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NEW MEXICO OZONE ATTAINMENT INITIATIVE PHOTOCHEMICAL MODELING STUDY - DRAFT MODELING PROTOCOL

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ACRONYMS AND ABBREVIATIONS

3SAQS	Three-State Air Quality Study
AIRS	Aerometric Information Retrieval System
AMET	Atmospheric Model Evaluation Tool
APCA	Anthropogenic Precursor Culpability Assessment
AQ	Air Quality
AQS	Air Quality System
BC	Boundary Condition
BLM	Bureau of Land Management
CAMx	Comprehensive Air-quality Model with extensions
CARB	California Air Resources Board
CASTNet	Clean Air Status and Trends Network
CB6r2	Carbon Bond mechanism version 6, revision 2
CMAQ	Community Multiscale Air Quality modeling system
CONUS	Continental United States
CPC	Center for Prediction of Climate
CSAPR	Cross State Air Pollution Rule
CSN	Chemical Speciation Network
EC	Elemental Carbon Fine Particulate Matter
ECMWF	European Center for Medium Range Weather Forecasting
EGU	Electrical Generating Units
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FB	Fractional Bias
FE	Fractional Error
FRM	Federal Reference Method
GCM	Global Chemistry Model
GEOS-Chem	Goddard Earth Observing System (GEOS) global chemistry model
GIRAS	Geographic Information Retrieval and Analysis System
IMPROVE	Interagency Monitoring of PROtected Visual Environments
IWDW	Intermountain West Data Warehouse
LCP	Lambert Conformal Projection
LSM	Land Surface Model
MADIS	Meteorological Assimilation Data Ingest System
MATS	Modeled Attainment Test Software
MCIP	Meteorology-Chemistry Interface Processor
MEGAN	Model of Emissions of Gases and Aerosols in Nature
MNGE	Mean Normalized Gross Error
MNB	Mean Normalized Bias
MNE	Mean Normalized Error
MOVES	Motor Vehicle Emissions Simulator
MOZART	Model for OZone And Related chemical Tracers
MPE	Model Performance Evaluation
MSKF	Multi-Scale Kain-Fritsch Cumulus Parameterization
NAAQS	National Ambient Air Quality Standard
NAM	North American Mesoscale Forecast System

NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NCDC	National Climatic Data Center
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NH_4	Ammonium Fine Particulate Matter
NMB	Normalized Mean Bias
NME	Normalized Mean Error
NMED	New Mexico Environmental Division
NO_2	Nitrogen Dioxide
NO_3	Nitrate Fine Particulate Matter
NOAA	National Oceanic and Atmospheric Administration
OA	Organic Aerosol Fine Particulate Matter
OAI	Ozone Attainment Initiative
OC	Organic Carbon Fine Particulate Matter
OSAT	Ozone Source Apportionment Technology
PAVE	Package for Analysis and Visualization
PBL	Planetary Boundary Layer
PGM	Photochemical Grid Model
PM	Particulate Matter
PPB	Parts Per Billion
PPM	Piecewise Parabolic Method
QA	Quality Assurance
QC	Quality Control
RMP	Resource Management Plan
RRF	Relative Response Factor
SCC	Source Classification Code
SIP	State Implementation Plan
SMOKE	Sparse Matrix Kernel Emissions modeling system
SNMOS	Southern New Mexico Ozone Study
SOA	Secondary Organic Aerosol
SO_2	Sulfur Dioxide
SO_4	Sulfate Fine Particulate Matter
TCEQ	Texas Commission on Environmental Quality
UNC-IE	University of North Carolina Institute for the Environment
USFS	United States Forest Service
VERDI	Visualization Environment for Rich Data Interpretation
VMT	Vehicle Miles Traveled
WBD	Wind Blown Dust model
WAQS	Western Air Quality Study
WESTAR	Western States Air Resources Council
WestJumpAQMS	West-Wide Jump-Start Air Quality Modeling Study
WESTUS	Western United States
WRAP	Western Regional Air Partnership
WGA	Western Governors' Association
WRF	Weather Research Forecast model

1. INTRODUCTION

This document is a Modeling Protocol and an informal Quality Assurance Project Plan (QAPP) for the New Mexico (NM) Ozone Attainment Initiative (OAI) Photochemical Modeling Study ("NM OAI Study"). The New Mexico Environmental Division (NMED) has contracted with a team consisting of Western States Air Resources Council (WESTAR) and Ramboll US Corporation to conduct the NM OAI Study. The NM OAI Study leverages the 2014 photochemical grid model (PGM) modeling platform developed by the Western Regional Air Partnership (WRAP) in the Western Air Quality Study (WAQS) and enhances it by adding a 4-km grid resolution modeling domain over New Mexico. 2023 future year modeling, source apportionment and control measure evaluation will be performed to assist the NMED in ozone air quality planning for the state.

1.1 NM OAI Project Genesis

The NMED Air Quality Bureau has authority over air quality management activities throughout the state of New Mexico, with the exception Bernalillo County and Tribal Lands. The City of Albuquerque/Air Quality Division has authority in Bernalillo County and, except for where Tribal Implementation Plans have been approved, EPA oversees air quality issues in Tribal Lands. The New Mexico Air Quality Control Act (NMAQCA) requires the NMED to develop a plan to address elevated ozone levels when air quality is within 95% of the ozone NAAQS (74-3-5.3, NMSA 1978[1]). The ozone NAAQS was revised in 2015 with a threshold of 0.070 ppm (70 ppb) with the relevant metric being the ozone Design Value (DV) that is expressed as the three-year average of the fourth highest Daily Maximum Average 8-hour (DMAX8) ozone concentrations. Figure 1-1 displays the trends in observed ozone DVs at 8 New Mexico monitoring sites from 2013 to 2018 and compares them with the 70 ppb 2015 ozone NAAQS (red line) and 95% of the 70 ppb NAAQS (i.e., ≥ 67 ppb; black line). This results in 7[2] counties in New Mexico under NMED jurisdiction with measured 2016-2018 ozone DVs at or exceeding 95% of the 70 ppb ozone NAAQS, as shown in Figure 1-1.

[1] https://law.justia.com/codes/new-mexico/2017/chapter-74/article-2/section-74-2-5.3/

[2] 8 total counties in New Mexico if you also include Bernalillo County whose air quality is under the jurisdiction of the City of Albuquerque.

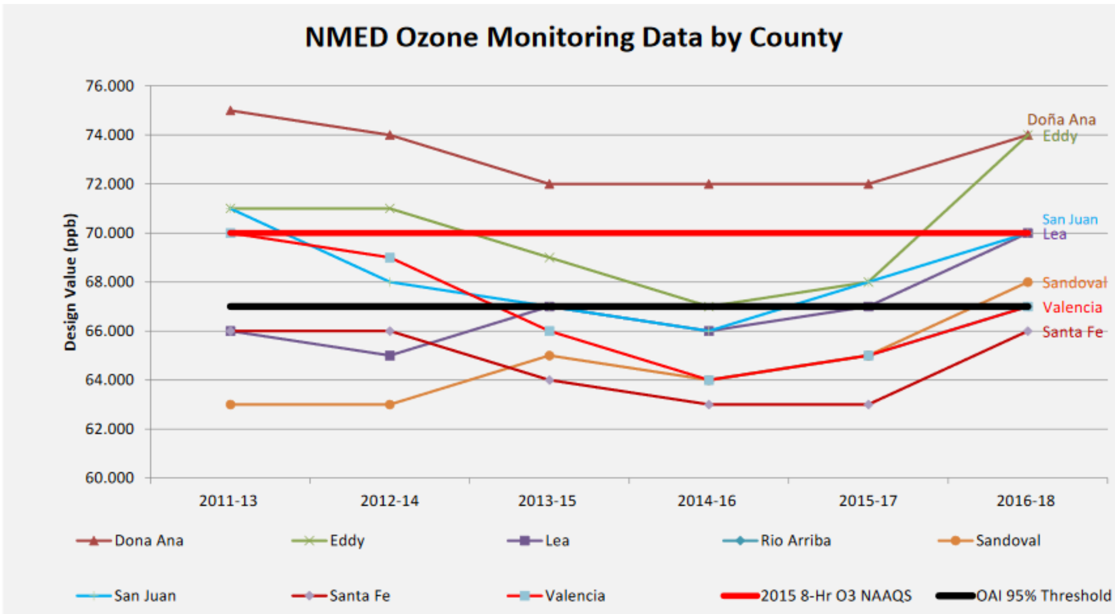


Figure 1-1. Trends in observed ozone DVs between 2013 and 2018 at 7 monitoring sites in New Mexico (Source: https://www.env.nm.gov/air-quality/wp-content/uploads/sites/2/2019/10/OAI_Presentation_09262019.pdf).

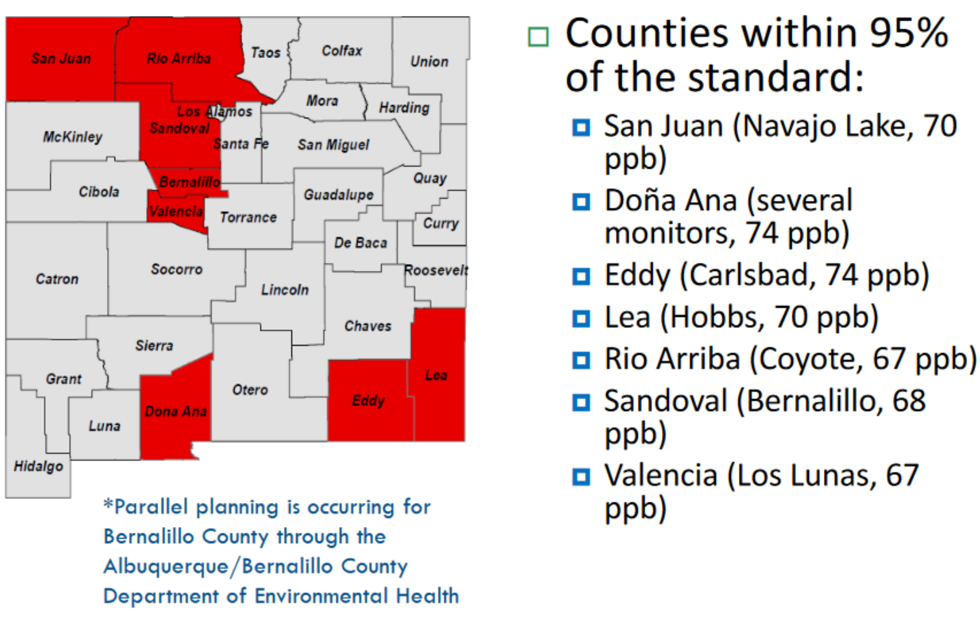


Figure 1-2. 7 counties in New Mexico under the jurisdiction of the NMED whose observed 2016-2018 ozone DVs are at or exceed 95% of the 2015 ozone NAAQS (70 ppb) (Source: https://www.env.nm.gov/air-quality/wp-content/uploads/sites/2/2019/10/OAI_Presentation_09262019.pdf).

To address the high observed ozone concentrations in New Mexico, the NMED has embarked on an Ozone Attainment Initiative (OAI[3]) to protect the ozone attainment status of the state and ensure health and welfare of the residents of the state for future generations. The OAI was initiated in Spring 2018. As part of the OAI, NMED released a Request for Proposal (RFP#20 667 4040 0001) the NM OAI Study. The NM OAI Study PGM modeling was awarded to a contracting team of WESTAR and Ramboll. This Modeling Protocol is the first major deliverable under that contract.

1.2 Overview of NM OAI Study Modeling Approach

This Modeling Protocol describes the modeling activities to be performed under the NM OAI Study. The NM OAI Study will conduct PGM modeling by enhancing the WRAP/WAQS 2014 modeling platform[4] to use a 4-km grid resolution domain covering New Mexico and surrounding areas, especially the oil and gas (O&G) production regions in the Permian and San Juan Basins. The NM OAI Study PGM modeling will conduct 2014 base year modeling and model performance evaluation as well as 2023 future year modeling. The 2023 future year modeling will include ozone source apportionment and control measure sensitivity modeling. The NM OAI Study PGM modeling will be conducted in accordance with EPA's guidance for ozone State Implementation Plan (SIP) attainment demonstration modeling.

1.2.1 EPA Guidance for Ozone Attainment Demonstration Modeling Protocols

A comprehensive Modeling Protocol for an 8-hour ozone SIP attainment demonstration study consists of many elements. Its main function is to serve as a roadmap for planning and communicating how a modeled attainment demonstration will be performed before it occurs. The protocol guides the technical details of a modeling study and provides a formal framework within which the scientific assumptions, operational details, commitments and expectations of the various participants can be set forth explicitly.

On November 28, 2018 EPA released a final 8-hour ozone modeling guidance (EPA, 2018d) that replaces the previous final guidance (EPA, 2007) and draft guidance (EPA, 2014d). The EPA 2018 ozone modeling guidance is similar to the draft 2014 guidance with updates (e.g., slight modification to the recommended ozone DV projection approach). As stated in EPA's latest modeling guidance (EPA, 2018d, pp. 15):

> "The most important function of the modeling protocol is to serve as a blueprint for planning how the modeled demonstration will be performed. The protocol should be a valuable communication device by which air agencies, EPA, and other stakeholders can assess the applicability of default recommendations and develop area-specific alternatives, where needed, prior to conducting the work to build the modeling system. A suitable protocol should lead to extensive participation by stakeholders in developing the demonstration. It should also reduce the risk of spending time and resources on efforts that are unproductive or inconsistent with EPA rules, policy, and guidance. While the modeling protocol

[3] https://www.env.nm.gov/air-quality/o3-initiative/

[4] http://views.cira.colostate.edu/wiki#WAQS-2014-Modeling-Platform

is initially developed at the beginning of a modeling exercise to foster communication, it is advisable to modify the document as needed throughout the modeling process when alterations from the original modeling plan are necessary. Again, any changes to the protocol should be fully communicated between affected air agencies, stakeholders, and the EPA."

1.2.1.1 Contents of the Modeling Protocol

EPA's 8-hour ozone SIP modeling guidance identifies specific "core elements" that should be part of any ozone SIP Modeling Protocol. These "core elements" are repeated below along with where they are addressed in this NM OAI Study Modeling Protocol (EPA, 2018d, pp. 15-16):

- Overview of the air quality issue being considered including historical background: Chapter 1 provides an overview of ozone issues in New Mexico including past and related ozone modeling studies for the region.
- List of the planned participants in the analysis and their expected roles: The principal participants in the NM OAI Study are listed in Table 1-1 at the end of Chapter 1.
- Schedule for completion of key steps in the analysis and final documentation: The current schedule is presented in Tables 1-2 and 1-3 at the end of Chapter 1.
- Description of the conceptual model for the area: The Conceptual Model of ozone formation in the NM OAI Study is provided in Section 1.4.
- Description of periods to be modeled, how they comport with the conceptual model, and why they are sufficient: Chapter 3 presents the Episode Selection and justifies the selection of the summer of 2014 modeling period for the NM OAI Study.
- Models to be used in the demonstration and why they are appropriate: Model selection and justification is presented in Chapter 2.
- Description of model inputs and their expected sources (e.g., emissions, meteorology, etc.): The source of data and description of the model inputs are given in Chapters 4, 5 and 6.
- Description and justification of the domain to be modeled (expanse and resolution): Domain selection and justification is provided in Chapter 4.
- Process for evaluating base year model performance (meteorology, emissions, and air quality) and demonstrating that the model is an appropriate tool for the intended use: The procedures for conducting the 2014 base case photochemical modeling and model performance evaluation is given in Chapter 7. Procedures for conducting the meteorological modeling and evaluation are provided in Chapter 5. Emission inputs are discussed in Chapter 6.
- Description of the future years to be modeled and how projection inputs will be prepared: Future year modeling procedures are provided in Chapter 8.
- Description of the NAAQS attainment test procedures and (if known) planned weight of evidence, and/or description of the procedures for calculating RPGs from the modeling outputs, as applicable: The ozone attainment demonstration procedures for the 2023 future years are described in Chapter 9 along with

potential additional weight of evidence (WOE) analysis to support the modeled attainment demonstration.

- Expected diagnostic or supplemental analyses needed to develop weight of evidence analyses: Potential WOE analysis are described in Chapter 9.
- Commitment to specific deliverables fully documenting the completed analysis: Deliverables to support the modeling component of the NM OAI Study are listed at the end of Chapter 9 with schedule for the deliverables listed in Tables 1-2 and 1-3.
- Quality Assurance Project Plan (QAPP): Although not part of EPA's guidance Modeling Protocol. Elements of a QAPP are contained throughout the Modeling Protocol and in each process of the PGM database development. Chapter 10 discusses the contents of a QAPP and where they can be found in this Modeling Protocol.

1.3 Related Studies

There are numerous other studies related to the NM OAI Study whose results may provide insight or provide data useful to the study that are summarized below.

1.3.1 Historic EPA and More Recent EPA-MJO-States Modeling Platforms

EPA routinely develops national PGM modeling platforms that are used to evaluate the air quality impacts of national rules, make transport assessments, such as the Cross-State Air Pollution Rule (CSAPR[5]), or other regional air quality analysis, such as the recent 2028 national regional haze modeling.[6] The national PGM modeling platforms typically coincide with the triennial National Emission Inventory (NEI[7]) years (e.g., 2008, 2011, 2014). Below we discuss the current (May 2020) status of EPA's more recent national PGM modeling platforms.

2011v6.3 Modeling Platform: The EPA 2011v6.3[8] PGM modeling platform is the result of many years of development and refinements (e.g., v6.0, v6.1 and v6.2[9]). It consists of a base year 2011 meteorological conditions and emissions and three future year emission scenarios: 2017, 2023 and 2028. It has been used in numerous EPA rulemakings (e.g., CSAPR Update). As with the other recent EPA modeling platforms, the 2011v6.3 modeling platform uses a 12-km grid resolution continental U.S. (12US2) modeling domain that is the red domain shown in Figure 1-3.

2014v7.1 Modeling Platform: The EPA 2014v7.1[10] PGM modeling platform was used in the 2014 National Air Toxics Assessment (NATA[11]) modeling. It also uses the 12-km 12US2 modeling (Figure 1-3, red domain). 2014 was a relatively low ozone year in the eastern U.S. so EPA did not pursue using the 2014 platform for national rulemakings

[5] https://www.epa.gov/csapr

[6] https://www.epa.gov/visibility/technical-support-document-epas-updated-2028-regional-haze-modeling

[7] https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

[8] https://www.epa.gov/air-emissions-modeling/2011-version-63-platform

[9] https://www.epa.gov/air-emissions-modeling/2011-version-6-air-emissions-modeling-platforms

[10] https://www.epa.gov/air-emissions-modeling/2014-version-71-platform

[11] https://www.epa.gov/national-air-toxics-assessment

(except for the NATA) developed a 2016 modeling platform for ozone, $PM_{2.5}$ and regional haze modeling.

2015 Alpha Modeling Platform: EPA has made data available to model 2015 using data based on the 2014v7.1 platform. However, a full 2015 PGM modeling platform was never developed.

2016 Modeling Platform: The EPA, Multi-Jurisdictional Organizations (MJOs), and states conducted a collaborative national emissions modeling platform[12] (2016 EMP) to develop a 2016 emissions inventory of comparable or better quality than the NEI, with projections to 2023 and 2028. Separately, EPA developed a 2016 PGM modeling platform that used the same 12-km grid resolution continental U.S. domain used in previous EPA PGM platforms (e.g., 2011) but added an expanded 36-km grid resolution 36US3 domain as shown in Figure 1-3. EPA has released several versions of their 2016 36/12-km PGM modeling platforms as follows:

- 2016v7.1 Alpha[13] PGM platform was available in June 2019 and uses the 2016 EMP Alpha version emissions, which were based mainly on the 2014 NEIv7.1 emissions (called the 2016fd emissions scenario by EPA).
- The 2016v7.2 Beta (called 2016ff by EPA) PGM platform uses the 2016 EMP Beta version emissions[14] from the EPA/MJO/states emissions collaborative study. The original 2016v7.2 Beta PGM platform was released in March 2019 through the Intermountain West Data Warehouse (IWDW[15]). EPA made some updates to the 2016v7.2 PGM platform and used the 2016v7.2 Beta Prime (called 2016fg by EPA) modeling platform for their preliminary 2028 regional haze modeling. Details on EPA's 2016v7.2 modeling platform are contained in a Technical Support Document (TSD; EPA, 2019).
- The final EPA 2016v1[16] (called 2016fh by EPA) PGM modeling platform uses the 2016 EMP version 1 emissions[17] from the EPA/MJO/states emissions collaborative study. It was released in November 2019 with updates to Commercial Marine Vessels (CMV) occurring in February 2020 and WRAP region O&G data, and is also available on the IWDW. The 2016v1 inventory included emission projections for 2023 and 2028.

[12] http://views.cira.colostate.edu/wiki/wiki/9169
[13] https://www.epa.gov/air-emissions-modeling/2016-alpha-platform
[14] http://views.cira.colostate.edu/wiki/wiki/10197
[15] http://views.cira.colostate.edu/iwdw/
[16] https://www.epa.gov/air-emissions-modeling/2016v1-platform
[17] http://views.cira.colostate.edu/wiki/wiki/10202

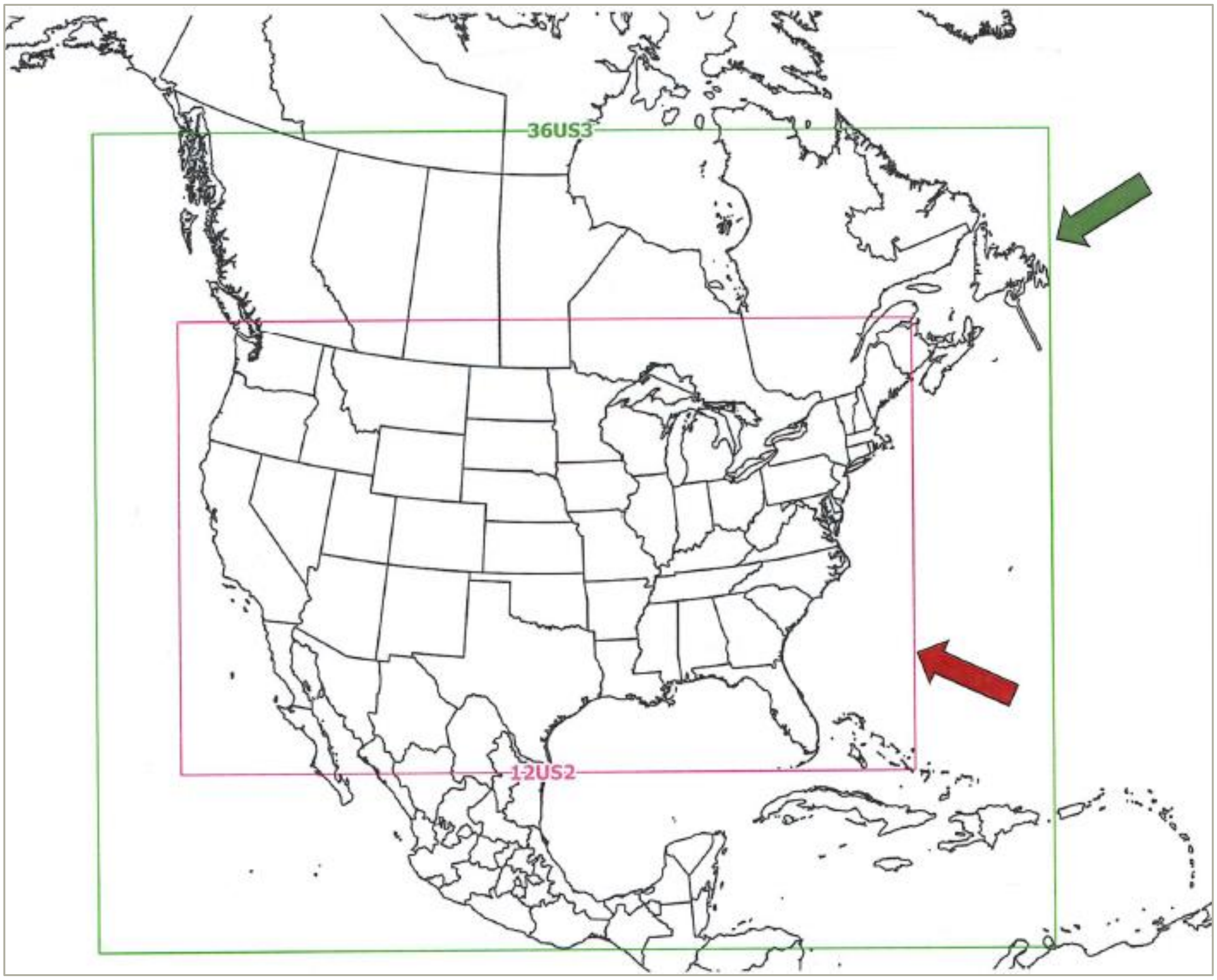


Figure 1-3. 36-km grid resolution 36US3 domain (green) and 12-km grid resolution 12US2 domain (red) used in EPA's 2016 modeling platform.

1.3.2 Denver Ozone SIP Modeling and Analysis

The Denver Metropolitan (DM) and North Front Range (NFR) ozone nonattainment area (NAA) has undergone several rounds of ozone SIPs to address attainment of a series of ozone NAAQSs.

Denver 2003 EAC SIP: The 2003 Denver Early Action Compact (EAC) SIP modeling performed 36/12/4/1.33 km photochemical modeling of the DM/NFR NAA for a summer 2002 period using the meteorological based on the MM5 model (McNally, Tesche and Morris, 2003), EPS3 emissions and CAMx photochemical grid models. The 1.33-km fine grid was ultimately not used because of little improvement in model performance over using a 4-km resolution grid at the expense of high additional computational requirements. The Denver EAC SIP developed an Ozone Action Plan[18] and

[18] http://www.colorado.gov/airquality/tech_doc_repository.aspx?action=open&file=EAC_SIP_031104-aqcc_DRAFT.pdf

demonstrated that the region would attain the 1997 ozone NAAQS by 2007 (Morris et al., 2004a,b,c,d).

Denver 2008 Ozone SIP: The 2008 Denver ozone SIP[19] modeling used the MM5 meteorological, SMOKE/CONCEPT emissions and CAMx photochemical grid models (Morris et al., 2007). The CONCEPT model was interfaced with link-based Vehicle Miles Traveled (VMT) and other mobile source activity data (e.g., speeds, fleet mix, temporal variations, etc.) from a Traffic Demand Model (TDM) operated by DRCOG, on-road emission factors from the MOBILE6 model and hourly meteorological data from MM5 to generate detailed on-road mobile source emissions for the DMA. Other emission inputs were generated using SMOKE. The MM5/SMOKE/CONCEPT/CAMx modeling system was applied to the June-July 2006 period and used to demonstrate that the DMA/NFR region would attain the 1997 8-hour ozone NAAQS by 2010 (Morris et al., 2008a,b,c; 2009a,b).

The 2008 ozone SIP 2006 modeling platform was also used to investigate improvements to the modeling system (Morris et al., 2011) and evaluate the VOC/NOx emissions inventory that suggested 2006 oil and gas emissions in Weld County were understated (Morris, Tai and Sturtz, 2011).

Denver 2016 Ozone SIP: The 2016 Denver ozone SIP[20] modeling addressed the 2017 attainment of the DM/NFR Moderate NAA under the 2008 ozone NAAQS (RAQC and CDPHE, 2016). The 2016 ozone SIP used a 2011 36/12/4-km modeling platform based on the WRAP/WAQS modeling platform available on the IWDW and adding a 4-km domain focused on Colorado (Ramboll and Alpine, 2015; 2016a,b; 2017).

The 2016 Denver ozone SIP 2011 36/12/4-km modeling platform was used to conduct additional future-year sensitivity modeling and other analysis in anticipation of the requirements needed to attain the 2015 ozone NAAQS. These results were presented at a November 2, 2017 Modeling Forum[21] and included the following:

- 2017 local source contributions to ozone concentrations in the DM/NFR NAA;
- Contributions of international anthropogenic emissions to 2011 ozone concentrations in the DM/NFR NAA; and
- Preliminary 2023 ozone projections and sensitivity to VOC/NOx anthropogenic emissions reductions.

Current Denver Ozone SIP 2020 and 2023 Attainment Demonstration Modeling: Current Denver ozone SIP efforts are using a 2016 36/12/4-km CAMx modeling platform based in part on EPA's 2016v1 modeling platform with new WRF meteorological modeling and a 4-km domain covering Colorado added. The new Denver 2016 36/12/4-km CAMx platform will be used to demonstrated attainment in 2020 to address the area as a

[19] https://www.colorado.gov/airquality/documents/deno308/
[20] https://raqc.org/sip/moderate-area-2008-8-hour-ozone-standard-state-implementation-plan/
[21] https://raqc.org/reports/?titlePost=Modeling+Forum

Serious NAA under the 2008 ozone NAAQS and in 2023 to address the area as a Moderate NAA under the 2015 ozone NAAQS.

1.3.3 West-wide Jumpstart Air Quality Modeling Study

The Western Regional Air Partnership (WRAP) initiated a new round of regional ozone, particulate matter, visibility and deposition modeling for the western U.S. starting with the West-wide Jumpstart Air Quality Modeling Study (WestJumpAQMS[22]; ENVIRON, 2013). WestJumpAQMS performed 36/12/4-km modeling for the 2008 calendar year with the 12-km domain focused on the western U.S., and the 4-km domain focused on the states of CO, NM, UT and WY (ENVIRON and Alpine, 2012). The WestJumpAQMS was completed in September 2013 and calculated, among other things, the contributions of transport to ozone in the Denver area and contributions of emissions from Colorado (including Denver) to downwind ozone and $PM_{2.5}$ concentrations (ENVIRON, Alpine and UNC, 2013). The 2008 base year from the WestJumpAQMS platform was used in the development of the 3-State Data Warehouse and Air Quality Study, the predecessor to the Intermountain West Data Warehouse and Western Air Quality Study, described next.

1.3.4 Intermountain West Data Warehouse and Western Air Quality Study

The WRAP Intermountain West Data Warehouse (IWDW[23]) was developed to be a repository and source of ambient air quality and modeling data that can be used by the western states. The Western Air Quality Study (WAQS) developed 2011 PGM modeling platforms to assess air quality, visibility and deposition in the western states and was used to populate the IWDW. The WAQS started by enhancing the WestJumpAQMS 2008 WRF/SMOKE/CAMx/CMAQ 36/12 km database and making it available through the IWDW. WAQS then developed new 2011 WRF/SMOKE/CAMx/CMAQ modeling platforms (Adelman, Shankar, Yang and Morris, 2014; 2016; Adelman and Baek, 2015) that was also made available through the IWDW. IWDW is not only a source of modeling data, but also includes data analysis and visualization tools and is a repository of data from other modeling studies.

1.3.5 Southern New Mexico Ozone Study (SNMOS)

The Southern New Mexico Ozone Study (SNMOS[24]) conducted WRF meteorological, SMOKE emissions and CAMx ozone modeling for a 2011 base and 2025 future year using a 12/4-km modeling domain, as shown in the right panel of Figure 1-4. SNMOS found that a vast majority of ozone in Southwestern New Mexico is due to ozone transport from outside of New Mexico. For example, Figure 1-4 (left panel) displays the 2011 and 2025 ozone contributions to the ozone Design Value (DV) at the Desert View monitoring site in Dona Ana County by geographic regions within the 12/4-km PGM modeling domain also shown in Figure 1-4. Only 3 percent of the 2011 ozone DV at Desert View is due to anthropogenic emissions from New Mexico, and New Mexico

[22] http://www.wrapair2.org/pdf/WestJumpAQMS_FinRpt_Finalv2.pdf

[23] http://views.cira.colostate.edu/iwdw/

[24] https://www.wrapair2.org/SNMOS.aspx

emissions contribute less than 2 percent of the projected 2025 ozone DV at Desert View.

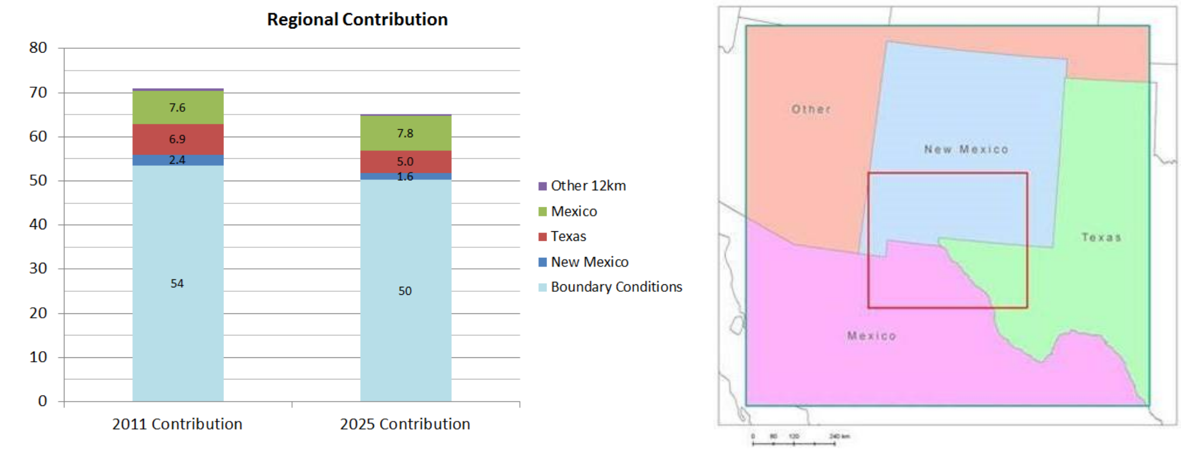
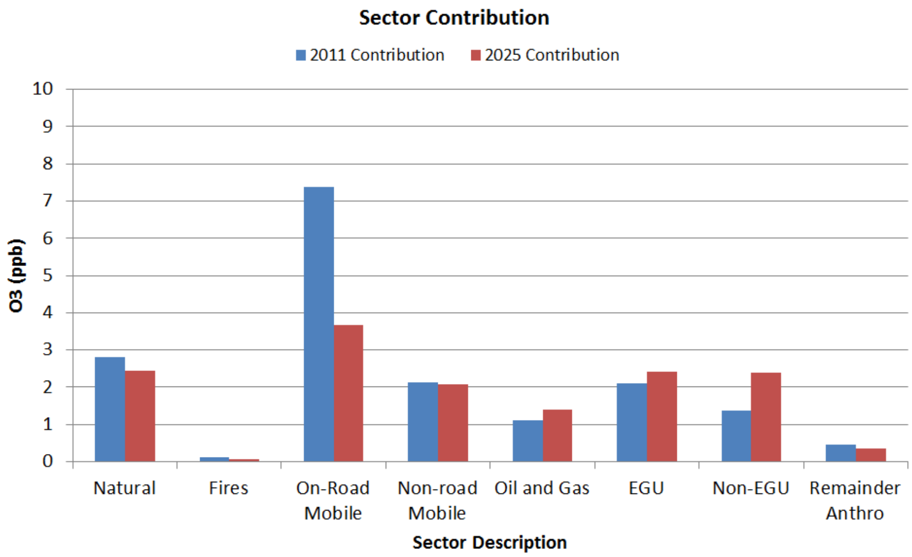


Figure 1-4. Contributions of geographic regions (including Boundary Conditions) to the 2011 and 2025 ozone Design Values at Desert View monitoring site in Dona Ana County in Southwestern New Mexico.

The SNMOS 2011 and 2025 ozone source apportionment modeling also obtained contributions by Source Sector in addition to the four Source Regions depicted in the left panel of Figure 1-4. Figure 1-5 displays the Source Sector contributions to the 2011 and 2025 ozone DV at Desert View monitor as well as the 10 highest Source Groups (i.e., Source Sector emissions from Source Regions) contributions. On-road mobile sources has the highest contribution to ozone DVs in both 2011 and 2025 (Figure 1-5, top panel), but that is mainly due to on-road mobile source emissions in Texas and Mexico that are the two highest contributing Source Groups (Figure 1-5, bottom panel).



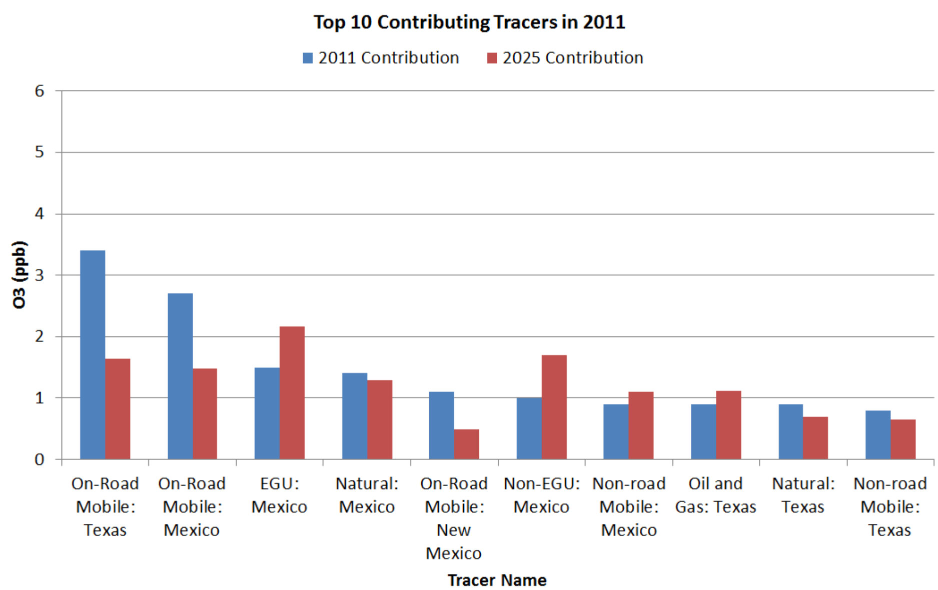


Figure 1-5. Contributions of Source Sector emissions within the 12/4-km modeling domain to the 2011 and 2025 ozone Design Value at Desert View monitoring site (top) and top ten Source Group contributions (bottom).

