

**STATE OF NEW MEXICO
ENVIRONMENTAL IMPROVEMENT BOARD**

IN THE MATTER OF PROPOSED NEW REGULATION,
20.2.50 NMAC – Oil and Gas Sector – Ozone Precursor Pollutants

No. EIB 21-27 (R)

DIRECT TESTIMONY OF ANGELA RASO

1 My name is Angel Raso, and I am a dispersion modeler for the New Mexico Environment
2 Department's ("Department" or "NMED") Air Quality Bureau ("Bureau"). I am presenting this
3 written testimony on behalf of the Department in this proceeding on proposed new air quality
4 regulations at 20.2.50 NMAC ("Part 50"). My testimony will address the chemistry of ozone in
5 the atmosphere, and NMED's review of the photochemical modeling performed by Ramboll for
6 this rulemaking.

7 **I. QUALIFICATIONS**

8 I have been a dispersion modeler for the Bureau for 3 years. As a dispersion modeler, I
9 routinely evaluate the air quality impacts of complex facilities. I hold a PhD in chemistry from
10 Purdue University, and a BA in chemistry from Whitman College. My PhD research focused on
11 the chemistry and interactions of ozone in the atmospheric boundary layer.

12 My full background and qualifications are set forth in my resume, which is marked as
13 NMED Exhibit 14.

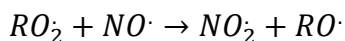
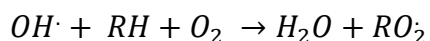
14 **II. TROPOSPHERIC OZONE FORMATION**

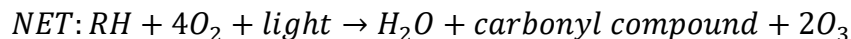
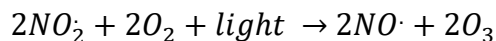
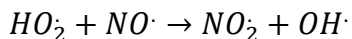
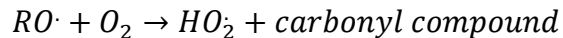
15 Dry air in the atmosphere is composed of 78.08% molecular nitrogen (N₂), 20.95%
16 molecular oxygen (O₂), 0.93% Argon, and 0.04% other trace gases by volume. In many respects
17 the most important trace gas in the atmosphere is ozone. The impacts of ozone depend on where
18 in the atmosphere it exists. In the upper atmosphere, stratospheric ozone absorbs biologically

1 harmful solar ultraviolet light, protecting living organisms. At the surface, high ozone
2 concentrations can be detrimental to human and plant health.

3 Rather than being directly emitted by sources ozone is produced by a set of chemical
4 reactions between Nitrous Oxides (NO_x) and Volatile Organic Compounds (VOCs). Therefore,
5 reductions in ozone concentration must be achieved through regulation of these precursor
6 pollutants. Nitric Oxide (NO) is formed when N₂ and O₂ combine under high heat. This occurs
7 both naturally (such as during lightning strikes), and due to human (anthropogenic) activities, such
8 as fossil fuel combustion. More than 90% of the NO released to the atmosphere is anthropogenic
9 [EPA 456/F-99-006R, 1999]. In the presence of ozone (O₃) and sunlight, NO and NO₂ are rapidly
10 interconverted. The sum of NO and NO₂ are referred to as NO_x. VOCs are a subset of hydrocarbons
11 that are volatile enough to evaporate and enter the atmosphere to undergo photochemical (light
12 dependent) chemical reactions. Most VOCs in the atmosphere are emitted by plant life. In some
13 areas with large anthropogenic emissions, such as densely populated cities, VOC emissions from
14 anthropogenic activities can be nearly equal to emissions from plants.

15 In the presence of sunlight, NO_x and VOCs react to form ozone. This cycle of radical
16 photochemical (involving light) reactions begins with ozone separating (undergoing photolysis) to
17 form a hydroxyl radical (OH). Hydroxyl radicals rapidly oxidize VOCs (shown in the reactions
18 below as hydrocarbons, RH). Oxidation of VOCs in the atmosphere causes them to become more
19 water soluble, and ultimately facilitates the removal of VOCs from the atmosphere. However, in
20 the presence of NO, each oxidized VOC produces two O₃ molecules without the net removal of
21 NO_x from the atmosphere.



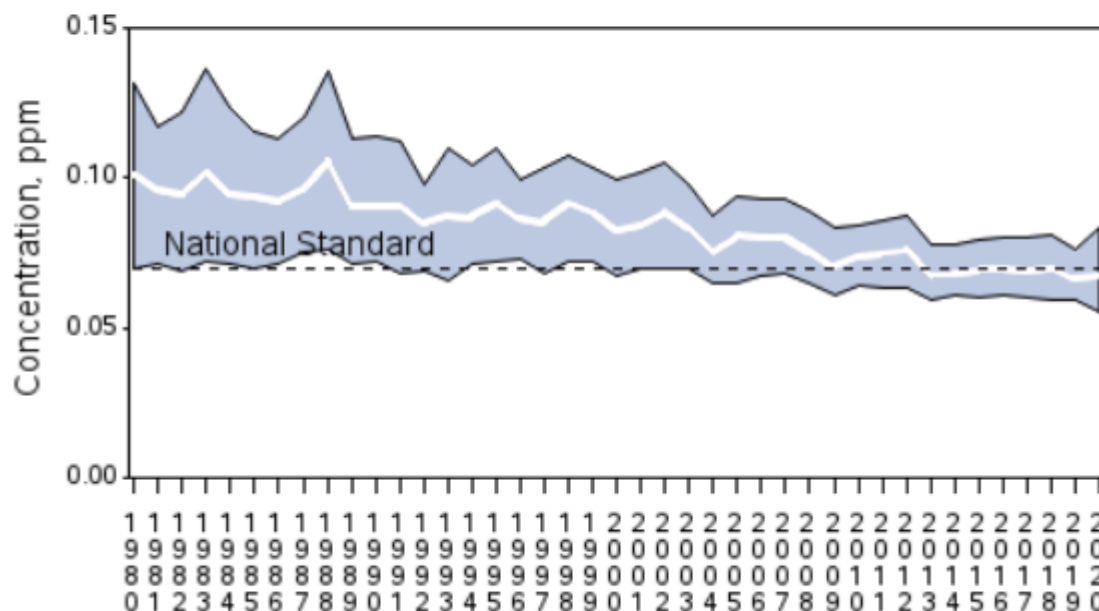


5 The formation of OH and subsequent oxidation reactions to form O₃ are highly dependent on light
6 and temperature. The dependence of these reactions on light and heat leads to the largest O₃
7 concentrations occurring on warm, sunny days during the summer.

8 Ozone has been regulated in the U.S. as a pollutant since the establishment of the National
9 Ambient Air Quality Standards (“NAAQS”) under the Clean Air Act in 1971. Since 1979, the U.S.
10 Environmental Protection Agency (“EPA”) has been incrementally decreasing the ozone NAAQS
11 as more evidence emerges on the public health and environmental consequences of ozone. Most
12 recently, EPA decreased the ozone NAAQS from 0.75 ppm (parts per million) to 0.70 ppm in
13 2015. Regulation has successfully reduced mean ozone concentrations in the U.S. by 33% since
14 1980, as shown in Figure 1.

Ozone Air Quality, 1980 - 2020

(Annual 4th Maximum of Daily Max 8-Hour Average)
National Trend based on 188 Sites



1980 to 2020 : 33% decrease in National Average

Figure 1: Mean (white line) and 10%-90% ozone daily values nationally for the U.S. from 1980-2020.¹

The photochemical cycle that leads to the formation of ozone is comprised of a complex series of emissions, chemical reactions, and physical processes and is dependent on the time of day, sunlight, temperature, and other meteorological conditions. Understanding the potential reductions in ozone concentrations from reductions in emissions of anthropogenic precursors requires an integrated assessment of these factors. In order to conduct this assessment, a photochemical model is utilized. Testimony on the photochemical modeling performed for this rulemaking will be presented by Ralph Morris of Ramboll.

¹ See <https://www.epa.gov/air-trends/ozone-trends>.

IV. NMED REVIEW OF RAMBOLL PHOTOCHEMICAL MODELING

On behalf of the Bureau, I reviewed the photochemical work products that were produced by Ramboll. A table of photochemical modeling products produced by Ramboll and reviewed by the Bureau is included below.

Product	Topics
NMED Exhibit 15 - Photochemical Modeling Protocol	Planning and Communication Document Describing Proposed Modeling Strategy
NMED Exhibit 16 - 2014 Modeling Platform Development and Model Evaluation	Work Product Document Describing Development of the Base Case Modeling and Evaluation of Modeling Performance
NMED Exhibit 17 - Air Quality Technical Support Document	Work Product Document Containing Technical Specifications of Modeling Performed
NMED Exhibit 18 - New Mexico OAI Study Photochemical First Monthly Webinar May 2020	• Existing Meteorological Modeling • Evaluation of Boundary Conditions • Modeling Protocol Overview • 2014 and Future Year Emissions
NMED Exhibit 19 - New Mexico OAI Study Photochemical Monthly Webinar June 2020	• 2014 and Future Year Emissions • Meteorological Modeling
NMED Exhibit 20 - 2014 and 2023 Emissions, CAMx WRF Sensitivity Tests and Final Model Configuration	• 2014 and Future Year Emissions, Quality Assurance and Processing • Photochemical Modeling, Sensitivity Tests, and Base Case Configuration
NMED Exhibit 21 - Emissions, CAMx, Base and Model Performance, 2023 CAMx Model Status	• 2014 and Future Year Emissions, Natural Sources and Processing • Photochemical Modeling, Base Case Configuration and Model Performance Evaluation
NMED Exhibit 22 - 2014 and 2028 Emissions Development	• Development of 2014 and Future Year Emissions Sources • Processing of Emissions for Modeling
NMED Exhibit 23 - Revised 2014v2 Base Case, 2028 Base Case	• 2014 Modeling • Future Year (2028) Base Case Modeling • Future Year (2028) Control Strategy Modeling

Modeling and 2028 NM O&G Control Strategy (Feb 2021)	• Design of Source Apportionment Modeling
NMED Exhibit 24 - Sensitivity of 2028 Ozone Projections to Current Year Ozone, Draft TSD	• Summary of Future Year (2028) modeling Design Value Projections • Sensitivity of Future Year Design Values to Current Year Design Values • Status of Ozone Source Apportionment Modeling
NMED Exhibit 25 - 2028 Source Sector APCA Ozone Source Apportionment Modeling, Revised Draft TSD (April 2021)	• Summary of Future Year Design Value Projections and Sensitivity • Future Year Source Sector Apportionment Modeling Results (APCA Modeling) • Status of Source Apportionment Results for VOC/NOx Sensitivity (OSAT Modeling)
NMED Exhibit 26 - 2028 VOC and NOx Sensitivity OSAT Ozone Source Apportionment Modeling and Draft Final TSD (April 2021)	• Overview of OSAT Modeling for VOC/NOx Sensitivity • Summary of Source Sector Apportionment Modeling (APCA modeling) • Future Year (2028) VOC/NOx Sensitivity OSAT Ozone Source Apportionment Modeling Results

- 1 A full discussion of the modeling and the deliverables produced by Ramboll is provided in the
- 2 testimony of NMED witness Ralph Morris.

Education

Purdue University, West Lafayette, IN

December 2018

Doctor of Philosophy, Analytical chemistry

Dissertation: "Halogen Photochemistry and Emissions from the Arctic Snowpack"

Advisor Dr. Paul B. Shepson, Dr. Kerri A. Pratt (University of Michigan)

Whitman College, Walla Walla, WA

May 2012

Bachelor of Arts, Chemistry. Mathematics minor.

Undergraduate Thesis: "Determining the Presence of Dense Non-Aqueous Phase Liquid (DNAPL) Pollutants in River Sediments"

Advisor Dr. Frank M. Dunnivant

Professional Experience

Dispersion Modeler, New Mexico Environment Department, Air Quality Bureau **September 2018 - Present**

- Evaluate facilities emissions for compliance with Ambient Air Quality Standards using dispersion models
- Assist with data analysis and evaluation related to emissions inventories
- Assist with special projects involving modeling and emissions inventories including; preparation for photochemical modeling, modeling for state implementation plans

Research Experience

Research Assistant, Purdue University

Fall 2012 – August 2018

- Lead field work based research on gas phase oxidation processes in the Arctic to understand a complex environmental system
- Collaboratively design and perform atmospheric chemistry experiments in the Arctic including eddy covariance flux measurements
- Full process responsibility for analytical measurements in a remote Arctic environment
- Coordinate logistical needs to ensure successful Arctic fieldwork in Barrow, Alaska
- Manage instrumentation including a homebuilt chemical ionization mass spectrometer, and an ion chromatography / liquid chromatography system
- Mentor and train students to safely and effectively use instrumentation
- Conduct zero- and one- dimensional photochemical modeling to understand and contextualize the importance of measurements

Visiting Research Assistant, University of Michigan

Fall & Winter 2015

- Collaboratively planned for a spring 2016 field study in Barrow, Alaska

**User, Environmental Molecular Sciences Laboratory,
Pacific Northwest National Laboratory**

October 2015

- Acquired first ever measurements of iodide in Arctic snow using ion chromatography coupled with inductively coupled plasma mass spectrometry (IC-ICPMS)

Undergraduate Research Assistant, Whitman College

Fall 2010 –Spring 2012

- Conducted research on dense non-aqueous phase liquids in mixed stream-bed media for detection at highly polluted sites using gas chromatography – electron capture detection

Teaching Experience

General Chemistry Adjunct, Santa Fe Community College

Spring & Fall 2019

- Instructed General Chemistry Laboratories

Analytical Chemistry TA, Purdue Chemistry Department

Fall 2013

- Instructed laboratory sessions for upper division chemistry students in a major required course

- Wrote and graded exam questions and graded written lab reports, giving important feedback to students

Fundamental General Chemistry TA, Purdue Chemistry Department

Spring 2013

- Instructed laboratory and recitation for students with no previous chemistry courses to give a gentle introduction to important laboratory and scientific skills

General Chemistry for Engineers TA, Purdue Chemistry Department

Fall 2012

- Instructed laboratory and recitation sessions to introduce freshman engineers and scientists to college level science courses.

Chemistry Tutor, Whitman Chemistry Department

2010 -2012

- Demonstrated concepts and problem solving techniques for students from general, organic and analytical chemistry classes in an open “drop in” environment using a variety of teaching methods

Organic Chemistry Laboratory Assistant, Whitman Chemistry Department

Fall 2011

- Supported students in an organic chemistry laboratory to ensure safe, time effective, and comprehensive completion of experiments

Quantitative Analysis Lab. Assistant, Whitman Chemistry Department

Fall 2011

- Supported students in a data rich laboratory to introduce analytical methods to chemistry majors
- Corrected spreadsheet style lab reports to give important feedback to students

Tutor, Whitman College Academic Resource Center

2010-2012

- Tutored general chemistry, organic chemistry, calculus I, calculus II and differential equations to support student understanding and grades

Publications and Presentations

- “Active Molecular Iodine Photochemistry in the Arctic” December 11, 2017. Oral Presentation, American Geophysical Union Meeting. New Orleans, La
- “Surface fluxes and recycling of molecular halogens above the snowpack” December 11, 2017. Poster, American Geophysical Union Meeting. New Orleans, La
- Raso, A. R. W., K. D. Custard, N. W. May, D. J. Tanner, M. K. Newburn, L. Walker, R. Moor, L. G. Huey, M. L. Alexander, P. B. Shepson, K. A. Pratt “Active Molecular Iodine Photochemistry in the Arctic” *Proceedings of the National Academy of Sciences* 114(38) 10053-10058
- Custard, K. D., A. R. W. Raso, K. A. Pratt, R. M. Staebler, and P. B. Shepson (2017) “Molecular halogen production in and flux measurements from tundra snow” *ACS earth and space chem.* 1(3), 142-151
- Raso, A.R.W., B. Elstrott, and F. M. Dunnivant, (2012) Envirolab: Simulations of Laboratory experiments in environmental chemistry [Computer Program]
- Available at <http://people.whitman.edu/~dunnivfm/software.html>
- “Mass transport and recycling of molecular halogens near the snowpack surface in Barrow (Utqiagvik), Alaska” December 12, 2016. American Geophysical Union Fall Meeting. San Francisco, Ca.
- “The impact of Molecular iodine photochemistry in the Arctic” December 17, 2014. Poster, American Geophysical Union Fall Meeting. San Francisco, Ca.
- “Determining the presence of dense non-aqueous phase liquid (DNAPL) pollutants in river sediments” March 26, 2012. Poster, National Spring Meeting of the American Chemical Society. San Diego, Ca.

