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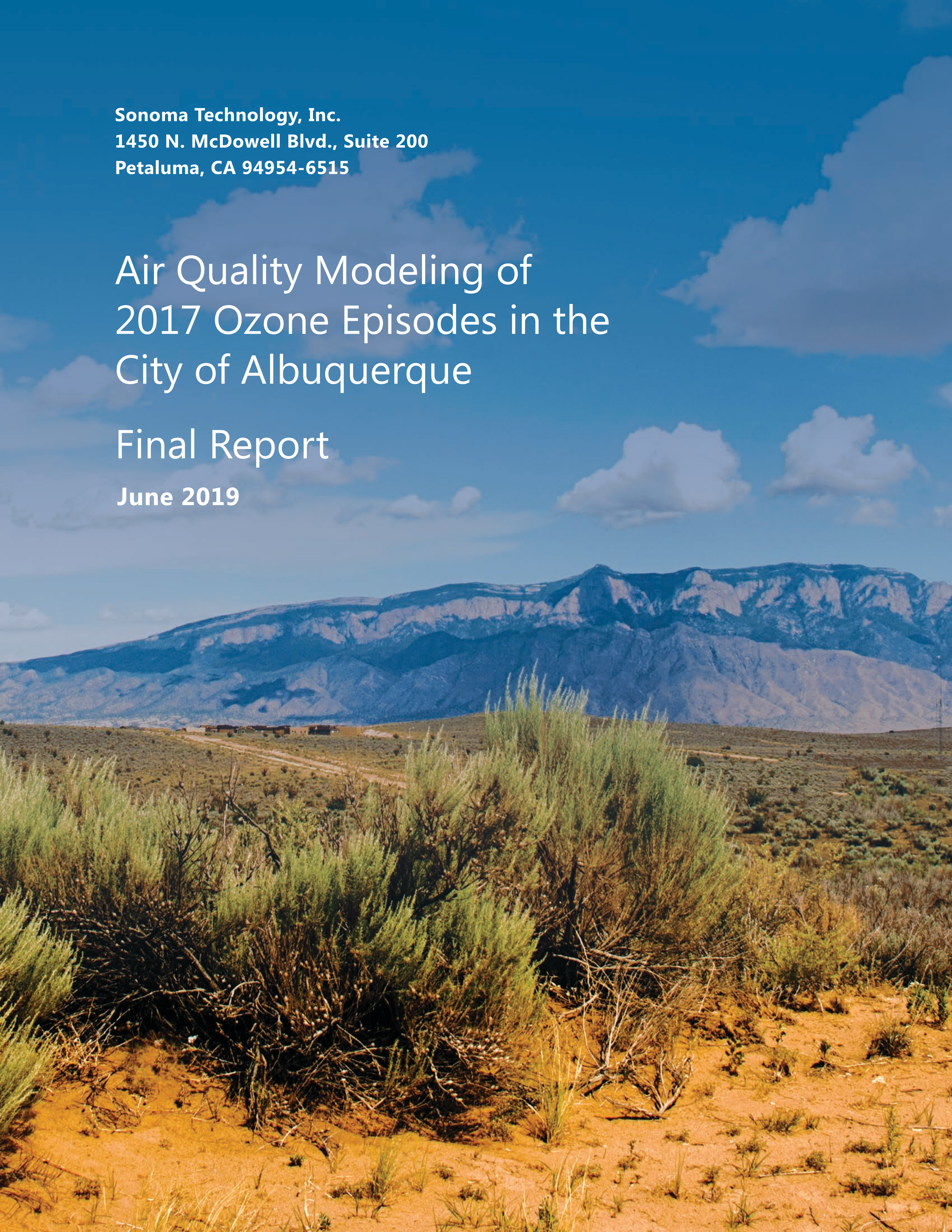
Air Quality Modeling of 2017 Ozone Episodes in the City of Albuquerque

Final Report

June 2019



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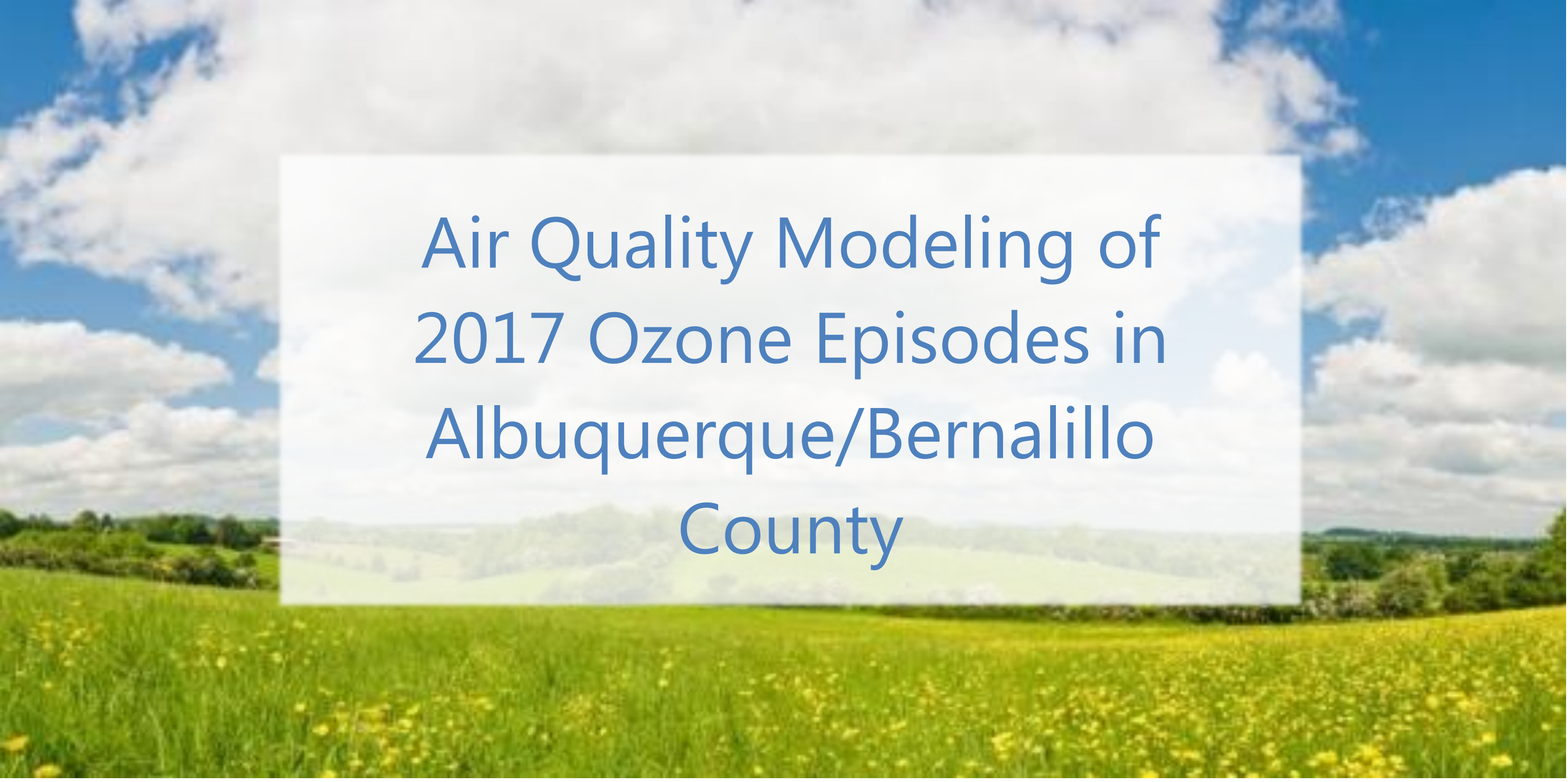

Air Quality Modeling of 2017 Ozone Episodes in Albuquerque/Bernalillo County

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Terms and Acronyms

Term	Definition
Albuquerque/Bernalillo County	Refers to all of Bernalillo County, including the incorporated Albuquerque City limits
Albuquerque EHD	City of Albuquerque Environmental Health Department
Albuquerque MSA	Albuquerque Metropolitan Statistical Area: includes Albuquerque/Bernalillo County as well as Sandoval, Torrance, and Valencia Counties in New Mexico
Alkane VOC	An organic compounds with low MIR, such as pentane, that are emitted from motor vehicles construction equipment, oil and gas exploration, and a variety of industrial processes
AMET	Atmospheric Model and Evaluation Tool
Anthropogenic	Man-made or human-caused (e.g., anthropogenic emissions)
Aromatic VOC	Class of VOC compounds that include benzene, and other compounds such as xylene and toluene that have similar chemical structure to benzene
Atmospheric boundary layer	The layer of atmosphere that is influenced by Earth's surface. The depth of the boundary layer is an important parameter for predicting ground-level pollutant concentrations.
AQI	EPA's Air Quality Index
AQS	EPA's Air Quality System
BEIS	Biogenic Emissions Inventory System
Biogenic	Originating from natural sources, such as plants and trees
Boundary Conditions	Data at the edges of the air quality modeling domain. Results from a global chemistry model simulation are typically used develop boundary conditions.
CAMD	EPA's Clean Air Markets Division
CAMx	Comprehensive Air Quality Model with Extensions
CB6	Carbon Bond 6 chemical mechanism
CEMS	Continuous emission monitoring system
Chemical mechanism	A reduced set of chemical reactions for air quality modeling. CB6 is a commonly used chemical mechanism.
CSAPR	EPA's Cross State Air Pollution Rule
EGU	Electrical generating unit
EPA	U.S. Environmental Protection Agency

Term	Definition
FDDA	Four Dimensional Data Assimilation
Heavy-duty vehicles	Heavy trucks and buses: large pick-ups, delivery trucks, recreational vehicles (RVs), and semi trucks
HMS	NOAA Hazard Mapping System
I&M	Inspection and Maintenance
IPM	Integrated Panning Model (for forecasting power plant emissions)
K	Kelvin (a unit of temperature)
KABQ	Albuquerque International Airport
Light-duty vehicles	Passenger cars and light trucks: minivans, passenger vans, pickup trucks, and sport-utility vehicles
LSM	Land surface model
MADIS	Meteorological Assimilation Data Ingest System
Meteorological	The weather (e.g., meteorological data)
MDT	Mountain Daylight Time
MIR	Maximum incremental reactivity: describes the ozone formation potential of organic compounds.
MOVES	EPA's MOtor Vehicle Emissions Simulator
MPE	Model performance evaluation
MSAT	mobile source air toxic
m/s	Meters per second
NAAQS	National Ambient Air Quality Standards
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NEI	National Emissions Inventory
NMB	Normalized mean bias
NME	Normalized mean error
NMED	New Mexico Environment Department
NPS	National Parks Service
NOAA	National Oceanic and Atmospheric Administration
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen

Term	Definition
NO_x-limited	Describes chemical conditions when the rate of ozone production is limited by the amount of NO_x in the atmosphere, and ozone concentrations are most effectively reduced by reducing NO_x emissions. Ozone is generally NO_x-limited in rural areas and downwind suburban areas.
Nudging	A data assimilation technique that continuously adjusts the modeled prediction toward observation data or toward a gridded analysis.
NWS	National Weather Service
NATA	National Air Toxics Assessment
Non-point sources	Emission sources that are individually too small in magnitude to report as a point sources. Examples include residential heating, commercial combustion, asphalt paving, and commercial and consumer solvent use.
Nonroad mobile sources	Pollution sources that move are known as “mobile sources”. “Nonroad” mobile sources include aircraft, locomotives, marine vessels, construction and agricultural equipment, industrial equipment, lawn and garden equipment, and land-based recreational vehicles (e.g, all-terrain vehicles).
Oil and gas sector	Processes related to the production, processing, and storage of oil and natural gas.
On-road mobile sources	Pollution sources that move are known as “mobile sources”. “On-road” mobile sources include vehicles used on roads for transportation of passengers or freight. On-road mobile sources include motorcycles, light-duty vehicles, and heavy-duty vehicles powered by gasoline or diesel fuel.
OSAT	Ozone Source Apportionment Technology, the ozone source apportionment modeling feature in CAMx
PAMS	Photochemical Assessment Monitoring Station
$PM_{2.5}$	Fine particulate matter
Point sources	Larger pollution sources that are located at a fixed, stationary location. Examples include large industrial facilities and electric power plants, airports, and smaller industrial, non-industrial, and commercial facilities. Fire emissions often modeled as point sources because emissions may be lofted well above ground level.
ppb	Parts per billion by volume
ppm	Parts per million by volume
SMOKE	Sparse Matrix Operator Kernel Emissions processing system
Solvent use	Refers to VOC emissions related to the commercial or residential use of cleaning solvents, paints, surface coating, inks, adhesives, and degreasers.

Term	Definition
Source Apportionment	The process of quantifying the contribution of emissions from various emission source categories and/or geographic regions to modeled or observed ozone concentrations.
Title V major point source	A point source facility that has the potential to emit regulated pollutants (e.g., $PM_{2.5}$, VOC, and various hazardous air pollutants) at rates that exceed specific emissions thresholds. Major point source facilities are required to obtain a Clean Air Act Title V operating permit and meet monitoring, reporting, compliance, and certification requirements.
Toluene VOC	An organic compound with high MIR that is use as a cleaning solvent in various industrial and manufacturing settings, and is also used in the manufacture of paints, coatings, inks, and adhesives. In this report, toluene also includes compounds with similar structure such as ethylbenzene.
USB	U.S. background ozone, defined by EPA as ozone concentration in the absence of United States anthropogenic ozone precursor emissions
USG	Unhealthy for Sensitive Groups
VMT	Vehicle miles traveled – a key measure of vehicle activity
VOC	Volatile organic compound
VOC-limited	Describes chemical conditions when the rate of ozone production is limited by the amount of VOC in the atmosphere, and ozone concentrations are most effectively reduced by reducing VOC emissions. Ozone can be VOC-limited in urban areas with a high population density.
QAPP	Quality assurance project plan
WRF	Weather Research and Forecasting Model
Xylene VOC	Organic compounds with high MIR. Xylenes occur naturally in petroleum and are therefore often emitted through combustion. Xylenes are also used as a solvent in chemical manufacture, agricultural sprays, adhesives, paints, and coatings.
$\mu g/m^3$	Micrograms per cubic meter

Executive Summary

Purpose and Motivation

Albuquerque/Bernalillo County[1] is currently in attainment of the 2015 National Ambient Air Quality Standard (NAAQS) for ozone (70 ppb). Ozone design values[2] in Albuquerque/Bernalillo County have been decreasing over the last 15 years, but have increased in recent years (Figure 1). The unofficial 2018 ozone design value in Albuquerque/Bernalillo County[3] is 70 ppb, which is on the cusp of exceeding the current federal standard.[4] Albuquerque/Bernalillo County is therefore at risk of exceeding the federal ozone standard in the future if there are high ozone days again in 2019 or 2020.

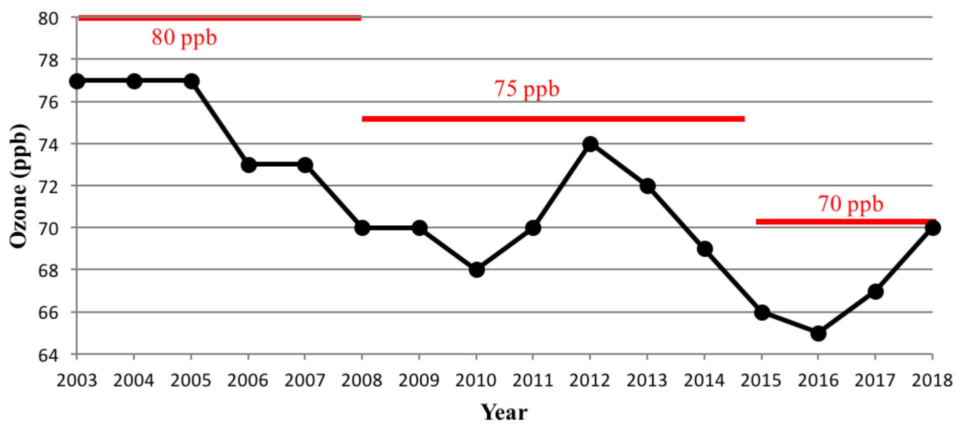


Figure 1. Ozone design values in Albuquerque/Bernalillo County from 2003 through 2018. The highest design value for each year across all monitoring sites in Albuquerque/Bernalillo County is shown (black dots). Data through 2017 are from the U.S. EPA's ozone design values reports (epa.gov/air-trends/air-quality-design-values). Data for 2018 are based on preliminary calculations by the Albuquerque EHD. Red lines indicate the ozone NAAQS over time.

The Albuquerque Environmental Health Department (EHD) retained Sonoma Technology, Inc. (STI) to conduct air quality modeling to assist the EHD with its air quality planning. The air quality modeling work conducted here focused on two episodes during June and July of 2017 when ground-level ozone concentrations in Albuquerque/Bernalillo County were Unhealthy for Sensitive Groups (USG)

[1]Throughout this report, Albuquerque/Bernalillo County refers to all of Bernalillo County, including the incorporated Albuquerque City limits.
[2] A design value is a statistic used to compare ambient air quality concentrations to the NAAQS. For the 8-hr ozone NAAQS, the design value is defined as the average of the annual fourth-highest daily maximum 8-hr average ozone concentrations over a three-year period. NAAQS attainment is achieved when the design value is less than or equal to the NAAQS.
[3] Based on preliminary calculations by the Albuquerque EHD.
[4] Because 70 ppb is less than or equal to the 8-hr ozone NAAQS of 70 ppb, the Albuquerque MSA remains in attainment of this federal air quality standard.

on the U.S. Environmental Protection Agency (EPA) Air Quality Index (AQI) scale. Ozone was USG on four of the modeled episode days, and Moderate on the EPA AQI scale on many of the modeled episode days. Based on the modeling analysis, the ozone in Albuquerque/Bernalillo County during the June 2017 episode was driven largely by emissions outside Albuquerque/Bernalillo County, whereas ozone during the July 2017 episode was driven more strongly by local emissions from within Albuquerque/Bernalillo County.

There were three key results from this modeling analysis:

- Ozone in Albuquerque/Bernalillo County is the result of local and non-local emissions, is impacted by wildfires, and is sensitive to statewide oil and gas emissions. If emission controls are needed in the future, local emission controls will be less effective at reducing ozone on days when ozone is driven primarily by long-range pollutant transport from outside Albuquerque/Bernalillo County (e.g., the June 2017 ozone episode). Conversely, local emission controls will be more effective at reducing ozone on days when ozone is driven more strongly by local emissions (e.g., the July 2017 ozone episode).
- On high ozone days during June and July 2017, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 5 and 16 ppb of ozone in Albuquerque/Bernalillo County.
- If projected reductions in local, regional, and nationwide emissions by 2025 materialize, these projected emission reductions would reduce ozone concentrations in Albuquerque/Bernalillo County by 3-7%. To put this into context, a 5% reduction of ozone concentrations by 2025 could reduce the future-year ozone design value in Albuquerque/Bernalillo County by 3-4 ppb, based on a current design value of 70 ppb.

This executive summary provides a brief overview of ozone air quality and modeling concepts, the modeling analyses that were conducted in this project, and the key findings from this modeling study.

Introduction

A refined understanding of the effects of local emissions and meteorology, long-range pollutant transport, and wildland/prescribed fires on ground-level ozone concentrations is important for effective air quality management and planning. Ambient observations and emissions inventories provide the basis for understanding complex air quality issues, such as ground-level ozone. State-of-the-science air quality modeling tools can be used to refine conceptual understanding of air quality issues and develop the scientific foundation for developing emission control strategies that (if needed) can help reduce local air pollutant concentrations.

The Albuquerque EHD retained STI to conduct air quality modeling to assist the EHD with its air quality planning process. The purpose of this work was to apply scientific data and modeling analyses to (1) further the understanding of ozone air quality in Albuquerque/Bernalillo County, and (2) understand emission control strategies that (if necessary) can be helpful for reducing ozone in the region. Multiple pollutants, including ozone, particulate matter, and their chemical precursors, were modeled, but the focus of this project is on ground-level ozone and its precursors. This modeling project builds upon the ongoing ambient air quality monitoring and emissions inventory development work conducted by Albuquerque EHD over the years, and provides an additional technical basis for future air quality planning. The modeling can also provide a starting point to support regulatory modeling should such a need arise in the future. An overview of key results from this study was presented to the Albuquerque/Bernalillo County Air Quality Control Board in October 2018.

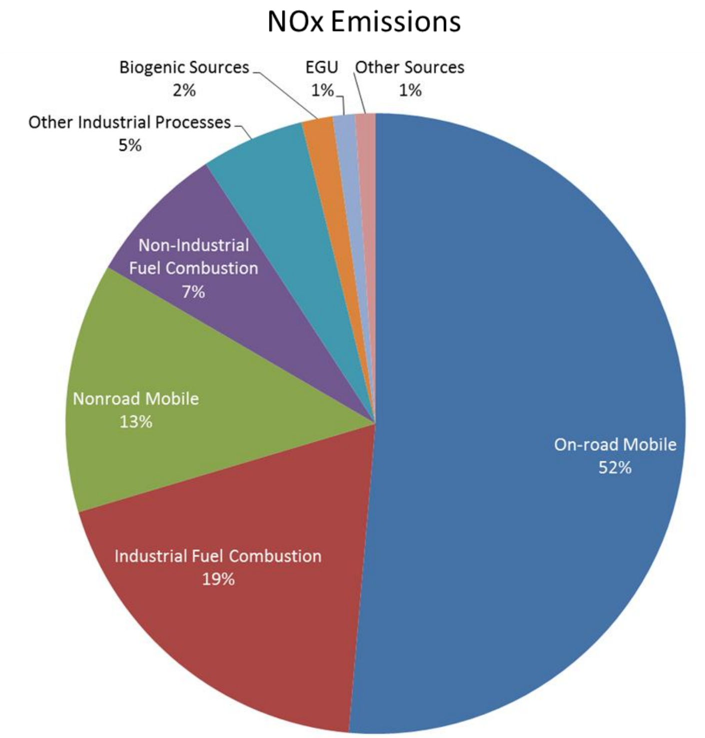
Ozone Air Quality and Modeling Concepts

Ground-Level Ozone

Ground-level ozone is a secondary pollutant formed from emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOC) in the presence of sunlight. Ground-level ozone can negatively affect human health and damage plants. The harmful effects of ground-level ozone should not be confused with the beneficial effects of ozone in Earth's upper atmosphere. Ozone chemistry is complex; for example, NO_x can create or destroy ozone depending on the concentrations of VOC and NO_x in the atmosphere. These complexities must be accounted for when evaluating potential ozone control strategies. Air quality models are needed to quantify the impacts of NO_x and VOC emission changes on ground-level ozone concentrations.

Emissions

The distribution of NO_x and VOC emissions in Albuquerque/Bernalillo County that contribute to ground-level ozone formation are shown in **Figure 2**. NO_x emissions are produced by combustion processes. Motor vehicles (i.e., cars and trucks on restricted and unrestricted access roadways) are the largest source of NO_x emissions (52%). NO_x emissions from other sources such as construction equipment, locomotives, and other industrial fuel combustion processes are also important, given that emissions from motor vehicles continue to be reduced through increasingly stringent emission control standards. VOC emissions are produced naturally from vegetation (known as biogenic emissions), and from a variety of consumer and industrial processes. The largest non-biogenic VOC source sector is solvent use, which includes emissions from numerous consumer and commercial sources such as dry cleaners, the use of consumer and commercial solvents, and the application of coatings and paints. Cars and trucks also produce VOC emissions through evaporative losses.



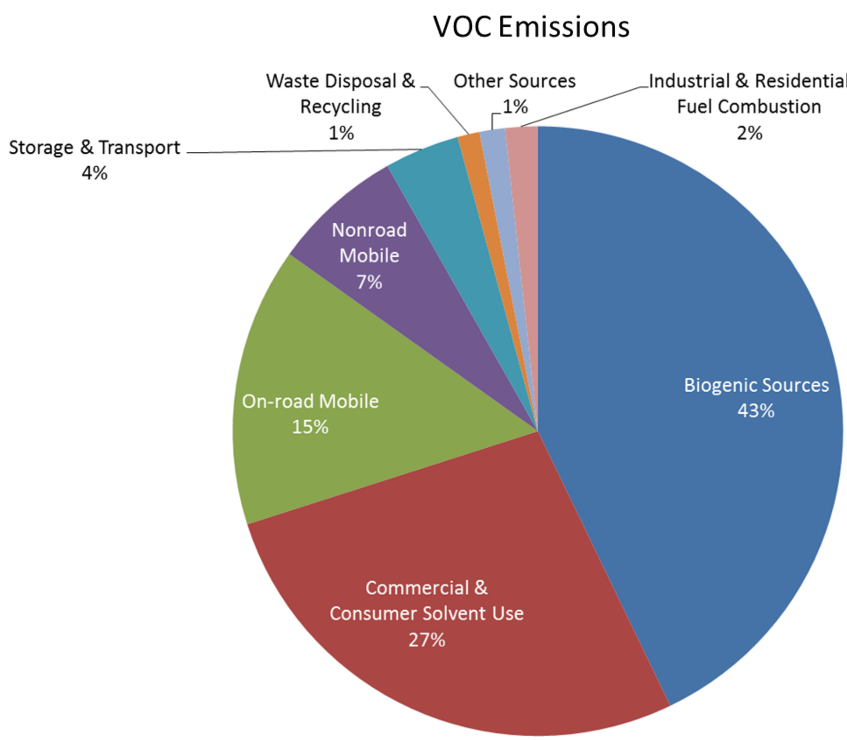


Figure 2. Distribution of annual 2014 emissions in Albuquerque/Bernalillo County.

Emissions from outside Albuquerque/Bernalillo County can also contribute to ozone formation in Albuquerque/Bernalillo County. Although there is no oil and gas extraction activity in Albuquerque/Bernalillo County, it is important to note that the oil and gas sector constitutes the largest source of anthropogenic (man-made) VOC emissions in the state of New Mexico. Ozone produced from both domestic and international emissions can also contribute to ozone concentrations in Albuquerque/Bernalillo County. Finally, fires also produce NO_x and VOC emissions and can lead to additional ozone formation regionally and locally. The role of local and non-local emissions on ozone in Albuquerque/Bernalillo County was investigated in this modeling project, and the results of this analysis can be found in the Summary of Key Findings.

Meteorology

Meteorology (weather) can affect ground-level ozone concentrations in several ways. Because sunlight facilitates ozone formation, the presence (or lack) of cloud cover can affect ozone concentrations. Warm days with a temperature-induced lid (an inversion) can trap ground-level ozone and its precursor emissions close to the ground. Atmospheric winds can transport and disperse ozone and its precursors, and can also transport ozone from long distances. Winds may vary vertically and horizontally and effect different emission sources in different ways. Based on the data analysis conducted during this project, the highest ozone concentrations in Albuquerque/Bernalillo County tend to occur during the afternoon hours on days with mostly clear skies, warm temperatures (80°F to 95°F), and light winds (less than about 10 mph). On many days during the summer, cloud cover, wind gusts, or precipitation from thunderstorms prevent ozone concentrations from reaching unhealthy levels. The role of weather on air quality is accounted for in this project through the use of a state-of-the-science numerical weather prediction model, similar to models that are used by meteorologists to develop weather forecasts.

Air Quality Models

Air quality models simulate all of the important processes that affect atmospheric pollutant concentrations, including emissions, transport (where pollutants go), diffusion (how pollutants are diluted), deposition (how pollutants are removed), and chemistry (how pollutants are created and destroyed). As shown in **Figure 3**, an air quality model represents the atmosphere as a series of boxes. The important processes are modeled within each box, and pollutants are transported between boxes based on meteorological conditions. The "grid resolution" of the model application refers to the size of these boxes being used to represent the atmosphere. For this project, the grid resolution was as small as 4 km (about 2.5 miles) over New Mexico.

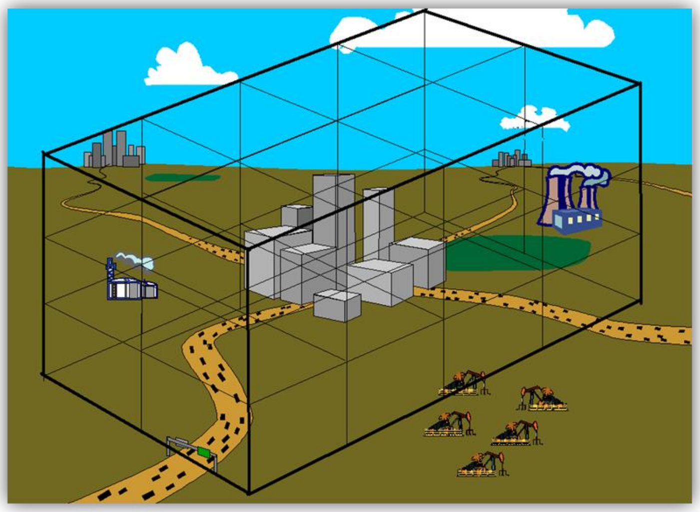


Figure 3. Conceptual diagram of an air quality model.

For this project, the Comprehensive Air Quality Model with Extensions (CAMx) was used. CAMx is an EPA-approved, state-of-the-science model. CAMx was designed to address multiple air quality issues, including ground-level ozone, fine particles, air toxics, acid deposition, and visibility degradation, and is widely used to address ozone air quality issues. Critical inputs to the air quality model include meteorology, emissions, and boundary conditions[5], and were developed with specialized state-of-the-science modeling systems that were used in the study.

Sensitivity Analysis and Source Apportionment

Sensitivity analysis involves the use of two simulations, a "base case simulation" and a "sensitivity simulation," to evaluate the air quality impact of an emission control scenario. In the sensitivity simulation, all input data remain identical to the base case except for one input variable of interest. For example, the base case might show ozone concentrations that result from current precursor emissions, while a sensitivity simulation might show ozone concentrations if NO_x emissions from motor vehicles in Albuquerque/Bernalillo County were reduced by 50%. The impact of the emission control scenario (in terms of ppb of ozone) is calculated from the difference between the base case and sensitivity simulation results. Once a base case simulation has been developed, many sensitivity simulations can be modeled to evaluate the potential impact on ground-level ozone from many different emission control strategies.

Source apportionment modeling quantifies the contribution of emissions from various emission source categories and/or geographic regions to modeled ozone concentrations. This is accomplished by tracking the NO_x and VOC emissions from specific sources or geographic areas as those emissions

[5] Boundary conditions refer to data at the edges of the modeling domain. Results from a global chemistry model simulation are typically used to develop boundary conditions.

form ozone downwind. In this project, the source apportionment analysis was used to identify and apportion the emission sources contributing to high ozone concentrations in Albuquerque/Bernalillo County. This source apportionment capability is included within the CAMx modeling system as an extension known as Ozone Source Apportionment Technology, or OSAT.

Study Methodology

The following key steps were taken to develop the air quality modeling analyses in this study.

- **Episode selection**. Modeling episodes were selected based on a review of ozone observation data in Albuquerque/Bernalillo County from 2013-2017. Two modeling episodes during June and July 2017 were selected. Ozone in Albuquerque/Bernalillo County was USG on EPA's AQI scale on four of the modeled episode days, and Moderate on the AQI scale on many of the modeled episode days. These episodes included most of the high ozone days that occurred in 2017.
- **Emissions modeling**. Emissions were based on the EPA 2014 National Emissions Inventory (NEI), with 2017 day-specific emissions for power plants and wildfires, and adjustments to account for changes in motor vehicle activity and fleet turnover between 2014 and 2017. The Sparse Matrix Operator Kernel Emissions (SMOKE) processing system was used to prepare emissions data for air quality modeling.
- **Meteorological modeling.** Weather inputs were developed with the Weather Research and Forecasting (WRF) numerical weather prediction model (version 3.9.1, released August 2017). Modeled winds, temperature, and humidity were evaluated against available observations. Model performance was within benchmarks established by the air quality modeling community.
- **Air quality modeling**. CAMx version 6.40 was used to simulate air quality during June and July 2017. Boundary conditions for CAMx were based on output from a global air quality model (MOZART) run by the National Center for Atmospheric Research (NCAR). The CAMx results were evaluated against available air quality observations. CAMx model performance was within benchmarks established by the air quality modeling community.
- **Source apportionment modeling.** Source apportionment modeling with CAMx OSAT was used to identify and apportion the emission sources contributing to high ozone concentrations.
- **Sensitivity modeling.** Eight emissions scenarios were developed to evaluate the sensitivity of ozone concentrations in Albuquerque/Bernalillo County to various changes in local and non-local emissions. Results from each simulation were compared against the baseline 2017 modeling results.
- **Future-year modeling**. The 2017 base-case emissions were projected to year 2025 based on future activity assumptions, regulations, and controls, and an air quality model simulation

was conducted based on these projected future-year emissions. Results from this simulation were compared to the 2017 simulation to assess how ozone in Albuquerque/Bernalillo County could be impacted by national, regional, and local changes in emissions that are expected to take place between 2017 and 2025. In addition, four future-year sensitivity analyses were conducted to evaluate the sensitivity of future ozone concentrations to various changes in local and non-local emissions.

Summary of Key Findings

Below is a summary of key findings from this project.

Source Apportionment Modeling

Modeled ozone source contributions on high ozone days in Albuquerque/Bernalillo County for the two modeling episodes in 2017 are shown in **Figure 4**. The source apportionment modeling analysis showed that the high ozone concentrations in the June 2017 ozone episode were largely driven by non-local emissions from outside Albuquerque/Bernalillo County, while the high ozone concentrations in the July episode were driven more strongly by local emissions from within Albuquerque/Bernalillo County. Therefore, we would expect that local emission controls within Albuquerque/Bernalillo County will not be effective at reducing ozone concentrations in Albuquerque/Bernalillo County when ozone is driven primarily by long-range pollutant transport, but will be more effective at reducing ozone concentrations when ozone is driven more strongly by local emissions. This finding was confirmed by the sensitivity modeling analysis. These results have important implications for air quality planning.

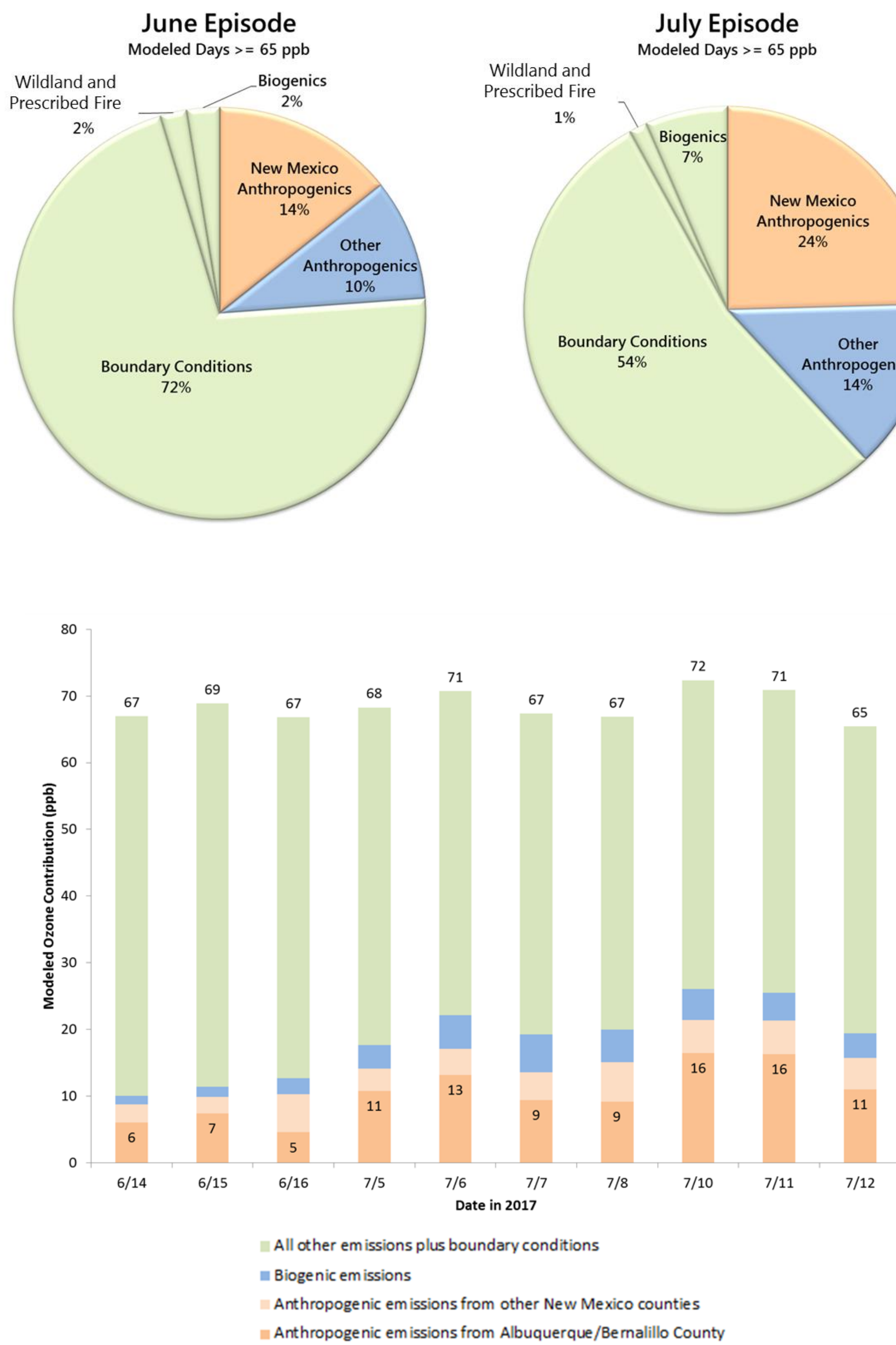


Figure 4. Modeled ozone source contributions on days in 2017 when the modeled peak 8-hr average ozone concentration in Albuquerque/Bernalillo County was greater than or equal to 65 ppb. The pie graph (top) shows contributions on a relative basis. The "Other Anthropogenics" wedge refers to contributions from anthropogenic emissions outside of New Mexico. The bar graph (bottom) shows contributions on an absolute (ppb) basis. The data labels show the modeled contribution due to anthropogenic emissions from Albuquerque/Bernalillo County, and the total modeled ozone in Albuquerque/Bernalillo County.

The key findings from the ozone source apportionment modeling analysis are as follows.

- Pollutant transport from outside New Mexico is important and accounts for over half of the ozone on high ozone days in Albuquerque/Bernalillo County.
- Local emissions in Albuquerque/Bernalillo County are also important. Half of the ozone generated by emissions from within Albuquerque/Bernalillo County is due to motor vehicles.
- On high ozone days during the June 2017 episode, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 5 and 7 ppb of ozone in Albuquerque/Bernalillo County. U.S. anthropogenic emissions outside of New Mexico contributed between 4 and 8 ppb of ozone.
- On high ozone days during the July 2017 episode, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 9 and 16 ppb of ozone in Albuquerque/Bernalillo County. U.S. anthropogenic emissions outside of New Mexico contributed between 7 and 10 ppb of ozone.
- On high ozone days, contributions from the Four Corners, San Juan, and Prewitt Escalante power plants in New Mexico were as large as 1 ppb but generally were less than 0.5 ppb in Albuquerque/Bernalillo County.
- Impacts from anthropogenic emissions in western states, including California, can be important. On many of the modeled days, ozone contributions in Albuquerque/Bernalillo County from California's emissions were greater than 1 ppb and larger than the ozone contributions from the Four Corners, San Juan, and Prewitt Escalante power plants in New Mexico.
- Ozone contributions in Albuquerque/Bernalillo County from wildfire smoke were as large as 2.0 ppb in the June episode and as large as 1.5 ppb in the July episode.
- Ozone contributions due to emissions from the Western Refining Gallup facility were negligible in Albuquerque/Bernalillo County.
- Emissions from nonroad[6] and non-mobile source sectors are becoming increasingly important as emissions from motor vehicles continue to decrease.

Ozone impacts from the Four Corners and San Juan power plants in northern New Mexico will likely be reduced in the future, given that two units at San Juan were decommissioned in December 2017, and NO_x emission controls were installed on two units at Four Corners in 2018.

Sensitivity Modeling

A series of sensitivity simulations were developed at the direction of and in consultation with the Albuquerque EHD to test the sensitivity of modeled ozone concentrations in Albuquerque/Bernalillo

[6] Nonroad refers to mobile sources that do not use roads, such as construction equipment and locomotives.

County to various changes in local and non-local emissions. Results from these sensitivity simulations can be used to assess (1) whether ozone reductions should be accomplished through reductions in NO_x emissions, VOC emissions, or both; and (2) under what types of conditions local emission reductions may be effective at reducing ozone.

Eight sensitivity scenarios were developed for this analysis and include

- 10% reduction of Albuquerque/Bernalillo County anthropogenic NO_x emissions.
- 10% reduction of Albuquerque/Bernalillo County anthropogenic VOC emissions.
- 25% reduction of Albuquerque/Bernalillo County on-road mobile source NO_x emissions.
- 25% reduction of New Mexico oil and gas emissions.
- Impact of the Albuquerque/Bernalillo County Inspection and Maintenance (I&M) program.
- Reeves and Rio Bravo power plants running at permitted emission levels.
- 100% reduction of Sandoval County anthropogenic emissions.
- 100% reduction of Valencia County anthropogenic emissions.

The results from these sensitivity modeling analyses built upon the findings from the source apportionment analysis and confirmed that local emission controls within Albuquerque/Bernalillo County would have been less effective at reducing the ozone concentrations in Albuquerque/Bernalillo County during the June episode, but would have been more effective at reducing ozone concentrations during the July episode.

The key findings from the sensitivity modeling analysis are as follows:

- NO_x emission controls will be effective at reducing ozone in Albuquerque/Bernalillo County. VOC emission controls may not be effective at reducing ozone unless they are substantial (>10%).
- Emissions from Valencia and Sandoval counties impact ozone in Albuquerque/Bernalillo County by as much as 4 ppb.
- The Reeves and Rio Bravo power plants would impact ozone in Albuquerque/Bernalillo County by as much as 3 ppb if they operated at permitted emission levels.
- The I&M program in Albuquerque/Bernalillo County reduces on-road mobile source NO_x emissions by 5% and VOC emissions by 7%, and reduces ozone in Albuquerque/Bernalillo County by up to 0.25 ppb.
- Ozone in Albuquerque/Bernalillo County is sensitive to emissions from oil and gas operations in New Mexico. Reducing NO_x and VOC emissions from the oil and gas sector in New Mexico by 25% would reduce ozone concentrations in Albuquerque/Bernalillo County by up to 1 ppb.

When considering the modeled ozone impact of the Albuquerque/Bernalillo County I&M program, note that the purpose of an I&M program is to ensure that motor vehicles are operating in a manner that meets federal, state, and local emission standards. Without an I&M program, there is risk that the motor vehicle emissions in Albuquerque/Bernalillo County would fail to meet the projections made by Albuquerque EHD. I&M programs can also produce benefits for other pollutants, such as NO_2 and particulate matter, which are important for protecting air quality near major roadways.

Future-Year Modeling

The 2017 base-case emissions were projected to year 2025 based on future activity assumptions, regulations, and controls; a future-year air quality model simulation was conducted based on these projected future-year emissions. Results from this future-year simulation were compared to the 2017 simulation to assess how ozone in Albuquerque/Bernalillo County could be impacted by national, regional, and local changes in emissions that are expected take place between 2017 and 2025.

In addition, four future-year sensitivity simulations were developed at the direction of and in consultation with the Albuquerque EHD:

- Reeves and Rio Bravo power plants in Bernalillo County operating at permitted emission levels.
- Expansion of the Albuquerque/Bernalillo County I&M Program to cover light-duty gasoline vehicles in Sandoval and Valencia counties.
- 25% reduction of anthropogenic NO_x and VOC emissions in Bernalillo, Sandoval, and Valencia counties.
- Electrification of the light-duty gasoline vehicle fleet in Albuquerque/Bernalillo County.

The key findings from the future-year modeling analysis are as follows:

- Projected emission reductions by 2025 would reduce peak 8-hr average ozone concentrations in Albuquerque/Bernalillo County by 3-7%. To put this into context, a 5% reduction of ozone concentrations by 2025 could reduce the future-year ozone design value in Albuquerque/Bernalillo County by 3-4 ppb, based on a current design value of 70 ppb.
- The Reeves and Rio Bravo power plants would increase ozone in Albuquerque/Bernalillo County in the future by as much as 4 ppb if they were operated at permitted emission levels.
- A 25% reduction of anthropogenic NO_x and VOC emissions in Bernalillo, Sandoval, and Valencia counties would reduce future ozone concentrations in Albuquerque/Bernalillo County by as much as 3 ppb. This result suggests that a multi-county approach to reducing emissions would be effective at reducing future ozone concentrations in Albuquerque/Bernalillo County.
- Replacing the light-duty gasoline vehicle fleet with electric vehicles in Albuquerque/Bernalillo County would reduce future ozone concentrations in Albuquerque/Bernalillo County by as much as 2 ppb.

- Expanding the I&M program to Sandoval and Valencia counties in the future would reduce ozone concentrations in Albuquerque/Bernalillo County by as much as 0.5 ppb.

VOC Emissions Analysis

The VOC emissions inventory in Albuquerque/Bernalillo County was analyzed to identify the VOCs and corresponding emission source categories that are most likely to contribute to ozone formation. VOCs mix with NO_x in the presence of sunlight to produce ground-level ozone. There are several dozen VOC species that can contribute to ozone formation, and some VOCs are much more reactive than others in terms of ozone formation. Understanding the composition and chemical reactivity of different VOC emissions is important for developing effective air quality control strategies.

The key findings from the VOC emissions inventory analysis are as follows:

- Aromatic VOCs such as xylenes and toluene are highly reactive and represent 38% of the anthropogenic VOC ozone-generating potential in the Albuquerque/Bernalillo County emissions inventory, despite representing only 10% of anthropogenic VOC emissions. Xylenes are used in many types of solvents and are also emitted from diesel engines; therefore, reducing emissions from solvent use and construction equipment could potentially reduce ozone concentrations in Albuquerque/Bernalillo County.
- Alkane VOCs such as pentane are less reactive compared to other VOCs, and therefore relatively large reductions in alkane VOC emissions would be needed to significantly reduce ozone in Albuquerque/Bernalillo County. Alkane VOCs represent over 50% of the anthropogenic VOC emissions in Albuquerque/Bernalillo County, but only 29% of the anthropogenic ozone-generating potential in the emissions inventory. Alkane VOCs are emitted from motor vehicles, construction equipment, oil and gas exploration, and a variety of industrial processes.
- Speciated VOC measurements are needed to confirm that the VOC emissions inventory is representing ambient VOC concentrations, and to develop a more detailed understanding of specific VOC species that may be contributing to ozone in Albuquerque/Bernalillo County. Speciated VOC measurements (i.e., measurements of individual VOC compounds, not just total VOC) would provide additional data to evaluate the existing VOC emission inventory, evaluate air quality model performance, track the effectiveness of VOC emission control programs, and protect public health.

1. Introduction

This report describes ozone air quality modeling that was conducted on behalf of the City of Albuquerque Environmental Health Department (Albuquerque EHD). This work included meteorological, emissions, and air quality modeling analyses, as well as source apportionment analysis, sensitivity modeling analyses, and future-year modeling analyses. The modeling approach, modeling episodes, input data sources, evaluation methods, technical analyses, and quality assurance/quality control (QA/QC) procedures described in this report are consistent with the modeling protocol and quality assurance project plan (QAPP) documents developed at the beginning of the project in consultation with the Albuquerque EHD. An overview of key results from this study was presented to the Albuquerque/Bernalillo County Air Quality Control Board in October of 2018.

Two high-ozone episodes in 2017 that occurred in Albuquerque/Bernalillo County[7] were modeled in this study, as shown in Table 1. The June 2017 ozone episode had two of the three highest 8-hour ozone concentrations for the year (76 ppb on June 14 and 72 ppb on June 15). The July 2017 ozone episode includes four days when 8-hour ozone concentrations were at or above 70 ppb in Albuquerque/Bernalillo County.

Table 1. Summary of modeling episodes. Days with peak 8-hr ozone greater than 70 ppb in Albuquerque/Bernalillo County are denoted in **bold**.

	June Episode	July Episode
Modeling Period	June 12–16, 2017	July 3–14, 2017
Peak Ozone Days	June 13, **14, 15**, 16	July 5, 6, **7**, **10**, 11
Peak 1-hr Ozone (ppb)	75, 84, 76, 71	78, 75, 85, 83, 72
Peak 8-hr Ozone (ppb)	67, **76**, **72**, 63	70, 69, **76**, **76**, 70

This introduction provides background and motivation for this air quality modeling study. The modeling episodes and ambient monitoring data are described in more detail in Chapters 2 and 3, while the modeling domains are described in Chapter 5. An analysis of VOC emissions with respect to their potential ozone reactivity is described in Chapter 4. The meteorological modeling conducted with the Weather Research and Forecasting (WRF) numerical weather prediction model for these episodes is described in Chapter 6. The emissions inventory and emissions modeling are described in Chapter 7. Air quality modeling conducted with the Comprehensive Air Quality Model with Extensions (CAMx) and the base-case model performance evaluation are described in Chapter 8.

[7] Throughout this report, "Albuquerque/Bernalillo County" and "Bernalillo County" refer to all of Bernalillo County, including the incorporated Albuquerque City limits.

Additional source apportionment modeling and sensitivity modeling analyses that were conducted are described in Chapters 9 and 10, and future-year modeling analyses are described in Chapter 11. Conclusions from the study can be found in Chapter 12. Key findings from this study are also described here in Chapter 1.

1.1 Background and Motivation

The Albuquerque EHD has primary responsibility for monitoring and regulating air quality emissions in the City of Albuquerque and throughout Bernalillo County, New Mexico. Actions implemented by Albuquerque EHD, such as its Vehicle Pollution Management Program, promote air quality awareness and reduce local emissions that can contribute to ozone pollution. Air quality regulations are approved by the Albuquerque/Bernalillo County Air Quality Control Board, whose members are appointed by elected officials in Albuquerque and Bernalillo County.

Albuquerque/Bernalillo County is currently in attainment of the 2015 National Ambient Air Quality Standard (NAAQS) for ozone (0.070 ppm). Ozone design values[8] in Albuquerque/Bernalillo County have been decreasing over the last 15 years, but have increased in recent years (Figure 5). The unofficial 2018 ozone design value in Albuquerque/Bernalillo County[9] is 70 ppb, which is on the cusp of exceeding the federal standard. Therefore Albuquerque/Bernalillo County is at risk of exceeding the federal ozone standard in the future if there are high ozone days again in 2019 or 2020.

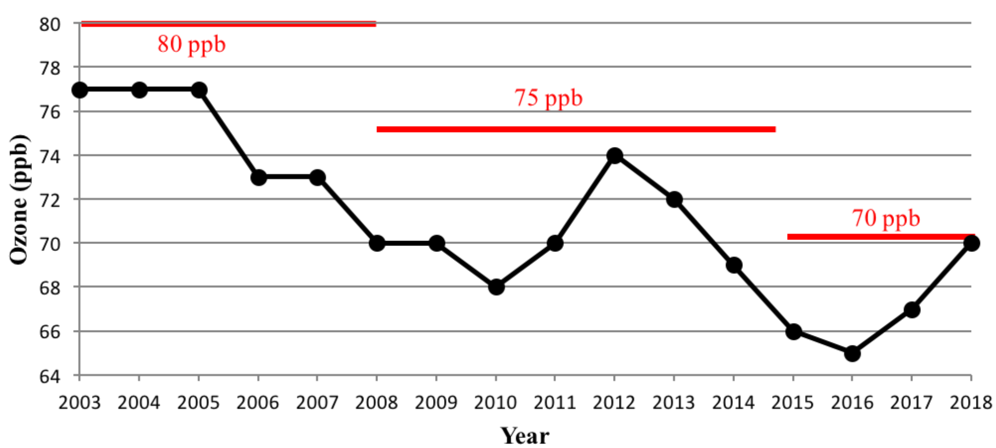


Figure 5. Ozone design values in Albuquerque/Bernalillo County from 2003 through 2018. The highest design value for each year across all monitoring sites in Albuquerque/Bernalillo County are shown (black dots). Data through 2017 are from EPA's ozone design values reports (epa.gov/air-trends/air-quality-design-values). Data for 2018 are based on preliminary calculations by the Albuquerque EHD. Red lines indicate the ozone NAAQS over time.

[8] A design value is a statistic used to compare ambient air quality concentrations to the NAAQS. For the 8-hr ozone NAAQS, the design value is defined as the average of the annual fourth-highest daily maximum 8-hr average ozone concentrations over a three-year period. NAAQS attainment is achieved when the design value is less than or equal to the NAAQS.

[9] Based on preliminary calculations by the Albuquerque EHD.

Ozone concentrations in Albuquerque/Bernalillo County are sensitive to both local and non-local emission sources. Source apportionment modeling conducted by the U.S. Environmental Protection Agency (EPA)[10] (U.S. Environmental Protection Agency, 2016b) projected that anthropogenic emissions in New Mexico would contribute up to 10 ppb of ozone in Albuquerque/Bernalillo County in 2017 (the ozone design value for Albuquerque/Bernalillo County in 2017 was 67 ppb), while the remaining 57 ppb ozone was due to: (1) non-anthropogenic (biogenic and wildfire) emissions from New Mexico and other states; (2) anthropogenic emissions from other states; and (3) emissions and long-range pollutant transport from outside the United States. Consistent with EPA's modeling, previous modeling conducted by the Albuquerque EHD in 2007 also showed that non-local emissions from outside Albuquerque/Bernalillo County, including emissions from wildfires, contributed to high ozone concentrations in Albuquerque/Bernalillo County (Wheeler et al., 2007). These modeling studies indicate that a significant portion of the ozone in Albuquerque/Bernalillo County is due to long-range pollutant transport from outside of New Mexico.

As anthropogenic precursor emissions decrease nationally, the fraction of ozone that can be attributed to background ozone[11] may increase. Background ozone concentrations at high-altitude western U.S. sites can range from 40 ppb to 60 ppb in the spring (Fiore et al., 2014), and observations and modeling have shown that background ozone concentrations have been increasing in the western United States over the last 25 years (Lin et al., 2017). Under a more stringent NAAQS, ozone originating from stratospheric intrusions, wildfire emissions, or international pollutant transport may cause exceedances of the ozone NAAQS.

A refined understanding of the effects of local emissions and meteorology, long-range pollutant transport, and wildland/prescribed fires on pollutant concentrations on high ozone days is important for effective air quality management and planning. The EHD retained Sonoma Technology, Inc. (STI) to conduct photochemical grid modeling analyses to assist the EHD with its air quality planning process. Multiple pollutants, including ozone, particulate matter, and their chemical precursors, were modeled, but the focus of this project is on ground-level ozone and its precursors. The modeling work focused on two ozone episodes described in Chapter 2. The analyses involved base-case modeling, sensitivity modeling, source apportionment modeling, and future-year modeling to address the following questions:

- Are current ozone concentrations in Albuquerque/Bernalillo County sensitive to volatile organic compound (VOC) controls, oxides of nitrogen (NO_x) controls, or both?
- What are the contributions from local and non-local emissions, including fires, on high ozone days?
- What are the contributions from key emission source sectors on high ozone days? For example, how much ozone do emissions from motor vehicles in Albuquerque/Bernalillo

[10] Future-year modeling in EPA's Final Cross State Air Pollution Rule (CSAPR) Update was based on a projected 2017 emissions inventory with year 2011 meteorology and boundary conditions.
[11] Here, background ozone is defined as the theoretical minimum ozone concentration achievable by U.S. regulatory policy.

County contribute? And to what extent do emissions from specific industries contribute to ozone in Albuquerque?

- How important is international, interstate, and intrastate pollutant transport in relation to local emissions on high ozone days in Albuquerque/Bernalillo County?
- What are the impacts of the Albuquerque/Bernalillo County Inspection and Maintenance (I&M) program on emissions and ozone air quality?
- What will future ozone concentrations be in Albuquerque/Bernalillo County?
- Are future ozone concentrations in Albuquerque/Bernalillo County sensitive to VOC controls, NO_x controls, or both?
- How will factors such as population and land use, industrial development, and control strategies affect future ozone concentrations in Albuquerque/Bernalillo County?

1.2 Study Methodology

The goal of the Albuquerque/Bernalillo County Ozone Modeling Analysis is to conduct a comprehensive photochemical modeling analysis that can be used as a technical basis for air quality planning. The modeling analysis, guided by the modeling protocol document developed in consultation with the Albuquerque EHD at the beginning of the project (Craig and Erdakos, 2018a), is designed to identify the processes responsible for high 8-hr ozone concentrations in the region and to assist the EHD with developing realistic emissions reduction strategies for their control. This work is intended to provide a more thorough understanding of ozone air quality in Albuquerque/Bernalillo County, and could also provide a starting point to support regulatory modeling should such a need arise in the future.

The following key steps were taken to develop the air quality modeling analyses in this study.

- **Episode selection**. Modeling episodes were selected based on a review of ozone observation data in Albuquerque/Bernalillo County from 2013-2017. Two modeling episodes during June and July 2017 were selected. Ozone in Albuquerque/Bernalillo County was Unhealthy for Sensitive Groups (USG) on EPA's Air Quality Index (AQI)[12] scale on four of the modeled episode days, and Moderate on the AQI scale on many of the modeled episode days. These episodes included most of the high ozone days that occurred in 2017 (see Chapter 2).
- **Emissions modeling**. Emissions were based on the EPA 2014 National Emissions Inventory (NEI), with 2017 day-specific emissions for power plants and wildfires, and adjustments to account for changes in motor vehicle activity and fleet turnover between 2014 and 2017. The Sparse Matrix Operator Kernel Emissions (SMOKE) processing system was used to prepare emissions data for air quality modeling (see Chapter 7).

[12] Current and forecasted AQI values are available through EPA's AirNow program at https://airnow.gov. The AQI translates air quality data into numbers and colors that help the general public understand when to take action to protect their health.

- **Meteorological modeling.** Weather inputs were developed with the Weather Research and Forecasting (WRF) numerical weather prediction model (version 3.9.1, release August 2017). Modeled winds, temperature, and humidity were evaluated against available observations. Model performance was within benchmarks established by the air quality modeling community (see Chapter 6).
- **Air quality modeling**. CAMx version 6.40 was used to simulate air quality during June and July 2017. Boundary conditions for CAMx were based on output from a global air quality model (MOZART) run by the National Center for Atmospheric Research (NCAR). The CAMx results were evaluated against available air quality observations. CAMx model performance was within benchmarks established by the air quality modeling community (see Chapter 8).
- **Source apportionment modeling.** Source apportionment modeling with CAMx OSAT was used to identify and apportion the emission sources contributing to high ozone concentrations (see Chapter 9).
- **Sensitivity Modeling.** Eight emissions scenarios were developed to evaluate the sensitivity of ozone concentrations in Albuquerque/Bernalillo County to various changes in local and non-local emissions. Results from each simulation were compared against the baseline 2017 modeling results (see Chapter 10).
- **Future-Year Modeling**. The 2017 base-case emissions were projected to year 2025 based on future activity assumptions, regulations, and controls, and an air quality model simulation was conducted based on these projected future-year emissions. Results from this simulation were compared to the 2017 simulation to assess how ozone in Albuquerque/Bernalillo County could be impacted by national, regional, and local changes in emissions that are expected take place between 2017 and 2025. In addition, four future-year sensitivity analyses were conducted to evaluate the sensitivity of future ozone concentrations to various changes in local and non-local emissions (see Chapter 11).

Other elements of this project included preparing a modeling protocol document (Craig and Erdakos, 2018a) and QAPP (Craig and Erdakos, 2018b)[13], selecting appropriate ozone modeling episodes (see Chapter 2) and modeling domains (see Chapter 5), analyzing ambient meteorological and air quality observations (see Chapter 3), and analyzing the VOC emissions inventory form an ozone reactivity perspective (see Chapter 4).

The technical approach and results from these project elements are described in this report.

[13] These documents were developed in accordance with appropriate guidance documents, such as the U.S. Environmental Protection Agency's (EPA) Draft Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze (U.S. Environmental Protection Agency, 2014a).

1.3 Models Used

The WRF numerical weather prediction model (Skamarock et al., 2008), the SMOKE processing system (Houyoux et al., 2000; Houyoux and Adelman, 2001), and the CAMx air quality model (ENVIRON International Corporation, 2016) were selected for this modeling analysis. These modeling tools represent the current state-of-the-science in meteorological, emissions, and photochemical modeling.

EPA does not recommend specific models for photochemical air quality modeling studies, and instead recommends that models be selected on a case-by-case basis. General criteria that EPA considers include

- The model has received scientific peer review.
- The model is scientifically appropriate and applicable for the intended purpose.
- Databases are available and adequate to support the model's application.
- Available performance evaluations have shown the model is not inappropriately biased.
- The model should be applied consistently with an established protocol on methods and procedures (fulfilled by this modeling protocol document)

The models selected here meet these criteria. An overview of these modeling systems and the specific rational for their selection in this project are provided in the modeling protocol document (Craig and Erdakos, 2018a).

1.4 Project Participants

Participants in the Albuquerque/Bernalillo County Ozone Modeling Analysis are identified in **Table 2**. STI conducted this modeling at the direction of and in consultation with the Albuquerque EHD. The project was directed by Fabian Macias of the EHD. Specific data analysis, modeling, and reporting activities were performed by staff at STI at the direction of Mr. Kenneth Craig, the Principal Investigator for the project.

Table 2. Project participants.

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Travis Miller Environmental Health Supervisor Vehicle Pollution and Emissions Inventory Division City of Albuquerque Air Quality Program 1500 Broadway NE Albuquerque, NM 87102	**Dan Gates** Senior Environmental Health Scientist Ambient Air Monitoring Division City of Albuquerque Air Quality Program 11850 Sunset Gardens SW Albuquerque, NM 87121
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2. Episode Selection

2.1 EPA Guidance

Guidelines for selecting modeling episodes, outlined in the EPA's guidance (U.S. Environmental Protection Agency, 2014a), seek to achieve a balance between sound science and regulatory needs and constraints. Modeling episodes, once selected, influence technical and policy decisions for many years. Primary criteria identified by EPA include

- Modeling time periods that are close to the most recently compiled and quality-assured NEI.[14]
- Modeling time periods in which observed 8-hr ozone concentrations are within a few parts per billion of the monitored design values.
- Modeling time periods before, during, and after pollution concentration episodes.[15]
- Simulating a range of meteorological conditions that accompany exceedances of the 8-hr ozone standard.
- Selecting periods for which adequate emissions, air quality, and meteorological data (including any special study data) are available to develop model inputs and evaluate model performance.

Note that in a modeled attainment demonstration, the modeling episode is often the entire ozone season (for an ozone demonstration) or the entire year (for an annual $PM_{2.5}$ demonstration) to ensure an adequate number of high pollution days are modeled. For this project, the episode selection is more restrictive to allow for a more focused assessment of specific time periods that led to high ozone in Albuquerque/Bernalillo County.

2.2 Episodes Selected

The two modeling episodes selected in consultation with the Albuquerque EHD for this project are shown in Table 3. As part of the episode selection process, STI assessed the availability of air quality monitoring and meteorological data in New Mexico and Albuquerque/Bernalillo County, including any available special study data, to ensure that suitable data were available to support modeling

[14] This recommendation also helps ensure that any emission projection period is as short as possible, and that the base-year ambient data is as current as possible. For attainment demonstrations, the emissions should also correspond with the period reflected by the 5-year design value window.

[15] It is advisable to model episodes that encompass the full cycle of a pollution episode, including a ramp-up to a high ozone period and a ramp-down to cleaner conditions.

analysis and evaluations. STI also reviewed local and regional air quality monitoring data, meteorological data, and smoke analyses to support the episode selection process.

Table 3. Summary of modeling episodes. Days with peak 8-hr ozone greater than 70 ppb are denoted in **bold**.

	June Episode	July Episode
Modeling Period	June 12–16, 2017	July 3–14, 2017
Peak Ozone Days	June 13, **14**, **15**, 16	July 5, 6, **7**, **10**, 11
Peak 1-hr Ozone (ppb)	75, 84, 76, 71	78, 75, 85, 83, 72
Peak 8-hr Ozone (ppb)	67, **76**, **72**, 63	70, 69, **76**, **76**, 70

Both of the selected episodes are from 2017 and include days with the highest monitored ozone concentrations for the year in Albuquerque/Bernalillo County, as shown in Table 4. The episodes also include days where ozone concentrations increase during the evening hours after dropping off their midday peaks (this phenomenon is referred to as "ozone kickup" by the Albuquerque EHD). As described below, the two ozone episodes occurred under very different meteorological conditions, and therefore provide a diverse set of conditions for studying high ozone in Albuquerque/Bernalillo County.

Table 4. Top ten 8-hr ozone concentrations (ppb) at Albuquerque/Bernalillo County monitoring sites in 2017. Days included in the modeling episodes are denoted in **bold**. The Air Quality Site (AQS) number is shown for each site.

Rank	Foothills (AQS 35-001-1012)	South Valley (AQS 35-001-0029)	Del Norte (AQS 35-001-0023)
1	**76 (June 14)**	**69 (June 15)**	**76 (July 7)**
2	**76 (July 10)**	**67 (July 6)**	**72 (July 10)**
3	**72 (June 15)**	66 (June 3)	**70 (July 5)**
4	**71 (July 7)**	**66 (June 14)**	**69 (June 14)**
5	**70 (July 11)**	65 (June 5)	**69 (July 6)**
6	**68 (July 24)**	**65 (July 7)**	**68 (June 15)**
7	67 (April 15)	64 (April 16)	67 (April 16)
8	67 (April 16)	63 (April 15)	66 (April 15)
9	**67 (June 13)**	63 (June 4)	66 (July 22)
10	67 (July 28)	**63 (June 16)**	**65 (July 4)**

2.2.1 June 2017 Ozone Episode

On June 14 and 15, the 8-hr average ozone concentration exceeded 70 ppb and was Unhealthy for Sensitive Groups on EPA's AQI scale at the Foothills monitor, and was near 70 ppb (Moderate AQI) at the South Valley and Del Norte monitors. The maximum 8-hr ozone concentration in Albuquerque/Bernalillo County exceeded 60 ppb on four of the six episode days. The 8-hr ozone concentration also exceeded 70 ppb on three consecutive days (June 14-16) at the Double Eagle monitor (not shown in Table 4). This ozone episode was responsible for two of the top five daily maximum 8-hr ozone concentrations for the year at the Foothills and South Valley sites, and two of the top-ten peak ozone days at the Del Norte site. Peak ozone concentrations remained in the Moderate AQI range through June 17. Wind speeds were lower than usual on the highest ozone days (June 14 and June 15), and were about 5 m/s during the daytime.

New Mexico was under the influence of a low-pressure trough during this ozone episode period (Figure 6). The upper-level low-pressure system with a closed circulation passed over the West Coast on June 11 and 12, and lifted northeast through the Intermountain West on June 13. A weak surface cold front associated with this upper-level trough passed through New Mexico from the northwest in the early morning hours of June 13, which briefly lowered the high temperature in the City of Albuquerque by a few degrees. Surface high pressure built in behind the front on June 14 and 15. Westerly and southwesterly flow aloft was conducive to long-range pollutant transport from Arizona and California. Atmospheric soundings showing aloft westerly winds over the City of Albuquerque on June 14 are shown in Figure 7.

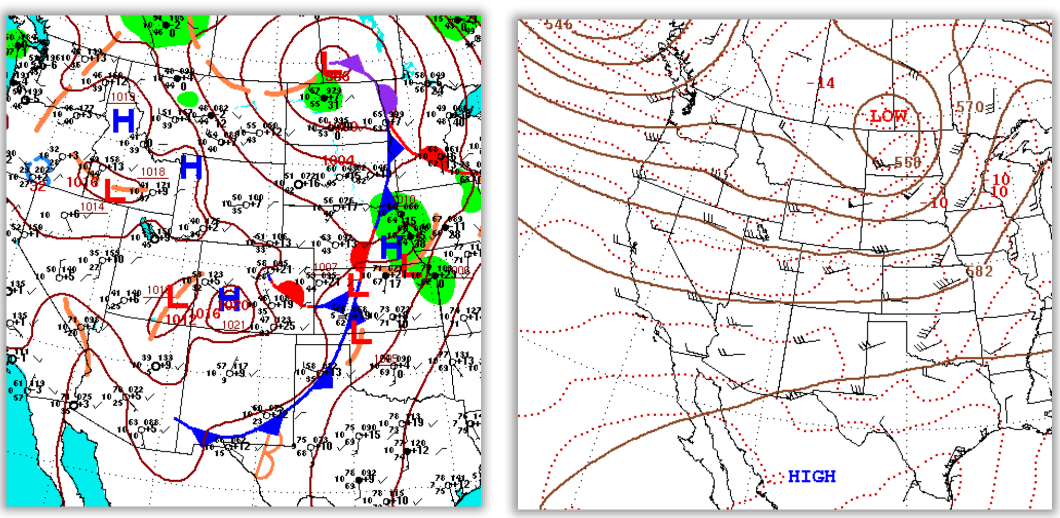

Figure 6. Surface (left) and 500 mb (right) weather maps on June 14, 2017. From NCEP Daily Weather Map archive (**http://www.wpc.ncep.noaa.gov/dwm**).

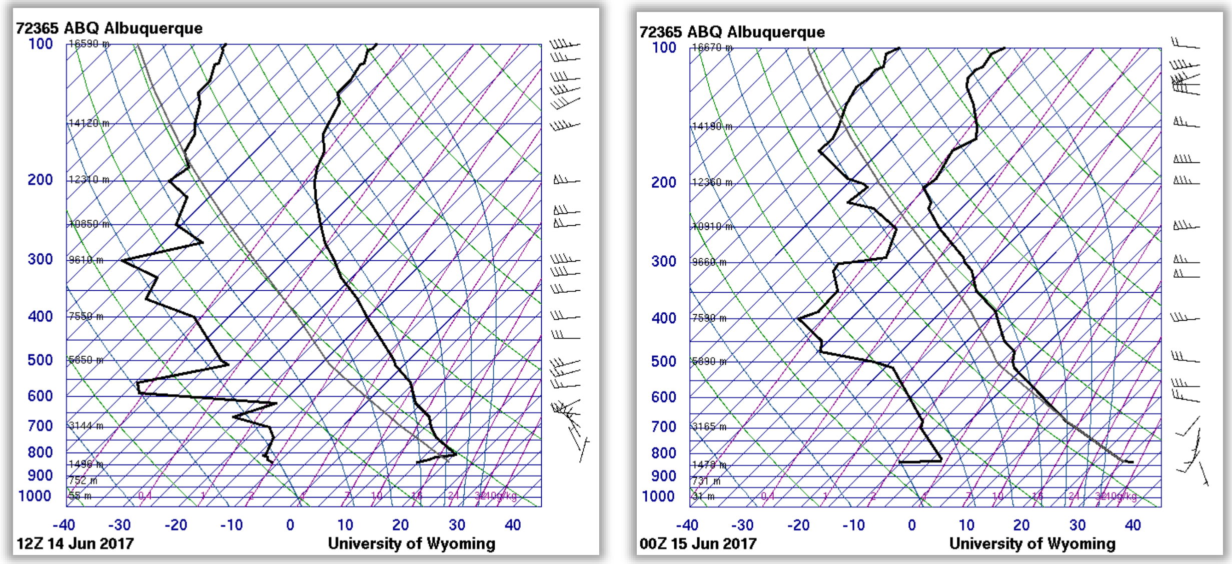

Figure 7. Atmospheric soundings at Albuquerque on June 14, 2017, at 0600 (left) and 1800 (right) local time, showing a surface-based inversion in the morning, a deep afternoon convective boundary layer, and a very dry atmosphere. From the University of Wyoming (http://weather.uwyo.edu/upperair/sounding.html).

Several fires were burning in Arizona and New Mexico during the June ozone episode, including fires to the north and southeast of Phoenix, Arizona, fires in the Gila National Forest of southwestern New Mexico, and fires north of Albuquerque/Bernalillo County in the Carson and Santa Fe National Forests. Evidence of enhanced smoke at the surface was not apparent in the $PM_{2.5}$ concentrations at the Del Norte monitor except perhaps for modest rises $PM_{2.5}$ concentrations on June 15 and June 16. Satellite imagery showed evidence of intermittent smoke over Albuquerque/Bernalillo County throughout the episode. Figure 8 shows the peak 8-hr average ozone concentrations, wildfire locations, and smoke analysis from the NOAA Hazard Mapping System (HMS) on June 14. Regionally, peak 8-hr ozone concentrations were in the Moderate AQI range (between 55 and 65 ppb) during much of the episode throughout Arizona and New Mexico, and in the USG range in the Phoenix area. On June 14 (see Figure 8), the peak 8-hr concentration was over 65 ppb at most urban and rural monitoring sites in northern New Mexico. Notably, the peak 8-hr concentration was 70 ppb at the New Mexico Environment Department (NMED) Santa Fe monitor on June 14.

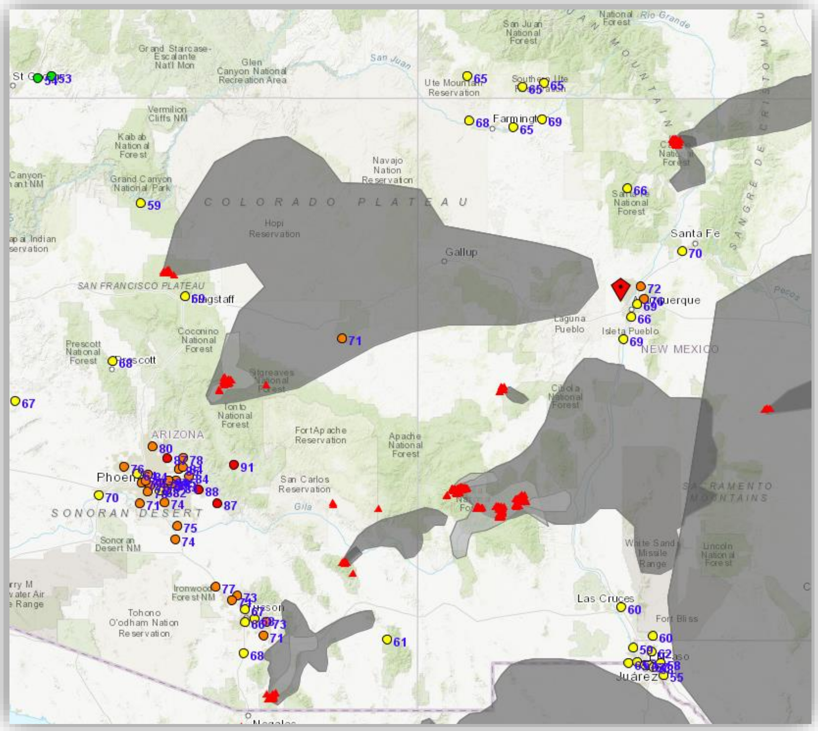

Figure 8. Maximum 8-hr average ozone concentrations (circles showing green, yellow, and orange AQI colors) with HMS satellite detections (red triangles) and HMS-analyzed smoke (gray shading) on June 14, 2017.

2.2.2 July 2017 Ozone Episode

The 8-hr average ozone concentration exceeded 70 ppb and was Unhealthy for Sensitive Groups on EPA's AQI scale at the Foothills and Del Norte monitors on July 7 and 10, and was 70 ppb (Moderate AQI) at those monitors on July 5 and 11. The maximum 8-hr ozone concentration also exceeded 70 ppb on July 7 and July 10 at the Double Eagle monitor. The maximum 8-hr ozone concentration in Albuquerque/Bernalillo County exceeded 60 ppb on 11 of the 14 days and was in the Moderate AQI range for much of the episode. This ozone episode was responsible for four of the top five daily maximum 8-hr ozone concentrations for the year at the Foothills site, and three of the top five peak ozone days at the Del Norte site.

New Mexico was under the influence of a strong high pressure system throughout the ozone episode period (Figure 9). The upper-level ridge of high pressure started building on July 1, was strongest on July 7, and then weakened slowly through the rest of the episode. The positioning of the high pressure ridge produced weak northeasterly flow aloft over New Mexico during much of the episode, which provided a transport pathway for emissions from the Colorado Front Range into Albuquerque/Bernalillo County. The closed clockwise circulation around the high pressure system was also conducive to regional ozone formation and pollutant recirculation. Ozone concentrations were in the Moderate AQI range at many urban and rural monitors throughout the West, and peak 8-

hr ozone concentrations exceeded 70 ppb in Phoenix, Salt Lake City, and Denver on some days during July 1-14. Figure 10 shows the peak 8-hr average ozone concentrations on July 7. Wildfire activity produced some regional smoke during the episode. Smoke was observed over New Mexico by NOAA's HMS analysts on July 7 (see Figure 3), but not on July 10.