Figure 1-6 examines the contributions of emissions from New Mexico to 2011 and 2025 ozone DVs at nine monitoring sites in Southeast New Mexico. With one exception, on-road mobile source emissions are the largest contributing Source Sector in New Mexico to 2011 ozone DVs in southeastern New Mexico with the contribution at the Solano monitoring site being higher than the others. The one exception is the Carlsbad monitoring site in Eddy County where O&G emissions is the largest contributing Source Sector in New Mexico due to its close proximity to the Permian Basin. Although on-road mobile source emissions are the largest contributor in 2011, it is also the Source

Sector whose New Mexico ozone contribution is reduced the most in 2025, by over a factor of two. This is in contrast to O&G whose contribution at the Carlsbad monitoring site is projected to increase between 2011 and 2025, although future year projections of O&G emissions are highly uncertain. In any event, by 2025 the SNMOS estimate that on-road mobile, non-road mobile and O&G Source Sectors in New Mexico will contribute the most, with New Mexico EGU and non-EGU point sources and other anthropogenic emission Source Sectors having relatively lower ozone contributions.

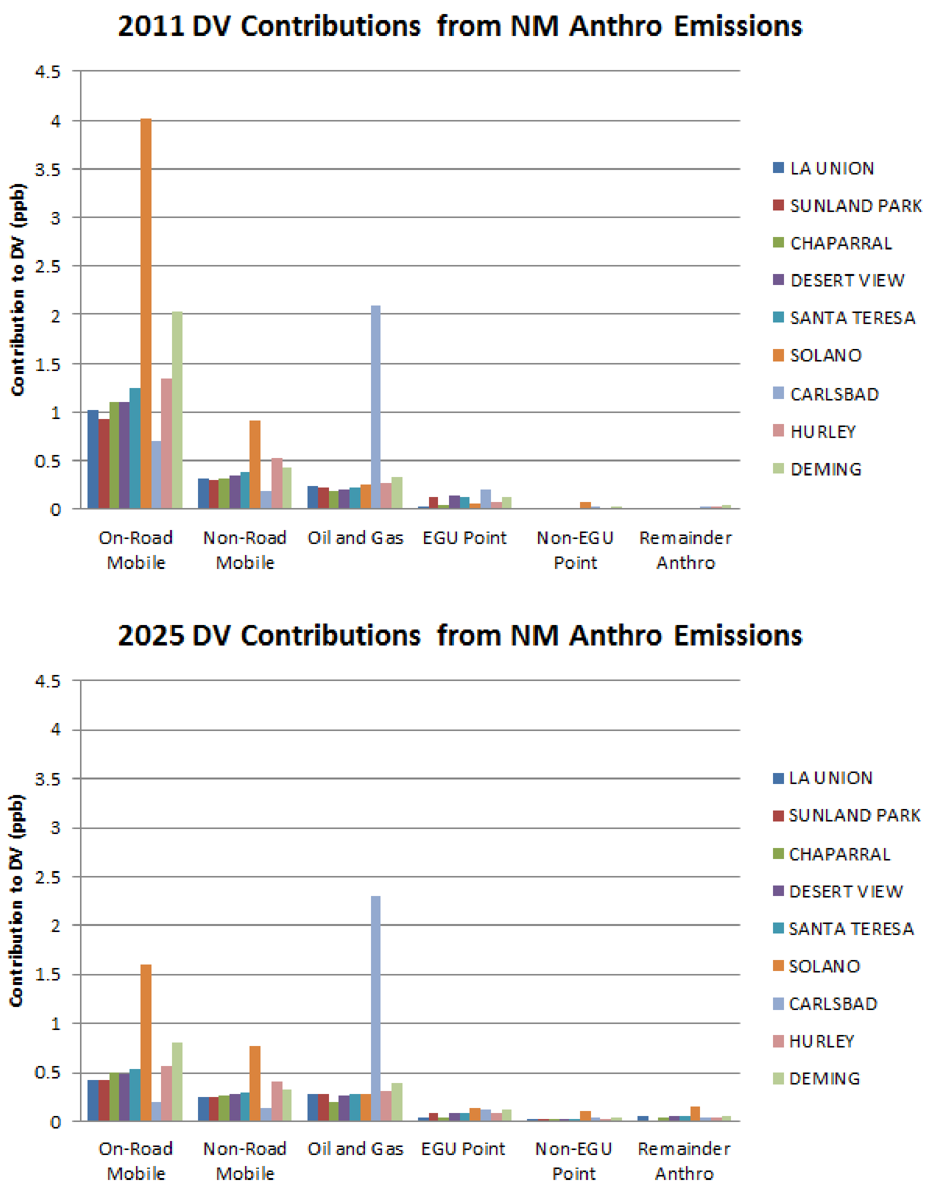


Figure 1-6. Contributions of major Source Sectors in New Mexico to 2011 (top) and 2025 (bottom) ozone DVs at nine monitoring sites in Southwestern New Mexico.

1.3.6 City of Albuquerque Ozone Modeling Study

The City of Albuquerque conducted an ozone modeling study[25] for two episodes in 2017: June 12-16, 2017 and July 3-14, 2017. The purpose of the study was to better understand the source of high ozone concentrations in Bernalillo County and what types of control strategies, if needed, would be most effective at reducing ozone concentrations in the County.

Figure 1-7 displays the maximum ozone DVs in Albuquerque from 2013 to 2018 and their relationship with the 80, 75 and 70 ppb ozone NAAQS. 2016 is a low point in the ozone DV trend (~65 ppb) followed by increases so by 2018 the maximum Bernalillo County ozone DV is at the 2015 ozone NAAQS.

The City of Albuquerque Ozone Modeling Study conducted WRF meteorological and SMOKE emissions modeling using a 12/4-km CAMx ozone modeling database, with the 4-km domain covering New Mexico and the 12-km domain covering the western states (Figure 1-7, right panel).

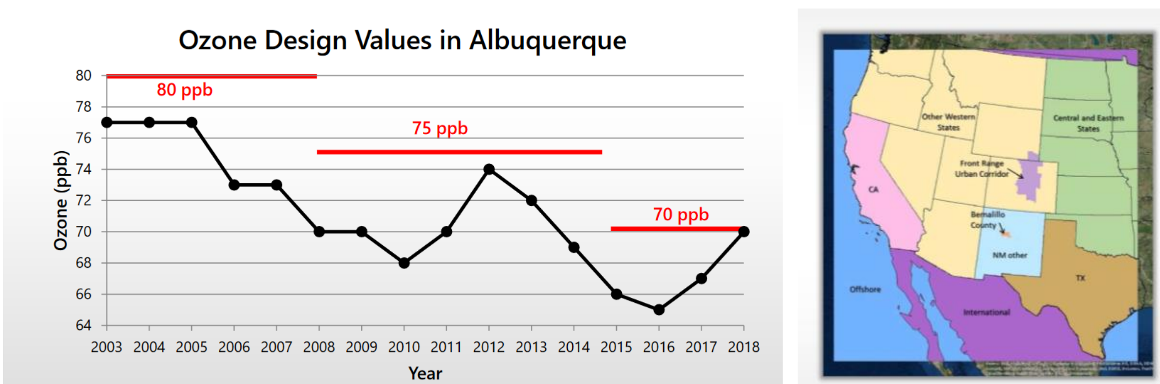


Figure 1-7. Trends in maximum ozone Design Values in Albuquerque from 2013 to 2018 (left) and 12-km modeling domain and source apportionment geographic regions (right).

Ozone source apportionment was performed to determine the geographic regions (Figure 1-7, right) that contributed to elevated ozone concentrations in Albuquerque. Figure 1-8 displays the contributions to ozone concentrations in Albuquerque for the June and July episodes. Anthropogenic emissions from New Mexico contributed 14% and 24% to ozone in Albuquerque during the, respectively, June and July 2017 episodes. And anthropogenic emissions from Bernalillo County accounted for up to 75% of the New Mexico contribution.

[25] https://www.cabq.gov/airquality/documents/06-ken-craig-sonoma-technology-inc-ozone-modeling-presentation-10-17-2018-aqcb-meeting.pdf

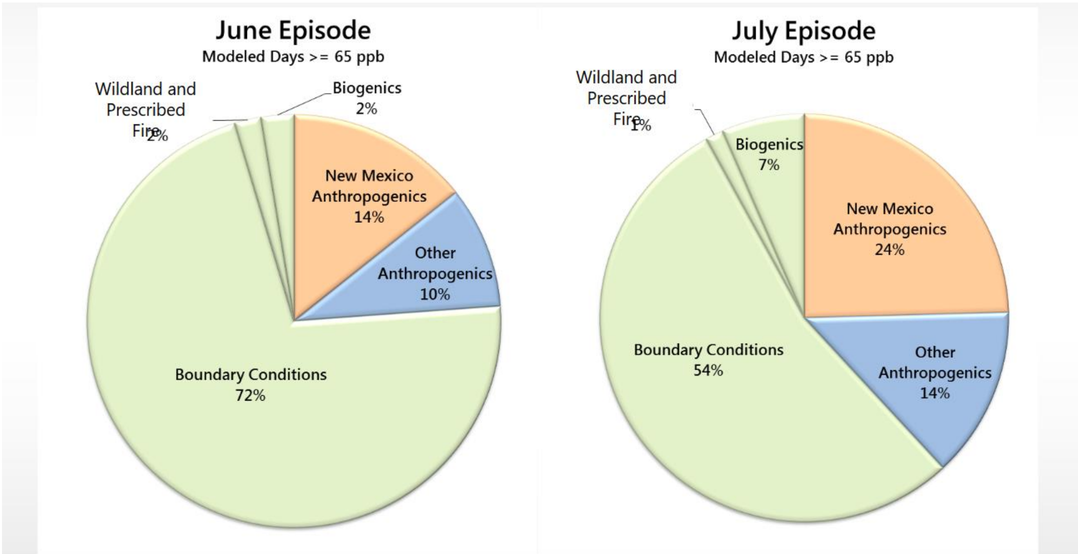


Figure 1-8. Contributions to ozone in Albuquerque during the June and July 2017 modeling episodes.

Although only two short episodes were modeled, so any conclusions are limited to those conditions, the City of Albuquerque Ozone Modeling Study concluded as follows:

- Transport from outside of New Mexico is always important and accounts for over half of the ozone in Albuquerque.
- Local emissions in Albuquerque and Bernalillo County are also important with half of the locally generated ozone due to on-road mobile sources in 2017.
- On high ozone days for the two modeled episodes, contributions from major power plants in northern New Mexico were small at sites in Albuquerque.
- Impacts from man-made emissions in western states, including California, are non-negligible.
- Ozone contributions from wildfire smoke were important for both episodes.
- As on-road mobile source emissions are reduced, emissions from non-road and non-mobile sources are becoming increasingly important. NOx emission controls are more effective at reducing high ozone concentrations in Albuquerque than VOC controls.
- Ozone in Albuquerque is sensitive to emissions from O&G sources throughout New Mexico.

1.3.7 Relationship Between Meteorology and Ozone in the Intermountain West Region

Reddy and Pfister (2016) and CDPHE and RAQC (2016c) analyzed meteorological factors that contributed to the interannual variability in midsummer ozone concentrations focusing mainly on Utah and Colorado. They analyzed ozone and meteorology for July during 1995-2013 and found several meteorological variables that were able to explain the years with higher ozone formation conditions. The most powerful meteorological variable for describing high ozone formation potential conditions (i.e. ozone conducive conditions) was the height of the 500 hPa[26] pressure level. The current Denver ozone SIP modeling study extended the analysis of meteorology conducive to ozone formation and observed ozone trends analysis of Reddy and Pfister (2016) and CDPHE and RAQC (2016c) to include the most recent years (through 2018) and for summer-average conditions. Figure 1-9 shows the relationship between summer-average 500 hPa heights and summer-average ozone at the Rocky Flats North (RFNO) monitoring site northwest of downtown Denver and the years 1995-2018, results for the other sites are similar.

Figure 1-10 displays the correlation between elevated ozone concentrations and 500 hPa heights in the western U.S. and some of the sites in New Mexico are also weakly to moderately correlated to the 500 hPa heights like the sites in Denver and Utah. Elevated ozone at sites in northwestern New Mexico show less correlation with 500 hPa heights as it is believed that the large point source NOx and oil and gas NOx and VOC emissions in the region swamp the signal.

[26] hPa is100 Pa where Pa is short for Pascal that is a unit of pressure where 500 hPa = 500 mb.

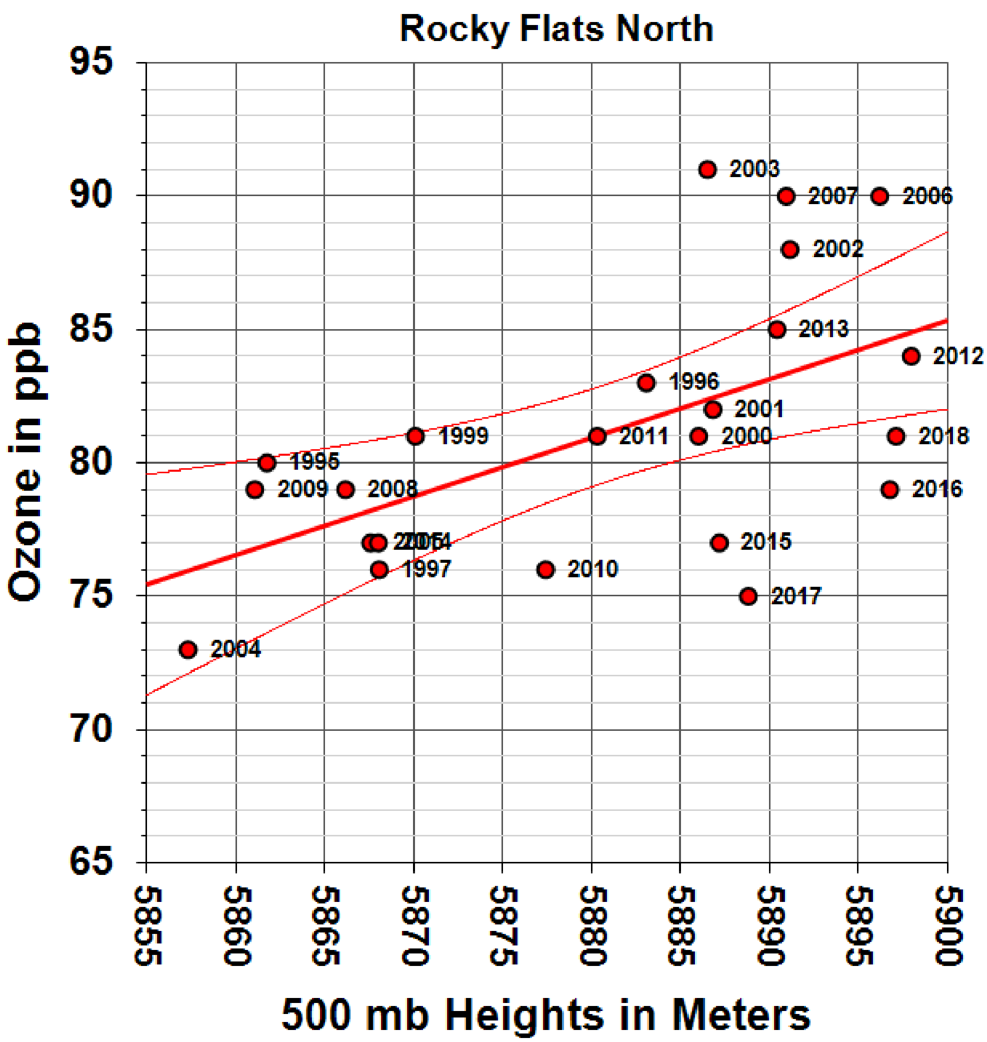


Figure 1-9. **Linear regression of the annual 4th highest MDA8 ozone concentrations and mean July through August NCEP/NCAR Reanalysis 500 hPa (or 500 mb) heights for the DM/NFR NAA region at the Rocky Flats North (RFNO) monitoring site for the years 1995 to 2018.**

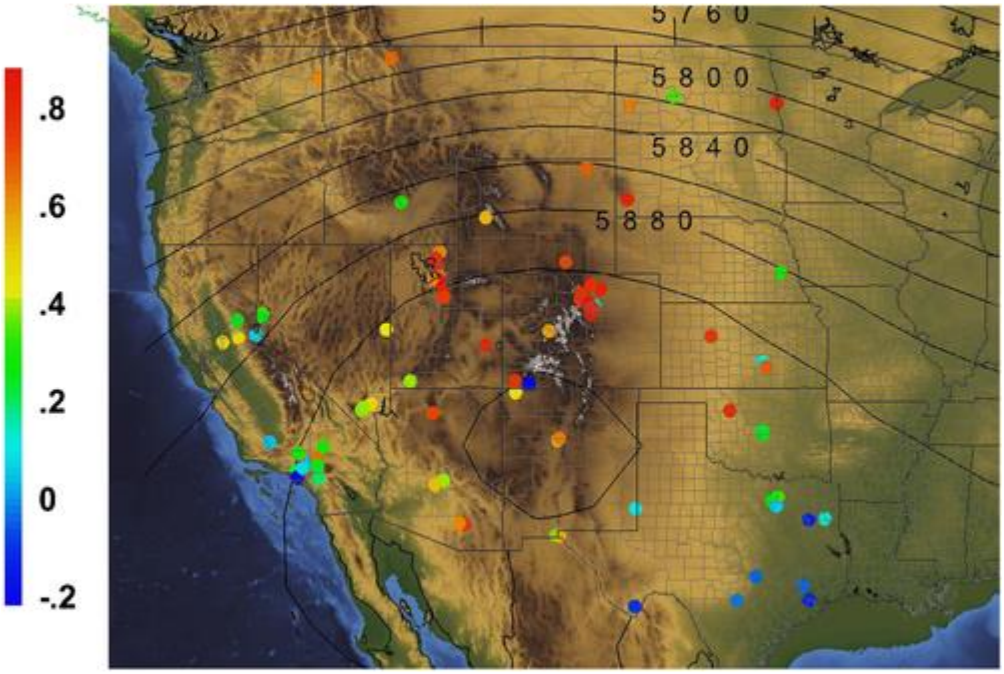


Figure 1-10. Correlation between 500 hPa heights and elevated ozone concentrations for monitoring sites in the western U.S.[27]

1.3.8 The Four Corners Air Quality Task Force

The Four Corners Air Quality Task Force (FCAQTF) was convened by the states of New Mexico and Colorado in 2005 and comprised of over 100 members and over 150 of interested parties. Its goals were to address air quality issues in the Four Corners region and consider mitigation options to reduce air pollution and acid deposition and improve visibility in the region. They found that transport from outside of the region was the largest contributor to ozone concentrations. Several large power plants and O&G production in the San Juan Basin, as well as mobile sources, also contributed to ozone in the region. The FCAQTF was completed in November 2007 with the release of a report[28] that contained over 100 potential mitigation measures for reducing emissions in the Four Corners region. The FCAQTF has been replaced by the Four Corners Air Quality Group (FCAQG[29]).

1.3.9 Other Studies

There are numerous other studies that may also be relevant to the NM OAI Study.

- Summary of State Regulations Applicable to Oil and Gas Sources in the WESTAR-WRAP Region (PDF) and companion spreadsheet (XLS)
- Final Work Products - Low and High Emissions Scenarios

[27] https://agupubs.onlinelibrary.wiley.com/cms/asset/192a6975-cd1c-4bce-a20a-a2a049ca4df6/jgrd52767-fig-0001-m.png
[28] https://www.env.nm.gov/wp-content/uploads/sites/2/2016/11/4CAQTF_Report_FINAL.pdf
[29] https://www.env.nm.gov/air-quality/fcaqg/

I. WESTAR-WRAP region Future Year Oil and Gas Emission Inventories for Two Additional Scenarios: Declined Vertical Wells and Increased Horizontal Wells Memorandum
II. Future Year Lower Scenario Inventory Spreadsheet
III. Future Year Higher Scenario Inventory Spreadsheet

- OGWG Projected Emissions from Baseline Year Emissions Inventory – October 11, 2019
  I. Final Report (revised version of March 5, 2020) and Inventory Spreadsheet for the "Continuation of Historical Trends" projection inventory. These data will be used in modeling and control analyses for Regional Haze planning.
  II. State of Colorado projections methodology (PDF) (January 2, 2020, data are included in Final Report and Inventory Spreadsheet above).
- OGWG Baseline Year Alaska and Intermountain Region Emissions Inventory revised final deliverables – Sept. 2019
  I. The Revised Final Report and Inventory Spreadsheet were completed in mid-Sept. and posted on Sept. 23, 2019. These files completely replace the previously posted July 2019 report and spreadsheet, while the gas profile information posted in July is unchanged. The July report and spreadsheet files have been removed to avoid confusion. The Revised Final Report includes updates from the July postings to include the: 1) Colorado O&G emissions based on new inventories provided by Colorado Department of Public Health and Environment and Southern Ute Indian Tribe and 2) Williston Basin casinghead gas emission inventory to correct emissions that were biased low based on EPA O&G Tool inputs.
- OGWG Emissions Survey for State Air Agencies and O&G Operators
  I. Complete survey (January 2019)
  II. Fleet turnover and controls-focused survey (January 2019)

San Juan & Permian Basins' O&G 2014 Emission Inventory Project

The National Park Service (NPS) has conducted studies of visibility impairment and nitrogen/sulfur deposition at National Parks throughout the U.S. For example, the Rocky Mountain Atmospheric Nitrogen and Sulfur Study (ROMANS) studied nitrogen deposition and potential mitigation scenarios at Rocky Mountains National Park (RMNP). RMNP studies have included data collection, data analysis, modeling and the development of a nitrogen deposition reduction plan. Details on these activities can be found at:

https://www.colorado.gov/pacific/cdphe/rocky-mountain-national-park-initiative

http://www.nature.nps.gov/air/studies/romans.cfm

The Bureau of Land Management (BLM) has conducted several iterations of the Colorado Air Resource Management Modeling Study (CARMMS) using a CAMx 4-km modeling database with a 4-km grid resolution domain covering Colorado and northwest New Mexico. Future year source apportionment modeling was conducted to assess the ozone, $PM_{2.5}$, visibility and sulfur and nitrogen deposition impacts at Class I and sensitive Class II Area due to oil and gas and mining development on Federal lands in Colorado and northern New Mexico.

https://www.blm.gov/sites/blm.gov/files/documents/files/program_natural%20resources_soil%20air%20water_airco_quicklins_CARMMS2.0.pdf

1.4 New Mexico Conceptual Models for High Ozone Concentrations

There are three interrelated but distinct Conceptual Models of ozone formation within New Mexico: southeastern New Mexico, Albuquerque and surrounding areas, and northwestern New Mexico. They share the attribute that ozone transport dominates ozone concentrations on all days. Days with the highest local ozone formation are typically hot summer days with slow winds and without an excessive amount of precipitation (summer monsoon).

1.4.1 Southeastern New Mexico

Ozone at monitoring sites in southeastern New Mexico, including Dona Ana, Eddy and Lea Counties, is dominated by ozone transport from outside of New Mexico. This transport includes long-range transport from the remainder of U.S. and global sources (e.g., Asia) as well as medium-range transport from Texas and Mexico. Current year on-road mobile source emissions tend to be the largest contributing Source Sector within southwestern New Mexico and nearby areas, with non-road mobile and O&G sources also contributing. With the exception of emissions from Mexico, the contributions of Electrical Generating Units (EGU) and other large industrial point sources tends to be smaller than the other Source Sectors.

The SNMOS discussed in Section 1.3.5 provides more details on the sources that contribute to elevated ozone concentrations in southeastern New Mexico. It found only 3% of the 2011 ozone Design Value was due to emissions from New Mexico. Emissions from nearby areas in Mexico and Texas contribute the most after long-range transport of ozone.

1.4.2 City of Albuquerque

Ozone transport also dominates elevated ozone concentrations in and near the City of Albuquerque. The Albuquerque modeling study discussed in Section 1.3.6 provides details on source contributions, but sources within New Mexico contributed a large fraction (e.g., 14% and 24%) to elevated ozone in Albuquerque with emissions from Albuquerque contributing up to 75% of the New Mexico contribution. Emissions from on-road and non-road mobile and state-wide O&G also have substantial contributions.

1.4.3 Northwest New Mexico

Although ozone transport dominates ozone in the New Mexico Four Corners region, there are significant contributions due to local power plants and O&G production in the San Juan Basin. The FCAQTF identified numerous local control measures that could mitigate elevated ozone concentrations in the region (see Section 1.3.7).

1.5 Overview of the Modeling Approach

The NM OAI Study will conduct photochemical modeling for a 2014 base and 2023 future year and perform 2023 ozone source apportionment and control strategy sensitivity modeling.

1.5.1 Episode Selection

The May-August 2014 modeling period was selected as it has a high quality emissions inventory with western state updates and has a PGM platform already developed from the WRAP/WAQS regional haze modeling (see Chapter 3 for more details).

1.5.2 Model Selection

Details on the rationale for model selection are provided in Chapter 2. The Weather Research Forecast (WRF) prognostic meteorological model was selected with the 4-km grid covering New Mexico. Emissions modeling will be performed using the Sparse Matric Operator Kernel Emissions (SMOKE) model for most source categories. The Model of Emissions of Gases and Aerosols from Nature (MEGAN) will be used for biogenic emissions and there are special processors for fires, windblown dust (WBD), lightning NOx (LNOx) and oceanic sea salt (NaCl) and Dimethyl Sulfide (DMS) emissions. The 2014 version of the MOtor Vehicle Emissions Simulator (MOVES2014b) on-road mobile source emissions model will be used with SMOKE-MOVES and WRF meteorological data to generate on-road mobile source emissions for the 4-km New Mexico and 12-km western U.S. modeling domains.

The Comprehensive Air-quality Model (CAMx) photochemical grid model (PGM) will be used because it supports two-way grid nesting, includes a subgrid-scale Plume-in-Grid module, contains a well-vetted ozone source apportionment tool and has a rich and successful history of application to the region.

1.5.3 Domain Selection

The same 36-km 36US and 12-km 12WUS2 modeling domains as used in the WRAP/WAQS 2014 modeling will be used in the NM OAI Study modeling. A higher resolution 4-km domain will be added covering New Mexico and adjacent areas. New 2014 36/12/4-km WRF meteorological modeling will be conducted to provide the higher resolution meteorological fields needed for the 4-km New Mexico domain. Details on the domain definition are presented in Chapter 4.

1.5.4 Base and Future Year Emissions Data

The 2014 base year emissions data will be based on the WRAP/WAQS 2014v2 emissions that was in turn based on the 2014NEIv2 with updates from western states. New emissions will be generated for natural emission sources (e.g., biogenic and LNOx) as needed. 2023 future year emissions will be mostly based on the EPA 2016v1 emissions (2023fh inventories). 2023 mobile source emissions will be created using SMOKE-MOVES modeling with 2023 MOVES emission factor look-up table and 2014 WRF meteorology. 2023 O&G emissions for the WRAP states will be based on the WRAP 2023 O&G emissions. The 2014 and 2023 emissions for New Mexico will be reviewed by NMED and updated as needed.

1.5.5 Emissions Input Preparation and QA/QC

Quality assurance (QA) and quality control (QC) of the emissions datasets are some of the most critical steps in performing air quality modeling studies. Because emissions processing is tedious, time consuming and involves complex manipulation of many different types of large databases, rigorous QA measures are a necessity to prevent errors in emissions processing from occurring. The NM OAI Study modeling study will perform a multistep emissions QA/QC approach as developed for the WRAP 2002 modeling (Adelman, 2004) and following the procedures in EPA's latest ozone modeling guidance (EPA, 2018a, pp. 60) and Section 2.20 of the SMOKE User's Manuel (UNC, 2018, pp. 94). This includes the initial emissions QA/QC by the NMED of their emissions for New Mexico as well as QA/QC by the WESTAR/Ramboll team.

1.5.6 Meteorology Input Preparation and QA/QC

The CAMx 2014 36/12/4-km meteorological inputs will be based on a new 2014 WRF meteorological modeling conducted by the Ramboll. The new WRF 2014 36/12/4-km modeling will be evaluated against measured meteorological parameters in a model performance evaluation. The 2014 36/12/4-km WRF output will be processed by WRFCAMx processors to generate meteorological inputs for CAMx. Details on the NM OAI Study 2014 36/12/4-km WRF modeling are provided in Chapter 5.

1.5.7 Initial and Boundary Conditions Development

Initial concentrations (IC) and Boundary Conditions (BCs) are important inputs to PGMs. We intend to run approximately the first two-weeks of May on the 36/12/4-km domains to spin-up the model before the first high ozone day in New Mexico (68 ppb on May 17). This will "wash out" the influence of the ICs before elevated ozone concentrations occur in New Mexico.

BCs for the 36-km 36US domain will be based on a 2014 simulation of the GEOS-Chem global chemistry model conducted by WRAP processed by the GC2CAMx converter. The result is day-specific diurnally varying BCs for the lateral boundaries around the 36-km 36US modeling domain (i.e., GCBC). The top BC (TopCon) will be based on a zero-gradient assumption where concentrations above the top of the model (at 50 mb, or ~19-km above sea level) are assumed to be the same as in the top vertical layer of the model.

1.5.8 Air Quality Modeling Input Preparation and QA/QC

Each step of the air quality modeling will be subjected to QA/QC procedures. These procedures include verification of model configurations, confirmation that the correct data were used and were processed correctly and other procedures. Visualization of model inputs are a critical component of the QA/QC process.

1.5.9 Model Performance Evaluation

The Model Performance Evaluation (MPE) will follow EPA's MPE recommendations in their ozone modeling guidance (EPA, 2007; 2014d; 2018a) and other sources (e.g., Simon, Baker and Phillips, 2012; Emery et al., 2016) and use many elements in EPA Region 8's MPE checklist (EPA, 2015a). The CAMx 2014 36/12/4-km base case simulation will focus on ozone and precursor model performance within the 4-km New Mexico domain. Details on the MPE are provided in Chapter 7.

1.5.10 Diagnostic Sensitivity Analyses

Depending on the results of the CAMx 2014 base case modeling and MPE, diagnostic sensitivity tests may be conducted to try and improve model performance. The definition of these diagnostic sensitivity tests will depend on the results of the initial MPE. The WRAP/WAQS development of the CAMx 2014 36/12-km modeling database conducted numerous sensitivity tests[30] leading to the final 2014v2 base case.

Under the NM OAI Study we expect most of the sensitivity tests to be conducted for the 2023 future-year where both emissions control strategy sensitivity and ozone source apportionment modeling is planned.

1.5.11 Future Year Control Strategy Modeling

Future year modeling for ozone will be performed for the 2023 future year. A CAMx 2023 36/12/4-km base case simulation will be conducted and projected 2023 ozone DVs calculated. The procedures to calculate projected 2023 ozone DVs will follow EPA's latest guidance (EPA, 2018d). These procedures use the modeling results in a relative fashion to scale the current year observed 8-hour ozone Design Values (DVCs) to project future year ozone Design Values (DVFs). The scaling factors are called Relative Response Factors (RRFs) and are the ratio of the future-year to current-year modeling results for the 10 highest base year modeled MDA8 ozone days near the monitoring site. EPA has developed the Speciated Modeled Attainment Test (SMAT[31]) tool that includes the recommended procedures in the latest EPA guidance for projecting ozone DVFs.

2023 future year control strategy sensitivity modeling will be performed. The future year controls will be defined by the NMED.

1.5.12 Future Year Source Apportionment Modeling

2023 future year ozone source apportionment modeling will be conducted using the CAMx Anthropogenic Precursor Culpability Assessment (APCA) ozone source apportionment tool. The WRAP 2014 GEOS-Chem global chemistry base case, ZROW and NAT simulation will be processed to isolate the contributions of U.S. anthropogenic, International anthropogenic and natural sources to the BCs. Within New Mexico, contributions will be obtained for the major Source Sectors. A NM OAI Study 2023 ozone source apportionment plan will be developed and discussed with NMED.

1.6 Project Participants and Contacts

The NMED is leading the NM OAI Study that is being carried out by the contracting team of WESTAR and Ramboll. Key participants in the NM OAI Study and their contact information are provided in Table 1-1.

[30] http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx
[31] https://www.epa.gov/scram/photochemical-modeling-tools

Table 1-1. Key participants and contact information for the NM OAI Study.

Organization	Individual(s) [Roll]	Address	Contact Information
New Mexico Environmental Division (NMED) Air Quality Bureau (AQB)			
NMED	Kerwin Singleton	Planning Section Chief NMED/AQB 525 Camino de los Marquez, Suite 1 Santa Fe, NM 87505	Bus: (505) 476-4350 Cell: (505) 669-3371 kerwin.singleton@state.nm.us
NMED	Bob Spillers	NMED/AQB 525 Camino de los Marquez, Suite 1 Santa Fe, NM 87505	Robert.Spillers@state.nm.us
NMED	Liz Busby-Kuehn	NMED/AQB 525 Camino de los Marquez, Suite 1 Santa Fe, NM 87505	Elizabeth.Kuehn@state.nm.us
NMED	Mike Baca	NMED/AQB 525 Camino de los Marquez, Suite 1 Santa Fe, NM 87505	michael.baca1@state.nm.us
Contractors (modeling team)			
WESTAR	Mary Uhl [Project Manager]	Executive Director WESTAR 3 Caliente Road #8 Santa Fe, NM 87508	Bus: (505) 930-5197 Fax: (505) 954-1216 maryuhl@westar.org
WESTAR	Tom Moore [Co-Principal Investigator]	WRAP Air Quality Program Manager c/o CSU/CIRA 1375 Campus Delivery Fort Collins, CO 80523-1375	Bus: (970) 49-8837 Cell: (970) 988-4055 tmoore@westar.org
Ramboll	Mr. Ralph Morris [Co-Principal Investigator]	Managing Principal Ramboll 7250 Redwood Blvd., Suite 105 Novato, CA 94945	bus: (415) 899-0708 Cell: (415) 713-2840 rmorris@ramboll.com
Ramboll	Marco Rodriguez [PGM Modeling Expert]	Ramboll 702 West Drake Road Building F Fort Collins, CO 80526	bus:(970) 237-4332 mrodriguez@ramboll.com
Ramboll	Tejas Shah [Emissions Modeling Expert]	Ramboll 7250 Redwood Blvd., Suite 105 Novato, CA 94945	bus: (415) 899-0735 tshah@ramboll.com
Ramboll	Jeremiah Johnson [Meteorological Modeling Expert]	Ramboll 7250 Redwood Blvd., Suite 105 Novato, CA 94945	Bus: (415) 899-0752 jjohnson@ramboll.com

1.7 Communication

Frequent communication between the NMED and the WESTAR and Ramboll modeling team and other potentially participants is anticipated. These communications will include e-mails, conference calls and potentially face-to-face meetings.

1.8 Schedule

The task structure and schedule for the NM OAI Study key deliverables are shown in Table 1-2. The study will be continuously documented with PowerPoint presentations and other documents that will be presented to the NMED each month in a webinar whose current schedule and topics are shown in Table 1-3. After each webinar, and with approval of the NMED, the presentations will be posted to a NM OAI Study webpage that will be hosted on the WRAP website. There are two formal reports for the study: (1) a 2014 base case modeling and model performance evaluation report prepared under Task 5, with a draft report currently scheduled for delivery in September 2020; and (2) an Air Quality Technical Support Document (AQTSD) that documents the entire study including the 2023 modeling prepared under Task 7, with a draft report currently scheduled for delivery in November 2020..

Table 1-2. Current schedule for NM OAI Study.