May 2020

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



RAMBOLL



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

Project name **New Mexico Environmental Division**
Project no. **1690017454**
Recipient **New Mexico Environmental Division**
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Version **V5.0**
Date **May 19, 2020**
Prepared by **Ralph Morris, Marco Rodriguez, Tejas Shah, Jeremiah Johnson, Fiona Jiang,
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CONTENTS

ACRONYMS and ABBREVIATIONS	viii
1. INTRODUCTION	1
1.1 NM OAI Project Genesis	1
1.2 Overview of NM OAI Study Modeling Approach	3
1.2.1 EPA Guidance for Ozone Attainment Demonstration Modeling Protocols	3
1.3 Related Studies	5
1.3.1 Historic EPA and More Recent EPA-MJO-States Modeling Platforms	5
1.3.2 Denver Ozone SIP Modeling and Analysis	7
1.3.3 West-wide Jumpstart Air Quality Modeling Study	9
1.3.4 Intermountain West Data Warehouse and Western Air Quality Study	9
1.3.5 Southern New Mexico Ozone Study (SNMOS)	9
1.3.6 City of Albuquerque Ozone Modeling Study	13
1.3.7 Relationship Between Meteorology and Ozone in the Intermountain West Region	14
1.3.8 The Four Corners Air Quality Task Force	17
1.3.9 Other Studies	17
1.4 New Mexico Conceptual Models for High Ozone Concentrations	19
1.4.1 Southeastern New Mexico	19
1.4.2 City of Albuquerque	19
1.4.3 Northwest New Mexico	19
1.5 Overview of the Modeling Approach	20
1.5.1 Episode Selection	20
1.5.2 Model Selection	20
1.5.3 Domain Selection	20
1.5.4 Base and Future Year Emissions Data	20
1.5.5 Emissions Input Preparation and QA/QC	21
1.5.6 Meteorology Input Preparation and QA/QC	21
1.5.7 Initial and Boundary Conditions Development	21
1.5.8 Air Quality Modeling Input Preparation and QA/QC	21
1.5.9 Model Performance Evaluation	21
1.5.10 Diagnostic Sensitivity Analyses	22
1.5.11 Future Year Control Strategy Modeling	22
1.5.12 Future Year Source Apportionment Modeling	22
1.6 Project Participants and Contacts	22
1.7 Communication	25
1.8 Schedule	25
2. MODEL SELECTION	28
2.1 Meteorological Model	29
2.2 Emissions Models	29

2.2.1	Sparse Matrix Operator Kernel Emissions (SMOKE)	29
2.2.2	MOtor Vehicle Emissions Simulator (MOVES)	30
2.2.3	SMOKE-MOVES	30
2.2.4	Model of Emissions of Gases and Aerosols from Nature (MEGAN)	30
2.3	Photochemical Grid Model	30
2.3.1	Comprehensive Air-quality Model with extensions (CAMx)	30
2.4	Final Justification for Model Selection	31
3.	EPISODE SELECTION	33
3.1	Candidate Year for Modeling Episodes	33
3.2	EPA Episode Selection Criteria	33
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	33
3.2.2	Model Time Periods in which Observed Ozone Concentrations are Close to the Appropriate Base Year Ozone Design Values.	33
3.3	Episode Selection Conclusions	34
4.	MODELING DOMAIN SELECTION AND DATA AVAILABILITY	35
4.1	Horizontal Domain	35
4.2	Data Availability	37
4.2.1	Emissions Data	37
4.2.2	Air Quality Data	38
4.2.3	Ozone Column Data	40
4.2.4	Meteorological Data	40
4.2.5	Initial and Boundary Conditions Data	40
5.	WRF METEOROLOGICAL MODELING	41
5.1	Description of WRF	41
5.2	WRF Model Domain	41
5.3	WRF Model Configuration	41
5.3.1	Model Vertical Resolution	42
5.3.2	Vertical Coordinate	43
5.3.3	Topographic Inputs	44
5.3.4	Vegetation Type and Land Use Inputs	45
5.3.5	Atmospheric Data Inputs	45
5.3.6	Time Integration	46
5.3.7	Diffusion Options	46
5.3.8	Lateral Boundary Conditions	46
5.3.9	Top and Bottom Boundary Conditions	46
5.3.10	Sea Surface Temperature Inputs	46
5.3.11	Four Dimensional Data Assimilation (FDDA)	46
5.3.12	New Lightning Data Assimilation	47
5.3.13	PBL and LSM Physics Options	47
5.3.14	Remaining WRF Physics Options	47
5.3.15	Application Methodology	48

5.4	WRF Model Evaluation	48
5.4.1	Quantitative Evaluation Using METSTAT	48
5.4.2	Statistical Benchmarks	50
5.4.3	Qualitative Evaluations Using PRISM Data	52
6.	PGM BASE YEAR INPUT PREPARATION PROCEDURES	54
6.1	Meteorological Inputs	54
6.1.1	WRFCAMx Processing of 2014 WRF Output	54
6.1.2	Treatment of Minimum Kv	54
6.2	Emission Inputs	55
6.2.1	Available Emissions Inventory Datasets	55
6.2.2	Development of CAMx Emission Inputs	55
6.3	Photochemical Model Inputs	59
6.3.1	PGM Science Configuration and Input Configuration	59
7.	2014 BASE CASE MODELING AND MODEL PERFORMANCE EVALUATION	61
7.1	2014 Base Case Modeling	61
7.2	EPA Model Performance Evaluation Recommendations	61
7.2.1	Overview of EPA Model Performance Evaluation Recommendations	61
7.2.2	WRAP/WAQS Companion Model Performance Evaluation	62
7.3	Overview of Evaluation of CAMx 2014 Base Case Procedures	62
7.3.1	Photochemical Model Evaluation Methodology	62
7.3.2	Model Performance Goals and Benchmarks	62
7.3.3	Available Aerometric Data for the Evaluations	63
7.4	Operational Evaluation	64
7.4.1	Atmospheric Model Evaluation Tool (AMET)	64
7.4.2	Example Operational Model Performance Evaluation Products	64
7.4.3	Scatter Plots of Model Performance	67
7.4.4	Time Series of Predicted and Observed Concentrations	69
7.4.5	Evaluation for the Modeled MDA8 Ozone Concentrations	69
7.5	Diagnostic Evaluation	70
7.5.1	Base Year Base Case Diagnostic Sensitivity Tests	70
7.5.2	Additional Diagnostic Evaluation Approaches	71
7.6	Dynamic Evaluation	71
7.6.1	Probabilistic Evaluation	72
8.	FUTURE YEAR MODELING	73
8.1	Future Year to be Modeled	73
8.2	Future Year Emissions	73
8.2.1	2023 Future Year Anthropogenic Emissions	73
8.2.2	Future Year Emissions Quality Assurance	74
8.3	Future Year CAMx Modeling	74
8.3.1	Future Year Ozone Source Apportionment Modeling	74
8.3.2	Future Year Sensitivity and Control Strategy Simulations	75
9.	FUTURE YEAR OZONE PROJECTIONS	76

9.1	EPA Recommended Future Year Ozone DV Projection Procedures	76
9.1.1	Base Year Ozone Design Value (DVB)	76
9.1.2	Calculation of Relative Response Factors (RRFs)	76
9.1.3	Flexibility in RRF Calculations	77
9.2	Unmonitored Area Analysis (UAA)	77
9.3	Weight of Evidence (WOE) Attainment Demonstration	78
9.4	Documentation of the PGM Modeling	78
10.	QUALITY ASSURANCE PROJECT PLAN (QAPP)	79
10.1	Title Page And Approval Page	79
10.2	Quality System Components	79
10.2.1	Roles of Personal for QA/QC of the NM OAI Study	79
10.2.2	QA/QC of the 2014 Base Year and 2023 Future Year Emissions Data	80
10.2.3	QA/QC of 2014 and 2023 Emissions Processing	80
10.2.4	QA/QC of the Meteorological Modeling	80
10.2.5	QA/QC of the Boundary Conditions	80
10.2.6	QA/QC of the Air Quality Modeling	80
10.3	Project Definition and Background	81
10.4	Data Quality Objectives	81
10.5	Project Organization and Responsibilities of the Researchers	81
10.6	Project Description, Documentation and Reporting	81
10.7	Reconcile with Data Quality Objectives	81
11.	REFERENCES	82

APPENDICES

Appendix A

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

Appendix B

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

TABLE OF TABLES

Table 1-1.	Key participants and contact information for the NM OAI Study.	24
Table 1-2.	Current schedule for NM OAI Study.	25
Table 1-3.	Current schedule for monthly webinars for the NM OAI Study.	27

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. 34	
Table 4-1. Lambert Conformal Conic (LCC) projection parameters for the NM OAI Study 36/12/4 modeling domains.	37
Table 4-2. Grid definitions for CAMx NM OAI Study 2014 36/12/4-km modeling domains.	37
Table 4-3. Overview of routine ambient data monitoring networks.	39
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.	43
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.	48
Table 5-3. Meteorological model performance benchmarks for simple and complex conditions.	51
Table 6-1. CAMx model configuration for the NM OAI Study.	60
Table 7-1. Recommended benchmarks for photochemical model statistics (Source: Emery et al., 2016).	63

TABLE OF FIGURES

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).	2
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).	2
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.	7
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.	10
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).	11
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.	12
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).	13
Figure 1-8. Contributions to ozone in Albuquerque during the June and July 2017 modeling episodes.	14
Figure 1-9. Linear regression of the annual 4 th 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.	16
Figure 1-10. Correlation between 500 hPa heights and elevated ozone concentrations for monitoring sites in the western U.S.	17
Figure 4-1. NM OAI Study modeling 2014 36/12/4-km PGM and emissions modeling domains.	36
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.	36
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).	44
Figure 5-2. Example Soccer plot of monthly temperature error and bias (K) for 4-km domain.	52
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).	66
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). 67

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). 68

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). 69

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 1978¹). 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 7² 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.

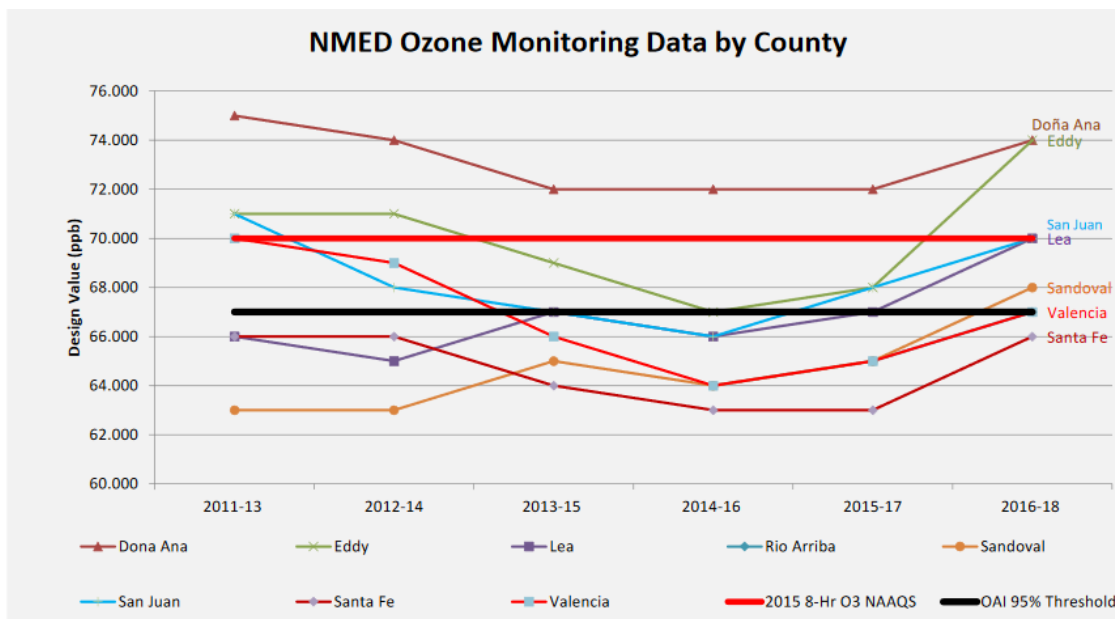
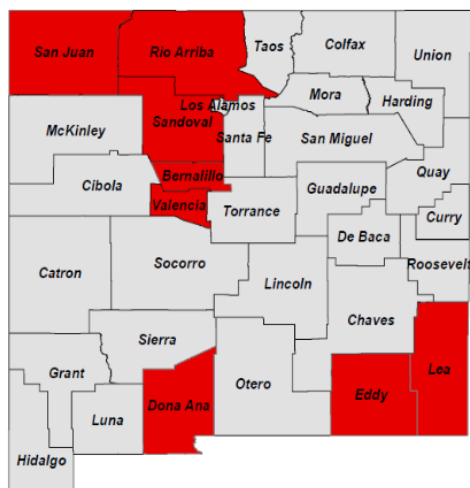


Figure 1-1. Trends in observed ozone DVs between 2013 and 2018 at 7 monitoring sites in New Mexico (Source: https://www.env.nm.gov/air-quality/wp-content/uploads/sites/2/2019/10/OAI_Presentation_09262019.pdf).



*Parallel planning is occurring for Bernalillo County through the Albuquerque/Bernalillo County Department of Environmental Health

- Counties within 95% of the standard:
 - San Juan (Navajo Lake, 70 ppb)
 - Doña Ana (several monitors, 74 ppb)
 - Eddy (Carlsbad, 74 ppb)
 - Lea (Hobbs, 70 ppb)
 - Rio Arriba (Coyote, 67 ppb)
 - Sandoval (Bernalillo, 68 ppb)
 - Valencia (Los Lunas, 67 ppb)

1

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 (OAI³) 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 platform⁴ 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 (CSAPR⁵), 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 (NEI⁷) 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 2011v6.3⁸ PGM modeling platform is the result of many years of development and refinements (e.g., v6.0, v6.1 and v6.2⁹). 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 2014v7.1¹⁰ PGM modeling platform was used in the 2014 National Air Toxics Assessment (NATA¹¹) 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 platform¹² (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 Alpha¹³ 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 emissions¹⁴ 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 (IWDW¹⁵). 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 2016v1¹⁶ (called 2016fh by EPA) PGM modeling platform uses the 2016 EMP version 1 emissions¹⁷ 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>

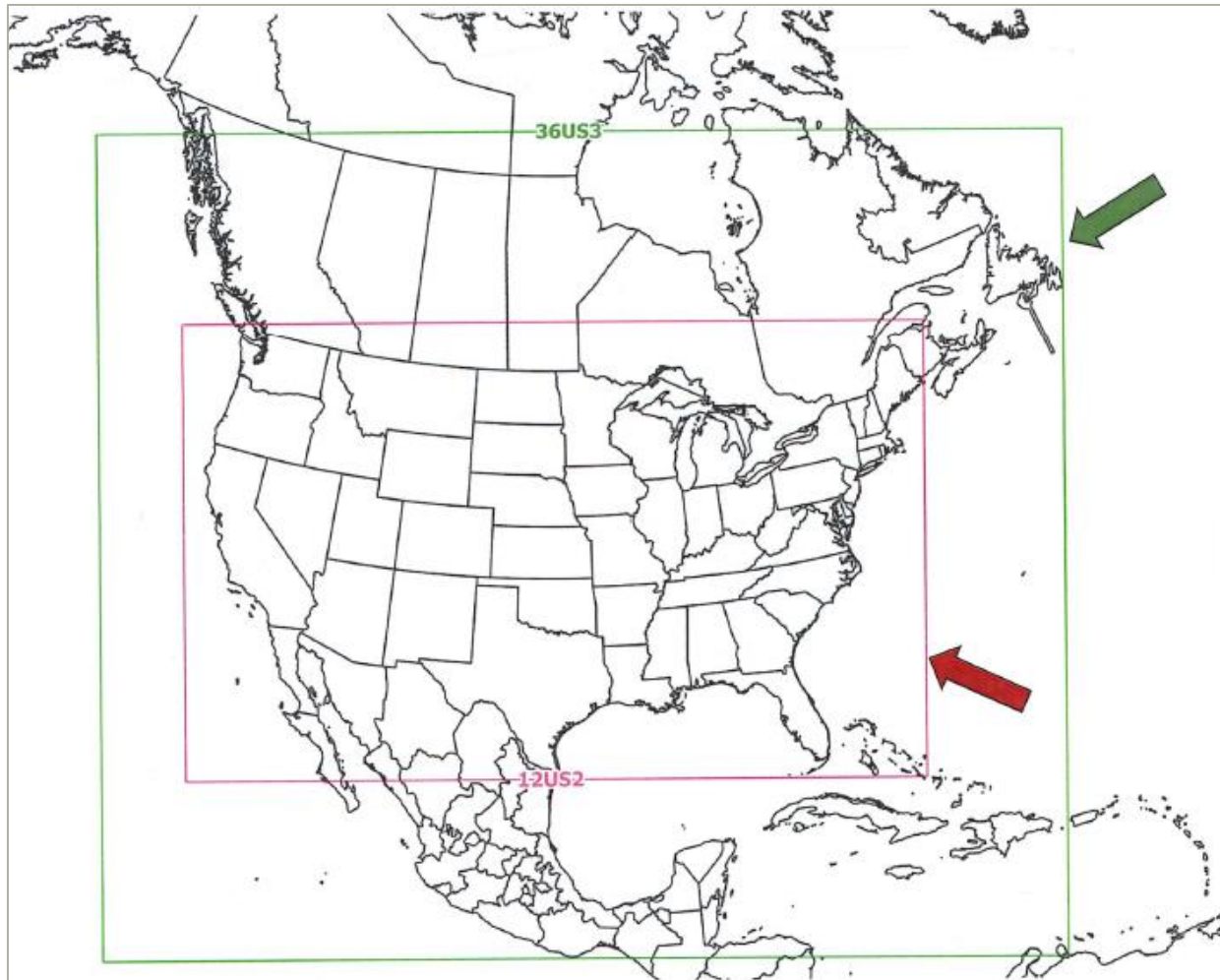


Figure 1-3. 36-km grid resolution 36US3 domain (green) and 12-km grid resolution 12US2 domain (red) used in EPA's 2016 modeling platform.

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 Plan¹⁸ 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 SIP¹⁹ 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 SIP²⁰ 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 Forum²¹ 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 (WestJumpAQMS²²; 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 (IWDW²³) 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 (SNMOS²⁴) 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.