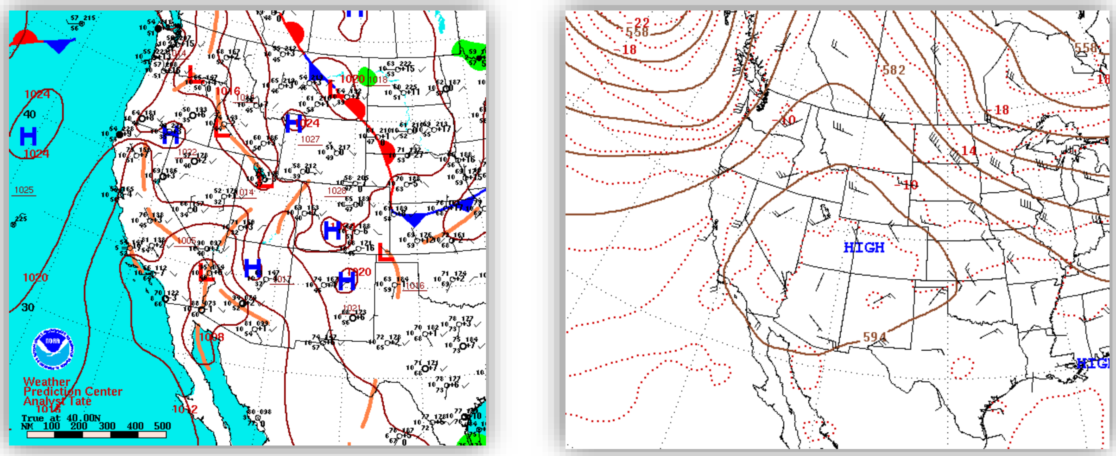

Figure 9. Surface (left) and 500 mb (right) weather maps showing a high pressure system over New Mexico on July 7, 2017. From NCEP Daily Weather Map archive (http://www.wpc.ncep.noaa.gov/dwm).

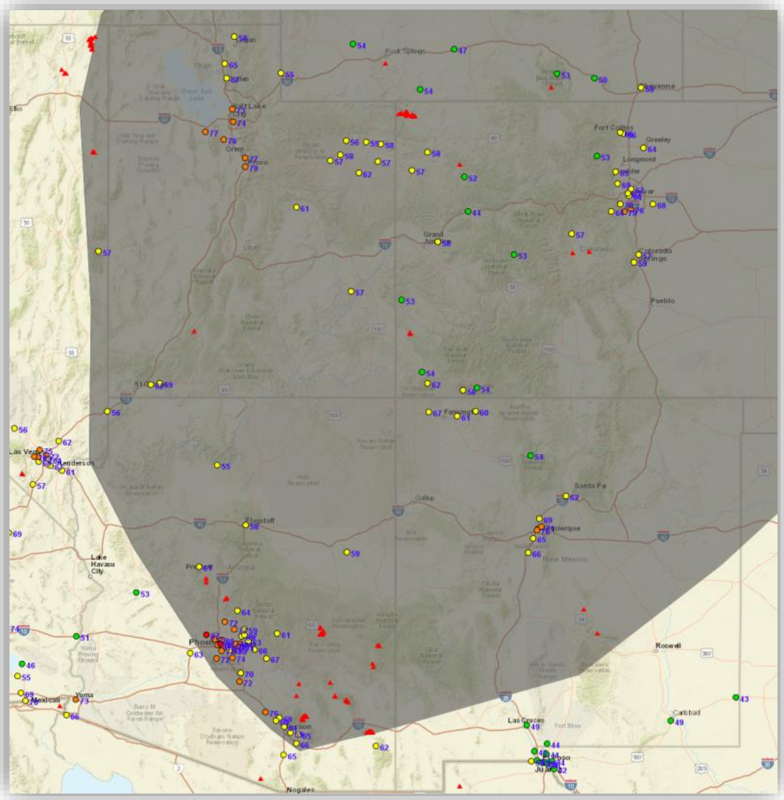

Figure 10. Maximum 8-hr average ozone concentrations (circles showing green, yellow, and orange AQI colors) with HMS satellite detections (red triangles) and HMS-analyzed smoke (gray shading) on July 7, 2017.

With high pressure overhead, surface winds were driven mostly by diurnal terrain-induced flows, with light and variable winds in the morning giving way to stronger, and at times gusty, afternoon winds. High temperatures in major cities in New Mexico and throughout the Intermountain West exceeded 90°F on most days; in the City of Albuquerque specifically, temperatures were seasonably hot and slightly above climatological average. Shallow surface-based morning inversions gave way to relatively deep (up to 5 km) and well-mixed boundary layers each afternoon (see Figure 11). On some of the days, afternoon thunderstorms produced partly cloudy conditions and enhanced local winds, which helped to lower peak ozone concentrations in Albuquerque/Bernalillo County. Little or no measurable precipitation fell in the City of Albuquerque during the episode. The ozone episode was ended by a weak cold front that passed through New Mexico from the north on July 14, and as a result, ozone concentrations in Albuquerque/Bernalillo County dropped below 55 ppb.

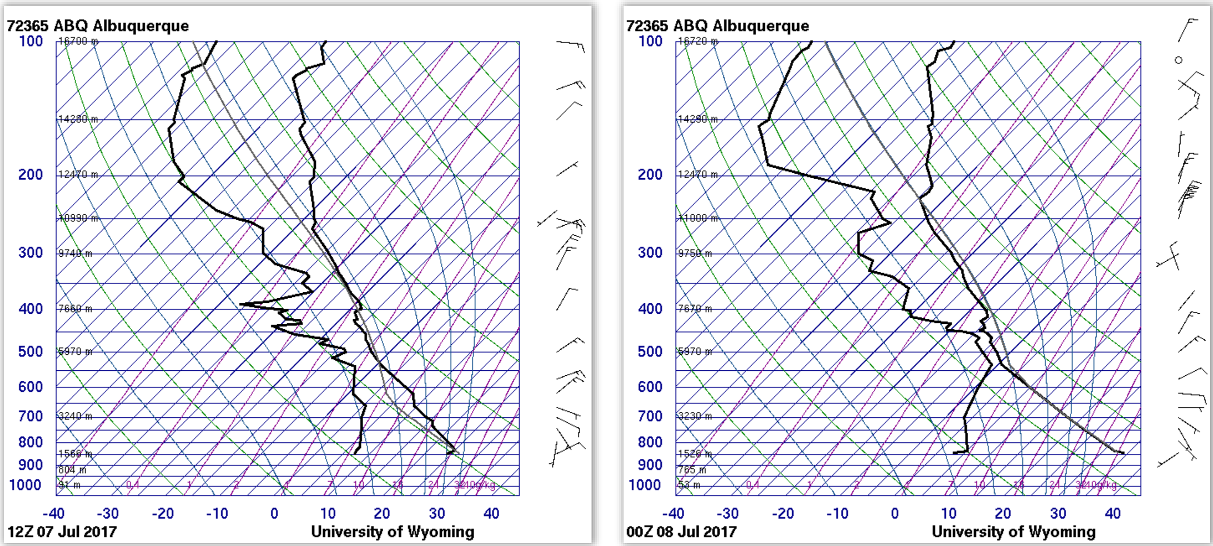

Figure 11. Atmospheric soundings at Albuquerque on July 7, 2017, at 0600 (left) and 1800 (right) local time, showing a shallow surface-based inversion in the morning and a well-mixed afternoon boundary layer with mixing up to 5 km. From the University of Wyoming (http://weather.uwyo.edu/upperair/sounding.html).

3. Ambient Data Summary

3.1 Overview

This chapter summarizes the available ambient monitoring data in Albuquerque/Bernalillo County and in the Albuquerque MSA[16] for June and July 2017. These ambient data were used to support photochemical grid modeling, to conduct model performance evaluation (MPE) of photochemical grid modeling results, and to support the conceptual understanding of ozone episodes in the region. The availability of ozone, surface meteorology, and other pollutant data is summarized, and the general relationship of ozone with NO_x and meteorology during June-July 2017 is reviewed. For each episode period, ozone data are compared with other hourly pollutant and meteorological data, and compared among sites; the possible impact of wildfire smoke is also assessed. Understanding the ambient conditions supported the development of the modeling approach and the model validation.

3.2 Data Availability

All available hourly meteorological, ozone, $PM_{2.5}$, NO_x, and NO_2 data for the state of New Mexico were downloaded from EPA's Air Quality System (AQS) in April 2018 for June-July 2017. No volatile organic compound (VOC) or air toxics data were available in the Albuquerque MSA during this time.

Data availability by site is summarized in Table 5, and available data are shown on a map in Figures 12 and 13. Monitoring sites in New Mexico are operated by several air quality management agencies. The Albuquerque EHD operates four monitoring sites in Albuquerque/Bernalillo County. Data from Foothills, Del Norte, and South Valley are reported to AQS. Data from the Double Eagle Airport site, west of the City of Albuquerque, are not reported to AQS. The New Mexico Environment Department (NMED) operates monitoring stations throughout New Mexico outside of Albuquerque/Bernalillo County, including the Bernalillo site in Sandoval County and the Los Lunas site in Valencia County. There are also monitoring sites in New Mexico operated by the National Parks Service (NPS) and by the Navajo Nation.

Ozone data are available for more than 98% of the time in June-July 2017 at the six ozone sites in the Albuquerque MSA. NO_x data are available at the Del Norte and South Valley sites. Surface meteorological data are available at Del Norte. A summary of the 10 days with the highest 8-hour maximum ozone concentrations in 2017 is shown in Table 6. The Foothills site typically has the highest concentrations and has the most days with 8-hour averaged ozone greater than 70 ppb.

[16] The Albuquerque MSA includes Albuquerque/Bernalillo County as well as Sandoval, Torrance, and Valencia Counties in New Mexico. The Albuquerque MSA had a population of 887,077 (or 41% of New Mexico's population) as of the 2010 U.S. Census.

Surface meteorological data are also available from the Albuquerque International Airport (KABQ) and the Double Eagle Airport, as shown in **Figures 14 and 15**. Data availability is good at KABQ, but less complete at Double Eagle Airport. When data are available at Double Eagle Airport, temperature differences between the two sites are apparent, as Double Eagle tends to be several degrees cooler at night than KABQ. Double Eagle Airport is a few miles west of the City of Albuquerque and is at a 500 ft higher elevation than KABQ. The urban heat island effect may partially explain these nocturnal temperature differences.

Table 5. Percent of hourly data available from AQS for New Mexico during June-July 2017; **bold** sites indicate monitoring sites in the Albuquerque MSA.

Operating Agency	AQS Site Code	Site Name	Wind Direction	Wind Speed	Outdoor Temperature	Relative Humidity	Barometric Pressure	Rain/Melt Precipitation	Solar Radiation	Oxides of Nitrogen (NO_x)	$PM_{2.5}$ - Local Conditions	Ozone	Nitrogen Dioxide (NO_2)
Albuquerque EHD	**35-001-0023**	**Del Norte**	**98**	**98**	**98**	**98**	**98**	**98**	**76**	**94**	**81**	**96**	**48**
Albuquerque EHD	**35-001-0029**	**South Valley**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**92**	**98**	**97**	**92**
Albuquerque EHD	**35-001-1012**	**Foothills**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**98**	**0**
NMED	**35-043-1001**	**Bernalillo**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**99**	**0**
NMED	**35-061-0008**	**Los Lunas**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**98**	**0**
Albuquerque EHD	**N/A**	**Double Eagle**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**98**	**0**
NMED	35-055-0005	Taos	0	0	0	0	0	0	0	0	97	0	0
NMED	35-049-0021	Santa Fe	0	0	0	0	0	0	0	0	99	99	0
Navajo Nation	35-045-1233	Shiprock	0	0	0	0	0	0	0	0	0	79	0
NMED	35-045-1005	Sub Station	100	100	100	0	0	0	100	49	0	99	0
NPS	35-045-0020	Chaco Culture	100	100	100	100	0	99	100	99	0	99	0
NMED	35-045-0018	Navajo Lake	100	100	100	0	0	0	100	97	0	100	0

Operating Agency	AQS Site Code	Site Name	Wind Direction	Wind Speed	Outdoor Temperature	Relative Humidity	Barometric Pressure	Rain/Melt Precipitation	Solar Radiation	Oxides of Nitrogen (NO_x)	$PM_{2.5}$ - Local Conditions	Ozone	Nitrogen Dioxide (NO_2)
NMED	35-045-0009	Bloomfield	98	98	100	0	0	0	98	92	0	97	0
NMED	35-039-0026	Coyote	0	0	0	0	0	0	0	0	0	98	0
NMED	35-025-0008	Hobbs Jefferson	0	0	0	0	0	0	0	98	96	99	0
NPS	35-015-3001	Carlsbad	100	100	100	100	0	100	100	0	0	100	0
NMED	35-015-1005	Carlsbad	0	0	0	0	0	0	0	98	0	99	0
NMED	35-013-0025	Las Cruces	0	0	0	0	0	0	0	0	99	0	0
NMED	35-013-0024	West Mesa	100	100	100	0	0	0	100	0	0	0	0
NMED	35-013-0023	Solano	0	0	0	0	0	0	0	0	0	99	0
NMED	35-013-0022	Santa Teresa	100	100	100	0	0	0	100	98	0	99	0
NMED	35-013-0021	Desert View	100	100	100	0	0	0	100	98	0	99	0
NMED	25-013-0020	Chaparral	100	100	100	0	0	0	100	0	0	99	0
NMED	35-013-0019	Holman Road	100	100	100	0	0	0	97	0	0	0	0
NMED	35-013-0016	Anthony	0	0	0	0	0	0	0	0	100	0	0
NMED	35-013-0008	La Union	100	100	100	0	0	0	100	0	0	99	0

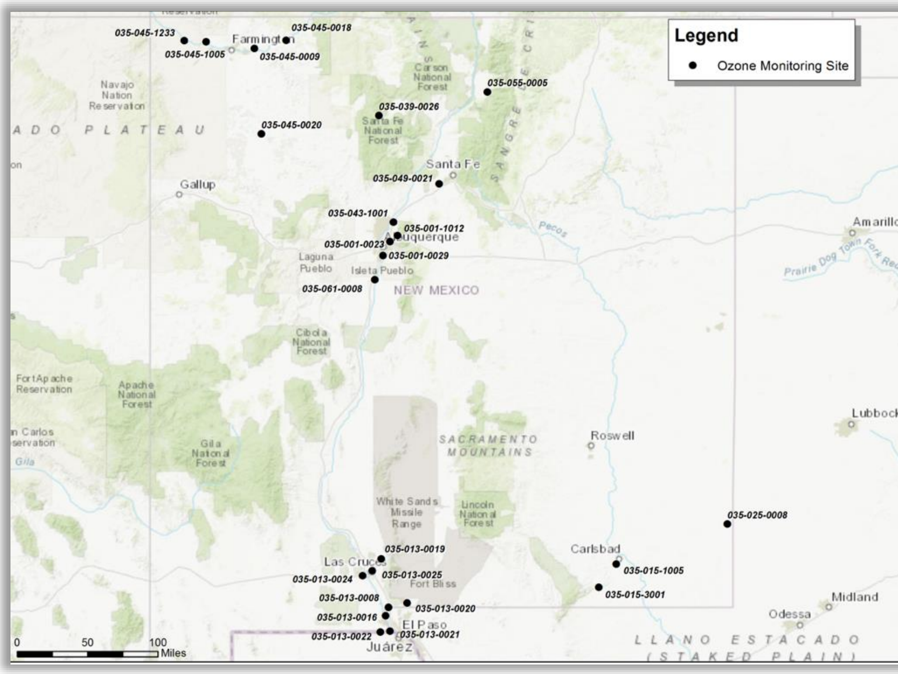

Figure 12. Locations of ozone monitoring sites in New Mexico.

Figure 13. Location of ozone monitoring sites in the Albuquerque MSA and in Santa Fe.

Table 6. Top ten 8-hr ozone concentrations (ppb) at Albuquerque/Bernalillo County monitoring sites in 2017. Days included in the modeling episodes are denoted in bold.

Rank	Foothills (AQS 35-001-1012)	South Valley (AQS 35-001-0029)	Del Norte (AQS 35-001-0023)
1	**76 (June 14)**	**69 (June 15)**	**76 (July 7)**
2	**76 (July 10)**	**67 (July 6)**	**72 (July 10)**
3	**72 (June 15)**	66 (June 3)	**70 (July 5)**
4	**71 (July 7)**	**66 (June 14)**	**69 (June 14)**
5	**70 (July 11)**	65 (June 5)	**69 (July 6)**
6	68 (July 24)	**65 (July 7)**	**68 (June 15)**
7	67 (April 15)	64 (April 16)	67 (April 16)
8	67 (April 16)	63 (April 15)	66 (April 15)
9	**67 (June 13)**	63 (June 4)	66 (July 22)
10	67 (July 28)	**63 (June 16)**	**65 (July 4)**

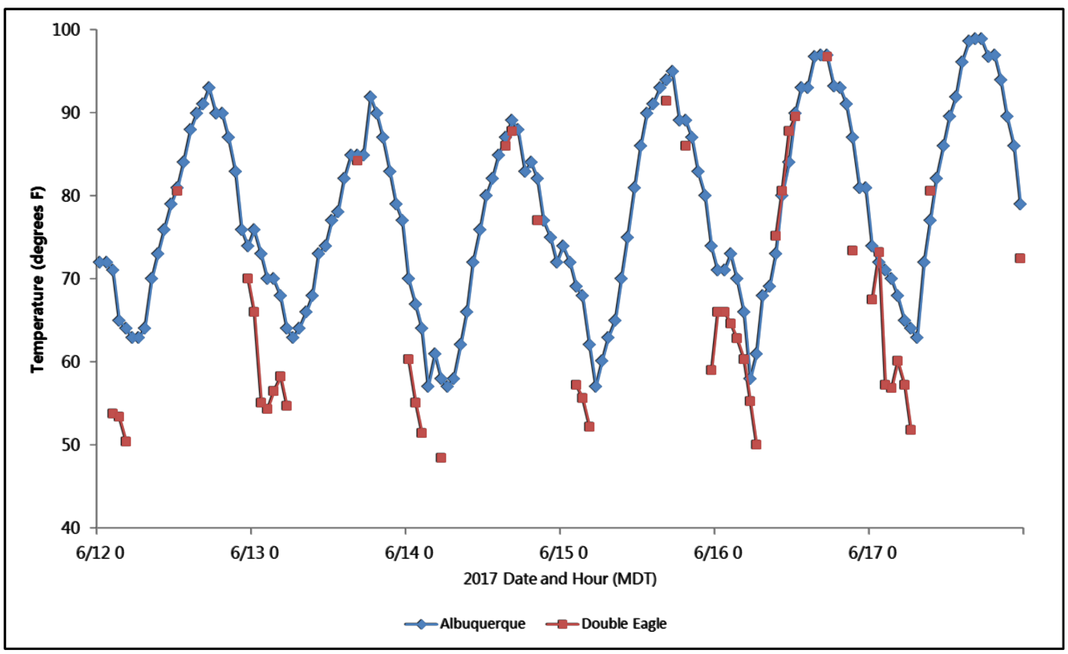

Figure 14. Time series of temperature (degrees F) at Albuquerque International Airport and Double Eagle Airport during June 12-17, 2017.

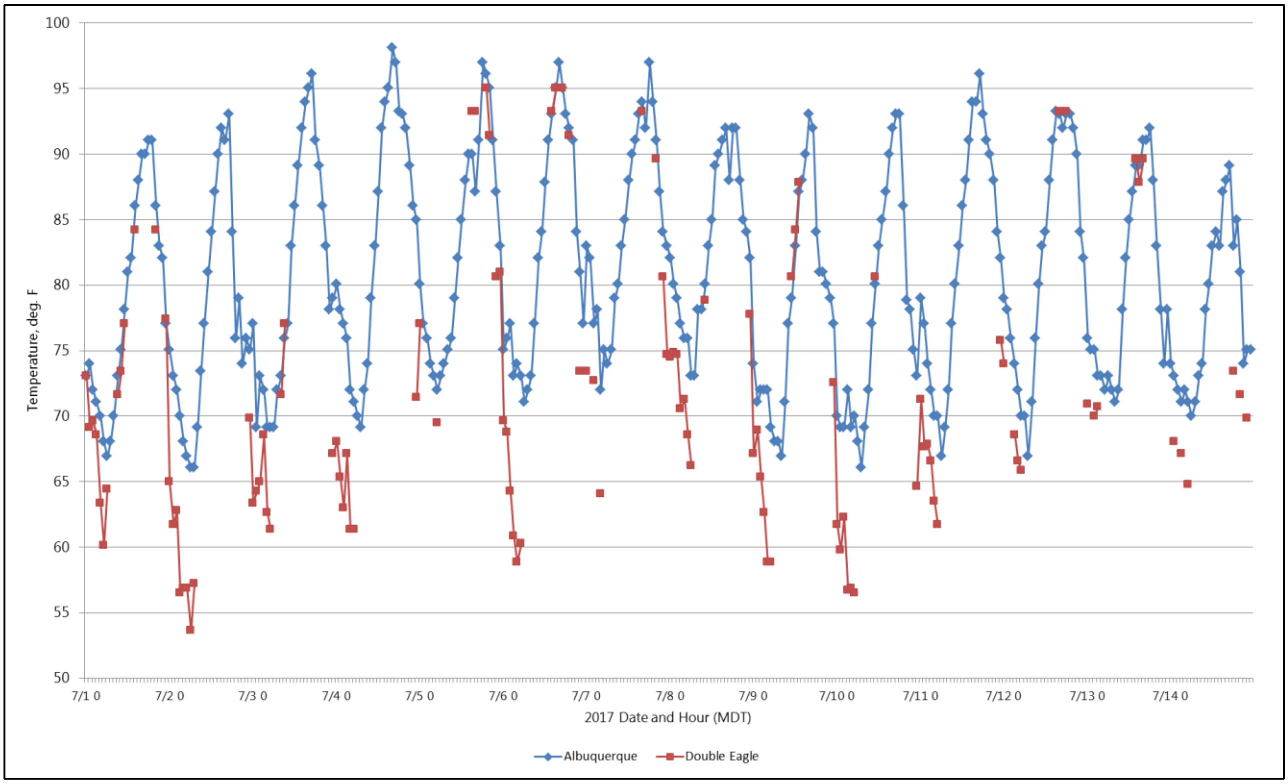

Figure 15. Time series of temperature (degrees F) at Albuquerque International Airport and Double Eagle Airport during July 1-14, 2017.

3.3 Ozone Variability

We examined how ozone varied among sites in the Albuquerque MSA and how ozone concentrations varied with wind speed, wind direction, and temperature during June-July 2017, to understand the basic trends in ozone in the area and whether the episode days in June and July were unusual for the season. Figure 16 shows a scatter plot matrix of hourly ozone data for June-July 2017 at five ozone monitoring sites in the Albuquerque MSA. These scatter plot matrices show the extent to which ozone data at one site is correlated to ozone data at any other site. Based on this plot, the correlation among sites is fairly high (r^2 ranging from 0.63 to 0.75), indicating that ozone concentrations are fairly homogeneous across the monitoring sites in the Albuquerque MSA. In other words, when ozone concentration is high at any one site, it is generally high at all sites. There are times when ozone concentrations are higher at Foothills than at urban core sites such as South Valley. Foothills is on the northeast outskirt of the City of Albuquerque and is typically less influenced by nighttime ozone titration from urban NO_x emissions.

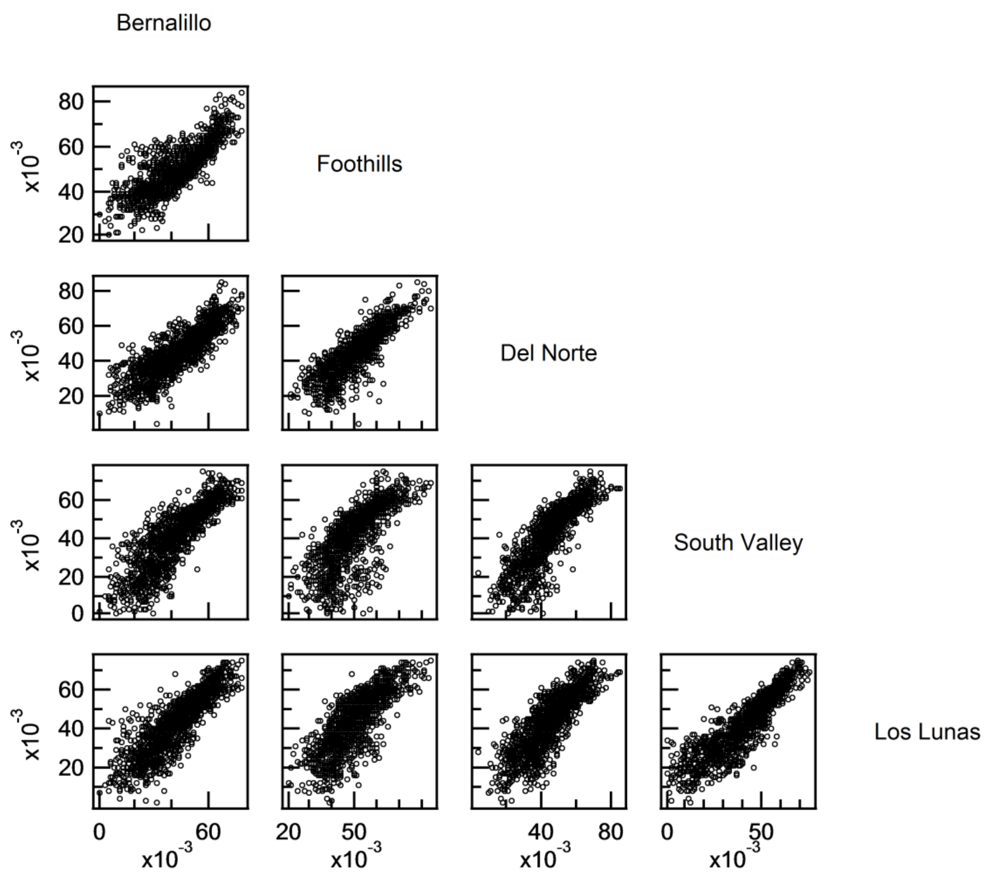

Figure 16. Scatter plot matrix of hourly ozone data (ppm) during June-July 2017 in the Albuquerque MSA, ordered from north to south.

Figures 17 and 18 show ozone concentrations at the Foothills site compared to temperature, wind direction, and wind speed during June-July 2017. Hourly ozone is greater than 0.070 ppm (70 ppb) when temperature is greater than 80°F, when winds are modest (1-5 m/s), and when winds are from the south. Southerly afternoon winds are common in the City of Albuquerque because of terrain-driven up-valley flow through the Rio Grande Valley. Winds from the northwest, north, or northeast at the Del Norte site were not associated with high ozone. When temperatures exceed 95°F, hourly ozone concentrations tend to be at or below 70 ppb. This may be due to increased vertical mixing induced by an extremely warm convective boundary layer, which would tend to reduce pollutant concentrations. Hot temperatures may also increase convective cloud development during the afternoon hours, which would reduce solar insolation and reduce ozone production via photochemistry. The timing of peak ozone was typically in the early afternoon, while peak temperatures typically occur later in the afternoon between 4:00 and 6:00 p.m.

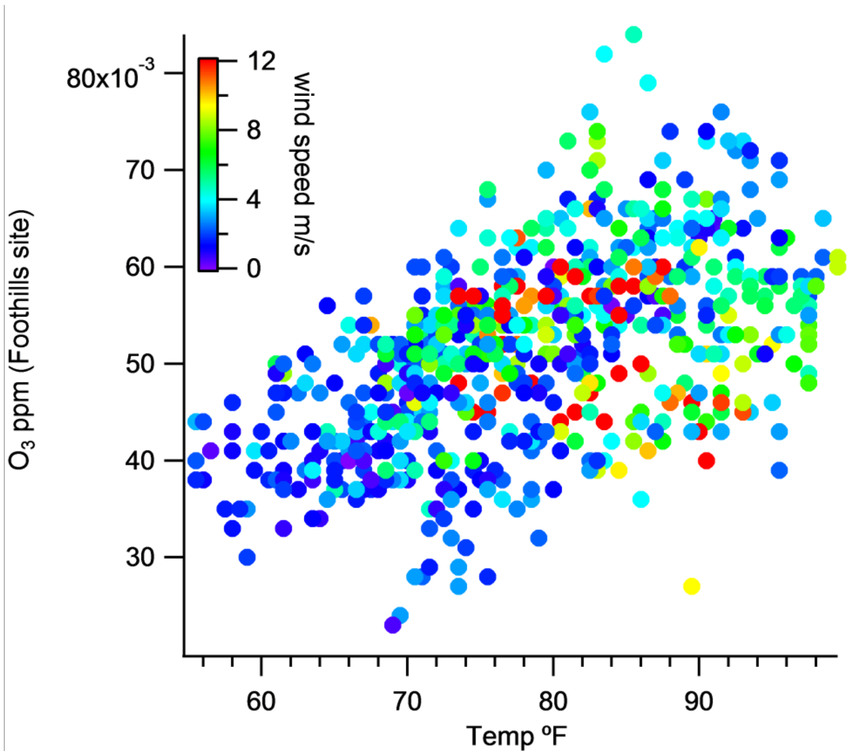

Figure 17. Hourly ozone (Foothills site, ppm) and temperature (Del Norte site, degrees F), colored by wind speed, in June-July 2017.

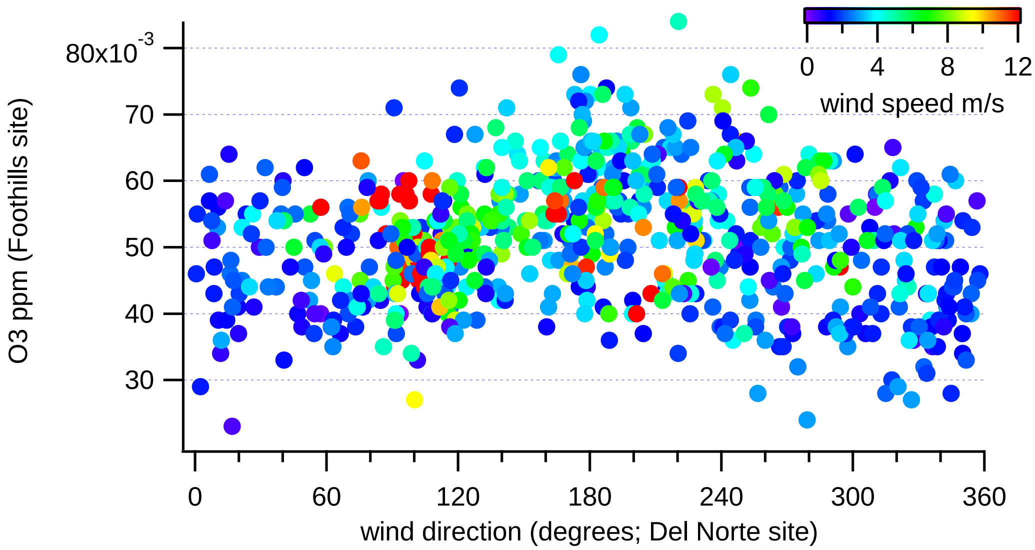

Figure 18. Hourly ozone (Foothills site, ppm) and wind direction (Del Norte site, degrees), colored by wind speed, in June-July 2017.

3.4 June 2017 Ozone Episode

The June 12-16 ozone episode had two of the three highest 8-hour ozone concentrations for the year at the Foothills site (76 ppb on June 14 and 72 ppb on June 15). **Figure 19** shows how hourly ozone concentrations at the Foothills site on each day in this period compared to the typical diurnal pattern; **Figure 20** shows a time series of ozone concentrations in the Albuquerque MSA plus meteorological, NO_x and $PM_{2.5}$ data. **Figure 21** shows a time series of ozone concentrations at the Double Eagle site. On June 13, ozone was not titrated as usual in the early morning; at Foothills, ozone is usually titrated to about 40 ppb in the early morning, and to even lower concentrations at other sites. There was a spike in NO_x concentrations in the afternoon of the 12th that may have influenced ozone titration on the morning of the 13th. On June 14, ozone rose rapidly in the morning to peak at 1:00 p.m. before slowly decreasing. On the following day, June 15, ozone rose from a similar level as on June 14 (approximately 40 ppb at 6:00 a.m.), and was higher than 70 ppb over multiple hours (from 11:00 a.m. to 6:00 p.m. at Foothills site). Wind speed was lower than usual on both days, about 5 m/s during the daytime, whereas on the prior days wind speeds were 9-10 m/s during the afternoon. Winds were generally from the north (down-valley) overnight and slowly shifted to coming from the south (up-valley) during the day. There was a modest rise in $PM_{2.5}$ in the morning of the 15th, but only to a 1-hr average of 14 µg/m^3.

Overall, the surface meteorology was similar on June 14 and June 15, but the diurnal ozone pattern was different. On June 14, hourly ozone concentrations at the Foothills site were notably higher than at other nearby sites and showed a "spike" at 2:00 p.m.; on the 15th, however, ozone concentrations were within a few ppb of each other at all sites, and there were sustained concentrations above 70 ppb for nearly eight consecutive hours. This pattern may suggest slightly different formation mechanisms on these two days or simply that ozone from the 14th was carried over to the 15th in the residual boundary layer. Ozone concentrations showed a similar diurnal pattern on the 16th, but a spike in NO_x on the morning of the 16th may have titrated some of the ozone from the prior day; in addition, sustained winds from the north on the 16th may have helped to modestly reduce ozone.

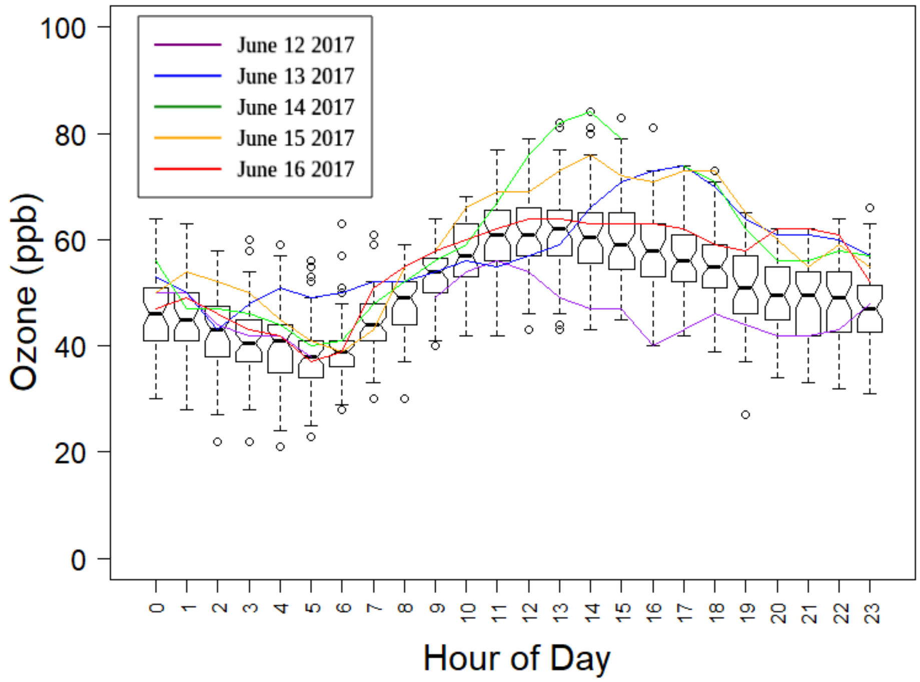

Figure 19. Hourly ozone at the Foothills site on June 12-16, 2017 (lines) and during June-July 2017 (box plot). Boxes represent the 25th and 75th percentiles, notches the median, and whiskers 1.5 times the 25th and 75th percentiles; concentrations beyond this range are plotted as individual circles.

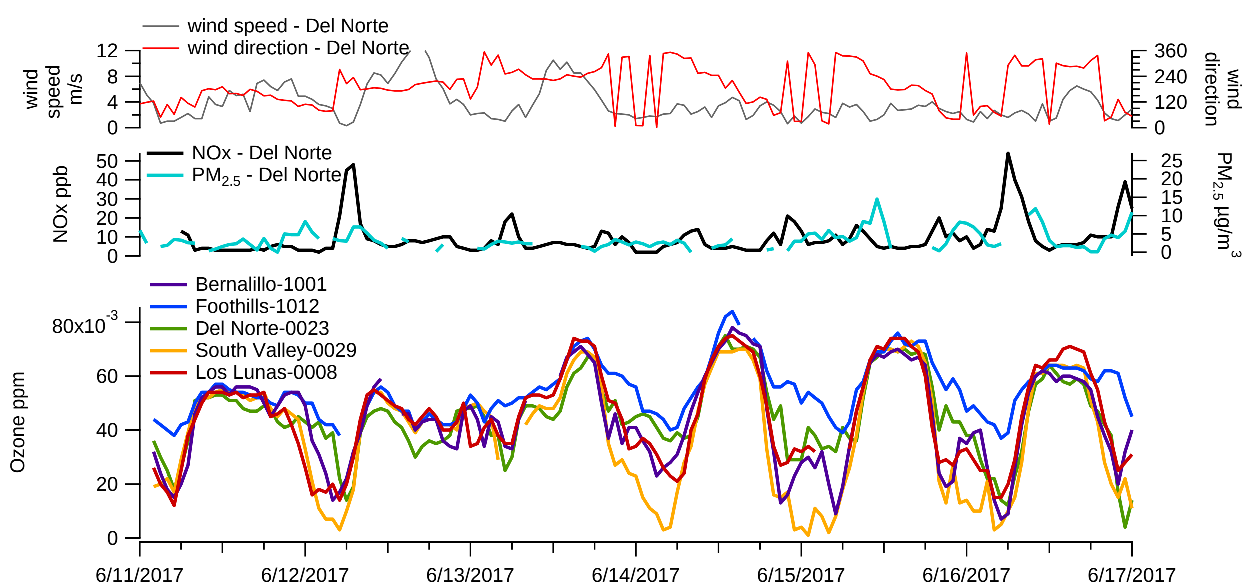

Figure 20. Time series of ozone in the Albuquerque MSA, and NO_x, $PM_{2.5}$, wind speed, and wind direction at the Del Norte site during June 11-17, 2017.

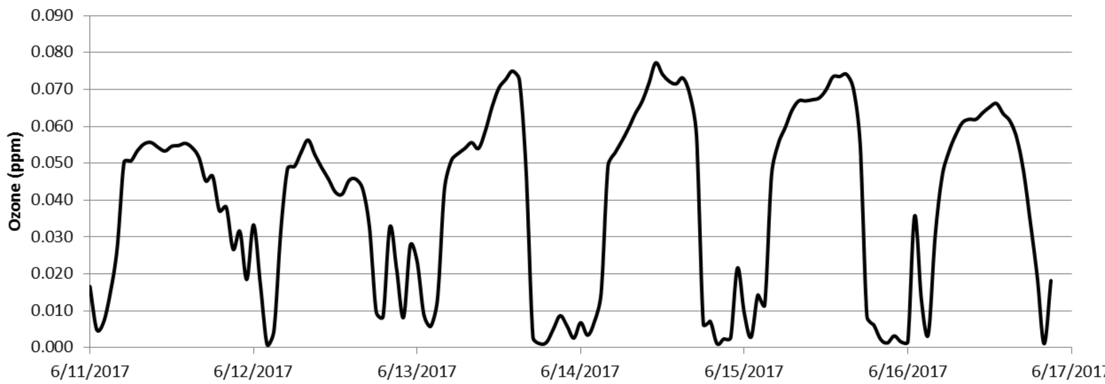

Figure 21. Time series of ozone concentrations (ppm) at the Double Eagle ozone monitor during June 11-17, 2017.

3.5 July 2017 Ozone Episode

The July 7-11 ozone episode includes three days when 8-hour ozone values were at or above 70 ppb at the Foothills site (71 ppb on July 7, 76 ppb on July 10, and 70 ppb on July 11). Figure 22 shows how hourly ozone concentrations at the Foothills site on each day in this period compared to the typical diurnal pattern; Figure 23 shows a time series of ozone in the Albuquerque MSA plus meteorological, NO_x, and $PM_{2.5}$ data. Figure 24 shows a time series of ozone concentrations at the Double Eagle site. As seen in the June episode, the diurnal characteristics of each day are slightly different. In the early morning of July 7, ozone was not as titrated as usual at Foothills; at 1:00 p.m., ozone peaked sharply at 81 ppb before decreasing to 67 ppb at 3:00 p.m. Notably, the peak ozone concentration was higher at Del Norte than at Foothills on July 7 (Foothills is typically the high ozone site). On July 10, ozone again peaked sharply at Foothills, though ozone started at 38 ppb at 5:00 a.m. with the typical amount of titration. On both the 7th and the 10th, ozone peaked at Del Norte and Foothills and then peaked at the Bernalillo site in Sandoval County, suggesting that an ozone plume was moving northwards. Then on the 11th, ozone concentrations were similar across all sites. NO_x and wind speed during these episodes showed a typical diurnal pattern.

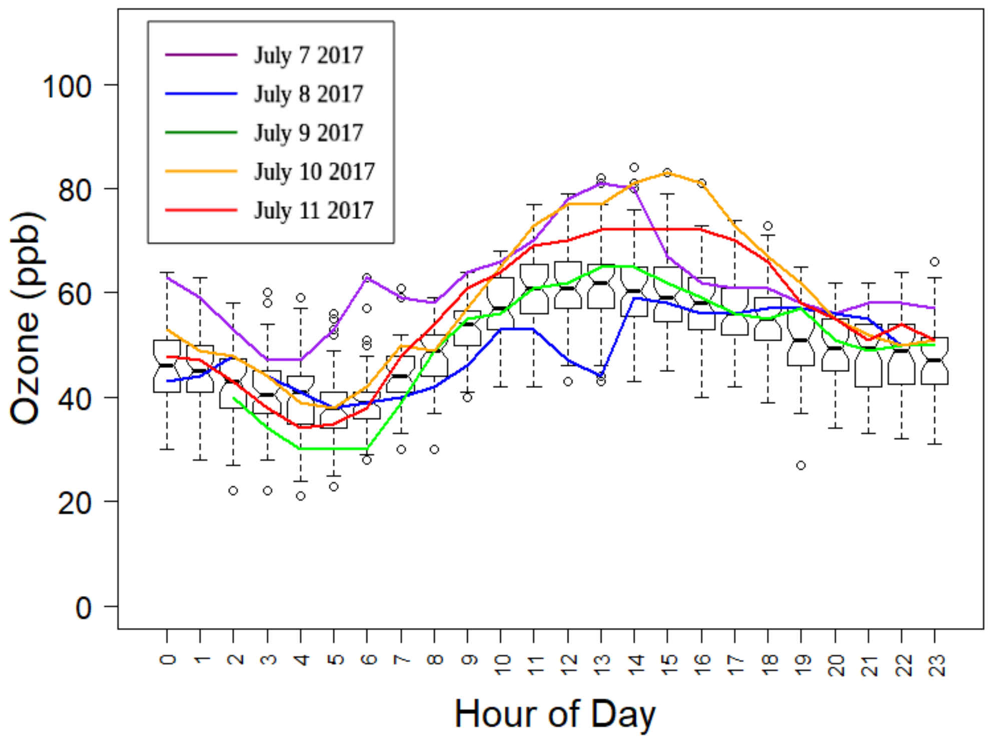

Figure 22. Hourly ozone concentrations (ppb) at the Foothills site on July 7-11, 2017 (lines) and during June-July 2017 (box plot). Boxes represent the 25th and 75th percentiles, notches the median, and whiskers 1.5 times the 25th and 75th percentiles; concentrations beyond this range are plotted as individual circles.

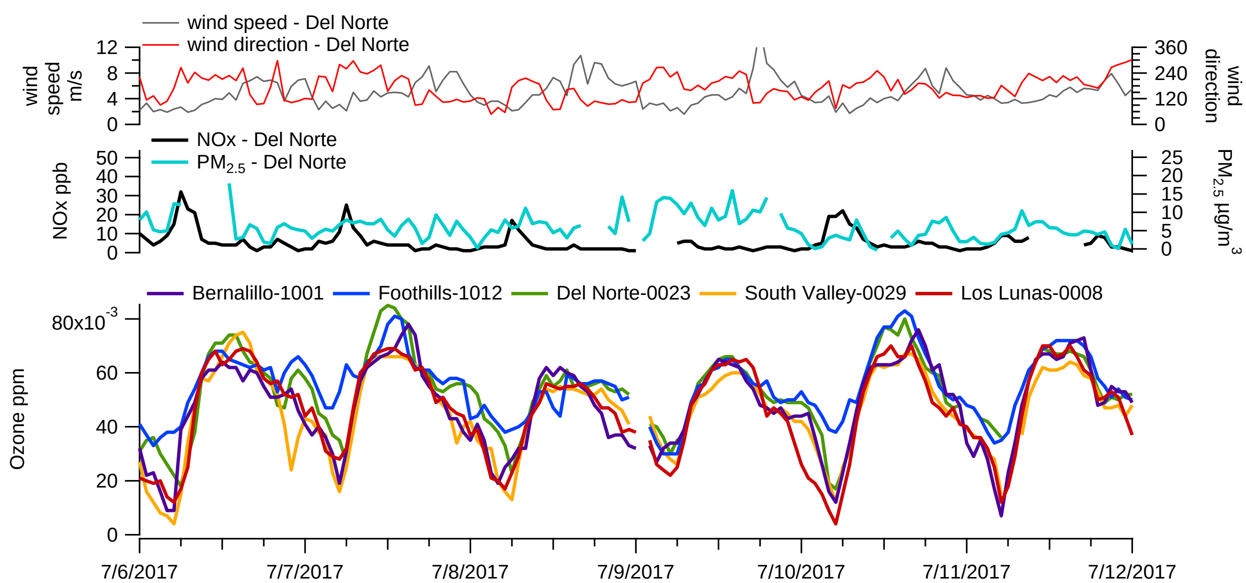

Figure 23. Time series of ozone in the Albuquerque MSA, and NO_x, $PM_{2.5}$, wind speed, and wind direction at the Del Norte site during July 6-12, 2017.

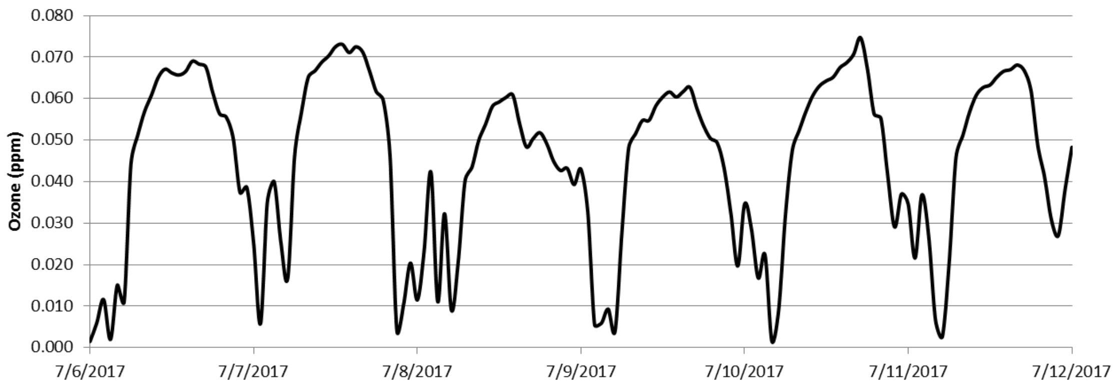

Figure 24. Time series of ozone (ppm) at the Double Eagle ozone monitor during July 6-12, 2017.

One reason the ozone patterns are somewhat different on July 7 compared to July 10 and 11 is likely that smoke from wildfires impacted air quality on the 7th. **Figure 25** shows HMS smoke plumes and wildfire locations, as well as daily 8-hour maximum ozone concentrations. On July 7, much of New Mexico was impacted by smoke from fires in southern Arizona as well as smoke transported from major fires in British Columbia the previous days. $PM_{2.5}$ concentrations on July 6 and 7 were somewhat elevated, likely from the smoke. On July 10 and 11, $PM_{2.5}$ concentrations were in a more typical range (less than 10 µg/m^3). Thus it may be that smoke influenced ozone on July 7 but did not influence ozone on July 10 or 11. The diurnal pattern of July 10 and 11 is somewhat similar to the diurnal pattern of the June 14-15 ozone episode, where ozone rapidly increased at Foothills site on the first day and then was sustained there at a level greater than 70 ppb over multiple hours on the second day, and where concentrations are similar across sites on the second day.

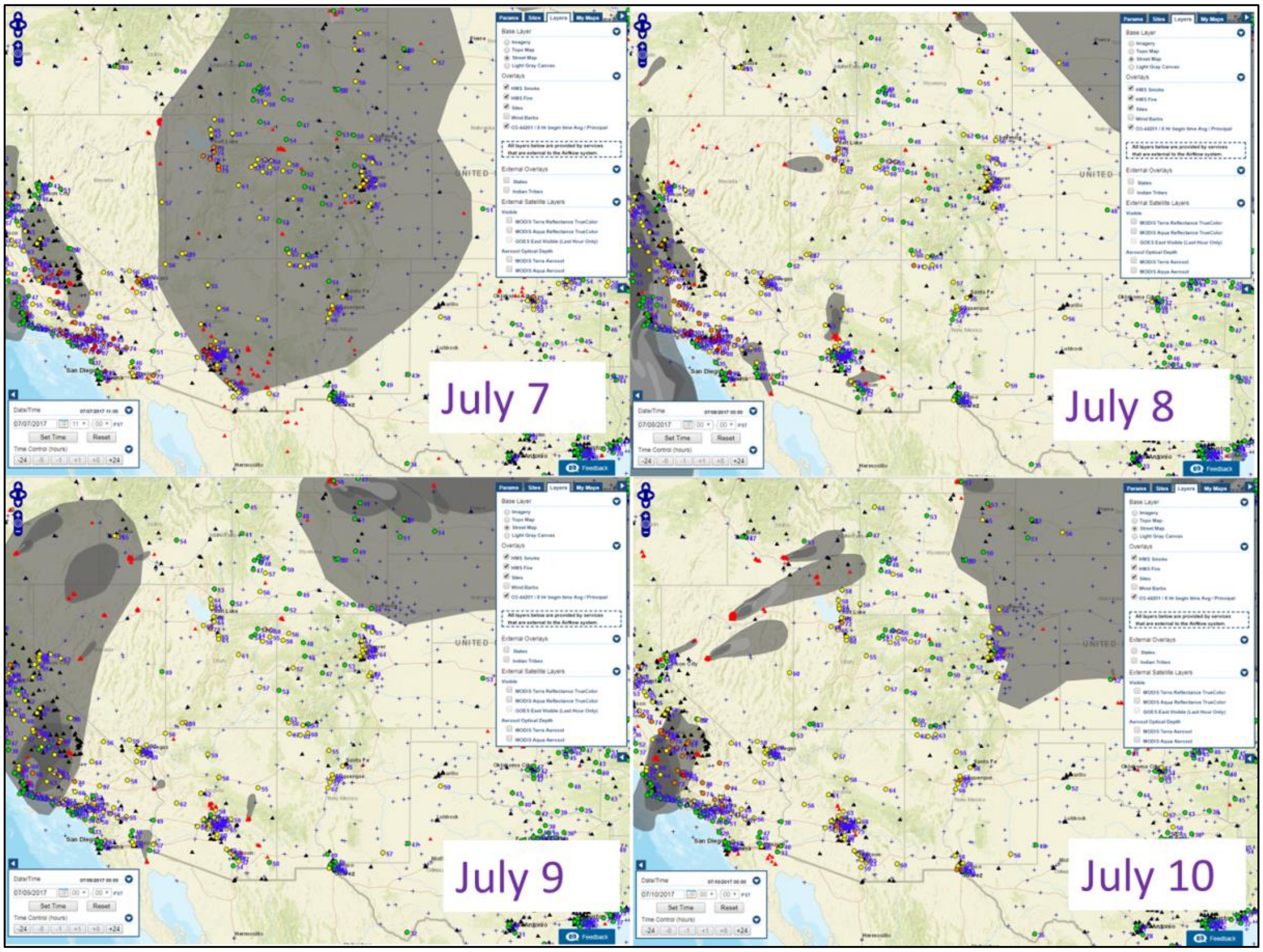

Figure 25. HMS smoke plumes (grey), wildfire locations (red triangles), and daily 8-hour maximum ozone on July 7-10, 2017. From **www.airnowtech.org**.

3.6 Summary

Ambient air quality and meteorological data in New Mexico and in the Albuquerque MSA are adequate and sufficiently complete to support ozone modeling efforts and air quality MPE. The presence of only two NO_x monitoring sites and the lack of VOC monitor data in the Albuquerque MSA limit the ability to evaluate ozone precursor concentrations in the region. Speciated VOC measurements (i.e., measurements of individual VOC compounds, not just total VOC) would provide additional data to evaluate the existing VOC emission inventory, evaluate air quality model performance, track the effectiveness of VOC emission control programs, and protect public health.

Ozone concentrations were typically highest at the Foothills site during the ozone episodes of 2017. The July 7 episode was likely impacted by wildfire smoke, but the other high-ozone days (June 14-15 and July 10-11) were not. The June 14-15 and July 10-11 episodes had similar characteristics, with a sharp peak in ozone at the Foothills site on the first day and elevated ozone concentrations citywide on the second day. On the high ozone days, the peak concentrations at the Foothills site occurred later in the afternoon (between 1 and 4 PM) compared to the monthly average peak concentration (around noon).

4. VOC Reactive Chemicals

4.1 Overview

This chapter summarizes and documents results of the VOC analysis conducted for the Albuquerque/Bernalillo County Ozone Modeling Analysis to determine the dominant VOC species from a ground-level ozone reactivity perspective. VOCs mix with NO_x in the presence of sunlight to produce ground-level ozone. Some VOCs are more reactive than others in terms of ozone formation. Understanding the composition and reactivity of VOC emissions is important when developing ozone control strategies. The reactivity of each VOC species was estimated using published maximum incremental reactivity (MIR) values that represent the ozone formation potential of various organic compounds (Carter, 2010a)[17]. Generally, the higher the MIR value, the more reactive the organic compound is for forming ozone. For example, ethane and propane, which have MIR values of 0.28 and 0.49, respectively, are far less reactive than ethyne and ethene, which have MIR values of 0.95 and 9.00, respectively.

This analysis was conducted based on anthropogenic VOC emissions data in Albuquerque/Bernalillo County from the EPA's 2014 NEI (2014v7.2 platform). This inventory was used to support air quality modeling of June-July 2017 ozone episodes (see Chapter 7). VOC emissions were processed using the latest version of the Sparse Matrix Operator Kernel Emissions (SMOKE) processing system. Aggregated VOC emissions from the inventory were speciated into the compounds required by the air quality model, and the emissions for each VOC species were weighted by the appropriate MIR value from Carter (2010a). The weighted emissions were then ranked to identify the top VOCs and corresponding emissions source categories that are most likely to contribute to ozone formation in Albuquerque/Bernalillo County.

Ideally, this analysis would be based on local VOC observations with detailed chemical speciation. For example, Photochemical Assessment Monitoring Station (PAMS) sites typically measure 56 target hydrocarbon species. However, after performing a thorough assessment of available data and after consulting Albuquerque EHD staff, we were not able to find recent ambient VOC data that were appropriate or adequate for this type of analysis. Thus, an important recommendation from this work is to perform a monitoring study to collect ambient, speciated VOC data (i.e., measurements of individual VOC compounds, not just total VOC) to confirm that the emissions inventory is representing ambient concentrations.

The key finding from this analysis is that xylenes VOC emissions, particularly from solvent use and construction equipment, represent a significant fraction of the anthropogenic VOC ozone generating potential in the inventory despite representing only 10% of anthropogenic VOC emissions.

[17] Downloaded October 2018 from https://www.cert.ucr.edu/~carter/SAPRC/saprc07.xls.

Controlling solvent use and reducing emissions from construction equipment could help reduce xylenes emissions, and potentially reduce ozone concentrations in Albuquerque/Bernalillo County.

Other key findings from this analysis are:

- Xylenes, alkanes, toluene, and alkenes are the top emitted anthropogenic VOCs from an ozone reactivity perspective. These VOCs collectively represent 75% of anthropogenic VOC emissions in Albuquerque/Bernalillo County, and 80% of the anthropogenic VOC ozone generating potential in the inventory.
- Alkane VOCs such as pentane represent over 50% of the anthropogenic VOC emissions in Albuquerque/Bernalillo County, but only 29% of the anthropogenic ozone generating potential in the inventory. Because alkane compounds are less reactive compared to other VOCs, relatively large reductions in alkane VOC emissions would be needed to significantly reduce ozone in Albuquerque/Bernalillo County. Alkane VOCs are emitted from motor vehicles, construction equipment, oil and gas exploration, and a variety of industrial processes.
- Xylenes emissions, which in this analysis include the chemical xylene plus all poly-substituted aromatic compounds, produce as much VOC ozone generating potential in Albuquerque/Bernalillo County as alkanes (e.g., pentane) despite representing only 10% of anthropogenic VOC emissions. Key sources of xylene emissions include solvent use and construction equipment.
- Aromatic VOCs, which in this analysis include xylenes, toluene, and alkyl-substituted aromatic compounds, represent 38% of the anthropogenic VOC ozone generating potential in the Albuquerque/Bernalillo County emissions inventory. These aromatic compounds are more reactive compared to other VOCs, and therefore modest reductions in these VOC emissions could impact ozone in Albuquerque/Bernalillo County. Toluene is used as a cleaning solvent in various industrial and manufacturing settings, and is also used in the manufacture of paints, coatings, inks, and adhesives.
- Ethene, formaldehyde, and ethanol emissions alone account for 12% of the anthropogenic VOC ozone generating potential in the Albuquerque/Bernalillo County emissions inventory.

When interpreting results based on a VOC modeling emissions inventory, note that many of the emitted VOCs represent more than one chemical compound. For example, xylenes is a lumped VOC group that includes the chemical xylene as well as all poly-substituted aromatic compounds (e.g., trimethylbenzenes). Likewise, toluene is a lumped group that includes the chemical toluene as well as all mono-alkyl-substituted compounds (e.g., ethylbenzene). Therefore, emissions and ozone-generating potential of lumped groups like xylenes and toluene include contributions from a variety of compounds in addition to the chemical species xylene and toluene. The ozone reactivity of these lumped groups is not precisely known because reactivity can vary substantially across the many species that are being represented.

4.2 VOC Emissions

Before performing the VOC analysis, a review of available VOC data for Albuquerque/Bernalillo County was conducted. Ideally, this analysis would be based on local, recent, temporally resolved, and speciated VOC data; however, after reviewing the data sources available, we concluded that none of the ambient data sets would adequately serve the objectives of the analysis. The data sets investigated included:

- Data from the PAMS network. Data from the PAMS network are well suited for this type of analysis; however, no PAMS sites are located in Albuquerque/Bernalillo County.
- Data from the National Air Toxics Assessment (NATA) and the National Air Toxics Trends Stations (NATTS) network. The NATA data have the temporal resolution and complete record of VOC species needed for this analysis; however, as is the case with the PAMS network, no NATTS sites are located in Albuquerque/Bernalillo County. Additionally, the NATTS data set does not include a complete set of VOCs needed for this type of analysis.
- Special study data collected as part of the Albuquerque County Community-Scale Air Toxics Monitoring and Risk Assessment Project (Kavouras et al., 2010). The data collected as part of this study did not include many of the key VOC species needed for the analysis and there were a limited number of samples collected.

Because appropriate and adequate ambient VOC data do not exist for this type of analysis, after evaluating air quality model performance (see Chapter 8), we determined that the modeled emissions inventory data could provide useful information for the VOC reactivity assessment.

The VOC emissions used in this analysis were based on version 2 of the EPA's 2014 NEI (2014v7.2 platform), with adjustments for day-specific power plant emissions and for changes in motor vehicle activity and fleet turnover between 2014 and 2017. These emissions data were the basis for air quality modeling (see Chapter 8). The emissions data processing is documented in detail in Chapter 7. Overall, the air quality model based on these emissions performed well and within model performance benchmarks that have been established by the air quality modeling community[18], and therefore the emissions inventory is adequately representative for this type of VOC analysis in the absence of ambient VOC data.

Before conducting the VOC reactivity analysis, we reviewed the VOC emissions inventory to provide context for the analysis results. Statewide, emissions from non-anthropogenic sources (i.e., biogenic emissions) are the largest source of VOCs, contributing approximately 82% of the statewide VOC inventory. Petroleum and related industries (i.e., oil and gas production) are the second largest contributors of VOCs statewide, representing 12% of total statewide VOC emissions and about two-thirds of statewide anthropogenic VOC emissions. Miscellaneous sources are the third largest and include a variety of widely distributed VOC emission sources, including small engines. Motor vehicles

[18] Normalized mean bias was within ±15% and normalized mean error was less than 35% of observations when the observed ozone concentrations were above 60 ppb.

(i.e., cars and trucks on restricted and unrestricted access roadways) are the fourth largest contributor, followed by consumer and commercial solvent use (e.g., dry cleaners, coating applications, and paints, among other sources), and nonroad equipment such as locomotives and construction equipment.

In Albuquerque/Bernalillo County, biogenic emissions also represent the largest source of VOC emissions, as shown in **Figure 26.** However, the mix of anthropogenic (i.e., non-biogenic) VOC emissions in Albuquerque/Bernalillo County is different than in New Mexico, in part because there is no significant oil and gas activity in Albuquerque/Bernalillo County. The largest anthropogenic source of VOC emissions in Albuquerque/Bernalillo County is solvent use (27% of total VOC emissions, or about 50% of anthropogenic VOC emissions). Motor vehicles are 15% of the total VOC inventory or about 25% (or 14.4 tons/day) of the anthropogenic VOC inventory in Albuquerque/Bernalillo County. Motor vehicles are also an important source of VOC emissions in other counties in the Albuquerque MSA. Motor vehicles from Sandoval, Valencia, and Torrance Counties combined emit 10.4 tons/day of VOC.

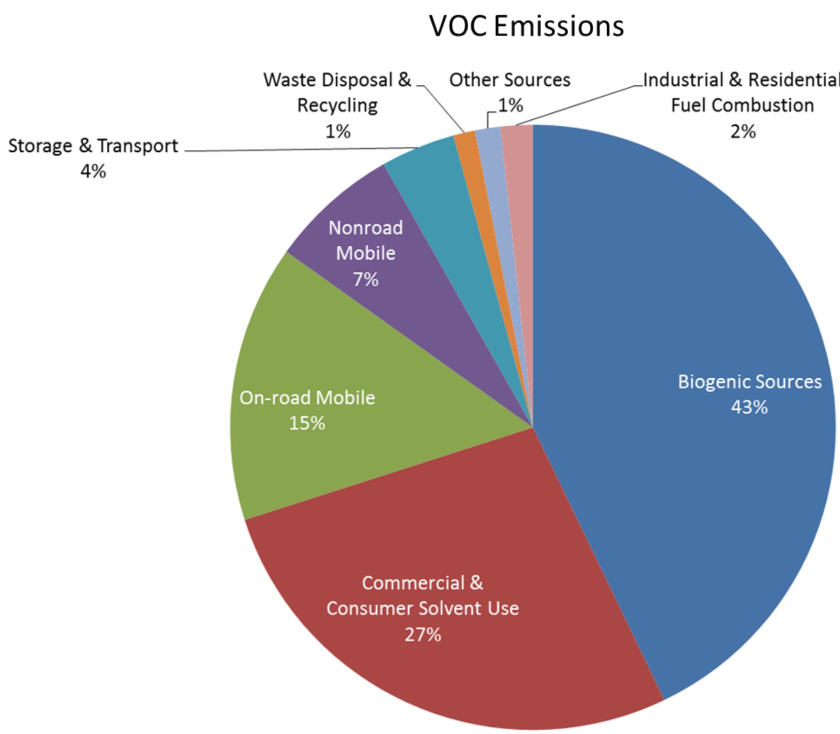

Figure 26. Annual 2014 VOC emissions in Albuquerque/Bernalillo County.

4.3 Analysis Approach

The NEI provides organic emissions as total mass either of total organic gas or VOCs from various sources. Chemical speciation profiles that define the chemical composition of various VOC emission sources are developed by EPA (U.S. Environmental Protection Agency, 2011) and implemented in the

SMOKE emissions processing system. The speciated VOC emissions are then assigned to the model species based on the Carbon Bond 6 (CB6) chemical mechansim as implemented in CAMx (Yarwood et al., 2010). The emitted VOC species for this analysis are shown in Table 7. The CB6 chemical mechanism lumps VOCs with similar chemical characteristics to represent the hundreds of organic compounds that are emitted. This approach collapses the full range of VOCs into a manageable number of species for air quality modeling purposes, but at the expense of potentially losing information about some specific VOC species. For example, xylene is a lumped VOC group in the CB6 mechanism that includes the chemical xylene as well as all poly-substituted aromatic compounds (e.g., trimethylbenzenes). Likewise, toluene is a lumped group that includes the chemical toluene as well as all mono-alkyl-substituted compounds (e.g., ethylbenzene). Lumped VOCs in this analysis are noted in Table 7.

Table 7. VOC species analyzed from the emissions inventory. Some VOCs represent lumped groups based on the CB6 chemical mechanism as implemented in CAMx.

Emitted Species	VOC Parameters	Lumped Group	Description
ACET	Acetone	No	Acetone
ACROLEIN	Acrolein	No	Acrolein
ALD2	Acetaldehyde	No	Acetaldehyde and parts of molecules that rapidly form acetaldehyde
ALDX	C3 or greater aldehydes	Yes	C3 or greater aldehydes and parts of molecules that rapidly form such aldehydes
BENZ	Benzene	No	Benzene
BUTADIENE13	1,3-butadiene	No	1,3-butadiene
ETH	Ethene	No	C2 alkene (C_2H_4)
ETHA	Ethane	No	C2 alkane (C_2H_6)
ETHY	Ethyne	Yes	Alkynes (hydrocarbons with C-C triple bonds)
ETOH	Ethanol	No	Ethyl alcohol (C_2H_5OH)
FORM	Formaldehyde	No	Formaldehyde (HCHO) and parts of molecules that rapidly form formaldehyde
IOLE	Internal Alkenes	Yes	C4 and greater internal alkenes
ISO	Isoprene	No	Primarily a biogenic VOC with small anthropogenic emissions
KET	Ketones	Yes	Ketones
MEOH	Methanol	No	Methyl alcohol (CH_3OH)
NAPH	Naphthalene	No	A polycyclic aromatic ($C_{10}H_8$)

Emitted Species	VOC Parameters	Lumped Group	Description
OLE	Alkenes (Olefins)	Yes	C3 and greater terminal alkenes
PAR	Alkanes (Paraffins)	Yes	C5 and greater Alkanes
PRPA	Propane	No	C3 Alkane (C_3H_8)
TERP	Terpenes	Yes	Primarily a biogenic VOC with small anthropogenic emissions
TOL	Toluene	Yes	Toluene and other monoalkyl aromatic compounds.
XYLMN	Xylenes	Yes	Xylene and other polyalkyl aromatic compounds, excluding naphthalene.

This analysis was conducted based on SMOKE-processed emissions data[19] for Albuquerque/Bernalillo County for July 1-14, 2017, and included all anthropogenic VOC emission source sectors. These dates were selected as representative summer emissions in Albuquerque/Bernalillo County. Biogenic and fire emissions were not included in this analysis because the purpose of this analysis is to determine VOCs and associated emissions sources that have the potential to be controlled.

Chemical reactivity varies for each VOC species. Relative ground-level ozone impacts of VOCs are quantified based on their MIR values. A higher MIR value represents a greater potential to form ozone per unit of VOC emission. The MIR scale was developed by Carter (2008) based on box-model simulations of ozone sensitivity to changes in VOC emissions under a variety of atmospheric conditions. The MIR data used in this analysis were taken from Carter (2010a; 2010b).[20]

Appropriate MIR values were determined for each emitted CB6 VOC species. The MIR for lumped groups was determined based on an appropriate representative proxy compound, as shown in Table 8. Since xylenes constitutes three structural forms[21] with varying ozone reactivity, the average MIR of the three forms of xylene was used as a proxy. MIR values for lumped VOC groups are approximate because there can be a wide range in reactivity over the individual chemicals that are represented by the lumped groups.

[19] Processed for the 4-km resolution CAMx modeling domain.
[20] Downloaded October 2018 from https://www.cert.ucr.edu/~carter/SAPRC/saprc07.xls.
[21] Xylenes refer to one of three structural isomers of dimethylbenzene, or a combination thereof. The three xylene isomers are ortho-xylene, meta-xylene, and para-xylene (o-xylene, m-xylene, and p-xylene).

Table 8. Proxy compound for determining MIR of lumped VOC groups.

Lumped VOC Groups	Proxy Compound for Determining MIR
C3 or greater aldehydes	Propionaldehyde
Internal alkenes with 4 or more carbons	C4 alkenes
Ketones	Methyl ethyl ketone
Alkenes with 3 carbons	Propene
Alkanes with 5 or more carbons	Branched C5 alkanes
Terpenes	Terpene
Xylenes	Average MIR of m-xylene, p-xylene, and o-xylene
Toluene	Toluene

Once the MIR values were determined, the ozone formation potential (tons/day) was calculated for each VOC species by multiplying its emissions by its MIR value. To support comparisons across VOC species, this analysis approach assumes that all VOC mass reacts in an environment with sufficient NO_x to support ozone formation. The actual amount of ozone that would be formed due to the VOC emissions varies spatially and temporally, and is dependent on meteorological and chemical conditions, particularly the ratio of ambient NO_x and VOC concentrations. All data were compiled, converted, summarized, and sorted using the R statistical software package.

4.4 VOC Analysis Results

The results of the VOC reactivity analysis for Albuquerque/Bernalillo County are shown in Table 9. The VOC species in Table 9 are ranked by their ozone generating potential (tons/day). The fraction of ozone generating potential (and emissions) due to emissions from the major inventory sectors are also shown for each VOC species. For context, Table 9 also shows the raw VOC emissions and the MIR values that were used. Note that higher MIR indicates higher chemical reactivity per unit of VOC emissions.

Table 9. Daily anthropogenic VOC emissions in Albuquerque/Bernalillo County ranked by ozone generating potential and the fractional contribution to the ozone generating potential from the major emission source sectors. The eight VOC species that collectively represent over 90% of the ozone generating potential in the inventory are shown in **bold**.

Pollutant	Lumped Group	Ozone Generating Potential (tons/day)	VOC Emissions (tons/day)	MIR Multiplier	Nonpoint Fraction (%)	Nonroad Fraction (%)	EGU Fraction (%)	Industrial Point (%)	RWC Fraction (%)	Motor Vehicle Fraction (%)
Xylenes	**Yes**	**27.82**	**3.60**	**7.73**	**72.4**	**24.8**	**0**	**1.5**	**0**	**1.2**
Alkanes	**Yes**	**27.52**	**18.98**	**1.45**	**81.3**	**13.6**	**0.1**	**4.1**	**0**	**1.0**
Toluene	**Yes**	**8.12**	**2.03**	**4.00**	**57.9**	**35.5**	**0**	**4.6**	**0**	**2.0**
Internal Alkenes	**Yes**	**7.94**	**0.65**	**12.22**	**60.9**	**29.0**	**0**	**8.5**	**0**	**1.6**
Alkenes	**Yes**	**5.68**	**0.49**	**11.66**	**44.1**	**38.4**	**0**	**13.8**	**0.1**	**3.7**
Ethene	**No**	**5.22**	**0.58**	**9.00**	**27.0**	**54.2**	**0**	**12.7**	**0.1**	**6.1**
Formaldehyde	**No**	**3.46**	**0.37**	**9.46**	**10.6**	**46.1**	**1.0**	**36.6**	**0.2**	**5.6**
Ethanol	**No**	**3.33**	**2.18**	**1.53**	**76.9**	**21.6**	**0**	**0.4**	**0**	**1.1**
Terpenes	Yes	1.10	0.27	4.04	99.4	0	0	0.5	0	0.1
Aldehydes (C3 or greater)	Yes	1.00	0.14	7.08	28.9	29.7	0	36.6	1.2	3.6
Acetaldehyde	No	0.74	0.11	6.54	16.4	56.6	0	19.2	0.3	7.6
Ketones	Yes	0.70	0.47	1.48	76.5	0.8	0	21.9	0.1	0.8
Naphthalene	No	0.69	0.21	3.34	91.6	5.0	0	2.4	0	1.0
Methanol	No	0.63	0.94	0.67	97.9	0.8	0	1.3	0	0
Propane	No	0.47	0.95	0.49	89.3	4.8	0.2	5.3	0	0.4
1,3-Butadiene	No	0.44	0.03	12.61	0.2	78.8	0	18.1	0.2	2.8
Acetone	No	0.38	1.07	0.36	94.8	0.9	0	4.2	0	0.1
Ethyne	No	0.34	0.36	0.95	5.0	86.1	0	5.6	0.1	3.2
Benzene	No	0.23	0.32	0.72	20.4	55.9	0.6	21.3	0.1	1.7
Acrolein	No	0.17	0.02	7.45	1.1	52.4	0	40.7	0	5.9
Isoprene	No	0.12	0.01	10.61	7.6	81.1	0	8.7	0.2	2.5
Ethane	No	0.04	0.13	0.28	9.7	26.3	0	59.0	0.2	4.9

Xylenes, which in this analysis include the major structure isomers of xylene along with other polyalkyl aromatic compounds in CB6 (e.g., trimethylbenzenes), are the top ozone generating anthropogenic VOC in Albuquerque/Bernalillo County. These aromatic compounds have a relatively high chemical reactivity (MIR=7.73) and are about five times more reactive than alkanes. As a result, xylenes represent 29% of the VOC ozone generating potential in the inventory, even though they represent only 10% of the anthropogenic VOC inventory. Xylenes occur naturally in petroleum and are therefore often emitted through combustion. Xylenes are an ingredient in aviation fuel and gasoline, are used as a solvent in chemical manufacture, agricultural sprays, adhesives, paints, and coatings, and are used as feedstock material in various industrial processes (U.S. Environmental Protection Agency, 1994a). 72% of xylenes emissions come from the non-point emissions sector, which is dominated by solvent use. Construction equipment and other nonroad vehicles and engines account for 25% of xylenes emissions. Because xylenes are highly reactive, relatively small reductions in xylenes VOC emissions could have a disproportionately large impact at reducing ozone in Albuquerque/Bernalillo County. Therefore, controlling solvent use and reducing emissions from construction equipment and other nonroad vehicles and engines could help reduce xylenes emissions, and potentially reduce ozone concentrations in Albuquerque/Bernalillo County.

The VOCs with the highest ozone generating potential (see Table 9) are xylenes, alkanes, toluene, and alkenes. Collectively, these VOCs represent 80% of the ozone formation potential among all anthropogenic VOC emissions in Albuquerque/Bernalillo County, and also represent 75% of total VOC emissions in the county. The top ranked "non-lumped" species in terms of ozone formation potential include ethene, formaldehyde, and ethanol, and they represent 12% of the VOC ozone generating potential. Ethene and formaldehyde have high ozone reactivity. Ethanol is less reactive, but ethanol emissions in the county are four to six times greater than ethene and formaldehyde emissions. The top eight VOCs in Table 9 represent over 90% of the anthropogenic ozone generating potential.

Alkanes are the second-highest ozone generating VOCs in the Albuquerque/Bernalillo County. In CB6, alkanes are a lumped species that represents VOCs with five or more single-bonded carbon atoms.[22] These alkane compounds are less reactive (MIR=1.45) compared to other VOCs, but they represent the majority (56%) of VOC emissions in the inventory. As a result, alkanes represent 29% of the anthropogenic VOC ozone generating potential in the inventory. About 80% of the alkanes VOCs come from the non-point source emissions sector, which is dominated in the county by solvent use, with smaller contributions from storage and transport activities, waste disposal and recycling, industrial, and miscellaneous VOC sources. Construction equipment and industrial sources also produce some alkane VOC emissions. Because alkane compounds are not very reactive (from an ozone generation perspective), relatively large reductions of alkane VOC emissions would likely be needed to significantly affect ozone in Albuquerque/Bernalillo County.

[22] Ethane (a C2 alkane) and propane (a C3 alkane) are represented separately in CB6, but are even less reactive than the heavier alkane compounds.

Toluene, which also includes other monoalkyl aromatic compounds (e.g., ethylbenzene) in CB6, is the third-highest ozone generating VOC in Albuquerque/Bernalillo County. Toluene has relatively high chemical reactivity (MIR=4.00), but is somewhat less reactive than xylenes. Toluene represents 8% of the VOC ozone generating potential in the inventory. Toluene and xylenes combined represent 38% of the anthropogenic VOC ozone generating potential in the inventory. Toluene is used as a cleaning solvent in various industrial and manufacturing settings, and is also used in the manufacture of paints, coatings, inks, and adhesives (U.S. Environmental Protection Agency, 1994b).

Alkenes, which include various double-bonded hydrocarbons in CB6, are among the most reactive VOCs in the inventory (MIR ranging from 11 to 12). Alkene emissions in Albuquerque/Bernalillo County are about 1 ton/day (about 3% of the anthropogenic VOC inventory), but they represent 14% of the anthropogenic VOC ozone generating potential in the inventory. About half of the alkene emissions come from the non-point emissions sector, which is dominated in the county by solvent use. Motor vehicles account for one-third of alkene VOC emissions, and industrial sources account for about 10% of alkene emissions. Motor vehicles are also sources of alkenes, since these hydrocarbons are a part of gasoline. As with xylenes and toluene, reductions in alkene VOC emissions could have a disproportionately large impact at reducing ozone in Albuquerque/Bernalillo County.