Task	Deliverable	Date
1. Formal Modeling Protocol/QAPP and Work Plan		
	Kick-Off Conference Call	Apr 2020
	Draft Modeling Protocol/QAPP and Work Plan	May 2020
	Webinar PPT on final approach and project plan	May 2020
	Final Modeling Protocol/QAPP and Work Plan	May2020
	Response-to-Comments (RTC) Document	May 2020
2. Base Year Meteorological Modeling (Met)		
2.1 Evaluate Met Modeling	*Webinar PPT on WAQS 12-km WRF MPE and WAQS 12-km PGM ozone performance in New Mexico*	May 2020
2.2 Additional Met Modeling	*Webinar PPT on WRF 4-km MPE in New Mexico and Comparison with WAQS 12-km WRF*	Jun 2020
2.3 Process Met Data	PGM summer 2014 36/12/4-km meteorological inputs	Jun 2020
3. Boundary Conditions (BC)		
3.1 Evaluate BC Data	*Webinar PPT on WRAP/WAQS 2014 GEOS-Chem BCs and latest updates to GEOS-Chem*	Jun 2020
4. Base Year (2014) and Future Year (2023) Emissions		
4.1 & 4.3. 2014 and 2023 Emissions for 4-km New Mexico Domain	*Webinar PPT on recommended sources for 2014 and 2023 emissions in the 4-km New Mexico domain*	May 2020

Task	Deliverable	Date
	Webinar PPT and tile plots/excel spreadsheets for selected 2014 and 2023 emissions for sources in the 4-km NM domain	Jun 2020
4.2 Mobile Sources		
4.2.1 Evaluate Mobile Emissions	*Webinar PPT on options for 2014 & 2023 mobile source emission inputs and advantages/disadvantages*	Jun 2020
	Webinar PPT on final 2014 & 2023 selected mobile source emissions options	Jun 2020
4.2.3 Prepare Mobile Source Emission Inputs	*Webinar PPT on SMOKE-MOVES modeling to generate 2014 and 2023 mobile source emission inputs for 4-km NM domain*	Aug 2020
	Model-ready 2014/2023 mobile source emissions inputs	Aug 2020
4.4 Biogenic/Natural Emissions	*Webinar PPT on biogenic and natural emission modeling*	Jul 2020
	Model-ready 2014 natural emissions inputs (Bio, LNOx, Fires)	Jul 2020
4.5 SMOKE Modeling	*Webinar PPT on SMOKE modeling 2014/2023 anthropogenic emissions*	Aug 2020
	Model-ready 2014/2023 anthropogenic emissions inputs	Aug 2020
4.6 FY Emissions Strategies	*Webinar PPT on FY 2023 SMOKE control/strategies*	Aug 2020
	Summary tables and tile plots of emissions for 2023 scenarios	Aug 2020
5. 2014 Base Year (2014) Air Quality Modeling		
	Webinar PPT on final 2014 base case and MPE	Sep 2020
	Draft report on 2014 base case, MPE and Tasks 2-5	Sep 2020
	Final Report on 2014 base case, MPE & Tasks 2-5	Oct 2020
	RtC on 2014 base case and MPE report	Oct 2020
6. Future Year (2023) Air Quality Modeling		
6.1 FY PGM Modeling	*Webinar PPT on FY 2023 PGM Modeling*	Oct 2020
	Difference plots of FY-BY Ozone Concentrations	Oct 2020
6.2 Modeled Attainment Test	*Webinar PPT on FY ozone DV projections*	Oct 2020

Task	Deliverable	Date
6.4 FY Source Apportionment	*Webinar PPT on FY Source Apportionment Modeling*	Nov 2020
	Interactive Excel spreadsheets with Source Apportionment modeling Results	Nov 2020
6.3 FY Controls Modeling	*Webinar PPT on FT control strategy/sensitivity*	Nov 2020
	Excel Spreadsheet of 2023 ozone DV projections	Nov 2020
7. Air Quality Technical Support Document and Data Transfer		
	Draft Air Quality Technical Support Document (AQTSD)	Nov 2020
	Final Air Quality Technical Support Document (AQTSD)	Dec 2020
	RtC document on AQTSD comments	Dec 2020
	Data Transfer of BY and FY modeling databases and results	Dec 2020

Table 1-3. Current schedule for monthly webinars for the NM OAI Study.

Webinar No.	Webinar Topics by Task	Date
1.	1. Modeling Protocol and Work Plan 2.1 Evaluate Existing Met 4.1 Recommend 2014 and 2023 Emissions 4.2.1 Recommend 2014 & 2023 Mobile Source Emissions	May 2020
2.	2.2 Additional Met Modeling 3.1 Evaluate BC Data 4.1 Summary of 2014 and 2023 Emissions	Jun 2020
3.	4.2.1 Summary of 2014 and 2023 Mobile Source Emissions 4.4 2014 Natural Emissions Results (e.g., Biogenic and LNOx)	Jul 2020
4.	4.2.3 2014 & 2023 SMOKE-MOVES Results for 4-km NM Domain 4.5 2014 & 2023 SMOKE Emissions Modeling Results	Aug 2020
5.	4.6 FY Emissions Strategy Results 5. 2014 CAMx Base Case Modeling and MPE	Sep 2020
6.	6.1 2023 CAMx Modeling Results 6.2 2023 Ozone Design Value Projections	Oct 2020
7.	6.3 2023 Control Strategy Results 6.4 2023 Source Apportionment Modeling Results	Nov 2020

2. MODEL SELECTION

This section introduces the models to be used in the NM OAI Study. The selection methodology presented follows EPA's guidance for regulatory modeling in support of ozone attainment demonstrations (EPA, 2007; 2014d; 2018d). Unlike some of EPA's previous ozone modeling guidance that specified a particular ozone model to be used (e.g., EPA's 1991 ozone modeling guidance that specified the Urban Airshed Model [UAM; Morris and Myers, 1990]), the EPA now recommends that models be selected for ozone, $PM_{2.5}$ and regional haze SIP modeling on a case-by-case basis (EPA, 2018d). The latest EPA ozone guidance (EPA, 2018d) explicitly mentions the CMAQ and CAMx PGMs as the most commonly used PGMs that would satisfy EPA's selection criteria but notes that this is not an exhaustive list and does not imply that they are "preferred" over other PGMs that could also be considered and used with appropriate justification. EPA's ozone modeling guidance lists several criteria for model selection that are paraphrased as follows (EPA, 2018d, pp. 24-27):

- It should not be proprietary;
- It should have received a scientific peer review;
- It should be demonstrated to be applicable to the problem on a theoretical basis;
- It should be used with data bases which are available and adequate to support its application;
- It should be shown to have performed well in past modeling applications;
- It should be applied consistently with an established protocol on methods and procedures;
- It should have a user's guide and technical description;
- The availability of advanced features (e.g., probing tools or science algorithms) is desirable; and
- When other criteria are satisfied, resource considerations may be important and are a legitimate concern.

For the NM OAI Study, we will use the same WRF/SMOKE/MOVES2014/MEGAN/CAMx modeling system as used in many recent studies and satisfies all the selection criteria above. The CAMx modeling system was used in the Western Regional Air Partnership (WRAP) West-wide Jump Start Air Quality Modeling Study (WestJumpAQMS; ENVIRON, 2011; ENVIRON and Alpine, 2012; ENVIRON, Alpine and UNC, 2013), Western Air Quality Study (WAQS; Adelman, Shankar, Yang and Morris, 2014; 2016), EPA's September 2019 Regional Haze modeling (EPA, 2019) and transport (CSAPR) modeling, and for a series of Denver ozone SIP modeling [e.g., 2003 EAC SIP (Morris et al., 2004c,b,c,d), 2008 SIP (Morris et al., 2007; 2008a,b,c) and 2016 SIP (Ramboll and Alpine, 2016a,b; 2017a; RAQC and CDPHE, 2017)] so has a long history of demonstrated success for simulating ozone concentrations in the western U.S.

2.1 Meteorological Model

The Weather Research and Forecasting (WRF) Model is a mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs (Skamarock, 2004; 2006; Skamarock et al., 2005; 2008; 2019). The Advanced Research WRF (ARW) version of WRF will be used in the NM OAI Study. It features multiple dynamical cores, sophisticated data assimilation system, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers. The effort to develop WRF has been a collaborative partnership, principally among the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), the National Centers for Environmental Prediction (NCEP) and the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). WRF allows researchers the ability to conduct simulations reflecting either real data or idealized configurations. WRF provides operational forecasting a model that is flexible and efficient computationally, while offering the advances in physics, numerics, and data assimilation contributed by the research community.

WRF is publicly available, has full documentation and has demonstrated success in simulating meteorological conditions in New Mexico and Intermountain West (IMW) to support PGM modeling efforts in numerous studies (e.g., SNOMS, WRAP WestJumpAQMS and WAQS, EPA national studies and more recent Denver ozone SIPs).

2.2 Emissions Models

2.2.1 Sparse Matrix Operator Kernel Emissions (SMOKE)

The Sparse Matrix Operator Kernel Emissions (SMOKE) is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, non-road, area, point, fire and biogenic emission sources for PGMs (Coats, 1995; Houyoux and Vukovich, 1999; UNC, 2019). As with most "emissions models," SMOKE is principally an emission processing system and not a true emissions modeling system in which emissions estimates are simulated from "first principles." This means that, except for mobile sources, its purpose is to provide an efficient, modern tool for converting an existing base emissions inventory data that is typically at the county or point source level into the hourly gridded speciated formatted emission files required by a PGM. SMOKE will be used to prepare emission inputs for non-road mobile, non-point (area) and point sources. SMOKE performs three main functions to convert emissions to the hourly gridded emission inputs for a PGM: (1) spatial allocation, spatial allocates county-level emissions to the PGM model grid cells typically using a surrogate distribution (e.g., population); (2) temporal allocation, allocates annual emissions to time of year (e.g., monthly or seasonally) and day-of-week (typically weekday, Saturday and Sunday); and (3) chemical speciation, maps the emissions to the species in the chemical mechanism used by the PGM, most important for VOC and $PM_{2.5}$ emissions.

2.2.2 MOtor Vehicle Emissions Simulator (MOVES)

The MOtor Vehicle Emissions Simulator (MOVES2014b) is EPA's latest on-road mobile source emissions model that was first released in July 2014 (EPA, 2014a,b,c). MOVES2014 includes the latest on-road mobile source emissions factor information. The NM OAI Study will use a version 2014b of MOVES (MOVES2014b[32]) with CB6 species that was released in August 2018.

2.2.3 SMOKE-MOVES

SMOKE-MOVES uses an Emissions Factor (EF) Look-Up Table from MOVES, vehicle miles travelled (VMT) and other activity data and hourly gridded meteorological data (typically from WRF) for the base modeling year and generates hourly gridded speciated on-road mobile source emissions inputs. SMOKE-MOVES will be used to generate on-road mobile source emissions for the 4-km New Mexico domain using the 4-km WRF data developed in this study. It will also be used to generate mobile source emissions inputs for the 12-km western U.S. domain.

2.2.4 Model of Emissions of Gases and Aerosols from Nature (MEGAN)

Biogenic emissions will be generated using version 3.1 of the Model of Emissions of Gases and Aerosols from Nature (MEGAN). MEGAN is the latest biogenic emissions model that was originally developed by researchers from the National Center for Atmospheric Research (NCAR) and is currently supported by the University of California at Irvine. MEGAN includes the full range of ozone and PM precursor species from biogenic sources (Guenther and Wiedinmyer, 2004; Wiedinmyer, Sakulyanontvittaya and Guenther, 2007). The NM OAI Study will use the latest version of MEGAN v3.1 that includes more western states plant emissions data that were implemented by WRAP (Sakulyanontvittaya, Yarwood and Guenther, 2012).

2.3 Photochemical Grid Model

2.3.1 Comprehensive Air-quality Model with extensions (CAMx)

The Comprehensive Air-quality Model with Extensions (CAMx; Ramboll, 2018a) is a state-of-science "One-Atmosphere" multi-scale photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at regional, urban and local scale typically for periods of a year. CAMx is a publicly available open-source computer modeling system for the integrated assessment of gaseous and particulate air pollution. Built on today's understanding that air quality issues are complex, interrelated, and reach beyond the urban scale, CAMx is designed to (a) simulate air quality over many geographic scales, (b) treat a wide variety of inert and chemically active pollutants including ozone, inorganic and organic $PM_{2.5}$ and PM_{10} and mercury and toxics, (c) provide source-receptor, sensitivity, and process analyses and (d) be computationally efficient and easy to use.

The U.S. EPA has approved the use of CAMx for numerous ozone and PM State Implementation Plans throughout the U.S. (including the Denver 2003, 2008 and 2016 ozone SIPs) and has used this model to evaluate regional mitigation strategies

[32] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100V7H1.pdf

including those for most recent national transport rules, such as the Cross-State Air Pollution Rule (CSAPR) and CSAPR Update. The most recent version of CAMx is Version 7.0 that was used in the WRAP/WAQS 2014v2 modeling and EPA's recent national Regional Haze modeling (EPA, 2019). The latest EPA ozone guidance (EPA, 2018d, pp. 24) explicitly mentions the CMAQ and CAMx PGMs as the most commonly used PGMs that would satisfy EPA's selection criteria but notes that this is not an exhaustive list and does not imply that they are "preferred" over other PGMs that could also be considered and used with appropriate justification. EPA has conducted an analysis of the appropriateness for using CAMx and CMAQ for single-source ozone and secondary $PM_{2.5}$ modeling justifying their use (EPA, 2017c).

2.4 Final Justification for Model Selection

At the beginning of this Chapter we presented EPA's criteria for model selection (EPA, 2018d). The proposed WRF/SMOKE/MOVES/CAMx modeling system satisfies all of these criteria as follows:

- It should not be proprietary: The WRF[33], SMOKE[34], MOVES[35], MEGAN[36] and CAMx[37] models are all publicly available at no cost and can be downloaded from their websites.
- It should have received a scientific peer review: All the models considered have been published in 100s of peer-review journal articles. The CAMx model has been subject to their own peer-review reports[38] and an assessment by EPA that they are suitable for ozone SIP modeling (EPA, 2018d).
- It should be appropriate for the specific application on a theoretical basis: The WRF model was designed to simulate time varying three-dimensional meteorological fields and provide all the meteorological information necessary for ozone modeling. The SMOKE, MOVES and MEGAN models provide the hourly gridded speciated emissions information required for ozone modeling. And the CAMx model was designed to have all the processes necessary to simulate ozone formation in the troposphere.
- It should be used with data bases which are available and adequate to support its application: The procedures outlined for the development of the 2014 modeling platform to support ozone modeling of New Mexico use databases that are adequate to support the meteorological, emission and photochemical model applications.
- It should be shown to have performed well in past modeling applications: The WRF/SMOKE/CAMx modeling system has a demonstrated history in simulating ozone formation in the western U.S. in general and New Mexico in particular. CAMx was used in the New Mexico EAC SIP, FCAQTF, CARMMS, WRAP WAQS[39]

[33] https://www.mmm.ucar.edu/weather-research-and-forecasting-model
[34] https://www.cmascenter.org/smoke/
[35] https://www.epa.gov/moves
[36] http://lar.wsu.edu/megan/
[37] http://www.camx.com/
[38] https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/1399874
[39] http://views.cira.colostate.edu/tsdw/

and WestJumpAQMS[40], and Denver ozone SIP modeling, including the 2008[41] and 2016[42] Denver ozone SIPs.

- It should be applied consistently with an established protocol on methods and procedures: The NM OAI Study WRF/SMOKE/CAMx application methodology follows the established procedures used in the past (e.g., see studies discussed above) with enhancements (i.e., 4-km New Mexico domain and use of latest model versions).
- It should have a user's guide and technical description: Each of the models cited has a technical description and procedures for application (see websites in footnotes). The CAMx model has an up-to-date and comprehensive user's guide (Ramboll, 2018a) that has a detailed technical description and procedures for application.
- The availability of advanced features (e.g., probing tools or science algorithms) is desirable: One of the reasons for selecting CAMx is due to the availability of advanced features such as the Plume-in-Grid module and Ozone Source Apportionment Technology (OSAT/APCA) in addition to latest science updates (e.g., CB6 chemistry and Decoupled Direct Method).
- When other criteria are satisfied, resource considerations may be important and are a legitimate concern: CAMx is computationally efficient and supports both MPI and OpenMP multi-processing approaches and allows for layer collapsing. CMAQ does not support OpenMP or allow for layer collapsing so runs over 1.5 times slower than CAMx.

[40] http://wrapair2.org/WestJumpAQMS.aspx
[41] https://www.colorado.gov/airquality/documents/deno308/
[42] https://raqc.org/sip/moderate-area-2008-8-hour-ozone-standard-state-implementation-plan/

3. EPISODE SELECTION

EPA's current and past 8-hour ozone modeling guidance (EPA, 2007; 2014d; 2018d) contains recommended procedures for selecting modeling episodes for demonstrating attainment of the ozone NAAQS. The NM OAI Study modeling will use the summer of 2014 as the base year modeling period because it is representative of high ozone conditions and has available modeling databases to leverage for the analysis.

3.1 Candidate Year for Modeling Episodes

Given the need to leverage an existing photochemical grid model (PGM) modeling platform for the NM OAI Study, there are only two candidate years for episode selection, 2014 and 2016. The WRAP/WAQS has developed a PGM modeling platform for the 2014 year and the EPA/MJO collaborative emissions study and EPA have built a PGM modeling platform for 2016. EPA's previous PGM modeling platform was for 2011, which is too old. And EPA is working on a new PGM modeling platform for 2017 that is not yet available.

3.2 EPA Episode Selection Criteria

EPA's 8-hour ozone SIP modeling guidance (EPA, 2018d) identifies specific criteria to consider when selecting one or more episodes for use in demonstrating attainment of the 8-hour ozone NAAQS. This guidance builds off the 1-hour ozone modeling guidance (EPA, 1991) and the original (EPA, 2007) and revised draft (EPA, 2014d) 8-hour ozone modeling guidance that recommends selecting multiple episodes representing diverse meteorological conditions that lead to exceedances of the ozone NAAQS in the region under study. For the NM OAI Study, an entire summer ozone season will be modeled to capture a wide range of different types of meteorological and emission conditions that lead to observed ozone high ozone concentrations at monitoring sites in New Mexico.

Below we address each of EPA's episode selection criteria (EPA, 2018a, pp. 19) and the justification for using the summer 2014 modeling period for the NM OAI Study.

3.2.1 Model a Time Period that Corresponds to a Year with an Available National Emissions Inventory (NEI) and has Air Quality and Meteorological Data Available

NEI's are prepared every three years. The most recent currently available NEIs are for the 2011 and 2014 years. The 2017 NEI is in preparation and a usable version is not yet available. Thus, the 2014NEI is the latest NEI available.

3.2.2 Model Time Periods in which Observed Ozone Concentrations are Close to the Appropriate Base Year Ozone Design Values*.*

Appendix A presents the observed MDA8 ozone concentrations at monitoring sites within the proposed 4-km New Mexico domain including those in New Mexico (FIP State Code = 35). Observed DMAX8 ozone concentrations that exceed the 2015 ozone NAAQS are colored red. And ozone values that are above approximately 95% of the 2015 ozone NAAQS but below the ozone NAAQS (i.e., 67 ppb ≤ ozone < 70 ppb) are colored yellow. The number of 2015 ozone NAAQS exceedances (i/e/., 71 ppb or higher) and between 67 and 71 ppb in the three main geographic regions in New Mexico are shown in Table 3-1.

For southeast New Mexico (e.g., Dona Ana County), the peak ozone in 2016 (79 ppb) is higher than in 2014 (76 ppb), but there are many more ozone exceedances days in 2014 (8) than 2016 (3). Both potential candidate modeling years have comparable levels to the observed highest 2014-2016 ozone DV in southeast New Mexico (74 ppb).The highest 2014-2016 ozone DV in northwest New Mexico is 70 ppb in San Juan County. Both candidate modeling years have a highest observed MDA8 ozone in 2014 and 2016 of 69 ppb and two days per year with ozone between 67 and 71 ppb.

Finally, for Bernalillo and Valencia Counties 2016 has a higher peak ozone than 2014 (70 vs. 68 ppb) and more days per year between 67 and 71 ppb (5 vs. 3 days per year).

Table 3-1. Maximum observed DMAX8 ozone concentrations and number of days ozone is above the 2015 ozone NAAQS or between 67 and 71 ppb in the three geographic regions of New Mexico and the 2014 and 2016 candidate modeling years.

NM Region	Max Ozone		Days ≥ 71 ppb		Days ≥ 67 ppb	
	2014	2016	2014	2016	2014	2016
NM All Sites	76	79	8	3	24	27
Albuquerque[a]	68	70	0	0	3	5
Southeast NM	76	79	8	3	21	22
Northwest NM	69	69	0	0	2	2

The Albuquerque geographic region in this table included Bernalillo and Valencia Counties.

3.3 Episode Selection Conclusions

Based on the above analysis, the May-August summer season of 2014 was selected for modeling, because:

- 2014 has a PGM modeling database developed by the WRAP/WAQS.
- It corresponds with a NEI emissions year.
- The 2014 emissions have been reviewed and updated by the western states.
- The ozone air quality is comparable to current ozone DVs.
- It has more ozone exceedance days (8) than the other candidate year (3).

4. MODELING DOMAIN SELECTION AND DATA AVAILABILITY

This Chapter summarizes the definition of the horizontal modeling domains for the NM OAI Study PGM modeling. This includes the map projection, domain coverage, grid resolution and grid nesting. As the vertical structure of the PGM model will be defined based on the vertical structure of the WRF meteorological model, it is discussed in Chapter 5. This Chapter also discusses emissions, aerometric and other data available for use in model input preparation and performance testing.

4.1 Horizontal Domain

The NM OAI Study modeling will use the same 36-km 36US and 12-km 12WUS2 domains as used in the WRAP/WAQS 2014 modeling platform. A 4-km New Mexico domain will be added to the 36/12-km domain structure. Figure 4-1 displays the 36/12/4-km domain structure with Figure 4-2 showing the 4-km New Mexico domain. New WRF 2014 36/12/4-km meteorological modeling will be conducted to generate finer scale 4-km meteorological conditions for the New Mexico domain and consistent meteorology among the 36/12/4-km domains.

CAMx will be run using the 36/12/4-km domain structure shown in Figure 4-1 using two-way interactive grid nesting.

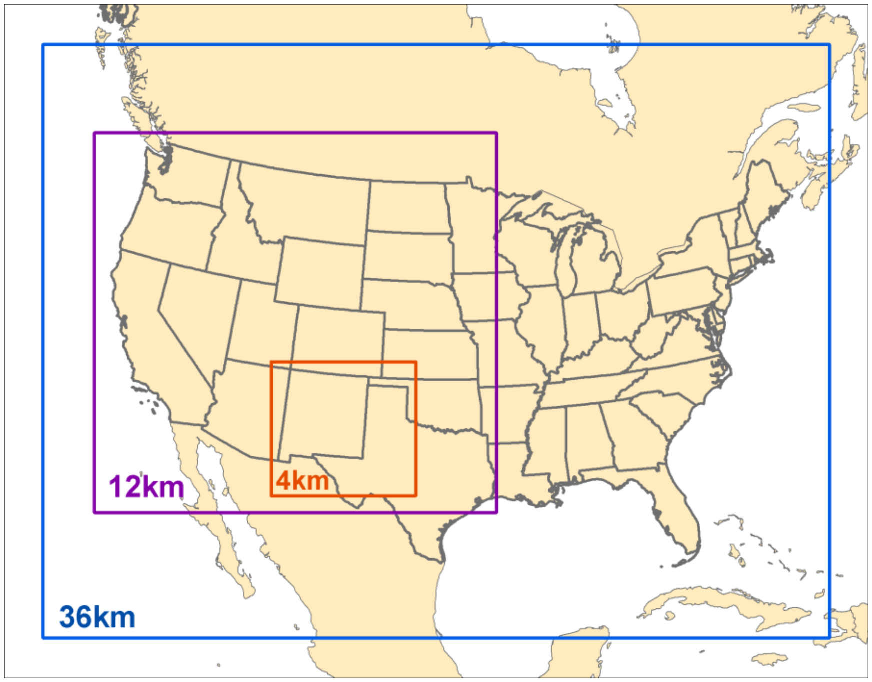


Figure 4-1. NM OAI Study modeling 2014 36/12/4-km PGM and emissions modeling domains.

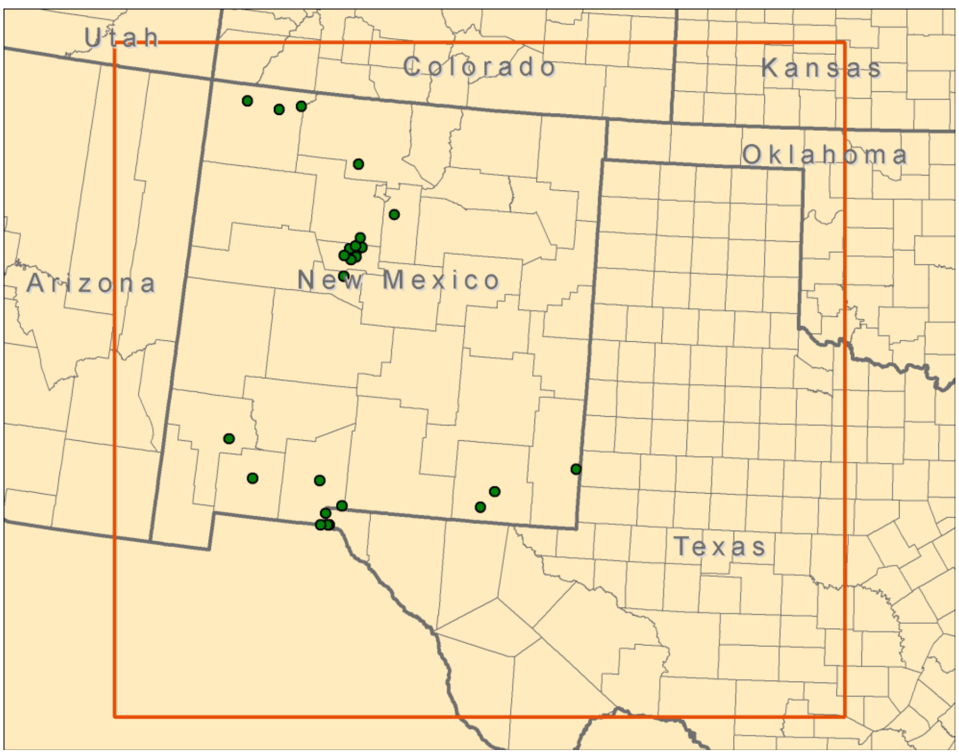


Figure 4-2. 4-km New Mexico modeling domain for PGM and emissions modeling, with locations of ozone monitors that were operating during some portion of 2014.

Table 4-1. Lambert Conformal Conic (LCC) projection parameters for the NM OAI Study 36/12/4 modeling domains.

Parameter	Value
Projection	Lambert-Conformal
1st True Latitude	33 degrees N
2nd True Latitude	45 degrees N
Central Longitude	-97 degrees W
Central Latitude	40 degrees N

Table 4-2. Grid definitions for CAMx NM OAI Study 2014 36/12/4-km modeling domains.

Grid	Origin (SW) (km)	Extent (NE) (km)	NX	NY
36-km	(-2736, -2088)	(2592, 1944)	148	112
12-km*	(-2388, -1236)	(336, 1344)	227	215
4-km*	(-1192, -1120)	(-212, -212)	245	227

*Definition includes outer row/column of buffer cells required by CAMx for nested domains

4.2 Data Availability

The CAMx modeling system requires emissions, meteorology, surface characteristics, initial and boundary conditions (IC/BC), and ozone column data for defining the inputs.

4.2.1 Emissions Data

Except for on-road mobile source emissions for the 4-km domain, the 2014 base year anthropogenic emissions inventory for New Mexico will be based on the WAQS 2014v2 emissions. The NMED will review the WAQS 2014v2 emissions for New Mexico and provide updates as needed. The sources of the 2014 emissions data are as follows.

- Major point source SO_2 and NO_x emissions will be based off measured Continuous Emissions Monitor (CEM) data that are available online from the EPA Clean Air Markets Division (CAMD[43]) website. These data are hour-specific for SO_2, NO_x, and heat input. The temporal variability of other pollutant emissions (e.g., PM) from the CEM sources will be simulated using the hourly CEM heat input data using the annual emissions from the WAQS 2014v2 emissions inventory.
- WRAP developed new 2014 oil and gas emissions for WRAP states that includes New Mexico that will be used. Outside of the WRAP states the EPA 2014NEI will be used.
- On-road mobile sources will be based on the EPA's MOVES2014 on-road emissions model (EPA, 2014a,b,c). The WAQS 36/12-km 2014v2 emissions will be used as is. Within the New Mexico 4-km domain, SMOKE-MOVES will be used

[43] http://www.epa.gov/AIRMARKETS/

with EPA's MOVES2014 2014 emission factor (EF) table and county-level vehicle activity data and 2014 hourly 4-km WRF meteorology developed in this study.

- The 2014 fire emissions developed for the 2014NEI and then updated by the WRAP Fire and Smoke Work Group will be used.
- 2014 biogenic emissions will be generated for the 36/12/4-km domains using version 3.1 of the Model of Emissions of Gases and Aerosols in Nature (MEGAN[44]) that was updated by WRAP[45] to include western U.S. plant types.
- Mexico and Canada emissions will be based on the EPA 2014 modeling platform.

4.2.2 Air Quality Data

Data from ambient air quality monitoring networks for gaseous species are used in the model performance evaluation. Table 4-3 summarizes routine ambient gaseous and PM monitoring networks available in the U.S. For this project only the routine ozone monitoring sites within the New Mexico 4-km modeling domain operating during 2014 (Figure 4-2) will be used to perform an operational evaluation of the CAMx 2014 4-km base case simulation.

[44] http://acd.ucar.edu/~guenther/MEGAN/MEGAN.htm

[45] http://www.wrapair2.org/pdf/WGA_BiogEmisInv_FinalReport_March20_2012.pdf

Table 4-3. Overview of routine ambient data monitoring networks.

Monitoring Network	Chemical Species Measured	Sampling Period	Data Availability/Source
The Interagency Monitoring of Protected Visual Environments (IMPROVE)	Speciated PM25 and PM10 (see species mappings)	1 in 3 days; 24 hr average	http://vista.cira.colostate.edu/improve/Data/IMPROVE/improve_data.htm
Clean Air Status and Trends Network (CASTNET)	Speciated PM25, Ozone (see species mappings)	Approximately 1-week average	http://www.epa.gov/castnet/data.html
National Atmospheric Deposition Program (NADP)	Wet deposition (hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium)), Mercury	1-week average	http://nadp.sws.uiuc.edu/
Air Quality System (AQS) or Aerometric Information Retrieval System (AIRS)	CO, NO2, O3, SO2, PM25, PM10, Pb	Typically, hourly average	http://www.epa.gov/air/data/
Chemical Speciation Network (CSN)	Speciated PM	24-hour average	http://www.epa.gov/ttn/amtic/amticpm.html
Photochemical Assessment Monitoring Stations (PAMS)	Varies for each of 4 station types.		http://www.epa.gov/ttn/amtic/pamsmain.html
National Park Service Gaseous Pollutant Monitoring Network	Acid deposition (Dry; SO4, NO3, HNO3, NH4, SO2), O3, meteorological data	Hourly	http://www2.nature.nps.gov/ard/gas/netdata1.htm

4.2.3 Ozone Column Data

Additional data used in the air quality modeling include ozone column data from the Ozone Monitoring Instrument (OMI) which continues the Total Ozone Mapping Spectrometer (TOMS) record for total ozone and other atmospheric parameters related to ozone chemistry (OMI officially replaced the TOMS ozone column satellite data on January 1, 2006). OMI data are available every 24-hours and are obtained from the TOMS ftp site.[46] The CAMx o3map program reads the OMI ozone column txt file data and interpolates to fill gaps and generated gridded daily ozone column input data. The OMI data are used in the CAMx (TUV) radiation models to calculate photolysis rates. The CAMx o3map processor also allows for the use of episode and monthly average data, although in this study daily data are used. Note that a new ozone column satellite product is available (OMPS) that may be used if appropriate.

4.2.4 Meteorological Data

Meteorological data for PGM modeling will be obtained from the WRF meteorological model as described in Chapter 5.

4.2.5 Initial and Boundary Conditions Data

Boundary conditions (BCs) for the 36-km 36US domain for both the base and future years will be derived from the output from a 2014 simulation of the GEOS-Chem global chemistry model conducted by WRAP.

[46] ftp://toms.gsfc.nasa.gov/pub/omi/data/

5. WRF METEOROLOGICAL MODELING

This chapter describes how the Weather Research Forecasting (WRF) meteorological model will be used to generate 2014 36/12/4-km meteorological inputs for CAMx photochemical grid modeling. The WRF model contains separate modules to compute different physical processes, such as surface energy budgets and soil interactions, turbulence, cloud microphysics, and atmospheric radiation. Within WRF, the user has many options for selecting the different schemes for each type of physical process. The WRF Pre-processing System (WPS) generates the initial conditions (ICs) and boundary conditions (BCs) and analysis fields used by WRF, based on topographic datasets, land use information, and larger-scale atmospheric and oceanic models.

5.1 Description of WRF

WRF's research and operational application ensures state-of-the-science physics and adaptability to a wide range of environments, through a broad selection of physics options, allowing us to develop the best-performing configuration for simulating meteorology in the region.

The non-hydrostatic version of the Advanced Research version of the Weather Research and Forecast (WRF-ARW) model (Skamarock et al., 2005; 2008; 2019) is a three-dimensional, limited-area, primitive equation, prognostic model that has been used widely in regional air quality model applications. WRF is a next-generation mesoscale prognostic meteorological model routinely used in urban- and regional-scale photochemical, fine particulate and regional haze regulatory modeling studies. Developed jointly by the National Center for Atmospheric Research (NCAR) and NCEP, WRF is maintained and supported as a community model by researchers and practitioners around the globe. It is suitable for use in a broad spectrum of applications across scales ranging from hundreds of meters to thousands of kilometers.

5.2 WRF Model Domain

The PGM (CAMx) 2014 36/12/4-km modeling domains were shown in Figure 4-1 in the previous Chapter. The WRF 2014 36/12/4-km modeling domains are defined slightly larger than the PGM 36/12/4-km domains so that any modeling artifacts that occur near the WRF boundaries as the BCs come into dynamic balance with the WRF numerical algorithms are not present in the PGM meteorological inputs.

5.3 WRF Model Configuration

Below we summarized the proposed WRF configuration and input to be used to generate 2014 36/12/4-km meteorological inputs for the PGM 2014 photochemical modeling. WPS and WRF version 4.2 are used for this modeling analysis. Previous studies utilizing WRF at high resolution over New Mexico, such as the WRAP WestJumpAQMS, WAQS, Southern New Mexico Ozone Study (SNMOS) and EPA modeling platform development, have evaluated different configurations of WRF. Table 5-1 below summarizes the WRF configurations used in the WAQS 2014 and EPA 2014/2015/2016 WRF modeling. Preliminary analysis of WAQS 12 km model performance in New Mexico shows superior summertime precipitation performance compared to EPA 2014 WRF modeling. Therefore, we propose that the NM OAI Study match the WRF physics configuration options used by 2014 WAQS modeling, except where noted below.

We propose to match the NM OAI 36/12-km WRF/PGM grid configuration (e.g., horizontal domains and vertical layer structure) with the WAQS 2014 WRF/PGM grid configuration in order the facilitate the use of data between the two studies. The following paragraphs describe the proposed WRF configuration for the NM OAI 2014 photochemical modeling.

5.3.1 Model Vertical Resolution

The WAQS 2011/2014 WRF modeling used 36 vertical levels (35 vertical layers) from the surface to a 50 mb (hPa) height (approximately 19-km above sea level). The EPA 2014 and 2015 WRF modeling used 35 vertical layers also up to a 50 mb height. Table 5-1 displays the 36-vertical layer structure used in the WAQS 2011/2014 WRF modeling that will be the layer structure proposed for our WRF 2014 NM OAI 36/12/4-km modeling.

Table 5-1. WRF 36 level vertical layer structure for the NM OAI study. This is the same WRF layer structure as used in WAQS 2011/2014 WRF modeling.

WRF Layer	Sigma	Pressure (mb)	Height (m)	Thickness (m)
36	0.0000	50.00	19260	2055
35	0.0270	75.65	17205	1850
34	0.0600	107.00	15355	1725
33	0.1000	145.00	13630	1701
32	0.1500	192.50	11930	1389
31	0.2000	240.00	10541	1181
30	0.2500	287.50	9360	1032
29	0.3000	335.00	8328	920
28	0.3500	382.50	7408	832
27	0.4000	430.00	6576	760
26	0.4500	477.50	5816	701
25	0.5000	525.00	5115	652
24	0.5500	572.50	4463	609
23	0.6000	620.00	3854	461
22	0.6400	658.00	3393	440
21	0.6800	696.00	2954	421
20	0.7200	734.00	2533	403
19	0.7600	772.00	2130	388
18	0.8000	810.00	1742	373
17	0.8400	848.00	1369	271
16	0.8700	876.50	1098	177
15	0.8900	895.50	921	174
14	0.9100	914.50	747	171
13	0.9300	933.50	577	84
12	0.9400	943.00	492	84
11	0.9500	952.50	409	83
10	0.9600	962.00	326	82
9	0.9700	971.50	243	82
8	0.9800	981.00	162	41
7	0.9850	985.75	121	24
6	0.9880	988.60	97	24
5	0.9910	991.45	72	16
4	0.9930	993.35	56	16
3	0.9950	995.25	40	16
2	0.9970	997.15	24	12
1	0.9985	998.58	12	12
0	1.0000	1000.00	0	

5.3.2 Vertical Coordinate

Since its inception, WRF has used the eta (sometimes called sigma or "terrain-following") vertical coordinate system. One weakness of the eta coordinate is that variations in terrain (especially steep topography) can increase numerical errors in the model. To reduce these errors, Park et al., (2018) developed a hybrid sigma–pressure coordinate that is now included as the default vertical coordinate system for the WRF model (Skamarock et al., 2019).

In Figure 5-1, we present vertical cross sections of layer interface heights over the Rocky Mountains during a strong near-surface wind event (Park et al., 2018). The left panel shows the results using the eta or terrain-following vertical coordinate and the right panel shows the same results but using the hybrid vertical coordinate. The eta coordinate cross-sections show the influence of terrain extending high into the stratosphere. This is a representation of numerical noise and results in erroneous vertical motion in the model. Park et al., (2018) found that the simulation using the eta vertical coordinate produced high turbulence forecasts aloft which were not observed by pilots or soundings. In CAMx, erroneous vertical motion can help transport stratospheric ozone toward the surface. In contrast, the same simulation using the hybrid vertical coordinate produced lower turbulence forecasts that agreed more closely with observations. The hybrid vertical coordinate cross-sections show a gradual damping of terrain effects with increasing altitude until the layer interfaces are flat aloft. The purpose of using the hybrid vertical coordinate in the CAMx is to better represent ozone in the upper troposphere and lower stratosphere. Eliminating this source of numerical noise reduces spurious downward transport of stratospheric ozone.

