equipment, locomotives, and aircraft. Results from photochemical modeling indicate that San Antonio is NO_X-limited: high ozone formation is more influenced by NO_X emissions than by VOC emissions.

1.4. *Background Ozone and Ozone Transport*

Back trajectories, upwind monitor readings, aircraft sampling, and photochemical models can be used to analyze transport. San Antonio is located to the southwest of Dallas/Fort Worth (DFW) and to the west of Houston, two nonattainment areas in Texas. Regional winds generally enter the city from the northeast to the southeast on high ozone days and often ozone and/or ozone precursor pollutants that originate from other regions and countries can impact local ozone monitors.

Surface back trajectories on days with low ozone are predominately from the southeast, while winds on high ozone days tend to be from the northeast, east, and southeast. The end points of 48-hour back trajectories on low ozone days tend to originate far out in the Gulf of Mexico, while the back trajectories on high ozone days tend to originate closer to San Antonio over eastern Texas. Since back trajectories on high ozone days travel fewer miles before arriving at local ozone monitors, high ozone days are associated with lighter transport level winds and local stagnation.

[6] Texas Commission on Environmental Quality (TCEQ). “Four Highest 8-hour Ozone Concentrations“ Available online: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/8hr_4highest.pl. Accessed 05/12/10.

The difference between the maximum peak ozone reading at local downwind ozone monitors and the minimal peak ozone readings at local upwind ozone monitors on high ozone days > 60 ppb from 2005 to 2010 was 14.3 ppb or 20.5%, indicating that transport may be responsible for up to 80% of ozone in the San Antonio area. Aircraft sampling indicates large ozone plumes from Houston and large point sources can impact areas hundreds of miles downwind including San Antonio monitors. This may increase the ozone levels at downwind monitors and increase the difficulty of attaining the new proposed 8-hour ozone standard.

1.5. *Seasonal Variations in Ozone Formation*
From April through June, there is a seasonal increase in the number of high ozone days in most Texas cities. This period represents the first and longest high ozone seasonal peak that San Antonio typically experiences. However, by early July the number of high ozone days decline. The next seasonal increase covers a period beginning in August and ending in late October, during which the frequency of high ozone days is slightly lower than the spring period.

Ozone readings fluctuate by season depending on several factors including variations in transport, meteorology, chemical loss of ozone, and upper stratospheric ozone levels. Since transport significantly influences local ozone concentrations, seasonal variations in wind direction, distance and direction of back trajectories, and chemical loss of ozone ~~can~~ are important factors to include in the analysis. There is a significant amount of ozone transport during the spring and fall ozone season peaks. Ozone transport is lowest in July before increasing again into the late summer and fall.

It is possible that a combination of greater tropospheric-stratospheric air exchange combined with higher North American stratospheric ozone levels during the early months of the ozone season is partially responsible for the higher ground level ozone observed in San Antonio during these months. Decreases in observed tropospheric and stratospheric ozone in the Northern Hemisphere from the spring to the fall seasons can be explained by increased chemical destruction of ozone. Chemical loss of tropospheric and stratospheric ozone can occur through the catalysis by NO_X in the summer time. The secession of this phenomenon could explain the decrease in ground level ozone from late June through July, which occurs before air mass stagnation and northeasterly winds contribute to a rebound in ground level ozone measurements during the fall ozone season peak.

1.6. *High Ozone Events*
Conceptual models can be used for selecting high ozone events for photochemical modeling episodes that are in compliance with EPA’s guidelines. The conceptual model process undertaken for identifying candidate photochemical modeling episodes, the analysis of these candidate episodes, and the determination of desirability of each candidate episode are provided in this report. The first Conceptual Model for the San Antonio region was developed in 2000 as a tool used to select the September 1999 photochemical modeling episode and later conceptual models were refined to select the June 2006 photochemical modeling episode.

High ozone events in 2010 were analyzed to identify possible additional modeling episodes. Modeling episodes should be long enough to include the full synoptic cycle of ozone formation, peak and dissipation at San Antonio monitors. Candidate modeling episodes should also include days with observed concentrations that are close to site-specific design values and reflect meteorological conditions that are commonly observed on high ozone days. The meteorological and emission data used to assess candidate episodes cover the years 2005 - 2010.

The more recent the episode, the more desirable it is for photochemical modeling. As more monitors and meteorological stations are installed (such as C622, owned by CPS Energy, which began operation during the summer of 2004[7]), more data becomes available to verify the performance of the photochemical model; this makes the development of a more recent episode desirable. Additional data, such as the 2005-2006 profiler measurements recorded at the New Braunfels Weather Station as well as aircraft sampling augment the model verification process and help determine episode desirability.

The Conceptual Model is continually updated in preparation for new modeling episodes as they become necessary. Based on EPA recommendations, "at a minimum, four criteria should be used to select time periods which are appropriate to model:

1) Simulate a variety of meteorological conditions:
   "8-Hour Ozone- Choose time periods which reflect a variety of meteorological conditions which frequently correspond with observed 8-hour daily maxima" > 70 ppb at multiple monitoring sites[8].
2) "Model time periods in which observed concentrations are close to the appropriate baseline design value.
3) Model periods for which extensive air quality/meteorological databases exist.
4) Model a sufficient number of days so that the modeled attainment test applied at each monitor violating the NAAQS is based on multiple days."[9]

"Those implementing the modeling/analysis protocol may use secondary episode selection criteria on a case by case basis. For example, prior experience modeling an episode or year may result in its being chosen over an alternative. Another consideration should be to choose time periods occurring during the 5-year period which serves as the basis for the baseline design value (DVB). If observed ozone exceedances occur on weekends, weekend days should be included within some of the selected time periods. If it has been determined that there is a need to model several nonattainment areas simultaneously (e.g., with a nested regional scale model application), a fourth secondary criterion is to choose time periods containing days of common interest to different nonattainment areas".[10] One of the key reasons the June 2006 photochemical model was selected was because many areas in Texas experienced elevated ozone events during this time period. Episodes that can be modeled in conjunction with other regions, like Austin or Houston, are more cost-efficient. The sharing of data makes this approach beneficial to all regions involved by reducing the cost for each region.

Keeping EPA's guidelines in mind, the next step is to garner available data relating to meteorological measurements, transport, and ozone levels. Analysis of this data will be used to determine the desirability, based on the selection criteria, of the candidate episodes for San Antonio. The conceptual model compares these results and ranks episodes based on desirability alone. This is the first step in considering an episode for photochemical

[7] TCEQ. "Heritage Middle School C622". Available online: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo.pl?cams=622. Accessed 06/28/10.
[8] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze", Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 140. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 04/26/11.
[9] *Ibid*, p. 141.
[10] *Ibid*.

modeling selection. Other factors will ultimately direct the choice of the models; these other factors include: the need for a new episode, cost issues, compatibility with desired episodes of other regions, additional information obtained through further study, and other relevant factors.

2. AIR QUALITY TRENDS IN THE SAN ANTONIO AREA

Analysis of air quality monitoring data between 2005 and 2010 indicates a general decline in ozone concentrations, suggesting San Antonio's air quality is improving. Although the region is currently in attainment of the 75 ppb 8-hour average ozone standard, the proposed revision to the standard, which could lower the allowable 8-hour average ozone concentration to either 60 ppb, 65 ppb, or 70 ppb, will likely present serious challenges to the San Antonio region.

Tropospheric ozone is a secondary pollutant because it is not usually emitted directly into the atmosphere, but forms as the result of photochemical reactions between other chemicals, principally NO_X and VOCs. To gain an understanding of how atmospheric and chemical processes impact the formation and dispersion of ozone, the following analysis is based on time periods when peak 8-hour ozone concentrations in the San Antonio area exceeded the proposed revision to the ozone standard, i.e., in the range of 60 – 70 ppb.

2.1. *Ozone Trends*

There are currently 17 air quality monitors in the San Antonio region that record air pollution measurements including ozone levels. The data collected at these sites is processed for quality assurance by the Texas Commission on Environmental Quality (TCEQ) and is accessible via the Internet.[11] Figure 2-1 displays the locations of the CAMS within the San Antonio region. All monitors indicated on the map, with the exception of three water-quality monitors at Calaveras Lake, measure the ambient levels of at least one air pollutant. In addition, several sites monitor meteorological conditions such as temperature, wind, speed, wind direction, precipitation, solar radiation, and relative humidity.

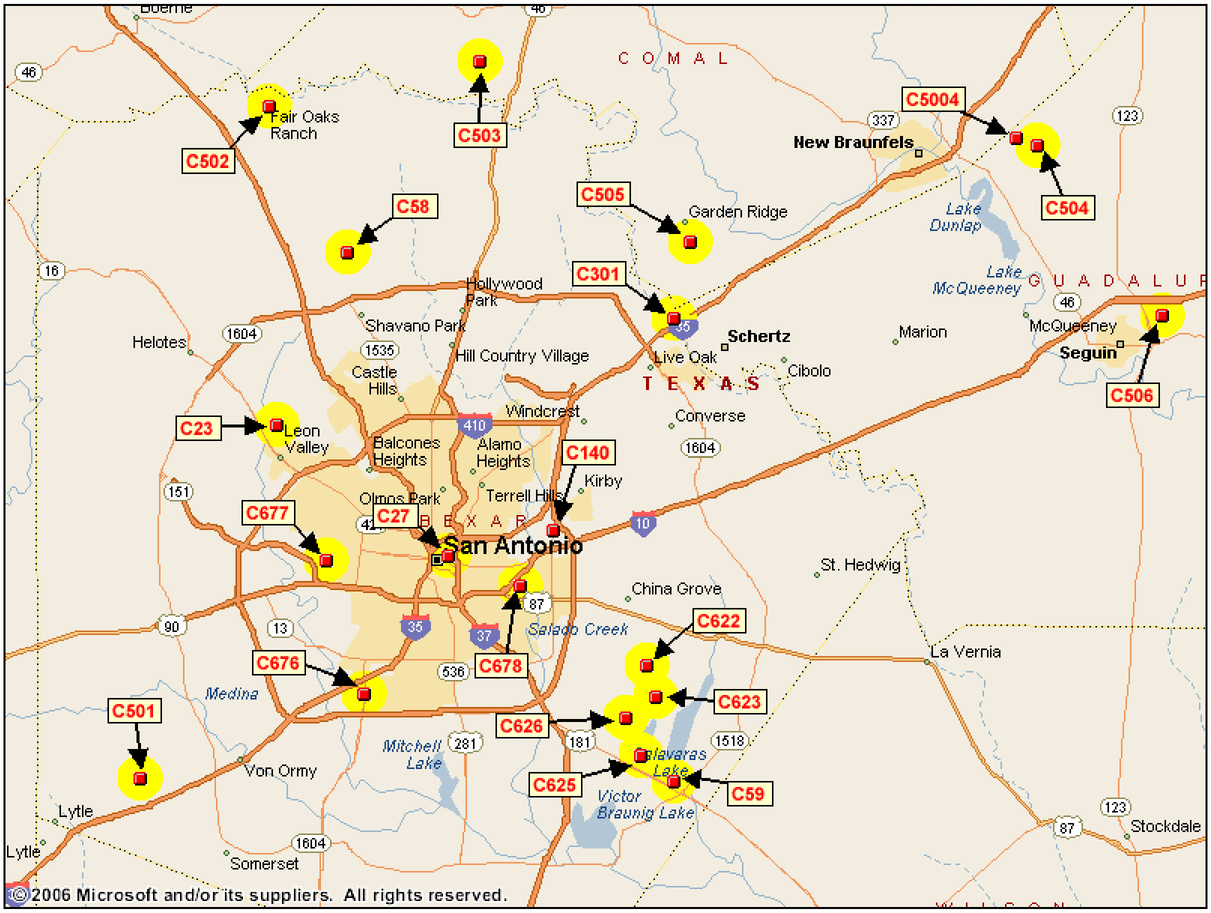
In addition to the ozone monitors at C23, C58, C59, C501, C502, C503, C504, C505, C506, C622, and C678, the map shows C27 (CO and NO_X), C140 (meteorological data), C301 ($PM_{2.5}$), C676 (meteorological data and $PM_{2.5}$), C677 (meteorological data, $PM_{2.5}$, and non-real-time VOC), and C5004 (meteorological data) sites. The three water quality monitors displayed on the map are C623, C625, and C626. Table 2-1 below lists all the local CAMS that record ozone concentrations.[12] Only C23, C58, C59, and C678 were active every year from 2000 to 2010.

The CAMS network in the San Antonio region includes both regulatory and non-regulatory monitors. Regulatory monitors meet EPA's requirements for equipment type, sitting criteria, and quality assurance. Regulatory monitors in the San Antonio area include three owned by TCEQ: C23, C58, and C59. Two monitors owned by CPS Energy, C622 and C678, are considered regulatory monitors in this report because they meet all site and data criteria required by EPA. AACOG owns a series of monitors, C501, C502, C503, C504, C505, and C506, which have been maintained since 2007 through the agency's subcontractor, Dios-Dado Environmental. These monitors are non-regulatory because they do not meet EPA guidelines for site selection[13] and the data does not meet EPA criteria for determination of

[11] TCEQ, "Select a Monitoring Site in Region 13 (San Antonio)". Available online: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/select_summary.pl?region13.gif. Accessed 05/13/10.
[12] *Ibid*.
[13] EPA, August 1998. "Guideline on Ozone Monitoring Site Selection". EPA-454/R-98-002. Office of Air and Radiation. Office of Air Quality Planning and Standards Research. Triangle Park, NC. Available online: http://www.epa.gov/ttnamti1/files/ambient/criteria/reldocs/r-98-002.pdf. Accessed 06/28/10.

attainment status. Although the AACOG monitors are non-regulatory, they provide valuable information useful for monitoring background conditions, improving the conceptual model, and evaluating model performance.

Figure 2-1: TCEQ, AACOG, and CPS Energy Monitoring Stations in San Antonio



The 8-hour ozone design values at C23 and C58 in northwest Bexar County from 2005 to 2010 are provided in figure 2-2. These monitors have had the highest design values in the San Antonio region since 2000. Furthermore, ozone measurements at the monitors during those years exceeded the upper limit (70 ppb) of the range under consideration for the revised standard. The two monitors now share the highest design value in the San Antonio area at 75 ppb. Since 2004, the local design value has decreased by 17.6% at C23 and 15.7% at C58. A regression analysis of the data indicates the 8-hour design values decreased at an average rate of 2.75 ppb per year at both C23 and C58 between 2004 and 2010.[14]

Table 2-1: Ozone-Recording CAMS Sites in the San Antonio Airshed, Ozone Season 2010

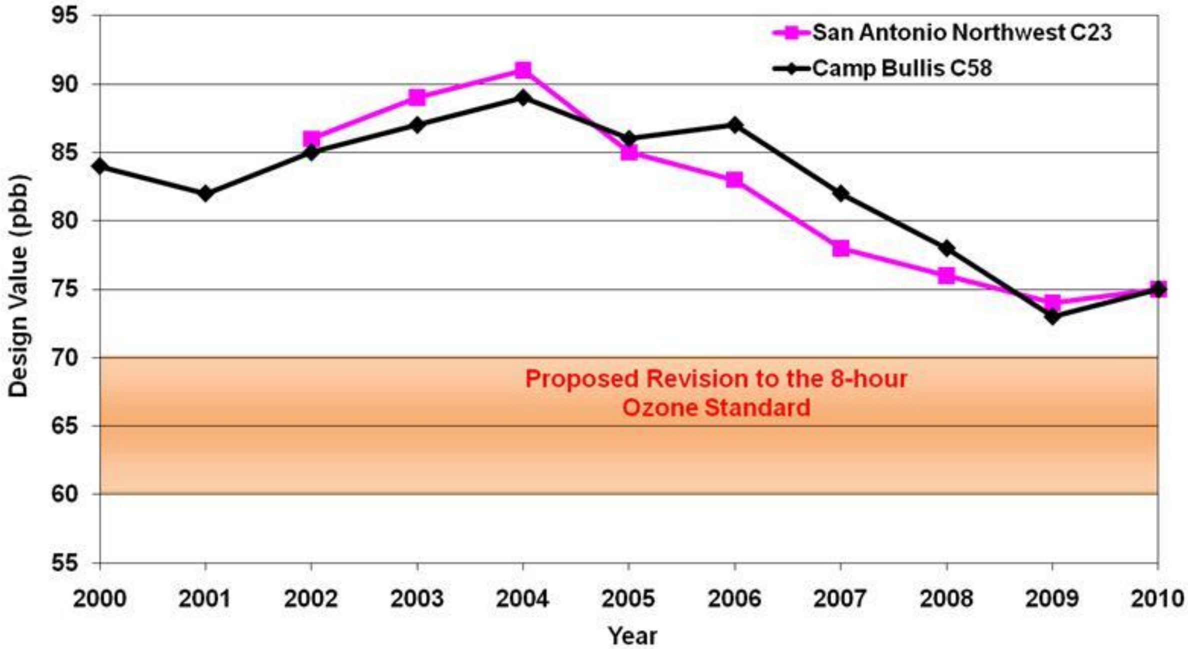
Designation / Site Name	Location Description	Data Measured	First date of reporting (online), Currently maintained by
CAMS 23 Marshall High School	6655 Bluebird Lane, San Antonio	Ozone, Meteorology	September 17,1996 TCEQ
CAMS 58 Camp Bullis	Near Wilderness road, San Antonio	NO_X, Ozone, Meteorology	August 12, 1998 TCEQ
CAMS 59 Calaveras Lake	14620 Laguna Road, San Antonio	NO_X, Ozone, Meteorology, $PM_{2.5}$	May 13, 1998 UT at Austin
CAMS 678 CPS Pecan Valley	802 Pecan Valley Dr. Eastern, San Antonio	CO, SO_2, NO_X, Ozone, Meteorology, $PM_{2.5}$	March 4, 1999 Dios-Dado for CPS
CAMS 501* Elm Creek Elementary	11535 Pearsall Rd., Bexar County	Ozone, Meteorology	June 17, 2002 Dios-Dado for AACOG
CAMS 502* Fair Oaks Ranch	7286 Dietz Elkhorn Rd., Fair Oaks Ranch	Ozone, Meteorology	June 28, 2002 Dios-Dado for AACOG
CAMS 503* Bulverde Elementary	1715 E. Ammann Rd. Bulverde, Comal County	Ozone, Meteorology	August 26, 2002 Dios-Dado for AACOG
CAMS 504* New Braunfels Airport	2090 Airport Rd. NB, Guadalupe County	Ozone	August 30, 2002 Dios-Dado for AACOG
CAMS 505* Garden Ridge	21340 FM 3009, City of Garden Ridge	Ozone	March 26, 2003 Dios-Dado for AACOG
CAMS 506* Seguin Outdoor Learn.	1865 Hwy 90 E, City of Seguin	Ozone	March 26, 2003 Dios-Dado for AACOG
CAMS 622 Heritage Middle School	7145 Gardner Road, San Antonio	CO, SO_2, NO_X, Ozone, Meteorology, $PM_{2.5}$	July 29, 2004 Dios-Dado for CPS

*"Data from this instrument does not meet EPA quality assurance criteria and cannot be used for regulatory purposes."[15]

[14] C23 R^2=0.90 and C58 R^2=0.91

[15] TCEQ. "Daily Maximum 8-hour Ozone Averages for September 2008". Available online: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/8hr_monthly.pl. Accessed 05/13/10.

Figure 2-2: Monitored 8-Hour Ozone Design Values at C23 and C58, 2000-2010

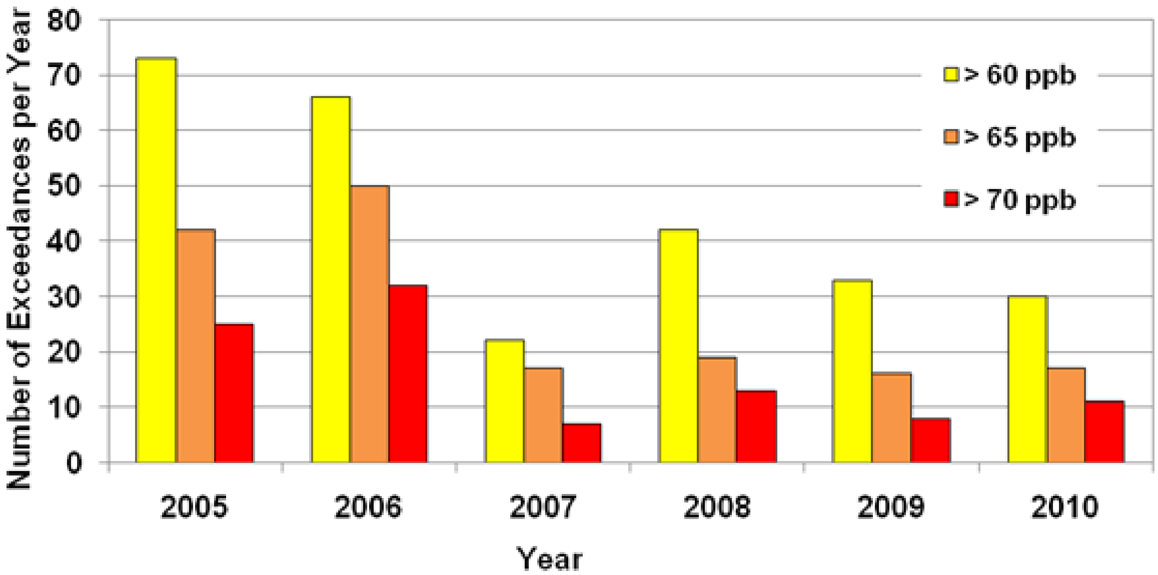


The numbers of high ozone days exceeding the proposed standards at regulatory monitors in the San Antonio area are provided in figure 2-3. Significant reductions in the number of exceedances of each proposed standard occurred from 2007 through 2010, compared to earlier years. Reductions in the numbers of exceedances of 70 ppb and 65 ppb were particularly steep, with 2007-2010 averages dropping 61% and 53%, respectively, from the 2000-2006 averages. This clearly demonstrates that while the design values, as moving averages, can be slower to change, the number of high ozone days occurring per year can fluctuate dramatically and there has been a significant reduction in the number of high ozone days in the last few years. All exceedances of the proposed ozone standard occurred during the ozone season, which extends from April through October in San Antonio.

2.2. *Variation between San Antonio Monitors*

Figure 2-4 shows peak 8-hour ozone measurements at C23 plotted against peak 8-hour ozone at C58 for 2005-2010. There is a strong correlation between the two monitors for ozone readings on all days including high ozone days. The strong correlation between the monitors indicates they are influenced by similar conditions on all days as well as high ozone days. Other monitor pairs in close proximity were plotted to determine the correlation between ozone measurements recorded at those monitors as provided in figures 2-4 through 2-13: C23/C58, C58/C502, C502/C503, C58/C503, C504/C506, C504/C505, C505/C506, C504/C675, C59/C622, and C622/C678.

Figure 2-3: Number of 8-Hour Ozone Exceedances of Proposed Standards of 60, 65, and 70 ppb at EPA Regulatory CAMS, 2005-2010



Since the x variable is close to 1 and the intercept value is small for C502/C503, C504/C506, and C59/C622 scatter plots, ozone values are similar for each pair of monitors. An excellent correlation exists between ozone measurements at C59 and C622, located in southeast Bexar County, as shown in figure 2-13 (R^2 = 0.96). The R^2 value provides a "goodness of fit" test between 0.0 and 1.0. A higher R^2 value indicates two variables may have a close correlation.[16] The high R^2 values for these monitor pairs that are located in close proximity to each other indicate, on most days, the monitors cover areas of similar meteorology and ozone-forming chemistry, and thus introduce some redundancy in the monitoring network.

However, the correlation of ozone measurements between monitors becomes weaker at higher proposed ozone standards, as shown in table 2-2. On days when locally produced ozone is not accumulated, all monitors are closer to background levels and therefore similar in ozone readings. This is especially true for the pair of C23 and C58, which shows high correlation on all days, R^2 = 0.93, but weaker correlation on days above 70 ppb, R^2 = 0.52. As will be discussed in following sections, both are located in a region that experiences high ozone, relative to the rest of the San Antonio area. The moderate correlation on high ozone days >70 ppb between C23 and C58 is in contrast to the relatively high correlation on high ozone days between C59 and C622 (R^2 = 0.79); two monitors that are further away from the urban core and are usually located upwind from San Antonio. Prevailing winds can produce narrow, concentrated ozone urban plumes that may not impact both C23 and C58 during the same high ozone event.

[16] GraphPad Software, Inc. "How Good is the Fit? Sum-of-Squares from Nonlinear Regression". Available online: http://www.graphpad.com/curvefit/goodness_of_fit.htm. Accessed 07/15/10.

Figure 2-5: Daily Maximum 8-hour ozone at C23 and C58, 2005-2010 Ozone Seasons

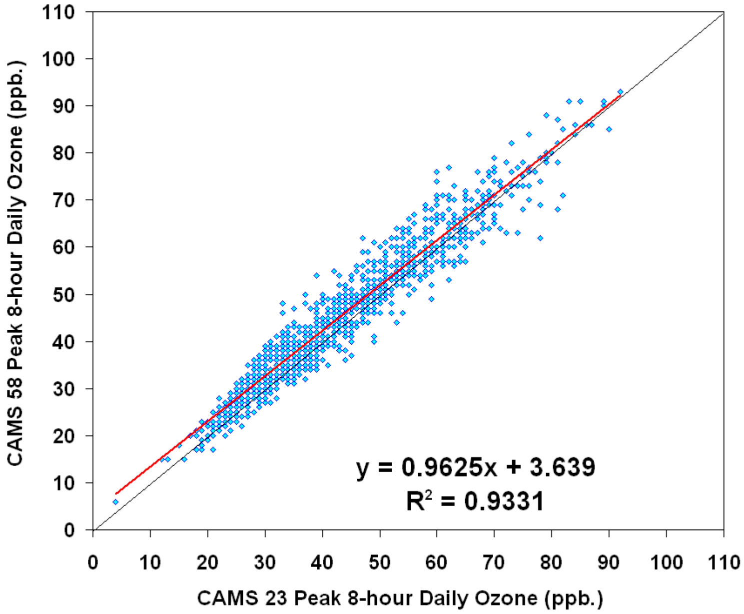


Figure 2-4: Daily Maximum 8-hour ozone at C58 and C502, 2005-2010 Ozone Seasons

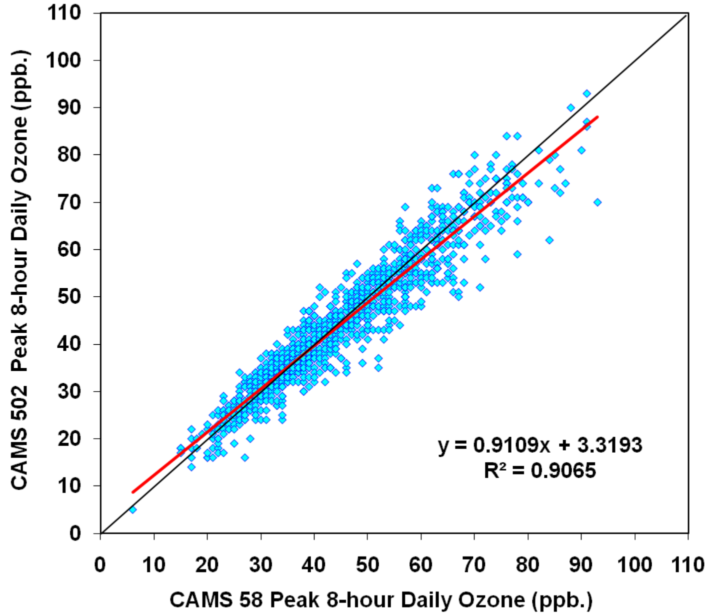


Figure 2-7: Daily Maximum 8-hour ozone at C58 and C503, 2005-2010 Ozone Seasons

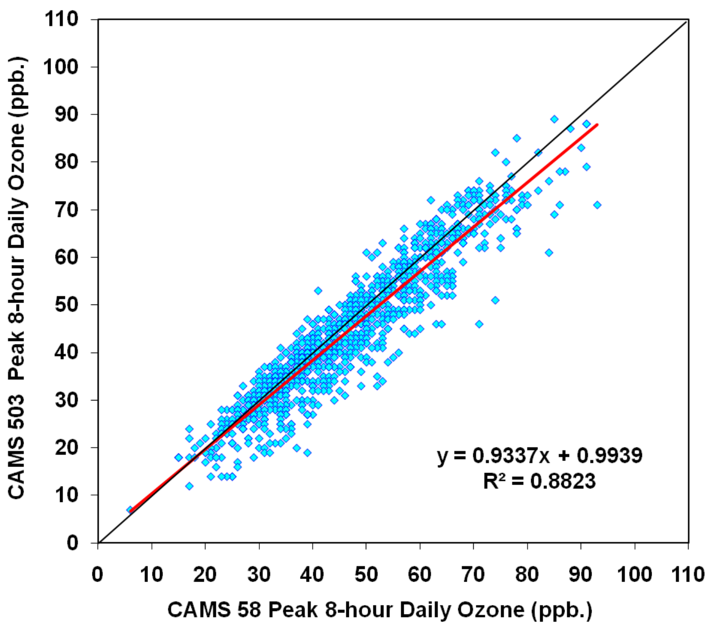


Figure 2-6: Daily Maximum 8-hour ozone at C502 and C503, 2005-2010 Ozone Seasons

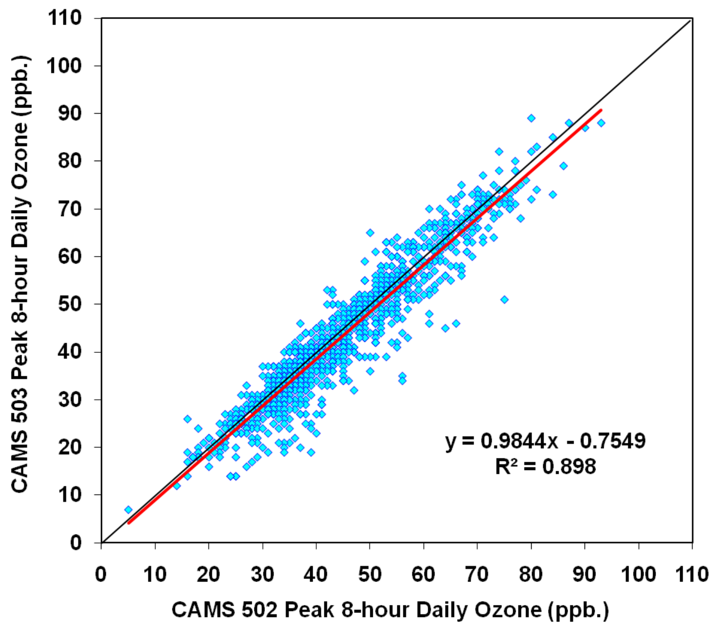


Figure 2-9: Daily Maximum 8-hour ozone at C504 and C675, 2006-2010 Ozone Seasons

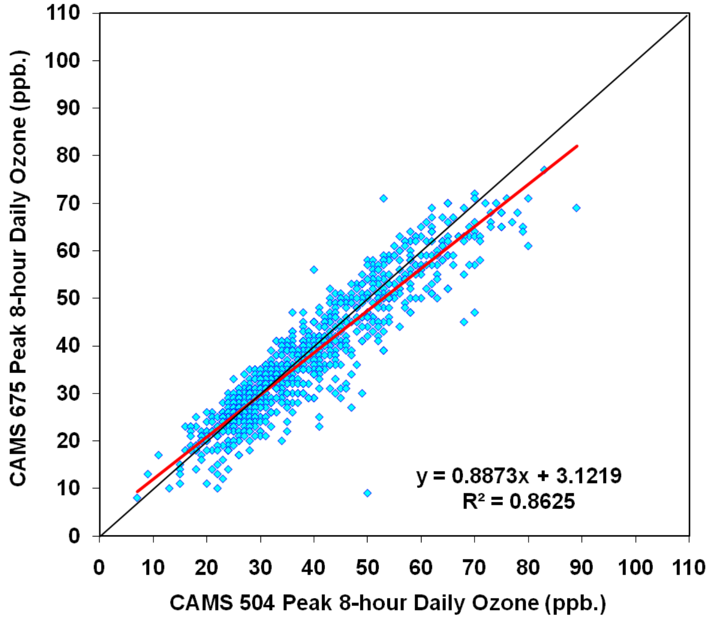


Figure 2-8: Daily Maximum 8-hour ozone at C505 and C506, 2005-2010 Ozone Seasons

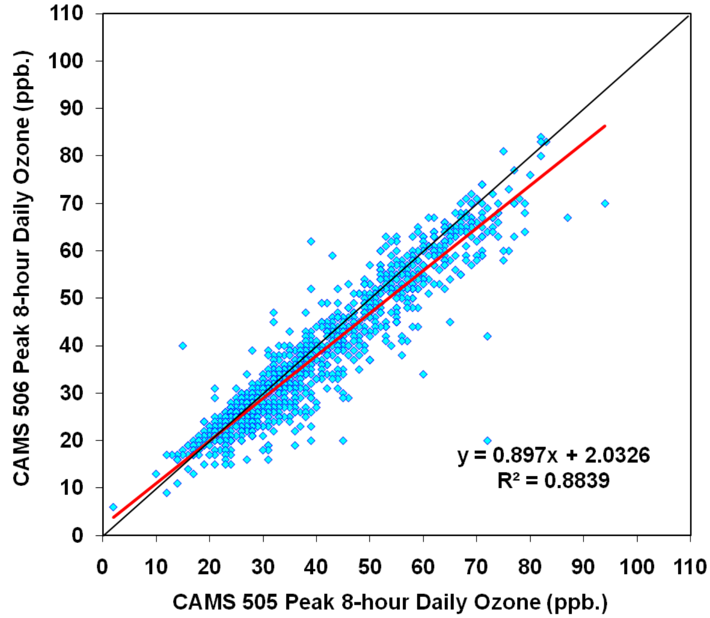


Figure 2-11: Daily Maximum 8-hour ozone at C504 and C505, 2005-2010 Ozone Seasons

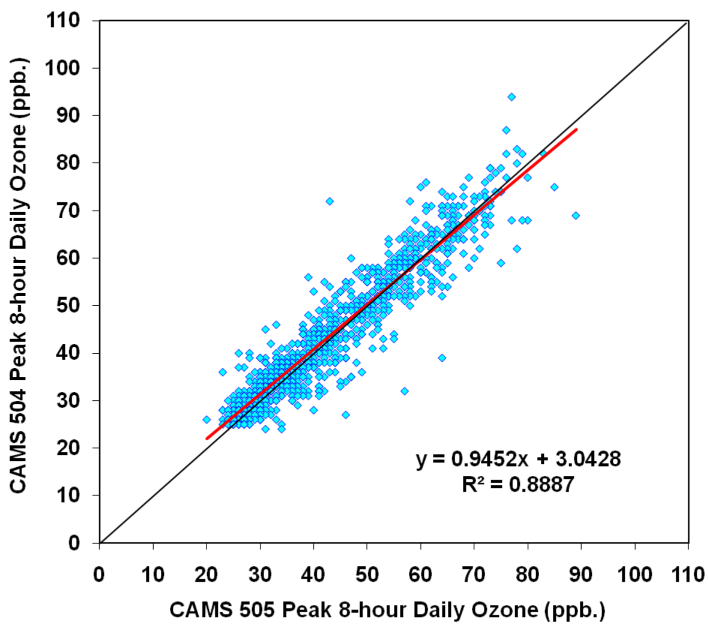


Figure 2-10: Daily Maximum 8-hour ozone at C504 and C506, 2005-2010 Ozone Seasons

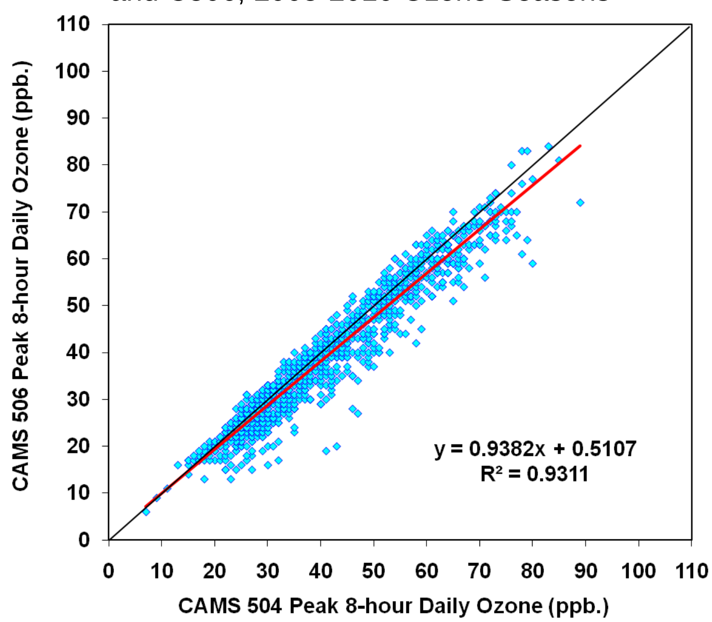


Figure 2-12: Daily Maximum 8-hour ozone at C622 and C678, 2005-2010 Ozone Seasons

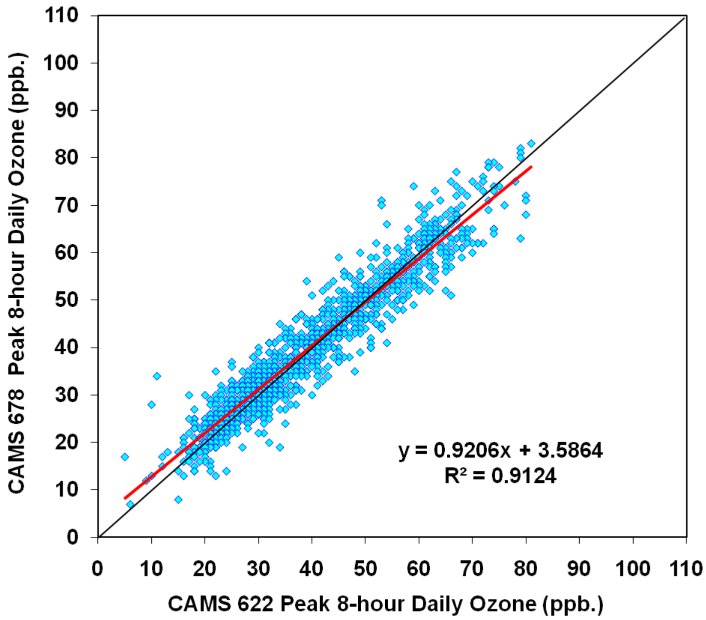
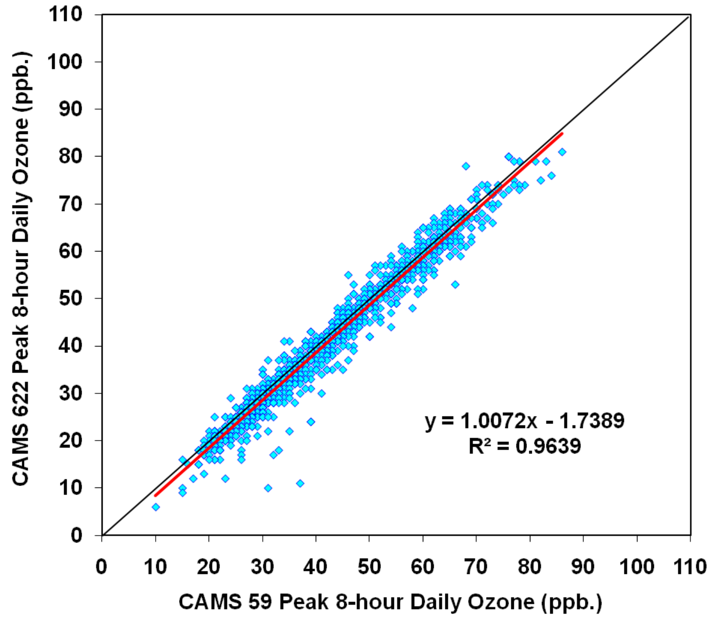


Figure 2-13: Daily Maximum 8-hour ozone at C59 and C622, 2005-2010 Ozone Seasons



The relationships between daily peak one-hour ozone values for monitor pairs are presented in Table 2-3. As with 8-hour ozone values, there are generally strong correlations between one-hour ozone values at different monitors for all ozone season days. The 8-hour values tend to indicate slightly stronger correlations between monitors during all ozone season days than the one-hour values, which is an expected result. Similarly, there's a weaker correlation for one-hour values between monitor pairs than the 8-hour values on higher ozone days.

Surprisingly, two combinations of monitors, C505 with C504 and C506, have very weak correlations between one-hour values on high ozone days. This might result from local cement kiln point source plumes influencing C505 in particular, since the correlation between C504 and C506 with other nearby monitors remains strong. Such plumes could cause spatial discrepancies in one-hour ozone values while 8-hour values remain less influenced.

The correlations between peak one-hour and 8-hour ozone measurements were compared to determine whether they exhibited similar patterns on high ozone days. The following figures, 2-15 and 2-16, show strong correlations between peak one-hour and 8-hour values at C58 and C23 (R^2 value of 0.95 for both monitors). The standard deviation between one-hour and 8-hour ozone on high ozone days is 4.56 ppb for C58 and 4.17 ppb for C23 on high ozone days > 60 ppb.

The strong correlation between 1-hour and 8-hour ozone readings at these two monitors downwind of San Antonio urban core suggests that they are measuring similar conditions. There are few extreme one-hour ozone values and narrow industrial plumes do not usually influence monitor readings. The similar, near 1:1 slopes of the two monitors suggest that neither monitor regularly experiences a rapid daily increase in ozone but rather a gradual increase in ozone throughout daylight hours that results from a semi-steady source of emissions including vehicles and point sources.

Table 2-2: Variation in Daily Peak 8-hr Ozone between CAMS in San Antonio Region,

Proposed 8-hour Standard	Parameter	CAMS Comparison									
		C58 C23	C58 C502	C502 C503	C58 C503	C504 C506	C504 C505	C505 C506	C504 C675	C59 C622	C622 C678
All Days	R^2	0.93	0.91	0.90	0.88	0.93	0.91	0.88	0.86	0.96	0.91
	SD (σ)	3.81	4.48	4.63	5.13	3.97	4.72	5.28	5.24	2.85	4.45
	Avg. Diff.	2.00	0.72	1.46	2.05	2.01	-0.34	2.18	1.25	1.45	-0.46
> 60 ppb	R^2	0.65	0.61	0.72	0.59	0.72	0.60	0.47	0.53	0.88	0.63
	SD (σ)	5.37	5.95	5.07	6.02	4.91	6.01	7.21	6.28	3.23	5.70
	Avg. Diff.	1.73	2.89	0.40	3.07	2.93	-0.94	3.57	2.39	1.04	-0.11
> 65 ppb	R^2	0.61	0.56	0.73	0.53	0.61	0.52	0.39	0.40	0.84	0.54
	SD (σ)	5.51	6.25	4.88	6.26	5.25	6.19	7.26	6.86	3.49	5.94
	Avg. Diff.	2.07	3.75	0.05	3.49	3.13	-1.21	4.14	3.55	0.94	-0.34
> 70 ppb	R^2	0.52	0.55	0.71	0.46	0.57	0.36	0.31	0.21	0.79	0.41
	SD (σ)	5.99	6.22	5.02	6.52	5.62	6.89	7.44	7.48	3.71	6.23
	Avg. Diff.	1.81	4.79	-0.10	4.31	3.76	-0.94	4.39	3.80	1.10	-0.89

Table 2-3: Variation in Daily Peak 1-hr Ozone between CAMS in San Antonio Region,

Proposed 8-hour Standard	Parameter	CAMS Comparison									
		C58 C23	C58 C502	C502 C503	C58 C503	C504 C506	C504 C505	C505 C506	C504 C675	C59 C622	C622 C678
All Days	R^2	0.90	0.89	0.86	0.86	0.91	0.87	0.83	0.85	0.95	0.89
	SD (σ)	5.07	5.47	6.12	6.24	4.90	6.12	6.82	5.65	3.33	5.32
	Avg. Diff.	2.42	0.85	1.76	2.48	2.07	-0.67	2.59	0.92	1.14	-0.72
> 60 ppb	R^2	0.64	0.61	0.62	0.58	0.63	0.44	0.35	0.53	0.85	0.58
	SD (σ)	6.72	7.30	7.12	7.31	6.07	7.95	8.50	7.00	4.27	7.02
	Avg. Diff.	1.96	3.12	0.58	3.65	2.98	-1.89	4.83	2.23	0.81	-1.05
> 65 ppb	R^2	0.59	0.55	0.58	0.51	0.54	0.31	0.28	0.40	0.83	0.53
	SD (σ)	6.82	7.67	7.37	7.57	6.28	8.46	8.35	7.58	4.22	7.01
	Avg. Diff.	2.26	4.08	0.03	4.04	3.60	-2.47	5.59	3.37	0.56	-1.33
> 70 ppb	R^2	0.58	0.63	0.68	0.52	0.44	0.15	0.33	0.29	0.76	0.38
	SD (σ)	7.22	7.31	6.93	7.83	6.48	9.99	7.76	8.06	4.63	7.72
	Avg. Diff.	2.11	4.70	0.29	4.99	4.10	-2.08	5.43	4.00	0.55	-1.76

2.3. *Spatial Variation in Ozone*

Ozone concentrations can vary by location in the San Antonio area. A spatial interpolation method was employed to identify typical ozone distributions on high ozone days. These patterns provide a more detailed description of the spatial variability in the factors contributing to high ozone levels. The 8-hour ozone design values at 11 ozone monitors in the San Antonio area were used to create the contoured areas of equal ozone concentration presented in figure 2-17. The design values for the latest five years, 2006, 2007, 2008, 2009, and 2010, were selected for analysis. This analysis supports the conclusions drawn from a review of ozone trend data, described previously, indicating ozone concentrations in the San Antonio region are decreasing. The analysis does not include the design values for 2005 for because C622 did not start operating until 2006.

Figure 2-15: C58 Maximum 1-Hour and 8-Hour Peak Ozone, 2005-2010

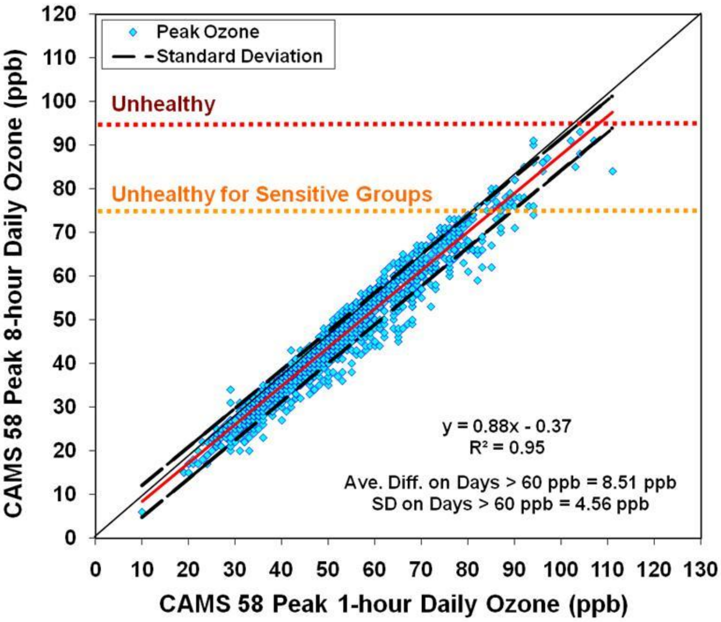
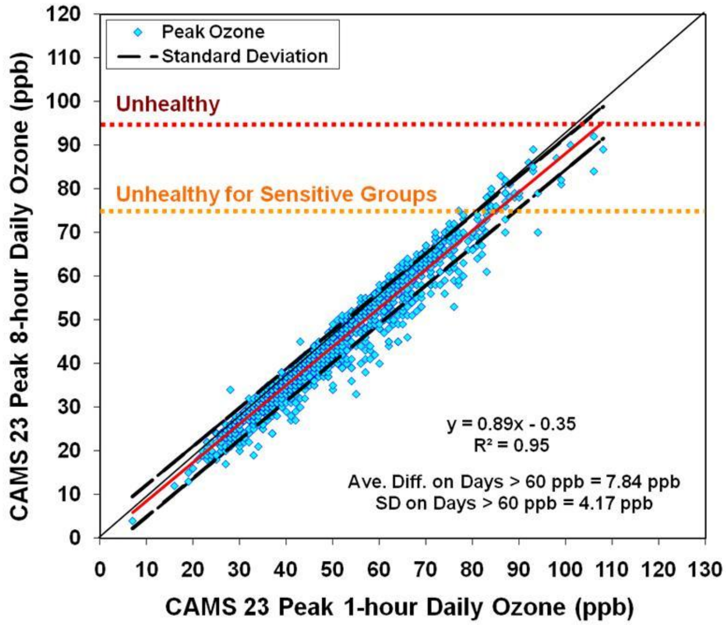


Figure 2-14: C23 Maximum 1-Hour and 8-Hour Peak Ozone, 2005-2010

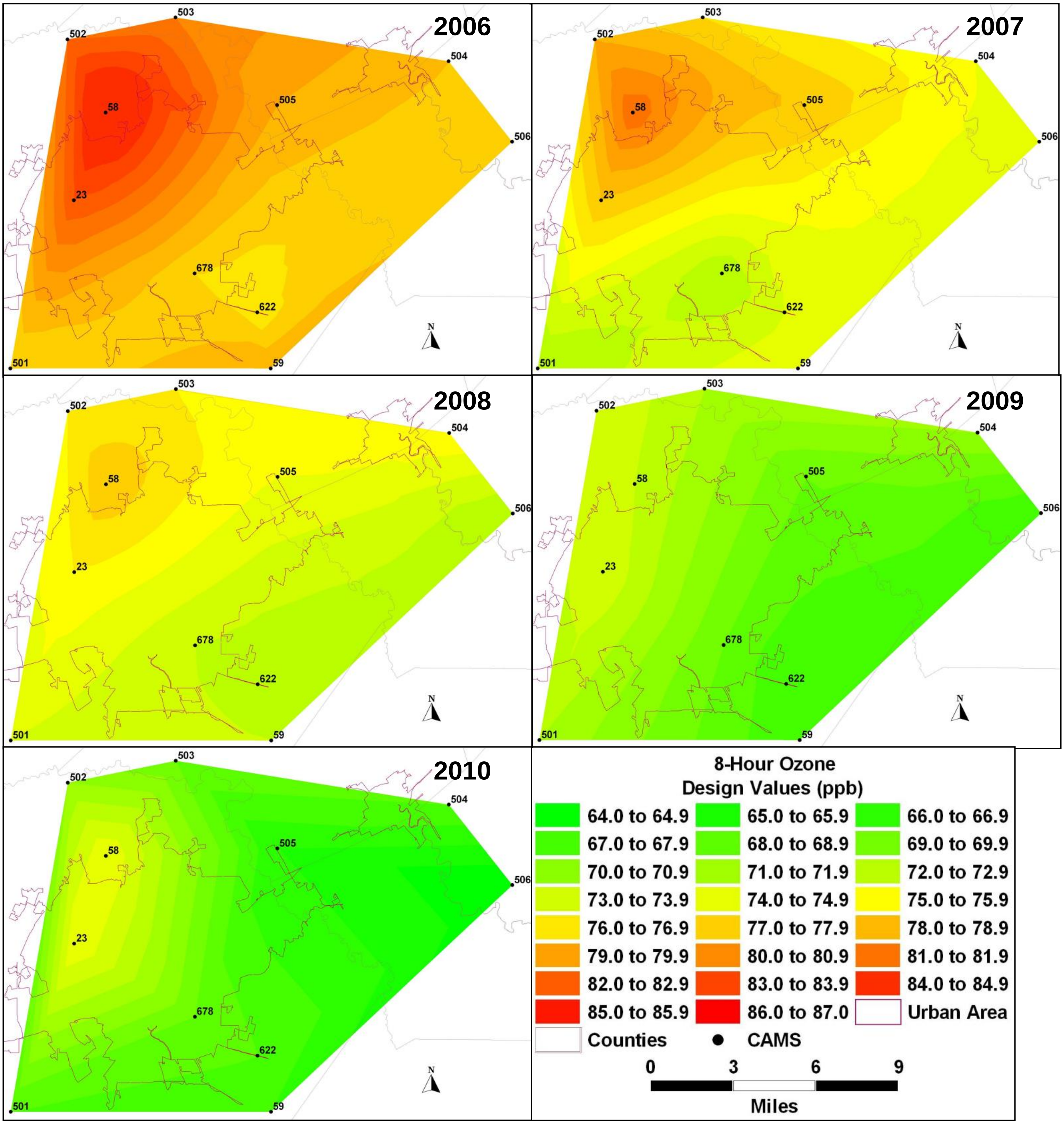


The highest 8-hour ozone design values in 2006, based on monitored ozone concentrations, exceeded 82 ppb and occurred in the northwestern portion of Bexar County: just northwest of the San Antonio city limit at Camp Bullis (CAMS 58), northwest of downtown at San Antonio Northwest (CAMS 23), and along the north-northwest border of Bexar County (CAMS 502 and 503). The lowest 8-hour ozone design values in 2006 occurred in a pocket in the southeastern part of San Antonio (CAMS 622), and along a southwest-to-northeast aligned swath running from CAMS 501 to CAMS 504 and 506. However, even the minimum 8-hour ozone design values in 2006 were above 75 ppb.

By 2009 and 2010, 8-hour ozone design values had dropped considerably across the region. While the highest concentrations still occurred at Camp Bullis (CAMS 58), and San Antonio Northwest (CAMS 23), the gradient between the lowest and highest values was smaller. The prevailing wind direction on high ozone days allows transported ozone to combine with local contributions to form high ozone at C23 and C58. The 2010 ozone peak value of 75 ppb is much lower than those recorded in 2006. The minimum 8-hour ozone concentration is at Seguin (CAMS 506) in 2010. This was the only monitor below the 65 ppb – the mid-range of the proposed revision to the ozone NAAQS.

Violations of the 60 ppb threshold – the lower limit of EPA's range proposed revision to the ozone NAAQS in 2010 – occurred at least two times per year at every monitor in the San Antonio MSA from 2005-2010, but occurred at least nine times per year at monitors which meet requirements for regulatory purposes. However, the number and location of monitors exceeding 60 ppb on each high ozone day varied greatly.

Figure 2-16: Contour Plots of 8-hour Ozone Design Values for 2006 – 2010



An analysis of high ozone days from 2005 – 2010 shows that, 17% of the time, only one monitor exceeded 60 ppb. More typically, multiple monitors in the San Antonio MSA recorded ozone concentrations exceeding 60 ppb on high ozone days. Concentrations of high ozone were observed on multiple monitors during the same ozone event. For example, on 30% of the high ozone days, more than two-thirds of the monitors measured exceedances of 60 ppb. On days when there were more than 9 monitors exceeding 60 ppb, upwind monitors indicated there were significant amounts of ozone transport above 60 ppb before local ozone contributions were added.

The frequencies of high ozone days above 60 ppb at each monitor, as well as all the monitors, are displayed in Table 2-4. The total number of 8-hour average ozone measurements above 60 ppb fell from a high of 542 in 2005 to 110 in 2010, a reduction of 80%. This represents both a significant decrease in the frequency of high ozone days and less extensive distribution of high ozone on days that did exceed the proposed standards. With the exception of 2008, the trend in the number of 8-hour measurements in excess of 60 ppb consistently declined during the six-year period.

C58 (214 days) and C23 (182 days) recorded the most 8-hour ozone averages above 60 ppb between 2005 and 2010 among regulatory monitors. C502 (176 days) and C503 (177 days) also had a high frequency of ozone days above 60 ppb over the same time period. All four monitors are located on the northwest side of San Antonio that is usually downwind of San Antonio's urban core, power plants, cement kilns, and industrial sites on high ozone days.

Table 2-4: Variation in Occurrences of High Daily 8-hr Ozone (>60 ppb) at CAMS in the San Antonio Area, 2005 – 2010

Monitor	2005	2006	2007	2008	2009	2010	05-10 Total
Northwest C23	50	40	17	29	30	16	182
Camp Bullis C58	59	55	21	31	22	26	214
Pecan Valley C678	33	39	11	27	15	9	134
Calaveras C59	53	50	11	21	6	12	153
Elm Creek C501	33	12	6	16	10	2	79
Fair Oaks C502	59	43	29	27	12	6	176
Heritage C622	48	40	12	20	8	14	142
Bulverde C503	62	47	26	23	12	7	177
Garden Ridge C505	53	28	21	23	11	7	143
New Braunfels C504	55	45	27	14	6	7	154
Seguin C506	37	35	15	13	9	4	113
No. of Monitors > 60 ppb	542	434	196	244	141	110	1,667
No. of Days > 60 ppb	91	69	39	48	34	31	312

The two regulatory-sited monitors that had the lowest number of high ozone days are C622 and C678. These monitors are located on the southeast side of San Antonio upwind of the city on most high ozone days. Similarly, the three non-regulatory CAMS with the lowest frequently of high ozone days, C501, C505, and C506, are located either northeast or southwest of the urban area, and therefore either upwind or out of the path of prevailing winds traveling over local urban areas, power plants, or large industrial facilities. Further research should include analyzing the changes in the spatial pattern of ozone for each hour of the day to determine how high ozone progresses through the region.

Overall from 2005-2010, an exceedance of 60 ppb ozone was observed at one or more monitors on 24.3% of all ozone season days. However, the frequency of high ozone days varied among monitors from an average of 13 per year (6.2% of the season) at C501 on the southwest side of San Antonio to 36 per year (16.7 % of the season) at C58 on the northwest side.

The progress achieved in recent years in reducing the number of high ozone days in the San Antonio area is evident in table 2-5 that compares the year-to-year differences in high ozone days at each monitor and the yearly totals of high ozone days. The number of high ozone days > 60 ppb occurring in the San Antonio area decreased consistently from 2005 to 2010, from 91 days in 2005 to 31 days in 2010, a decrease of 66%. The number of days exceeding the two higher thresholds under consideration for the proposed revision to the standard decreased even more significantly over the same period, with days greater than 65 ppb decreasing 71% and days over 70 ppb decreasing 74%.

Table 2-5: Variation in Frequencies of Peak 8-hr Ozone Values at CAMS in the San Antonio MSA, 2005-2010

Monitor	2005	2006	2007	2008	2009	2010
Northwest C23	23.6%	19.0%	8.2%	14.1%	14.2%	7.5%
Camp Bullis C58	28.5%	26.2%	10.1%	15.0%	10.4%	12.3%
Pecan Valley C678	5.9%	18.3%	5.3%	12.7%	7.0%	4.5%
Calaveras C59	25.4%	23.5%	5.2%	10.2%	3.0%	5.7%
Elm Creek C501	16.4%	7.9%	4.2%	7.8%	4.9%	1.4%
Fair Oaks C502	29.1%	22.6%	13.7%	12.9%	5.6%	4.0%
Heritage C622	23.8%	19.0%	5.6%	9.4%	3.9%	6.5%
Bulverde C503	29.7%	25.0%	12.3%	10.7%	6.7%	6.5%
Garden Ridge C505	26.5%	18.5%	10.3%	10.9%	5.2%	4.8%
New Braunfels C504	26.6%	24.2%	13.0%	6.5%	2.8%	4.7%
Seguin C506	19.9%	21.7%	7.2%	6.1%	4.2%	2.7%
Percent of All Days > 60 ppb	42.5%	32.2%	18.2%	22.4%	15.9%	14.5%

The percentage of high ozone days listed in table 2-5 reflects the general decrease in high ozone occurrences since 2005. Overall, the percentage of ozone season days when 8-hour average ozone values exceeded 60 ppb at any area monitor fell from 42.5% in 2005 to only 14.5% in 2010. Monitors away from the urban core have experienced particularly large decreases in the percentage of high ozone days. At the urban monitors, C678 and C23, reductions are not as significant. Since NO_X emissions have decreased rapidly in the last five years, there might be less of a NO_X disbenefit in the urban core and not as significant a reduction in ozone readings.

Eight-hour daily maxima in excess of 60 ppb are associated with characteristic spatial patterns on many high ozone days. High ozone occurs at clusters of monitors located in proximity to each other on these days. Clusters of monitors that recorded elevated ozone levels were grouped based on readings above 60 ppb from 2005-2010. By selecting monitors that recorded ozone within one standard deviation of peak 8-hour values within the San Antonio area on high ozone days, spatial clusters of monitors were determined. The most common patterns of elevated ozone that were found and the percentages of all high ozone days that each pattern accounted for are as follows:

- CAMS 23, 58, 502, 503, and 505: 38.1 % Northwest
- CAMS 59, 622, and 678: 4.8 % Southeast
- CAMS 504, 506, and 675: 3.5 % Northeast
- All other combinations of monitors: 53.6 %

A cluster of monitors located in the northwest San Antonio area (CAMS 23, 58, 502, 503, and 505) recorded elevated ozone values with high frequency. Combinations involving at least one of these monitors but no others in the San Antonio area accounted for 38 percent of all high ozone days. This dominant pattern suggests that winds out of the south, southeast, and east, which are frequently observed on high ozone days, arrive at the monitors after accumulating additional local ozone and ozone precursors from the urban core, power plants, cement kilns, and other industrial sources.

Another two clusters were observed in the southeastern (consisting of CAMS 59, 622, and 678) and far northeastern (CAMS 504, 506, and 675) vicinities of the San Antonio area, but these clusters accounted for far fewer days. Transported ozone precursor emissions and ozone from the north could be impacting these monitor clusters. The ozone plumes could continue farther southeast, south, and southwest while not impacting other monitors in the region.

2.4. *Temporal Variation in Ozone*

The frequency of high ozone occurrences can vary by time of the day, day of the week, and season. Different mixtures of emission sources, meteorological patterns, and transport can cause temporal variations in ozone formation and accumulation. To develop effective control measures to reduce ozone, temporal patterns should be identified and analyzed with the help of photochemical models.

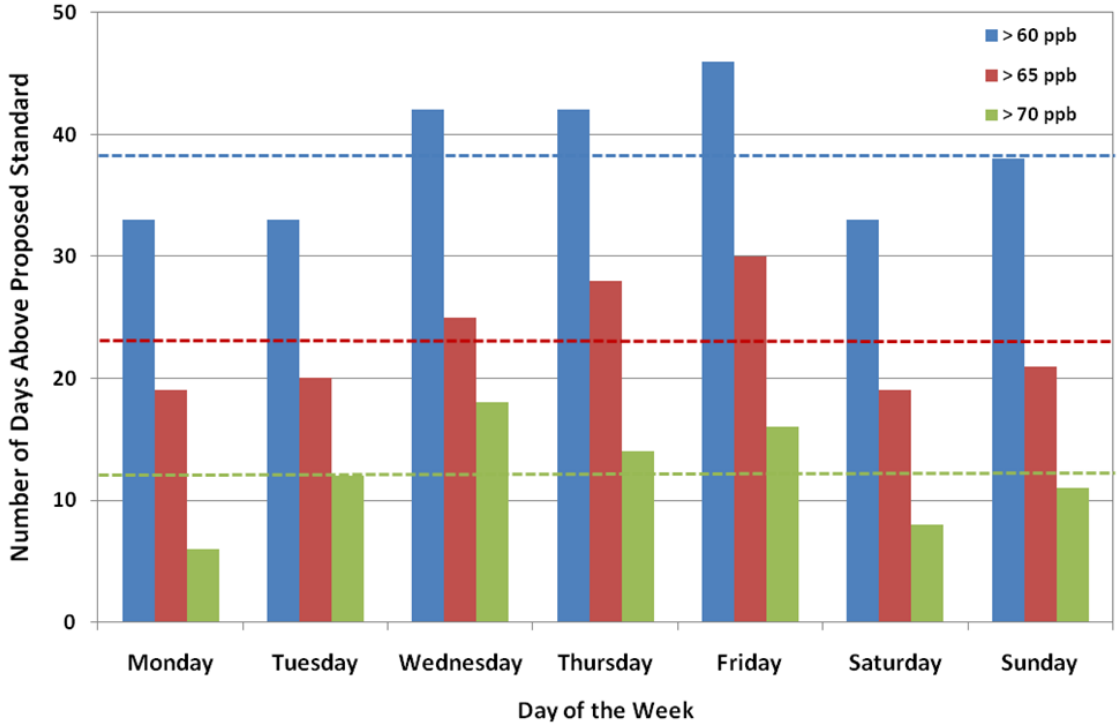
2.4.1. Day of the Week Variation

It is important to determine if there is a correlation between the day of the week and ozone readings. Differences in the frequency of weekday and weekend ozone give a preliminary indication as to the most effective ozone control strategy. For example, if high ozone measurements occur on a weekday, a different mixture of emission sources could be impacting ozone formation and different control strategies may be needed to reduce peak ozone concentrations during the week versus the weekend. High ozone on the weekend can be caused by a decrease in the occurrence of a NO_X disbenefit on the weekend when NO_X emissions are reduced. If the NO_X disbenefit is not as strong, recorded ozone levels can increase.

Figure 2-17 shows the number of high ozone days (exceeding each of the three proposed standards) recorded on each day of the week from 2005-2010. The three colored dashed lines on the chart represent the average number of high ozone days. The days with the most exceedances of each of the three proposed ozone standards (60 ppb, 65 ppb, and 70 ppb) were Wednesday, Thursday, and Friday. For all proposed standards, there were both weekday and weekend high ozone days.

Between 2005 and 2010, 26.6% percent of high ozone days > 60 ppb occurred on the weekends (71 days out of 267 high ozone days recorded at regulatory monitors). The percentage of weekend high ozone days is very close to the 28.6% of high ozone days expected to occur on the two weekend days. For the two higher proposed standards there were slightly fewer high ozone days on weekends from 2005 to 2010, with 24.7% and 22.4% of exceedances of the 65 ppb and 70 ppb proposed standards, respectively.