4.5 Discussion and Recommendations

A VOC analysis was conducted to determine the dominant anthropogenic VOC species in Albuquerque/Bernalillo County from a ground-level ozone reactivity perspective. The reactivity of each VOC species was estimated using published MIR values that represent the ozone formation potential of various organic compounds. Xylenes are the most-emitted VOCs from an ozone reactivity perspective. Because xylenes are highly reactive, relatively small reductions in xylenes VOC emissions could have a disproportionately large impact at reducing ozone in Albuquerque/Bernalillo County. Controlling solvent use and reducing emissions from construction equipment and other nonroad vehicles and equipment could help reduce xylenes emissions, and potentially reduce ozone concentrations.

Xylenes, alkanes, toluene, and alkenes collectively represent 75% of anthropogenic VOC emissions in Albuquerque/Bernalillo County, and 80% of the anthropogenic VOC ozone generating potential in the inventory. Lower reactivity alkane VOCs are the dominant anthropogenic VOCs emitted, but represent only about one quarter of the anthropogenic VOC ozone generating potential in Albuquerque/Bernalillo County. Higher reactivity aromatic VOCs, including xylenes and toluene, represent 38% of the anthropogenic VOC ozone generating potential in the emissions inventory. It's important to remember that lumped groups like xylenes and toluene include contributions from a variety of compounds in addition to the chemical species xylene and toluene.

This analysis only considers VOC emissions based on their potential to form ozone. Only anthropogenic emissions were considered, but biogenic VOCs such as isoprene are highly reactive and are a large portion of the overall VOC emissions inventory in Albuquerque/Bernalillo County. Many anthropogenic VOCs are emitted in relatively small quantities and thus do not contribute significantly to the calculated ozone generating potential. Motor vehicles co-emit a large number of VOCs with varying ozone reactivity. However, many VOCs, such as benzene, acrolein, naphthalene, and 1,3-butadiene, are also considered hazardous air pollutants and are associated with short-term health effects and long-term cancer risk. In recent years, mobile source air toxics (MSATs) have received considerable attention, particularly for communities located near major freeways and roadways with significant diesel truck traffic. MSAT emissions from diesel construction equipment are also important. For example, over half of the benzene and acrolein emissions, and over three-quarters of the 1,3-butadiene emissions in Albuquerque/Bernalillo County, come from the nonroad emissions sector. Analyses from the most recent community-scale VOC measurements in Albuquerque/Bernalillo County, collected from 2007 to 2009 indicated that traffic was a significant source of aromatic VOCs (Kavouras et al., 2015).

Ideally, this analysis would be based on local VOC observations with detailed chemical speciation. For example, PAMS sites typically measures 56 target hydrocarbon species. However, after performing a thorough assessment of available data, and after consulting Albuquerque EHD staff, we were not able to find recent ambient VOC data that were appropriate for this type of analysis. Thus, an important recommendation from this work is to perform a monitoring study to collect ambient, speciated VOC data (i.e., measurements of individual VOC compounds, not just total VOC). Such measurements could be used to corroborate the results of this analysis and confirm that the emissions inventory is representing ambient concentrations, as well as to develop a more detailed understanding of specific VOC species that may be contributing to ozone in Albuquerque/Bernalillo County.

5. Domain Selection

5.1 EPA Guidance

Guidelines for selecting modeling domains, outlined in the EPA's guidance (U.S. Environmental Protection Agency, 2014a), are driven by the geographic area(s) of interest, the nature of the pollution problem being modeled, and the spatial scale of emissions impacting the area(s) of interest. Important principles include:

- Selecting domains that are large enough to capture the key emission sources and any recirculation due to shifting wind directions.
- Minimizing boundary influences[23] by using a sufficiently large model domain and using output from a larger regional or global modeling simulation to provide boundary conditions.
- Using adequate horizontal grid resolution to capture complex meteorology and strong gradients in emissions sources. For urban air quality assessments, resolution between 4 km and 12 km is typically used.
- Selecting a vertical grid structure with
  - A sufficient number of layers (typically between 14 and 35 layers in the air quality model) between the surface and the tropopause (50 or 100 mb) to adequately represent diffusion and transport throughout the troposphere.
  - Sufficiently high resolution within the boundary layer to capture diurnal variability in mixing heights, with vertical layers matching the vertical layer structure of the meteorological model as closely as possible.
  - A lowest layer no more than about 40 m thick, to adequately represent important processes at the land-atmosphere interface and within the surface boundary layer.

5.2 Horizontal Domain

Modeling domains involve a trade-off between the need to have high-resolution domains for New Mexico and Albuquerque/Bernalillo County versus the need to include a large regional domain to capture emissions and pollutant transport over a broad area. The City of Albuquerque lies within the Rio Grande Valley, with the Sandia Mountain Range located directly to the east. The Sandia Mountain Range and the Rio Grande Valley induce complex diurnal flows that affect pollutant transport throughout Albuquerque/Bernalillo County. The nested grid approach is a computationally efficient way to characterize important regional-scale processes that affect pollutant concentrations in Albuquerque/Bernalillo County, while simulating the important local-scale flows at high resolution over a constrained region of interest.

[23] In this context, the goal is to provide the best possible representation of ozone and precursor pollutants from emissions that occur outside the modeling domain, and to minimize the influence of any numerical issues that may degrade results at or near the domain boundaries.

Therefore, a nested-grid approach with three modeling domains was selected for the meteorological, emissions, and air quality modeling. The domains, shown in Figure 27, include (1) a 36-km domain covering the continental United States; (2) a 12-km domain covering the western United States and northern Mexico; and (3) a 4-km domain covering much of New Mexico. The outer 36-km domain is selected for consistency with the existing Regional Planning Organization and EPA modeling domain for the continental United States, and is defined such that boundaries are far away from the western states. The 12-km domain is similar to the 12-km domain used in recent modeling work conducted by the Western Regional Air Partnership and is chosen to capture regional pollutant transport in the western United States.

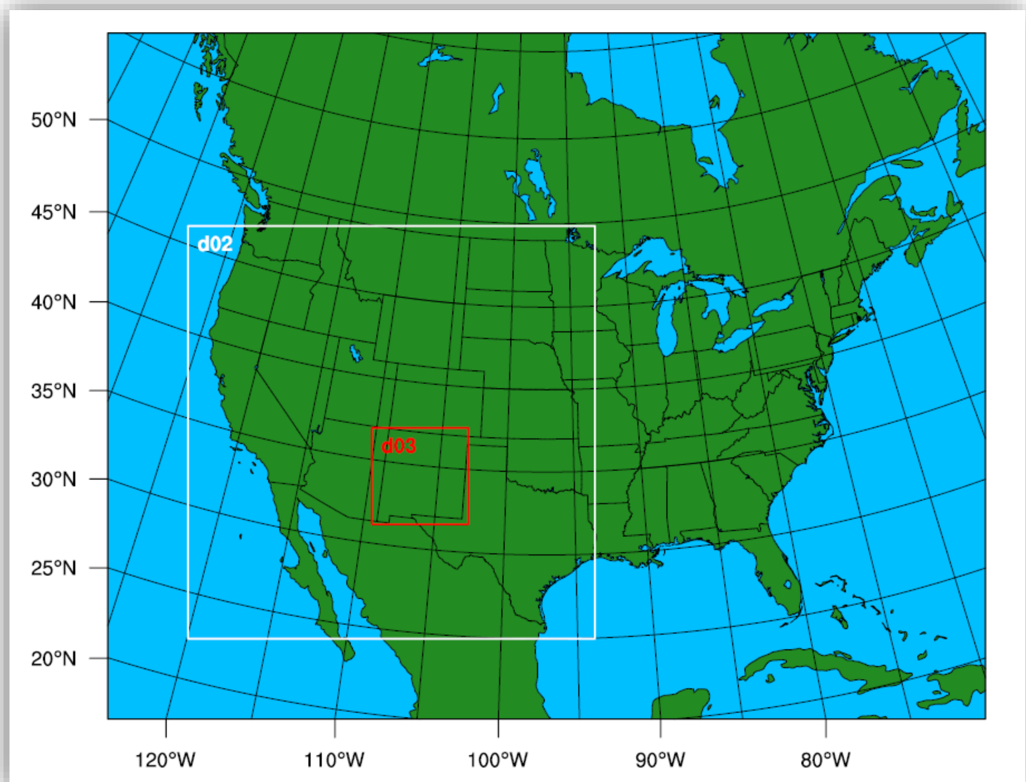

Figure 27. WRF modeling domains.

The 4-km domain is large enough to encompass emissions sources in New Mexico that may affect ozone concentrations in Albuquerque/Bernalillo County, and to capture the forcing mechanisms that drive diurnal flows through the Rio Grande Valley. The 4-km domain includes all of New Mexico, plus small portions of neighboring Arizona, Colorado, Texas, and Utah. Most of the emissions in the 4-km domain are from New Mexico. A 4-km grid resolution has been sufficient to support regulatory modeling efforts throughout the western United States, including the Denver Front Range region and Southern California. A 4-km grid was also used in prior modeling work that STI conducted for the

Albuquerque EHD. The domains are defined on a Lambert Conformal with the specifications given in Tables 10 and 11.

Table 10. Projection parameters for the modeling domains.

Parameter	Value
Projection	Lambert Conformal Conic
1st True Latitude	33.0 degrees N
2nd True Latitude	45.0 degrees N
Central Longitude	97.0 degrees W
Central Latitude	40.0 degrees N

Table 11. WRF modeling domain specifications.

Parameter	Domain 1	Domain 2	Domain 3
Cell Size	36 km	12 km	4 km
Cells East-West	165	229	169
Cells North-South	129	232	169
Vertical Layers	36	36	36
Southwest Corner (X)	-2,952 km	-2412 km	-1,164 km
Southwest Corner (Y)	-2,304 m	-1,656 km	-912 km

The air quality modeling domains are similar to the WRF modeling domains, but are slightly smaller, as they are inset from the corresponding WRF domains with at least a 5 grid-cell buffer to avoid numerical complications with the WRF boundary conditions. The air quality modeling domains are shown in Figure 28.

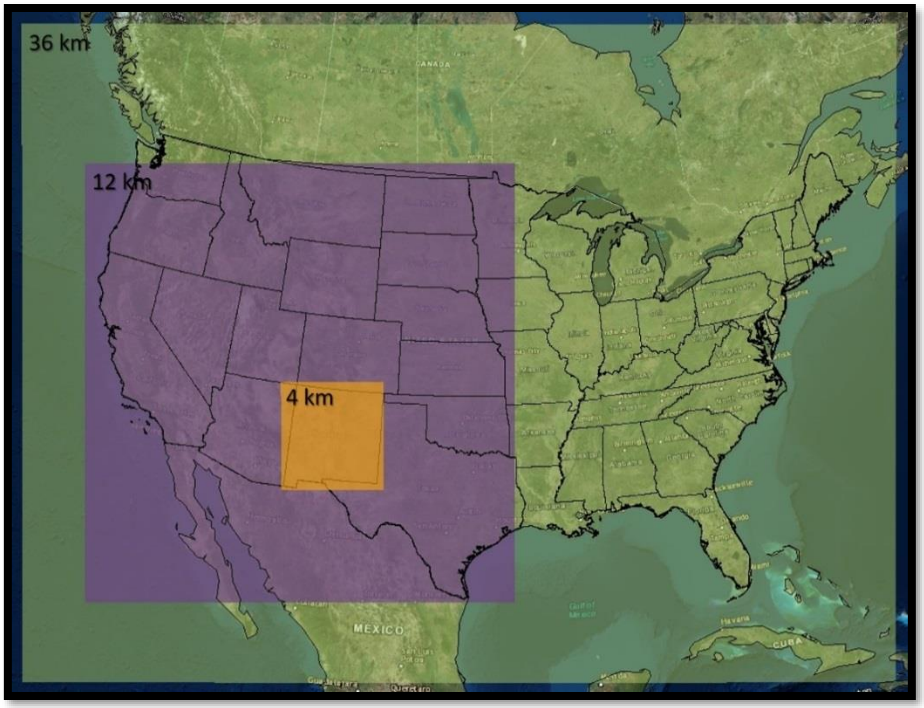

Figure 28. Air quality modeling domains.

The three modeling domains were run in CAMx in a fully nested mode with two-way feedback. Note that the domains are structured such that a higher-resolution 1.33 km domain can be added in the future. Some flow features may not be resolvable even at a 4-km resolution. Modeling at a 1.33-km resolution would require new spatial emissions surrogates. Spatial surrogates are derived from raw land use or demographic data and are used to allocate county-level emissions to the modeling grid cells. EPA has developed surrogates for the United States at a 4-km resolution, but new surrogates must be developed to support modeling at a higher resolution. Intuitively, one would expect more accurate results with higher resolution. In practice, higher resolution alone does not always improve overall model performance (Simon et al., 2012), but could improve model performance at specific locations that are strongly influenced by local wind patterns or are close to large emission sources.

5.3 Vertical Domain Structure

The WRF vertical grid includes 37 vertical layer interfaces (36 vertical layers) from the surface up to 50 mb (about 19 km AGL), with higher resolution (i.e., thinner layers) in the boundary layer. The lowest model layer is 12 m deep. To constrain CAMx computational time, multiple WRF layers are combined into single CAMx layers using a layer-averaging technique. For this project, the 36 WRF layers are collapsed into 26 CAMx layers in a way that preserves vertical resolution in the lower atmosphere, and maintains adequate vertical resolution in the upper troposphere and lower stratosphere. The WRF and CAMx vertical grid structures, and the WRF layer collapsing scheme, are shown in Table 12.

Table 12. Vertical grid structure for the WRF and CAMx modeling domains, and the approach for collapsing the 36 WRF layers into 26 CAMx layers.

WRF					CAMx		
Layer	Sigma	Pressure (mb)	Height (m)	Thickness (m)	Layer	Height (m)	Thickness (m)
36	0	50	19260	2055	26	19260	3905
35	0.0270	76	17205	1850			
34	0.0600	107	15355	1725	25	15355	3429
33	0.1000	145	13630	1701			
32	0.1500	193	11929	1389	24	11929	2569
31	0.2000	240	10541	1181			
30	0.2500	287	9360	1032	23	9360	1952
29	0.3000	335	8327	920			
28	0.3500	383	7408	832	22	7408	1592
27	0.4000	430	6576	760			
26	0.4500	478	5816	701	21	5816	1353
25	0.5000	525	5115	652			
24	0.5500	573	4463	609	20	4463	609
23	0.6000	620	3854	461	19	3854	573
22	0.6500	668	3281	440	18	3281	540
21	0.7000	715	2741	421	17	2741	412
20	0.7400	753	2329	403	16	2329	295
19	0.7700	782	2031	388	15	2031	289
18	0.8000	810	1742	373	14	1742	188
17	0.8200	829	1554	271	13	1554	185
16	0.8400	848	1369	177	12	1369	181
15	0.8600	867	1188	174	11	1188	179
14	0.8800	886	1009	171	10	1009	175
13	0.9000	905	834	84	9	834	172
12	0.9100	915	747	84			
11	0.9200	924	662	83	8	662	170
10	0.9300	934	577	82			
9	0.9400	943	492	82	7	492	166
8	0.9500	952	409	41			
7	0.9600	962	326	24	6	326	83
6	0.9700	972	243	24	5	243	81
5	0.9800	981	162	16	4	162	41
4	0.9850	986	121	16		121	41
3	0.9900	991	80	16	3	80	40
2	0.9950	995	40	12	2	40	20
1	0.9975	998	20	12	1	20	20
0	1.0000	1000	0		0	0	

6. Meteorological Modeling

6.1 Overview

High-quality meteorological data that reproduce key phenomena in the air quality modeling context (e.g., terrain-induced circulations, and the evolution and magnitude of boundary layer wind, temperature, moisture, turbulence, and depth) are needed to support an air quality modeling analysis. This chapter summarizes and documents the WRF meteorological modeling of ozone episodes in Albuquerque/Bernalillo County during June and July of 2017, and the meteorological model performance evaluation (MPE) that was conducted.

The goal of this MPE is to assess the suitability of the WRF output to support subsequent air quality modeling analyses, and determine whether WRF is adequately replicating the key processes that influence air quality in Albuquerque/Bernalillo County. This MPE consists of a statistical analysis of biases and errors in near-surface temperature, winds, and moisture, and a visual analysis of spatial plots, time series plots, and vertical profiles.

The emphasis of this MPE is on the meteorological contributions to ozone formation, pollutant transport, and diffusion, with particular focus on performance in Albuquerque/Bernalillo County. In June-July 2017, hourly ozone in Albuquerque/Bernalillo County was highest (>70 ppb) during periods of warm temperatures (80°F to 95°F), light winds (1-5 m/s) from the south, and limited cloud cover (see Chapter 3). Regional recirculation and long-range transport of ozone and its precursors are also important, and ozone contributions from local and regional fires contribute to local ozone on some days. The WRF modeling summarized here reproduced the local and regional meteorological conditions that are associated with high ozone concentrations in Albuquerque/Bernalillo County.

Based on the MPE results and our statistical and diagnostic review, the WRF modeling conducted is suitable for use in subsequent air quality modeling work. Overall, the statistical evaluation metrics were within performance benchmarks established by the air quality modeling community. Overall model performance was best for temperature. The observed trends in temperature, wind, and humidity were well characterized by WRF. Although hourly agreement was imperfect, low wind speed conditions associated with the highest ozone days in Albuquerque/Bernalillo County were generally captured by the model. The important WRF biases to note include a cold daytime temperature bias (up to 2 K), a warm nighttime temperature bias (>2 K), a high moisture bias (1-2 g/kg), and a low wind speed bias (around 0.5 m/s).

6.2 WRF Configuration

WRF modeling was conducted to develop gridded meteorological data fields for two modeling episodes in accordance with the modeling protocol document (Craig and Erdakos, 2018a). WRF simulations were conducted for the modeling grids described in Chapter 5. The version of WRF (version 3.9.1, released August 2017) current at the time of the study was used. Standard tools from the WRF Pre-processing System were used to develop the WRF inputs. Terrain data for WRF were developed using the standard WRF terrain database from the National Center for Atmospheric Research (NCAR), which are based on U.S. Geological Survey topographic datasets. For the 4-km modeling grid, terrain data at 900 m (30 arcseconds) resolution were interpolated to the modeling grid cells.

The key WRF modeling options and settings that were used are summarized in **Table 13**. The Pleim-Xiu land surface model was used with soil temperature and moisture nudging. The OBSGRID preprocessing program was used with weather observations from the Meteorological Assimilation Data Ingest System (MADIS) to perform an objective analysis on the North American Regional Reanalysis (Mesinger et al., 2006) first-guess meteorological fields. The surface temperature and moisture fields produced by this OBSGRID analysis were also used by the Pleim-Xiu land surface model (LSM) soil temperature and moisture nudging scheme. WRF was executed in 5.5-day blocks initialized at 1200 UTC every five days. Twelve hours of spin-up[24] were included in each modeling block, but data from the spin-up periods were not used in the MPE or subsequent air quality applications. Soil temperature and moisture fields were carried between run blocks to avoid spinning up the LSM again. Continuous two-way nesting was used with no feedback from the nested grids into their parent grids.

Data assimilation was used to improve the quality of WRF meteorological outputs for retrospective air quality modeling applications, and has been shown to improve air quality model performance (Godowitch et al., 2015). Four-Dimensional Data Assimilation (FDDA) uses Newtonian relaxation (nudging) to continuously adjust the modeled state toward a gridded three-dimensional model analysis, individual observations, or both. For this study, an FDDA approach was used that includes analysis nudging[25] above the boundary layer in the 36-km and 12-km grids.

[24] "Spin-up" refers to the time period after the model is initialized when the model is adjusting from the initial atmospheric state. Modeling results from the spin-up periods are not reliable and therefore are excluded from the analysis. The length of spin-up needed depends on the model and on the intended application. For WRF, a 12-hour spin-up period is considered adequate for air quality modeling applications. For CAMx, several days of spin-up are needed.

[25] Analysis nudging is a data assimilation technique that adjusts modeled wind, temperature, and humidity values toward "observed" values in a gridded 3-D atmospheric analysis at each model timestep. This approach prevents the model solution from deviating too far from the observed atmospheric state during the simulation and improves overall model performance.

Table 13. WRF physics options.

Option	Package
Boundary layer parameterization	ACM2
Land surface physics	Pleim-Xiu LSM with soil temperature and moisture nudging
Microphysics	WSM6 Single-moment 6-class scheme
Shortwave radiation	Rapid Radiative Transfer Model (RRTMG)
Longwave radiation	RRTMG
Cumulus parameterization	Kain-Fritsch in the 36/12-km domains None in the 4-km domain
FDDA Analysis Nudging	Applied to winds, temperature, and moisture in the 36-km and 12-km domains, with no temperature and moisture nudging within the PBL
FDDA Observation Nudging	None
Input gridded data for initial and boundary conditions	North American Regional Reanalysis (32 km resolution)

6.3 Data Sources

Meteorological observations for the MPE were acquired from MADIS, which compiles and quality-assures observations from the NWS and other weather observation networks throughout the United States. There are two NWS sites in Albuquerque/Bernalillo County: the Albuquerque International Airport (KABQ) and the Double Eagle Airport. Data from both sites were included in the evaluation, but as noted in Chapter 3, meteorological data availability is good at KABQ, but less complete at the Double Eagle Airport. NWS upper-air sounding data are available every 12 hours at Albuquerque. Upper-air observations were not included in the statistical evaluation, but vertical soundings and mixing heights were extracted from the WRF output and compared to the observed soundings. In addition, surface and upper-air weather maps from the NOAA Daily Weather Maps[26] were used to qualitatively evaluate large-scale atmospheric patterns predicted by WRF in the 12-km and 36-km domains.

6.4 Model Performance Evaluation Approach

Meteorological model performance was evaluated using time series and spatial plots comparing observed and predicted parameters, and by conducting statistical evaluations of those comparisons. The goal of this MPE is to assess the suitability of the WRF output to support air quality modeling

[26] Acquired from http://origin.wpc.ncep.noaa.gov/dailywxmap/index.html.

analyses, and determine whether WRF is adequately replicating the key processes that influence local and regional air quality. The emphasis of this MPE was on the meteorological contributions to ozone formation, pollutant transport, and diffusion. WRF was applied and evaluated in a challenging region with local wind flows influenced by the Sandia Mountain Range and larger-scale diurnal flows through the Rio Grande Valley.

The Atmospheric Model and Evaluation Tool (AMET)[27] (Appel et al., 2017; 2011) was used to conduct the evaluation. AMET was developed by the EPA and uses the MySQL database and R statistical software to calculate MPE statistics and generate analysis graphics. Hourly NWS data were acquired from MADIS and used in the evaluation. Equations for calculating the statistical metrics used in this MPE are given in **Table 14**. This MPE consisted of an operational statistical analysis of biases and errors in near-surface temperature, winds, and humidity. Observations and modeled predictions were paired in space and time for the statistical analysis based on a nearest-neighbor approach.

Since the mid-1990s, model performance evaluations have been performed for WRF and its predecessors. The results of these evaluations provide a foundation against which to compare the current WRF modeling. With these past simulations as a guide, the model performance benchmarks suggested by Emery et al. (2001) and Kemball-Cook et al. (2005) were used. These benchmarks are shown alongside the statistical performance results to place the MPE results into context. Note that complex terrain is more challenging for meteorological models, because some terrain features may not be resolvable even by high-resolution (e.g., 4-km or 1-km) domains, and meteorological observations at the surface will be less representative of modeled grid volume averages in complex terrain. Therefore, the benchmarks for complex terrain are somewhat less stringent. Albuquerque/Bernalillo County is considered a region of complex terrain for modeling purposes because large mountain ranges (e.g., the Sandia Mountains) significantly influence meteorological conditions and drive localized wind patterns that can vary over short distances.

[27] AMET software and documentation are available through the Community Modeling and Analysis System Center at https://www.cmascenter.org.

Table 14. Statistical model performance metrics.

Parameter	Definition[a]
Mean bias (MB)	$\frac{1}{N}\sum(M_i - O_i)$
Mean error (ME)	$\frac{1}{N}\sum\lvert M_i - O_i\rvert$
Root mean squared error (RMSE)	$\sqrt{\frac{\sum(M_i - O_i)^2}{N}}$
Normalized mean bias (NMB)	$100\% * \frac{\sum(M_i - O_i)}{\sum O_i}$
Normalized mean error (NME)	$100\% * \frac{\sum\lvert M_i - O_i\rvert}{\sum O_i}$
Coefficient of determination (r2)	$\frac{[(M_i - \bar{M})(O_i - \bar{O})]^2}{\sum(M_i - \bar{M})^2 \sum(O_i - \bar{O})^2}$
Index of Agreement (IOA)	$1 - \frac{\sum(O_i - M_i)^2}{\sum(\lvert M_i - \bar{O}\rvert + \lvert O_i - \bar{O}\rvert)^2}$

[a] M_i is the modeled concentration at time and location *i*; O_i is the observed concentration at time and location *i*, N is the number of paired observation/model concentrations, $\bar{M}$ is the mean modeled concentration, and $\bar{O}$ is the mean observed concentration.

6.5 Summary of Model Performance

The overall WRF model performance was good for June-July 2017, and the statistical evaluation metrics were within performance benchmarks established by the air quality modeling community. The combined performance statistics for surface temperature, winds, and water vapor mixing ratio for both modeling episodes are summarized for the 4-km domain in Table 15, and for the 12-km domain in Table 16.

Table 15. WRF MPE results for the 4-km grid and model performance metrics, with benchmarks for simple and complex terrain. Green cells indicate metrics that fell within the performance benchmark for complex terrain. **Bold** values indicate statistical metrics that also fell within the more stringent performance benchmarks for simple terrain. Yellow cells indicate values that fell outside the performance benchmark. Benchmarks for complex terrain have not been established for some parameters and metrics, and in those cases the benchmark for simple terrain is used.

Parameter	Statistical Metric	Value	Benchmark (Simple Terrain)	Benchmark (Complex Terrain)
Wind Speed	RMSE	2.4	≤ 2.0 m/s	≤ 2.5 m/s
	Bias	-0.6	≤ ±0.5 m/s	≤ ±1.5 m/s
	IOA	0.5	≥ 0.6	No benchmark
Wind Direction	Gross Error	50	≤ 30 degrees	≤ 55 degrees
	Bias	**4**	≤ ±10 degrees	No benchmark
Temperature	Gross Error	**2.0**	≤ 2.0 K	≤ 3.5 K
	Bias	**0.0**	≤ ±0.5 K	≤ ±2.0 K
	IOA	**0.9**	≥ 0.8	No benchmark
Humidity (Mixing Ratio)	Gross Error	**1.7**	≤ 2.0 g/kg	≤ 2.0 g/kg
	Bias	**1.0**	≤ ±1.0 g/kg	≤ ±1.0 g/kg
	IOA	**0.8**	≥ 0.6	No benchmark

For both the 4-km and 12-km domains, WRF performance was within the performance benchmarks for complex terrain for all parameters and metrics except the IOA for wind speed on the 4-km domain. In many cases, the WRF performance was also within the more stringent performance benchmarks for simple terrain. Model performance was best for temperature, with error less than or equal to 2 K and low overall bias. There was a persistent high bias in water vapor mixing ratio (humidity), and a persistent low bias in wind speed. Overall performance was slightly better in the 12-km domain than in the 4-km domain, as there were more observations to compare against in the 12-km domain.

Table 16. WRF MPE results for the 12-km grid and model performance metrics, with benchmarks for simple and complex terrain. Green cells indicate values that fell within the performance benchmark for complex terrain. **Bold** values indicate statistical metrics that also fell within the more stringent performance benchmarks for simple terrain. Benchmarks for complex terrain have not been established for some parameters and metrics, and in those cases the benchmark for simple terrain is used.

Parameter	Statistical Metric	Value	Benchmark (Simple Terrain)	Benchmark (Complex Terrain)
Wind Speed	RMSE	**2.0**	≤ 2.0 m/s	≤ 2.5 m/s
	Bias	**-0.2**	≤ ±0.5 m/s	≤ ±1.5 m/s
	IOA	**0.6**	≥ 0.6	No benchmark
Wind Direction	Gross Error	39	≤ 30 degrees	≤ 55 degrees
	Bias	**4**	≤ ±10 degrees	No benchmark
Temperature	Gross Error	**1.8**	≤ 2.0 K	≤ 3.5 K
	Bias	**-0.1**	≤ ±0.5 K	≤ ±2.0 K
	IOA	**0.9**	≥ 0.8	No benchmark
Humidity (Mixing Ratio)	Gross Error	**1.7**	≤ 2.0 g/kg	≤ 2.0 g/kg
	Bias	**0.4**	≤ ±1.0 g/kg	≤ ±1.0 g/kg
	IOA	**0.9**	≥ 0.6	No benchmark

6.6 Model Performance for Temperature

WRF model performance for surface temperature throughout the 4-km and 12-km domains was good and within performance benchmarks. Performance statistics for each episode are shown in Table 17. Temperature is typically overpredicted by the model by up to 2 K during the nighttime hours, and underpredicted by up to 2 K during the day. These offsetting biases result in a low overall bias. These diurnal tendencies can be seen in the scatterplot of modeled and observed temperatures (Figure 29) and in the diurnal plot of model errors (Figure 30).

Model performance at KABQ was also good, including on the ozone days of June 14-16, July 7, and July 10, as shown in the time series plots for the June (Figure 31) and July (Figure 32) modeling episodes. In general, there is good agreement in the temperature diurnal cycle, although there are slight differences in timing between the model and observations. For example, the peak temperature in WRF tends to be 1-2 hours earlier than the observed peak, and this leads to an underprediction during the evening hours. WRF captures the observed day-to-day temperature variability and accurately predicts daytime peak temperatures on most days, but does not capture some of the localized hourly temperature variations that occurred at KABQ on some evenings and nights. The model also correctly depicted the warmer temperatures in the July episode compared to the June episode. Model performance at KABQ was slightly better in June than in July.

Table 17. WRF performance for temperature for each episode. Green cells indicate values that fell within the performance benchmark for complex terrain.

Domain	Statistical Metric	Benchmark	Value for June Modeling Episode	Value for July Modeling Episode
4-km	Gross Error	≤ 3.5 K	2.0	2.0
	Bias	≤ ±2.0 K	0.1	-0.1
	IOA	≥ 0.8	0.9	0.9
12-km	Gross Error	≤ 3.5 K	1.8	1.9
	Bias	≤ ±2.0 K	0.0	-0.2
	IOA	≥ 0.8	0.9	0.9

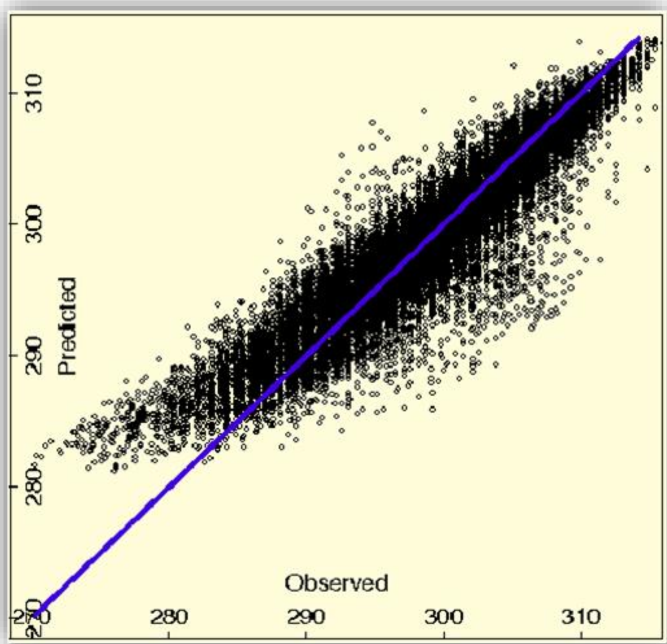

Figure 29. Scatterplot of observed and predicted temperature (K) for both modeling episodes over the 4-km grid.

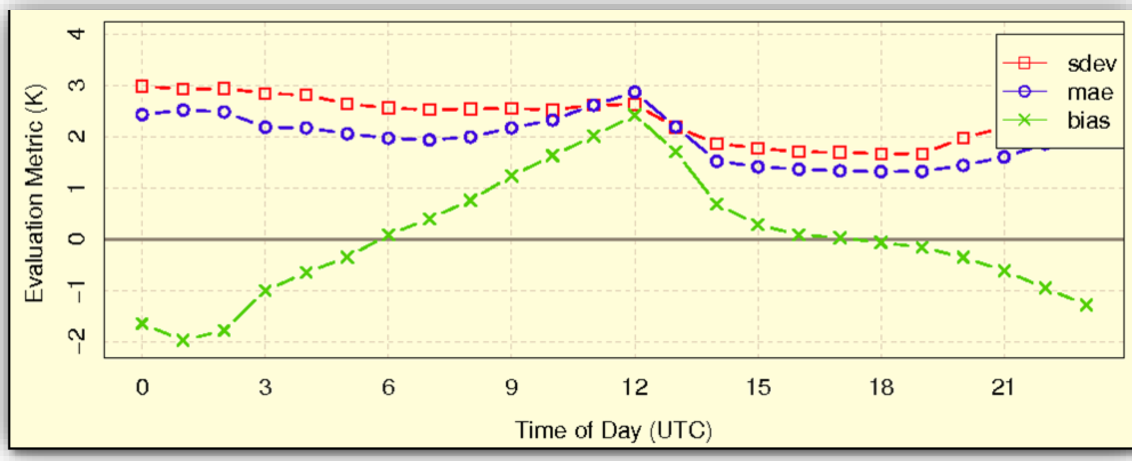

Figure 30. Diurnal temperature performance for both modeling episodes over the 4-km grid. Standard deviation (sdev), mean absolute error (mae), and bias are shown.

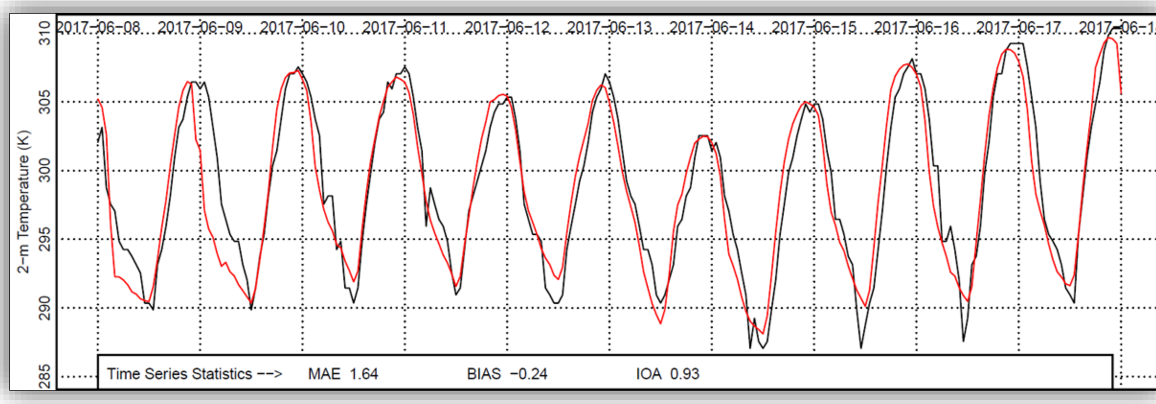

Figure 31. Time series of observed (black line) and predicted (red line) temperature for the June modeling episode at Albuquerque International Airport (KABQ). Performance statistics at KABQ are also shown.

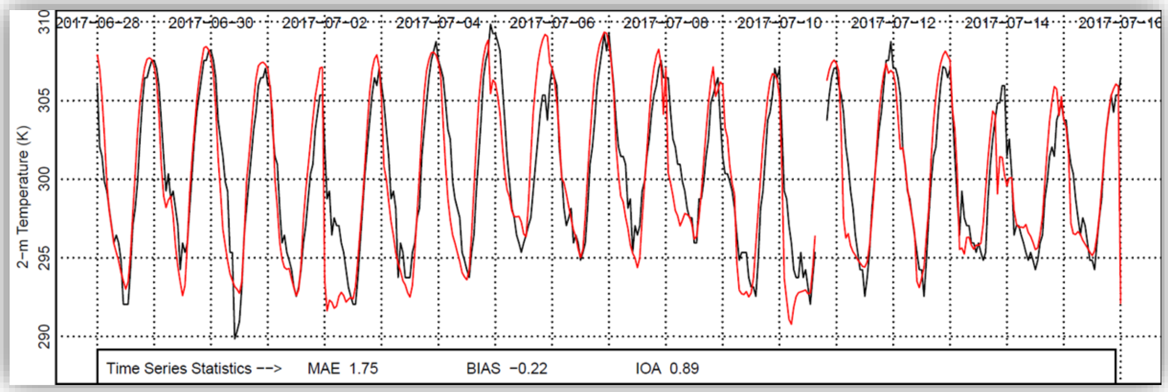

Figure 32. Time series of observed (black line) and predicted (red line) temperature for the July modeling episode at Albuquerque International Airport (KABQ). Performance statistics at KABQ are also shown.

6.7 Model Performance for Water Vapor Mixing Ratio

WRF model performance for water vapor mixing ratio (humidity) throughout the 4-km and 12-km domains, and at KABQ, were reasonably well correlated with observations and within performance benchmarks except for the 4-km domain bias in the June episode. Performance statistics for each episode are shown in Table 18. In the 4-km domain, performance for humidity was slightly better in the June episode than in the July episode (the reverse was true for the 12-km domain). The model had a persistent high humidity bias in both episodes that was most prevalent during the late afternoon and early evening hours. These tendencies can be seen in the scatterplot of modeled and observed humidity (Figure 33) and in the diurnal plot of model errors (Figure 34).

Table 18. WRF performance for water vapor mixing ratio (humidity) for each episode. Green cells indicate values that fell within the performance benchmark. Yellow cells indicate values that were outside the performance benchmark.

Domain	Statistical Metric	Benchmark	Value for June Modeling Episode	Value for July Modeling Episode
4-km	Gross Error	≤ 2.0 g/kg	1.8	1.7
	Bias	≤ ±1.0 g/kg	1.2	0.9
	IOA	≥ 0.6	0.7	0.8
12-km	Gross Error	≤ 2.0 g/kg	1.5	1.8
	Bias	≤ ±1.0 g/kg	0.3	0.5
	IOA	≥ 0.6	0.9	0.9

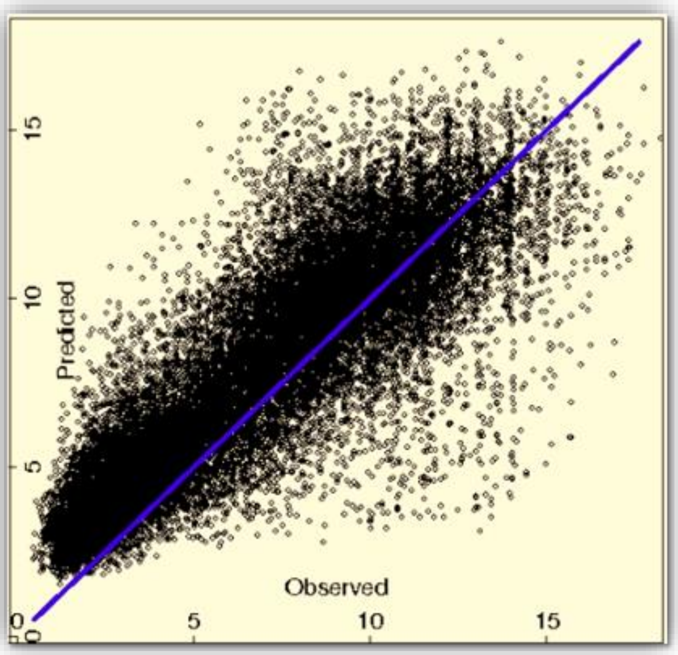

Figure 33. Scatterplot of observed and predicted water vapor mixing ratio (g/kg) for both modeling episodes over the 4-km grid.

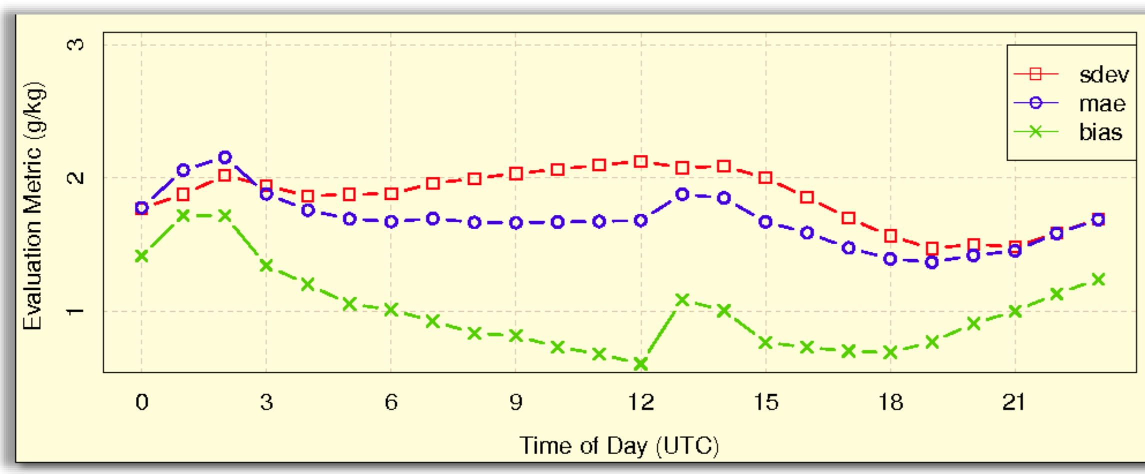

Figure 34. Diurnal water vapor mixing ratio performance for both modeling episodes over the 4-km grid. Standard deviation (sdev), mean absolute error (mae), and bias are shown.

Model performance for humidity at KABQ was reasonable, but errors were somewhat larger than for the domain-wide statistics. Despite the biases (about 1.9 g/kg during the June episode and 1.3 g/kg during the July episode), WRF tracked changes in humidity very well, as shown in the time series plots in Figures 35 and 36. For example, WRF predicted the abrupt reduction in humidity associated with a dry frontal passage on June 9, and the continued drying trend through June 14 (see Figure 35). The bias was less pronounced on the high ozone days of June 14-16. The atmosphere was extremely dry over Albuquerque/Bernalillo County during the June ozone episode, and the moisture bias may have somewhat affected predictions of the temperature diurnal cycle; however, the modeled atmosphere was still very dry, and this moisture bias did not result in any spurious modeled cloud development that would have limited solar radiation. WRF also captured the higher mixing ratio in the July modeling episode.

Some more significant discrepancies between modeled and observed mixing ratios (>2 g/kg) occurred on some days, possibly due to mismatches between modeled and observed convection. Thermodynamic profiles from the model and from observed soundings supported scattered high-based convection in New Mexico during the July modeling period. Modeled convection typically is not well correlated in space and time with observed convection, which can result in increased model errors in wind, temperature, and moisture.

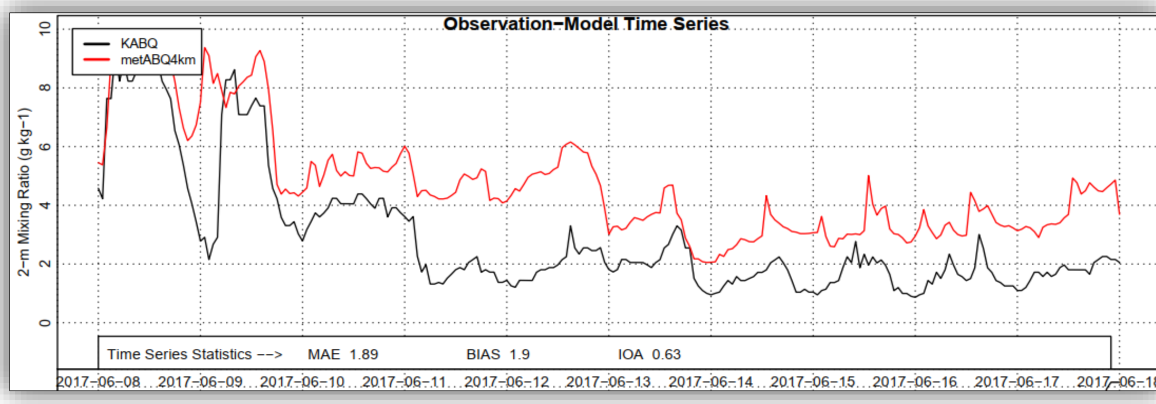

Figure 35. Time series of observed (black line) and predicted (red line) water vapor mixing ratio for the June modeling episode at Albuquerque International Airport (KABQ). Performance statistics at KABQ are also shown.

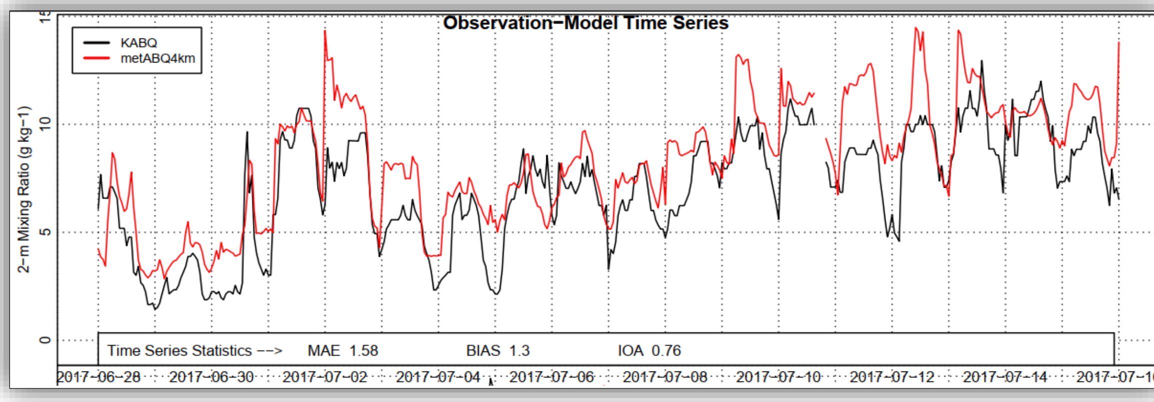

Figure 36. Time series of observed (black line) and predicted (red line) water vapor mixing ratio for the July modeling episode at Albuquerque International Airport (KABQ). Performance statistics at KABQ are also shown.

6.8 Model Performance for Winds

Model performance for winds was good considering the complex terrain in New Mexico and in Albuquerque/Bernalillo County. Performance statistics for wind speed and wind direction for each episode are shown in Table 19. Except for the wind speed IOA (a measure of hourly agreement between modeled and observed values), the model performance was reasonable and within performance benchmarks for complex terrain. Generally, the WRF performance for wind was better in the June modeling episode than in the July modeling episode. There was consistent low wind speed bias of between 0.50 and 0.75 m/s through most of the diurnal cycle, and wind speed errors tended to be larger during the afternoon hours due largely to timing mismatches of localized terrain-driven wind shifts or convective-driven winds. Directional errors tended to be larger in the night and morning hours when the winds drop from their afternoon maxima and at times become light and directionally variable. These tendencies can be seen in the scatterplot of modeled and observed wind speed (Figure 37) and in the diurnal plots of wind errors (Figures 38 and 39).

Table 19. WRF performance for winds for each episode. Green cells indicate values that fell within the performance benchmarks for complex terrain. Yellow cells indicate values that were outside the performance benchmark.

Domain	Parameter	Statistical Metric	Benchmark	Value for June Modeling Episode	Value for July Modeling Episode
4-km	Wind Speed	RMSE	≤ 2.5 m/s	2.1	2.5
		Bias	≤ ±1.5 m/s	-0.5	-0.7
		IOA	≥ 0.6	0.6	0.4
4-km	Wind Direction	Gross Error	≤ 55 degrees	42	55
		Bias	≤ ±10 degrees	5	3
12-km	Wind Speed	RMSE	≤ 2.5 m/s	2.0	2.0
		Bias	≤ ±1.5 m/s	-0.3	-0.1
		IOA	≥ 0.6	0.5	0.7
12-km	Wind Direction	Gross Error	≤ 55 degrees	43	33
		Bias	≤ ±10 degrees	4	4

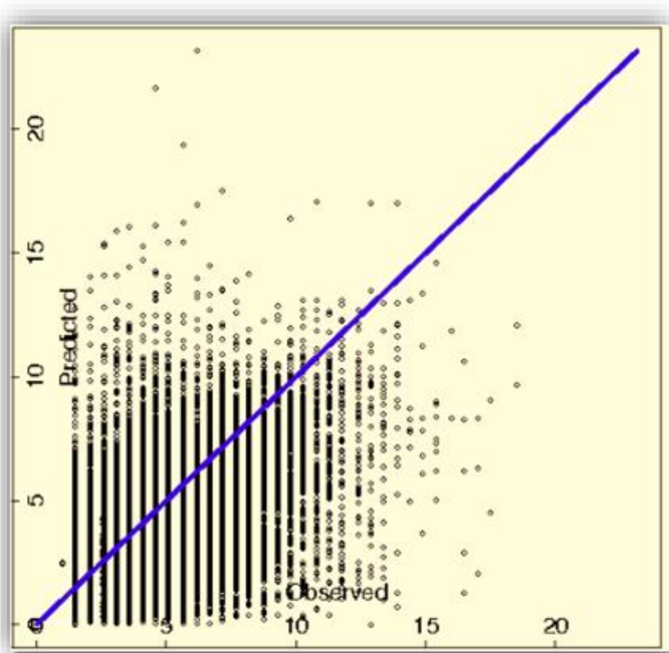

Figure 37. Scatterplot of observed (x-axis) and predicted (y-axis) wind speed (m/s) for both modeling episodes over the 4-km grid.

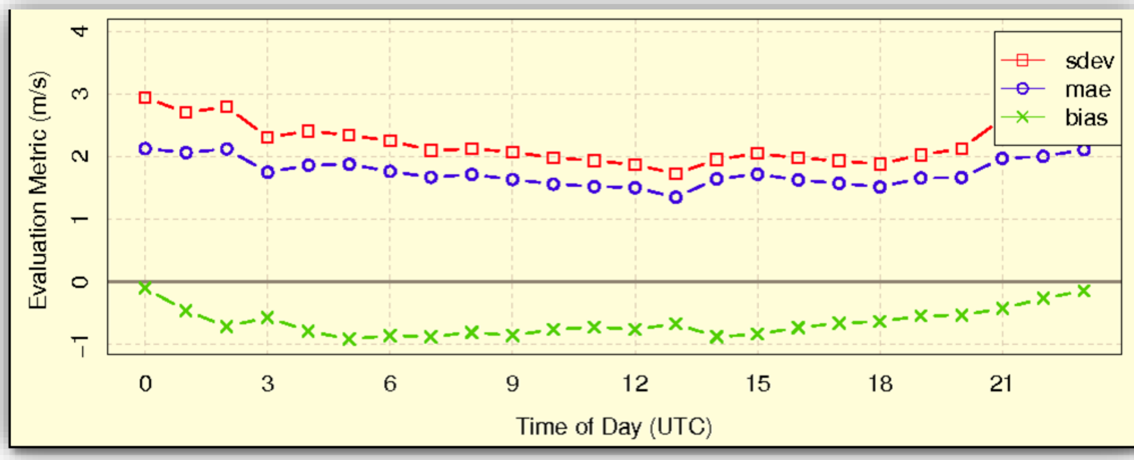

Figure 38. Diurnal wind speed performance for both modeling episodes over the 4-km grid. Standard deviation (sdev), mean absolute error (mae), and bias are shown.

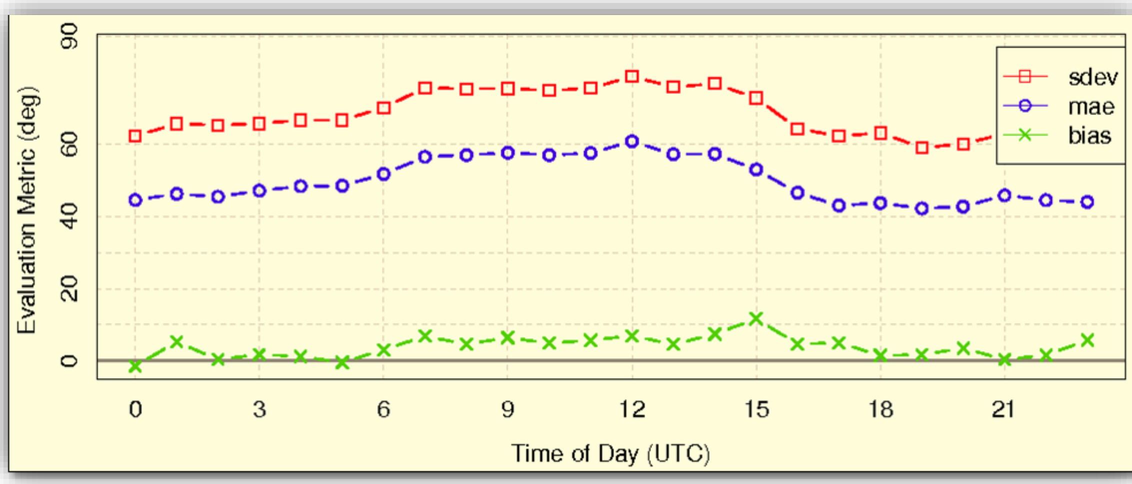

Figure 39. Diurnal wind direction performance for both modeling episodes over the 4-km grid. Standard deviation (sdev), mean absolute error (mae), and bias are shown.

The timing of modeled diurnal winds through the Rio Grande Valley was reasonable, with down-valley winds (blowing from the north) noted during the nighttime hours and up-valley winds (blowing from the south) during the afternoon hours. However, WRF did not always capture the timing of these diurnal wind flow changes, and these mismatches affected overall model performance for winds. On some evenings WRF depicted some easterly downslope flow off the Sandia Mountains.

Time series of observed and modeled wind speeds at KABQ are shown in Figures 40 and 41. The statistical performance for wind speed was better in June than in July. WRF reproduced day-to-day changes in wind speed quite well. For example, with some underprediction, WRF reproduced the increased afternoon winds at KABQ on June 12 and June 13. This was followed by a period of relatively low wind speeds (less than 5 m/s) on the high ozone days of June 14 and 15. Although hourly agreement was imperfect, WRF captured the observed low wind speed conditions. Low wind speed conditions are associated with high ozone concentrations in Albuquerque/Bernalillo County during the ozone episodes (see Chapter 3).

For the July modeling episode, the low wind speed bias at KABQ was more pronounced, and overall agreement with hourly observations was not as good. Several days when the model missed short-term wind events at KABQ (when observed winds exceeded 10 m/s) contributed to the overall performance statistics. However, on the high ozone days of July 7 and 10, WRF reproduced the low wind speed conditions that were observed. It is notable that on July 8 and July 9, WRF predicted wind speeds of around 10 m/s during the mid-afternoon hours. Afternoon winds also increased for a brief time in the observations on these days. This may explain why ozone concentrations were lower on these days compared to July 7 and 10. The July episode had more atmospheric moisture and instability compared to the June episode; therefore, convection was more prevalent. Modeled hourly winds were often in poor agreement with observations during times when modeled convection occurred.

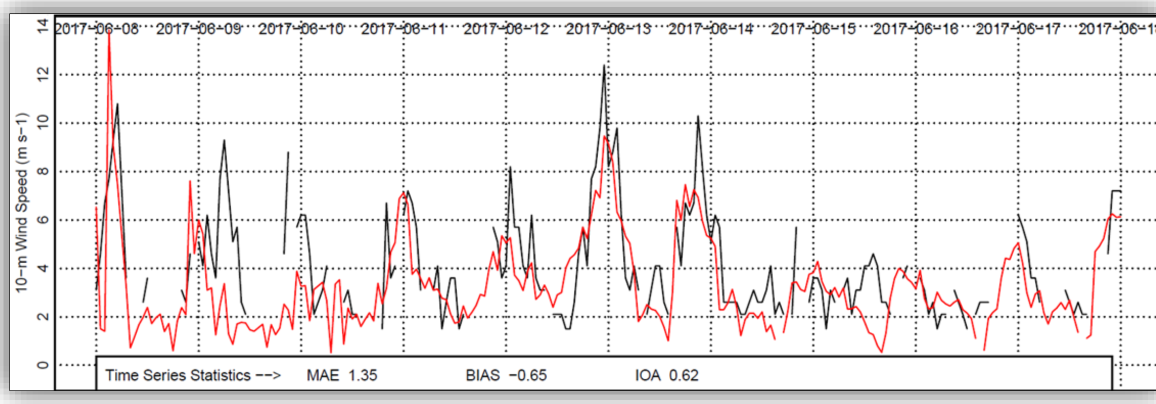

Figure 40. Time series of observed (black line) and predicted (red line) wind speed (m/s) for the June modeling episode at Albuquerque International Airport (KABQ). Performance statistics at KABQ are also shown.

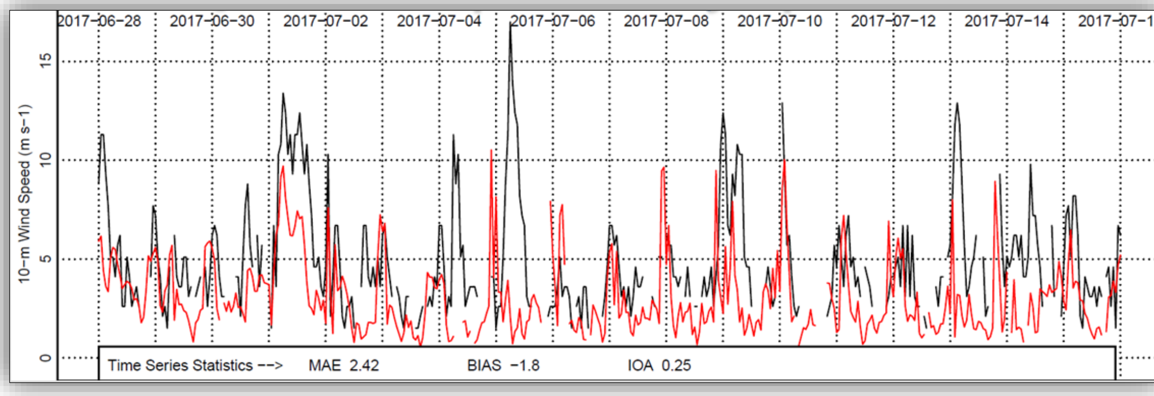

Figure 41. Time series of observed (black line) and predicted (red line) wind speed (m/s) for the July modeling episode at Albuquerque International Airport (KABQ). Performance statistics at KABQ are also shown.

6.9 Regional Model Performance

For large-scale weather conditions in the 36-km and 12-km grids, WRF model patterns compared well with historic NCEP daily weather maps.[28] For the June modeling episode, the WRF model captured the timing and passage of a cold front that preceded the ozone episode (see Figure 6). The front brought very dry conditions to Albuquerque/Bernalillo County. Wind speeds decreased after the frontal passage as surface high pressure built in behind the front.

For the July modeling episode, the WRF model captured the upper-level high pressure system that was centered over the Four Corners region (see Figure 9). During the episode, the upper-level ridge shrank and weakened slowly, which the WRF model captured. The model properly characterized the northeasterly flow aloft at KABQ during the July modeling episode. Surface meteorology in New Mexico was driven by high pressure, as seen in Figure 42 on July 7 at 4:00 p.m. MDT. July 7 was a high ozone day in Albuquerque/Bernalillo County (the peak 8-hour ozone was 76 ppb) with closed circulation patterns and sinking air flow from aloft. These large-scale flow conditions are associated with high pressure systems and are conducive to regional ozone formation and pollutant recirculation.

[28] Acquired from http://origin.wpc.ncep.noaa.gov/dwm/dwm.shtml.

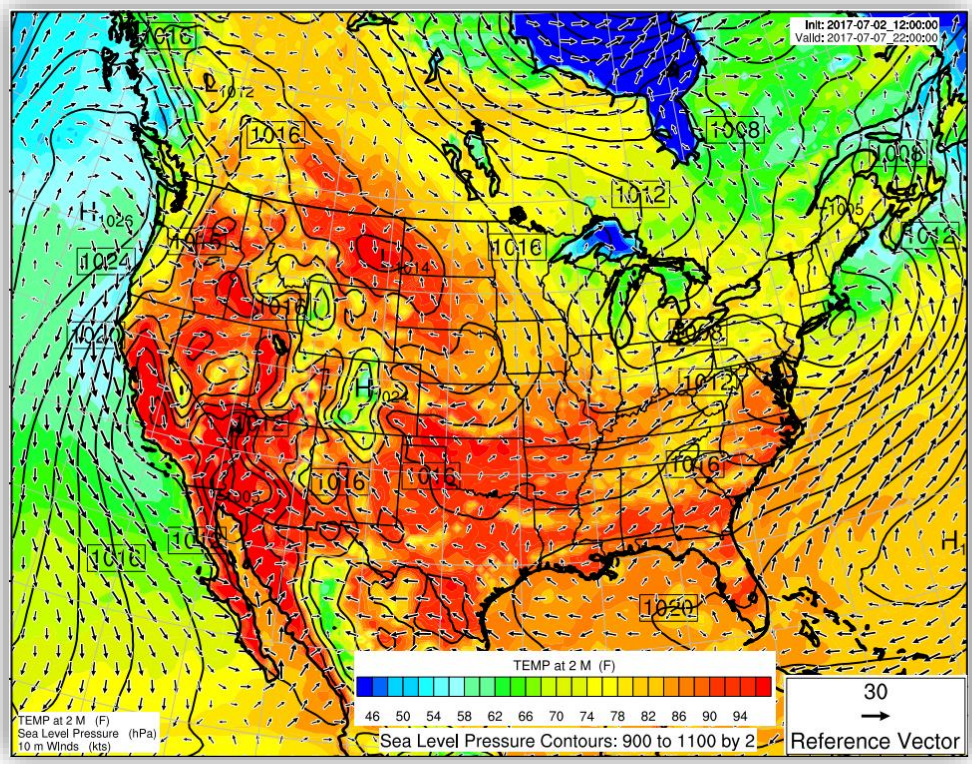

Figure 42. Surface spatial plot of WRF temperature (colors) and winds (vectors) for the 36-km domain for July 7, 2017, at 4:00 p.m. MDT, showing a high pressure system over the western United States.

6.10 Mixing Heights and Vertical Soundings

In Albuquerque for the June and July modeled episodes, shallow surface-based morning inversions gave way to relatively deep (between 3 and 5 km), well-mixed boundary layers in the afternoon. Modeled boundary layer heights are shown in Figures 43 and 44. Notably, the modeled mixing heights were lower on many of the high ozone days, for example, June 14 and July 7-10.

On June 14, which was a high ozone day in Albuquerque/Bernalillo County, observational soundings at Albuquerque (Figure 45) showed the morning inversion and low mixing heights, and the growing mixing heights as the day progressed. The atmospheric profile is matched in WRF model sounding plots at Albuquerque (Figure 46). The WRF model reasonably captured the morning wind shear, with light northeasterly flow near the surface turning westerly around 3,000 meters in elevation. In the afternoon of June 14, the WRF model matched southerly observational winds at the surface, turning toward the west with increasing height. The WRF soundings on this day also show the dry atmospheric profile. The modeled afternoon mixing height was comparable to the observed mixing height.

Similarly, the observational atmospheric sounding profiles on the July 7 peak ozone day (Figure 47) match WRF model sounding plots reasonably well (Figure 48), as the WRF model captured the morning inversion and low mixing height. Light and variable near-surface winds were also captured in WRF. The modeled afternoon mixing height was comparable to the observed mixing height.

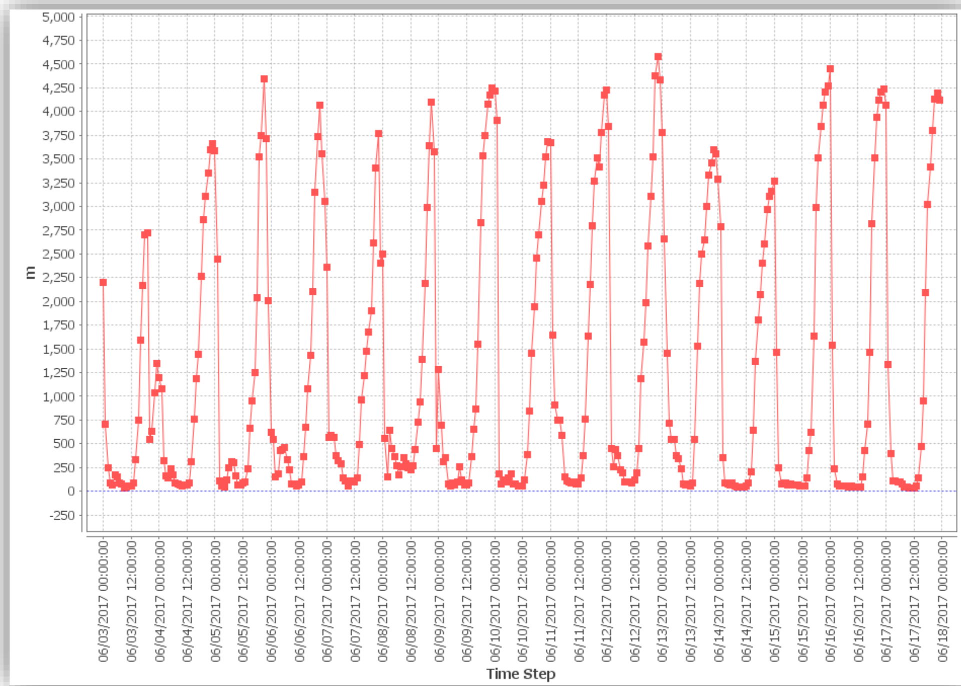

Figure 43. WRF boundary layer heights (m above ground level) during the June modeling episode at Albuquerque. Times are in UTC.

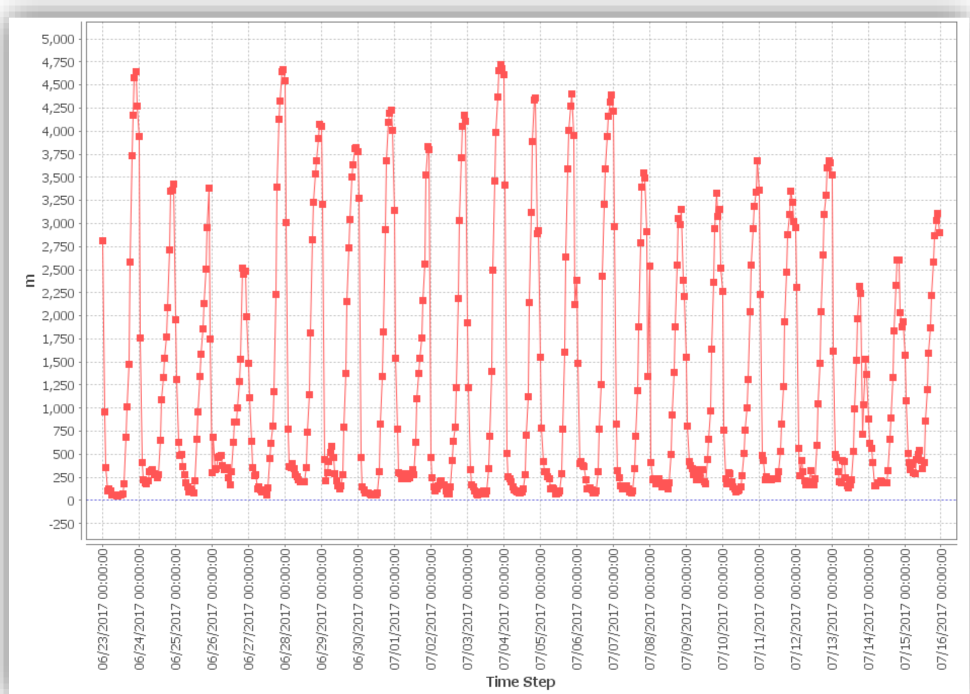

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Figure 44. WRF boundary layer heights (meters above ground level) during the July modeling episode at Albuquerque. Times are in UTC.

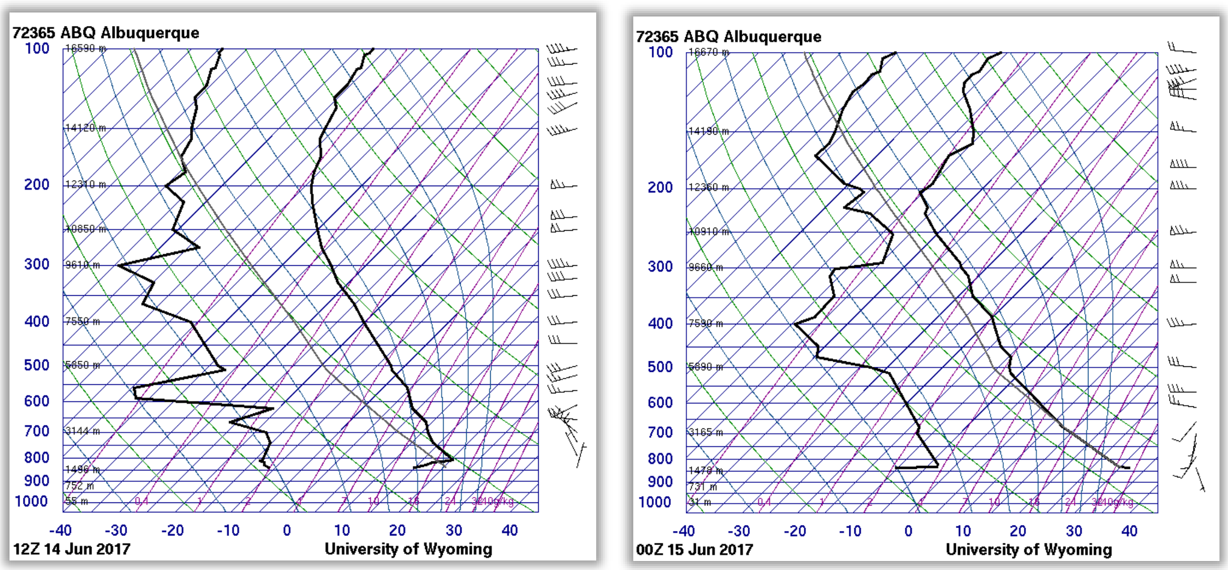

Figure 45. Observational atmospheric soundings at Albuquerque on June 14, 2017, at 6:00 a.m. (left) and 6:00 p.m. (right) local time, showing a surface-based inversion in the morning, and a deep boundary layer in the afternoon, with very dry air. (http://weather.uwyo.edu/upperair/sounding.html).

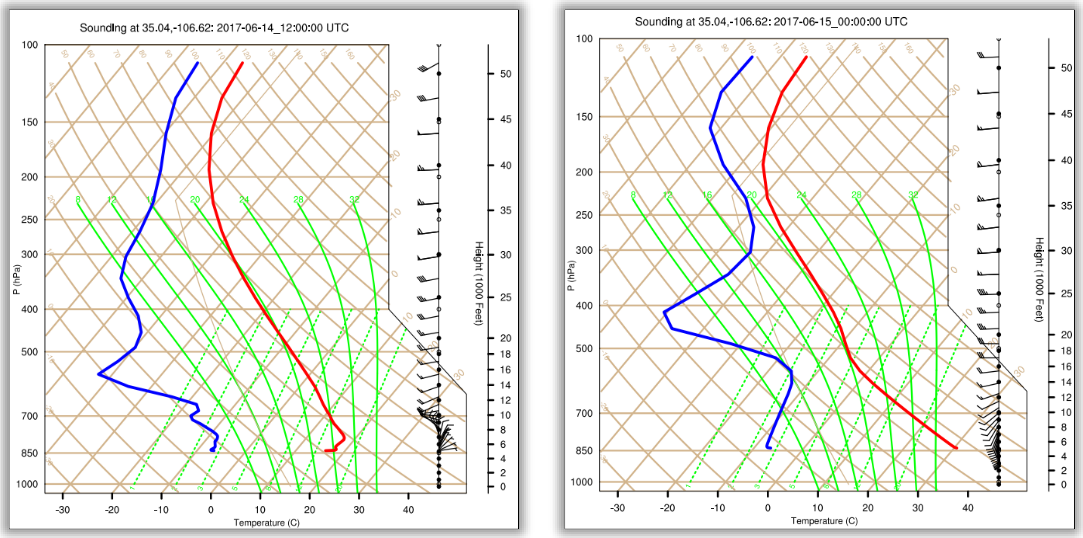

Figure 46. WRF modeled atmospheric soundings at Albuquerque on June 14, 2017, at 6:00 a.m. (left) and 6:00 p.m. (right) local time.

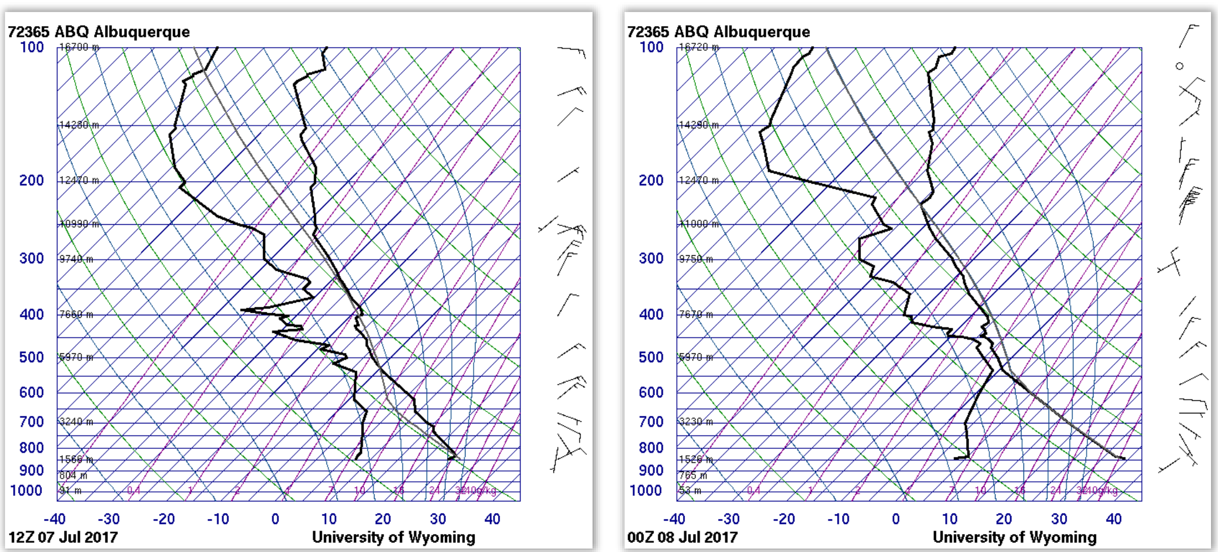

Figure 47. Observational atmospheric soundings at Albuquerque on July 7, 2017, at 6:00 a.m. (left) and 6:00 p.m. (right) local time, showing a shallow surface-based inversion in the morning and a well-mixed afternoon boundary layer (http://weather.uwyo.edu/upperair/sounding.html).

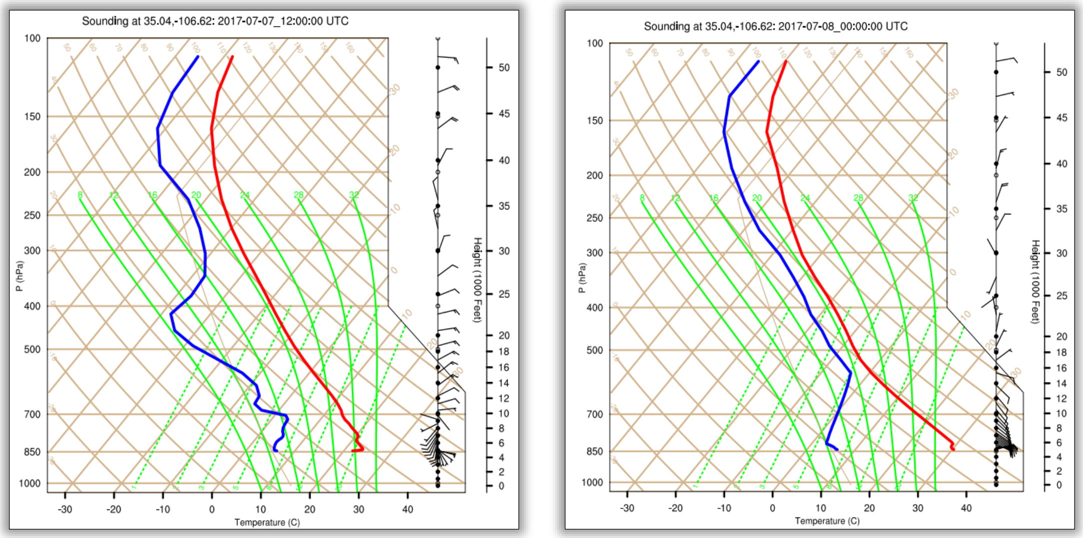

Figure 48. WRF modeled atmospheric soundings at Albuquerque on July 7, 2017, at 6:00 a.m. (left) and 6:00 p.m. (right) local time.