We will use a new version of the WRFCAMx processor that has been updated to use WRF's hybrid vertical coordinate.

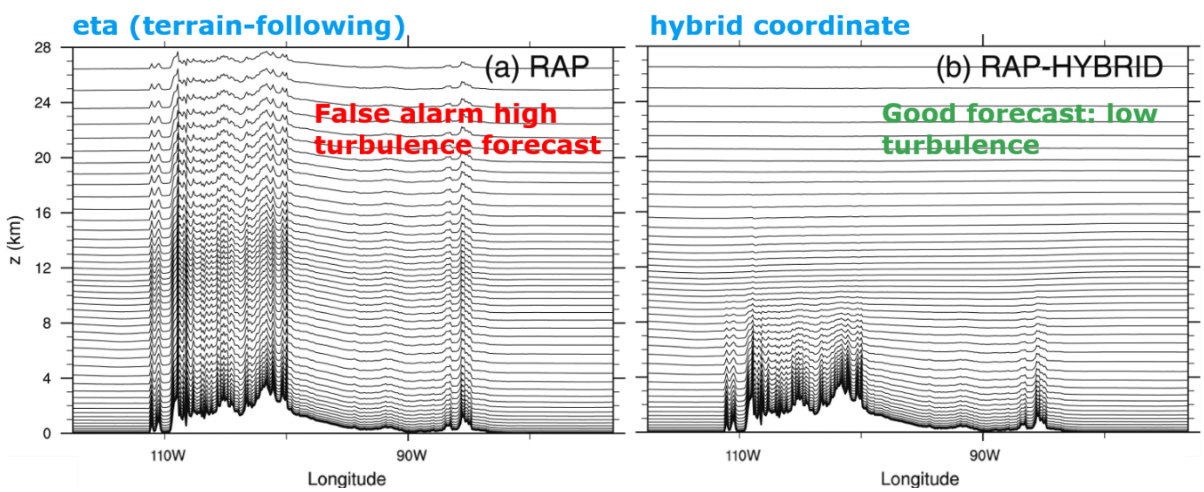


Figure 5-1. Cross-sections of layer interface heights over the Rocky Mountains for the eta (left panel) and hybrid (right panel) vertical coordinates for the WRF-Based Rapid Refresh (RAP) model. Adapted from Park et al., (2018).

5.3.3 *Topographic Inputs*

Topographic information for WRF will be based on a combination of the standard WRF terrain databases and high-resolution terrain. The 36-km 36US domain will use the 10-minute global data, the 12-km 12WUS2 domain will use the 2-minute data, and the 4-km New Mexico domain will use the 30 second data.

5.3.4 Vegetation Type and Land Use Inputs

Vegetation type and land use information will use the United States Geological Survey (USGS) land use databases from the most recently released WRF databases provided with the WRF distribution. Standard WRF surface characteristics corresponding to each land use category will be employed.

5.3.5 Atmospheric Data Inputs

WRF relies on other model or re-analysis output meteorological fields to provide initial and boundary conditions (IC/BC) and fields for the four-dimensional data assimilation (FDDA). FDDA refers to the nudging of the WRF meteorological fields to observed analysis fields so that the WRF meteorological fields better represent what was observed and prevent the model from drifting away from the observed meteorology. As seen in Table 5-2, both the WAQS 2014 and EPA 2014/2015/2016 12-km WRF modeling used the 12-km resolution North American (NAM) analysis fields for IC/BC and analysis nudging.

We propose to use both NAM and the ~30 km European Center for Medium-Range Weather Forecasting (ECMWF) Re-Analysis (ERA5[47]) dataset analysis fields for IC/BC and FDDA. We have found from previous work that the ERA-Interim (lower resolution predecessor to ERA5) dataset has lower humidity near the surface and higher humidity aloft, leading to lower convective available potential energy (CAPE), which lowers overall precipitation rates, especially during the summer Monsoon season. Many WRF simulations of the southwest U.S. summer Monsoon have featured an over-prediction of summertime (convective) precipitation when the NAM analysis fields are used. The Southern New Mexico Ozone Study (SNMOS) conducted PGM ozone sensitivity modeling using meteorological fields based on WRF simulations using the NAM and ERA analysis fields and found that the PGM ozone performance using the WRF/ERA meteorological inputs produced superior ozone performance than when WRF/NAM inputs were used.[48]

The ERA5 is a fairly new analysis fields product that has not been used in WRF modeling as extensively as the ERA fields. We will conduct WRF and PGM sensitivity modeling using the NAM and ERA5 analysis fields to determine which configuration provides the best meteorological inputs and potentially resultant ozone model performance. The ERA5 fields will be objectively re-analyzed using meteorological observational data to the higher resolution for the 36-km and 12-km grid domains using the OBSGRID program. These fields are used both to initialize the model and used with analysis nudging (on selected domains) to guide the model to best match the observations. The initialization dataset with the best WRF performance will be chosen for the final PGM configuration.

[47] https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era5

[48] https://www.wrapair2.org/SNMOS.aspx

5.3.6 Time Integration

Third-order Runge-Kutta integration will be used (rk_ord = 3). The maximum time step, defined for the outer-most domain (36 km) only, should be set by evaluating the following equation:

$$dt = \frac{6dx}{F_{map}}$$

Where dx is the grid cell size in km, Fmap is the maximum map factor (which can be found in the output from REAL.EXE), and dt is the resulting time-step in seconds. For the case of the 36 km RPO domain, dx = 36 and Fmap = 1.08, so *dt* should be taken to be less than 200 seconds. Longer time steps risk CFL errors, associated with large values of vertical velocity, which tend to occur in areas of steep terrain (especially during stable conditions typical of winter). For this WRF run, adaptive time-stepping will be used with a maximum timestep of 180s.

5.3.7 Diffusion Options

Horizontal Smagorinsky first-order closure (km_opt=4) with sixth-order numerical diffusion and suppressed up-gradient diffusion (diff_6^{th}_opt=2) will be used.

5.3.8 Lateral Boundary Conditions

Lateral boundary conditions will be specified from the initialization dataset on the 36-km WRF domain with continuous updates nested from each "parent" domain to its "child" domain, using one-way nesting (feedback=0).

5.3.9 Top and Bottom Boundary Conditions

The implicit Rayleigh dampening for the vertical velocity will be used for the top boundary conditions. Consistent with the model application for non-idealized cases, the bottom boundary condition was selected as physical, not free-slip.

5.3.10 Sea Surface Temperature Inputs

The water temperature data for the refined WRF configurations will be taken from the Fleet Numerical Meteorology and Oceanography Center (FNMOC)[49]. The FNMOC product has horizontal resolution of about 9-km in the mid-latitudes but is produced *four* times per day using AVHRR satellite sensors and in-situ observations.

5.3.11 Four Dimensional Data Assimilation (FDDA)

Analysis nudging will be used for winds, temperature, and humidity on the 36-km and 12-km domains. Both surface and aloft nudging will be used but nudging for temperature and mixing ratio will not be not performed within the boundary layer. Observation nudging will not be performed even on the 4-km domain.

[49] http://www.usgodae.org/cgi-bin/datalist.pl?summary=Go&dset=fnmoc_ghrsst

5.3.12 New Lightning Data Assimilation

More recently, the assimilation of lightning data in WRF simulations has been shown to improve the locations and amounts of convective precipitation. The use of lighting detection networks, such as the National Lightning Detection Network (NLDN), have been used in WRF simulations and used to force deep convection (thunderstorms) when lightning is observed and only allow shallow convection when lightning is not present. The use of the new lightning assimilation approach has been demonstrated to improve both WRF convective precipitation as well as PGM concentration and deposition performance (Heath et al., 2016). The new lightning data assimilation algorithms will not be used in the 2014 WRF modeling for the NM OAI Study for the following reasons: (1) it would have to be tested and evaluated and there is insufficient time in the schedule to conduct such diagnostic testing; (2) the NLDN data used to date with the WRF lightning assimilation is a commercial product that is expensive and not in the budget; and (3) the implementation of the lightning detection data assimilation in WRF has a flaw that it doesn't distinguish between no lightning detects and missing data and suppresses convection in areas with missing data (e.g., over the Gulf of Mexico).

5.3.13 PBL and LSM Physics Options

The YSU Planetary Boundary Layer (PBL) and Noah Land Surface Model (LSM) physics options will be used in the NM OAI Study 2014 36/12/4-km modeling. Previous WRF sensitivity modeling for the IMW region found the YSU/Noah PBL/LSM schemes produces the most realistic meteorological fields. Note that EPA's 2014/2015/2016 WRF modeling uses the ACM2 PBL and Pleim-Xiu (PX) LSM schemes (Table 5-2). The WAQS tried to evaluate WRF using the ACM2/PX PBL/LSM and found it more difficult to implement and didn't always run so that annual fields could not be generated. Furthermore, the PX LSM scheme requires each run segment of a WRF run soil moisture inputs to be initialized using the previous WRF run segment PX output so that an annual WRF simulations must be run in series. This contrasts with the Noah LSM scheme that initializes soil moisture based on observations with some spin-up time (typically 12-hours) that allows annual WRF runs to be performed using parallel run segments (e.g., 5.5 day run segments). Thus, annual WRF simulations using the YSU/NOAH PBL/LSM physics options can be completed much faster than when ACM2/PX is used.

5.3.14 Remaining WRF Physics Options

Table 5-2 lists the remaining WRF physics options for the NM OAI Study 2014 36/12/4-km WRF application. These are standard WRF physics options and consistent with the WRF options used in the WAQS 2014 and EPA 2014/2015/2016 WRF modeling. Our preliminary comparison of 2014 WAQS and 2014 EPA WRF modeling for summertime precipitation performance in New Mexico finds that WAQS WRF outperformed EPA WRF modeling. Therefore, we propose to use the same microphysics and cumulus schemes for the NM OAI Study as used in 2014 WAQS (Thompson and Multi-Scale Kain-Fritsch, respectively).

Table 5-2. Proposed NM OAI 2014 WRF model configuration and comparison with the WRF configuration used in the WAQS 2014 and EPA 2014/2015 WRF modeling.

WRF Option	Proposed NM OAI	2014 WAQS	2014/2015 EPA
Domains run	36/12/4-km	36/12/4-km	12-km
Microphysics	Thompson	Thompson	Morrison 2
LW Radiation	RRTMG	RRTMG	RRTMG
SW Radiation	RRTMG	RRTMG	RRTMG
Sfc Layer Physics	MM5 similarity	MM5 similarity	MM5 similarity
LSM	Noah	Noah	Pleim-Xiu
PBL scheme	Yonsei University (YSU)	YSU	ACM2
Cumulus	36/12/4-km Multi-scale Kain Fritsch	36/12-km Multi-scale_Kain Fritsch; 4-km None	Kain-Fritsch
BC, IC Analysis Nudging Source	12-km NAM/ERA5	12-km NAM	12-km NAM
Analysis Nudging Grids	36/12-km	36/12-km	12-km
Obs Nudging	None	4-km	None
Sea Sfc Temp	FNMOC	FNMOC	FNMOC

5.3.15 Application Methodology

The WRF model will be executed in 5.5-day blocks initialized at 12Z every five days. Model results will be output every 60 minutes, split at twelve (12) hour intervals. Twelve (12) hours of spin-up is included in each 5-day block before the data is used in the subsequent evaluation and PGM meteorological inputs.

5.4 WRF Model Evaluation

Quantitative and qualitative evaluations of the NM OAI Study 2014 WRF 36/12/4-km simulation will be conducted. The quantitative evaluations compare integrated surface hourly meteorological observations with WRF predictions matched by time and location. The qualitative evaluations compared time series plots of modeled wind speed and wind direction to the observations at specific sites. The evaluation is conducted for meteorological observation sites across the western U.S., with particular focus on sites within the 4-km New Mexico domain.

5.4.1 Quantitative Evaluation Using METSTAT

A quantitative model performance evaluation of the NM OAI Study 2014 WRF modeling will be performed using the publicly-available METSTAT software (Ramboll Environ, 2015) evaluation tool. Output from the WRF meteorological model will be compared against meteorological observations from the various networks operating in the study area. This is carried out both graphically and statistically to evaluate model performance for surface winds, temperatures, humidity, and the placement, intensity, and evolution of key weather phenomena. The purpose of these evaluations is to establish a first-order acceptance/rejection of the simulation in adequately replicating the weather phenomena in the study area. Thus, this approach screens for obvious model flaws and errors.

5.4.1.1 Quantitative Statistics

The quantitative analysis will be conducted using METSTAT. Statistical measures calculated by METSTAT include observation and prediction means, prediction bias, and prediction error that are given as follows.

Mean Observation (M_o) is calculated using values from all sites for a given time period by Eq. **(5-1)**:

$$M_o = \frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I} O_j^i \qquad (5\text{-}1)$$

where O_j^i is the individual observed quantity at site *i* and time *j*, and the summations are over all sites (I) and over time periods (J).

Mean Prediction (M_p) is calculated from simulation results that are interpolated to each observation used to calculate the mean observation for a given time period by Eq. **(5-2)**:

$$M_p = \frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I} P_j^i \qquad (5\text{-}2)$$

where P_j^i is the individual predicted quantity at site *i* and time *j*. Note the predicted mean wind speed and mean resultant direction are derived from the vector-average (for east-west component *u* and north-south component *v*), from which the

Bias (B) is calculated as the mean difference in prediction-observation pairings with valid data within a given analysis region and for a given time period by Eq. **(5-3)**:

$$B = \frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I}\left(P_j^i - O_j^i\right) \qquad (5\text{-}3)$$

Gross Error (E) is calculated as the mean *absolute* difference in prediction-observation pairings with valid data within a given analysis region and for a given time period by Eq. **(5-4)**:

$$E = \frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I}\left|P_j^i - O_j^i\right| \qquad (5\text{-}4)$$

Note that the bias and gross error for winds are calculated from the predicted-observed residuals in speed and direction (not from vector components *u* and *v*). The direction error for a given prediction-observation pairing is limited to range from 0 to ±180°.

Root Mean Square Error (RMSE) is calculated as the square root of the mean squared difference in prediction-observation pairings with valid data within a given analysis region and for a given time period by Eq **(5-5)**:

$$RMSE = \left[\frac{1}{IJ} \sum_{j=1}^{J} \sum_{i=1}^{I} \left(P_j^i - O_j^i \right)^2 \right]^{\frac{1}{2}} \qquad (5\text{-}5)$$

The RMSE, as with the gross error, is a good overall measure of model performance. However, since large errors are weighted heavily (due to squaring), large errors in a small sub-region may produce a large RMSE even though the errors may be small and quite acceptable elsewhere.

5.4.1.2 METSTAT Processing

METSTAT was developed to calculate and graphically present statistics associated with temporally paired meteorological model predictions and observations. The horizontal analysis range can be given for an entire output grid, by a coordinate box, or as a list of specific site identifiers (such as WBAN or AIRS numbers), as labeled on the observational file. This allows for an evaluation at a single site, a subset of specific sites (e.g., within a state) or over an entire regional domain. The program then proceeds to calculate statistics for each hour and for each day of the time window.

The process involves statistical comparisons of model data from the WRF grid cells to observational measurements located with each grid cell. METSTAT evaluates wind speed and direction, air temperature, and air humidity using both bias and error statistics. METSTAT has been widely applied to WRF runs for many years, across many modeling domains. Using a consistent definition of the statistical quantities to be calculated and a consistent methodology for pairing observations in time, METSTAT allows for more straightforward comparisons between model applications in widely different regions and time periods.

5.4.2 Statistical Benchmarks

METSTAT calculates statistical performance metrics for bias, error and correlation for surface winds, temperature, and mixing ratio (i.e., water vapor or humidity). To evaluate the performance of a meteorological model simulation for air quality model applications, a number of performance benchmarks for comparison are typically used. Table 5-3 lists the meteorological model performance benchmarks for simple (Emery et al., 2001) and complex (Kemball-Cook et al., 2005) situations. The simple benchmarks were developed by analyzing well-performing meteorological model evaluation results for simple, mostly flat terrain conditions and simple meteorological conditions (e.g., stationary high pressure) that were mostly conducted to support air quality modeling studies (e.g., ozone SIP modeling). The complex benchmarks were developed during the Western Regional Air Partnership (WRAP) regional haze modeling and are performance benchmarks for more complex conditions, such as the complex terrain of the Rocky Mountains and Alaska (Kemball-Cook et al., 2005). McNally (2009) analyzed multiple annual runs that included complex terrain conditions and suggested an alternative set of benchmarks for temperature under more complex conditions. The purpose of the benchmarks is to understand how good or poor the results are relative to other model applications run for the U.S.

The NM OAI Study 2014 WRF application will compare the WRF meteorological variables to the benchmarks as an indication of WRF model performance. These benchmarks include bias and error in temperature, wind direction and mixing ratio as well as the wind speed bias and Root Mean Squared Error (RMSE) between the models and databases.

Table 5-3. Meteorological model performance benchmarks for simple and complex conditions.

Parameter	Emery et al. (2001)	Kemball-Cook et al. (2005)	McNally (2009)	Resulting Criteria
Conditions	Simple	Complex	Complex	Complex
Temperature Bias	≤ ±0.5 K	≤ ±2.0 K	≤ ±1.0 K	≤ ±1.0 K
Temperature Error	≤ 2.0 K	≤ 3.5 K	≤ 3.0 K	≤ 3.0 K
Temperature IOA	≥ 0.8	(not addressed)	(not addressed)	≥ 0.8
Humidity Bias	≤ ±1.0 g/kg	≤ ±0.8 g/kg	≤ ±1.0 g/kg	≤ ±1.0 g/kg
Humidity Error	≤ 2.0 g/kg	≤ 2.0 g/kg	≤ 2.0 g/kg	≤ 2.0 g/kg
Humidity IOA	≥ 0.6	(not addressed)	(not addressed)	≥ 0.6
Wind Speed Bias	≤ ±0.5 m/s	≤ ±1.5 m/s	(not addressed)	≤ ±1.5 m/s
Wind Speed RMSE	≤ 2.0 m/s	≤ 2.5 m/s	(not addressed)	≤ 2.5 m/s
Wind Speed IOA	≥ 0.6	(not addressed)	(not addressed)	≥ 0.6
Wind Dir. Bias	≤ ±10 degrees	(not addressed)	(not addressed)	≤ ±10 degrees
Wind Dir. Error	≤ 30 degrees	≤ 55 degrees	(not addressed)	≤ 55 degrees

The output from the 2014 36/12/4-km WRF simulations will be compared against meteorological data obtained from the National Climate Data Center's (NCDC) global-scale, quality-controlled DS3505 integrated surface hourly observational (ISHO) data (NOAA-NCDC, 2015) as verification data. Global hourly and synoptic observations are compiled from numerous sources into a single common ASCII format and common data model. The DS3505 database contains records of most official surface meteorological stations from airports, military bases, reservoirs/dams, agricultural sites, and other sources dating from 1901 to the present.

A standard set of statistical metrics from the METSTAT package will be used. These metrics will be calculated on hourly, daily and monthly time frames for wind speed, wind direction, temperature, and humidity at the surface, using all available observational weather data. The WRF surface meteorological model performance metrics will be compared against the simple and complex model performance goals using "soccer plots." Soccer plots use two WRF performance metrics as X-axis and Y-axis values (e.g., temperature bias as X, and temperature error as Y) along with the performance benchmarks. The closer the symbols are to the zero origin, the better the model performance. It is also easy to see when the two WRF performance metrics fall within the benchmark lines. Figure 5-2 displays an example WRF monthly temperature soccer plot from the 2011 WRF simulations used in the 2017 Denver ozone SIP modeling. We will present WRF 2014 monthly-averaged surface meteorological model performance from the 4-km New Mexico domain with additional performance products produced for the 12-km 12WUS2 and 36-km 36US domains.

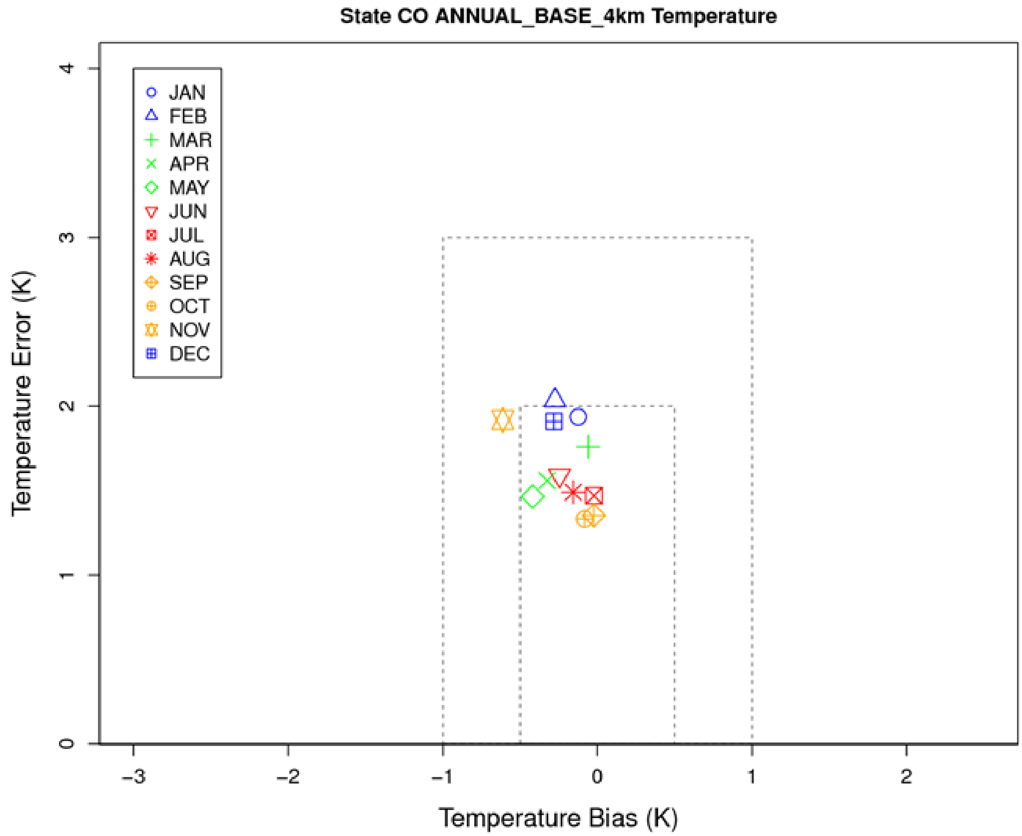


Figure 5-2. Example Soccer plot of monthly temperature error and bias (K) for 4-km domain.

5.4.3 Qualitative Evaluations Using PRISM Data

Oregon State University (OSU) publishes precipitation analysis fields based on observations that can be used to qualitatively evaluate the WRF precipitation fields. The Parameter-elevation Relationships on Independent Slopes Model (PRISM[50]) is used to generate the precipitation analysis fields (Daly et al., 2008). The PRISM interpolation method was used to develop data sets that reflected, as closely as possible, the current state of knowledge of spatial climate patterns in the United States. PRISM calculates a climate – elevation regression for each digital elevation model

[50] http://prism.oregonstate.edu/

(DEM) grid cell, and stations entering the regression are assigned weights based primarily on the physiographic similarity of the station to the grid cell. Factors considered are location, elevation, coastal proximity, topographic facet orientation, vertical atmospheric layer, topographic position, and orographic effectiveness of the terrain.

Spatial plots of the WRF monthly precipitation fields will be compared with the PRISM spatial maps for the 12-km 12WUS2 and 4-km New Mexico modeling domains in a qualitative model evaluation (note that PRISM does not include any analysis fields outside of the U.S.). Daily PRISM precipitation fields will be compared against the WRF daily spatial maps within the 12WUS2 domain and the New Mexico 4-km domain. The WRF performance for daily convective precipitations will be analyzed in particular as overstated summer convective precipitation can suppress ozone formation and its correct simulation is critically important for ozone modeling in New Mexico during the summer monsoon season. In the past WRF has had difficulty in accurately predicting the spatial extent and magnitude of the summer convective precipitation in the IMW region. Note that the PRISM precipitation interpolation scheme works better for synoptic weather systems than for convective showers that can be spotty and intermittent. So even though quantitative statistics can be calculated using the PRISM and WRF precipitation data, the evaluation will still be qualitative in nature as the PRISM interpolation scheme has greater uncertainties for convective precipitation.

6. PGM BASE YEAR INPUT PREPARATION PROCEDURES

This section summarizes the procedures to be used for developing the base case meteorological, emissions, and air quality inputs for the CAMx photochemical grid model and the summer 2014 modeling period. The modeling procedures used in the NM OAI Study modeling are consistent with almost 30 years of EPA ozone modeling guidance documents (e.g., EPA, 1991; 1999; 2005a; 2007; 2014d; 2018d), past modeling studies of the western U.S. conducted by WRAP and others (see, for example, Morris et al., 2004a,b, 2005a,b; 2007; 2008a,b,c; Tesche et al., 2005a,b; Stoeckenius et al., 2009; ENVIRON, Alpine and UNC, 2013; Adelman, Shankar, Yang and Morris, 2014; 2016), Denver 8-hour ozone SIP modeling (Morris and Mansell, 2003a; Morris et al., 2004d; Morris et al., 2008a,b; Ramboll and Alpine, 2016a,b; 2017a; RAQC and CDPHE, 2017) as well as the methods used by EPA in support of their recent Transport analysis (EPA, 2010; 2015b, EPA, 2016c) and national regional haze modeling (EPA, 2019).

6.1 Meteorological Inputs

Procedures for WRF meteorological modeling for the NM OAI Study 2014 36/12/4-km applications were described in Chapter 5. The WRF meteorological model output data will be processed to provide inputs for the CAMx photochemical grid model.

6.1.1 WRFCAMx Processing of 2014 WRF Output

The WRFCAMx processor maps WRF meteorological fields to the format required by CAMx. It also calculates turbulent vertical exchange coefficients (Kz) that define the rate and depth of vertical mixing in CAMx. Steps in the WRFCAMx processing include:

- Reading in meteorological model output files;
- Extracting meteorological data for PGM domain;
- Collapsing meteorological data if coarser vertical resolution data is requested in the PGMs than used in WRF;
- Computing vertical diffusivities (Kz); and
- Output the meteorological fields in the formats used by CAMx.

Several options are available to derive vertical turbulent exchange coefficient (also known as: Kv, Kz or vertical diffusivity) fields from WRF output in WRFCAMx. When TKE (turbulent kinetic energy) is not available from the WRF output (as is the case with the YSU PBL selected WRF physics options), Kv fields are diagnosed from wind, temperature, and Planetary Boundary Layer (PBL) parameters in WRFCAMx. For this application the CMAQ-like Kv profile option was selected in WRFCAMx, although the YSU Kv profile options will also be investigated.

6.1.2 Treatment of Minimum Kv

The CAMx Kv_patch pre-processor program sets the minimum Kv value to 0.1 to 1.0 m^2/s depending on the amount urban land use category in grid cell in the lowest 100 m of the atmosphere. This is done to account for the urban heat island effect that enhances vertical mixing through-out the day.

6.2 Emission Inputs

6.2.1 Available Emissions Inventory Datasets

The emissions inventories developed for the CAMx 2014 36/2/4-km base case modeling will be based on the WRAP/WAQS 2014v2 emissions inventory. Within the 36-km 36US North American and 12-km 12WUS2 western U.S. domains, the 2014v2 base case emissions developed by WRAP/WAQS will be used as is.

For the 4-km New Mexico domain, the WRAP/WAQS 2014v2 emissions will be reviewed by the NMED, who will provide updates as needed. For on-road mobile sources, the 4-km domain emissions will be based on MOVES2014 model, 2014 activity data and day-specific hourly gridded 2014 WRF meteorology run through SMOKE-MOVES.

6.2.2 Development of CAMx Emission Inputs

CAMx emission inputs will be generated mainly by the SMOKE and MEGAN emissions models. CAMx requires two emission input files for each day: (1) low level gridded emissions that are emitted directly into the first layer of the model from sources whose emissions are released at the surface with little or no plume rise; and (2) elevated point sources (stacks) with plume rise calculated from stack parameters and meteorological conditions. CAMx will be operated using version 6 revision 4 of the Carbon Bond chemical mechanism (CB6r4) (Yarwood et al., 2010).

A 2014 base case 4-km New Mexico domain emission inputs for CAMx and the May to August 2014 modeling period will be based on the WRAP/WAQS 2014v2 emissions that were based on the 2014NEIv2 with updates provide by the western states. The New Mexico emissions from the 2014v2 database will be reviewed by the NMED who will provide updates as needed. The 2014v2 emissions for New Mexico and portions of surrounding states within the 4-km New Mexico domain will be processed by the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (UNC, 2015). SMOKE version 4.7 is the current version of SMOKE that was released in October 2019.[51]

6.2.2.1 Day-Specific On-Road Mobile Source Emissions

The 2014 on-road mobile source emission inputs for the 4-km New Mexico domain will be generated using the SMOKE-MOVES emissions model. SMOKE-MOVES will use a 2014 mobile source emission factor (EF) lookup table generated by the Motor Vehicle Emission Simulator (MOVES2014[52]) model (EPA, 2014a,b,c). The SMOKE-MOVES default county-level 2014 vehicle activity data for New Mexico will be reviewed by NMED and updated as needed. SMOKE-MOVES uses the 2014 MOVES EF lookup table, hourly gridded 4-km meteorological data from the 2014 WRF simulation conducted in this study and 2014 county-level activity data (e.g., vehicle miles travelled [VMT],

[51] https://www.cmascenter.org/smoke/

[52] http://www.epa.gov/oms/models/moves/#user

speed, etc.) to generate 2014 day-specific hourly gridded on-road mobile source emission inputs for CAMx and the 4-km New Mexico domain.

6.2.2.2 Point Source Emissions

2014 point source emissions will be based on the WRAP/WAQS 2014v2 emissions inventory. The 2014v2 New Mexico point source emissions will be reviewed by NMED and updated a needed. Point sources will be processed in two streams: (1) major point sources with Continuous Emissions Monitoring (CEM) devices, which are primarily fossil-fueled Electrical Generating Units (EGU) with capacity of 25 MW or greater; and (2) point sources without CEMs. For point sources with CEM data, day-specific hourly NO_X and SO_2 emissions will be used for the 2014 base case emissions scenario. The VOC, CO and PM emissions for point sources with CEM data will be based on the annual data in the 2014v2 inventory temporally allocated to each hour of the year using the CEM hourly heat input. The hourly CEM data available in the Acid Rain database on the EPA Clean Air Market Division (CAMD) website fills hours with missing CEM data with maximum potential to emit (PTE) emission rates and flags the data. This is because the purpose of the Acid Rain database is to assure that the source is not emitting higher emissions than its cap. Using PTE emissions rates is inappropriate for PGM modeling since the goal is to be accurate. Thus, a data filling program is used that uses the missing data flags to identify hours when the data filled PTE emissions occur, and they are replaced with typical emission rates.

For all point sources the locations of the point sources will be converted to the LCC coordinate system used in the modeling. Non-CEM point sources will be processed by SMOKE to generate the temporally varying (i.e., seasonal, day-of-week and hour-of-day) speciated emissions needed by CAMx. The 2014 point source emissions without CEM data will be processed using SMOKE using the default temporal (e.g., monthly, day-of-week and hourly) and speciation profiles.

6.2.2.3 Area and Non-Road Source Emissions

The 2014v2 area and non-road sources will be spatially allocated to the 4-km New Mexico grid using an appropriate surrogate distribution (e.g., population for home heating, etc.). The area sources will be temporally allocated by month and by hour of day using the SMOKE source-specific temporal allocation factors. The SMOKE source-specific CB6r4 speciation allocation profiles will also be used.

6.2.2.4 Episodic Biogenic Emissions

Biogenic emissions will be generated using Version 3.1 of the MEGAN biogenic emissions model. MEGAN uses high resolution GIS data on plant types and biomass loadings and the 2014 WRF surface temperature fields, and solar radiation to develop hourly emissions for biogenic species on the 36/12/4-km grids. MEGAN generates gridded, speciated, temporally allocated emission files. The MEGAN biogenic emissions will be used for the 36-km 36US, 12-km 12WUS2 and 4-km New Mexico modeling domains. Note that the BEIS biogenic emissions were used in the WRAP/WAQS 2014v2 modeling platform. WRAP/WAQS conducted sensitivity tests using MEGAN v3.0 and BEIS biogenic emissions and found they produced comparable ozone estimates (because the isoprene emissions were similar), but CAMx with BEIS has better Organic

Aerosol (OA) performance[53] than CAMx with MEGAN v3.0 biogenic emissions so WAQS selected BEIS. Since then MEGAN has been updated to version 3.1 and the CAMx OA performance is now similar using MEGAN v3.1 and BEIS.

6.2.2.5 Wildfires, Prescribed Burns, Agricultural Burns

2014 emissions from open-land burning including wildfires, prescribed burns and agricultural burning will be based on the WRAP/WAQS 2014v2 emissions inventory. The WRAP Fire and Smoke Work Group (FSWG[54]) processed the 2014NEIv2 Bluesky/SMARTFIRE fire emissions for the U.S. and classified them as either wildfires (WF), prescribed burns (Rx) or agricultural burning (Ag) and made other updates for the 2014v2 inventory. The 2014NEIv2 fire emissions for Mexico and Canada will be used as is.

6.2.2.6 Other Natural Emissions

Lightning NO_x (LNOx), oceanic sea salt (SSA) and dimethyl sulphide (DMS) and windblown dust (WBD) emissions will be generated using special CAMx processors and WRF 2014 meteorological data.

6.2.2.7 QA/QC and Emissions Merging

The emissions for the 4-km New Mexico domain will be processed by major source category in several different "streams", including area sources, on-road mobile sources, non-road mobile sources, biogenic sources, non-CEM point sources, CEM point sources using day-specific hourly emissions, and emissions from fires. Separate Quality Assurance (QA) and Quality Control (QC) will be performed for each stream of emissions processing and in each step following the procedures developed by WRAP (Adelman, 2004). SMOKE includes advanced quality assurance features that include error logs when emissions are dropped or added. In addition, we will generate visual displays that include:

- Spatial plots of the hourly emissions for each major species (e.g., NO_X, VOC, and CO).
- Summary tables of emissions for major species for each grid and by major source category.
- This QA information will be examined against the original point and area source data and summarized in an overall QA/QC assessment.

Scripts to perform the emissions merging of the appropriate biogenic, on-road, non-road, area and low-level point sources (i.e., point sources with little or no plume rise so they are released into the first layer of the PGM) emission files will be written to generate the CAMx-ready two-dimensional day and domain-specific hourly speciated gridded emission inputs. The point source and fire, emissions would be processed into the day-specific hourly speciated emissions in the CAMx-ready point source format.

[53] http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx
[54] https://www.wrapair2.org/FSWG.aspx

For the 36/12-km domains we plan on using the model-ready emissions from the WRAP/WAQS 2014v2 modeling platform, with the exception of biogenic emissions where we would replace the BEIS biogenic emissions with those from MEGAN.

The resultant CAMx model-ready emissions will be subjected to a final QA using spatial maps to: (1) assure that the emissions were merged properly and CAMx inputs contain the same total emissions; and (2) provide additional QA/QC information.

6.2.2.8 Use of the Plume-in-Grid (PiG) Subgrid-Scale Plume Treatment

CAMx includes a Plume-in-Grid (PiG) sub-model treats the early plume chemistry and dynamics of emissions from point sources and then releases the emissions into the grid model farther downwind at such time that the plume is adequately resolved by the grid. Large NO_X emissions point sources within the 4-km New Mexico domain will be selected for treatment by the subgrid-scale PiG module. The selection of which sources to be treated by the PiG module will be made after a review of the inventory.

6.2.2.9 QA/QC of Model-Ready Emissions

In addition to the CAMx-ready emission input files generated for each hour of all days modeled in the May-August 2014 modeling period, a number of quality assurance (QA) files will be prepared and used to check for gross errors in the emissions inputs. Importing the model-ready emissions into PAVE or VERDI and examine both the spatial and temporal distribution of the emission to investigate the quality and accuracy of the emissions inputs.

- Visualizing the model-ready emissions with the scale of the plots set to a very low value, we can determine whether there are areas omitted from the raw inventory or if emissions sources are erroneously located in water cells;
- Spot-checking the holiday emissions files to confirm that they are temporally allocated like Sundays;
- Producing pie charts emission summaries that highlight the contribution of each emissions source component (e.g. non-road mobile);
- Normalizing the emissions by population for each state will illustrate where the inventories may be deficient and provide a reality check of the inventories.

State inventory summaries prepared prior to the emissions processing will be used to compare against SMOKE output report totals generated after each major step of the emissions generation process. To check the chemical speciation of the emissions to CB6 species, we will compare reports generated with SMOKE to target these specific areas of the processing. For speciation, the inventory state import totals will be compared against the same state totals with the speciation matrix applied.

The quantitative QA analyses often reveal significant deficiencies in the input data or the model setup. It may become necessary to tailor these procedures to track down the source of each major problem. As such, one can only outline the basic quantitative QA steps that we will perform in an attempt to reveal the underlying problems with the inventories or processing.