Figure 2-17: Number of High Ozone Days by Day of the Week, 2005-2010



The chi-square (X^2) goodness-of-fit test[17] was performed on the day-of-the-week distribution of high ozone days for each proposed standard to determine whether the distributions are random or significant in the San Antonio region. Following is the calculation used to determine if the distribution is significant.

Equation (1)
Chi-Square goodness-of-fit test

$$X^2 = \sum (f_o - f_e)^2 / f_e$$

Where,

X^2 = Chi-square (X^2) goodness-of-fit
f_o = Frequency of "Observed" value (from Figure 2-17)
f_e = Frequency of "Expected" value or total in sample divided by number of categories (267 high ozone days / 7 time periods = 38.14)

Chi-Square goodness-of-fit test for high ozone days' day-of-the-week frequency in San Antonio:

X^2 = 4.48

The Phi or Cramer's V test is used to determine the degree of significance of the chi-square results by eliminating sample size impact.[18] The chi-square value has a range of $[0 - \infty]$; when augmenting with the phi test, the results are reduced to a more manageable range of

[17] Jones, James, Professor of Mathematics, Richland Community Collage. "Math 170: Intro to Statistics Chapter 12 Lecture Notes". Available online: http://www.richland.edu/james/lecture/m170/ch12-fit.html. Accessed 06/30/10.

[18] Garson, Davis, North Carolina State University. "Nominal Association: Phi, Contingency Coefficient, Tschuprow's T, Cramer's V, Lambda, Uncertainty Coefficient". Available online: http://www2.chass.ncsu.edu/garson/pa765/assocnominal.htm. Accessed: 06/30/10.

[0 – 1.0]. For a chi-square representing a uniform distribution, the phi results would be closer to 0.0.

Equation (2)
Cramer's V test

$$\varphi = \sqrt{X^2 / f_o}$$

Where,

φ	= Phi value
X^2	= Chi-square (from equation 1)
f_o	= Frequency of "Observed" value (267)

The phi results for the high ozone days > 60 ppb based on daily periods:

$$\varphi = \sqrt{(4.48 / 267)}$$
$$= 0.13$$

The chi-square (X^2) goodness-of-fit test and Phi (φ) were performed on the daily distribution for high ozone days to determine if there was a significant difference in the distribution of high ozone by the day of the week.

60 ppb standard	Chi-square (X^2)	= 4.48 (from equation (1))
	Significant at 95%	= **no** (4.48 < 12.59)
	Phi (φ)	= 0.13
65 ppb standard	Chi-square (X^2)	= 5.31 (from equation (1))
	Significant at 95%	= **no** (5.31 < 12.59)
	Phi (φ)	= 0.18
70 ppb standard	Chi-square (X^2)	= 8.96 (from equation (1))
	Significant at 95%	= **no** (8.96 < 12.59)
	Phi (φ)	= 0.32

The results indicate there is no significant variability as to which day of the week elevated ozone concentrations occur. The chi-square test confirms that, except for random variation, high ozone days ***occur with equal frequency*** in the San Antonio region for any day of the week. It is just as likely to have high ozone concentrations on one given day of the week as on another day of the week. Although the results were not significant for the 70 ppb proposed standard, the analysis did indicate a moderate Phi value. It should be kept in mind that EPA guidance recommends selecting modeling episodes that contain weekend days, if it is common for a region to have high ozone days on weekends.[19] However, given the differences in locally contributed ozone on weekdays versus Saturdays and Sundays, further research on day of the week recorded ozone should include the analysis of ozone pre-cursor emissions and other pollutants on weekdays and weekends.

2.4.2. Ozone Diurnal Variations

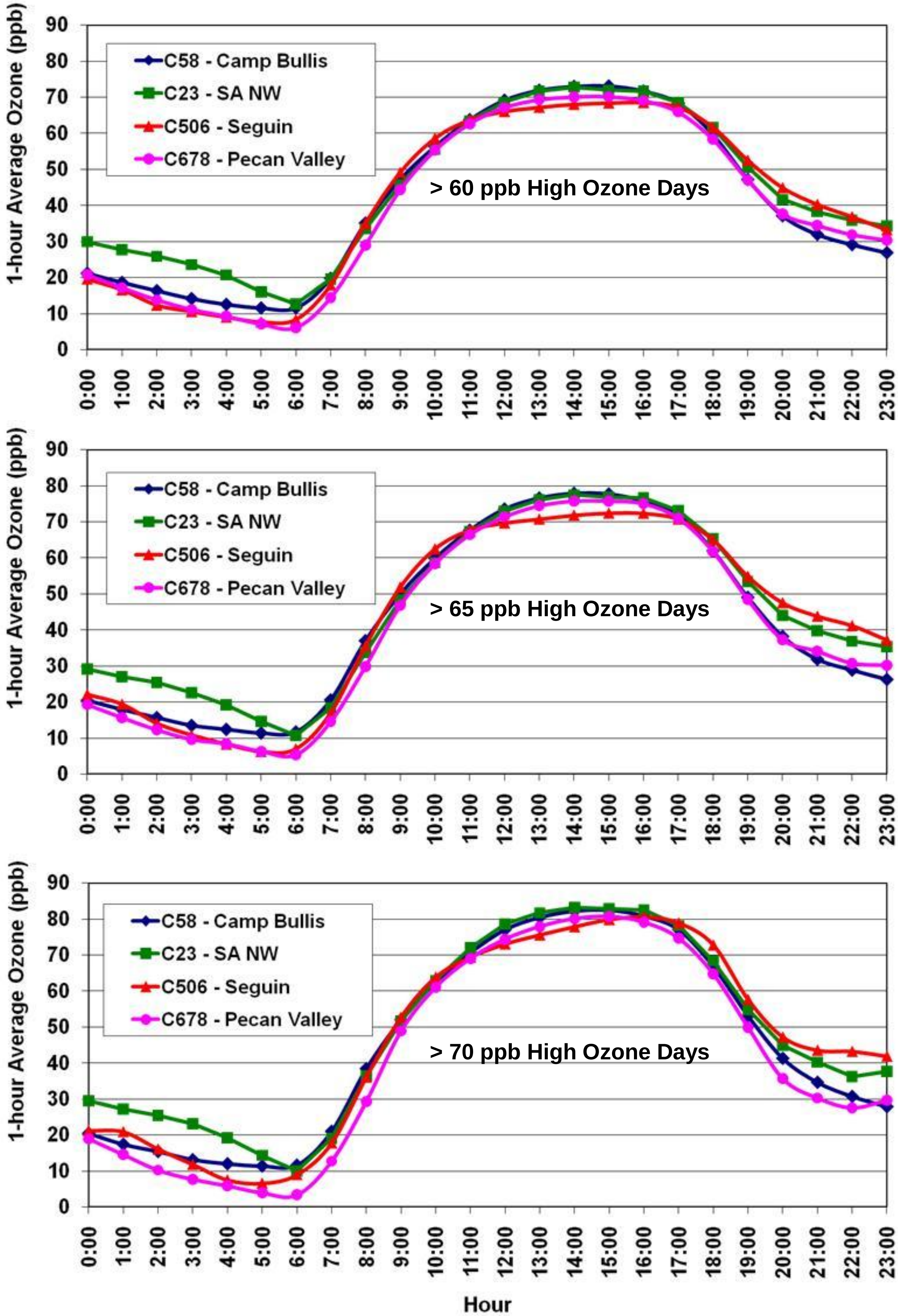
Since ozone forms in the presence of ultraviolet energy from sunlight, there are variations in the ground level ozone diurnal cycle, starting from low (regional background) levels before sunrise and increasing during the morning and into the afternoon, before decreasing in the

[19] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze", Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 141. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

evening as energy flux from the sun ceases to drive ozone production. Ozone concentrations rise rapidly in the morning sunlight because local NO_X and VOC emissions react with precursor emissions remaining from the previous day as well as with transported emissions. Figure 2-19 provides the average high ozone day's diurnal profile based on ozone measurements recorded at C23, C58, C678, and C506 between 2005 and 2010, for proposed standards of 60 ppb, 65 ppb, and 70 ppb. On average, the lowest ozone readings at all monitors are recorded just before sunrise from 5-6 a.m.

Although the four monitors are in different parts of the city, they all show similar patterns in the morning when ozone values increase between the 6 a.m. morning minimum and the 2 p.m. afternoon peak. Comparison of the peak ozone levels at these four monitors reflects the higher average 8-hour ozone values recorded at C23 and C58, which are typically downwind monitors, compared to the other two monitors. C678 recorded the lowest ozone profile during the nighttime. Since C678 is located near downtown San Antonio, this may be the result of NO_X scavenging of ozone during the nighttime. It is possible that the monitor's proximity to the urban core produces measurements that are affected by elevated NO_X emissions occurring overnight from urbanized sources and accumulating at the monitor due to light winds and limited nocturnal mixing.

Figure 2-18: Average Diurnal Profiles on 60, 65, and 70 ppb 8-Hour High Ozone Days, 2005-2010



2.5. *Summary of Air Quality Trends in the San Antonio Area*

Analysis of local trends shows monitored ozone readings are decreasing over time and San Antonio's air quality is improving. As the ozone standard is lowered, San Antonio will have a challenge to meet the new proposed standard. Air quality trends in the San Antonio area include:

- Between 2005 and 2010, the local design value has decreased by 11.8% at C23 and 12.8% at C58.
- The 8-hour design values decreased at an average rate of 2.75 ppb per year at both C23 and C58 between 2005 and 2010.
- Significant reductions in the number of high ozone days of each proposed standard occurred between 2005 and 2010.
- The number of high ozone days > 60 ppb occurring in the San Antonio area decreased consistently from 2005 to 2010, from 91 days in 2005 to 31 days in 2010, a decrease of 66%. Even greater reductions occurred for the less stringent proposed standards, with decreases of 71% and 74% for 65 ppb and 70 ppb, respectively, occurring from 2005 to 2010.
- There is a strong correlation between C23 and C58 ozone monitors for all days, indicating they are usually influenced by similar conditions. However, the two monitors have a weaker correlation on high ozone days, perhaps because prevailing winds can produce narrow, concentrated ozone urban plumes that may not impact both C23 and C58 during the same high ozone event.
- Ozone readings between C502/C503 and C504/C506 monitors located northeast of San Antonio had a relatively high correlation for all days and high ozone days, likely because the pairs are either upwind or downwind of San Antonio on many days.
- Ozone readings at monitors located in southeast Bexar County, C59 and C622, had a high correlation due to their proximity to each other and positioning upwind of San Antonio or out of the path of San Antonio's urban plume on most days.
- The high R^2 values for ozone date from these monitor pairs that are located in ~~close~~ proximity to each other indicate, on most days, the monitors cover areas of similar meteorology and ozone-forming chemistry, and thus introduce some redundancy in the monitoring network.
- Ozone measurements at C505 were weakly correlated with those of C504 and C506. This might result from nearby point source plumes influencing C505.
- There was a strong correlation between peak one-hour and 8-hour values at C58 and C23. The strong correlation suggests that few of the extreme one-hour ozone values at the monitors were caused by industrial plume spikes.
- The 8-hour ozone design values at all monitors were above 75 ppb in 2006. By 2010, 8-hour ozone design values had dropped considerably across the region.
- No regulatory monitor in the San Antonio region meets the 65 ppb proposed revision to the ozone NAAQS, and C23 and C58 fail to meet the 70 ppb proposed revision.
- On days when there were more than 9 monitors exceeding 60 ppb, there was a significant amount of ozone transport arriving into the region before local ozone contributions were added.
- The three non-regulatory CAMS which least frequently recorded high ozone days, C501, C504, and C506, are located either northeast or southwest of the urban area, and therefore either upwind of the city or not in the path of prevailing winds traveling over local urban areas, power plants, or large industrial facilities.
- When 8-hour daily maxima in excess of 60 ppb do occur, there is a characteristic (typical) spatial pattern where the high values were measured. A cluster of monitors located in the northwest of the San Antonio area (CAMS 23, 58, 502, 503, and 505) recorded high ozone values with high frequency. Combinations involving at least

one of these monitors but no other monitors in the San Antonio area accounted for 38 percent of all high ozone days. This frequent pattern suggests that winds out of the south, southeast, and east, which are often observed on high ozone days, allows local emissions from the urban core to produce ozone at downwind monitors.

- Another two clusters were observed in the southeast (consisting of CAMS 59, 622, and 678) and far northeast (CAMS 504, 506, and 675) vicinities of the San Antonio area, but these clusters only accounted for few days Transported ozone precursor emissions and ozone from the north could be impacting these monitor clusters. The ozone plumes could continue farther southeast, south, and southwest while not impacting other monitors in the region.
- For all proposed standards, high ozone days occur on both weekdays and on weekends. Between 2005 and 2010, 26.6% percent of high ozone days > 60 ppb occurred on the weekends. A different mixture of emission sources could be impacting ozone formation on the weekend and different control strategies may be needed to reduce peak ozone concentrations on those days. High ozone on the weekend can be caused by a decrease in the occurrence of a NO_X disbenefit on the weekend because NO_X emissions are lower.
- Since ozone forms in the presence of ultraviolet energy from sunlight, ground level ozone concentrations vary during the diurnal cycle, starting from low ozone before sunrise and increasing during the morning and into the afternoon, and then decreasing in the evening as energy flux from the sun ceases to drive ozone production. Ozone readings rise rapidly in the morning because local NO_X and VOC emissions react with precursor emissions remaining from the previous day and transported emissions.
- Urban core monitors tended to have lower nighttime diurnal ozone readings. These readings may be due to NO_X scavenging in the urban core from vehicle and point source NO_X emissions.

3. METEOROLOGICAL AND OZONE PRECURSOR EMISSIONS IN THE SAN ANTONIO AREA

Meteorological processes have a significant impact on ozone formation because meteorology influences the concentration, location, and transport of ozone pre-cursor emissions. Other key processes impacting ozone levels, including chemical reaction rates and some human behavior, are also influenced by meteorological factors.

Certain identifiable regional-scale meteorological pressure systems are associated with high ozone events. Prevailing wind directions, wind speeds, mixing, and dispersion conditions are influenced by high-pressure systems. High-pressure systems suppress vertical mixing of pollutants and influence wind direction, and are characterized by clear skies, relatively low wind speeds, and low humidity in San Antonio. These meteorological conditions typically increase ozone formation and transport of pollutants into the San Antonio area and generate elevated concentrations of local ozone.

The study of daily weather maps,[20] courtesy of the National Oceanic and Atmospheric Administration (NOAA) Central Library Data Imaging Project, provides a means of characterizing weather patterns. As discussed, weather patterns can produce conditions suitable for the formation of ozone; therefore, weather maps were reviewed to determine meteorological patterns on high ozone days. Areas of high pressure lead to stagnant air over Texas, limited frontal movement, and clear skies typical of high ozone days. Figure 3-1 displays the NOAA weather maps for June 28, 2006 when peak 8-hour ozone in San Antonio reached 88 ppb. As indicated in the figure, there was a high-pressure system over San Antonio, stagnant air, clear skies, and no precipitation during this period of high ozone. A high-pressure system occurred at both the surface level and 500-millibar height over the south central U.S. In the region from Alabama to Texas, there was no precipitation on this day. This pattern is typical of conditions on high ozone days.

Movement of frontal and high-pressure systems can impact ozone formation in the San Antonio region. Figure 3-2 shows the movement of a front through the San Antonio region on May 14th and 15th, 2006. On both of these days, wind vectors changed and the area recorded moderate peak ozone measurements (65 on May 14th and 63 ppb on May 15th). Once the frontal zone moved through the region, a high-pressure system arrived over San Antonio resulting in elevated ozone from May 17th – 19th, 2006 at local monitors (78, 79, and 76 ppb). For the Houston area TCEQ states, "when synoptic (large-scale) weather systems move through the region, ozone and precursor emissions tend to be diluted and carried out of the city, rather than concentrated in still, stagnating air, to be heated, reacted and turned into ozone. Days dominated by strong synoptic weather systems tend to experience low ozone levels."[21] These regional meteorological patterns also increase ozone formation in the San Antonio area.

3.6. *Analysis of Annual Design-Value-Cycle Variations in Meteorological Parameters*

In figure 3-3, the number of annual high ozone days (eight-hour average ozone concentrations > 60 ppb) was plotted against a number of meteorological factors: total precipitation, average maximum temperature, average surface wind speed between 6 am and 2 pm, relative humidity at 2 pm, and average daily maximum solar radiation. The correlation between the number of high ozone days and typical ozone season meteorological conditions was weak or non-existent for each factor.

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[20] NOAA National Centers for Environmental Prediction, Hydrometeorological Prediction Center. "Daily Weather Maps". Available online: http://www.hpc.ncep.noaa.gov/dailywxmap/index.html. Accessed 05/26/10.

[21] TCEQ Data Analysis Team, May, 2009. "Draft: Houston-Galveston-Brazoria Nonattainment Area Ozone Conceptual Model". Austin, Texas. p. 1-9. Available online: http://www.tceq.state.tx.us/assets/public/implementation/air/am/modeling/hgb8h2/doc/HGB8H2_Conceptual_Model_20090519.pdf. Accessed 07/02/10. Originally published in Banta, R.M., C.J. Senff, J. Nielson-Gammon, L.S. Darby, T.B. Ryerson, R.J. Alvarez, S.P. Sandberg, E.J. Williams, and M. Trainer. 2005. "A Bad Air Day in Houston". Bulletin of the American Meteorological Society. 86(5): 657-669.

Figure 3-1: Daily Weather Maps for June 28, 2006

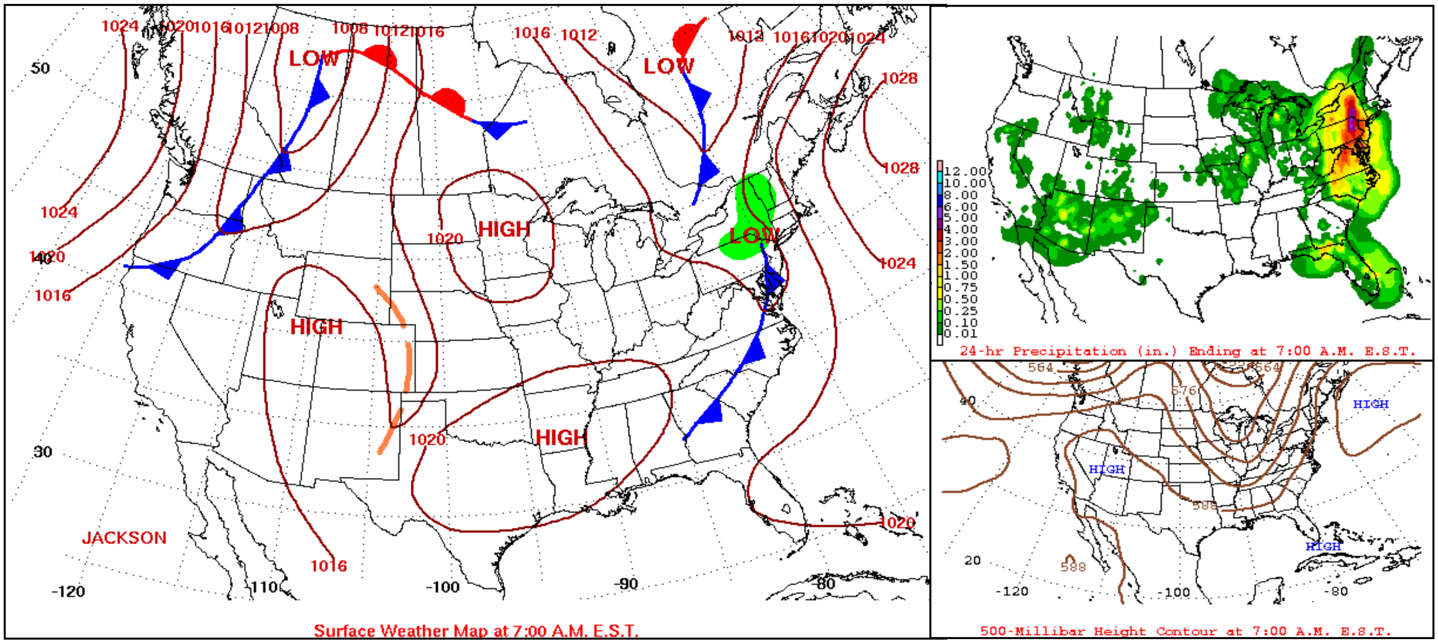
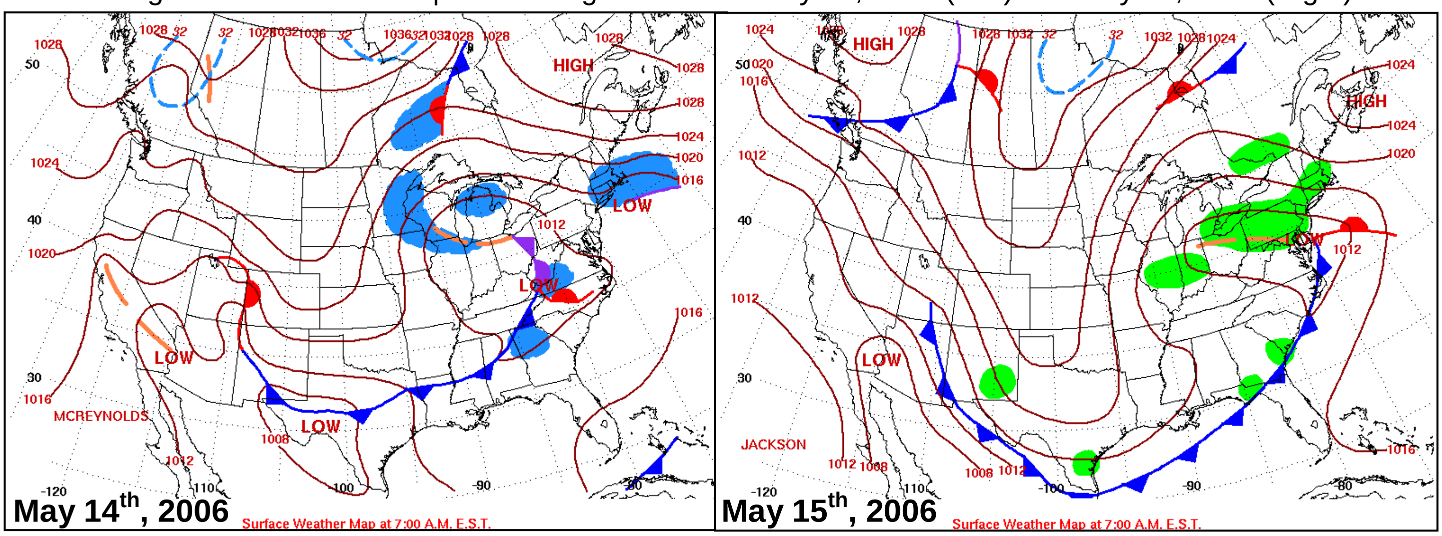
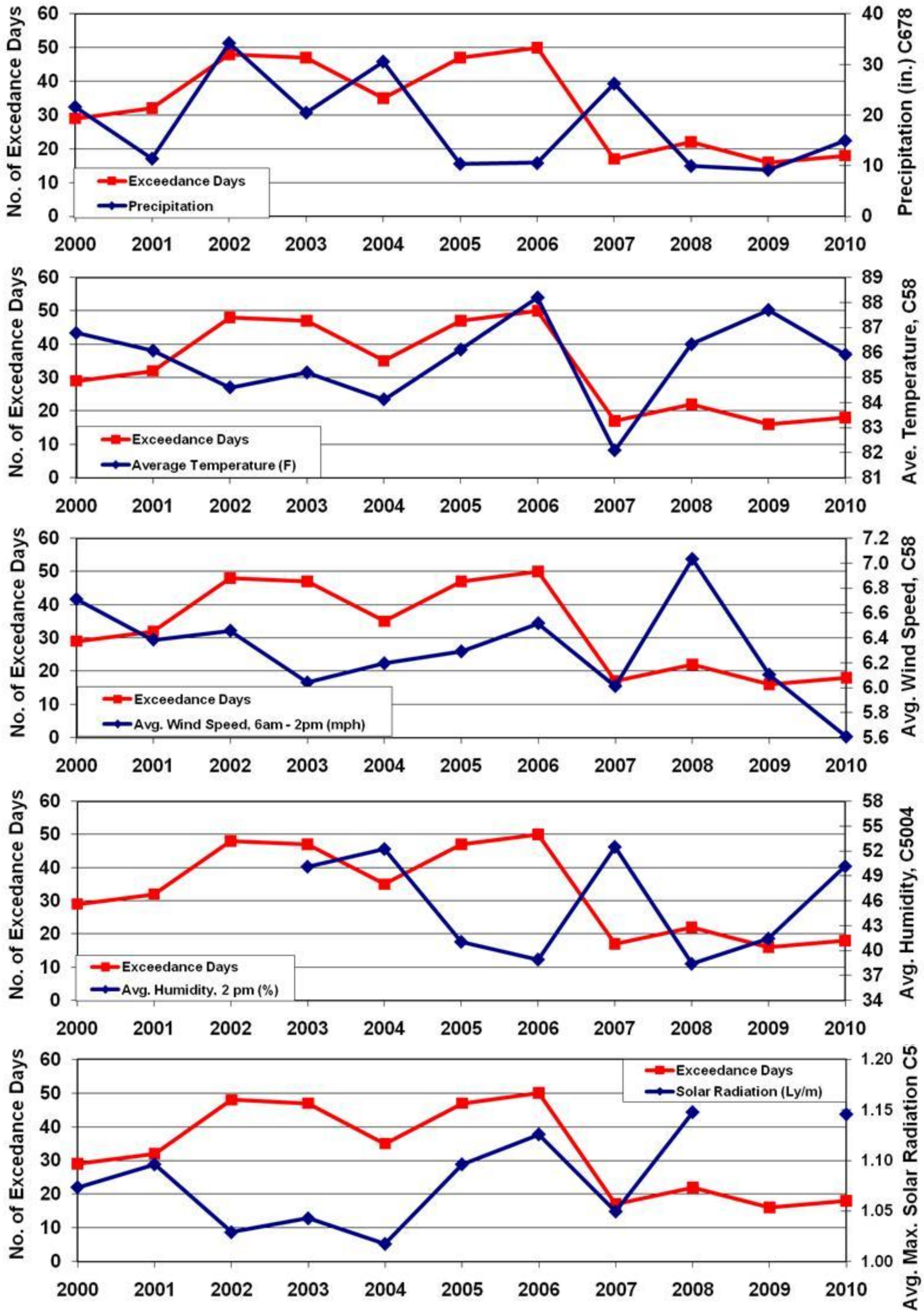


Figure 3-2: Weather Maps Indicating Cold Front: May 14, 2006 (Left) and May 15, 2006 (Right)



There does not seem to be a correlation between the number of annual high ozone days and ozone season total precipitation. In 2002 there was a significant amount of precipitation and San Antonio had a high number of high ozone days. The pattern was reversed for 2007, when precipitation was high but there were few high ozone days. Furthermore, there appears to be little correlation between the number of high ozone days and average wind speed or solar radiation. These results indicate changes in the annual average meteorological conditions analyzed for this study do not have strong impacts on the number of high ozone days. Daily meteorological factors and transport can have a stronger correlation with high ozone days than annual ozone season meteorological patterns.

Figure 3-3: Annual 8-Hour Ozone High Ozone Days > 60 ppb and Meteorological Averages during the 2000-2010 Ozone Seasons: Precipitation, Temperature, Wind Speed, Humidity, and Solar Radiation



3.7. *Analysis of Local Meteorological Data*

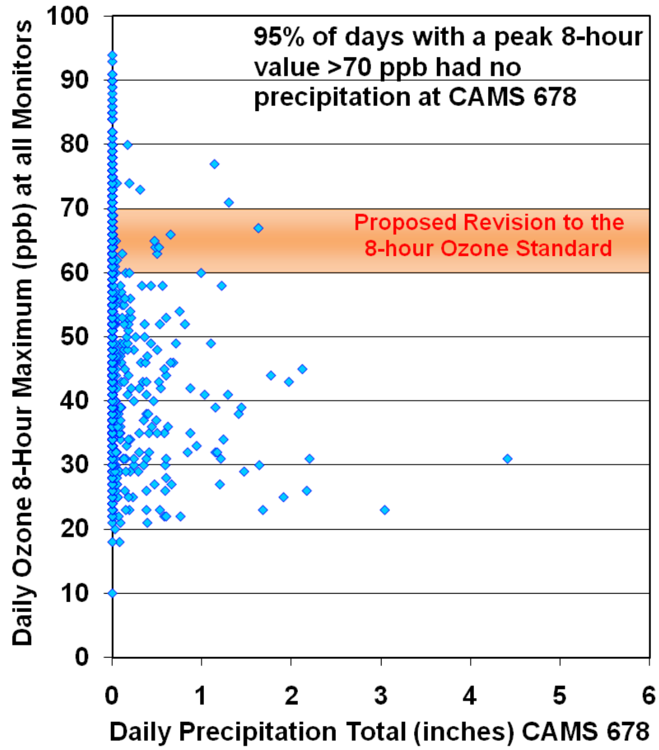
Historical meteorological data can play a significant role in identifying factors that led to elevated ozone. Meteorological variables analyzed included precipitation, relative humidity, temperature, solar radiation, atmospheric stability, and wind speed and direction. Days that had insufficient data capture rates (less than 70%) or were missing critical time periods were removed from the analysis.

3.7.1. Precipitation

Several meteorological parameters are needed to produce precipitation. The first is moisture, in the form of clouds. Cloud cover reduces the amount of solar radiation reaching ground level; this is not conducive to the formation of ozone. The second is low pressure or rising air, which is the key to cloud formation. This can occur for three reasons: convection of unstable air, convergence of air masses, or topographical lifting.[22]

The San Antonio region is located on the southern edge of the Balcones Escarpment, which generates topographical lifting of the warm, moist air from the Gulf of Mexico. In addition, cloud formation in San Antonio during the ozone season can be caused by frontal activity (converging with the gulf air) or convection; all involve movement of air masses. High ozone levels, on the other hand, are generally associated with areas of stagnant air and high pressure, which trap pollutants at ground level. Figure 3-4 shows that days with higher levels of ozone are unlikely to have much rainfall. By using the data in figure 3-4, it was determined that 18 percent of all days during the 2005-2010 ozone seasons had precipitation yet only 5 percent of days that exceeded the high end (70 ppb) of the proposed standard had precipitation. Likewise, only 5 percent of days that exceeded the proposed 65 ppb standard had precipitation and 6 percent of the days that exceeded the 60 ppb proposed standard had precipitation.

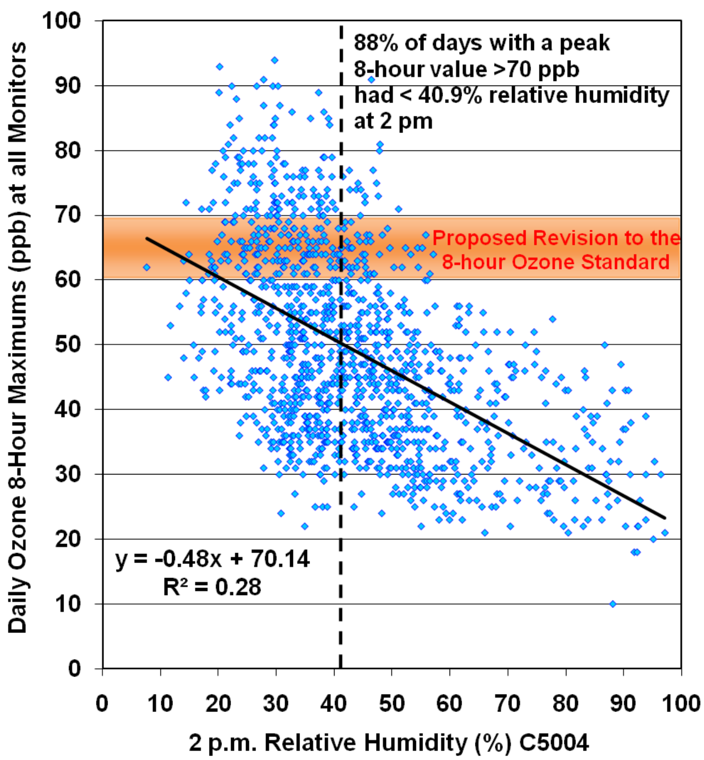
Figure 3-4: Daily 8-Hour Ozone Maximums and C678 Daily Precipitation, 2005-2010



Of the six days in which eight-hour average ozone concentrations exceeded 70 ppb and there was precipitation, three days had only trace amounts (less than 0.2 inches). On the two days in which rainfall was significant (1.30 inches on June 18, 2006 and 1.14 inches on June 1, 2005) and the 8-hour average ozone concentrations were above 70 ppb, precipitation occurred before five a.m. From this analysis it's evident that ozone exceedance days are negatively correlated with precipitation. Considering the meteorological parameters above, this was an anticipated relationship.

[22] University of Illinois, "Clouds and Precipitation Module". Available online: http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/home.rxml. Accessed 06/28/10.

Figure 3-5: Daily 8-Hour Ozone Maximums and C5004 Relative Humidity at 2 p.m., 2005-2010 Ozone Seasons



3.7.2. Relative Humidity

"Relative humidity is a measure of the moisture present in the air expressed in percent. Warmer air has the ability to hold more water than colder air. One-hundred percent relative humidity is totally saturated air (the air cannot hold any more moisture)."[23]

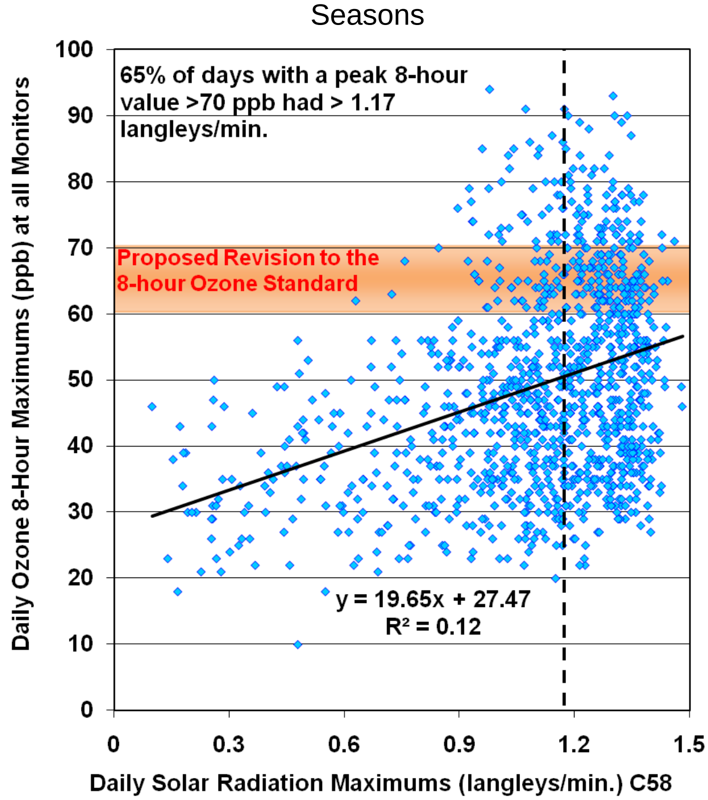
The median relative humidity at 2 p.m. in San Antonio was 40.9 percent during the 2005-2010 ozone seasons. However, figure 3-5 shows that on 88 percent of days that exceeded the proposed 70 ppb ozone standard, the relative humidity was below 40.9 percent. Similar results were calculated for the proposed 65 ppb standard and the proposed 60 ppb standard: 85 percent and 80 percent of the days were dryer than the median. The R^2 value (0.28) shows a moderate relationship between monitored ozone values and relative humidity at 2 p.m.

3.7.3. Solar Radiation

According to the TCEQ website, "Solar radiation is the total electromagnetic radiation emitted by the sun".[24] Solar radiation is the driving force behind the photochemical reactions that form ozone. In order to receive the highest levels of solar radiation, the skies need to be clear. Therefore, a correlation between high solar radiation levels and high ozone concentrations is expected.

Figure 3-6 shows that 65% of all 2005 – 2010 ozone season days with 8-hour ozone concentrations above 70 ppb occurred when maximum solar radiation was above the season's median of 1.17 langleys/minute. While the daily solar radiation maximum was less than 0.9 langleys/minute on 17.4% of all ozone season days, only one of the days exceeding 70 ppb occurred when the maximum solar radiation was less than 0.9

Figure 3-6: Daily 8-Hour Ozone Maximums and C58 Daily Peak Solar Radiation, 2005-2010 Ozone Seasons



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[23] TCEQ. "Relative Humidity". Available online: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/daily_info.pl?parameter:62201. Accessed 06/28/10.

[24] TCEQ. "Solar Radiation". Available online: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/daily_info.pl?parameter:63301. Accessed 06/28/10.

langleys/minute.

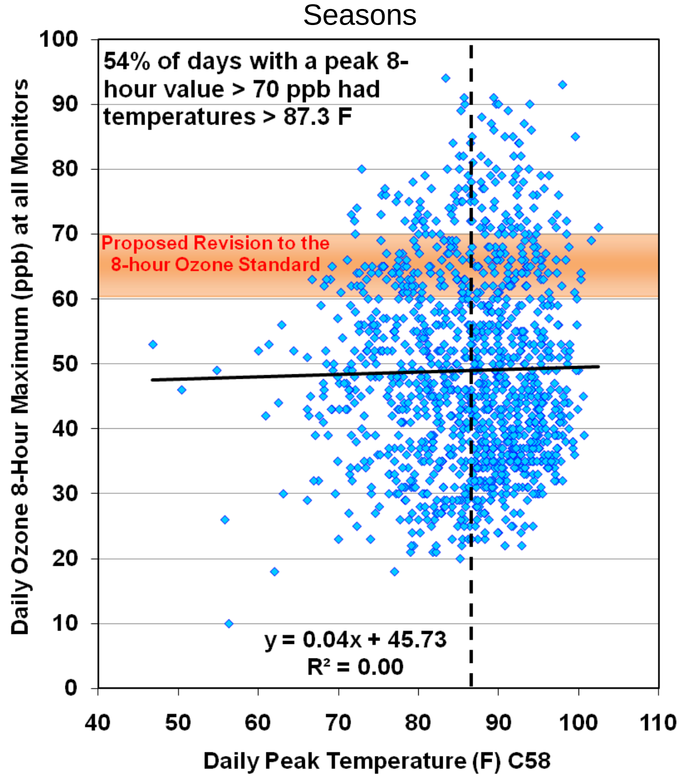
The median solar radiation on days with ozone exceeding 70 ppb was 1.22 langleys/minute, whereas the median values for days exceeding 65 and 60 ppb was 1.21 langleys/minute. On days when the peak 8-hour average was below 40 ppb, the median solar radiation was only 1.08 langleys/minute.

3.7.4. Temperatures

Figure 3-7 provides a scatter-chart of daily maximum 8-hour peak ozone concentrations compared to the daily peak temperatures at C58. The median daily peak temperature during the 2005-2010 ozone seasons was 87.3° F. Whereas, the daily median peak temperature for days exceeding 70 ppb was 88.1° F. For days exceeding 65 ppb the median was 88.3° F, and for days exceeding 60 ppb it was 87.0° F.

Many days when peak temperatures rose above 87.3°F, eight hour average ozone concentrations remained below 60 ppb. There was no correlation between the peak temperature on ozone season days and eight-hour average ozone concentrations; the R^2 was 0.00. The relationship between ozone and temperature was only slightly stronger when restricting the analysis to days when the 8-hour peak was greater than 60 ppb. For that data set, the R^2 value measured only 0.04.

Figure 3-7: Daily 8-Hour Ozone Maximums and Daily Peak Temperatures, 2005-2010 Ozone Seasons



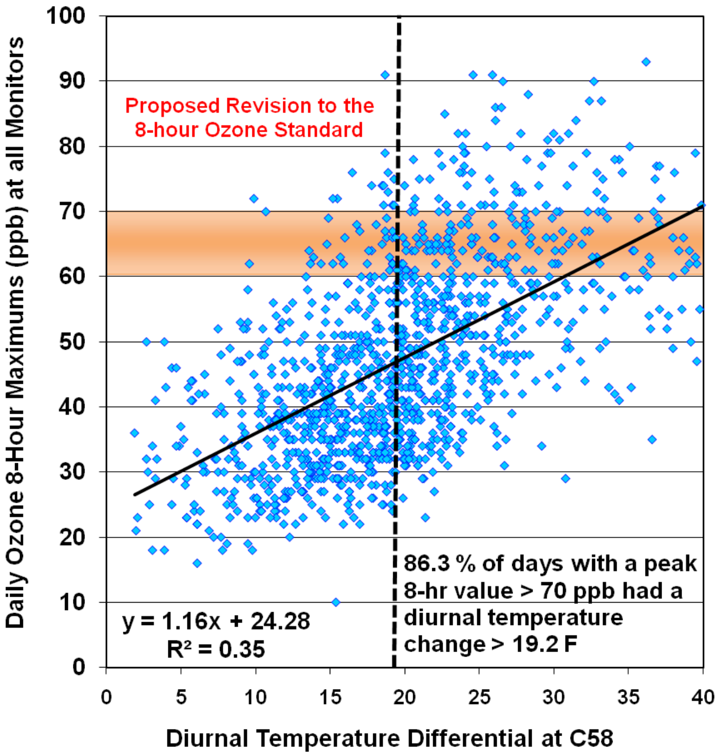
3.7.5. Diurnal Temperature Change

The daily maximum 8-hour peak ozone concentrations in San Antonio compared to the daily ozone season diurnal temperature changes at C58 are displayed in Figure 3-8. The median daily temperature difference for all 2005-2010 ozone season days was 19.2° F. Whereas, the daily median temperature difference for days exceeding 70 ppb was greater at 26.1° F. For days exceeding 65 ppb the median was 26.0° F, and for days exceeding 60 ppb the median was 25.5° F.

The temperature difference surpassed 19.2° F on 86.3% of days when 8-hour average ozone concentrations exceeded 70 ppb, 85.4% of days above 65 ppb, and 83.7% of days above 60 ppb. This relationship may be reflective of the overall weather conditions that contribute to high ozone formation. Days with clear skies and ample solar radiation tend to produce high maximum temperatures, and clear skies also allow for greater radiative cooling at night, thus expanding the diurnal temperature range. Additionally, higher temperature changes may translate into elevated mixing heights which can introduce transported ozone precursors from upper air layers. In contrast, cloudy days, which inhibit ozone-forming photochemistry, tend to produce minimized diurnal temperature ranges.

Most striking is the strength of the correlation between temperature range and ozone relative to other meteorological factors. The R^2 between daily peak 8-hour ozone concentrations and diurnal temperature differentials was 0.35, indicating a moderate correlation. The correlation with 8-hour ozone values is stronger for temperature ranges than for either humidity or maximum solar radiation.

Figure 3-8: Daily 8-Hour Ozone Maximums and C58 Daily Diurnal Temperature Change, 2005-2010 Ozone Seasons



Thus, light winds are conducive to ozone accumulation. However, the R^2 value was low (0.07) indicating the relationship between wind speed and high ozone days is very weak. There were only six days (1.9% of high ozone days) between 2005 and 2010 when the daytime wind speed at C58 was greater than 10 mph and the daily peak 8-hour ozone was greater than 60 ppb. According to TCEQ findings in Houston for the strongest wind speeds, "some of the decrease in ozone concentrations was due to the pollution plume being blown out of the network before the photochemical reactions were complete, and also, an ozone plume becomes narrower with increasing wind speed, making it harder to detect with a monitoring network."[26]

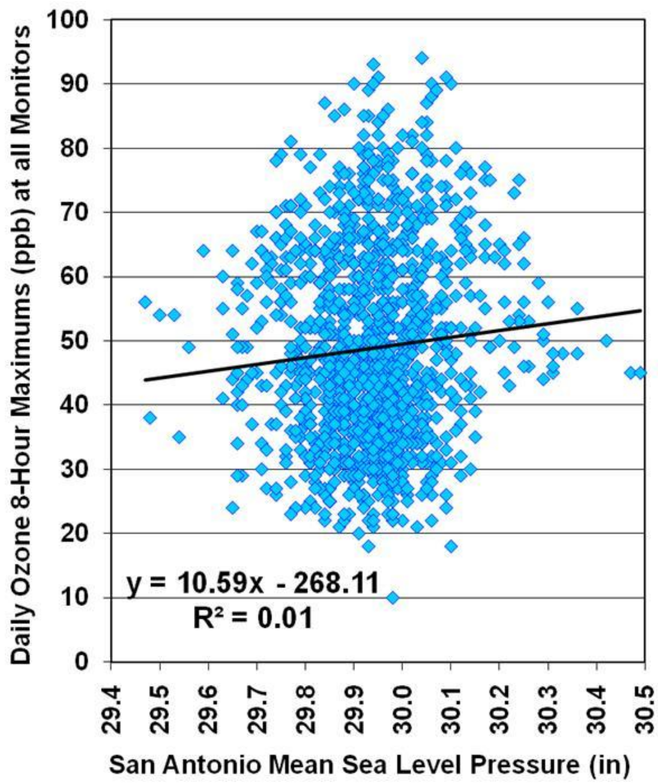
3.7.6. Atmospheric Pressure

Average sea-level pressure is 101.325 kilopascal (kPa or 1013.25 millibars) or 29.921 inches of mercury (in Hg). When the 2005-2010 mean sea-level pressure[25] was plotted against maximum 8-hour ozone values, as shown in figure 3-9, there was no significant relationship. Since the R^2 value was only 0.01, measured mean sea level pressure had no significant impact on ozone readings at the monitors.

3.7.7. Wind Speeds

The wind speed scatter-plot in figure 3-10 charts wind speed daily averages of the hourly readings between 6 a.m. and 2 p.m. against the daily average 8-hour ozone maximums. The average wind speed for all days was 5.8 mph during the ozone season, while the average wind speed for days exceeding 70 ppb was 4.5 mph. For days with peak ozone values below 40 ppb, the average wind speed was 6.6 mph.

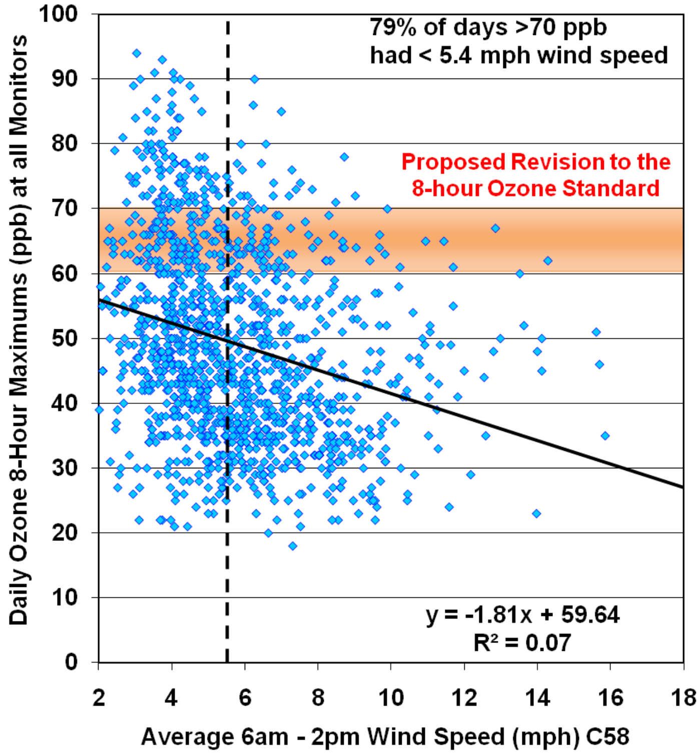
Figure 3-9: Daily Ozone 8-Hour Maximum and Mean Sea Level Pressure, 2005-2010 Ozone Seasons



[25] Weather Underground, Inc., 2008. "History for San Antonio, TX". Available online: http://www.wunderground.com/history/. Accessed 06/22/10.

[26] Ellis B. Cowling, Cari Furiness, Basil Dimitriades, Southern Oxidants Study Office of the Director at North Carolina State University, and David Parrish, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, 31 October 2006 [8 November revision]. "Preliminary Findings from the Second Texas Air Quality Study (TexAQS II)". A Report to the Texas Commission on Environmental Quality by the TexAQS II Rapid Science Synthesis Team TCEQ Contract Number 582-4-65614. p. 26. Available online: http://www.tceq.state.tx.us/assets/public/implementation/air/am/workshop/20061012-13/RSST_Preliminary_Findings_Report_20061031.pdf. Accessed 06/21/10.

Figure 3-10: Daily 8-Hour Ozone Max. & C58 Ave. Daytime Wind Speed, 2005-2010 Ozone Seasons

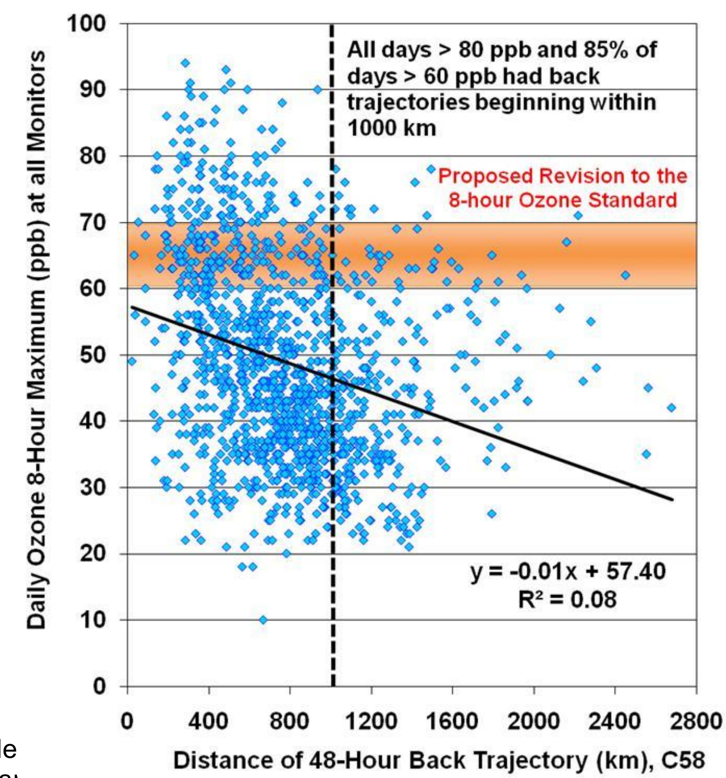


Photochemical modeling results from the June 2006 modeling episode and aircraft sampling in central Texas indicate a similar phenomenon could be occurring in the San Antonio area.[27] Modeling and aircraft sampling indicate ozone plumes and maximum ozone readings can occur far beyond the existing ground-based monitoring network. The local monitoring network only extends a maximum of 20 miles downwind from the San Antonio urban core in a limited number of directions. These monitors are not located far enough to determine whether high ozone values are occurring farther downwind. These results demonstrate that high ozone reading and violations of the ozone standard are significantly impacted by the location of monitors in an urban area.

Figure 3-11: Daily 8-Hour Ozone Max. & C58 Back Trajectory Origin Distance, 2005-2010 Ozone Seasons

3.7.8. Distance to 48-Hour Back Trajectory Origin

Back trajectories, the paths travelled by parcels of air over some period of time en route to a particular location, were determined for all ozone season days from 2005-2010 using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model maintained by The Air Resources Laboratory of the NOAA, which allows public use via the Internet at their Realtime Environmental Applications and Display System (READY) webpage.[28] The scatter-plot in figure 3-11 presents back trajectory origin distances versus the 8-hour ozone maximum for the San Antonio region. Back trajectory origins of shorter distance generally indicate more stagnated regional (and local) air movement, and therefore conditions more suited to ozone precursor accumulation, both from local and regional sources. Although the correlation between back trajectory distance and ozone is weak (R^2 = 0.08), the vast majority of high ozone days coincide with slow-moving air parcels (85% of



[27] AACOG, October 2009. "June 2006 Ozone Episode Bexar County Metropolitan Planning Organization, San Antonio, Texas, p. 6-2 – 6-6.
[28] NOAA, Feb. 26, 2019. "Realtime Environmental Applications and Display sYstem (READY)". Available online: http://www.arl.noaa.gov/ready.html. Accessed 05/24/10.

all days with 8-hour ozone values greater than 60 ppb had back trajectories originating within 1000 km of C58). Thus while 48-hour back trajectories of less than 1000 km are not predictive of high ozone concentrations, high ozone days rarely occur when back trajectories originate further than 1000 km.

3.7.9. Wind Direction

C58 and C23 wind roses that compare the frequency of wind directions on high ozone days (above 70 ppb) and low ozone days (<40 ppb) are presented in figure 3-12 through figure 3-19 (wind roses for days exceeding the mid- and lower-ranges of the proposed standard are in Appendix E). The wind rose charts were created using WRPLOT View software developed by Lakes Environmental Software.[29] The length of the bar within each sector indicates the frequency of occurrence of a particular wind direction, while the color chart indicates the distribution of wind speeds. Surface winds were summarized by morning time period: 0600–0900 CST and afternoon time period: 1200–1500 CST. The red line represents the resulting wind direction for each wind rose. Distinguishing features in the wind roses for high ozone days, when contrasted to those of low ozone days, may help to define the wind and/or transport patterns leading to high ozone.

The distribution of observed surface winds at C58 indicates prevailing morning winds from the northwest on high ozone days. A comparison of the charts for days with 8-hour ozone averages above 70 ppb suggests air flow reversal is associated with high ozone, with winds arriving at the monitors from the northwest in the morning and shifting so that winds arrive from the southeast in the afternoon. This may result in recirculation of local and transported ozone precursor emissions. In contrast, low ozone days exhibit persistent morning and afternoon wind directions from the south to southeast. Morning winds were more likely to be calm (< 1 knot) on days when 8-hour ozone averages exceeded 70 ppb (5.21%) than on low ozone days (2.47%).

There is a similar pattern at C23, with a strong tendency for winds to be from the north-northeast to northwest during the mornings on high ozone days and to shift to the east and southeast in the afternoon. Similar to C58, low ozone days at C23 exhibit a different morning wind direction from the south to southeast. High ozone days had more calm morning winds (6.12% for days when the 8-hour average exceeded 70 ppb) than days of low ozone (2.36%). Overall, morning wind speeds on high ozone days were lower than days of low ozone at C58 and C23.

During the afternoon, winds tended to have a south to southeast component on all days for both high and low ozone days. Afternoon wind speeds on high ozone days were lower at both C58 and C23 when compared to low ozone days, and afternoon winds were slightly more easterly on days of high ozone than on days of low ozone. Transport of ozone and ozone pre-cursor emissions in the morning have a greater impact on ozone formation later in the day at local monitoring sites.

[29] Lakes Environmental Software. May 19, 2010. "WRPLOT View: Wind Rose Plots for Meteorological Data". Version 6.5.1. Available online: http://www.lakes-environmental.com/lakewrpl.html. Accessed 06/21/10.

Figure 3-12: Morning Wind Rose on High Ozone Days (>70 ppb) at C58, 0600-0900 CST, 2005-2010

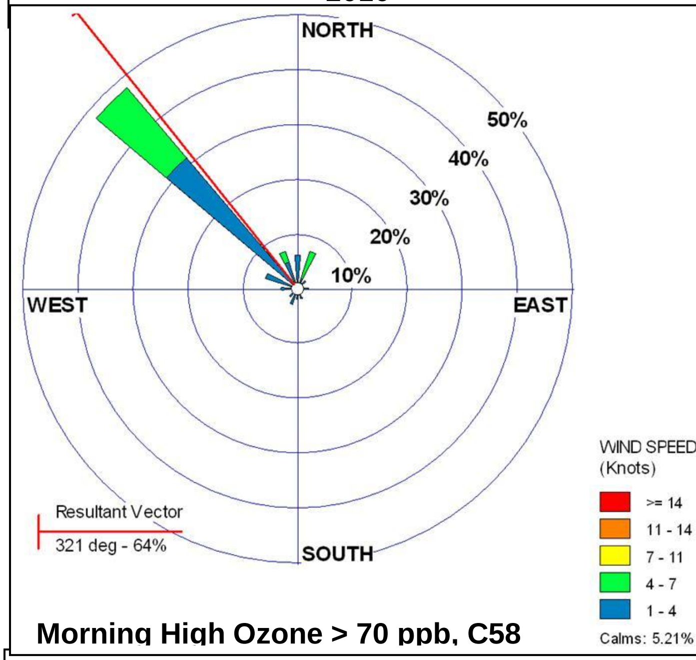


Figure 3-14: Morning Wind Rose on Low Ozone Days (<40 ppb) at C58, 0600-0900 CST, 2005-2010

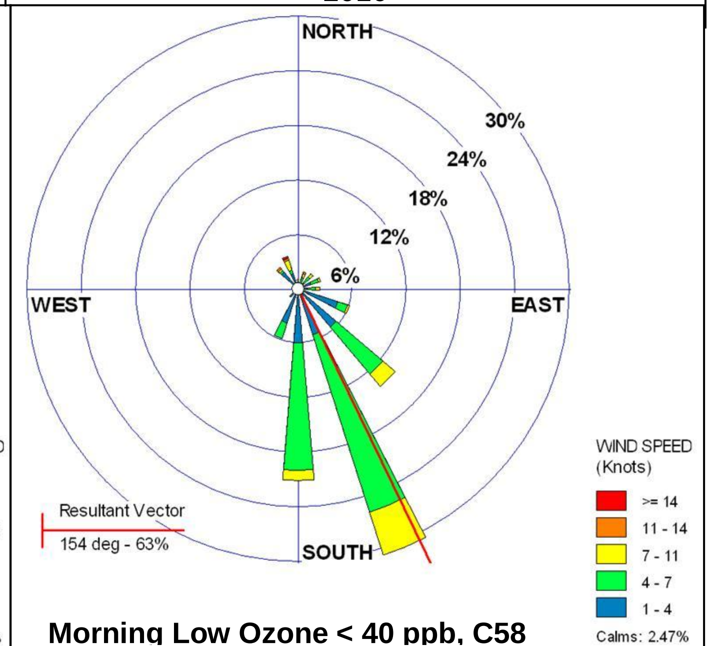


Figure 3-15: Afternoon Wind Rose on High Ozone Days (>70 ppb) at C58, 1200-1500 CST, 2005-2010

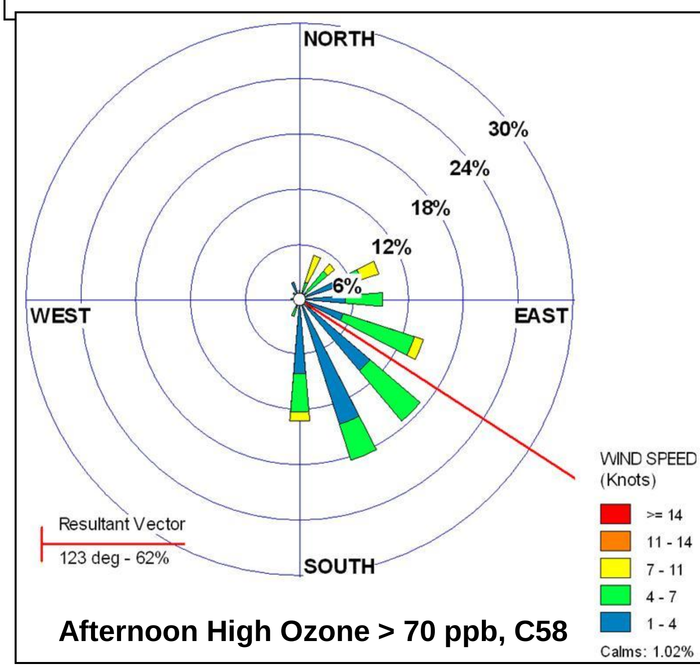


Figure 3-13: Afternoon Wind Rose Low Ozone Days (<40 ppb) at C58, 1200-1500 CST, 2005-2010

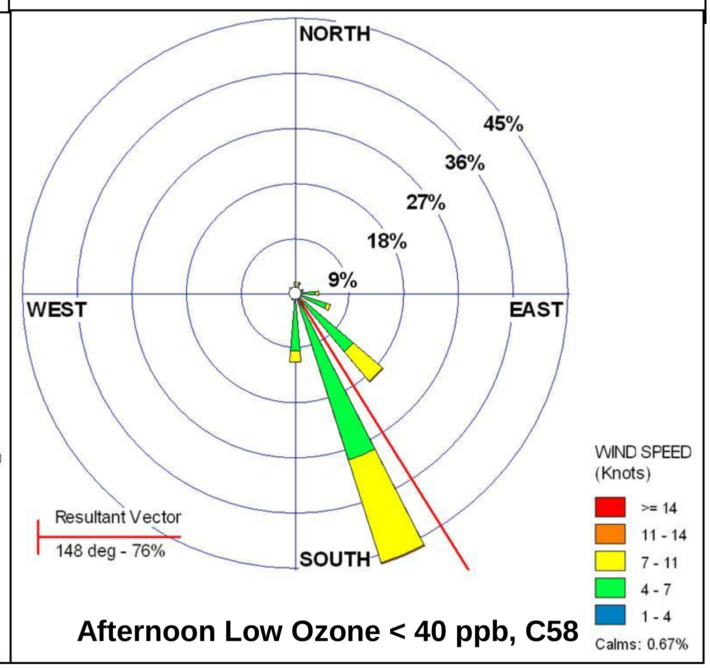


Figure 3-16: Morning Wind Rose on High Ozone Days (>70 ppb) at C23, 0600-0900 CST, 2005-2010

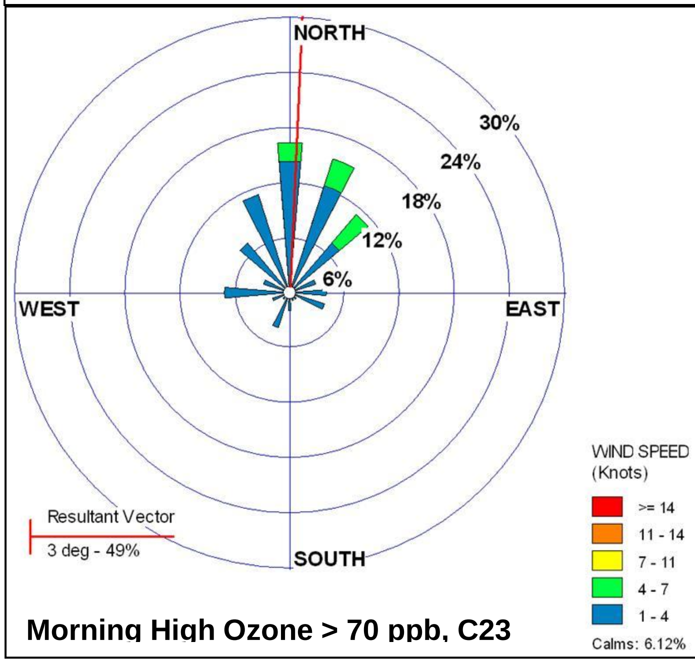


Figure 3-19: Morning Wind Rose on Low Ozone Days (<40 ppb) at C23, 0600-0900 CST, 2005-2010

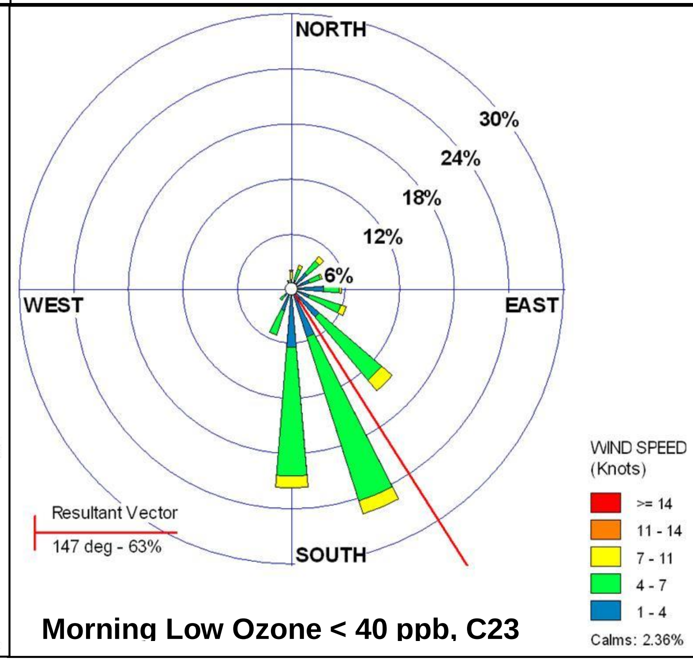


Figure 3-17: Afternoon Wind Rose on High Ozone Days (>70 ppb) at C23, 1200-1500 CST, 2005-2010

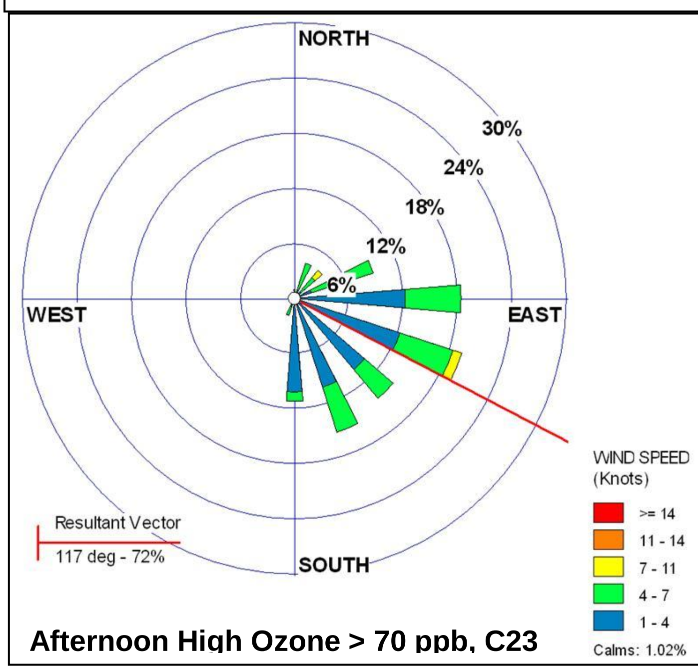
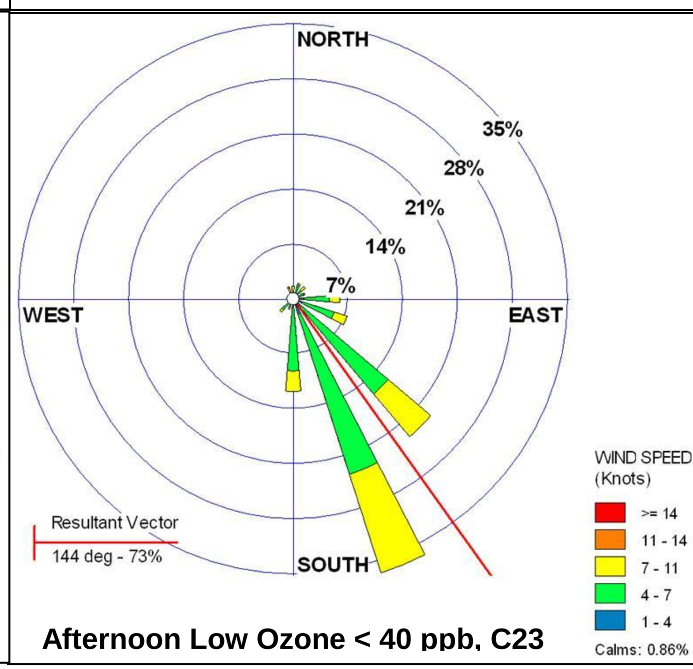


Figure 3-18: Afternoon Wind Rose on Low Ozone Days (<40 ppb) at C23, 1200-1500 CST, 2005-2010



Loops of resultant wind vectors for C23 and C58 are presented in figure 3-20 for both low ozone days and high ozone days of 8-hour ozone values above 70 ppb (wind vectors on days exceeding the mid- and lower-range of the proposed standard can be viewed in Appendix F).[30] The average wind vectors were plotted for every hour of the day and wind speeds were represented by distance from the origin. Average ozone values during the ozone season were calculated for each hour and are represented by the color code for each data point. The daily average wind vector distance and direction were plotted as a blue arrow on the chart. The average wind vector at both CAMS tended to be from the southeast on low ozone days. The wind directions were from areas over the Gulf of Mexico that contained few precursor emissions. Since wind speeds are stronger on low ozone days, local emissions do not accumulate to form high ozone .