6.11 Summary

Based on the MPE results and our statistical and diagnostic review of WRF modeling results, the WRF modeling conducted is suitable for use in subsequent air quality modeling work. The overall model performance was good and within benchmarks established by the air quality modeling community. In Albuquerque/Bernalillo County, the observed trends in temperature, wind, and humidity were well characterized by WRF. Overall model performance was best for temperature. The error and bias for winds were good considering the challenging complex terrain in New Mexico and in Albuquerque/Bernalillo County. Although hourly agreement was imperfect, low wind speed conditions associated with the highest ozone days in Albuquerque/Bernalillo County were captured by the model. The important WRF biases to note included a cold daytime temperature bias (up to 2 K), a warm night-time temperature bias (>2 K), a high moisture bias (1-2 g/kg), and a low wind speed bias (around 0.5 m/s). Although the use of FDDA observation nudging could improve statistical model performance, particularly for wind, based on our review of the WRF output we feel that the WRF data are reasonable and suitable to support air quality analysis. It would be straightforward to conduct another WRF simulation with observation nudging and evaluate the impact.

Understanding the strengths and weakness of the meteorological model inputs is important for putting air quality model results into context, and for anticipating potential challenges that may be encountered in the air quality modeling. Based on these MPE results, surface winds were the most challenging aspect of the modeling. Because of the complex terrain, differences in the timing and occurrence of terrain-driven diurnal wind shifts can affect ozone model performance. Complex terrain is more challenging for meteorological models, because some terrain features may not be resolvable even by high-resolution (e.g., 4-km or 1-km) domains, and meteorological observations at the surface will be less representative of modeled grid volume averages.

7. Emissions (Base Case)

7.1 Overview

This chapter summarizes and documents results of the base-case emissions modeling that was conducted to support air quality modeling of ozone episodes in Albuquerque/Bernalillo County during June and July of 2017. The emissions modeling was conducted for the modeling grids described in Chapter 5. EPA's 2014 emissions modeling platform was used as the starting point.

Based on our review of the base-case emissions modeling results, the emissions data developed here are suitable for use in subsequent air quality modeling work. The daily NO_x and VOC emissions in Albuquerque/Bernalillo County were consistent with the annual emissions totals reported in EPA's 2014 NEI. Similarly, the daily emissions in the 4-km domain, which includes New Mexico and small portions of Colorado, Utah, Texas, and Arizona, were consistent with the annual emissions totals reported in the 2014 NEI for New Mexico. In Albuquerque/Bernalillo County, on-road mobile sources were the dominant anthropogenic NO_x and VOC emission sources, but NO_x and VOC emissions from nonroad and non-point sources were also significant. On a domain-wide basis, emissions from oil and gas activity were also significant.

7.2 Emissions Processing

The base-case emissions for air quality modeling were prepared using version 2 of the EPA's 2014 NEI (2014v7.2 platform). The emissions in EPA's modeling platform are primarily based on the 2014NEIv2 for point sources, non-point (formerly called "stationary area") sources, commercial marine vessels, on-road and nonroad mobile sources, wildland fires, and prescribed fires. The modeling platform includes hourly 2014 continuous emission monitoring system (CEMS) data for electrical generating units (EGUs), hourly on-road mobile source emissions (calculated from hourly emissions by vehicle type, fuel type process, and road type), and 2014 day-specific wildfire and prescribed fire emissions. For EGU sources, the 2014 CEMS data from the NEI was substituted with 2017 CEMS data from EPA's Air Markets Program database (https://ampd.epa.gov/ampd). For wildland and prescribed fire sources, day-specific emissions for June-July 2017 were developed. In addition to the NEI data, emissions from the Canadian and Mexican inventories—as well as several other non-NEI data sources—are included in EPA's emissions modeling platform.

The NEI emissions sectors are shown in Table 20. Although the focus of this project is on ground-level ozone and its precursors, other pollutants such as particulate matter and its chemical precursors were also modeled. Therefore, EPA's complete criteria pollutant emissions inventory was used. Additional information about the 2014 NEI and emission modeling platform can be found in EPA technical support documents (U.S. Environmental Protection Agency, 2016a, 2017).

Table 20. Emissions modeling sectors. The term "in-line" means that plume rise calculations are done inside the air quality model instead of being computed by SMOKE. The term "point" indicates that SMOKE maps the source from a point location to a grid cell. The term "surrogates" indicates that spatial surrogates are used to allocate county emissions to grid cells. The term "area-to-point" indicates that the SMOKE area-to-point feature is used to grid the emissions (U.S. Environmental Protection Agency, 2016a).

Emissions Source Sector	Spatial	Inventory	Temporal Approach[1]	Plume Rise
Area fugitive dust (afdust)	Surrogates	Annual	week	--
Agricultural (ag)	Surrogates	Annual and daily[2]	all	--
Agricultural fires (agfire)	Surrogates	Annual	mwdss	--
Biogenic (beis)	Land use	Computed hourly	n/a	--
Locomotives (rail)	Surrogates	Annual	aveday	--
Commercial marine vessels (cmv)	--	Annual	aveday	--
Remaining non-point (nonpt)	Surrogates & area-to-point	Annual	week	--
Nonroad (nonroad)	Surrogates & area-to-point	Monthly	mwdss	--
Non-point oil and gas (np_oilgas)	Surrogates	Annual	week	--
On-road mobile sources (onroad)	Surrogates	Monthly activity, computed hourly	all	--
On-road California (onroad_ca_adj)	Surrogates	Monthly activity, computed hourly	all	--
Other dust not from the 2014 NEI (othafdust)	Surrogates	Annual	week	--
Other non-NEI non-point and nonroad (othar)	Surrogates	Annual & monthly	week	--
On-road sources from Canada (onroad_can)	Surrogates	Monthly	week	--
On-road sources from Mexico (onroad_mex)	Surrogates	Monthly	week	--
Other point sources not from the 2014 NEI (othpt)	Point	Annual	mwdss	In-line
Agricultural fires with point resolution (ptagfire)	Point	Daily	all	layer 1
Point source oil and gas (pt_oilgas)	Point	Annual	mwdss	In-line
EGU units (ptegu)	Point	Daily & hourly	all	In-line
Point source fires-flaming (ptfire_f)	Point	Daily	all	In-line
Point source fires-smoldering (ptfire_s)	Point	Daily	all	layer 1
Non-U.S. fires (ptfire_mxca)	Point	Daily	all	In-line
Remaining non-EGU point (ptnonipm)	Point	Annual	mwdss	In-line
Residential Wood Combustion (rwc)	Surrogates	Annual	met-based	--

[1] The term "all" indicates hourly emissions are calculated for every day of the year; "week" indicates hourly emissions are computed for all days in one representative week; "mwdss" indicates hourly emissions computed for one representative Monday, representative weekday (Tuesday through Friday), representative Saturday, and representative Sunday for each month; and "aveday" indicates hourly emissions computed for one representative day each month.

[2] Livestock emissions are calculated daily, while emissions from fertilizers are calculated annually.

County-level emissions estimates were processed using SMOKE version 4.5. Daily emission input files were developed for the three modeling domains described in Chapter 5. Our approach to emissions data preparation is similar for all the domains, but the 4-km domain requires more attention because it circumscribes the region of interest for this analysis. Within this region, increases in the degrees of accuracy and resolution in the emission inventories will produce the greatest benefits.

National spatial surrogate data developed by EPA for the 4-km domain were used to disaggregate county-level emissions onto the 4-km grid cells. EPA's national 12-km resolution spatial surrogates data sets were used to aggregate emissions onto the 12-km domain, and were further aggregated to form the 36-km spatial surrogates for developing emission for the 36-km domain.

For on-road mobile sources outside Albuquerque/Bernalillo County, emissions were projected from 2014 to 2017 using scaling factors to account for changes in vehicle miles traveled (VMT) and emissions between 2014 and 2017. Emission reductions due to fleet turnover during this period were greater than emission increases due to increased VMT, and therefore projected mobile source emissions are lower in 2017 compared to 2014. Scaling factors of 0.71 for NO_x and 0.72 for VOC were developed based on national-scale MOVES simulations, using national default inputs to estimate the net emissions change due to VMT changes and fleet turnover.

STI previously worked with the Albuquerque EHD to collect local input data for the EPA's MOVES model to support the development of a 2014 on-road mobile source emissions inventory for Albuquerque/Bernalillo County. These local data included VMT and vehicle registration data, and the resulting emissions estimates were submitted to EPA for use in developing the 2014 NEI. These data, combined with episode-specific meteorological data from the WRF model, were used to develop the 2014 on-road mobile source emissions in Albuquerque/Bernalillo County. Scaling factors of 0.74 for NO_x and 0.77 for VOC were used to project these mobile source emissions to 2017. These scaling factors were developed from MOVES simulations that involved local travel activity, fuel types, vehicle fleet mix, and age distribution, and accounted for VMT changes and fleet turnover in Albuquerque/Bernalillo County from 2014 to 2017. These MOVES-based scaling factors are different than the nationwide scaling factors because of differences in vehicle fleets, vehicle age distributions, fuel types, and I&M programs from national averages.

Biogenic emissions were prepared using the Biogenic Emissions Inventory System (BEIS) version 3.61, based on the hourly meteorological data developed with WRF for the 2017 modeling episodes. The BEIS model also accounts for NO_x emissions due to biogenic processes, such as microbial decay in soils. The soil NO_x emissions are highly uncertain and are much smaller than biogenic VOC emissions, but biogenic NO_x emissions can be a substantial portion of the inventory in rural areas that lack significant anthropogenic NO_x sources. The Model of Emissions of Gases and Aerosols in Nature (MEGAN) was originally proposed for this project, but MEGAN required model-ready leaf area index data inputs for 2017 that were not yet available. Therefore, BEIS was used.

Day-specific wildland and prescribed fire emissions data were developed for the modeling episodes based on methods used to develop the EPA wildland fire emissions inventory (Huang et al., 2016;

Pavlovic and Huang, 2017). The preparation of the fire emissions began with raw input fire activity data and ended with daily estimates of emissions from each included fire location. Several fire activity data sets were reconciled into a single, comprehensive fire location data set using the SmartFire2 data processing system (airfire.org/smartfire). SmartFire2 reconciles multiple data sets to retain the best available information for each aspect of each fire event. The reconciled fire locations, along with available fuel moisture and fuel loading data, were used in the BlueSky Framework (Larkin et al., 2009) to estimate $PM_{2.5}$, VOC, and NO_x emissions from the fires. The BlueSky Framework links independent models of fire information, fuel loading, fire consumption, and fire emissions (see airfire.org/bluesky). The fire emissions data were spatially allocated to the modeling grids and merged with data from other emission sectors using SMOKE.

7.3 Summary of Emissions Results – 4-km Domain

The summary of emissions for the 4-km modeling domain is shown in **Table 21**. The emissions are shown for July 7, 2014, which was a weekday and a high ozone day in Albuquerque/Bernalillo County, and it is therefore considered a representative summer weekday. For many emission sectors, this is reasonably representative of the entire year, while for some sectors such as biogenic, emissions are much higher in the summer than in the winter. The total domestic on-road mobile source emissions in Table 21 (289 tons/day of NO_x and 102 tons/day of VOC) include component emissions from the four MOVES on-road mobile source classifications described in **Table 22**. On-road mobile source emissions from Mexico (the onroad_mex sector) are also important, particularly for the El Paso, Texas, area; they represent about 15% of NO_x emissions and over 50% of VOC emissions from on-road mobile sources in the 4-km domain.

Table 21. Summary of emissions on the 4-km grid for July 7, 2017, which is considered a representative summer weekday. The EGU (ptegu) emissions are based on 2017 CEMS data. The U.S. on-road mobile source emissions for 2017 are reduced by 29% for NO_x and 28% for VOC compared to the values shown here. For Albuquerque/Bernalillo County, the on-road mobile source emissions are reduced by 26% (NO_x) and 23% (VOC). Sectors are defined in Table 20.

Sector	NOx [tons/day]	VOC [tons/day]
ag	0.0	8.7
beis	172.0	12351.5
nonpt	13.4	119.2
nonroad	24.7	33.0
np_oilgas	115.7	724.9
onroad_RPD	242.2	47.2
onroad_RPP	0.0	9.0
onroad_RPV	23.1	40.9
onroad_RPH	23.3	4.9
onroad_mex	50.8	31.5
othar	4.5	49.9
othpt	5.7	8.3
ptegu	111.0	3.2
ptnonipm	10.0	9.1
pt_oilgas	68.5	23.7
rail	44.2	3.3
rwc	0.0	0.1
ptnonipm_Western	0.8	0.1
Total:	909.8	13468.3

Table 22. Summary of MOVES on-road mobile source emission factor classifications.

Sector	Description	Example
onroad_RPD	Emissions based on MOVES rate-per-distance calculations	Running exhaust, evaporative emissions, brake and tire wear
onroad_RPP	Emissions based on MOVES rate-per-profile calculations	Fuel vapor venting (emissions are dependent on temperature profiles)
onroad_RPV	Emissions based on MOVES rate-per-vehicle calculations	Start exhaust, evaporative emissions
onroad_RPH	Emissions based on MOVES rate-per-hour calculations	Idle and auxiliary power unit exhaust

On-road mobile sources are an important component of the inventory, as they account for one-third of the NO_x inventory and 10% of the anthropogenic VOC inventory in the 4-km domain. As emissions from this sector continue to decrease in response to more stringent emission controls, emissions from other sectors—such as oil and gas, rail, and nonroad—are becoming larger portions of the emissions inventory. For example, the oil and gas sector accounts for over 20% of the NO_x emissions in the 4-km domain. Notably, biogenic NO_x emissions, which are highly uncertain, are about 10% of the domain-wide NO_x inventory on typical summer days. EGUs were the largest source of NO_x emissions behind biogenic, oil and gas, and on-road mobile sources, and accounted for over 10% of the domain-wide NO_x emissions. Rail emissions accounted for about 5% of domain-wide NO_x emissions.

The oil and gas sector (the sum of pt_oilgas and np_oilgas sectors in Table 21) accounts for about two-thirds of the anthropogenic VOC emissions in the 4-km domain. This is consistent with the statewide VOC inventory (see **Table 23**). Emissions from the oil and gas sector are an active area of research and a significant source of uncertainty, particularly for fugitive losses.

For comparison and context, the annual 2014 emissions for New Mexico are shown in Table 23 for VOC, and in **Figure 49** for NO_x. Note that the 4-km domain includes all of New Mexico and small portions of Arizona, Utah, Colorado, Texas, and Mexico. As a result, small portions of the oil and gas exploration areas of west Texas and southern Colorado are reflected in the 4-km domain emissions. Statewide annual NO_x emissions from on-road mobile sources are about one-third of the total NO_x inventory, which is in agreement with Table 21. Statewide VOC emissions from the oil and gas sector are about two-thirds of the anthropogenic VOC inventory, which is also in agreement with Table 21. Comparisons such as these are among the quality assurance checks conducted on the emissions data files.

From a total VOC perspective, biogenic emissions dominate the emissions inventory nationally (about 70% of annual VOC emissions) and in New Mexico (about 82% of annual VOC emissions). As with the modeled biogenic emissions in this project, the annual NEI estimates are also based on BEIS. Biogenic VOC emissions are spatially heterogeneous, and are dominant during the summer months and where there is significant vegetation. As an example, the biogenic VOC emissions from July 7, 2017 are shown in **Figure 50**. To put the statewide biogenic VOC emissions of 1.3 million tons into perspective, the biogenic VOC emissions in Georgia, a smaller (in terms of square miles) but more heavily vegetated state than New Mexico, is approximately 1.8 million tons. From an emissions density perspective, the biogenic VOC emissions “per square mile” from Georgia are about three times the biogenic VOC emissions per square mile in New Mexico.

Table 23. Summary of 2014 VOC emissions in New Mexico. Total anthropogenic VOC emissions in New Mexico were 272,088 tons. Nonroad refers to off-road mobile sources that use gasoline, diesel, and other fuels, such as construction equipment, locomotives, lawn and garden equipment, aircraft ground support equipment, and off-road vehicles. From EPA's 2014 NEI.

Sector	Emissions [tons/year]
Biogenic	1,256,514
Petroleum & Related Industries	175,223
Miscellaneous	25,636
On-road Mobile Sources (motor vehicles)	24,625
Solvent Use	22,503
Nonroad	9,526
Storage & Transport	7,465
Fuel Comb. Industrial	2,848
Fuel Comb. Other	2,108
Waste Disposal & Recycling	1,553
Fuel Comb. Elec. Util.	309
Other Industrial Processes	290
Metals Processing	1

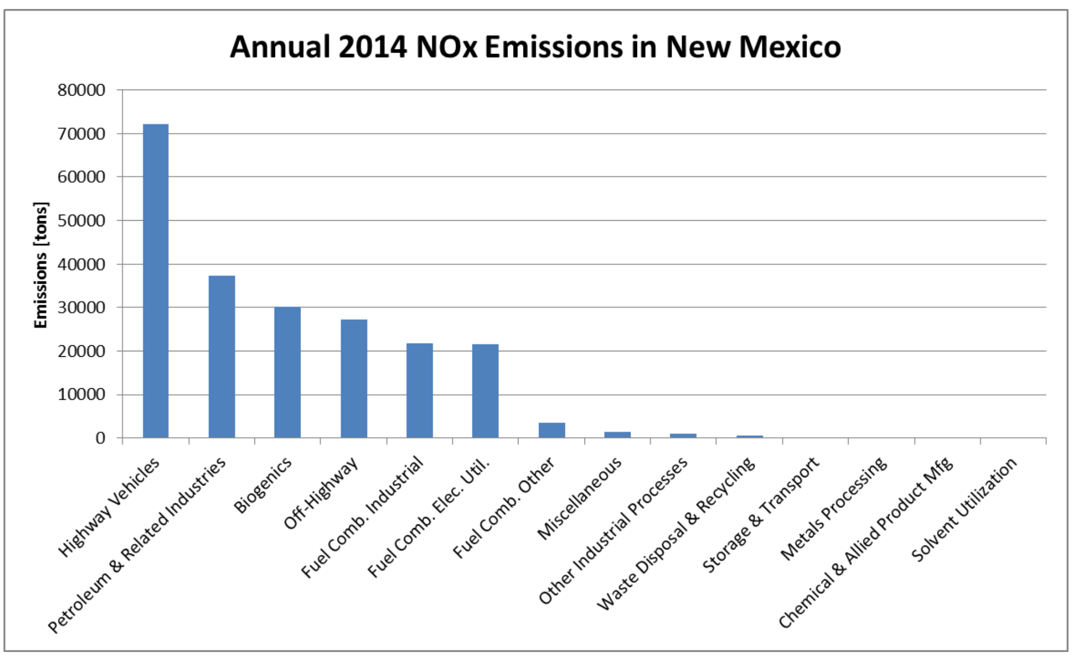

Figure 49. Summary of 2014 NO_x emissions in New Mexico in 2014. Total anthropogenic NO_x emissions in New Mexico were 186,869 tons. From EPA's 2014 NEI.

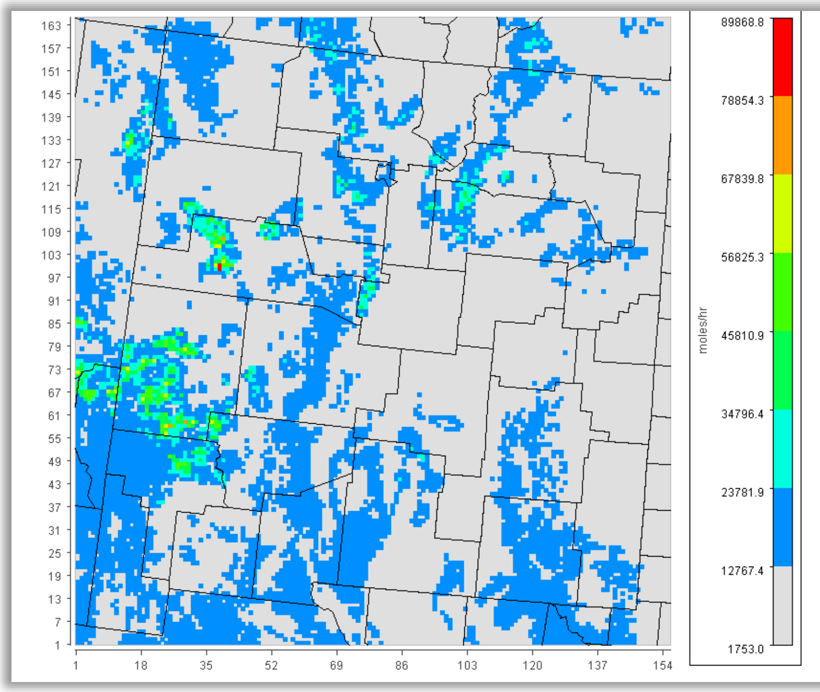

Figure 50. Biogenic VOC emissions on July 7, 2017 for the 4-km domain.

The emissions for the 4-km modeling domain for the four counties in the Albuquerque MSA are shown in Table 24 for July 7, 2017, a representative summer weekday. On-road mobile source emissions in Albuquerque/Bernalillo County (30.8 tons/day of NO_x and 14.5 tons/day of VOC) were nearly 66% of the NO_x inventory and 25% of the anthropogenic VOC inventory. On an annual basis, on-road mobile sources are about half of the NO_x emissions in Albuquerque/Bernalillo County (see Figure 51), which underscores the prominence of mobile source emissions in Albuquerque/Bernalillo County. Emissions from motor vehicles in other counties in the Albuquerque MSA are also important. Motor vehicles from Sandoval, Valencia, and Torrance Counties combined emit 29.7 tons/day of NO_x and 10.4 tons/day of VOC, largely from the towns of Rio Rancho and Bernalillo (in Sandoval County), from the Los Lunas area (in Valencia County), and from interstate freeway traffic (see Table 24 and Figure 51).

On-road mobile sources are still by far the largest anthropogenic emission sector in the Albuquerque MSA, as the region lacks significant NO_x sources from other sectors—such as oil and gas and EGUs—that are more prominent in the statewide inventory. Note that on-road mobile source emissions will continue to decline over time due to fleet turnover toward cleaner vehicles (even with increased VMT). As a result, emissions from other sectors such as the nonroad and non-point sectors[29] will become larger portions of the emissions inventory over time. For example, the nonroad and non-point sources already constitute 25% of the NO_x inventory and nearly 70% of the anthropogenic VOC inventory in Albuquerque/Bernalillo County.

[29] Nonroad sources include construction vehicles and activity. Non-point sources include a variety of activities such as residential heating, commercial combustion, asphalt paving, and commercial and consumer solvent use, that are too small in magnitude to report as a point sources. Both nonroad and non-point sources are represented as area sources in the emissions modeling.

Table 24. Summary of modeled county-level emissions in the Albuquerque MSA on July 7, 2017, a representative summer weekday and a high ozone day. The EGU (ptegu) emissions are based on 2017 CEMS data. For Bernalillo County, the on-road mobile source emissions for 2017 are reduced by 26% for NO_x, and 23% for VOC, compared to the values shown here. The U.S. on-road mobile source components (i.e., onroad_RPD, RPP, RPV, and RPH) shown are before applying the reduction factors. Sectors are defined in Table 20.

Bernalillio

Sector	NOx [tons/day]	VOC [tons/day]
ag	0.0	0.0
beis	1.3	101.8
nonpt	7.8	28.1
nonroad	4.6	6.8
np_oilgas	0.0	0.0
onroad_RPD	25.6	6.6
onroad_RPP	0.0	1.5
onroad_RPV	3.5	6.0
onroad_RPH	1.7	0.3
onroad_mex	0.0	0.0
othar	0.0	0.0
othpt	0.0	0.0
ptegu	1.2	0.0
ptnonipm	3.5	1.7
pt_oilgas	0.0	0.0
rail	0.0	0.0
rwc	0.0	0.0
ptnonipm_Western	0.0	0.0
Total:	49.2	152.9

Sandoval

Sector	NOx [tons/day]	VOC [tons/day]
ag	0.0	0.1
beis	3.2	304.9
nonpt	0.4	5.7
nonroad	0.6	0.8
np_oilgas	0.6	5.7
onroad_RPD	12.3	2.5
onroad_RPP	0.0	0.5
onroad_RPV	1.3	2.2
onroad_RPH	0.1	0.0
onroad_mex	0.0	0.0
othar	0.0	0.0
othpt	0.0	0.0
ptegu	0.0	0.0
ptnonipm	0.1	0.1
pt_oilgas	0.0	0.0
rail	0.0	0.0
rwc	0.0	0.0
ptnonipm_Western	0.0	0.0
Total:	18.5	322.3

Valencia

Sector	NOx [tons/day]	VOC [tons/day]
ag	0.0	0.2
beis	1.1	112.0
nonpt	0.1	2.8
nonroad	0.4	0.4
np_oilgas	0.0	0.0
onroad_RPD	6.2	1.4
onroad_RPP	0.0	0.4
onroad_RPV	0.9	1.6
onroad_RPH	0.1	0.0
onroad_mex	0.0	0.0
othar	0.0	0.0
othpt	0.0	0.0
ptegu	0.2	0.0
ptnonipm	0.2	0.0
pt_oilgas	0.0	0.0
rail	3.8	0.3
rwc	0.0	0.0
ptnonipm_Western	0.0	0.0
total	12.9	119.2

Torrance

Sector	NOx [tons/day]	VOC [tons/day]
ag	0.0	0.1
beis	6.9	183.8
nonpt	0.0	0.9
nonroad	0.1	0.2
np_oilgas	0.0	0.0
onroad_RPD	6.9	0.9
onroad_RPP	0.0	0.1
onroad_RPV	0.2	0.4
onroad_RPH	1.7	0.4
onroad_mex	0.0	0.0
othar	0.0	0.0
othpt	0.0	0.0
ptegu	0.0	0.0
ptnonipm	0.0	0.0
pt_oilgas	0.2	0.0
rail	4.8	0.4
rwc	0.0	0.0
ptnonipm_Western	0.0	0.0
total	20.9	187.1

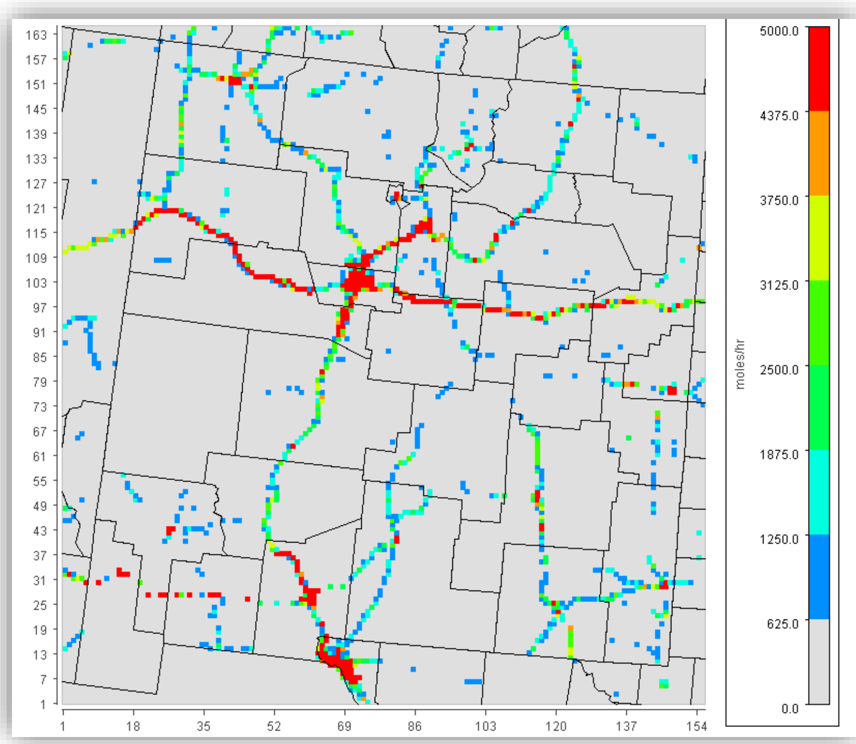

Figure 51. On-road mobile source NO_x emissions on July 7, 2017, for the 4-km domain.

Rail emissions account for over 8 tons/day of NO_x emissions in Valencia and Torrance counties, where the region's main rail lines are located. These rail emissions represent 25% of the NO_x emissions inventory in those counties. There are rail lines in Albuquerque/Bernalillo County, but while their emissions were present in EPA's 2014 NEI, they were absent from EPA's modeling platform data. The rail lines in Albuquerque/Bernalillo County are less active and carry significantly lower volumes (in terms of tons/year of freight) than rail lines in Valencia and Torrance counties[30], and the NEI rail NO_x emissions in Albuquerque/Bernalillo County was less than 0.1 tons/day, or 0.15% of total NO_x emissions. Therefore, the absence of Albuquerque/Bernalillo County rail emissions in the modeling is not expected to impact the air quality modeling results.

The dominant anthropogenic VOC sources in Albuquerque/Bernalillo County are the on-road mobile source sector and the non-point sector. Although the oil and gas sector (the sum of pt_oilgas and np_oilgas sectors in Table 20) dominates the anthropogenic VOC inventory on a statewide basis, most of the oil and gas emissions occur outside the Albuquerque MSA. Therefore, any ozone impacts from oil and gas emissions will result from transport of those emissions into Albuquerque/Bernalillo County. For comparison and context, summaries of annual 2014 NO_x and VOC emissions for Albuquerque/Bernalillo County are shown in Figures 52 and 53.

[30] The BNSF Railway Transcon route passes through Valencia and Torrance Counties, carries 80 to 120 trains per day, and more than 80 million tons/year of freight. The rail lines through Albuquerque/Bernalillo County carry 5-10 million tons/year of freight along with Amtrak (2 trains per day) and New Mexico Rail Runner (up to 22 trains per day) passenger rail service. See the 2014 New Mexico Department of Transportation State Rail Plan at http://dot.state.nm.us/content/nmdot/en/Transit_Rail.html.

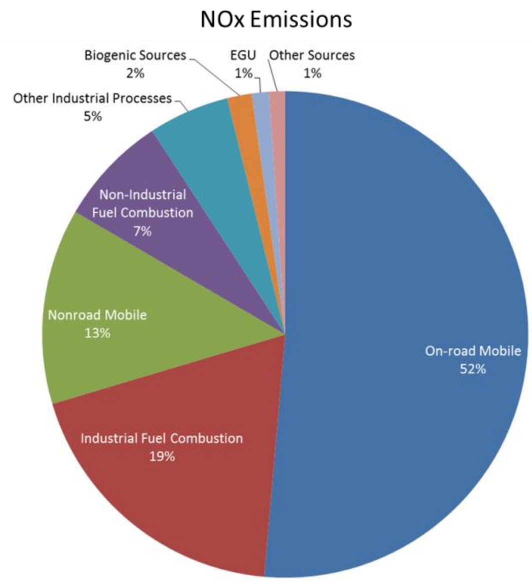

Figure 52. Summary of annual 2014 NO_x emissions in Albuquerque/Bernalillo County, from EPA's 2014 NEI. Total NO_x emissions were 17,876 tons. "Other sources" include waste and disposal recycling, petroleum and related industries, storage and transport, metals processing, chemical manufacturing, and solvent use.

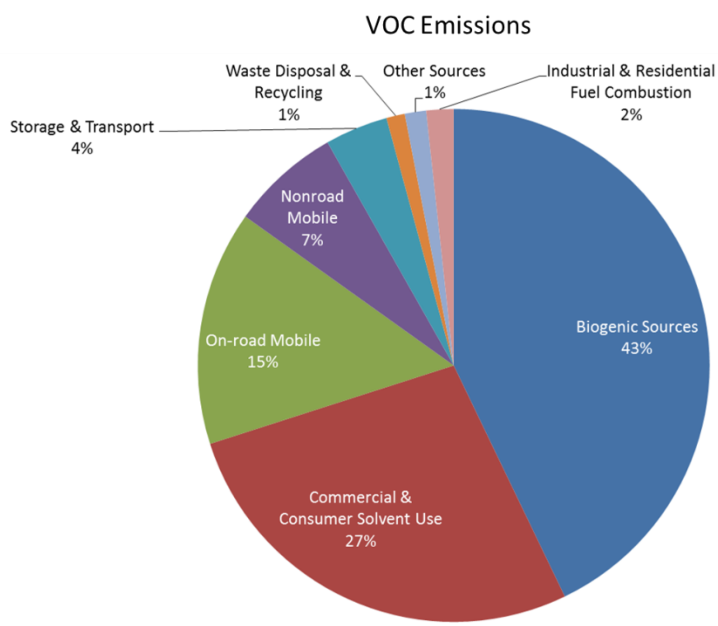

Figure 53. Summary of annual 2014 VOC emissions in Albuquerque/Bernalillo County, from EPA's 2014 NEI. Total VOC emissions were 12,719 tons. "Other sources" include EGUs, industrial facilities, and petroleum and related industries.

7.4 Summary

Based on our review of the base-case (2017) emissions modeling results, the base-case emission inputs were determined to be suitable for use in subsequent air quality modeling work. Understanding the emissions inventory and emissions modeling inputs is important to put air quality model results into context, and anticipate challenges that may be encountered in the air quality modeling. Within Albuquerque/Bernalillo County, on-road mobile sources are an important contributor to the NO_x emissions inventory. Outside Albuquerque/Bernalillo County, NO_x and VOC emissions from the oil and gas sector are substantial, and the transport of those emissions into Albuquerque/Bernalillo County could be important. Although no large EGU sources exist in the Albuquerque MSA, a few large EGU sources in New Mexico could also be important, and potential ozone contributions from these sources are examined in the source apportionment modeling analysis (see Chapter 9).

8. Air Quality Modeling (Base Case)

8.1 Overview

Base-case air quality modeling with the CAMx model was conducted for the selected episodes described in Chapter 2, based on the meteorological inputs described in Chapter 6 and the emissions inputs described in Chapter 7. CAMx is based on a "one atmosphere" approach and therefore includes chemistry options for treating ozone, particulate matter, and their precursors. Although ozone is the focus of this project, $PM_{2.5}$ was also modeled since the formation of both ozone and $PM_{2.5}$ involve many of the same atmospheric pollutants.

This chapter describes the base-case air quality modeling of Albuquerque/Bernalillo County ozone episodes during June and July 2017 and documents the results of the MPE that was conducted. The MPE results and our statistical and diagnostic review indicate that the base-case CAMx modeling is suitable for use in subsequent air quality modeling work and is a useful tool for understanding ozone air quality in Albuquerque/Bernalillo County and evaluating the impacts of future changes in emissions. The overall model performance was within accepted benchmarks for good air quality model performance (bias within ±15% of observed values and a mean normalized error of less than 35%). In Albuquerque/Bernalillo County, CAMx tracked day-to-day changes in peak 8-hour ozone concentration well, which indicates that the model captured the important local and regional meteorological conditions that affect pollutant concentrations in the region. The modeling results indicate that the ozone concentrations recorded during the June episode were impacted by (1) more prevalent non-local ozone, and (2) emissions from local and regional fires. Conversely, ozone plumes from local emissions were more prevalent during the July episode. The CAMx modeling summarized here reproduced ozone trends that were observed in Albuquerque/Bernalillo County, New Mexico, and the western United States.

Although hourly agreement was imperfect and CAMx did not always reproduce the highest ozone concentrations at the monitoring sites, the model produced ozone plumes with realistic spatial extents, with peak modeled 8-hour average ozone concentrations that were quite comparable to the maximum observed concentrations in Albuquerque/Bernalillo County. The modeled ozone plumes were sometimes displaced from their observed locations. One notable modeling challenge is that substantial mobile source NO_x emissions from I-25 and I-40 are mixed into 4 km x 4 km grid cells. This resulted in a reduction of modeled ozone concentrations in portions of the City of Albuquerque and is likely responsible for the significant negative bias in modeled ozone concentrations at the Del Norte monitor. Modeling at a higher spatial resolution (e.g., 1 km) could improve model performance at the Del Norte site because the spatial distribution of NO_x emissions from motor vehicles would be more accurately represented within the City of Albuquerque. Model performance is better at other sites. This tendency is accounted for in subsequent analyses by considering the modeled ozone source contributions at other monitoring site locations, and by considering grid cells in Albuquerque/Bernalillo County where concentrations within the modeled plume were highest.

8.2 CAMx Configuration and Inputs

8.2.1 CAMx Configuration

CAMx modeling was conducted for two modeling episodes described in Chapter 2 and for the modeling grids described in Chapter 3. Table 25 shows CAMx configurations that were used. CAMx modeling was based on revision 2 of the Carbon Bond 6 (CB6) gas phase chemistry mechanism. Although ozone is the focus for this project, aerosol chemistry is also considered in keeping with the "one atmosphere" approach to air quality modeling.

Table 25. CAMx model configuration.

Science Option	Configuration
Model Code	CAMx version 6.40
Grid Interaction	Two-way continuous nesting
Initial Conditions	• 10-day spin-up on 36-km grid • 3-day spin-up on inner grids (initialized from the 36-km output)
Boundary Conditions	• 36 km: from MOZART • 12 km: from the 36-km domain • 4 km: from the 12-km domain
Gas Phase Chemistry	CB06r2
Aerosol Chemistry	Coarse/Fine (CF) 2-mode model with SOAP organic chemistry, ISORROPIA inorganic thermodynamics, and RADM aqueous chemistry
Meteorological Processor	WRFCAMx
Horizontal Diffusion	K-theory 1st order closure
Vertical Diffusion	CMAQ-like scheme in WRF2CAMx with Kz_min = 0.1 m^2/s (except up to 1.0 m^2/s in urban areas, via KVPATCH)
Dry Deposition	Zhang
Wet Deposition	Scavenging model
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI)
Vertical Advection Scheme	Implicit backward-Euler integration
Integration Time Step	Wind speed dependent, but generally 5 to 60 seconds for the 4-km grid, 1-5 minutes for the 12-km grid, and 5-15 minutes for the 36-km grid
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM)

8.2.2 Meteorological Inputs

Meteorological inputs to the CAMx model were developed using WRF, as described in Chapter 6. The key input fields include three-dimensional winds, temperature, moisture, and turbulence parameters. The most recent version of the WRF-to-CAMx model interface (WRFCAMx) program, with a minimum eddy diffusivity (Kv) value of 0.1 m^2/s, was used to process the WRF output data and prepare the CAMx-ready meteorological input files. The KVPATCH utility was used to increase minimum Kv values over urban land surfaces to 1.0 m^2/s, where turbulence and diffusion are enhanced. Urban grid cells were identified based on the input land use data set. WRF was executed in 5.5-day blocks initialized at 12:00 UTC every five days. Twelve hours of spin-up[31] were included in each modeling block, but data from the spin-up periods were not used in the air quality model. Data from the modeling blocks were used to develop a continuous input dataset for CAMx.

8.2.3 Emissions Inputs

The development of emissions inputs to the CAMx model is described in Chapter 7. On-road mobile sources were the dominant anthropogenic source of NO_x and VOC emissions in Albuquerque/Bernalillo County. Both NO_x and VOC emissions from nonroad and non-point sources were also significant. In New Mexico, emissions from oil and gas activity were also significant.

8.2.4 Boundary and Initial Conditions

Boundary conditions represent pollution inflow into the model, while initial conditions represent the starting point for the model. The initial and boundary conditions were based on 6-hour data from the Model for Ozone and Related chemical Tracers (MOZART) (Emmons et al., 2010), as made available from the National Center for Atmospheric Research (**http://www.acom.ucar.edu/wrf-chem/mozart.shtml**). Data were prepared for CAMx using the "mozart2camx" pre-processing program. MOZART outputs were used to define boundary conditions for the 36-km domain. Boundary conditions for the 12-km and 4-km domains were provided by CAMx outputs from their parent domains. The impact of initial concentrations on the air quality simulation is minimized by using a 10-day model spin-up period.

8.2.5 Photolysis Rates

The Tropospheric Ultraviolet and Visible (TUV) radiative transfer model was used to calculate day-specific photolysis rate inputs. The "look-up" tables generated by TUV provide photolysis rates as a

[31] "Spin-up" refers to the time period after the model is initialized when the model is adjusting from the initial atmospheric state. Modeling results from the spin-up periods are not reliable and therefore are excluded from the analysis. The length of spin-up needed depends on the model and on the intended application. For WRF, a 12-hour spin-up period is considered adequate for air quality modeling applications. For CAMx, several days of spin-up are needed.

function of latitude, altitude, solar zenith angle, surface ultraviolet albedo, and column ozone. The column ozone data were based on data from the Ozone Monitoring Instrument (OMI) satellite platform. Data gaps were filled by temporal interpolation between days with valid data. Ultraviolet albedo is based on land use data.

8.3 Model Performance Evaluation Approach

Air quality model performance was evaluated using time series and spatial plots comparing observed and predicted parameters, and by conducting a statistical evaluation of those parameters. The goals of this MPE were to review the base-case modeling and provide insights on ozone episodes in Albuquerque/Bernalillo County, assess the suitability of the CAMx output to support subsequent air quality sensitivity modeling analyses, and determine whether CAMx is adequately replicating the key processes that influence local and regional air quality.

The emphasis of this MPE is on ozone formation, pollutant transport, and diffusion, with a particular focus on the model's performance in Albuquerque/Bernalillo County and the Albuquerque MSA within the 4-km modeling domain. An evaluation was also conducted for the 12-km modeling domain, since results from this domain also influence the source apportionment analysis described in Chapter 9. Capturing regional recirculation and long-range transport of ozone and its precursors is important to characterize the apportionment of ozone.

The Atmospheric Model Evaluation Tool (AMET)[32] (Appel et al., 2017; 2011) was used to conduct the evaluation. AMET was developed by the EPA and uses the MySQL database and R statistical software to calculate MPE statistics and generate analysis graphics. Hourly ozone concentration data from EPA's AQS were used in the evaluation. Equations for calculating the statistical metrics used in this MPE are given in Table 26. This MPE consisted of a statistical analysis of biases and errors in near-surface ozone concentrations, and a visual analysis of spatial and time series plots. Observations and modeled predictions were paired in space and time for the statistical analysis based on a nearest-neighbor approach.

[32] AMET software and documentation are available through the Community Modeling and Analysis System Center at https://www.cmascenter.org.

Table 26. Statistical model performance metrics.

Parameter	Definition[a]
Mean bias (MB)	$\frac{1}{N}\sum(M_i - O_i)$
Mean error (ME)	$\frac{1}{N}\sum\lvert M_i - O_i\rvert$
Root mean squared error (RMSE)	$\sqrt{\frac{\sum(M_i - O_i)^2}{N}}$
Fractional bias (FB)	$100\% * \frac{2}{N}\sum\frac{(M_i - O_i)}{(M_i + O_i)}$
Fractional error (FE)	$100\% * \frac{2}{N}\sum\frac{\lvert M_i - O_i\rvert}{(M_i + O_i)}$
Normalized mean bias (NMB)	$100\% * \frac{\sum(M_i - O_i)}{\sum O_i}$
Normalized mean error (NME)	$100\% * \frac{\sum\lvert M_i - O_i\rvert}{\sum O_i}$
Coefficient of determination (r2)	$\frac{[(M_i - \bar{M})(O_i - \bar{O})]^2}{\sum(M_i - \bar{M})^2\sum(O_i - \bar{O})^2}$
Index of Agreement (IOA)	$1 - \frac{\sum(O_i - M_i)^2}{\sum(\lvert M_i - \bar{O}\rvert + \lvert O_i - \bar{O}\rvert)^2}$

[a] M_i is the modeled concentration at time and location *i*, O_i is the observed concentration at time and location *i*, N is the number of paired observation/model concentrations, $\bar{M}$ is the mean modeled concentration, and $\bar{O}$ is the mean observed concentration.

Ozone data from six monitoring sites in the Albuquerque MSA were included in the evaluation (see Chapter 3). Data from the Double Eagle site were included only for the statistical evaluation of peak 8-hr average ozone concentrations. Ozone data in the Albuquerque MSA are available for more than 98% of the time in June–July 2017. For ozone precursor species, NO_x observations are available at the Del Norte and South Valley sites. VOC observations are not available in Albuquerque/Bernalillo County or in the Albuquerque MSA, which is a limitation of this MPE.

Since the mid-1990s, model performance evaluations have been conducted for CAMx and its predecessors. The results of these evaluations provide a foundation to compare against the current CAMx modeling. Using these past simulations as a guide, two sets of air quality model performance benchmarks are considered. These benchmarks are shown alongside the statistical performance results to place the MPE results into context.

Benchmarks that were introduced in earlier EPA modeling guidance for the 1-hour ozone standard (U.S. Environmental Protection Agency, 1991) are provided in Table 27. Additional model performance goals for mean fractional bias (MFB) and mean fractional error (MFE) are frequently used in the scientific literature (Boylan and Russell, 2006) and are listed in Table 28. The use of normalized mean bias (NMB) and normalized mean error (NME) to characterize air quality model performance is consistent with the recommendations in Simon et al. (2012) and current modeling guidance. In practice, ozone model performance statistics are calculated for all observation-prediction pairs when the observed maximum daily average 8-hour ozone concentration is greater than or equal to 60 ppb. The use of a threshold concentration is preferred in order to assess model performance for the range of ozone concentrations that are of importance in most modeling applications.

Table 27. Model performance benchmarks for all observation-prediction pairs when the observed ozone concentration is above 60 ppb.

Metric	Benchmark
Normalized Mean Bias (NMB)	≤ ±15%
Normalized Mean Error (NME)	≤ 35%

Table 28. Air quality model performance benchmarks for MFB and MFE.

Mean Fractional Bias	Mean Fractional Error	Comment
≤ ±15%	≤35%	Level of performance that would be considered "good" for ozone, and "exceptional" for individual PM species. For individual PM species, measurement uncertainties may exceed this goal.
≤ ±30%	≤50%	Performance goal that would be considered "acceptable" for ozone, and "good" for individual PM species.
≤ ±60%	≤75%	Performance criteria that would be considered "average" or "acceptable" for individual PM species. For ozone and PM species with significant abundance, exceeding these criteria could indicate problems with the modeling system.

8.4 Summary of Model Performance

The CAMx model performance was good in both the 4-km and 12-km domains for the modeled 2017 ozone episode days. The combined hourly ozone performance statistics with no concentration cutoff are shown in Table 29. Hourly ozone performance statistics for observed ozone concentrations greater than 60 ppb are shown in Table 30. CAMx performance was always within benchmarks for acceptable model performance, and in most cases was also within benchmarks for good model performance. CAMx generally overpredicted ozone concentrations when considering the full range of ozone concentrations, and underpredicted observed concentrations when ozone was high (>60 ppb). The index of agreement was relatively high (0.75 and higher), indicating good overall agreement between predictions and observations on an hourly basis. Overall, statistical model performance was slightly better during the July episode than during the June episode, though there were fewer modeled days in the June episode.

Table 29. CAMx ozone MPE results with no ozone concentration cutoff for the **June and July** episodes. Green cells indicate metrics that fell within the benchmark for good model performance. N is the number of observations.

Statistical Metric	Value 12-km Grid June Episode	Value 4-km Grid June Episode	Value 12-km Grid July Episode	Value 4-km Grid July Episode	Benchmark
N	512	27	517	26	–
MB [ppb]	1.5	1.2	1.1	0.6	–
ME [ppb]	9.9	10.3	10.0	9.6	–
RMSE [ppb]	12.6	13.6	13.0	12.4	–
NMB [%]	4.0	3.0	2.7	1.3	≤ ±15%
NME [%]	27.6	25.0	26.0	21.9	≤35%
FB [%]	11.4	9.0	11.0	3.5	≤ ±15%
FE [%]	31.5	34.1	29.7	25.6	≤35%
R	0.71	0.68	0.70	0.59	–
IOA	0.83	0.80	0.82	0.75	–

Table 30. CAMx ozone MPE results for concentrations >60 ppb for the **June and July** episodes. Green cells indicate metrics that fell within the benchmark for good model performance. Yellow cells indicate values that fell within the benchmark for acceptable model performance. N is the number of observations.

Statistical Metric	Value 12-km Grid June Episode	Value 4-km Grid June Episode	Value 12-km Grid July Episode	Value 4-km Grid July Episode	Benchmark
N	214	26	413	25	–
MB [ppb]	-10.9	-8.4	-13.4	-9.5	–
ME [ppb]	11.9	9.0	14.5	10.5	–
RMSE	14.5	10.9	18.4	12.7	–
NMB [%]	-15.5	-12.7	-19.4	-14.5	≤ ±15%
NME [%]	16.9	13.6	20.9	16.1	≤35%
FB [%]	-17.4	-14.0	-22.0	-16.3	≤ ±15%
FE [%]	18.7	14.9	23.6	17.8	≤35%

Spatial plots of NMB and NME in the 4-km domain when ozone was greater than 60 ppb are shown in Figure 54 for the June episode and Figure 55 for the July episode. Consistent with Table 29 and 30 above, CAMx underpredicts ozone concentrations at the higher concentration range. Based on Figure 54 and 55, the model error was smaller in the Albuquerque MSA compared to the El Paso area. The modeling errors in El Paso are likely influenced by uncertainty in the Mexico emissions inventory. Notably, the model performed well at monitoring sites in northwestern New Mexico in the Farmington area, where there are significant NO_x emissions from power plants and VOC emissions from nearby oil and gas extraction.

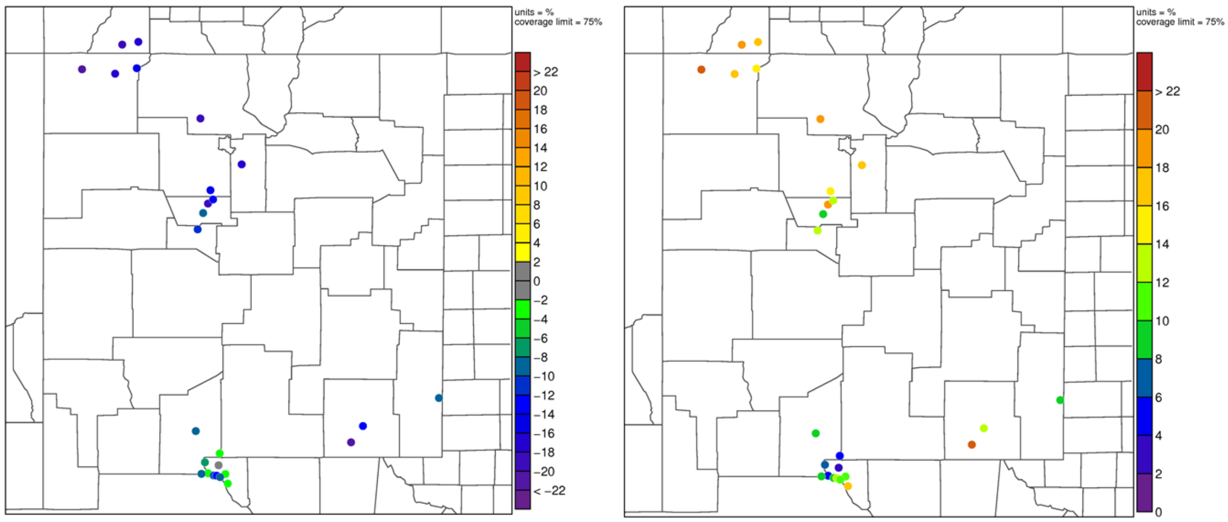

Figure 54. Ozone NMB (left) and NME (right) for the 4-km domain during hours with ozone greater than 60 ppb during June 12-16, 2017.

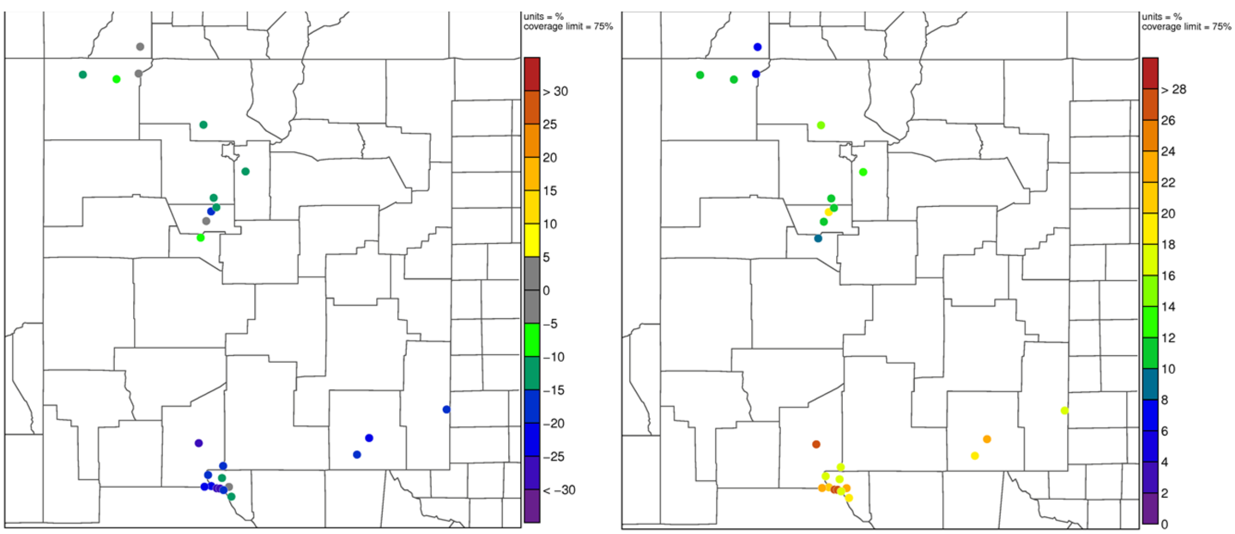

Figure 55. Ozone NMB (left) and NME error (right) for the 4-km domain during hours with ozone greater than 60 ppb during July 3-14, 2017.

Hourly performance statistics for five ozone sites in the Albuquerque MSA are shown in Table 31 for the June episode and Table 32 for the July episode. Overall, CAMx performs well, and performance metrics were within the benchmarks for good or acceptable model performance. The model performed best at South Valley, with very low bias during the July episode. Biases and errors were largest at Del Norte. Consistent with the domain-wide statistics, CAMx underpredicted ozone when concentrations were above 60 ppb, and performance was slightly better for the July episode than for the June episode. Based on our review of the modeling outputs, non-local influences, in part from fires, were more prevalent in the June episode than in the July episode.

Table 31. CAMx ozone MPE results in the Albuquerque MSA for concentrations greater than 60 ppb for the **June** episode. Green cells indicate metrics that fell within the benchmark for good model performance. Yellow cells indicate values that fell within the benchmark for acceptable model performance.

Metric	Del Norte	South Valley	Foothills	Bernalillo	Los Lunas
MB [ppb]	-13.1	-5.6	-8.3	-9.7	-8.1
ME [ppb]	13.1	6.1	8.4	9.7	9.1
RMSE	13.9	7.7	10.1	11.3	10.9
NMB [%]	-19.3	-8.4	-12.2	-14.4	-11.8
NME [%]	19.3	9.1	12.3	14.4	13.2
FB [%]	-21.8	-9.0	-13.2	-15.8	-12.9
FE [%]	21.8	9.7	13.3	15.8	14.4

Table 32. CAMx ozone MPE results in the Albuquerque MSA for concentrations greater than 60 ppb for the **July** episode. Green cells indicate metrics that fell within the benchmark for good model performance. Yellow cells indicate values that fell within the benchmark for acceptable model performance.

Metric	Del Norte	South Valley	Foothills	Bernalillo	Los Lunas
MB [ppb]	-12.1	0.2	-7.1	-7.1	-5.2
ME [ppb]	12.1	6.5	7.6	7.6	5.7
RMSE	13.8	7.1	9.0	9.2	7.1
NMB [%]	-18.0	0.3	-10.8	-11.0	-8.0
NME [%]	18.2	10.1	11.5	11.8	8.8
FB [%]	-20.6	-0.2	-11.5	-11.8	-8.4
FE [%]	20.7	10.1	12.2	12.5	9.3

When considering daily maximum 8-hour average ozone concentrations, the model performance statistics for high observed ozone days (>60 ppb) at the Albuquerque MSA sites was also good, as summarized in Tables 33 and 34. The Double Eagle site was not included in the hourly ozone performance statistics, but was included in the evaluation of peak 8-hour ozone concentrations. The best performing site was South Valley in both the June and July episodes. Biases and errors were largest at Double Eagle (June episode) and Del Norte (July episode). Double Eagle is west of the City of Albuquerque; therefore, with winds blowing from the west during the June episode, a low bias at Double Eagle indicates that CAMx may underrepresent the inflow of ozone into Albuquerque/Bernalillo County. Performance at Double Eagle was much better in the July episode.

Table 33. CAMx peak 8-hour ozone MPE results in the Albuquerque MSA for concentrations greater than 60 ppb in the 4-km domain for the **June** episode. Green cells indicate values that fell within the benchmark for good model performance.

Metric	Del Norte	South Valley	Foothills	Bernalillo	Los Lunas	Double Eagle
NMB (%)	-9%	-7%	-12%	-12%	-11%	-14%
NME (%)	9%	7%	12%	12%	11%	14%
FB (%)	-17%	-8%	-12%	-17%	-12%	-15%
FE (%)	17%	8%	12%	17%	12%	15%

Table 34. CAMx peak 8-hour ozone MPE results in the Albuquerque MSA for concentrations greater than 60 ppb in the 4-km domain for the **July** episode. Green cells indicate values that fell within the benchmark for good model performance.

Metric	Del Norte	South Valley	Foothills	Bernalillo	Los Lunas	Double Eagle
NMB (%)	-11%	1%	-7%	-7%	-4%	-5%
NME (%)	11%	3%	7%	7%	4%	5%
FB (%)	-15%	1%	-9%	-11%	-8%	-9%
FE (%)	15%	6%	9%	11%	8%	9%

Model performance varied from day to day, and CAMx did not always perfectly match the observed ozone plumes. However, the model did well on most days at predicting the area-wide maximum 8-hour average ozone concentration, as shown in Figures 56 and 57. Consistent with the performance statistics, CAMx was better at predicting peak ozone concentrations in the July episode compared to the June episode. Note that the high ozone days in the Albuquerque MSA were June 14-15, July 7, and July 10-11.

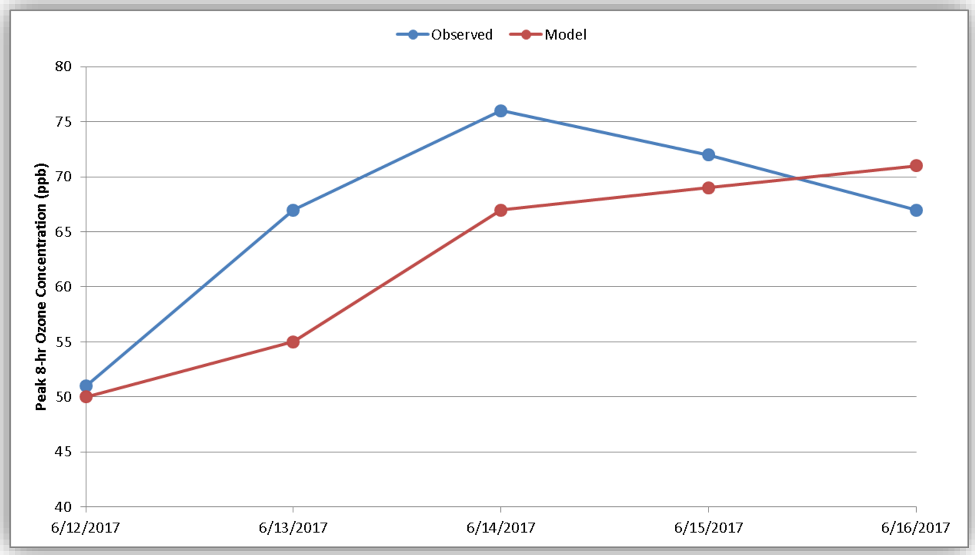

Figure 56. Peak modeled (red line) and observed (blue line) 8-hour ozone concentration in the Albuquerque MSA during the **June** episode.

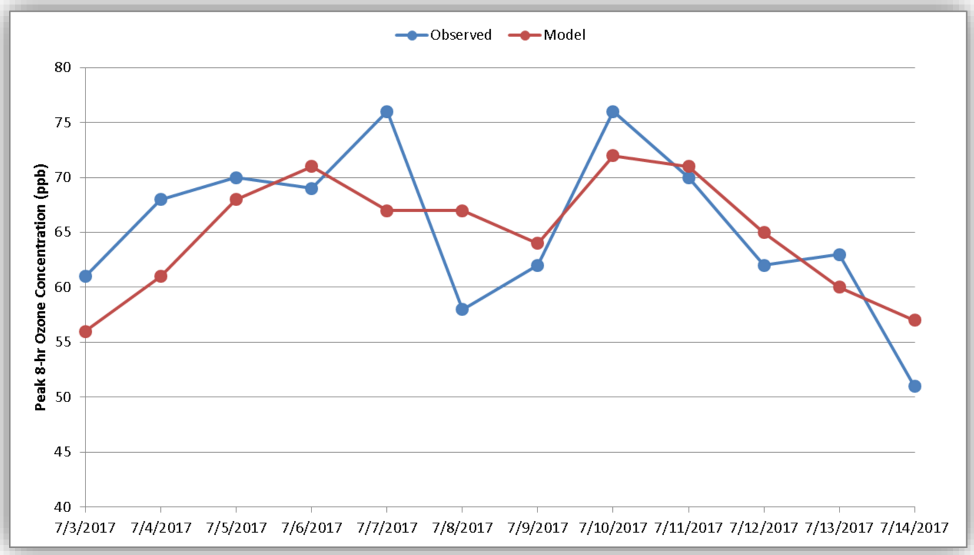

Figure 57. Peak modeled (red line) and observed (blue line) 8-hour ozone concentration in the Albuquerque MSA during the **July** episode.

8.5 June 2017 Ozone Episode

As shown in the spatial plots of modeled peak 8-hr average ozone concentrations in **Figure 58**, the June episode started with relatively low ozone concentrations across New Mexico due to a frontal passage and an associated increase in wind speeds. Ozone concentrations in Albuquerque/Bernalillo County increased as surface high pressure built behind the front on June 13. On June 12 and 13, peak modeled ozone concentrations ranged from 40 to 55 ppb. CAMx did not capture the observed increase in ozone concentrations on June 13. The observed and modeled wind speeds in the City of Albuquerque on the afternoon of June 13 were from the west at 10-20 mph, yet observed ozone concentrations spiked to the 70 ppb range during the afternoon hours. This spike occurred at all six ozone monitors in the Albuquerque MSA. Also, the maximum observed 8-hour ozone on June 13 was 71 ppb at the NMED Coyote monitor in the Santa Fe National Forest, and 65 ppb at the NMED Santa Fe monitor. This indicates that CAMx missed some regional pollutant transport or failed to fully characterize fire influences on June 13.

The model did capture the observed increase in ozone on subsequent days, as regional concentrations increased to 55-70 ppb on June 14-16. Modeled ozone concentrations in Albuquerque/Bernalillo County were influenced by regional fires, and potentially by emissions from Phoenix as well, as the regional winds were generally blowing from the west and southwest during the June episode. Modeled ozone concentrations were closer to observed values on June 14, and closer still on June 15. On June 15, the modeled peak 8-hr average ozone concentration reached 66 ppb at the South Valley monitor, 67 ppb at the Foothills monitor, 62 ppb at the Bernalillo monitor (in Sandoval County), 65 ppb at the Los Lunas monitor (in Valencia County), and 62 ppb at the Double Eagle monitor. Observed 8-hour ozone concentrations on June 15 ranged from 67 to 72 ppb.

Figures 59 and 60 show the modeled peak 8-hr average ozone concentrations in Albuquerque/Bernalillo County on June 14 and 15 overlaid with the monitored concentrations. The modeled concentrations are generally 5-10 ppb lower than the monitored concentrations, and the peak modeled concentration are displaced from the observed peak. Concentrations in the 60-65 ppb range are modeled across much of the Albuquerque MSA, and this widespread ozone is reflected in the observations. The highest ozone concentrations on both days were modeled east of the Foothills site (the high ozone site on these days), which suggests that WRF did not fully capture the local wind flow effects of the Sandia Mountains on these days. There were also some local mismatches between modeled and observed winds in Albuquerque/Bernalillo County.

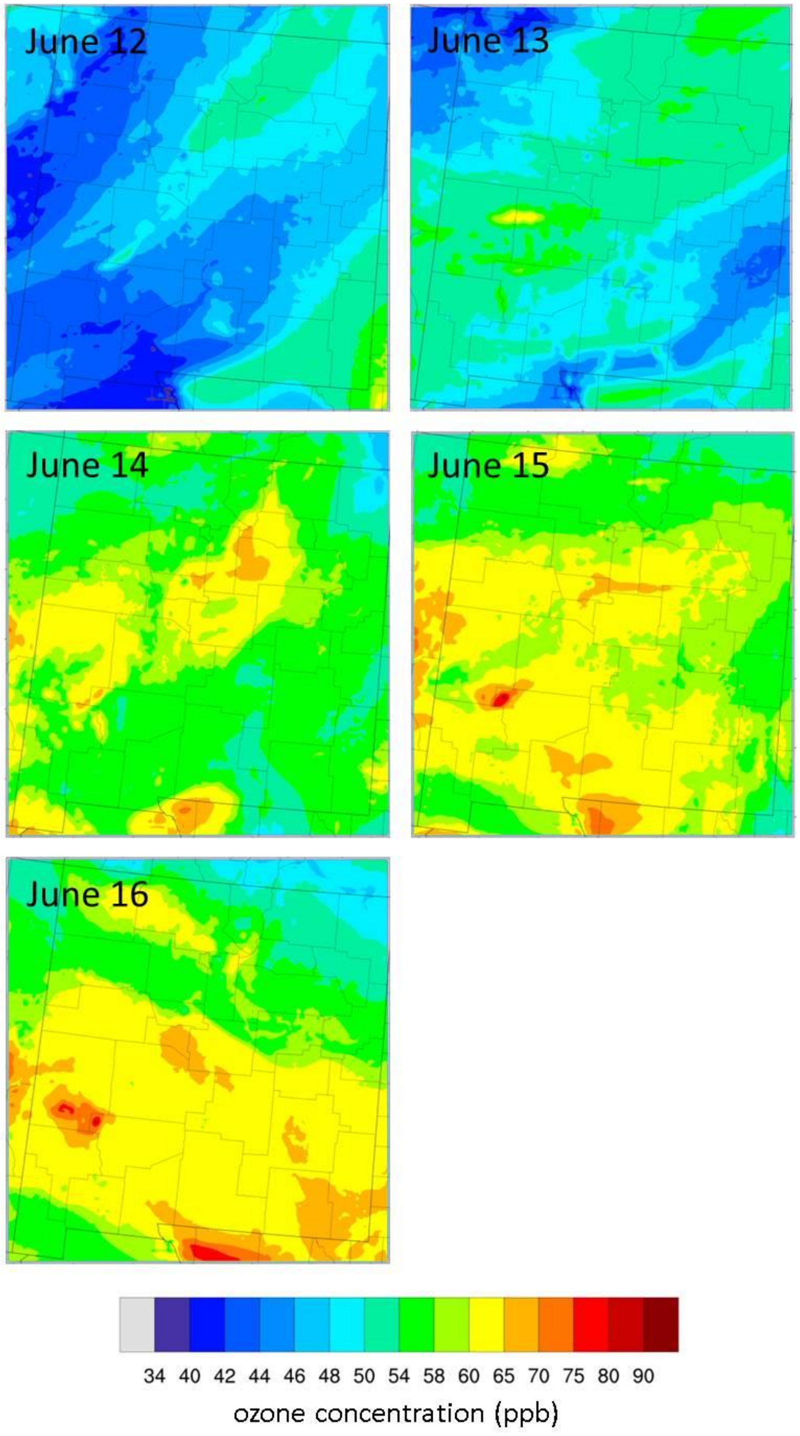

Figure 58. Spatial plots of modeled peak 8-hr average ozone concentrations in the 4-km domain for the June episode.

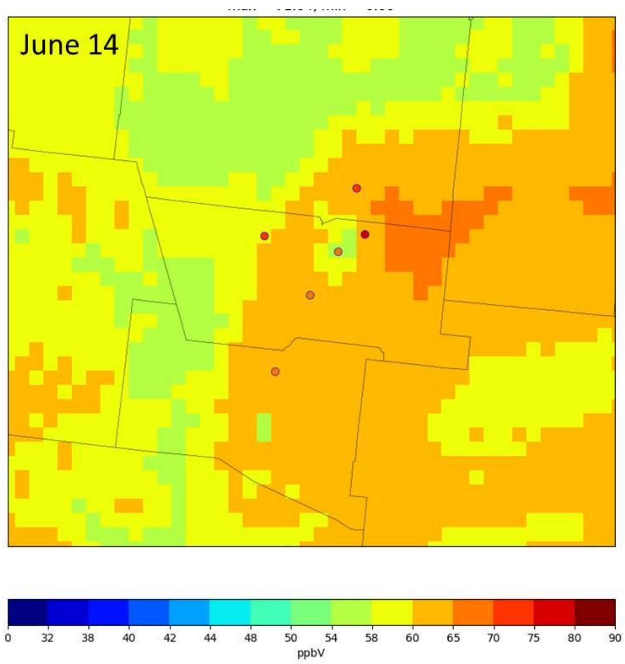

Figure 59. Spatial plot of peak 8-hr ozone concentrations in the Albuquerque MSA, with overlay of monitored concentrations, on June 14.

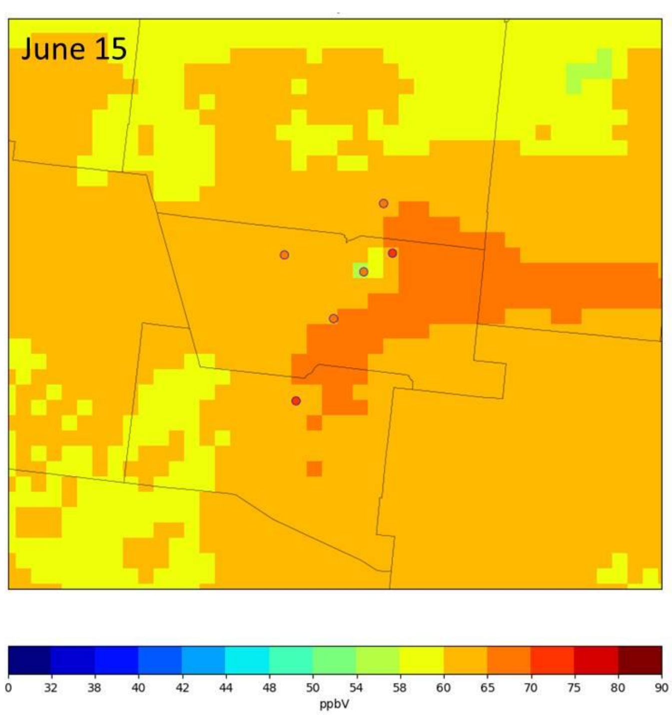

Figure 60. Spatial plot of peak 8-hr ozone concentrations in the Albuquerque MSA, with overlay of monitored concentrations, on June 15.

Modeled ozone concentrations are lower in the 4-km grid cell containing the Del Norte monitor on both June 14 and 15. The lower concentration relative to the surrounding grid cells is a result of high modeled NO_2 concentrations (see Figure 61), which are associated with emissions from I-40 being allocated to this grid cell of the 4-km domain. This grid cell is also close to I-25.

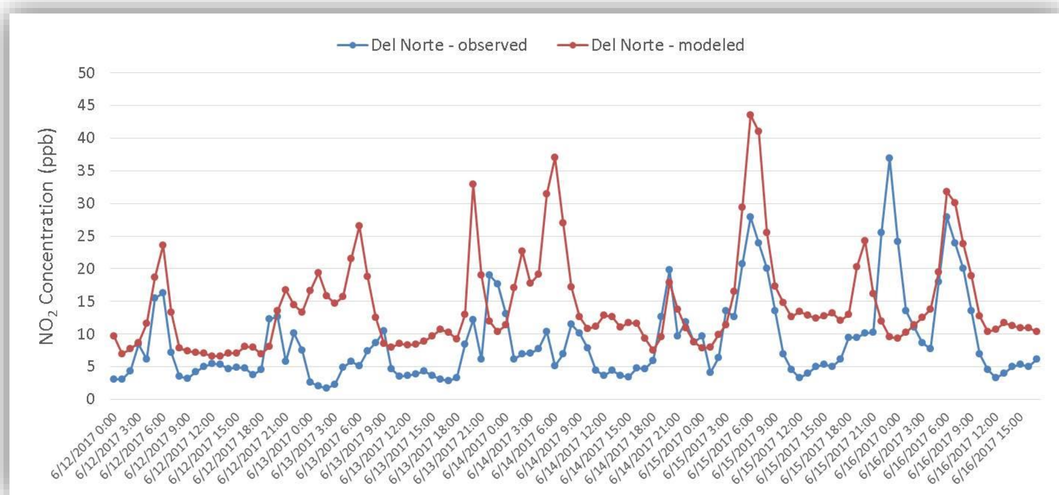

Figure 61. Hourly observed (blue line) and modeled (red line) NO_2 concentrations at the Del Norte monitor during the June episode.

Time series of the observed and modeled hourly ozone concentrations in the Albuquerque MSA are shown in Figures 62 and 63. In general, the model underpredicts the highest observed concentrations during the day and overpredicts the lowest observed concentrations at night. The magnitude of these biases is larger at the Double Eagle site than at the other sites. CAMx underpredicts both daytime and nighttime ozone concentrations at the Del Norte monitor. At most sites, the highest daytime ozone concentrations are sustained for several hours, while the modeled ozone drops more quickly in the late afternoon. For example, at South Valley, CAMx accurately predicts the daytime ozone peak (both timing and magnitude) on June 13-15, but the model does not sustain those peaks. One exception is at the Bernalillo site in Sandoval County, where modeled concentrations remain high throughout the afternoon on most of the episode days.

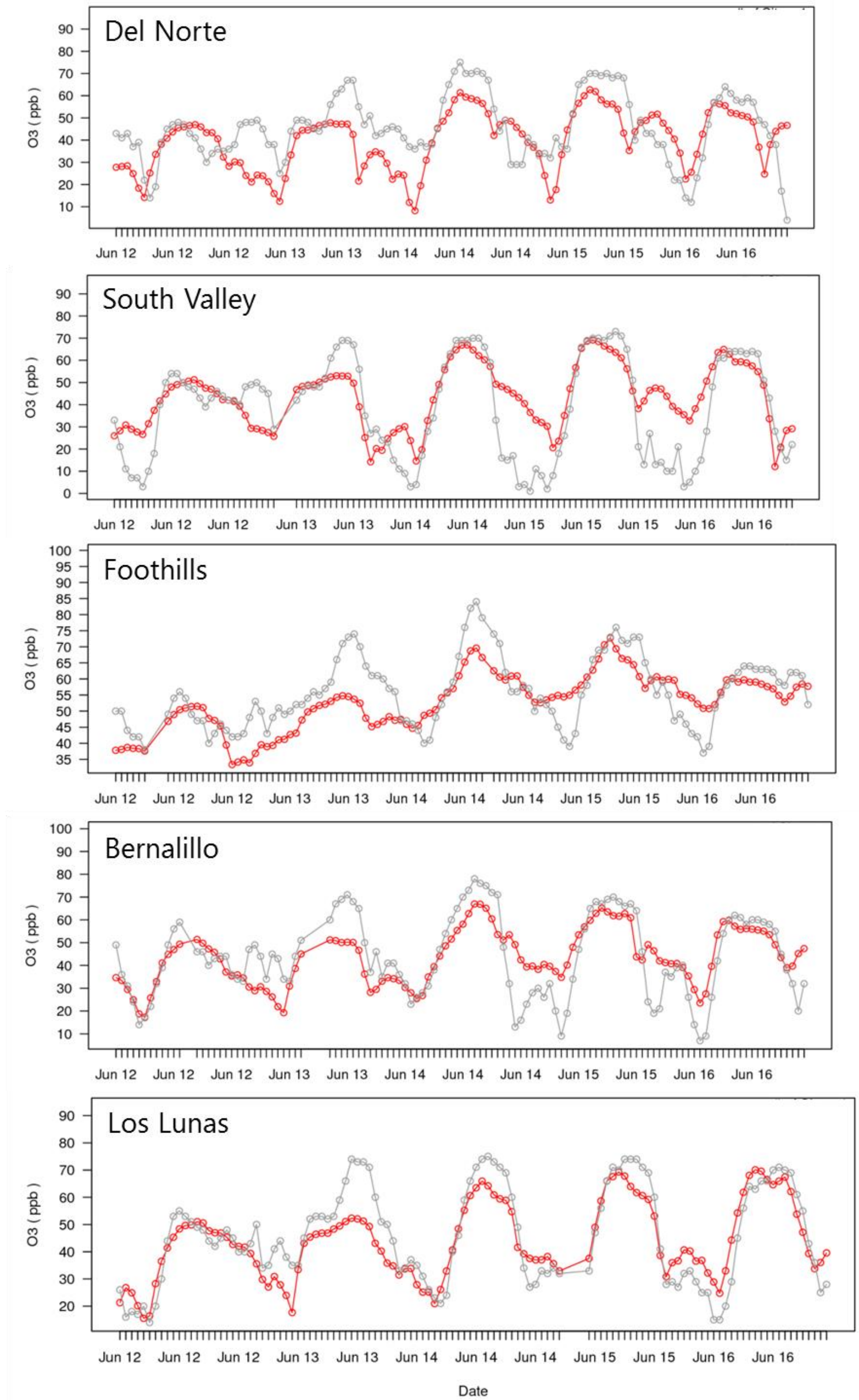

Figure 62. Time series of hourly observed (gray line) and modeled (red line) ozone concentrations in the Albuquerque MSA during June 12-16, 2017.