6.3 Photochemical Model Inputs

6.3.1 PGM Science Configuration and Input Configuration

This section describes the CAMx configuration and science options to be used in the NM OAI Study ozone modeling. Table 6-1 summarizes the CAMx configuration to be used, with more details provided below.

6.3.1.1 PGM Model Versions

The latest version 7.0 (v7.0) of CAMx will be used in the NM OAI Study. This is the same version as used in the WRAP/WAQS 2014v2, Representative Baseline and 2028 On-the-Books (OTB) modeling as well as EPA in their national Regional Haze modeling (EPA, 2019). The model will be configured to predict both ozone and PM species.

6.3.1.2 PGM Grid Nesting Strategy

CAMx will be operated using the 36/12/4-km nested grid structure using two-way grid nesting for all simulations.

6.3.1.3 Initial and Boundary Conditions

Boundary Conditions for the CAMx most outer 36-km 36US modeling domain will be based on output from a 2014 simulation of the GEOS-Chem global chemistry conducted by WRAP for their 2014v2 modeling platform. For their 2014v1 modeling platform WRAP used BCs based on EPA's 2014 GEOS-Chem simulation. EPA's 2014 modeling platform was used in the 2014 National Air Toxics Assessment (NATA[55]). However, EPA's 2014 BCs produced a large sulfate overestimation bias in June and July and a year-round ozone overestimation bias. So, WRAP conducted their own 2014 GEOS-Chem modeling to generate new BCs that did not have those problems.

CAMx will be started on May 1, 2016 using the 36/12/4-km domains that will give it over two-weeks to initialize the model before the first high ozone day on May 17, 2014.

6.3.1.4 Other PGM Model Options

The CAMx model options and setup are defined in Table 6-1. The PPM advection solver (Colella and Woodward, 1984) will be used for horizontal transport along with the spatially varying (Smagorinsky) horizontal diffusion approach. K-theory will be used for vertical diffusion. The CB6r4 gas-phase chemical mechanism is selected because it includes the very latest chemical kinetic rates with halogen chemistry that affects ozone levels over the ocean. The latest aerosol mechanism will be used in CAMx along with the standard wet and dry deposition schemes. The Plume-in-Grid module will be used to treat the near-source chemistry and dispersion of major NO_X emissions sources in the New Mexico 4-km domain. For the future year modeling the same point sources will be selected for the plume-in-grid treatment, if they are still operating.

[55] https://www.epa.gov/national-air-toxics-assessment

Table 6-1. CAMx model configuration for the NM OAI Study.

Science Options	CAMx	Comment
Model Codes	CAMx v7.0	Latest version of CAMx used in WRAP/WAQS 2014v2 and EPA Regional Haze modeling
Horizontal Grid Mesh	36/12/4-km	
36-km grid	148 x 112 cells	36US domain
12-km grid	227 x 215 cells	12WUS2 domain. Includes buffer cells
4-km grid	245 x 227 cells	New Mexico 4-km domain. Includes buffer cells
Vertical Grid Mesh	25 vertical layers, defined by WRF	Layer 1 thickness ~20 m. Model top at 50 mb (~19 km)
Grid Interaction	36/12/4 km two-way nesting	
Initial Conditions	Start on May 1, 2014	First high ozone day is May 17, 2014
Boundary Conditions	WRAP 2014 GEOS-Chem	For 36US domain
Emissions		
Baseline Emissions Processing	SMOKE, SMOKE-MOVES2014, MEGAN	WRAP/WAQS 2014v2 emissions and EPA 2023fh for future year
Sub-grid-scale Plumes	Plume-in-Grid for major NO_X sources in New Mexico	Keep same PiG sources in 2014 and 2023 emission years
Chemistry		
Gas Phase Chemistry	CB6r4	Latest chemical reactions and kinetic rates with halogen chemistry (Yarwood et al., 2010)
Meteorological Processor	WRFCAMx	Compatible with CAMx v7.0
Horizontal Diffusion	Spatially varying	K-theory with Kh grid size dependence
Vertical Diffusion	CMAQ-like Kv	Evaluate YSU Kv scheme
Diffusivity Lower Limit	Kv-min = 0.1 to 1.0 m^2/s in lowest 100 m	Depends on urban land use fraction
Deposition Schemes		
Dry Deposition	Zhang dry deposition scheme	(Zhang et. al, 2001; 2003)
Wet Deposition	CAMx -specific formulation	rain/snow/graupel
Numerics		
Gas Phase Chemistry Solver	Euler Backward Iterative(EBI)	EBI fast and accurate solver
Vertical Advection Scheme	Implicit scheme w/ vertical velocity update	Emery et al., (2009a,b; 2011)
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM) scheme	Colella and Woodward (1984)
Integration Time Step	Wind speed dependent	~0.5-1 min (4-km), 1-5 min (12-km), 5-15 min (36-km)

7. 2014 BASE CASE MODELING AND MODEL PERFORMANCE EVALUATION

This Chapter describes the CAMx 2014 base case simulations and procedures for model performance evaluation (MPE). The primary purposes of the MPE is to establish the reliability of the CAMx 2014 base case modeling for predicting maximum daily average 8-hour (MDA8) ozone and related concentrations in New Mexico to have confidence that the modeled ozone responses to changes in emissions within New Mexico are accurate enough for air quality planning. The CAMx 2014 base case model estimates are compared against the observed ambient ozone and other concentrations to establish that the model is able to reproduce the current year observed concentrations, so it is likely a reliable tool for estimating future year ozone levels. The model performance evaluation will include many types of graphical and statistical comparisons of the predicted and observed ozone concentrations including spatial plots, scatter plots and time series analysis.

7.1 2014 Base Case Modeling

A CAMx 2014 May-August 36/12/4-km base case simulation will be performed following the procedures outlined in the previous Chapters. The CAMx 2014 base case simulations will then be subjected to a model performance evaluation following the procedures outlined in this Chapter.

7.2 EPA Model Performance Evaluation Recommendations

7.2.1 Overview of EPA Model Performance Evaluation Recommendations

EPA's ozone modeling guidance (EPA, 2018d) describes a MPE framework that has four components:

- Operation Evaluation: The Operation Evaluation compares the modeled concentration estimates against concurrent observations using statistical and graphical analysis aimed at determining how well the model simulates the base year observed concentrations (i.e., does the model get the right answer).
- Diagnostic Evaluation: The Diagnostic Evaluation evaluates various components of the modeling system. It focuses on process-oriented evaluation and whether the model simulates the important processes for the air quality problem being studied (i.e., does the model get the right answer for the right reason).
- Dynamic Evaluation: The ability of the model's air quality predictions to correctly respond to changes in emissions and meteorology is part of the Dynamic Evaluation. This can include running the model for historical years to see whether the model's predictions match the changes in observations; comparison of model performance on weekdays versus weekend days can also help elucidate whether the model response to changes in emissions correctly.
- Probabilistic Evaluation: The Probabilistic Evaluation assess the level of confidence in the model predictions and estimates model uncertainty through techniques such as ensemble model simulations.

EPA's guidance recommends that "At a minimum, a model used for air quality planning should include a complete operational MPE using all available ambient monitoring data for the base case model simulations period" (EPA, 2018d, pg. 68). And goes on to say, "Where practical, the MPE should also include some level of diagnostic evaluation." EPA notes that there is no single definite test for evaluating model performance, but instead there are a series of statistical and graphical MPE elements to examine model performance in as many ways as possible while building a "weight of evidence" (WOE) that the model is performing sufficiently well for the air quality problem being studied.

7.2.2 WRAP/WAQS Companion Model Performance Evaluation

The WRAP/WAQS has conducted CAMx 2014v2 36/12-km base case modeling and MPE. The MPE of the WRAP/WAQS 2014v2 platform results will be used to help interpret the NM OAI Study MPE and put it into context.

7.3 Overview of Evaluation of CAMx 2014 Base Case Procedures

This section describes the procedures for evaluating the performance of the CAMx model focusing on ozone and related species in New Mexico.

7.3.1 Photochemical Model Evaluation Methodology

The CAMx performance evaluations will follow the procedures recommended in the EPA photochemical modeling guidance documents (EPA, 1991; 1999; 2005a; 2007; 2014d; 2018d), EPA MPE Checklist (EPA, 2015a,b), procedures discussed by Boylan and Russell (2006), Simon, Baker and Phillips (2012) and Emery and co-workers (2016). The NM OAI Study CAMx 2014 MPE will be conducted in a series of levels with each level diving more deeply into the MPE. An initial performance would focus on ozone performance at key monitors in New Mexico in 2014 to identify systematic problems that would require immediate corrective action. The MPE would then be expanded to ozone and ozone precursors across New Mexico and nearby states, especially those portions within the 4-km New Mexico domain. Finally, a broad-brush evaluation would be conducted across the western U.S. for ozone and where available its precursors.

7.3.2 Model Performance Goals and Benchmarks

EPA first proposed the use of ozone model performance goals in their 1991 ozone modeling guidance (EPA, 1991) with goals for bias (≤±15%) and error (≤35%). Since then, EPA has de-emphasized the use model performance goals as some users were focusing on achieving the model performance goals not on whether the model was accurately simulating atmospheric processes that led to the high ozone concentrations. However, model performance goals are still useful for interpreting model performance and putting the model performance into context. Since the EPA 1991 ozone guidance performance goals, Boylan and Russell (2006) extended the performance goals to PM species and visibility. Simon, Baker and Phillips (2012) summarized the model performance statistics from 69 PGM applications from 2006 to 2012 and found lots of variability but were able to isolate model performance statistical levels for the best performing models.

Emery et al., (2016) built off the work of Simon, Baker and Phillips (2012) adding additional PGM model applications and coming up with a set of PGM model performance goals and criteria based on the variability in the past PGM model performance. "Goals" indicate statistical values that about a third of the top performance past PGM applications have met and should be viewed as the best a model can be expected to achieve. "Criteria" indicates statistics values that about two thirds of past PGM applications have met and should be viewed as what a majority of the models have achieved. We will compare the CAMx 2014 base case simulations model performance statistics for normalized mean bias (NMB), normalized mean error (NME) and correlation coefficient (r) against the model performance goals and criteria summarized by Emery et al., (2016) that are given in Table 7-1.

Table 7-1. Recommended benchmarks for photochemical model statistics (Source: Emery et al., 2016).

Species	NMB		NME		r	
	Goal	Criteria	Goal	Criteria	Goal	Criteria
1-hr & MDA8 Ozone	<±5%	<±15%	<15%	<25%	>0.75	>0.50
24-hr $PM_{2.5}$, SO_4, NH_4	<±10%	<±30%	<35%	<50%	>0.70	>0.40
24-hr NO_3	<±15%	<±65%	<65%	<115%	NA	NA
24-hr OC	<±15%	<±50%	<45%	<65%	NA	NA
24-hr EC	<±20%	<±40%	<55%	<75%	NA	NA

7.3.3 *Available Aerometric Data for the Evaluations*

The following monitoring networks were operating in 2014 so these data that can be used in the MPE.

EPA AQS Surface Air Quality Data: Data files containing hourly-averaged concentration measurements at a wide variety of state and EPA monitoring networks are available in the Air Quality System (AQS[56]) database throughout the U.S. Typical surface measurements at the ground level routine AIRS monitoring stations include ozone, NO_2, NO_X and CO.

IMPROVE Monitoring Network: The Interagency Monitoring of Protected Visual Environments (IMPROVE[57]) network collects 24-hour average $PM_{2.5}$ and PM_{10} mass and speciated $PM_{2.5}$ concentrations at many sites across the U.S. on a 1:3 day sampling frequency, including most Class I areas.

CSN Monitoring Network: The Chemical Speciation Network (CSN[58]) collects 24-hour average speciated $PM_{2.5}$ components on a 1:3 or 1:6-day sampling frequency. CSN monitoring sites tend to be urban oriented as compared to IMPROVE sites that are typically rural.

[56] http://www.epa.gov/ttn/airs/airsaqs/aqsweb/
[57] http://vista.cira.colostate.edu/IMPROVE/
[58] http://www.epa.gov/ttnamti1/speciepg.html

FRM Monitoring Network: 24-hour total $PM_{2.5}$ mass is collected using the federal Reference Method (FRM[59]) on a 1:3-day sampling schedule.

CASTNet Monitoring Network: The Clean Air Status and Trends Network (CASTNet[60]) operates approximately 80 monitoring sites in mainly rural areas across the U.S. CASTNet sites typically collect hourly ozone and weekly speciated $PM_{2.5}$, including HNO3. There is one CASTNet site located in the northwest corner of New Mexico (Chaco Culture NHP), although there are several more within the 4-km New Mexico modeling domain in neighboring states (i.e., Colorado and Arizona).

NADP Network: The National Acid Deposition Program (NADP[61]) collects weekly samples of SO_4, NO_3 and NH_4 in precipitation (wet deposition). There are also some sites that collect daily samples as well as mercury.

7.4 Operational Evaluation

As noted above, the Operational Evaluation compares the modeled concentrations with concurrent observations. Various tools and graphical displays and statistical methods are used as part of the Operational Evaluation as discussed below.

7.4.1 Atmospheric Model Evaluation Tool (AMET)

The Atmospheric Model Evaluation Tool (AMET[62]) (Appel et al., 2011) is a suite of software designed to facilitate the analysis and evaluation of predictions from meteorological and air quality models. AMET matches the model output for grid cells with observations from monitoring site locations from one or more networks of monitors. AMET also does species mappings to map the modeled species to the corresponding observations. These pairings of values (model and observation) are then used to statistically and graphically analyze the model's performance using a variety of techniques, many of which will be used in the CAMx 2014 base case MPE. The latest version of AMET is version 1.4, but AMET website doesn't have any information on its release date or documentation so we assume the documentation for AMET v1.3[63] is pertinent for AMET v1.4.

7.4.2 Example Operational Model Performance Evaluation Products

Below we use the results from the 2016 Denver ozone SIP (RAQC and CDPHE, 2016) modeling MPE (Ramboll and Alpine, 2017) for the 2011 CAMx ozone modeling platform to illustrate the type of MPE products that will be produced in the NM OAI Study. Summary tables of ozone statistical model performance metrics across sites in New Mexico will be produced. Such ozone performance statistics can be calculated with and without observed cut-off concentrations as illustrated in the next section. AMET comes pre-loaded with observation data from multiple networks that were described previously:

[59] http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm
[60] http://java.epa.gov/castnet/
[61] http://nadp.sws.uiuc.edu/NADP/
[62] https://www.cmascenter.org/amet/
[63] https://www.cmascenter.org/help/documentation.cfm

- Air Quality System (AQS) network
- Clean Air Status and Trends Network (CASTNET)
- Interagency Monitoring of PROtected Visual Environments (IMPROVE)
- Mercury Deposition Network (MDN)
- National Atmospheric Deposition Program (NADP)
- South-Eastern Aerosol Research and Characterization Study (SEARCH)
- Chemical Speciation Network (CSN; formerly STN)

AMET will be the primary MPE tool used in the CAMx 2014 base case simulations augmented by other MPE tools as necessary. Some example MPE displays are described in the following sections.

7.4.2.1 Soccer Plots for Comparing Performance Statistics with Goals and Criteria

Soccer Plots display ozone (or other species) model performance statistics against model performance goals and/or criteria using a scatter plot, such as bias on the x-axis and error on the y-axis. When the statistics achieves the goal, it falls within the box outlined by the goals. For example, Figure 7-1 shows ozone monthly fractional bias and error (FB and FE) performance statistics against a 15% and 35% performance goal, respectively, for the 2011 CAMx base case from the 2016 Denver ozone SIP. The Soccer Plots are for hourly (right) and MDA8 (left) ozone using no (top) and a 60 ppb (bottom) cut-off concentration. Using Soccer Plots, it is easy to determine when the performance statistics are achieving the goals and as the symbols approach the (0,0) origin that indicates better model performance. Although the example in Figure 7-1 is for monthly performance, the different symbols could be for different monitoring sites, specific modeling days with ozone exceedance days, stratified by observed ozone concentrations or stratified by any other variable that provides insight into the MPE.

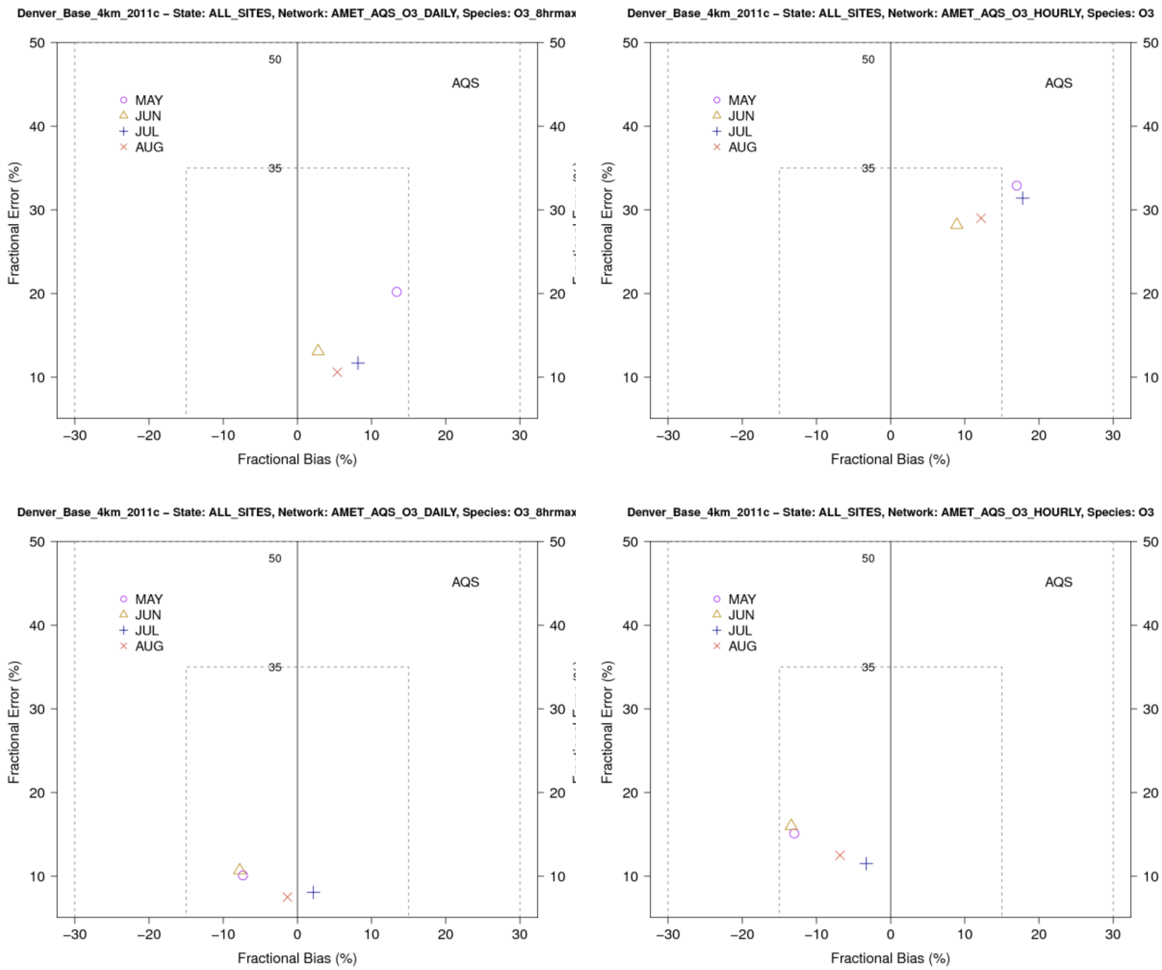


Figure 7-1. Example Soccer Plots of MDA8 (left) and hourly (right) ozone bias (FB) and error (FE) performance using no (top) and 60 ppb (bottom) observed ozone cut-off concentration (Source: Ramboll and Alpine, 2017).

7.4.2.2 Spatial Maps of Statistical Model Performance

AMET can generate spatial maps of different statistical performance metrics where the different colored symbols at the locations of monitoring sites allows an assessment of performance by geographic location. For example, Figure 7-2 displays the MDA8 ozone monthly bias (NMB) spatial plot from the CAMx 2011 base case simulation and shows an overestimation bias in May at many sites (yellow) with most of the sites achieving the <±15% performance goal for the other three months. The exception is the DMAS site in downtown Denver and the FTCO site in Fort Collins that are located close to mobile NOx emissions that titrate the ozone that is not reproduced by the model due to dilution of the local NOx emissions across a 4-km grid cell.

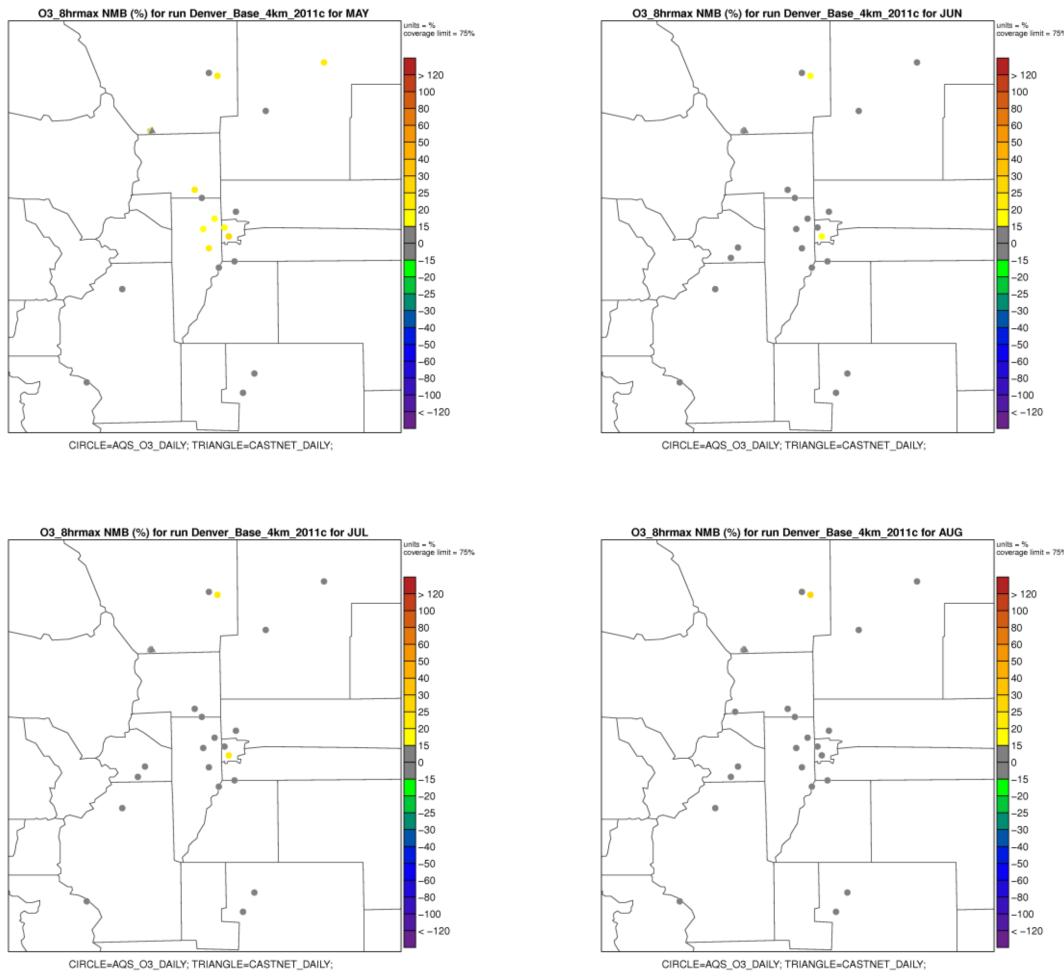


Figure 7-2. Spatial statistics plot of MDA8 monthly ozone model performance for Normalized Mean Bias (NMB), AQS sites in the Denver Metro/NFR NAA using no observed ozone cut-off concentration and May (top left), June (top right), July (bottom left) and August (bottom right) (Source: Ramboll and Alpine, 2017).

7.4.3 Scatter Plots of Model Performance

Scatter Plots are a main stay of MPE as they allow you to directly see the point-by-point comparison of predicted and observed concentrations. Figure 7-3 shows example MDA8 (left) and hourly (right) ozone scatter plots for July without (top) and with a 60 ppb observed ozone cut-off concentration from the CAMx 2011 base case simulations. In this case ozone performance for two different CAMX base cases are shown (red and blue symbols) and summary performance statistics are also displayed. The model has difficulty in predicting the lowest observed hourly ozone concentrations (see comment above on DMAS and FTCO ozone over-prediction bias), which appears to have little effect on MDA8 ozone MPE or hourly ozone performance when a 60 ppb observed ozone cut-off is used.

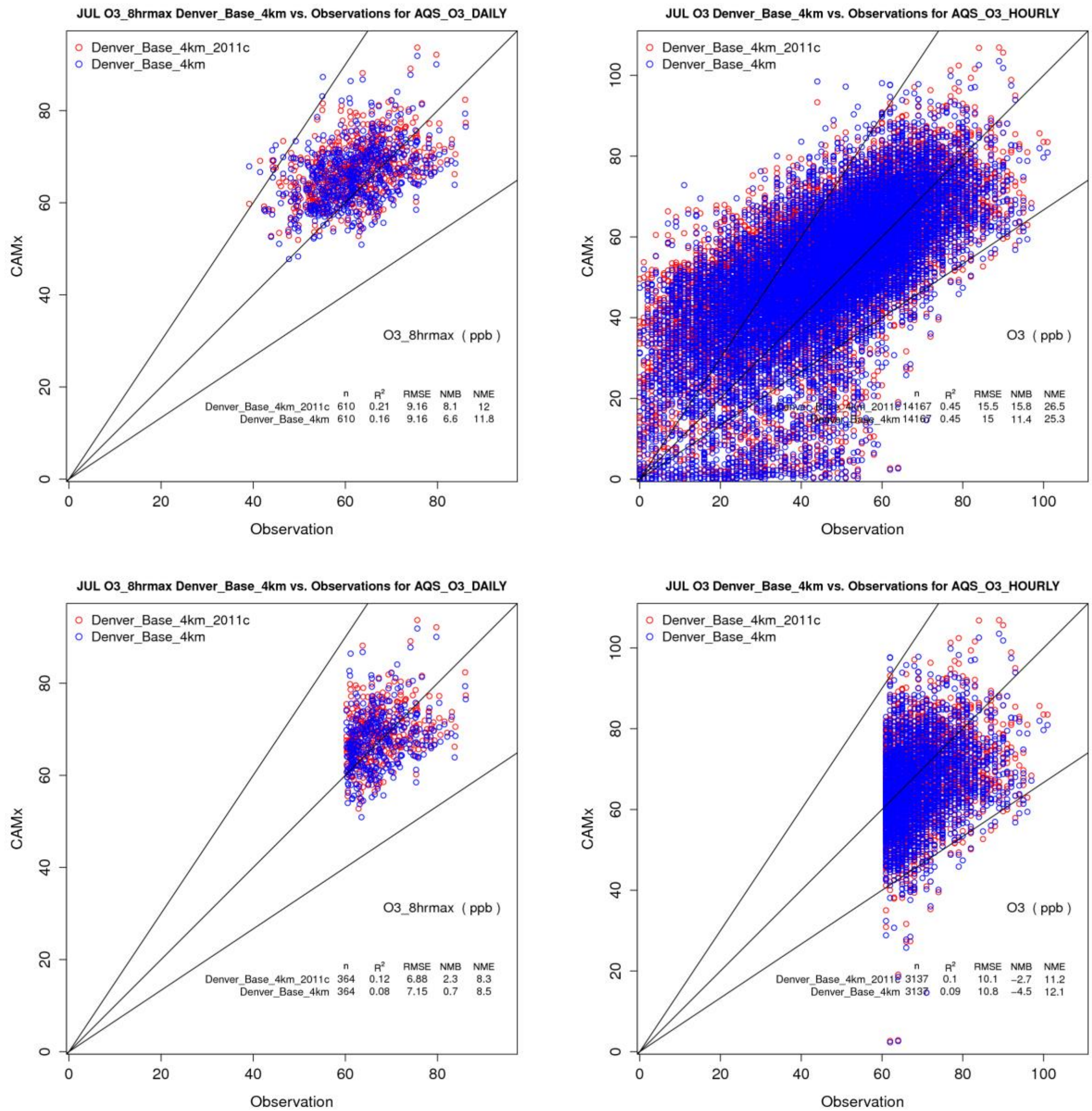


Figure 7-3. Scatter plots and model performance statistics for MDA8 (left) and hourly (right) ozone concentrations using no (top) and 60 ppb (bottom) observed ozone cut-off concentrations during the month of July (Source: Ramboll and Alpine, 2017).

7.4.4 Time Series of Predicted and Observed Concentrations

Time series of predicted and observed concentrations is another main stay of a MPE and focuses of the temporal evaluation of model performance at particular sites. For example, Figure 7-4 displays time series of predicted and observed July and August MDA8 ozone concentrations at the RFNO monitoring site for two CAMx 2011 base case simulations from 2016 Denver ozone SIP. These displays not only include the MDA8 ozone concentrations levels but the daily bias (i.e., different in the predicted and observed MDA8 ozone.

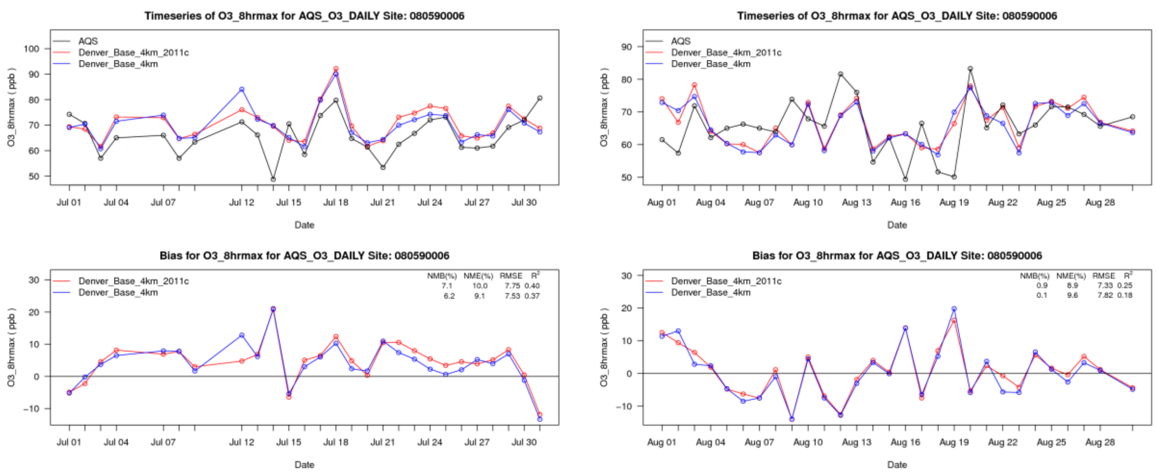


Figure 7-4. Time series of predicted and observed (black) MDA8 ozone concentrations (top panel) and bias (bottom panel) at Rocky Flats North (RFNO) for the preliminary 2011b1 (blue) and final 2011c (red) CAMx 4 km base case simulations and the months of July (left) and August (right) (Source: Ramboll and Alpine, 2017).

7.4.5 Evaluation for the Modeled MDA8 Ozone Concentrations

An important component of a PGM MPE is to evaluate the model for how well it predicts the modeled 10 highest MDA8 ozone concentrations because of the way the base and future year modeling results are used to project future year ozone DVs. The relative change in the base and future modeling results are used to project the current year observed ozone DVs to the future year. EPA's modeling guidance (EPA, 2018d) describes how to use the PGM modeling results to make the future year ozone DV projections with details presented in Chapter 8. The 10 highest base year modeled MDA8 ozone concentrations near a monitoring site are used to make the future year DV projections. It is desirable for the modeled MDA8 ozone concentrations on these 10 highest modeled base year ozone concentrations to match the observed MDA8 ozone concentrations on the same day sufficiently well. Thus, the model performance for the days used in the future year ozone DV projections are evaluated. As discussed in more detai8l in Chapter 8, alternative ozone DV projection techniques use the 10 highest modeled MDA8 ozone concentrations near a monitor just on those days in which the modeled MDA8 ozone reproduces the observed MDA8 ozone with some performance criteria (e.g., < 10%. < 15%, < 20%).

7.5 Diagnostic Evaluation

The goal of the diagnostic evaluation is to assure that the model is simulating the correct physical and chemical processes that control the formation of ozone from the precursor emissions. Such processes include transport, dispersion, deposition and chemical transformation. The diagnostic evaluation investigates the processes that determine the ambient concentrations of ozone and related pollutants to develop confidence that the model's ozone response to changes in emissions will be accurate.

7.5.1 Base Year Base Case Diagnostic Sensitivity Tests

When developing a PGM base year base case model configuration, diagnostic sensitivity tests are frequently used to evaluate the sensitivity of the model to alternative inputs or model options in an effort to obtain a better performing base year base case simulation. For example, if two WRF base year simulations are available, the PGM could be run with both sets of WRF meteorological inputs to determine which one produces better performing PGM simulations. However, care must be taken that compensatory errors are not introduced.[64] For the NM OAI Study that is leveraging the WRAP/WAQS 2014v2 modeling platform, many diagnostic tests have already been performed so additional diagnostic sensitivity tests are likely not needed unless performance issues arise. The WRAP/WAQS modeling conducted the following diagnostic sensitivity tests that led to the 2014v2 base case CAMx configuration.

- Boundary Conditions (BC) Sensitivity: WRAP/WAQS initially used BCs based on EPA's 2014 GEOS-Chem simulation and found them inadequate so WRAP conducted their own 2014 GEOS-Chem simulation and generated BCs that greatly improved model performance.
- Vertical Mixing Sensitivity: This is a frequent sensitivity test to analyze alternative formulation of vertical mixing (Kz) formulations and the treatment of the minimum Kz near the surface that is especially important for cities where the urban heat island affects vertical mixing.
- Other Meteorological Sensitivity: The WRAP/WAQS evaluated the EPA's 2014 WRF meteorological simulations as input to CAMx and selected the WAQS 12-km data due to better precipitation model performance.
- Emissions Sensitivity: Increases or decreases in emissions (e.g., VOC and/or NO_x) from specific source categories or other emissions perturbation:
  - Top down studies have suggested oil and gas emissions may be under- or over-estimated.
  - Some studies have suggested MOVES mobile source NOx emissions may be overestimated, particularly in urban areas.
  - NO_x emissions are almost always produced by combustion so typically are hotter than ambient air so have some buoyancy and plume rise even if

[64] Compensatory errors can occur when two incorrect inputs compensate for each other so the PGM achieves seemingly good model performance, but for the wrong reason. For example, PGM modeling of Los Angeles in the late 1970s and early 1980s had a deficient VOC emissions inventory that was compensated for by overstated the Boundary Conditions.

emitted at the surface (e.g., mobile sources). By trapping them in the lowest layer (20-m in this case) it may overstate surface NO_x emissions. Emitting some of the NO_x in layer 2 may alleviate this condition, alternative the surface minimum Kz mixing parameter may also address this issue.

  - Biogenic and lightning NO_x emissions are uncertain and the sensitivity to their estimates could be investigated.

- Other Sensitivity: In the development of the CAMx 2014 base case modeling platform we may find inputs or parameterizations that are uncertain how to define so warrant further investigation.

When the initial results of the CAMx 2014 base year base case MPE are obtained, they will be shared with NMED to determine a path forward and if additional sensitivity tests may be needed and as time and resource constraints allow.

7.5.2 *Additional Diagnostic Evaluation Approaches*

Diagnostic Evaluation of a PGM can use several different techniques to diagnose features regarding model performance, such as evaluation of how the model responds to changes in inputs or simulates specific processes important for simulating the air quality issue being studied. The CAMx is instrumented with "probing tools" that can explore attributes of the model during a simulation, including ozone and particulate source apportionment (OSAT/PSAT), Decoupled Direct Method (DDM) sensitivity and Process Analysis. The most common type of diagnostic evaluation involves using the Brute Force (BF) approach where a model base case and model perturbation case is performed, and the sensitivity of the model estimates are the differences in the output concentrations between the two BF runs.

The comparison of modeling results with observations for key indicator species can also be a useful diagnostic evaluation technique. Section 3.4.2 of EPA's PGM modeling guidance list several species indicator ratios that suggest whether the atmosphere and/or model ozone formation is more VOC-limited or NO_x-limited (EPA, 2018a, pp. 92-95). However, many of these indicator ratios involve species not routinely measured and may require more precision than typically obtained.

Although a comprehensive diagnostic sensitivity analysis may not be possible given resource and time constraints, some elements of a Diagnostic Evaluation is expected to occur.

7.6 Dynamic Evaluation

The Dynamic Evaluation evaluates a PGM for the way it is primary used in an ozone SIP as it evaluates how well the modeled ozone response to emissions changes with observed responses. The most comprehensive dynamic evaluation is to compare model responses to observed historical changes in ozone concentrations in a retrospective analysis. Because differences in meteorology between years can have as much or even more effect on observed ozone concentrations, such dynamic evaluation could include not only running with different historical years of emissions, but also running with different historical years of meteorology. Thus, this kind of retrospective analysis dynamic evaluation can be quite resource and time intensive. The WRAP/WAQS is conducting a Dynamic Evaluation of their 2014v2/RepBase modeling platform by back casting 2014v2 emissions to 2002 and comparing the changes in observed and modeled concentrations form a past year (2002), to a current year (2014 and RepBase) that can be potentially used as a Dynamic Evaluation in the NM OAI Study.