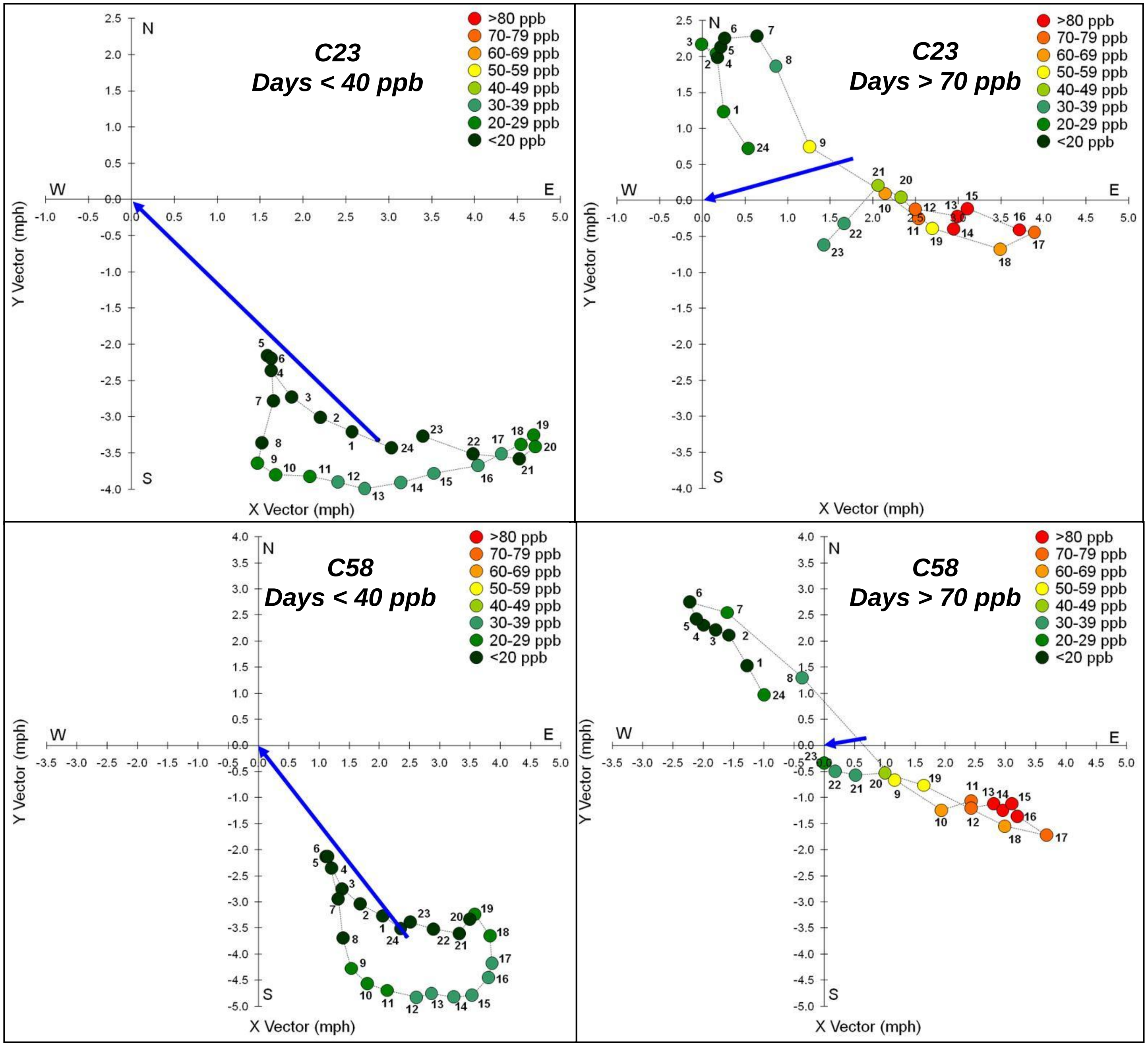
There are several different and distinct meteorological conditions that result in high ozone events in the San Antonio area. The wind vectors on high ozone days were slower and originated from the east and northeast. At C23, the wind slowly changes direction at the monitor from the north to the east in a clockwise fashion. The directions of the wind vectors indicate that there is some short distance transport of emissions from the north and northeast on high ozone days that accumulates with local and transported emissions from the urban area east of the monitor later in the day to form ozone.

Analysis of C58 wind vectors shows there is often a flow reversal of winds arriving at the monitor from the northwest in the morning before 7 am on days when the 8-hour ozone average exceeds 70 ppb. In the Houston area according to the TCEQ, "under this pattern, the early morning emission plumes are pushed back over the high-emission industrial and urban areas, where they can receive a second dose of fresh emissions. The winds that cause a flow reversal can be a rapid veering pattern, a rapid backing pattern (i.e., counterclockwise wind shift), or simply an abrupt ~180° wind shift."[31] These winds can bring in recirculation of local and transported ozone precursor emissions and ozone from the previous day that combines with emissions from the east to form ozone. Local precursor, transported, and previous day emissions are accumulated in the morning from the rotating wind vectors to form high ozone readings in the afternoon under sunny conditions. Research should continue on wind vector data to determine whether different wind patterns cause high ozone at each monitor.

[30] Average standard deviation for all wind directions was 79 degrees at C23 and 83 degrees at C58. The average standard deviation for wind speed was 2.5 mph at C23 and 3.2 mph at C58.

[31] Ellis B. Cowling, Cari Furiness, Basil Dimitriades, Southern Oxidants Study Office of the Director at North Carolina State University, and David Parrish, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, 31 October 2006 [8 November revision]. "Preliminary Findings from the Second Texas Air Quality Study (TexAQS II)". A Report to the Texas Commission on Environmental Quality by the TexAQS II Rapid Science Synthesis Team TCEQ Contract Number 582-4-65614. p. 21. Available online: http://www.tceq.state.tx.us/assets/public/implementation/air/am/workshop/20061012-13/RSST_Preliminary_Findings_Report_20061031.pdf. Accessed 06/21/10.

Figure 3-20: Hourly Average Resultant Wind Vectors at C23 and C58 on Low Ozone Days and High Ozone Days > 70 ppb, 2005-2010



3.7.10. Multivariate Correlation of Local Meteorological Factors

To determine the impact of multiple meteorological factors on ozone formation, multivariate correlations were calculated at C58 for the following nine meteorological variables: relative humidity (%), resulting wind speed (mph), temperature (F), solar radiation (langleys/min.), resulting morning wind direction (°), resulting afternoon wind direction (°), back trajectory direction (°), back trajectory distance (km), and diurnal temperature change (°). The analysis was conducted using a table of data with 1,278 observations from 2005 to 2010. Multivariate analysis was conducted to determine the impacts of multiple local meteorological factors on ozone formation since no individual meteorological factor had a strong correlation with ozone formation.

The multivariate analysis was designed to give a basic understanding of what combination of meteorological factors can have the greatest impact on local ozone concentrations. The multivariate correlation input parameters used in the analysis are provided in table 3-1. These meteorological variables were sorted into four categories, which were determined for each ozone season day (Table 3.2). Figures 3-21 – 3-26 plot the results for relative humidity, resulting wind speed, solar radiation, and temperature. The black lines represent the median value for each meteorological factor, red circles are days of high ozone > 70 ppb, and the black dots are the median value for days of high ozone.

Table 3-1: Summary of Multivariate Correlation Input Parameters

Meteorological Factor	Time of Day	Duration	N	CAMS
Relative Humidity, % (RH)	2 p.m.	1 hour	1,246	C5004
Resulting Wind Speed, mph (WS)	6 am – 2 pm	8-hours	1,265	C58
Temperature, F (T)	Maximum Daily Value	1 hour	1,230	C58
Solar Radiation, langleys/min. (SR)	Maximum Daily Value	1 hour	1,132	C58
Morning Wind Direction, degrees (MWD)	6 – 9 am CST	3 hours	1,250	C58
Afternoon Wind Direction, degrees (AWD)	noon – 3 p.m. CST	3 hours	1,262	C58
Back Trajectory Direction, degrees (BTDIR)	3 pm	48 hours	1,278	C58
Back Trajectory Distance, km (BTDIS)	3 pm	48 hours	1,278	C58
Diurnal Temperature Change, F (DTC)	Maximum Difference	1 hour	1,234	C58

Table 3-2: Categories for each Multivariate Parameter

Parameter	Category 1		Category 2		Category 3		Category 4	
	Values	N	Values	N	Values	N	Values	N
RH	0 – 32.3	310	32.4 – 40.8	313	40.9 – 52.1	315	52.1 – 100	317
WS	0 – 4.95	320	4.96 – 6.01	313	6.02 – 7.48	315	7.49 – 21.74	317
T	46.7 – 80.9	309	81.0 – 87.3	305	87.3 – 92.2	308	92.2 – 102.6	309
SR	0 – 0.99	282	1.00 – 1.17	282	1.18 – 1.29	280	1.30 – 1.49	288
MWD	0 – 135	249	136 – 170	323	171 – 300	324	301 – 359	354
AWD	0 – 100	211	101 – 150	386	151 – 180	458	181 – 359	207
BTDIR	271 – 70	324	71 – 120	333	121 – 140	370	141 – 270	251
BTDIS	0 – 507	321	508 – 750	321	751 – 990	319	991 – 2,679	317
DTC	0 – 14	268	15 – 19	320	20 – 24	342	24 – 45	304

The ranking for each multivariate correlation is provided below in tables 3-3, 3-4, and 3-5 for each value under consideration for the revised ozone standard, based on the Chi-square value. For the lowest value under consideration for the proposed standard, 60 ppb, the strongest multivariate correlation was back trajectory direction - diurnal temperature change and humidity - back trajectory distance. Morning wind direction - diurnal temperature change and back trajectory distance - diurnal temperature change also had a very strong correlation with high ozone days. The lowest correlation with high ozone days was wind speed - afternoon wind direction, temperature - wind speed, and temperature - afternoon wind direction.

For individual metrological factors, the factors that were most often associated with days exceeding the 70 ppb proposed standard using the multivariate correlation was humidity at 2 p.m. and diurnal temperature change. Diurnal temperature change allows for rapid rise in mixing heights in the morning allowing upper air pollution to be mixed downward with local emissions sources to form ozone. Temperature, solar radiation, and afternoon wind direction were the least likely to be associated with days of high ozone. These meteorological factors had very little impact on monitored ozone in the San Antonio MSA.

Future studies may benefit from such analyses as location of high-pressure systems, 1,000-meter back trajectory direction and distance, monitored ozone pre-cursor emissions, tropospheric ozone measurements, frontal movements, cloud cover, high pressure systems, and other metrological factors. Furthermore, a cluster approach for determining meteorological factors that can generate high ozone levels, could offer additional insight into the factors influencing local ozone formation. Multivariate analysis should also be conducted on C23 data in the future because high ozone at this monitor may be influenced by a different set of metrological conditions than those at C58. Mixing heights, temperature inversion layers, and other elevated meteorological conditions can have an impact on ozone formation, however there are not enough data points to conduct a multivariate analysis on these meteorological factors.

Figure 3-21: C58 Daily Maximum Temperature and C58 Daily Peak Solar Radiation, 2005-2010 Ozone Seasons

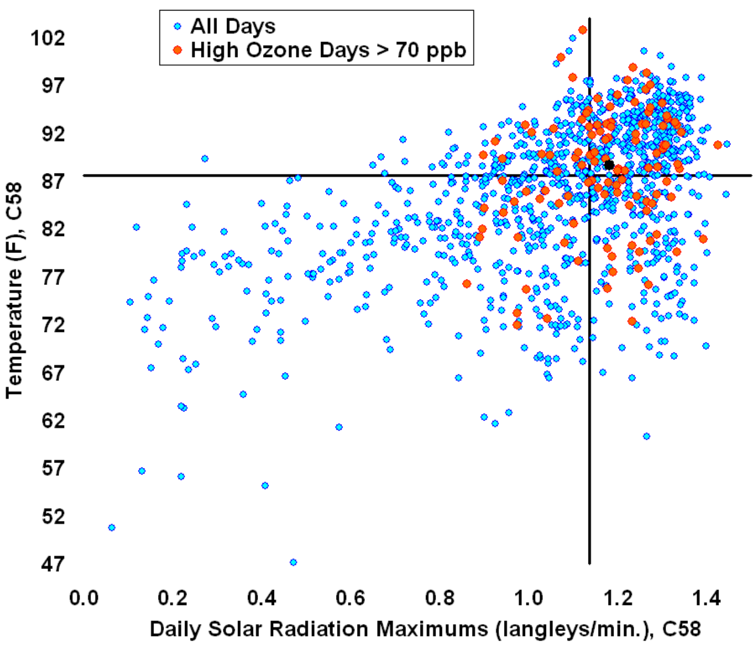


Figure 3-22: C5004 Relative Humidity at 2 p.m. and Daily Maximum Temperature, 2005-2010 Ozone Seasons

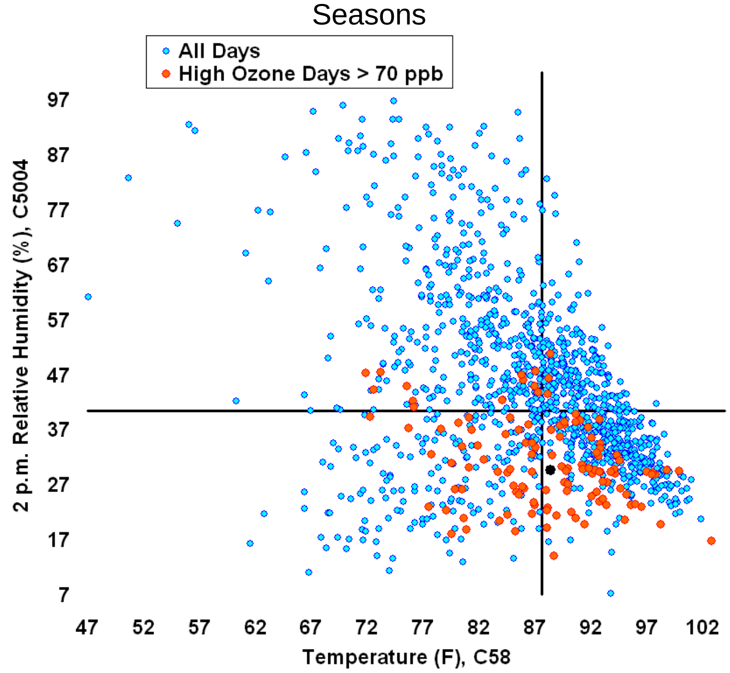


Figure 3-24: C58 Daily Maximum Temperature and C58 Average Daytime Wind Speed, 2005-2010 Ozone Seasons

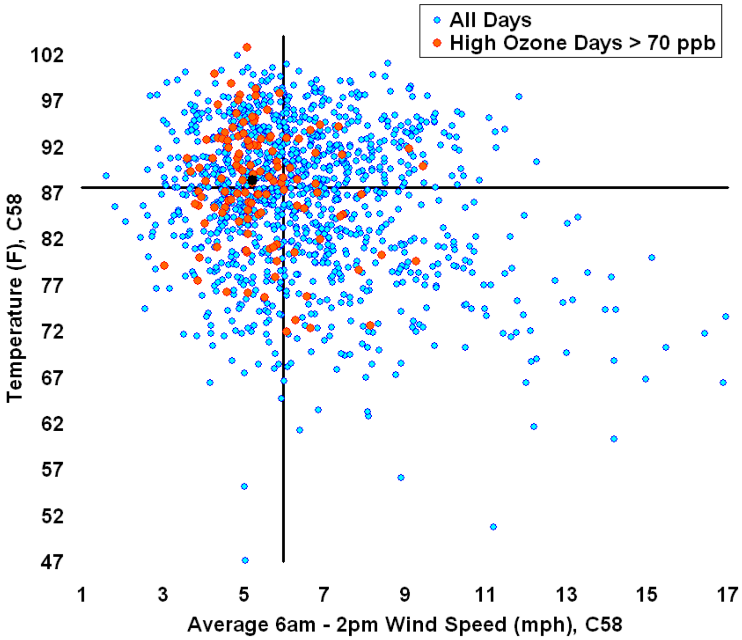


Figure 3-23: C58 Average Daytime Wind Speed and C58 Daily Peak Solar Radiation, 2005-2010 Ozone Seasons

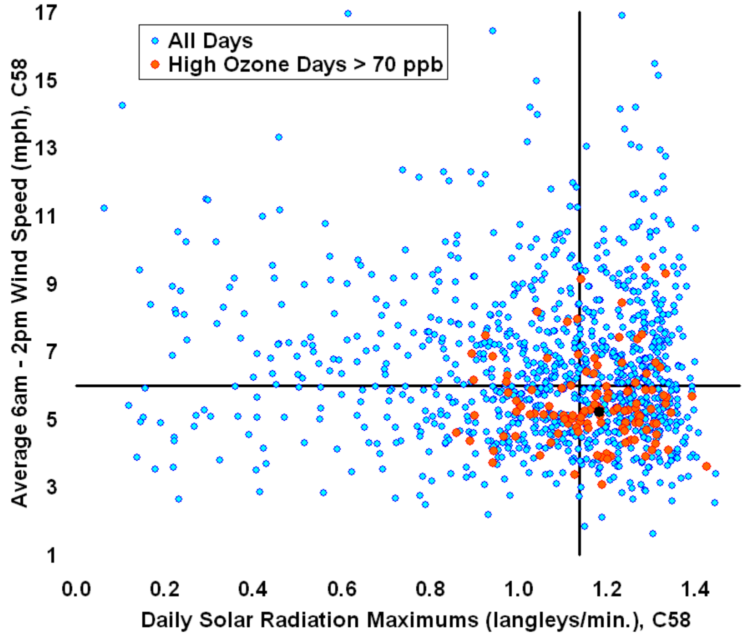


Figure 3-26: C5004 Relative Humidity at 2 p.m. and C58 Average Daytime Wind Speed, 2005-2010 Ozone Seasons

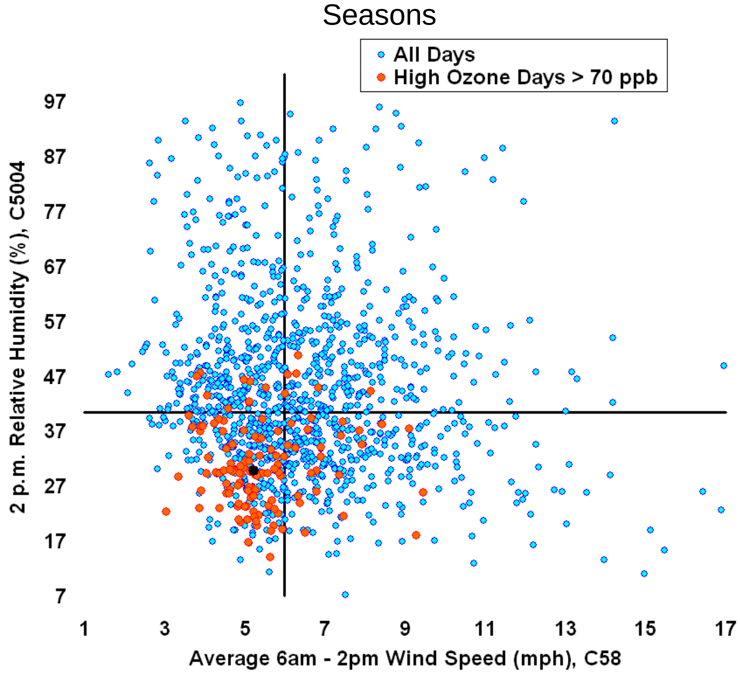


Figure 3-25: C5004 Relative Humidity at 2 p.m. and C58 Daily Peak Solar Radiation, 2005-2010 Ozone Seasons

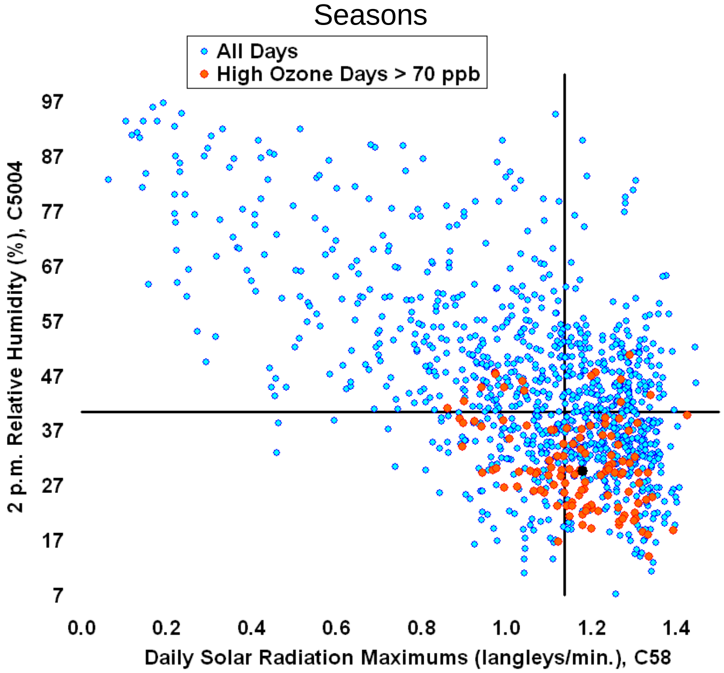


Table 3-3: Ranking of Meteorological Factors from the Multivariate Correlation Analysis for the 60 ppb Proposed Standard, 2005-2010

Rank	Meteorological Factor, 2005 - 2010	n	χ^2	Significant?	φ_c
1	Back Trajectory Direction - Diurnal Temperature Change	299	275	Yes	0.678
2	Humidity - Back Trajectory Distance	306	266	Yes	0.660
3	Morning Wind Direction - Diurnal Temperature Change	299	258	Yes	0.657
4	Back Trajectory Distance - Diurnal Temperature Change	299	251	Yes	0.648
5	Humidity - Back Trajectory Direction	306	256	Yes	0.646
6	Solar Radiation - Diurnal Temperature Change	274	222	Yes	0.636
7	Afternoon Wind Direction - Diurnal Temperature Change	301	233	Yes	0.622
8	Temperature - Diurnal Temperature Change	301	232	Yes	0.620
9	Humidity - Morning Wind Direction	306	233	Yes	0.618
10	Humidity - Diurnal Temperature Change	298	225	Yes	0.614
11	Wind Speed - Diurnal Temperature Change	301	218	Yes	0.602
12	Temperature - Humidity	298	204	Yes	0.585
13	Wind Speed - Humidity	308	203	Yes	0.574
14	Solar Radiation - Humidity	282	181	Yes	0.567
15	Back Trajectory Direction - Back Trajectory Distance	309	192	Yes	0.557
16	Solar Radiation - Back Trajectory Direction	282	173	Yes	0.554
17	Humidity - Afternoon Wind Direction	308	179	Yes	0.540
18	Morning Wind Direction - Back Trajectory Direction	307	176	Yes	0.536
19	Solar Radiation - Morning Wind Direction	282	160	Yes	0.533
20	Morning Wind Direction - Back Trajectory Distance	307	170	Yes	0.527
21	Wind Speed - Back Trajectory Direction	309	164	Yes	0.515
22	Temperature - Back Trajectory Direction	299	153	Yes	0.505
23	Wind Speed - Morning Wind Direction	309	154	Yes	0.499
24	Solar Radiation - Back Trajectory Distance	282	138	Yes	0.494
25	Temperature - Morning Wind Direction	299	136	Yes	0.477
26	Morning Wind Direction - Afternoon Wind Direction	309	131	Yes	0.461
27	Afternoon Wind Direction - Back Trajectory Direction	309	130	Yes	0.458
28	Wind Speed - Back Trajectory Distance	309	116	Yes	0.434
29	Afternoon Wind Direction - Back Trajectory Distance	309	115	Yes	0.431
30	Temperature - Back Trajectory Distance	299	104	Yes	0.416
31	Solar Radiation - Afternoon Wind Direction	284	95	Yes	0.410
32	Solar Radiation - Wind Speed	284	82	Yes	0.379
33	Temperature - Solar Radiation	274	78	Yes	0.378
34	Wind Speed - Afternoon Wind Direction	311	64	Yes	0.322
35	Temperature - Wind Speed	301	48	Yes	0.282
36	Temperature - Afternoon Wind Direction	301	47	Yes	0.279

Table 3-4: Ranking of Meteorological Factors from the Multivariate Correlation Analysis for the 65 ppb Proposed Standard, 2005-2010

Rank	Meteorological Factor, 2005 - 2010	n	χ^2	Significant?	φ_c
1	Humidity - Back Trajectory Distance	195	268	Yes	0.830
2	Back Trajectory Distance - Diurnal Temperature Change	190	224	Yes	0.767
3	Wind Speed - Humidity	197	223	Yes	0.753
4	Humidity - Morning Wind Direction	195	216	Yes	0.744
5	Morning Wind Direction - Diurnal Temperature Change	190	210	Yes	0.743
6	Temperature - Humidity	190	207	Yes	0.738
7	Back Trajectory Direction - Diurnal Temperature Change	190	202	Yes	0.729
8	Humidity - Back Trajectory Direction	195	206	Yes	0.727
9	Wind Speed - Diurnal Temperature Change	192	195	Yes	0.713
10	Temperature - Diurnal Temperature Change	192	194	Yes	0.710
11	Afternoon Wind Direction - Diurnal Temperature Change	192	187	Yes	0.699
12	Solar Radiation - Diurnal Temperature Change	175	170	Yes	0.697
13	Humidity - Diurnal Temperature Change	190	184	Yes	0.696
14	Solar Radiation - Humidity	180	164	Yes	0.674
15	Morning Wind Direction - Back Trajectory Distance	195	177	Yes	0.673
16	Humidity - Afternoon Wind Direction	197	167	Yes	0.651
17	Temperature - Back Trajectory Direction	190	159	Yes	0.647
18	Wind Speed - Morning Wind Direction	197	163	Yes	0.642
19	Temperature - Morning Wind Direction	190	156	Yes	0.642
20	Back Trajectory Direction - Back Trajectory Distance	197	160	Yes	0.638
21	Solar Radiation - Morning Wind Direction	180	142	Yes	0.627
22	Solar Radiation - Back Trajectory Distance	180	133	Yes	0.607
23	Morning Wind Direction - Back Trajectory Direction	195	134	Yes	0.587
24	Temperature - Back Trajectory Distance	190	128	Yes	0.580
25	Morning Wind Direction - Afternoon Wind Direction	197	132	Yes	0.578
26	Wind Speed - Back Trajectory Direction	197	131	Yes	0.576
27	Afternoon Wind Direction - Back Trajectory Distance	197	119	Yes	0.549
28	Wind Speed - Back Trajectory Distance	197	116	Yes	0.542
29	Solar Radiation - Back Trajectory Direction	180	103	Yes	0.535
30	Solar Radiation - Afternoon Wind Direction	182	82	Yes	0.474
31	Solar Radiation - Wind Speed	182	77	Yes	0.461
32	Afternoon Wind Direction - Back Trajectory Direction	197	82	Yes	0.457
33	Wind Speed - Afternoon Wind Direction	199	79	Yes	0.445
34	Temperature - Afternoon Wind Direction	192	62	Yes	0.401
35	Temperature - Wind Speed	192	58	Yes	0.389
36	Temperature - Solar Radiation	175	51	Yes	0.380

Table 3-5: Ranking of Meteorological Factors from the Multivariate Correlation Analysis for the 70 ppb Proposed Standard, 2005-2010

Rank	Meteorological Factor, 2005 - 2010	n	χ^2	Significant?	φ_c
1	Humidity - Back Trajectory Distance	123	221	Yes	0.948
2	Wind Speed - Humidity	125	200	Yes	0.895
3	Humidity - Back Trajectory Direction	123	181	Yes	0.857
4	Temperature - Humidity	121	169	Yes	0.835
5	Back Trajectory Distance - Diurnal Temperature Change	120	161	Yes	0.820
6	Wind Speed - Diurnal Temperature Change	122	159	Yes	0.808
7	Humidity - Morning Wind Direction	123	157	Yes	0.799
8	Back Trajectory Direction - Diurnal Temperature Change	120	153	Yes	0.797
9	Morning Wind Direction - Diurnal Temperature Change	120	149	Yes	0.788
10	Temperature - Back Trajectory Direction	120	143	Yes	0.773
11	Humidity - Diurnal Temperature Change	121	143	Yes	0.768
12	Morning Wind Direction - Back Trajectory Distance	122	136	Yes	0.746
13	Solar Radiation - Diurnal Temperature Change	114	125	Yes	0.742
14	Afternoon Wind Direction - Diurnal Temperature Change	122	134	Yes	0.741
15	Solar Radiation - Humidity	117	128	Yes	0.741
16	Temperature - Diurnal Temperature Change	122	134	Yes	0.740
17	Humidity - Afternoon Wind Direction	125	135	Yes	0.734
18	Wind Speed - Morning Wind Direction	124	132	Yes	0.728
19	Wind Speed - Back Trajectory Direction	124	131	Yes	0.728
20	Back Trajectory Direction - Back Trajectory Distance	124	128	Yes	0.719
21	Temperature - Morning Wind Direction	120	114	Yes	0.690
22	Solar Radiation - Back Trajectory Distance	116	94	Yes	0.637
23	Solar Radiation - Morning Wind Direction	116	92	Yes	0.628
24	Temperature - Back Trajectory Distance	120	94	Yes	0.625
25	Morning Wind Direction - Back Trajectory Direction	122	95	Yes	0.624
26	Wind Speed - Back Trajectory Distance	124	94	Yes	0.617
27	Morning Wind Direction - Afternoon Wind Direction	124	88	Yes	0.594
28	Afternoon Wind Direction - Back Trajectory Distance	124	87	Yes	0.593
29	Solar Radiation - Back Trajectory Direction	116	74	Yes	0.565
30	Wind Speed - Afternoon Wind Direction	126	80	Yes	0.565
31	Solar Radiation - Wind Speed	118	67	Yes	0.534
32	Afternoon Wind Direction - Back Trajectory Direction	124	65	Yes	0.510
33	Solar Radiation - Afternoon Wind Direction	118	60	Yes	0.503
34	Temperature - Wind Speed	122	51	Yes	0.458
35	Temperature - Afternoon Wind Direction	122	49	Yes	0.450
36	Temperature - Solar Radiation	114	30	No	0.364

3.7.11. Conclusion Regarding Local Meteorological Data Analysis

Local meteorological conditions that are conducive to ozone formation include lack of precipitation, low atmosphere moisture content present in the afternoon, and large diurnal temperature changes. Peak temperature during the ozone season and mean sea-level pressure had no significant correlation with ozone readings.

The wind vectors on high ozone days were more stagnated and typically originated from the east and northeast. An analysis of wind vectors at C23 on high ozone days indicate a common trend: the wind slowly changes direction at the monitor from the north to the east in a clockwise fashion during the day. C58 wind vectors show there is a flow reversal of winds arriving at the monitors from the northwest before seven am. These winds can bring in recirculation of local ozone precursors emissions and ozone from the previous day that combines with emissions from the east to form ozone.

For the upper range of the proposed standard (70 ppb), the strongest multivariate correlation was humidity - back trajectory distance. Humidity - back trajectory direction and wind speed – humidity also had a very strong correlation with high ozone days. Metrological conditions measured directly at the monitoring sites do not provide all the data necessary to identify factors that influence the formation of ozone. Thus, analysis of emissions, profiler data, regional weather patterns, aircraft sampling, and photochemical modeling is required to fill in the gaps that monitoring data can't provide.

3.8. *Criteria and Other Pollutants*

The EPA Office of Air Quality Planning and Standards (OAQPS) sets the NAAQS for six criteria pollutants: carbon monoxide (CO_2), lead (Pb), nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$), ozone, and sulfur dioxide (SO_2). Except for Pb, all the criteria pollutants are monitored in the San Antonio region. NO_X, SO_2, and $PM_{2.5}$ were analyzed to determine whether correlations exist between these other criteria pollutants and ozone. In addition to comparisons with other pollutants, ozone was studied in terms of the presence of chemical precursors, in particular, volatile organic compounds. AACOG performed volatile organic compounds (VOC) canister sampling in 2006 with the assistance of TCEQ.

3.8.1. NO_X

A majority of NO_X emissions are created from the combustion of fossil fuel in on-road vehicles, power plants, cement kilns, off-road equipment, and boilers Higher NO_X concentrations can scavenge ozone under certain conditions, so a positive correlation with ozone becomes untenable. NO_X readings at downwind monitors can be diluted before arriving while continuously forming ozone en-route, leading to a situation of elevated ozone with low NO_X concentrations. In addition, NO_X is necessary for ozone formation catalysis but does not control rates of ozone formation. Other factors such as VOC concentrations and solar radiation obscure the role of NO_X in ozone formation.

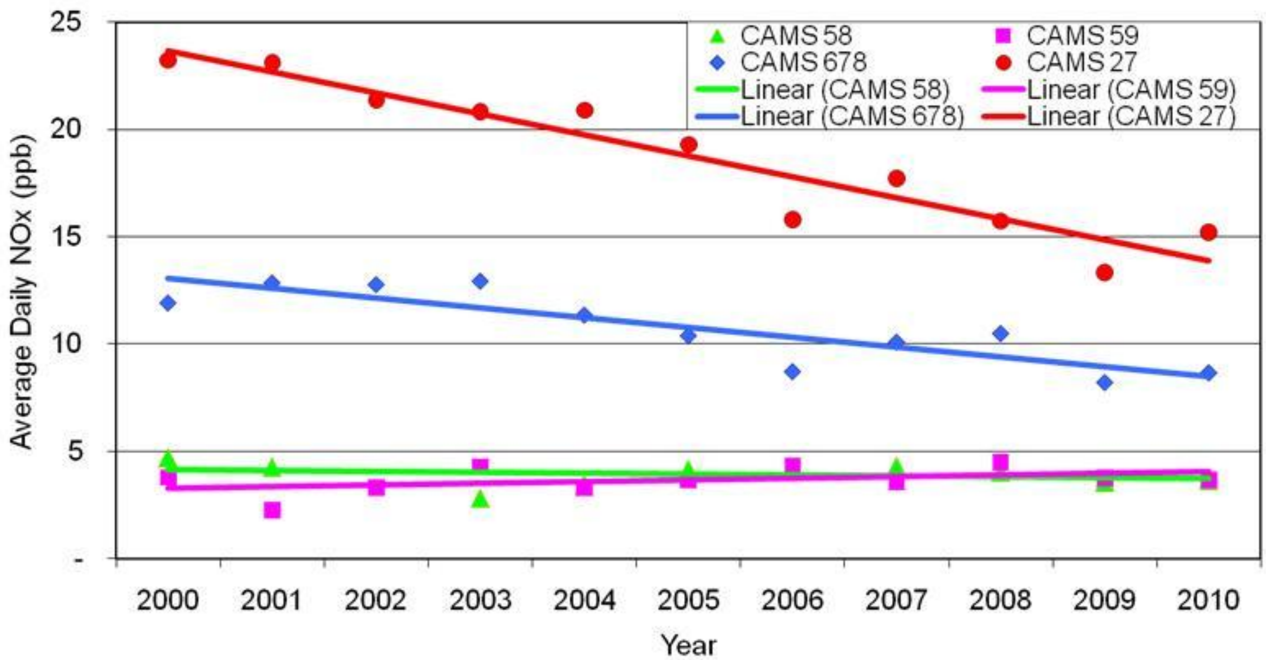
Average ozone season NO_X concentrations reached moderate levels, 15.2 ppb, at only one monitor in 2010:$_X$ C27 located in downtown San Antonio (table 3-6). The three monitors located in rural areas, C58, C59, and C622, recorded low ozone season average NO_X emissions. These rural sites lack major sources of NO_X emissions that directly impact monitoring sites. C59 is recording low background NO_X emissions coming into the San Antonio region and there has not been a significant change in transported NO_X emissions from this direction in the last 10 years.

Table 3-6: Annual Maximum and Average NO_X Values in the San Antonio Area by Monitor,

Ozone Season Maximum Hourly NO_X (ppb)						Ozone Season Average NO_X (ppb)				
Year	C58	C59	C678	C622	C27	C58	C59	C678	C622	C27
2000	33.9	105.5	246.6	-	223.9	4.7	3.8	11.9	-	23.2
2001	35.7	80.2	238.8	-	305.3	4.3	2.3	12.6	-	23.1
2002	-	138.8	274.6	-	222.7	-	3.3	12.8	-	21.4
2003	72.6	101.0	262.3	-	251.2	2.8	4.3	12.9	-	20.8
2004	28.9	106.8	249.4	99.3	275.6	3.5	3.3	11.4	6.7	20.9
2005	30.1	124.0	223.3	143.6	193.1	4.2	3.7	10.4	6.0	19.3
2006	32.4	64.6	208.3	83.9	160.1	4.3	4.3	8.7	5.2	15.8
2007	42.3	95.0	187.5	148.5	230.0	4.3	3.6	10.1	4.0	17.7
2008	75.2	90.7	210.5	121.8	238.0	4.1	4.5	10.5	4.2	15.7
2009	41.5	84.0	174.0	75.9	322.0	3.6	3.7	8.2	5.3	13.3
2010	42.1	90.5	167.8	96.7	322.0	3.7	3.7	8.7	5.2	15.2

As shown in figure 3-27, both C27 and C678 recorded significant decreases in NO_X emissions from 2000 to 2010. Since these monitors are located within the urban core, the decrease in NO_X can be attributed to controls put on major NO_X sources including power plants and cement kilns, and significant reductions of NO_X emissions from on-road and off-road vehicles. C58 and C59 are sited in rural areas removed from major NO_X sources, consequently average NO_X concentrations are low at these monitors and there is no significant difference between NO_X averages measured from 2000 to 2010. Data from C58 in 2002 was not included in the analysis because the NO_X monitor had a lower completion rate (84%) for data collection during the ozone season and some of the data reported by the monitor was questionable during this period.

Figure 3-27: Annual Average NOx Trends in the San Antonio Area by Monitor, 2000 – 2010[32]



Hourly NO_X concentrations at each monitoring site were plotted for all days, days > 60 ppb peak ozone, and days < 40 ppb peak ozone in figure 3-28. NO_X values for C678 are bimodal with a maximum peak between 5 am and 8 am, while C27 had a distinct peak in the early morning hours. Before sunrise, there is a significant concentration of NO_X emissions especially at C27 and C678 urban monitors. After sunrise, NO_X emissions react with VOCs to form ozone in the presence of ultraviolet energy from the sun (figure 3-29), which has the effect of lowering NO_X concentrations. Additionally, NO_X can be diluted by the diurnal rising of the inversion layer.

C27 NO_X readings were generally higher during the day than the other three NO_X monitors, indicating that there is a constant supply of ground level NO_X emissions in proximity to the monitoring site. Heavily traveled highways surround C27 and these vehicles release NO_X emissions near the monitoring site. Ground level NO_X emission sources at the other monitors are not as concentrated as ground level NO_X emission sources near C27. On days of high ozone, C678 also records high NO_X emissions in the early morning because of local NO_X sources. At C58 there was no significant difference between NO_X on days when ozone concentrations were > 60 ppb and days < 40 ppb. There are no significant sources of NO_X emissions in proximity to C58. .

[32] Standard Deviation (σ) of NO_x emissions from 2000-2010 for each CAMS is: C27 = 3.41, C678 = 1.75, C58 = 0.55, and C59 = 0.61

Figure 3-28: NO_x Diurnal Pattern by Monitor for San Antonio, 2005-2010

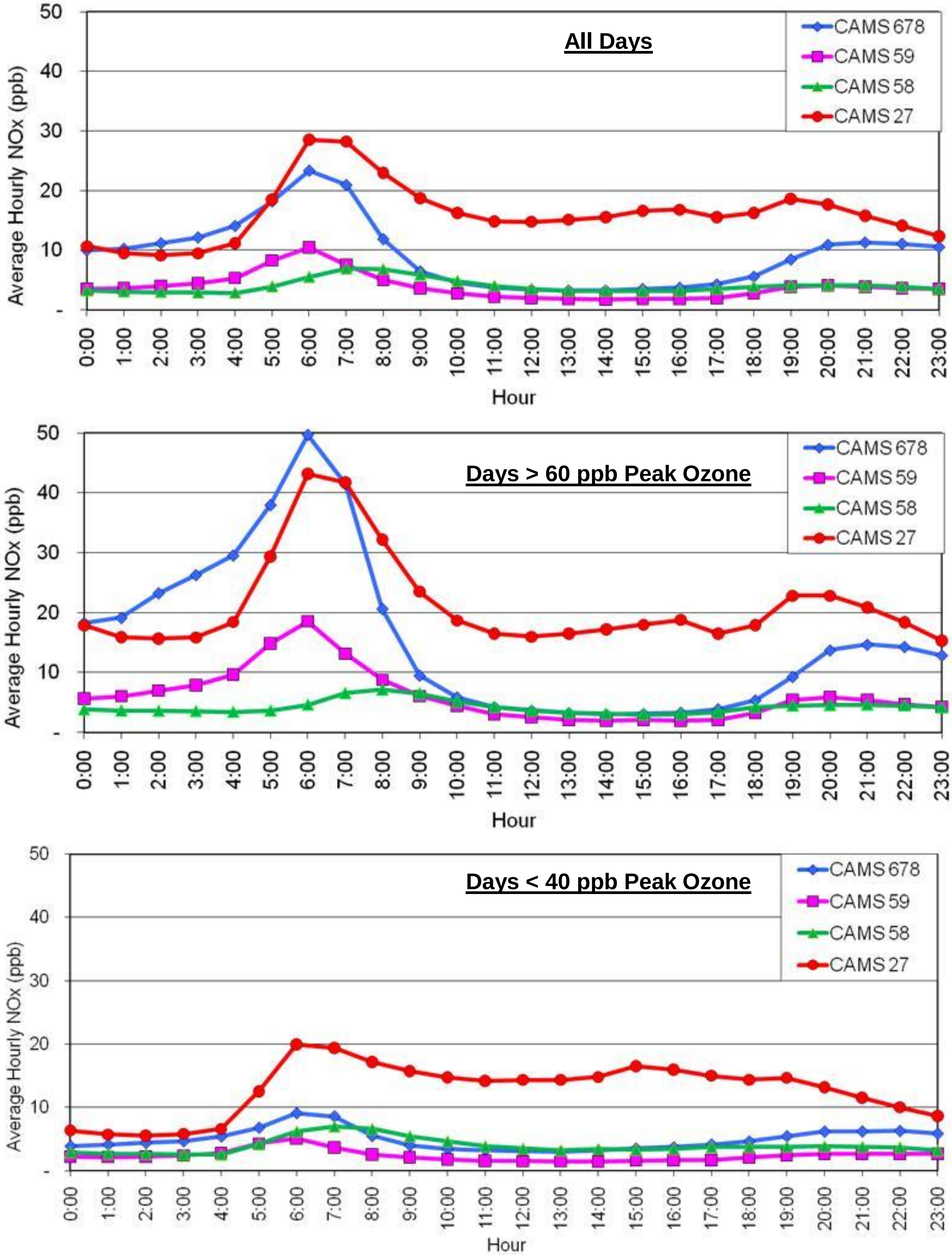
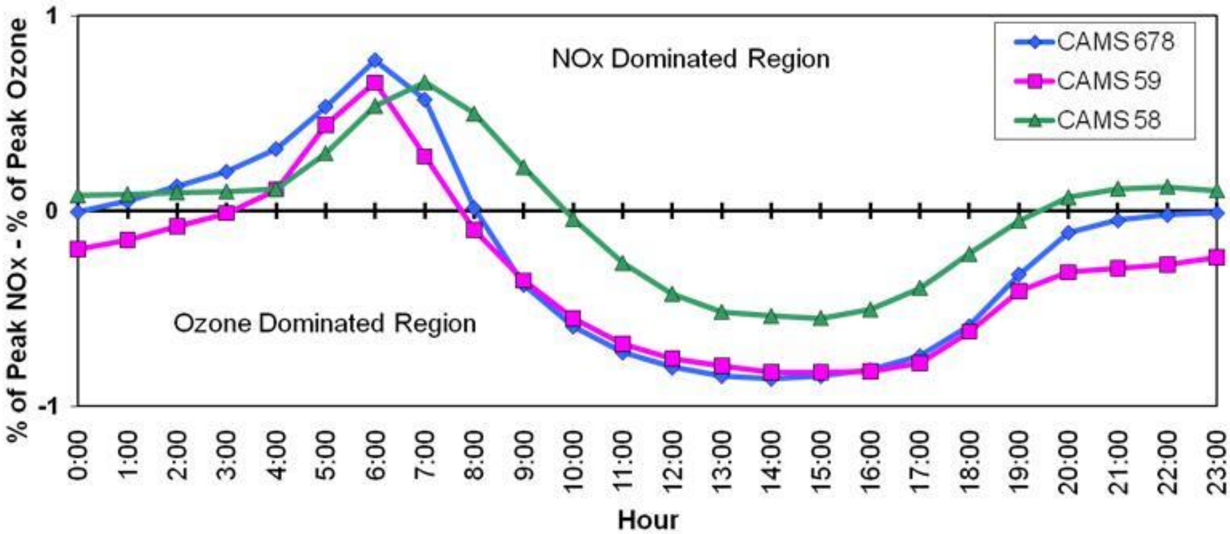


Figure 3-29 demonstrates the relationship between NO_X and ozone concentrations which occur as diurnal cycles. Early morning hours at each of the three monitors are dominated by NO_X, as ozone has been sufficiently scavenged by the reaction of NO and ozone to form NO_2 and oxygen. NO_X concentrations are also dominant in these hours due to the surge in NO_X production in the early morning due to increased traffic and industrial activity. Beginning shortly after sunrise, ozone is produced by photochemistry and NO_X is diluted and lost through the aforementioned processes so that ozone concentrations become dominant during the remaining daylight hours.

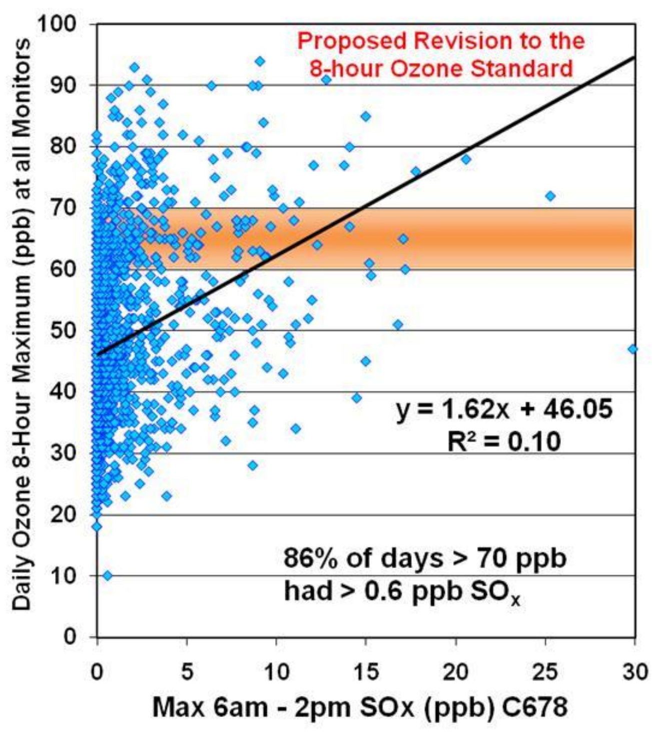
Figure 3-29: Percentage of Peak NO_X – Percentage of Peak Ozone by Monitor for San Antonio Area, 2005-2010



3.8.2. SO_2

SO_2 concentrations are measured at C622 and C678. When 2005 – 2010 data collected at these monitors was compared with ozone measurements, the results indicated a very weak relationship between maximum morning SO_2 readings and maximum 8-hour ozone values (figure 3-30). Maximum morning SO_2 was above the median of 0.6 ppb on 86 percent of the days when eight-hour ozone averages were above 70 ppb, and 74 percent of days when eight-hour ozone averages were above 60 ppb. On low ozone (<40 ppb) days, maximum morning SO_2 values were above 0.6 ppb only 26 percent of the time.

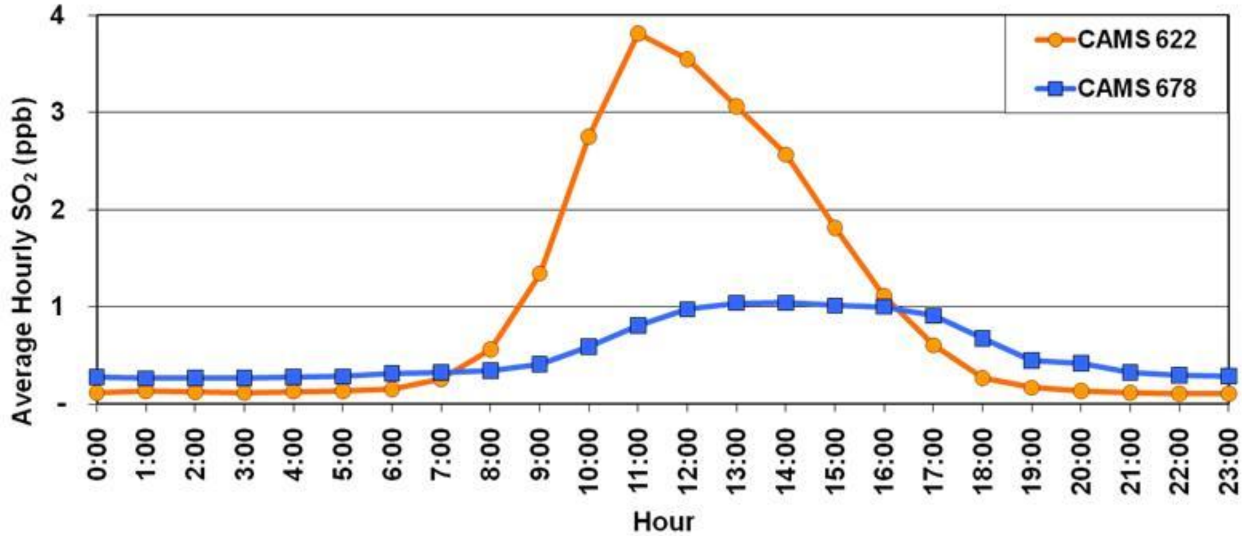
Figure 3-30: Daily Ozone 8-Hour Maximums and SO_2 Maximums (6 am – 2 pm) C678, 2005-2010



When the diurnal cycle of SO_2 emissions are plotted by hour in figure 3-31, C622 records higher levels of SO_2 during the daytime than C678. Being located downwind of nearby power plants, C622 could be impacted by local SO_2 point source emissions. During the midday, diurnal winds typically shift to the southeast to transport SO_2 from local point sources to C622. Although SO_2 emissions are present at both C622 and C678, SO_2 emissions are low and measurements decreased about 68 percent at C678 and

29 percent at C622 between 2005 and 2010.

Figure 3-31: SO_2 Diurnal Pattern by Monitor for San Antonio, 2005-2010



3.8.3. $PM_{2.5}$

Particulate matter (PM) in the atmosphere is comprised of a variety of solids and liquids including sulfates, dust, and smoke. For the purposes of this analysis, PM particles with diameters of 2.5 micrometers or less ($PM_{2.5}$) were used because $PM_{2.5}$ can stay suspended in the atmosphere over long periods of time and be transported over great distances.

The 24-hour average $PM_{2.5}$ for the 2005-2010 ozone seasons was analyzed; although, this is not the same as the measure used for a $PM_{2.5}$ violation under the NAAQS. According to the NAAQS, "the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 µg/m^3". Also, "the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15.0 µg/m^3".[33] The San Antonio region is not currently in danger of violating the $PM_{2.5}$ NAAQS and all the local $PM_{2.5}$ monitors are non-regulatory. The 2008-2010 three-year average of the 24-hour 98th percentile concentration is 22.07 µg/m^3 and the 2008-2010 three-year annual mean is 9.27 µg/m^3

Figure 3-32: Daily Ozone 8-Hour Maximums and $PM_{2.5}$ Daily Averages C301, 2005-2010 Ozone Seasons

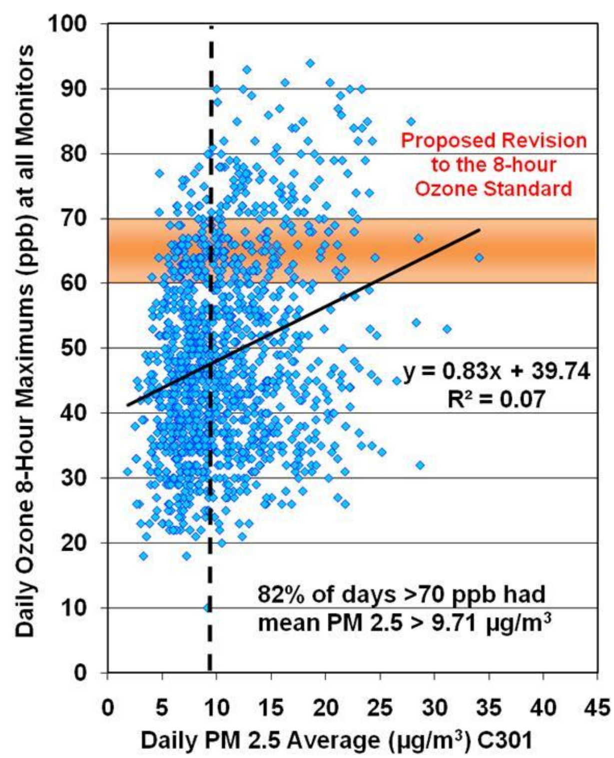


Figure 3-32 displays ozone season $PM_{2.5}$ readings at CAMS 301 plotted against daily ozone 8-hour maximums. As shown in the scatter plot, 82 percent of days when eight-hour ozone averages exceeded 70 ppb the average

[33] EPA, October 20th, 2008. "National Ambient Air Quality Standards". Available online: http://www.epa.gov/air/criteria.html. Accessed 06/22/10.

$PM_{2.5}$ was above the median of 9.71 µg/m^3, whereas only 39% of days below 40 ppb ozone had a $PM_{2.5}$ average above 9.71 µg/m^3. The relationship between $PM_{2.5}$ and 8-hour ozone peaks is very weak with an R^2 value of only 0.07.

The highest $PM_{2.5}$ 24-hour average was recorded on May 7th, 2009 (29 µg/m³); this high value was attributed to transported smoke from agricultural burning in Mexico and Central America. Table 3-7 lists all the hourly $PM_{2.5}$ concentrations greater than 70 µg/m³ recorded between 2005-2010. Three of the six days occurred during the ozone season, but none were associated with high 8-hour ozone values.

Table 3-7: Daily PM2.5 1-hr Peak & 24-hr Average Concentrations > 70 mg/m³ with Corresponding Peak 8-hr Average Ozone Concentrations, 2005 – 2009

Date	$PM_{2.5}$ 1-hour Average	$PM_{2.5}$ 24-hour Average	Peak 8-hour Ozone	TCEQ PM Event Description
12/31/05	114	24	43	Firework-smoke w/stagnant air
01/01/06	78	20	41	
09/21/06	136	16	43	
01/01/07	110	17	37	Firework-smoke w/stagnant air[34]
10/02/07	126	18	42	
05/07/09	82	29	52	Smoke from agricultural burning in Mexico and Central America[35]

It is uncertain to what extent, and under what conditions, $PM_{2.5}$ has a direct or indirect effect on ozone levels or the duration of high ozone levels. Dave Sullivan, formerly with TCEQ, offered three main points to consider when studying ozone levels in comparison to monitored PM. The main points are:

1. Air stagnation leads to air pollution accumulation; thus, many pollutants will have elevated readings when wind speeds are low. This may cause a positive correlation without a causal relationship.
2. Unlike ozone, PM is both a primary and a secondary pollutant. It is difficult to determine what portion is emitted directly and what portion is formed in the air. It can be assumed, however, that if “there is significant photochemistry forming ozone, we can expect PM to be formed also.”
3. At times, the source of primary PM can also be a source of secondary ozone. This could be true in the case of a fire, which produces smoke, NO_X, and VOC.[36]

In essence, the relationship between ozone and PM cannot be simply determined. Even though the relationship may seem to have a positive correlation at times, this cannot be proved as of yet.[37]

3.8.4. Non-methane Hydrocarbon Surface Measurements

TCEQ provided VOC canister sampling equipment for analysis of VOCs at three CAMS stations in 2006: C23, C58, and C678. AACOG staff collected ambient air samples in 2006 on days the TCEQ

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[34] TCEQ. “Air Pollution Events: Texas Fireworks Smoke, January 1, 2007”. Available online: http://www.tceq.state.tx.us/assets/public/compliance/monops/air/sigevents/07/event2007-01-01tx.html. Accessed 06/28/10.

[35] TCEQ. “Texas Smoke May 5-11, 2009”. Available online: http://www.tceq.state.tx.us/compliance/monitoring/air/monops/air-pollution-events/2009/090507-tx-smoke. Accessed 06/22/10.

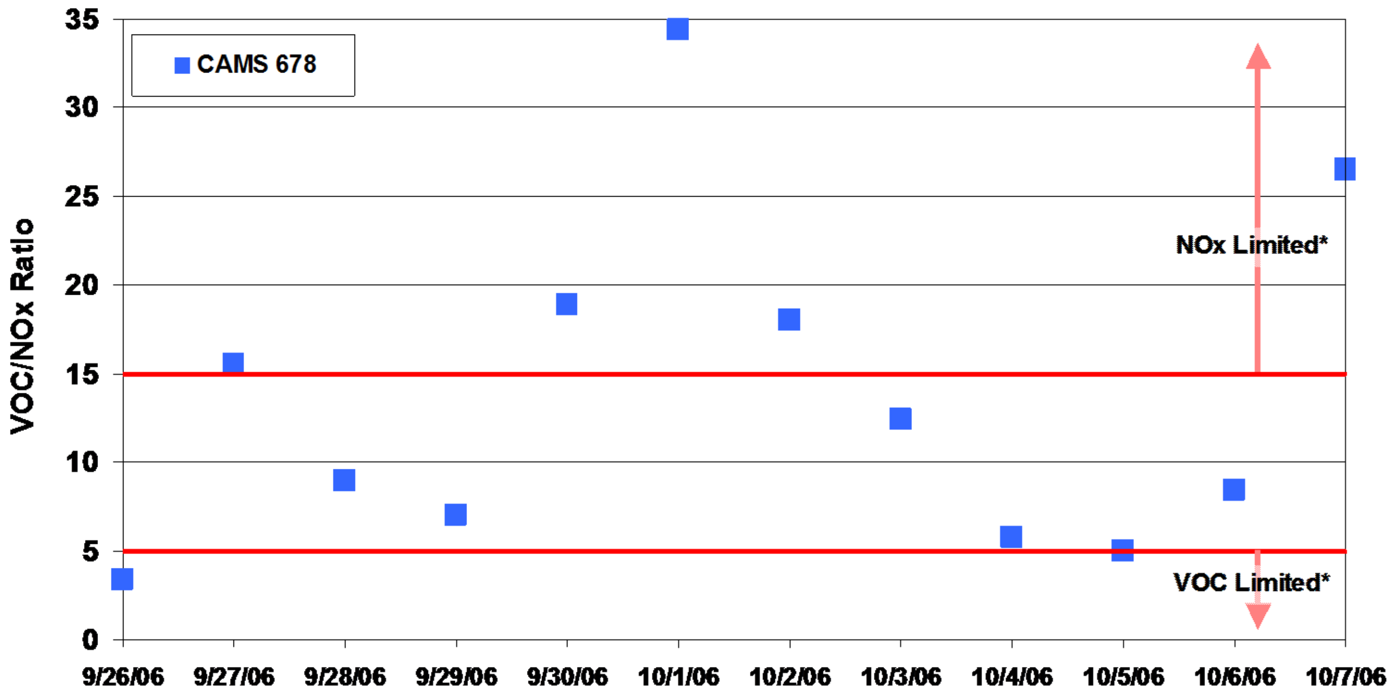
[36] TCEQ, E-mail correspondence from Dave Sullivan, Manager, Monitoring Data Management & Analysis Section, Monitoring Operations Division. Subject: Re:Ozone 2002 spreadsheet and Excuse Petition. Received 3/4/03.

[37] *Ibid*.

determined as potential high ozone days during August and September. The resulting VOC data from C678 was compared with NO_X data obtained from C678 in figure 3-33.

VOC and NO_X limitation thresholds noted on the figure are based on a study conducted in Dallas.[38] Days considered VOC limited are those with ratios less than 5 VOC/NO_X. On those days, VOCs contribute more to ozone production than NO_X. The days with ratios greater than 15 VOC/NO_X are considered NO_X limited. Ratios between 5 and 15 are considered both NO_X and VOC limited. Only one of the sampling days at C678 was VOC limited (September 26th, 2006) based on the Dallas study definition, while five days were NO_X limited. The results from the canister sampling match the output from the June 2006 photochemical model which shows San Antonio regulatory monitors are NO_X-limited. In areas that are NO_X limited, ozone formation is more controlled by NO_X emissions than by VOC emissions. In these areas, NO_X controls would be more effective at reducing ozone.

Figure 3-33: VOC to NOx Ratios at C678 from Late September – Early October 2006



3.9. *Analysis of Upper Air Measurements*

In 2005, a 915-MHz radar wind profiler (RWP), radio acoustic sounding system (RASS), and surface meteorological station were installed in Guadalupe County, east of I-35. The profiler recorded upper air measurements from June 30th to October 15th in 2005 and 2006. The data included measurements on 46 high ozone days > 60 ppb eight hour average, 22 of which were during the existing June 2006 episode.