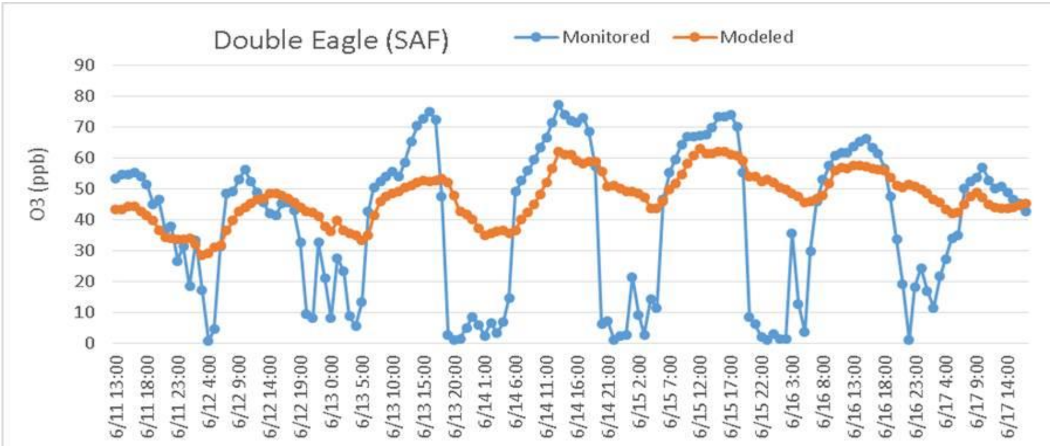

Figure 63. Time series of hourly observed (blue line) and modeled (orange line) ozone concentrations during June 12-17, 2017, at the Double Eagle monitor.

Time series of the observed and modeled peak 8-hr average ozone concentrations in the Albuquerque MSA are shown in **Figures 64 and 65**.

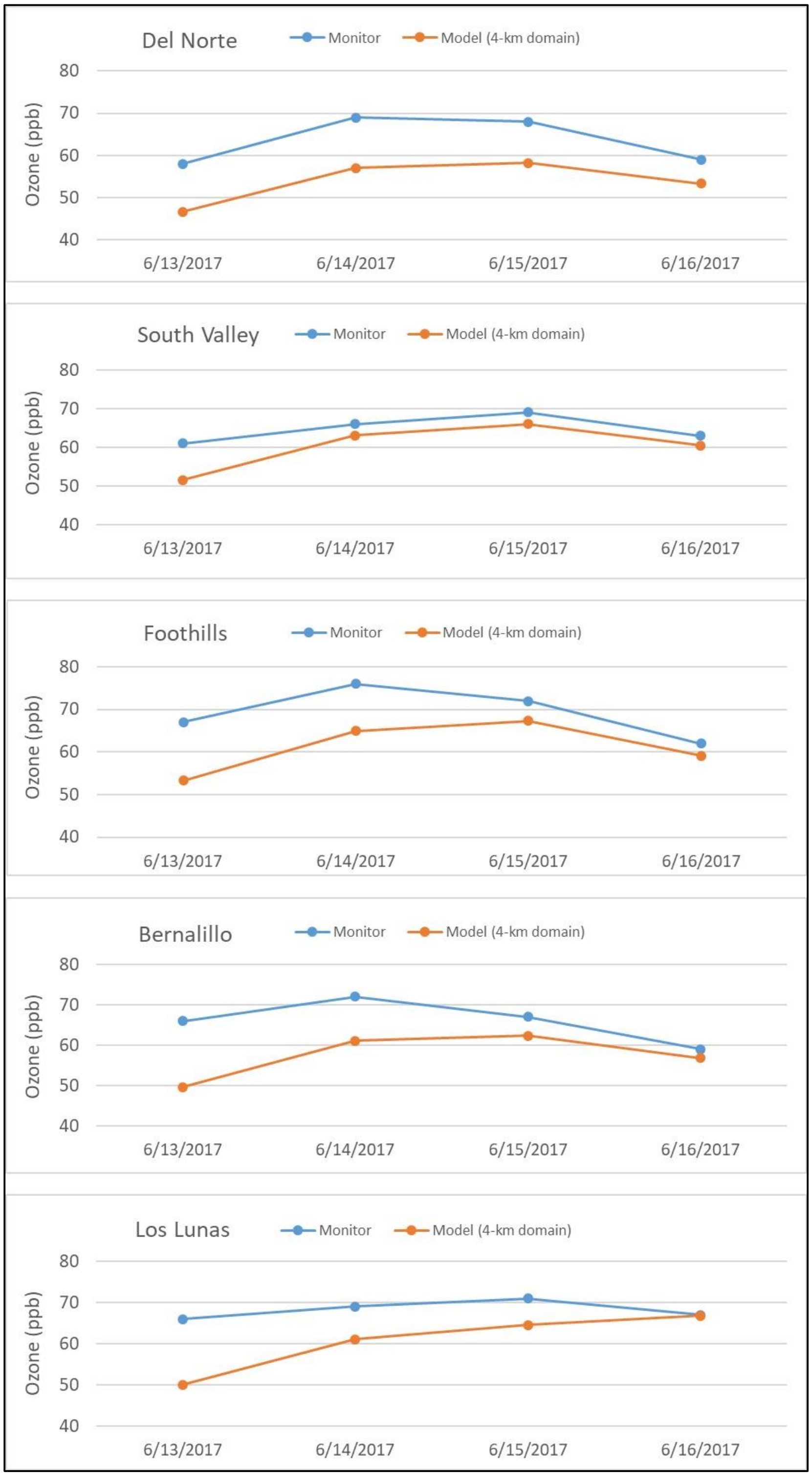

Figure 64. Time series of observed (blue line) and modeled (orange line) peak 8-hr average ozone concentrations in the Albuquerque MSA during June 13-16, 2017.

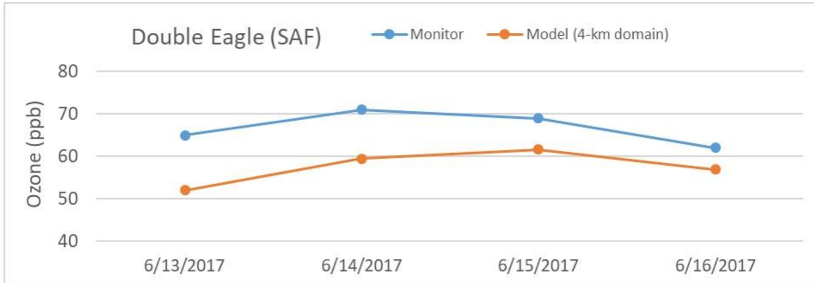

Figure 65. Time series of observed (blue line) and modeled (orange line) peak 8-hr average ozone concentrations at the Double Eagle site during June 13-16, 2017.

8.6 July 2017 Ozone Episode

The spatial plots of modeled peak 8-hr average ozone concentrations for the July episode (Figure 66) show the locally influenced ozone concentrations in Albuquerque/Bernalillo County. Figures 67 and 68 show the modeled peak 8-hr average ozone concentrations in Albuquerque/Bernalillo County on July 7 and 10, overlaid with the monitored concentrations. Modeled concentrations in Albuquerque/Bernalillo County increase between July 4 and July 7, the first day with observed ozone greater than 70 ppb in the July episode. Modeled concentrations then decrease on July 8 and July 9 before peaking again on July 10 and July 11, the last two episode days with 8-hour ozone greater than 70 ppb. Throughout New Mexico, modeled peak 8-hr average ozone concentrations were 50-60 ppb, while high concentrations in Albuquerque/Bernalillo County were 60-70 ppb. The highest modeled concentrations occur on July 10 and 11, with the highest 8-hour concentration (71 ppb) modeled on July 10 at the South Valley monitor. The modeled ozone concentrations are generally 5-10 ppb lower than the monitored concentrations.

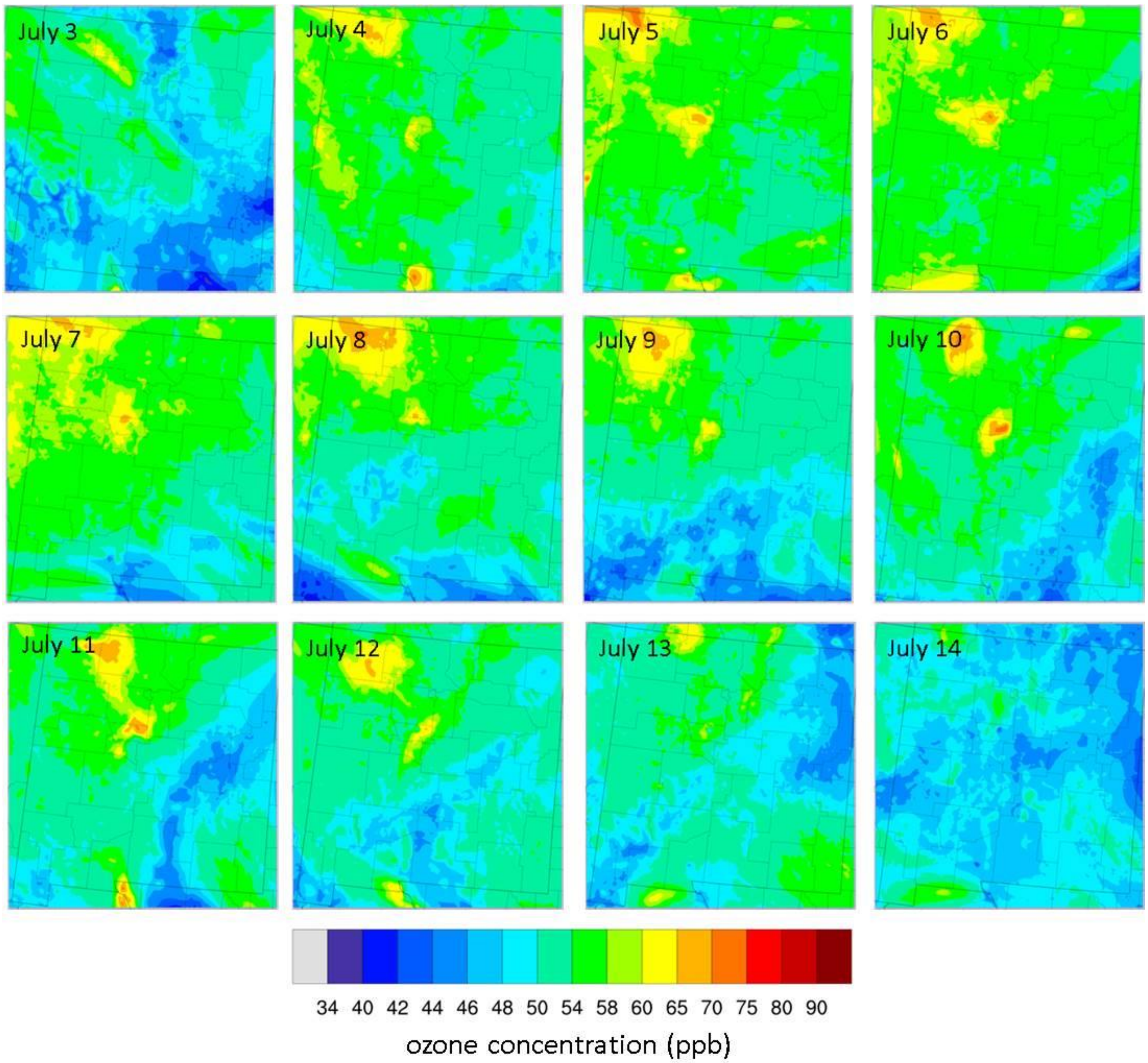

Figure 66. Spatial plots of modeled peak 8-hr average ozone concentrations in the 4-km domain for the July episode.

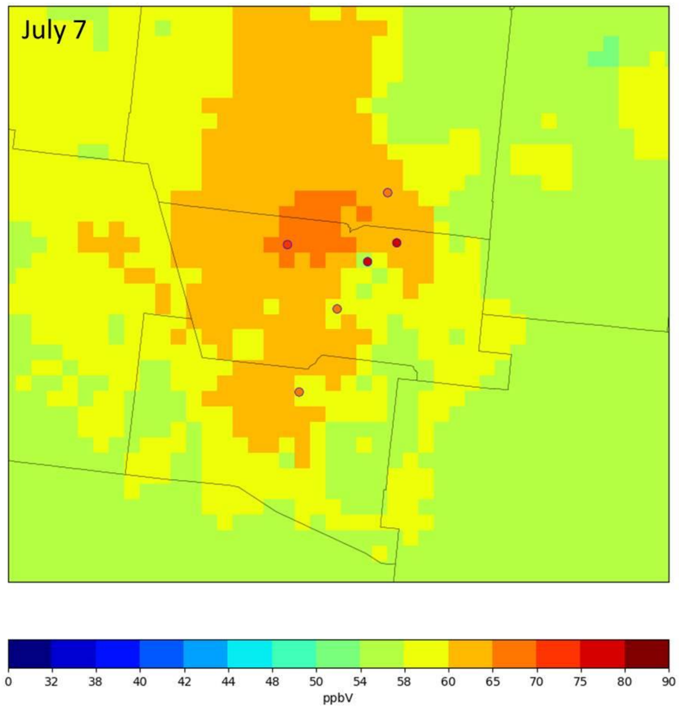

Figure 67. Spatial plot of peak 8-hr ozone concentrations in the Albuquerque MSA, with overlay of monitored concentrations, on July 7.

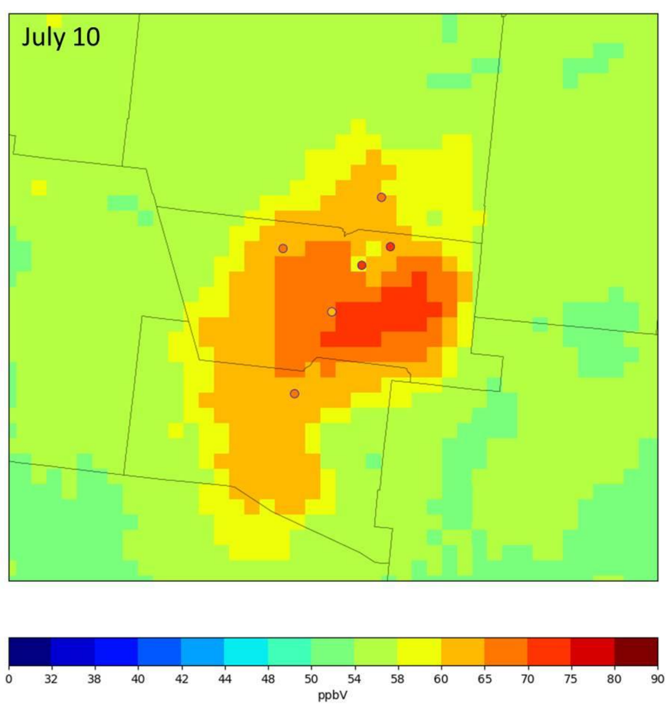

Figure 68. Spatial plot of peak 8-hr ozone concentrations in the Albuquerque MSA, with overlay of monitored concentrations, on July 10.

CAMx underpredicted peak 8-hr ozone concentrations on July 7. The highest modeled 8-hr ozone concentration in Albuquerque/Bernalillo County was 67 ppb, while the highest observation was 76 ppb at the Del Norte site. On several days during the July modeling episode, scattered thunderstorms were observed and modeled in the high terrain in northern New Mexico. Outflow boundaries from these thunderstorms impacted winds in Albuquerque/Bernalillo County on some afternoons. The WRF model did not reproduce the exact timing and location of these thunderstorms and their associated winds. On July 7, WRF modeled a thunderstorm over the Sandia Mountains that briefly produced strong northeast winds across the City of Albuquerque (Figure 69) and disrupted CAMx predictions of ozone formation and pollutant transport. Based on satellite imagery, some clouds did develop over the Sandia Mountains on July 7, and thunderstorms were observed north of the City of Albuquerque, but those storms did not affect observed winds at the Albuquerque airport. Despite this mismatch between observed and modeled winds, CAMx still produced a peak 8-hr ozone concentration near 70 ppb in Albuquerque/Bernalillo County on July 7. The air quality model still produces useful results despite imperfect hourly agreement with observations.

Figure 69. Temperature (colors), wind vectors (arrows), and terrain (contour lines) modeled by WRF in the Albuquerque MSA on July 7, 2017, at 6:00 p.m. local time.

CAMx was able to produce peak 8-hour ozone concentrations in excess of 70 ppb on both July 10 and July 11. On July 10, Foothills was the high ozone site, but CAMx placed the highest ozone concentrations to the east and south of the City of Albuquerque. On July 11, the highest modeled concentrations were east and northeast of the City of Albuquerque. The peak modeled concentrations tended to be displaced from the peak monitored locations. The extent of the ozone plume across the Albuquerque MSA was modeled well on July 10, as the model produced 8-hour ozone concentrations of 60-65 ppb to the south at Los Lunas (in Valencia County), to the north at

Bernalillo (in Sandoval County), and to the west at Double Eagle, where the observed 8-hour ozone was 67 ppb.

As in the June episode, higher modeled concentrations are displaced from the monitor locations, and on some days, modeled ozone concentrations are lower at the 4-km grid cell containing the Del Norte monitor. High modeled NO_2 concentrations, associated with emissions from I-40 being allocated to this grid cell of the 4-km domain, are shown in Figure 70. Figure 71 shows the 4-km model grid cells in the vicinity of the Del Norte monitor.

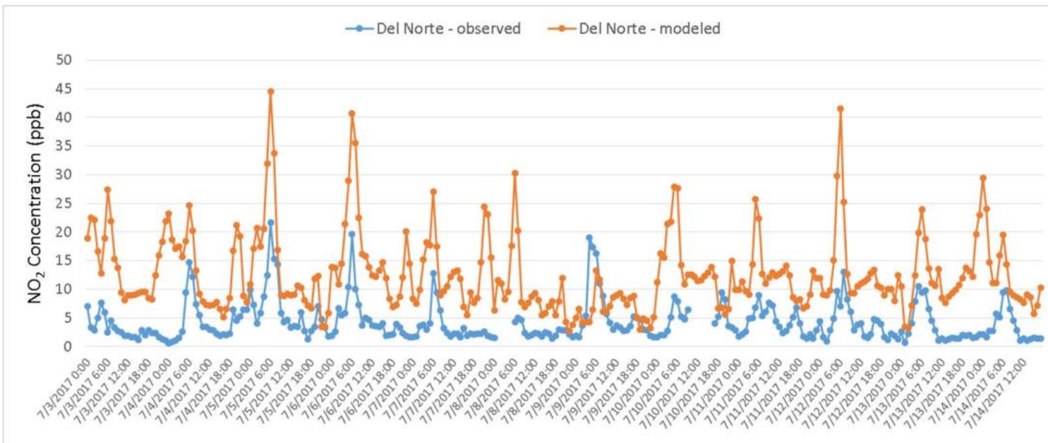

Figure 70. Hourly observed (blue line) and modeled (red line) NO_2 concentrations at the Del Norte monitor during the July episode.

Figure 71. Grid cells of the 4-km domain (white squares) in the City of Albuquerque near the Del Norte air quality monitoring site.

Time series of the observed and modeled hourly ozone concentrations in the Albuquerque MSA are shown in **Figures 72 and 73**. In general, the model underpredicts the highest observed concentrations during the day and overpredicts the lowest observed concentrations at night. Compared to the June episode, the model does a slightly better job of capturing the high ozone concentrations at most sites. Nighttime ozone is overpredicted, especially at Double Eagle and South Valley, but the daytime ozone predictions at Double Eagle and South Valley are quite good.

CAMx underpredicts both daytime and nighttime ozone concentrations at the Del Norte monitor. Compared to the June episode, the model was somewhat better at sustaining the highest ozone concentrations during the afternoon hours. The modeled ozone still tends to drop more quickly in the late afternoon compared to the observations.

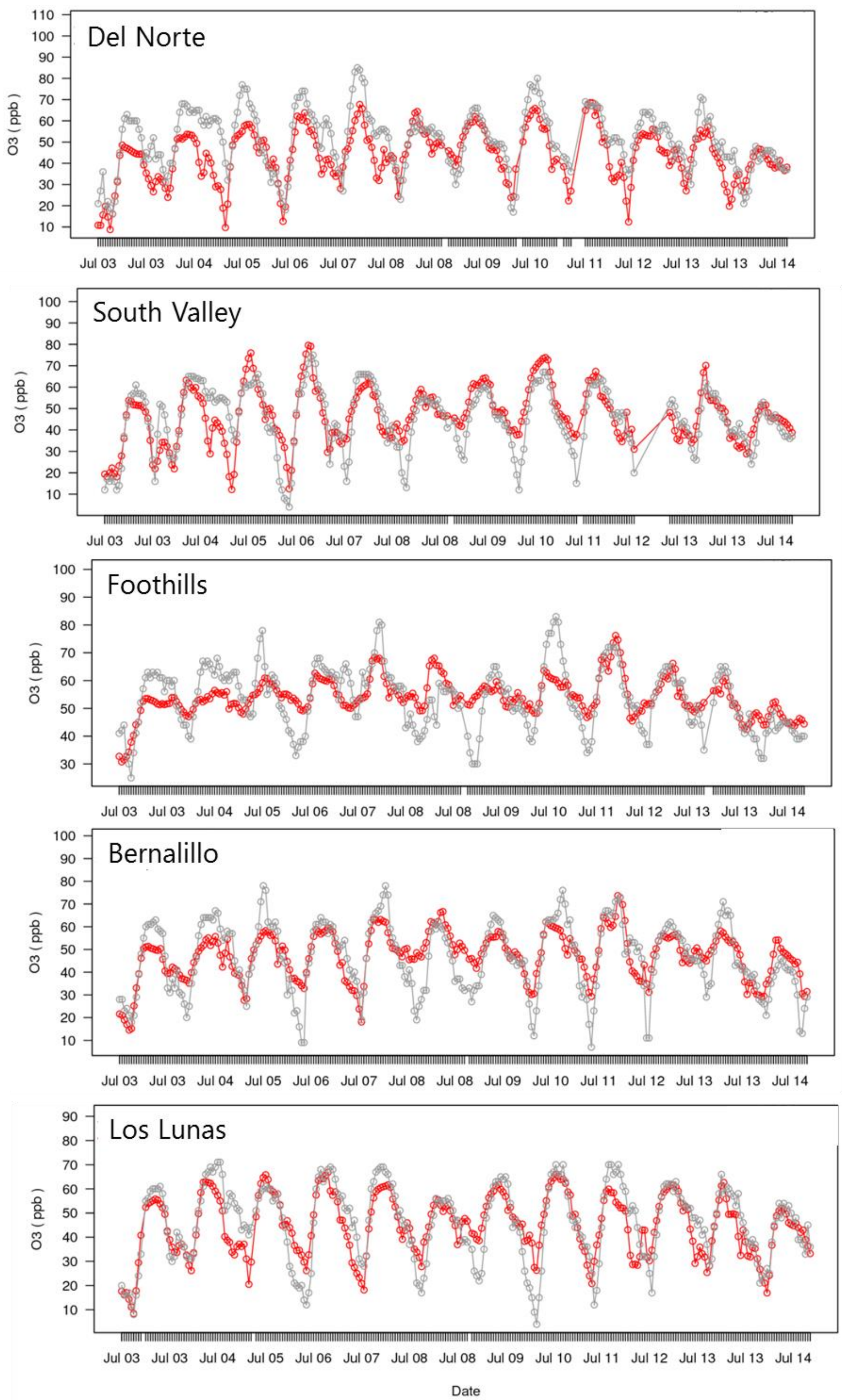

Figure 72. Time series of hourly observed (gray line) and modeled (red line) ozone concentrations in the Albuquerque MSA during July 3-14, 2017.

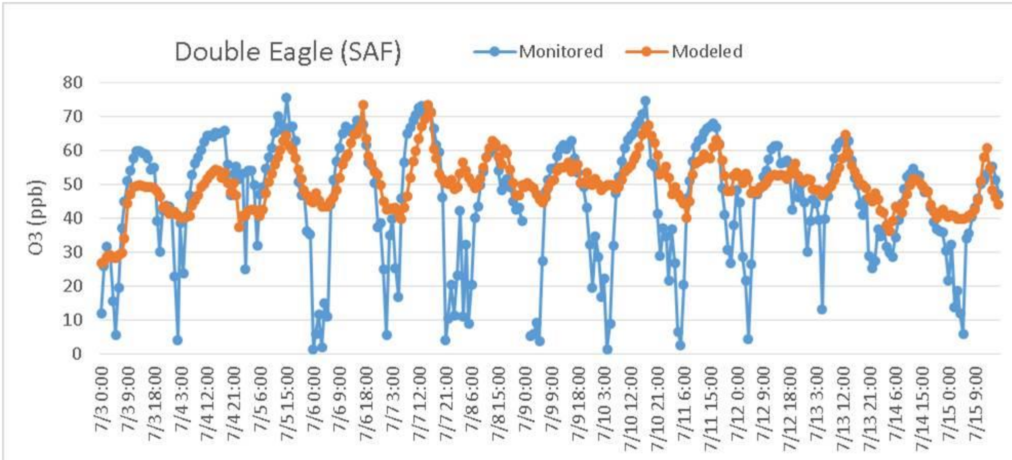

Figure 73. Time series of hourly observed (blue line) and modeled (orange line) ozone concentrations at the Double Eagle monitor during July 3-15, 2017.

Time series of the observed and modeled peak 8-hr average ozone concentrations in the Albuquerque MSA are shown in **Figures 74 and 75**. Similar to the hourly results, the overall agreement between observed and modeled peak 8-hr ozone concentrations is good; the agreement is noticeably better in this episode than in the June episode. The model result is particularly good at the South Valley, Los Lunas, and Double Eagle monitoring sites, although the model underpredicts the high ozone concentration on July 7. The model also underpredicts the high ozone concentration on July 7 at the Del Norte site, and on July 10 at the Del Norte and Foothills sites.

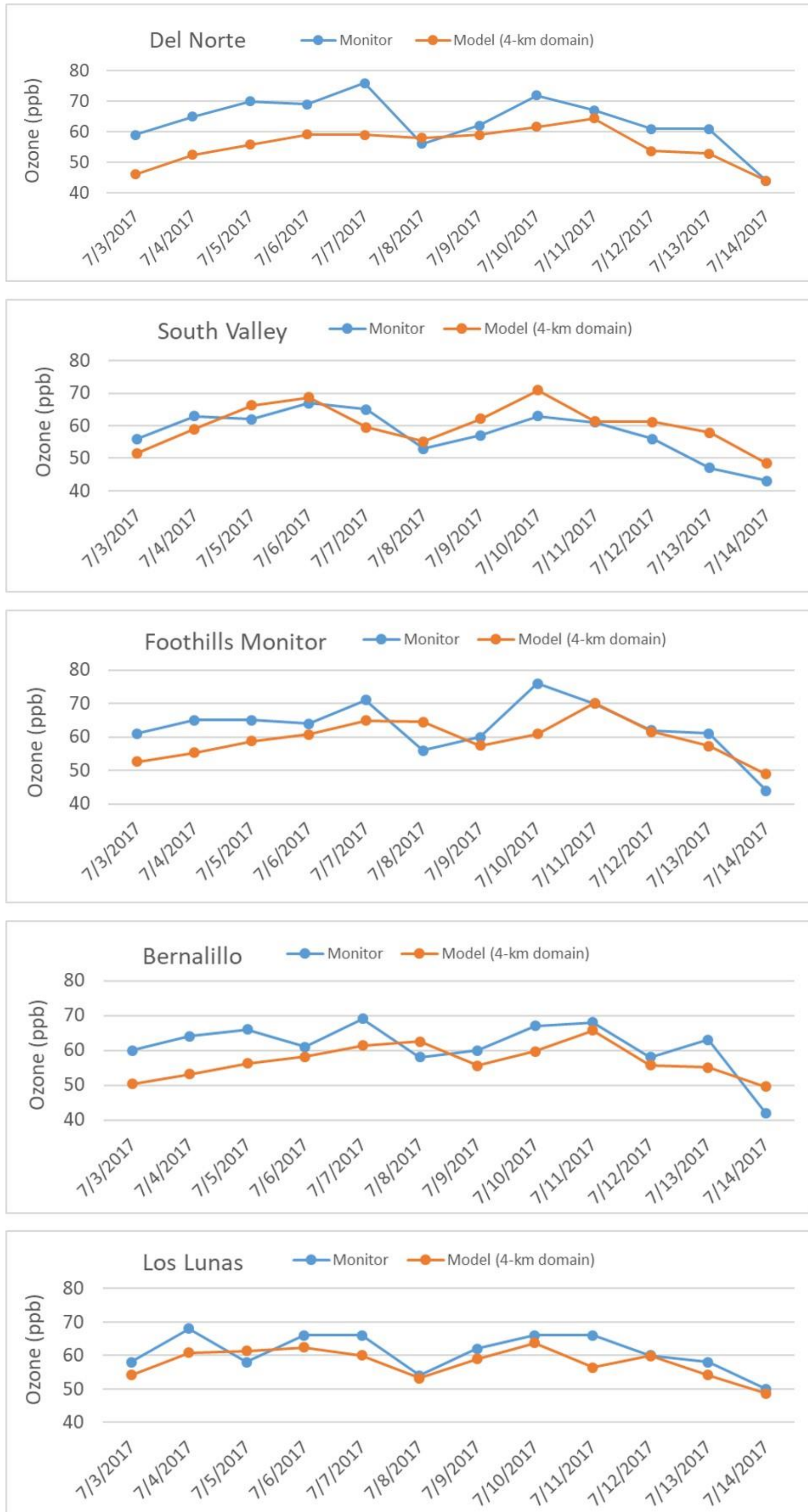

Figure 74. Time series of observed (blue line) and modeled (orange line) peak 8-hr average ozone concentrations in the Albuquerque MSA during July 3-14, 2017.

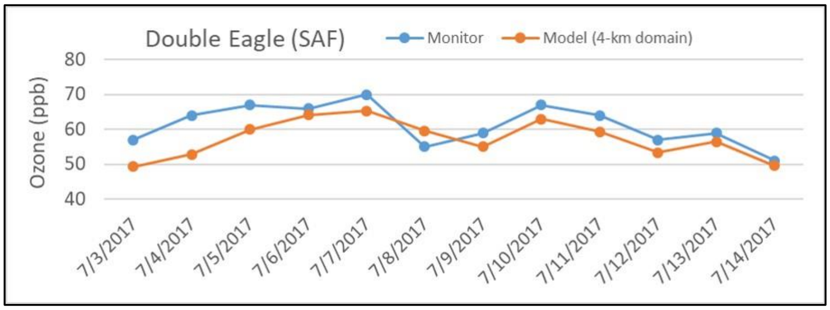

Figure 75. Time series of observed (blue line) and modeled (orange line) peak 8-hr average ozone concentrations at the Double Eagle site during July 3-14, 2017.

8.7 Summary

Based on the MPE results and our statistical and diagnostic review, the base-case CAMx modeling is suitable for use in air quality modeling work, and is a useful tool for understanding ozone air quality and evaluating the impacts of future changes in emissions in Albuquerque/Bernalillo County. The overall model performance was within benchmarks for good air quality model performance (bias within ±15% of observed values and mean normalized error less than 35%). In the Albuquerque MSA, CAMx tracked the observed day-to-day changes in peak 8-hour ozone concentration, which indicates that the model captured the important local and regional meteorological conditions that affect pollutant concentrations in the region.

The model results showed a consistent low bias when observed ozone concentrations were high (>60 ppb), which is not unusual for an air quality model. In the 4-km domain, the mean bias was around -9 ppb and the mean normalized error was around 15%. Model performance was better at some ozone monitors, with the best overall performance at the South Valley. Overall performance was slightly better for the July episode than for the June episode.

Although hourly agreement was imperfect and CAMx did not always reproduce the highest ozone concentrations at the Albuquerque MSA monitoring sites, the model did produce ozone plumes with realistic spatial extents, with peak modeled 8-hour average ozone concentrations that were quite comparable to the maximum observed concentrations. The modeled ozone plumes were therefore displaced from their observed locations. One notable modeling challenge is that substantial mobile source NO_x emissions from I-25 and I-40 are mixed into 4-km grid cells near the Del Norte site. This resulted in a reduction of modeled ozone concentrations around the Del Norte site, and is likely responsible for the additional bias and error at the Del Norte site. Therefore, it is important to examine model results at multiple sites when using the model to assess ozone impacts from emission controls. Based on the MPE results, reductions in mobile source NO_x emissions may actually increase modeled ozone at Del Norte and reduce modeled ozone elsewhere.

Understanding the strengths and weakness of the air quality modeling results is important to put the results into context, and to anticipate potential challenges that may be encountered in the air quality modeling. As we anticipated from the WRF MPE, surface winds were a challenging aspect of the modeling. Differences in the timing and magnitude of terrain-driven diurnal wind shifts can affect ozone model performance. This impacted the CAMx model performance on some days, resulting in ozone plumes with reasonable magnitude and spatial extent, but imperfect placement and timing. Note that complex terrain is more challenging for the air quality modeling system because some terrain features, such as the Sandia Mountains, cannot be fully resolved by the modeling grid.

Air quality observations are not fully representative of modeled grid volume averages, and emissions must artificially be mixed into relatively large grid volumes. Modeling at a higher spatial resolution (e.g., 1 km) could improve model performance, particularly at the Del Norte site, because the spatial distribution of NO_x emissions from motor vehicles would be more accurately represented within the City of Albuquerque. This could reduce the emissions allocated to the model grid cell containing the Del Norte monitor and help alleviate the large ozone underestimation at that site.

9. Source Apportionment

9.1 Overview

This chapter documents results from the CAMx source apportionment modeling of ozone episodes in Albuquerque/Bernalillo County during June and July 2017. The source apportionment modeling was conducted using the Ozone Source Apportionment Technology (OSAT) feature in CAMx. A source tagging strategy was developed in consultation with Albuquerque EHD staff to evaluate the role of local and non-local emissions, specific emission source sectors (biogenic emissions, on-road mobile sources, and fires), and selected individual emission sources on ozone concentrations in Albuquerque/Bernalillo County. The modeling episodes selected for this analysis represent the majority of high ozone days in Albuquerque/Bernalillo County during 2017, and are described in Chapter 2.

Figure 76 summarizes the average ozone source contributions in Albuquerque/Bernalillo County for days in the June 2017 and July 2017 modeling episodes when the peak modeled ozone concentration in Albuquerque/Bernalillo County was greater than or equal to 65 ppb. The source apportionment results show stark differences between the June and July 2017 ozone episodes. The high ozone concentrations in Albuquerque/Bernalillo County during the June episode were largely driven by non-local emissions from outside Albuquerque/Bernalillo County and New Mexico, whereas the high ozone concentrations during the July episode were driven more strongly by local emissions from within Albuquerque/Bernalillo County and New Mexico.

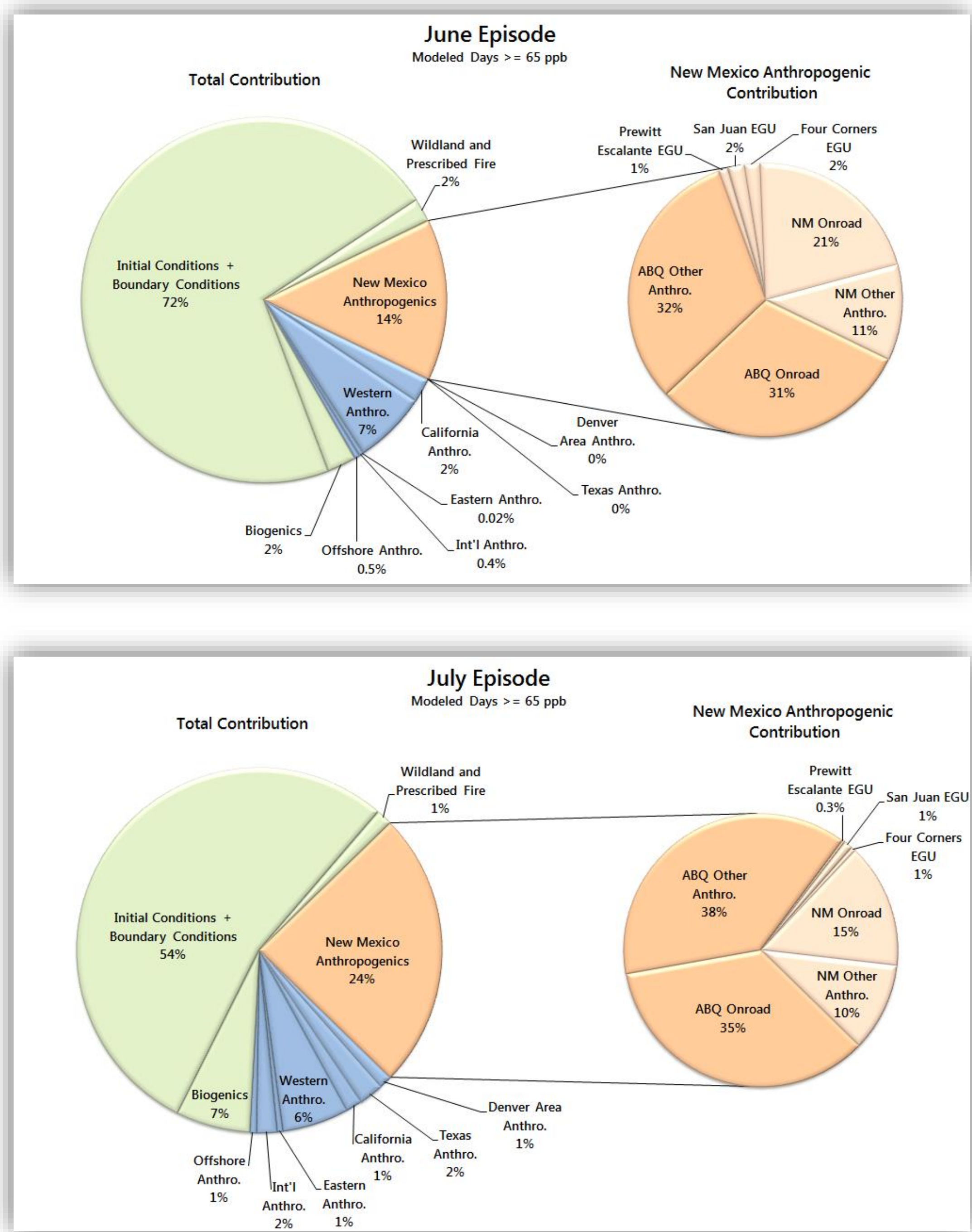

Figure 76. Average ozone source contributions in Albuquerque/Bernalillo County for days in the June episode (top) and July episode (bottom) when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb. The pie charts on the left represent the total ozone contribution, and the pie charts on the right represent the portion of ozone contributed by anthropogenic emissions in New Mexico.

These source apportionment results have important implications for air quality planning. The meteorological conditions, fire activity, and regional pollutant transport patterns that were associated with high ozone in Albuquerque/Bernalillo County were very different between the two modeling episodes. During the June episode, contributions from the western states and the CAMx boundary condition dominated ozone in Albuquerque/Bernalillo County and throughout New Mexico. Modeled ozone contributions from fires were up to 2 ppb in Albuquerque/Bernalillo County, and greater than 5 ppb in New Mexico as a result of fires burning within the state. Given the relatively small contributions from local anthropogenic emissions in June (about 6 ppb), local emission controls within Albuquerque/Bernalillo County would not be effective for reducing ozone concentrations in Albuquerque/Bernalillo County under these meteorological conditions. During the July episode, ozone contributions due to anthropogenic emissions from within Albuquerque/Bernalillo County were more prominent (12 ppb), and therefore local emission controls within Albuquerque/Bernalillo County would be more effective at reducing ozone concentrations under similar meteorological conditions.

Ozone contributions in Albuquerque/Bernalillo County from the Four Corners, San Juan, and Prewitt Escalante power plants in New Mexico were less than 1 ppb (combined) on most days, as the regional wind patterns often limited their influence. On many days, ozone contributions from anthropogenic emissions in California, Texas, and other western states were larger than contributions from the major New Mexico power plants. The recent decommissioning of two units at the San Juan power plant, and the recent addition of NO_x emission controls at the Four Corners power plant, will reduce future air quality impacts from these facilities.

9.2 CAMx Source Apportionment Configuration

9.2.1 Modeling Approach

Ozone concentrations observed at any site may result from a combination of transported and locally produced ozone. Locally produced ozone may be a result of local or transported ozone precursors. Successful air quality planning requires an understanding of source contributions to ozone concentrations. The OSAT method developed for CAMx quantifies the contribution of various emissions source categories and regions to modeled ozone concentrations. This is accomplished by tracking the NO_x and VOC emissions from each upwind source category and/or region of interest as well as the ozone produced by reactions of those emissions. Source contribution analysis can be used to identify and apportion the emissions sources contributing to local ozone concentrations. For example, source contribution analysis can be used to answer questions such as "How much lower would ozone values have been without wildfire emissions?" or "How much ozone in Albuquerque/Bernalillo County comes from emission sources outside Albuquerque/Bernalillo County?"

Version 6.4 of CAMx includes recent updates to OSAT, known as OSAT3. OSAT3 includes an improved approach to handle NO_x recycling and uses additional internal tracers to track source attribution of nitrogen through all forms of reactive nitrogen. The OSAT3 update improves estimates of local vs. non-local ozone contributions compared to prior versions of OSAT, and tends to allocate more ozone to long-range pollutant transport and less to local production.

The CAMx source apportionment modeling was conducted with the Anthropogenic Precursor Culpability Assessment (APCA) option enabled. APCA is a variant of OSAT that takes into account the fact that certain source categories, such as biogenic emissions, are not controllable. For example, in situations where anthropogenic NO_x combines with biogenic VOC, APCA allocates the resulting ozone production to the anthropogenic NO_x emission source. As a result, using APCA results in more ozone formation attributed to anthropogenic NO_x sources and less ozone formation attributed to biogenic VOC sources. The use of APCA is not discussed in EPA modeling guidance, but is consistent with EPA's use of source apportionment in its CSAPR rulemaking (U.S. Environmental Protection Agency, 2016b).

9.2.2 Source Tagging Strategy

A tagging strategy was developed in consultation with Albuquerque EHD staff to capture potential ozone contributions from major NO_x and VOC emission sources upwind of Albuquerque/Bernalillo County. To meet the objectives of the source contribution analysis, OSAT was configured to track ozone source contributions from several geographic source groups and emission source groups. Ozone contributions from a particular emissions source group are tracked for each source region. The combination of source region and emission source group is known as a "source tag." A total of 42 source tags were defined for this source apportionment assessment, which includes initial and boundary conditions that are tracked automatically by OSAT.

The nine source regions for this study are shown in **Figures 77 and 78**. A separate source region is defined for the Denver area because emissions from that region may influence ozone concentrations in Albuquerque/Bernalillo County. Note that contributions from ozone and ozone precursors produced overseas (e.g., pollutant transport from Asia) are tracked through OSAT's boundary condition tracers on the 36-km domain.[33] CAMx tracks these boundary condition tracers as they propagate into the nested grids. International emissions from portions of Canada and Mexico that are within the modeling domain are represented by a single International source group. In Albuquerque/Bernalillo County, contributions from this international source category are mostly from Mexico since Canada is much further away than Mexico. Emissions from large water bodies, including the Pacific Ocean, Atlantic Ocean, Gulf of Mexico, and U.S. Great Lakes, are combined into a single "Offshore" source region. In some cases, a small portion of land-based emissions may be

[33] Transport of ozone and precursor pollutants from Asia is predicted by the MOZART global model. The MOZART concentrations are brought into CAMx through the lateral boundary conditions of the 36-km domain and tracked by OSAT.

misallocated to the offshore category (and vice versa) due to imprecise alignment of model grid cells with the coastlines.

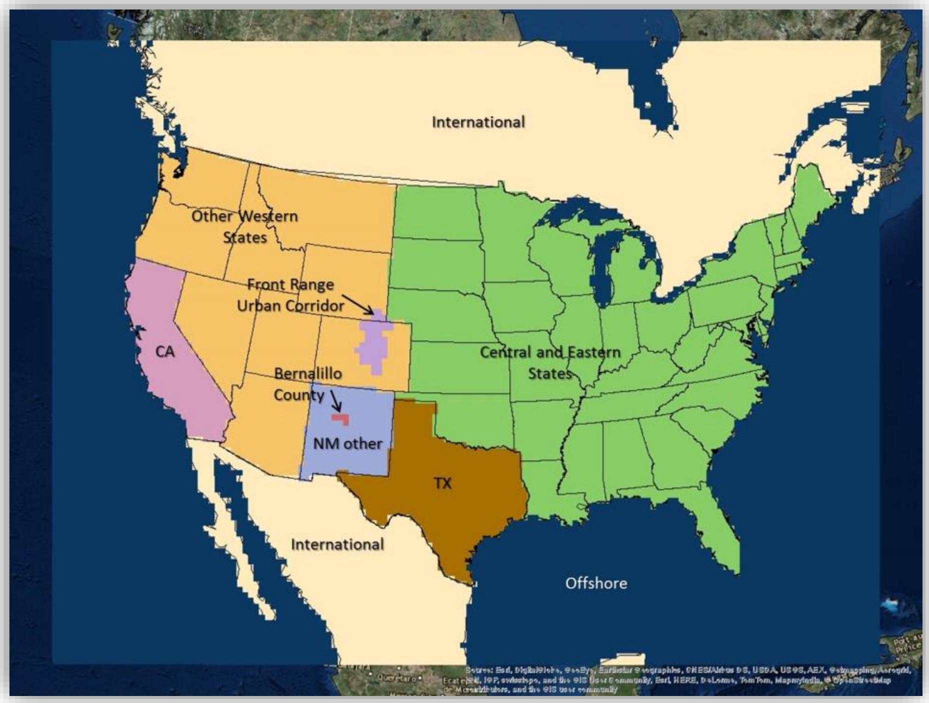

Figure 77. Geographic source regions for the source apportionment modeling analysis, as depicted on the 36-km modeling domain.

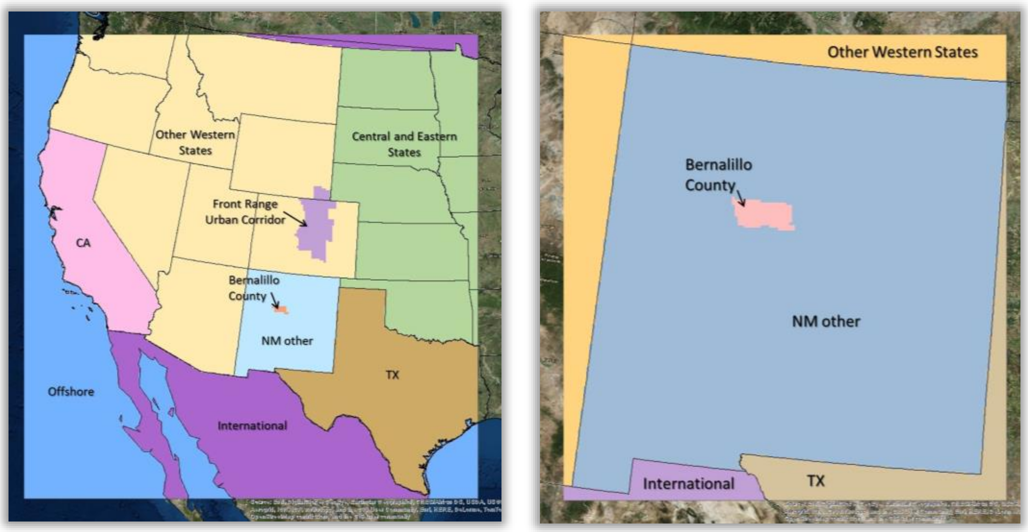

Figure 78. Geographic source regions for the source apportionment modeling analysis, as depicted on the 12-km (left) and 4-km (right) modeling domains.

In addition to the geographic source regions, ozone contributions were also tracked from four emissions source sectors:

- Biogenic sources
- On-road mobile sources
- Wildland fire
- Other anthropogenic emissions (e.g., nonroad mobile sources, EGU and non-EGU point sources, oil and gas sector, and other area sources).

Ozone contributions were also tracked from three individual EGU point sources and one refinery:

- Prewitt Escalante Generating Station
- PNM San Juan Generating Station
- Four Corners Power Plant
- Western Refining Gallup Refinery

The Escalante generating station is 85 miles west-northwest of the City of Albuquerque, while the San Juan and Four Corners power plants are in northwestern New Mexico about 150 miles from the City of Albuquerque. The Western Refining Gallup refinery is approximately 125 miles west-northwest from the City of Albuquerque. These four sources were tagged individually in the OSAT modeling. The average daily NO_x emissions from these sources are shown in Table 35. The Western Refining Gallup refinery also emitted 0.1 tons/day of VOC.[34]

Table 35. Average daily NO_x emissions [tons/day] for individually tagged point sources in the source apportionment modeling.

Source	June Episode	July Episode
Prewitt Escalante	5	9
San Juan	54	53
Four Corners	31	33[a]
Western Refining Gallup	1	1

[a] Four Corners was not fully operational between July 9 and July 15. The NO_x emissions from Four Corners averaged 55 tons/day between July 3 and July 8.

The oil and gas sector is the biggest source of anthropogenic VOC emissions in New Mexico (see Chapter 7). However, resources were not sufficient to specifically track contributions from the oil and gas sector in this OSAT analysis; instead, this sector is included in the "other anthropogenic"

[34] The Gallup refinery is permitted to emit 811 tons/year (2.22 tons/day) of NO_x and 800 tons/year (2.19 tons/day) of VOCs. The facility reported 404 tons/year (1.1 tons/day) of NO_x emissions for the 2014 NEI.

category. There is significant oil and gas activity in the northwestern and southeastern parts of New Mexico, and compressor stations are scattered throughout the Rio Grande Valley. The potential impact of oil and gas emissions on ozone in Albuquerque/Bernalillo County are explored as a sensitivity simulation in Chapter 10.

9.3 Data Analysis Approach

Raw output from a CAMx OSAT simulation consists of hourly ozone contributions from each source tag at each model grid cell. These hourly contributions were extracted and post-processed for all grid cells in Albuquerque/Bernalillo County. For each day and each grid cell, an 8-hr average ozone contribution for each source tag was calculated, based on the time period with the highest modeled 8-hr average concentration at the receptor. This approach reflects contributions when the total modeled ozone concentrations are highest, and ensures that ozone contributions from all source tags sum to total modeled 8-hr ozone concentration each day.

Ozone contributions can be determined by using the modeled 8-hr contributions in either an "absolute" or a "relative" sense. In the results shown here, absolute modeled contributions are used. Relative fractional (percentage) contributions are also shown. These fractional contributions can be combined with measured ambient concentrations to calculate ozone apportionment based on the relative source contributions.

The overall base-case model performance was within benchmarks established by the air quality modeling community (see Chapter 8), but on some days the modeled ozone plumes were displaced from their observed positions. Therefore, to obtain a representative analysis of ozone source contributions, the daily contribution was calculated for the grid cell with the highest modeled ozone in Albuquerque/Bernalillo County.

For each episode, the daily 8-hr ozone contributions for each tag were averaged across all days with modeled ozone concentrations greater than or equal to 65 ppb. This analysis approach is similar to the analysis approach established by EPA to support the CSAPR modeling analysis (U.S. Environmental Protection Agency, 2015b), except that the threshold used here is 65 ppb instead of 70 ppb. A 65 ppb threshold was selected here to ensure that all days with significant modeled ozone in Albuquerque/Bernalillo County were included in the analysis.

Several definitions of background ozone are used by EPA and researchers, depending on the study purpose and intended applications. Table 36 summarizes three common definitions of background ozone. Each definition builds upon the other. For example, natural background includes both the North American Background (NAB) and the U.S. Background (USB). Here, "background ozone" is defined as USB, which is the theoretical minimum ozone concentration achievable by U.S. regulatory policy. USB was also used by EPA to support the 2015 ozone NAAQS assessment (U.S. Environmental Protection Agency, 2014b).

Table 36. Definitions of background ozone.

Type	Definition
Natural Background	Ozone concentration in the absence of all anthropogenic ozone precursor emissions
North American Background	Ozone concentration in the absence of North American anthropogenic ozone precursor emissions
U.S. Background	Ozone concentration in the absence of United States anthropogenic ozone precursor emissions

9.4 June 2017 Ozone Episode

Figure 79 summarizes the average ozone source contributions in Albuquerque/Bernalillo County for days in the June 2017 modeling episode when the peak modeled ozone concentration in Albuquerque/Bernalillo County was greater than or equal to 65 ppb, based on the daily data shown in Tables 37 and 38. Green wedges in the pie charts indicate contributions from the boundary conditions, biogenic emissions, and wildland fire. These sources, along with international anthropogenic emissions, make up the U.S. background ozone contribution. The blue wedges in Figure 79 indicate anthropogenic emissions outside of New Mexico, while orange wedges indicate anthropogenic emissions from within New Mexico. Figure 79 is based on OSAT results from the three highest modeled ozone days, June 14-16. CAMx was one day late in capturing the local and regional increase in ozone concentrations, and therefore did not reproduce the high observed ozone concentrations in Albuquerque/Bernalillo County on June 13 (see Chapter 8).

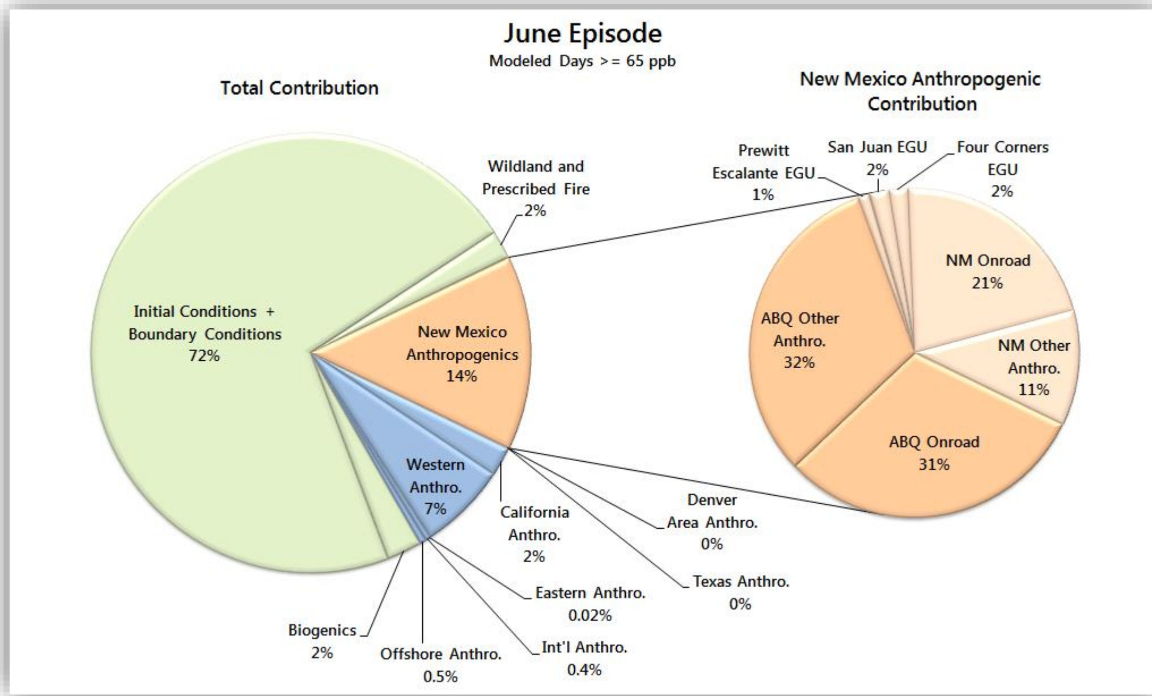

Figure 79. Average ozone source contributions in Albuquerque/Bernalillo County for days in the **June episode** when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb. The chart on the left represents the total ozone contribution (68 ppb), and the chart on the right represents the portion of ozone (14%, or 10 ppb) due to anthropogenic emissions in New Mexico.

Table 37. Modeled daily ozone source contributions (ppb and percentage) in Albuquerque/Bernalillo County for the **June episode** due to anthropogenic emissions from Albuquerque/Bernalillo County (ABQ), New Mexico (NM), the Denver Front Range areas (DEN), Texas (TX), California (CA), other western states (West), other eastern states (East), Canada and Mexico (Intl), fire, offshore sources (Ofsh), biogenic sources (Biog), and boundary conditions (BC). The total indicates the peak modeled 8-hr ozone concentration in Albuquerque/Bernalillo County. **Bold** values indicate days when the modeled peak 8-hr average ozone was greater than or equal to 65 ppb.

Date	ABQ	NM	DEN	TX	CA	West	East	Intl	Fire	Ofsh	Biog	BC	Total
6/12/2017	2.43 (5%)	1.14 (2%)	0.00 (0%)	0.00 (0%)	0.00 (0%)	0.32 (1%)	0.00 (0%)	0.71 (1%)	0.91 (2%)	0.56 (1%)	0.61 (1%)	43.87 (87%)	50.55
6/13/2017	1.78 (3%)	1.54 (3%)	0.00 (0%)	0.00 (0%)	1.21 (2%)	1.48 (3%)	0.03 (0%)	0.56 (1%)	0.27 (0%)	0.46 (1%)	0.78 (1%)	46.45 (85%)	54.56
6/14/2017	**6.08 (9%)**	**2.69 (4%)**	**0.00 (0%)**	**0.00 (0%)**	**1.24 (2%)**	**2.44 (4%)**	**0.02 (0%)**	**0.29 (0%)**	**0.52 (1%)**	**0.44 (1%)**	**1.31 (2%)**	**51.92 (78%)**	**66.95**
6/15/2017	**7.40 (11%)**	**2.52 (4%)**	**0.00 (0%)**	**0.00 (0%)**	**1.16 (2%)**	**5.03 (7%)**	**0.01 (0%)**	**0.29 (0%)**	**1.60 (2%)**	**0.25 (0%)**	**1.52 (2%)**	**49.08 (71%)**	**68.86**
6/16/2017	**4.57 (7%)**	**5.72 (9%)**	**0.00 (0%)**	**0.00 (0%)**	**1.97 (3%)**	**5.70 (9%)**	**0.01 (0%)**	**0.20 (0%)**	**2.06 (3%)**	**0.28 (0%)**	**2.37 (4%)**	**43.91 (66%)**	**66.79**

Table 38. Modeled daily ozone source contributions (ppb and percentage relative to the U.S. anthropogenic ozone contribution [Total Anthro]) for Albuquerque/Bernalillo County for the **June episode** due to on-road mobile source emissions from Albuquerque/Bernalillo County (ABQ Onroad) and New Mexico (NM Onroad), other anthropogenic emissions groups in Albuquerque/Bernalillo County (ABQ Other Anthro) and New Mexico (NM Other Anthro), the three individual EGU point sources in New Mexico that were tagged, Western Refining Gallup facility, and anthropogenic emissions outside of New Mexico (Other Anthro). Total Anthro indicates the total modeled U.S. anthropogenic ozone contribution in Albuquerque/Bernalillo County. **Bold** values indicate days when the total modeled peak 8-hr average ozone was greater than or equal to 65 ppb.

Date	ABQ Onroad	ABQ Other Anthro	Prewitt Escalante EGU	San Juan EGU	Four Corners EGU	Western Refining	NM Onroad	NM Other Anthro	Other Anthro	Total Anthro
6/12/2017	1.12 (22%)	1.31 (25%)	0.00 (0%)	0.00 (0%)	0.00 (0%)	0.00 (0%)	0.68 (13%)	0.46 (9%)	1.59 (31%)	5.16
6/13/2017	0.86 (12%)	0.92 (13%)	0.13 (2%)	0.00 (0%)	0.00 (0%)	0.02 (0%)	0.83 (12%)	0.56 (8%)	3.74 (53%)	7.06
6/14/2017	**2.85 (22%)**	**3.23 (25%)**	**0.06 (0%)**	**0.06 (0%)**	**0.05 (0%)**	**0.01 (0%)**	**1.64 (12%)**	**0.87 (7%)**	**4.43 (34%)**	**13.20**
6/15/2017	**3.71 (22%)**	**3.69 (22%)**	**0.04 (0%)**	**0.02 (0%)**	**0.02 (0%)**	**0.01 (0%)**	**1.61 (10%)**	**0.83 (5%)**	**6.75 (41%)**	**16.68**
6/16/2017	**2.36 (13%)**	**2.21 (12%)**	**0.23 (1%)**	**0.49 (3%)**	**0.47 (3%)**	**0.02 (0%)**	**2.97 (16%)**	**1.55 (8%)**	**8.15 (44%)**	**18.45**

During the June episode, the modeled peak 8-hr average ozone concentration in Albuquerque/Bernalillo County was greater than 65 ppb on 3 days, with an average of 68 ppb on those days (the averaged peak monitored ozone on these days was 72 ppb). Of that 68 ppb, U.S. anthropogenic sources outside Albuquerque/Bernalillo County contributed 16 ppb (24% of total ozone), while the boundary conditions contributed 48 ppb (71% of total ozone). The remaining 4 ppb (5% of total ozone) came from anthropogenic international emissions (mostly from Mexico), biogenic emissions, and fire.

Emissions from fires contributed between 0.5 and 2.0 ppb of ozone (around 2% of total ozone) in Albuquerque/Bernalillo County on the high ozone days. Contributions from fire emissions in New Mexico and outside New Mexico on June 15 are shown in Figure 80. The largest ozone contributions from fires were modeled south and west of Albuquerque/Bernalillo County.

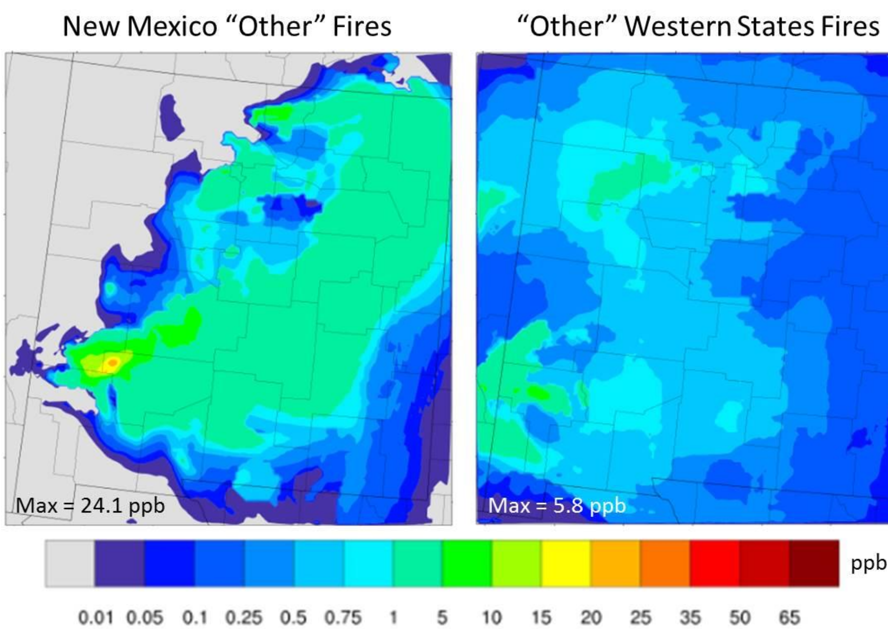

Figure 80. Modeled daily 8-hr ozone contributions on June 15, 2017, from fire emissions in New Mexico (left) and outside New Mexico (right). Green contours indicate ozone contributions of at least 1 ppb.

Notably, between June 13 and June 14 the ozone contribution from boundary conditions increased by 5 ppb, and ozone contributions from both local and non-local anthropogenic source groups increased as well. CAMx underestimated the peak 8-hr ozone concentration in Albuquerque/Bernalillo County by 12 ppb on June 13. This underestimation was likely due to underrepresented regional ozone contributions, and lower-than-expected local photochemical ozone production. Fire contributions were also low on June 13 compared to other modeled days; therefore, fire contributions may have also been underrepresented in the model on June 13.

Because the regional winds were blowing from the west and southwest during the June episode, there were some ozone contributions from anthropogenic emissions in California and the western states, but negligible contributions from the Denver Front Range region, Texas, and the eastern states. Anthropogenic emissions from California contributed between 1 and 2 ppb of ozone in Albuquerque/Bernalillo County during the June episode, while anthropogenic emissions from other western states contributed up to 6 ppb of ozone.

The New Mexico Anthropogenic wedge in Figure 79 includes contributions from anthropogenic emissions within New Mexico, which accounted for 14% of the total ozone in Albuquerque/Bernalillo County and more than half of the total U.S. anthropogenic ozone contribution during the June episode. The pie chart on the right in Figure 79 further subdivides New Mexico's anthropogenic contribution by on-road mobile source emissions from Albuquerque/Bernalillo County (ABQ Onroad) and elsewhere in New Mexico (NM Onroad), contributions from Prewitt Escalante, Four Corners, and San Juan EGUs, and other anthropogenic emissions from Albuquerque/Bernalillo County (ABQ Other Anthro) and elsewhere in New Mexico (NM Other Anthro). Nearly two-thirds of the in-state anthropogenic ozone contribution in Albuquerque/Bernalillo County comes from local emissions in Albuquerque/Bernalillo County, split almost equally between on-road mobile sources and other anthropogenic source sectors.

On high ozone days, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 5 and 7 ppb of ozone in Albuquerque/Bernalillo County. On-road mobile source emissions from Albuquerque/Bernalillo County contributed between 2 and 4 ppb of ozone, while on-road mobile source emissions from other counties in New Mexico contributed another 2 ppb.

Emissions from the Four Corners, San Juan, and Prewitt Escalante power plants in New Mexico contributed up to 1.2 ppb of ozone (combined) in Albuquerque/Bernalillo County on June 16, and no ozone on the other days. Contributions from the Four Corners and San Juan EGUs were more pronounced north of Albuquerque/Bernalillo County, but winds were not favorable for transporting those emissions further south into Albuquerque/Bernalillo County (see **Figure 81**). The ozone contribution from the Western Refining Gallup facility was negligible in Albuquerque/Bernalillo County on all modeled days and therefore is not represented in Figure 79. Outside of Albuquerque/Bernalillo County, emissions from the Western Refining Gallup facility contributed up to 0.7 ppb of ozone in New Mexico during the June episode.

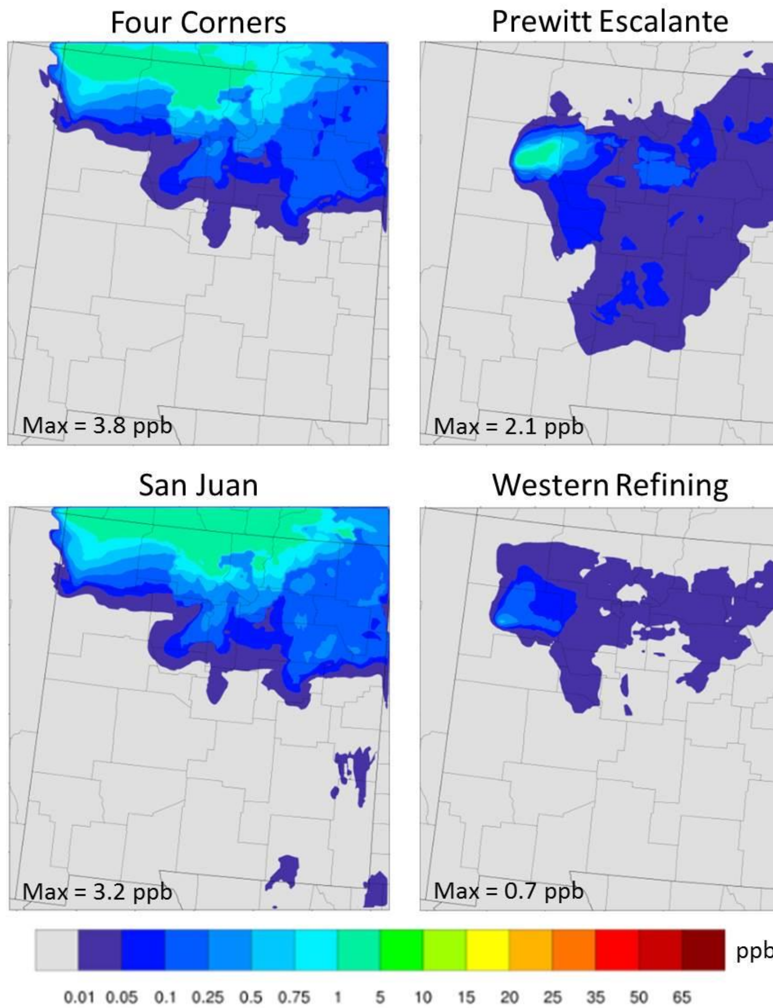

Figure 81. Modeled daily 8-hr ozone contributions on June 15, 2017, from the Four Corners, San Juan, and Prewitt Escalante EGUs and the Western Refining Gallup refinery. Green contours indicate ozone contributions of at least 1 ppb.

Emissions from non-EGU point sources (e.g., various industrial facilities, oil and gas exploration and production), nonroad mobile sources (e.g., construction equipment and locomotives), and other area sources (e.g., gas stations, dry cleaners, and livestock facilities) contributed significantly to ozone in Albuquerque/Bernalillo County. As emissions from on-road mobile sources and EGUs have decreased over time, the proportion of emissions from other emission source sectors has increased. This is consistent with findings from other recent modeled source apportionment assessments for major U.S. cities (Collet et al., 2014; Vijayaraghavan et al., 2016), and therefore it is important to account for non-EGU point sources, nonroad mobile sources, and other area sources when considering ozone impacts and potential emission control strategies. Potential ozone impacts from oil and gas exploration in New Mexico are examined in a sensitivity modeling scenario in Chapter 10.

9.5 July 2017 Ozone Episode

Figure 82 summarizes the average ozone source contributions in Albuquerque/Bernalillo County for days in the July 2017 modeling episode when the peak modeled ozone concentration in Albuquerque/Bernalillo County was greater than or equal to 65 ppb, based on the daily data shown in Tables 39 and 40. Green wedges in the pie charts indicate contributions from the boundary conditions, biogenic emissions, and wildland fire. These sources, along with international anthropogenic emissions, make up the U.S. background ozone contribution. The blue wedges in Figure 82 indicate anthropogenic emissions outside of New Mexico, while the orange wedges indicate anthropogenic emissions from within New Mexico. Figure 82 is based on OSAT results from the seven highest modeled ozone days (July 5-8 and July 10-12). On July 8, CAMx over-predicted ozone concentrations in Albuquerque/Bernalillo County (67 vs. 58 ppb), likely due to the lack of cloud cover in the model compared to the observations (see Chapter 8).

During the July episode, the modeled peak 8-hr average ozone concentration in Albuquerque/Bernalillo County was greater than 65 ppb on seven days, with an average of 69 ppb on those days (the averaged peak monitored ozone on these days was also 69 ppb). Of that 69 ppb, U.S. anthropogenic sources contributed 26 ppb (38% of total ozone), while the boundary conditions contributed 37 ppb (54% of total ozone). The remaining 6 ppb (8% of total ozone) came from anthropogenic international emissions (mostly from Mexico), biogenic emissions, and fire. Contributions from U.S. background ozone were smaller in the July episode than in the June episode. Anthropogenic international emissions (mostly from Mexico) were more important in the July episode and contributed between 0.6 and 2.4 ppb of ozone, or around 2% of total ozone in Albuquerque/Bernalillo County on high ozone days. Fires contributed between 0.6 and 1.5 ppb of ozone (around 1% of total ozone on average) in Albuquerque/Bernalillo County on the high ozone days, with larger fire contributions on July 10-12 compared to July 5-8. Notably, the ozone contribution from boundary conditions decreased (from 40 to 35 ppb) as the July ozone episode progressed, while ozone contributions from fire increased.

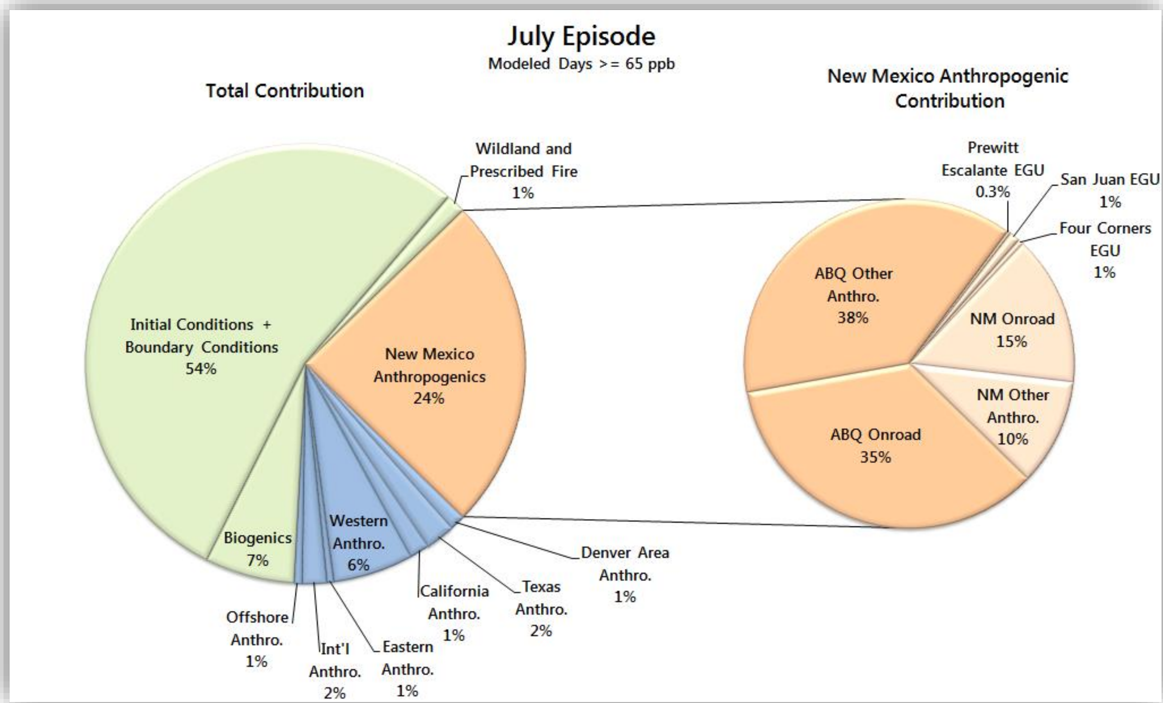

Figure 82. Average ozone source contributions in Albuquerque/Bernalillo County for days in the **July episode** when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb. The chart on the left represents the total ozone contribution (69 ppb), and the chart on the right represents the portion of ozone (24%, or 17 ppb) due to anthropogenic emissions in New Mexico.

Table 39. Modeled daily ozone source contributions (ppb and percentage) in Albuquerque/Bernalillo County for the **July episode** due to anthropogenic emissions from Albuquerque/Bernalillo County (ABQ), New Mexico (NM), the Denver Front Range areas (DEN), Texas (TX), California (CA), other western states (West), other eastern states (East), Canada and Mexico (Intl), fire, offshore sources (Ofsh), biogenic sources (Biog), and boundary conditions (BC). The total indicates the peak modeled 8-hr ozone concentration in Albuquerque/Bernalillo County. **Bold** values indicate days when the modeled peak 8-hr average ozone was greater than or equal to 65 ppb.