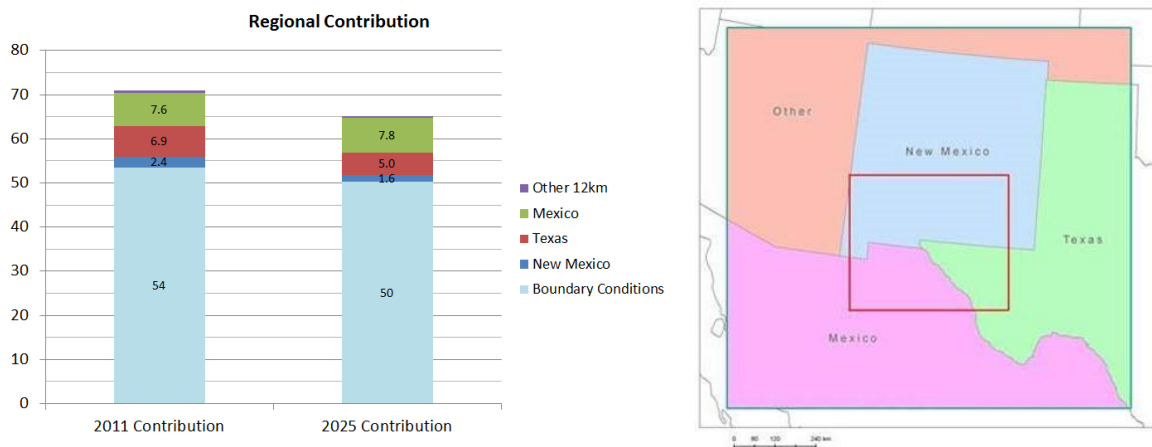


Figure 1-4. Contributions of geographic regions (including Boundary Conditions) to the 2011 and 2025 ozone Design Values at Desert View monitoring site in Dona Ana County in Southwestern New Mexico.

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.

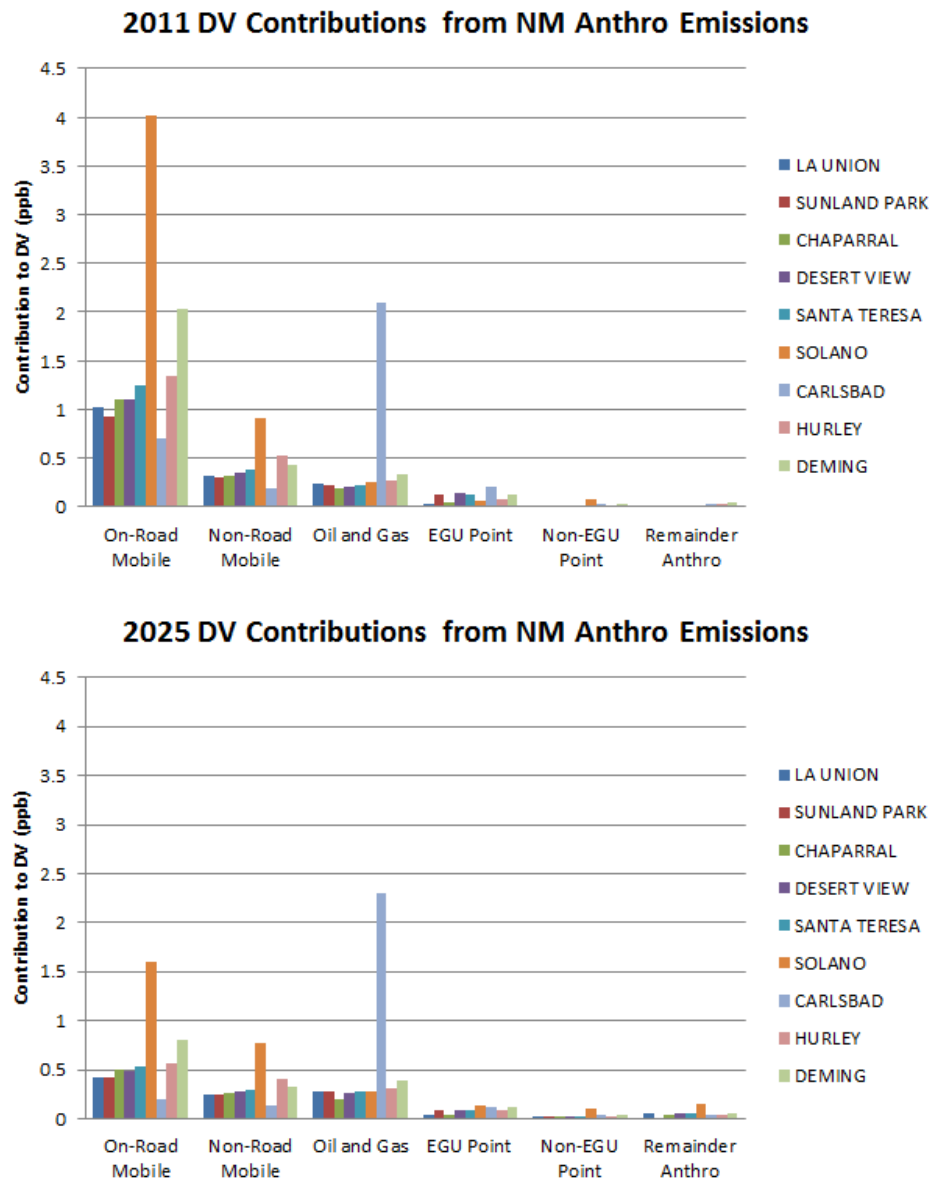


Figure 1-6. Contributions of major Source Sectors in New Mexico to 2011 (top) and 2025 (bottom) ozone DVs at nine monitoring sites in Southwestern New Mexico.

1.3.6 City of Albuquerque Ozone Modeling Study

The City of Albuquerque conducted an ozone modeling study²⁵ 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).

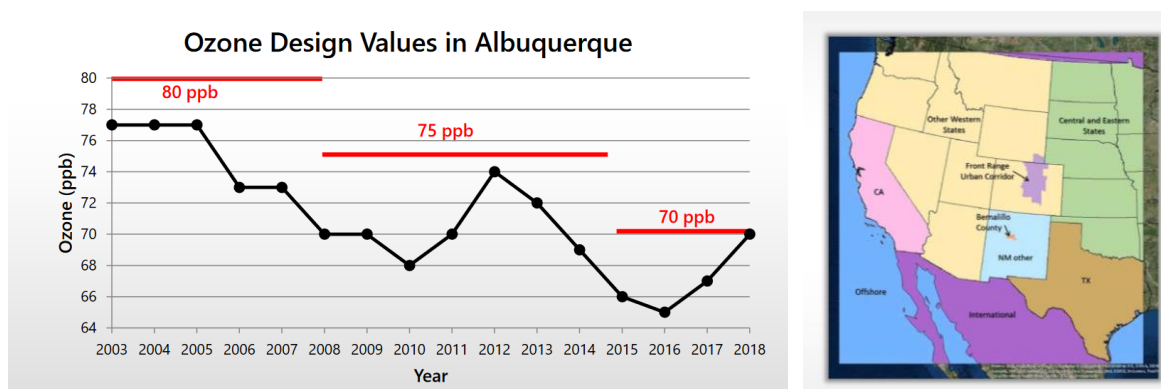


Figure 1-7. Trends in maximum ozone Design Values in Albuquerque from 2013 to 2018 (left) and 12-km modeling domain and source apportionment geographic regions (right).

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>

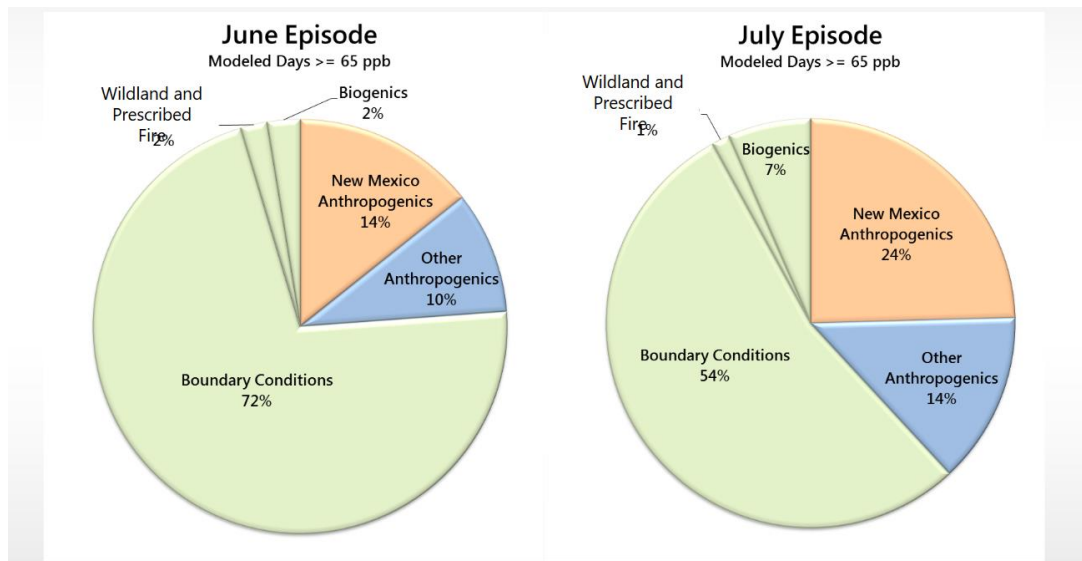


Figure 1-8. Contributions to ozone in Albuquerque during the June and July 2017 modeling episodes.

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. NO_x 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 hPa²⁶ 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 is 100 Pa where Pa is short for Pascal that is a unit of pressure where 500 hPa = 500 mb.

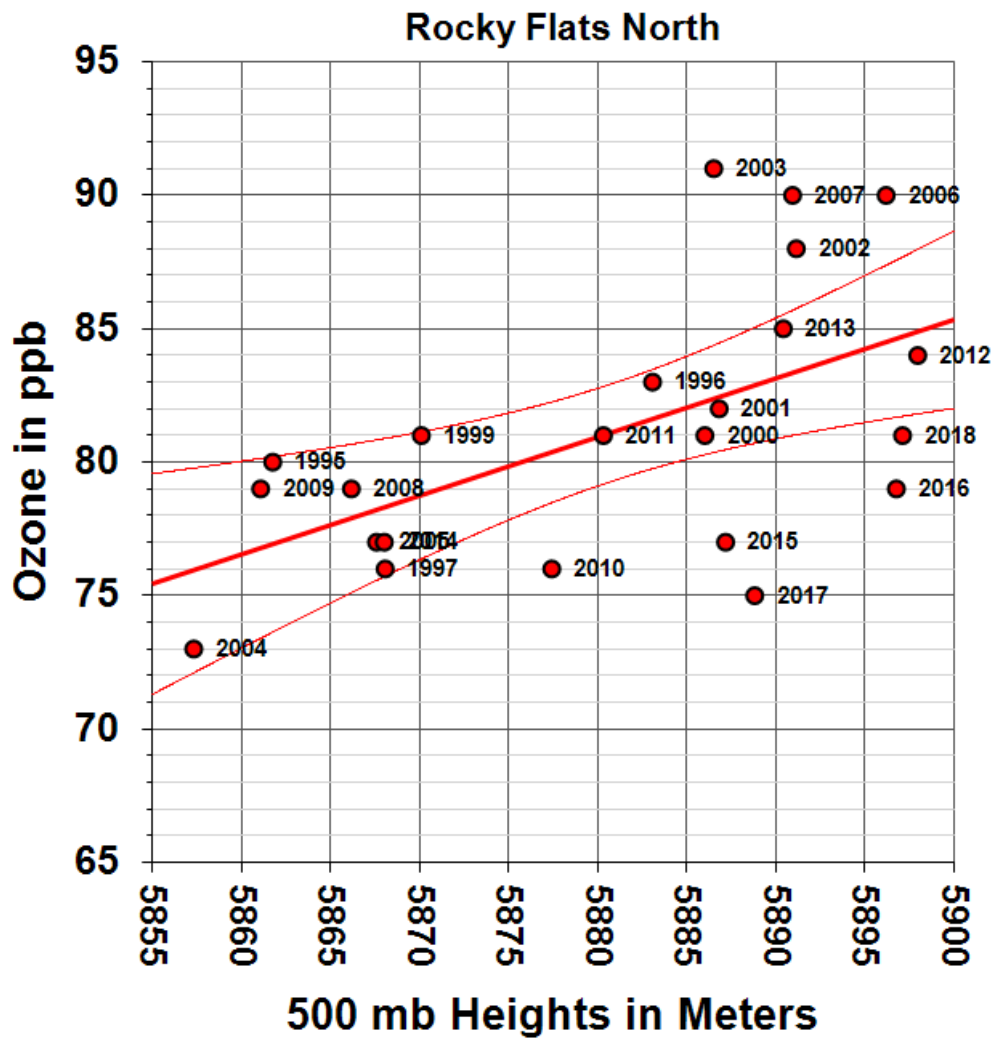


Figure 1-9. Linear regression of the annual 4th highest MDA8 ozone concentrations and mean July through August NCEP/NCAR Reanalysis 500 hPa (or 500 mb) heights for the DM/NFR NAA region at the Rocky Flats North (RFNO) monitoring site for the years 1995 to 2018.

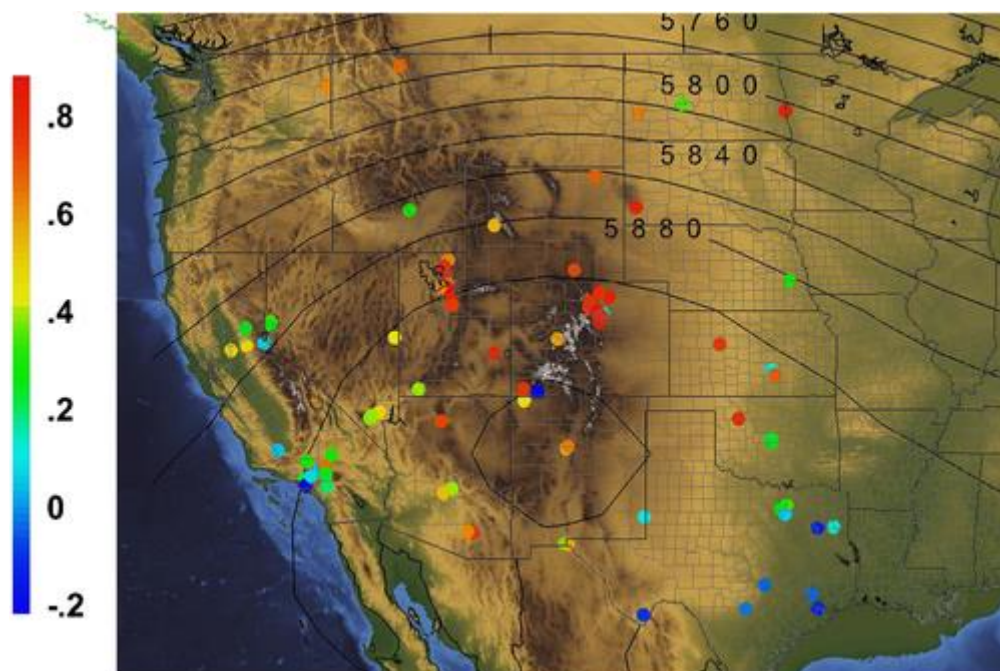


Figure 1-10. Correlation between 500 hPa heights and elevated ozone concentrations for monitoring sites in the western U.S.²⁷

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 report²⁸ 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 (FCAQG²⁹).

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_quicklinks_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 NO_x (LNO_x) 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 LNO_x) 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 Manual (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 tests³⁰ 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 (DVs). 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 (SMAT³¹) tool that includes the recommended procedures in the latest EPA guidance for projecting ozone DVs.

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 (AQTS) 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
	<i>Webinar PPT on final approach and project plan</i>	May 2020
	Final Modeling Protocol/QAPP and Work Plan	May 2020
	Response-to-Comments (RTC) Document	May 2020
2. Base Year Meteorological Modeling (Met)		
2.1 Evaluate Met Modeling	<i>Webinar PPT on WAQS 12-km WRF MPE and WAQS 12-km PGM ozone performance in New Mexico</i>	May 2020
2.2 Additional Met Modeling	<i>Webinar PPT on WRF 4-km MPE in New Mexico and Comparison with WAQS 12-km WRF</i>	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	<i>Webinar PPT on WRAP/WAQS 2014 GEOS-Chem BCs and latest updates to GEOS-Chem</i>	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	<i>Webinar PPT on recommended sources for 2014 and 2023 emissions in the 4-km New Mexico domain</i>	May 2020

Task	Deliverable	Date
	<i>Webinar PPT and tile plots/excel spreadsheets for selected 2014 and 2023 emissions for sources in the 4-km NM domain</i>	Jun 2020
4.2 Mobile Sources		
4.2.1 Evaluate Mobile Emissions	<i>Webinar PPT on options for 2014 & 2023 mobile source emission inputs and advantages/disadvantages</i>	Jun 2020
	<i>Webinar PPT on final 2014 & 2023 selected mobile source emissions options</i>	Jun 2020
4.2.3 Prepare Mobile Source Emission Inputs	<i>Webinar PPT on SMOKE-MOVES modeling to generate 2014 and 2023 mobile source emission inputs for 4-km NM domain</i>	Aug 2020
	Model-ready 2014/2023 mobile source emissions inputs	Aug 2020
4.4 Biogenic/Natural Emissions	<i>Webinar PPT on biogenic and natural emission modeling</i>	Jul 2020
	Model-ready 2014 natural emissions inputs (Bio, LNOx, Fires)	Jul 2020
4.5 SMOKE Modeling	<i>Webinar PPT on SMOKE modeling 2014/2023 anthropogenic emissions</i>	Aug 2020
	Model-ready 2014/2023 anthropogenic emissions inputs	Aug 2020
4.6 FY Emissions Strategies	<i>Webinar PPT on FY 2023 SMOKE control/strategies</i>	Aug 2020
	Summary tables and tile plots of emissions for 2023 scenarios	Aug 2020
5. 2014 Base Year (2014) Air Quality Modeling		
	<i>Webinar PPT on final 2014 base case and MPE</i>	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	<i>Webinar PPT on FY 2023 PGM Modeling</i>	Oct 2020
	Difference plots of FY-BY Ozone Concentrations	Oct 2020
6.2 Modeled Attainment Test	<i>Webinar PPT on FY ozone DV projections</i>	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 (MOVES2014b³²) 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 PM₁₀ 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 WRF³³, SMOKE³⁴, MOVES³⁵, MEGAN³⁶ and CAMx³⁷ 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 reports³⁸ 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 WAQS³⁹

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 WestJumpAQMS⁴⁰, and Denver ozone SIP modeling, including the 2008⁴¹ and 2016⁴² 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., $67 \text{ ppb} \leq \text{ozone} < 70 \text{ ppb}$) 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 exceedance 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 $\geq$ 71 ppb		Days $\geq$ 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

^a 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.