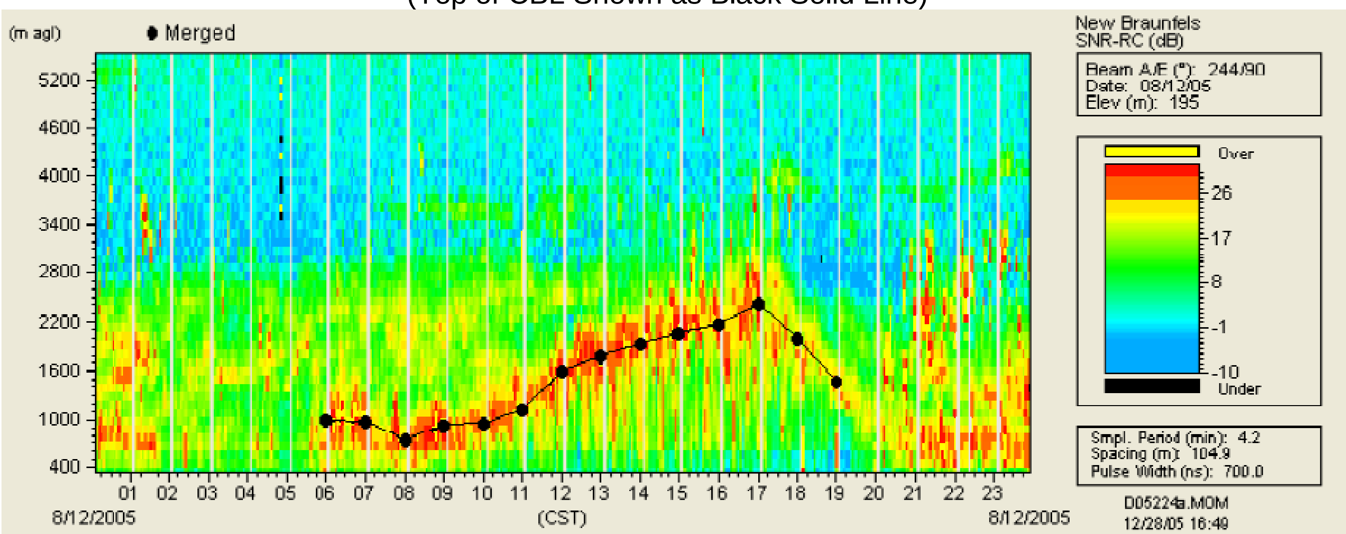
The mixing height was calculated based on the RWP reflectivity data (or signal-to-noise ratio [SNR] data). As calculated by STI, the "RWP reflectivity data are strongly influenced by the refractive index of the atmosphere. Turbulence produces variations in atmospheric temperature, humidity, and pressure, which in turn cause variations in the radar refractive index. In the planetary boundary layer (PBL) or mixing height, humidity fluctuations contribute most to the variations in the radar refractive

[38] Fernando Mercado, February 18, 2005. "Quantitative Comparison of VOC:NOx Ratios in DFW". Data Analysis, TCEQ. Austin, Texas. Available online: http://www.tceq.state.tx.us/assets/public/implementation/air/am/committees/pmt_dfw/20050303/20050303-Mercado-voc_nox_ratios.pdf. Accessed 06/17/10.

index."[39] Temperature data collected by RASS, coupled with surface temperature measurements, were used to provide estimates of the shallow boundary layers depths.[40]

"Viewing time-height cross-sectional plots of the SNR data can be an effective method of estimating mixing height in real time or for post-analysis. Figure 3-34 shows time-height SNR data at New Braunfels. Blue and green in the cross-section show weak signal returns, and orange and red show strong returns. The black line during daylight hours indicates the mixing height analyzed from the SNR."[41] It is important to "view SNR plots in conjunction with vertical velocity, spectral width, and RASS temperature to ensure that peak SNR properly characterizes the surface-based mixing height."[42] Since several variables are used to estimate the mixing layer, the accuracy of the calculated mixing-height may vary and should be noted when comparing the profiler data to predicted mixing height in meteorological models.

Figure 3-34: Time-height Cross-Section of RWP SNR Data at New Braunfels on August 12, 2005 (Top of CBL Shown as Black Solid Line)[43]



The impact of mixing height on ozone formation can be significant. On days when the peak 8-hr ozone average was less than 40 ppb, mixing heights were higher in the early morning (before 9 am) compared to high ozone days. Through the hours of 9 am to 2 pm there was a gradual rise in the mixing height level on low ozone days before leveling off in the late afternoon hours (figure 3-35). In contrast, mixing heights on high ozone days were lower in the early morning hours. This was followed by a rapid rise in mixing height, occurring between 8 am – 2 pm, and then a leveling out through the late afternoon hours. Late afternoon mixing height was greater on high ozone days compared to the mixing heights on low ozone days.

Low nighttime mixing heights can trap nocturnal pollutants from the local area as well as emissions from the previous day; when combined with a rapid rise in mixing height that allows downward mixing

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[39] Clinton P. MacDonald and Charley A. Knoderer, December 28, 2006. "Summary Of The New Braunfels 2005 And 2006 Radar Profiler Operations and Data Availability Final Report STI-905027.12-3092A-FR". Sonoma Technology, Inc. Petaluma, CA, p. 6-1.

[40] *Ibid*.

[41] *Ibid*.

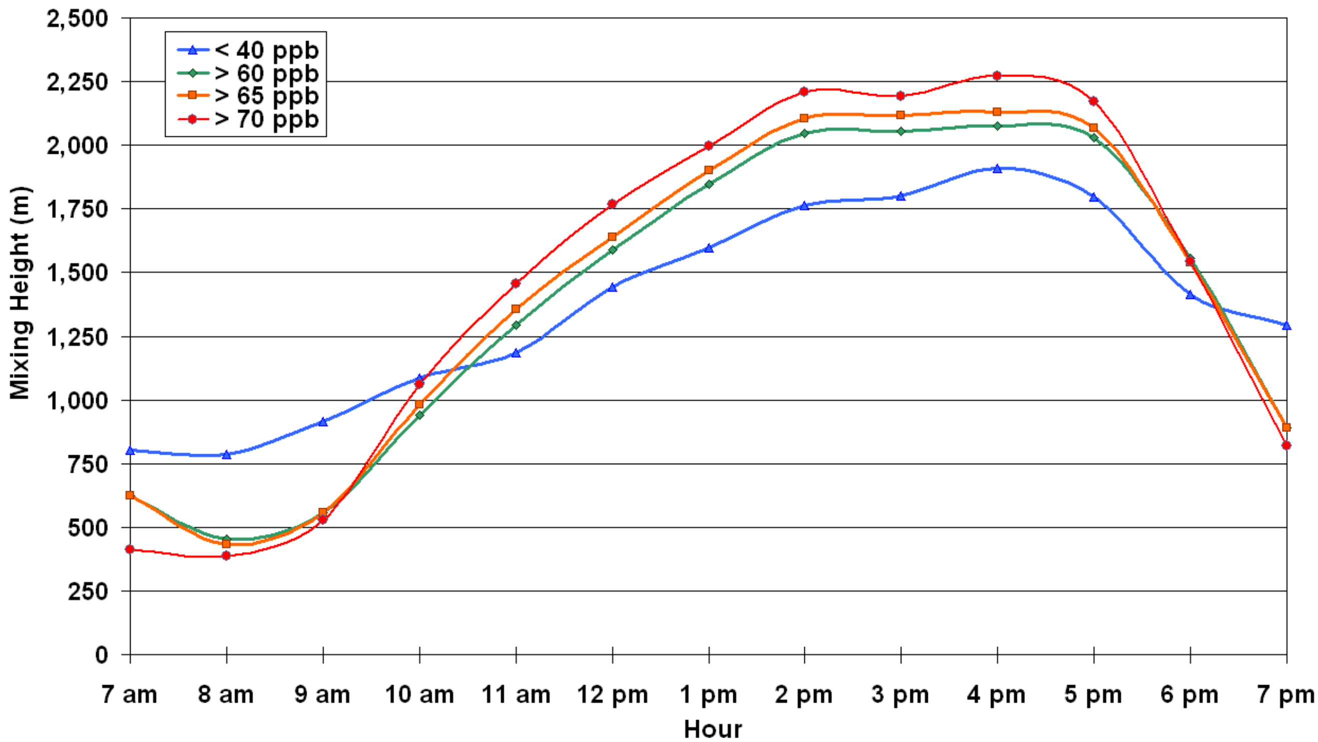
[42] *Ibid*.

[43] *Ibid*., p. 6-2.

of transported pollutants from higher inversion layers, ozone can become significantly elevated.[44] With low wind speeds on mornings of high ozone, the "trapped" ozone concentrations from the previous day remain in the region.[45] Thus, a major factor in high ozone formation is convective activities that lead to mixing height rise. According to a study performed by the New York State Department of Environmental Conservation,

> "Occurrence and timing of convective development is crucial in terms of peak ozone since cloudiness … will act to limit insolation and halt the chemical production of surface-based ozone. The stable layer also acts to limit the vertical extent of the mixed layer, reducing "venting" of pollutants. At the same time, sufficient vertical mixing is maintained to allow transport of ozone from the layers just above the surface that can exist from the previous day's activity."[46]

Figure 3-35: Hourly Mixing Height Measured by New Braunfels Profiler, <40 ppb, >60 ppb, >65 ppb, and >70 ppb 8-hour Average Ozone, 2005-2006[47]



Mixing height is an important consideration in evaluating the formation of ground-level ozone. Lower nighttime mixing height with low wind speed and a rapid mixing height rise in the early afternoon hours appear to be key factors in the photochemical process leading to high ozone concentrations in the San Antonio region. In the future, collection of additional upper air data could aid greatly in the analysis of ozone formation and meteorological trends that can influence ground level ozone measurements. In light of

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[44] Richard S. Artz, 2006. NOAA ARL Monthly Activity Report March 2006: "*14. Coupling of CMAQ and HYSPLIT Models,*" pp. 4-5. Available online: http://www.arl.noaa.gov/documents/activity/monthly/mar2006.pdf. Accessed on 06/17/2010.

[45] *Ibid*.

[46] Gaza, Robert S, 1997. Journal of Applied Meteorology, Article: pp. 961–977: *Mesoscale Meteorology and High Ozone in the Northeast United States*, p. 4 of 13. Available online: http://ams.allenpress.com/perlserv/?request=get-document&doi=10.1175%2F1520-0450(1998)037%3C0961%3AMMAHOI%3E2.0.CO%3B2. Accessed on 06/17/2010.

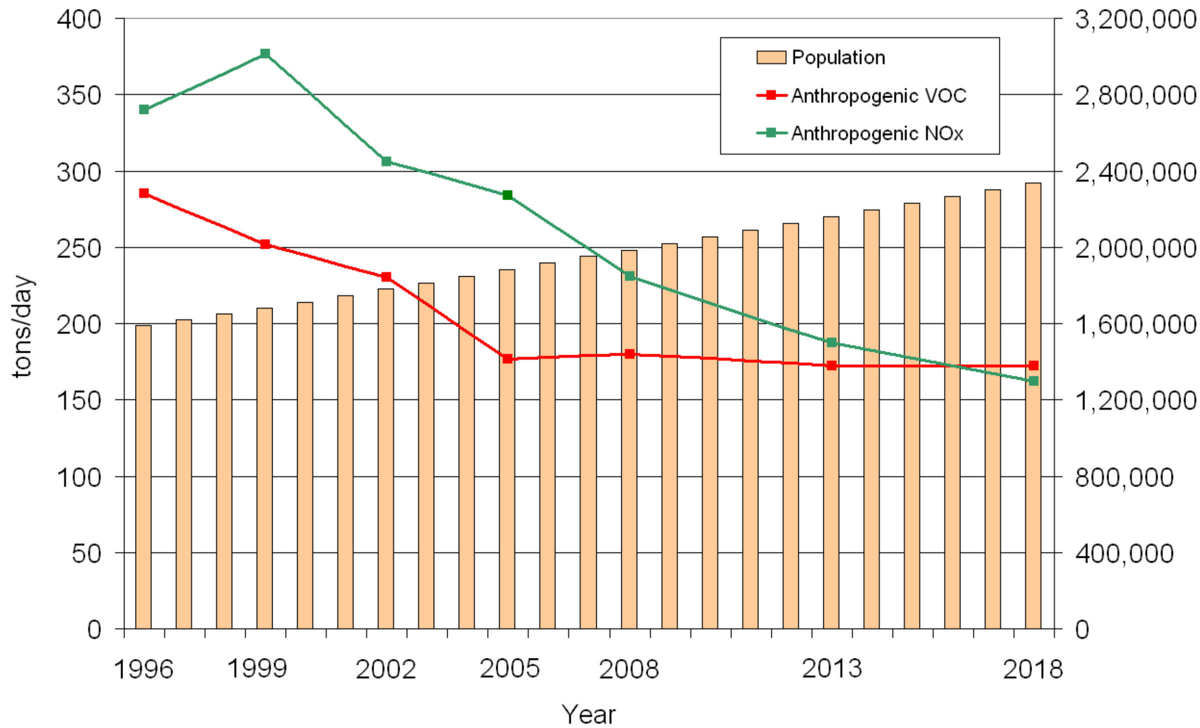
[47] For days > 65 ppb, the results was significant at P = 0.01 for the morning, 7 a.m. – 9 a.m. (Chi-square = 9.6) and the afternoon, noon – 5 p.m. (Chi-square = 13.3)

seasonal ozone patterns and changes in seasonal transport, it is particularly important to understand the effect of mixing height evolution on ozone formation. Downward mixing of ozone and ozone precursors from upper layers of the atmosphere may play an important, not fully recognized role in ground level ozone formation.

3.10. *Local VOC and NO_X Emission Trends*

A trend analysis of local ozone season daily VOC and NO_X emissions was developed to provide insight into historical and future emissions, while accounting for the impacts of population and economic changes. The following figure (3-36), which was generated from available historical estimates and forecasted emission factors and growth, depicts a downward trend in emissions.[48] Since population continues to rise in the region, the future reductions in emissions are significant. It is projected that NO_X emissions shall continue a downward trend, in large part due to improvements in vehicle emission standards, while VOC emissions have remained steady since 2005 and are expected to remain steady through 2018.

Figure 3-36: Trend Lines for VOC and NOx Emissions in the San Antonio MSA 1996 to 2018



Due to federal, state, and local emission control policies, the downward trend of NO_X emissions should be sustained through 2018, despite predicted growth in population economic activities, and the addition of several new or proposed point sources including the Spruce 2 power plant, Toyota manufacturing facility, and several new cement kilns. The MOVES model shows a downward trend in on-road emissions even with the increase in vehicle population. Texas Water Development Board provided the population projections for the San Antonio MSA.[49]

A comparison between ozone trends and local annual ozone precursor emission rates is provided in figures 3-37 and 3-38. While VOC emissions have remained steady since 2005, NO_X emission

[48] AACOG, October 2009. "Emissions Trend Analysis for the San Antonio MSA: 1996, 1999, 2002, 2005, 2008, 2013, & 2018". San Antonio-Bexar County Metropolitan Planning Organization, San Antonio, Texas, p. 7-2.
[49] Texas Water Development Board. "County Population Projections for 2002 – 2060". Texas. Available online: http://www.twdb.state.tx.us/data/popwaterdemand/2003Projections/Population Projections/STATE_REGION/County_Pop.htm. Accessed 08/4/2009

reductions have continued to have a positive impact on ozone readings. The number of high ozone days greater than 60 ppb dramatically dropped from 2005 to 2010. In the future, NO_X emissions are predicted to decrease further through the next decade from improvements in on-road emission controls, and this trend can result in further reductions in the design value and the frequency of high ozone days.

Figure 3-37: Ozone Design Values and Trend Lines for VOC and NOx Emissions in the San Antonio MSA, 2005 to 2010

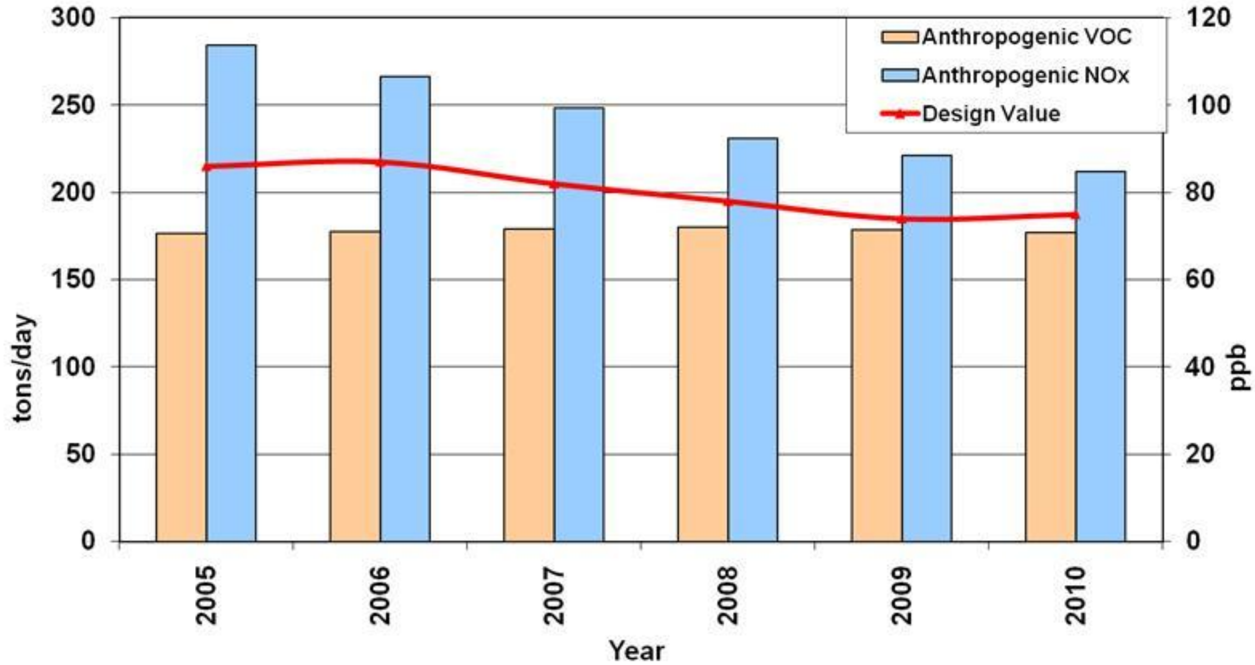
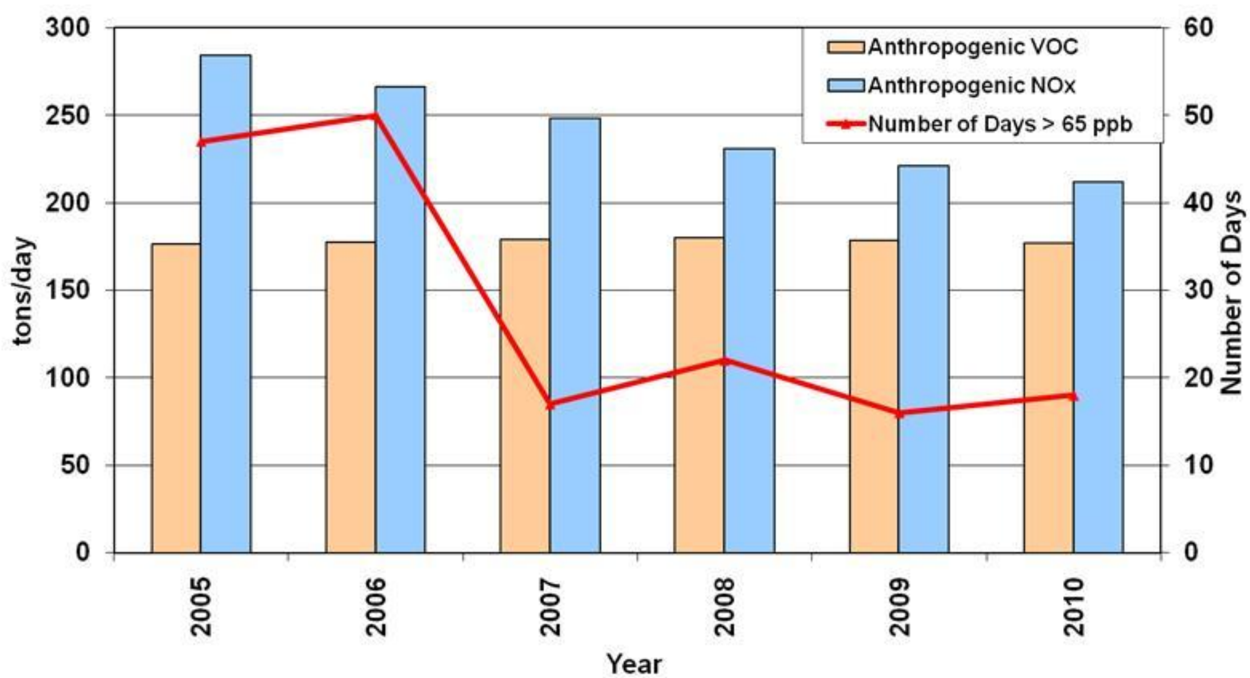


Figure 3-38: Number of High Ozone Days > 65 ppb and Trend Lines for VOC and NOx Emissions in the San Antonio MSA, 2005 to 2010



3.11. *Summary of Meteorological Data and Ozone Precursor Emissions in the San Antonio Area*

Preliminary analysis indicates a number of local meteorological and emission factors that contribute to elevated ozone concentrations in the San Antonio region. The following summarize the relationship between local meteorology and ozone photochemistry:

- Days with elevated ozone readings typically include stagnated winds over Texas, limited frontal movement, no precipitation, reduced mixing, and clear skies.
- High ozone days are typically absent of strong synoptic weather systems.
- Local meteorological conditions during high ozone days include no precipitation, low atmospheric moisture content present in the afternoon, and clear skies.
- There was no significant correlation between peak ozone season temperature and ozone readings.
- Wind vectors on high ozone days were more stagnated and often originated from the east and northeast.
- At C23 on high ozone days, the wind slowly changed direction at the monitor from the north-northeast to the east-southeast in a clockwise fashion during the day.
- C58 wind vectors on high ozone days show there is a flow reversal of winds arriving at the monitors from the northwest in the morning before 7 am to arrive from the southeast in the afternoon. These winds can bring in recirculation of local ozone precursor emissions and ozone from the previous day that combines with emissions from the east to form ozone. This wind reversal with recirculation of pollutants is similar to diurnal sea-breeze patterns observed in the Houston area.
- The strongest multivariate correlations on days when eight-hour ozone averages exceeded 60 ppb were back trajectory direction - diurnal temperature change and humidity - back trajectory distance. Morning wind direction - diurnal temperature change and back trajectory distance - diurnal temperature change were also strongly correlated with high ozone days. The lowest correlation with high ozone days was wind speed - afternoon wind direction, temperature - wind speed, and temperature - afternoon wind direction.
- There was a significant decrease in NO_X emissions from 2000 to 2010. The decrease can be attributed to controls put on major NO_X sources including power plants and cement kilns, and significant reductions of NO_X emissions from on-road vehicles.
- C59 is recording low background NO_X emissions coming into the San Antonio region from the southwest
- Since C59 is an upwind monitor site on most high ozone days and monitored NO_X concentrations are low, there is not a significant amount of NO_X being transported into San Antonio from the southeast.
- Before sunrise, there can be significant concentrations of NO_X emissions at C27 and C678 urban monitors. After sunrise, NO_X emissions react with VOCs to form ozone in the presence of ultraviolet energy from sunshine, which has the effect of lowering NO_X concentrations.
- There was little to no correlation between maximum morning SO_2 readings and ozone.
- The meteorological conditions that cause transported $PM_{2.5}$ may contribute to a *regional* impact on ozone readings.
- The relationship between ozone and PM cannot be simply determined. Even though the relationship may seem to have a positive correlation at times, this cannot be proved as of yet.
- The results from non-methane hydrocarbon sampling indicated that San Antonio is usually NO_X limited, meaning high ozone concentrations are determined by NO_X emissions and not by VOC emissions. This result is consistent with the observation that NO_X and ozone concentrations have both decreased in recent years while VOC concentrations have remained steady.
- Mixing heights are typically lower in the early morning hours and experience a rapid rise in the late morning through early afternoon on high ozone days. Low nighttime mixing height can trap nocturnal pollutants from the local area as well as emissions from the previous day. When

combined with a rapid rise in mixing height that allows downward mixing of transported pollutants from higher inversion layers, ozone can become significantly elevated.

- Trend line analysis indicates local NO_X emissions should continue a downward trend, in large part due to improvements in vehicle emission standards, while local VOC emissions are expected to remain steady.

4. BACKGROUND OZONE AND OZONE TRANSPORT INTO THE SAN ANTONIO AREA

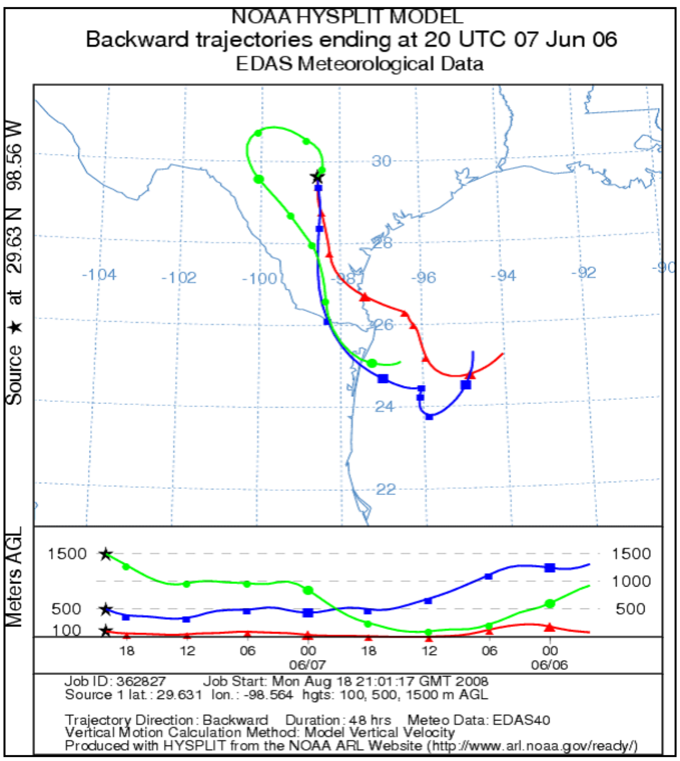
Air samples collected at San Antonio monitors are impacted by transported ozone and ozone precursor emissions from sources outside of the region and outside of Texas. The timing, location, and intensity of ozone events are influenced by the interaction between local and regional wind patterns. Improving the understanding of transport will help in photochemical modeling episode selection and the development of appropriate control strategies. Transported ozone periodically arrives in San Antonio at concentrations above the low range of the proposed ozone standard (60 ppb) and even above the high end of the range (70 ppb). Local emission contributions can further exacerbate the high ozone on these days.

When high concentrations of ozone arrive in San Antonio by transport, it will be very difficult for the region to meet the proposed ozone standard. Analysis of regional transport can provide an understanding of high ozone in San Antonio. These analyses include transport of pollutants, analysis of upwind monitors, ozone readings in other regions, aircraft sampling, and photochemical modeling.

4.1. *Back Trajectories*

The Air Resources Laboratory of NOAA maintains the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model and allows public use via the Internet at their Realtime Environmental Applications and Display System (READY) webpage.[50] This versatile model can be run as a trajectory (parcel displacement) or air dispersion model, using either forecast or archived meteorological data. The model and database are applicable across the United States, which provides a national reference for air trajectory and dispersion modeling needs. The back trajectories needed for the analyses of transport were created using this model.

Figure 4-1: HYSPLIT Back Trajectories Beginning at C58, June 7, 2006.



The approximate pathways of air entering San Antonio on days of interest were determined using HYSPLIT. Figures 4-1 to 4-3 contain back trajectories over 48 hours (2 day path) for air parcels terminating at C58 on a high ozone days during the June 2006 photochemical modeling episode. By creating back trajectories, air parcels were analyzed to determine emission sources and causes of elevated ozone concentrations. According to TCEQ, "The meteorological dynamics that cause air to rise or fall, and that determine its path can affect air quality by carrying air pollutants many miles from their sources."[51] Given a final geographic destination for an air parcel, back trajectories show the path followed

[50] NOAA, Feb. 26, 2019. "Realtime Environmental Applications and Display sYstem (READY)". Available online: http://www.arl.noaa.gov/ready.html. Accessed 05/24/10.

[51] TCEQ, Air Monitoring, Sept. 24, 2009. "Air Trajectories: Where did the Air Come from and Where is It Going?". Available online: http://www.tceq.state.tx.us/compliance/monitoring/air/monops/airtraj.html. Accessed 05/24/10.

by the air parcel before reaching the destination. Back trajectories track air displacement over time, distance, and emission source regions.

Figure 4-2: HYSPLIT Back Trajectories Beginning at C58, June 8, 2006.

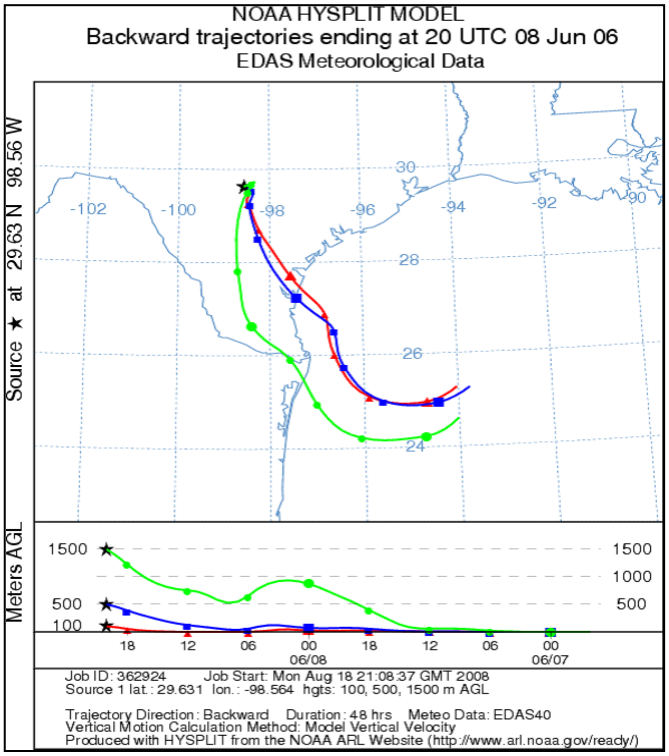
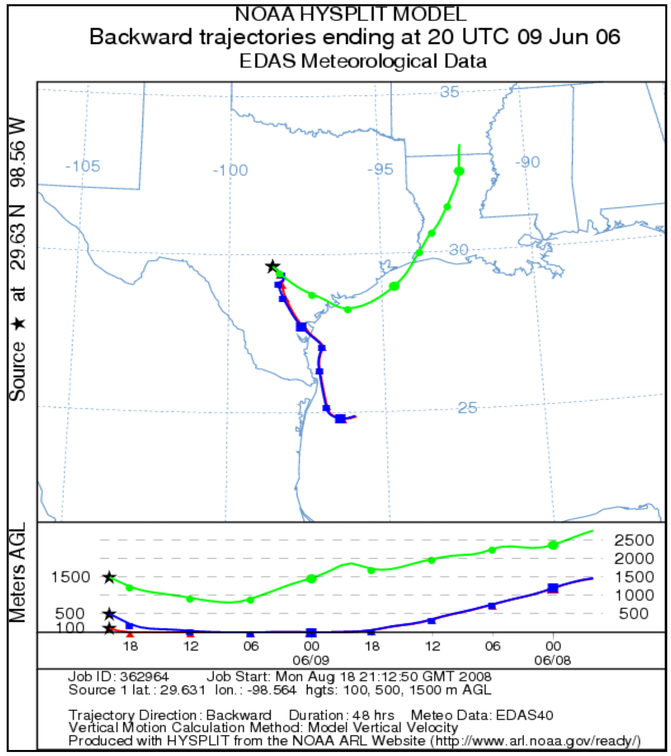


Figure 4-3: HYSPLIT Back Trajectories Beginning at C58, June 9, 2006



As displayed in the figures, back trajectories are split into 100 (red), 500 (blue), and 1,500-meter (green) elevations. The plots show that winds came from the southeast on these high ozone days at both the 100-meter and 500-meter elevations. By using the data represented in these figures, wind directions and emission source regions can be estimated.

When using the HYSPLIT model, limitations of trajectory analysis should be noted. TCEQ states that "it is important to point out that transport layer back trajectories for ozone episodes are based upon archived upper air data from meteorological models, and interpolated from a coarse grid which smoothes out the local perturbations and geographical details. Trajectories developed from transport layer winds do not necessarily represent the wind fields at the surface, especially on a day-to-day basis. Individual trajectories have error bars, which increase with time and distance, and so must be interpreted with caution. However, when a large number of trajectories for ozone episodes are analyzed statistically, they provide a reliable picture of the most likely flow patterns and source regions affecting an area."[52]

"Surface winds and surface trajectories have the opposite limitations. Winds measured at surface sites reflect only the surface conditions and the geographic features near the measurement site. Surface winds measured at CAMs and other surface stations may be affected by local obstructions and may not represent areas outside the immediate vicinity of the measurement site. Surface winds also do not necessarily represent the wind speed and direction in the transport layer. Therefore

[52] Technical Support Section, Technical Analysis Division TCEQ, December 13, 2002. "Conceptual Model for Ozone Formation in the Houston-Galveston Area Appendix A to Phase I of the Mid Course Review Modeling Protocol and Technical Support Document". Austin, Texas. p. 21. Available online: http://www.tceq.state.tx.us/assets/public/implementation/air/am/docs/hgb/protocol/HGMCR_Protocol_Appendix_A.pdf. Accessed 05/24/10.

individual trajectories based on winds at surface monitors must be interpreted carefully. However, conclusions drawn from time and space averages of surface winds are reliable if used in a general rather than site or day specific sense."[53] Both back trajectories and surface wind measurements should be used to analyze patterns on high ozone days along with other meteorological factors.

By running 100-meter and 1,000-meter 48-hour back trajectories for the 265-high ozone days in the San Antonio area as recorded at regulatory-sited monitors from 2005 to 2010, spatial patterns were identified on high ozone days. Figure 4-4 shows C58 back trajectories on high ozone days greater than 60 ppb. The HYSPLIT model produces air parcel positions for every hour by latitude, longitude, and height. Back trajectories demonstrate that, on high ozone days, it is rare for air arriving at C58 to come from the west, northwest, or southwest. A quantitative refinement of this data is presented next (figures 4-5 to 4-7) for days in which the San Antonio area experienced 8-hour ozone averages >60 ppb, >65, ppb and >70 ppb. For this analysis, the region of central Texas within a 250-mile radius of C58 was partitioned into octants: northern, northeastern, eastern, southeastern, etc. The region was further subdivided by distance boundaries: area within 50 miles of C58, 50 to 100 miles of C58, etc., out to 250 miles from C58. Figure 4-4 contains the percentage of hourly air parcel positions within each sub-division and the total for each octant is located just outside the 250-mile circle. The total for each distance sub-division of these octants will be referred to as "bin counts".

By analyzing the directional distribution of bin counts, it was determined that there was no significant difference in the back trajectories' directions on high ozone days greater than 60 ppb, 65 ppb, and 70 ppb. For days exceeding 60 ppb, 1.9% of the bin counts were located in the northern octant and within 50 miles of C58; 2.1% were in the same octant, but between 50 and 100 miles of C58. Due north of C58, outside the 250-mile boundary, the percentage in bold, 9.9%, indicates the percentage of all hourly coordinates that passed through the western octant within 250 miles of the monitor. About 72% of 100-meter 48-hour back trajectories came from the northeast, east, and southeast on days of high ozone > 60 ppb. Most of the rest of the back trajectories on high ozone days > 60 ppb were from the south (12.9%) and north (9.9%). Winds from the west, northwest, and southwest were rare on high ozone days > 60 ppb. The development of the Eagle Ford Shale may increase the number of high ozone days with winds originating from the south and southeast. Days when the eight-hour average ozone levels were greater than 70 ppb had slightly more back trajectories from the northeast compared to the analyses conducted for 60 and 65 ppb.

Back trajectories on low ozone days were predominately from the Gulf of Mexico where there are very few anthropogenic emission sources (figure 4-8). These 48-hour back trajectories often traveled hundreds of miles over the Gulf of Mexico before arriving in the San Antonio region. Only a few back trajectories on low ozone days were from the north and northeast regions. The few back trajectories that were from the north on low ozone days tended to travel west of large anthropogenic emissions sources in Dallas and Austin before arriving in the San Antonio area. On high ozone days > 60 ppb, there was a different pattern of back trajectories. Figure 4-9 shows there were a higher percentage of back trajectories that passed over Dallas and Austin on high ozone days. Such air parcels can accumulate significant amounts of ozone and ozone pre-cursor emissions before arriving at San Antonio monitors.

Distribution of back trajectory endpoints showed a similar pattern on low and high ozone days (figure 4-10 and 4-11). Most back trajectory endpoints on low ozone days were far out in the Gulf of Mexico, while back trajectory endpoints on days of high ozone tended to originate over East Texas or near the Texas coast. The locations of back trajectory endpoints on high ozone days indicate transport may have a significant impact on local ozone. The trajectories originated in areas that contain large emissions sources. Background sources of transport can accumulate for several days over Texas before arriving at San Antonio monitors. Also, the endpoints on high ozone days > 60 ppb tended to be closer to San Antonio, signifying lower wind speeds on high ozone days.

[53] *Ibid*.

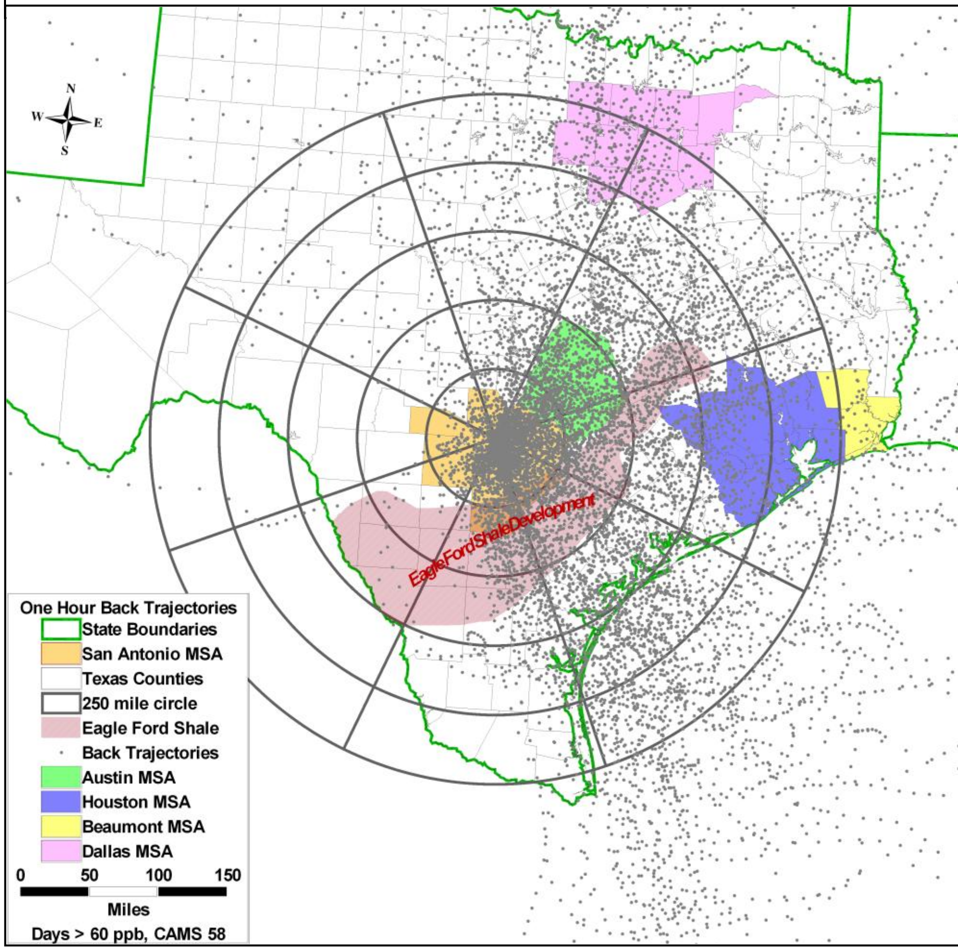


Figure 4-5: Pattern of High Ozone Days > 60 ppb Air Parcel Paths Arriving in San Antonio, 2005 – 2010

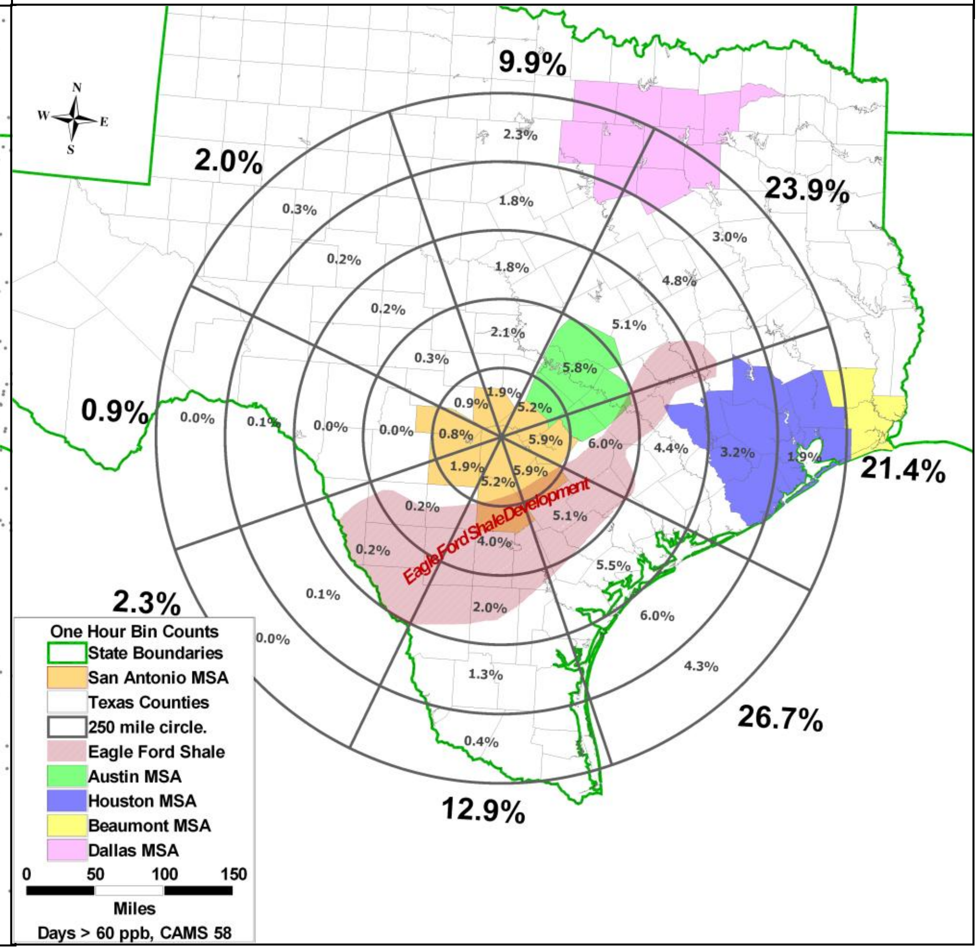
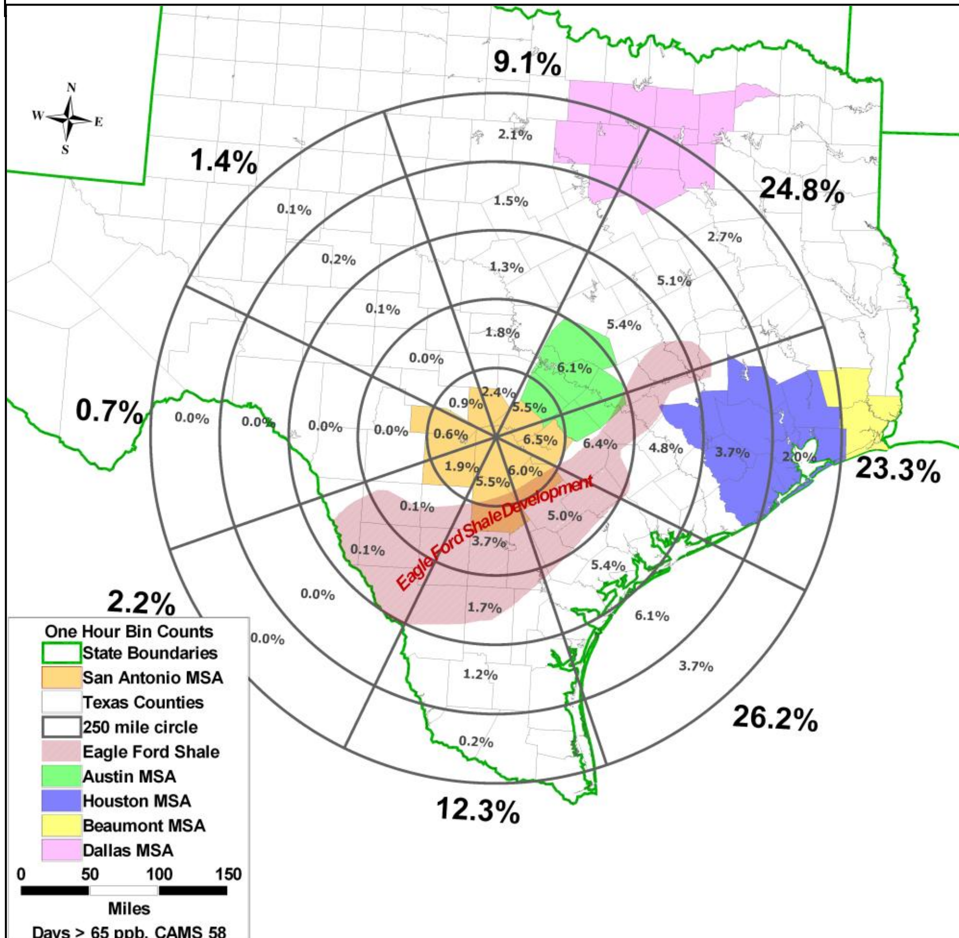
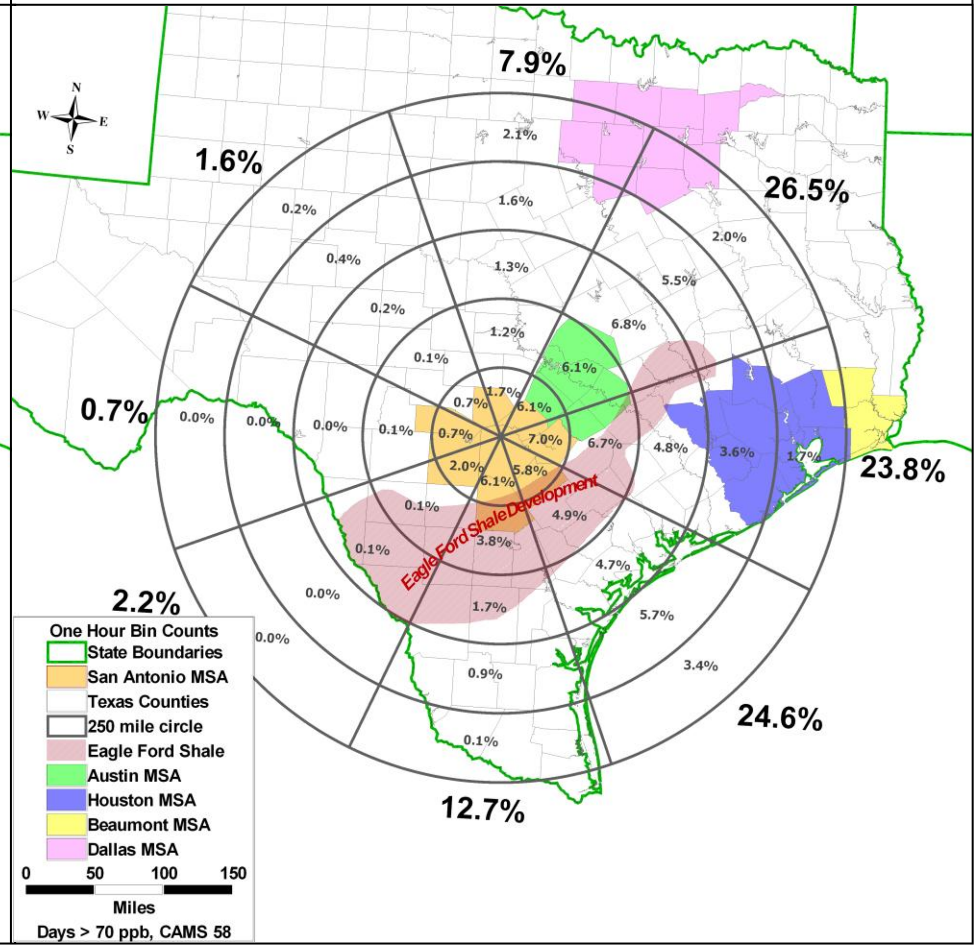


Figure 4-4: Back Trajectory Percentages by Directional Octant on High Ozone Days > 60 ppb, 2005 – 2010

100 meter 48 hour back trajectories

Figure 4-7: Back Trajectory Percentages by Directional Octant on High Ozone Days > 65 ppb, 2005 – 2010	Figure 4-6: Back Trajectory Percentages by Directional Octant on High Ozone Days > 70 ppb, 2005 – 2010





100 meter 48 hour back trajectories

Figure 4-9: Density of Hourly Back Trajectory Bin Counts on Low Ozone Days < 40 ppb, 2005 – 2010

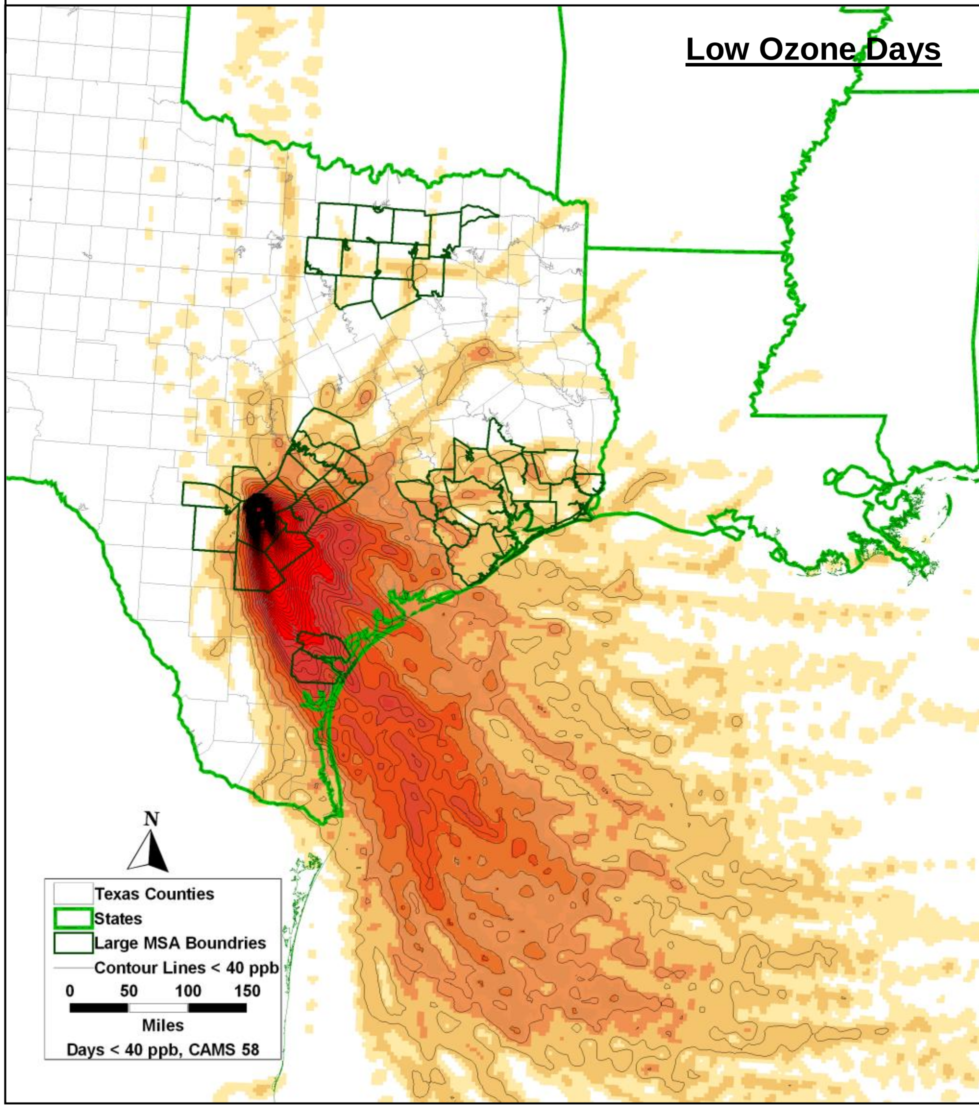


Figure 4-8: Density of Hourly Back Trajectory Bin Counts on High Ozone Days > 60 ppb, 2005 – 2010

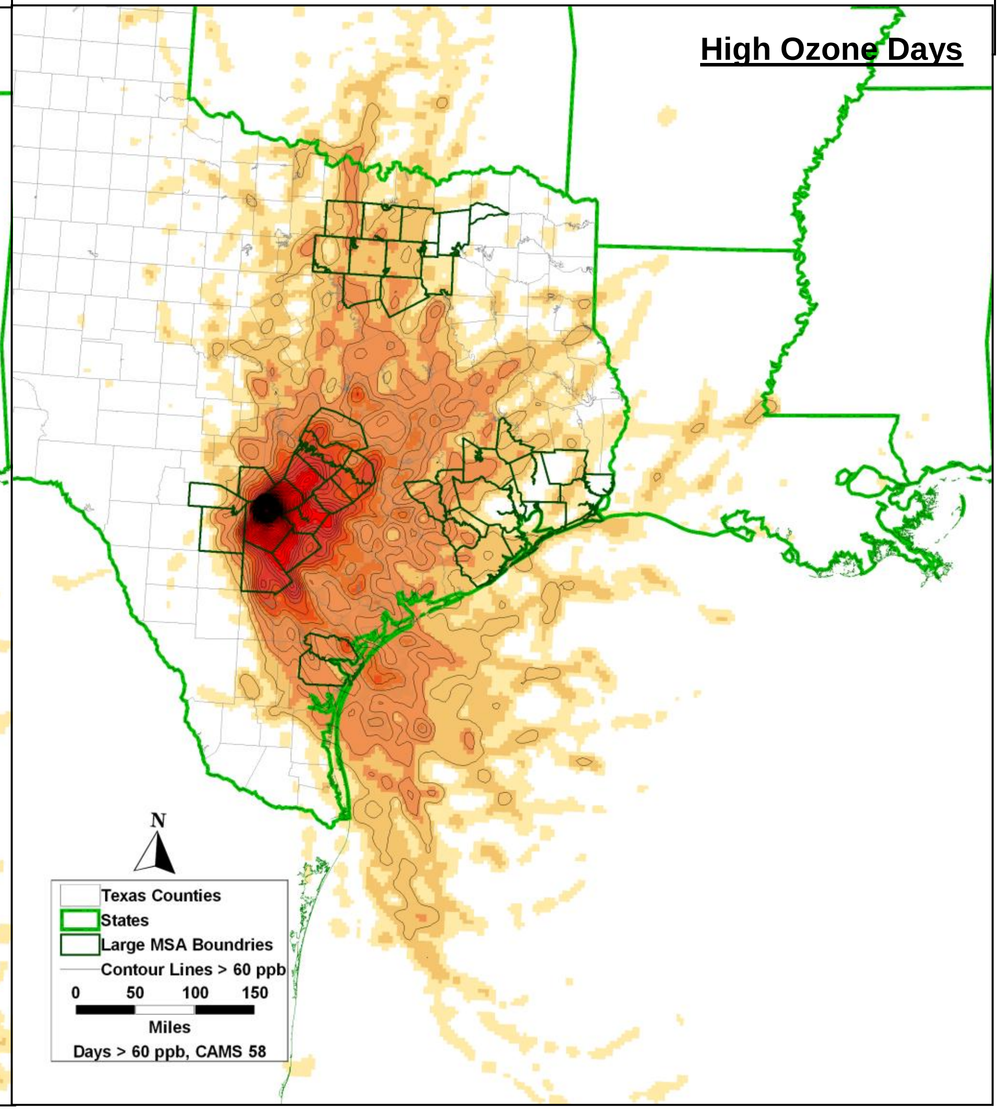


Figure 4-11: Density of 48-hour End Point Back Trajectory Counts on Low Ozone Days < 40 ppb, 2005 – 2010

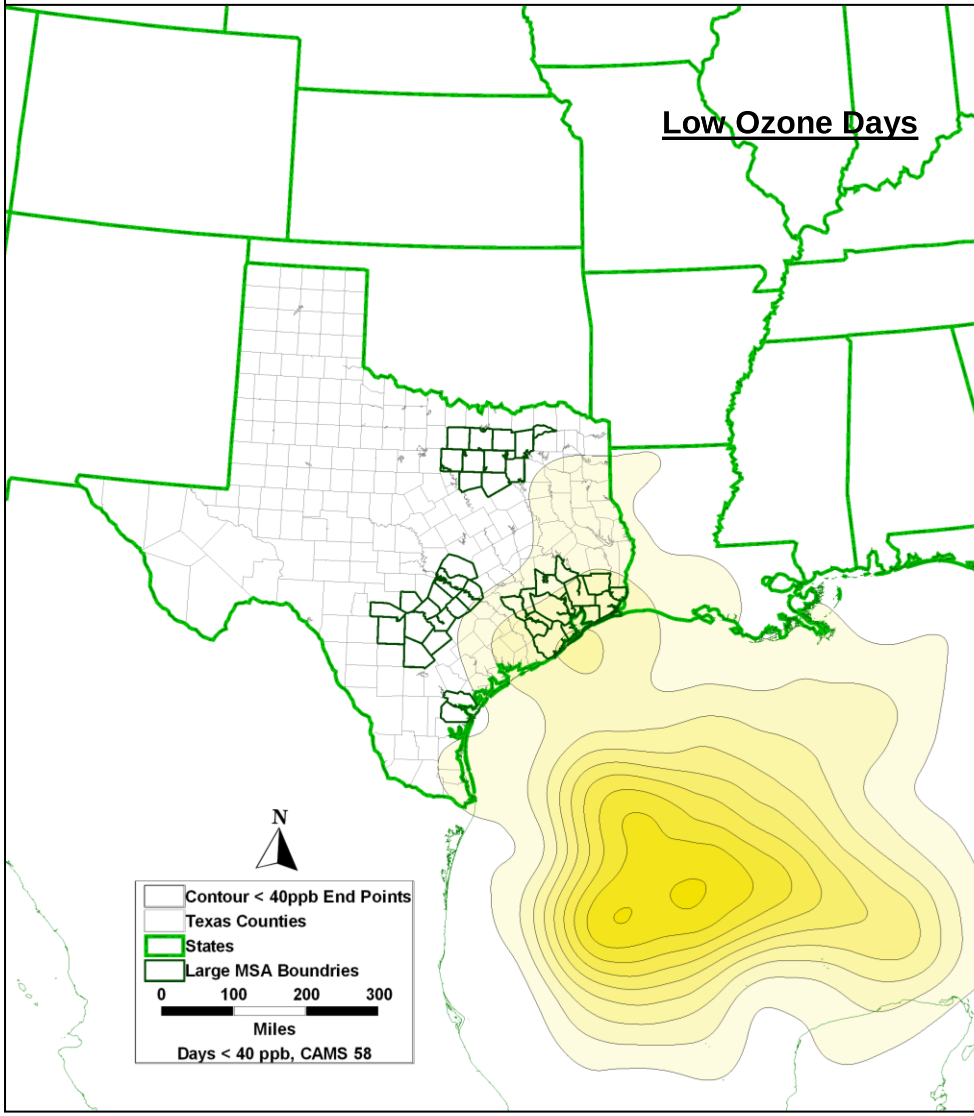
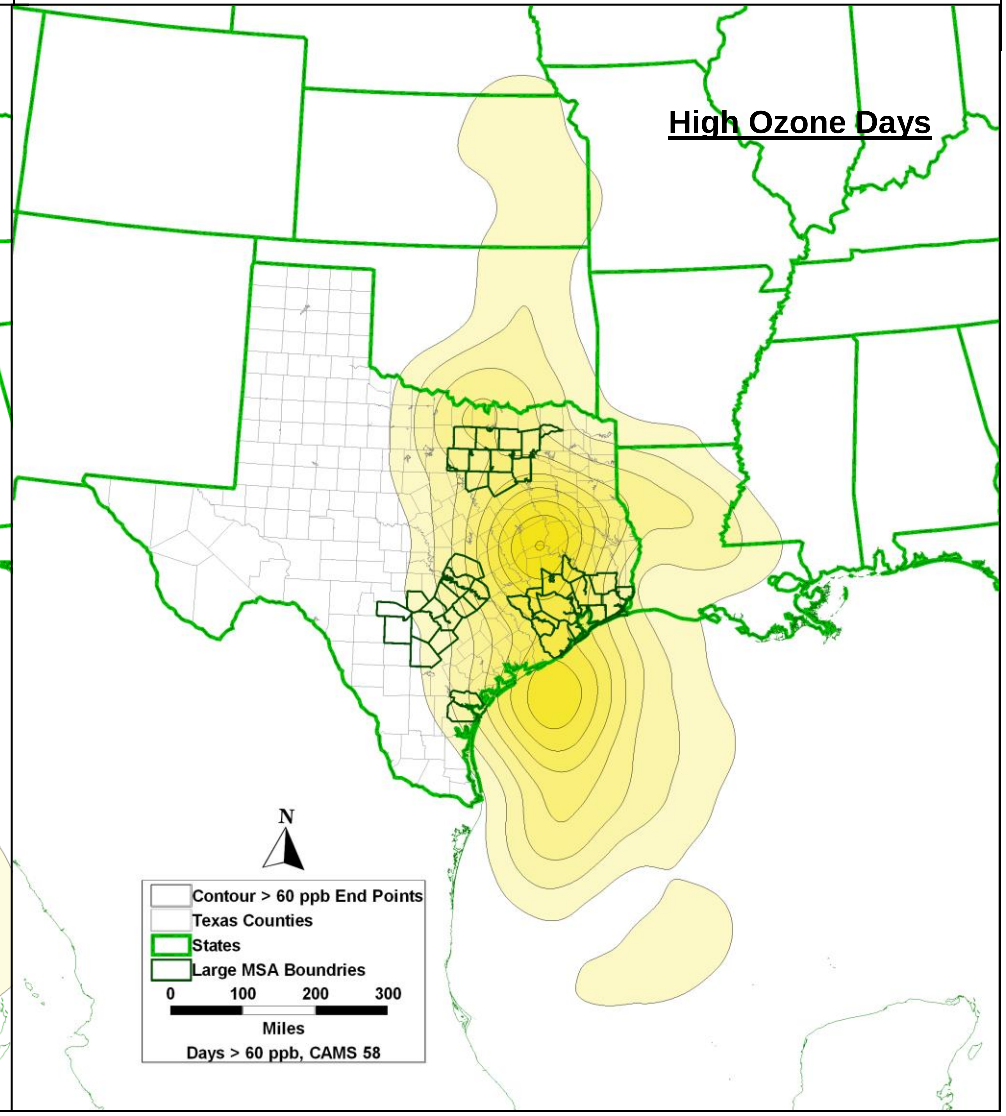
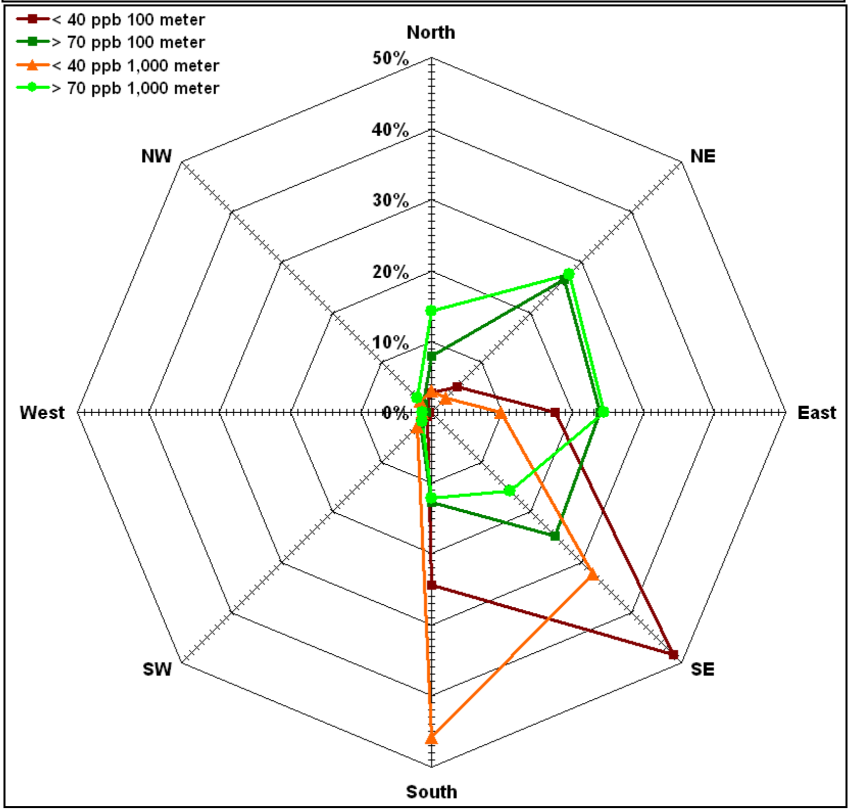


Figure 4-10: Density of 48-hour End Point Back Trajectory Counts on High Ozone Days > 60 ppb, 2005 – 2010



Analysis of back trajectories on high and low ozone days revealed that the majority of the 100-meter back trajectories on low ozone days came from the southeast (48.2%). These 48-hour back trajectories on low ozone days often originated over the Gulf of Mexico. There are few anthropogenic emission sources over the Gulf of Mexico compared to areas east and northeast of San Antonio. Figure 4-12 shows that this pattern was significantly different on high ozone days when northeast 100-meter back trajectories were more frequent. On low ozone days, only 7.7% of back trajectories were from the north and northeast compared to 34.4% on high ozone days > 70 ppb. In the case of 1,000-meter back trajectories, a similar pattern on high ozone days is evident with winds from the north (11.8%), northeast (27.4%), and east (25.9%). On days of low ozone, the 1,000-meter back trajectories were predominately from the south (48.2%) and southeast (25.6%).

Figure 4-12: Statistical Analysis of San Antonio's 250-mile Back Trajectory Wind Directions: <40 ppb and >70 ppb Ozone Season Days 2005-2010



Back trajectories were analyzed to determine the origin distance from C58 on high ozone days and low ozone days (<40 ppb). The statistical analysis included 100-meter back trajectories on 242 high ozone days and 418 days of low ozone from 2005 to 2010. As shown in figure 4-13, 81.1% of the 48-hour back trajectories on high ozone days > 70 ppb originated within 250 miles of C58, whereas on low ozone days only 52.1% originated within the same distance. Back trajectories on high ozone days originated closer to San Antonio and traveled shorter distances. These findings indicate winds are often lighter on high ozone days.