Date	ABQ	NM	DEN	TX	CA	West	East	Intl	Fire	Ofsh	Biog	BC	Total
7/3/2017	5.79 (10%)	1.87 (3%)	0.00 (0%)	0.07 (0%)	1.92 (3%)	2.28 (4%)	0.01 (0%)	2.11 (4%)	1.33 (2%)	1.45 (3%)	1.84 (3%)	37.12 (67%)	55.79
7/4/2017	5.02 (8%)	9.08 (15%)	0.00 (0%)	0.03 (0%)	2.24 (4%)	4.23 (7%)	0.01 (0%)	1.67 (3%)	1.51 (2%)	1.19 (2%)	2.84 (5%)	32.99 (54%)	60.81
7/5/2017	**10.79 (16%)**	**3.33 (5%)**	**0.97 (1%)**	**0.01 (0%)**	**1.92 (3%)**	**5.52 (8%)**	**0.02 (0%)**	**0.60 (1%)**	**0.91 (1%)**	**0.54 (1%)**	**3.54 (5%)**	**40.14 (59%)**	**68.29**
7/6/2017	**13.19 (19%)**	**3.89 (6%)**	**0.87 (1%)**	**0.75 (1%)**	**0.95 (1%)**	**3.81 (5%)**	**0.23 (0%)**	**0.62 (1%)**	**0.73 (1%)**	**0.31 (0%)**	**5.04 (7%)**	**40.34 (57%)**	**70.73**
7/7/2017	**9.40 (14%)**	**4.21 (6%)**	**0.52 (1%)**	**2.95 (4%)**	**0.60 (1%)**	**2.32 (3%)**	**0.77 (1%)**	**1.13 (2%)**	**0.57 (1%)**	**0.27 (0%)**	**5.69 (8%)**	**38.91 (58%)**	**67.34**
7/8/2017	**9.18 (14%)**	**5.95 (9%)**	**0.90 (1%)**	**2.76 (4%)**	**0.70 (1%)**	**3.09 (5%)**	**0.67 (1%)**	**1.57 (2%)**	**0.99 (1%)**	**0.51 (1%)**	**4.82 (7%)**	**35.73 (53%)**	**66.87**
7/9/2017	9.14 (14%)	4.26 (7%)	0.49 (1%)	1.02 (2%)	1.09 (2%)	5.92 (9%)	0.25 (0%)	1.40 (2%)	1.32 (2%)	0.48 (1%)	4.05 (6%)	34.15 (54%)	63.57
7/10/2017	**16.47 (23%)**	**4.96 (7%)**	**1.36 (2%)**	**0.67 (1%)**	**0.97 (1%)**	**5.81 (8%)**	**0.30 (0%)**	**1.10 (2%)**	**1.46 (2%)**	**0.38 (1%)**	**4.61 (6%)**	**34.28 (47%)**	**72.37**
7/11/2017	**16.27 (23%)**	**5.07 (7%)**	**0.76 (1%)**	**0.99 (1%)**	**0.69 (1%)**	**4.19 (6%)**	**0.30 (0%)**	**1.22 (2%)**	**1.13 (2%)**	**0.33 (0%)**	**4.13 (6%)**	**35.84 (51%)**	**70.92**
7/12/2017	**11.03 (17%)**	**4.70 (7%)**	**0.34 (1%)**	**1.85 (3%)**	**1.38 (2%)**	**3.57 (5%)**	**0.23 (0%)**	**2.38 (4%)**	**1.03 (2%)**	**0.64 (1%)**	**3.71 (6%)**	**34.59 (53%)**	**65.45**
7/13/2017	7.65 (13%)	5.16 (9%)	0.21 (0%)	1.18 (2%)	2.66 (4%)	3.14 (5%)	0.19 (0%)	2.47 (4%)	1.29 (2%)	0.99 (2%)	3.53 (6%)	31.73 (53%)	60.20
7/14/2017	5.20 (10%)	4.26 (8%)	0.06 (0%)	2.68 (5%)	0.62 (1%)	0.69 (1%)	0.27 (1%)	3.26 (6%)	0.42 (1%)	0.75 (1%)	2.81 (5%)	32.82 (61%)	53.84

Table 40. Modeled daily ozone source contributions (ppb and percentage relative to the U.S. anthropogenic ozone contribution) in Albuquerque/Bernalillo County for the **July episode** due to on-road mobile source emissions from Albuquerque/Bernalillo County (ABQ Onroad) and New Mexico (NM Onroad), other anthropogenic emissions groups in Albuquerque/Bernalillo County (ABQ Other Anthro) and New Mexico (NM Other Anthro), the three individual EGU point sources that were tagged, the Western Refining Gallup facility, and anthropogenic emissions outside of New Mexico (Other Anthro). Total Anthro indicates the total modeled U.S. anthropogenic ozone contribution in Albuquerque/Bernalillo County. **Bold** values indicate days when the total modeled peak 8-hr ozone was greater than or equal to 65 ppb.

Date	ABQ Onroad	ABQ Anthro Other	Prewitt Escalante EGU	San Juan EGU	Four Corners EGU	Western Refining	NM Onroad	NM Anthro Other	Other Anthro	Total Anthro
7/3/2017	2.72 (18%)	3.07 (20%)	0.18 (1%)	0.02 (0%)	0.04 (0%)	0.04 (0%)	0.93 (6%)	0.65 (4%)	7.85 (51%)	15.50
7/4/2017	2.34 (10%)	2.68 (11%)	0.04 (0%)	1.11 (5%)	1.51 (6%)	0.00 (0%)	3.71 (16%)	2.71 (12%)	9.37 (40%)	23.47
7/5/2017	**5.24 (22%)**	**5.55 (23%)**	**0.01 (0%)**	**0.13 (1%)**	**0.16 (1%)**	**0.00 (0%)**	**2.20 (9%)**	**0.83 (4%)**	**9.58 (40%)**	**23.70**
7/6/2017	**6.73 (27%)**	**6.46 (26%)**	**0.01 (0%)**	**0.10 (0%)**	**0.14 (1%)**	**0.00 (0%)**	**2.23 (9%)**	**1.42 (6%)**	**7.54 (31%)**	**24.63**
7/7/2017	**4.48 (20%)**	**4.92 (22%)**	**0.00 (0%)**	**0.02 (0%)**	**0.03 (0%)**	**0.00 (0%)**	**2.46 (11%)**	**1.70 (8%)**	**8.56 (39%)**	**22.17**
7/8/2017	**4.49 (18%)**	**4.69 (19%)**	**0.00 (0%)**	**0.04 (0%)**	**0.05 (0%)**	**0.00 (0%)**	**3.63 (14%)**	**2.23 (9%)**	**10.20 (40%)**	**25.33**
7/9/2017	4.13 (17%)	5.01 (21%)	0.07 (0%)	0.13 (1%)	0.13 (1%)	0.00 (0%)	1.97 (8%)	1.97 (8%)	10.64 (44%)	24.05
7/10/2017	**7.49 (23%)**	**8.99 (28%)**	**0.17 (1%)**	**0.28 (1%)**	**0.17 (1%)**	**0.02 (0%)**	**2.26 (7%)**	**2.07 (6%)**	**10.58 (33%)**	**32.03**
7/11/2017	**7.76 (26%)**	**8.51 (29%)**	**0.10 (0%)**	**0.28 (1%)**	**0.09 (0%)**	**0.01 (0%)**	**2.46 (8%)**	**2.13 (7%)**	**8.47 (28%)**	**29.81**
7/12/2017	**5.15 (20%)**	**5.88 (23%)**	**0.06 (0%)**	**0.37 (1%)**	**0.06 (0%)**	**0.01 (0%)**	**2.21 (8%)**	**1.98 (8%)**	**10.41 (40%)**	**26.13**
7/13/2017	3.87 (16%)	3.78 (16%)	0.13 (1%)	0.87 (4%)	0.07 (0%)	0.01 (0%)	2.06 (9%)	2.02 (9%)	10.84 (46%)	23.65
7/14/2017	2.48 (14%)	2.71 (15%)	0.05 (0%)	0.10 (0%)	0.01 (0%)	0.01 (0%)	1.93 (11%)	2.17 (12%)	8.33 (47%)	17.79

The regional winds during the July episode were generally blowing from the northeast, east, and southeast, depending on the day. As a result, there were some ozone contributions from anthropogenic emissions in Texas (as much as 3 ppb on a given day) and from the Denver Front Range region (as much as 1.4 ppb on a given day) on many of the modeled high-ozone days in Albuquerque/Bernalillo County. Because of regional recirculation, there were also significant ozone contributions from anthropogenic emissions in California and other western states (up to 6 ppb on a given day). There were also small ozone contributions of up to 1% of total ozone from eastern states, compared to a negligible contribution during the June episode.

The New Mexico Anthropogenic wedge in Figure 82 includes contributions from anthropogenic emissions within New Mexico, which accounted for 24% of the total ozone in Albuquerque/Bernalillo County and about two-thirds of the total U.S. anthropogenic ozone contribution during the July episode. In-state contributions were much larger in July than in June. The pie chart on the right in Figure 82 further subdivides New Mexico's anthropogenic contribution by on-road mobile sources in Albuquerque/Bernalillo County (ABQ Onroad) and elsewhere in New Mexico (NM Onroad), contributions from Prewitt Escalante, Four Corners, and San Juan EGUs, and other anthropogenic emissions from Albuquerque/Bernalillo County (ABQ Other Anthro) and elsewhere in New Mexico (NM Other Anthro). About 75% of the in-state anthropogenic ozone contribution in Albuquerque/Bernalillo County comes from emissions in Albuquerque/Bernalillo County (compared to about two-thirds of the in-state contribution in the June episode), split almost equally between on-road mobile sources and other anthropogenic source sectors.[35] Ozone contributions from on-road mobile sources on July 10 are shown in Figure 83.

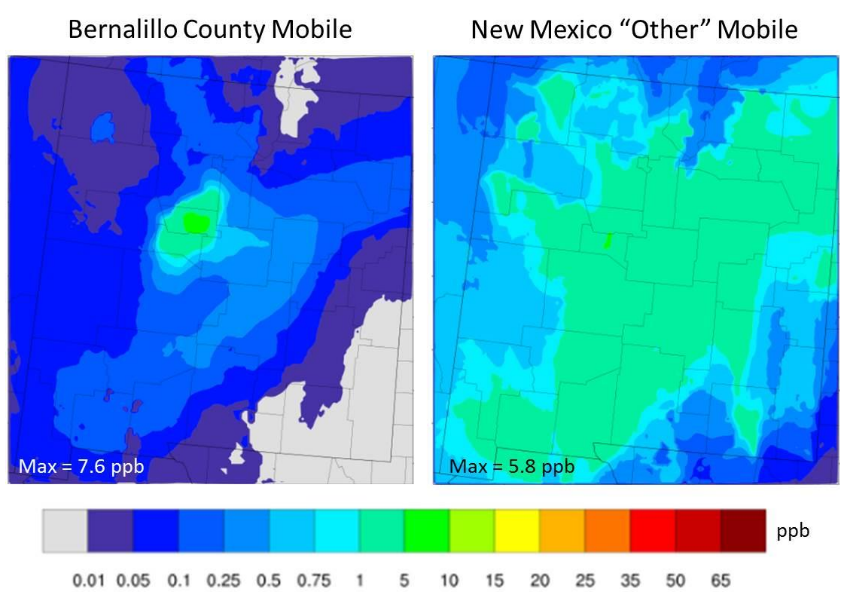

Figure 83. Modeled daily 8-hr ozone contributions on July 10, 2017, from on-road mobile sources in Albuquerque/Bernalillo County (left) and from other counties in New Mexico (right). Green contours indicate ozone contributions of at least 1 ppb. The ozone contributions from on-road mobile source emissions in Albuquerque/Bernalillo County were as large as 7.6 ppb.

[35] This includes emissions from construction equipment and other "nonroad" engines and vehicles, EGUs, and industrial fuel combustion. Rail emissions from Bernalillo County were not included in EPA's 2014 modeling platform, but those emissions are small (less than 0.1 tons/day of NO_x) and would not significantly impact the ozone source apportionment modeling analysis.

On high ozone days, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 9 and 16 ppb of ozone in Albuquerque/Bernalillo County (compared to 5-7 ppb in the June episode). On-road mobile sources from Albuquerque/Bernalillo County contributed between 5 and 8 ppb of ozone, while on-road mobile sources from other counties in New Mexico contributed another 2-3 ppb, with some of that coming from Sandoval and Valencia Counties.

Emissions from the Four Corners, San Juan, and Prewitt Escalante power plants in New Mexico contributed up to 0.6 ppb (combined) of ozone in Albuquerque/Bernalillo County on July 10. The Four Corners EGU was not fully operational between July 9 and July 15, and therefore the modeled ozone impacts from Four Corners were negligible on those days. When Four Corners was fully operational, its daily emissions were higher in July than in June (see Table 35). The ozone contribution from Prewitt Escalante was never more than 0.2 ppb in Albuquerque/Bernalillo County on any given day during the July episode, and was negligible on several days. As in the June episode, the ozone contribution from the Western Refining Gallup facility was negligible in Albuquerque/Bernalillo County.

Emissions from non-EGU point sources (e.g., various industrial facilities, oil and gas exploration and production), nonroad mobile sources (e.g., construction equipment and locomotives), and other area sources (e.g., gas stations, dry cleaners, and livestock facilities) contributed significantly to ozone in Albuquerque/Bernalillo. As emissions from on-road mobile sources and EGUs have decreased over time, the proportion of emissions from other emission source sectors has increased. Therefore it is important to account for non-EGU point sources, nonroad mobile sources, and other area sources when considering ozone impacts and potential emission control strategies. Potential ozone impacts from oil and gas exploration in New Mexico are examined in a sensitivity modeling scenario in Chapter 10.

9.6 Summary

Ozone source apportionment modeling of the Albuquerque/Bernalillo County ozone episodes during June and July 2017 was conducted using CAMx. Calculations of ozone contributions were based on 8-hr averages and the highest modeled ozone concentrations in Albuquerque/Bernalillo County. The source apportionment results show stark differences between the June and July 2017 ozone episodes. The ozone in Albuquerque/Bernalillo County during the June episode was driven largely by emissions outside of New Mexico, whereas ozone during the July episode was driven more strongly by local anthropogenic emissions from within Albuquerque/Bernalillo County and New Mexico.

On high ozone days during the June episode, the boundary conditions accounted for 48 ppb of ozone in Albuquerque/Bernalillo County (or 72% of total ozone), while U.S. anthropogenic sources contributed 16 ppb (24% of total ozone). The remaining 4 ppb (4% of total ozone) came from anthropogenic international emissions (mostly from Mexico), biogenic emissions, and fire, with fires contributing about 1.5 ppb of ozone. On high ozone days, anthropogenic emissions from within

Albuquerque/Bernalillo County contributed between 5 and 7 ppb of ozone in Albuquerque/Bernalillo County, with around half of that from on-road mobile source. U.S. anthropogenic emissions outside of New Mexico contributed between 4 and 8 ppb of ozone in Albuquerque/Bernalillo County. Major power plants in New Mexico contributed up to around 1 ppb of ozone in Albuquerque/Bernalillo County on one day (June 16) during the episode.

On high ozone days during the July episode, the boundary conditions contributed 37 ppb (54% of total ozone) while U.S. anthropogenic sources contributed 26 ppb (38% of total ozone). The remaining 6 ppb (8% of total ozone) came from anthropogenic international emissions (mostly from Mexico), biogenic emissions, and fire. On high ozone days, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 9 and 16 ppb of ozone in Albuquerque/Bernalillo County, with about half of that from on-road mobile sources. U.S. anthropogenic emissions from outside of New Mexico contributed between 7 and 10 ppb, with some contributions from emissions in Texas (as much as 3 ppb on a given day) and from the Denver Front Range region (as much as 1.4 ppb on a given day). Major power plants in New Mexico contributed less than 1 ppb of ozone in Albuquerque/Bernalillo County during the July episode

These source apportionment results have important implications for air quality planning. The meteorological conditions, fire activity, and regional pollutant transport patterns that were associated with high ozone in Albuquerque/Bernalillo County were very different between the two modeling episodes. During the June episode, contributions from the western states and the CAMx boundary condition dominated the modeled ozone in Albuquerque/Bernalillo County. Modeled ozone contributions from fires were up to 2 ppb in Albuquerque/Bernalillo County, and greater than 5 ppb in New Mexico as a result of fires burning within the state. Given the relatively small contributions from local anthropogenic emissions within Albuquerque/Bernalillo County during the June episode (5-7 ppb), local emission controls within Albuquerque/Bernalillo County would not be effective for reducing ozone concentrations in Albuquerque/Bernalillo County under similar meteorological conditions. During the July episode, ozone contributions due to anthropogenic emissions within Albuquerque/Bernalillo County were more prominent (9-16 ppb), and therefore local emission controls within Albuquerque/Bernalillo County would be more effective for reducing ozone concentrations in Albuquerque/Bernalillo County under similar meteorological conditions.

Ozone contributions in Albuquerque/Bernalillo County from the Four Corners, San Juan, and Prewitt Escalante power plants in New Mexico were less than 1 ppb (combined) on most days as the regional wind patterns often prevented emissions from these power plants from reaching Albuquerque/Bernalillo County. On many days, ozone contributions from anthropogenic emissions in California, Texas, and other western states were larger than contributions from the major New Mexico power plants. The recent decommissioning if two units at the San Juan power plant, and the recent addition of NO_x emission controls at the Four Corners power plant, will reduce future air quality impacts from these facilities.

10. Sensitivity Analysis

10.1 Overview

This chapter summarizes and documents the results from eight base-case sensitivity air quality simulations conducted for ozone episodes in Albuquerque/Bernalillo County during June and July 2017 using CAMx. The intent of these simulations was to test the sensitivity of ozone levels in Albuquerque/Bernalillo County to various local and non-local changes in VOC and NO_x emissions. The results discussed in this chapter can be used to assess (1) whether ozone reductions should be accomplished through reductions in NO_x emissions, VOC reductions, or both; and (2) under what types of conditions local emission reductions may be effective at reducing ozone concentrations. This analysis therefore has important implications for air quality planning.

The eight sensitivity simulations summarized here were developed in consultation with the Albuquerque EHD and include

- 10% reduction of Albuquerque/Bernalillo County anthropogenic NO_x emissions.
- 10% reduction of Albuquerque/Bernalillo County anthropogenic VOC emissions.
- 25% reduction of Albuquerque/Bernalillo County on-road mobile source NO_x emissions.
- 25% reduction of New Mexico[36] oil and gas emissions.
- 5% increase in on-road mobile source NOx emissions and 7% increase in on-road mobile source VOC emissions in Albuquerque/Bernalillo County, to reflect the impact of the Albuquerque/Bernalillo County Inspection and Maintenance (I&M) program.
- An increase in NO_x emissions from the Reeves and Rio Bravo power plants to 11.8 tons/day and 3.5 tons/day, respectively, to reflect the operation of these plants at permitted emission levels.
- 100% reduction of Sandoval County anthropogenic emissions.
- 100% reduction of Valencia County anthropogenic emissions.

The results from these sensitivity modeling analyses built upon the findings from the source apportionment analysis (see Chapter 9): ozone in Albuquerque/Bernalillo County was more sensitive to changes in local NO_x emissions in the July episode compared to the June episode. The results confirmed that emission reductions within Albuquerque/Bernalillo County would be less effective at reducing the ozone concentrations in Albuquerque/Bernalillo County for meteorological conditions

[36] Oil and gas emissions were reduced throughout the 4-km modeling domain. The 4-km modeling domain includes all of New Mexico, plus small portions of neighboring Arizona, Colorado, Texas, and Utah. Almost all of the oil and gas activity in the 4-km domain is from New Mexico.

encountered during the June episode, but would be more effective at reducing ozone concentrations for meteorological conditions encountered during the July episode.

The key findings from the sensitivity modeling analysis are as follows:

- NO_x emission controls will be effective at reducing ozone in Albuquerque/Bernalillo County. VOC emission controls may not be effective at reducing ozone unless they are substantial (>10%).
- Emissions from Valencia and Sandoval counties impact ozone in Albuquerque/Bernalillo County by as much as 4 ppb.
- The Reeves and Rio Bravo power plants would impact ozone in Albuquerque/Bernalillo County by as much as 3 ppb if they operated at permitted emission levels.
- The I&M program in Albuquerque/Bernalillo County reduces on-road mobile source NO_x emissions by 5% and VOC emissions by 7%, and reduces ozone in Albuquerque/Bernalillo County by up to 0.25 ppb.
- Ozone in Albuquerque/Bernalillo County is sensitive to emissions from oil and gas operations in New Mexico. Reducing NO_x and VOC emissions from the oil and gas sector in New Mexico by 25% would reduce ozone concentrations in Albuquerque/Bernalillo County by up to 1 ppb.

10.2 Analysis Approach

CAMx sensitivity modeling was conducted for the June and July 2017 ozone episodes in Albuquerque/Bernalillo County described in Chapter 2. The 2017 base-case CAMx simulations described in Chapter 8 are the basis for this analysis. The CAMx configurations and inputs that were used for these sensitivity simulations are the same as those for the base-case modeling, except for changes in the NO_x and VOC emissions that were associated with each emissions sensitivity case.

A sensitivity analysis involves two types of CAMx simulations: a base-case simulation, and one or more sensitivity simulations. Here, the base case refers to the 2017 base-case simulation described in Chapter 8. In each sensitivity simulation, all input data and modeling options remain unchanged from the base case except for one input variable of interest. In this analysis, emissions inputs for eight alternative emissions scenarios were developed. To determine the impact of the emission control, a CAMx simulation with the alternative emissions is conducted, and then the difference in modeled concentrations between the base-case and sensitivity simulation is calculated. This approach was used to estimate the air quality impacts of the sensitivity scenarios described in this chapter.

Raw output from a CAMx simulation consists of hourly ozone concentrations at each model grid cell for the modeling episodes. Hourly ozone concentrations from CAMx were extracted and post-processed for all grid cells in the 4-km resolution domain. For each modeled episode day, the peak 8-hr average ozone concentration was calculated at each grid cell in the 4-km domain. The results from the sensitivity simulations were compared to those from the base-case simulations at the six ozone monitoring sites in the Albuquerque MSA. The overall base-case model performance was within the benchmarks established by the air quality modeling community (see Chapter 8), but on some days the modeled ozone plumes were displaced from their observed positions. Therefore, sensitivity modeling results were also analyzed for the grid cell with the highest daily modeled 8-hr ozone in Albuquerque/Bernalillo County (the "Bernalillo County Grid Cell with Modeled Maximum" location).

Results of this sensitivity modeling analysis are described below. Results are shown for the eight sensitivity scenarios for each of the two modeling episodes, starting with the June episode. Differences in modeled peak 8-hr ozone concentrations, as well as spatial plots of modeled ozone differences, are provided below.

10.3 June 2017 Ozone Episode

Peak 8-hr average ozone concentrations during the June episode were relatively insensitive to changes in NO_x and VOC emissions in Albuquerque/Bernalillo County. Of the sensitivity scenarios that were modeled, the largest changes in ozone occurred in the simulation with a 25% reduction of NO_x and VOC emissions from the oil and gas sector. Small decreases—up to 0.4 ppb, in peak 8-hr average ozone concentrations at several sites across the sensitivity simulations—indicate NO_x-limited conditions in Albuquerque/Bernalillo County. Peak 8-hr average ozone concentrations increased as a result of NO_x emission reductions within the urban core of Albuquerque, including a 1.5 ppb (2.6%) increase at the Del Norte site, which was related to the underprediction of ozone concentration at that site in the base-case modeling (see Chapter 8).

10.3.1 10% Reduction in NO_x Emissions

Figure 84 and Table 41 show the modeled impacts of a 10% reduction in NO_x emissions in Albuquerque/Bernalillo County during the June episode. Spatial plots of the absolute concentration differences are shown in **Figure 85**. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing NO_x emissions would decrease ozone concentrations.

Reducing NO_x emission in Albuquerque/Bernalillo County decreased modeled ozone concentrations at some sites in the Albuquerque MSA and increased ozone concentrations at others. The modeled peak 8-hr average ozone concentration decreased by as much as 0.24 ppb (0.4%) in Albuquerque/Bernalillo County. The peak 8-hr ozone concentration increased at the Del Norte, South Valley, and Foothills sites on most days in the June episode, and at the Bernalillo site (in Sandoval County) on June 12. This modeled increase was most pronounced at the Del Norte site (with a maximum increase of about 1 ppb), where the base-case modeling showed lower ozone concentrations relative to the surrounding grid cells. The increases in ozone might indicate VOC-limited conditions within some portions of the Albuquerque urban core. Under this chemistry regime, decreasing NO_x emissions will decrease NO_x-titration of ozone, leading to an increase in ozone concentration. There were high-modeled NO_2 concentrations associated with large NO_x emissions from I-40 that were allocated to the grid cell of the 4-km domain in which the Del Norte site is located. This resulted in a large ozone underestimation at the Del Norte site, and therefore the modeled VOC-limited conditions are likely an artifact of poor model performance at the Del Norte site. Elsewhere in Albuquerque/Bernalillo County, ozone concentrations generally decreased slightly or were unaffected in this sensitivity scenario.

The spatial plots in Figure 85 indicate that the majority of NO_x emissions in Albuquerque/Bernalillo County originated in the City of Albuquerque. While the reduction in local NO_x emissions produced an ozone dis-benefit within the city, it appears that there was less NO_x available to form ozone downwind of the city.

Figure 84. Differences in peak 8-hr average ozone concentrations between the 10% NO_x reduction sensitivity simulation and the base-case simulation in the June ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 41. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 10% NO_x reduction sensitivity simulation and the base-case simulation for the June ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.96	1.8%	0.57	1.3%	N/A	1.5%
South Valley	0.46	0.8%	-0.11	-0.2%	0.05	0.2%
Foothills	0.16	0.3%	-0.03	-0.1%	0.02	0.1%
Bernalillo	0.10	0.2%	-0.15	-0.3%	N/A	-0.1%
Los Lunas	0.00	0.0%	-0.11	-0.2%	-0.05	-0.1%
Double Eagle	0.00	0.0%	-0.17	-0.3%	N/A	-0.1%
Bernalillo County Grid Cell with Modeled Maximum	0.02	0.0%	-0.24	-0.4%	-0.18	0.0%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

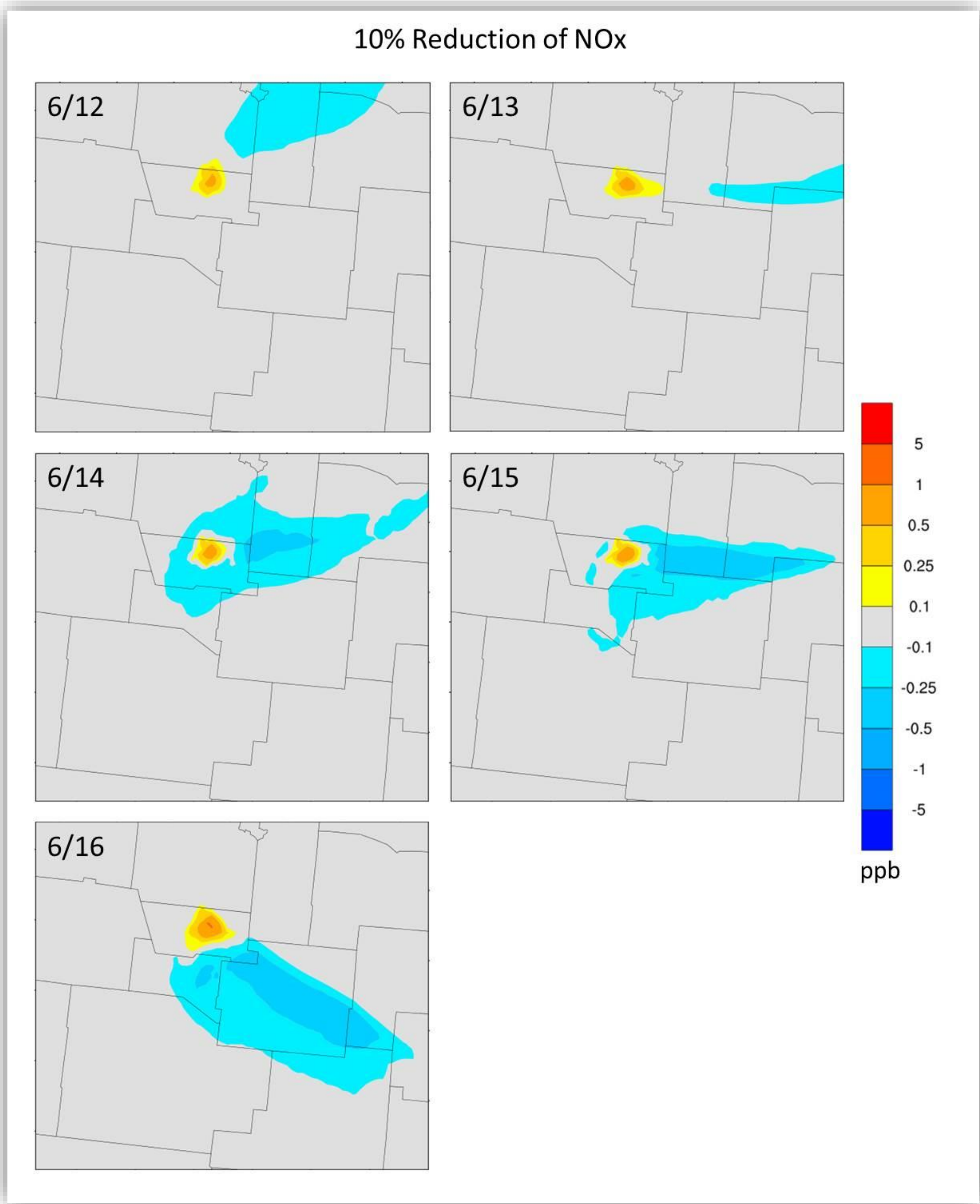

Figure 85. Differences between peak 8-hr average ozone concentrations modeled in the 10% NO_x reduction sensitivity simulation and in the base-case simulation for the June episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.3.2 10% Reduction in VOC Emissions

Figure 86 and Table 42 show the modeled impacts of a 10% reduction of VOC emissions in Albuquerque/Bernalillo County during the June ozone episode. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing VOC emissions would decrease ozone concentrations. Modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County were insensitive to a 10% change in local VOC emissions. Reducing VOC emissions by 10% in Albuquerque/Bernalillo County resulted in negligible decreases (no larger than 0.1 ppb) in peak 8-hr ozone concentrations.

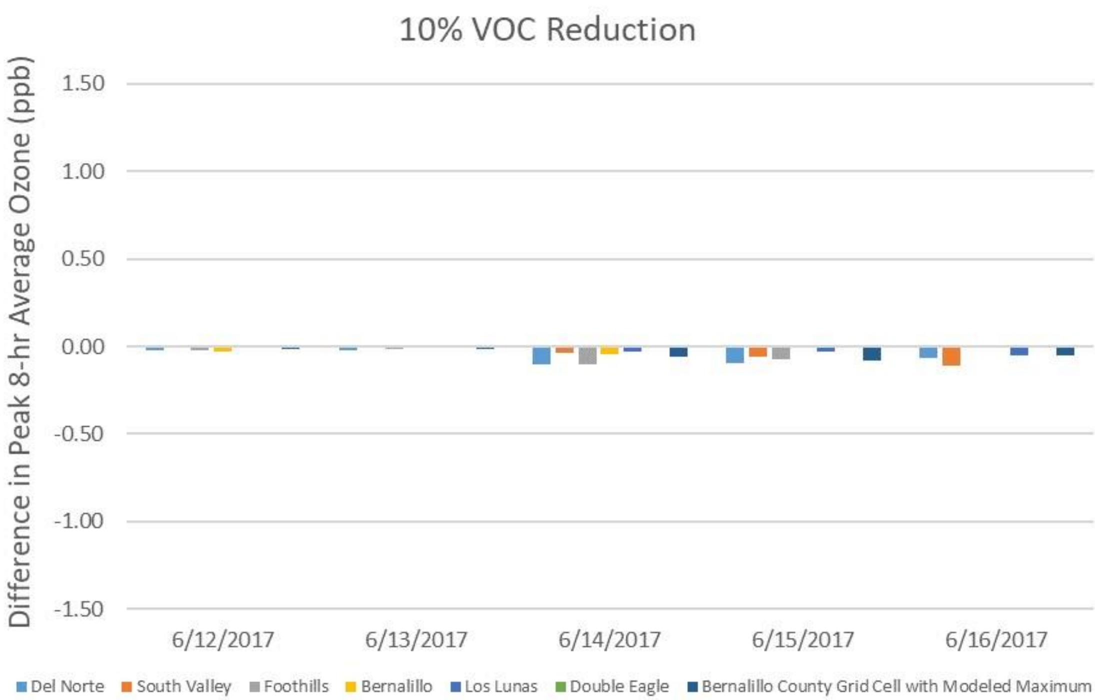

Figure 86. Differences in peak 8-hr average ozone concentrations between the 10% VOC reduction sensitivity simulation and base-case simulation in the June ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 42. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 10% VOC reduction sensitivity simulation and the base-case simulation for the June ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	-0.02	-0.1%	-0.10	-0.2%	N/A	-0.1%
South Valley	-0.00	-0.0%	-0.11	-0.2%	-0.06	-0.1%
Foothills	0.00	0.0%	-0.11	-0.2%	-0.07	-0.1%
Bernalillo	0.00	0.0%	-0.04	-0.1%	N/A	-0.0%
Los Lunas	0.00	0.0%	-0.05	-0.1%	-0.05	-0.0%
Double Eagle	0.00	0.0%	-0.01	-0.0%	N/A	0.0%
Bernalillo County Grid Cell with Modeled Maximum	-0.01	-0.0%	-0.08	-0.1%	-0.06	-0.1%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

10.3.3 25% Reduction in On-Road NO_x Emissions

Figure 87 and Table 43 show the modeled impacts of a 25% reduction of NO_x emissions from on-road mobile sources in Albuquerque/Bernalillo County during the June ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 88. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing on-road mobile source NO_x emissions would decrease ozone concentrations.

The impact of reducing on-road mobile source NO_x emissions on peak 8-hr ozone concentrations ranged from a 0.3 ppb (0.5%) decrease (on June 14 at the Bernalillo County Grid Cell with Modeled Maximum ozone) to a 1.5 ppb (2.6%) increase (on June 15 at the Del Norte site). The spatial distribution of the modeled impacts (see Figure 88) was similar to the spatial distribution shown in Figure 85, but the magnitude of the impacts was slightly larger. As previously discussed, the modeled increase in ozone concentrations at the Del Norte site was likely an artifact of poor model performance at the Del Norte monitoring site.

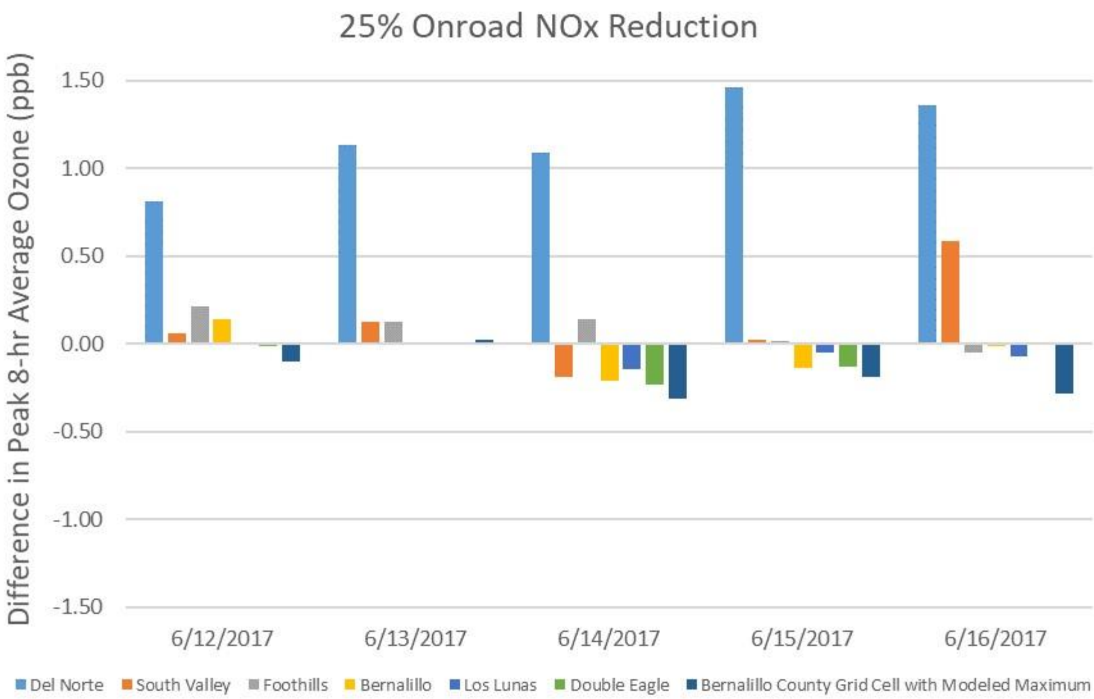

Figure 87. Differences in peak 8-hr average ozone concentrations between the 25% on-road NO_x reduction simulation and base-case simulation in the June ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 43. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 25% on-road NO_x reduction sensitivity simulation and the base-case simulation for the June ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	1.46	2.6%	0.81	1.8%	N/A	2.2%
South Valley	0.59	1.0%	-0.19	-0.3%	0.02	0.2%
Foothills	0.21	0.4%	-0.05	-0.1%	0.02	0.2%
Bernalillo	0.14	0.3%	-0.21	-0.3%	N/A	-0.1%
Los Lunas	0.00	0.0%	-0.15	-0.2%	-0.08	-0.1%
Double Eagle	0.00	-0.0%	-0.23	-0.4%	N/A	-0.1%
Bernalillo County Grid Cell with Modeled Maximum	0.02	0.0%	-0.32	-0.5%	-0.26	-0.3%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

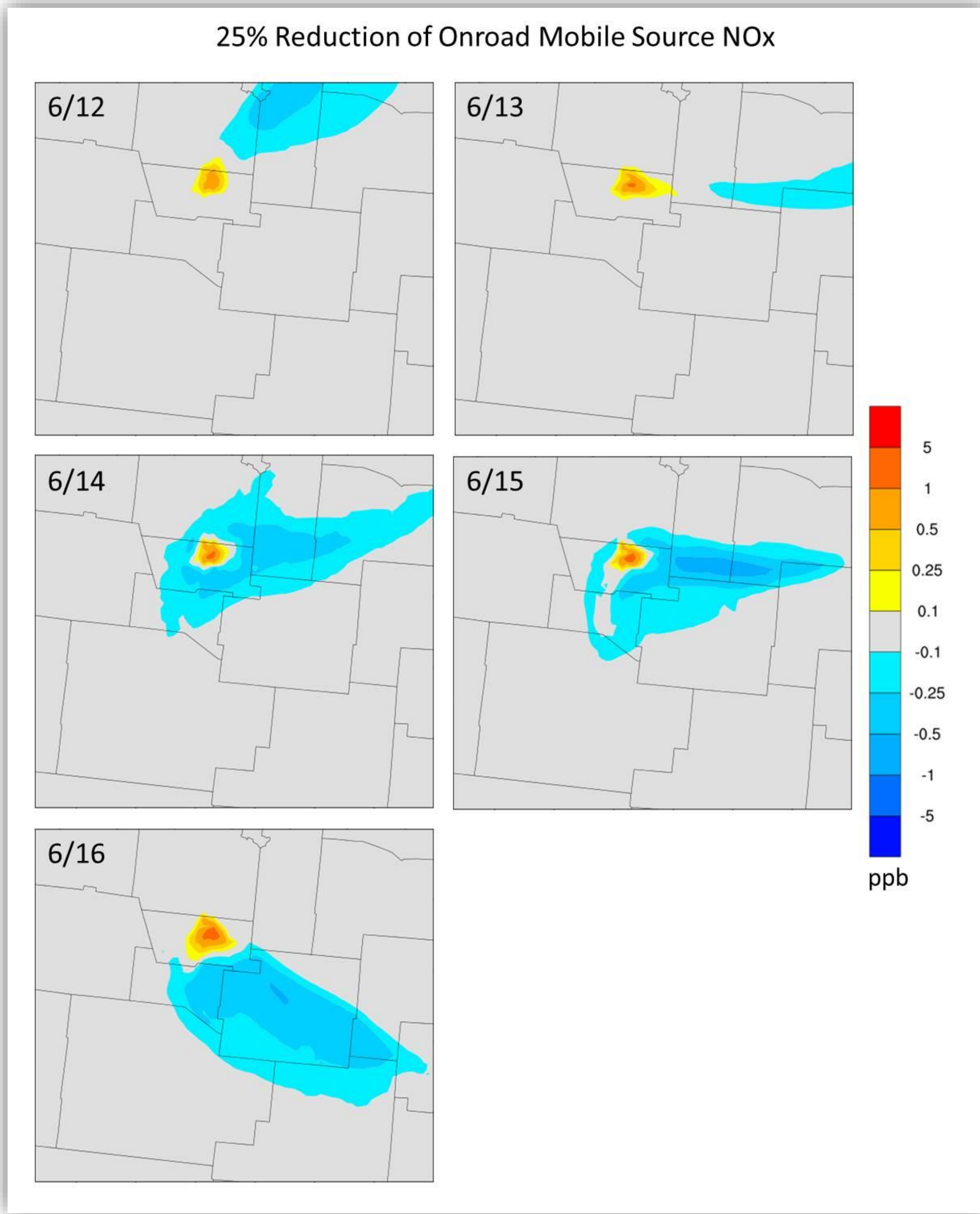

Figure 88. Differences between peak 8-hr average ozone concentrations modeled in the 25% on-road NO_x reduction sensitivity simulation and in the base-case simulation for the June episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.3.4 25% Reduction in NO_x and VOC Emissions in the Oil and Gas Sector

Figure 89 and Table 44 show the modeled impacts of 25% reductions of NO_x and VOC emissions from the oil and gas sector in New Mexico during the June ozone episode. Spatial plots of the absolute concentration are shown in Figure 90. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing emissions from the oil and gas sector in New Mexico would decrease ozone concentrations.

Reducing domain-wide emissions from the oil and gas sector by 25% decreased the peak 8-hr average ozone concentrations in the Albuquerque MSA by as much as 0.4 ppb (0.7%). On each day during the episode, the modeled impacts were similar at all sites in the Albuquerque MSA. The spatial distribution of modeled ozone impacts on June 16 (Figure 91) shows that oil and gas emissions affected modeled ozone concentrations in Albuquerque/Bernalillo County and throughout the 4-km domain. The largest ozone impacts (> 1 ppb) were located within or near the oil and gas producing regions of northwest and southeast New Mexico.

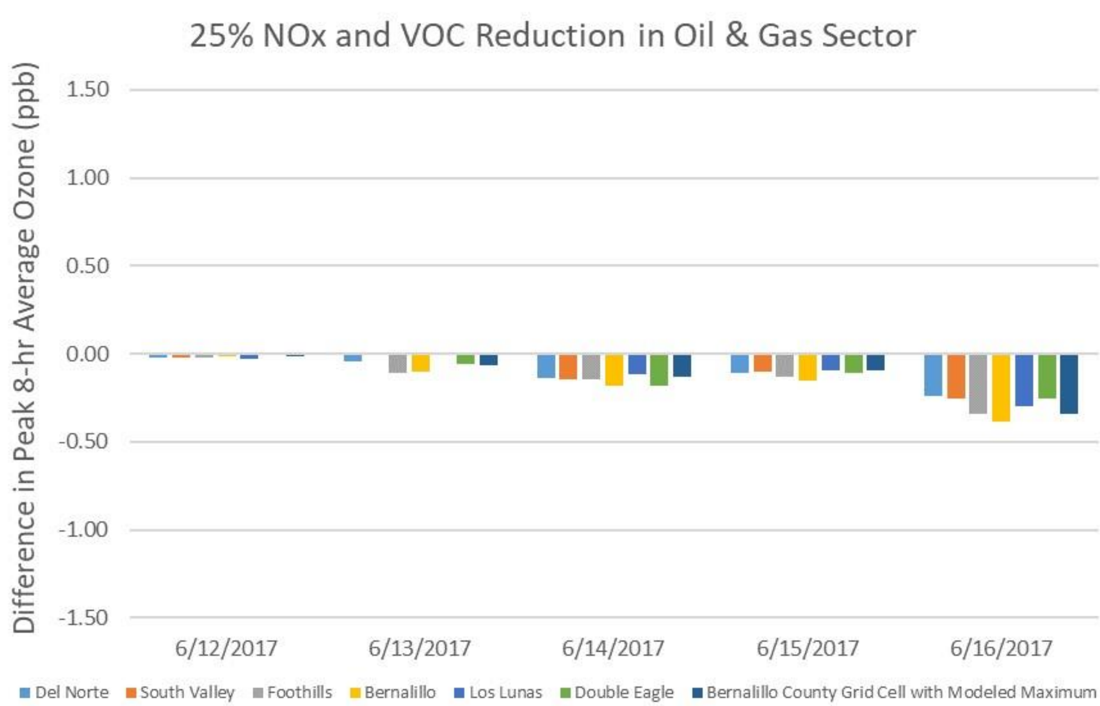

Figure 89. Differences in peak 8-hr average ozone concentrations between the 25% reductions in NO_x and VOC emissions from the oil and gas sector simulation and the base-case simulation in the June ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 44. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 25% NO_x and VOC reductions in the oil and gas sector sensitivity simulation and the base-case simulation for the June ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	-0.02	-0.1%	-0.24	-0.5%	N/A	-0.2%
South Valley	-0.01	-0.0%	-0.25	-0.4%	-0.10	-0.2%
Foothills	-0.02	-0.1%	-0.34	-0.6%	-0.13	-0.3%
Bernalillo	-0.02	-0.0%	-0.39	-0.7%	N/A	-0.3%
Los Lunas	-0.01	-0.0%	-0.30	-0.5%	-0.30	-0.2%
Double Eagle	0.00	-0.0%	-0.25	-0.5%	N/A	-0.2%
Bernalillo County Grid Cell with Modeled Maximum	-0.01	-0.0%	-0.34	-0.5%	-0.19	-0.2%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

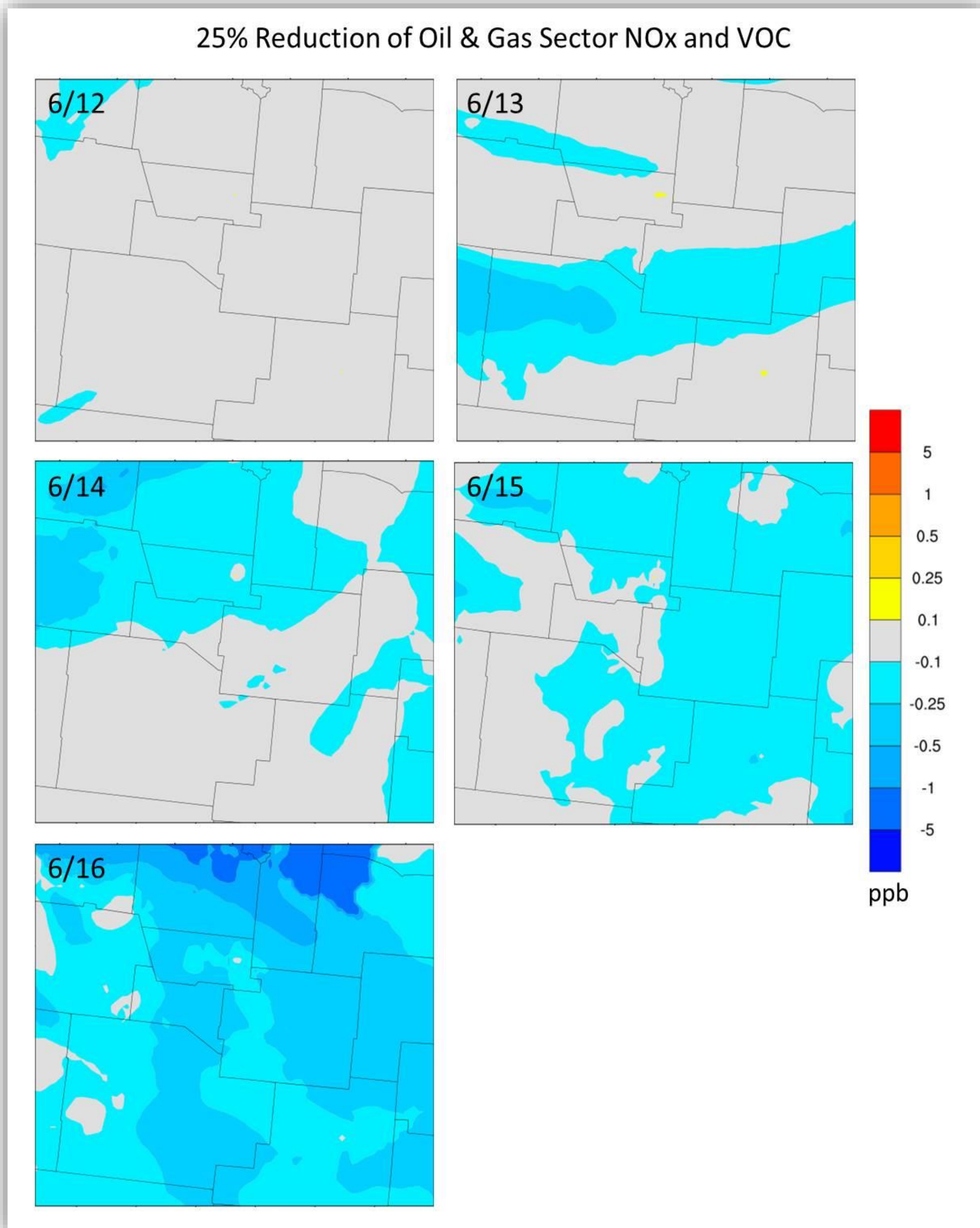

Figure 90. Differences between peak 8-hr average ozone concentrations modeled in the 25% reductions in NO_x and VOC emissions from the oil and gas sector sensitivity simulation and in the base-case simulation for the June episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

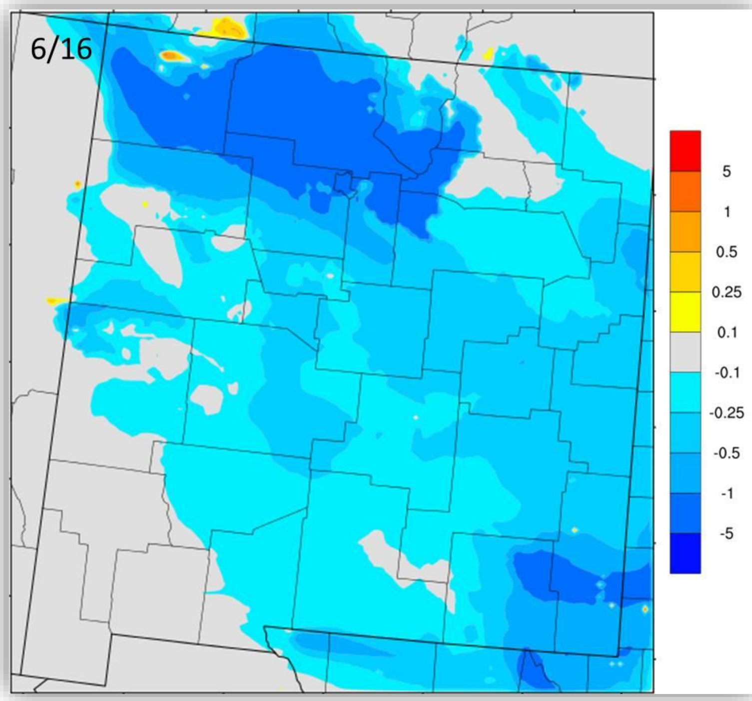

Figure 91. Spatial plot of the differences in peak 8-hr average ozone concentrations modeled in the 25% reduction in both NO_x and VOC emissions from the oil and gas sector in the 4-km resolution modeling domain simulation and in the base-case simulation on June 16. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.3.5 Impact of the Albuquerque/Bernalillo County I&M Program

Figure 92 and Table 45 show the modeled impacts of 5% and 7% increases of on-road mobile source NO_x and VOC emissions, respectively, reflecting the impact of the Albuquerque/Bernalillo County I&M program during the June ozone episode. In this sensitivity simulation, there is an increase in modeled on-road mobile source emissions associated with the possibility of not having an I&M program; therefore, a positive difference in modeled ozone concentrations indicates a modeled benefit of the Albuquerque/Bernalillo County I&M program.

The increase in modeled on-road mobile source emissions associated with the possibility of not having an I&M program resulted in increases of up to 0.1 ppb in modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County. Therefore, the I&M program had a small positive impact at reducing modeled ozone concentrations during the June episode.

The purpose of an I&M program is to ensure that motor vehicles are operating in a manner that meets federal, state, and local emission standards. The Albuquerque EHD uses the EPA MOVES model and detailed travel activity data to estimate motor vehicle emissions in Albuquerque/Bernalillo County. Compliance with the current I&M program is built into the MOVES model modeling conducted by Albuquerque EHD, and these emissions estimates are reported to EPA and included in the NEI. Without an I&M program, there is risk that the motor vehicle emissions in Albuquerque/Bernalillo County would fail to meet the projections made by Albuquerque EHD. The actual impact on emissions and ozone air quality will be sensitive to how vehicle owners might maintain their vehicles in the absence of an I&M program, and therefore how much credit (in terms of emissions reductions) should be assumed for I&M program compliance. I&M programs can produce benefits for other pollutants, such as NO_2 and particulate matter, which are important for protecting air quality near major roadways.

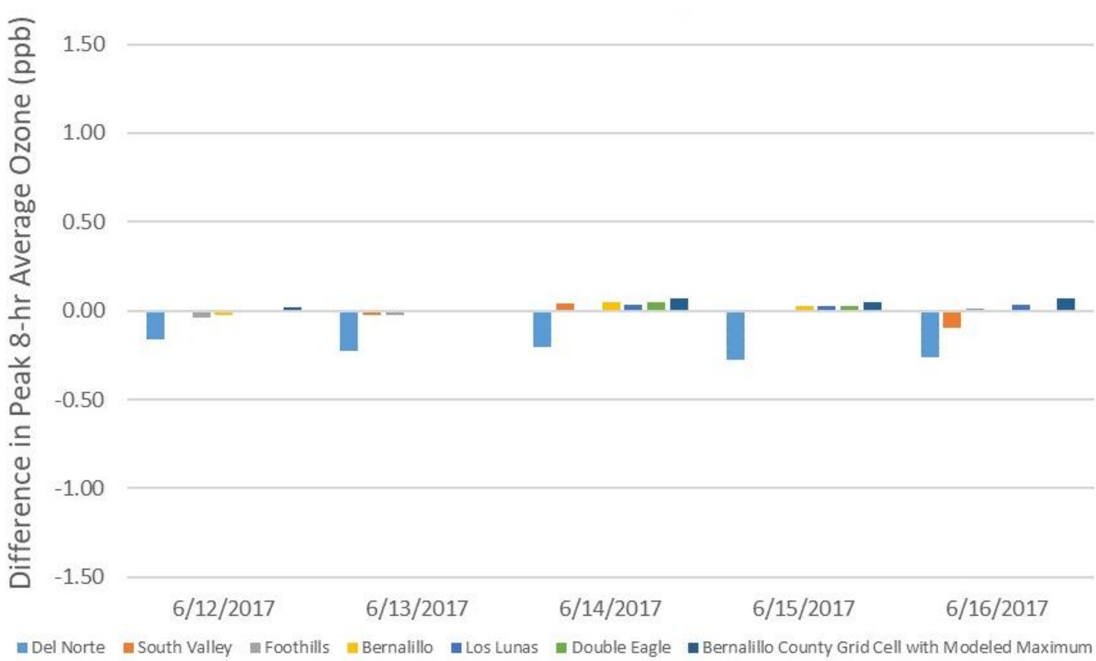

Figure 92. Differences in peak 8-hr average ozone concentrations between the I&M program sensitivity simulation and the base-case simulation in the June ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 45. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the Albuquerque/Bernalillo County I&M program sensitivity simulation and the base-case simulation for the June ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	-0.16	-0.4%	-0.28	-0.5%	N/A	N/A
South Valley	0.04	0.1%	-0.10	-0.2%	0.00	0.0%
Foothills	0.01	0.0%	-0.04	-0.1%	0.01	0.0%
Bernalillo	0.05	0.1%	-0.02	-0.1%	N/A	N/A
Los Lunas	0.04	0.1%	0.00	0.0%	0.03	0.0%
Double Eagle (SAF)	0.05	0.1%	0.00	0.0%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	0.07	0.1%	-0.00	-0.0%	0.06	0.1%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

10.3.6 Operation of Reeves and Rio Bravo Power Plants at Permitted Emission Levels

The Rio Bravo and Reeves EGUs are located in Bernalillo County near the City of Albuquerque and are considered "peaker plants" because they operate as needed when energy demand is high. These power plants receive an operating permit from the Albuquerque EHD under EPA's Title V major point source program. These power plants are permitted to operate within a specified amount of emissions with daily and annual emission limits, and they report their hourly emissions to EPA's Clean Air Markets Division (CAMD). During June 2017, these facilities operated well below their permitted emission levels. To simulate the potential air quality impacts of the Rio Bravo and Reeves facilities operating at permitted emission levels, the daily NO_x and VOC emissions for those facilities in the modeling inventory were set to the permitted emission levels. This sensitivity simulation is intended to examine potential air quality impacts if these facilities had emitted at permitted levels.

Figure 93 and Table 46 show the modeled impacts of increasing NO_x emissions from the Reeves and Rio Bravo power plants to permitted emission levels (11.8 and 3.5 tons/day, respectively) during the June ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 94. In this sensitivity simulation, a positive difference in modeled ozone concentration indicates that increasing emissions at the Reeves and Rio Bravo power plants to permitted emission levels would increase ozone concentrations.

Increasing the NO_x emissions from these two power plants to permitted levels increased modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County by as much as 0.5 ppb during the June episode. At the Del Norte monitoring site, the modeled ozone concentration decreased by as much as 0.8 ppb. The plots in Figure 94 illustrate the spatial extent of the ozone impacts. These results show that if the Reeves and Rio Bravo power plants had operated at permitted emission levels, ozone concentrations during the June 2017 episode in Albuquerque/Bernalillo County would likely have been higher.

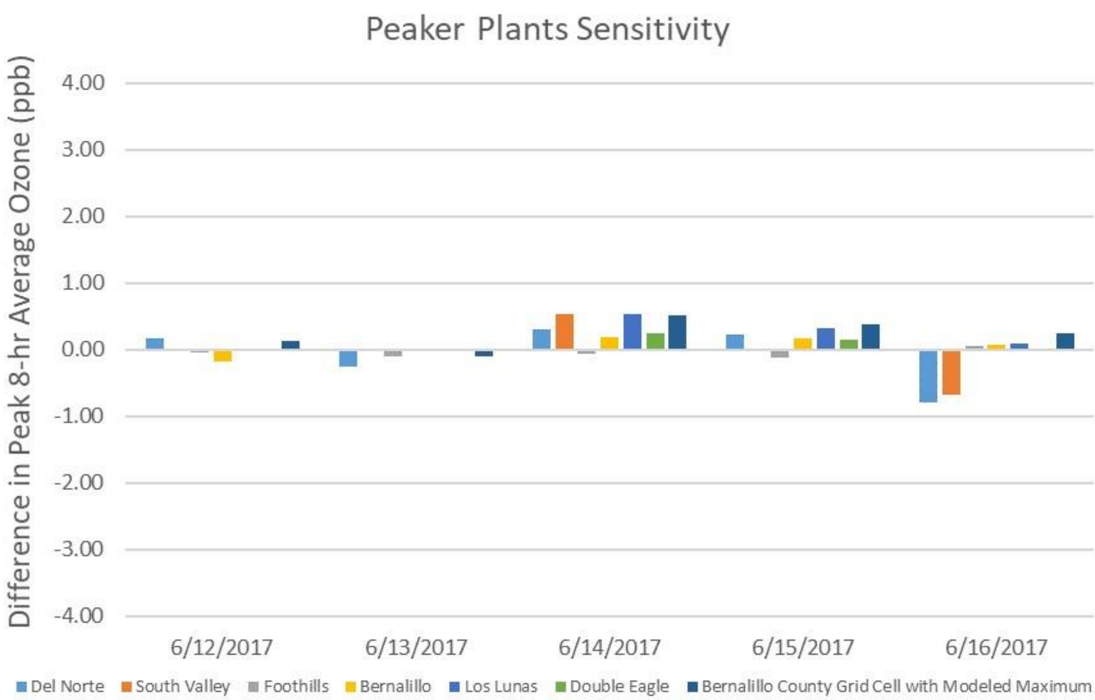

Figure 93. Differences in peak 8-hr average ozone concentrations between the simulation with Reeves and Rio Bravo power plants operating at permitted emission levels and the base-case simulation in the June ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 46. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the sensitivity simulation with the Reeves and Rio Bravo power plants operating at permitted emission levels and the base-case simulation for the June ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.29	0.5%	-0.79	-1.5%	N/A	N/A
South Valley	0.53	0.9%	-0.68	-1.1%	-0.02	-0.0%
Foothills	0.05	0.1%	-0.12	-0.2%	-0.12	-0.2%
Bernalillo	0.17	0.3%	-0.19	-0.4%	N/A	N/A
Los Lunas	0.53	0.9%	0.00	0.0%	0.08	0.1%
Double Eagle (SAF)	0.25	0.4%	0.00	0.0%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	0.52	0.8%	-0.10	-0.2%	0.38	0.6%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

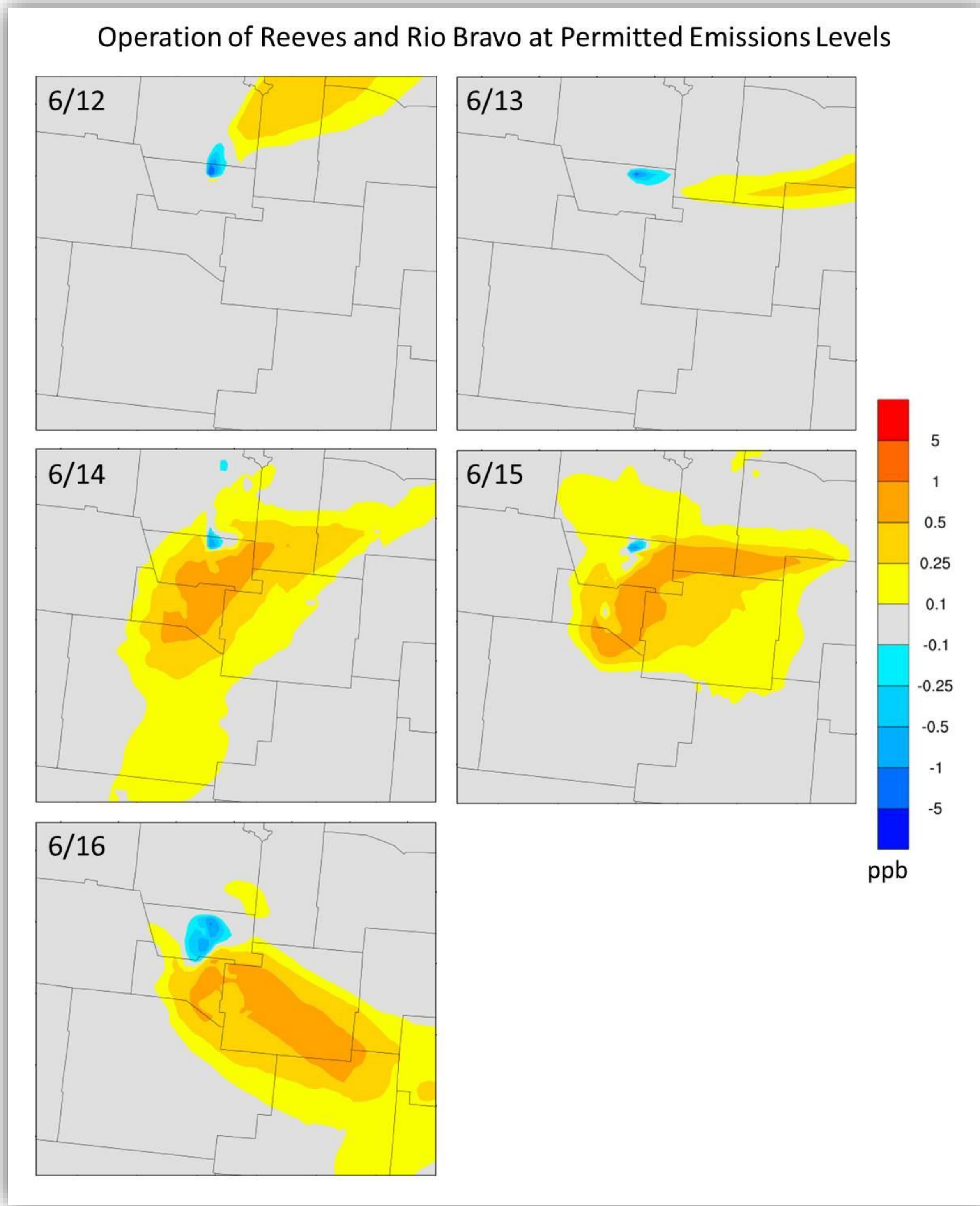

Figure 94. Differences between peak 8-hr average ozone concentrations modeled in the sensitivity simulation with Reeves and Rio Bravo power plants operating at permitted emission levels and in the base-case simulation for the June episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.3.7 100% Reduction of Sandoval County Emissions

Figure 95 and Table 47 show the modeled impacts of removing all anthropogenic emissions from Sandoval County during the June ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 96. This type of sensitivity simulation is also referred to as a "zero-out" simulation since the anthropogenic emissions in Sandoval County are set to zero. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that removing anthropogenic emissions from Sandoval County would decrease ozone concentrations.

Removing anthropogenic emissions from Sandoval County decreased modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County during the June episode. The largest reductions (up to 1.5 ppb) were at the Foothills site, which is the closest Albuquerque/Bernalillo site to Sandoval County. Reductions in ozone concentration were also modeled at the Del Norte site (up to 1.0 ppb). There were modeled increases (between 1 and 2 ppb) in peak 8-hr ozone concentration at the Bernalillo site in Sandoval County on three of the five days in the June episode, but there were also modeled decreases in ozone concentration of greater than 1 ppb elsewhere in Sandoval County (see Figure 96). Results from this simulation show that ozone in Albuquerque/Bernalillo County is sensitive to anthropogenic emissions from Sandoval County.

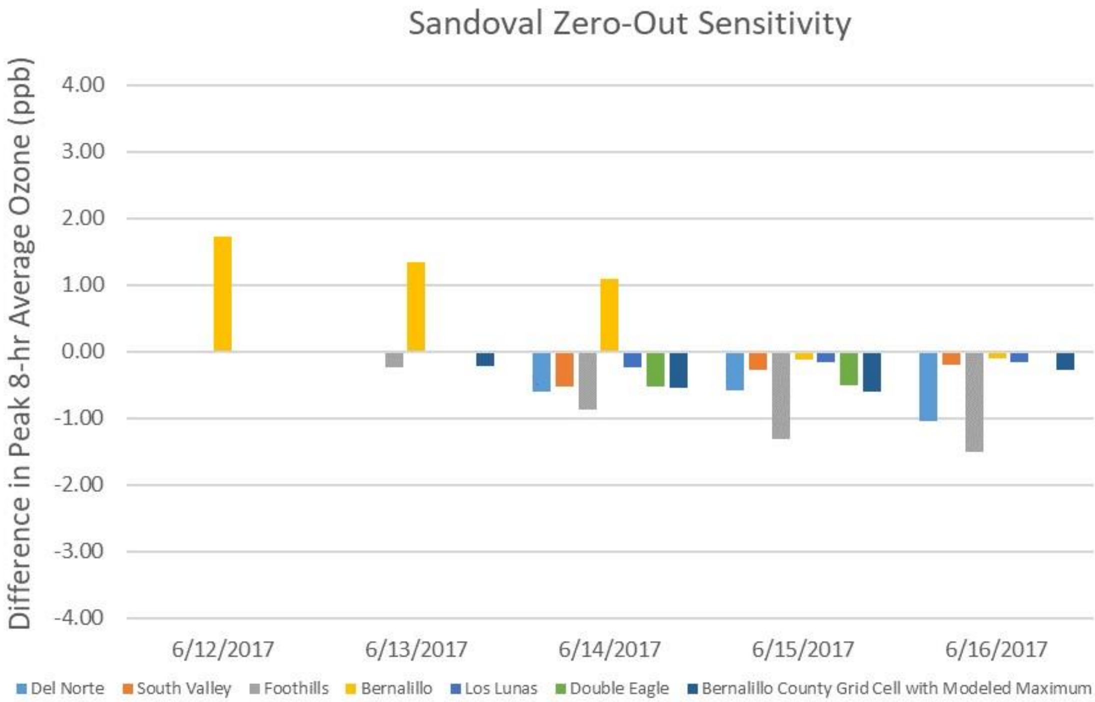

Figure 95. Differences in peak 8-hr average ozone concentrations between the Sandoval County anthropogenic emissions zero-out sensitivity simulation and the base-case simulation in the June ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 47. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the Sandoval County anthropogenic emissions zero-out sensitivity simulation and the base-case simulation for the June ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.00	0.0%	-1.04	-2.0%	N/A	N/A
South Valley	0.00	0.0%	-0.52	-0.8%	-0.27	-0.4%
Foothills	-0.01	-0.0%	-1.51	-2.6%	-1.32	-2.0%
Bernalillo	1.72	3.5%	-0.12	-0.2%	N/A	N/A
Los Lunas	0.00	0.0%	-0.25	-0.4%	-0.16	-0.2%
Double Eagle (SAF)	0.00	0.0%	-0.53	-0.9%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	-0.01	-0.0%	-0.60	-0.9%	-0.47	-0.7%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

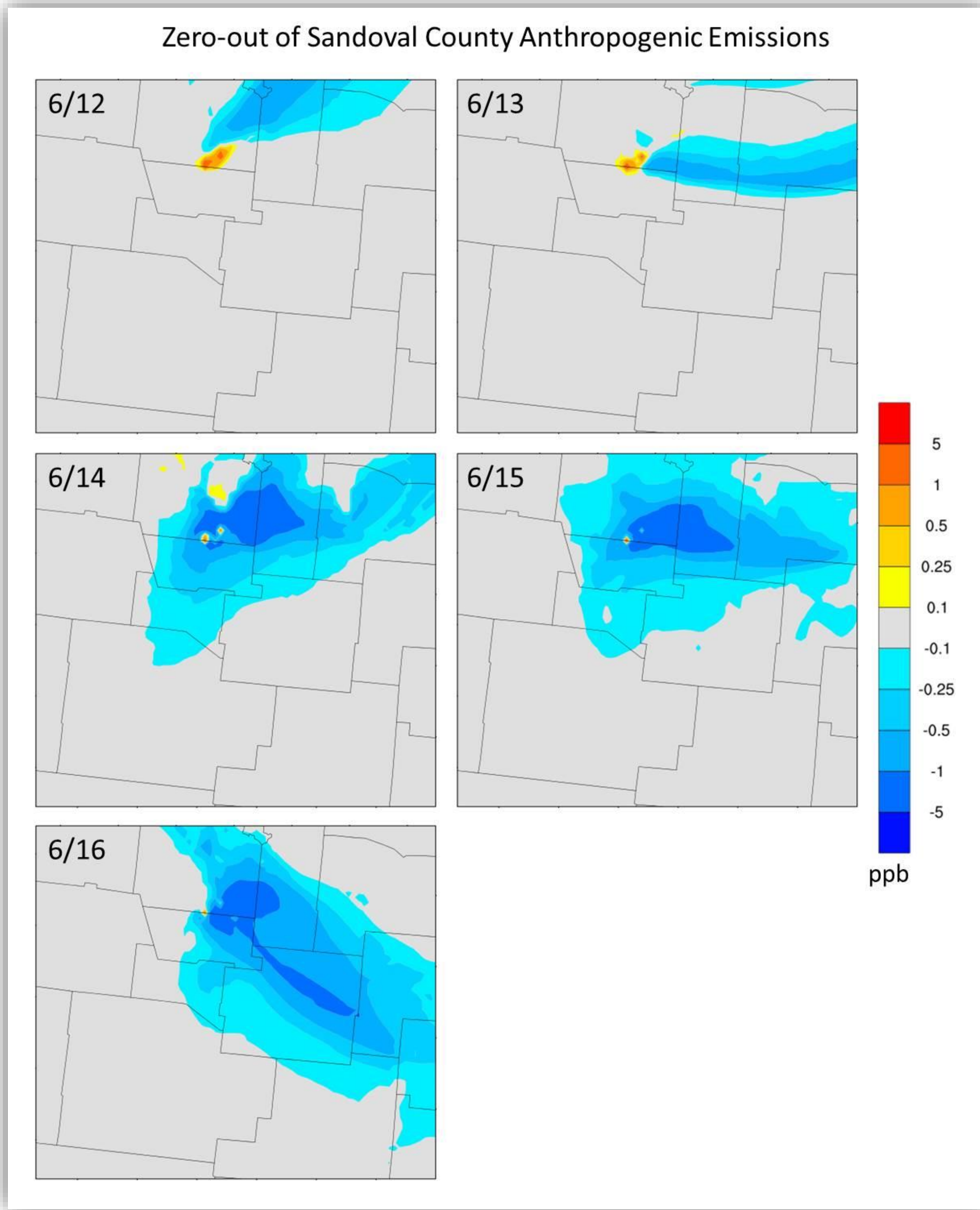

Figure 96. Differences between peak 8-hr average ozone concentrations modeled in the Sandoval County anthropogenic emissions zero-out sensitivity simulation and in the base-case simulation for the June episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.3.8 100% Reduction of Valencia County Emissions

Figure 97 and Table 48 show the modeled impacts of removing anthropogenic emissions from Valencia County during the June ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 98. This type of sensitivity simulation is also referred to as a "zero-out" simulation since the anthropogenic emissions in Valencia County are set to zero. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that removing anthropogenic emissions from Valencia County would decrease ozone concentrations.

Removing anthropogenic emissions from Valencia County decreased modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County during the June episode. The largest reductions (up to 2.1 ppb) were at the South Valley site, which is the closest Albuquerque/Bernalillo County site to Valencia County. Maximum daily reductions in peak 8-hr ozone concentrations ranged from 0.7-2.1 ppb across all sites in the Albuquerque MSA. Modeled ozone concentrations increased by 1.1 ppb on June 13 at the Los Lunas site, but outside of Los Lunas, decreases in ozone concentration of greater than 1 ppb were modeled in Valencia County on most episode days (see Figure 98). In the June episode, ozone concentrations in Albuquerque/Bernalillo County were more sensitive to Valencia County emissions compared to Sandoval County emissions. Results from this simulation show that ozone in Albuquerque/Bernalillo County is sensitive to anthropogenic emissions from Valencia County.