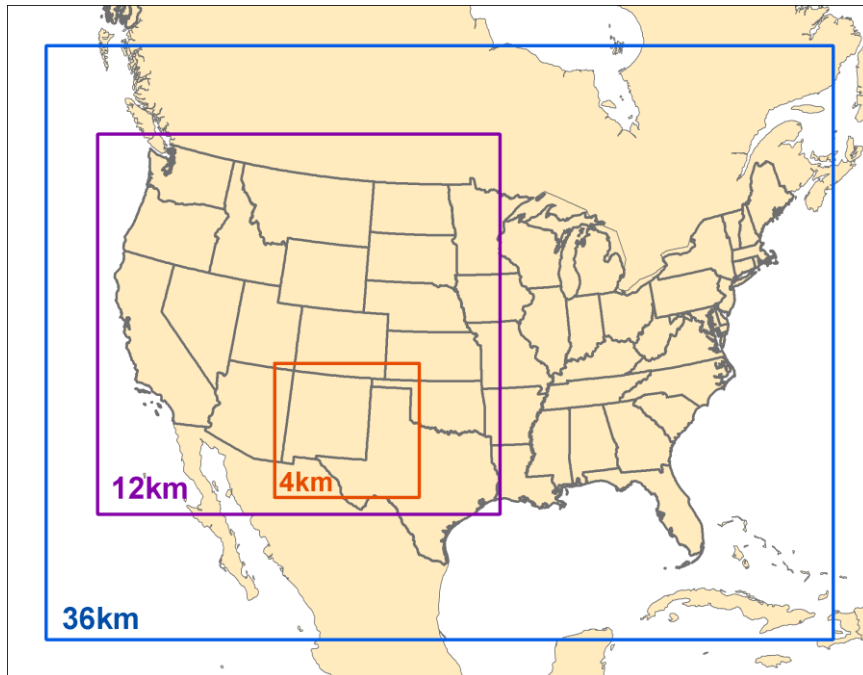


Figure 4-1. NM OAI Study modeling 2014 36/12/4-km PGM and emissions modeling domains.

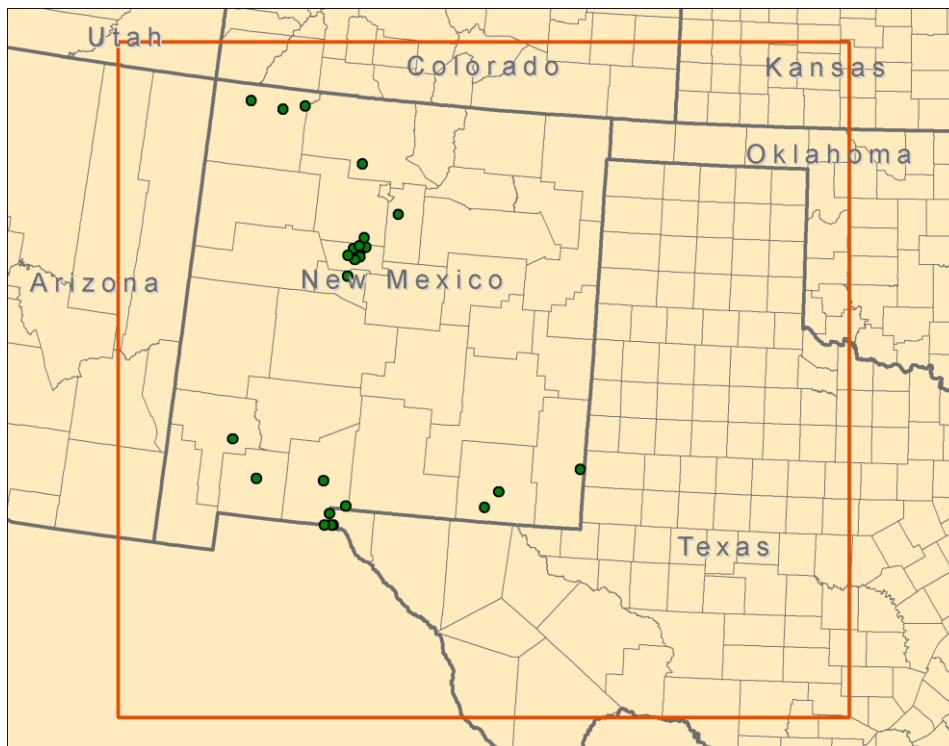


Figure 4-2. 4-km New Mexico modeling domain for PGM and emissions modeling, with locations of ozone monitors that were operating during some portion of 2014.

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 SO₂ 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 (CAMD⁴³) website. These data are hour-specific for SO₂, 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 (MEGAN⁴⁴) that was updated by WRAP⁴⁵ 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 to 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.

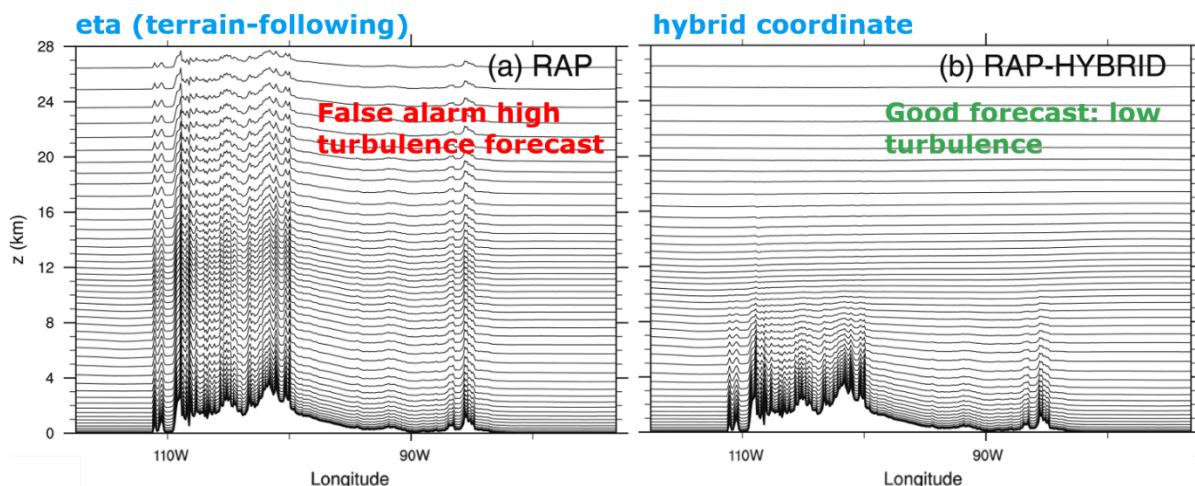


Figure 5-1. Cross-sections of layer interface heights over the Rocky Mountains for the eta (left panel) and hybrid (right panel) vertical coordinates for the WRF-Based Rapid Refresh (RAP) model. Adapted from Park et al., (2018).

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 (ERA5⁴⁷) 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, F_{map} 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 $F_{map} = 1.08$, 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 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 lightning 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)**:

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

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)**:

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

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)**:

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

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)**:

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

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 $\pm 180^\circ$.

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):

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

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	$\leq \pm 0.5$ K	$\leq \pm 2.0$ K	$\leq \pm 1.0$ K	$\leq \pm 1.0$ 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	$\leq \pm 1.0$ g/kg	$\leq \pm 0.8$ g/kg	$\leq \pm 1.0$ g/kg	$\leq \pm 1.0$ 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	$\leq \pm 0.5$ m/s	$\leq \pm 1.5$ m/s	(not addressed)	$\leq \pm 1.5$ 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	$\leq \pm 10$ degrees	(not addressed)	(not addressed)	$\leq \pm 10$ 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.

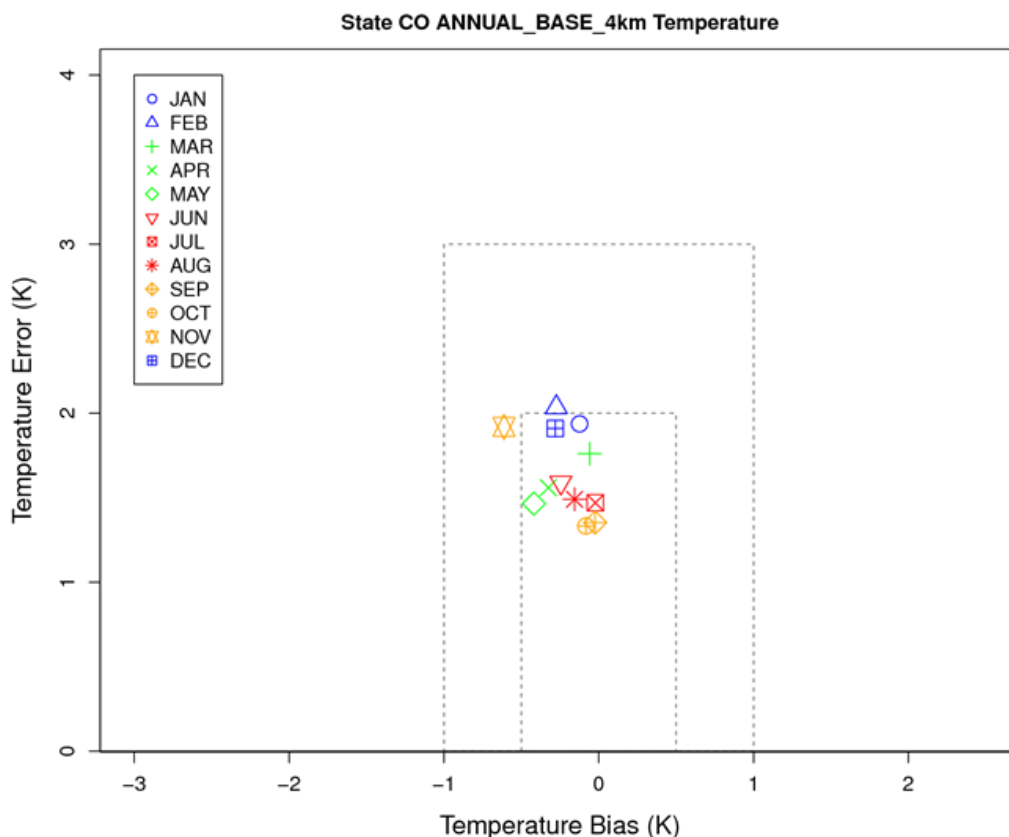


Figure 5-2. Example Soccer plot of monthly temperature error and bias (K) for 4-km domain.

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 (PRISM⁵⁰) 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 m²/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 (MOVES2014⁵²) 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 as 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 SO₂ 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) performance⁵³ 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 (FSWG⁵⁴) 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 (LNO_x), 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 (NATA⁵⁵). 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
<u>Horizontal Grid Mesh</u>	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
<u>Emissions</u>		
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
<u>Chemistry</u>		
Gas Phase Chemistry	CB6r4	Latest chemical reactions and kinetic rates with halogen chemistry (Yarwood et al., 2010)
Meteorological Processor	WRF-CAMx	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
<u>Deposition Schemes</u>		
Dry Deposition	Zhang dry deposition scheme	(Zhang et. al, 2001; 2003)
Wet Deposition	CAMx -specific formulation	rain/snow/graupel
<u>Numerics</u>		
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 ($\leq \pm 15\%$) and error ($\leq 35\%$). 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 (AQS⁵⁶) database throughout the U.S. Typical surface measurements at the ground level routine AIRS monitoring stations include ozone, NO₂, NO_x and CO.

IMPROVE Monitoring Network: The Interagency Monitoring of Protected Visual Environments (IMPROVE⁵⁷) network collects 24-hour average PM_{2.5} and PM₁₀ 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 (CSN⁵⁸) 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 (FRM⁵⁹) on a 1:3-day sampling schedule.

CASTNet Monitoring Network: The Clean Air Status and Trends Network (CASTNet⁶⁰) 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 (NADP⁶¹) collects weekly samples of SO₄, NO₃ and NH₄ 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 (AMET⁶²) (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 v1.3⁶³ 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.

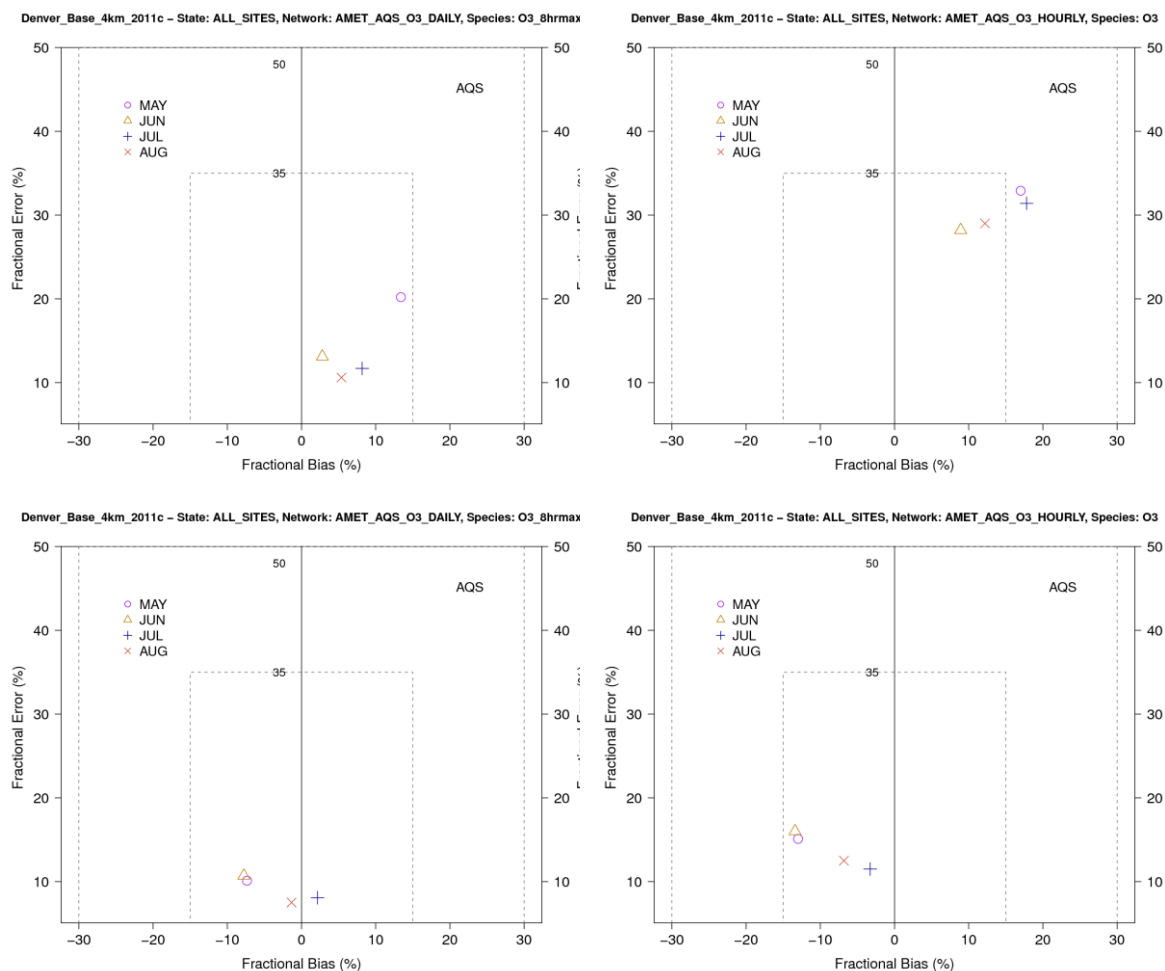


Figure 7-1. Example Soccer Plots of MDA8 (left) and hourly (right) ozone bias (FB) and error (FE) performance using no (top) and 60 ppb (bottom) observed ozone cut-off concentration (Source: Ramboll and Alpine, 2017).

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 $\leq \pm 15\%$ performance goal for the other three months. The exception is the DMAS site in downtown Denver and the FTCS site in Fort Collins that are located close to mobile NO_x emissions that titrate the ozone that is not reproduced by the model due to dilution of the local NO_x emissions across a 4-km grid cell.