Back trajectories and daily weather maps were reviewed to classify days as "stagnated", "weak transport", or "transport" on high ozone days and low ozone days (<40 ppb). Days when the 48-hour 100-meter back trajectories stayed within about 250 miles of San Antonio were called "stagnated" days (less than 5 mph over the 48 hour period), especially if the back trajectory changed direction several times. If the 48-hour back trajectory originated farther than 500 miles from San Antonio, the back trajectory was labeled as "transport" (winds >10 mph over the period). All other back trajectories were labeled as "weak transport". The data provided in table 4-1 shows that 37 percent of high ozone days > 60 ppb had stagnated back trajectories compared to only 7 percent of low ozone days. Days of high ozone > 65 ppb (44%) and > 70 ppb (44%) also had more stagnated winds compared to days of low ozone. Low ozone days had a higher percentage of "transport" days (58%) compared to high ozone days (15%-24%).

Figure 4-13: Days < 40 ppb Ozone and High Ozone Days, 2005-2010 Cumulative Percentage of Back Trajectories Begin Points, C58 (100-meter 48-hour Back Trajectories)

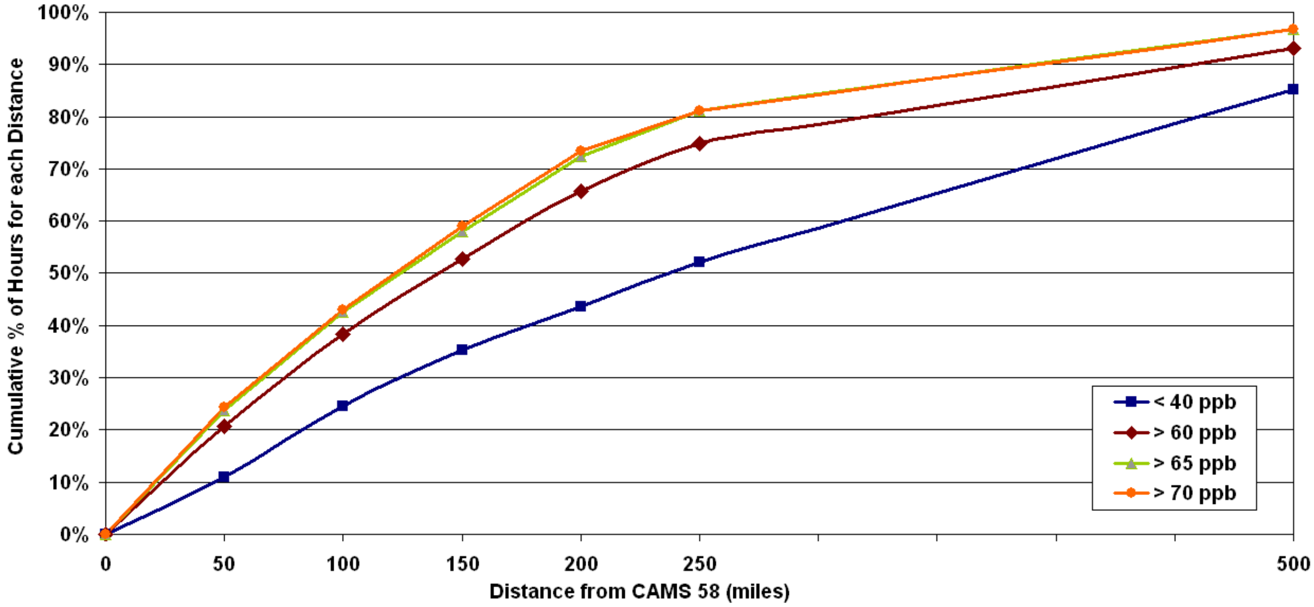


Table 4-1: Back Trajectories Classification on High Ozone Days and Low Ozone Days, 2005 - 2010

Back Trajectory Classification (2005-2010)	Stagnated		Weak Transport		Transport		Total	
	Number of Days	Percent	Number of Days	Percent	Number of Days	Percent	Number of Days	Percent
High Ozone Days > 60 ppb	98	37%	104	39%	63	24%	265	100%
High Ozone Days > 65 ppb	72	44%	67	41%	26	16%	165	100%
High Ozone Days > 70 ppb	43	44%	39	40%	15	15%	97	100%
Low Ozone Days < 40 ppb	28	7%	148	35%	242	58%	418	100%

4.2. *Upwind Monitors*

Ozone readings at upwind monitor sites on high ozone days can be used to estimate the amount of transport coming into the San Antonio region. Figure 4-14 shows the 8-hour ozone design values at all regulatory and non-regulatory CAMS in the San Antonio metropolitan statistical area (MSA). The monitors represented by yellow bars on the chart are normally located up-wind on days of high ozone: C59, C622, C504, C505, and C506. The downwind monitors represented by purple bars have a 2010 ozone design value between 68 and 75 ppb, while the upwind monitors have a design value between 64 and 68 ppb. This indicates that there are small differences in ozone design values between monitors that are typically in upwind and downwind locations. The difference between the highest 2010 design value, 75 ppb at C23 and C58, and the lowest design value, 64 ppb at C506, is only 14.7 percent. Ozone readings on some days at upwind monitor sites exceeded the proposed standard, making it difficult for the San Antonio region to demonstrate attainment with only local emission controls.

Figure 4-14: Monitored Design Values for the San Antonio MSA, 2010

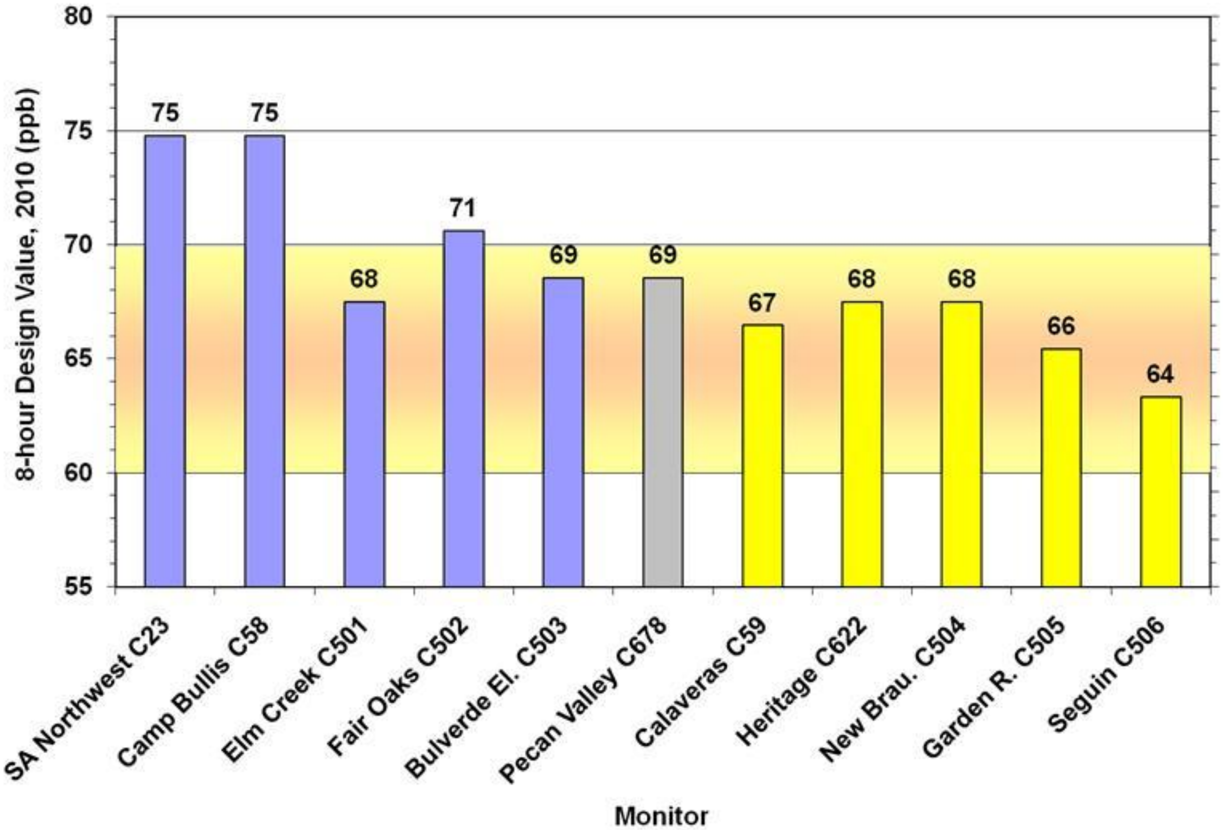


Figure 4-15 shows daily peak 8-hour average ozone levels in the San Antonio area and the background ozone transported into the region from 2005-2010. Background ozone concentrations were determined by the lowest 8-hour peak ozone readings from upwind monitors in the San Antonio area. San Antonio's contribution is derived from the difference between the measured peak ozone reading on a particular day with the lowest background ozone reading on the same day (figure 4-16). Since the R^2 value for the relationship between peak ozone concentrations and San Antonio's contribution is only 0.12, there is a high degree of variability, which indicates local contributions are not good indicators of peak values. On high ozone days, the average difference between upwind and downwind monitors was 14.3 ppb (20.5 %) for peaks > 60 ppb, 15.2 ppb (20.5%) for peaks > 65 ppb, and 16.6 ppb (21.4%) for peaks > 70 ppb. These results indicate that, on high ozone days, transported ozone represents the majority of peak concentrations recorded at downwind monitors while the local contribution is only about 21 percent of total ozone.

Although significant amounts of transported ozone arrive in the San Antonio region, concentrations have decreased over the last five years. From 2006 to 2010, the 4th highest eight-hour average ozone readings at upwind monitors decreased approximately 3.0 ppb per year (figure 4-17).[54] The 4th highest eight-hour average ozone readings for all upwind monitors was greater than 62 ppb in 2010 and still exceeds 60 ppb, the lower range of the proposed standard, on some days. The number of high ozone days > 60 ppb at upwind monitors decreased 82 percent between 2005 and 2010 (figure 4-18). There was a similar decrease in the number of high ozone days > 65 ppb (89%) and > 70 ppb (93%) at the upwind monitors between the two years.

[54] The results are statistically significant. C59: σ = 7.3, C622: σ = 6.1, C504: σ = 7.6, C505: σ = 7.4, C506: σ = 6.8.

Figure 4-16: Measured Peak 8-Hour Ozone in the San Antonio Area as a Function of the Background Ozone Transported into the Region, 2005 – 2010

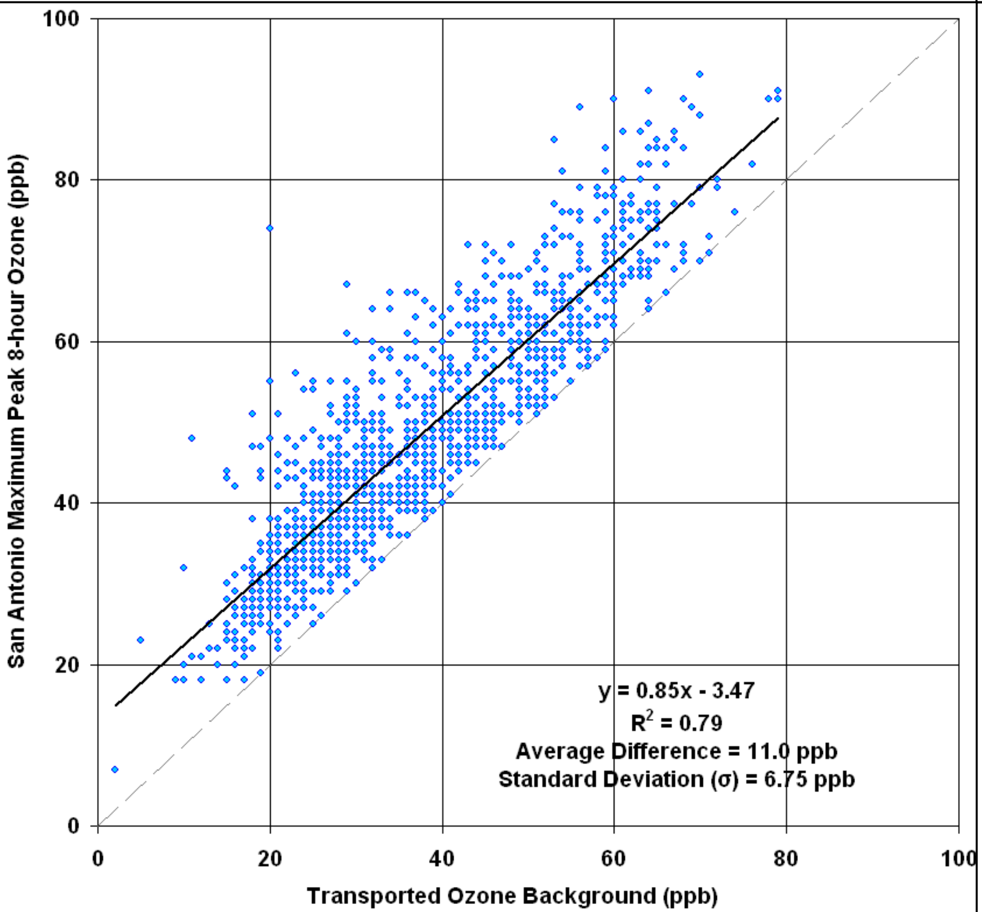


Figure 4-15: Measured Peak 8-Hour Ozone in the San Antonio Area and the Local San Antonio Contribution to that Peak, 2005 – 2010

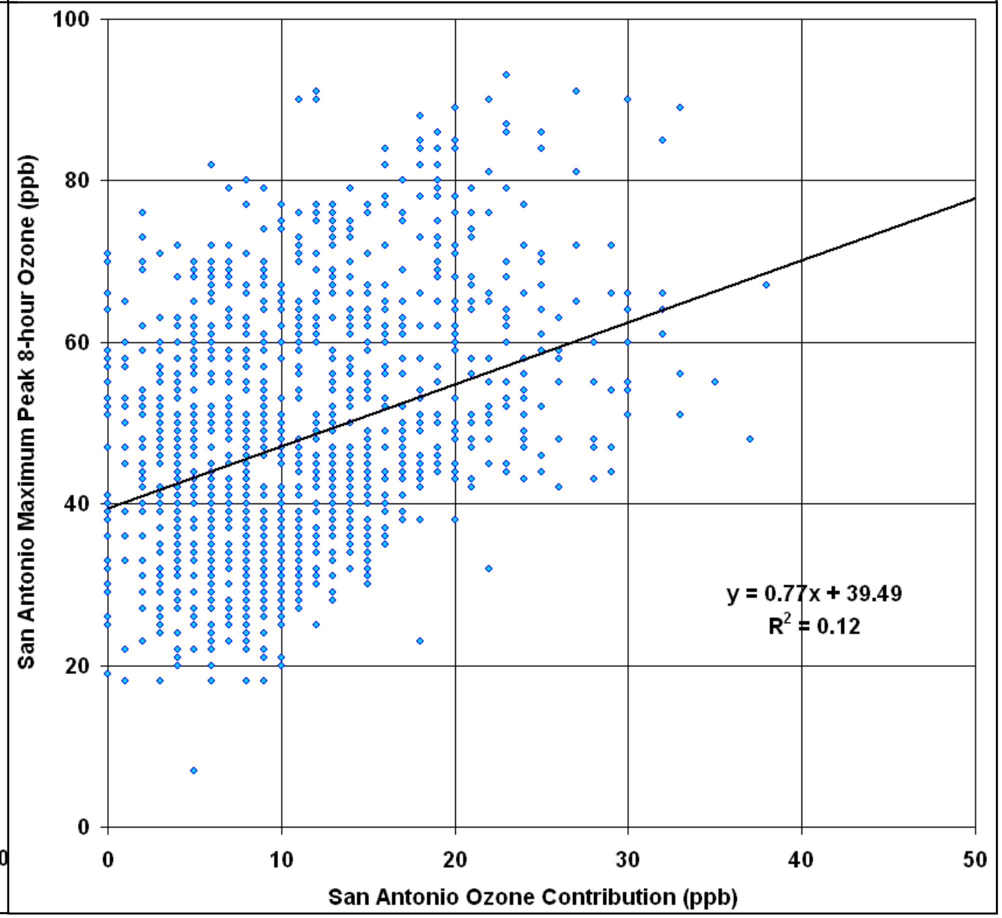


Figure 4-17: Trends in San Antonio MSA Background Ozone on the Annual 4th Highest Eight-hour Average Ozone Day, 2005 - 2010

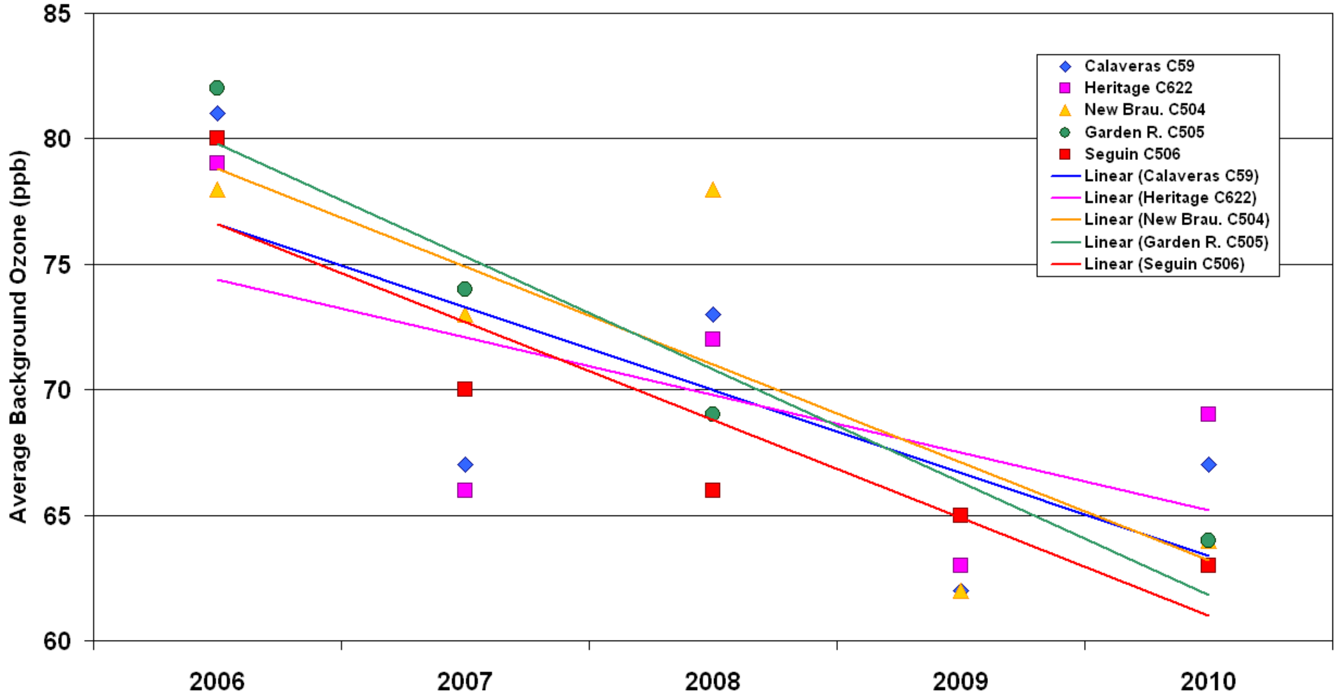
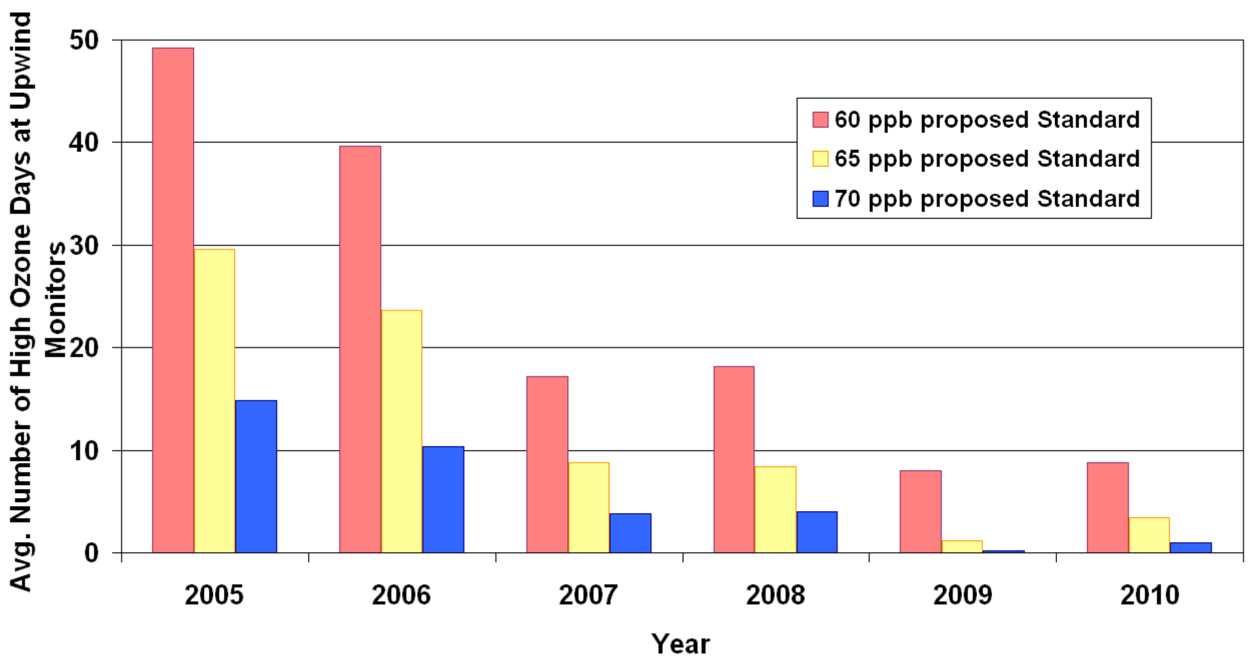
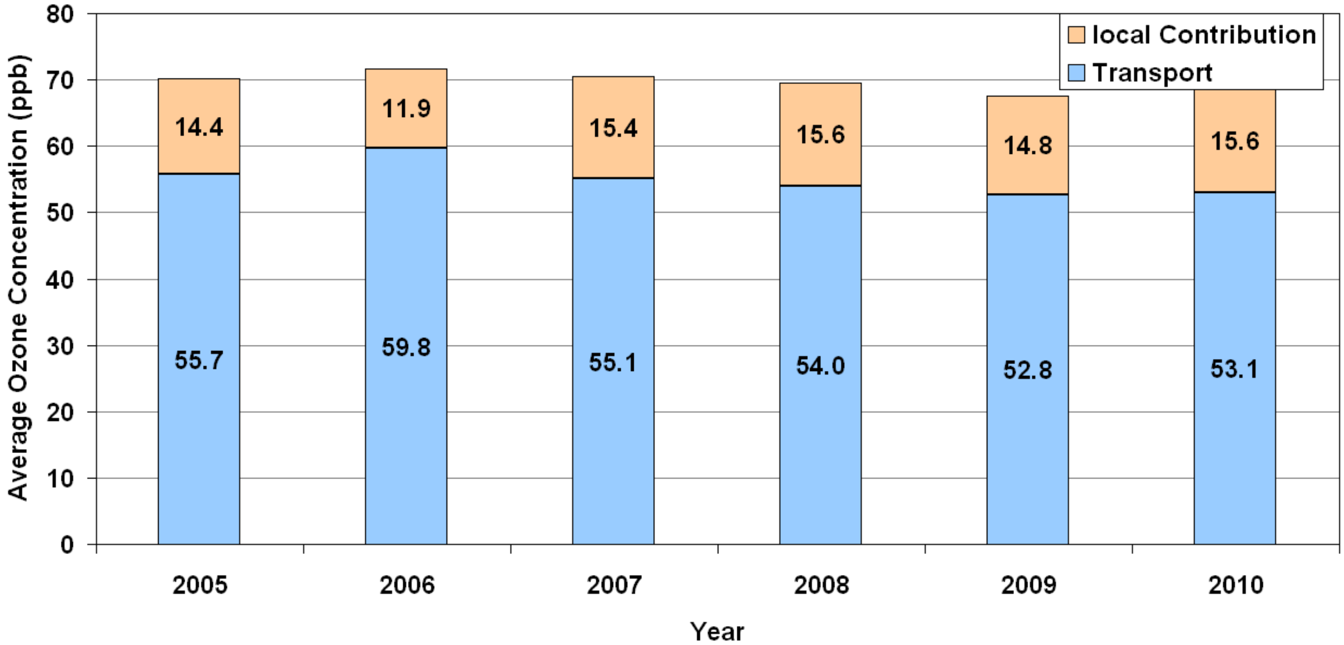


Figure 4-18: Average Number of High Ozone Days at Upwind Monitors, 2005 – 2010



The amount of transported ozone has decreased over the last 5 years: from 59.8 ppb in 2006 to 53.1 ppb in 2010 on average for all days over 60 ppb. However, local contributions to ozone have not changed significantly in the last six years (figure 4-19).

Figure 4-19: San Antonio Background Ozone by Year, days >60 ppb, 2005-2010



San Antonio's peak ozone readings were plotted against peak ozone readings in other Texas cities to determine the correlation between urban areas (figures 4-20 to 4-26). Austin had the highest correlation with San Antonio ozone readings (R^2 = 0.82 for all days): the cities are close geographically and have similar mobile source emission profiles. Also, back trajectories and photochemical modeling analysis indicate San Antonio monitors can be impacted by transport from Austin. Table 4-2 shows the R^2 value between San Antonio and Austin was the highest of any Texas urban area for the entire range of the proposed ozone standard.

Both Victoria and Waco ozone readings had a strong correlation with peak ozone in San Antonio on all days. Houston had the second highest R^2 value on all days that exceeded each of the three proposed thresholds, indicating that San Antonio is commonly impacted by transport from Houston during high ozone events. The three cities that are the farthest away from San Antonio - Dallas, Tyler/Longview, and Waco – generally had the lowest correlation with ozone readings in San Antonio.

During the spring ozone season peak, there was generally a weaker correlation between other urban areas and San Antonio ozone readings on high ozone days > 60 ppb. As shown with the back trajectory analysis, this seasonal peak was more dominated by long distance transport than the August-September fall seasonal peak. However, San Antonio's correlation to peak ozone readings in Houston and Dallas, was significantly weaker on high ozone days during the fall ozone season peak compared to the spring. All other cities had a slightly higher correlation with San Antonio ozone readings on high ozone days during the fall ozone season peak. Winds during the fall ozone season peak were more from the east/southeast and stagnated, with 60% of 48-hour back trajectories originating within 150 miles of San Antonio.

Figure 4-21: Daily Maximum 8-hour Ozone in San Antonio and Austin, 2005-2010

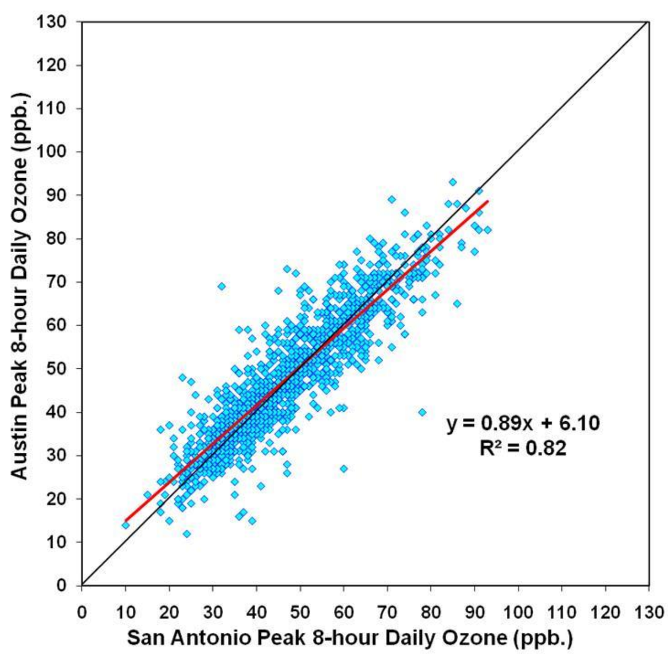


Figure 4-20: Daily Maximum 8-hour Ozone in San Antonio and Corpus Christi, 2005-2010

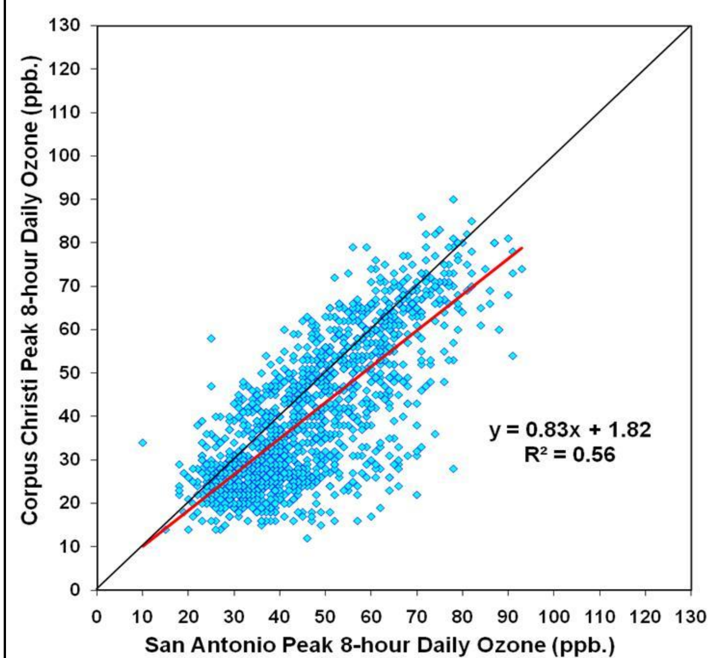


Figure 4-23: Daily Maximum 8-hour Ozone in San Antonio and Dallas, 2005-2010

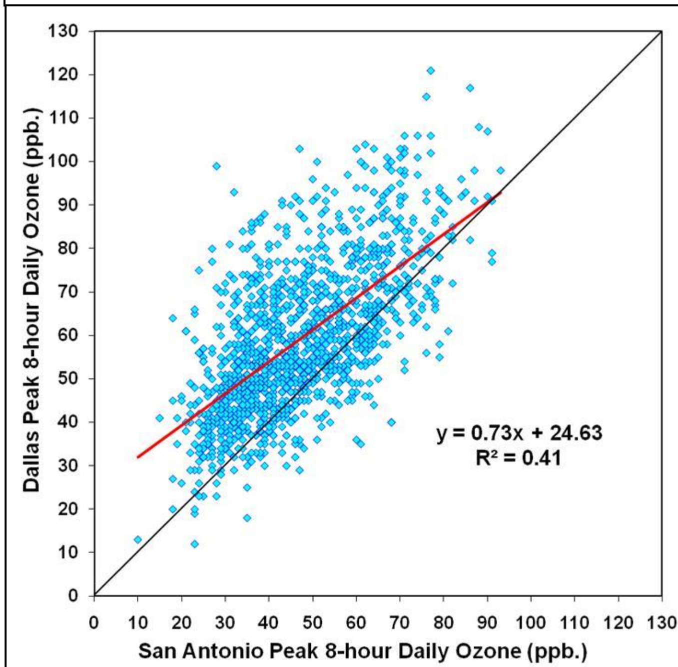


Figure 4-22: Daily Maximum 8-hour Ozone in San Antonio and Houston, 2005-2010

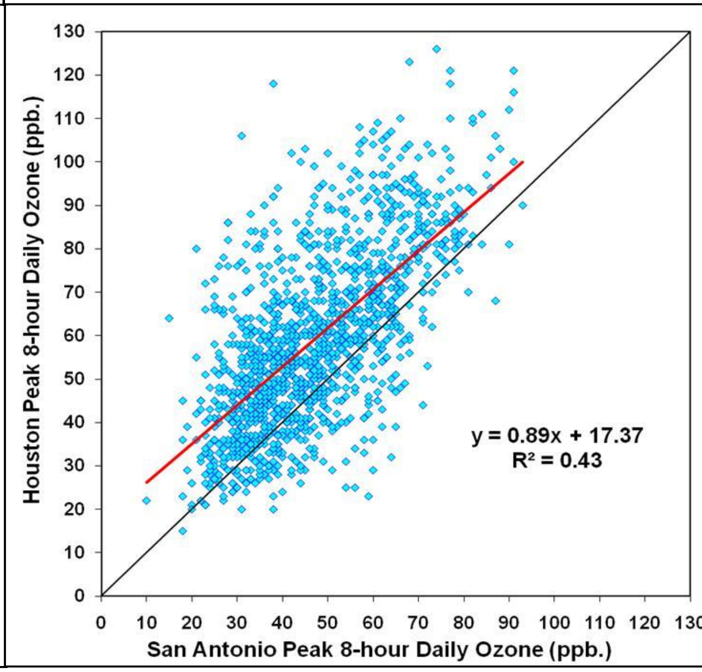


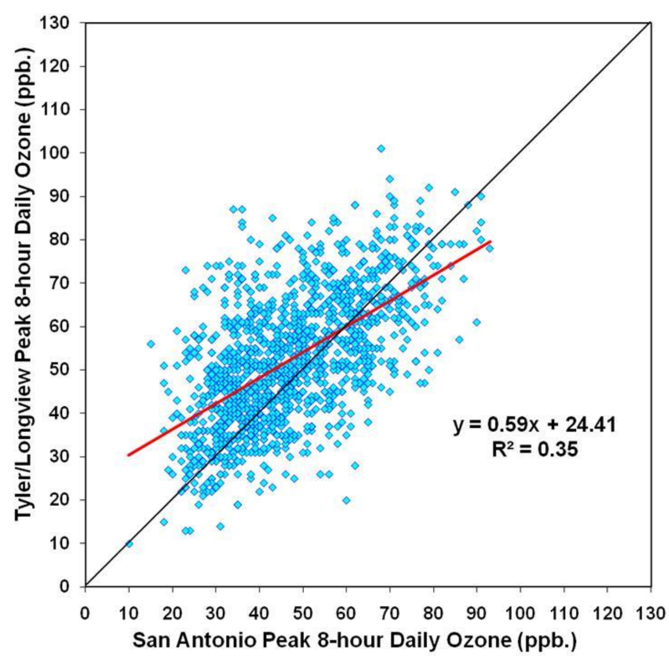
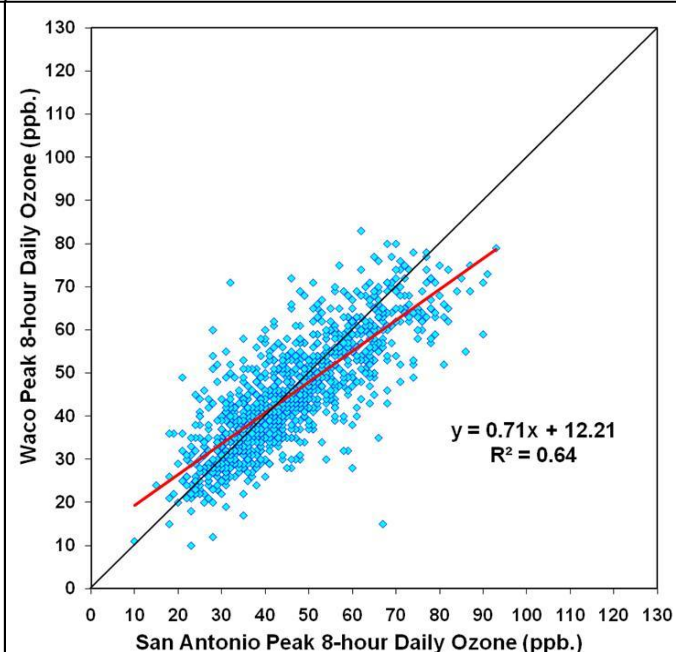
Figure 4-25: Daily Maximum 8-hour Ozone in San Antonio and Tyler/Longview, 2005-2010	Figure 4-24: Daily Maximum 8-hour Ozone in San Antonio and Waco, 2006-2010
	

Figure 4-26: Daily Maximum 8-hour Ozone in San Antonio and Victoria, 2005-2010

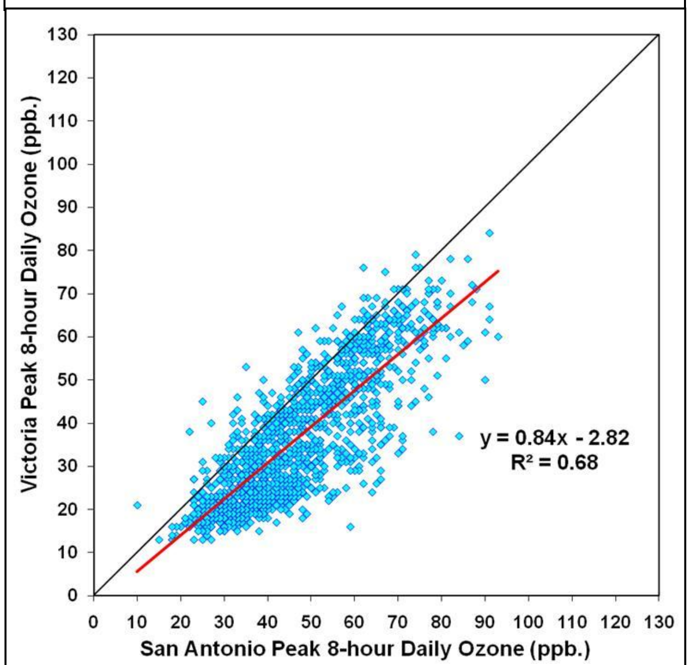


Table 4-2: Correlation of San Antonio Peak 8-Hour Ozone Readings with Other Urban Areas, 2005 – 2010

Proposed Standards	Parameter	Austin	Corpus Christi	Dallas	Houston	Tyler/ Longview	Waco	Victoria
All Days	R^2	0.82	0.56	0.41	0.43	0.35	0.64	0.68
	Standard Deviation (σ)	6.3	11.2	13.8	15.4	13.6	9.0	9.0
	Average Difference	0.8	-6.3	12.1	12.1	5.3	-0.9	-10.4
> 60 ppb	R^2	0.43	0.19	0.16	0.20	0.16	0.15	0.17
	Standard Deviation (σ)	6.5	12.9	13.9	14.8	11.3	9.4	10.9
	Average Difference	-1.9	-9.5	6.6	10.5	-3.7	-7.8	-13.5
> 65 ppb	R^2	0.29	0.14	0.06	0.14	0.06	0.06	0.13
	Standard Deviation (σ)	6.9	12.8	14.2	13.7	11.8	9.8	10.6
	Average Difference	-2.3	-9.8	7.0	11.5	-4.0	-9.1	-14.6
> 70 ppb	R^2	0.29	0.05	0.07	0.19	0.09	0.04	0.04
	Standard Deviation (σ)	7.1	11.5	14.3	13.0	11.2	8.1	10.2
	Average Difference	-4.1	-9.5	4.7	10.0	-6.9	-11.5	-15.7

4.3. *Sampling of Industrial and Urban Plumes by Aircraft*

Baylor Institute of Air Science (BIAS) collected continuous O_3, NO_X, SO_2, and CO measurements from urban and industrial plumes using a Cessna 172 aircraft in the Austin region. The aircraft also collected meteorological data (temperature, pressure, wind speed, wind direction) and volatile organic compound (VOC) canister samples.[55] Examining the data collected by aircraft on September 17, 2007 reveals the extent of the Houston urban ozone plume and its impact downwind of the source region (Figure 4-27).[56] Portions of the Houston ozone plume were above 85 ppb as the aircraft tracked ozone concentrations towards Waco. These transported pollutants can mix down to the surface and impact monitors in other urban areas including San Antonio.

Other cities and industrial facilities upwind of local monitors can impact ozone and emission precursor transport into the San Antonio region. The BIAS Cessna also collected air samples in the Austin region during September 2006.[57] Austin urban and Alcoa-Sandow facility ozone plumes are shown in figure 4-28 traveling southwest of the Austin urban core towards San Antonio.[58] Multiple regions and industrial plumes can impact San Antonio on high ozone days. These plumes will make it very difficult for San Antonio to attain a stricter ozone standard.

[55] Maxwell Shauck, *et. al.* Baylor Institute for Air Science, Baylor University and Martin Buhr, Air Quality Design, Inc., March 2007. “Airborne Air Quality Sample Collection in Central Texas during the 2006 Ozone Season”. Waco, Texas p. 1.
[56] CAPCOG, July 11, 2008. “Preliminary Discussion Draft of CACAC Comments for TCEQ Public Meeting on Ozone NNA Designation”. Austin, Texas.
[57] Maxwell Shauck, Grazia Zanin, Sergio Alvarez, Levi Kauffman, Timothy Compton, Baylor Institute for Air Science Airborne, and Martin Buhr, Air Quality Design, Inc., March 2007. “Air Quality Sample Collection in Central Texas during the 2006 Ozone Season: Final Report”. Baylor University, Waco, Texas. Sponsored by Capital Area Council Of Governments (CAPCOG), Austin, Texas, p. 1.
[58] *Ibid*., p. 20.

Figure 4-27: Baylor University Airborne Ozone (ppbv) Sampling: Houston Urban Ozone Plume – September 17, 2007

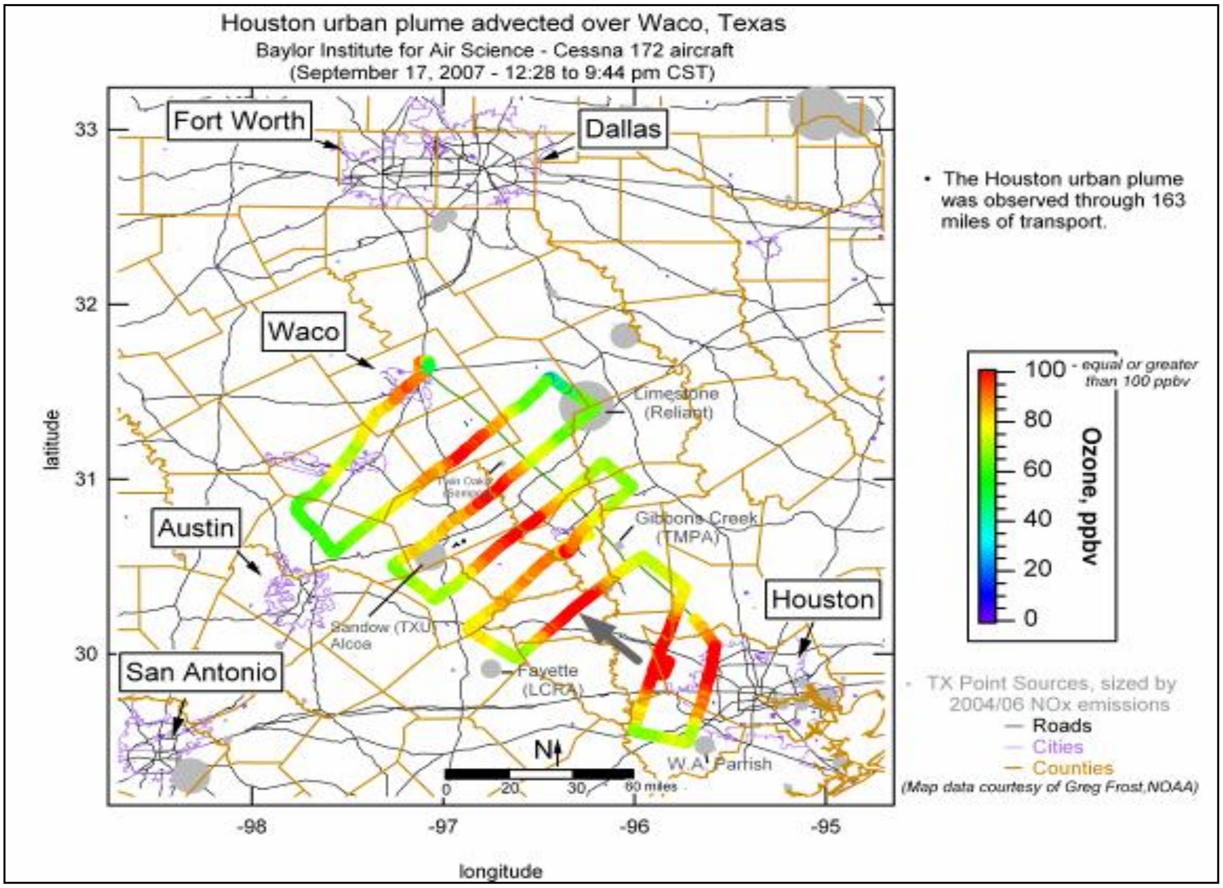
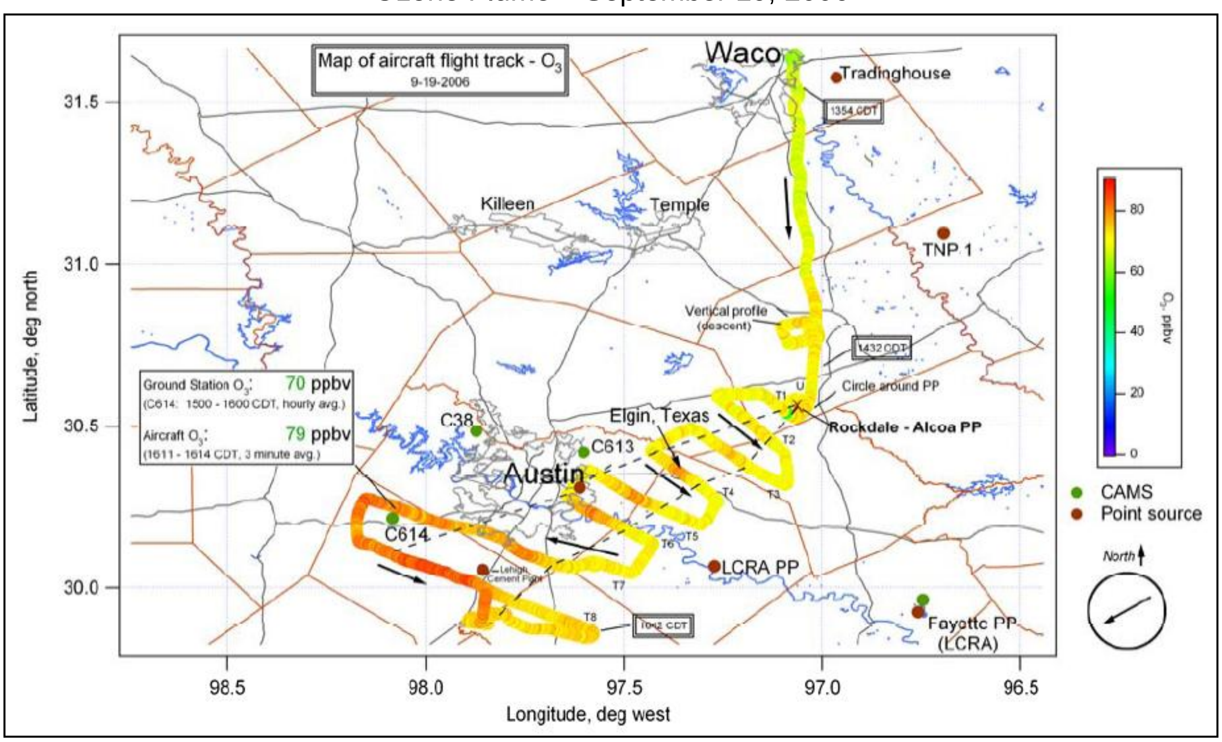


Figure 4-28: Baylor University Airborne Ozone (ppbv) Sampling: Austin and Alcoa-Sandow Facility Ozone Plume – September 19, 2006



4.4. *Transport Analysis in the Photochemical Model*

Past modeling efforts included the development of a May 29th to June 16th, 2006 photochemical modeling episode for the San Antonio, Austin, and Dallas areas. The modeled episode included several periods of high ozone in these cities.[59] Once complete, the June 2006 model was projected to the year 2013 using forecasted changes in such variables as population, land use, and emissions. Since photochemical models simulate the atmospheric and meteorological conditions that impact high ozone during a particular episode, an important advantage the models provide is the ability to test various scenarios, such as changes in emission rates, under the same set of meteorological conditions that favor high ozone concentrations.

Photochemical model sensitivity runs are used throughout model development as diagnostic tools. The process used to conduct the analysis involves perturbing model inputs, re-running the model, and analyzing model outputs. Results are analyzed in terms of whether the model responded to changes in input and, further, whether the model responded in a manner considered appropriate for the input modifications. In the zero-out runs, for example, all anthropogenic emissions from a discrete geographical areas are removed from the CAMx model to determine their impact on ozone concentrations in the target area, which was San Antonio for this analysis. Furthermore, the analyses are run for future time periods to provide an indication of ozone sensitivity given expected changes in population and other factors.

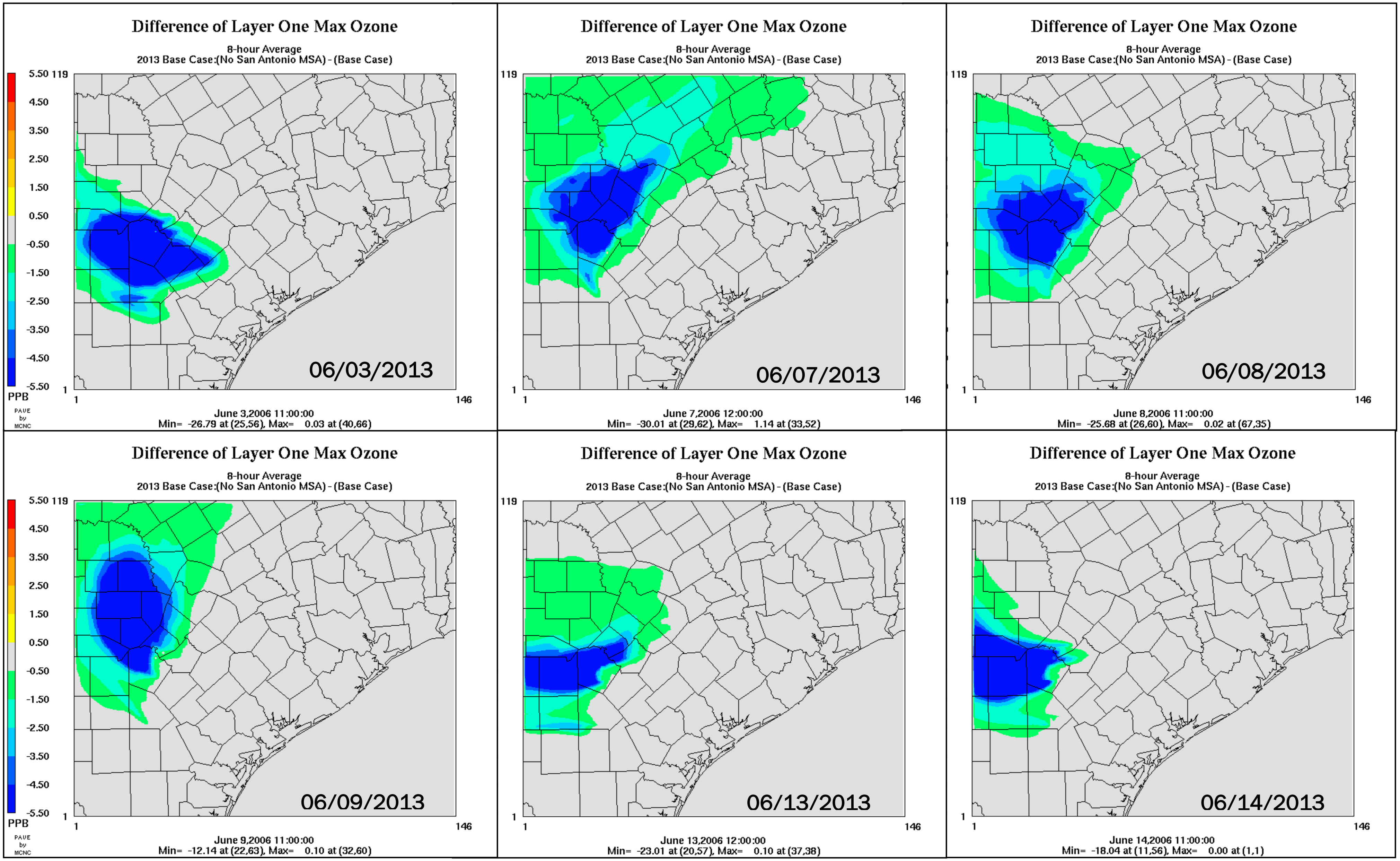
After removing the San Antonio eight-county MSA anthropogenic emissions from model inputs, the 2013 ozone design value, as shown in Table 4-3 decreased by 17.1 ppb (24.7%) at C23 and 14.0 ppb (20.0%) at C58. Figure 4-29 shows large areas of ozone reductions greater than 5 ppb on days of high ozone when San Antonio's anthropogenic emissions were removed. Similarly, other urban areas in Texas (such as Houston and Austin) can have a significant impact on local ozone in San Antonio. Transported emissions and ozone from these Texas cities impact local ozone readings at San Antonio monitors. When Houston's precursor anthropogenic emissions were removed from the model, the 2013 design value decreased 2.7% at C23 and 2.4% at C58. Austin (1.7% at C58) and Corpus Christi (0.6% at C23) also had a significant impact on the 2013 design values when each urban area's anthropogenic emissions were removed from the model.

Table 4-3: Predicted Reductions in Ozone DesignValue from Zeroing Out Selected Texas MSA, 2006 and 2013

Zero-out Run	CAMS	2006		2013	
		ppb.	Percentage	ppb.	Percentage
Zero-out San Antonio	C23	19.9	26.6%	17.1	24.7%
	C58	16.5	21.9%	14.0	20.0%
Zero-out Austin	C23	1.1	1.4%	0.7	0.9%
	C58	1.8	2.3%	1.2	1.7%
Zero-out Corpus Christi	C23	0.2	0.2%	0.2	0.3%
	C58	0.4	0.5%	0.4	0.6%
Zero-out Houston	C23	2.3	3.0%	1.9	2.7%
	C58	2.0	2.6%	1.7	2.4%
Zero-out Beaumont	C23	0.3	0.4%	0.2	0.3%
	C58	0.3	0.4%	0.2	0.3%
Zero-out Dallas	C23	0.2	0.3%	0.1	0.2%
	C58	0.2	0.3%	0.2	0.2%
Zero-out Tyler/Longview	C23	0.2	0.3%	0.2	0.2%
	C58	0.2	0.3%	0.2	0.2%

[59] TCEQ. "Daily Maximum 8-hour Ozone Averages." Austin, Texas. Available online: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/8hr_monthly.pl. Accessed 06/03/10.

Figure 4-29: Zero-Out San Antonio MSA, June 3, 7, 8, 9, 13, and 14, 2013



4.5. *Regional Point Sources Contributions*

Figures 4-30 and 4-31 identify total NO_X and VOC emissions, by county, from large industrial point sources in 2008[60]. Many counties in south, east, and northeast Texas contain large NO_X and VOC point sources. These point sources are located in regions that are typically upwind of San Antonio on days when the region experiences high ozone levels. NO_X and VOC point sources can play a significant role in creating elevated ozone concentrations, especially during days when large air masses from the northeast move into the San Antonio region.

Figure 4-30: County totals for NOx Point Source Emissions in Eastern Texas, 2008

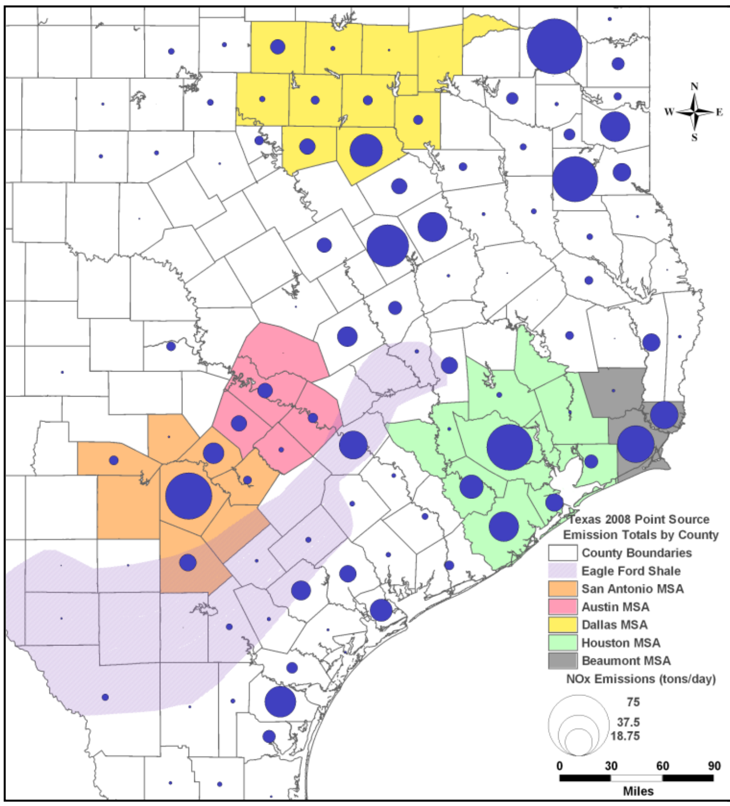
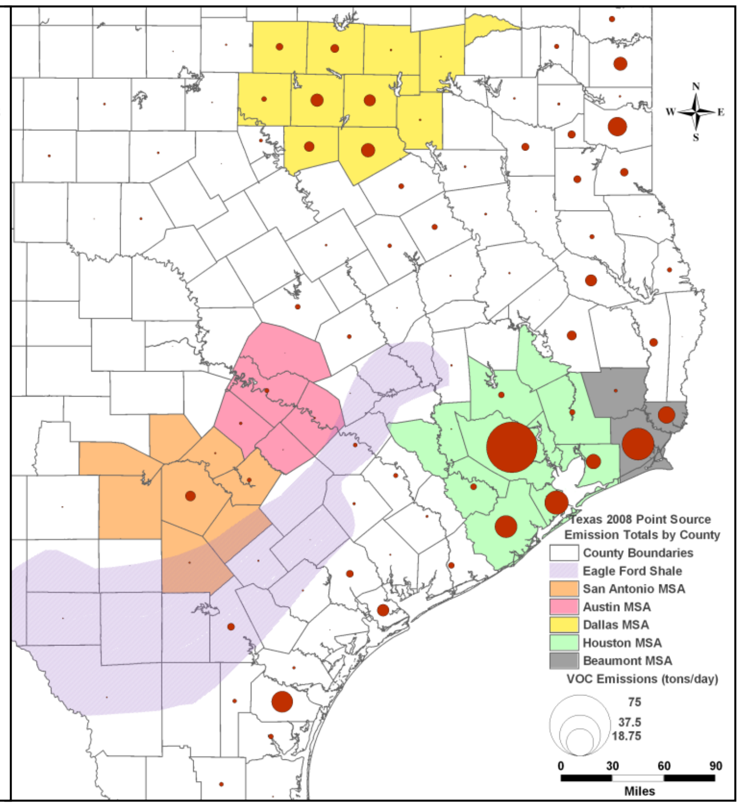


Figure 4-31: County totals for VOC Point Source Emissions in Eastern Texas, 2008

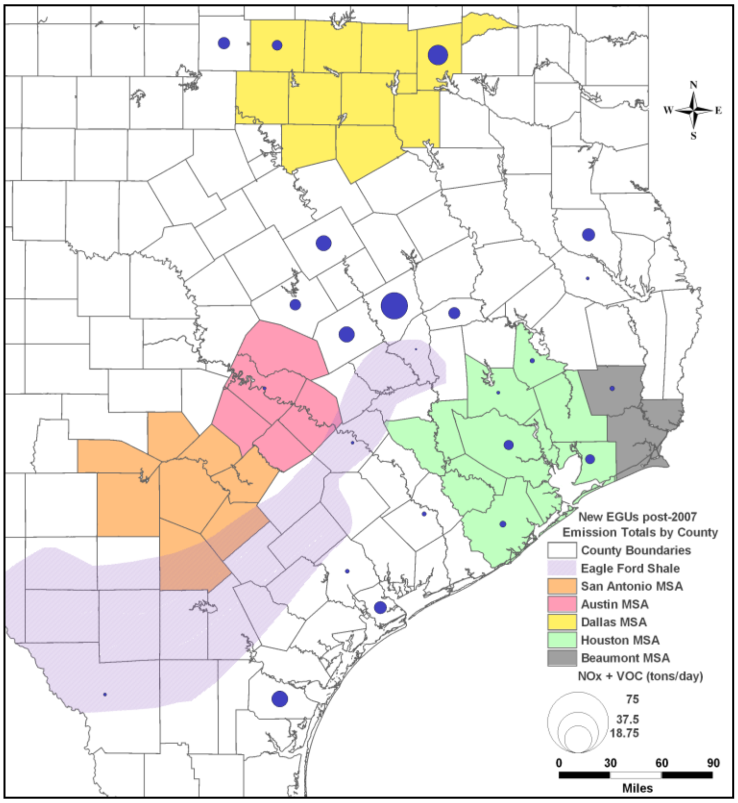


New power plants, cement kilns, and other point sources must be taken into consideration when conducting air analyses, because they can have significant impacts on San Antonio's future air quality. As shown in figure 4-32, permits have been issued for new electric generation units[61] located northeast and southeast of San Antonio. These regions are typically upwind of San Antonio on high ozone days. Potential point sources can generate significant additional NO_X and VOC emissions, making it more difficult for San Antonio to comply with stricter ozone standards. Development of the Eagle Ford Shale oil and gas deposits southeast of San Antonio could increase ozone pre-cursor emissions upwind of San Antonio on high ozone days.

[60] TCEQ. June 16, 2010. "Detailed Data from the Point Source Emissions Inventory". Austin, Texas. Available online: http://www.tceq.texas.gov/implementation/air/industei/psei/psei.html. Accessed 02/14/11 and Alamo Area Council of Governments, October 2009. "Emissions Trend Analysis for the San Antonio MSA: 1996, 1999, 2002, 2005, 2008, 2013, & 2018". San Antonio – Bexar County Metropolitan Planning Organization

[61] TCEQ, March 10, 2010. "Appendix B, Emissions Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 8-hour Ozone Standard". Austin, Texas, p. B-82 - B-84. Available online: http://www.tceq.state.tx.us/implementation/air/sip/HGB_eight_hour.html. Accessed 02/14/11

Figure 4-32: County Totals for Newly-Permitted Electric Generation Units in Eastern Texas, post-2007



4.6. ***Background Ozone and Ozone Transport Summary***

Analysis of background ozone and ozone transport indicates a number of regional factors that contribute to elevated local ozone concentrations. Typical background conditions associated with high ozone events are identified through the study of regional meteorology and emissions. Findings on background ozone and ozone transport that typify high ozone events include:

- The timing, location, and intensity of ozone events are influenced by the interaction between local and regional wind patterns.
- Surface back trajectories on days with low ozone were predominately from the southeast, while winds on high ozone days were from the northeast, east, and southeast. A similar pattern occurred with 1,000-meter back trajectories where days of high ozone values are associated with winds that originate from the northeast, east, and southeast.
- 48-hour back trajectories on low ozone days tended to originate far out in the Gulf of Mexico, while the back trajectories on high ozone days tended to originate closer to San Antonio and over Eastern Texas.
- Back trajectories on high ozone days originated closer to San Antonio and travelled fewer miles to arrive at local ozone monitoring stations indicating winds are often lighter on high ozone days.
- The San Antonio local contribution (the difference between the maximum peak ozone reading and the minimal peak ozone readings at ozone monitors on high ozone days > 60 ppb) was 14.3 ppb or 20.5%.
- The annual 4^{th} highest eight-hour average ozone reading and the number of high ozone days at upwind monitors decreased from 2006 to 2010.
- The amount of transported ozone has decreased over the last 5 years: from 59.8 ppb in 2006 to 53.1 ppb in 2010 on average for all days over 60 ppb. However, local contributions to ozone has not changed significantly in the last 6 years

- Austin ozone readings had a high correlation with San Antonio readings because the cities are close o each other. Also, back trajectories and photochemical modeling analyses showed San Antonio monitors can be impacted by transport from Austin.
- Houston had a strong correlation with San Antonio on high ozone days suggesting that San Antonio is impacted by transport from Houston. The cities that are the farthest away from San Antonio, Dallas and Tyler/Longview, had the lowest correlation with ozone readings in San Antonio.
- Aircraft sampling indicated large ozone plumes from Houston and industrial facilities can impact areas hundreds of miles downwind including San Antonio. Depending on wind direction, this may increase ozone in the San Antonio region and make it more difficult to comply with a stricter8-hour ozone standard.
- There was a reduction of 17.1 ppb in the 2013 ozone design value when all local anthropogenic emissions from the eight-county San Antonio MSA were removed from the photochemical model (24.7% reduction).
- New point sources being built in Texas may make it more difficult for San Antonio to attain proposed stricter 8-hour ozone standard.