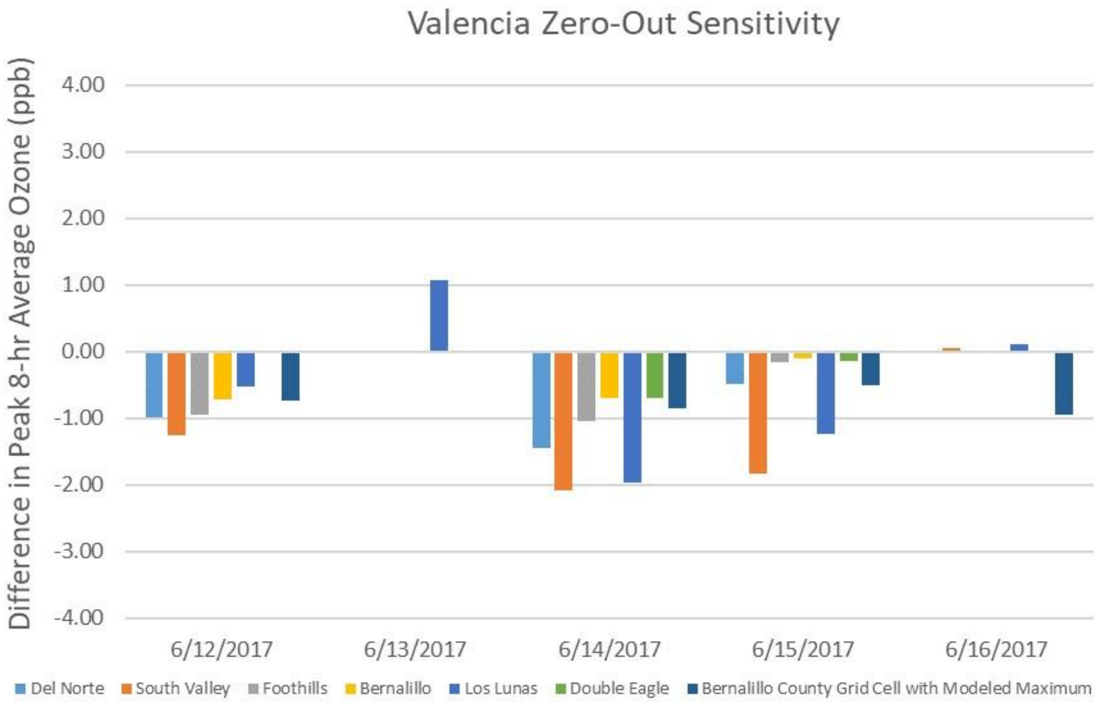

Figure 97. Differences in peak 8-hr average ozone concentrations between the Valencia County anthropogenic emissions zero-out sensitivity simulation and the base-case simulation in the June ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 48. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations modeled in the Valencia County anthropogenic emissions zero-out sensitivity simulation and in the base-case simulation for the June ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.01	0.0%	-1.46	-2.6%	N/A	N/A
South Valley	0.04	0.1%	-2.08	-3.3%	-1.84	-2.8%
Foothills	0.00	0.0%	-1.04	-1.9%	-0.16	-0.2%
Bernalillo	0.00	0.0%	-0.73	-1.5%	N/A	N/A
Los Lunas	1.08	2.2%	-1.96	-3.2%	0.1	0.2%
Double Eagle (SAF)	0.00	0.0%	-0.69	-1.2%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	0.00	0.0%	-0.95	-1.4%	-0.77	-1.1%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

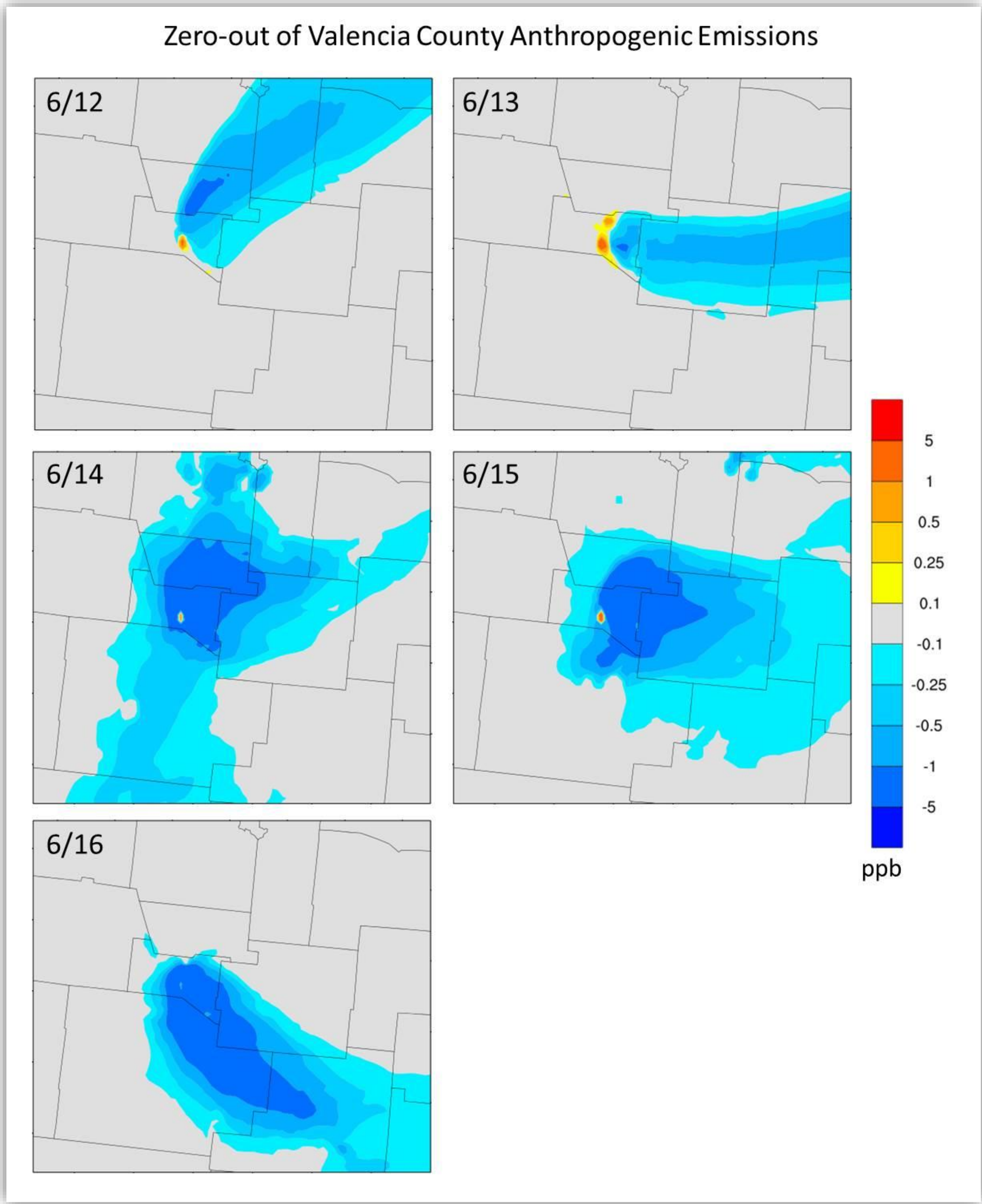

Figure 98. Differences between peak 8-hr average ozone concentrations modeled in the Valencia County anthropogenic emissions zero-out sensitivity simulation and in the base-case simulation for the June episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.4 July 2017 Ozone Episode

Modeled ozone concentrations in Albuquerque/Bernalillo County were more sensitive to changes in emissions during the July episode compared to the June episode. Therefore, for any given sensitivity scenario, the change in modeled ozone concentration was typically larger during the July episode. Of the sensitivity scenarios that were modeled, the largest changes in ozone occurred in the simulation with a 25% reduction in Albuquerque/Bernalillo County on-road mobile source NO_x emissions. The modeled peak 8-hr average ozone concentration in Albuquerque/Bernalillo County was relatively insensitive to the 10% reduction in local VOC emissions. The 25% reduction of both NO_x and VOC emissions from the oil and gas sector throughout New Mexico decreased peak 8-hr average ozone concentrations in Albuquerque/Bernalillo County by an average of 0.3 ppb across all episode days and sites, and by more than 1 ppb on one episode day. The results of these sensitivity simulations indicate that local NO_x emissions, as well as statewide oil and gas sector emissions, impacted ozone concentrations in Albuquerque/Bernalillo County during the July episode. As in the June episode, reducing NO_x emissions in Albuquerque/Bernalillo County increased peak 8-hr average ozone concentrations at the Del Norte site during the July episode.[37]

10.4.1 10% Reduction in NO_x Emissions

Figure 99 and Table 49 show the modeled impacts of a 10% reduction of NO_x emissions in Albuquerque/Bernalillo County during the July ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 100. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing NO_x emissions would decrease ozone concentrations.

In the July episode, reducing NO_x emissions in Albuquerque/Bernalillo County by 10% decreased modeled peak 8-hr average ozone concentrations by as much as 1.0 ppb on high ozone days. The largest decreases were 0.9 ppb at the South Valley site on July 10, 0.8 ppb at the Foothills site on July 11, and 1.0 ppb at the Bernalillo County Grid Cell with Modeled Maximum ozone on July 10. These results indicate NO_x-limited conditions in Albuquerque/Bernalillo County. As in the June episode, reducing NOx emissions increased modeled ozone concentrations at the Del Norte site.[37]

[37] As discussed earlier, the increase in ozone at the Del Norte site are likely an artifact of poor model performance at that site, and it should not be considered a reliable result to inform air quality management decisions.

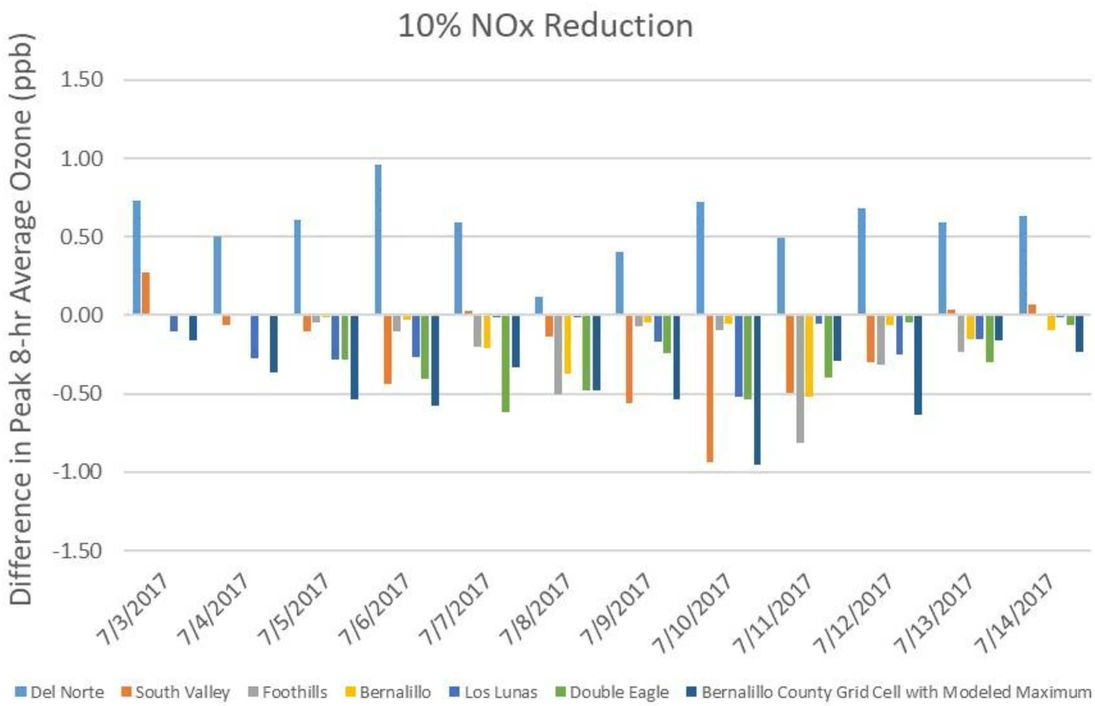

Figure 99. Differences in peak 8-hr average ozone concentrations between the 10% reduction in local NO_x emissions simulation and the base-case simulation in the July ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 49. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 10% NO_x reduction sensitivity simulation and the base-case simulation for the July ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.96	1.6%	0.12	0.2%	N/A	1.1%
South Valley	0.27	0.5%	-0.94	-1.3%	-0.49	-0.3%
Foothills	0.00	0.0%	-0.81	-1.2%	-0.81	-0.3%
Bernalillo	0.00	0.0%	-0.52	-0.8%	-0.52	-0.2%
Los Lunas	-0.01	-0.0%	-0.52	-0.8%	N/A	-0.3%
Double Eagle	0.00	0.0%	-0.62	-1.0%	N/A	-0.5%
Bernalillo County Grid Cell with Modeled Maximum	-0.16	-0.3%	-0.95	-1.3%	-0.54	-0.7%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

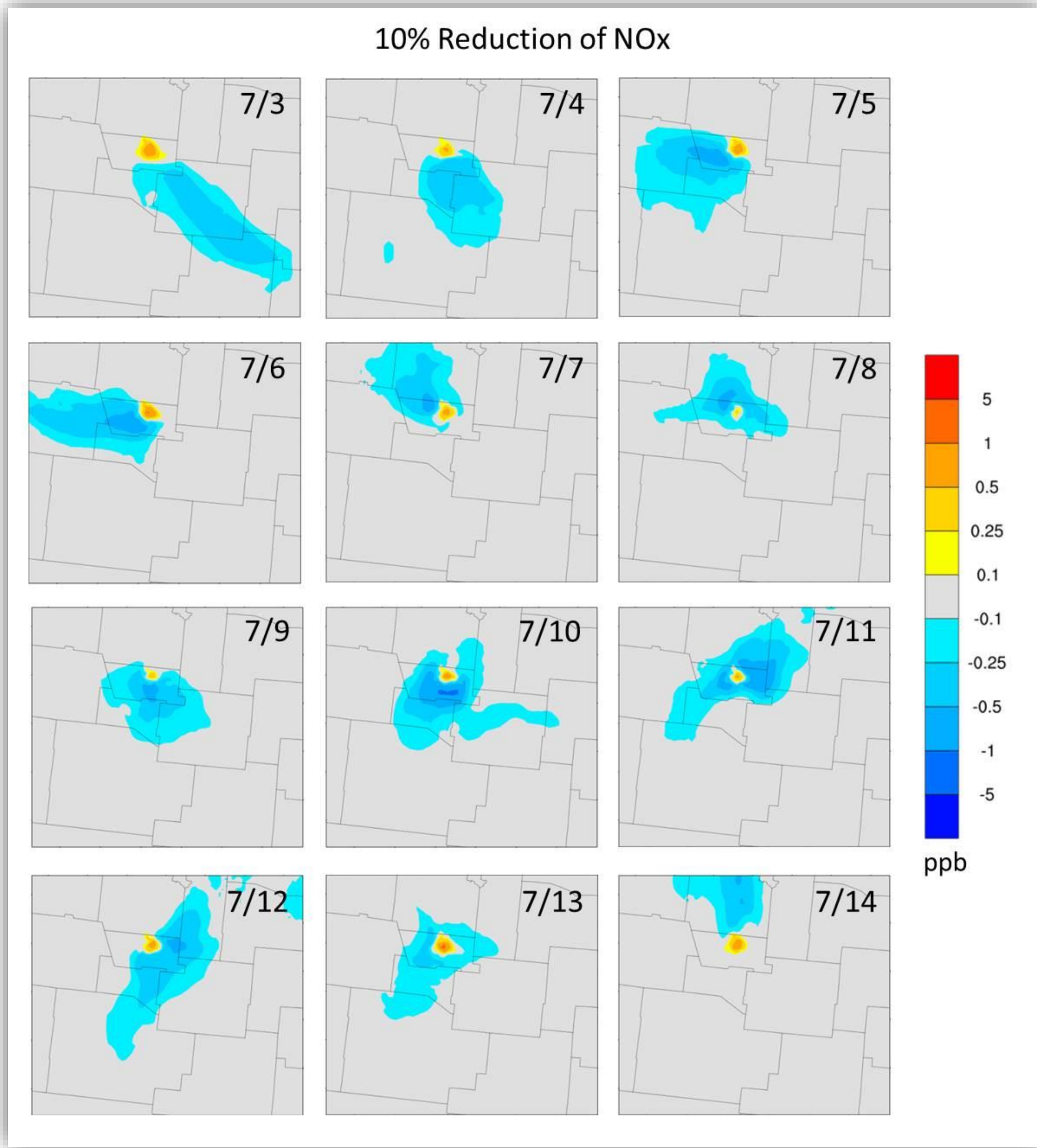

Figure 100. Differences between peak 8-hr average ozone concentrations modeled in the 10% NO_x reduction sensitivity simulation and in the base-case simulation for the July episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.4.2 10% Reduction in VOC Emissions

Figure 101 and Table 50 show the modeled impacts of a 10% reduction of VOC emissions in Albuquerque/Bernalillo County during the July ozone episode. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing VOC emissions would decrease ozone concentrations. As in the June episode, peak 8-hr ozone concentrations in Albuquerque/Bernalillo County were relatively insensitive to a 10% changes in local VOC emissions. Peak 8-hr ozone concentrations in Albuquerque/Bernalillo County decreased by no more than 0.25 ppb (0.4%).

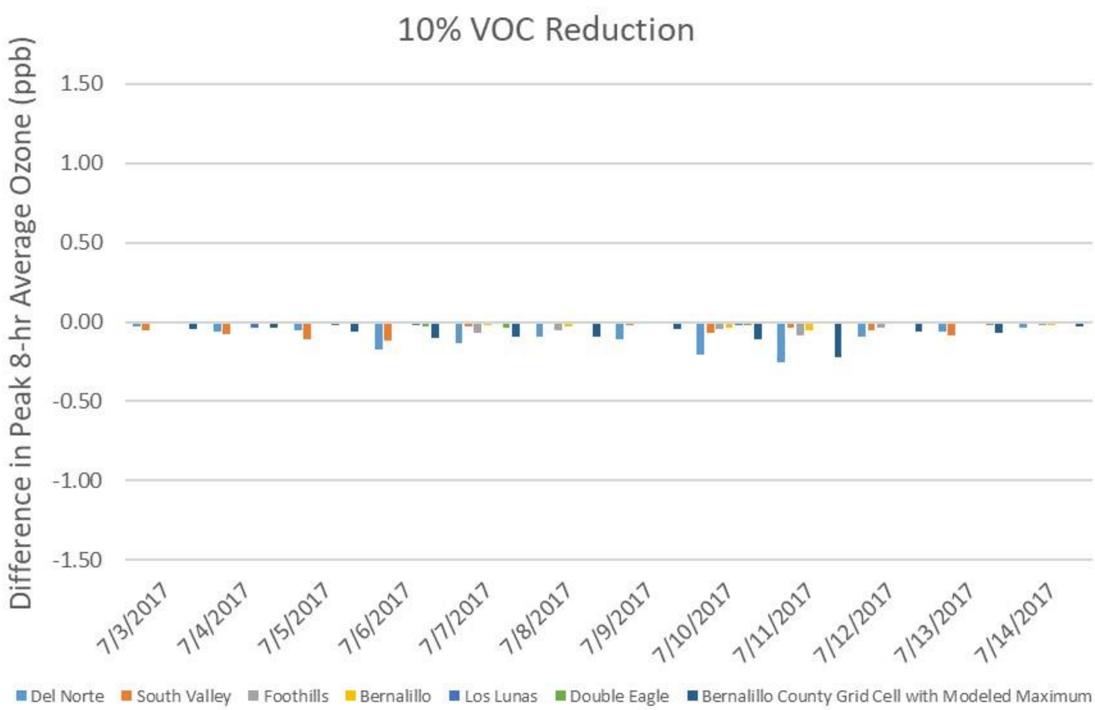

Figure 101. Differences in peak 8-hr average ozone concentrations between the 10% reduction in local VOC emissions simulation and the base-case simulation in the July ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 50. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 10% VOC reduction sensitivity simulation and the base-case simulation for the July ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	-0.03	-0.1%	-0.25	-0.4%	N/A	-0.2%
South Valley	-0.01	-0.0%	-0.11	-0.2%	-0.10	-0.1%
Foothills	0.00	0.0%	-0.08	-0.1%	-0.08	-0.0%
Bernalillo	0.00	0.0%	-0.05	-0.1%	-0.05	-0.0%
Los Lunas	0.00	0.0%	-0.04	-0.1%	N/A	-0.0%
Double Eagle	0.00	0.0%	-0.03	-0.1%	N/A	-0.0%
Bernalillo County Grid Cell with Modeled Maximum	-0.03	-0.1%	-0.22	-0.3%	-0.11	-0.1%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

10.4.3 25% Reduction in On-Road NO_x Emissions

Figure 102 and Table 51 show the modeled impacts of a 25% reduction of NO_x emissions from on-road mobile sources in Albuquerque/Bernalillo County during the July ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 103. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing on-road mobile source NO_x emissions would decrease ozone concentrations.

Reducing on-road mobile source NO_x emissions in Albuquerque/Bernalillo County by 25% decreased peak 8-hr average ozone concentrations at all monitoring sites in the Albuquerque MSA except Del Norte.[38] The largest decreases in modeled ozone were 1.2 ppb at the South Valley site on July 10, 1.1 ppb at the Foothills site on July 11, and 1.1 ppb at the Bernalillo County Grid Cell with Modeled Maximum ozone on July 10. Ozone impacts in this simulation were larger than those for the same sensitivity simulation in the June episode, as ozone in Albuquerque/Bernalillo County was more sensitive to emissions from Albuquerque/Bernalillo County during the July episode.

[38] As discussed earlier, the increase in ozone at the Del Norte site was likely an artifact of poor model performance at that site, and it should not be considered a reliable result to inform air quality management decisions.

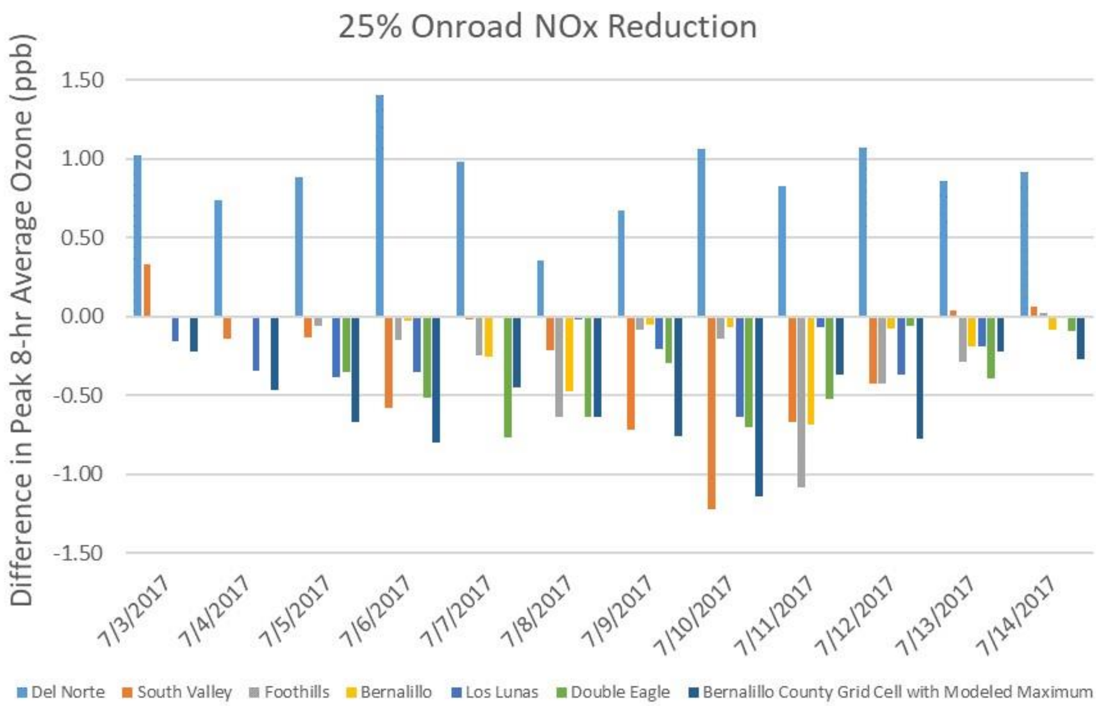

Figure 102. Differences in peak 8-hr average ozone concentrations between the 25% reduction in local on-road NO_x emissions simulation and the base-case simulation in the July ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 51. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 25% on-road NO_x reduction sensitivity simulation and the base-case simulation for the July ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	1.40	2.4%	0.35	0.6%	N/A	1.6%
South Valley	0.33	0.6%	-1.22	-1.7%	-0.65	-0.5%
Foothills	0.02	0.1%	-1.09	-1.6%	-1.09	-0.4%
Bernalillo	0.00	0.0%	-0.69	-1.0%	-0.69	-0.3%
Los Lunas	-0.01	-0.0%	-0.64	-1.0%	N/A	-0.4%
Double Eagle	0.01	0.0%	-0.77	-1.2%	N/A	-0.6%
Bernalillo County Grid Cell with Modeled Maximum	-0.22	-0.4%	-1.14	-1.6%	-0.69	-0.9%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

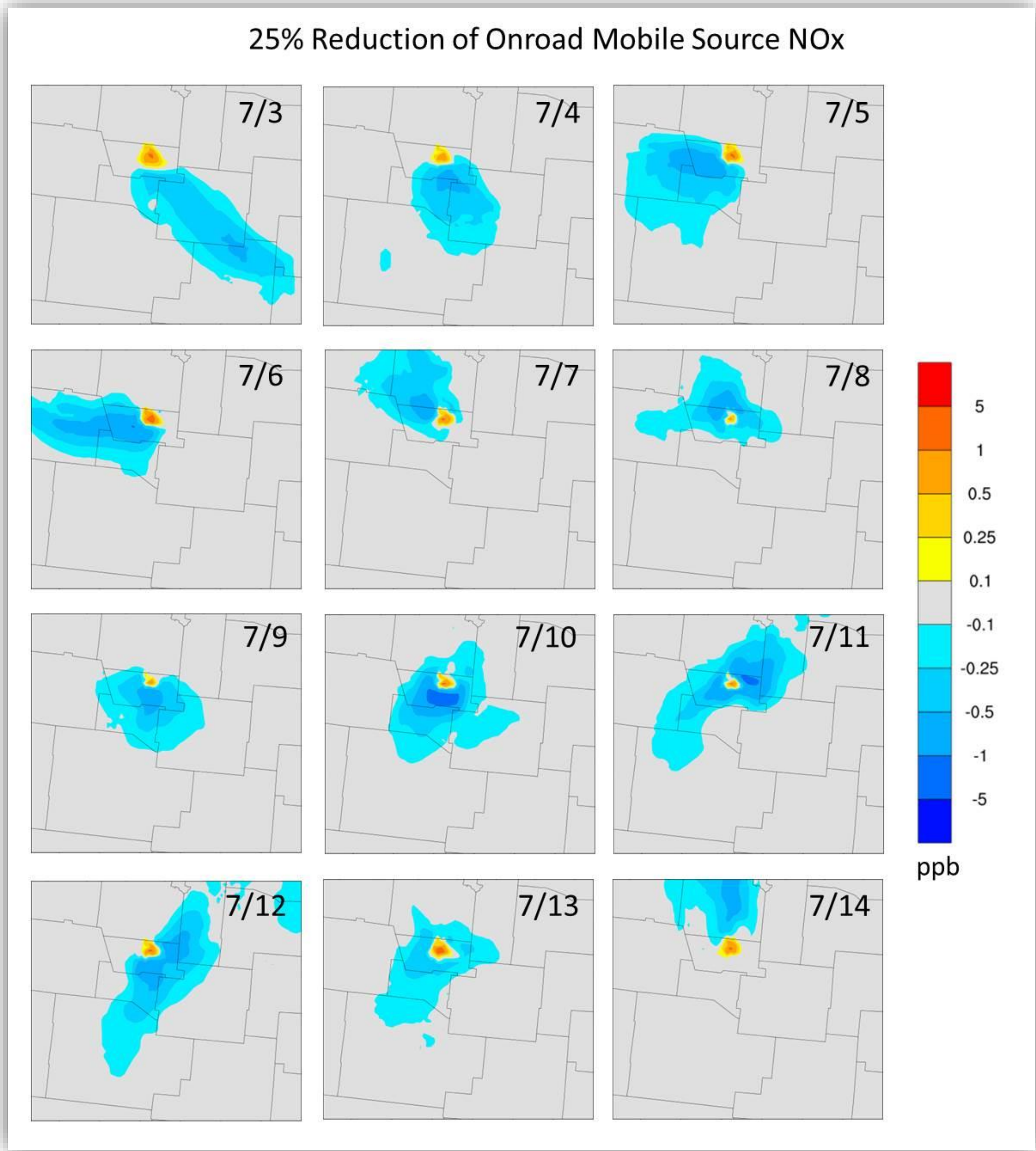

Figure 103. Differences between peak 8-hr average ozone concentrations modeled in the 25% on-road NO_x reduction sensitivity simulation and in the base-case simulation for the July episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.4.4 25% Reduction in NO_x and VOC Emissions in the Oil and Gas Sector

Figure 104 and Table 52 show the modeled impacts of a 25% reduction of NO_x and VOC emissions from the oil and gas sector in New Mexico during the July ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 105. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing emissions from the oil and gas sector in New Mexico would decrease ozone concentrations.

Reducing domain-wide NO_x and VOC emissions from the oil and gas sector decreased peak 8-hr ozone concentrations in the Albuquerque MSA. On high ozone days, the largest decrease in Albuquerque/Bernalillo County was around 0.5 ppb. On average, the decreases in ozone concentrations during the July episode were more than a factor of two larger than those in the June episode. This was due to meteorological conditions during July 2017 that favored pollutant transport from the oil and gas producing regions to Albuquerque/Bernalillo County.

A notable result from this sensitivity simulation is the large decrease in peak 8-hr average ozone concentrations in the Albuquerque MSA on July 4 compared to other days in this episode. One possible explanation for this is recirculation, which is apparent in the sequence of spatial plots in Figure 106. On July 3, the impact of reducing NO_x and VOC emissions from the oil and gas sector extends from northwestern New Mexico toward the southeast. This impact shifts southward on July 4 and then westward on July 5. This clockwise circulation continues on the following days.

The spatial distribution of modeled ozone impacts (see Figure 106) shows that oil and gas emissions affected modeled ozone concentrations in Albuquerque/Bernalillo County and throughout the 4-km domain. The largest ozone impacts (> 1 ppb) were located within or near the oil and gas producing regions of northwest and southeast New Mexico.

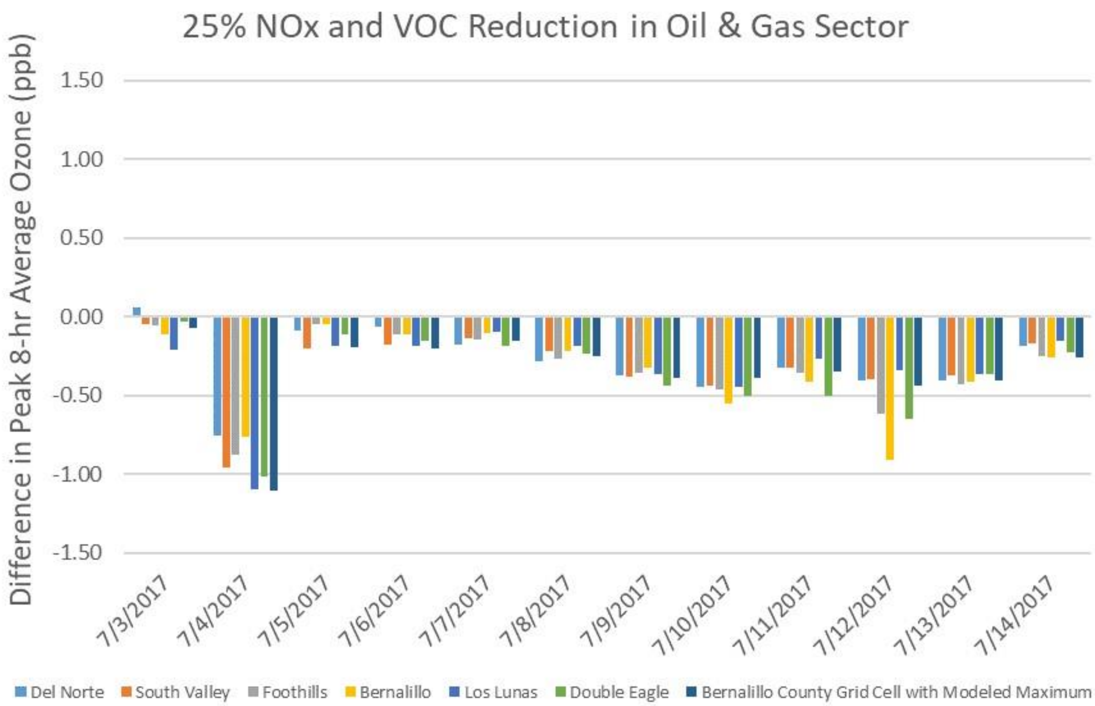

Figure 104. Differences in peak 8-hr average ozone concentrations between the 25% reductions in NO_x and VOC emissions from the oil and gas sector simulation and the base-case simulation in the July ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 52. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 25% NO_x and VOC reductions in the oil and gas sector sensitivity simulation and the base-case simulation for the July ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.06	-0.1%	-0.76	-1.5%	N/A	-0.5%
South Valley	-0.04	-0.1%	-0.96	-1.6%	-0.27	-0.2%
Foothills	-0.05	-0.1%	-0.88	-1.6%	-0.36	-0.6%
Bernalillo	-0.05	-0.1%	-0.91	-1.6%	-0.41	-0.6%
Los Lunas	-0.09	-0.2%	-1.10	-1.8%	N/A	-0.6%
Double Eagle	-0.03	-0.1%	-1.02	-0.7%	N/A	-0.7%
Bernalillo County Grid Cell with Modeled Maximum	-0.07	-0.1%	-1.10	-1.8%	-0.28	-0.6%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

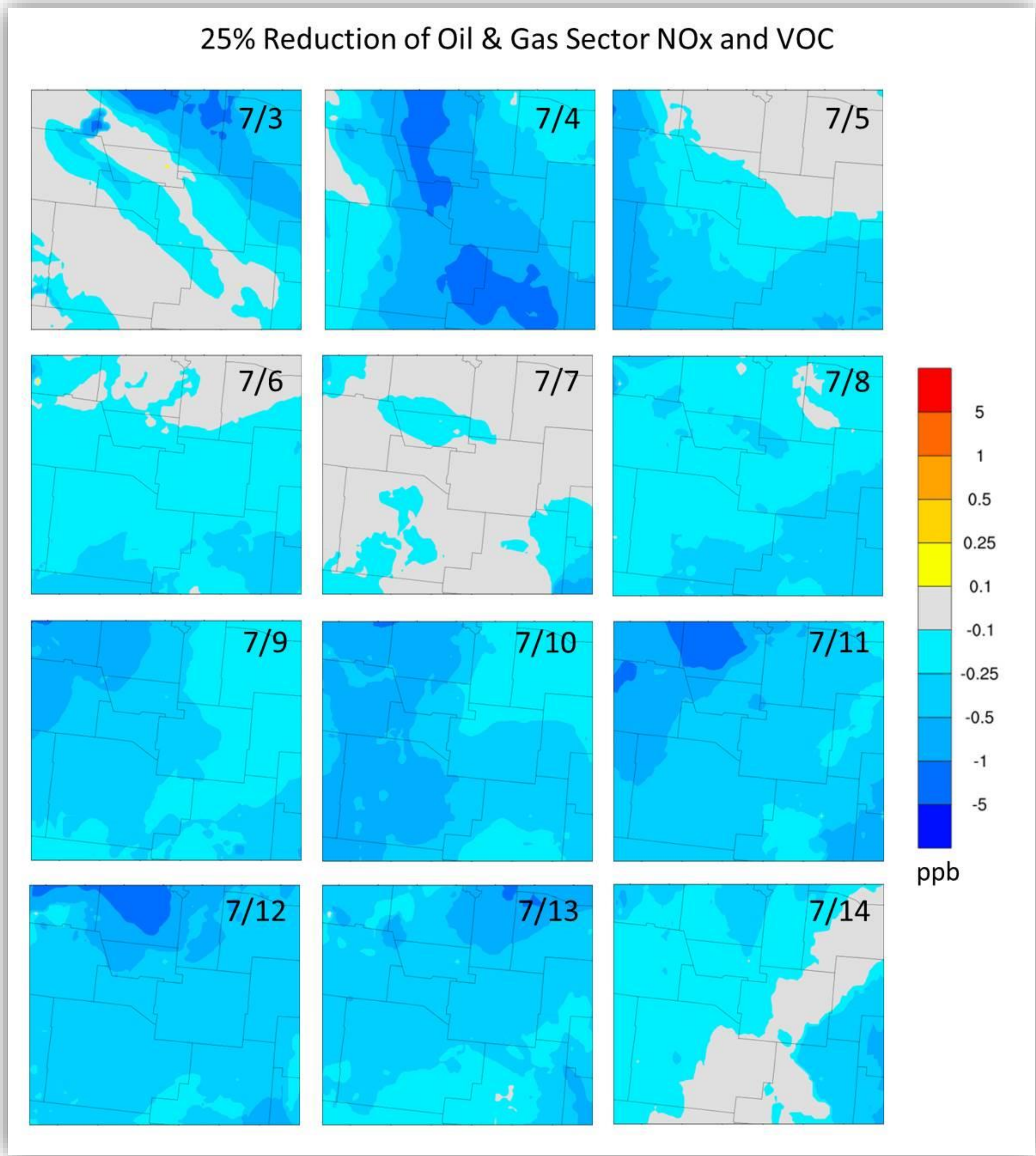

Figure 105. Differences between peak 8-hr average ozone concentrations modeled in the 25% NO_x and VOC reductions in the oil and gas sector sensitivity simulation and in the base-case simulation for the July episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

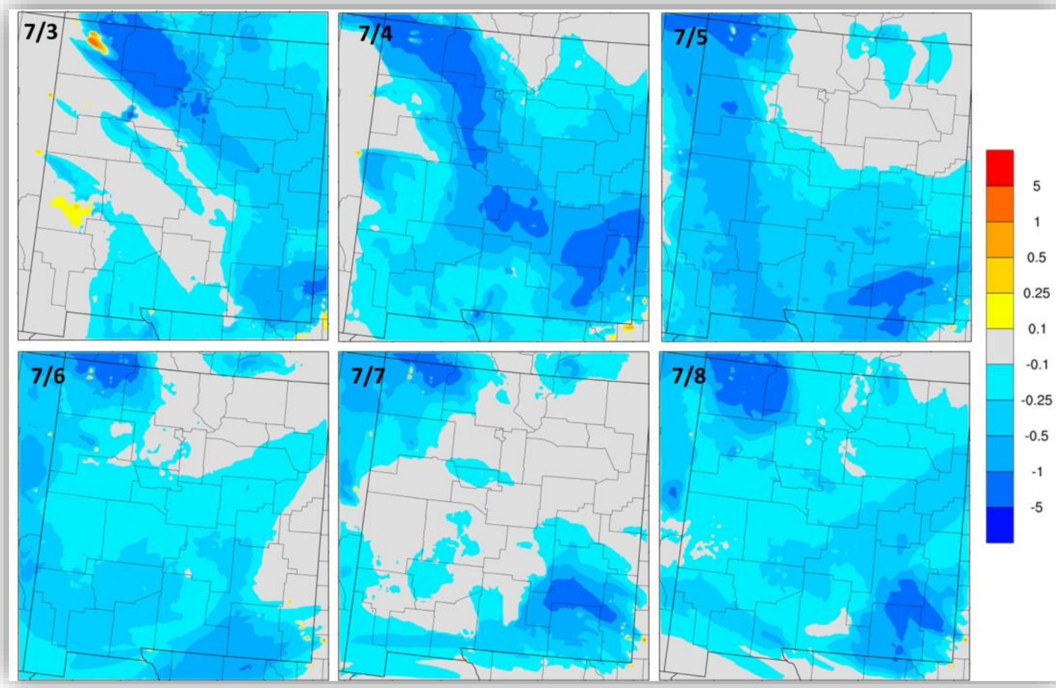

Figure 106. Differences between peak 8-hr average ozone concentrations modeled in the 25% NO_x and VOC reductions in the oil and gas sector sensitivity simulation and in the base-case simulation for the July episode in the full 4-km resolution modeling domain. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.4.5 Impact of the Albuquerque/Bernalillo County I&M Program

Figure 107 and Table 53 show the modeled impacts of 5% and 7% increases of on-road mobile source NO_x and VOC emissions, respectively, reflecting the impact of the Albuquerque/Bernalillo County I&M program during the July ozone episode. In this sensitivity simulation, there is an increase in modeled on-road mobile source emissions associated with the possibility of not having an I&M program; therefore, a positive difference in modeled ozone concentrations indicates a modeled benefit of the Albuquerque/Bernalillo County I&M program.

The increase in modeled on-road mobile source emissions associated with the possibility of not having an I&M program resulted in increases of up to 0.25 ppb in modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County. Therefore the I&M program had a small positive impact at reducing ozone concentrations during the July episode.

The purpose of an I&M program is to ensure that motor vehicles are operating in a manner that meets federal, state, and local emission standards. The Albuquerque EHD uses the EPA MOVES model and detailed travel activity data to estimate motor vehicle emissions in Albuquerque/Bernalillo County. Compliance with the current I&M program is built into the MOVES model modeling conducted by Albuquerque EHD, and these emissions estimates are reported to EPA and included in the NEI. Without an I&M program, there is risk that the motor vehicle emissions in Albuquerque/Bernalillo County would fail to meet the projections made by Albuquerque EHD. The actual impact on emissions and ozone air quality will be sensitive to how vehicle owners might maintain their vehicles in the absence of an I&M program, and therefore how much credit (in terms of emissions reductions) should be assumed for I&M program compliance. I&M programs can produce benefits for other pollutants, such as NO_2 and particulate matter, which are important for protecting air quality near major roadways.

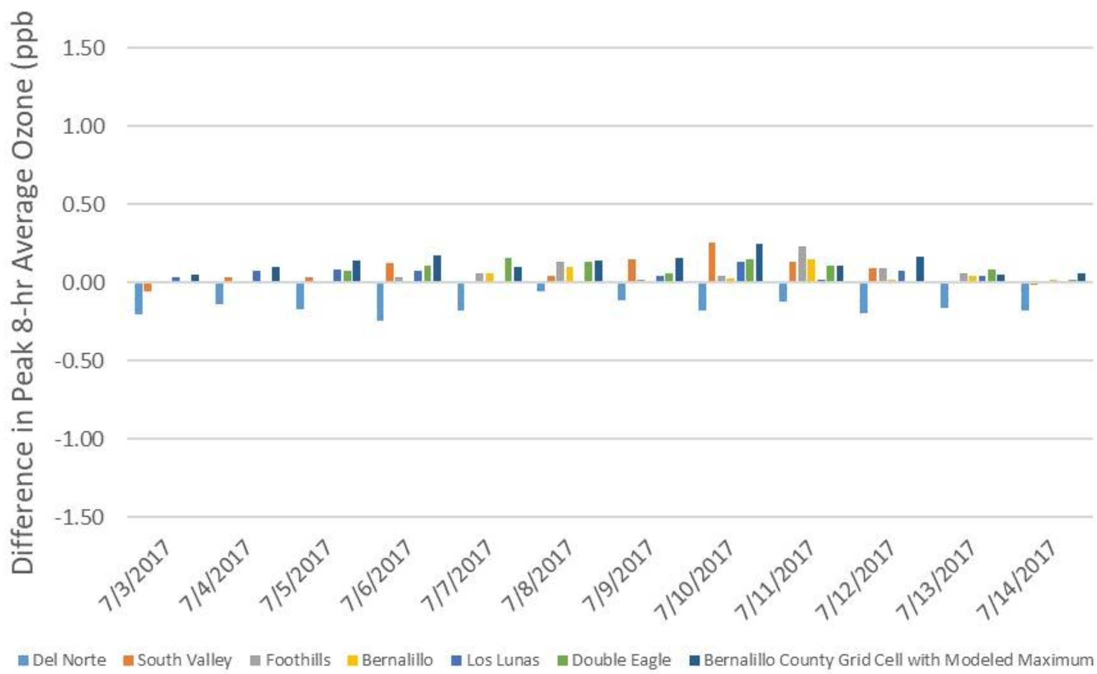

Figure 107. Differences in peak 8-hr average ozone concentrations between the sensitivity simulation with 5% and 7% increases in NO_x and VOC emissions, respectively, from removing the Albuquerque/Bernalillo County I&M program and the base-case simulation in the July ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 53. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the Albuquerque/Bernalillo County I&M program sensitivity simulation and the base-case simulation for the July ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	-0.06	-0.1%	-0.25	-0.4%	N/A	N/A
South Valley	0.25	0.4%	-0.06	-0.1%	0.14	0.2%
Foothills	0.23	0.3%	0.00	0.0%	0.23	0.3%
Bernalillo	0.15	0.2%	0.00	0.0%	0.15	0.2%
Los Lunas	0.13	0.2%	0.00	0.0%	N/A	N/A
Double Eagle (SAF)	0.16	0.2%	0.00	0.0%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	0.24	0.3%	0.05	0.1%	0.14	0.2%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

10.4.6 Operation of Reeves and Rio Bravo Power Plants at Permitted Emission Levels

The Rio Bravo and Reeves EGUs are located in Bernalillo County near the City of Albuquerque and are considered “peaker plants” because they operate as needed when energy demand is high. These power plants receive an operating permit from the Albuquerque EHD under EPA’s Title V major point source program. These power plants are permitted to operate within a specified amount of emissions with daily and annual emission limits, and they report their hourly emissions to EPA’s Clean Air Markets Division (CAMD). During July 2017, these facilities operated well below their permitted emission levels. To simulate the potential air quality impacts of the Rio Bravo and Reeves facilities operating at permitted emission levels, the daily NO_x and VOC emissions for those facilities in the modeling inventory were set to the permitted emission levels. This sensitivity simulation is intended to examine potential air quality impacts if these facilities had emitted at permitted levels.

Figure 108 and Table 54 show the modeled impacts of increasing NO_x emissions from the Reeves and Rio Bravo power plants to permitted emission levels (11.8 and 3.5 tons/day, respectively) during the July ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 109. In this sensitivity simulation, a positive difference in modeled ozone concentration indicates that increasing emissions at the Reeves and Rio Bravo power plants to permitted emission levels would increase ozone concentrations.

Increasing the NO_x emissions from these two power plants to permitted levels increased modeled peak 8-hr ozone concentrations in the Albuquerque MSA during the July episode. The maximum increases ranged from about 1-3 ppb. The greatest increase was at the South Valley monitoring site on July 10 (2.9 ppb). The ozone impacts during the July episode were greater than during the June episode. The plots in Figure 109 illustrate the spatial extent of the ozone impacts. These results show that if the Reeves and Rio Bravo power plants had operated at permitted emission levels, ozone concentrations during the July 2017 episode in Albuquerque/Bernalillo County would likely have been higher.

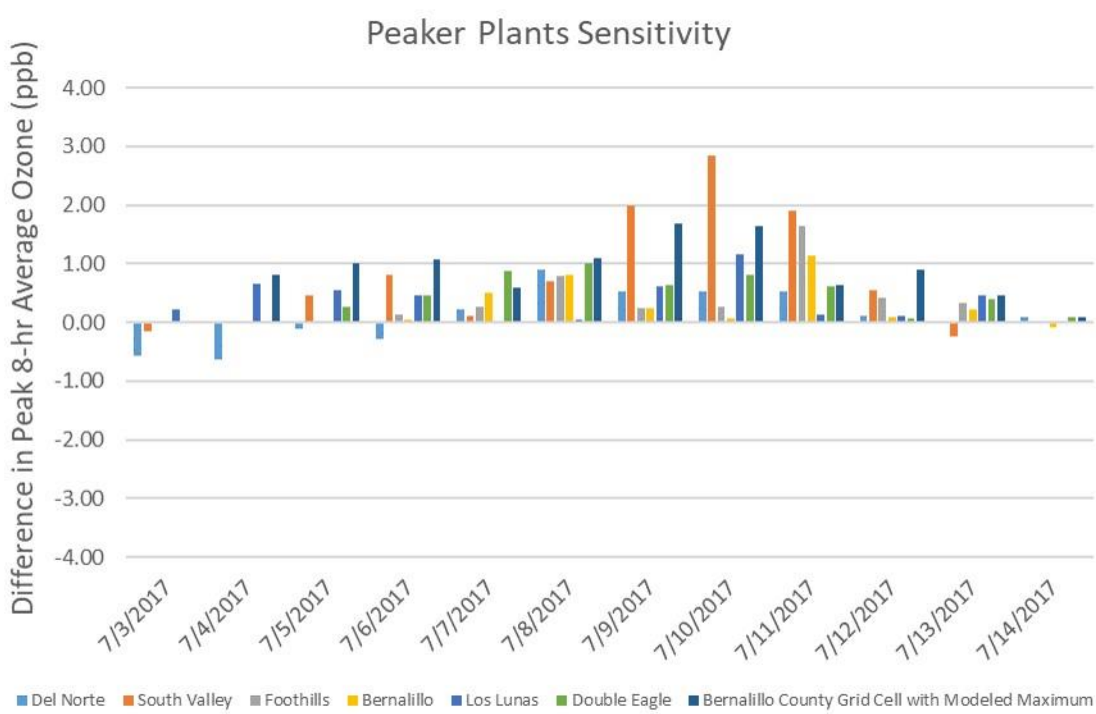

Figure 108. Differences in peak 8-hr average ozone concentrations between the simulation with Reeves and Rio Bravo power plants operating at permitted emission levels and the base-case simulation in the July ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 54. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the sensitivity simulation with the Reeves and Rio Bravo power plants operating at permitted emission levels and the base-case simulation for the July ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.89	1.5%	-0.63	-1.3%	N/A	N/A
South Valley	2.85	4.0%	-0.23	-0.4%	1.37	2.2%
Foothills	1.64	2.3%	0.00	0.0%	1.64	2.3%
Bernalillo	1.13	1.7%	-0.08	-0.2%	1.13	1.7%
Los Lunas	1.16	1.8%	0.01	0.0%	N/A	N/A
Double Eagle (SAF)	1.01	1.7%	0.00	0.0%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	1.69	2.7%	0.00	0.0%	1.07	1.6%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

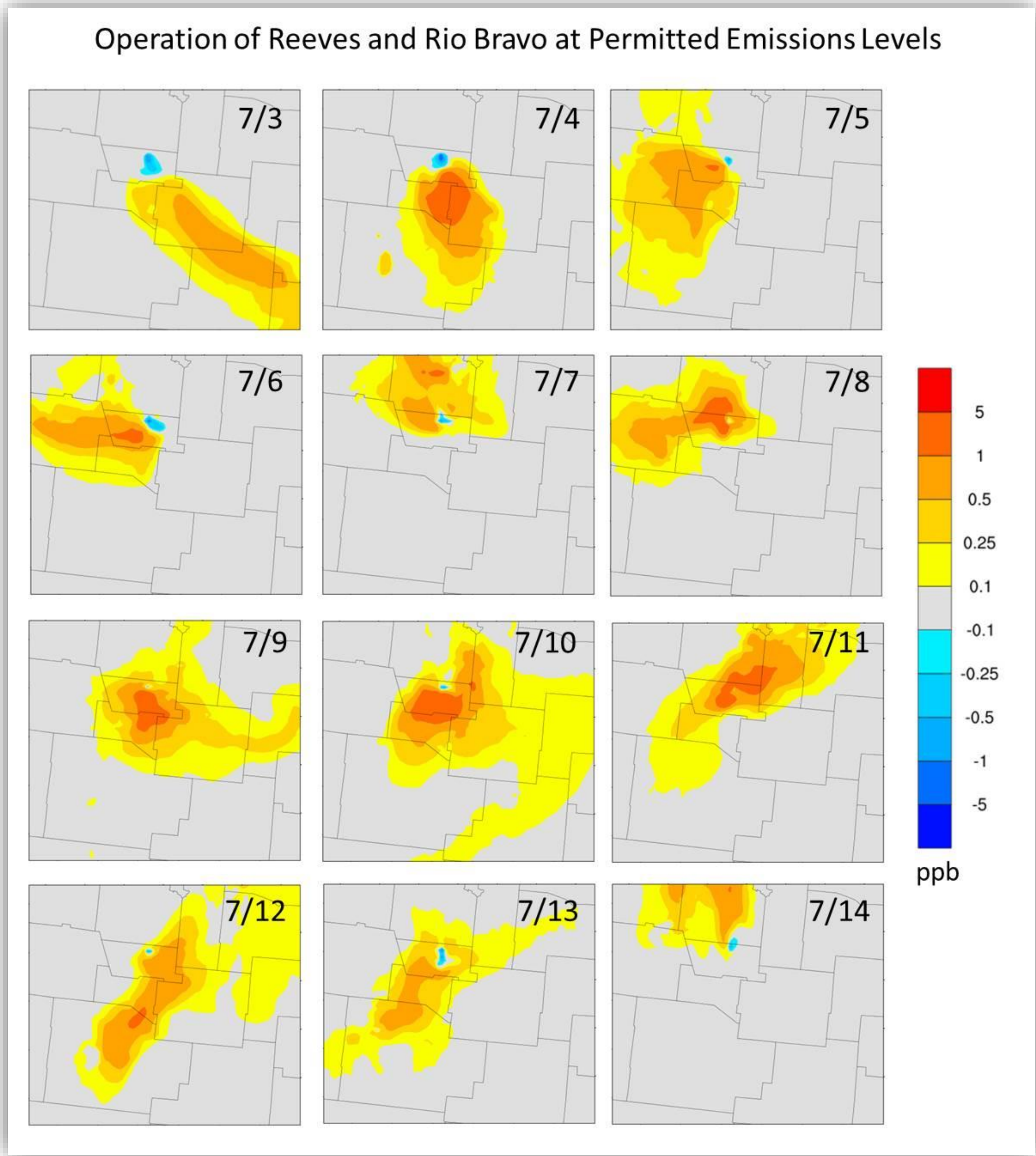

Figure 109. Differences between peak 8-hr average ozone concentrations modeled in the sensitivity simulation with Reeves and Rio Bravo power plants operating at permitted emission levels and in the base-case simulation for the July episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.4.7 100% Reduction of Sandoval County Emissions

Figure 110 and Table 55 show the modeled impacts of removing all anthropogenic emissions from Sandoval County during the July ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 111. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that removing anthropogenic emissions in Sandoval County would decrease ozone concentrations.

Removing anthropogenic emissions in Sandoval County decreased modeled peak 8-hr ozone concentrations in the Albuquerque MSA during the July episode. As during the June episode, the largest reduction (up to 2.9 ppb) was at the Foothills site, which is the closest Albuquerque/Bernalillo County site to Sandoval County. Reductions greater than 1 ppb were modeled at most sites. There were modeled increases (up to 1.5 ppb) in peak 8-hr ozone concentration at the Bernalillo site in Sandoval County on three of the twelve days in the July episode, but there were also modeled decreases in ozone concentration of greater than 1 ppb elsewhere in Sandoval County (see Figure 111). Results from this simulation show that ozone in Albuquerque/Bernalillo County is sensitive to anthropogenic emissions in Sandoval County.

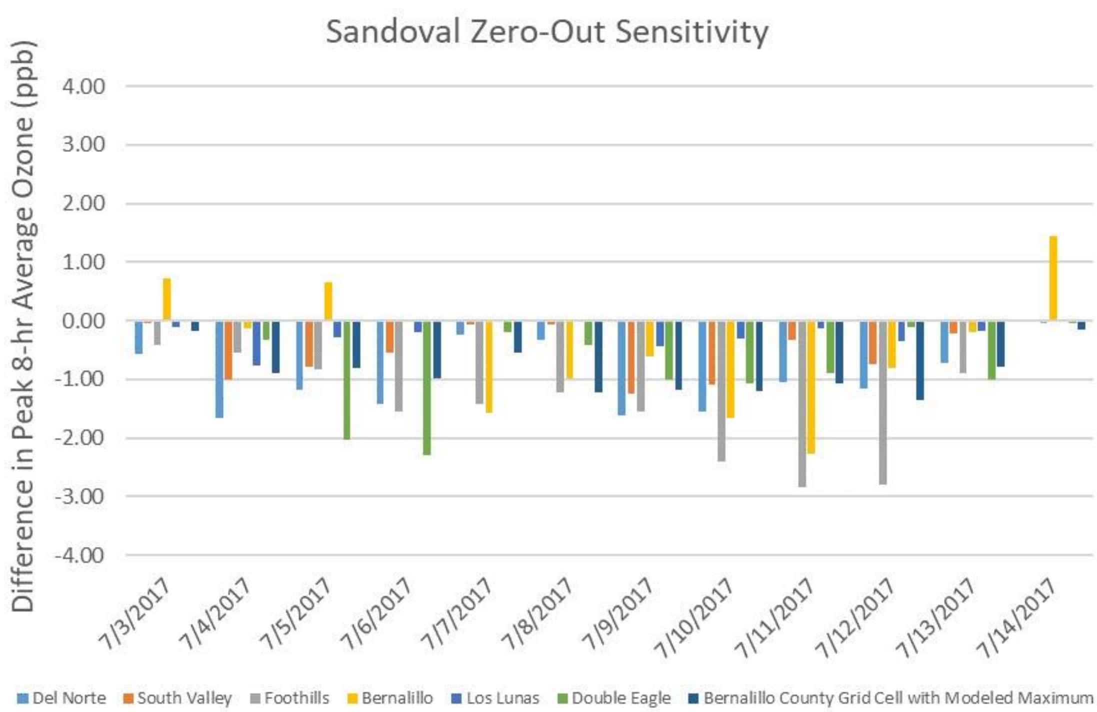

Figure 110. Differences in peak 8-hr average ozone concentrations between the Sandoval County anthropogenic emissions zero-out sensitivity simulation and the base-case simulation in the July ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 55. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the Sandoval County anthropogenic emissions zero-out sensitivity simulation and the base-case simulation for the July ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	-0.03	-0.1%	-1.67	-3.2%	N/A	N/A
South Valley	-0.02	-0.0%	-1.25	-2.0%	-0.80	-1.2%
Foothills	-0.04	-0.1%	-2.85	-4.6%	-2.85	-4.1%
Bernalillo	1.45	2.9%	-2.26	-3.4%	-2.26	-3.4%
Los Lunas	-0.01	-0.0%	-0.75	-1.2%	N/A	N/A
Double Eagle (SAF)	0.00	0.0%	-2.28	-3.6%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	-0.16	-0.3%	-1.34	-2.0%	-0.95	-1.4%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

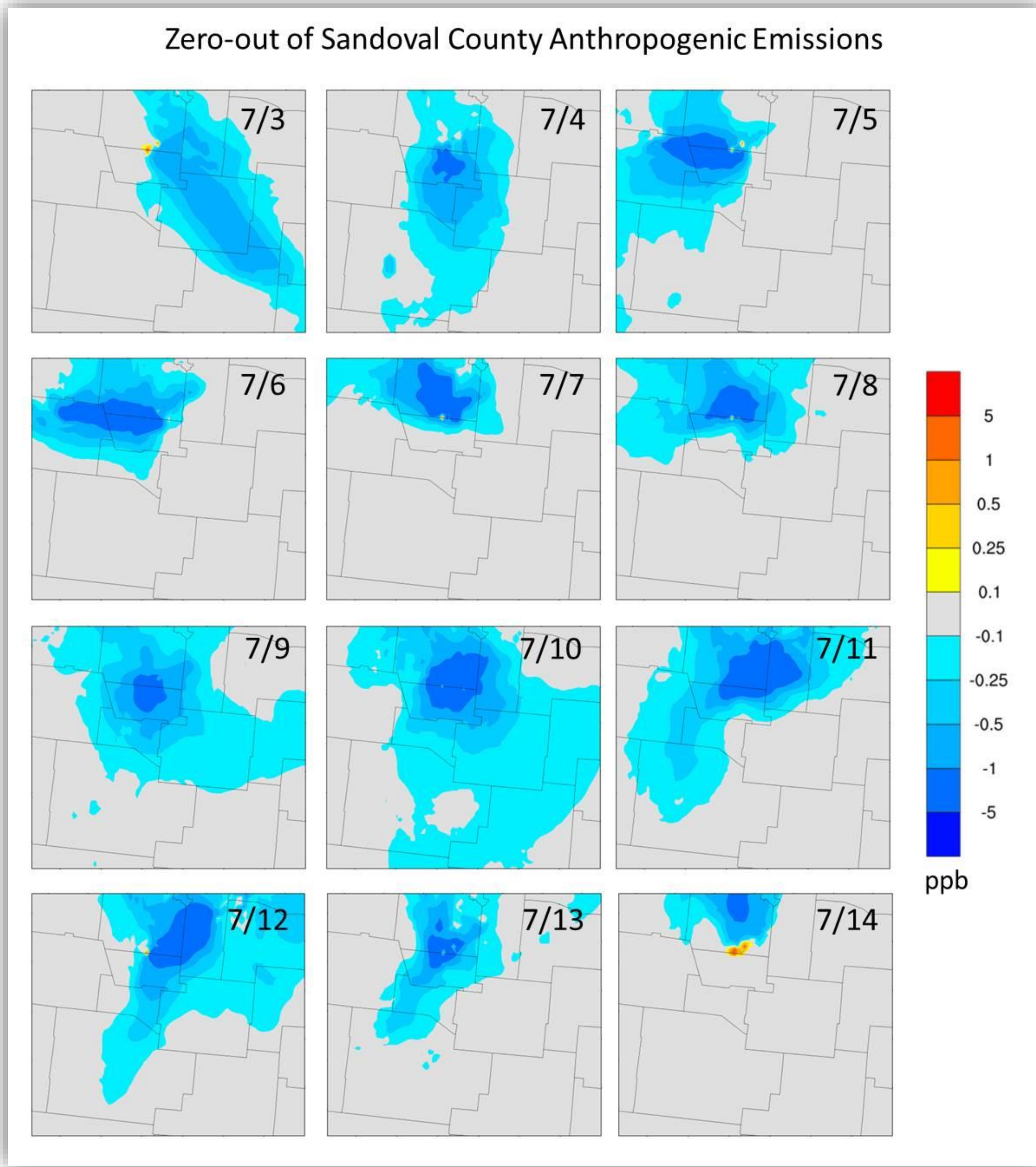

Figure 111. Differences between peak 8-hr average ozone concentrations modeled in the Sandoval County anthropogenic emissions zero-out sensitivity simulation and in the base-case simulation for the July episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.4.8 100% Reduction of Valencia County Emissions

Figure 112 and Table 56 show the modeled impacts of a zero-out of anthropogenic emissions from Valencia County during the July ozone episode. Spatial plots of the absolute concentration differences are shown in **Figure 113**. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that removing anthropogenic emissions from Valencia County would decrease ozone concentrations.

Removing anthropogenic emissions from Valencia County decreased modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County during the July episode. The largest decreases (up to 1.8 ppb) occurred at the South Valley site, which is the closest Albuquerque/Bernalillo County site to Valencia County. Outside Albuquerque/Bernalillo County, modeled ozone concentrations decreased at the Los Lunas site (in Valencia County) on all days in the July episode. The decrease at Los Lunas was greater than 2 ppb on half the episode days, and almost 4 ppb on three of the episode days. Modeled ozone concentrations decreased by at least 1 ppb on each episode day in Albuquerque/Bernalillo County or Valencia County (see Figure 113). Results from this simulation show that ozone in Albuquerque/Bernalillo County is sensitive to anthropogenic emissions in Valencia County.

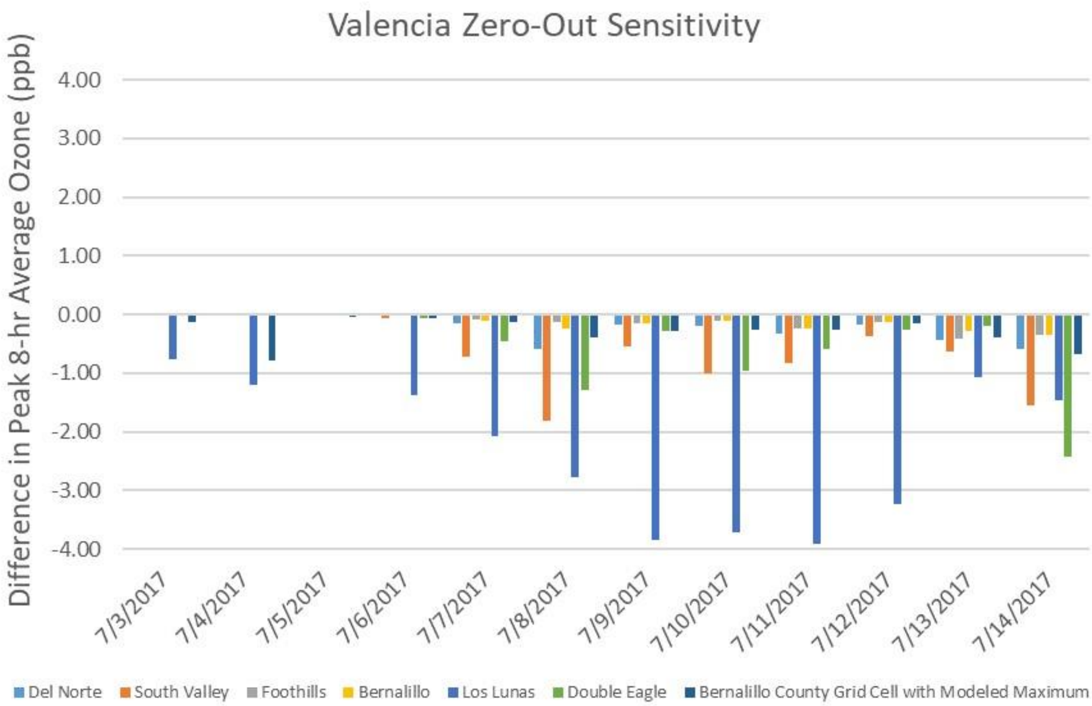

Figure 112. Differences in peak 8-hr average ozone concentrations between the Valencia County anthropogenic emissions zero-out sensitivity simulation and the base-case simulation in the July ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 56. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the Valencia County anthropogenic emissions zero-out sensitivity simulation and the base-case simulation for the July ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.00	0.0%	-0.59	-1.3%	N/A	N/A
South Valley	0.00	0.0%	-1.80	-3.3%	-0.36	-0.5%
Foothills	0.00	0.0%	-0.40	-0.7%	-0.25	-0.4%
Bernalillo	0.00	0.0%	-0.35	-0.7%	-0.23	-0.3%
Los Lunas	-0.01	-0.0%	-3.90	-6.9%	N/A	N/A
Double Eagle (SAF)	0.00	0.0%	-2.42	-4.9%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	-0.03	-0.1%	-0.78	-1.3%	-0.26	-0.4%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

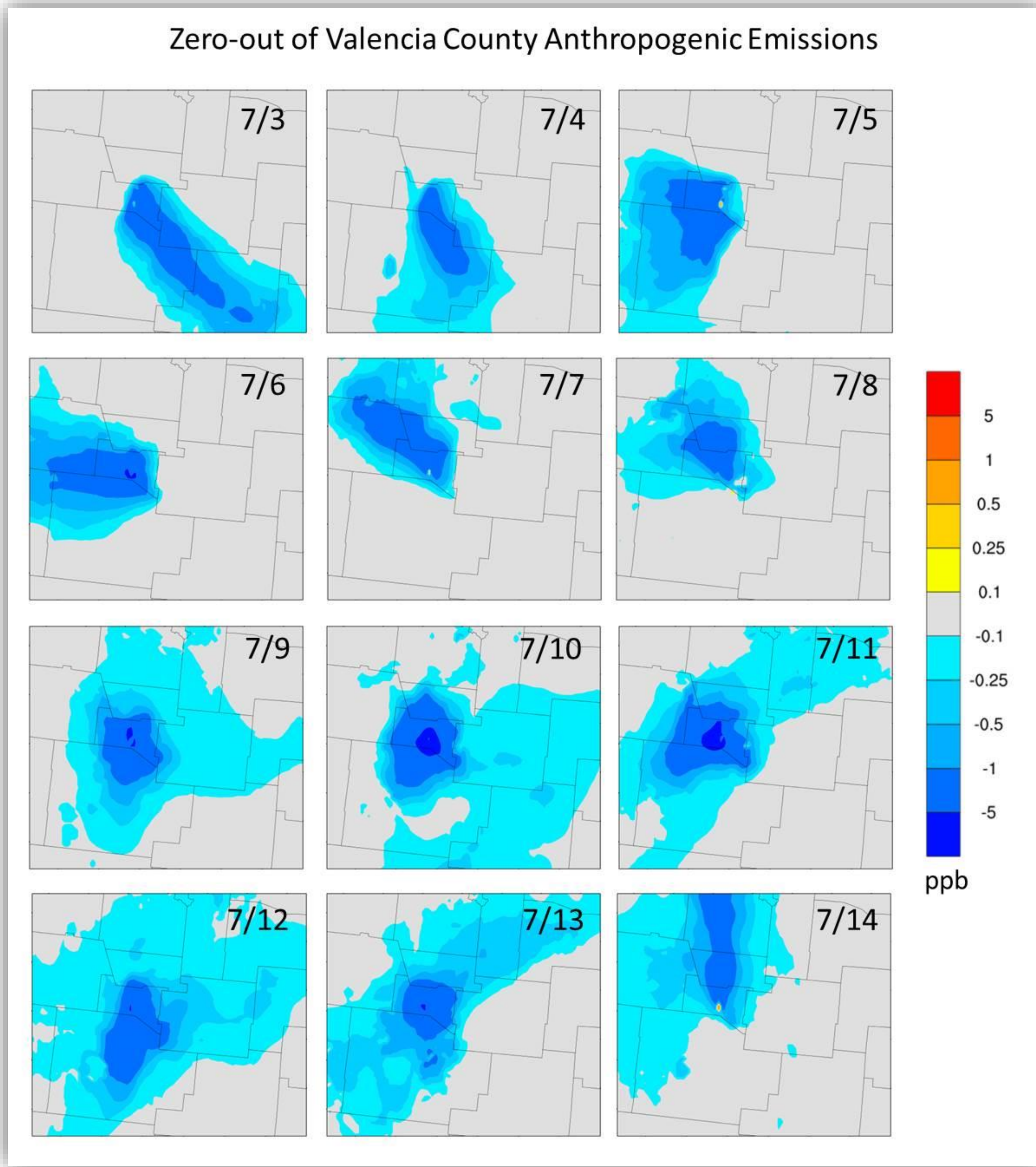

Figure 113. Differences between peak 8-hr average ozone concentrations modeled in the Valencia County anthropogenic emissions zero-out sensitivity simulation and in the base-case simulation for the July episode. Warm colors indicate an increase in ozone, while cool colors indicate a decrease.

10.5 Summary

Sensitivity simulations for the June and July 2017 ozone episodes in Albuquerque/Bernalillo County were conducted using CAMx. The impact of various NO_x and VOC emission reduction scenarios on daily peak 8-hr ozone concentrations were quantified to provide a deeper understanding of the base-case modeling results, and to demonstrate how specific emission reductions might affect ozone concentrations in Albuquerque/Bernalillo County. Ozone concentrations in Albuquerque/Bernalillo County were more sensitive to changes in local NO_x emissions in the July episode compared to the June episode, given that ozone in the July episode was driven more strongly by local emissions than in the June episode. This is consistent with findings from the base-case and source apportionment modeling analyses.

The sensitivity simulations with NO_x emission reductions in Albuquerque/Bernalillo County for both episodes showed decreased peak 8-hr average ozone concentrations at most ozone monitoring sites and on most episode days. The decreases were as large as 0.3 ppb in the June episode and 1.2 ppb in the July episode, indicating NO_x-limited conditions in Albuquerque/Bernalillo County. Ozone concentrations in Albuquerque/Bernalillo County were insensitive to the 10% reduction of local VOC emissions.

Reducing NO_x emissions in Albuquerque/Bernalillo County increased the modeled peak 8-hr average ozone concentrations at the Del Norte monitoring site, where the base-case model performance was poor (normalized mean bias was greater than ±15%). As explained in Chapter 8, the base-case simulation showed a significant negative bias in modeled ozone concentrations at the Del Norte site, likely due to high modeled NO_2 concentrations and corresponding ozone titration. Reduction of NO_x, especially on-road mobile source NO_x emissions, limits that titration, leading to modeled increases in ozone. Therefore, the modeling results at the Del Norte site in this case should not be relied upon to inform air quality management decisions. Modeling at a higher spatial resolution (e.g., 1 km) could improve model performance, particularly at the Del Norte site, because the spatial distribution of NO_x emissions from motor vehicles would be more accurately represented within the City of Albuquerque. This could reduce the emissions allocated to the model grid cell containing the Del Norte monitor and help alleviate the large ozone underestimation at that site.

During both episodes, reducing statewide NO_x and VOC emissions from the oil and gas sector resulted in a decrease in ozone concentrations in Albuquerque/Bernalillo County, by as much as 0.4 ppb during the June episode and 1.1 ppb during the July episode. Emissions from the oil and gas sector affected modeled ozone concentrations in Albuquerque/Bernalillo County and throughout the 4-km domain. The largest ozone impacts (> 1 ppb) were located within or near the oil and gas producing regions of northwest and southeast New Mexico. Albuquerque/Bernalillo County is most impacted by emissions from the oil and gas sector on days when meteorological conditions are favorable for transporting these emissions into Albuquerque/Bernalillo County.

Additional sensitivity simulations were conducted to assess the impact of the Albuquerque/Bernalillo County I&M program on ozone in Albuquerque/Bernalillo County, understand how changes in NO_x emissions from the Reeves and Rio Bravo power plants could impact ozone in the region, and to understand potential ozone contributions due to emissions in Sandoval and Valencia counties.

The sensitivity modeling analysis showed that the Bernalillo/Albuquerque I&M program, which reduces on-road mobile source NO_x emissions by 5% and VOC emissions by 7%, reduces ozone concentrations in Albuquerque/Bernalillo County by up to 0.25 ppb. Therefore, the I&M program had a small positive impact at reducing modeled ozone concentrations. When NO_x emissions from the Reeves and Rio Bravo power plants were increased to their permitted levels, peak 8-hr ozone concentrations in Albuquerque/Bernalillo County increased by 0.1-0.5 ppb during the June episode and 1-3 ppb during the July episode. These results showed that if these two power plants had operated at permitted emission levels, ozone concentrations during these two episodes in Albuquerque/Bernalillo County would likely have been higher.

Removing anthropogenic emissions from Sandoval County reduced modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County by as much as 1.5 ppb during the June episode and 2.9 ppb during the July episode. Removing anthropogenic emissions from Valencia County reduced peak 8-hr ozone concentrations in Albuquerque/Bernalillo County by about 2 ppb during both episodes, and reduced ozone concentrations in Los Lunas (in Valencia County) by as much as 4 ppb. These results showed that ozone in Albuquerque/Bernalillo County is sensitive to emissions in Sandoval and Valencia counties, and emissions from these counties can contribute to ozone in Albuquerque/Bernalillo County.

11. Future-Year Modeling and Analysis

11.1 Overview

This chapter describes the results from future-year (2025) air quality simulations conducted for the Albuquerque/Bernalillo County Ozone Modeling Analysis. This future-year analysis involved projecting emissions from 2017 to 2025 under varying scenarios. The results discussed in this chapter can be used to assess (1) how ozone in Albuquerque/Bernalillo County could be impacted by national, regional, and local changes in emissions that are expected to take place between now and 2025; (2) how future ozone concentrations in Albuquerque/Bernalillo County might be affected by changes in emissions as a result of an expanded Inspection and Maintenance (I&M) program, tri-county emissions reductions, local power plants operating at permitted emission levels, and the electrification of the gasoline vehicle fleet in Albuquerque/Bernalillo County. This analysis therefore has important implications for air quality planning.

A 2025 future-year emissions inventory was developed, and a future-year base-case CAMx simulation was conducted based on the June and July 2017 ozone episodes in Albuquerque/Bernalillo County. The results of this future-year base-case simulation were compared to the 2017 base-case simulation. Emissions were the only modeling input that was changed. Meteorology, boundary conditions, and other modeling inputs and options were unchanged from the 2017 base-case simulation.

In addition, four future-year sensitivity simulations were developed at the direction of and in consultation with the Albuquerque EHD

- Reeves and Rio Bravo power plants in Bernalillo County operating at permitted emission levels.
- Expansion of the Albuquerque/Bernalillo County I&M program to cover light-duty gasoline vehicles in Sandoval and Valencia counties.
- 25% reduction of anthropogenic NO_x and VOC emissions in Bernalillo, Sandoval, and Valencia counties (a "tri-county" emissions reduction).
- Electrification of the light-duty gasoline vehicle fleet in Albuquerque/Bernalillo County.

These sensitivity simulations were not intended to test specific emissions control programs, but rather were developed to test the sensitivity of future ozone to various types of possible emission changes. The results of these sensitivity simulations were compared to the 2025 future-year base-case simulation.

Throughout this chapter, the June 2017 episode is referred to as the regionally dominated ozone event, since the high ozone concentrations during June 2017 were largely driven by non-local and regional emissions and meteorology. The July 2017 episode is referred to as the locally dominated ozone event, since the high ozone concentrations during July 2017 were driven more strongly by local emissions and meteorology. In the future-year modeling, we use the 2017 meteorology to represent future meteorological conditions to evaluate impacts of future emission changes. Therefore, in the future-year context it is more appropriate to describe these events by their nature, rather than by calendar month.

Key results from the future-year air quality modeling analysis are as follows:

- Projected emissions reductions by 2025 would reduce peak 8-hr average ozone concentrations in Albuquerque/Bernalillo County by 3-7%. This result suggests that if projected reductions in local, regional, and nationwide emissions by 2025 materialize, these reductions would reduce future ozone concentrations in Albuquerque/Bernalillo County.
- Ozone in Albuquerque/Bernalillo County in year 2025 would be more sensitive to local changes in emissions during locally dominated ozone events, where local influences in ozone are more prevalent.
- The Reeves and Rio Bravo power plants would increase ozone in Albuquerque/Bernalillo County by up to 4 ppb in the future if they were operated at permitted emission levels.
- Expanding the I&M program to Sandoval and Valencia counties in the future would reduce ozone concentrations in Albuquerque/Bernalillo County by as much as 0.5 ppb.
- Replacing the light-duty gasoline vehicle fleet with electric vehicles in Albuquerque/Bernalillo County would reduce future ozone concentrations in Albuquerque/Bernalillo County in 2025 by as much as 2 ppb.
- Modeled ozone conditions in Albuquerque/Bernalillo County would continue to be NO_x-limited in 2025, and reducing local NO_x emissions would be effective in reducing ozone concentrations in the future.
- Reducing anthropogenic NO_x and VOC emissions by 25% in Bernalillo, Sandoval, and Valencia counties would reduce future ozone concentrations in Albuquerque/Bernalillo County by as much as 3 ppb. This result suggests that a multi-county approach to reducing emissions would be effective at reducing future ozone concentrations in Albuquerque/Bernalillo County.

11.2 Future-Year Emissions Approach

11.2.1 2025 Base-Case Emissions

The 2025 future-year emissions for this analysis were based on EPA's 2025 future-year projections (U.S. Environmental Protection Agency, 2015a).[39] The approach to projecting the 2017 base-year

[39] EPA's 2025 emissions inventory was developed from its 2011 base year emissions platform. EPA has not yet developed an emissions projection from its more recent 2014 and 2016 base-year emissions platform. Projection methods are specific to each

inventory involved developing adjustment factors for each emissions source sector, based on differences between the 2017 base-year inventory and EPA's 2025 future-year inventory. Because local emission trends do not always reflect state or national trends, separate adjustment factors for New Mexico and Albuquerque/Bernalillo County were developed for most sectors. Biogenic and fire emissions were unchanged from the 2017 base-year inventory.