Another dynamic evaluation approach that is not as resource intensive as a retrospective modeling analysis is to stratify the operational model performance under varying conditions, such as day-of-week (e.g., weekday vs. weekend day), by season or by region. When the model shows the same ozone response as observed across these different chemical regimes, it supports the assertion that the modeled ozone concentrations would respond correctly to changes in emissions over time.

7.6.1 Probabilistic Evaluation

The probabilistic evaluation attempts to assess the level of confidence in the model predictions through techniques such as ensemble of model simulations. At this time, there are no plans to incorporate the probabilistic evaluation as part of the NM OAI Study.

8. FUTURE YEAR MODELING

This Chapter describes the 2023 future year modeling to evaluate source contributions to ozone concentrations in New Mexico and potential control strategies designed to reduce ozone.

8.1 Future Year to be Modeled

There is no Federal regulation guiding the NM OAI Study future year modeling. Thus, we selected the 2023 future year due to the available of EPA's 2023fh emissions inventories developed as part of the EPA 2016v1 modeling platform. EPA also developed a 2028fh emissions that is too far out in the future and portions of a 2020 emissions inventory that is too current. Thus, the 2023 future year seemed an ideal choice for the NM OAI Study.

8.2 Future Year Emissions

2023 future year anthropogenic emissions will be used in the future year modeling. The following natural emission sources will be assumed to remain unchanged from 2014 base year base case levels:

- Biogenic emissions.
- Lighting NOx emissions.
- Ocean Sea Salt and DMS emissions.
- Windblown Dust.
- Open Land Fires (Wildfires, Prescribed Burns and Agricultural Burning).

8.2.1 2023 Future Year Anthropogenic Emissions

The primary source of the 2023 future year anthropogenic emissions is the 2023fh emission projections from the joint EPA/MJO 2016 emissions inventory collaborative development study. EPA's 2016v1 modeling platform included model-ready 2023 emissions for the 36/12-km domains that can be used "as is" for the NM OAI Study except for on-road mobile source emissions that were developed using SMOKE-MOVES and the 2016 meteorological conditions. For the 12-km 12WUS2 domain we will run SMOKE-MOVES using the 2023 MOVES EF Look-Up table, 2023 vehicle activity and the 2014 WRF meteorological conditions.

For the 4-km New Mexico domain, the EPA 2023fh New Mexico emissions will be reviewed and updated by NMED as needed and processed with SMOKE to generate 4-km resolution emission inputs for the 4-km New Mexico domain. The 2023 MOVES inputs and 2023 vehicle activity data will also be reviewed and updated by NMED as needed and SMOKE-MOVES run using the 2023 MOVES EF Look-Up table, 2023 vehicle activity and 4-km hourly gridded WRF data to generate 2023 on-road mobile emission inputs.

8.2.2 *Future Year Emissions Quality Assurance*

Similar QA/QC procedures (e.g., as described in Adelman, 2004; UNC, 2018; EPA, 2018a) will be performed on the future year model-ready emissions inventories as were utilized in checking the base year datasets described previously. Standard inventory assessment methods will be employed to generate the future year emissions data including, but not limited to: (a) visualizing the model-ready emissions graphically, (b) spot-checking the holiday emissions files to confirm that they are temporally allocated like Sundays, (c) producing pie charts emission summaries for each source category, and (d) normalizing the emissions by population for each state to reveal where the future year inventories may be suspect. Of particular importance will be the comparison of the 2014 base year and 2023 future year emissions by source category and region to make sure the expected changes occurred in the modeling inventories.

8.3 Future Year CAMx Modeling

The 2023 future year CAMx base case modeling will be performed the same way that the 2024 base year base case modeling was performed only using the 2023 future year anthropogenic emissions. The CAMx PGM will be applied on the 36/12/4-km nested grid domain structure using two-way grid nesting. Due to uncertainties in global emissions, the BCs based on the WRAP 2014 GEOS-Chem simulation will also be used for 2023.

Future year ozone DV projections will be made using the 2014 base case and 2023 future year CAMx simulation outputs following the procedures given in Chapter 9 that use EPA’s latest 8-hour ozone modeling guidance (EPA, 2018d).

8.3.1 *Future Year Ozone Source Apportionment Modeling*

The CAMx Anthropogenic Precursor Culpability Assessment (APCA) version of the Ozone Source Apportionment Technology (OSAT) will be used to estimate 2023 future year contributions of emissions from U.S. and international anthropogenic emissions and natural emissions from different geographic regions on ozone concentrations in New Mexico. A 2023 future year CAMx 36/12/4-km nested grid simulations will be conducted using geographic source regions defined by New Mexico and other nearby state boundaries and separating anthropogenic sources from natural sources. Fires would also be treated as a separate source category. The CAMx 2023 future year ozone source apportionment modeling will also provide separate contributions by Source sector for emissions in New Mexico and outside New Mexico as follows:

- Upstream Oil and Gas.
- Midstream Oil and Gas.
- EGU Point.
- Non-EGU Point.
- On-Road Mobile.
- Non-Road Mobile.
- Other Anthropogenic.

- Fires (WF, Rx and Ag).
- Natural
- BC from International Anthropogenic Emissions.
- BC from US Anthropogenic Emissions.
- BC from Natural Sources.
- Initial Concentrations.

The exact definition of the 2023 ozone source apportionment modeling will be documented and provided to NMED for review and refinements later in the NM OAI Study.

8.3.2 Future Year Sensitivity and Control Strategy Simulations

2023 future year control strategy sensitivity simulations will be conducted. The definitions for the 2023 control strategy sensitivity scenarios will be provided by NMED at a later date,

9. FUTURE YEAR OZONE PROJECTIONS

EPA's latest ozone State Implementation Plan (SIP) modeling guidance (EPA, 2018d) contains detailed procedures for how to use base year and future year photochemical grid model (PGM) modeling results to make future year ozone Design Value (DV) projections. The EPA-recommended ozone attainment demonstration includes a model attainment test for projecting base year ozone DVs to the future year and a weight of evidence (WOE) analysis used to confirm and corroborate the modeled attainment demonstration test. EPA has developed the Speciated Modeled Attainment Test (SMAT[65]) tool that includes the EPA (2018d) recommended procedures for projecting ozone DVFs.

9.1 EPA Recommended Future Year Ozone DV Projection Procedures

The procedures for making future year ozone DV projections are outlined in Chapter 4 of EPA's latest ozone modeling guidance (EPA, 2018d, pp. 99-110). EPA recommends using PGM modeling results in a relative fashion the scale base year ozone DV (DVB) to estimate the future year ozone DV (DVF). The model derived scaling factors are called Relative Response Factors (RRF) and are the ratio of future to base year ozone modeling results.

$$DVF = DVB \times RRF$$

Below we highlight the key elements in EPA's recommended ozone DV projection approach, more details and justification for the approach are provided in EPA's modeling guidance (EPA, 2018d).

9.1.1 Base Year Ozone Design Value (DVB)

The DVB is defined as the average of three-years of ozone DVs centered on the base modeling year. As an ozone DV is defined as the three-year average of the 4th highest MDA8 ozone concentrations at a monitor, the DVB is based on 5 years of 4th highest MDA8 ozone concentrations centered on the base year so the highest weight (3x) is on the 4th highest MDA8 ozone for the base year with less weights in the 2 years before and after the base year (i.e., weighting factors of 1, 2, 3, 2, 1).

For the NM OAI Study modeling, the base year is 2014 so that the DVB at each site will be defined from three years of ozone DVs as follows:

$$DVB_{2014} = (DV_{2012\text{-}2014} + DV_{2013\text{-}2015} + DV_{2014\text{-}2016}) / 3$$

9.1.2 Calculation of Relative Response Factors (RRFs)

The RRF is defined as the ratio of the average of the PGM future year (FY) to base year (BY) MDA8 ozone concentrations near the monitor for the 10 days with the -highest base year modeled MDA8 ozone concentrations near the monitoring site.

[65] https://www.epa.gov/scram/photochemical-modeling-tools

$$RRF = \sum MDA8\ Ozone_{FY} / \sum MDA8\ Ozone_{BY}$$

Near the Monitor: By near the monitor, the highest modeled base year MDA8 ozone is selected in a 3x3 array of grid cells centered on the monitor is used. For the future year, the future year MDA8 ozone is selected from the same grid cell in the 3x3 array centered on the monitor as used in the base year.

10 Highest Base Year MDA8 Ozone Days: The RRF is based on the 10 days with the highest base year modeled MDA8 ozone concentrations near the monitor, provided the base year MDA8 ozone is greater or equal to 60 ppb. If there are less than 10 days with base year MDA8 ≥ 60 ppb, then just the days ≥ 60 ppb are used provided there are at least 5 days. If there are less than 5 days with base year MDA8 ozone ≥ 60 ppb EPA recommends that RRFs not be calculated for that site.

9.1.3 Flexibility in RRF Calculations

EPA's modeling guidance includes the flexibility to modify the recommended ozone DV projection procedure. For example, there may be a reason that grid cells in the 3x3 array centered on the monitor may not be representative of conditions at the monitor. For example, if a grid cell is dominated by water so has different mixing characteristics or the monitor is in an area with sharp terrain gradients.

There may be also reasons that one of the highest 10 base year MDA8 ozone days should not be used in the RRF. For example, if the modeled base year MDA8 ozone is highly influenced by emissions from wildfires it could be excluded and then the next highest modeled MDA8 ozone included so that 10 modeled days are still used in the RRF.

The PGM model performance on the 10 highest modeled MDA8 ozone days may also be considered in selected the top 10 modeled MDA8 ozone days to use in the RRFs.

9.2 Unmonitored Area Analysis (UAA)

An unmonitored area analysis (UAA) will be conducted using the SMAT tool. The UAA first interpolates the ozone DVB to each 4-km grid cell in the New Mexico 4-km domain. The interpolation will be done with and without accounting for modeled concentration gradients. Once a gridded field of ozone DVB is obtained, the ozone DVB are projected to the future using the same procedures as used in the modeled attainment test only the modeling results at the grid cell containing the monitor is used and there is typically some relaxation of the requirement for MDA8 ozone to be above 60 ppb since the UAA is making projections in fairly clean ozone concentrations regions. The gridded future year ozone DVFs are then analyzed to determine locations with grid cells that exceed the ozone NAAQS. Note that estimate locations of ozone DVFs above the ozone NAAQS in the UAA does not necessarily imply a failure to demonstrate attainment. For example, when modeled concentration fields are used in the UAA ozone DVB interpolation frequently at locations of wildfires the ozone DVB and DVF are above the NAAQS. But any UAA ozone DVF exceedances of the NAAQS should be identified and explained in the analysis.

9.3 Weight of Evidence (WOE) Attainment Demonstration

The Weight of Evidence (WOE) is a necessary and critically important component of the ozone attainment demonstration. As stated in EPA's modeling guidance, "By definition, models are simplistic approximations of complex phenomena" (EPA, 2018a, pp. 169). EPA guidance recommends three types of supplemental analysis to support a modeled attainment demonstration:

1. Additional modeling analysis.
2. Analysis of trends in ambient concentrations and emissions.
3. Additional emission controls.

As the NM OAI Study is not a formal regulatory SIP ozone attainment demonstration study, then a formal WOE is not needed. However, the concept of a WOE should be integrated into the NM OAI Study.

9.4 Documentation of the PGM Modeling

Results of the NM OAI Study will be documented in PowerPoint (PPT) presentations and other documents that will be presented to the NMED in monthly webinars following the schedule in Tables 1-2 and 1-3. After each webinar presentations and with approval from NMED, the documents will be posted to a webpage on the WRAP website, like we did for the Southern New Mexico Ozone Study (SNMOS[66]). Two formal reports will be generated, one on the developed of the NM OAI Study 2014 36/12/4-km CAMx modeling platform and model performance evaluation and an Air Quality Technical Support Document (AQTSD) that documents the entire study including the 2023 future year modeling, ozone design Value projections, source apportionment modeling and control strategy sensitivity modeling.

[66] https://www.wrapair2.org/SNMOS.aspx

10. QUALITY ASSURANCE PROJECT PLAN (QAPP)

This Modeling Protocol also serves as an informal Quality Assurance Project Plan (QAPP) for the NM OAI Study. A formal QAPP is a stand-alone document that discusses the Quality Assurance (QA) and Quality Control (QC) aspects of a study. QAPPs are typically required for Federal studies and are designed to assure that data are collected in the most rigorous ways possible, subjected to detailed QA/QC and have a chain of custodia review of data to preserve the quality. QAPPs are particularly important for measurement studies where the study must assure that the data collected meet a level of QA/QC as, unlike a modeling study where one can go back and rerun the model, if data collected at a certain time and place is ruled invalid there is no way to collect the measurement data under the same circumstances. This is not to say QA/QC is not important for modeling studies and, as shown below, this Modeling Protocol is full of QA/QC processes in each step of the modeling.

EPA has developed a template for developing a formal QAPP.[67] EPA has also developed a document that describes the elements of a QAPP.[68] Below we go through each of the seven elements EPA recommends be part of a QAPP and discuss where they can be found in this Modeling Protocol.

10.1 Title Page And Approval Page

As this is not a formal QAPP , there is no Approval Page. However, we have a list of Project Participants in Table 1-1 that are responsible for reviewing and accepting the Modeling Protocol/QAPP.

10.2 Quality System Components

This section of a QAPP describes the study's quality assurance program and procedures and who has responsibility for the QA/QC. Below we point to sections in this Modeling Protocol where rigorous QA/QC procedures are put in place for the NM OAI Study.

10.2.1 Roles of Personal for QA/QC of the NM OAI Study

The two Co-Principal Investigators, Tom Moore of WESTAR and Ralph Morris of Ramboll, have overall responsibility for the QA/QC of the NM OAI Study. Together they have over 50 years' experience in managing large air quality studies including instituting comprehensive QA/QC procedures. In Table 1-1 we also list the leads for each major component of the modeling study (emissions, meteorological and photochemical modeling) who will oversee the QA/QC of each component of the database development. Also listed in Table 1-1 is the NM OAI Study Project Manager and staff at NMED who will review and comment on each phase of the study. Each month during the NM OAI Study we will have a Webinar and present elements of the study to the NMED for their review and comment following the schedule in Table 1-3.

[67] https://www.epa.gov/quality/quality-assurance-project-plan-development-tool
[68] https://www.epa.gov/sites/production/files/2015-05/documents/assess4.pdf

10.2.2 QA/QC of the 2014 Base Year and 2023 Future Year Emissions Data

The QA/QC of the base and future year emissions data is described in Section 1.5.4. The 2014 base year emissions were based on the 2014NEIv2 that have gone through several rounds of review and updates by EPA and the states. The WRAP states then conducted further review and updates of the 2014NEIv2 emissions in two phases to develop the WRAP/WAQ 2014v1 and final 2014v2 emissions used in the WRAP/WAQS 2014v2 modeling platform. Finally, under the NM OAI Study, the NMED will make further review of the New Mexico emissions in the 2014v2 inventory and make updates as needed.

The 2023 future year emissions used in the study are part of EPA's 2016v1 modeling platform (2023fh inventory). They are the result of several iterations of EPA making future year emission projections and represent their current best estimate of future year emissions. The NMED will also review the 2023 emissions for New Mexico and make updates as needed.

10.2.3 QA/QC of 2014 and 2023 Emissions Processing

Section 1.5.5 describes the process that will be used in processing the 2014 and 2023 emissions into the gridded, hourly and speciated emissions inputs needed for the CAMx PGM. The NM OAI Study modeling study will perform a multistep emissions QA/QC approach as developed for the WRAP 2002 modeling (Adelman, 2004) and following the procedures in EPA's latest ozone modeling guidance (EPA, 2018a, pp. 60) and Section 2.20 of the SMOKE User's Manuel (UNC, 2018, pp. 94). These steps include making sure that the mass input to the emissions models is consistent with the output and generation numerous QA/QC visualization graphics, including spatial maps and time series plots. Sections 6.2.2.7 and 6.2.2.9 provide more details on the QA/QC process for the emissions modeling. The QA/QC of the 2023 emissions processing is discussed in Section 8.2.2.

10.2.4 QA/QC of the Meteorological Modeling

The QA/QC of the meteorological modeling is briefly discussed in Section 1.5.6 with a more detailed discussions contained in Chapter 5. The NM OAI Study has separate work elements to evaluate the performance of the current WRAP/WAQS 2014 WRF simulation in New Mexico as well as a more detailed evaluation of the 36/12/4-km WRF simulation being conducted under the NM OAI Study that is described in Section 5.4.

10.2.5 QA/QC of the Boundary Conditions

The WRAP/WAQS study did a detailed QA/QC of EPA's 2014 GEOS-Chem modeling that was used in the initial BCs in the 2014v1 platform and found the ozone BCs to be inadequate, so WRAP ended up doing their own 2014 GEOS-Chem modeling that improved the 2014 BCs. The NM OAI Study will conduct a QA/QC of the WRAP 2014 GEOS-Chem BCs for sites in New Mexico

10.2.6 QA/QC of the Air Quality Modeling

The QA/QC of the CAMx air quality modeling will included independent review of the run scripts against the Modeling Protocol to make sure that the model configuration is correct, as discussed in Section1.5.7. The NM OAI Study CAMx 36/12/4-km base case simulation will be subjected to a model performance evaluation (MPE) to assure that the model is replicating 2014 observed ozone concentrations sufficiently well that it can be used for making future year ozone projections (Section 1.5.9). Chapter 7 goes into details on how the CAMx Operational MPE will be conducted that includes statistical performance measures that are compared against Goals and Criteria and graphical MPE products. Elements of Diagnostic MPE being conducted are discussed in Section 1.5.10 with details of the diagnostic model performance evaluation provided in Section 7.5.

10.3 Project Definition and Background

Section 1-1 provides the impetus for the NM OAI Study with an overview of the study provided in Section 1-2. The background on related studies in provided in Section 1.3.

10.4 Data Quality Objectives

The data quality objectives for the meteorological, emissions and photochemical modeling are contained in Chapters 5, 6 and 7 respectively. Of particular note are meteorological model performance benchmarks listed in Table 5-3 that the NM OAI Study WRF 22014 36/12/4-km simulation will be compared against as part of the assessment of the meteorological data quality. Similarly, Table 7-1 contains model Performance Goals and Criteria that the CAMx 2014 base case simulation model performance will be compared against as part of the assessment of the data quality of the photochemical model simulation.

10.5 Project Organization and Responsibilities of the Researchers

Table 1-2 lists the organization of the NM OAI Study by task with schedule. The responsibilities of the NM OAI Study project participants are given in Table 1-1.

10.6 Project Description, Documentation and Reporting

This Modeling Protocol has a complete description of how the NM OAI Study will be carried. A description of the documentation and how the study will be reported is given in Section 1.8. And a summary of the documentation is also provided at the end of Chapter 9.

10.7 Reconcile with Data Quality Objectives

This Modeling Protocol provides a roadmap for how the NM OAI Study will be conducted. However, it is a living document that can be modified as issues or new information comes up. During the course of the study, WESTAR/Ramboll will have regular webinars that are scheduled monthly to go over progress and results for the previous month. If issues come up or problems are encountered, the WESTAR/Ramboll team will discuss them with the NMED and develop corrective action to reconcile any issues/difficulties.

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APPENDIX A

Observed MDA8 Ozone Concentrations during 2014. Red indicates ozone ≥71 ppb and yellow indicates ozone between 67 and 71 ppb.

Observed MDA8 Ozone Concentrations during 2014. Red indicates ozone ≥71 ppb and yellow indicates ozone between 67 and 71 ppb.

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Montezuma	Bernalillo	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
1-Jan	36	28	43	38	43	39	36	32	39	36	38		37	47	42	39	32	36	37	34	32	33		47	43	47	42
2-Jan	42	34		28	32	30	35	29	37	32	37		33	47	46	31	29	26	39	36	34	35		47	35	47	46
3-Jan	47	32		26	30	28	33	23	32	30	35		30	47	48	29	31	27	41	28	29	36		48	33	47	48
4-Jan	44	42		40	44	40	40	33	42	37	43		34	51	44	41	40	40	36	37	41	31		51	44	51	44
5-Jan	45	41		38	43	42	38	33	43	36	35		35	50	42	40	38	39	34	38	39	38		50	43	50	42
6-Jan	42	35		34	38	35	35	28	37	27	34		32	50	42	38	32	33	33	34	34	35		50	38	50	42
7-Jan	34	27		19	28	24	26	21	31	26	28		28	47	39	29	26	25	30	24	26	33		47	28	47	39
8-Jan	39	23		22	28	25	30	32	39	37	40		32	49	40	27	18	10	32	27	37	24		49	30	49	40
9-Jan	43	35		24	24	22	29	28	37	33	26		27	48	43	24	28	16	31	28	34	33		48	29	48	43
10-Jan	42	39		38	42	40	38	36	43	40	44		38	52	43	39	37	40	40	36	41	43		52	42	52	43
11-Jan	41	36		35	36	36	33	31	35	35	39		36	49	39	35	29	30	39	32	29	40		49	36	49	39
12-Jan	45	42		38	44	41	38	33	42	38	42		36	50	43	41	40	43	38	35	40	36		50	44	50	43
13-Jan	41	32	44	37	42	38	37	32	40	35	41		36	48	42	39	36	34	44	31	28	41		48	42	48	42
14-Jan	42	39	46	38	44	41	38	26	43	33	44		40	51	44	41	38	37	46	28	30	40		51	44	51	44
15-Jan	40	30	47	36	40	34	37	30	40	38	41		36	49	42	39	35	32	41	32	35	38		49	40	49	42
16-Jan	40	31	47	38	43	36	38	29	44	33	40		40	53	42	40	30	34	44	32	34	41		53	43	53	42
17-Jan	44	31	45	27	16	31	35	31	44	38	43		37	53	42	36	31	29	50	37	36	37		53	35	53	42
18-Jan	41	34	42	33	36	34	36	33	41	37	41		37	51	41	37	28	33	47	34	37	43		51	36	51	41
19-Jan	39	33	42	28	31	34	32	27	43	35	44		43	53	44	34	29	27	48	37	39	40		53	34	53	44
20-Jan	36	30	43	34	38	31	36	31		34	42		38	50	42	37	21	32	44	27	34	40		50	38	50	42
21-Jan	35	33	40	30	33	32	32	32		36	42		39	52	45	34	30	31	45	38	38	39		52	33	52	45
22-Jan	31	18	39	18	25	26	28	23		29	34		27	52	40	27	23	22	42	22	3	40		52	28	52	40
23-Jan	40	36	33	32	30	32	34	29			35		31	42	37	32	35	32	35	35	32	34		42	34	42	37
24-Jan	39	30	31	17	25	23	25	22			34		33	44	42	28	25	28	35	25	27	35		44	28	44	42
25-Jan	44	25	45	26	29	30	36	23			31		25	47	44	35	21	32	36	31	30	38		47	36	47	44
26-Jan	47	30	43	37	38	39	38	29			32		26	51	44	40	28	37	35	37	40	37		51	39	51	44
27-Jan	45	38	42	26	32	30	29	20			36		33	47	41	31	30	29	35	31	30	35		47	32	47	41
28-Jan	45	50	52	43	40	32	41	21			33		31	53	50	37	47	32	33	32	31	35		53	43	53	50
29-Jan	48	35	48	35	33	37	39	18		33	32		27	49	47	35	31	32	36	32	25	37		49	39	49	47

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
30-Jan	45	29	37	30	33	30	32	29		38	39		29	52	37	33	30	33	42	33	40	35		52	33	52	37
31-Jan	45	39	44	39	37	39	36	29	36	36	43		34	48	46	38	37	35	38	35	38	28		48	39	48	46
1-Feb	45	41	43	41	45	43	38	27	35	34	42		36	48	44	41	36	45	39	35	36	31		48	45	48	44
2-Feb	46	40	42	42	42	42	39	25	37	37	32		33	56	46	41	38	38	34	34	38	38		56	42	56	46
3-Feb	47	42	39	39	43	41	39	26	39	36	27		28	53	45	42	41	40	31	41	40	35		53	43	53	45
4-Feb	48	41	42	36	42	40	37	32	44	39	44		38	54	44	40	38	45	45	40	41	29		54	45	54	44
5-Feb	48	35	41	22	27	26	23	20	28	24	33		33	46	42	29	37	27	33	29	28	38		46	27	46	42
6-Feb	44	38	43	18	22	20	24		33	24	32		33	44	44	24	38	24	31	34	33	39		44	24	44	44
7-Feb	45	35	43	31	37	35	34	44	43		38		28	53	45	37	35	39	37	38	42	33		53	39	53	45
8-Feb	47	38	44	37	36	39	37	46	45		44		40	54	46	39	32	39	43	40	43	41		54	39	54	46
9-Feb	40	34	36	34	36	36	34	40	39		40		40	47	40	36	28	35	42	35	37	28		47	36	47	40
10-Feb	46	36	41	36	40	35	35	41	39		21		24	45	39	37	33		35	34	38	35		45	40	45	39
11-Feb	47	41	44	34	38	37	36	30	32		22		33	49	43	37	35		32	30	31	35		49	38	49	43
12-Feb	46	32	46	38	42	41	38	31	47		45		33	41	46	40	34	30	40	39	41	43		47	42	47	46
13-Feb	37	32	36	27	31	33	31	34	36		37		37	32	37	32	28	32	41	29	32	41		37	33	37	37
14-Feb	35	33	35	28	33	33	31	33	35	29	25		37	34	36	31	29	34	38	31	31	44		37	34	37	36
15-Feb	39	28	35	29	27	30	28	32	32	33	22		32	33	33	28	26	31	37	27	30	32		33	31	33	33
16-Feb	45	32	45	36	40	38	36	38	40	39	25		37	38	41	37	23	40	40	34	38	41		41	40	40	41
17-Feb	45	44	45	42	42	43	41	31	38	28	28		38	38	48	42	38	43	45	32	35	43		48	43	38	48
18-Feb	48	29	46	38	42	41	41	37	40	29	28		40	40	47	31	32	44	46	33	37	49		47	44	40	47
19-Feb	52	45	45	44	48	46	44	36	42	40	32		39	40	48	45	44	48	45	32	44	41		48	48	42	48
20-Feb	49	43	43	40	44	43	39	46	45	47	34		45	34	44	41	41	44	53	42	40	44		47	44	47	44
21-Feb	47	42	42	38	41	40	40	39	46	42	31		41	46	45	39	33	38	46	33	47	44		46	41	46	45
22-Feb	50	42	45	42	44	45	42	47	53	49	38		50	51	44	40	39	43	45	43	50	44		53	45	53	44
23-Feb	54	41	46	43	44	46	44	49	53	50	32		46	51	47	42	38	43	44	46	49	43		53	46	53	47
24-Feb	53	43	49	41	46	47	45	39	42	40	35		43	42	50	41	41	36	47	38	38	44		50	47	43	50
25-Feb	45	48	51	35	37	35	38	34	38	35	26		31	38	48	37	45	37	38	31	34	35		48	38	38	48
26-Feb	47	40	45	37	41	41	41	36	41		19		31	39	49	39	39	41	26	38	37	33		49	41	41	49
27-Feb	42	37	44	38	41	40	39	36	37		25		39	38	43	38	34	41	34	33	33	40		43	41	39	43
28-Feb	40	40	40	41	43	43	43	32	35		29		45	33	46	42	39	42	39	30	31	47		46	43	45	46
1-Mar	38	34	39	33	28	32	32	26	27		22		33	25	28	34	32	28	37	25	25	37		34	33	33	34
2-Mar	49	42	45	40	46	45	43	44	45		21		33	44	45	42	44	45	35	43	44	36		46	46	45	45
3-Mar	51	43	46	43	44	45	43	32	39		21		31	44	47	42	39	44	38	34	38	39		47	45	44	47
4-Mar	38	41	43	39	42	42	41	41	42		29		38	43	48	41	37	43	38	41	43	45		48	43	43	48

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
5-Mar	52	35	50	43	48	46	42	46	46		35		38	46	48	44	38	47	49	43	43	35		48	48	46	48
6-Mar	49	44	50	41	41	44	41	43	51		33		47	48	52	41	40	41	51	46	48	47		52	44	51	52
7-Mar	52	44	43	43	49	48	45	50	54		40		53	51	48	45	44	50	51	47	49	49		54	50	54	48
8-Mar	48	44	43	40	40	42	38	38	39		33		40	41	46	39	44	40	42	38	37	41		46	42	41	46
9-Mar	52	41	41	44	45	46	39	42	41		33		43	42	46	44	41	47	46	42	40	44		47	47	43	46
10-Mar	51	11	47	41	42	45	38	45	47		35		46	46	47	39	35	43	42	44	45	50		47	45	47	47
11-Mar	56	29	47	46	49	49	46	51	54	52	37		49	52	54	45	48	50	50	47	49	46		54	50	54	54
12-Mar	54	50	52	44	47	47	40	42	42	42	27		41	44	46	43	46	44	45	42	41	49		47	47	44	46
13-Mar	49	49	51	43	46	45	42	42	46	44	34		43	45	47	44	48	43	47	42	43	47		48	46	46	48
14-Mar	51	44	49	43	43	43	40	47	50	49	36		44	50	47	42	46	43	50	46	46	50		50	43	50	47
15-Mar	55	55	52	46	47	47	45	48	49	49	39		48	51	48	44	52	47	53	46	45	51		52	47	51	52
16-Mar	52	46	49	50	50	51	46	50	52	52	36		42	51	52	47	46	49	47	49	48	42		52	51	52	52
17-Mar	56	50	52	49	51	46	47	46	49	48	35		46	48	53	48	50	51	48	43	48	46		53	51	49	53
18-Mar	56	44	43	44	48	50	43	52	54	52	39		48	52	47	43	43	51	54	48	49	47		54	51	54	47
19-Mar	54	51	50	47	48	47	43	43	44	45	37		45	48	53	44	44	45	46	42	42	47		53	48	48	53
20-Mar	55	52	53	46	48	50	45	41	47	43	33		46	47	55	46	50	47	50	41	41	49		55	50	47	55
21-Mar	56	51	51	50	53	51	48	48	51	50	38		52	50	54	50	48	52	51	44	47	48		54	53	52	54
22-Mar	56	54	53	44	49	49	44	43	45	44	38		44	45	56	47	55	48	45	42	41	43		56	49	45	56
23-Mar	59	52	52	50	51	51	46	44	43	45	36		42	46	53	49	52	48	41	41	41	42		53	51	46	53
24-Mar	56	45	54	50	54	52	49	48	50	51	39		50	52	56	49	50	54	43	51	47	45		56	54	52	56
25-Mar	52	53	54	46	49	51	46	44	45	45	37		48	50	52	46	52	47	43	43	43	46		52	51	50	52
26-Mar	56	50	52	46	48	45	46	44	47	46	32		44	45	52	46	52	46	42	40	43	45		52	48	47	52
27-Mar	54	49	51	47	52	50	49	43	47	45	34		44	46	49	48	47	51	50	40	45	48		52	52	47	49
28-Mar	53	49	47	44	48	47	46	46	50	48	35		48	49	51	44	47	48	49	43	44	49		51	48	50	51
29-Mar	56	53	52	50	53	54	50	52	53	54	39		53	49	51	50	50	48	54	49	49	50		54	54	54	51
30-Mar	57	51	54	51		54	51	51	55	53	35		50	54	56	51	53	53	52	47	50	54		56	54	55	56
31-Mar	54	50	49	52	53	53	49	49	52	50	38	47	51	50	52	49	50	53	55	46	46	51		53	53	52	52
1-Apr	57	54	58	46		48	47	49	47	51	39	56	50	51	52	45	54	48	51	46	48	49		56	48	56	54
2-Apr	59	54	56	53		57	53	50	53	51	39	52	50	52	57	51	55	54	53	45	50	54		57	57	53	57
3-Apr	53	54	52	49		53	50	55	58	55	46	57	57	53	54	49	51	53	53	53	53	52		58	53	58	54
4-Apr	59	57	56	53		56	52	48	51	50	40	52	52	50	55	51	55	51	51	47	47	53		56	56	52	55
5-Apr	58	60	57	55		57	53	54	56	56	39	53	50	58	56	53	59	56	53	51	54	49		59	57	58	59
6-Apr	53	53	50	49		52	50	52	54	53	41	54	50	51	54	48	51	52	58	51	50	45		54	52	54	54
7-Apr	55	47	50	52		55	51	52		52	40	51		52	55	50	51	54	52	49	41	48		55	55	52	55

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
8-Apr	50	44	48	47		49	47	50	53	53	33	48		43	54	45	46	51	53	55	49	49		54	51	53	54
9-Apr	54	51	50	49		49	48	46	50	49	35	53	49	49	53	46	48	48	54	46	44	53		53	49	53	53
10-Apr	51	54	54	53		57	52	49	54	51	37	51	48	51	57	50	53	59	56	47	47	53		59	59	54	57
11-Apr	56	55	55	51		54	52	47	52	50		55		48	58	50	50	53	53	44	45	68		58	54	55	58
12-Apr	55	56	56	46		50	46	41	44	43		45		46	54	46	54	48	47	40	42	51		54	50	46	54
13-Apr	59	56	54	54		55	53	49	52	51		55		52	53	52	54	56	56	45	49	50		56	56	55	54
14-Apr	52	54	57	44		45	43	40	41	41	36	41	44	55	49	43	48	43	45	38	38	47		55	45	55	49
15-Apr	53	51	53	48		51	47	47	53	50	36	50	49	49	53	47	46	46	50	47	47	53		53	51	53	53
16-Apr	58	50	52	50		54	49	53	57	56	40	60	51	56	53	48	49	54	52	50	54	55		60	54	60	53
17-Apr	54	57	52	56		57	53	56	54	60	40	53	50	55	59	51	51	55	56	52	50	37		60	57	60	59
18-Apr	56	59	59	55		58	54	53	54	56	34	50	51	53	58	55	57	52	47	50	50	52		58	58	56	58
19-Apr	52	59	57	47		50	43	44	45	47	26	43	41	48	54	47	60	43	44	42	42	47		60	50	48	60
20-Apr	55	55	53	50		51	48	49	54	52	33	55	54	55	55	49	52	49	47	53	48	53		55	51	55	55
21-Apr	59	64	61	59		60	56	61	55	64	38	55	57	54	64	54	60	57	51	59	54	61		64	60	64	64
22-Apr	61	60	61	56		59	56	54	59	59	36	59	68	54	59	56	58	54	59	53	52	66		68	59	68	59
23-Apr	61	60	60	54		56	55	50	55	54	38	61	56	53	59	54	58	56	53	48	51	61		61	56	61	59
24-Apr	62	55	58	55		58	52	58	60	61	37	58	56	57	62	51	53	55	58	59	55	56		62	58	61	62
25-Apr	53	65	64	52		55	52	49	55	52	35	56	56	56	60	51	60	50	59	46	48	62		60	55	56	60
26-Apr	53	46	53	50		51	50	49	51	51	38	51	52	46	56	49	51	49	52	47	47	53		56	51	52	56
27-Apr	59	55	54	52		56	51	54	57	57	42	56	55	53	55	50	53	55	50	53	52	47		57	56	57	55
28-Apr	57	59	58	54		55	55	54	57	55	41	57	55	54	59	53	57	53	52	52	50	54		59	55	57	59
29-Apr	56	53	49	57		59	54	62	63	61	44	60	55	58	53	52	52	54	58	58	56	44		63	59	63	53
30-Apr	56	56	49	54		58	49	45	48	48	34	47	45	50	50	47	47	55	48	46	44	50		58	58	50	50
1-May	56	54	55	52		53	49	47	49	51		53	51	52	53	48	51	49	56	48	46	49		53	53	53	53
2-May	51	51	51	48		51	48	49	55	52		49	52	52	54	47	49	47	59	54	48	53		55	51	55	54
3-May	52	59	59	50		52	48	48	54	52		53	51	49	55	46	53	45	54	52	48	53		55	52	54	55
4-May	59	56	56	57		59	55	53	58	57		59	55	55	57	51	54	54	56	51	50	57		59	59	59	57
5-May	59	56	55	54		56	56	46	52	50		58	58	48	59	51	52	51	54	45	46	57		59	56	58	59
6-May	55	57	56	53		56	53	40	46	43		53	53	42	59	50	53	49	47	37	40	56		59	56	53	59
7-May	60	58	58	53		56	54	47	53	51	53	57	45	52	50	51	57	54	43	46	52	46		57	56	57	57
8-May	60	48	48	51		53	51	54	56	57	61	61	55	54	49	50	47	53	49	52	52	57		61	53	61	50
9-May	59	56	58	56		58	56	54	59	58	64	63	58	55	58	55	54	55	57	53	54	55	56	64	58	64	58
10-May	56	57	56	57		60	56	52	56	56	57	56	54	51	56	58	55	51	54	51	49	62	57	60	60	57	58
11-May	65	59	61	58		61	57	50	52	53	58	57	56	50	61	57	58	58	59	48	50	57	50	61	61	58	61