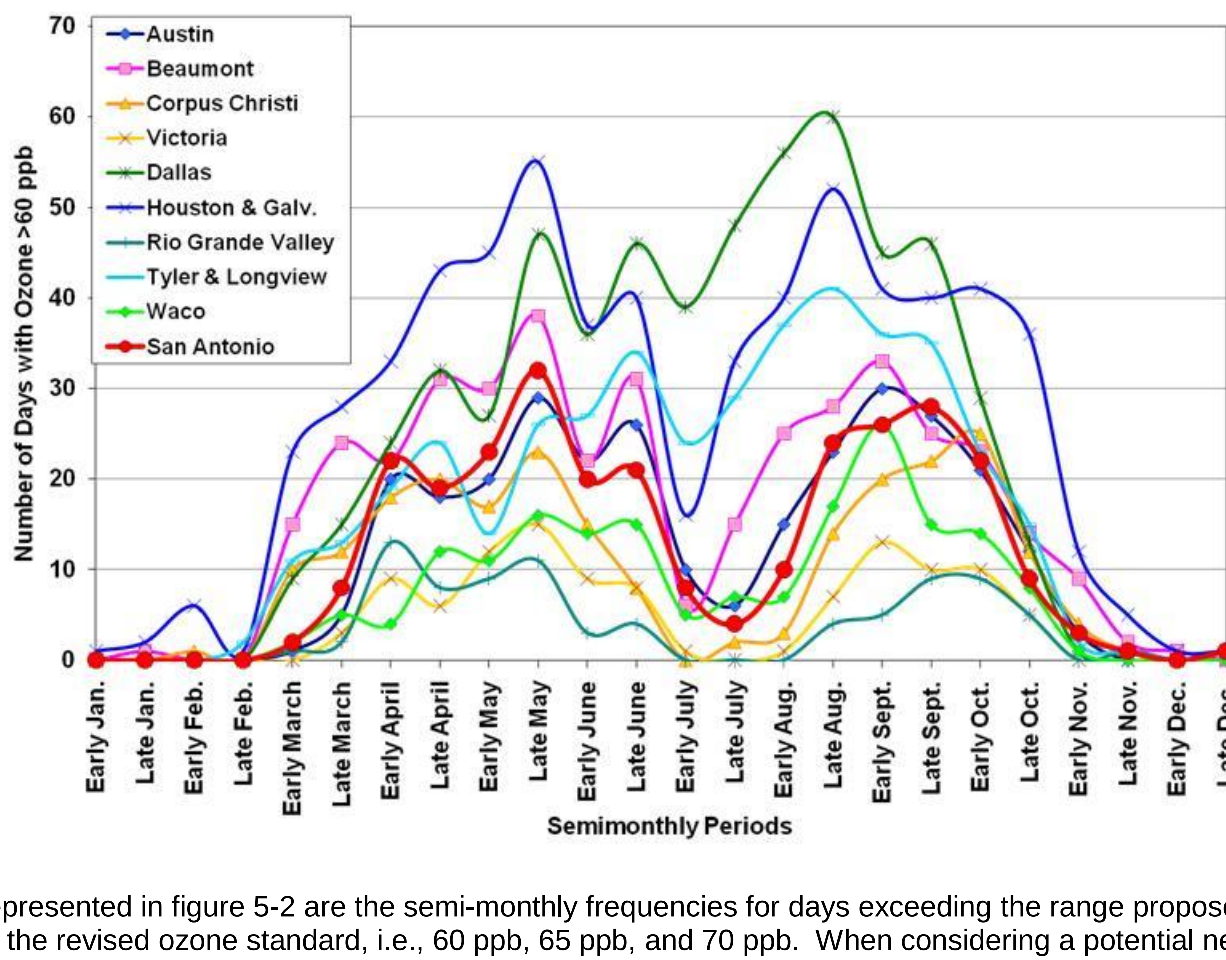
5. SEASONAL OZONE DIFFERENCES

Ozone readings fluctuate by season depending on several factors including variations in transport, meteorology, chemical loss of ozone, and upper stratospheric ozone levels. Since transport is a significant factor in local ozone concentrations, seasonal variations in wind direction, speed and direction of back trajectories, and chemical loss are important considerations during the conceptual model process.

5.1. *Annual Ozone Variation*

Figure 5-1 presents the total number of high ozone days >60 ppb in the most densely populated areas of east Texas. The data, from 2005 to 2010, was organized by semi-monthly periods. The graph clearly demonstrates that the majority of ozone exceedances in Texas occur between April and early October. From April to June, there is a seasonal apex in the number of high ozone days in most Texas cities. This e first seasonal peak begins as early as March in some areas. The period also represents the first high ozone seasonal peak that San Antonio typically experiences. However, by early July the number of local high ozone days decline. The next seasonal peak covers a slightly shorter period in the following graphic (Figure 5-1). This peak occurs from late August to early October.

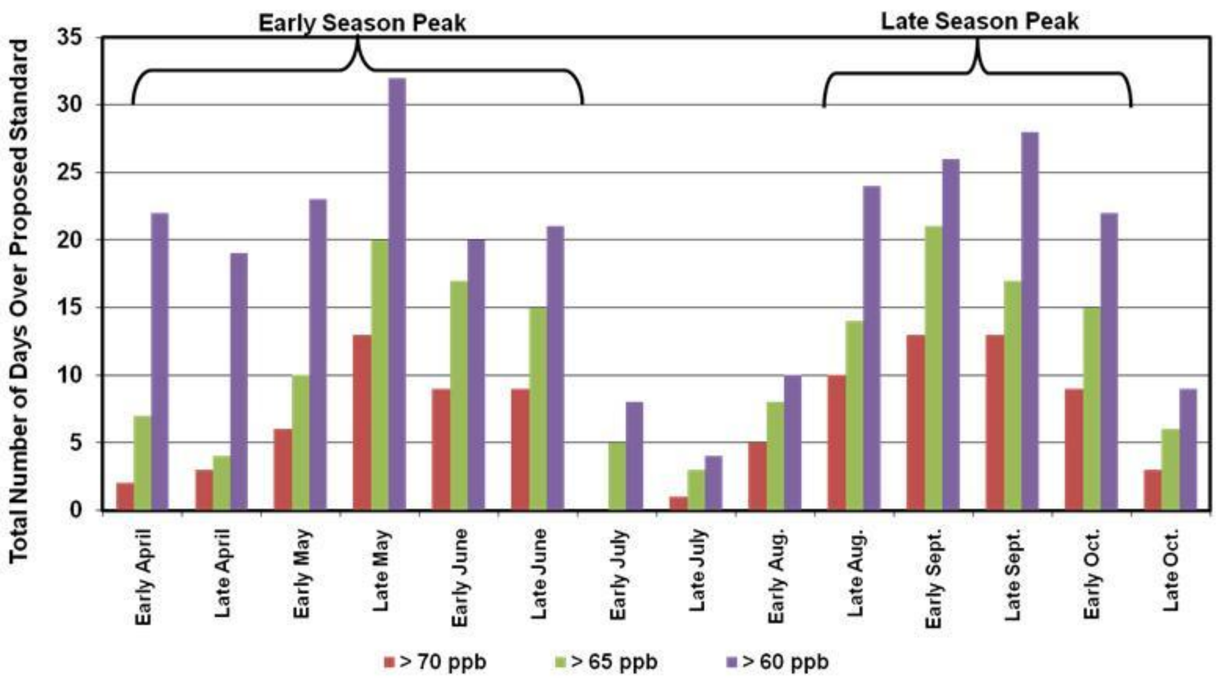
Figure 5-1: High Ozone Days > 60 ppb by Semi-Monthly Periods for Selected Texas Regions, 2005-2010



Represented in figure 5-2 are the semi-monthly frequencies for days exceeding the range proposed for the revised ozone standard, i.e., 60 ppb, 65 ppb, and 70 ppb. When considering a potential new standard of 60 ppb over less stringent proposed standards, there becomes a substantial increase in the frequency of high ozone days in April through May, essentially forming one extended peak through the first three months of the season, as discussed previously.

An analysis of 2005 - 2010 San Antonio data indicates more exceedances of the current 75 ppb standard during the second seasonal peak than the first seasonal peak, and accounts for 55.8% of days above the proposed 70 ppb standard over the same period. Conversely, the second seasonal peak accounts for only 46.5% of days above 60 ppb. Therefore the first seasonal peak is characterized by a greater frequency of high ozone days (above 60 ppb), while the second seasonal peak is characterized by more extreme "high" 8-hr ozone values. Each ozone season peak has very different metrological and transport factors that impact local monitored ozone. Since the two ozone seasonal peaks vary greatly by emission sources, transport, and intensity, different control measures might be needed to reduce ozone based on time of year.

Figure 5-2: Number of Days with 8-hr Ozone Averages > 60 ppb, > 65 ppb, and > 70 ppb by Semi-monthly Periods for San Antonio, 2005 – 2010



Chi-Square Goodness-of-Fit Test for Ozone Season Uniformity

The chi-square (X^2) goodness-of-fit test[62] and Phi (φ) test were performed on the semi-monthly distribution of high ozone days for each level of the proposed range under consideration for the new ozone standard to determine whether the distributions are random or significant in the San Antonio region. The chi-square value was compared to a probability chart to determine if the results are significant.[63]

60 ppb Significant at 99.5% = **yes** (46.48 > 29.82)
65 ppb Significant at 99.5% = **yes** (42.30 > 29.82)
70 ppb Significant at 99.5% = **yes** (40.21 > 29.82)

Since the results (46.48, 42.30, and 40.21) are all greater than 29.82, the semi-monthly pattern is significant for each proposed standard at the 99.5% level.

[62] Jones, James, Professor of Mathematics, Richland Community College. "Math 170: Intro to Statistics Chapter 12 Lecture Notes". Available online: http://www.richland.edu/james/lecture/m170/ch12-fit.html. Accessed 06/30/10.

[63] Jones, James, Professor of Mathematics, Richland Community College. "Table: Chi-Square Probabilities". Available online: http://www.richland.edu/james/lecture/m170/tblchi.html. Accessed 06/30/10.

60 ppb Phi (φ) = 0.42
65 ppb Phi (φ) = 0.51
70 ppb Phi (φ) = 0.65

The results of the Phi (φ) test for each proposed standard (0.42, 0.51, and 0.65) are all greater than 0.2 and therefore the results indicate a significant variability in the frequency of high ozone days over the period. The chi-square test confirms high ozone days do not occur with equal frequency in the San Antonio region. It is not just as likely for a high ozone day to occur during one given semi-monthly period as during another given time period. Both tests indicate that high ozone days appear to follow a seasonal (non-random) pattern with peaks and valleys during the ozone season.

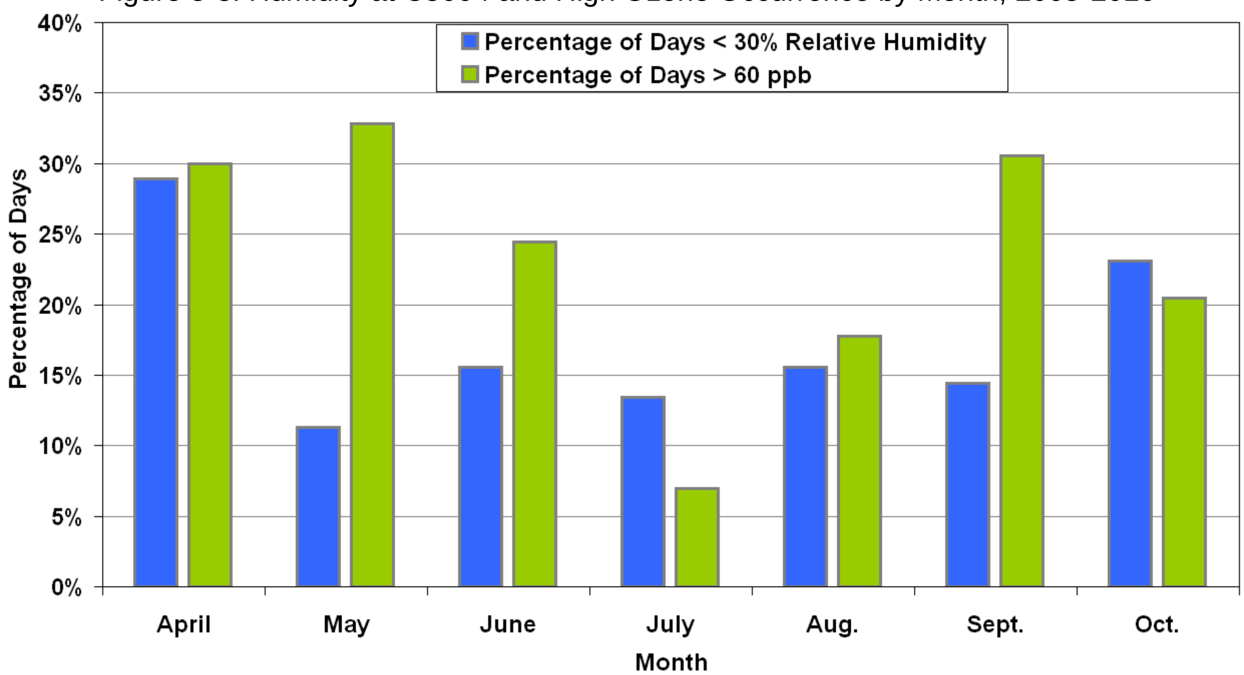
5.2. *Meteorological Seasonal Variations*

According to multivariate correlation analysis, individual metrological factors that had the highest correlation with days exceeding eight-hour average ozone concentrations of 60 ppb were humidity at 2 p.m., diurnal temperature change, morning wind direction, and back trajectory direction. Due to the influence of these factors in the formation of ground level ozone, each factor was analyzed to determine the extent to which monthly variations of these factors impact ozone levels.

5.2.1. Humidity

As demonstrated in section 3.3.2., humidity has one of the strongest correlations with ozone among meteorological factors, with an R^2 value of 0.28 for all days. Lower relative humidity is related to high rates of ozone formation. The relationship between relative humidity and ozone was further investigated by comparing the frequency of low humidity days versus the frequency of high ozone days by each month of the ozone season. Figure 5-3 displays the percentage of days in each month from 2005-2010 that had relative humidity below 30% versus the percentage of days when 8-hour ozone averages were above 60 ppb. There is significant variation by month, with little predictability between average monthly humidity and ozone readings.

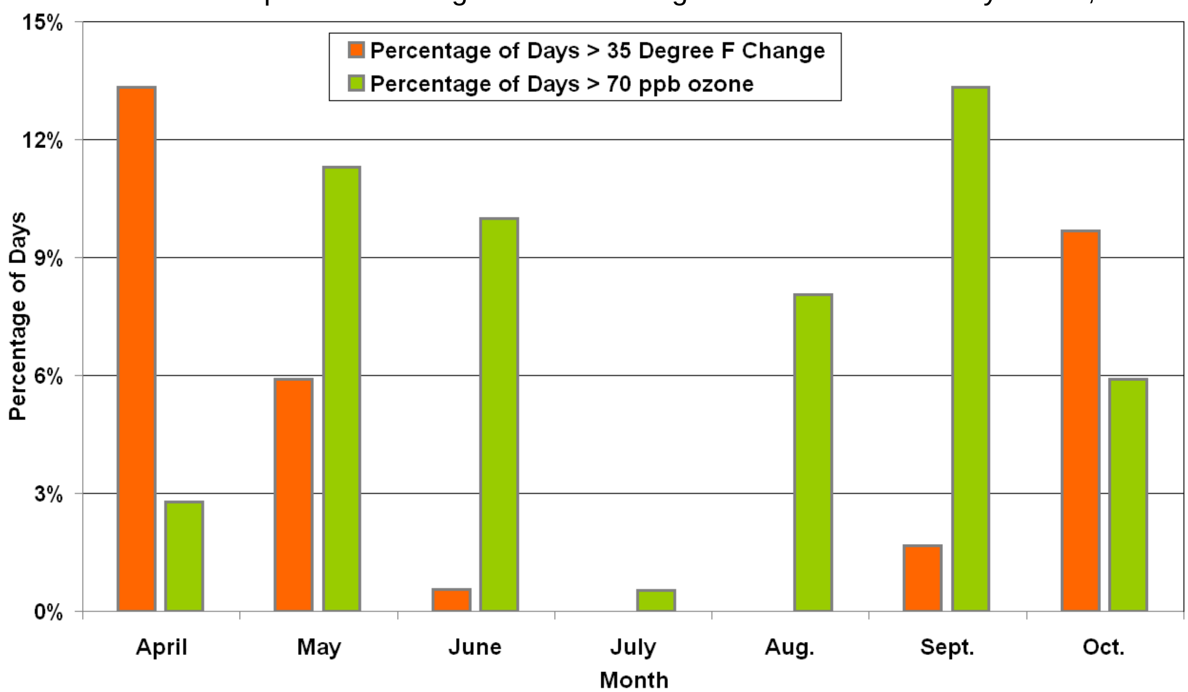
Figure 5-3: Humidity at C5004 and High Ozone Occurrence by Month, 2005-2010



5.2.2. Diurnal Temperature Change

A moderate correlation exists between the magnitude of temperature changes within a single day (from the overnight low to the afternoon high) and ozone values from 2005-2010. Comparing the percentage of high ozone days (greater than 70 ppb ozone) versus the percentage of days with a large diurnal temperature change (greater than 35 °F) by month, as displayed in figure 5-4, indicates no correlation between the two factors.

Figure 5-4: Diurnal Temperature Change at C58 and High Ozone Occurrence by Month, 2005-2010



5.2.3. Seasonal Wind Direction Variation

C23 and C58 average hourly wind vector plots for all days during the months of June through September are presented in figures 5-5 and 5-6. Wind speeds and directions are similar during the months of June, July, and August at both monitors, but show a different pattern for September. Plots for June, July, and August show the characteristic dominance of south-easterly winds during these months. During September winds at both monitors reverse during the day, which results in an easterly average daily resultant wind vector. C58 experiences particularly calm winds during the middle of the day and a shorter, more northeasterly average daily resultant wind vector. During September, however, the wind vector plot for C58 indicates there is a flow reversal of winds arriving at the monitor from the northwest in the morning before 7 am , which does not occur during the other three months.

Hourly wind vectors at C58 during June and July are further dissected by weekly periods so as to investigate the importance of wind patterns during these months. The hourly wind plots, as well as the corresponding 8-hr ozone average for each week, are presented in figures 5-7 and 5-8. As described earlier, June and July have similar overall wind patterns but greatly differing ozone trends. Plots for June (figure 5-7) indicate that wind speed is fairly well correlated with ozone levels, as the two weeks with the strongest winds have 8-hour ozone averages of 44 and 45 ppb, while the two weeks with the weakest winds have 8-hour ozone averages of 51 and 52 ppb. However, in the month of July (figure 5-8), weekly plots generally have resultant wind vectors of smaller magnitude than in June, yet no weekly 8-hour ozone value exceeds 42 ppb. This analysis gives further evidence that factors other than prevailing wind/horizontal air movement are more influential in affecting local ozone levels during the month of July.

Figure 5-5: Hourly Average Resultant Wind Vectors at C23 by Month, 2005-2010

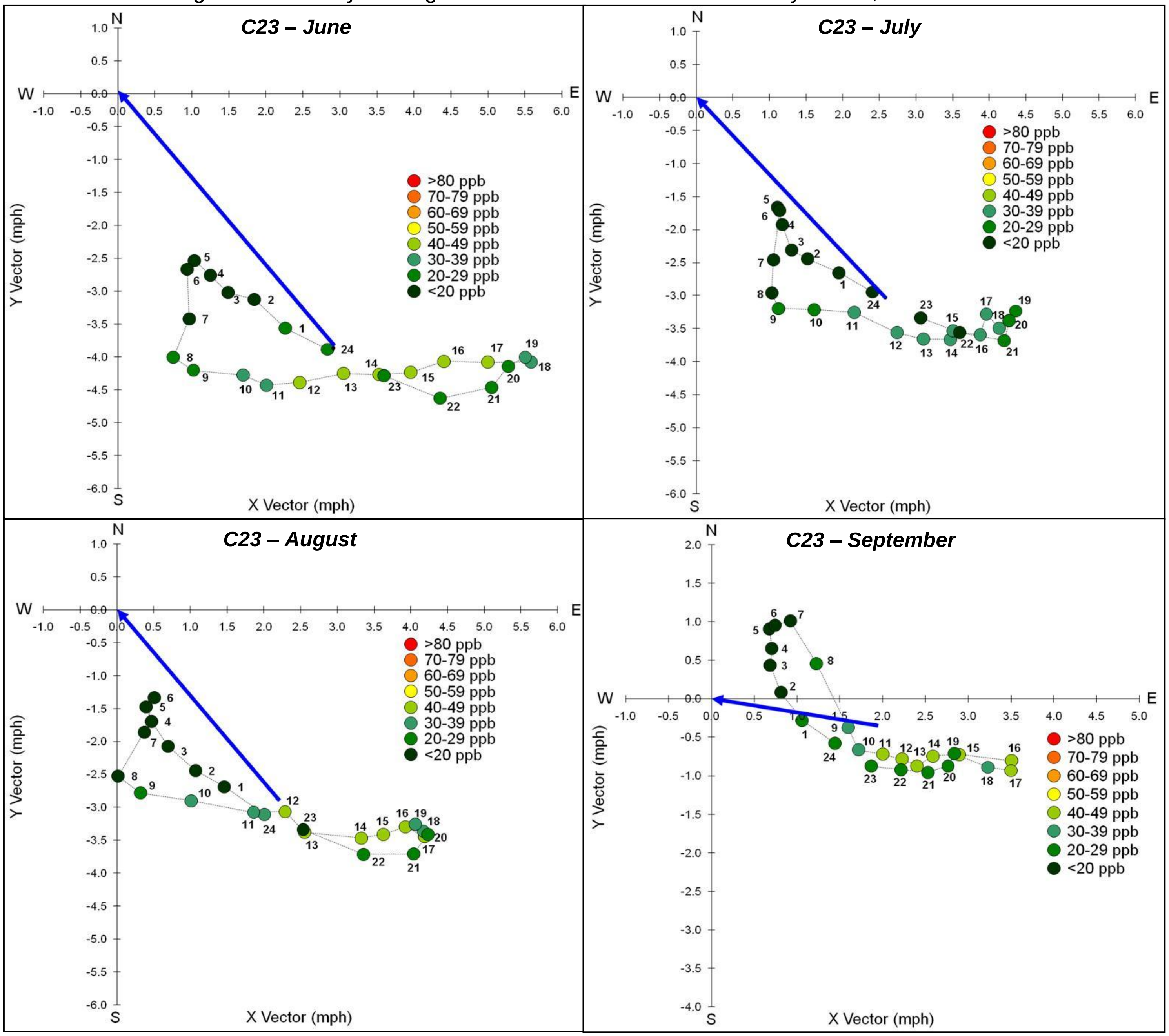


Figure 5-6: Hourly Average Resultant Wind Vectors at C58 by Month, 2005-2010

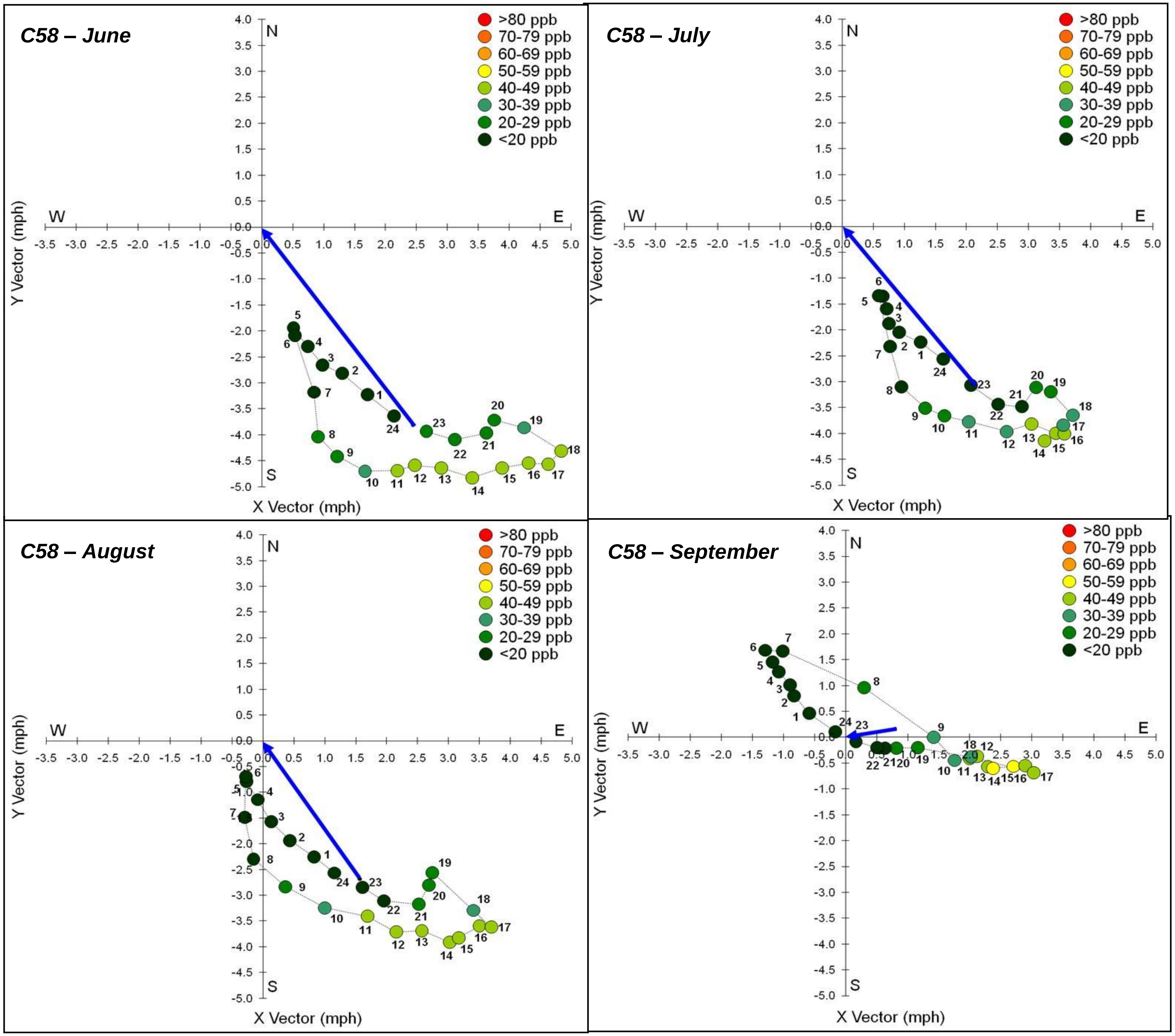


Figure 5-7: Hourly Average Resultant Wind Vectors at C58 by Each Week of June, 2005-2010

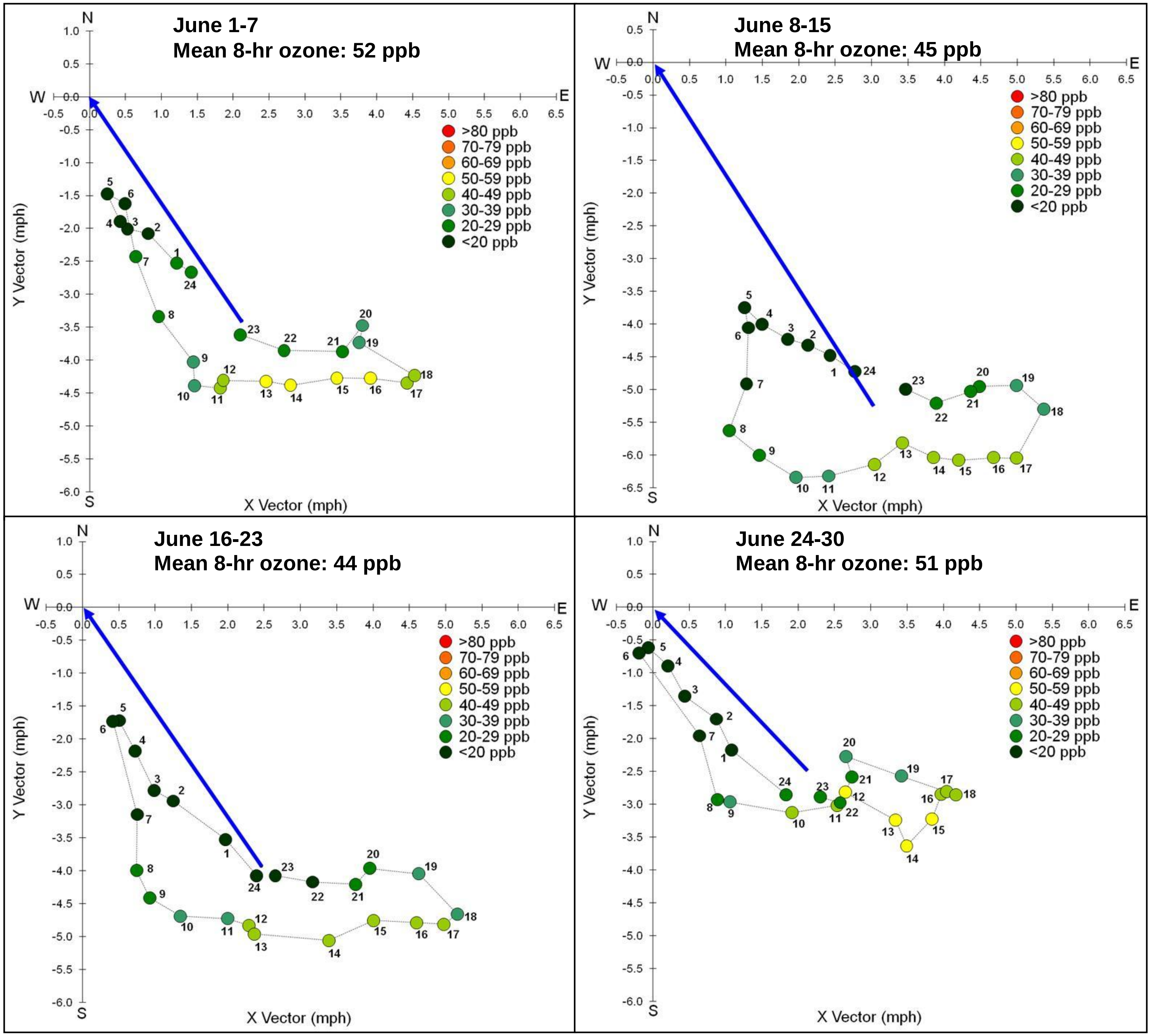
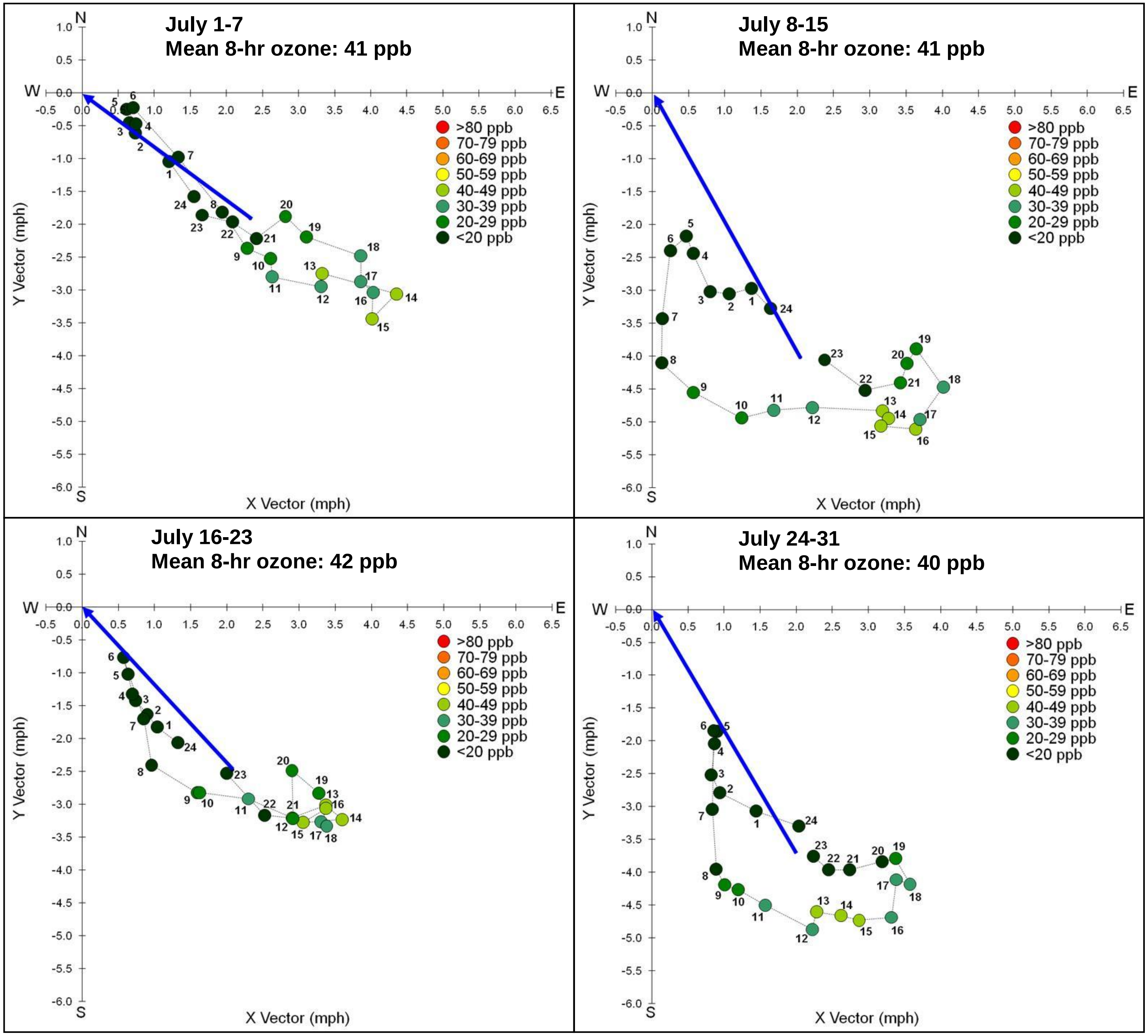


Figure 5-8: Hourly Average Resultant Wind Vectors at C58 by Each Week of July, 2005-2010



5.2.4. Back Trajectory Direction

Back trajectories were analyzed by month to determine if there were seasonal variations on high ozone days. As figure 5-9 shows, there were pronounced differences in seasonal wind flow on days of high ozone. The largest percentage of 100-meter back trajectories, 55.8%, on high ozone days > 60 ppb, originated from the southeast during the month of June, while only 6.1% originated from the northeast and only 7.5% originated from the east. A similar pattern occurred on high ozone days in July. High ozone days in September had significantly different patterns of back trajectories. High ozone day wind trajectories during September were somewhat likelier to originate from the northeast (23.7%) and east (28.5%),

Figure 5-9: Statistical Analysis of San Antonio's 250-mile Back Trajectory Wind Directions By Month, High Ozone Days > 60 ppb, 2005-2010

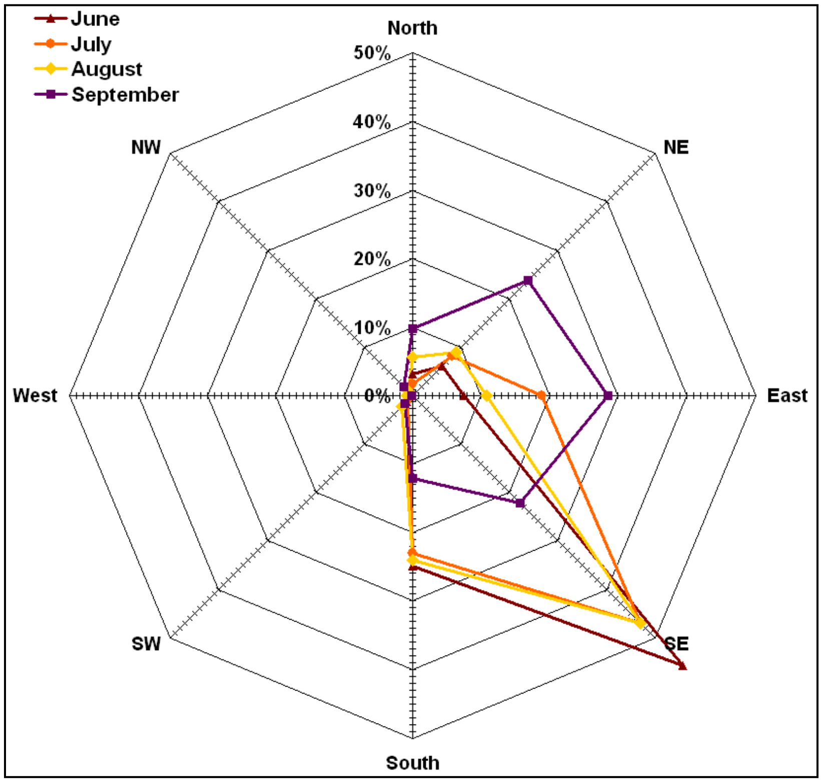
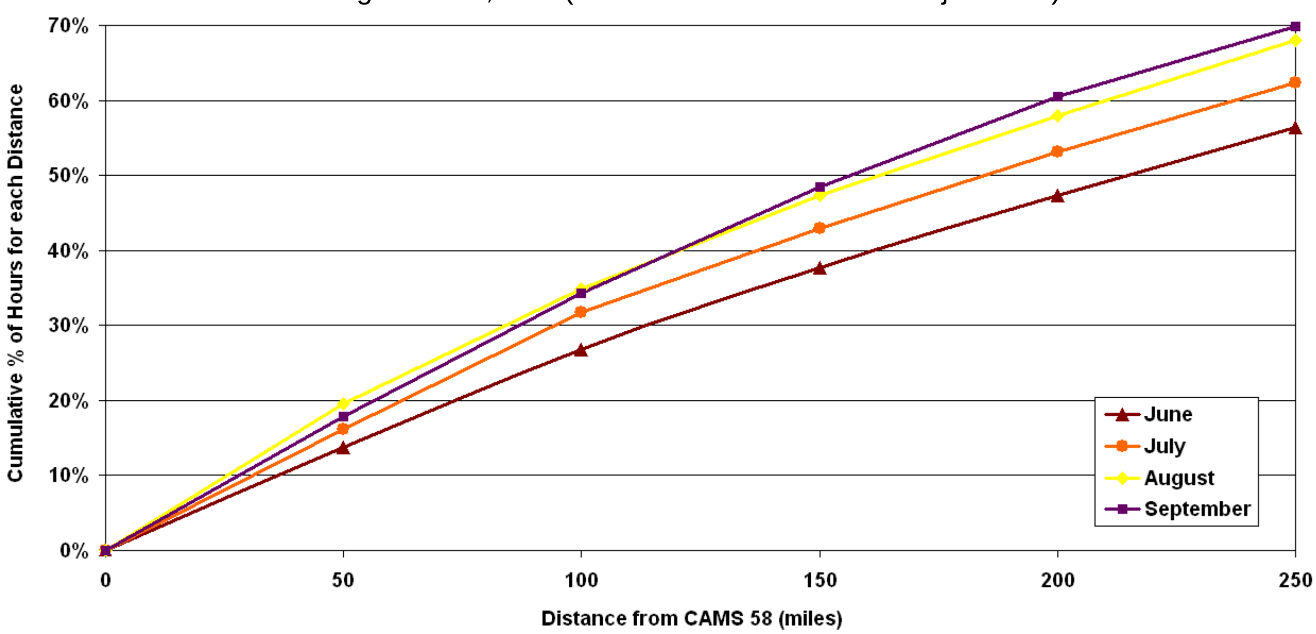


Figure 5-10: High Ozone Days > 60 ppb, 2005-2010 Cumulative Percentage of Back Trajectories Begin Points, C58 (100-meter 48-hour Back Trajectories)



Back trajectories were also analyzed to determine the distance of the origin from C58 during each month. Back trajectories during June and July often originated farther from C58 compared to August and September (figure 5-10). During August and September, 68.9% of the 48-hour back trajectories originated within 250 miles of C58. Only 56.3% of the back trajectories in June originated within 250 miles of C58. This indicates local or short-range transport emissions may have a greater impact on ozone formation during August, September, and October, while June could be more dominated by transport. A significant percentage, 30%, of days during September had stagnated back trajectories (table 5-1). On the other hand, only 9% of the back trajectories during the June ozone season peak were stagnated. Back trajectories during May, June, and July traveled farther and faster before arriving in San Antonio compared to August, September, and October.

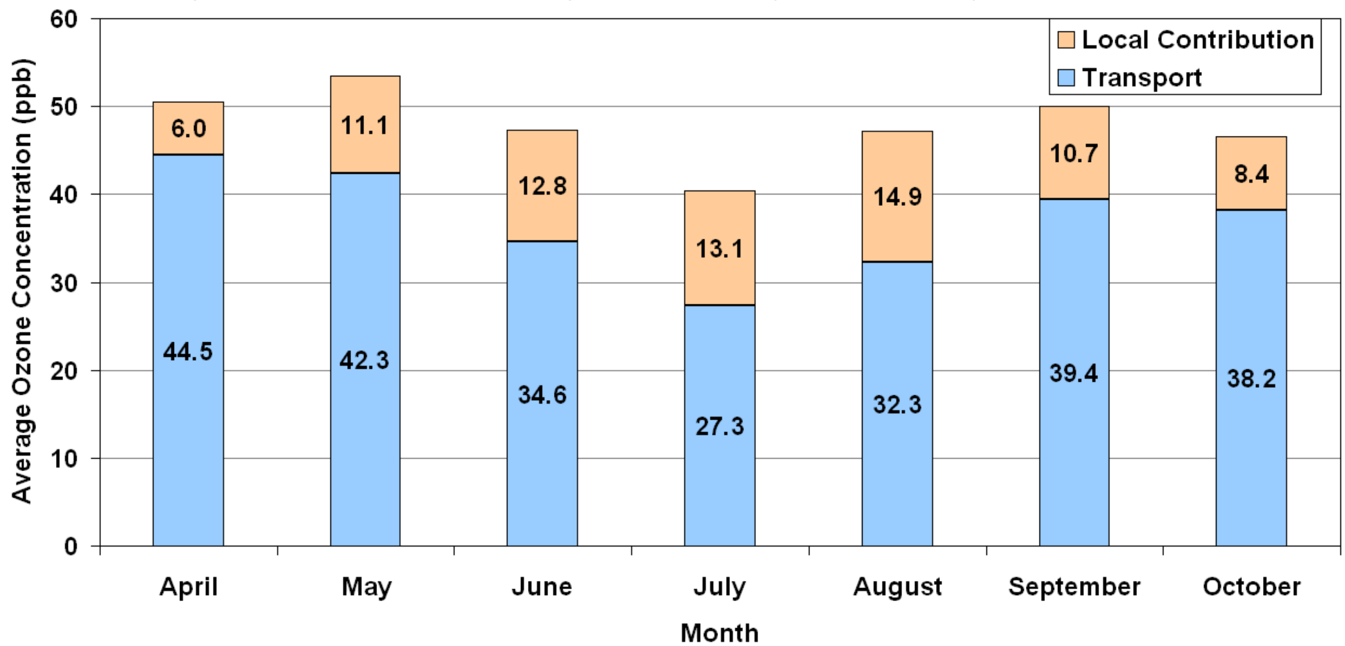
Table 5-1: Back Trajectories Classification by Month for All Days, 2005 - 2010

Back Trajectory Classification (2005-2010 - All Days)	Stagnated		Weak Transport		Transport		Total	
	Number of Days	Percent	Number of Days	Percent	Number of Days	Percent	Number of Days	Percent
April	19	10%	48	27%	**114**	**63%**	181	100%
May	22	12%	56	30%	106	58%	184	100%
June	16	9%	85	47%	79	44%	180	100%
July	19	10%	86	46%	81	44%	186	100%
August	39	21%	93	50%	54	29%	186	100%
September	**54**	**30%**	69	38%	57	32%	180	100%
October	42	23%	80	43%	62	34%	184	100%

5.3. ***Seasonal Variation at Upwind Monitors***

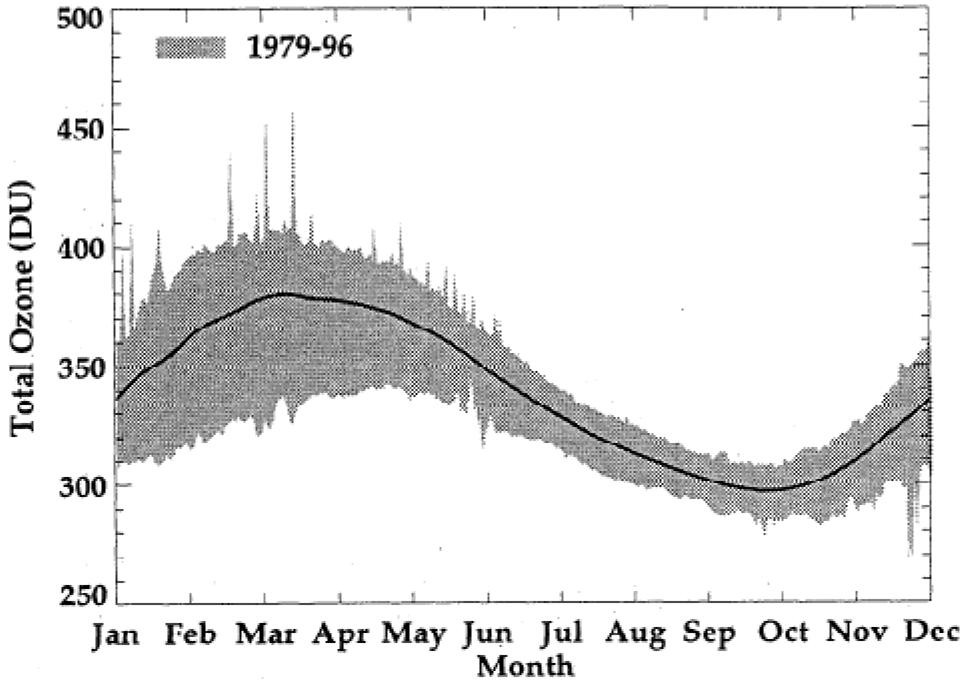
There is a significant amount of ozone transport during the spring and fall ozone season peaks. The values in figure 5-11 represent the average highest ozone readings at upwind monitors compared to the lowest average readings at downwind monitors, by month. This data indicates April is distinguished as the month with the highest average ozone transport at 44.5 ppb, but the lowest average local contribution at 6 ppb. Transport in July decreases because there is reduce transport of upper stratospheric ozone mixing with ground level emissions due to chemical loss of upper stratospheric ozone. The amount of transported ozone increases during the fall seasonal peak in late August to early October.

Figure 5-11: San Antonio Background Ozone by Month, All Days, 2005-2010



5.4. *Tropospheric and Stratospheric Seasonal Ozone Variation*
Several studies have found that tropospheric and stratospheric ozone decreases from the spring to the fall seasons. Figure 5-12 shows the "time series of northern midlatitude total ozone between 30ºN and 60ºN averaged from 1987 to 1997. The thick line represents the time mean, while shading represents the range of values obtained from 1979 to 1996."[64] According to Cordero and Kawa, there is weak downward motion in the circulation of the lower midlatitude stratosphere between 15 and 20 km in altitude (the lower portion of the stratosphere) during the early summer (May-June).[73] The authors note that this motion occurs as an exception to the general upward motion in the Northern Hemisphere (NH) stratosphere during the early summer.

Figure 5-12: Total Ozone Mapping Spectrometer (TOMS) Total Ozone 30ºN – 60ºN Average



Since stratospheric ozone is much higher in concentration than tropospheric ozone, as shown in figure 5-13,[65] this motion can introduce elevated ozone levels into the troposphere of the midlatitudes (i.e. Texas) that counteracts the ozone-moderating effects of the transport of relatively unpolluted air from the Gulf of Mexico during June. This is a potential explanation as to why elevated ozone concentrations are more likely to occur in May and June than July in much of Texas. In mid to late summer (July-August), the circulation shifts to a downward motion north of 40ºN, and the vertical transport becomes increasingly stronger through September and October.[73] This phenomenon might likewise add to the elevated tropospheric ozone present in the northeast U.S. which is sometimes transported into Texas during the fall ozone season peak in late August to early October.

A springtime ozone maximum occurring at midlatitudes in the northern hemisphere has also been referred to and modeled in a study by Mauzerall et al.[66] According to the authors, the discrepancy

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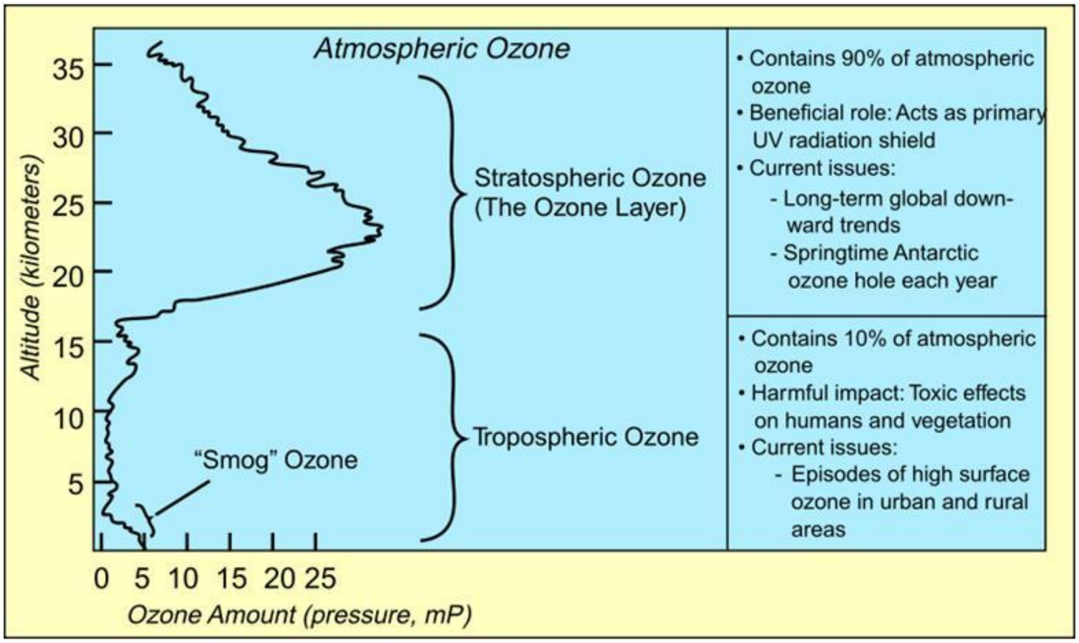
[64] Cordero E.C. and Kawa S.R. "Ozone and Tracer Transport Variation in the Summer Northern Hemisphere Stratosphere", Journal of Geophysical Research. 106.D11 (June 16, 2001): 228. Available online: http://www.met.sjsu.edu/~cordero/research/Papers/jgr2001.pdf. Accessed 04/01/11.
[65] Schoeberl M.R. "Chapter 7: Ozone and Stratospheric Chemistry", 1999 EOS Science Plan. Ed. Greenstone R. and King, M.D. National Aeronautics and Space Administration, 1999. p.311. Available online: http://eospso.gsfc.nasa.gov/science_plan/Ch7.pdf. Accessed 04/07/11.
[66] Mauzerall, D.L., Narita, D., Akimoto, H., Horowitz, L., Walters, S., Hauglustaine, D.A., and Brasseur, G. "Seasonal Characteristics of Tropospheric Ozone Production and Mixing Ratios Over East Asia: A Global Three

between the observed and modeled ozone concentrations in winter and spring was most likely due to an under-representation in the model of the influx of stratospheric ozone, which has a broad maximum from winter to spring. They also stated the combination of such stratospheric influx with a sharp increase in photochemical buildup from February to May could explain the observed spring maximum from April to May observed at mid-latitude sites.

Figure 5-13: Distribution of Atmospheric Ozone by Altitude in Partial Pressure



The observed decline in tropospheric and stratospheric ozone in the Northern Hemisphere from the spring to the fall seasons can be explained by increased chemical destruction of ozone. Chemical loss of tropospheric and stratospheric ozone can occur through the catalysis by NO_X in the summer time. Crutzen and Brühl addressed "the cause of the largely natural total ozone decline in the stratosphere from its spring maximum to fall minimum in the northern hemisphere and show that this is mainly due to NO_X-catalyzed ozone destruction".[67] "For all years, net ozone production takes place between the "subtropical barrier", at about 30° N, and 50° N. Nevertheless, also in this latitude region the ozone content declines due to transport to higher latitudes where very strong chemical ozone loss takes place due to summer time NO_X activation."[68]

As evidence of elevated background ozone caused by transport and/or introduction from the upper atmosphere, David Parish found there is a strong correlation between tropospheric ozone at 1 to 2.5 km above the surface and ground level ozone on the west coast of North America.[69] Further research is needed to determine the correlation between stratospheric and upper tropospheric ozone levels and ground level ozone in the San Anton region. The decrease in tropospheric ozone from

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Dimensional Transport Model Analysis." American Geophysical Union, 2000. p. 2-21. Available online: http://www.princeton.edu/~mauzeral/syllabi/jointpaper.pdf. Accessed 04/07/11.

[67] Crutzen, Paul J. and Brühl, Christoph, Atmospheric Chemistry Division, Max Planck Institute for Chemistry, Mainz, Germany, "Catalysis by NOx as the Main Cause of the Spring to Fall Stratospheric Ozone Decline in the Northern Hemisphere", The Journal of Physical Chemistry. A, 2001, 105(9), (December 21, 2000): pp 1579–1582.

[68] *Ibid*.

[69] David Parrish, NOAA/ESRL Chemical Sciences Division, March 30, 2011. "Transported Background Ozone: Impact on Air Quality at U.S. West Coast". Available online: http://www.utexas.edu/research/ceer/Documents/PDFs/Ozone/Current%20Presenter-%20David%20Parrish.pdf. Accessed 04/01/11.

spring to summer may result in less vertical ozone transport between atmospheric layers and a decrease in the number of ozone exceedances observed in July.

Although concentrations are typically low in July, ozone levels again increase in the fall in San Antonio. Local wind directions change in the fall and local and regional meteorological patterns become more conducive to high ozone days. There is an increase in the frequency of stagnated winds with local or short-range transport emissions from the northeast which can cause elevated ozone during August, September, and October.

5.5. *Ozone Seasonal Difference Summary*

Seasonal variations in ozone levels are impacted by transport of ozone and ozone precursors into the San Antonio region.

- From April through June, a seasonal increase in the number of high ozone days develops in most Texas cities. This period represents the first and longest high ozone seasonal peak that San Antonio typically experiences. However, by early July the number of high ozone days declines. The next seasonal increase covers a period beginning in August and ending in late October, during which the frequency of high ozone days is slightly lower than the spring period.
- The spring seasonal ozone peak is of longer duration than the fall seasonal peak for southern and coastal cities in Texas, and generally contains more high ozone days.
- There is much variation in measures of humidity versus ozone by month, with little predictability for ozone based on humidity alone.
- Although the magnitude of temperature change within a single day has a relatively high correlation with ozone values, diurnal temperature change during any given month is a poor predictor for high ozone occurrence.
- Resultant wind vectors are shorter in July than in June, indicating more stagnated winds for July compared to June, yet July actually experiences fewer high ozone days. Hourly wind vectors plotted for each week in June indicate that wind speed is fairly well correlated with ozone levels. In the month of July, weekly plots generally have resultant wind vectors of smaller magnitude than in June, but weekly 8-hour ozone values are significantly lower. This analysis gives further evidence that factors other than prevailing wind/horizontal air movement may have greater influence on local ozone levels during the month of July.
- Back trajectories tended to travel increasingly shorter distances each month from June through September indicating stagnate air conditions. Back trajectories in June, July, and August originated predominantly from the southeast and south, but back trajectories in September originated equally as often from the northeast, east, and southeast, with smaller fractions originating from the north and south.
- There is a significant amount of ozone transport during the spring and fall ozone season peaks. During the ozone season, the month most affected by transport (highest ozone average measured at upwind monitors) is April, but the month is also characterized by the lowest average local contribution . Transport is lowest in July before increasing again into the late summer and fall. The mid summer months of June through August account for the largest fractions of local contributions to ozone.
- It is possible that a combination of greater tropospheric-stratospheric air exchange combined with higher North American stratospheric ozone levels during the early months of the ozone season is partially responsible for the higher ground level ozone observed in San Antonio during these months. Likewise, the secession of this phenomenon could explain the decrease in ground level ozone from late June through July which occurs before air mass stagnation and northeasterly transport contributes to a rebound in ground level ozone measurements.

6. METEOROLOGICAL PATTERNS DURING SAN ANTONIO OZONE EVENTS, 2010

Computer simulations that replicate high ozone events are valuable tools on which to base control strategy analyses and predict the impacts of socioeconomic factors, such as changes in population and land use, on ozone formation. Simulations must account for the complex chemical and atmospheric processes that influence ozone formation, dispersion, and deposition. Because simulations are based on atmospheric and meteorological conditions coinciding with local elevated ozone episodes, they allow analysts to predict the impact of emission controls and other emission rate perturbations under “worse case” circumstances.

According to EPA guidance, preferred modeling episodes should exhibit a variety of local and regional meteorological conditions conducive to the formation of high ozone, contain days in which observed concentrations are close to the baseline design value, be supported by extensive air quality and meteorological data bases, and include a sufficient number of high ozone days. Other factors that increase the suitability of modeling a particular high ozone event over another episode include prior modeling of the event by other regions, concurrence with a time period included in the calculation of the current baseline design value, and the inclusion of several weekend high ozone days.

6.1. *June 2006 Photochemical Modeling Episode*

A photochemical modeling episode is being updated for the May 29th to July 2nd, 2006 high ozone event. TCEQ, Austin, San Antonio, and other potential non-attainment areas are modeling this high ozone event in support of SIP development. The June 2006 episode occurred during the TexAQS II study in Texas and is therefore supported by a wealth of data and technical analysis. Furthermore, the episode falls within the 2006-2010 modeling design value period.. During the June 2006 episode, meteorology was typical of conditions on high ozone days, which is ideal for modeling purposes (table 6-1). Temperatures ranged from 86.5^{o} F degrees on June 2nd to a peak of 98.0^{o} F on June 13th. The ozone event was characterized by high solar radiation on all high ozone days besides June 2nd and low afternoon relative humidity from 20% to 38%.

Back trajectories at 100 meters were primarily from the southeast (38.8%) and south (22.7%) during the episode on high ozone days greater than 60 ppb (figure 6-1). There were also some winds from the east (15.8%) and northeast (13.7%) on several episode days. The June 26th, 2006 high ozone day had unusually high wind speed (9.5 mph) and the back trajectory indicated the winds traveled a significant distance before arriving at C58. There were 1.30 inches of precipitation on the June 18th high ozone day. Although it is uncommon to experience precipitation on a high ozone day, the rainfall occurred between 2 a.m. and 5 a.m. in the morning, before sunrise.

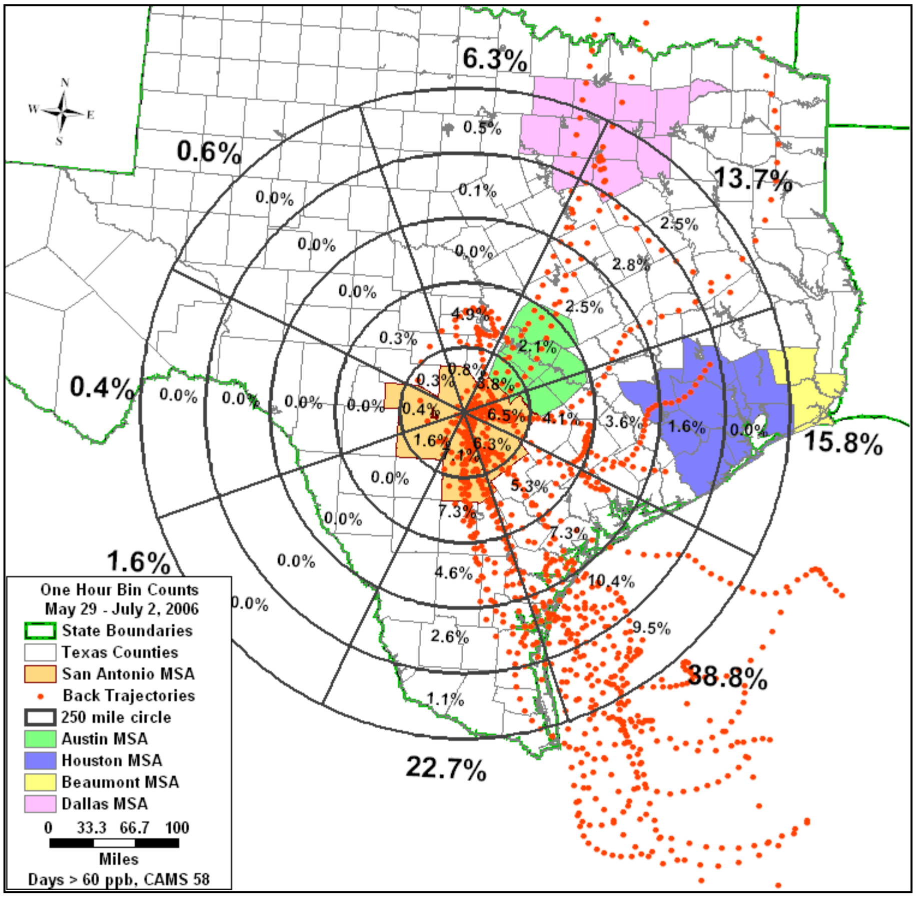
According to the TCEQ, “Plume Animation shows the estimated plume tracks from large industrial sources of oxides of nitrogen (NO_X) and/or volatile organic compounds (VOC), as well as plume tracks for the center of the broad urban plumes coming from Downtown Austin, Downtown San Antonio, and other major urban centers. The plume animation suggests that urban and industrial emissions from the San Antonio area were in the vicinity of the highest ozone measurements in the San Antonio area and that the highest ozone levels may have been well downwind to the west and southwest of the San Antonio area where there are no monitoring sites.”[70]

[70] TCEQ, March 8, 2010. “2006 Air Pollution Events: Descriptions and Analyses of Large-scale Air Pollution Events in Texas during 2006.” Austin, Texas. Available online: http://www.tceq.state.tx.us/compliance/monitoring/air/monops/sigevents06.html. Accessed 06/03/10.

Table 6-1: June 2006 Episode Meteorological Conditions Compared to Typical Meteorological Conditions in the San Antonio Region on Days > 60 ppb.

Existing Episode	Day	Peak 1-hour ppb Ozone at regulatory monitors	Peak 8-hour ppb Ozone at regulatory monitors	Peak Temperature at C58 > 87.3°F	Wind Speed 6 am – 2 pm at C58 < 7.0 mph	Precipitation (inches) at C678 - None	Max. Solar Radiation at C58 > 1.172 langleys/min.	Relative Humidity at 2p.m. C5004 < 40.9%	Morning Wind Direction at C58 (6-9)	Afternoon Wind Direction at C58 (12-15)	Back Trajectory Classification
June 2006	2	78	66	**86.5**	6.7	0	**0.940**	35.5%	NW	NE	Stagnated
	3	86	80	89.7	4.9	0	**1.148**	27.5%	NW	SE	Stagnated
	4	81	73	90.9	4.9	0	1.277	30.9%	SW	SE	Stagnated
	5	69	63	92.0	6.0	0	1.336	31.4%	SW	SE	Weak Transport
	6	76	66	92.8	5.5	0	1.272	26.9%	S	S	Weak Transport
	7	87	76	94.3	5.0	0	1.309	31.8%	SW	S	Weak Transport
	8	96	84	92.6	4.4	0	1.291	29.6%	SW	SE	Weak Transport
	9	86	77	92.5	5.5	0	1.369	29.6%	NW	SE	Weak Transport
	10	74	69	92.8	5.7	0	1.364	24.8%	SW	S	Weak Transport
	11	67	64	93.5	**7.1**	0	1.354	26.4%	S	SE	Weak Transport
	12	78	70	93.8	5.3	0	1.304	30.0%	S	SE	Weak Transport
	13	106	93	98.0	5.3	0	1.301	20.2%	NW	E	Weak Transport
	14	94	90	93.9	**7.4**	0	1.305	29.4%	NE	E	Stagnated
	15	71	67	93.2	**9.0**	0	1.261	32.1%	SE	SE	Weak Transport
	18	79	71	90.4	4.3	**1.30**	1.345	38.8%	E	S	Transport
	19	85	65	93.5	3.7	0	1.357	35.7%	W	N	Transport
	25	70	65	91.2	6.3	0.04	1.216	31.5%	NW	NE	Stagnated
	26	86	78	89.6	**9.5**	0	1.324	26.1%	N	NE	Transport
	27	98	82	87.9	5.8	0	1.238	23.1%	N	NE	Weak Transport
	28	101	87	90.0	5.9	0	1.338	22.3%	NW	E	Weak Transport
	29	94	91	89.4	4.9	0	1.174	27.8%	W	SE	Stagnated
	30	87	71	91.6	4.7	0	1.276	30.3%	SE	SE	Weak Transport

Figure 6-1: May 29th to July 2nd, 2006 Photochemical Modeling Episode Days > 60 ppb



100 meter, 48 hour back trajectories

6.2. *High Ozone Events in the San Antonio Area*

Analysis of high ozone events from recent years can be used to isolate possible modeling episodes. TCEQ archived air quality data indicates that the number of high ozone days > 70 ppb, > 65 ppb, and > 60 ppb varies from year to year. After compiling a list of high ozone days occurring in 2010, possible ozone episodes were identified for photochemical modeling. Data on other high ozone events from 2005 to 2009 are provided in the 2009 Conceptual model of the San Antonio region.

When developing a list of candidate episodes for modeling, only the most recent six years (2005-2010) of high ozone events were considered because earlier years are neither feasible or cost effective for emission inventory and photochemical modeling development. Also, preference is placed on recent high ozone events, since San Antonio is developing the June 2006 episode. Choosing an episode older than the region's last existing photochemical modeling episode or before TexAQS II would not be recommended because meteorological and ozone data was not as extensively collected at monitors before 2005. Also, earlier high ozone events would not reflect current emissions and air quality measurements needed for testing control strategies.