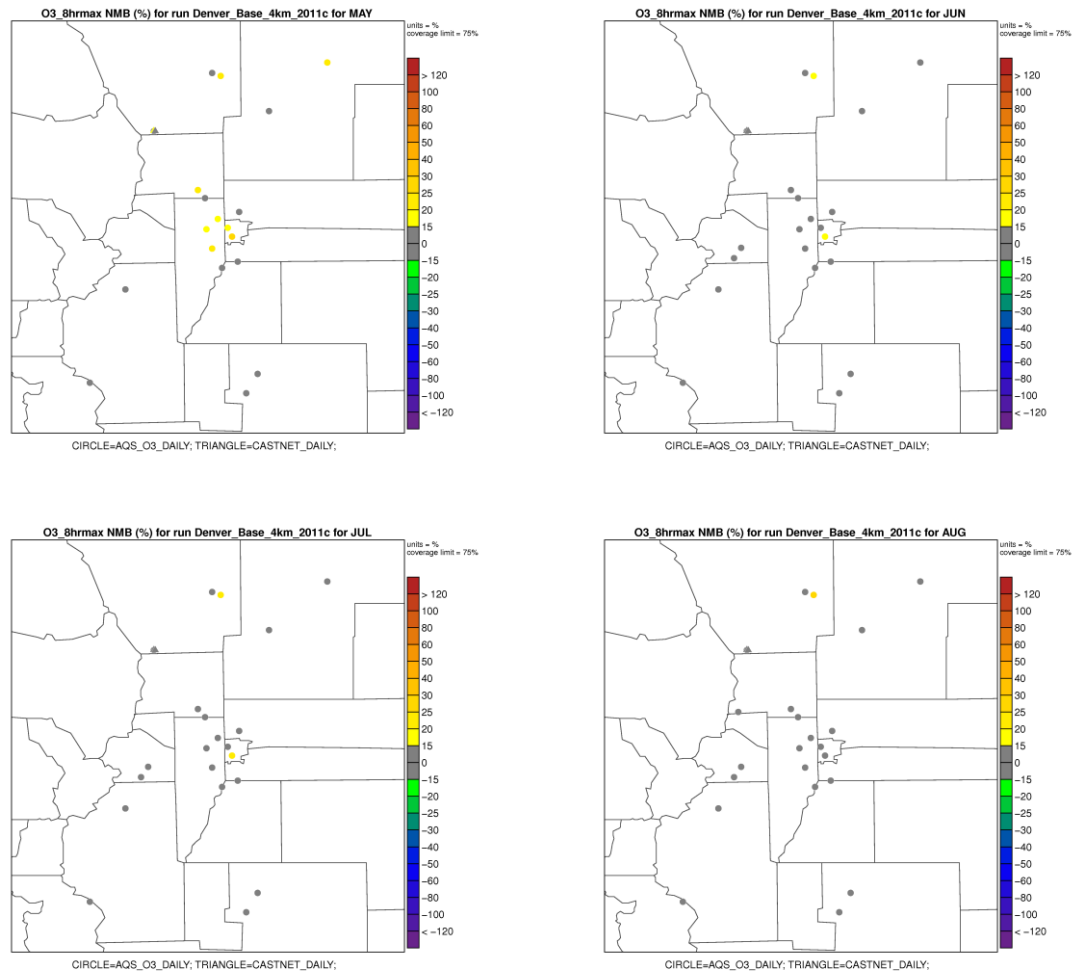


Figure 7-2. Spatial statistics plot of MDA8 monthly ozone model performance for Normalized Mean Bias (NMB), AQS sites in the Denver Metro/NFR NAA using no observed ozone cut-off concentration and May (top left), June (top right), July (bottom left) and August (bottom right) (Source: Ramboll and Alpine,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

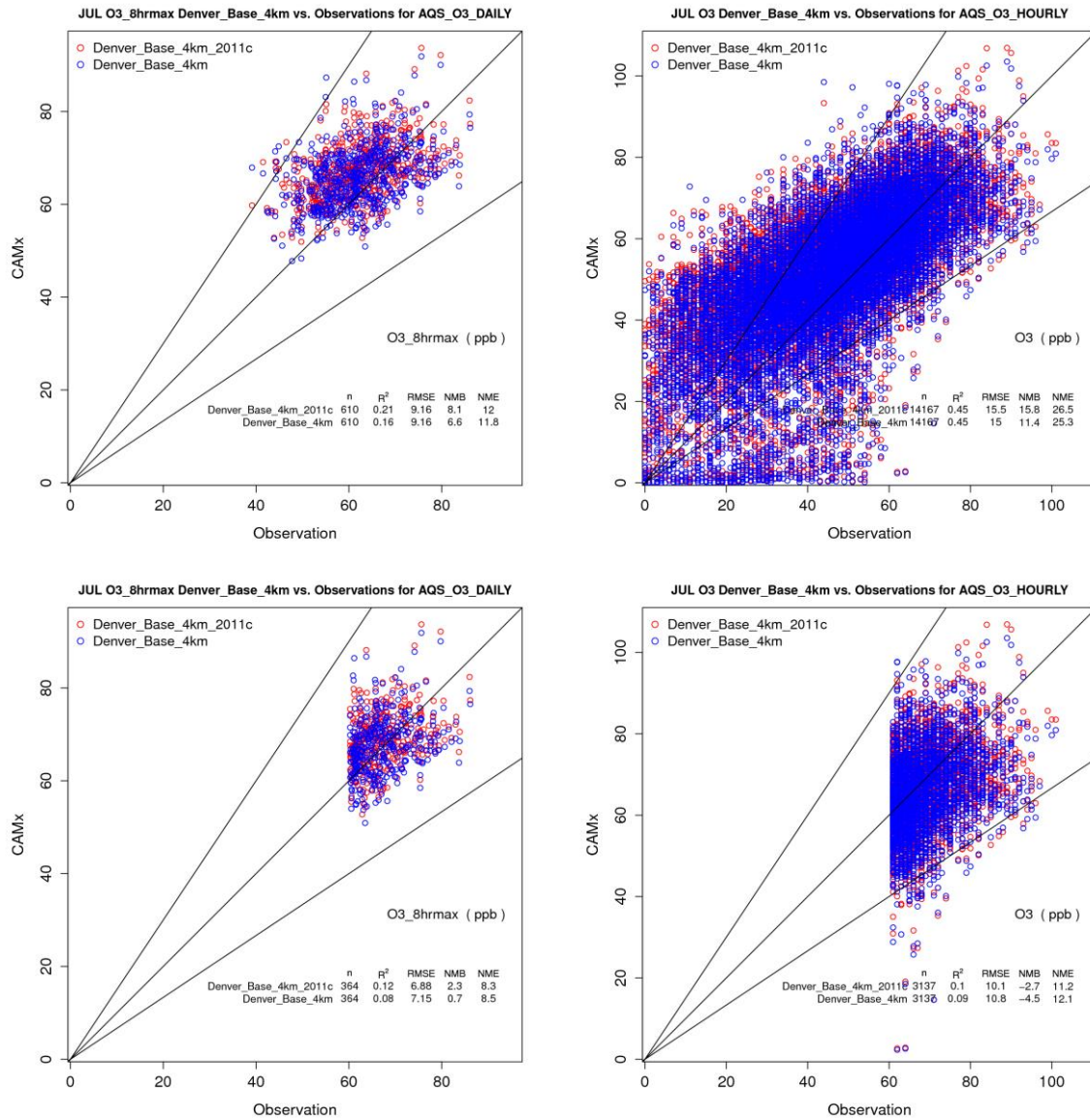


Figure 7-3. Scatter plots and model performance statistics for MDA8 (left) and hourly (right) ozone concentrations using no (top) and 60 ppb (bottom) observed ozone cut-off concentrations during the month of July (Source: Ramboll and Alpine, 2017).

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).

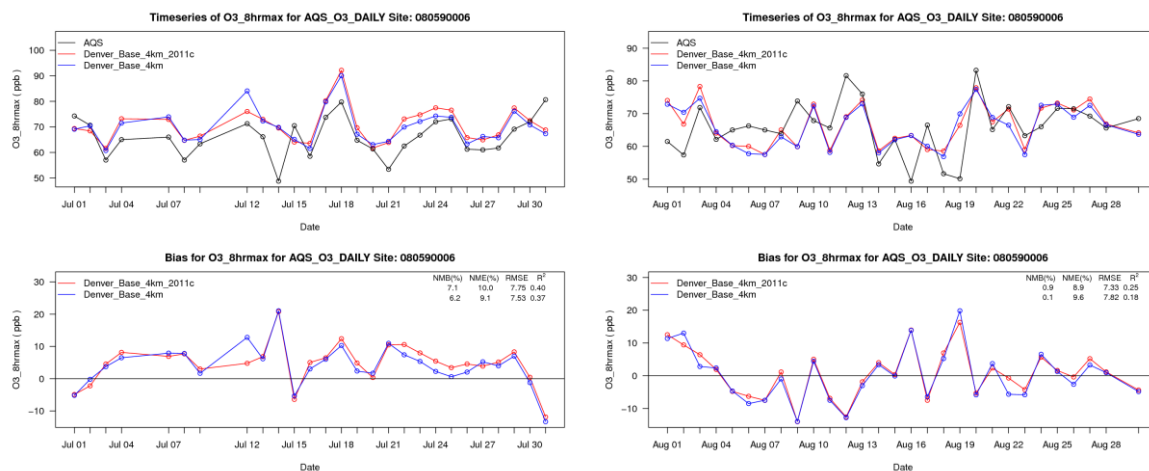


Figure 7-4. Time series of predicted and observed (black) MDA8 ozone concentrations (top panel) and bias (bottom panel) at Rocky Flats North (RFNO) for the preliminary 2011b1 (blue) and final 2011c (red) CAMx 4 km base case simulations and the months of July (left) and August (right) (Source: Ramboll 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 detail 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 NO_x 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 from 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 availability 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 NO_x 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 (SMAT⁶⁵) 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:

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

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>

$$RRF = \sum \text{MDA8 Ozone}_{FY} / \sum \text{MDA8 Ozone}_{BY}$$

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 (SNMOS⁶⁶). 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 custodial 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 Personnel 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 Manual (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 Section 1.5.7. 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 is 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 2014 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	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					
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	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				
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	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	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				
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	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				
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	47	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
12-Oct	51	43	44	45		47	49	49	51	51	48		47	48	47	49	41	51	46	48	50	45	42	51	51	51	49
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				
29-Oct	44	38	45			40	48	40	43	43	56		50	40	50	43	33	44	41	39	42	45		56	48	56	50
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
7-Nov	44	31	45	33		37	37	39	44	40	40		30	39	48	41	30	37	35	37	41	44		48	37	44	48
8-Nov	41	40	46	40		43	44	37	39	38	40		29	38	42	43	36	43	44	36	38	39		44	44	40	43
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
6-Dec	25	26		25		26	34	42	42	41	44		26		33	29	22	26	40	41	41	34		44	34	44	33
7-Dec	20	30		33		38	38	38	42	42	35		15		41	36	18	34	32	38	41	36		42	38	42	41
8-Dec	26	26	39	17		21	29	32	39	32	33		25		34	24	22	24	29	32	39	41		39	29	39	34
9-Dec	22	31	40	13		18	28	30	34	31	24		17		35	22	24	26	27	32	32	44		35	28	34	35
10-Dec	24	29	35	27		28	34	19	32		23		17		34	27	10	31	24	28	28	25		34	34	32	34
11-Dec	17	28	37	17		22	30	27	39	34	25		15		37	24	17	27	30	30	36	25		39	30	39	37
12-Dec	37	27	40	14		22	37	31	41	35	23		12		35	21	28	24	34	18	32	31		41	37	41	35
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
14-Dec	38	38	39	38		44	41	41		42	45		26		41	40	34	41	40	40	44	37		45	44	45	41
15-Dec	36	32	43	34		25	40	33	33	35	38		23		41	37	27	36	41	24	24	31		41	40	38	41
16-Dec	35	32	43	17		15	26	35	40	36	31		20		37	25	29	15	37	35	39	36		40	26	40	37
17-Dec	36	29	38	20		27	31	39	43	41	43		22		36	18	20	24	36	37	42	22		43	31	43	36
18-Dec	41	32	39	27		33	36	34	34	38	39		24		41	32	24	35	40	32	36	17		41	36	39	41
19-Dec	39	34	42	32		39	38	30	36	34	37		16		43	36	18	37	42	24	35	21		43	39	37	43
20-Dec	35	27	40	23		29	34	33	40	37	36		17		43	23	17	32	36	30	36	32		43	34	40	43
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	Montezuma	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	Montezuma	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	Montezuma	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	Montezuma	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	Montezuma	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	Montezuma	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
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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
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September 2020

NEW MEXICO OZONE ATTAINMENT INITIATIVE PHOTOCHEMICAL MODELING STUDY – 2014 MODELING PLATFORM DEVELOPMENT AND MODEL EVALUATION



NEW MEXICO OZONE ATTAINMENT INITIATIVE PHOTOCHEMICAL MODELING STUDY – 2014 MODELING PLATFORM DEVELOPMENT AND MODEL EVALUATION

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CONTENTS

ACRONYMS and ABBREVIATIONS	viii
1. INTRODUCTION	1
1.1 NM OAI Project Genesis	1
1.2 Conceptual Model for High Ozone Concentrations in New Mexico	3
1.2.1 Southern New Mexico	3
1.2.2 Bernalillo County and Vicinity	7
1.2.3 Northern New Mexico	8
1.3 Overview of NM OAI Study Modeling Approach	10
1.3.1 WRAP-WAQS 2014 PGM Platform Development Study	11
1.3.2 EPA 2016v1 Modeling Platform	12
1.3.3 Episode Selection	13
1.3.4 Model Selection	13
1.3.5 Domain Selection	14
1.3.6 Base and Future Year Emissions Data	16
1.3.7 Initial and Boundary Conditions Development	16
1.3.8 Diagnostic Sensitivity Analyses	16
1.3.9 Model Performance Evaluation	16
1.3.10 Future Year Base and Control Strategy Modeling	17
1.3.11 Future Year Source Apportionment Modeling	17
2. 2014 WRF METEOROLOGICAL MODELING	18
2.1 WRF Meteorological Model	18
2.2 WRF Horizontal Modeling Domain	18
2.3 WRF Model Configuration	19
2.3.1 Model Vertical Resolution	20
2.3.2 Vertical Coordinate	20
2.3.3 Topographic Inputs	22
2.3.4 Vegetation Type and Land Use Inputs	22
2.3.5 Atmospheric Data Inputs	22
2.3.6 Time Integration	23
2.3.7 Diffusion Options	23
2.3.8 Lateral Boundary Conditions	24
2.3.9 Top and Bottom Boundary Conditions	24
2.3.10 Sea Surface Temperature Inputs	24
2.3.11 Four Dimensional Data Assimilation (FDDA)	24
2.3.12 New Lightning Data Assimilation	24
2.3.13 PBL and LSM Physics Options	24
2.3.14 Remaining WRF Physics Options	25
2.3.15 Application Methodology	26
2.4 WRF Model Evaluation	26
2.4.1 Quantitative Evaluation Using METSTAT	26
2.4.2 Qualitative Evaluations Using PRISM Data	37
2.4.3 Conclusions of 2014 WRF Model Performance	40

3.	BOUNDARY CONDITION INPUTS	41
3.1	WRAP 2014 GEOS-Chem Modeling	41
3.2	2014 GEOS-Chem Model Evaluation	43
4.	2014 EMISSION INPUTS	44
4.1	Available Emissions Inventory Datasets	44
4.2	Development of CAMx Emission Inputs	44
4.2.1	Day-Specific On-Road Mobile Source Emissions	44
4.2.2	Point Source Emissions	45
4.2.3	Area and Non-Road Source Emissions	45
4.2.4	Episodic Biogenic Emissions	45
4.2.5	Wildfires, Prescribed Burns, Agricultural Burns	46
4.2.6	Other Natural Emissions	46
4.2.7	QA/QC of Emissions Processing and Emissions Merging	46
4.2.8	Use of the Plume-in-Grid (PiG) Subgrid-Scale Plume Treatment	47
4.2.9	QA/QC of Model-Ready Emissions	47
4.2.10	Summary of Emissions for 4-km New Mexico Domain	48
5.	DIAGNOSTIC SENSITIVITY TESTS	54
5.1	WRF-CAMx Processing of 2014 WRF Output	54
5.1.1	Treatment of Minimum Kv	54
5.1.2	Layer Collapsing Strategy	54
5.2	CAMx Meteorological Diagnostic Sensitivity Tests	56
5.3	Summary CAMx Diagnostic Sensitivity Tests	63
6.	FINAL MODEL BASE CASE CONFIGURATION	64
6.1	Meteorological Inputs	64
6.2	Emission Inputs	64
6.3	Photochemical Model Inputs	64
6.3.1	PGM Science Configuration and Input Configuration	64
7.	2014 BASE CASE MODELING AND MODEL PERFORMANCE EVALUATION	67
7.1	2014 Base Case Modeling	67
7.2	EPA Model Performance Evaluation Recommendations	67
7.2.1	Overview of EPA Model Performance Evaluation Recommendations	67
7.3	Overview of Evaluation of CAMx 2014 Base Case Procedures	68
7.3.1	Photochemical Model Evaluation Methodology	68
7.3.2	Model Performance Goals and Benchmarks	68
7.3.3	Available Aerometric Data for the Evaluations	69
7.3.4	Atmospheric Model Evaluation Tool (AMET)	69
7.4	Ozone Evaluation Across the 4-km New Mexico Domain	70
7.5	Ozone Evaluation Across New Mexico	71
7.6	Ozone Evaluation in New Mexico Subregions	74
7.7	Ozone Evaluation at Individual New Mexico Monitoring Sites	76
7.8	Ozone Performance Related to Future Year Ozone Projections	83
7.8.1	Bloomfield Top 10 Ozone Performance	84

7.8.2	Desert View Top 10 Ozone Performance	86
7.8.3	Carlsbad Top 10 Ozone Performance	87
8.	SUMMARY AND CONCLUSIONS	88
9.	REFERENCES	90

APPENDIX

Appendix A Time Series of Predicted and Observed MDA8 Ozone Concentrations at Sites in New Mexico