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
12-May	50	32	40	45		46	42	55	57	58	49	47	48	56	43	44	40	42	53	55	53	43	45	58	46	58	44
13-May	55	49	51	46		46	41	42	44	45	47	44	45	42	46	43	48	42	47	42	40	42	51	48	46	47	48
14-May	58	53	51	54		55	50	50	49	53	57	54	52	52	54	51	53	54	52	49	45	57	52	57	55	57	54
15-May	55	53	50	52		52	52	57	63	59	57	57	55	51	59	52	49	51	64	56	58	57	51	63	52	63	59
16-May	56	52	51	49		52	51	54	58	57	62	58	57	53	57	49	51	53	60	54	51	56	50	62	53	62	57
17-May	68	52	55	55		55	55	58	63	62	68		60	58	57	54	56	51	62	63	56	60	54	68	55	68	57
18-May	61	68	65	61		61	62	55	59	58	70	62	61	54	66	60	62	57	62	53	51	58	61	70	62	70	66
19-May	61	62	59	58		58	59	53	56	57	64	61	58	55	63	57	57	55	55	49	53	61	58	64	59	64	63
20-May	53	58	56	55		56	56	51	55	54	62	61	60	49	61	54	53	52	54	49	48	63	56	62	56	62	61
21-May	51	47	48	51		52	52	50	56	55	62	57	52	47	57	52	44	50	49	50	49	56	51	62	52	62	57
22-May	46	49	49	46		46	48	44	48	48	45	42	34	38	49	47	45	45	47	43	42	43	48	49	48	48	49
23-May	48	43	47	43		45	44	43	51	47	52	51	47	36	42	45	40	42	55	47	47	43	49	52	45	52	45
24-May	61	50	53	44		44	46	46	50	52	55	54	47	52	48	43	56	44	53	43	44	49	60	56	46	55	56
25-May	58	58	51	56		55	56	54	58	58	59	55	57	56	59	55	51	55	48	55	51	57	47	59	56	59	59
26-May	55	60	62	62		62	59	53	55	56	56	55	55	52	63	58	59	62	51	53	49	55	60	63	62	56	63
27-May	59	54	53	63		63	58	60	61	64	67	65	65	55	55	57	55	61	61	61	55	66	53	67	63	67	57
28-May	59	59	57	62		58	62	65	63	72	75	74	68	59	58	61	52	59	65	60	58	65	59	75	62	75	61
29-May	52	61	58	63		61	64	67	66	72	72	69	65	57	57	64	59	58	60	64	62	63	55	72	64	72	64
30-May	56	47	57	56		53	57	59	66	63	69	60	69	52	55	54	58	56	65	59	60	66	50	69	57	69	58
31-May	56	57	54	56		55	56	57	63	61	72	63	73	51	55	57	51	55	65	54	55	62	55	73	56	73	57
1-Jun	51	55	56	49		49	51	45	49	49	60	53	60	44	55	48	53	50	63	44		66	67	60	51	60	55
2-Jun	46	66	61	59		55	58	53	54	55	62	56	64	40	54	55	56	47	52	57	54	52	64	64	59	64	56
3-Jun	46	41	53	53		51	54	49	57	54	54	51	53	47	49	52	39	52	38	44	46	52	69	57	54	57	52
4-Jun	57	59	64	51		52	52	49	54	53	57	49	50	46	57	46	54	54	45	56	46	60	69	57	54	57	57
5-Jun	65	71	68	60		59	59	52	53	55	60	52	56	53	64	60	66	60	41	55	51	63	65	66	60	60	66
6-Jun	71	70	67	62		62	58	52	57	57	47	42	40	57	68	60	69	63	32	54	63	47	45	69	63	57	69
7-Jun	71	67	67	51		50	47	62	67	66	51	49	40	59	56	52	61	53	31	61	63	54	61	67	53	67	61
8-Jun	67	59	57	61		63	58	52	59	56	45	43	46	58	62	59	60	65	35	52	59	59	62	65	65	59	62
9-Jun	63	61	56	62		64	57	65	65	69	58	56	51	60	67	57	52	67	53	64	65	47	59	69	67	69	67
10-Jun	67	42	61	64		65	60	72	70	76	74		66	65	63	62	60	64	60	70	71	61	64	76	65	76	63
11-Jun	54	59	61	43		44	45	44	48	47	62		61	43	53	43	54	48	52	41	44	67	65	62	48	62	54
12-Jun	55	65	58	62		61	59	41	46	44	60	59	57	43	56	60	60	61	44	45	46	50	56	62	62	60	60
13-Jun	46	46	47	41		43	41	51	42	55	58	52	58	38	42	45	42	44	46	46	54	56	60	58	44	58	45
14-Jun	69	61	63	52		52	55	39	43	43	46	43	49	42	64	54	61	52	48	38	39	61	59	64	55	49	64

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
15-Jun	66	62	63	57		57	55	35	38	38	50	43	50	37	61	56	56	53	44	34	38	58	60	61	57	50	61
16-Jun	48	53	56	41		42	40	40	44	43	52		46	42	46	40	46	44	43	37	39	45	55	52	44	52	46
17-Jun	42	45	42	40		40	40	36	40	39	47	47	49	40	47	38	43	44	42	39	39	49	41	49	44	49	47
18-Jun	44	34	47	32		32	32	35	40	38	41	40	52	28	39	32	40	35	43	36	36	43	49	52	35	52	40
19-Jun	45	57	56	48		47	46	37	40	40	44	45	55	31	57	47	55	45	43	45	41	38	50	57	48	55	57
20-Jun	49	56	51	41		42	40	48	43	53	39	42	42	39	52	43	55	44	33	41	43	39	51	55	44	53	55
21-Jun	41	50	51	47		48	45	63	53	64	42		43	44	47	45	49	49	39	52	57	36	49	64	49	64	49
22-Jun	43	54	50	41		42	40	41	43	44	50		57	38	45	41	51	42	45	42	39	46	49	57	42	57	51
23-Jun	47	53	47	47		48	47	45	46	47	53	51	54	42	47	47	50	49	41	52	46	51	42	54	49	54	50
24-Jun	47	58	55	46		46	45	42	46	45	55		72	39	55	45	55	45	50	46	43	55	45	72	46	72	55
25-Jun	49	59	53	53		50	50	42	46	46	48		46	42	54	51	52	49	42	43	44	45	51	54	53	48	54
26-Jun	51	49	48	47		46	46	41	44	45	56	60	48	40	53	46	47	45	44	41	42	48	48	60	47	60	53
27-Jun	50	47	45	50		53	49	36	42	40	42		44	43	48	51	43	53	47	35	42	50	45	53	53	44	51
28-Jun	62	60	57	56		59	54	44	54	47	51		54	48	65	54	56	59	46	42	47	51	48	65	59	54	65
29-Jun	50	56	53	60		59	56	41	48	45			51	43	55	54	57	60	43	40	43	50	59	60	60	51	57
30-Jun	49	47	44	51		51	48	37	44	41	45		44	39	51	45	45	48	37	35	38	45	51	51	51	45	51
1-Jul	47	49	46	46		45	39	41	43	44	47	51	39	45	47	50	42	47	41	42	42	46	60	51	47	51	50
2-Jul	47	49	50	51		52	46	47	49	52	47	42	43	35	45	53	49	53	34	44	48	41	41	53	53	52	53
3-Jul	49	52	50	55		55	50	46	43	51	47		44	48	45	58	51	56	35	42	43	38	41	58	56	51	58
4-Jul	50	51	52	55		53	49	43	41	47	41	41	36	40	48	54	52	53	31	39	41	37	47	55	55	47	54
5-Jul	53	48	46	60		57	55	47	50	49	43	43	40	47	44	54	50	57	36	42	51	43	49	60	60	50	54
6-Jul	54	60	53	60		61	52	39	43	43	40	45	40	48	59	54	61	57	39	37	40	44		61	61	48	61
7-Jul	56	60	63	64		59	59	58	55	63	54	56	43	52	52	63	62	59	34	50	57	52		64	64	63	63
8-Jul	54	56	59	51		49	43	55	51	61	51		53	55	47	48	56	52	33	49	51	43	46	61	52	61	56
9-Jul	56	50	56	56		57	52	50	47	55	43		41	51	44	51	54	59	34	45	48	41	52	59	59	55	54
10-Jul	56	60	59	60		58	54	51	44	57	41		40	49	52	57	58	58	40	43	47	44	38	60	60	57	58
11-Jul	55	62	55	63		64	56	42	41	44	39		39	45	57	59	59	61	35	38	40	38	39	64	64	45	59
12-Jul	58	55	52	65		60	60	41	39	46	41		37	48	55	59	57	63	39	36	40	39		65	65	48	59
13-Jul	62	56	59	43		45	40	42	39	46	48		39	46	45	43	51	49	34	38	38	49	39	51	49	48	51
14-Jul	54	51	55	60		68	52	41	45	46	47	44	43	48	45	48	54	61	36	43	47	45	45	68	68	48	54
15-Jul	53	36	50	50		51	42	67	60	72	53		50	61	42	43	49	50	38	57	62	50	52	72	51	72	49
16-Jul	47	47	47	51		54	43	48	56	54	59		58	53	44	45	47	53	43	53	53	50		59	54	59	47
17-Jul	57	55	57	60		58	54	47	52	52	52		43	47	58	56	54	59	52	58	51	42	44	60	60	52	58
18-Jul	54	57	59	61		65	57	50	68	56	56		63	44	58	57	58	63	42	57	73	47		68	65	68	58

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
19-Jul	49	58	57	52		64	61	46	53	52	52		56	51	57	59	59	68	49	50	50	51		68	68	56	59
20-Jul	47	52	50	55		60	48	47	55	52	58		55	48	52	47	49	56	51	52		57	31	60	60	58	52
21-Jul	41	49	41	56		53	48	48	54	53	59		59	49	54	48	39	51	48	66	55	55	34	59	56	59	54
22-Jul	51	48	45	54		55	47	67	59	71	52		52	55	48	48	51	57	45	58	62	46	38	71	57	71	51
23-Jul	58	51	57	54		54	48	45	48	51	57		58	56	52	52	48	52	47	43	45	54	46	58	54	58	52
24-Jul	55	58	59	57		55	52	56	54	51	65		64	52	52	55	51	51	54	51	56	61		65	57	65	55
25-Jul	57	51	59	62		58	53	65	67	69	61	61	58	54	62	56	52	57	52	51	63	63	40	69	62	69	62
26-Jul	61	57	58	64		64	54	59	61	61	55	48	55	56	56	55	48	60	50	53	60	54	39	64	64	61	56
27-Jul	63	59	57	56		59	50	58		61	53	53	51	54	56	51	52	61	45	51	55	66		61	61	61	56
28-Jul	60	55	60	57		56	50	52		57	53		48	55	41	58	44	55	39	47	51	51	38	58	57	57	58
29-Jul	60	58	59	58		54	50	55		59	56	52	50	57	46	56	55	53	43	59	65	45	46	59	58	59	56
30-Jul	54	56	55	66		63	54	57		59	55	51		57	59	60	45	61	48	66	54	50		66	66	59	60
31-Jul	54	48	54	53		52	48	62		67	43			55	46	54	46	50	49	53	58	56		67	53	67	54
1-Aug	56	48	54	56		54	48	49		52	46		55	52	43	54	46	55	41	49	51	56		56	56	55	54
2-Aug	54	49	53	56		52	50	54		56	57		52	57	46	50	41	53	49	50	49	56		57	56	57	50
3-Aug	51	51	56	57		58	48	54		58	63		58	57	51	58	42	58	51	51	52	56	41	63	58	63	58
4-Aug	50	52	54	57		56	49	56		60	61		60	51	45	54	51	49	57	51	55	59		61	57	61	54
5-Aug	51	56	55	59		57	50	59	63	66	64		58	60	52		51	56	59	62	70	61		66	59	66	52
6-Aug	55	53	56	55		52	51	61	74	62	62		61	58	51	47	52	55	54	56	70	55		74	55	74	52
7-Aug	59	59	55	43		43	42	53	57	58	54		59	52	45	43	53	39	48	57	59	56	32	59	43	59	53
8-Aug	57	51	52	60		57	56	58	55	61	52		48	55	50	60	52	57	44	73	58	53	38	61	60	61	60
9-Aug	58	54	56	59		56	51	48	48	53	49		43	49	57	56	54	57	42	46	49	43		59	59	53	57
10-Aug	56	53	56	53		50	47	41	41	46	48		45	47	52	51	56	52	46	43	43	51		56	53	48	56
11-Aug	52	55	56	58		55	48	44	43	48			45	50	51	51	53	57	37	42	43	57		58	58	50	53
12-Aug	48	53	57	48		60	53	42	39	45			59	46	50	46	54	57	36	36	39	55		60	60	59	54
13-Aug	47	39	47	41		41	36	48	45	50			61	47	40	45	36	42	52	40	45	58		61	42	61	45
14-Aug	52	44	48	53		51	43	41	49	47			53	50	49	52	46	51	55	41	48	56		53	53	53	52
15-Aug	52	45	51	52		52	47	52	56	54			51	50	52	53	49	49	49	57	54	54		56	52	56	53
16-Aug	55	45	46	49		54	37	51	53	54			53	53	44	49	46	58	43	61	54	57		58	58	54	49
17-Aug	51	44	49	53		54	42	52	57	55			59	51	39		49	56	44	57	65	59		59	56	59	49
18-Aug	51	51	50	59		55	53	63	57	69			61	56	43	63	51	57	45	58	57	55	38	69	59	69	63
19-Aug	42	48	52	52		50	48	46	54	51	55	42	60	50	51	55	48	54	45	49	51	48	40	60	54	60	55
20-Aug	49	52	52	47		48	42	43	47	47	49	56	47	43	55	47	48	51	42	46	45	55		56	51	56	55
21-Aug	46	49	49	54		53	51	39	45	44	40	54	47	45	48	55	44	54	50	46	43	50		55	54	54	55

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
22-Aug	46	43	48	41		40	36	46	60	50	46	56	52	43	39		41	43	43	48	58	53		60	43	60	41
23-Aug	48	53	54	51		49	47	38	42	43	49	59	59	40	54		51	48	42	44	43	52	44	59	51	59	54
24-Aug	45	61	59	56		55	49	47	53	48	43	55	50	41	52		53	55	38	45	50	48		56	56	55	53
25-Aug	42	55	52	50		50	46	43	51	45	45	42	45	43	45		45	49	40	44	52	47		51	50	51	45
26-Aug	37	43	48	41		41	40	42	45	43	47	51	51	39	34		41	42	44	49	44	39		51	42	51	41
27-Aug	40	54	53	39		41	35	56	51	59	36	46	52	46	44		46	43	50	60	52	51		59	43	59	46
28-Aug	55	48	49	52		52	38	47	46	48	47	63	51	44	55		44	55		62	46	48		63	55	63	55
29-Aug	56	54	51	62		58	57	62	54	64	51	68	59	53	49		56	57		57	56	55		68	62	68	56
30-Aug	52	54	54	54		55	49	67	67	68	54	70	55	50	51		50	55		55	67	55		70	55	70	51
31-Aug	49	49	51	55		53	51	46	50	49	51	60	52	48	56		46	54		50	48	51		60	55	60	56
1-Sep	45	47	49	52		50	46	45	47	47	45	55		46	50		43	50		46	43	58		55	52	55	50
2-Sep	47	54	48	50		51	46	48	55	50	49	56		44	49		45	53		57	56	51		56	53	56	49
3-Sep	47	51	48	51		50	48	52	51	56	39	49		43	46		43	52		41	50	40		56	52	56	46
4-Sep	42	41	41	47		44	42	36	37	39	37	39		36	44		38	46		34	35	37		47	47	39	44
5-Sep	45	47	47	51		45	44	28	34	33	37	39		43	41		49	51		30	33	32		51	51	43	49
6-Sep	45	46	48	40		36	42	31	31	32	20	24		39	38		49	41		29	30	28		49	42	39	49
7-Sep	47	47	47	45		43	40	25	26	28	35	33		31	39		44	42		27	24	35		45	45	35	44
8-Sep	33	49	42	35		32	32	39	50	41	47	42		34	38		40	35	36	34	52	46		50	35	50	40
9-Sep	35	31	37	36		36	35	33	39	36	35	50		39	36		30	39	36	34	36	47		50	39	50	36
10-Sep	55	48	48	49		50		36	39	38	38	51		35	54		42	55	40	41	36	41		55	55	51	54
11-Sep	58	58	60	55		52	56	33	40	36	40	45		38	62		56	55	34	35	35	38		62	56	45	62
12-Sep	58	52	52	28		25	38	33	36	36	21	23		44	48		54	35	31	34	34	17		54	38	44	54
13-Sep	48	48	51	33		34	37	30	30	33	25	27		32	43		46	35	22	27	30	30		46	37	33	46
14-Sep	41	49	55	34		33	38	29	28	32	32	28	17	33	42		47	33	20	27	28	27		47	38	33	47
15-Sep	44	49	51	38		35	42	24	26	25	29	32	26	34	46		50	38	25	21	25	26		50	42	34	50
16-Sep	33	48	48	28		27	32	32	26	34	38	38		24	38	29	45	29	32	32	25	32		45	32	38	45
17-Sep	30	43	44	21		25	28	38		42	44	40		31	35	27	38	31	37	32	34	37		44	31	44	38
18-Sep	34	47	52	45		39	48	24		29	32	38		29	46	48	47	42	32	25	25	35		48	48	38	48
19-Sep	44	47	43	40		41	42	28	29	31	27	27		32	42	45	47	38	33	33	28	33		47	42	32	47
20-Sep	45	48	50	41		43	41	43	31	47	28	27		42	47	41	47	44	32	56	41	29	34	47	44	47	47
21-Sep	39	41	41	34		34	37	34	30	38	27	31		33	40	35	37	34	30	30	31	39	38	40	37	38	40
22-Sep	39	38	43	30		32	35	22	27	24	37	46	34	32	31	33	35	33	48	25	27	43	42	46	35	46	35
23-Sep	44	33	46	40		42	45	52	32	55	40	45	52	36	51	46	42	44	50	38	50	51	45	55	45	55	51
24-Sep	50	49	52	51		50	52	42	40	48	47	45	49	45	44	48	48	51	47	38	40	51	46	52	52	49	48

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
25-Sep	47	50	53	48		50	50	52	48	56	59	57	52	46	45	51	49	49	50	48	49	45	50	59	50	59	51
26-Sep	51	49	48	44		47	48	59	54	63	60	53	59	50	45	50	51	47	48	51	55	57	48	63	48	63	51
27-Sep	46	50	51	47		51	51	52	46	57	42	41	41	46	46	53	46	51	37	46	46	45	48	57	51	57	53
28-Sep	42	36	40	34		38	37	36	43	37	40	41	49	28	39	39	34	38	34	43	44	46	44	49	38	49	39
29-Sep	49	41	51	38		41	47	31	39	35	42	43	47	22	42	42	40	40	37	32	36	42	51	47	47	47	42
30-Sep	54	48	51	49		36	54	29	36	33	40	54	36	41	54	53	48	52	36	30	38	46	47	54	54	54	54
1-Oct	57	45	47	47		51	53	44	54	50	53		50	54	51	52	44	54	36	43	49	52	48	54	54	54	52
2-Oct	52	47	48	45		43	51	51	48	54	45		42	53	49	50	39	54	51	50	47	45	50	54	54	54	50
3-Oct	46	30	47	44		42	48	50	50	54	47		55	50	49	46	37	52	49	48	47	44	52	55	52	55	49
4-Oct	45	39	43	41		39	44	52	57	55			52	52	45	43	36	47	47	56	54	50	43	57	47	57	45
5-Oct	46	41	45	40		39	45	47	46	49			43	50		46	36	46	48	46	43	54	44	50	46	50	46
6-Oct	47	47	51	46		40	53	39	42	42			50	43	58	52	41	50	45	40	40	54	53	58	53	50	58
7-Oct	48	52	52	45		41	51	43	37	46			49	46	55	48	38	47	46	42	41	52	52	55	51	49	55
8-Oct	38	45	51	32		27	38	42	49	45			45	35	46	38	42	36	47	45	48	53	45	49	38	49	46
9-Oct	41	34	35	28		27	36	28	32	31	30		36	32	31	35	34	33	46	27	36	44	44	36	36	36	35
10-Oct	50	33	40	30		31	35	38	40	41	35		33	41	36	33	35	37	36	41	39	29	51	41	37	41	36
11-Oct	50	41	48	42		39	49	47	46	54	40		37	42	45	47	45	43	35	40	48	42	44	54	49	54	47
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13-Oct	42	39	42	36		35	42	43	43	45	41		40	42	44	41	34	41	44	45	42	39	43	45	42	45	44
14-Oct	42	43	45	36		37	42	15	49	47	50		44	47	43	38	34	42	44	43	46	44	38	50	42	50	43
15-Oct	42	37	47	31		34	44	50	50	56	56		46	45	42	41	40	42	43	48	49	48	44	56	44	56	42
16-Oct	40	49	54	45		42	53	40	48	35	54		37	44	53	48	46	46	45	43	43	49	45	54	53	54	53
17-Oct	38	40	50	44		45	49	39	44	41	55		54	43	45	41	37	43	42	46	38	50	46	55	49	55	45
18-Oct	34	43	45	46		48	51	54	50	54	55		40	50	40	53	39	51	47	56	53	42	42	55	51	55	53
19-Oct	42	40	42	42		45	47	42	40	44	47		36	41	39	46	42	42	36	43	41	42	43	47	47	47	46
20-Oct	44	25	43	31		34	35	34	36	35	42		46	39	41	37	35	37	34	35	36	41	41	46	37	46	41
21-Oct	41	23	41			39	42	38	38	41	39		44	36	36	41	34	40	35	37	39	48	37	44	42	44	41
22-Oct	44	38	48			38	42	38	40	42	41		41	38	44	39	37	42	35	38	42	44	46	44	42	42	44
23-Oct	43	41	49			40	47	42	50	48	35		35	43	47	44	37	45	30	54	48	41	43	50	47	50	47
24-Oct	43	42	47			44	48	43	49	45	51		41	42	45	44	38	45	35	56	47	48	44	51	48	51	45
25-Oct	38	43	47			43	46	39	44	42	48		38	37	44	43	43	45	36	46	44	44	43	48	46	48	44
26-Oct	37	35	42			35	39	33	38	36	39		38	34	41	36	32	36	36	37	35		42	41	39	39	41
27-Oct	44	45	49			41	46	31	35	33	33		29	33	47	43	41	43	38	29	33		45	47	46	35	47
28-Oct	46	41	47			38	43	42	43	41	42		41	37	50	14	36	45	46	39	41		44	50	45	43	50

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
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30-Oct	46	39	42			44	50	41	42	38	44		48	43	46	45	32	46	38	40	39	45		50	50	48	46
31-Oct	45	47	51			47	48	45	47	47	48		36	50	48	49	44	47	45	46	47	39		50	48	50	49
1-Nov	38	39	42			40	41	36	40	37	43		41	36	42	40	36	40	45	37	38	41		43	41	43	42
2-Nov	46	30	50			33	35	40	41	41	39		37		33	30	31	36	46	41	42	42		41	36	41	33
3-Nov	45	44	44			49	51	28	31	29	34		31	34	48	48	40	53	41	32	31	34		53	53	34	48
4-Nov	44	41	42			38	41	33	34	33	27		26	35	45	39	30	27	33	31	32	26		45	41	35	45
5-Nov	40	32	41			37	41	32	35	30	35		34	39	48	38	29	39	37	32	36	41		48	41	39	48
6-Nov	45	28	47	34		35	40	25	40	31	34		39	41	43	37	32	39	39	34	37	42		43	40	41	43
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9-Nov	44	40	46	37		40	42	39	46	41	44		32	41	49	40	40	37	39	44	47	38		49	42	46	49
10-Nov	48	40	52	39		42	45	39	44	41	45		29	44	47	45	38	44	38	36	42	40		47	45	45	47
11-Nov	43	45	51	30		37	41	37	42	39	35		28	39	50	36	42	39	32	37	40	36		50	41	42	50
12-Nov	41	40	47	24		29	29	31	35	31	35		27	34	40	31	38	29	35	34	35	32		40	29	35	40
13-Nov	37	31	37	27		28	32	29	34	30	30		22	35	29	26	32	30	35	32	33	30		35	32	35	32
14-Nov	37	28	41	31		33	37	28	31	31	31		23	34	40	34	17	33	28	31	30	31		40	37	34	40
15-Nov	45	40	47	42		47	47	35	42	36	42		24	41	46	45		45	30	32	40	42		47	47	42	46
16-Nov	46	43	46	39		45	43	36	38	37	31		25	44	43	43		43	35	36	37	36		45	45	44	43
17-Nov	40	31	48	38		39	43	34	41	35	41		30	41	44	30	25	39	42	40	40	42		44	43	41	44
18-Nov	41	31	44	36		35	44	34	42	36	36		27	43	44	38	26	38	38	30	35	41		44	44	43	44
19-Nov	42	30		26		32	39	35	24	37	43		26	40	44	33	27	33	37	31	31	41		44	39	43	44
20-Nov	44	31		28		33	39	35	41	34	44		26	30	45	33	26	33	38	32	36	40		45	39	44	45
21-Nov	42	34		19		23	33	27	38	32	39		25		38	29	29	30	38	27	34	44		39	33	39	38
22-Nov	44	36		28		42	41	39	44	41	42		23		47	37	31	36	42	38	43	42		47	42	44	47
23-Nov	44	42		40		44	43	46	49	47	45		27		43	42	39	43	42	45	47	38		49	44	49	43
24-Nov	42	40		36		41	41	37	41	38	40		22		42	39	37	40	43	33	38	40		42	41	41	42
25-Nov	41	36		35		36	41	36	41	38	40		20		43	37	31	33	43	33	39	37		43	41	41	43
26-Nov	35	26		26		33	36	32	37	35	36		24		36	33	24	32	41	23	27	39		37	36	37	36
27-Nov	33	27		26		34	32	25	38	27	44		26		39	29	23	32	40	32	35	37		44	34	44	39
28-Nov	38	30		25		31	39	28	35	38	44		25		44	30	27	28	47	32	32	36		44	39	44	44
29-Nov	38	34		32		37	41	34	41	38	43		28		41	33	28	33	43	33	36	35		43	41	43	41
30-Nov	41	28		26		32	39	37	43	40	43		27		40	30	22	31	43	36	40	34		43	39	43	40
1-Dec	39	31		24		24	37	25	36	26	25		15		37	29	28	27	31	28	32	31		37	37	36	37

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Nav-ajo	La Plata	Monte-zuma	Berna-lillo	Berna-lillo	Berna-lillo	Berna-lillo	Dona Ana	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Luna	Rio Arriba	Sand-oval	San Juan	Val-encia	Brew-ster	El Paso	El Paso	Lamp-asas	San Juan	Maxi-mum	Maxi-mum	Maxi-mum	Maxi-mum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	001	013	013	013	015	015	025	029	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0027	0029	1012	0017	0020	0021	1005	3001	0008	0003	0026	1001	0009	0008	0101	0057	0058	9991	0004				
2-Dec	32	23		1		19	35	22	33	22	26		15		37	22	28	12	34	27	30	28		37	35	33	37
3-Dec	22	35		17		25	27	28	16	31	40		23		31	25	21	29	31	27	27	29		40	29	40	31
4-Dec	41	20		20		16	31	19	25	22	15		9		34	29	13	13	28	21	30	18		34	31	25	34
5-Dec	39	27		24		6	37	28	37	33	36		21		30	25	20	31	33	30	34	39		37	37	37	30
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13-Dec	42	42	45	34		39	44	35	25	36	34		19		47	41	28	39	42	38	44	32		47	44	36	47
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21-Dec	33	30	37	31		29	38	38	40	39	41		24		38	35	23	28	40	36	41	36		41	38	41	38
22-Dec	36	38	43	32		36	38	34	36	36	34		21		42	35	35	36	37	33	35	42		42	38	36	42
23-Dec	42	46	44	36		42	44	39	44	40	39		26		46	41	39	41	39	40	41	36		46	44	44	46
24-Dec	41	38	40	34		37	40	34	37	39	41		23		42	35	25	37	42	36	37	39		42	40	41	42
25-Dec	42	36	44	39		41	43	36	44	40	34		19		41	40	34	39	43	34	44	34		44	43	44	41
26-Dec	37	37	39	36		42	41	30	38	34	42		23		43	39	26	39	40	34	40	23		43	42	42	43
27-Dec	39	32	40	32		35	37	32	38	33	15		17		39	35	21	31	37	37	37	32		39	37	38	39
28-Dec	39	28	38	31		36	36	35	40	39	36		20		43	33	24	31	36	35	36	34		43	36	40	43
29-Dec	43	33	41	28		28	37	35	41	38	42		21		43	30	28	29	35	33	38	29		43	37	42	43
30-Dec	43	34	39	21		27	23	27	31	27	21		20		29	21	27	24	14	25	29	30		31	27	31	29
31-Dec	32	31	35	14		22	20	17	22	18	28		17		32	24	26	20	16	19	19	28		32	22	28	32

APPENDIX B

Observed MDA8 Ozone Concentrations during 2016. Red indicates ozone ≥71 ppb and yellow indicates ozone between 67 and 71 ppb.

Observed MDA8 Ozone Concentrations during 2016. Red indicates ozone ≥71 ppb and yellow indicates ozone between 67 and 71 ppb.

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
1-Jan	29	40	46	29	40	33	25	26	33		38	34	34	35	32	21	26	25	36		40	40	38	35
2-Jan	31	35	48	34	38	37	29	27	37		30	40	33	35	34	28	27	27	38		40	38	37	40
3-Jan	32	35	48	28	37	28	35	32	41		40	40	30	33	29	21	34	31	41		41	37	41	40
4-Jan	32	36	47	30	34	41	31	27	40		33	41	38	35	27	26	29	29	39		41	41	40	41
5-Jan		37	40	25	30	32	27	14	29		22	41	30	32	28	26	15	21	28		41	32	29	41
6-Jan		36	41	31	40	37	39	40	39		28	42	35	18	33	40	34	40	20		42	40	40	42
7-Jan		37	43	33	38	39	40	41	43		38	44	36	33	37	43	38	41	32		44	39	43	44
8-Jan		39	44	37	45	44	43	43	44		38	46	40	32	44	45	37	42	21		46	45	44	46
9-Jan		38	45	36	43	41	40	41	26		26	43	38	31	40	43	36	39	34		43	43	41	43
10-Jan		41	44	35	41	42	34	38	28		33	46	40	33	39	38	33	37	25		46	42	38	46
11-Jan	37	35	43		40	41	40	40	40		36	45	38	29	37	39	35	37	42		45	41	40	45
12-Jan	41	32	39	31	29	40	34	36	37		39	44	35	32	25	40	29	23	32		44	40	39	44
13-Jan	37	37	46	34	33	43	37	38	39		37	49	37	28	33	39	24	28	37		49	43	39	49
14-Jan	41	42	50	38	45	46	42	44	43		40	47	43	33	37	46	34	43	41		47	46	44	47
15-Jan	40	37	46	38	41	41	44	44	46		41	47	38	31	38	43	39	43	41		47	41	46	47
16-Jan	41	38	50	43	47	48	43	42	44		35	49	44	38	44	46	37	38	34		49	48	44	49
17-Jan	39	36	49	40	45	46	41	40	42		42	45	41	38	43	42	35	37	19		46	46	42	45
18-Jan	37	40	47	36	36	42	38	39	25		31	44	31	35	35	41	32	36	26		44	42	39	44
19-Jan	41	36	42	38	39	42	40	42	40		40	47	39	31	39	41	33	37	35		47	42	42	47
20-Jan	41	44	48	40	45	44	43	41	43		34	45	42	40	43	43	36	41	38		45	45	43	45
21-Jan	42	38	46	39	44	45	44	44	43		41	46	42	32	43	46	40	41	40		46	45	44	46
22-Jan	40	41	48	32	36	45	38	40	41		39	47	36	36	38	42	34	33	39		47	45	41	47
23-Jan	46	44	55	27	38	43	38	43	39		39	49	32	41	34	43	34	34	37		49	43	43	49
24-Jan	46	45	45	45	51	49	45	44	47		44	47	45	39	46	52	38	47	40		51	51	47	47
25-Jan	42	40	45	40	46	46	46	45	44		43	44	42	32	44	43	38	43	41		46	46	46	44
26-Jan	41	41	45	35	35	41	38	39	30		34	47	36	36	38	36	35	36	38		47	41	39	47
27-Jan	40	39	45	36	35	44	37	40	40		38	48	40	33	37	40	37		42		48	44	40	48
28-Jan	43	43	46	34	36	42	36	40	41		38	49	34	32	37	40	36		41		49	42	41	49
29-Jan	41	41	46	36	40	41	36	40	45		41	48	40	29	41	41	31	31	40		48	41	45	48
30-Jan	45	40	45	39	45	42	42	43	47		42	44	39	34	41	44	35	41	35		47	45	47	44

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
31-Jan	42	35	43	44	49	46	43	44	46		42	46	44	38	45	46	39	42	39		49	49	46	46
1-Feb	43	44	46	41	46	45	43	44	46		43	48	44	39	44	43	39	42	36		48	46	46	48
2-Feb	41	41	45	37	43	41	37	44	44		40	42	40	39	41		40	41	40		44	43	44	42
3-Feb	41	38	45	38	44	42	39	43	43		41	43	40	39	42	45	36	40	41		44	44	43	43
4-Feb	41	39	45	38	39	44	40	38	42		42	46	40	33	41	45	39	38	41		46	44	42	46
5-Feb	42	38	46	40	44	43	44	43	45		42	47	41	35	43	45	40	40	41		47	44	45	47
6-Feb	42	44	48	43	46	46	42	42	45		43	48	44	33	42	44	34	38	44		48	46	45	48
7-Feb	40	45	50	42	47	45	41	42	45		43	51	42	30	43	40	33	36	44		51	47	45	51
8-Feb	40	53	49	42	45	45	41	39	47		43	50	44	35	42	43	35	42	43		50	45	47	50
9-Feb	40	53	55	41	44	44	42	38	48		46	51	41	35	43	43	39	40	43		51	44	48	51
10-Feb	44	46	57	39	44	45	42	40	47		42	56	42	41	41	41	36	37	44		56	45	47	56
11-Feb	42	51	50	42	42	43	43	46	47		45	51	43	35	42	46	40	34	43		51	43	47	51
12-Feb	40	49	52	43	42	45	41	47	44		53	50	42	38	43	48	35	39	44		53	45	53	50
13-Feb	45	51	52	37	47	45	46	45	64		52	48	41	45	42	50	39	43	50		64	47	64	48
14-Feb	41	42	47	41	47	42	46	46	46		44	45	42	35	44	50	41	43	40		47	47	46	45
15-Feb	41	39	44	38	42	39	43	42	47		43	42	38	37	41	45	38	39	42		47	42	47	42
16-Feb	39	41	43	35	38	39	39	41	42		35	42	29	30	38	46	36	37	41		42	39	42	42
17-Feb	42		48	33	41	44	45	60	56		46	43	36	38	39	50	42	42	44		60	44	60	43
18-Feb	42	28	51	40	47	43	51	53	58		48	44	41	35	43	54	48	48	42		58	47	58	44
19-Feb	38	42	48	34	35	40	48	47	48		38	39	37	36	36	47	41	45	42		48	40	48	39
20-Feb	40	46	50	39	45	47	47	46	51		44	46	39	40	42	47	43	41	50		51	47	51	46
21-Feb	44	49	49	46	49	46	42	45	44		42	47	44	43	46	34	41	41	44		49	49	45	47
22-Feb	44	40	48	43	49	46	51	52	43		34	48	45	41	44	44	46	49	41		52	49	52	48
23-Feb	46	45	44	37	42	34	44	49	32		37	45	37	38	43	49	44	43	35		49	43	49	45
24-Feb	48	44	46	33	44	47	40	45	45		44	49	42	34	44	43	43	40	45		49	47	45	49
25-Feb	49	45	45	45	46	44	44	45	43		40	49	45	20	47	45	45	43	43		49	47	45	49
26-Feb	47	49	47	43	46	46	51	53	51		45	50	45	41	47	51	48	51	47		53	47	53	50
27-Feb	49	46	48	45	49	49	50	51	53		50	49	44	42	50	50	45	46	49		53	50	53	49
28-Feb	45	42	45	45	46	46	53	53	49		45	45	44	36	49	52	50	48	43		53	49	53	45
29-Feb	44	44	45	39	42	44	48	49	52		47	47	41	37	44	50	41	44	46		52	44	52	47
1-Mar	44	38	38	39	40	42	46	48	50		46	45	37	36	42	47	42	43	46		50	42	50	45
2-Mar	53	48	50	43	44	47	47	50	51		44	49	46	41	47	49	42	46	44		51	47	51	49
3-Mar	51	49	52	48	48	52	48	55	52		48	54	45	41	49	54	43	45	49		55	52	55	54
4-Mar	52	50	53	53	50	53	50	52	55		46	52	49	43	49	52	46	47	49		55	53	55	52