With the addition of 2010 meteorological and ozone data to the conceptual model, a list of ten high ozone events were defined:

- April 2 – May 6, 2005
- May 20 – June 2, 2005 (TexAQS II Modeling Episode)
- Aug. 22 – Sept. 9, 2005
- Oct. 9 – Oct. 28, 2005
- May 9 – 20, 2006

- Aug. 17 – Oct. 9, 2006 (TexAQS II Modeling Episode)
- Sept. 17 – Oct. 3, 2008
- May 18 – June 6, 2009
- August 23 - 29, 2010
- September 28 - October 17, 2010

All high ozone events listed above represent episodic cycles of ozone formation in the San Antonio region. According to the EPA, "preference should be given to modeling" ozone cycles rather than individual high ozone days.[71] Other episodes that were modeled by other regions in Texas included the June 17-30, 2005 and July 26 – Aug 8, 2005 TexAQS II modeling episodes. These episodes were not considered because there were an insufficient number of high ozone days in San Antonio. The region experienced only two days above 70 ppb and only four days above 60 ppb during the June 2005 TexAQS II modeling episode. Likewise, the region experienced only two days above 70 ppb and only five days above 60 ppb during the July 2005 TexAQS II modeling episode.

Table 6-2 shows the days above 70 ppb, day of the week, peak 1-hour ozone, peak 8-hour ozone, and potential candidate episodes in 2010. Appendix A contains further details on high ozone days above 60 ppb during 2010.

Table 6-2: 2010 Days > 70 ppb and Possible Modeling Episodes

Date	Day of Week	Peak 1 Hour	Peak 8 Hour	Notes
5/28/2010	Fri	96	86	
5/29/2010	Sat	74	71	
8/25/2010	Wed	77	72	Candidate Episode
8/26/2010	Thu	79	72	
8/27/2010	Fri	85	80	
8/28/2010	Sat	98	87	
9/30/2010	Thu	85	73	Candidate Episode
10/6/2010	Wed	84	75	
10/7/2010	Thu	85	75	
10/8/2010	Fri	80	72	
10/16/2010	Sat	91	78	

6.2.1. Description of 2010 High Ozone Events

August 25 - 29, 2010

High eight-hour average ozone values between 62 and 87 ppb were recorded from August 25th to 29th, 2010. During this period, moderate winds were recorded from the north/northwest in the early morning while shifting to the northeast and southeast during the afternoon. C58 recorded high temperatures between 86.7^{o} F and 93.2^{o} F with no precipitation. On most days wind speeds were between 4.3 and 6.9 mph, but wind speeds picked up on August 25th, reaching 9.1 mph. On August 24th a front went through the San Antonio area causing clear skies and stagnated air conditions that supported elevated ozone levels. During most of the episode, a constant high-pressure system existed over the mid and southwest U.S. including San Antonio with few frontal movements.

September 28 - October 17, 2010

A period of high ozone occurred during late September and early October 2010. Recorded peak 8-hour ozone averages were between 63 ppb and 78 ppb on several days during the high ozone event. During

[71] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze". Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 142. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

this time period, light winds were recorded from the northwest in the early morning. In the afternoon, several different wind directions were recorded on high ozone days: south, southeast, and north. On most high ozone days, back trajectories indicated stagnated air conditions in the San Antonio area. Recorded maximum and minimum peak temperatures were only moderate, between 75.6 and 86.4^{o} F, however recorded maximum solar radiation was high.

There was a high upper air pressure system and stagnant air over the south central U.S. from September 28th to October 1st, 2010. By October 2nd the high pressure system moved away from the region and peak ozone levels decreased. Another high-pressure system was over south Texas between October 5th and 8th,which also coincided with a period of elevated ozone. A front moved through Texas on October 13th resulting in a high pressure system arriving in San Antonio by October 15th and contributing to elevated eight-hour average ozone concentrations that peaked at 78 ppb on Oct 16th.

6.2.2. Minimum Number of Days per Candidate Episode

EPA recommends selecting modeling episodes that contain a minimum of 10 days with ozone concentrates ≥ 70 ppb in order to generate "robust" relative reduction factors, used in the attainment test. However, in regions where ozone levels do not often exceed these levels for long periods of time, a minimum of 5 days is acceptable. EPA does not recommend modeling episodes with less than 5 days of ozone levels ≥ 70 ppb.[72] Due to the expense and time required to model episodes, it is not practical to model all high ozone days for a given year using a SIP quality photochemical model.

According to this criterion, an episode that does not have at least 5 days with ozone concentrations ≥ 70 ppb is not preferred. As shown on table 6-3, the 6 high ozone events with at least 5 days of ozone ≥ 70 ppb occurring between 2005 and 2010 are:

- Aug. 22 – Sept. 9, 2005
- May 9 – 20, 2006
- Aug. 17 – Oct. 9, 2006
- Sept. 17 – Oct. 3, 2008
- May 18 – June 6, 2009
- Sept. 28 – Oct 17, 2010

There was only one high ozone event with more than 10 days ≥ 70 ppb: Aug. 17 – Oct. 9, 2006 (table 6-3). However, the Aug. 17 – Oct. 9, 2006 episode is 53 days long which would require additional resources to model. Most of the episodes have at least 10 days ≥ 60 ppb with the exception of the May 20 – June 2, 2005 and Aug. 23 to Aug 29, 2010 high ozone events.

Only one high ozone event episode, May 18 – June 6, 2009, represents a time period when 8-hour ozone averages exceeded 70 ppb at both C23 and C58 for at least five days. There were six high ozone events that had a minimum of 5 days > 65 ppb at both monitors: April 2 – May 6, 2005, May 20 – June 2, 2005, Aug. 22 – Sept. 9, 2005, Aug. 17 – Oct. 9, 2006, Sept. 17 – Oct. 3, 2008, and May 18 – June 6, 2009. All high ozone events had at least 5 days > 60 ppb at both monitors besides the Aug. 25 – 29, 2010 high ozone event (table 6-4).

In order to ensure there are sufficient high ozone days for attainment tests, the number of modeling days needed at each monitor was determined. The 2006 baseline and 2013 future emissions were analyzed in the existing June 2006 photochemical modeling episode. By using the 4 km x 4 km grid

[72] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze", Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 147. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

cells, the day-to-day variability of relative response factors (RRF) at each site was calculated (figure 6-2). Only sites (C23, C58, C622, and C678) where the baseline 8-hour ozone averages were greater than 60 ppb on 10 or more days were used in the analysis. The CAMx photochemical model is less responsive at lower levels of the ozone standard because the background concentrations do not respond to local controls.

Table 6-3: High Ozone Events and Number of Days Above 70 ppb, 65 ppb, and 60 ppb.

High Ozone Event	Number of Days > 70 ppb	Number of Days > 65 ppb	Number of Days > 60 ppb
June 2 – 30, 2006	13	18	22
April 2 – May 6, 2005	4	6	19
May 20 – June 2, 2005	4	7	8
Aug. 22 – Sept. 9, 2005	7	11	14
Oct. 9 – 28, 2005	3	5	11
May 9 – 20, 2006	5	5	11
Aug. 17 – Oct. 9, 2006	11	20	23
Sept. 17 – Oct. 3, 2008	7	7	13
May 18 – June 6, 2009	6	9	12
Aug. 23 – 29, 2010	4	4	5
Sept. 28 – Oct. 17, 2010	5	8	10

Figure 6-2: Daily Relative Response Factors as a Function of Daily Maximum Base Modeled Concentrations for Monitors in the San Antonio MSA, 2006 to 2013

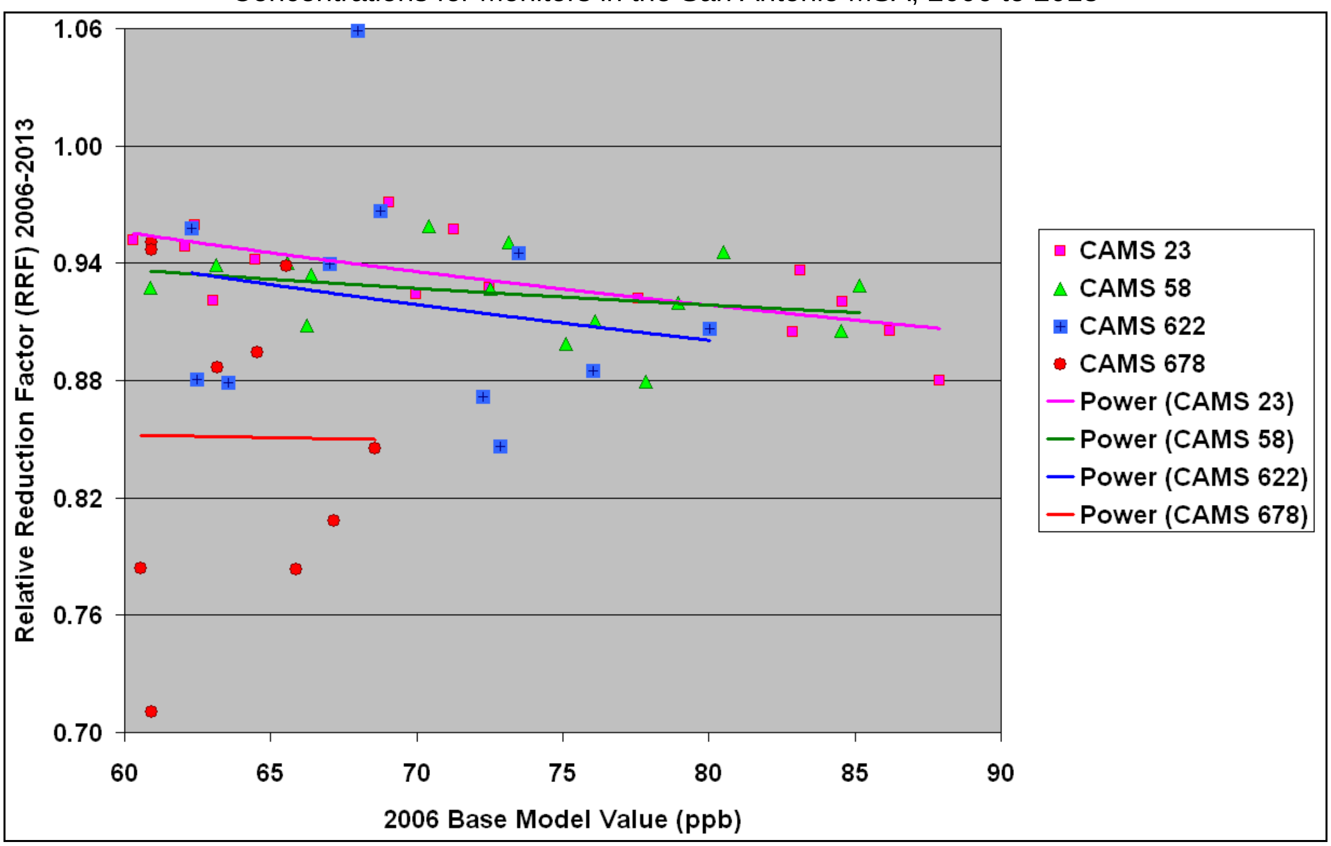


Table 6-4: Daily Peak 8-hour Ozone Concentrations at Each Monitor during High Ozone Events , 2010

Candidate Episodes	Date	C23	C58	C678	C59	C622	# w/Min. of 5 Days > 70 ppb	# w/Min. of 5 Days > 65 ppb	# w/Min. of 5 Days > 60 ppb	# w/Min. of 10 Days > 70 ppb	# w/Min. of 10 Days > 65 ppb	# w/Min. of 10 Days > 60 ppb
Aug. 25 – 29, 2010	8/25/2010	**62**	**65**	**62**	**72**	**70**	0	0	1 (C58)	0	0	0
	8/26/2010	**69**	**72**	**63**	**62**	**62**						
	8/27/2010	**80**	**80**	**74**	**69**	**71**						
	8/28/2010	**87**	**86**	**73**	**67**	**68**						
	8/29/2010	57	**62**	49	46	48						
Total at each Monitor	# Days > 70 ppb	2	3	2	1	1						
	# Days > 65 ppb	3	3	2	3	3						
	# Days > 60 ppb	4	5	4	4	4						
Sept. 28 – Oct. 16, 2010	9/28/2010	52	54	**62**	**67**	**69**	0	1 (C58)	4 (C23, C58, C59, and C622)	0	0	3 (C23, C58, and C678
	9/29/2010	55	54	57	**67**	**63**						
	9/30/2010	54	53	60	**73**	**70**						
	10/1/2010	53	57	55	**63**	**62**						
	10/5/2010	**62**	**65**		55	57						
	10/6/2010	**69**	**75**		59	**63**						
	10/7/2010	**69**	**75**		**62**	58						
	10/8/2010	**65**	**72**		**62**	**61**						
	10/15/2010	60	**66**	49	54	59						
	10/16/2010	**72**	**78**	**64**	60	**61**						
Total at each Monitor	# Days > 70 ppb	1	4	0	1	0						
	# Days > 65 ppb	3	5	0	3	2						
	# Days > 60 ppb	5	6	2	6	7						

In order to choose a high ozone event with a sufficient number of days to calculate monitored attainment, the variability of the mean RRF as a function of the number of days was determined. According to the EPA, "using information on the variability of the model response on individual days, we are able to measure the variability of the mean RRF on any subset of days. The analysis used datasets of 25, 50, and 100 days. The standard deviation of the daily RRFs was used to create the datasets and measure the variability of the RRFs."[73] The mean RRF for a 50-day sample size was 0.919 at C23 and 0.922 at C58. The standard deviation of the daily RRFs was 0.0217 at C23 and 0.0236 at C58 for 70 ppb.

The number of days needed to provide the mean RRF calculation at both C23 and C58 is provided in table 6-5. The number of days required for both a ± 1% and ± 2% accuracy at a 95% confidence interval for each proposed standard was calculated. Based on the 25-day sample, 11 to 13 days are needed to replicate the mean RRF to within ± 1% accuracy for a 95% confidence interval.
The following formula was used to calculate the number of days required to determine the mean RRF to within ± 1% and ± 2% at a 95% confidence interval:[74]

Formula (1)

$$n = \frac{N(\sigma^2)}{N(TSEM/2)^2 + \sigma^2}$$

Where:

n = Number of days (subset of mean RRF population)
N = Mean RRF population (e.g. 25 days)
σ = Standard deviation of the daily RRFs
TSEM = Twice the standard error of the mean RRF (e.g. ± 1%)

Table 6-5: Number of Days Needed to Replicate the 25/50/100 Day Dataset Mean RRF to within ± 1% and ± 2%, with a 95% Confidence Interval

Proposed Standard	CAMS	Mean RRF (50 days)	Standard Deviation (50 days)	± 1%			± 2%		
				25 days	50 days	100 days	25 days	50 days	100 days
60 ppb	C23	0.932	2.33%	12	16	18	5	5	6
	C58	0.925	2.07%	11	13	15	4	4	5
65 ppb	C23	0.925	2.46%	13	17	20	5	6	6
	C58	0.924	2.19%	11	14	16	5	5	5
70 ppb	C23	0.919	2.17%	11	14	16	4	5	5
	C58	0.922	2.36%	12	16	19	5	5	6

Table 6-6 lists the number of days when 8-hour average ozone concentrations exceeded 60 ppb, 65 ppb, and 70 ppb at CAMS 23 and CAMS 58 during each of the ozone events under analysis, and indicates whether those numbers meet the minimum days required to accurately replicate – within 1% and 2% -- the mean RRF of a 25-day dataset. Each high ozone event is also combined with the existing June 2 – 30, 2006 episode to determine if the number of days is within ± 1% and ± 2% accuracy. Only the Sept. 17 – Oct. 3, 2008 and the May 18 – June 6, 2009 combined with the existing June 2 – 30, 2006 episode have enough high ozone days at both monitors to meet the ± 1% accuracy test for an ozone standard set at 70 ppb.

[73] *Ibid*., p. 144.
[74] Brian Timin, EPA. "Draft Final Ozone Guidance Comments and Proposed Changes". Presented at the 3rd PM/RH/O3 Modeling Workshop, New Orleans, LA. Available online: http://cleanairinfo.com/modelingworkshop/presentations/O3_Guidance_Timin.pdf. Accessed 05/18/10

Table 6-6: Minimum Numbers of Days for Each High Ozone Event, 2005-2010

Candidate Episode	CAMS	> 70 ppb			> 65 ppb			> 60 ppb		
		# of Days	Meet ± 1%	Meet ± 2%	# of Days	Meet ± 1%	Meet ± 2%	# of Days	Meet ± 1%	Meet ± 2%
June 2 – 30, 2006	C23	7	**No**	Yes	8	**No**	Yes	13	Yes	Yes
	C58	12	Yes	Yes	17	Yes	Yes	21	Yes	Yes
April 2 – May 6, 2005	C23	1	**No**	**No**	5	**No**	Yes	15	Yes	Yes
	C58	3	**No**	**No**	5	**No**	Yes	15	Yes	Yes
May 20 – June 2, 2005	C23	3	**No**	**No**	5	**No**	Yes	5	**No**	Yes
	C58	2	**No**	**No**	5	**No**	Yes	8	**No**	Yes
Aug. 22 – Sept. 9, 2005	C23	2	**No**	**No**	8	**No**	Yes	9	**No**	Yes
	C58	5	**No**	Yes	9	**No**	Yes	11	Yes	Yes
Oct. 9 – Oct. 28, 2005	C23	2	**No**	**No**	4	**No**	**No**	5	**No**	Yes
	C58	2	**No**	**No**	5	**No**	Yes	7	**No**	Yes
May 9 – 20, 2006	C23	2	**No**	**No**	4	**No**	**No**	8	**No**	Yes
	C58	3	**No**	**No**	3	**No**	**No**	8	**No**	Yes
Aug. 17 – Oct. 9, 2006	C23	3	**No**	**No**	7	**No**	Yes	14	Yes	Yes
	C58	10	**No**	Yes	18	Yes	Yes	20	Yes	Yes
Sept. 17 – Oct. 3, 2008	C23	6	**No**	Yes	7	**No**	Yes	9	**No**	Yes
	C58	3	**No**	**No**	6	**No**	Yes	11	Yes	Yes
May 18 – June 6, 2009	C23	6	**No**	Yes	9	**No**	Yes	12	Yes	Yes
	C58	5	**No**	Yes	8	**No**	Yes	11	Yes	Yes
Aug. 23 – 29, 2010	C23	2	**No**	**No**	3	**No**	**No**	4	**No**	**No**
	C58	3	**No**	**No**	3	**No**	**No**	5	**No**	Yes
Sept. 28 – Oct. 17, 2010	C23	1	**No**	**No**	3	**No**	**No**	5	**No**	Yes
	C58	4	**No**	**No**	5	**No**	Yes	6	**No**	Yes

Candidate Episode	CAMS	> 70 ppb			> 65 ppb			> 60 ppb		
		# of Days	Meet ± 1%	Meet ± 2%	# of Days	Meet ± 1%	Meet ± 2%	# of Days	Meet ± 1%	Meet ± 2%
April 2 – May 6, 2005 + June 2 – 30, 2006	C23	8	**No**	Yes	13	Yes	Yes	28	Yes	Yes
	C58	15	Yes	Yes	17	Yes	Yes	27	Yes	Yes
May 20 – June 2, 2005 + June 2 – 30, 2006	C23	10	**No**	Yes	13	Yes	Yes	18	Yes	Yes
	C58	14	Yes	Yes	17	Yes	Yes	20	Yes	Yes
Aug. 22 – Sept. 9, 2005 + June 2 – 30, 2006	C23	9	**No**	Yes	16	Yes	Yes	22	Yes	Yes
	C58	17	Yes	Yes	21	Yes	Yes	23	Yes	Yes
Oct. 9 – Oct. 28, 2005 + June 2 – 30, 2006	C23	9	**No**	Yes	12	**No**	Yes	18	Yes	Yes
	C58	14	Yes	Yes	17	Yes	Yes	19	Yes	Yes
May 9 – 20, 2006 + June 2 – 30, 2006	C23	9	**No**	Yes	12	**No**	Yes	21	Yes	Yes
	C58	15	Yes	Yes	15	Yes	Yes	20	Yes	Yes
Aug. 17 – Oct. 9, 2006 + June 2 – 30, 2006	C23	10	**No**	Yes	15	Yes	Yes	27	Yes	Yes
	C58	22	Yes	Yes	30	Yes	Yes	32	Yes	Yes
Sept. 17 – Oct. 3, 2008 + June 2 – 30, 2006	C23	13	Yes	Yes	15	Yes	Yes	22	Yes	Yes
	C58	15	Yes	Yes	18	Yes	Yes	23	Yes	Yes
May 18 – June 6, 2009 + June 2 – 30, 2006	C23	13	Yes	Yes	17	Yes	Yes	25	Yes	Yes
	C58	17	Yes	Yes	20	Yes	Yes	23	Yes	Yes
Aug. 23 – 29, 2010 + June 2 – 30, 2006	C23	9	**No**	Yes	11	**No**	Yes	17	Yes	Yes
	C58	15	Yes	Yes	15	Yes	Yes	17	Yes	Yes
Sept. 28 – Oct. 17, 2010 + June 2 – 30, 2006	C23	8	**No**	Yes	11	**No**	Yes	18	Yes	Yes
	C58	16	Yes	Yes	17	Yes	Yes	18	Yes	Yes

The Oct. 9 – Oct. 28, 2005, May 9 – 20, 2006, Aug. 23 – 29, 2010, and Sept. 28 – Oct. 17, 2010 events combined with the existing June 2 – 30, 2006 episode did not have enough high ozone days to meet the RRF test with ± 1% accuracy at C23 for the 65 ppb threshold. Therefore, these episodes are not considered suitable modeling episodes. Below is a list of high ozone events and their ranking in accordance with EPA's modeling guidance on the minimum number of days per high ozone event, as calculated for a 65 ppb threshold[75].

- April 2 – May 6, 2005 - meets minimal requirements
- May 20 – June 2, 2005 - meets minimal requirements (TexAQS II Modeling Episode)
- Aug. 22 – Sept. 9, 2005 - meets minimal requirements
- Oct. 9 – Oct. 28, 2005 - not preferred
- May 9 – 20, 2006 - not preferred but could be combined with the existing June 2006 episode
- Aug. 17 – Oct. 9, 2006 - meets minimal requirements (TexAQS II Modeling Episode)
- Sept. 17 – Oct. 3, 2008 - meets minimal requirements
- May 18 – June 6, 2009 - meets minimal requirements
- Aug. 23 – 29, 2010 - not preferred
- Sept. 28 – Oct. 17, 2010 - not preferred

The episodes that are not preferred will be left in the list of high ozone events, so they can be analyzed against other EPA criteria.

6.3. *Air Quality Characteristics of High Ozone Events*

The initial candidate episode selection, as stated, is based on the number of high ozone days and if the episode occurred in 2005 or later. The list was further reduced by the first desirability factor: episodes that meet EPA guidance on the minimum number of high ozone days. However, for the remaining analysis, the 2010 high ozone events will be analyzed. Earlier potential episodes were analyzed in previous conceptual models for the San Antonio region. The analysis of these events will focus on the local and regional criteria listed in chapters 2, 3, and 4. From this analysis, candidates can become more or less desirable as a possible choice for future modeling. Rankings based on this desirability are presented in Chapter 7.

The ozone characteristics analyzed for modeling desirability include:

- Local ozone seasonal peaks
- Day of the week correlation
- One-hour and 8-hour peak correlation
- Site specific design value v. high ozone concentrations comparison (± 10 ppb of design value at each CAMS)

<u>Local Ozone Seasonal Peaks</u>

The San Antonio region typically experiences two *seasonal peaks* during the ozone season: May - June and August – October. All of the high ozone events in the San Antonio region during 2010 were within the two ozone seasonal peaks. .

[75] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze", Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 147. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

Day of the week correlation

Since it is common for high ozone concentrations to occur on weekend days in the San Antonio region, a Saturday or Sunday high ozone day should be included in a modeling episode. The June event on which the 2006 modeled episode was based included six weekend days when 8-hour ozone concentrations exceeded 60 ppb. This episode already provides sufficient days on weekends to meet the requirement of having a weekend day.

All high ozone events from 2005 to 2010 had days of high ozone on the weekend with the September 2006 episode having 4 high ozone days on the weekend greater than 70 ppb. Both the September 2008 and May 2009 high ozone events had three high ozone days on the weekend greater than 70 ppb. Although the April 2005 high ozone event had 6 days of high ozone on the weekends, the highest 8-hour average on the weekend was only 65 ppb. Similarly, the highest ozone value on a weekend day during the May 2006 event was only 62 ppb. Both the Aug. 23 – 29, 2010 and Sept. 28 – Oct. 17, 2010 high ozone events only had one weekend day that exceeded 65 ppb and 70 ppb.

One-hour to Eight-hour Correlation

There is a strong correlation between peak one-hour and eight-hour ozone on high ozone days in the San Antonio area. The average difference between one-hour and eight-hour ozone on high ozone days when eight-hour averages exceeded 60 ppb is 8.47 ppb with a standard deviation of 4.31 ppb at regulatory monitors (table 6-8). Anomalies, such as elevated one-hour high values, are not typical on high ozone days in San Antonio and these events should be avoided in a modeling episode.

Table 6-7: Comparison between 1-hour and 8-hour Ozone on High Ozone Days, 2005-2010

Proposed 8-hour Ozone Standard	Number of High Ozone Days	Average Peak 1 hour Ozone	Average Peak 8 hour Ozone	Difference	Standard Deviation
> 70 ppb	95	86.56	77.44	9.12	4.29
> 65 ppb	161	82.44	73.53	8.91	4.17
> 60 ppb	266	77.90	69.42	8.47	4.31

Table 6-8 lists the observed and predicted one-hour ozone for high ozone events in 2010. The predicted one-hour values are based on the recorded eight-hour values for the day. All the high ozone days during the Aug. 23 – 29, 2010 episodes were within one standard deviation. Although four of the high ozone days during Sept. 28 – Oct. 17, 2010 were not within one standard deviation, the differences were within two standard deviations. Appendix B contains the one-hour versus eight-hour scatter plots for each high ozone event.

Site Specific Design Value v. High Ozone Concentrations Comparison

According to the EPA selection criteria, episodes with high ozone values close to site-specific design values (ozone concentrations within ±10 ppb of design values for each CAMS) are more desirable for modeling. For this measure, a weighted modeling design value covering a five-year period that straddles the high ozone event, is calculated for each regulatory-sited CAMS monitor. A weighted modeling design value was used in the calculations because it "takes into account the emissions and meteorological variability that occurs over the full five year period".[76] Also, the weighted modeling design value "is thought to be more representative of the baseline emissions and meteorology

[76] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze", Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 22. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

period".[77] There are two regulatory monitors with a current modeling design value greater than 70 ppb: C23 and C58 (table 6-9).

Table 6-8: Observed and Predicted Correlation with Trend Line for 2010 High Ozone Events, Days > 60 ppb

Episode	Day	Peak 1-hour Ozone at Regulatory Monitors (ppb)	Peak 8-hour Ozone at Regulatory Monitors (ppb)	Difference between one-hour and 8-hour (ppb)	Predicted 1-Hour Daily High (ppb)	Observed 1 Hour - Predicted 1 Hour (ppb)	Within 1 Standard Deviation	Within 2 Standard Deviation
Aug. 25 – 29, 2010	8/25/2010	77	72	5	80	-3	Yes	Yes
	8/26/2010	79	72	7	80	-1	Yes	Yes
	8/27/2010	85	80	5	88	-3	Yes	Yes
	8/28/2010	98	87	11	95	3	Yes	Yes
	8/29/2010	70	62	8	70	0	Yes	Yes
Sept. 28 – Oct. 16, 2010	9/28/2010	83	69	14	77	6	**No**	Yes
	9/29/2010	83	67	16	75	8	**No**	Yes
	9/30/2010	85	73	12	81	4	Yes	Yes
	10/1/2010	68	63	5	71	-3	Yes	Yes
	10/5/2010	72	65	7	73	-1	Yes	Yes
	10/6/2010	84	75	9	83	1	Yes	Yes
	10/7/2010	85	75	10	83	2	Yes	Yes
	10/8/2010	80	72	8	80	0	Yes	Yes
	10/15/2010	81	66	15	74	7	**No**	Yes
	10/16/2010	91	78	13	86	5	**No**	Yes

Table 6-9: Weighted Modeling Design Values, San Antonio CAMS, 2010

CAMS Station	Weighted Modeling Design Value	**± 10 ppb of design value**
C23	75	**65 - 85**
C58	75	**65 - 85**
C59	67	**57 - 77**
C622	68	**68 - 88**
C678	69	**59 - 79**

In table 6-10, observed ozone concentrations are compared to the ± 10 ppb range of the weighted modeling design value. The right-hand columns list the percentage of those days that were within 60 ppb, 65 ppb, and 70 ppb. Using this percentage, the desirability of the episodes can be estimated for this criterion. "Ambient (and modeled) concentrations that are more than 10 ppb above the design value are preferable to episodes with ambient concentrations that are more than 10 ppb below the design value."[78] Greater priority should be placed on correlations with C23 and C58 compared to other monitors, since the weighted modeling design values at C58 and C23 are greater than 70 ppb.

[77] *Ibid*., p. 23.
[78] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze", Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 143. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

Table 6-10: High Ozone Event Peak 8-Hour Ozone on Days > 60 ppb for Each CAMS Compared to the Site-Specific Weighted Modeling Design Values and the Percentage of Daily Ozone Readings within ±10 ppb, 2010

Candidate Episode	Day	C23		C58		C59		C622		C678		% within 10 ppb					
												70 ppb Standard		**65 ppb Standard**		**60 ppb Standard**	
		Design Value	Peak Ozone	Design Value	Peak Ozone	Design Value	Peak Ozone	Design Value	Peak Ozone	Design Value	Peak Ozone	**All 5 CAMS**	**C23 & C58**	**All 5 CAMS**	**C23 & C58**	**All 5 CAMS**	**C23 & C58**
Aug. 25 – 29, 2010	25	75	62	75	65	67	72	68	70	69	62	**88.9%**	**80.0%**	**92.9%**	**83.3%**	**85.7%**	**66.7%**
	26		69		72		62		62		63						
	27		80		80		69		71		74						
	28		87		86		67		68		73						
	29		57		62		46		48		49						
Sept. 28 – Oct. 16, 2010	28	75	52	75	54	67	67	68	69	69	62	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**96.2%**	**90.9%**
	29		55		54		67		63		57						
	30		54		53		73		70		60						
	1		53		57		63		62		55						
	5		62		65		55		57		-						
	6		69		75		59		63		-						
	7		69		75		62		58		-						
	8		65		72		62		61		-						
	15		60		66		54		59		49						
	16		72		78		60		61		64						

Peak eight-hour average ozone concentrations on all days and at every monitor during the Sept. 28 – Oct. 16, 2010 high ozone event, were within 10 ppb of the weighted modeling design value for the > 65 ppb and >70 ppb thresholds. Although the relationship was not as strong for the Aug. 25 – 29, 2010 episode --80 percent of the values at C23 and C58 were within 10 ppb for the 70 ppb threshold -- these results are still high and the episode meets EPA's modeling eligibility guidelines.

6.4. *Meteorological Conditions during High Ozone Events*

Local Meteorology
Meteorological conditions for each ozone event were compared to meteorological conditions that occur on typical high ozone days. In chapter 3, ozone season days over several years were compared with various conditions to determine the variety of meteorological conditions associated with high ozone days. Table 6-11 lists temperature, wind speeds, precipitation, solar radiation, relative humidity, and wind direction for each high ozone event in 2010.

Meteorological conditions during the Aug. 23 – 29, 2010 high ozone event were typical, based on historical data. However, humidity (43%+) and solar radiation (1.0 langleys/min) were a little lower than typical on August 26th and 29th. Daily peak temperatures were lower than typical during the Sept. 28 – Oct. 17, 2010 high ozone event. Conversely, the high solar radiation, low humidity, and stagnated winds experienced during this timeframe were typical for high ozone days.

Wind Direction
Statistical analyses of C23 afternoon wind direction plots are located in Appendix C. the morning and afternoon wind directions at C58 and C23 during the Aug. 17 – Oct. 9, 2006 high ozone event most closely matched historical data for typical wind directions during periods of elevated ozone. . Wind directions at C23 and C58 during the April 2 – May 6, 2005, Oct. 9 – 28, 2005, and Sept. 17 – Oct. 3, 2008 high ozone events were close enough to typical high ozone event wind patterns to be considered adequate for modeling purposes.

On the other hand, wind directions during the May 9 – 20, 2006 and the May 18 – June 6, 2009 high ozone events were least likely to match directions on typical high ozone days (table 6-12). Morning and afternoon wind directions measured at C58 were particularly atypical of high ozone events. .

Mixing Heights
"Preference should be given to days with measurements aloft. These preferences result from a desire to incorporate a rigorous model performance evaluation as a part of the attainment demonstration."[79]
For a detailed description of mixing heights calculated from data measured at the TexAQS II Profiler installed near New Braunfels provides for the periods of June 30th, 2005 to October 15th, 2006, see the 2009 Conceptual Model for the San Antonio region. Profiler data is available for four high ozone events: August 22 – Sept. 9, 2005, October 9 – 28, 2005, June 2 – 30, 2006 (existing modeling episode), and August 17 – October 9, 2006 (TexAQS II modeling episode)

[79] U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group, April 2007. "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze", Research Triangle Park, North Carolina. EPA -454/B-07-002. p. 143. Available online: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf. Accessed 05/10/10.

Table 6-11: Comparison of 2010 High Ozone Event Meteorological Conditions to Typical Meteorological Conditions in the San Antonio Region on High Ozone Days > 60 ppb.

Candidate Episode	Date	Peak 1-hour ppb Ozone at regulatory monitors	Peak 8-hour ppb Ozone at regulatory monitors	Peak Temperature at C58 > 87.3°F	Wind Speed 6 am – 2 pm at C58 < 7.0 mph	Precipitation (inches) at C678 - None	Max. Solar Radiation at C58 > 1.172 langleys /min.	Relative Humidity at C5004 2p.m. < 40.9%	Morning Wind Direction at C58 (6-9)	Afternoon Wind Direction at C58 (12-15)	Back Trajectory Classification
Aug. 25 – 29, 2010	8/25/2010	77	72	91.5	**9.1**	0	1.177	37.8%	N	NE	Transport
	8/26/2010	79	72	**86.7**	6.9	0	**0.977**	**45.3%**	N	NE	Transport
	8/27/2010	85	80	92.5	6.4	0	1.190	24.3%	N	NE	Weak Transport
	8/28/2010	98	87	93.2	4.6	0	1.348	27.8%	NW	SE	Weak Transport
	8/29/2010	70	62	89.3	4.3	0	**1.000**	**43.9%**	NW	SE	Stagnated
Sept. 28 – Oct. 16, 2010	9/28/2010	83	69	**83.2**	2.9	0	1.270	30.4%	NW	N	Transport
	9/29/2010	83	67	**86.4**	3.6	0	1.263	32.1%	NW	NW	Stagnated
	9/30/2010	85	73	**84.1**	**7.4**	0	1.263	36.5%	NW	NE	Weak Transport
	10/1/2010	68	63	**84.6**	5.6	0	1.232	36.8%	NW	N	Stagnated
	10/5/2010	72	65	**75.6**	5.3	0	1.208	32.4%	NW	E	Weak Transport
	10/6/2010	84	75	**77.2**	3.9	0	1.225	23.3%	NW	SE	Stagnated
	10/7/2010	85	75	**78.8**	3.1	0	1.224	22.7%	NW	S	Stagnated
	10/8/2010	80	72	**79.6**	4.0	0	1.213	26.5%	NW	S	Stagnated
	10/15/2010	81	66	**83.3***	4.1	0	**1.170**	19.8%	NW	SE	Transport
	10/16/2010	91	78	**81.2***	3.4	0	**1.163**	29.0%	NW	S	Stagnated

*Peak Temperature at CAMS23

Table 6-12: Comparison of High Ozone Events Wind Direction to Typical Wind Direction on High Ozone Days for Each Proposed Standard, 2005-2009 (Absolute Percentage Difference)

Candidate Episode	60 ppb		65 ppb		70 ppb	
	C23	C58	C23	C58	C23	C58
June 2 – 30, 2006	48.3%	46.0%	45.5%	**38.9%**	**51.6%**	48.9%
April 2 – May 6, 2005	48.9%	49.7%	57.6%	67.9%	59.3%	76.4%
May 20 – June 2, 2005	72.6%	59.7%	75.8%	63.0%	77.8%	65.5%
Aug. 22 – Sept. 9, 2005	61.2%	74.2%	60.9%	69.5%	62.7%	84.0%
Oct. 9 – 28, 2005	58.1%	69.6%	58.1%	78.7%	62.4%	51.9%
May 9 – 20, 2006	72.9%	74.0%	81.5%	78.4%	84.6%	93.7%
Aug. 17 – Oct. 9, 2006	**39.1%**	**37.7%**	**44.4%**	41.6%	61.3%	**37.6%**
Sept. 17 – Oct. 3, 2008	70.6%	83.4%	66.7%	72.0%	51.4%	58.7%
May 18 – June 6, 2009	56.3%	85.7%	57.6%	88.7%	86.5%	112.3%
Aug. 25 – 29, 2010	88.1%	*100.2%*	111.6%	*97.4%*	103.2%	*120.4%*
Sept. 28 – Oct. 16, 2010	*99.7%*	78.8%	*115.8%*	79.1%	*107.8%*	81.5%

Aircraft Sampling

Aircraft sampling can provide useful information on meteorological conditions, ozone precursors, and ozone aloft. This data is invaluable because the aircraft can track urban and industrial plumes as they move downwind from emission sources. While CAMS monitors are stationary and only record ground level measurements, the data provided by aircraft sampling helps analysts to identify long distance transport and verify the ability of photochemical models to replicate atmospheric conditions at higher altitudes. . During two high ozone events, Aug. 22 – Sept. 9, 2005 and Aug. 17 – Oct. 9, 2006, aircraft were operating in Texas and took air quality samples as part of the TexAQS II study. Although most of these flights during the high ozone events occurred in the Houston, Dallas, and Northeast Texas area, they provide additional information on background levels of ozone and ozone precursors. The 2009 Conceptual Model for the San Antonio region provides a more detailed description of aircraft sampling operations and the data collected during these two high ozone events.

Extreme Weather during High Ozone Events

Meteorology during extreme weather can be difficult to model and could make an ozone event less desirable for modeling. Hurricanes and other tropical depressions can impact the weather in the San Antonio region. These types of systems often come inland from the Gulf of Mexico. Historical weather reports[80] and NOAA daily weather maps[81] were checked every day during high ozone events. There was no extreme weather during the Aug. 25 – 29, 2010 and Sept. 28 – Oct. 16, 2010 high ozone events.

6.5. *Background Ozone and Ozone Transport during High Ozone Events*

The combined numbers of air parcels by back trajectory octant and distance from C58 are used to typify air parcel distribution on high ozone days. About 72% of 100-meter 48-hour back trajectories ending at C58 came from the northeast, east, and southeast on high ozone days greater than 60 ppb. Most of the other back trajectories were from the south (13%) and north (10%). Back trajectories from the west, northwest, and southwest were rare on high ozone days. Figures 6-3 and 6-4 indicate the percentage of air parcels within each direction for each high ozone event in 2010. The maps include non-attainment and potential non-attainment areas within a 250-mile diameter centered around C58.

[80] National Climate Data Center. "Storm Events". http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms. Accessed 05/24/10.

[81] NOAA National Centers for Environmental Prediction, Hydrometeorological Prediction Center. Daily Weather Maps. Available online: http://www.hpc.ncep.noaa.gov/dailywxmap/index.html. Accessed 05/26/2010.

In table 6-13, the directional ratios of the air parcel hourly points from the HYSPLIT model for the combination of all 2005 - 2010 high ozone days greater than 60 ppb are compared to the directional ratios for each individual high ozone event including the modeled June 2006 episode. To be a strong candidate for modeling, the episode's back trajectory patterns should exhibit a high correlation with typical air parcel movement on high ozone days in San Antonio. For each high ozone event, the absolute difference was calculated using the following formula:

Formula (2)

$$AD = \Sigma [|(TRAJ_{episodeA} - TRAJ_{2000\text{-}2010A})|]$$

Where:

AD = Absolute Difference

$TRAJ_{episodeA}$ = Episode Back Trajectories Percentage for Direction A (North, NW, West, SW, South, SE, East, NE)

$TRAJ_{2000\text{-}2010A}$ = 2005-2010 Back Trajectories Percentage for Direction A

A lower absolute difference indicates a better fit with all back trajectories on days with peak ozone greater than 60 ppb.

During the June 2006 episode, a greater percentage of back trajectories originated from the southeast (39%) and south (23%) than is typical of high ozone days. Whereas the episode had fewer back trajectories from the east (16%) and northeast (14%) than typical for elevated ozone days. Combining the June 2006 episode with the October 2005, September 2006, or August 2005 high ozone event provides a variety of back trajectories that correspond well with typical back trajectories on high ozone days. The absolute total bias calculated for these episode combinations are only between 12 and 20 percent. As noted in Chapter 3, back trajectories exhibit different patterns in the spring seasonal ozone peak and the fall seasonal ozone peak. By combining a spring season episode, the existing June 2006, and a fall season episode listed above, the models can replicate a variety of back trajectory directions on typical high ozone days. Both the August 2010 and the October 2010 episode improved the variety of back trajectories, with a total bias of 25 – 26 percent.

When combining trajectory data for the May 2005 and June 2006 or the May 2006 and June 2006 episodes, there was poor correlation with typical back trajectory directions on high ozone days. Adding these two May episodes with the existing June 2006 episode did not significantly increase the variety of back trajectory directions available for modeling on high ozone days. By adding these high ozone events, the absolute bias only improved by 3-6 percent when compared to the June 2006 episode alone. These high ozone events would not be recommended for modeling based on the back trajectory analysis.

Hourly back trajectory distance was calculated for each high ozone event. For all high ozone days from 2005 to 2010, 73.3% of hourly counts were within 250 miles of C58, while 17.8% of the counts were between 250 miles and 500 miles of C58. The hourly back trajectory distances during the Aug. 25 – 29, 2010 and the Aug. 17 – Oct. 9, 2006 high ozone events matched almost exactly with back trajectories for high ozone days > 60 ppb. Most of the other high ozone events exhibited a good relationship between back trajectory distance on all high ozone days and high ozone during each episode.

Figure 6-3: August 25th to 29th, 2010 Candidate Photochemical Modeling Episode High Ozone Days > 60 ppb.

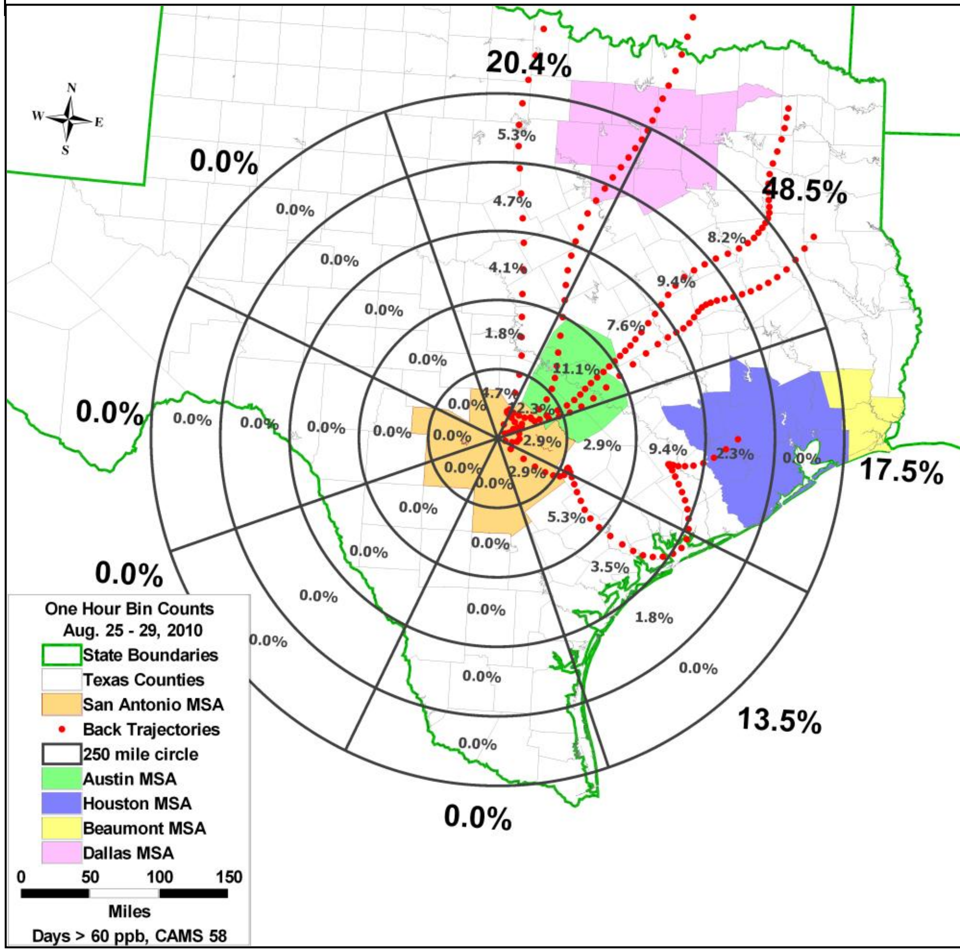


Figure 6-4: Sept. 28th to Oct. 16th, 2010 Candidate Photochemical Modeling Episode High Ozone Days > 60 ppb.

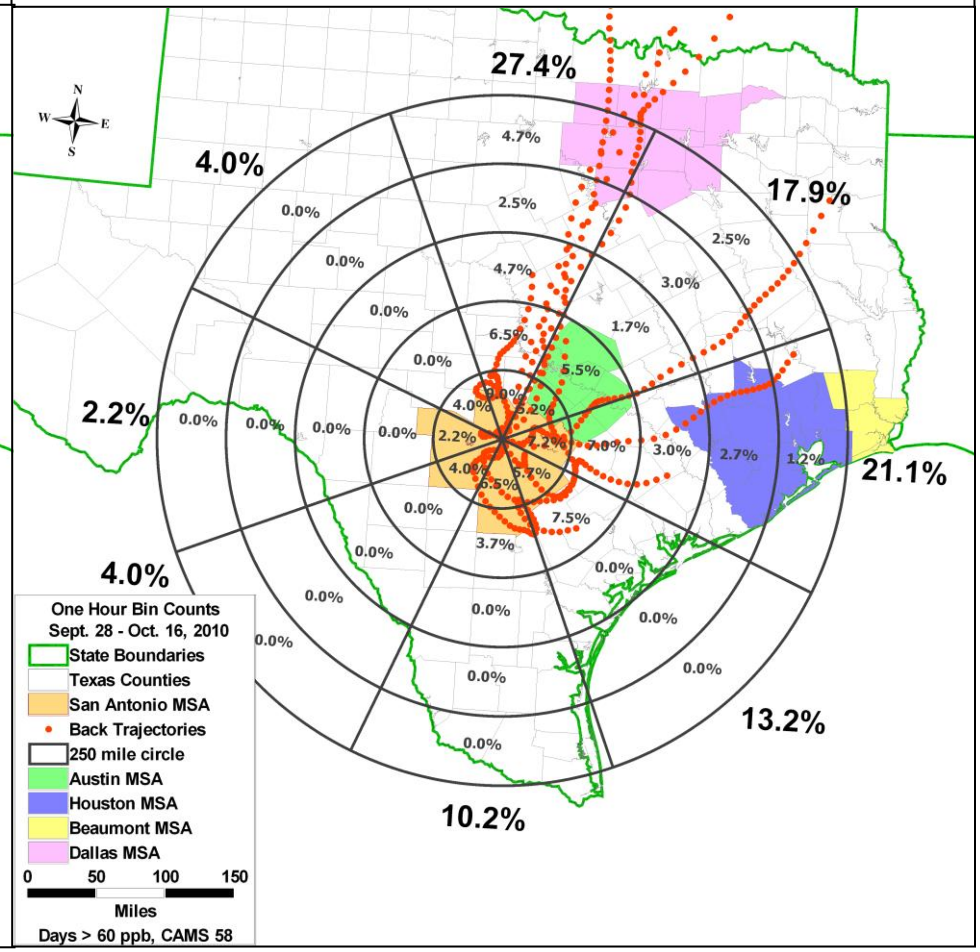


Table 6-13: Octant Percentages and Comparative Ratios for Each High Ozone Event Combined with the Existing June 2006 Episode's Back Trajectories on Days > 60 ppb

Exceedance Days	South West	West	North West	North	North East	East	South East	South	Absolute Total Bias
2005-2010 all exceedance days	2%	1%	2%	10%	24%	21%	27%	13%	-
June 2006 episode	2%	0%	1%	6%	14%	16%	39%	23%	44%
April 2005 and June 2006	2%	1%	2%	7%	14%	21%	35%	19%	29%
May 2005 and June 2006	2%	0%	0%	5%	16%	17%	39%	22%	41%
August 2005 and June 2006	2%	1%	1%	9%	16%	23%	33%	15%	20%
October 2005 and June 2006	2%	0%	0%	7%	24%	22%	28%	18%	12%
May 2006 and June 2006	1%	1%	2%	12%	15%	13%	34%	23%	38%
September 2006 and June 2006	2%	0%	0%	7%	22%	23%	30%	17%	16%
September 2008 and June 2006	1%	0%	1%	6%	37%	16%	24%	15%	30%
May 2009 and June 2006	1%	0%	0%	5%	16%	21%	38%	17%	31%
August 2010 and June 2006	1%	0%	0%	9%	20%	16%	34%	19%	26%
October 2010 and June 2006	2%	1%	2%	14%	15%	18%	30%	18%	25%

The only high ozone event that had a poor relationship with typical back trajectory distance was the May 9 – 20, 2006 high ozone period (table 6-15). Back trajectories during this high ozone event traveled significantly farther in 48 hours compared to average high ozone days. The results indicate there was significant transport into the San Antonio region during this episode.

Table 6-14: Distance from C58 Back Trajectory Counts and Percentages for Each High Ozone Event on Days > 60 ppb

Candidate Episode	< 250 miles		250 - 500 miles		> 500 miles		Absolute Difference
	Count	Percentage	Count	Percentage	Count	Percentage	
All Days 2005-2010	9,596	73.3%	2,335	17.8%	1,152	8.8%	-
June 2 – 30, 2006	756	65.1%	281	24.2%	124	10.7%	16.5%
April 2 – May 6, 2005	507	84.1%	89	14.8%	7	1.2%	21.5%
May 20 – June 2, 2005	288	71.6%	100	24.9%	14	3.5%	14.1%
Aug. 22 – Sept. 9, 2005	558	86.1%	82	12.7%	8	1.2%	25.5%
Oct. 9 – 28, 2005	438	65.0%	154	22.8%	82	12.2%	16.7%
May 9 – 20, 2006	292	49.3%	259	43.8%	41	6.9%	51.8%
Aug. 17 – Oct. 9, 2006	834	75.5%	213	19.3%	57	5.2%	7.3%
Sept. 17 – Oct. 3, 2008	561	89.9%	63	10.1%	0	0.0%	33.1%
May 18 – June 6, 2009	471	81.8%	97	16.8%	8	1.4%	16.8%
Aug. 25 – 29, 2010	171	71.3%	44	18.3%	25	10.4%	4.2%
Sept. 28 – Oct. 16, 2010	402	83.8%	73	15.2%	5	1.0%	20.8%

6.6. *Consideration for Regional Joint Modeling*

Beyond the EPA recommended criteria listed above, a major factor involved in the selection of a new photochemical modeling episode is the cost of photochemical model development. If episode modeling can be combined with existing modeling efforts in other cities or several regions can share the cost of modeling, a high ozone event can become more desirable. The proposed lowering of the NAAQS ozone concentration standard jeopardizes the attainment status of several Texas regions; therefore it would be efficient to develop any new modeling episode with these regions. Table 6-16 shows there were high ozone readings in other Texas cities during every 2010 high ozone event occurring in the San Antonio region. During the Aug. 25 – 29, 2010 and Sept. 28 – Oct. 16, 2010 high ozone events, many other regions in the state had exceedances above the proposed standard.

Table 6-15: High Ozone Event High Ozone Days Maximum 8-Hour Averages for Selected Cities within Texas, 2010

Candidate Episode	Date	San Antonio	Austin	Corpus Christi	Victoria	Houston	Dallas	Tyler/ Longview	Waco	Beaumont
Aug. 25 – 29, 2010	8/25/2010	**72**	**72**	**76**		**81**	**67**	**67**	**65**	**68**
	8/26/2010	**72**	**72**	**82**	**70**	**76**	**82**	**62**	**64**	**67**
	8/27/2010	**80**	**80**	**80**	**73**	**88**	**92**	**74**	**75**	**68**
	8/28/2010	**87**	**78**	**80**	**68**	**68**	**91**	**71**	**75**	
	8/29/2010	**62**					**67**			
Sept. 28 – Oct. 16, 2010	9/28/2010	**69**	**64**	**64**		**85**	**64**	**62**		**76**
	9/29/2010	**67**	**64**	**74**	**65**	**88**		**62**		**81**
	9/30/2010	**73**	**71**	**72**	**67**	**88**	**63**	**66**	**66**	**76**
	10/1/2010	**63**	**64**	**75**	**65**	**86**				**70**
	10/2/2010			**74**	**61**	**74**			**62**	**62**
	10/3/2010			**72**						
	10/4/2010					**66**				
	10/5/2010	**65**					**65**	**63**		
	10/6/2010	**75**	**69**	**71**		**78**	**67**	**78**	**64**	**62**
	10/7/2010	**75**	**70**	**83**	**61**	**92**	**66**	**80**	**63**	**80**
	10/8/2010	**72**	**76**	**79**	**65**	**94**	**72**	**74**	**75**	**85**
	10/9/2010					**88**	**62**	**77**		**74**
	10/10/2010					**63**		**78**		
	10/13/2010			**63**		**67**				
	10/14/2010					**65**				
	10/15/2010	**66**		**70**		**87**				**72**
	10/16/2010	**78**	**73**	**70**	**64**	**95**	**68**	**71**	**72**	**78**

7. CONCLUSION AND SUMMARY OF HIGH OZONE EVENTS

Forecasting future air quality and modeling air quality control strategies are among the basic elements of a SIP. Since control strategy modeling requires extensive technical analyses of control strategy impacts under the variety of meteorological conditions that are conducive of high ozone, it is important that each photochemical modeling episode be built upon a time period characterized by such meteorological conditions. The conceptual model examines air quality trends, meteorology patterns, precursor emissions, and ozone transport on high ozone days in San Antonio and serves as a basis for ranking candidate episodes. Continued research on ozone formation in San Antonio is necessary to ensure the region meets attainment standards.

Since 2004, San Antonio's 8-hour ozone design value has decreased significantly from 91 ppb to 75 ppb. The 2008-2010 design value (truncated average) was 75 ppb at C23 and 75 ppb at C58, indicating that the San Antonio region ended 2010 with two regulatory monitors exceeding 70 ppb, the high end of the range under consideration for the revised ozone standard. Although current design values at all regulatory-sited monitors are above 65 ppb – the mid-point of the range under consideration for the revised standard-- significant reductions in the number of exceedances have occurred from 2006 through 2010. Reductions in the numbers of exceedances of 70 ppb and 65 ppb were particularly steep, with 2007-2010 average number of exceedance days dropping 61% and 53%, respectively, from the 2000-2006 averages. A cluster of regulatory and non-regulatory monitors located northwest of the San Antonio urban core (CAMS 23, 58, 502, 503, and 505) often records ozone values exceeding the proposed revision to the standard. Local and transported emissions often impact these monitors on high ozone days.

There is no ~~a~~ significant variability in the frequency of high ozone days by the day of the week. Based on data for ozone concentrations that exceeded the range of values under consideration for the revised standard, high ozone days occurred on both weekdays and on weekends. Between 2005 and 2010, 26.6% percent of high ozone days > 60 ppb occurred on the weekends. A different mixture of emission sources could be impacting ozone formation on the weekend than weekdays and different control strategies may be needed to reduce peak ozone concentrations.

Local conditions that typify high ozone events include light winds over Texas, limited frontal movement, no precipitation, and clear skies. Typical local meteorological conditions that are conducive to ozone formation include days with no precipitation, low atmospheric moisture content present in the afternoon, and clear skies. There was no significant correlation between peak temperature and ozone readings. Mixing heights are typically lower in the early morning hours and experience a rapid rise in the late morning through early afternoon on high ozone days.

The timing, location, and intensity of ozone events are influenced by the interaction between local and regional wind patterns. The wind vectors on high ozone days were more stagnated and frequently originated from the east and northeast. Often on high ozone days, the wind at C23 slowly changed direction at the monitor from the north to the east in a clockwise fashion during the day. The directions of the wind vectors indicate emissions transport occurs from the north and northeast on high ozone days and combines with local and transported emissions from the urban area east of the monitor later in the day to form ozone. C58 wind vectors show there is a flow reversal of winds arriving at the monitors from the northwest in the morning before 7:00 to out of the southeast later in the day. Such shifts in winds with a rotational wind pattern is similar to observed winds in Houston when heating of the atmosphere in the morning mixes winds aloft down to the surface. These wind patterns can facilitate recirculation of pollutants, allowing local ozone precursor emissions and ozone to combine with transported and local emissions from the previous day and form greater concentrations of ozone.

The strongest multivariate correlation at the 60 ppb threshold was back trajectory direction - diurnal temperature change and humidity - back trajectory distance. The strongest multivariate correlation for days over the 65 ppb and 70 ppb standard was humidity – back trajectory distance. Wind Speed – humidity and humidity – back trajectory direction were also strongly correlated with high ozone days. The lowest correlation with high ozone days was wind speed - afternoon wind direction, temperature - wind speed, and temperature - afternoon wind direction.

Of the five NO_X monitors in the San Antonio area, only one, C27, records moderate amounts of NO_X emissions, likely due to its proximity to downtown and major highways. Although C27 records the highest NO_X in the region, NO_X emissions at the monitor significantly decreased from 2000 to 2010. The decrease in NO_X can be attributed to controls put on major NO_X sources including power plants and cement kilns, and most importantly, significant reductions of NO_X emissions from on-road and off-road vehicles. Local NO_X emissions should continue a downward trend, in large part due to improvements in vehicle emission standards, while local VOC emissions will likely remain steady. C59 is an upwind monitor site on most high ozone days and NO_X readings are low at the monitor, indicating that there was not a significant amount of NO_X being transported into San Antonio from the southeast from 2000 to 2010.

Surface back trajectories on days with low ozone were predominately from the southeast, while winds on high ozone days were from the northeast, east, and southeast. A similar pattern occurred with 1,000-meter back trajectories in which days of high ozone values are associated with winds that originate from the northeast, east, and southeast. Back trajectories on high ozone days originated closer to San Antonio and were shorter, indicating transport level winds are often weaker on high ozone days. End points of 48-hour back trajectories on low ozone days tended to originate far out in the Gulf of Mexico.

The difference between the maximum peak ozone readings and the minimal peak ozone readings at ozone monitors on high ozone days > 60 ppb from 2005-2010 was 14.3 ppb or 20.5%, suggesting that San Antonio adds an estimated 14 ppb or 20% to the ambient ozone concentrations. Ozone readings at upwind monitors have decreased by an average of 2.4 ppb per year since 2006 on all days, and by 7.1 ppb on days when 8-hour averages exceeded 60 ppb. Likewise, the number of high ozone days > 60 ppb at upwind monitors decreased 82 percent between 2005 and 2010. There was a similar decrease in the number of high ozone days at the upwind monitors for the 65 ppb (89%) and 70 ppb (93%) thresholds. Although the amount of transported ozone has decreased over the last five years, local contribution to ozone has not changed significantly in the last six years

Aircraft sampling indicated large ozone plumes from upwind urban areas and industrial facilities could impact areas hundreds of miles downwind including the San Antonio area. This may increase the ozone at downwind monitor sites and cause the region to have difficulty attaining a stricter 8-hour ozone standard. Additionally, new point sources being built in Texas may increase ozone-forming emissions in the San Antonio area in the future and possibly weaken the region's ability to meet federal ozone standards for years to come.

From April through June, there is a seasonal increase in the number of high ozone days in most Texas cities. This period represents the first and longest high ozone seasonal peak that San Antonio typically experiences. However, by early July the number of high ozone days decline. The next seasonal increase covers a period beginning in August and ending in late October, during which the frequency of high ozone days is slightly lower than the spring period.

Analysis of seasonal trends showed that back trajectories arrive from progressively shorter distances from June through September, indicating progressively stagnated air parcels. The directions of back trajectory origin have strong southeast and south components, with a minor east component during the months of June, July, and August. In September, however, back trajectories originate with almost equal frequency from the northeast, east, and southeast, with small percentages originating from the north and south.

There is a significant amount of ozone transport during the spring and fall ozone season peaks. Transported ozone is highest in April, but average local contribution is lower in April. Transport is lowest in July before increasing again in the late summer and fall. The summer months of June through August account for the largest fractions of local contributions to ozone. A combination of greater tropospheric-stratospheric air exchange combined with higher North American stratospheric ozone levels during the early months of the ozone season may be partially responsible for the higher ground level ozone observed in San Antonio during these months. Likewise, the cessation of this phenomenon could explain the decrease in ground level ozone from late June through July, which occurs before air mass stagnation and northeasterly transport contribute to an increase in ground level ozone measurements during the fall ozone seasonal peak.

The meteorology and transport patterns during high ozone events from 2005 to 2010 were analyzed to determine whether the episodes were suitable for photochemical modeling. To be suitable for modeling, high ozone events should include days with observed concentrations that are close to site-specific design values and reflect meteorological conditions that are commonly observed. In ranking the high ozone events for desirability, the selection criteria were reviewed and all events were weighted against typical meteorological conditions on high ozone days. The first step was to compare each episode with desirable criteria. The recommended criteria used for episode selection are listed below. Ozone and meteorological conditions evaluated for each high ozone event included:

- ✓ **Number of High Ozone Days**
  - *Number of Days at C23 Ozone > proposed standard*
  - *Number of Days at C58 Ozone > proposed standard*
- ✓ **Typical Seasonal and Daily Variation of High Ozone Days**
  - *Within Ozone Seasonal Peaks*
  - *Weekend High Ozone Day*
- ✓ **Monitored Ozone Values**
  - *One-Hour/8-hour Correlation*
  - *Percent of High Ozone Days ± 10 ppb of Design Value*
  - *Occurs during the three-year period used to calculate the design value*
- ✓ **Typical Local Meteorological Characteristics of High Ozone Days**
  - *Temperature* - high (>87.3^{o} F)
  - *Wind Speed at Monitors* - low speed (<7.0 mph)
  - *Precipitation* - no precipitation
  - *Solar Radiation/Cloud Cover* - generally clear skies (>1.172 langleys/min.)
  - *Relative Humidity* - low afternoon humidity (<40.9% relative humidity)
  - *Wind Direction at C23 and C58*
- ✓ **Typical Regional Meteorological Characteristics on High Ozone Days**
  - *Extreme Weather Events* - unusual meteorological events
  - *Back Trajectories*

- ✓ **Meteorological Data Availability (TexAQS II)**
- ✓ **Joint Modeling (Cost Reduction)**

Tables 7-1, 7-2, and 7-3 list the degrees of desirability from 0 to 4 for each high ozone event based on the above criteria for a range of ambient ozone values: 60 ppb, 65 ppb, and 70 ppb. The following degrees of desirability are provided on the table:

- White = 0 / excellent
- Yellow = 1 / good
- Light Orange = 2 / fair
- Orange = 3 / weak
- Red = 4 / poor

The methodologies used to determine the degrees of desirability are listed in Appendix D. These degrees (0-4) are only relevant within each category and do not have the same value from one category to another. It is important for a high ozone event to have high readings at both C58 and C23 because they are the regulatory monitors currently in excess of 70 ppb, the high end of the range under consideration for the proposed revision to the ozone standard. In order to test control strategies for possible ozone reduction, the episode should demonstrate characteristics typical of periods of high ozone at the regulatory monitors that record the highest ozone in the region and at as many additional monitors as possible.

Table 7-4 provides a summary of the ranking for each high ozone event that occurred between 2005 and 2010 with respect to the thresholds under consideration for the proposed revision to the ozone standard: 60 ppb, 65 ppb, and 70 ppb. The Aug. 17 – Oct. 9, 2006 high ozone event and the current June 2 – 30, 2006 modeling episode had the highest rankings. The Aug. 17 – Oct. 9, 2006 high ozone event extended a sufficient number of days at C58 to model and data collected during the event indicated typical ozone readings, typical wind directions on high ozone days, and typical back trajectories on high ozone days. Furthermore, there are extensive meteorological and ozone data sets available for this time period that would benefit modeling efforts. However, this event extends a significantly longer period of time than episodes modeled in the past, which might increase costs.

Three other high ozone events were characterized by typical ozone and meteorological conditions: Aug. 22 – Sept. 9, 2005, Sept. 17 – Oct. 3, 2008, and May 18 – June 6, 2009. The remaining six high ozone events had poor scores in several categories and these episodes would not be ideal candidates for modeling. The Sept. 17 – Oct. 3, 2008 and May 18 – June 6, 2009 high ozone events are desirable from the standpoint that they occurred within the last 3 years. However, these candidates lack the extensive meteorological data sets available for episodes that occurred during TexAQS II and these episodes would require additional costs to model because no other entity is currently modeling these periods. One-hour peak ozone on four days during the Sept. 17 – Oct. 3, 2008 high ozone event was significantly higher than the 8-hour average including September 26th and October 1st, when the one-hour ozone values peaked at 94 ppb and 99 ppb. Wind direction at C58 was not typical during the May 18 – June 6, 2009 high ozone event and back trajectories analysis indicates winds were more dominated by a southeastern flow.