TABLE OF TABLES

Table 1-1.	Lambert Conformal Conic (LCC) projection parameters for the NM OAI Study 36/12/4 modeling domains.	15
Table 1-2.	Grid definitions for CAMx NM OAI Study 2014 36/12/4-km modeling domains.	15
Table 2-1.	WRF 36 level vertical layer structure for the NM OAI study. This is the same WRF layer structure as used in WAQS 2011/2014/2016 and EPA 2016 WRF modeling.	21
Table 2-2.	NM OAI Study 2014 WRF model configuration and comparison with the WRF configuration used in the WRAP-WAQS 2014 and EPA 2014/2015/2016 WRF modeling.	25
Table 2-3.	Meteorological model performance benchmarks for simple and complex conditions.	29
Table 3-1.	2014 GEOS-Chem simulation model configuration used by WRAP whose output is used to define the 2014 day-specific diurnally varying BC inputs for the NM OAI Study photochemical modeling.	41
Table 4-1.	2014 base case biogenic emissions summary by month (in short tons per day) for the 4-km New Mexico domain.	46
Table 4-2.	New Mexico 4-km domain emissions processing categories.	49
Table 4-3.	2014 base case anthropogenic emissions summary (episode average short tons per day) by source category for the 4-km New Mexico domain.	50
Table 5-1.	WRF to CAMx vertical layer collapsing strategy used in the NM OAI Study.	55
Table 6-1.	Final CAMx model configuration for the NM OAI Study.	66
Table 7-1.	Recommended benchmarks for photochemical model statistics (Source: Emery et al., 2016).	69

Table 7-2.	AQS monitoring sites categorized into subregions of southern New Mexico (orange), Bernalillo County (yellow) and southern New Mexico (blue).	75
Table 7-3.	Region specific NMB and NME values for MDA8 Ozone and MDA8 Ozone when Observed Value is above 60 ppb.	75
Table 7-4.	CAMx 2014 base case model performance statistics for MDA8 Ozone concentrations by monitoring site for summer (May15-Aug) modeling period.	77
Table 7-5.	2014 Base Case model performance statistics of MDA8 Ozone with an observed ozone 60 ppb cut-off by monitoring site for summer (May 15-Aug) modeling period.	78
Table 7-6.	Predicted and observed MDA8 ozone concentrations (ppb) at Bloomfield for CAMx 2014 base case for modeled ranked 36 highest MDA8 ozone concentrations.	85
Table 7-7.	Predicted and observed MDA8 ozone concentrations (ppb) at Desert View for CAMx 2014 base case for modeled ranked 36 highest MDA8 ozone concentrations.	86
Table 7-8.	Predicted and observed MDA8 ozone concentrations (ppb) at Carlsbad for CAMx 2014 base case for modeled ranked 36 highest MDA8 ozone concentrations.	87

TABLE OF FIGURES

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).	2
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).	2
Figure 1-3.	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 southern New Mexico (left) and 12/4-km modeling domain and definition of source regions (right).	4
Figure 1-4.	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).	5
Figure 1-5.	Contributions of major Source Sectors in New Mexico to 2011 (top) and 2025 (bottom) ozone DVs at nine monitoring sites in Southwestern New Mexico.	6
Figure 1-6.	Contributions to ozone in Albuquerque during the June and July 2017 modeling episodes.	7
Figure 1-7.	Linear regression of the annual 4 th 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.	9
Figure 1-8.	Correlation between 500 hPa heights and elevated ozone concentrations for monitoring sites in the western U.S.	10
Figure 1-9.	36-km continental U.S. (36US1) and 12-km western U.S. (12WUS2) modeling domains used in the WRAP-WAQS CAMx 2014v2 modeling platform.	12
Figure 1-10.	NM OAI Study 2014 36/12/4-km PGM and emissions modeling domains.	14
Figure 1-11.	4-km New Mexico modeling domain for PGM and emissions modeling, with locations of New Mexico ozone monitors that were operating during some portion of 2014.	15
Figure 2-1.	WRF 36-km (outer extent), 12-km (d02) and 4-km (d03) modeling domains used in the NM OAI Study.	19
Figure 2-2.	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).	22
Figure 2-3.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface wind speed (m/s) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	31
Figure 2-4.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface wind direction (degrees) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	32
Figure 2-5.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface temperature (K) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	33

Figure 2-6.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface humidity (g/kg) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	34
Figure 2-7.	Time series plot of predicted and observed (black) daily humidity (g/kg) at Las Cruces International Airport for the WRF/ERA5 (red) and WRF/NAM (blue) simulations.	35
Figure 2-8.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface humidity (g/kg) model performance at Las Cruces International Airport against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	36
Figure 2-9.	May monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).	38
Figure 2-10.	June monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).	38
Figure 2-11.	July monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).	39
Figure 2-12.	June monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).	39
Figure 4-1.	New Mexico 2014 base case anthropogenic NO _x and VOC emissions by source category.	51
Figure 4-2.	Spatial distribution of the non-point (top) and point (bottom) source oil and gas NO _x (left) and VOC (right) emissions (episode avg tons per day) for New Mexico 4-km domain.	52
Figure 4-3.	Spatial distribution of on-road (top), rail (middle) and non-point/non-road equipment (bottom) NO _x (left) and VOC (right) emissions (episode avg tons per day) for New Mexico 4-km domain.	53
Figure 5-1.	Comparison of sensitivity tests NMB with 60 ppb cutoff spatial plots over NM.	57
Figure 7-1.	Scatter plot of predicted and observed MDA8 ozone across the AQS and CASTNET monitoring sites within the 4-km New Mexico domain during the modeling period (May 15-Aug 31, 2014) for the CAMx 2014 base case simulations.	70

- Figure 7-2. Spatial distribution of CAMx 2014 base case simulation period (May15-Aug 31) site-specific Normalized Mean Bias within the 4-km domain for MDA8 O3 (left) and MDA8 O3 above 60ppb cut-off (right). 71
- Figure 7-3. Scatter plots of predicted and observed MDA8 ozone (left) and MDA8 ozone when observed value is above 60 ppb cut-off (right) across the AQS monitoring sites in New Mexico during modeling period (May15-Aug 31) for the CAMx 2014 base case simulations. 72
- Figure 7-4. Soccer plots of MDA8 ozone (left) and MDA8 ozone when observed value is above a 60 ppb cut-off (right) with monthly average NMB and NME values across sites in New Mexico. The dashed lines represents the performance goals and criteria. 73
- Figure 7-5. Spatial distribution of site-specific Normalized Mean Bias for sites in New Mexico and the CAMx 2014 May-August base case simulation for all MDA8 ozone data (left) and MDA8 ozone with observed value above a 60 ppb cut-off (right). 73
- Figure 7-6. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at Bloomfield monitoring site (Site ID: 350450009). 79
- Figure 7-7. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at Coyote Ranger monitoring site (Site ID: 350390026). 80
- Figure 7-8. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at South Valley monitoring site (Site ID: 350010029). 81
- Figure 7-9. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at Desert View monitoring site (Site ID: 350130021). 82
- Figure 7-10. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at Carlsbad monitoring site (Site ID: 350151005). 83

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
ERA5	ECMWF global hourly meteorological forecasts at 30-km
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
LCC	Lambert Conformal Conic 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 presents the development and evaluation of a photochemical grid model (PGM) modeling platform 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 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 covering New Mexico and adjacent regions. Future year modeling, source apportionment and control measure evaluation are planned 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 1978¹). 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 Maximum Daily Average 8-hour (MDA8) 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 7² 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.

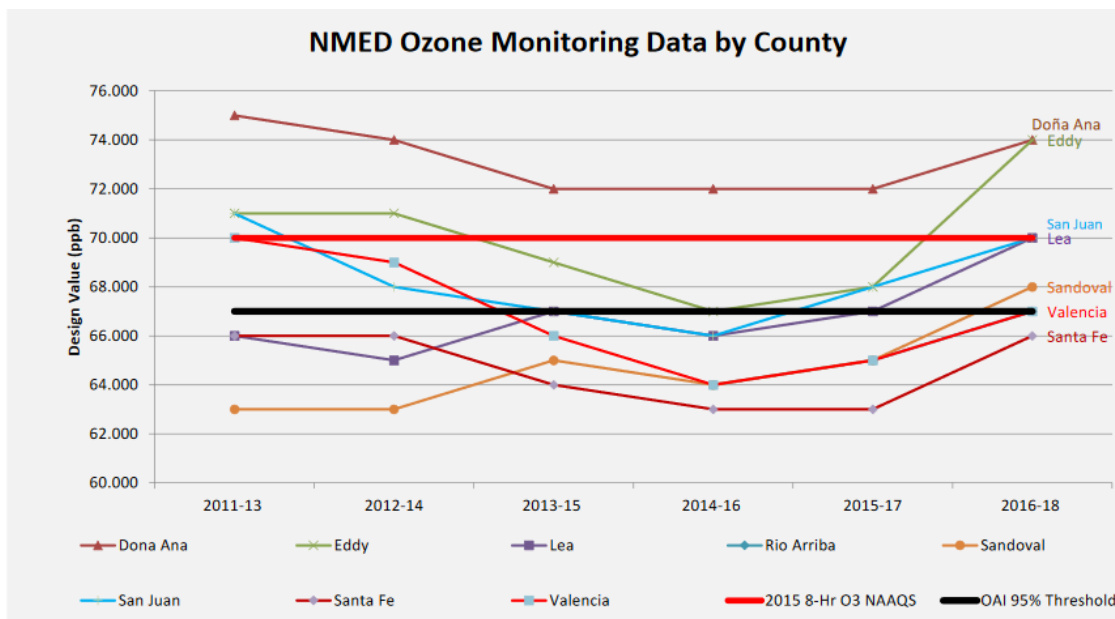
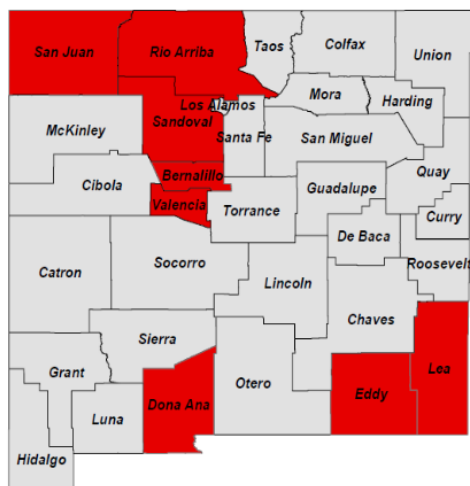


Figure 1-1. Trends in observed ozone DVs between 2013 and 2018 at 7 monitoring sites in New Mexico (Source: https://www.env.nm.gov/air-quality/wp-content/uploads/sites/2/2019/10/OAI_Presentation_09262019.pdf).



*Parallel planning is occurring for Bernalillo County through the Albuquerque/Bernalillo County Department of Environmental Health

- Counties within 95% of the standard:
 - San Juan (Navajo Lake, 70 ppb)
 - Doña Ana (several monitors, 74 ppb)
 - Eddy (Carlsbad, 74 ppb)
 - Lea (Hobbs, 70 ppb)
 - Rio Arriba (Coyote, 67 ppb)
 - Sandoval (Bernalillo, 68 ppb)
 - Valencia (Los Lunas, 67 ppb)

1

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 (OAI³) 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) for the NM OAI Study and the NM OAI Study PGM modeling was awarded to a contracting team of WESTAR and Ramboll. .

1.2 Conceptual Model for High Ozone Concentrations in New Mexico

There are three interrelated but distinct Conceptual Models of ozone formation within New Mexico: southern New Mexico, Bernalillo County and surrounding areas, and northern New Mexico. All three regions 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).

1.2.1 Southern New Mexico

Ozone at monitoring sites in southern 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., Central America and 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 southern 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 Southern New Mexico Ozone Study (SNMOS⁴) conducted 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 1-3. SNMOS found that a vast majority of ozone in southern New Mexico is due to ozone transport from outside of New Mexico. For example, the left panel in Figure 1-3 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 shown in the right panel in Figure 1-3. Only 3 percent of the 2011 ozone DV at the Desert View monitor in Dona Ana County is due to anthropogenic emissions from New Mexico, and New Mexico emissions contribute less than 2 percent of the projected 2025 ozone DV at Desert View (not shown).

³ <https://www.env.nm.gov/air-quality/o3-initiative/>

⁴ <https://www.wrapair2.org/SNMOS.aspx>

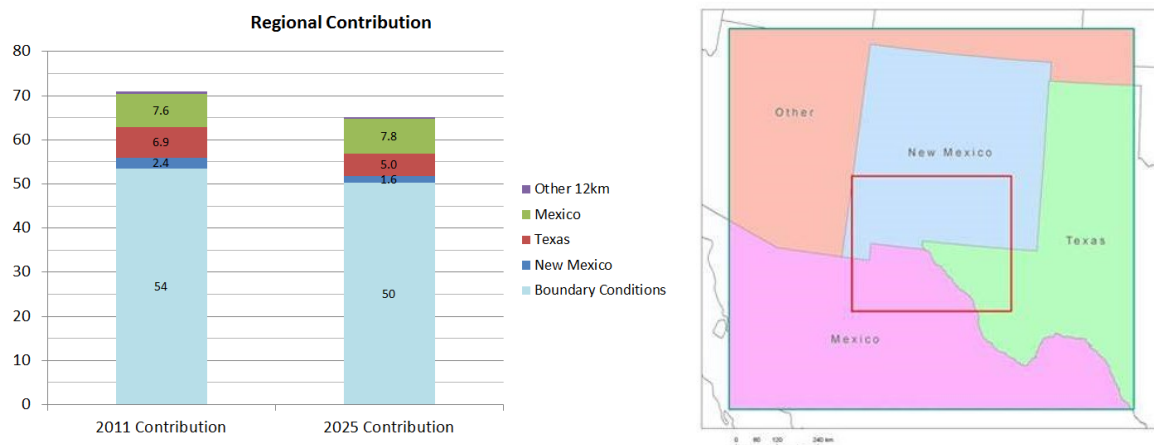


Figure 1-3. Contributions of geographic regions (including Boundary Conditions) to the 2011 and 2025 ozone Design Values at Desert View monitoring site in Dona Ana County in southern New Mexico (left) and 12/4-km modeling domain and definition of source regions (right).

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 right panel of Figure 1-3. Figure 1-4 displays the Source Sector contributions to the 2011 and 2025 ozone DV at the 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 1-4, 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 1-4, bottom panel).

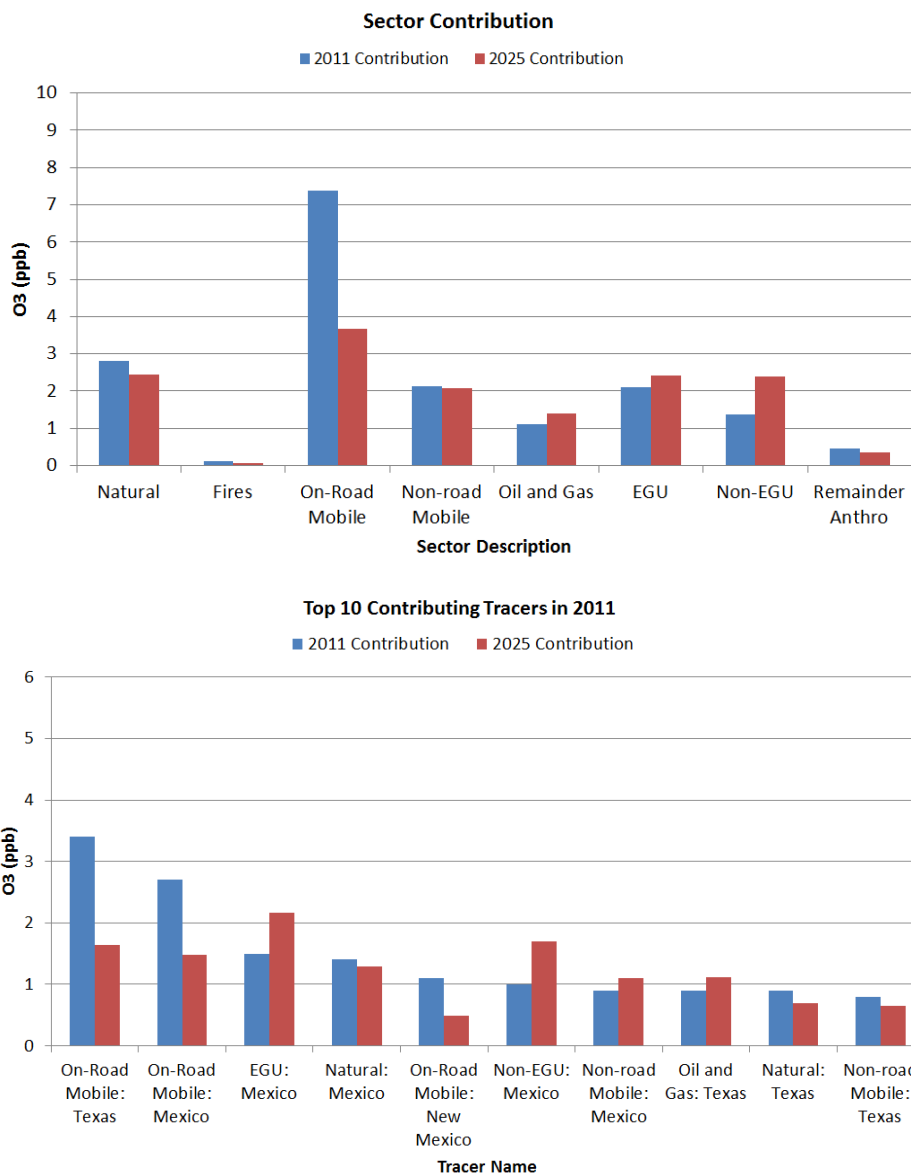


Figure 1-4. Contributions of Source Sector emissions within the 12/4-km modeling domain to the 2011 and 2025 ozone Design Value at Desert View monitoring site (top) and top ten Source Group contributions (bottom).