For EGU point sources in the United States outside of New Mexico, NO_x emissions were reduced by 16% and SO_2 emissions were reduced by 30%, compared to 2017 emissions. These adjustments were based on nationwide power plant emissions reductions between 2017 and 2025 from EPA's Integrated Planning Model (IPM) power sector projections.[40] VOC emissions for EGUs were unchanged for 2025 because VOC emissions from power plants are small and IPM does not consider VOC emission changes. Although specific emissions reductions at individual facilities might differ from a nationwide average, this approach provides a reasonable estimate of future-year emissions from power plants outside of New Mexico.

For the EGUs within New Mexico, nationwide adjustment factors were not used, and the following projection assumptions were used:

- Eliminated emissions from Units 2 and 3 at the San Juan Generating Station (as those units were decommissioned as of December 2017), and kept emissions from Units 1 and 4 unchanged from 2017, resulting in a 50% reduction in emissions from San Juan in 2025 compared to 2017.
- Reduced NO_x emissions by 90% for Units 4 and 5 at the Four Corners Generating Station (as selective catalytic reduction controls were applied to these units in 2018),[41] resulting in a 90% reduction in NO_x emissions from Four Corners in 2025 compared to 2017.
- Reduced NO_x emissions by 51% for other EGU point sources in New Mexico, based on IPM projections of 2025 EGU emissions in New Mexico. Emissions reductions for EGUs in New Mexico are expected to outpace reductions at the national level.

For on-road mobile sources, separate projection factors were developed for New Mexico and all other states:

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source sector, and can involve running specific modeling tools or adjusting the base year emissions according to the best estimate of changes in activity and technology that are expected to occur. EPA's 2025 inventory accounts for Federal and State regulations that were promulgated or under reconsideration by December 2014. For EGUs, the projected emissions were based on IPM version 5.14 and include the Final Mercury and Air Toxics (MATS) rule announced on December 21, 2011; the Cross-State Air Pollution Rule issued July 6, 2011; and actions EPA has taken to implement the Regional Haze Rule, but not the Clean Power Plan. For on-road mobile sources, the projected emissions include EPA's Tier-3 Vehicle Emissions and Fuel Standards Program (March, 2014), light-duty vehicle greenhouse gas emissions and corporate average fuel economy standards (May 2010 for model year 2012-2016, and October 2012 for model year 2017), and California's LEVIII emissions program.

[40] More details on the IPM projections can be found at https://www.epa.gov/airmarkets/integrated-planning-model-ipm-results-viewer.

[41] Units 1 through 3 at the Four Corners Generating Station were already decommissioned prior to 2017, and therefore there were no emissions from these units in the 2017 or 2025 emission inventories.

- The EPA MOVES model was used to model the on-road mobile source emissions in New Mexico in years 2017 and 2025 using Bernalillo County's local activity data as input. The projection factor was then calculated as the ratio between the 2017 and 2025 emission levels.
- The national default in MOVES was used to model the nationwide emission level for all other states in 2017 and 2025. The ratio between these two calendar years was used as the projection factor for all states other than New Mexico.

The MOVES-based approach used here accounts for emission changes due to expected increases in VMT (which increases emissions), and due to vehicle feet turnover (which decreases emissions). In New Mexico and throughout the United States, the effect of vehicle fleet turnover will continue to drive large NO_x emissions reductions from cars and trucks over the next several years, as newer vehicles with more stringent emission control standards replace older vehicles. In New Mexico, NO_x emissions from cars and trucks estimated by MOVES are expected to decrease by 50% between 2017 and 2025. This is a significant reduction that is important for understanding future air quality.

For the oil and gas sector, emissions for New Mexico and all other states were projected to 2025 based on fuel consumption data from the U.S. Energy Information Administration's (EIA) 2018 Annual Energy Outlook.[42] The ratio between the fuel consumption in 2017 and 2025 was used as the projection factor.

For agriculture, nonpoint, nonroad, non-IPM point sources, and residential wood burning sectors, projection factors were calculated only for the entire nation because specific information for New Mexico was not available. These projection factors were calculated as the ratio between the emission levels in 2025 (projected from EPA's 2011 NEI platform by EPA) to the emission levels in 2014 (derived from EPA's 2014 NEI platform).

Tables 57 and 58 summarize the projected nationwide emission changes between 2017 and 2025 that were used to develop the 2025 future-year emissions inventory. Substantial decreases in nonroad emissions, which includes locomotives and construction equipment, are the result of fleet turnover toward newer equipment that are subjected to EPA's Tier 4 nonroad compression ignition exhaust emissions standards.[43] Decreases in residential wood combustion are less important during the ozone season, when residential wood burning is minimal. Increased emissions from the oil and gas sector reflect expected increases in oil and gas exploration and activity in the coming years based on the EIA's Annual Energy Outlook.

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[42] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=2-AEO2018&region=1-8&cases=ref2018.

[43] See https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf.

Table 57. Projected nationwide emissions changes between 2017 and 2025.

Sector	NO_X	VOC
Nonpoint	+11%	+1%
Nonroad	-43%	-27%
Oil and gas	+11%	+11%
On-road mobile sources	-50%	-45%
Point (EGUs)	-16%	0%
Point (other industry)	+51%	+6%
Rail	-24%	-32%
Residential wood combustion	+30%	+39%

Table 58. Projected New Mexico emission changes between 2017 and 2025.

Sector	NO_X	VOC
Oil and gas	+8%	+8%
On-road mobile sources	-51%	-35%
Point (EGUs)	-51%	0%

11.2.2 2025 Sensitivity Simulation Emissions

In addition to the 2025 future-year base-case simulation, emissions were developed for four future-year sensitivity simulations at the direction of and in consultation with the Albuquerque EHD:

- Reeves and Rio Bravo power plants in Bernalillo County operating at permitted emission levels.
- Expansion of the Albuquerque/Bernalillo County I&M program to cover light-duty gasoline vehicles in Sandoval and Valencia counties.
- 25% reduction of anthropogenic NO_x and VOC emissions in Bernalillo, Sandoval, and Valencia counties (a “tri-county” emissions reduction).
- Electrification of the light-duty gasoline vehicle fleet in Albuquerque/Bernalillo County.

The Rio Bravo and Reeves EGUs are located in Bernalillo County near the City of Albuquerque and are considered “peaker plants” because they operate as needed when energy demand is high. These power plants receive an operating permit from the Albuquerque EHD under EPA’s Title V major point source program. These power plants are permitted to operate within a specified amount of emissions with daily and annual emission limits, and they report their hourly emissions to EPA’s Clean Air Markets Division (CAMD). During June and July of 2017, these facilities operated well within their permitted emission levels, as shown in Table 59. To simulate the potential air quality impacts of the Rio Bravo and Reeves facilities operating at permitted emission levels, the daily NO_x and VOC emissions for those facilities in the future-year modeling inventory were set to the permitted emission levels shown in Table 59. This sensitivity simulation is intended to examine potential air quality impacts if these facilities were to emit at permitted levels during ozone episodes in the future.

Table 59. Comparison of actual vs. permitted NO_x emissions at the Reeves and Rio Bravo power plants in Bernalillo County. Actual NO_x emissions are from EPA’s CAMD for June and July 2017.

Facility	Actual NO_x	Permitted NO_x
Reeves	0.5-2.0 tons/day	11.8 tons/day
Rio Bravo	0.2-0.4 tons/day	3.5 tons/day

To simulate the impact of expanding the Albuquerque/Bernalillo County I&M program to Sandoval and Valencia counties, MOVES was used to model the on-road mobile source emissions in year 2025 for both counties. County-specific input data were based on the county database developed for the 2014 NEI. For each county, two MOVES runs were implemented: one with the I&M program, and the other without the program. Then, the ratio between the emissions outputs from the two runs were used as an adjustment factor. The resulting NOx emissions reductions in Sandoval and Valencia counties were 5-6%. The resulting VOC emissions reduction in Sandoval and Valencia were around 7%. On a relative basis, these reductions are similar to reductions resulting from the Albuquerque/Bernalillo County I&M program.

The base-case modeling indicated that ozone in Albuquerque/Bernalillo County could be sensitive to emissions from Sandoval and Valencia counties. In many cases, a regional multi-county strategy is effective and is warranted to reduce ozone concentrations in a metropolitan area. A tri-county emissions reduction scenario was therefore developed to test the sensitivity of future ozone in Albuquerque/Bernalillo County to a regional reduction in emissions across the Sandoval, Bernalillo, and Valencia tri-county region. To develop this sensitivity scenario, the anthropogenic NOx and VOC emissions in Bernalillo, Sandoval, and Valencia counties were scaled down from their projected 2025 levels by 25%.

To simulate the effects of electrifying all light-duty gasoline vehicles in Albuquerque/Bernalillo County, the SMOKE emissions processing report was used to determine the emission contribution from gasoline vehicles for Bernalillo County, and these emissions were then subtracted from the total on-road mobile source emissions. The resulting reduction of NO_x emissions was 56%, and the reduction of VOC emissions was 90%. This scenario was developed to test the potential sensitivity of future ozone to a large change in NO_x emissions that might only be possible through complete electrification of the gasoline-powered vehicle fleet, with the understanding that a complete fleet electrification within a few years is not realistic. For this scenario, only the NO_x and VOC emissions from the on-road mobile source sector in Albuquerque/Bernalillo County were changed. No attempt was made to model potential changes in vehicle activity (and therefore changes in the spatial distribution of emissions) that might arise from fleet electrification, or to model changes in electricity demand and corresponding changes in EGU emissions that might be associated with vehicle electrification.

11.3 Future-Year Air Quality Modeling Approach

A sensitivity analysis involves two types of CAMx simulations: a base-case simulation, and one or more sensitivity simulations. Here, the base case refers to both the 2017 and 2025 base-case simulations described previously. A sensitivity simulation involves developing an alternative emissions scenario, sometimes referred to as an emission control scenario. To determine the impact of the emission control, a CAMx simulation is conducted with the alternative emissions, and then the difference in pollutant concentrations between the base-case and sensitivity simulations is calculated. For these future-year analyses, the 2025 base-case simulation results were compared with the 2017 base-case simulation results, and the 2025 sensitivity simulation results were compared with the 2025 base-case simulation results. The second comparison approach was used to estimate the air quality impacts of the four future-year sensitivity scenarios described in this chapter.

Raw output from a CAMx simulation consists of hourly ozone concentrations at each model grid cell for the modeling episodes. Hourly ozone concentrations from CAMx were extracted and post-processed for all grid cells in the 4-km domain. For each modeled episode day, the peak 8-hr average ozone concentration was calculated at each grid cell. The comparisons were made at the six ozone monitoring sites in the Albuquerque MSA. Modeling results were also analyzed for the grid cell with the highest daily modeled 8-hr ozone in Albuquerque/Bernalillo County in the 2017 base-case (the “Bernalillo County Grid Cell with Modeled Maximum” location).

Results of the future-year base-case modeling and sensitivity modeling analyses are described below. Results are shown for all scenarios for each modeling episodes. Differences in modeled peak 8-hr ozone concentrations, as well as spatial plots of modeled ozone differences, are provided.

11.4 Future-Year Air Quality Modeling Results (Comparison to 2017 Base Case)

The changes in modeled peak 8-hr ozone concentration from the 2017 base-case to the 2025 base-case for one day in each modeled ozone episode are shown in Figure 114. A negative difference in modeled ozone concentrations indicates that the modeled changes in emissions between 2017 and 2025 would decrease ozone concentrations. In general, there are widespread reductions in peak 8-hr ozone across New Mexico. The reductions at the Albuquerque MSA monitoring sites range from about 1 to 5 ppb across the two ozone episodes. The modeling shows increases in ozone concentration at the Del Norte monitoring site, for which the 2017 base-case modeling underpredicted ozone concentrations (see Chapter 8).[44]

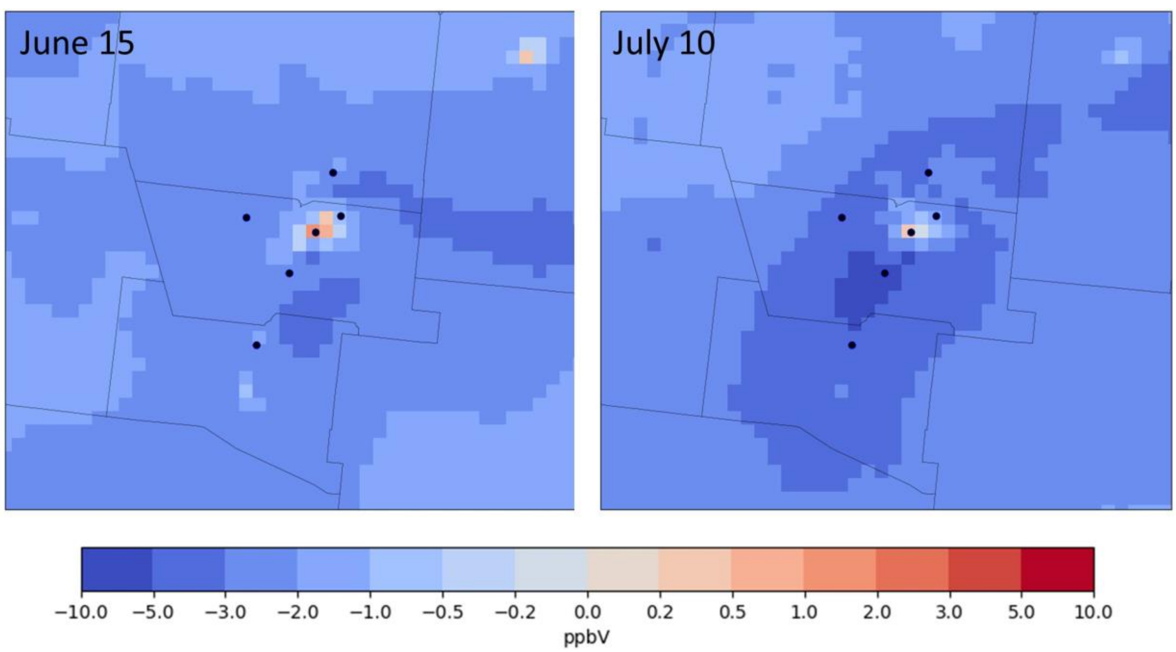

Figure 114. Differences between modeled peak 8-hr ozone concentrations in the 2025 future-year base-case and 2017 base-case modeling for one day in the June ozone episode and one day in the July ozone episode. Black circles represent the Albuquerque MSA monitoring sites.

11.4.1 Regionally Dominated Ozone Episode (June episode)

Results from the 2025 base-case simulation for the regionally driven ozone episode are summarized in Tables 60 through 62 and in Figure 115. The tables show the peak 8-hr average ozone

[44] As with the 2017 sensitivity simulations (see Chapter 10), when NO_x emissions were reduced, the reduction in NOx emissions reduces NOx titration of ozone in the grid cell containing the Del Norte site. This result is an artifact of the poor model performance for that site.

concentrations modeled in the 2017 and 2025 base-case simulations for the Albuquerque MSA monitoring sites and for the grid cell with the highest ozone concentration in Albuquerque/Bernalillo County ("Bernalillo County Grid Cell with Modeled Maximum") in the 2017 base-case simulation. The figure shows the change in modeled concentrations from the 2017 to the 2025 base-case simulation. The highest modeled 8-hr concentration of 69 ppb in 2017 occurred at the Bernalillo County Grid Cell with Modeled Maximum ozone on June 15 (see Table 62). That value dropped to 66 ppb in the 2025 base-case simulation. Modeled concentrations decreased by as much as 3.7 ppb in the 2025 base-case simulation compared to the 2017 base-case simulation.

Table 60. Modeled peak 8-hr ozone concentrations (ppb) in the 2017 and 2025 base-case simulations at the Del Norte, South Valley, and Foothills monitoring sites during the regionally dominated ozone episode.

Date	Del Norte		South Valley		Foothills	
	2017	2025	2017	2025	2017	2025
6/12	45	47	49	49	50	50
6/13	47	48	51	50	53	52
6/14	57	57	63	60	65	63
6/15	58	59	66	63	67	65
6/16	53	54	60	59	59	56

Table 61. Modeled peak 8-hr ozone concentrations (ppb) in the 2017 and 2025 base-case simulations at the Bernalillo, Los Lunas, and Double Eagle monitoring sites during the regionally dominated ozone episode.

Date	Bernalillo		Los Lunas		Double Eagle	
	2017	2025	2017	2025	2017	2025
6/12	49	50	49	49	47	47
6/13	50	49	50	50	52	51
6/14	61	60	61	59	60	57
6/15	62	61	65	63	62	59
6/16	57	55	67	64	57	55

Table 62. Modeled peak 8-hr ozone concentrations (ppb) in the 2017 and 2025 base-case simulations at the grid cell location of the highest peak 8-hr ozone concentration in the 2017 base-case simulation ("Bernalillo County Grid Cell with Modeled Maximum") during the regionally dominated ozone episode.

Date	Bernalillo County Grid Cell with Modeled Maximum	
	2017	2025
6/12	51	50
6/13	55	54
6/14	67	65
6/15	69	66
6/16	68	64

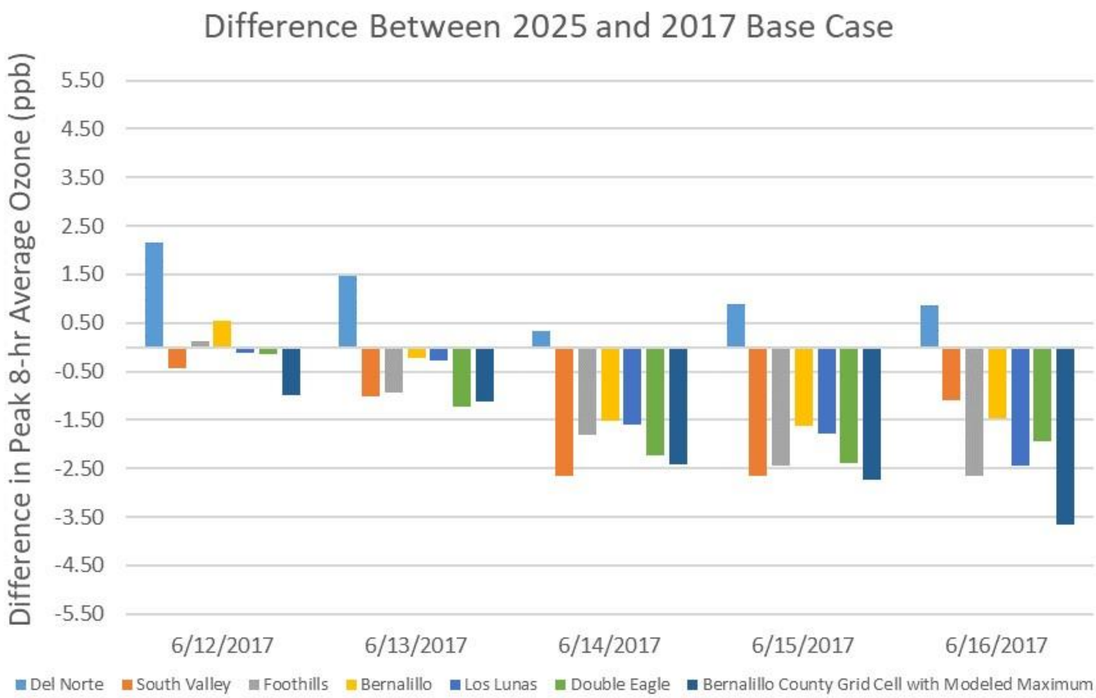

Figure 115. Differences in peak 8-hr average ozone concentrations between the 2025 future-year base-case and the 2017 base-case simulation in the regionally dominated ozone episode at the Albuquerque MSA sites, and at the grid cells where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

11.4.2 Locally Dominated Ozone Episode (July Episode)

Results from the 2025 base-case simulation for the locally dominated ozone episode are summarized in Tables 63 through 65 and in Figure 116. The tables show the peak 8-hr average ozone concentrations modeled in the 2017 and 2025 base-case simulations for the Albuquerque MSA monitoring sites and for the Bernalillo County Grid Cell with Modeled Maximum ozone in the 2017 base-case simulation. The figure shows the change in modeled concentration from the 2017 to the 2025 base-case simulation. In the 2017 base-case simulation, the modeled peak 8-hr average ozone concentration exceeded 70 ppb at the South Valley monitor on July 10 (71 ppb) and at Bernalillo County Grid Cell with Modeled Maximum ozone on July 6 (71 ppb), July 10 (72 ppb), and July 11 (71 ppb). These values were reduced to below 70 ppb in the 2025 base-case simulation. Overall, modeled concentrations in 2025 were as much as 5.2 ppb lower than in 2017 across sites and days in the episode. Modeled concentrations increased from 2017 to 2025 at the Del Norte site, but only on half of the episode days.

Table 63. Modeled peak 8-hr ozone concentrations (ppb) in the 2017 and 2025 base-case simulations at Del Norte, South Valley, and Foothills monitoring sites during the locally dominated ozone episode.

Date	Del Norte		South Valley		Foothills	
	2017	2025	2017	2025	2017	2025
7/3	46	48	52	51	53	51
7/4	52	51	59	56	55	53
7/5	56	55	66	63	59	56
7/6	59	60	69	65	61	58
7/7	59	60	60	58	65	62
7/8	58	58	55	53	65	62
7/9	59	58	62	59	57	55
7/10	62	61	71	66	61	58
7/11	64	64	61	58	70	65
7/12	54	54	61	58	62	58
7/13	53	53	58	56	57	55
7/14	44	45	48	47	49	48

Table 64. Modeled peak 8-hr ozone concentrations (ppb) in the 2017 and 2025 base-case simulations at the Bernalillo, Los Lunas, and Double Eagle monitoring sites during the locally dominated ozone episode.

Date	Bernalillo		Los Lunas		Double Eagle	
	2017	2025	2017	2025	2017	2025
7/3	50	50	54	53	49	49
7/4	53	51	61	57	53	49
7/5	56	55	61	59	60	56
7/6	58	57	62	60	64	61
7/7	61	59	60	58	65	62
7/8	63	60	53	51	60	57
7/9	56	54	59	56	55	53
7/10	60	58	64	59	63	59
7/11	66	62	56	54	59	56
7/12	56	54	60	56	53	51
7/13	55	53	54	52	56	53
7/14	50	49	49	48	50	48

Table 65. Modeled peak 8-hr ozone concentrations (ppb) in the 2017 and 2025 base-case simulations at the grid cell location of the highest peak 8-hr ozone concentration in the 2017 base-case simulation ("Bernalillo County Grid Cell with Modeled Maximum") during the locally dominated ozone episode.

Date	Bernalillo County Grid Cell with Modeled Maximum	
	2017	2025
7/3	56	54
7/4	61	57
7/5	68	64
7/6	71	67
7/7	67	64
7/8	67	64
7/9	63	60
7/10	72	68
7/11	71	68
7/12	65	62
7/13	60	57
7/14	54	52

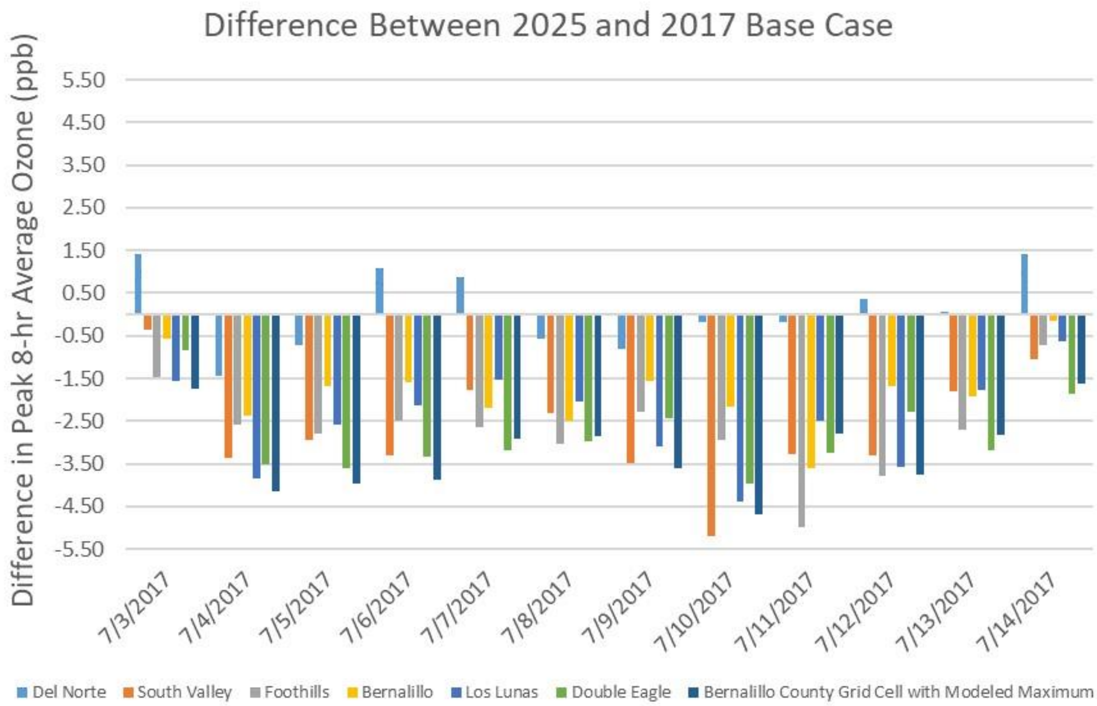

Figure 116. Differences in peak 8-hr average ozone concentrations between the 2025 future-year base-case and the 2017 base-case simulation in the locally dominated ozone episode at the Albuquerque MSA sites, and at the grid cells where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

11.5 Future-Year Sensitivity Analysis

Results from the future-year sensitivity simulations were compared to results from the 2025 base-case simulation at Albuquerque MSA monitoring sites. Modeling results were also analyzed for the grid cells with the highest daily modeled 8-hr ozone in Albuquerque/Bernalillo County in the 2017 base case (the "Bernalillo County Grid Cell with Modeled Maximum" locations).

11.5.1 Operation of Reeves and Rio Bravo Power Plants at Permitted Emission Levels

Figure 117 and Table 66 show the modeled impacts of increasing NO_x and VOC emissions from the Rio Bravo and Reeves power plants to permitted emission levels during the regionally dominated ozone episode; **Figure 118 and Table 67** show the impacts during the locally dominated episode. Spatial plots of the absolute concentration differences are shown in **Figure 119**. In this sensitivity simulation, a positive difference in modeled ozone concentration indicates that increasing emissions at the Reeves and Rio Bravo power plants to permitted emission levels in the future would increase ozone concentrations.

Increasing emissions from the Rio Bravo and Reeves power plants increased modeled ozone concentrations on most days and sites in both modeling episodes. In the regionally dominated ozone episode, concentrations increased by as much as 1.3 ppb; in the locally dominated ozone episode, concentrations increased by as much as 4.3 ppb. The smaller increase during the regionally dominated ozone episode reflects the greater regional influence on ozone during that episode. Across days and sites where the 2025 base-case ozone levels were greater than or equal to 65 ppb, the average increase in ozone ranged from 0.2 to 0.9 ppb in the regionally dominated ozone episode, and from 1.7 to 2.4 ppb in the locally dominated ozone episode.

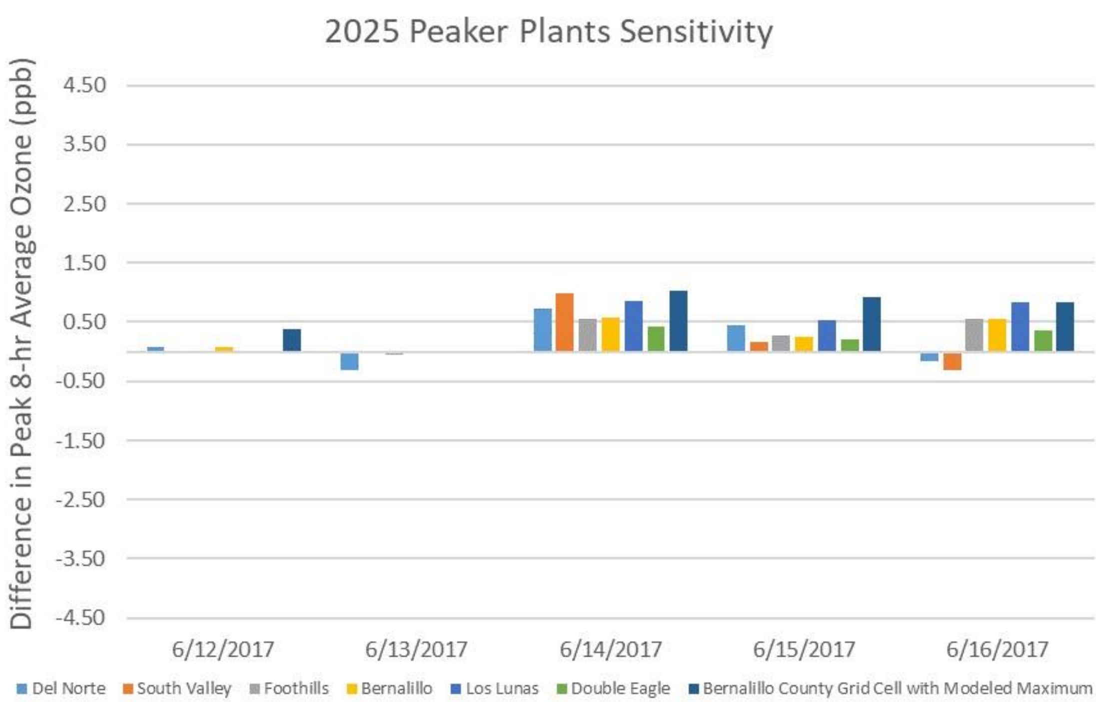

Figure 117. Differences in peak 8-hr average ozone concentrations between the 2025 peaker plants sensitivity simulation and the 2025 base-case simulation in the regionally dominated ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 66. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 2025 peaker plants sensitivity simulation and the 2025 base-case simulation for the regionally dominated ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.72	1.3%	-0.30	-0.6%	N/A	N/A
South Valley	0.98	1.6%	-0.32	-0.5%	0.17	0.3%
Foothills	0.56	1.0%	-0.06	-0.1%	0.27	0.4%
Bernalillo	0.58	1.0%	0.00	0.0%	N/A	N/A
Los Lunas	0.86	1.5%	0.00	0.0%	0.84	1.3%
Double Eagle (SAF)	0.42	0.7%	0.00	0.0%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	1.33	2.1%	0.10	0.2%	0.92	1.4%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

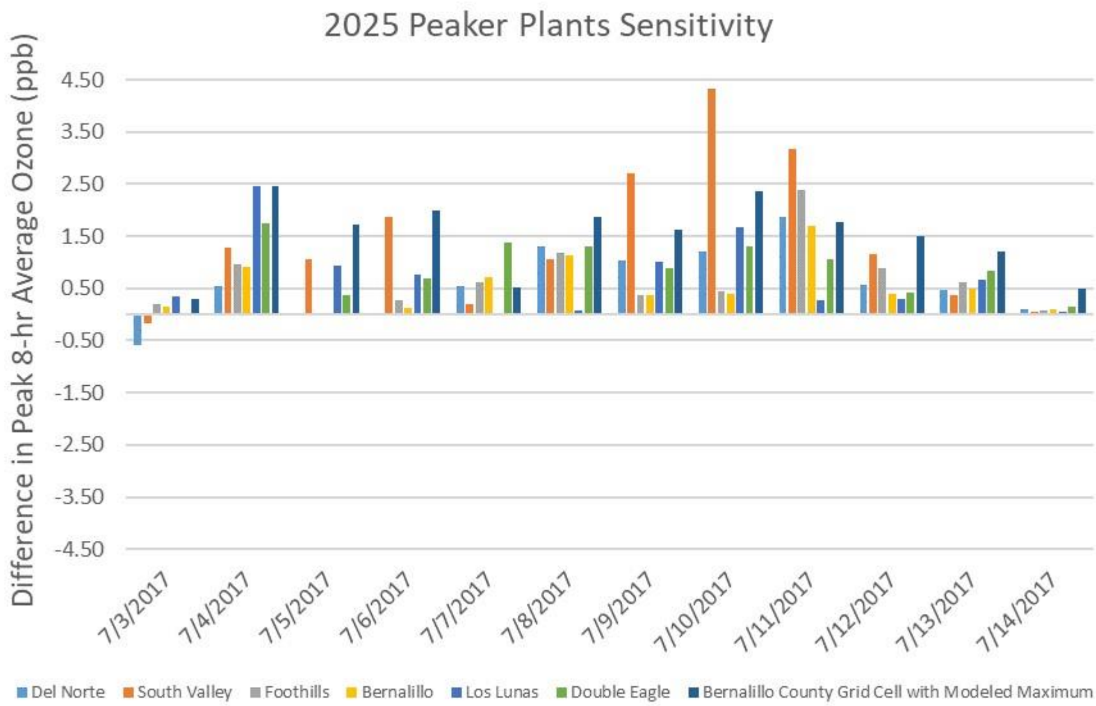

Figure 118. Differences in peak 8-hr average ozone concentrations between the 2025 peaker plants sensitivity simulation and the 2025 base-case simulation in the locally dominated ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 67. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 2025 peaker plants sensitivity simulation and the 2025 base-case simulation for the locally dominated ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	1.88	2.9%	-0.60	-1.3%	N/A	N/A
South Valley	4.33	6.6%	-0.16	-0.3%	2.42	3.5%
Foothills	2.38	3.7%	0.03	0.1%	2.38	3.4%
Bernalillo	1.70	2.7%	0.03	0.1%	1.70	2.6%
Los Lunas	2.46	4.3%	0.03	0.0%	N/A	N/A
Double Eagle (SAF)	1.75	3.6%	0.00	0.0%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	2.50	4.4%	0.31	0.6%	1.90	3.0%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

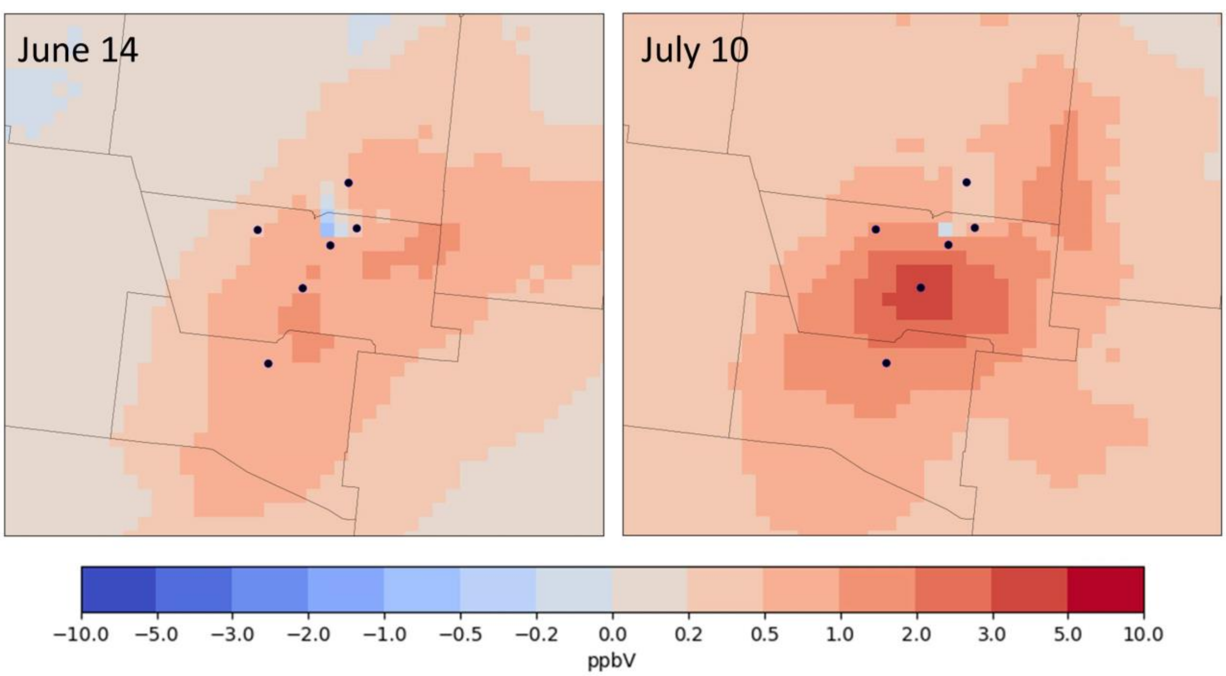

Figure 119. Differences between modeled peak 8-hr ozone concentrations in the 2025 peaker plants sensitivity simulations and the 2025 base-case simulations for one day in each episode. Black circles represent the Albuquerque MSA monitoring sites.

The spatial plots in Figure 119 illustrate the widespread increase in ozone concentrations across the Albuquerque MSA when these two power plants are operated at permitted emission levels. The plots also show the greater influence of local emissions on ozone concentrations during the locally dominated ozone episode.

11.5.2 I&M Program Expansion

Tables 68 and 69 show the modeled impacts of expanding the Albuquerque/Bernalillo County I&M program to Sandoval and Valencia counties during the two ozone episodes. Expanding the I&M program decreased ozone concentrations in Albuquerque/Bernalillo County by as much as 0.5 ppb (at the Bernalillo County Grid Cell with Modeled Maximum ozone), and would therefore provide a small positive future ozone benefit in the region. This impact was similar in magnitude to the ozone benefits that were modeled from the Albuquerque/Bernalillo County I&M program (see Chapter 10). Although expanding the I&M program to Sandoval and Valencia counties had a relatively small impact on modeled future ozone in Albuquerque/Bernalillo County, the I&M program in Albuquerque/Bernalillo County continues to be an important way to control future NO_x and VOC emissions.

The purpose of an I&M program is to ensure that motor vehicles are operating in a manner that meets federal, state, and local emission standards. The Albuquerque EHD uses the EPA MOVES model and detailed travel activity data to estimate motor vehicle emissions in Albuquerque/Bernalillo County. Compliance with the current I&M program is built into the MOVES model modeling conducted by Albuquerque EHD, and these emissions estimates are reported to EPA and included in the NEI. Without an I&M program, there is risk that the motor vehicle emission in Albuquerque/Bernalillo County would fail to meet the projections made by Albuquerque EHD. The actual impact on future emissions and ozone air quality will be sensitive to how vehicle owners maintain their vehicles in the absence of an I&M program, and therefore how much credit (in terms of emissions reductions) should be assumed for I&M program compliance. I&M programs can also produce benefits for other pollutants, such as NO_2 and particulate matter, which are important for protecting air quality near major roadways.

Table 68. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 2025 I&M expansion sensitivity simulation and the 2025 base-case simulation for the regionally dominated ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	0.00	0.0%	-0.04	-0.1%	N/A	N/A
South Valley	0.00	0.0%	-0.05	-0.1%	-0.05	-0.1%
Foothills	0.00	0.0%	-0.04	-0.1%	-0.03	-0.1%
Bernalillo	0.03	0.1%	0.00	0.0%	N/A	N/A
Los Lunas	0.03	0.1%	-0.03	-0.1%	-0.01	-0.0%
Double Eagle (SAF)	0.00	0.0%	-0.02	-0.0%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	0.48	0.8%	-0.03	-0.1%	-0.02	-0.0%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

Table 69. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 2025 I&M expansion sensitivity simulation and the 2025 base-case simulation for the locally dominated ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	-0.01	-0.0%	-0.04	-0.1%	N/A	N/A
South Valley	0.00	0.0%	-0.04	-0.1%	-0.02	-0.0%
Foothills	0.00	0.0%	-0.06	-0.1%	-0.06	-0.1%
Bernalillo	0.02	0.1%	-0.04	-0.1%	-0.04	-0.1%
Los Lunas	-0.00	-0.0%	-0.09	-0.2%	N/A	N/A
Double Eagle (SAF)	0.00	0.0%	-0.04	-0.1%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	0.50	0.8%	-0.03	-0.0%	-0.02	-0.0%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

11.5.3 25% Reduction in Anthropogenic NO_x and VOC Emissions

Figure 120 and Table 70 show the modeled impacts of decreasing anthropogenic NO_x and VOC emissions in Albuquerque/Bernalillo County, Sandoval County, and Valencia County during the regionally dominated ozone episode; Figure 121 and Table 71 show the impacts during the locally dominated ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 122. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that reducing emissions in the three counties would decrease future ozone concentrations.

Reducing anthropogenic emissions by 25% in Albuquerque/Bernalillo County, Sandoval County, and Valencia County decreased the peak modeled 8-hr ozone concentrations by as much as 2.9 ppb (4.3%) at the Bernalillo County Grid Cell with Modeled Maximum ozone on July 10. On most days and at most sites in the Albuquerque MSA, the modeled ozone concentrations decreased, through the modeled ozone increased by up to 1.2 ppb (2.4%) at the Del Norte site. On days when the 2025 base-case modeling produced ozone concentrations greater than or equal to 65 ppb, modeled ozone concentrations decreased by as much as 1.1 ppb during the regionally dominated episode, and by as much as 2.5 ppb during the locally dominated episode.

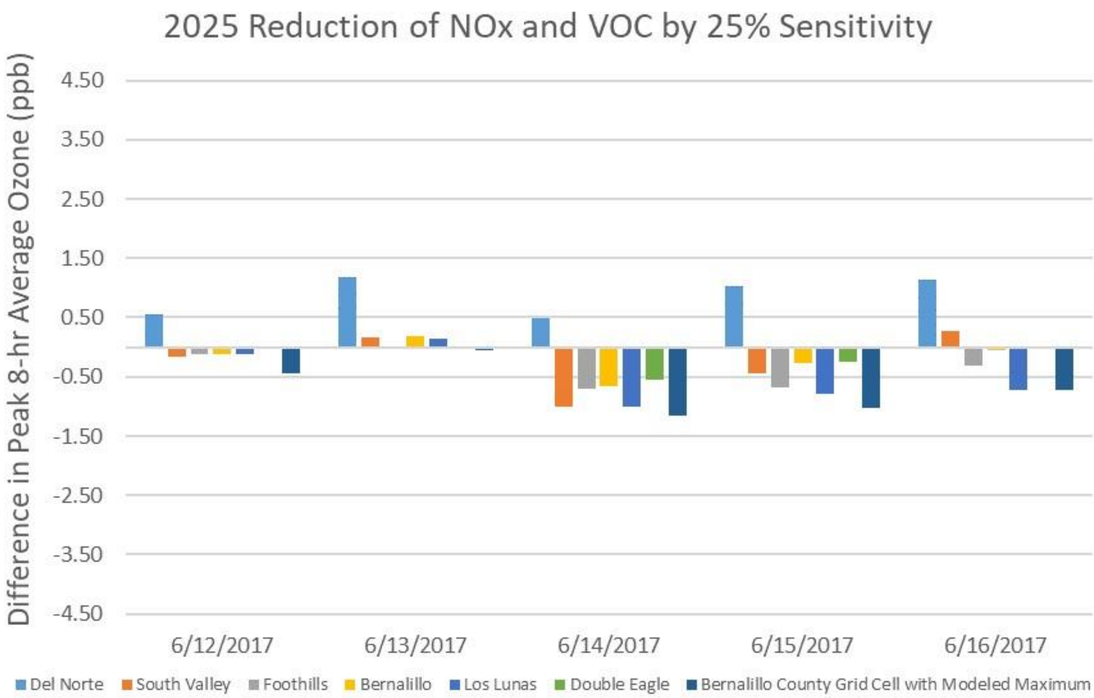

Figure 120. Differences in peak 8-hr average ozone concentrations between the 2025 anthropogenic NO_x and VOC 25% reduction sensitivity simulation and the 2025 base-case simulation in the regionally dominated ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 70. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 2025 anthropogenic NO_x and VOC 25% reduction sensitivity simulation and the 2025 base-case simulation for the regionally dominated ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	1.17	2.4%	0.48	0.8%	N/A	N/A
South Valley	0.27	0.5%	-1.01	-1.7%	-0.44	-0.7%
Foothills	-0.03	-0.1%	-0.70	-1.1%	-0.67	-1.0%
Bernalillo	0.19	0.4%	-0.66	-1.1%	N/A	N/A
Los Lunas	0.15	0.3%	-1.00	-1.7%	-0.72	-1.1%
Double Eagle (SAF)	-0.01	-0.0%	-0.54	-1.0%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	0.03	0.1%	-1.16	-1.8%	-1.03	-1.6%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

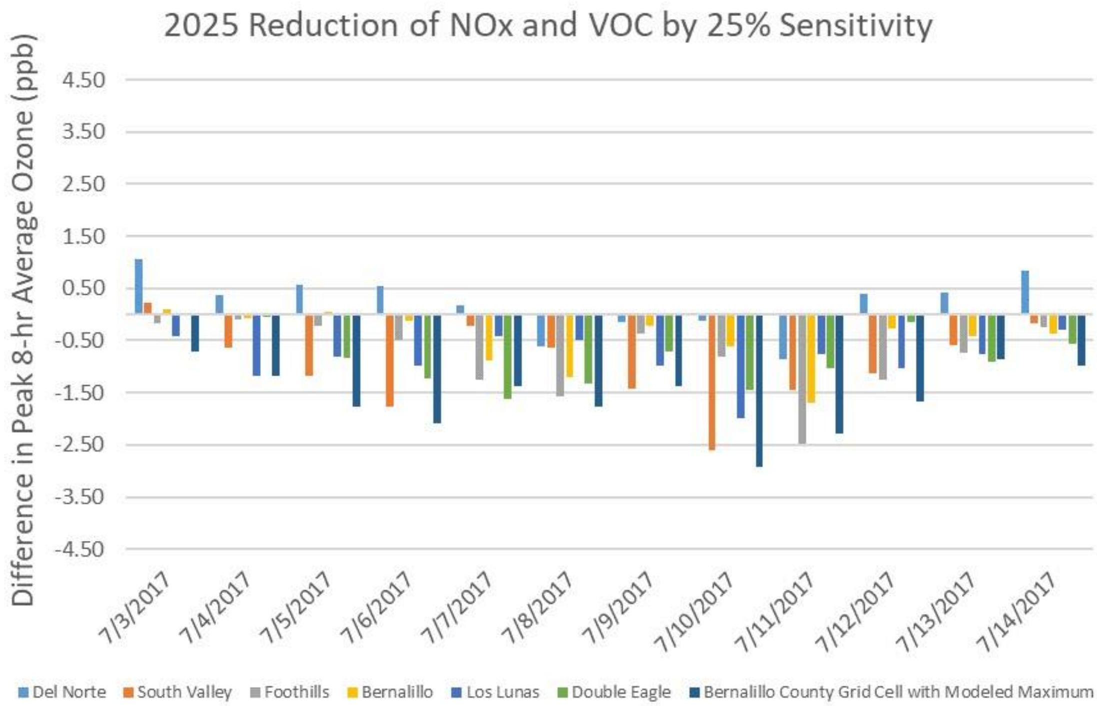

Figure 121. Differences in peak 8-hr average ozone concentrations between the 2025 anthropogenic NO_x and VOC 25% reduction sensitivity simulation and the 2025 base-case simulation in the locally dominated ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 71. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 2025 anthropogenic NO_x and VOC 25% reduction sensitivity simulation and the 2025 base-case simulation for the locally dominated ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	1.07	2.2%	-0.85	-1.3%	N/A	N/A
South Valley	0.22	0.4%	-2.61	-4.0%	-1.85	-2.7%
Foothills	-0.09	-0.2%	-2.49	-3.8%	-2.49	-3.6%
Bernalillo	0.10	0.2%	-1.70	-2.7%	-1.70	-2.6%
Los Lunas	-0.28	-0.6%	-1.99	-3.4%	N/A	N/A
Double Eagle (SAF)	0.00	0.0%	-1.62	-2.6%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	-0.60	-1.0%	-2.91	-4.3%	-2.02	-3.1%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation. N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

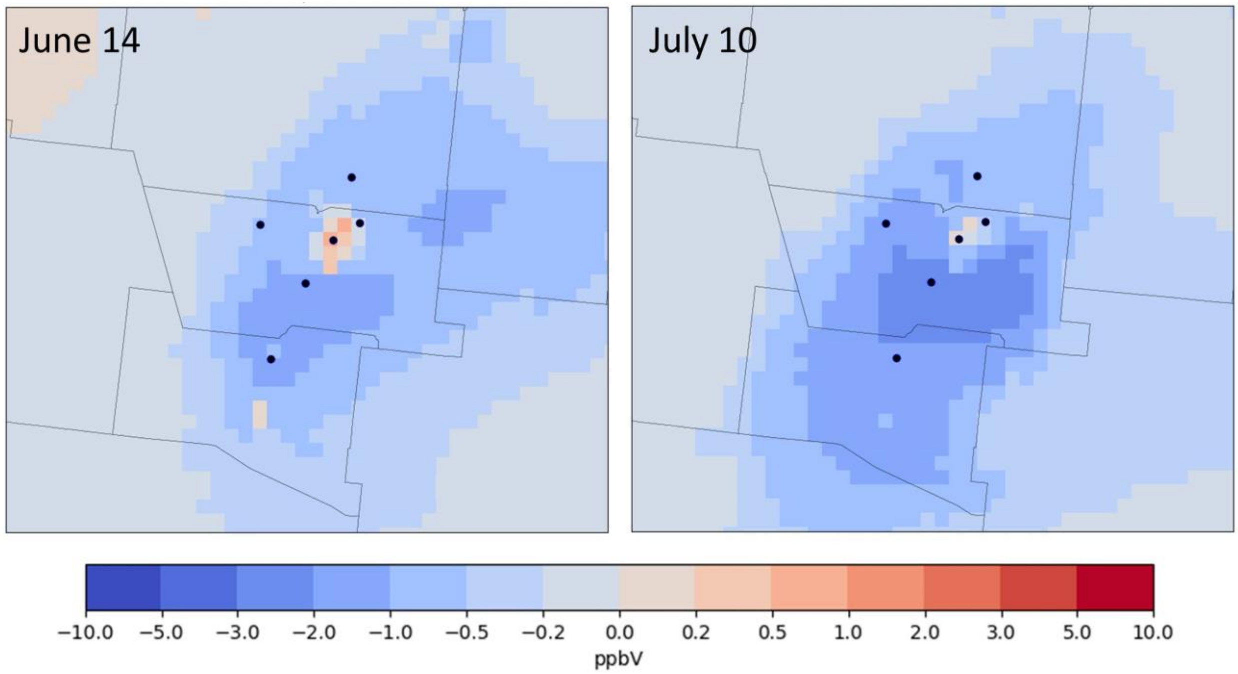

Figure 122. Differences between modeled peak 8-hr ozone concentrations in the 2025 anthropogenic NO_x and VOC 25% reduction sensitivity simulations and the 2025 base-case simulations for one day in each ozone episode. Black circles represent the monitoring sites listed in Table 61.

The spatial plots in Figure 122 illustrate the decrease in ozone concentrations in Albuquerque/Bernalillo County when anthropogenic NO_x and VOC emissions in Bernalillo, Sandoval, and Valencia counties are reduced by 25%. The modeled ozone reductions were larger in the regionally dominated ozone episode (July 10 in Figure 122) compared to the locally dominated ozone episode (June 14 in Figure 122). The grid cells shaded red, indicate an increase in ozone concentration, represent modeled VOC-limited conditions at or near the Del Norte monitoring site.[45]

11.5.4 Transition of All Light-Duty Gasoline-Powered Vehicles to Electric-Powered

Figure 123 and Table 72 show the modeled impacts of transitioning all light-duty gasoline-powered vehicles in Albuquerque/Bernalillo County to electric-powered vehicles during the regionally dominated ozone episode; Figure 124 and Table 73 show the impacts during the locally dominated ozone episode. Spatial plots of the absolute concentration differences are shown in Figure 125. In this sensitivity simulation, a negative difference in modeled ozone concentrations indicates that electrifying the light-duty gasoline-powered vehicle fleet in Albuquerque/Bernalillo County would decrease future ozone concentrations.

[45] This was likely an artifact of poor model performance at the Del Norte site in the 2017 base-case modeling.

Transitioning all light-duty gasoline-powered vehicles to electric power in 2025 resulted in reductions in modeled peak 8-hr ozone concentrations in Albuquerque/Bernalillo County by as much as 0.8 ppb (1.1%) during the regionally dominated ozone episode and 1.9 ppb (2.8%) during the locally dominated ozone episode. Note that this sensitivity simulation did not include electrification of diesel-powered vehicles, which are an important source of NO_x emissions in Albuquerque/Bernalillo County.

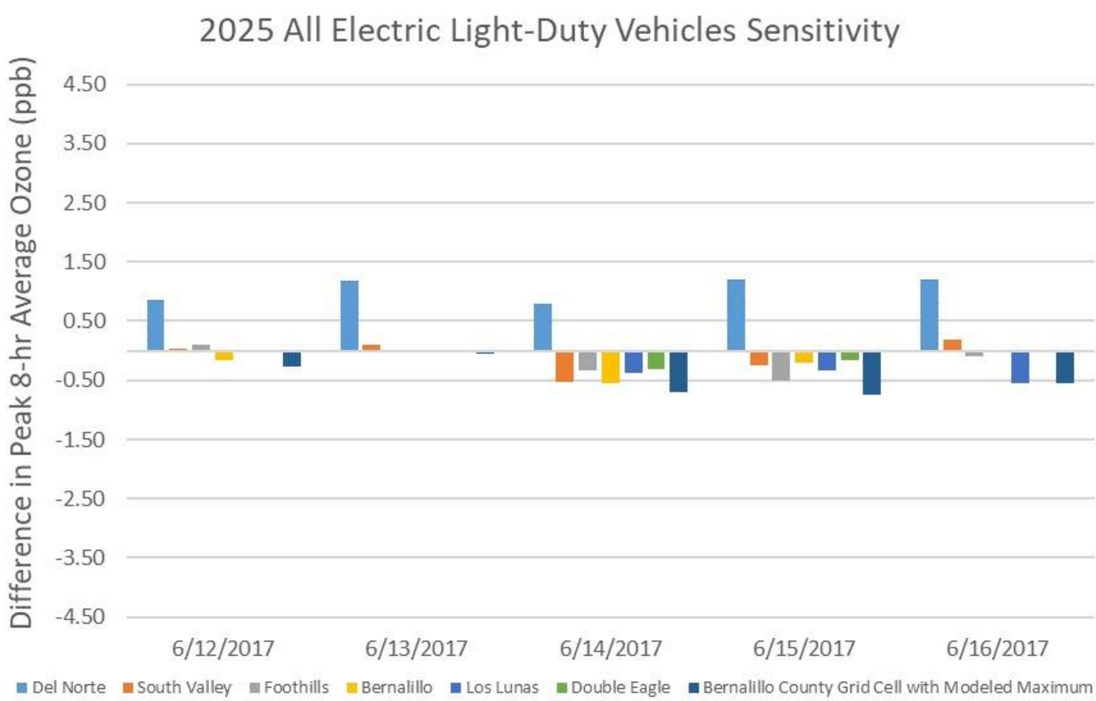

Figure 123. Differences in peak 8-hr average ozone concentrations between the 2025 all-electric light-duty vehicles sensitivity simulation and the 2025 base-case simulation in the regionally dominated ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 72. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 2025 all-electric light-duty vehicles sensitivity simulation and the 2025 base-case simulation for the regionally dominated ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	1.21	2.4%	0.79	1.4%	N/A	N/A
South Valley	0.18	0.3%	-0.54	-0.9%	-0.25	-0.4%
Foothills	0.09	0.2%	-0.51	-0.8%	-0.51	-0.8%
Bernalillo	0.00	0.0%	-0.55	-0.9%	N/A	N/A
Los Lunas	0.00	0.0%	-0.54	-0.8%	-0.54	-0.8%
Double Eagle (SAF)	-0.00	-0.0%	-0.30	-0.5%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	0.04	0.1%	-0.75	-1.1%	-0.75	-1.1%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

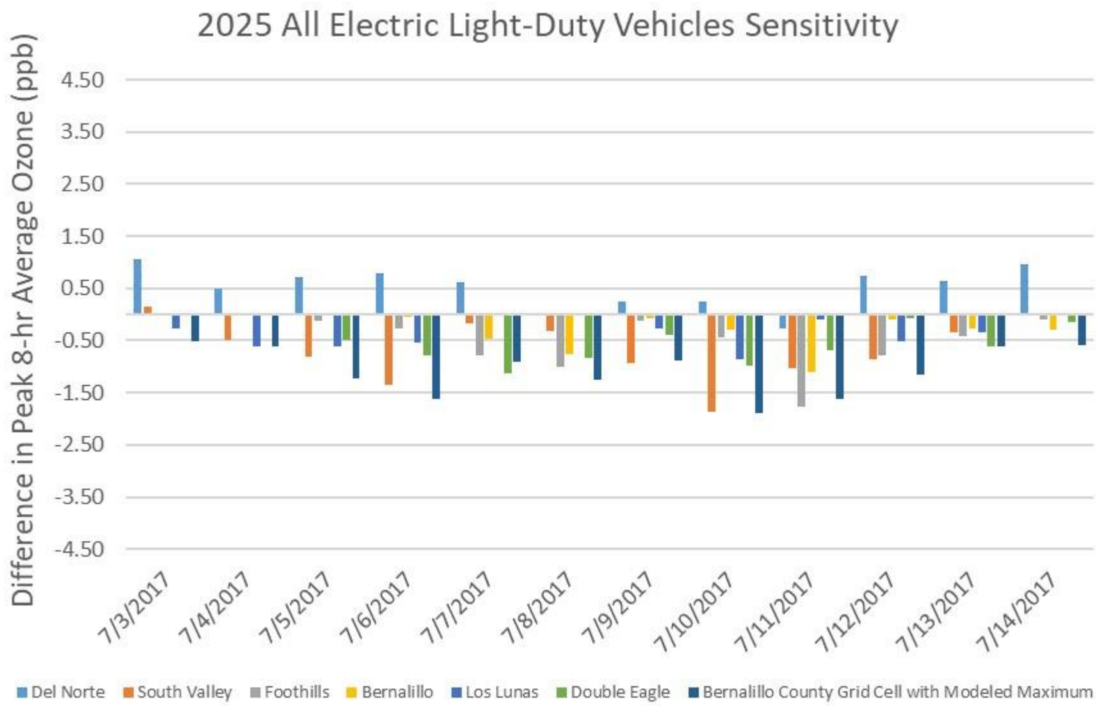

Figure 124. Differences in peak 8-hr average ozone concentrations between the 2025 all-electric light-duty vehicles sensitivity simulation and the 2025 base-case simulation in the locally dominated ozone episode at the Albuquerque MSA sites, and at the grid cell where the highest ozone concentration was modeled in the base-case simulation (Bernalillo County Grid Cell with Modeled Maximum).

Table 73. Maximum, minimum, and average absolute (ppb) and relative (%) differences in peak 8-hr average ozone concentrations between the 2025 all-electric light-duty vehicles sensitivity simulation and the 2025 base-case simulation for the locally dominated ozone episode.

Site	Maximum		Minimum		Average[a]	
	ppb	%	ppb	%	ppb	%
Del Norte	1.06	2.2%	-0.26	-0.4%	N/A	N/A
South Valley	0.14	0.3%	-1.86	-2.8%	-1.34	-1.9%
Foothills	0.00	0.0%	-1.77	-2.7%	-1.77	-2.5%
Bernalillo	0.00	0.0%	-1.11	-1.8%	-1.11	-1.7%
Los Lunas	-0.02	-0.0%	-0.85	-1.4%	N/A	N/A
Double Eagle (SAF)	0.00	0.0%	-1.12	-1.8%	N/A	N/A
Bernalillo County Grid Cell with Modeled Maximum	-0.36	-0.6 %	-1.90	-2.8%	-1.34	-2.1%

[a] The average is calculated for days when modeled peak 8-hr average ozone concentrations were greater than or equal to 65 ppb in the base-case simulation; N/A indicates that there were no days in the episode when the peak concentration was greater than or equal to 65 ppb.

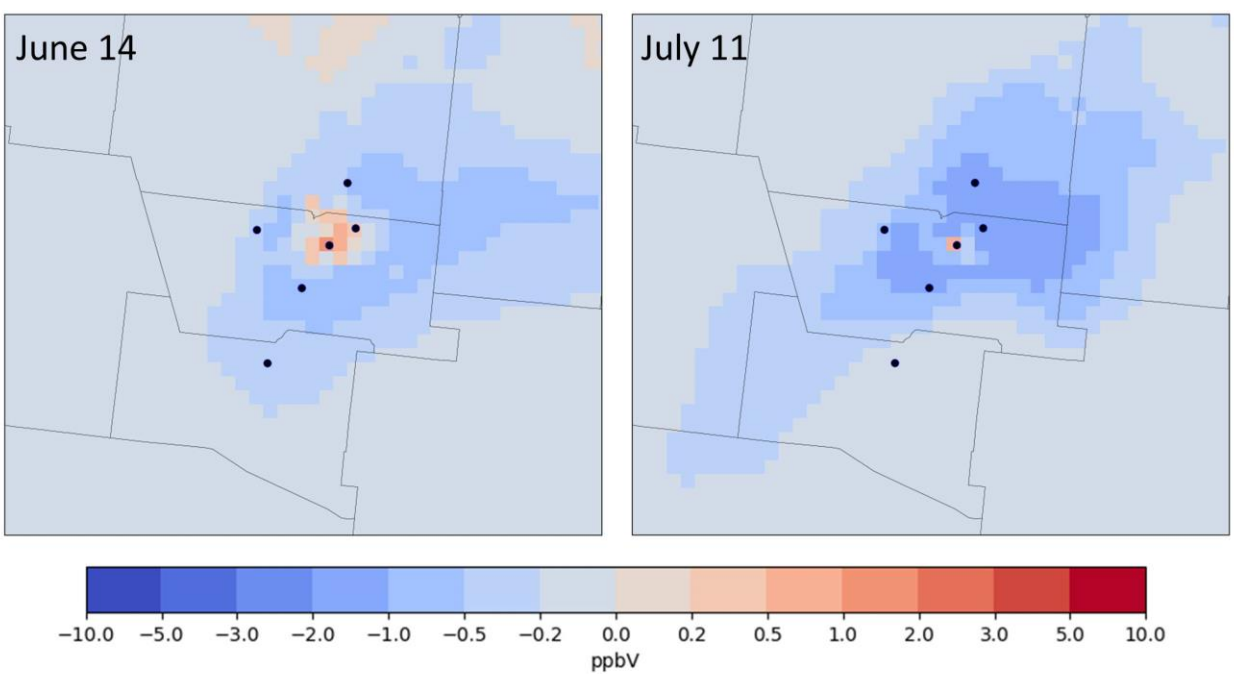

Figure 125. Differences between modeled peak 8-hr ozone concentrations in the 2025 all-electric light-duty vehicles sensitivity simulations and the 2025 base-case simulations for one day in each ozone episode. Black circles represent the monitoring sites.

11.6 Summary

Emissions used in the 2017 base-case modeling were projected to year 2025, and 2025 future-year air quality modeling was conducted using CAMx. Sensitivity simulations were also conducted for the 2025 future year to quantify the impact of various scenarios on daily peak 8-hr ozone concentrations in Albuquerque/Bernalillo County and to demonstrate how specific changes in emissions might affect future ozone concentrations. Future ozone concentrations in Albuquerque/Bernalillo County were more sensitive to local changes in emissions in the locally dominated ozone episode, compared to the regionally dominated ozone episode. This is consistent with findings from the 2017 base-case source apportionment and sensitivity modeling analyses.

The 2025 base-case modeling showed an overall decrease in peak 8-hr ozone concentrations in Albuquerque/Bernalillo County compared to the 2017 base case, by as much as 5 ppb. Therefore, if projected reductions in local, regional, and nationwide emissions by 2025 materialize, these future emissions reductions would reduce future ozone concentrations in Albuquerque/Bernalillo County.

If the Rio Bravo and Reeves power plants were to operate at permitted emission levels in the future, ozone concentrations in Albuquerque/Bernalillo County would increase by as much as 4 ppb.

Expanding the Albuquerque/Bernalillo County I&M program to Sandoval and Valencia counties decreased future-year ozone concentrations in Albuquerque/Bernalillo County by as much as 0.5 ppb, and would therefore provide a small positive future ozone benefit in the region. This impact was similar in magnitude to the ozone benefits that were modeled from the Albuquerque/Bernalillo County I&M program in 2017 (see Chapter 10).

Reducing anthropogenic NO_x and VOC emissions in Bernalillo, Sandoval, and Valencia counties reduced modeled future-year peak 8-hr ozone concentrations by as much as 3 ppb in the locally dominated ozone episode. This result suggests that a multi-county approach to reduce emissions in Bernalillo, Sandoval, and Valencia Counties would be effective at reducing future ozone concentrations in Albuquerque/Bernalillo County.

Transitioning all light-duty gasoline-powered vehicles to electric-powered vehicles in 2025 resulted in a decrease in modeled future-year peak 8-hr ozone concentrations. The maximum decrease in modeled ozone was 0.8 ppb during the regionally dominated ozone episode and 1.9 ppb during the locally dominated ozone episode.

Future-year changes in NO_x and VOC emissions resulted primarily in decreases in peak 8-hr ozone concentrations across the 2025 base-case and 2025 sensitivity simulations in which emissions were reduced. This indicates that there will be NO_x-limited conditions in Albuquerque/Bernalillo County in the future. This result is consistent with the 2017 base-case, source apportionment, and sensitivity simulations.

12. Conclusions

Ozone air quality modeling was conducted to assist the Albuquerque EHD with its air quality planning process. The purpose of this work was to apply scientific data and modeling analyses to (1) further the understanding of ozone air quality in Albuquerque/Bernalillo County, and (2) understand emission control strategies that (if necessary) can be helpful for reducing ozone in the region. This work included a full complement of meteorological, emissions, and air quality modeling analyses, as well as source apportionment analysis, sensitivity modeling analyses, and future-year modeling analyses. This modeling project builds upon the ongoing ambient air quality monitoring and emissions inventory development work conducted by Albuquerque EHD over the years, and provides an additional technical basis for future air quality planning. The modeling can also provide a starting point to support regulatory modeling should such a need arise. An overview of key results from this study was presented to the EHD and to the Albuquerque/Bernalillo County Air Quality Control Board in October 2018.

The air quality modeling work conducted here focused on two episodes during June and July of 2017 when ground-level ozone concentrations in Albuquerque/Bernalillo County were USG on EPA's AQI scale. Ozone was USG on four of the modeled episode days, and Moderate on many of the modeled episode days. Based on the modeling analysis, the ozone in Albuquerque/Bernalillo County during the June 2017 episode was driven largely by contributions from non-local and regional emissions, whereas ozone during the July 2017 episode was driven more strongly by local emissions from within Albuquerque/Bernalillo County.

The meteorological, emissions, and air quality modeling were conducted with WRF, SMOKE, and CAMx, respectively. Modeling was conducted on three nested-domains: (1) a 36-km domain covering the continental United States; (2) a 12-km domain covering the western United States and northern Mexico; and (3) a 4-km domain covering much of New Mexico, including the Albuquerque MSA and Albuquerque/Bernalillo County.

There were three key results from this modeling analysis:

- Ozone in Albuquerque/Bernalillo County is the result of local and non-local emissions, is impacted by wildfires, and is sensitive to statewide oil and gas emissions. If emission controls are needed in the future, local emission controls will be less effective at reducing ozone on days when ozone is driven primarily by long-range pollutant transport from outside Albuquerque/Bernalillo County (e.g., the June 2017 ozone episode). Conversely, local emission controls will be more effective at reducing ozone on days when ozone is driven more strongly by local emissions (e.g., the July 2017 ozone episode).
- On high ozone days during June and July 2017, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 5 and 16 ppb of ozone in Albuquerque/Bernalillo County.

- If projected reductions in local, regional, and nationwide emissions by 2025 materialize, these projected emissions reductions would reduce ozone concentrations in Albuquerque/Bernalillo County by 3-7%. To put this into context, a 5% reduction of ozone concentrations by 2025 could reduce the future-year ozone design value in Albuquerque/Bernalillo County by 3-4 ppb, based on a current design value of 70 ppb.

Below is a summary of key findings from this project.

Source Apportionment Modeling

The source apportionment modeling analysis showed that the high ozone concentrations in the June 2017 ozone episode were largely driven by non-local and regional ozone contributions, while the high ozone concentrations in the July episode were driven more strongly by local emissions from within Albuquerque/Bernalillo County. Therefore, we would expect that local emission controls within Albuquerque/Bernalillo County would not have been effective at reducing the ozone concentrations in Albuquerque/Bernalillo County during the June episode, but would have been more effective at reducing ozone concentrations emissions during the July episode. These results have important implications for air quality planning.

The key findings from the ozone source apportionment modeling analysis are as follows.

- Pollutant transport from outside New Mexico is important and accounts for over half of the ozone on high ozone days in Albuquerque/Bernalillo County.
- Local emissions in Albuquerque/Bernalillo County are also important. Half of the ozone generated by emissions from within Albuquerque/Bernalillo County is due to motor vehicles.
- On high ozone days during the June 2017 episode, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 5 and 7 ppb of ozone in Albuquerque/Bernalillo County. U.S. anthropogenic emissions outside of New Mexico contributed between 4 and 8 ppb of ozone.
- On high ozone days during the July 2017 episode, anthropogenic emissions from within Albuquerque/Bernalillo County contributed between 9 and 16 ppb of ozone in Albuquerque/Bernalillo County. U.S. anthropogenic emissions outside of New Mexico contributed between 7 and 10 ppb of ozone.
- On high zone days, contributions from the Four Corners, San Juan, and Prewitt Escalante power plants in New Mexico were as large as 1 ppb but were generally less than 0.5 ppb in Albuquerque/Bernalillo County.
- Impacts from anthropogenic emissions in western states, including California, can be important. On many of the modeled days, ozone contributions in Albuquerque/Bernalillo County from California’s emissions were greater than 1 ppb and larger than the ozone

contributions from the Four Corners, San Juan, and Prewitt Escalante power plants in New Mexico.

- Ozone contributions in Albuquerque/Bernalillo County from wildfire smoke were as large as 2.0 ppb in the June episode and as large as 1.5 ppb in the July episode.
- Ozone contributions due to emissions from the Western Refining Gallup facility were negligible in Albuquerque/Bernalillo County.
- Emissions from nonroad and non-mobile source sectors are becoming increasingly important as emissions from motor vehicles continue to decrease.

Ozone impacts from the Four Corners and San Juan power plants in northern New Mexico will likely be reduced in the future, given that two units at San Juan were decommissioned in December 2017, and NO_x emission controls were installed on two units at Four Corners in 2018.

Sensitivity Modeling

A series of sensitivity simulations were developed at the direction of and in consultation with the Albuquerque EHD to test the sensitivity of modeled ozone concentrations in Albuquerque/Bernalillo County to various changes in local and non-local emissions. Results from these sensitivity simulations can be used to assess (1) whether ozone reductions should be accomplished through reductions in NO_x emissions, VOC emissions, or both; and (2) under what types of conditions local emission reductions may be effective at reducing ozone.

Eight sensitivity scenarios were developed for this analysis and include

- 10% reduction of Albuquerque/Bernalillo County anthropogenic NO_x emissions.
- 10% reduction of Albuquerque/Bernalillo County anthropogenic VOC emissions.
- 25% reduction of Albuquerque/Bernalillo County on-road mobile source NO_x emissions.
- 25% reduction of New Mexico oil and gas emissions.
- Impact of the Albuquerque/Bernalillo County I&M program.
- Reeves and Rio Bravo power plants running at permitted emission levels.
- 100% reduction of Sandoval County anthropogenic emissions.
- 100% reduction of Valencia County anthropogenic emissions.

The results from these sensitivity modeling analyses built upon the findings from the source apportionment analysis and confirmed that local emission controls within Albuquerque/Bernalillo County would have been less effective at reducing the ozone concentrations in Albuquerque/Bernalillo County during the June episode, but would have been more effective at reducing ozone concentrations during the July episode.

The key findings from the sensitivity modeling analysis are as follows:

- NO_x emission controls will be effective at reducing ozone in Albuquerque/Bernalillo County. VOC emission controls may not be effective at reducing ozone unless they are substantial (>10%).
- Emissions from Valencia and Sandoval counties impact ozone in Albuquerque/Bernalillo County by as much as 4 ppb.
- The Reeves and Rio Bravo power plants would impact ozone in Albuquerque/Bernalillo County by as much as 3 ppb if they operated at with permitted emission levels.
- The I&M program in Albuquerque/Bernalillo County reduces on-road mobile source NO_x emissions by 5% and VOC emissions by 7%, and reduces ozone in Albuquerque/Bernalillo County by up to 0.25 ppb.
- Ozone in Albuquerque/Bernalillo County is sensitive to emissions from oil and gas operations throughout New Mexico. Reducing NO_x and VOC emissions from the oil and gas sector in New Mexico by 25% would reduce ozone concentrations in Albuquerque/Bernalillo County by up to 1 ppb.

When considering the modeled ozone impact of the Albuquerque/Bernalillo County I&M program, note that the purpose of an I&M program is to ensure that motor vehicles are operating in a manner that meets federal, state, and local emission standards. Without an I&M program, there is risk that the motor vehicle emissions in Albuquerque/Bernalillo County would fail to meet the projections made by Albuquerque EHD. I&M programs can also produce benefits for other pollutants, such as NO_2 and particulate matter, which are important for protecting air quality near major roadways.

Future-Year Modeling

The 2017 base-case emissions were projected to year 2025 based on future activity assumptions, regulations, and controls; a future-year air quality model simulation was conducted based on these projected future-year emissions. Results from this future-year simulation were compared to the 2017 simulation to assess how ozone in Albuquerque/Bernalillo County could be impacted by national, regional, and local changes in emissions that are expected take place between 2017 and 2025.

In addition, four future-year sensitivity simulations summarized here were developed at the direction of and in consultation with the Albuquerque EHD:

- Reeves and Rio Bravo power plants in Bernalillo County operating at permitted emission levels.
- Expansion of the Albuquerque/Bernalillo County I&M Program to cover light-duty gasoline vehicles in Sandoval and Valencia counties.
- 25% reduction of anthropogenic NO_x and VOC emissions in Bernalillo, Sandoval, and Valencia counties.
- Electrification of the light-duty gasoline vehicle fleet in Albuquerque/Bernalillo County.

The key findings from the future-year modeling analysis are as follows:

- Projected emission reductions by 2025 would reduce peak 8-hr average ozone concentrations in Albuquerque/Bernalillo County by 3-7%. To put this into context, a 5% reduction on ozone concentrations by 2025 could reduce the future-year ozone design value in Albuquerque/Bernalillo County by 3-4 ppb, based on a current design value of 70 ppb.
- The Reeves and Rio Bravo power plants would increase ozone in Albuquerque/Bernalillo County in the future by as much as 4 ppb if they were operated at permitted emission levels.
- A 25% reduction of anthropogenic NO_x and VOC emissions in Bernalillo, Sandoval, and Valencia counties would reduce future ozone concentrations in Albuquerque/Bernalillo County by as much as 3 ppb. This result suggests that a multi-county approach to reducing emissions would be effective at reducing future ozone concentrations in Albuquerque/Bernalillo County.
- Replacing the light-duty gasoline vehicle fleet with electric vehicles in Albuquerque/Bernalillo County would reduce future ozone concentrations in Albuquerque/Bernalillo County by as much as 2 ppb.
- Expanding the I&M program to Sandoval and Valencia counties in the future would reduce ozone concentrations in Albuquerque/Bernalillo County by as much as 0.5 ppb.

VOC Emissions Analysis

The key findings from the VOC emissions inventory analysis are as follows:

- Aromatic VOCs such as xylenes and toluene are highly reactive and represent 38% of the anthropogenic VOC ozone-generating potential in the Albuquerque/Bernalillo County emissions inventory, despite representing only 10% of anthropogenic VOC emissions. Xylenes are used in many types of solvents and are also emitted from diesel engines; therefore, reducing emissions from solvent use and construction equipment could potentially reduce ozone concentrations in Albuquerque/Bernalillo County.
- Alkane VOCs such as pentane are less reactive compared to other VOCs, and therefore relatively large reductions in alkane VOC emissions would be needed to significantly reduce ozone in Albuquerque/Bernalillo County. Alkane VOCs represent over 50% of the anthropogenic VOC emissions in Albuquerque/Bernalillo County, but only 29% of the anthropogenic ozone generating potential in the emissions inventory. Alkane VOCs are emitted from motor vehicles, construction equipment, oil and gas exploration, and a variety of industrial processes.
- Speciated VOC measurements are needed to confirm that the VOC emissions inventory is representing ambient VOC concentrations, and to develop a more detailed understanding of specific VOC species that may be contributing to ozone in Albuquerque/Bernalillo County. Speciated VOC measurements (i.e., measurements of individual VOC compounds, not just

total VOC) would provide additional data to evaluate the existing VOC emission inventory, evaluate air quality model performance, track the effectiveness of VOC emission control programs, and protect public health.

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