Table 7-1: Ratings for High Ozone Events Selection Criteria for the San Antonio Region, 2005-2010 Based on Days in which 8-hour Ozone Averages > 60 ppb

High Ozone Event	# Days at **C23** Ozone > 60 ppb	# Days at **C58** Ozone > 60 ppb	Within Ozone Seasonal Peak	Weekend High Ozone Day	One-Hour/8-hour Correlation	% of High Ozone Days ± 10 ppb of Design Value	Within the Latest Design Value	Typical Local Meteorological Conditions	Wind Direction at C23 and C58	Extreme Weather Events	Back Trajectories	Meteorological Data Availability (TexAQS II)	Joint Modeling (Cost Reduction)	Sum of Scores
June 2 – 30, 2006	0	0	0	0	1	3	2	0	0	0	2	0	0	8
April 2 – May 6, 2005	0	0	0	0	3	4	3	4	0	0	0	2	4	20
May 20 – June 2, 2005	3	2	0	0	0	4	3	2	2	2	1	1	0	20
Aug. 22 – Sept. 9, 2005	1	0	0	0	2	4	3	0	2	2	0	0	4	18
Oct. 9 – 28, 2005	3	2	0	0	1	3	2	4	1	2	3	0	4	25
May 9 – 20, 2006	2	2	0	0	1	3	2	1	2	0	3	1	4	21
Aug. 17 – Oct. 9, 2006	0	0	0	0	1	3	2	2	0	0	0	0	0	8
Sept. 17 – Oct. 3, 2008	1	0	0	0	1	1	0	1	2	0	4	2	4	16
May 18 – June 6, 2009	0	0	0	0	1	0	0	2	2	0	1	2	4	12
Aug. 25 – 29, 2010	4	3	0	0	0	1	0	1	3	0	4	2	4	22
Sept. 28 – Oct. 16, 2010	3	3	0	1	3	0	0	1	3	0	2	2	4	22

*Note: The smaller the number, the better the rating. However, ***all aspects are not equal in value***, so the final rating is for comparison, only. Before episode selection, all aspects must be weighed based on the contribution to the episode as a whole.

Table 7-2: Ratings for High Ozone Events Selection Criteria for the San Antonio Region, 2005-2010 Based on Days in which 8-hour Ozone Averages > 65 ppb

High Ozone Event	# Days at **C23** Ozone > 65 ppb	# Days at **C58** Ozone > 65 ppb	Within Ozone Seasonal Peak	Weekend High Ozone Day	One-Hour/8-hour Correlation	% of High Ozone Days ± 10 ppb of Design Value	Within the Latest Design Value	Typical Local Meteorological Conditions	Wind Direction at C23 and C58	Extreme Weather Events	Back Trajectories	Meteorological Data Availability (TexAQS II)	Joint Modeling (Cost Reduction)	Sum of Scores
June 2 – 30, 2006	2	0	0	0	1	1	2	0	0	0	2	0	0	8
April 2 – May 6, 2005	3	3	0	2	0	4	3	3	1	0	0	2	4	25
May 20 – June 2, 2005	3	3	0	0	0	3	3	1	2	2	1	1	0	19
Aug. 22 – Sept. 9, 2005	2	1	0	1	2	4	3	0	2	2	0	0	4	21
Oct. 9 – 28, 2005	4	3	0	0	3	2	2	4	2	2	3	0	4	29
May 9 – 20, 2006	4	4	0	2	1	1	2	1	2	0	3	1	4	25
Aug. 17 – Oct. 9, 2006	2	0	0	0	1	1	2	2	0	0	0	0	0	8
Sept. 17 – Oct. 3, 2008	2	3	0	0	0	0	0	0	2	0	4	2	4	17
May 18 – June 6, 2009	2	2	0	0	1	0	0	1	3	0	1	2	4	16
Aug. 25 – 29, 2010	4	4	0	1	0	0	0	1	4	0	4	2	4	24
Sept. 28 – Oct. 16, 2010	4	3	0	1	4	0	0	1	4	0	2	2	4	25

*Note: The smaller the number, the better the rating. However, ***all aspects are not equal in value***, so the final rating is for comparison, only. Before episode selection, all aspects must be weighed based on the contribution to the episode as a whole.

Table 7-3: Ratings for High Ozone Events Selection Criteria for the San Antonio Region, 2005-2010 Based on Days in which 8-hour Ozone Averages > 70 ppb

High Ozone Event	# Days at **C23** Ozone > 70 ppb	# Days at **C58** Ozone > 70 ppb	Within Ozone Seasonal Peak	Weekend High Ozone Day	One-Hour/8-hour Correlation	% of High Ozone Days ± 10 ppb of Design Value	Within the Latest Design Value	Typical Local Meteorological Conditions	Wind Direction at C23 and C58	Extreme Weather Events	Back Trajectories	Meteorological Data Availability (TexAQS II)	Joint Modeling (Cost Reduction)	Sum of Scores
June 2 – 30, 2006	2	0	0	0	1	0	2	0	1	0	2	0	0	8
April 2 – May 6, 2005	4	4	4	2	1	4	3	4	2	0	0	2	4	34
May 20 – June 2, 2005	4	4	0	2	1	1	3	3	2	2	1	1	0	24
Aug. 22 – Sept. 9, 2005	4	3	0	1	1	1	3	0	2	2	0	0	4	21
Oct. 9 – 28, 2005	4	4	0	1	2	0	2	4	1	2	3	0	4	27
May 9 – 20, 2006	4	4	0	2	1	0	2	1	3	0	3	1	4	25
Aug. 17 – Oct. 9, 2006	4	1	0	0	0	0	2	1	0	0	0	0	0	8
Sept. 17 – Oct. 3, 2008	3	4	0	0	0	0	0	0	1	0	4	2	4	18
May 18 – June 6, 2009	3	3	0	0	2	0	0	1	4	0	1	2	4	20
Aug. 25 – 29, 2010	4	4	0	1	0	0	0	1	4	0	4	2	4	24
Sept. 28 – Oct. 16, 2010	4	4	0	1	1	0	0	1	4	0	2	2	4	23

*Note: The smaller the number, the better the rating. However, ***all aspects are not equal in value***, so the final rating is for comparison, only. Before episode selection, all aspects must be weighed based on the contribution to the episode as a whole.

Table 7-4: Summary of Scores for each High Ozone Event, 2005-2010

High Ozone Event	Score for Different Proposed Standards			Average Score
	60 ppb	65 ppb	70 ppb	
June 2 – 30, 2006	8	8	8	8
April 2 – May 6, 2005	20	25	34	26
May 20 – June 2, 2005	20	19	24	21
Aug. 22 – Sept. 9, 2005	18	21	21	20
Oct. 9 – 28, 2005	25	29	27	27
May 9 – 20, 2006	21	25	25	24
Aug. 17 – Oct. 9, 2006	8	8	8	8
Sept. 17 – Oct. 3, 2008	16	17	18	17
May 18 – June 6, 2009	12	16	20	16
Aug. 25 – 29, 2010	22	24	24	23
Sept. 28 – Oct. 16, 2010	22	25	23	23

Although the Aug. 25 – 29, 2010 and Sept. 28 – Oct. 16, 2010 high ozone events are the latest potential modeling periods, each event has undesirable factors that could influence modeling decisions. The Aug. 25 – 29, 2010 includes only two days when eight-hour ozone averages were above 70 ppb at C23 and only three days above 70 ppb at C58. Wind directions and back trajectories were not typical on all high ozone days during this period. In addition, wind directions were not typical on high ozone days during the Sept. 28 – Oct. 16, 2010 high ozone event. This event only contains 1one day above 70 ppb at C23 and four days above 70 ppb at C58.

In table 7-5, the candidates are divided into three groups: suitable candidate episodes, other potential desirable candidate episodes, and undesirable candidate episodes. The table lists a summary of the high ozone event choices and significant characteristics. This ordering is not steadfast and is based on the desired selection criteria of each episode. No value was placed on the importance of the criteria; thus, judgment should not lie solely on the ratings in this conclusion, but should be based on the analysis of the data with respect to the importance it bears on modeling. These candidates represent the choices available for a new photochemical model. In making a final selection for potential future photochemical modeling episodes, these aspects as well as any new data, should be considered.

Table 7-5: Summary of Ozone and Meteorological Characteristics of High Ozone Events

High Ozone Event	Desirable Characteristics	Undesirable Characteristic
Suitable Candidate Episodes		
Aug. 17 – Oct. 9, 2006	• Contains 10 days above 70 ppb at C58 • Within ozone seasonal peaks • Typical local meteorological conditions on high ozone days • Typical wind directions on high ozone days • Typical back trajectories on high ozone days • TexAQS II meteorological and ozone data available • Model is already under development by other areas in Texas	• Contains only 3 days above 70 ppb at C23 • Long episode that might increase the cost of modeling
Other Potential Desirable Candidate Episodes		
May 18 – June 6, 2009	• Contains 9 days above 65 ppb at C23 • Within ozone seasonal peaks • Typical local meteorological conditions on high ozone days • Episode is within the latest design value	• Wind directions are not typical of high ozone days • Back Trajectories are not typical on all high ozone days
Sept. 17 – Oct. 3, 2008	• Within ozone seasonal peaks • Typical local meteorological conditions on high ozone days • Episode is within the latest Design Value • Typical Wind Directions on high ozone days	• Contains only 3 days above 70 ppb at C58 • Back trajectories are not typical of high ozone days
Aug. 22 – Sept. 9, 2005	• Within ozone seasonal peaks • Typical local meteorological conditions on high ozone days • Typical back trajectories on high ozone days • TexAQS II meteorological and ozone data available	• Contains only 2 days above 70 ppb at C23 • Wind directions are not typical of high ozone days
Undesirable Candidates Episodes		
May 20 – June 2, 2005	• Within ozone seasonal peaks • TexAQS II meteorological and ozone data available • Model is already under development by other areas in Texas	• Contains only 3 days above 70 ppb at C23 • Contains only 2 days above 70 ppb at C58 • Did not have any weekend exceedances (70 ppb standard) • Back trajectories are not typical of all high ozone days
Aug. 25 – 19, 2010	• Episode is within the latest design value • Good correlation between 1-hour and 8-hour ozone values • Typical local meteorological conditions on high ozone days	• Contains only 2 days above 70 ppb at C23 • Contains only 3 days above 70 ppb at C58 • Wind directions are not typical on high ozone days • Back trajectories are not typical of all high ozone days
Sept. 28 – Oct. 16, 2010	• Episode is within the latest Design Value	• Contains only 1 day above 70 ppb at C23 • Contains only 4 days above 70 ppb at C58 • Wind Directions are not typical on high ozone days
May 9 – 20, 2006	• Good correlation between 1-hour and 8- hour ozone values • Typical local meteorological conditions on high ozone days • TexAQS II meteorological and ozone data available	• Contains only 4 days above 65 ppb at C23 • Contains only 3 days above 65 ppb at C58 • Wind directions are not typical on high ozone days • Back trajectories are not typical of all high ozone days

High Ozone Event	Desirable Characteristics	Undesirable Characteristic
April 2 – May 6, 2005	• **Good correlation between 1-hour and 8-hour ozone values**	• **Contains only 1 day above 70 ppb at C23** • **Contains only 3 days above 70 ppb at C58** • **Only 25% of high ozone days are ± 10 ppb of the 70 ppb DV (C23 & C58)** • **Not within ozone seasonal peaks** • **Did not have any weekend exceedances of 70 ppb** • **Does not have typical local meteorological conditions** • **Back trajectories are not typical on high ozone days**
Oct. 9 – 28, 2005	• **Typical back trajectories on high ozone days** • **TexAQS II meteorological and ozone data available**	• **Contains only 2 days above 70 ppb at C23** • **Contains only 2 days above 70 ppb at C58** • **Not within ozone seasonal peaks** • **Does not have typical local meteorological conditions**

APPENDIX A: DAYS > 60 PPB AND POSSIBLE MODELING EPISODES, 2010

Date	Day of Week	Peak 1 Hour	Peak 8 Hour	Notes
4/20/2010	Tue	76	64	
4/28/2010	Wed	68	63	
5/3/2010	Mon	65	62	
5/4/2010	Tue	68	65	
5/5/2010	Wed	75	70	
5/7/2010	Fri	73	61	
5/27/2010	Thu	70	65	
5/28/2010	Fri	96	86	
5/29/2010	Sat	74	71	
5/30/2010	Sun	68	62	
6/4/2010	Fri	73	68	
8/17/2010	Tue	77	66	
8/18/2010	Wed	76	64	
8/25/2010	Wed	77	72	Candidate Episode
8/26/2010	Thu	79	72	
8/27/2010	Fri	85	80	
8/28/2010	Sat	98	87	
8/29/2010	Sun	70	62	
9/4/2010	Sat	73	61	
9/5/2010	Sun	70	66	
9/16/2010	Thu	82	65	
9/28/2010	Tue	83	69	Candidate Episode
9/29/2010	Wed	83	67	
9/30/2010	Thu	85	73	
10/1/2010	Fri	68	63	
10/5/2010	Tue	72	65	
10/6/2010	Wed	84	75	
10/7/2010	Thu	85	75	
10/8/2010	Fri	80	72	
10/15/2010	Fri	81	66	
10/16/2010	Sat	91	78	

APPENDIX B: PEAK 1-HOUR AND 8-HOUR OZONE

Figure B-1: Peak 1-hour and 8-hour Ozone, June 2006 Existing Episode

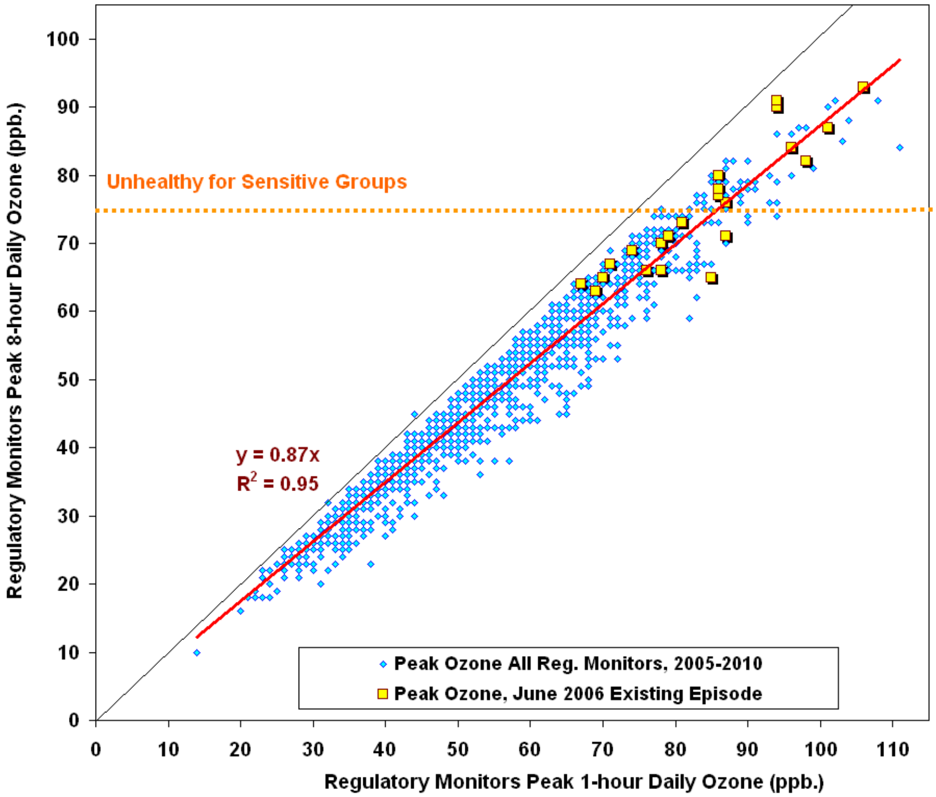


Figure B-2: Peak 1-hour and 8-hour Ozone, Aug. 25 – 29, 2010 High Ozone Event

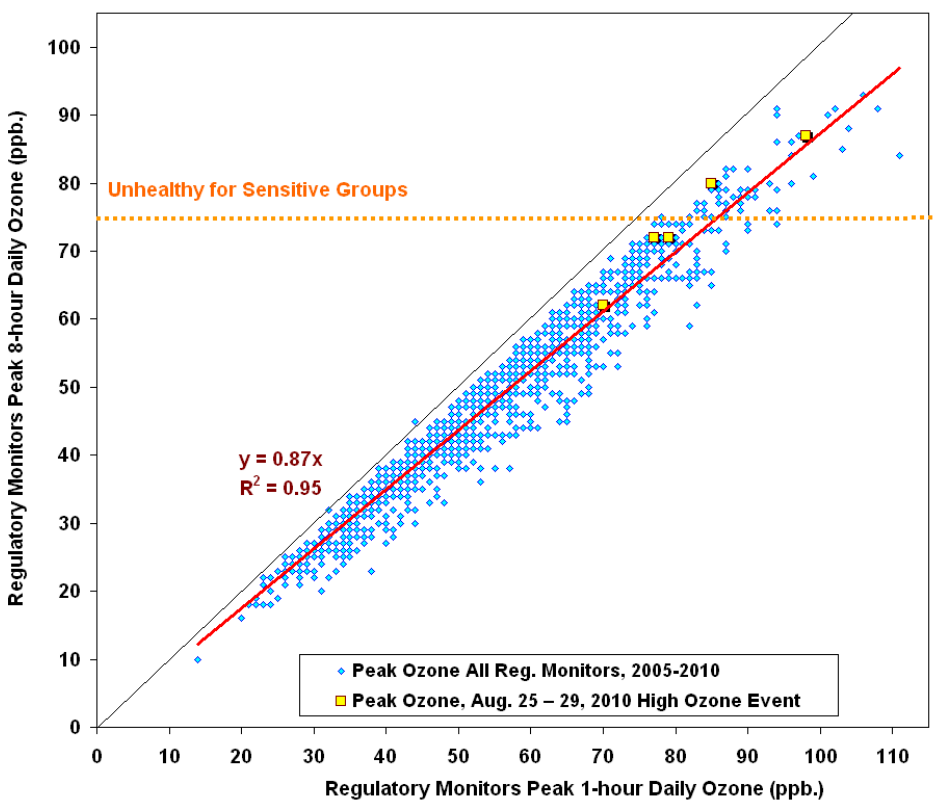
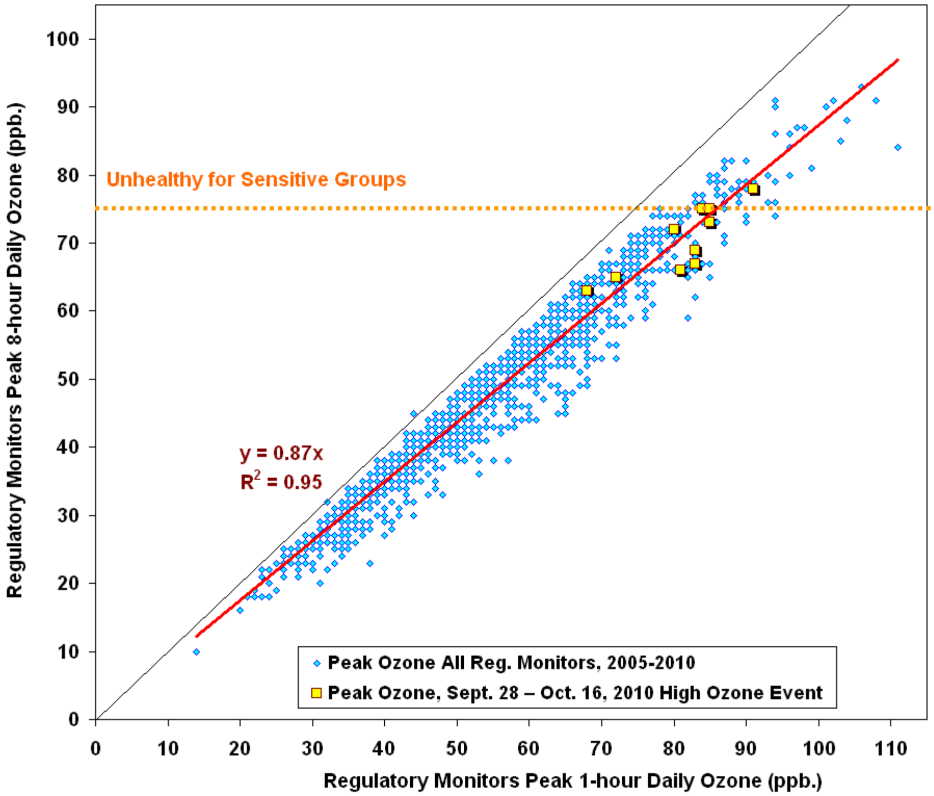


Figure B-3: Peak 1-hour and 8-hour Ozone, Sept. 28 – Oct. 16, 2010 High Ozone Event



APPENDIX C: DIRECTIONAL OCTANT PERCENTAGES

Table C-1: Directional Octant Percentages and Comparative Ratios for each High Ozone Event and the Existing June 2006 Episodes Wind Direction on Days When 8-hour Average Ozone Concentrations were > 60 ppb

Monitor	Episode	N	NE	E	SE	S	SW	W	NW	Absolute Difference
Morning Wind Direction (6 - 9 a.m.) at C23 on Days > 60 ppb	All Days (2005-2010) > 60ppb	26.1%	21.6%	8.7%	7.4%	7.4%	9.7%	9.4%	9.7%	-
	June 2 – 30, 2006	13.6%	13.6%	4.5%	13.6%	9.1%	27.3%	9.1%	9.1%	51.0%
	April 2 – May 6, 2005	8.3%	25.0%	25.0%	8.3%	12.5%	0.0%	8.3%	12.5%	57.0%
	May 20 – June 2, 2005	0.0%	25.0%	0.0%	12.5%	12.5%	12.5%	25.0%	12.5%	69.7%
	Aug. 22 – Sept. 9, 2005	42.9%	21.4%	0.0%	0.0%	0.0%	7.1%	14.3%	14.3%	52.5%
	Oct. 9 – 28, 2005	41.7%	33.3%	16.7%	0.0%	0.0%	0.0%	0.0%	8.3%	70.4%
	May 9 – 20, 2006	9.1%	27.3%	0.0%	27.3%	9.1%	18.2%	0.0%	9.1%	71.4%
	Aug. 17 – Oct. 9, 2006	20.0%	40.0%	12.0%	4.0%	12.0%	4.0%	8.0%	0.0%	**52.5%**
	Sept. 17 – Oct. 3, 2008	38.5%	46.2%	0.0%	0.0%	0.0%	7.7%	0.0%	7.7%	73.7%
	May 18 – June 6, 2009	16.7%	33.3%	25.0%	8.3%	16.7%	0.0%	0.0%	0.0%	76.3%
	Aug. 25 – 29, 2010	40.0%	40.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	87.1%
	Sept. 28 – Oct. 16, 2010	50.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	40.0%	*108.4%*
Afternoon Wind (noon - 3p.m.) at C23 on Days > 60 ppb	All Days (2005-2010) > 60ppb	4.5%	11.9%	23.5%	35.5%	19.0%	3.2%	1.0%	1.3%	-
	June 2 – 30, 2006	0.0%	9.1%	45.5%	36.4%	9.1%	0.0%	0.0%	0.0%	45.6%
	April 2 – May 6, 2005	8.0%	0.0%	16.0%	44.0%	20.0%	4.0%	0.0%	8.0%	40.9%
	May 20 – June 2, 2005	0.0%	0.0%	25.0%	62.5%	0.0%	12.5%	0.0%	0.0%	75.5%
	Aug. 22 – Sept. 9, 2005	14.3%	7.1%	42.9%	21.4%	7.1%	0.0%	0.0%	7.1%	69.9%
	Oct. 9 – 28, 2005	0.0%	33.3%	25.0%	25.0%	16.7%	0.0%	0.0%	0.0%	45.7%
	May 9 – 20, 2006	18.2%	27.3%	0.0%	27.3%	27.3%	0.0%	0.0%	0.0%	74.5%
	Aug. 17 – Oct. 9, 2006	8.0%	20.0%	16.0%	36.0%	16.0%	4.0%	0.0%	0.0%	**25.7%**
	Sept. 17 – Oct. 3, 2008	0.0%	23.1%	46.2%	15.4%	15.4%	0.0%	0.0%	0.0%	67.5%
	May 18 – June 6, 2009	0.0%	8.3%	41.7%	33.3%	16.7%	0.0%	0.0%	0.0%	36.2%
	Aug. 25 – 29, 2010	0.0%	40.0%	40.0%	20.0%	0.0%	0.0%	0.0%	0.0%	89.0%
	Sept. 28 – Oct. 16, 2010	20.0%	10.0%	20.0%	0.0%	40.0%	0.0%	10.0%	0.0%	*91.0%*

Monitor	Episode	N	NE	E	SE	S	SW	W	NW	Absolute Difference
Morning Wind Direction (6 - 9 a.m.) at C58 on Days > 60 ppb	All Days (2005-2010) > 60ppb	15.0%	4.2%	5.4%	6.1%	11.8%	5.8%	5.8%	46.0%	-
	June 2 – 30, 2006	9.1%	4.5%	4.5%	9.1%	13.6%	22.7%	9.1%	27.3%	51.1%
	April 2 – May 6, 2005	12.5%	12.5%	12.5%	16.7%	12.5%	8.3%	0.0%	25.0%	58.5%
	May 20 – June 2, 2005	12.5%	12.5%	0.0%	12.5%	25.0%	0.0%	0.0%	37.5%	55.9%
	Aug. 22 – Sept. 9, 2005	7.1%	0.0%	0.0%	0.0%	7.1%	0.0%	0.0%	85.7%	79.4%
	Oct. 9 – 28, 2005	8.3%	8.3%	16.7%	0.0%	0.0%	0.0%	0.0%	66.7%	72.2%
	May 9 – 20, 2006	20.0%	10.0%	0.0%	0.0%	40.0%	0.0%	10.0%	20.0%	86.5%
	Aug. 17 – Oct. 9, 2006	24.0%	4.0%	4.0%	0.0%	12.0%	0.0%	8.0%	48.0%	**26.8%**
	Sept. 17 – Oct. 3, 2008	23.1%	0.0%	0.0%	0.0%	7.7%	0.0%	0.0%	69.2%	62.6%
	May 18 – June 6, 2009	25.0%	0.0%	16.7%	16.7%	16.7%	0.0%	0.0%	25.0%	73.3%
	Aug. 25 – 29, 2010	60.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	40.0%	90.0%
	Sept. 28 – Oct. 16, 2010	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	*108.0%*
Afternoon Wind (noon - 3p.m.) at C58 on Days > 60 ppb	All Days (2005-2010) > 60ppb	7.6%	12.7%	12.1%	32.1%	26.7%	3.8%	1.0%	4.1%	-
	June 2 – 30, 2006	4.5%	18.2%	13.6%	45.5%	18.2%	0.0%	0.0%	0.0%	40.9%
	April 2 – May 6, 2005	12.0%	0.0%	8.0%	40.0%	24.0%	4.0%	0.0%	12.0%	**40.8%**
	May 20 – June 2, 2005	0.0%	12.5%	0.0%	25.0%	50.0%	0.0%	0.0%	12.5%	63.4%
	Aug. 22 – Sept. 9, 2005	7.1%	14.3%	35.7%	21.4%	7.1%	0.0%	7.1%	7.1%	68.9%
	Oct. 9 – 28, 2005	0.0%	25.0%	33.3%	16.7%	25.0%	0.0%	0.0%	0.0%	67.1%
	May 9 – 20, 2006	18.2%	18.2%	9.1%	9.1%	36.4%	0.0%	0.0%	9.1%	61.4%
	Aug. 17 – Oct. 9, 2006	12.0%	12.0%	4.0%	52.0%	20.0%	0.0%	0.0%	0.0%	48.6%
	Sept. 17 – Oct. 3, 2008	0.0%	53.8%	23.1%	15.4%	7.7%	0.0%	0.0%	0.0%	104.3%
	May 18 – June 6, 2009	25.0%	8.3%	0.0%	8.3%	58.3%	0.0%	0.0%	0.0%	98.1%
	Aug. 25 – 29, 2010	0.0%	60.0%	0.0%	40.0%	0.0%	0.0%	0.0%	0.0%	*110.5%*
	Sept. 28 – Oct. 16, 2010	20.0%	10.0%	10.0%	20.0%	30.0%	0.0%	10.0%	0.0%	49.5%

Table C-2: Directional Octant Percentages and Comparative Ratios for each High Ozone Events and the Existing June 2006 Episodes Wind Direction on Days When 8-hour Average Ozone Concentrations were > 65 ppb

Monitor	Episode	N	NE	E	SE	S	SW	W	NW	Absolute Difference
Morning Wind Direction (6 - 9 a.m.) at C23 on Days > 65 ppb	All Days (2005-2010) > 60ppb	28.8%	21.2%	8.1%	6.1%	6.1%	9.6%	9.1%	11.1%	-
	June 2 – 30, 2006	11.1%	16.7%	5.6%	16.7%	11.1%	22.2%	5.6%	11.1%	56.6%
	April 2 – May 6, 2005	7.1%	35.7%	28.6%	7.1%	7.1%	0.0%	7.1%	7.1%	74.3%
	May 20 – June 2, 2005	0.0%	28.6%	0.0%	0.0%	14.3%	14.3%	28.6%	14.3%	85.9%
	Aug. 22 – Sept. 9, 2005	46.2%	23.1%	0.0%	0.0%	0.0%	7.7%	7.7%	15.4%	**47.0%**
	Oct. 9 – 28, 2005	33.3%	33.3%	16.7%	0.0%	0.0%	0.0%	0.0%	16.7%	61.6%
	May 9 – 20, 2006	20.0%	40.0%	0.0%	20.0%	20.0%	0.0%	0.0%	0.0%	93.3%
	Aug. 17 – Oct. 9, 2006	19.0%	42.9%	14.3%	4.8%	4.8%	4.8%	9.5%	0.0%	56.6%
	Sept. 17 – Oct. 3, 2008	36.4%	45.5%	0.0%	0.0%	0.0%	9.1%	0.0%	9.1%	63.6%
	May 18 – June 6, 2009	22.2%	22.2%	22.2%	11.1%	22.2%	0.0%	0.0%	0.0%	72.7%
	Aug. 25 – 29, 2010	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Sept. 28 – Oct. 16, 2010	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	*120.2%*
Afternoon Wind (noon - 3p.m.) at C23 on Days > 65 ppb	All Days (2005-2010) > 60ppb	3.0%	10.6%	27.8%	36.9%	17.7%	2.5%	0.5%	1.0%	-
	June 2 – 30, 2006	0.0%	11.1%	44.4%	33.3%	11.1%	0.0%	0.0%	0.0%	34.3%
	April 2 – May 6, 2005	0.0%	0.0%	21.4%	42.9%	21.4%	7.1%	0.0%	7.1%	41.0%
	May 20 – June 2, 2005	0.0%	0.0%	28.6%	57.1%	0.0%	14.3%	0.0%	0.0%	65.7%
	Aug. 22 – Sept. 9, 2005	15.4%	7.7%	46.2%	23.1%	0.0%	0.0%	0.0%	7.7%	74.8%
	Oct. 9 – 28, 2005	0.0%	16.7%	33.3%	16.7%	33.3%	0.0%	0.0%	0.0%	54.5%
	May 9 – 20, 2006	0.0%	40.0%	0.0%	40.0%	20.0%	0.0%	0.0%	0.0%	69.7%
	Aug. 17 – Oct. 9, 2006	9.5%	19.0%	19.0%	38.1%	14.3%	0.0%	0.0%	0.0%	**32.3%**
	Sept. 17 – Oct. 3, 2008	0.0%	18.2%	54.5%	9.1%	18.2%	0.0%	0.0%	0.0%	69.7%
	May 18 – June 6, 2009	0.0%	0.0%	44.4%	33.3%	22.2%	0.0%	0.0%	0.0%	42.4%
	Aug. 25 – 29, 2010	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*123.2%*
	Sept. 28 – Oct. 16, 2010	12.5%	12.5%	12.5%	0.0%	50.0%	0.0%	12.5%	0.0%	111.4%

Monitor	Episode	N	NE	E	SE	S	SW	W	NW	Absolute Difference
Morning Wind Direction (6 - 9 a.m.) at C58 on Days > 65 ppb	All Days (2005-2010) > 60ppb	15.7%	4.1%	4.6%	4.6%	10.2%	4.6%	4.6%	51.8%	-
	June 2 – 30, 2006	11.1%	5.6%	5.6%	11.1%	11.1%	22.2%	5.6%	27.8%	53.0%
	April 2 – May 6, 2005	15.4%	15.4%	15.4%	15.4%	7.7%	0.0%	0.0%	30.8%	67.0%
	May 20 – June 2, 2005	14.3%	14.3%	0.0%	0.0%	28.6%	0.0%	0.0%	42.9%	63.9%
	Aug. 22 – Sept. 9, 2005	7.7%	0.0%	0.0%	0.0%	7.7%	0.0%	0.0%	84.6%	58.6%
	Oct. 9 – 28, 2005	16.7%	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	66.7%	90.2%
	May 9 – 20, 2006	50.0%	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%	25.0%	67.3%
	Aug. 17 – Oct. 9, 2006	19.0%	4.8%	4.8%	0.0%	4.8%	0.0%	9.5%	57.1%	**37.3%**
	Sept. 17 – Oct. 3, 2008	27.3%	0.0%	0.0%	0.0%	9.1%	0.0%	0.0%	63.6%	52.9%
	May 18 – June 6, 2009	33.3%	0.0%	11.1%	22.2%	11.1%	0.0%	0.0%	22.2%	78.1%
	Aug. 25 – 29, 2010	75.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	75.0%
	Sept. 28 – Oct. 16, 2010	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	*96.4%*
Afternoon Wind (noon - 3p.m.) at C58 on Days > 65 ppb	All Days (2005-2010) > 60ppb	5.5%	15.1%	12.1%	38.2%	22.6%	2.5%	0.5%	3.5%	-
	June 2 – 30, 2006	0.0%	16.7%	16.7%	44.4%	22.2%	0.0%	0.0%	0.0%	**24.9%**
	April 2 – May 6, 2005	0.0%	0.0%	7.1%	57.1%	14.3%	7.1%	0.0%	14.3%	68.7%
	May 20 – June 2, 2005	0.0%	14.3%	0.0%	28.6%	42.9%	0.0%	0.0%	14.3%	62.0%
	Aug. 22 – Sept. 9, 2005	7.7%	15.4%	38.5%	23.1%	0.0%	0.0%	7.7%	7.7%	80.5%
	Oct. 9 – 28, 2005	0.0%	16.7%	33.3%	16.7%	33.3%	0.0%	0.0%	0.0%	67.2%
	May 9 – 20, 2006	20.0%	20.0%	20.0%	0.0%	40.0%	0.0%	0.0%	0.0%	89.4%
	Aug. 17 – Oct. 9, 2006	9.5%	14.3%	4.8%	57.1%	14.3%	0.0%	0.0%	0.0%	45.9%
	Sept. 17 – Oct. 3, 2008	0.0%	54.5%	18.2%	18.2%	9.1%	0.0%	0.0%	0.0%	91.2%
	May 18 – June 6, 2009	33.3%	11.1%	0.0%	11.1%	44.4%	0.0%	0.0%	0.0%	99.3%
	Aug. 25 – 29, 2010	0.0%	75.0%	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	*119.8%*
	Sept. 28 – Oct. 16, 2010	12.5%	12.5%	0.0%	25.0%	37.5%	0.0%	0.0%	12.5%	61.7%

Table C-3: Directional Octant Percentages and Comparative Ratios for each High Ozone Events and the Existing June 2006 Episodes Wind Direction on Days when 8-hour Ozone Concentrations were > 70 ppb

Monitor	Episode	N	NE	E	SE	S	SW	W	NW	Absolute Difference
Morning Wind Direction (6 - 9 a.m.) at C23 on Days > 70 ppb	All Days (2005-2010) > 60ppb	29.4%	25.4%	8.7%	5.6%	3.2%	7.1%	9.5%	11.1%	-
	June 2 – 30, 2006	7.1%	21.4%	7.1%	14.3%	0.0%	28.6%	7.1%	14.3%	66.7%
	April 2 – May 6, 2005	9.1%	45.5%	27.3%	9.1%	0.0%	0.0%	9.1%	0.0%	84.3%
	May 20 – June 2, 2005	0.0%	33.3%	0.0%	0.0%	16.7%	16.7%	16.7%	16.7%	87.3%
	Aug. 22 – Sept. 9, 2005	42.9%	42.9%	0.0%	0.0%	0.0%	0.0%	0.0%	14.3%	68.3%
	Oct. 9 – 28, 2005	40.0%	40.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	68.3%
	May 9 – 20, 2006	20.0%	40.0%	0.0%	20.0%	20.0%	0.0%	0.0%	0.0%	91.7%
	Aug. 17 – Oct. 9, 2006	7.7%	53.8%	7.7%	7.7%	7.7%	0.0%	15.4%	0.0%	81.9%
	Sept. 17 – Oct. 3, 2008	50.0%	25.0%	0.0%	0.0%	0.0%	12.5%	0.0%	12.5%	**54.8%**
	May 18 – June 6, 2009	16.7%	16.7%	33.3%	16.7%	16.7%	0.0%	0.0%	0.0%	98.4%
	Aug. 25 – 29, 2010	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	90.5%
	Sept. 28 – Oct. 16, 2010	60.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	40.0%	*119.0%*
Afternoon Wind (noon - 3p.m.) at C23 on Days > 70 ppb	All Days (2005-2010) > 60ppb	1.6%	10.3%	31.7%	31.0%	21.4%	3.2%	0.0%	0.8%	-
	June 2 – 30, 2006	0.0%	7.1%	50.0%	28.6%	14.3%	0.0%	0.0%	0.0%	36.5%
	April 2 – May 6, 2005	0.0%	0.0%	27.3%	36.4%	27.3%	9.1%	0.0%	0.0%	**34.3%**
	May 20 – June 2, 2005	0.0%	0.0%	33.3%	50.0%	0.0%	16.7%	0.0%	0.0%	68.3%
	Aug. 22 – Sept. 9, 2005	0.0%	14.3%	42.9%	28.6%	0.0%	0.0%	0.0%	14.3%	57.1%
	Oct. 9 – 28, 2005	0.0%	20.0%	20.0%	20.0%	40.0%	0.0%	0.0%	0.0%	56.5%
	May 9 – 20, 2006	0.0%	40.0%	0.0%	40.0%	20.0%	0.0%	0.0%	0.0%	77.5%
	Aug. 17 – Oct. 9, 2006	7.7%	15.4%	15.4%	38.5%	23.1%	0.0%	0.0%	0.0%	40.7%
	Sept. 17 – Oct. 3, 2008	0.0%	12.5%	50.0%	12.5%	25.0%	0.0%	0.0%	0.0%	48.0%
	May 18 – June 6, 2009	0.0%	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	74.6%
	Aug. 25 – 29, 2010	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	*115.9%*
	Sept. 28 – Oct. 16, 2010	0.0%	20.0%	20.0%	0.0%	60.0%	0.0%	0.0%	0.0%	96.5%

Monitor	Episode	N	NE	E	SE	S	SW	W	NW	Absolute Difference
Morning Wind Direction (6 - 9 a.m.) at C58 on Days > 70 ppb	All Days (2005-2010) > 60ppb	14.5%	4.0%	4.0%	4.8%	6.5%	4.0%	4.8%	57.3%	-
	June 2 – 30, 2006	14.3%	7.1%	7.1%	7.1%	0.0%	28.6%	7.1%	28.6%	70.7%
	April 2 – May 6, 2005	20.0%	10.0%	20.0%	20.0%	0.0%	0.0%	0.0%	30.0%	85.2%
	May 20 – June 2, 2005	16.7%	16.7%	0.0%	0.0%	33.3%	0.0%	0.0%	33.3%	83.3%
	Aug. 22 – Sept. 9, 2005	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	85.5%
	Oct. 9 – 28, 2005	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	80.0%	56.5%
	May 9 – 20, 2006	50.0%	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%	25.0%	108.1%
	Aug. 17 – Oct. 9, 2006	7.7%	7.7%	7.7%	0.0%	7.7%	0.0%	7.7%	61.5%	**31.4%**
	Sept. 17 – Oct. 3, 2008	12.5%	0.0%	0.0%	0.0%	12.5%	0.0%	0.0%	75.0%	47.6%
	May 18 – June 6, 2009	50.0%	0.0%	0.0%	16.7%	16.7%	0.0%	0.0%	16.7%	115.1%
	Aug. 25 – 29, 2010	75.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	*121.0%*
	Sept. 28 – Oct. 16, 2010	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	85.5%
Afternoon Wind (noon - 3p.m.) at C58 on Days > 70 ppb	All Days (2005-2010) > 60ppb	4.0%	15.1%	15.1%	35.7%	26.2%	1.6%	0.8%	1.6%	-
	June 2 – 30, 2006	0.0%	14.3%	21.4%	42.9%	21.4%	0.0%	0.0%	0.0%	**27.0%**
	April 2 – May 6, 2005	0.0%	0.0%	9.1%	54.5%	18.2%	9.1%	0.0%	9.1%	67.7%
	May 20 – June 2, 2005	0.0%	16.7%	0.0%	33.3%	33.3%	0.0%	0.0%	16.7%	47.6%
	Aug. 22 – Sept. 9, 2005	0.0%	14.3%	42.9%	28.6%	0.0%	0.0%	14.3%	0.0%	82.5%
	Oct. 9 – 28, 2005	0.0%	20.0%	20.0%	20.0%	40.0%	0.0%	0.0%	0.0%	47.3%
	May 9 – 20, 2006	20.0%	20.0%	20.0%	0.0%	40.0%	0.0%	0.0%	0.0%	79.4%
	Aug. 17 – Oct. 9, 2006	7.7%	7.7%	7.7%	53.8%	23.1%	0.0%	0.0%	0.0%	43.7%
	Sept. 17 – Oct. 3, 2008	0.0%	50.0%	12.5%	25.0%	12.5%	0.0%	0.0%	0.0%	69.8%
	May 18 – June 6, 2009	33.3%	16.7%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	109.5%
	Aug. 25 – 29, 2010	0.0%	75.0%	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	*119.8%*
	Sept. 28 – Oct. 16, 2010	0.0%	20.0%	0.0%	20.0%	60.0%	0.0%	0.0%	0.0%	77.5%

APPENDIX D: RATINGS CRITERIA FOR EPISODE SELECTION

1. # Days at C23 Ozone > Proposed Standard

60 ppb Standard

- ranking of 4 = C23 had less than 5 days above the proposed standard
- ranking of 3 = C23 had 5-6 days above the proposed standard
- ranking of 2 = C23 had 7-8 days above the proposed standard
- ranking of 1 = C23 had 9-11 days above the proposed standard
- ranking of 0 = C23 had more than 12 days above the proposed standard

65 ppb Standard

- ranking of 4 = C23 had less than 5 days above the proposed standard
- ranking of 3 = C23 had 5-6 days above the proposed standard
- ranking of 2 = C23 had 7-9 days above the proposed standard
- ranking of 1 = C23 had 10-12 days above the proposed standard
- ranking of 0 = C23 had more than 13 days above the proposed standard

70 ppb Standard

- ranking of 4 = C23 had less than 5 days above the proposed standard
- ranking of 3 = C23 had 5-6 days above the proposed standard
- ranking of 2 = C23 had 7-8 days above the proposed standard
- ranking of 1 = C23 had 9-10 days above the proposed standard
- ranking of 0 = C23 had more than 11 days above the proposed standard

2. # Days at C58 Ozone > Proposed Standard

60 ppb Standard

- ranking of 4 = C58 had less than 5 days above the proposed standard
- ranking of 3 = C58 had 5-6 days above the proposed standard
- ranking of 2 = C58 had 7-8 days above the proposed standard
- ranking of 1 = C58 had 9-10 days above the proposed standard
- ranking of 0 = C58 had more than 11 days above the proposed standard

65 ppb Standard

- ranking of 4 = C58 had less than 5 days above the proposed standard
- ranking of 3 = C58 had 5-6 days above the proposed standard
- ranking of 2 = C58 had 7-8 days above the proposed standard
- ranking of 1 = C58 had 9-10 days above the proposed standard
- ranking of 0 = C58 had more than 11 days above the proposed standard

70 ppb Standard

- ranking of 4 = C58 had less than 5 days above the proposed standard
- ranking of 3 = C58 had 5-6 days above the proposed standard
- ranking of 2 = C58 had 7-8 days above the proposed standard
- ranking of 1 = C58 had 9-11 days above the proposed standard
- ranking of 0 = C58 had more than 12 days above the proposed standard

3. Within Ozone Seasonal Peak

- ranking of 4 = If episode is not within the ozone seasonal peaks
- ranking of 2 = If episode had only 1 - 5 high ozone day(s) within the ozone seasonal peaks
- ranking of 0 = If the full episode is within the ozone seasonal peaks

4. Weekend High Ozone Days
   - ranking of 2 = no weekend high ozone days
   - ranking of 1 = one weekend high ozone days
   - ranking of 0 = two or more weekend high ozone days

   note: no ranking of 3 or 4 were allocated because this criteria was not considered as significant because the existing June 2006 already has several weekend high ozone days

5. One-Hour/8-hour Correlation
   - ranking of 4 = if less than 51% of the days are within one standard deviation
   - ranking of 3 = if 51-60% of the days are within one standard deviation
   - ranking of 2 = if 61-70% of the days are within one standard deviation
   - ranking of 1 = if 71-80% of the days are within one standard deviation
   - ranking of 0 = if more than 80% of the days are within one standard deviation

6. % of High Ozone Days ± 10 ppb of Design Value
   - ranking of 4 = <30% of the days at C23 and C58 within ± 10 ppb of the Design Value
   - ranking of 3 = 30% - 42.9% of the days at C23 and C58 within ± 10 ppb of the Design Value
   - ranking of 2 = 43% - 55.9% of the days at C23 and C58 within ± 10 ppb of the Design Value
   - ranking of 1 = 56% - 79.9% of the days at C23 and C58 within ± 10 ppb of the Design Value
   - ranking of 0 = >80% of the days at C23 and C58 within ± 10 ppb of the Design Value

7. Within the Latest Design Value
   - ranking of 3 = Episode Occurred in 2005
   - ranking of 2 = Episode Occurred in 2006
   - ranking of 1 = Episode Occurred in 2007
   - ranking of 0 = Episode Occurred between 2008 and 2010

8. Typical Local Meteorological Conditions - based on the percentage of unusual meteorological conditions on high ozone days (For example, high ozone days when temperature < 87.3°F, Wind Speed 6 am – 2 pm > 6.9 mph, Precipitation > 0 inches, Max. Solar Radiation < 1.172 langleys /min., Relative Humidity at 2p.m. > 40.9%)
   - ranking of 4 = >32% unusual meteorological conditions
   - ranking of 3 = 26% - 31.9% unusual meteorological conditions
   - ranking of 2 = 20% - 26.9% unusual meteorological conditions
   - ranking of 1 = 14% - 19.9% unusual meteorological conditions
   - ranking of 0 = <14% unusual meteorological conditions

9. Wind Direction at C23 and C58
   - ranking of 4 = If absolute difference of Wind Direction is >95% at both C23 and C58
   - ranking of 3 = If absolute difference of Wind Direction is 80% - 94.9% at both C23 and C58
   - ranking of 2 = If absolute difference of Wind Direction is 65% - 79.9% at both C23 and C58
   - ranking of 1 = If absolute difference of Wind Direction is 50% - 64.9% at both C23 and C58
   - ranking of 0 = If absolute difference of Wind Direction is <50% at both C23 and C58

10. Extreme Weather Events
- ranking of 4 = If three extreme weather events occurred during the episode
- ranking of 3 = If two extreme weather events occurred during the episode
- ranking of 2 = If one extreme weather event occurred during the episode or if daily rainfall > 0.20 inches
- ranking of 1 = If one significant weather event occurred during the episode or if daily rainfall > 0.10 inches
- ranking of 0 = If no significant or extreme weather events occurred during the episode

11. Back Trajectories
- ranking of 4 = if the absolute difference in back trajectories is > 59.9%
- ranking of 3 = if the absolute difference in back trajectories is 50% - 59.9%
- ranking of 2 = if the absolute difference in back trajectories is 40% - 49.9%
- ranking of 1 = if the absolute difference in back trajectories is 30% - 39.9%
- ranking of 0 = if the absolute difference in back trajectories is < 30%

12. Meteorological Data Availability (TexAQS II)
- ranking of 2 = If the episode did not occur during TexAQS II
- ranking of 1 = If the episode occurred during TexAQS II
- ranking of 0 = If the episode occurred during TexAQS II and data was available from the New Braunfels profiler

13. Joint Modeling (Cost Reduction)
- ranking of 4 = If the episode is not already under development by another entity in Texas
- ranking of 0 = If the high ozone event is already under development by another entity in Texas

APPENDIX E: WIND ROSES AT C23 AND C58

Figure E-1: Morning Wind Rose on High Ozone Days (>60 ppb) at C58, 0600-0900 CST, 2005-2010

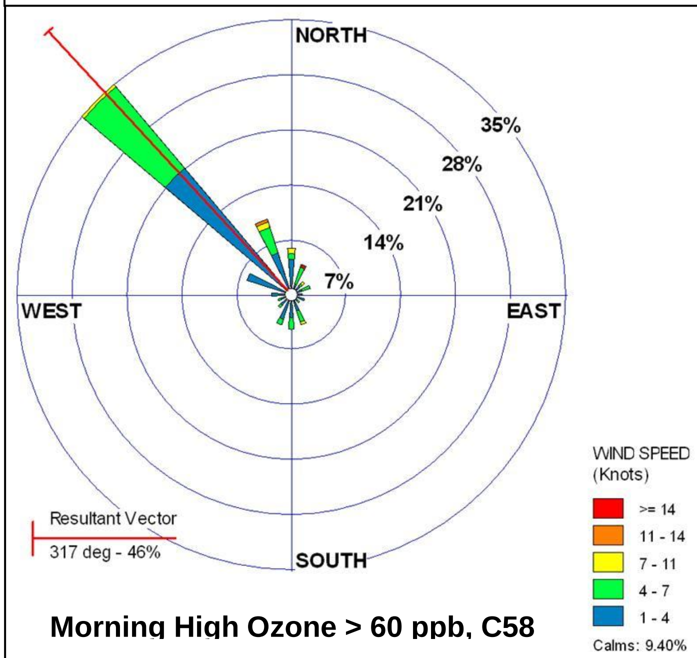


Figure E-2: Morning Wind Rose on High Ozone Days (>65 ppb) at C58, 0600-0900 CST, 2005-2010

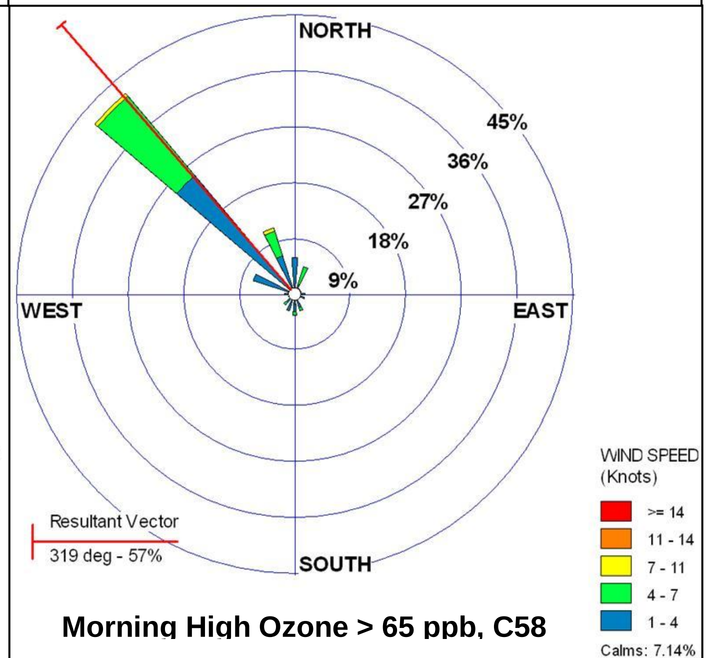


Figure E-3: Morning Wind Rose on High Ozone Days (>60 ppb) at C23, 0600-0900 CST, 2005-2010

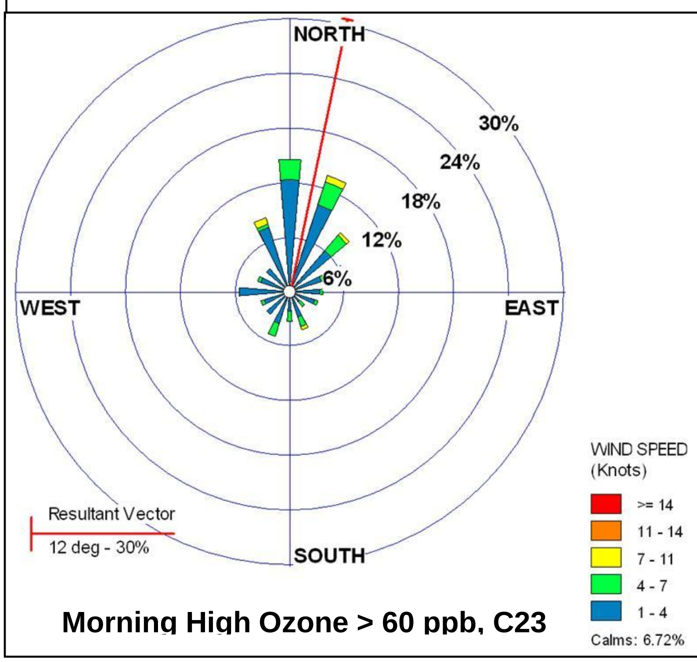


Figure E-4: Morning Wind Rose on High Ozone Days (>60 ppb) at C23, 0600-0900 CST, 2005-2010

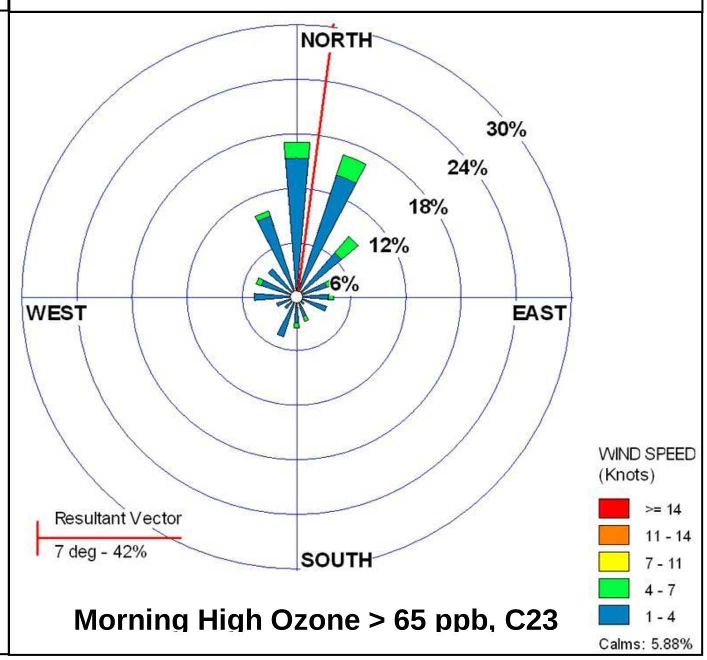


Figure E-5: Afternoon Wind Rose on High Ozone Days (>60 ppb) at C58, 0600-0900 CST, 2005-2010

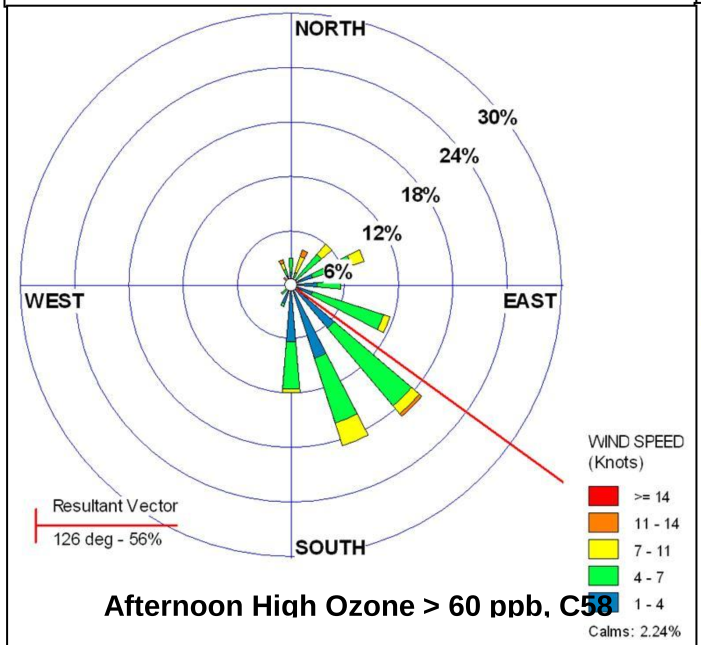


Figure E-6: Afternoon Wind Rose on High Ozone Days (>65 ppb) at C58, 0600-0900 CST, 2005-2010

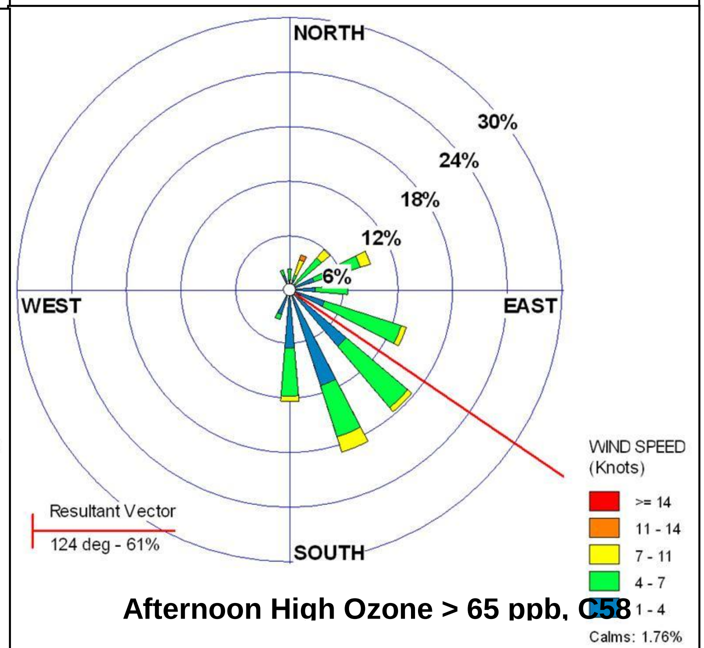


Figure E-7: Afternoon Wind Rose on High Ozone Days (>60 ppb) at C23, 0600-0900 CST, 2005-2010

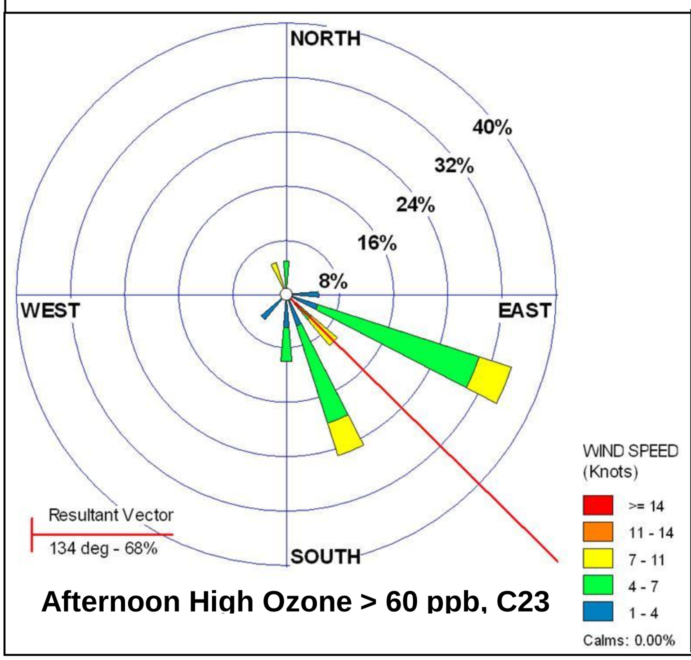
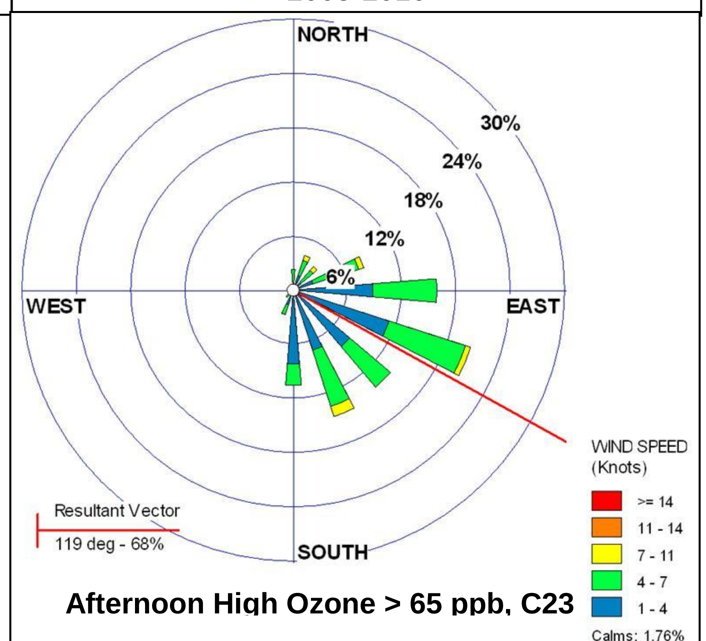


Figure E-8: Afternoon Wind Rose on High Ozone Days (>60 ppb) at C23, 0600-0900 CST, 2005-2010



APPENDIX F: HOURLY WIND VECTORS

Figure F-1: Hourly Wind Vectors at C23 on Days > 60 ppb

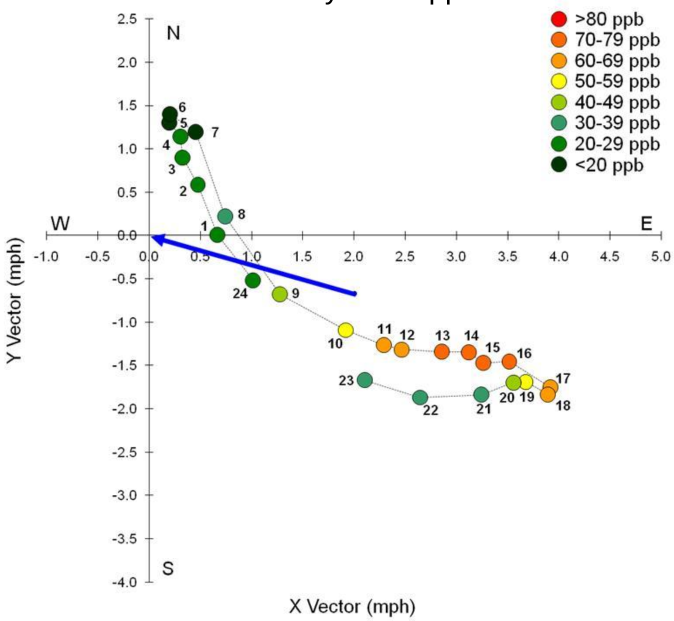


Figure F-2: Hourly Wind Vectors at C23 on Days > 65 ppb

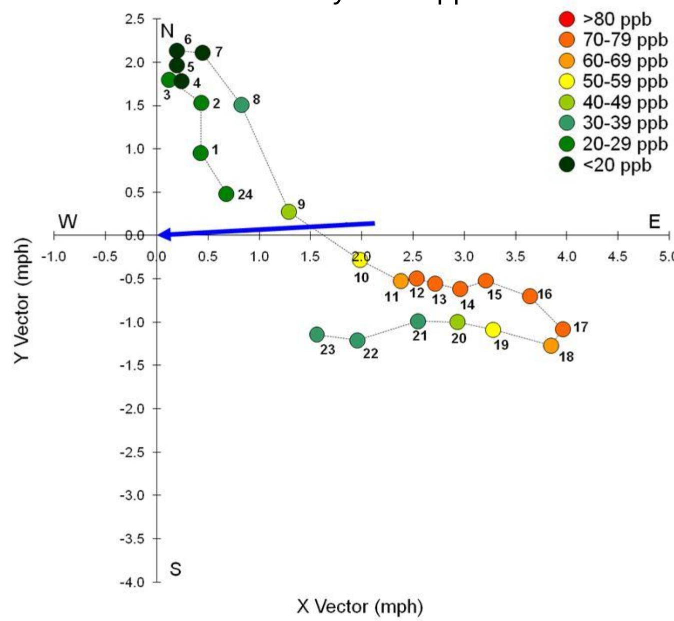


Figure F-3: Hourly Wind Vectors at C58 on Days > 60 ppb

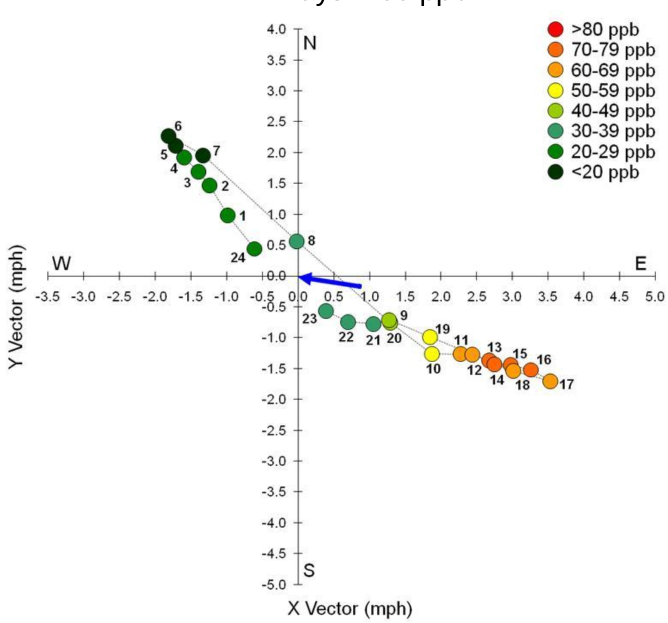


Figure F-4: Hourly Wind Vectors at C58 on Days > 65 ppb