Figure 1-5 examines the contributions of emissions from New Mexico to 2011 and 2025 ozone DVs at nine monitoring sites in southern New Mexico. With one exception, on-road mobile source emissions are the largest contributing Source Sector in New Mexico to 2011 ozone DVs in southern New Mexico with the on-road mobile contribution at the Solano monitoring site being higher than the others. The one exception is the furthest east Carlsbad monitoring site in Eddy County where O&G emissions are the largest contributing Source Sector in New Mexico due to being within the Permian Basin O&G development region. 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.

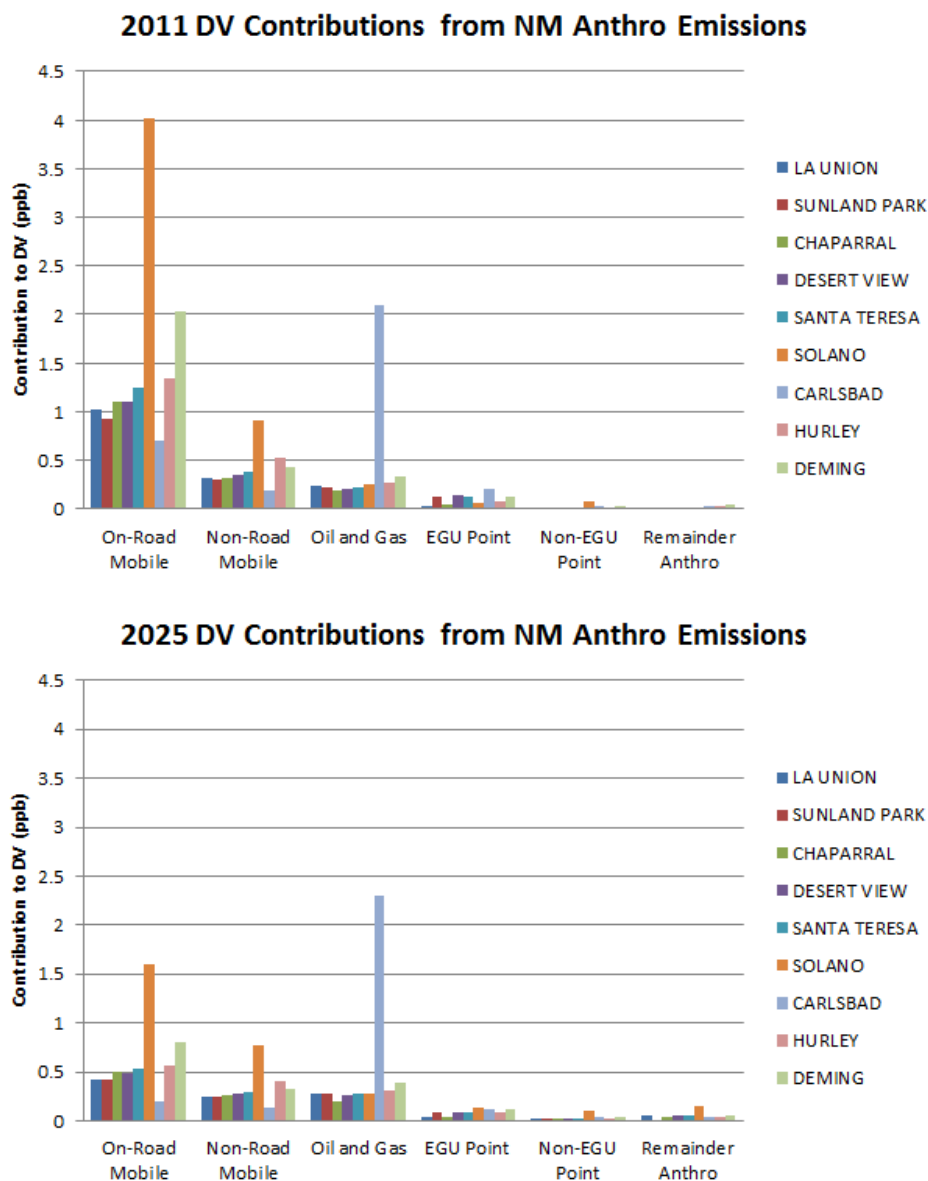


Figure 1-5. Contributions of major Source Sectors in New Mexico to 2011 (top) and 2025 (bottom) ozone DVs at nine monitoring sites in Southwestern New Mexico.

1.2.2 Bernalillo County and Vicinity

High ozone in Bernalillo County and nearby areas is dominated by ozone transport and shares some of same ozone Conceptual Model attributes as northern New Mexico, with the addition of local contributions from a major city (Albuquerque). The City of Albuquerque conducted an ozone modeling study⁵ 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. Ozone source apportionment was performed to determine the geographic regions that contributed to elevated ozone concentrations in Albuquerque. Figure 1-6 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. But sources other than New Mexico anthropogenic emissions (e.g., natural sources and sources outside of New Mexico) were the largest contributor accounting for 86% and 76% of the ozone during the, respectively, June and July episodes.

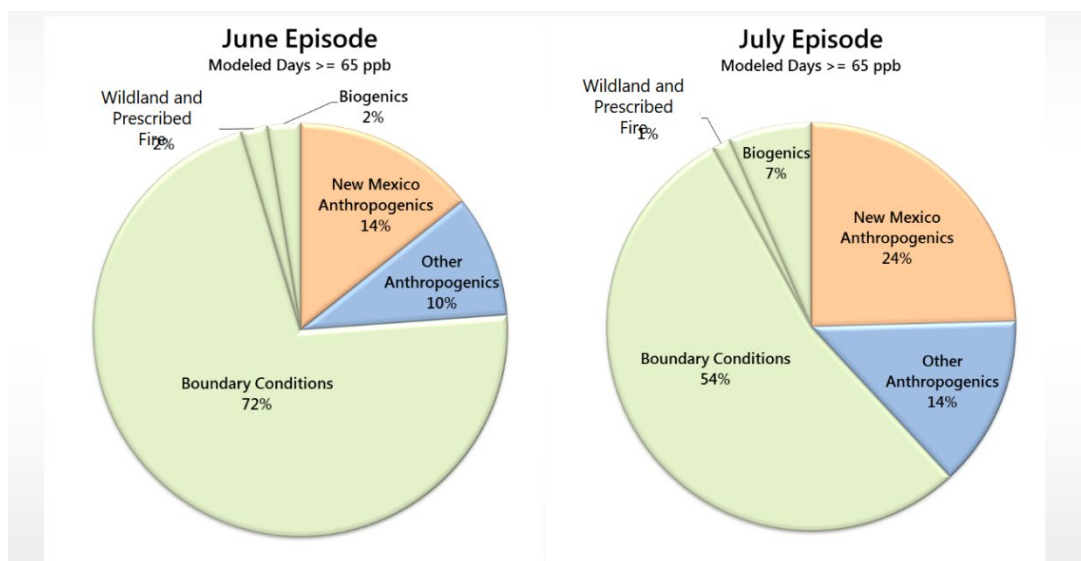


Figure 1-6. Contributions to ozone in Albuquerque during the June and July 2017 modeling episodes.

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.

⁵ <https://www.cabq.gov/airquality/documents/06-ken-craig-sonoma-technology-inc-ozone-modeling-presentation-10-17-2018-aqcb-meeting.pdf>

- 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 more 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.

1.2.3 Northern New Mexico

The Four Corners Air Quality Task Force (FCAQTF) conducted a comprehensive modeling study of the region and found, although there are significant contributions due to local power plants and O&G production in the San Juan Basin, ozone transport was by far the largest contributor. The FCAQTF identified numerous local control measures that could help mitigate elevated ozone concentrations in the 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 that is also relevant to northern New Mexico. Reddy and Pfister 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 hPa⁶ pressure level. The Denver 2017 ozone SIP modeling study (CDPHE and RAQC, 2016c) extended the analysis to include more recent years and for summer-average conditions. Figure 1-7 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 that shows years with higher 500 hPa heights tend to have higher ozone, and vice versa.

Figure 1-8 displays the correlation between elevated ozone concentrations and 500 hPa heights in the western U.S. 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 northern 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. But the presence of a large high pressure over the region, which results in slow winds and hot temperatures, is correlated with high ozone concentrations in northern New Mexico.

⁶ hPa is 100 Pa where Pa is short for Pascal that is a unit of pressure where 500 hPa = 500 mb.

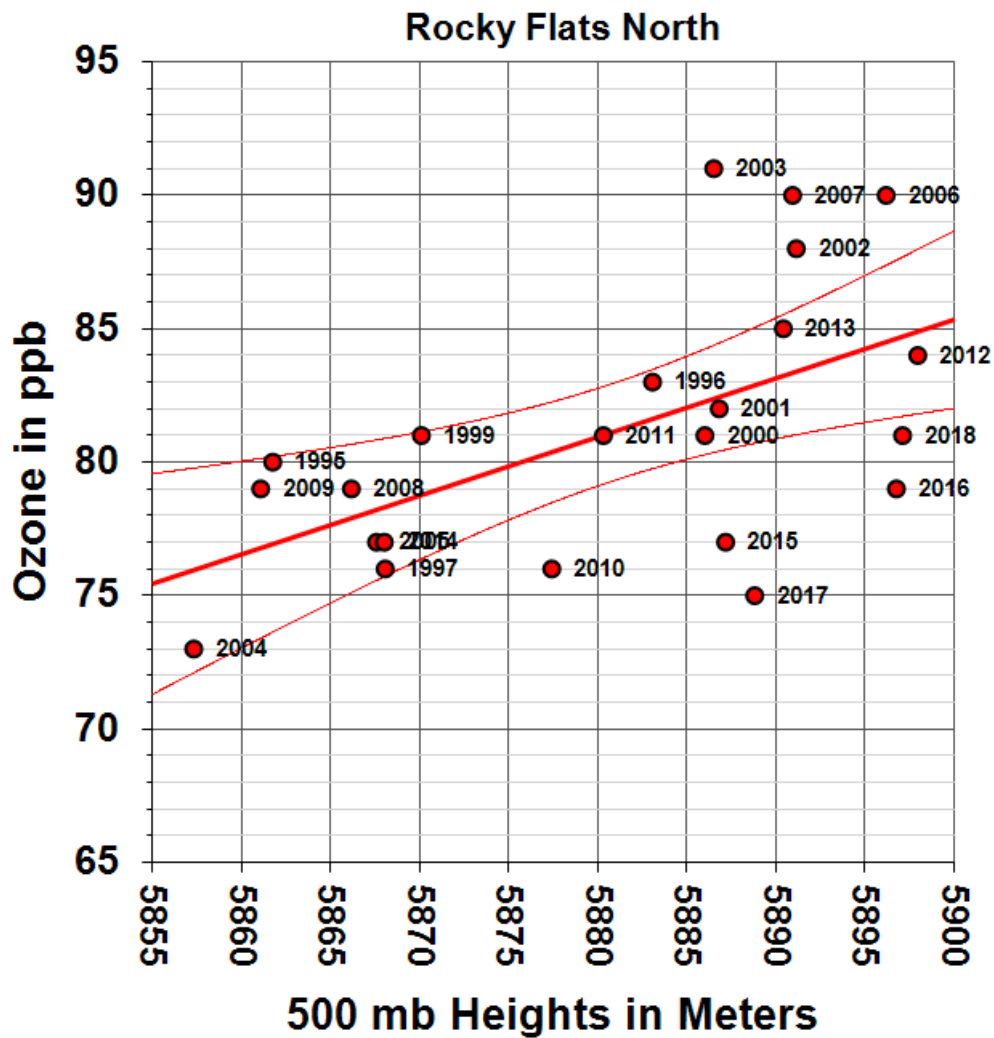


Figure 1-7. Linear regression of the annual 4th highest MDA8 ozone concentrations and mean July through August NCEP/NCAR Reanalysis 500 hPa (or 500 mb) heights for the DM/NFR NAA region at the Rocky Flats North (RFNO) monitoring site for the years 1995 to 2018.

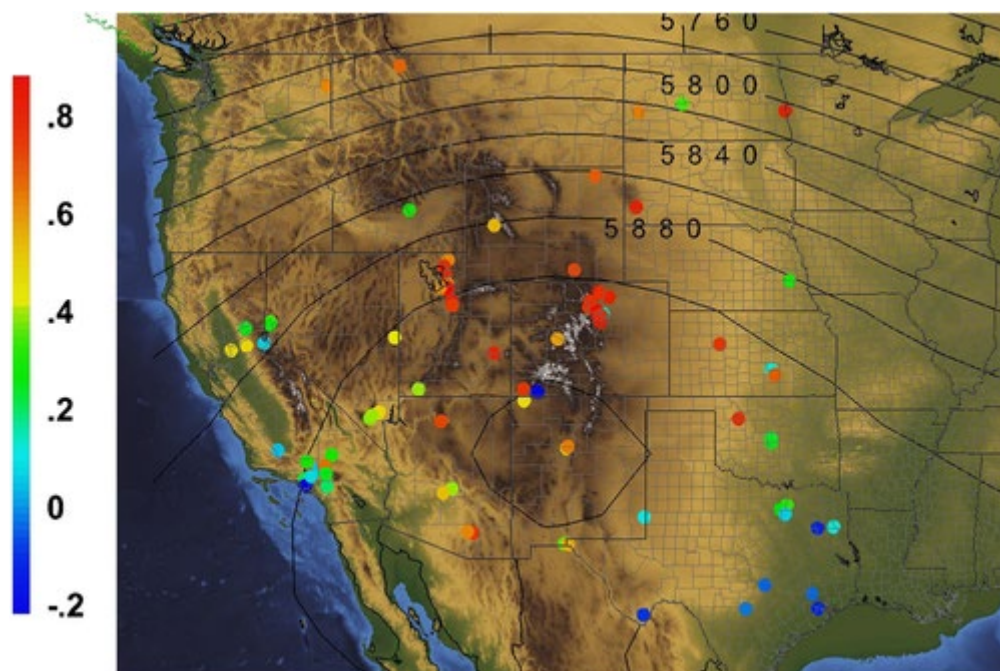


Figure 1-8. Correlation between 500 hPa heights and elevated ozone concentrations for monitoring sites in the western U.S.⁷

1.3 Overview of NM OAI Study Modeling Approach

The procedures used for the NM OAI Study photochemical modeling were described in a detailed Modeling Protocol dated May 19, 2020 (Ramboll and WESTAR, 2020a⁸). A description of the tasks and schedule for completing the NM OAI Study is contained in a Work Plan (Ramboll and WESTAR, 2020b⁹) with presentations, results and reports posted to the NM OAI Study webpage¹⁰ as they are produced.

The NM OAI Study is conducting PGM modeling by enhancing the WRAP-WAQS 2014v2 36/12-km PGM modeling platform¹¹ with the addition of a new 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 is performing 2014 base year modeling and model performance evaluation. Future year modeling will also be conducted. The NM OAI Study PGM modeling is being conducted in accordance with EPA's guidance for ozone State Implementation Plan (SIP) attainment demonstration modeling (EPA, 2018d).

⁷ <https://agupubs.onlinelibrary.wiley.com/cms/asset/192a6975-cd1c-4bce-a20a-a2a049ca4df6/jgrd52767-fig-0001-m.png>

⁸ https://www.wrapair2.org/pdf/NM_OAI_Modeling_Protocol_v5.pdf

⁹ https://www.wrapair2.org/pdf/NM_OAI_Work_Plan_v2.pdf

¹⁰ <https://www.wrapair2.org/NMOAI.aspx>

¹¹ <http://views.cira.colostate.edu/wiki#WAQS-2014-Modeling-Platform>

The two main studies that the NM OAI Study modeling is leveraging off of to cost-effectively develop a PGM modeling platform for analyzing ozone issues in New Mexico are discussed below.

1.3.1 WRAP-WAQS 2014 PGM Platform Development Study

The WRAP-WAQS developed an annual 2014 PGM modeling platform to address air quality issues in the western states. The initial use of the WRAP-WAQS 2014 PGM modeling platform is to address the western state technical needs for their Regional Haze SIPs that are scheduled to be submitted to EPA by July 2021. But the platform is designed so it can be used to address visibility, ozone, particulate matter, deposition and other air quality and air quality related values issues in the western states.

An initial WRAP-WAQS 2014v1 PGM modeling platform was developed in 2019 for the CAMx and CMAQ PGMs that is documented in a webpage¹² on the Intermountain West Data Warehouse (IWDW). Additional diagnostic sensitivity tests were conducted to address several model performance issues culminating in the WRAP-WAQS 2014v2 36/12-km CAMx modeling database that was used as the starting point for the NM OAI Study CAMx summer of 2014 36/12/4-km modeling database. The develop of the WRAP-WAQS 2014v2 PGM database and model performance evaluation is available in a webpage¹³ on the IWDW.

The WRAP-WAQS 2014v2 CAMx platform used a 36/12-km grid resolution domains structure as shown in Figure 1-9. Meteorological inputs were based on the WAQS 2014 36/12/4-km WRF meteorological model simulation (Bowden, Talgo and Adelman, 2016¹⁴). The 2014 emissions were based on the 2014 National Emissions Inventory (2014NEI¹⁵) with updates from western states¹⁶. Boundary Condition (BC) inputs were based on a WRAP 2014 GEOS-Chem model simulation.

Because the NM OAI Study requires a 4-km modeling domain for New Mexico, new summer of 2014 36/12/4-km WRF meteorological modeling was conducted that was used to develop 36/12/4-km meteorological inputs for CAMx. The NM OAI Study defined their 36/12-km domains to match WRAP-WAQS 2014v2 36/12-km domains so the WRAP-WAQS 2014v2 36/12-km emission and some other inputs (e.g., BCs) can be directly used in the NM OAI Study PGM modeling.