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
5-Mar	50	51	50	49	52	52	50	51	45		57	54	50	47	51	52	45	46	51		57	52	57	54
6-Mar	42	40	47	41	43	42	47	49	39		43	43	40	38	42	44	42	45	38		49	43	49	43
7-Mar	50	47	47	49	47	49	41	44	47		41	50	49	44	47	49	40	41	40		50	49	47	50
8-Mar	48	48	49	45	45	46	48	49	48		47	49	45	44	47	47	45	46	42		49	47	49	49
9-Mar	47	42	50	48	47	49	45	47	46		43	49	47	44	51	46	43	42	42		51	51	47	49
10-Mar	49	48	44	49	51	51	49	51	48		45	41	51	43	52	47	47	45	47		52	52	51	51
11-Mar	47	48	46	45	48	47	57	62	53		53	44	45	46	49	46	52	54	52		62	49	62	46
12-Mar	53	49	53	50	52	53	52	51	55		51	51	51	51	56	48	52	55	40		56	56	55	51
13-Mar	48	47	45	49	49	49	50	51	53		48	47	47	43	48	49	47	47	47		53	49	53	47
14-Mar	46	47	47	46	47	47	46	48	48		45	48	46	44	47	56	42	45	44		48	47	48	48
15-Mar	50	51	50	48	49	49	49	52	52		50	52	48	48	51	49	49	47	50		52	51	52	52
16-Mar	47	51	48	47	47	48	49	50	56		52	51	47	46	49	52	45	44	50		56	49	56	51
17-Mar	47	37	46	46	46	47	48	50	51		49	49	45	43	47	50	45	45	51		51	47	51	49
18-Mar	48	44	48	44	45	45	49	51	44		42	48	44	41	49	52	45	46	39		51	49	51	48
19-Mar	43	43	46	44	46	45	41	45	47		42	44	43	41	45	41	42	40	44		47	46	47	44
20-Mar	50	46	47	45	46	45	42	49	46		48	48	44	44	44	41	44	42	46		49	46	49	48
21-Mar	53	53	55	53	52	54	49	51	50		45	56	53	52	51	45	46	48	46		56	54	51	56
22-Mar	53	52	54	52	49	51	55	56	58		51	52	49	51	50	52	49	55	50		58	52	58	52
23-Mar	43	40	44	44	45	44	57	57	55		50	43	42	39	48	55		53	53		57	48	57	43
24-Mar	50	48	46	48	48	49	45	48	48		43	51	47	46	50	47	49	43	46		51	50	48	51
25-Mar	51	50	53	44	50		52	56	55		52	51	47	48	51	47	51	51	50		56	51	56	51
26-Mar	55	54	52	51	53		53	55	56		51	55	50	51	53	52	50	50	48		56	53	56	55
27-Mar	56	56	52	56	56	50	53	58	47		45	54	52	51	55	41	49	50	48		58	56	58	54
28-Mar	47	50	51	49	49	50	47	48	53		47	50	48	46	49	48	43	45	45		53	50	53	50
29-Mar	51	48	50	51	48	51	48	50	53		51	48	50	48	48	53	45	46	51		53	51	53	50
30-Mar	51	48	47	50	52	51	47	46	45		45	50	51	45	53	58	43	49	48		53	53	47	51
31-Mar	47	47	46	49	51	49	48	49	50		49	49	47	43	52	57	49	47	51		52	52	50	49
1-Apr	44	49	47	46	46	44	43	50	33		38	47	46	47	46	48	48	42	45		50	46	50	47
2-Apr	49	52	50	51	51	50	47	50	50		40	46	49	46	52	46	46	44	49		52	52	50	49
3-Apr	47	47	44	47	47	46	51	50	43		44	50	45	42	48	51	50	46	50		51	48	51	50
4-Apr	56	47	44	47	43	47	55	56	54		45	46	47	41	47	55	53	51	56		56	47	56	47
5-Apr	55	53	52	54	50	53	58	59	58		51	54	52	51	57	55	54	55	55		59	57	59	54
6-Apr	53	50	51	50	51	48	54	62	52		49	53	49	47	49	55	55	51	51		62	51	62	53
7-Apr	48	54	48	50	49	50	51	42	48		49	50	47	50	49	50	39	47	44		51	50	51	50

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
8-Apr	46	45	46	44	41	43	44	50	54		48	41	41	40	45	47	48	41	49		54	45	54	41
9-Apr	50	49	48	51	49	50	52	51	55		55	52	50	48	51	47	50	47	56		55	51	55	52
10-Apr	43	54	49	54	53	54	45	46	49		47	53	53	48	54	44	43	42	51		54	54	49	53
11-Apr	45	46	43	50	46	50	49	48	45		43	45	48	42	50	49	46	45	29		50	50	49	48
12-Apr	50	48	47	45	43	45	44	44	27		28	44	43	47	47	36	39	40	41		47	47	44	47
13-Apr	48	49	47	49	46	49	53	52	52		48	49	47	45	49	51	52	49	46		53	49	53	49
14-Apr	53	52	51	55	52	54	55	54	58		51	50	54	48	55	50	51	51	57		58	55	58	54
15-Apr	55	55	53	53	53	53	52	53	53	53	51	54	50	51	56	55	49	52	43		56	56	53	54
16-Apr	42	64	62	49	47	49	52	53	63	64	59	59	49	44	48	55	49	49	41		64	49	64	59
17-Apr	39	48	42	44	41	43	51	52	46	47	47	42	40	41	45	57	52	50	32		52	45	52	42
18-Apr	53	45	46	38	36	40	47	54	46	46	46	39	39	37	43	32	48	47	47		54	43	54	39
19-Apr	55	42	51	52	49	51	56	56	49	51	47	55	49	47	53	39	56	51	34		56	53	56	55
20-Apr	57	50	53	50	49	53	59	59	59	64	53	55	49	50	53	53	54	55	52		64	53	64	55
21-Apr	58	59	56	59	53	56	59	67	53	53	57	55	53	55	58	51	54	53	56		67	59	67	55
22-Apr	57	59	59	57	54	59	57	57	62	59	60	57	58	55	56	53	55	52	62		62	59	62	58
23-Apr	56	55	65	53	49	53	55	50	56	57	57	53	53	58	53	57	51	49	61		58	53	57	58
24-Apr	63	58	59	64	62	61	53	51	53	57	52	61	60	57	64	50	47	48	74		64	64	57	61
25-Apr	61	62	64	59	56	59	58	56	55	60	57	60	56	59	57	52	50	53	61		60	59	60	60
26-Apr	52	53	53	55	52	46	61	61	60	60	59	56	54	50	55	58	56	56	57		61	55	61	56
27-Apr	54	50	47	47	45	48	57	58	60	64	59	49	47	44	49	60	55	52	50		64	49	64	49
28-Apr	60	60	59	59	57	58	52	50	48	51	56	58	58	53	60	56	50	53	56		60	60	56	58
29-Apr	49	63	60	58	50	57	62	60	63	63	62	60	58	57	56	59	59	56	36		63	58	63	60
30-Apr	51	52	48	48	45	47	58	59	59	61	56	49	45	46	48	60	57	54	42		61	48	61	49
1-May	57	46	46	45	40	43	42	44	33	33	35	42	45	37	44	53	39	39	35		45	45	44	45
2-May	57	54	51	56	52	56	47	48	44	49	47	48	53	52	54	37	43	42	52		56	56	49	53
3-May	60	61	49	57	54	54	53	60	58	59	54	53	52	56	61	44	51	49	56		61	61	60	56
4-May	59	63	61	59	55	61	63	66	63	69	59	56	60	57	61	61	59	58	50		69	61	69	60
5-May	61	64	62	62	59	62	61	61	64	61	58	60	62	57	61	61	55	55	65		64	62	64	62
6-May	54	62	58	60	58	58	61	60	57	53	57	62	59	53	60	57	52	54	57		62	60	61	62
7-May	51	62	57	60	58	58	66	67	51	65	49	57	58	55	61	51	60	62	57		67	61	67	58
8-May	53	56	54	57	54	56	63	62	59	64	60	56	56	53	56	54	59	57	61		64	57	64	56
9-May	50	49	50	47	46	48	55	53	53	55	55	48	46	45	51	60	49	51	53		55	51	55	48
10-May	52	54	52	56	52	55	59	60	60	70	63	56	53	51	56	58	56	55	58		70	56	70	56
11-May	55	49	55	55	52	55	63	63	57	68	58	56	54	52	55	54	57	57	55		68	55	68	56

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
12-May	56	66	61	64	59	60	54	61	49	50	50	61	56	61	59	42	51	50	54		64	64	61	61
13-May	60	61	60	60	55	57	64	71	54	54	52	62	57	58	60	51	53	58	61		71	60	71	62
14-May	53	62	62	54	50	53	55	59	47	52	42	52	53	54	50	57	55	52	45		59	54	59	54
15-May	58	51	51	53	50	52	54	51	43	54	37	55	52	48	53	55	47	47	36		55	53	54	55
16-May	55	59	56	55	55	56	37	39	36	43	45	56	55	52	60	45	34	39	44		60	60	45	56
17-May	53	59	55	39	36	39	39	49	24	27	31	44	44	53	40	50	44	44	35		53	40	49	53
18-May	58	41	41	35	36	39	31	37	30	30	34	40	36	38	42	28	34	35	50		42	42	37	40
19-May	56	56	56	44	50	53	52	58	49	46	43	53	50	55	53	36	56	56	45		58	53	58	55
20-May	57	63	60	57	57	52	55	56	55	54	58	59	59	55	59	46	52	55	64		59	59	58	59
21-May	57	67	61	58	60	59	53	56	53	50	50	64	61	58	61	49	52	50	45		64	61	56	64
22-May	47	54	57	56	55	57	52	54	56	66	58	55	57	49	59	51	51	54			66	59	66	57
23-May	59	67	66	52	53	54	50	53	52	63	56	49	52	58	58	49	50	48			63	58	63	58
24-May	59	63	64	55	58	58	56	60	58	69	57	60	57	55	61	42	56	56	49		69	61	69	60
25-May	54	75	67	60	57	60	50	50	46	50	49	64	61	65	60	33	46	52	63		65	60	50	65
26-May	61	67	66	62	62	65	54	57	54	62	53	65	64	64	67	51	54	59	59		67	67	62	65
27-May	56	59	58	57	58	58	60	63	58	69	61	61	59	56	64	65	62	60	64		69	64	69	61
28-May	63	63	55	58	57	60	67	66	63	65	69	54	59	55	60	53	61	63	62		69	60	69	59
29-May	58	72	67	55	53	53	47	51	41	43	48	63	57	65	57	41	50	46	57		65	57	51	65
30-May	49	63	56	54	51	53	37	41	50	49	42	54	55	53	52	37	42	40	52		55	54	50	55
31-May	54	61	55	52	54	53	47	48	46	50	52	53	52	55	52	42	44	46	55		55	54	52	55
1-Jun	53	56	55	56	54	56	46	53	50	53	51	48	60	54	55	52	50	47	46	45	60	56	53	60
2-Jun	56	57	52	58	53	55	55	61	49	51	50	52	54	54	58	55	68	57	46	49	61	58	61	54
3-Jun	49	52	50	51	50	55	55	67	54	55	55	51	50	49	56	53	55	52	45	49	67	56	67	51
4-Jun	48	43	48	56	53	53	52	60	50	51	50	37	56	40	57	49	48	50	52	28	60	57	60	56
5-Jun	56	56	54	54	50	53	57	65	54	61	55	49	56	55	54	55	52	54	60	47	65	54	65	56
6-Jun	67	57	61	61	56	61	64	79	63	62	63	50	61	54	61	61	55	63	56	55	79	61	79	61
7-Jun	54	59	57	58	54	60	69	64	61	62	64	56	60	49	58	64	53	60	57	52	69	60	69	60
8-Jun	59	57	54	56	52	58	55	55	65	66	66	59	60	56	56	60	54	52	64	53	66	58	66	60
9-Jun	58	54	53	54	48	52	57	58	57	56	56	51	52	52	56	49	55	51	55	50	58	56	58	52
10-Jun	54	50	48	49	49	48	56	57	56	60	49	44	46	47	54	46	59	56	55	42	60	54	60	47
11-Jun	52	56	48	50	47	52	58	59	56	57	51	48	52	50	53	50	55	54	46	48	59	53	59	52
12-Jun	58	63	54	55	52	54	59	60	58	60	58	55	52	56	57	50	55	53	59	44	60	57	60	56
13-Jun	53	57	50	55	48	56	51	53	60	60	65	56	58	48	53	47	43	50	45	45	65	56	65	58
14-Jun	63	62	57	60	54	61	53	54	55	60	52	56	59	52	62	46	46	48	51	50	62	62	60	59

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
15-Jun	56	69	66	61	59	63	54	52	55	56	55	61	64	58	63	45	49	47	59	60	64	63	56	64
16-Jun	55	71	54	55	50	57	52	54	51	57	65	60	57	56	57	44	45	48	63	49	65	57	65	60
17-Jun	52	66	55	60	54	57	60	61	56	51	59	55	55	53	57	48	57	54	62	49	61	60	61	55
18-Jun	58	71	69	69	66	70	55	68	62	60	61	56	67	64	69	50	60	49	47	49	70	70	68	67
19-Jun	55	62	57	62	59	60	52	63	52	53	53	57	59	62	65	42	46	49	49	48	65	65	63	62
20-Jun	55	54	53	59	54	58	54	59	51	54	52	48	60	52	56	40	48	50	50	44	60	59	59	60
21-Jun	57	61	62	58	53	59	55	70	47	45	33	49	65	56	57	30	52	56	47	56	70	59	70	65
22-Jun	55	59	64	62	57	63	58	59	44	48	43	57	63	58	61	33	59	53	48	55	63	63	59	63
23-Jun	54	48	63	65	59	66	66	65	45	50	48	57	62	56	63	41	62	77	48	54	66	66	66	62
24-Jun	49	58	55	59	57	62	59	69	50	56	53	56	59	56	56	45	61	63	51	50	69	62	69	59
25-Jun	56	59	59	54	53	54	56	61	49	54	43	53	53	57	54	45	69	56	45	51	61	54	61	57
26-Jun	52	59	57	55	52	53	46	59	47	51	52	50	55	52	58	40	51	48	37	55	59	58	59	55
27-Jun	55	60	57	60	52	57	51	54	30	42	40	51	60	59	56	32	45	47		51	60	60	54	60
28-Jun	49	52	53	44	40	44	34	37	38	38	40	47	46	47	42	39	29	33		48	47	44	40	47
29-Jun	48	49	52	48	42	51	41	49	52	54	52	40	53	43	44	40	37	38		40	54	51	54	53
30-Jun	45	50	53	50	49	39	48	57	55	57	57	38	49	48	51	48	43	45		43	57	51	57	49
1-Jul	41	38	41	40	41	39	46	47	53	48	53	38	42	34	43	45	43	44		39	53	43	53	42
2-Jul	49	48	50	52	52	51	57	59	48	53	52	51	52	45	55	52	41	52		46	59	55	59	52
3-Jul	54	58	61	54	53	54	55	58	54	56	58	63	54	57	57	52	47	51		58	63	57	58	63
4-Jul	45	58	54	54	51	51	56	57	51	53	58	54	50	52	53	51	59	53		51	58	54	58	54
5-Jul	48	55	52	50	46	49	54	55	52	53	59	48	51	51	50	51	62	48		48	59	50	59	51
6-Jul	45	48	47	50	46	49	55	53	48	52	52	51	50	48	51	43	50	47	52	52	55	51	55	51
7-Jul	47	38	51	52	51	53	55	52	52	54	53	47	52	47	54	45	50	48		49	55	54	55	52
8-Jul	46	51	45	52	48	50	60	55	53	57	63	56	48	54	53	49	55	51		39	63	53	63	56
9-Jul	48	57	54	57	52	52	58	56	62	60	55	58	54	59	57	51	64	53		49	62	57	62	59
10-Jul	50	59	54	51	46	50	54	52	53	54	53	53	51	52	52	50	52	45		55	54	52	54	53
11-Jul	45	55	58	45	40	43	52	48	50	51	54	46	45	48	48	49	41	45	56	57	54	48	54	48
12-Jul	52	60	58	46	41	48	48	46	46	50	49	56	48	59	45	42	42	40	58	52	59	48	50	59
13-Jul	52	57	55	53	52	49	49	51	48	47	53	59	51	56	54	40	51	42	61	56	59	54	53	59
14-Jul	49	61	58	57	56	56	53	52	51	50	47	62	57	60	58	44	48	43	58	54	62	58	53	62
15-Jul	46	66	61	67	58	61	51	61	54	57	57	59	60	61	58	43	46	46	58	57	67	67	61	61
16-Jul	43	61	59	52	47	49	68	65	58	58	48	48	51	53	49	38	55	67	53	55	68	52	68	53
17-Jul	42	48	44	44	44	41	60	56	52	52	44	45	42	48	48	39	56	53	49	45	60	48	60	48
18-Jul	46	59	52	54	48	51	60	61	47	50	44	45	51	48	53	36	57	60	42	34	61	54	61	51

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
19-Jul	43	61	58	63	53	59	59	70	46	47	47	43	61	61	56	39	54	56	46	39	70	63	70	61
20-Jul	60	68	60	60	55	60	54	61	47	48	42	53	59	65	61	40	41	49	45	44	65	61	61	65
21-Jul	55	68	62	62	57	61	44	55	48	51	48	56	62	65	61	45	39	41	52	52	65	62	55	65
22-Jul	58	68	64	65	59	64	48	62	49	53	51	60	62	69	63	40	44	44	51	48	69	65	62	69
23-Jul	55	48	51	60	60	58	55	69	55	60	46	53	57	53	64	39	47	51	54	48	69	64	69	57
24-Jul	54	48	49	65	59	61	51	64	52	53	48	49	60	56	62	37	48	49	50	46	65	65	64	60
25-Jul	56	54	53	70	63	60	50	54	48	50	50	49	63	60	65	43	47	46	47	49	70	70	54	63
26-Jul	56	52	51	62	62	59	50	66	51		54	51	58	57	63	47	47	47	65	44	66	63	66	58
27-Jul	54	56	52	68	66	63	58	60	63		61	49	58	61	66	52	52	52	53	50	68	68	63	61
28-Jul	52	41	58	65	63	61	63	66	63		62	54	58	56	64	43	58	56	61	50	66	65	66	58
29-Jul	54	57	56	54	55	54	51	53	52		50	56	57	60	54	39	46	47	54	52	60	55	53	60
30-Jul	55	58	56	56	54	56	49	56	53		45	51	59	58	53	44	47	47	51	48	59	56	56	59
31-Jul	55	64	61	64	60	60	57	57	51		47	57	62	62	62	45	48	53	49	51	64	64	57	62
1-Aug	57	49	55	64	59	60	64	50	48		50	46	58	59	63	42	48	59	51	57	64	64	64	59
2-Aug	54	55	56	60	54	55	59	54	53	49	51	48	58	55	54	38	53	58	47	48	60	60	59	58
3-Aug	53	61	66	49	45	49	65	49	52	49	47	40	51	64	49	39	56	59	53	51	65	49	65	64
4-Aug	58	49	53	50	49	50	68	58	56	52	55	40	53	51	50	40	63	63	50	44	68	50	68	53
5-Aug	48	43	50	53	52	53	66	58	56	53	52	39	54	43	54	41	57	65	51	49	66	54	66	54
6-Aug	47	60	56	59	56	61	60	67	51	50	50	42	59	63	57	38	57	55	49	44	67	61	67	63
7-Aug	53	58	57	63	61	64	55	56	49	52	38	47	62	58	61	31	48	53	50	46	64	64	56	62
8-Aug	55	62	57	54	51	57	64	64	50	50	44	48	55	59	56	32	54	68	41	47	64	57	64	59
9-Aug	44	56	53	56	50	58	57	53	51	49	49	46	56	57	56	33	51	52	53	45	58	58	57	57
10-Aug	48	43	50	53	49	53	62	46	53	46	48	42	56	57	49	35	52	57	53	45	62	53	62	57
11-Aug	58	51	50	50	50	54	54	52	40	41	52	52	50	48	52	40	54	49	54	48	54	54	54	52
12-Aug	53	41	54	56	56	55	48	54	49	52	54	56	52	52	58	42	52	47	56	46	58	58	54	56
13-Aug	55	52	51	56	57	57	48	49	48	52	58	42	55	55	56	51	44	48	54	48	58	57	58	55
14-Aug	55	57	58	56	55	56	50	54	50	51	45	48	54	56	57	47	49	49	47	47	57	57	54	56
15-Aug	55	57	56	62	57	62	61	64	55	57	52	47	56	57	58	52	52	54	52	47	64	62	64	57
16-Aug	53	54	57	55	55	56	59	64	58	58	57	50	49	53	56	52	55	54	52	49	64	56	64	53
17-Aug	53	56	53	55	53	58	54	56	52	52	50	43	58	58	54	36	47	47	49	48	58	58	56	58
18-Aug	52	54	52	51	51	56	54	65	49	46	38	46	53	50	54	25	54	52	46	43	65	56	65	53
19-Aug	51	51	53	53	52	54	60	56	47	42	42	43	52	55	52	28	58	58	44	51	60	54	60	55
20-Aug	54	57	50	60	54	58	48	47	51	49	45	41	56	53	56	30	41	42	37	44	60	60	51	56
21-Aug	54	55	53	51	51	52	45	49	43	46	51	45	53	51	48	34	42	42	49	49	53	52	51	53

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
22-Aug	56	52	51	53	50	54	71	61	48	44	40	48	53	50	51	34	44	66	47	45	71	54	71	53
23-Aug	47	48	51	50	44	49	57	47	40	39	41	48	51	48	51	38	46	54	45	36	57	51	57	51
24-Aug	54	32	50	51	48	52	55	51	42	40	39	41	49	47	50	45	46	47	50	44	55	52	55	49
25-Aug	50	43	55	58	52	56	56	63	39	39	41	43	52	53	53	42	47	54	47	51	63	58	63	53
26-Aug	49	61	56	49	46	51	58	63	57	47	44	49	49	53	48	40	45	53	44	46	63	51	63	53
27-Aug	45	53	50	48	47	49	60	55	51	44	45	43	49	46	48	32	42	58	48	46	60	49	60	49
28-Aug	50	54	45	48	46	49	54	59	48	44	46	43	46	48	47	35	53	49	44	45	59	49	59	48
29-Aug	50	49	47	50	44	51	46	48	50	50	38	46	47	50	47	38	41	41	39	46	51	51	50	50
30-Aug	48	50	51	42	42	42	39	37	37	36	32	44	46	51	45	36	32	35	38	44	51	45	39	51
31-Aug	48	52	49	46	42	45	39	45	35	34	34	40	46	48	44	36	35	35	38	46	48	46	45	48
1-Sep	43	47	51	54	46	50	44	49	44	42	42	36	44	45	47	37	36	41	40	46	54	54	49	45
2-Sep	44	46	47	43	39	46	50	60	53	49	51	35	45	49	40	40	40	47	40	40	60	46	60	49
3-Sep	44	47	48	45	43	48	58	49	46	43	46	35	47	46	44	44	40	51	46	36	58	48	58	47
4-Sep	39	44	42	42	42	46	58	44	47	40	41	42	44	39	43	44	40	52	44	38	58	46	58	44
5-Sep	40	46	43	42	42	46	45	46	42	39	34	41	43	42	43	33	36	39	38	39	46	46	46	43
6-Sep	35	46	40	42	41	47	37	35	31	26	30	39	44	40	42	27	28	29	32	42	47	47	37	44
7-Sep	37	46	47	31	30	35	35	33	28	23	32	29	32	38	31	33	24	31	29	46	38	35	35	38
8-Sep	39	48	47	46	41	51	37	35	34	39	34	50	48	42	44	30	32	32	31	43	51	51	39	50
9-Sep	45	42	47	43	44	45	50	47	49	46	48	46	44	40	49	32	51	48	46	42	50	49	50	46
10-Sep	45	51	51	40	39	42	39	39	32	30	37	42	44	43	41	26	33	34	40	46	44	42	39	44
11-Sep	45	48	47	45	41	48	61	68	38	34	36	46	45	48	43	32	46	59	38	44	68	48	68	48
12-Sep	38	43	40	40	37	44	48	43	45	41	39	37	40	37	39	32	42	41	42	38	48	44	48	40
13-Sep	34	41	38	42	40	45	43	40	49	45	45	39	42	36	41	38	41	38	30	30	49	45	49	42
14-Sep	37	35	47	34	33	38	51	47	43	42	42	35	37	33	34	34	38	45	29	35	51	38	51	37
15-Sep	37	49	52	40	37	43	51	45	39	39	35	38	41	41	36	34	38	44	39	45	51	43	51	41
16-Sep	45	49	48	41	40	42	39	36	42	41		39	43	48	40	35	37	31	44	46	48	42	42	48
17-Sep	45	50	49	48	44	49	50	47	42	41		47	46	48	45	32	68	48	37	47	50	49	50	48
18-Sep	50	51	52	48	46	51	45	45	39	45		54	48	48	51	30	53	42	43	48	54	51	45	54
19-Sep	44	57	54	55	52	59	51	47	43	47	45	52	54	52	55	29	50	47	50	48	59	59	51	54
20-Sep	33	46	45	39	39	35	50	39	42	46	34	46	42	47	41	32	30	42	43	35	50	41	50	47
21-Sep	36	37	36	42	40	40	47	38	40	44	37	32	44	37	41	38	37	42	40	35	47	42	47	44
22-Sep	42	26	43	34	34	33	45	39	44	46	42	33	38	35	34	44	33	39	44	43	46	34	46	38
23-Sep	50	45	49	41	39	42	42	41	44	37	44	42	44	45	43	42	35	39	43	45	45	43	44	45
24-Sep	43	40	42	39	39	40	46	44	42	42	44	46	40	39	42	36	42	41	47	37	46	42	46	46

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
25-Sep	42	47	43	42	40	40	43	45	32	35	34	44	41	46	42	34	43	42	38	40	46	42	45	46
26-Sep	44	35	46	44	42	45	40	38	31	39	37	38	41	47	44	34	34	36	43	39	47	45	40	47
27-Sep	38	51	54	46	44	46	43	51	54	48	55	40	47	48	46	36	44	42	47	44	55	46	55	48
28-Sep	32	45	50	49	42	48	39	47	41	48	53	41	48	43	43	29	32	37	49	46	53	49	53	48
29-Sep	31	35	38	49	39	45	55	55	54	58	43	41	50	27	42	38	47	50	38	31	58	49	58	50
30-Sep	34	45	40	40	40	36	57	48	49	40	45	37	38	34	44	39	39	49	46	27	57	44	57	38
1-Oct	39	43	42	40		38	45	44	50		42	43	40	39	40	37	40	39	45	29	50	40	50	43
2-Oct	33	45	44	42		41	47	43	51		47	41	42	40	42	34	37	38	41	39	51	42	51	42
3-Oct	53	48	54	46	43	47	38	33	39		37	48	45	46	48	33	28	40	42	49	48	48	39	48
4-Oct	46	49	46	47	44	45	49	48	48		45	47	46	42	49	31	38	42	47	42	49	49	49	47
5-Oct	49	48	53	44	41	45	45	44	50		46	51	47	46	42	33		38	50	48	51	45	50	51
6-Oct	54	47	49	51	49	52	44	42	50		41	52	51	47	51	34		36	46	43	52	52	50	52
7-Oct	47	48	53	45	36	46	43	42	40		36	44	49	45	47	28	34	37	45	43	49	47	43	49
8-Oct	41	43	48	26	31	30	32	33	30		35	37	30	40	37	27	27	28	44		40	37	35	40
9-Oct	41	32	42	37	36	39	35	38	40		40	35	38	34	36	40	28	32	32		40	39	40	38
10-Oct	34	36	44	37	34	38	43	54	40		37	40	39	41	40	38	36	46	39		54	40	54	41
11-Oct	33	37	43	36	31	36	39	37	40		38	36	37	35	33	33	31	33	37		40	36	40	37
12-Oct	36	39	45	38	35	39	41	37	42		33	41	37	36	37	35	36	33	28		42	39	42	41
13-Oct	41	43	46	35	34	37	56	54	36		29	42	37	38	37	34	36	48	28		56	37	56	42
14-Oct	41	43	47	37	35	41	46	45	55		41	44	41	38	39	32	37	42	34		55	41	55	44
15-Oct	43	45	50	44	40	43	45	43	45		42	46	43	44	42	40	35	36	43		46	44	45	46
16-Oct	42	41	42	43		42	45	43	50		47	47	43	40	41	41	36	38	43		50	43	50	47
17-Oct	39	31	44	39	31	40	43	41	46		46	41	40	39	38	42	33	38	41		46	40	46	41
18-Oct	43	43	46	41	38	41	46	43	45		43	46	41	39	40	40	33	39	45		46	41	46	46
19-Oct	45	47	49	43	35	47	44	43	46		40	50	47	44	46	41	33	35	53		50	47	46	50
20-Oct	47	47	52	44	44	46	46	48	47		46	44	46	44	47	44	40	42	44		48	47	48	46
21-Oct	47	50	53	41	41	47	51	52	54		49	49	44	47	46	44	43	50	48		54	47	54	49
22-Oct	43	46	49	47	42	50	59	46	49		44	45	46	44	46	42	44	59	49		59	50	59	46
23-Oct	45	43	45	43	37	43	45	60	54		50	43	42	40	43	39	51	44	50		60	43	60	43
24-Oct	41	39	44	34	34	40	45	49	51		46	40	38	38	37	38	45	47	51		51	40	51	40
25-Oct	35	32	35	33	33	33	45	44	48		42	33	33	33	38	37	37	39	39		48	38	48	33
26-Oct	38	35	39	35	32	37	37	38	41		43	37	35	34	36	37	33	30	43		43	37	43	37
27-Oct	41	37	43	33	34	44	46	52	48		43	38	34	39	35	37	38	44	43		52	44	52	39
28-Oct	41	37	43	43	41	48	46	41	37		39	40	43	39	40	40	33	39	44		48	48	46	43

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
29-Oct	29	30	32	30	31	33	47	48	49		41	33	30	28	34	42	44	40	44		49	34	49	33
30-Oct	36	30	36	32	32	38	51	55	42		41	35	35	29	33	42	37	45	36		55	38	55	35
31-Oct	31	35	39	33	8	37	39	39	46		40	38	34	34	35	41	35	34	42		46	37	46	38
1-Nov	41	37	42	23	19	33	37	37	39		38	39	23	37	21	44	29	32	36		39	33	39	39
2-Nov	42	42	46	37	34	37	31	31	27		29	44	39	40	35	41	23	27	26		44	37	31	44
3-Nov	34	28	41	40	35	40	34	34	18		33	40	38	31	35	30	32	30	41		40	40	34	40
4-Nov	38	27	40	35	31	40	33	33	35		38	32	33	29	32	28	28	30	44		40	40	38	33
5-Nov	35	33	37	29	28	32	23	29	25		29	28	30	29	31	28	23	20	33		32	32	29	30
6-Nov	39	30	39	39	36	42	41	40	35		32	39	41	31	37	30	36	36	24		42	42	41	41
7-Nov	39	34	41	31	29	39	40	38	37		34	37	32	33	32	43	31	35	22		40	39	40	37
8-Nov	42	26	44	35	32	37	41	41	39		40	36	37	37	38	35	33	36	40		41	38	41	37
9-Nov	43	39	40	39	38	42	42	42	36		28	40	37	36	39	28	36	38	38		42	42	42	40
10-Nov	42	35	37	34	32	37	33	33	34		29	39	35	33	35	28	29	30	39		39	37	34	39
11-Nov	43	39	44	34	33	39	35	36	32		29	41	30	35	36	27	31	33	35		41	39	36	41
12-Nov	43	40	46	37	36	41	37	40	37		36	42	37	35	37	29	32	34	38		42	41	40	42
13-Nov	42	39	47	38	38	43	43	40	39		40	45	39	37	36	32	35	38	39		45	43	43	45
14-Nov	46	37	49	39		44	44	41	42		43	46	37	29	39	40	31	36	44		46	44	44	46
15-Nov	42	36	45	32		40	41	41	47		41	45	30	35	38	42	31	35	45		47	40	47	45
16-Nov	46	40	45	34		40	39	38	45		46	44	31	39	31	42	32	37	48		46	40	46	44
17-Nov	44	41	43	45		41	44	41	43		39	45	46	40	46	38	33	42	42		46	46	44	46
18-Nov	40	36	39	35		39	42	41	36		35	45	39	32	38	45	35	39	40		45	39	42	45
19-Nov	39	40	44	31		36	39	38	41		41	37	35	40	35	37	34	37	40		41	36	41	40
20-Nov	35	36	40	34		37	40	38			39	39	36	35	34	38	32	37	40		40	37	40	39
21-Nov	41	30	34	33		35	33	32			30	38	31	28	35	39	25	38	33		38	35	33	38
22-Nov	37	31	32	27		29	45	44	42		40	32	30	30	35	39	37	42	37		45	35	45	32
23-Nov	38	32	41	26		35	39	36	42		38	33	28	32	31	39	34	36	39		42	35	42	33
24-Nov	41	37	42	44	43	42	47	40	42		42	45	41	37	44	37	40	41	41		47	44	47	45
25-Nov	38	39	45	34	35	40	39	38	35		33	39	37	37	38	30	34	36	40		40	40	39	39
26-Nov	41	39	44	20	19	32	33	30	31		26	38	30	35	26	29	28	32	34		38	32	33	38
27-Nov	43	43	44	45	43	44	45	44	45		39	46	44	43	45	41	38	44	41		46	45	45	46
28-Nov	39	35	39	36	37	33	46	45	50		44	40	37	36	39	48	38	47	41		50	39	50	40
29-Nov	37	34	39	34	33	34	43	42	42		38	39	36	34	37	45	34	40	40		43	37	43	39
30-Nov	39	33	40	33	34	38	40	37	39		39	41	36	30	36	42	26	33	39		41	38	40	41
1-Dec	37	34	38	30	25	30	34	28	39		41	43	33	28	33	38	27	31	39		43	33	41	43

State	AZ	CO	CO	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	TX	TX	TX	TX	UT	NM	NM	NM	NM
County	Navajo	La Plata	Monte-zuma	Bernalillo	Bernalillo	Bernalillo	Dona Ana	Dona Ana	Eddy	Eddy	Lea	Rio Arriba	Sandoval	San Juan	Valencia	Brewster	El Paso	El Paso	Lampasas	San Juan	Maximum	Maximum	Maximum	Maximum
State Code	04	08	08	35	35	35	35	35	35	35	35	35	35	35	35	48	48	48	48	49	Sites			
County Code	017	067	083	001	001	001	013	013	015	015	025	039	043	045	061	043	141	141	381	037				
Site ID	0119	7001	0101	0023	0029	1012	0020	0021	1005	3001	0008	0026	1001	0009	0008	0101	0057	0058	9991	0004				
2-Dec	35	41	44	38	36	41	40	33	29		25	38	38	38	38	37	30	36	38		41	41	40	38
3-Dec	36	36	42	33	34	37	28	28	23		29	45	35	28	37	17	21	25	34		45	37	29	45
4-Dec	38	33	36	38	35	39	40	36	24		29	45	39	30	34	25	35	36	40		45	39	40	45
5-Dec	42	38	41	25	26	39	44	40	42		37	43	31	33	33	32	30	43	36		44	39	44	43
6-Dec	44	33	40	28	22	36	44	41	37		38	44	24	32	35	38	33	39	37		44	36	44	44
7-Dec	41	45	44	36	31	40	41	31	22		22	43	38	40	37	33	22	38	24		43	40	41	43
8-Dec	37	36	40	20	21	25	25	22	26		27	33	24	38	26	25	22	24	29		38	26	27	38
9-Dec	38	36	39	9	22	28	26	18	19		21	41	24	30	26	23	20	22	24		41	28	26	41
10-Dec	40	32	38	26	25	35	28	30	32		27	42	29	30	29	29	26	27	32		42	35	32	42
11-Dec	35	31	34	32	24	36	41	39	38		35	35	33	24	32	33	31	38	36		41	36	41	35
12-Dec	36	22	34	20	17	35	38	35	32		29	38	15	27	28	36	24	35	31		38	35	38	38
13-Dec	36	30	37	32	27	38	34	30	38		31	40	31	21	34	31	26	31	36		40	38	38	40
14-Dec	33	27	34	27	26	34	34	33	32		29	37	30	24	28	30	26	29	26		37	34	34	37
15-Dec	29	19	29	20	15	31	30	31	23		16	36	19	19	20	25	22	31	26		36	31	31	36
16-Dec	35	36	40	29	29	31	35	31	33		28	35	30	35	28	54	22	33	28		35	31	35	35
17-Dec	42	44	43	42	43	44	47	46	35		31	47	43	41	44	38	43	48	35		47	44	47	47
18-Dec	41	39	48	41	38	46	39	34	32		33	46	42	33	38	31	30	35	35		46	46	39	46
19-Dec	34	35	41	35	32	44	35	27	31		32	43	37	26	29	36	28	30	37		44	44	35	43
20-Dec	28	32	35	29	23	36	34	29	31		29	42	32	30	31	31	22	20	42		42	36	34	42
21-Dec	28	35	36	23	32	34	21	25	25		31	40	27	29	27	31	14	11	38		40	34	31	40
22-Dec	30	19	31	13	19	26	28	24	41		38	39	22	26	23	43	25	26	35		41	26	41	39
23-Dec	34	22	27	24	22	33	37	33	36		35	34	23	22	25	39	25	29	33		37	33	37	34
24-Dec	43	41	45	38	36	41	41	40	41		35	47	38	42	37	33	37	42	38		47	41	41	47
25-Dec	43	43	42	43	44	46	41	40	47		46	47	43	39	45	37	36	40	42		47	46	47	47
26-Dec	40	41	40	39	33	43	36	35	41		44	44	41	40	40	34	28	30	45		44	43	44	44
27-Dec	28	45	35	33	31	36	36	33	34		35	41	38	42	34	30	22	30	37		42	36	36	42
28-Dec	27	34	39	20	11	38	33	31	36		35	43	34	30	18	34	20	25	41		43	38	36	43
29-Dec	23	34	34	22	19	24	35	30	40		39	39	33	26	22	40	31	33	41		40	24	40	39
30-Dec	30	34	38	19	23	29	30	30	30		32	42	25	33	25	33	24	25	37		42	29	32	42
31-Dec	35	22	26	26	24	33	28	26	33		31	38	26	26	25	33	23	34	35		38	33	33	38