¹² http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx

¹³ https://views.cira.colostate.edu/iwdw/docs/WRAP_WAQS_2014v2_MPE.aspx

¹⁴ http://views.cira.colostate.edu/wiki/Attachments/Modeling/WAQS_2014_WRF_MPE_January2016.pdf

¹⁵ <https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data>

¹⁶ https://www.wrapair2.org/pdf/WRAP%20Regional%20Haze%20SIP%20Emissions%20Inventory%20Review%20Documentation_for_Docket%20Feb2019.pdf

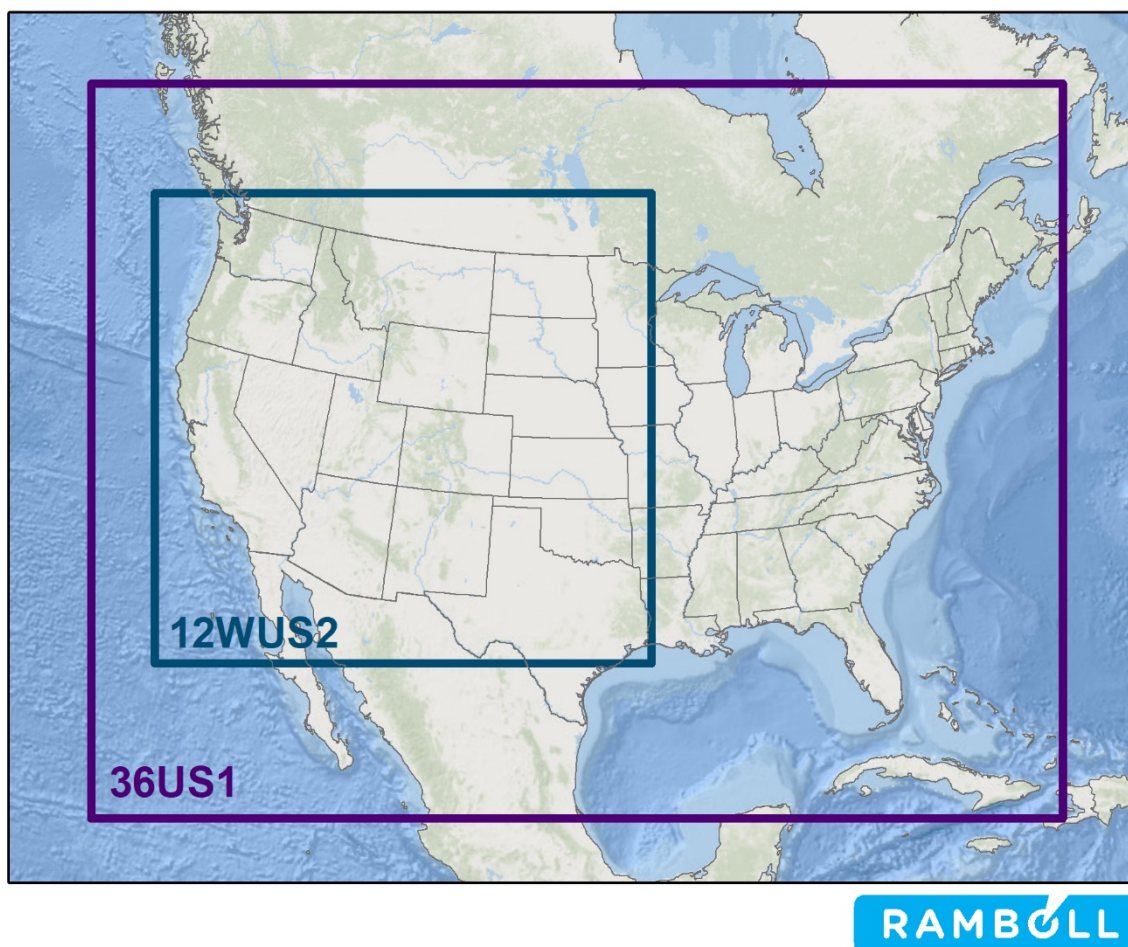


Figure 1-9. 36-km continental U.S. (36US1) and 12-km western U.S. (12WUS2) modeling domains used in the WRAP-WAQS CAMx 2014v2 modeling platform.

1.3.2 EPA 2016v1 Modeling Platform

The EPA, Multi-Jurisdictional Organizations (MJOs), and states conducted a collaborative national 2016 emissions modeling platform¹⁷ (2016 EMP) study to develop a 2016 emissions inventory of comparable quality to the NEI. Separately, EPA developed a 2016 PGM modeling platform that used a 12-km grid resolution continental U.S. domain and an expanded 36-km grid resolution 36US3 domain. EPA has released several versions of their 2016 36/12-km PGM modeling platform with version 1 being the latest version (2016v1).

EPA's 2016v1¹⁸ PGM modeling platform uses the 2016 EMP version 1 emissions¹⁹ from the EPA/MJO/states emissions collaborative study (called 2016fh). It was released in

¹⁷ <http://views.cira.colostate.edu/wiki/wiki/9169>

¹⁸ <https://www.epa.gov/air-emissions-modeling/2016v1-platform>

¹⁹ <http://views.cira.colostate.edu/wiki/wiki/10202>

October 2019 with future year emissions for 2023 and 2028 (2023fh and 2028fh inventories). Since the release of the EPA 2016v1 modeling platform in October 2019, there have been several updates to the emissions, as follows:

1. Updates to 2023 and 2028 EGU emissions to address the accidental dropping of NO_x and SO₂ emissions for a few EGU sources (January 2020). EPA found that source/hour where the heat input, steam load, and gross load are all zero in the hourly CEMs data, SMOKE will set all emissions to zero for that source/hour, even if the CEMs NO_x or SO₂ for that source/hour is not zero.²⁰
2. The 2023 and 2028 Commercial Marine Vessel (CMV) emissions were updated to address hoteling and to match the 2016 days-of-week (February 2020).²¹
3. The WRAP 2016 and 2023 O&G emissions were added as an option to EPA's 2016 and 2023 O&G estimates (April 2020). This resulted in double counting as EPA incorrectly had O&G emissions in files that were not supposed to include O&G emissions (i.e., non-EGU point) so corrections have to be made if the WRAP 2023 O&G emissions are used.
4. New 2016, 2023 and 2028 airport emissions for all airports to correct an error that resulted in airport emissions that are a little more than half of the airport emissions in the initial release of the 2016v1 inventories.
5. The SMOKE processing of the 2016 EGU emissions dropped some EGUs as duplicates when they were not. This appears to be a minor issues for EGUs in the western states (August 2020).

The NM OAI Study plans to use the EPA 2016v1 emission projections in their future year modeling.

1.3.3 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 that can be leveraged for the NM OAI Study. Details on the episode selection are contained in Chapter 3 of the NM OAI Study Modeling Protocol (Ramboll and WESTAR, 2020a).

1.3.4 Model Selection

Details on the rationale for model selection are provided in Chapter 2 of the NM OAI Study Modeling Protocol (Ramboll and WESTAR, 2020a). The Weather Research Forecast (WRF) prognostic meteorological model was selected. 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 v3.1) will be used for biogenic emissions. There are special processors for fires, windblown dust (WBD), lightning NO_x (LNO_x) and oceanic sea salt (NaCl) and Dimethyl Sulfide (DMS) emissions that were used. The 2014 version of the MOTO Vehicle Emissions Simulator (MOVES2014b) on-road mobile source emissions model

²⁰ ftp://newftp.epa.gov/Air/emismod/2016/v1/2023fh1_2028fh1_addendum/README_2023fh1_2028fh1_ptegu_addendum.txt

²¹ <http://views.cira.colostate.edu/wiki/wiki/11205>

will be used with SMOKE-MOVES and WRF meteorological data to generate on-road mobile source emissions for the 4-km New Mexico modeling domain.

The Comprehensive Air-quality Model with extensions (CAMx) photochemical grid model (PGM) was used because it supports two-way grid nesting, was used in the WRAP-WAQS regional haze modeling, contains a well-vetted ozone source apportionment tool and has a rich and successful history of application to the region.

1.3.5 Domain Selection

The NM OAI Study modeling is using the same 36-km 36US and 12-km 12WUS2 domains as used in the WRAP-WAQS 2014 modeling platform (Figure 1-9). A new 4-km New Mexico domain was added to the 36/12-km domain structure. Figure 1-10 displays the 36/12/4-km domain structure with Figure 1-11 showing the 4-km New Mexico domain. New WRF 2014 36/12/4-km meteorological modeling was conducted to generate finer scale 4-km meteorological conditions for the New Mexico domain and consistent meteorology among the 36/12/4-km domains. The domains use a Lambert Conformal Conic (LCC) projection using the parameters given in Table 1-1 with the definitions of the extent of the 36/12/4-km domains given in Table 1-2. CAMx will be run using the 36/12/4-km domain structure shown in Figure 1-10 using two-way interactive grid nesting.

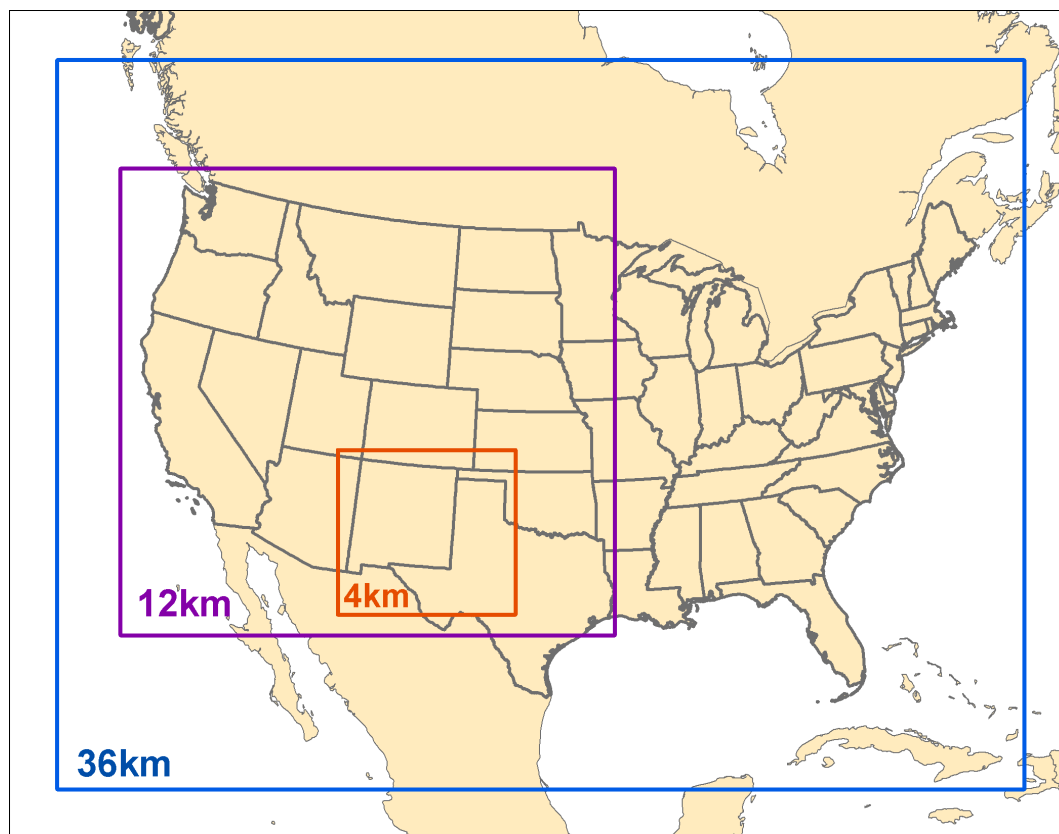


Figure 1-10. NM OAI Study 2014 36/12/4-km PGM and emissions modeling domains.

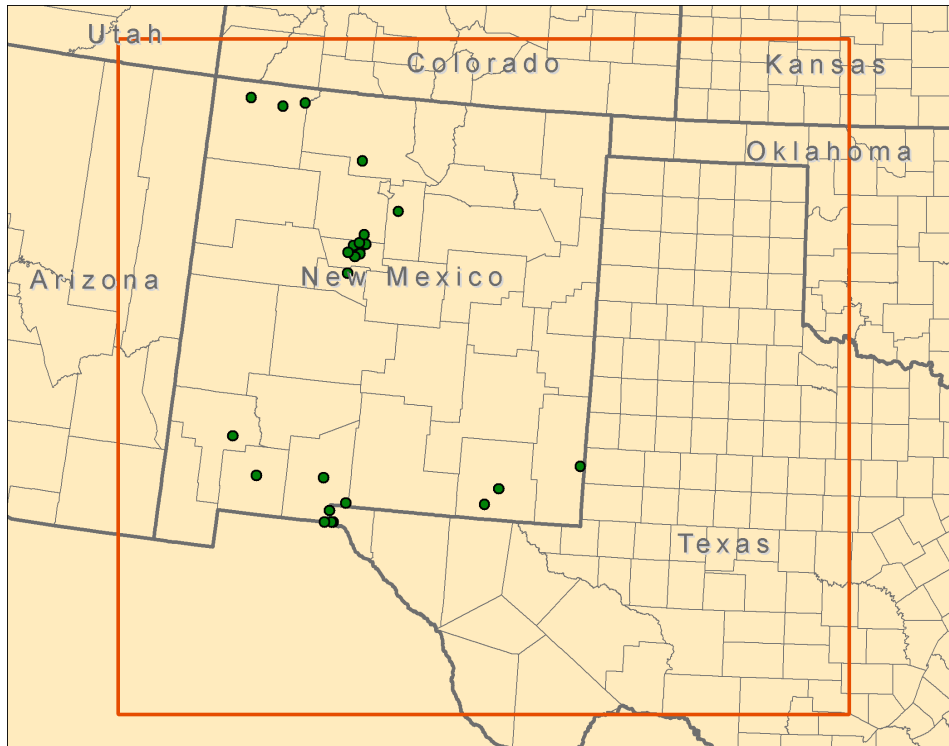


Figure 1-11. 4-km New Mexico modeling domain for PGM and emissions modeling, with locations of New Mexico ozone monitors that were operating during some portion of 2014.

Table 1-1. 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 1-2. 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

1.3.6 Base and Future Year Emissions Data

The 2014 base year emissions data were based on the WRAP-WAQS 2014v2 emissions that were in turn based on the 2014NEIv2 with updates from western states. New emissions were generated for natural emission sources (e.g., biogenic and LNOx). Future year emissions are based on the EPA 2016v1 modeling platform. The 2014, 2023 and 2028 emissions for New Mexico were reviewed by NMED and updated to address their comments.

1.3.7 Initial and Boundary Conditions Development

The first two-weeks of May were run 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 washes out the influence of the initial concentrations (IC) before elevated ozone concentrations occur in New Mexico.

Boundary conditions (BC) for the outer 36-km 36US domain were 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. The top BC (TopCon) was based on a zero-gradient assumption where concentrations above the top of the model (above 50 mb, or ~19-km above sea level) are assumed to be the same as in the top vertical layer of CAMx.

Chapter 3 has more details on the development of the 2014 CAMx BC inputs. Because of uncertainties in international emissions and their projections, the 2014 BCs will be held constant for the future year modeling.

1.3.8 Diagnostic Sensitivity Analyses

The NM OAI Study conducted four diagnostic sensitivity tests for the CAMx 2014 36/12/4-km base case that compared the CAMx ozone performance for four alternative meteorological inputs. The NM OAI Study conducted two WRF 2014 36/12/4-km WRF simulations that used different analysis fields as input. The two 2014 36/12/4-km WRF outputs were processed with WRFCAMx using two different options for vertical turbulent exchange (i.e., vertical mixing) coefficients (Kv or Kz). This resulted in four different CAMx meteorological inputs that were evaluated using CAMx diagnostic sensitivity tests that are described in Chapter 5.

1.3.9 Model Performance Evaluation

The NM OAI Study CAMx 2014 36/12/4-km base case simulation Model Performance Evaluation (MPE) followed EPA's MPE recommendations in their ozone modeling guidance (EPA, 2018a) and other sources (e.g., Simon, Baker and Phillips, 2012; Emery et al., 2016). The CAMx 2014 36/12/4-km base case simulation MPE focuses on ozone model performance within the 4-km New Mexico domain, and especially within New Mexico. The CAMx 2014 MPE is presented in Chapter 7.

1.3.10 Future Year Base and Control Strategy Modeling

Future year modeling for ozone will be performed using the EPA 2016v1 platform 2028 emission projections. A CAMx future year 36/12/4-km base case simulation will be conducted and used to project future year ozone design values (DVs). The procedures to calculate projected 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 (DVs). 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 (SMAT²²) tool that includes the recommended procedures in the latest EPA guidance for projecting ozone DVs.

The current NM OAI Study also plans to conduct future year emission reduction control strategy sensitivity modeling. The future year modeling will be discussed in a separate report at a later date.

1.3.11 Future Year Source Apportionment Modeling

The current NM OAI Study has plans to conduct future year ozone source apportionment modeling 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 future year ozone source apportionment plan will be developed and discussed with NMED prior to conducting the source apportionment modeling.

²² <https://www.epa.gov/scram/photochemical-modeling-tools>

2. 2014 WRF METEOROLOGICAL MODELING

The NM OAI Study conducted 2014 36/12/4-km WRF meteorological modeling to generate CAMx meteorological inputs for the summer of 2014 and the 36/12/4-km domain structure shown in Figure 1-10.

2.1 WRF 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 was used in the NM OAI Study.

This chapter describes the application and evaluation of the WRF meteorological model 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.

2.2 WRF Horizontal Modeling Domain

The PGM (CAMx) 2014 36/12/4-km modeling domains were shown in Figure 1-10 in the previous Chapter. The WRF 2014 36/12/4-km modeling domains are shown in Figure 2-1 and were 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.

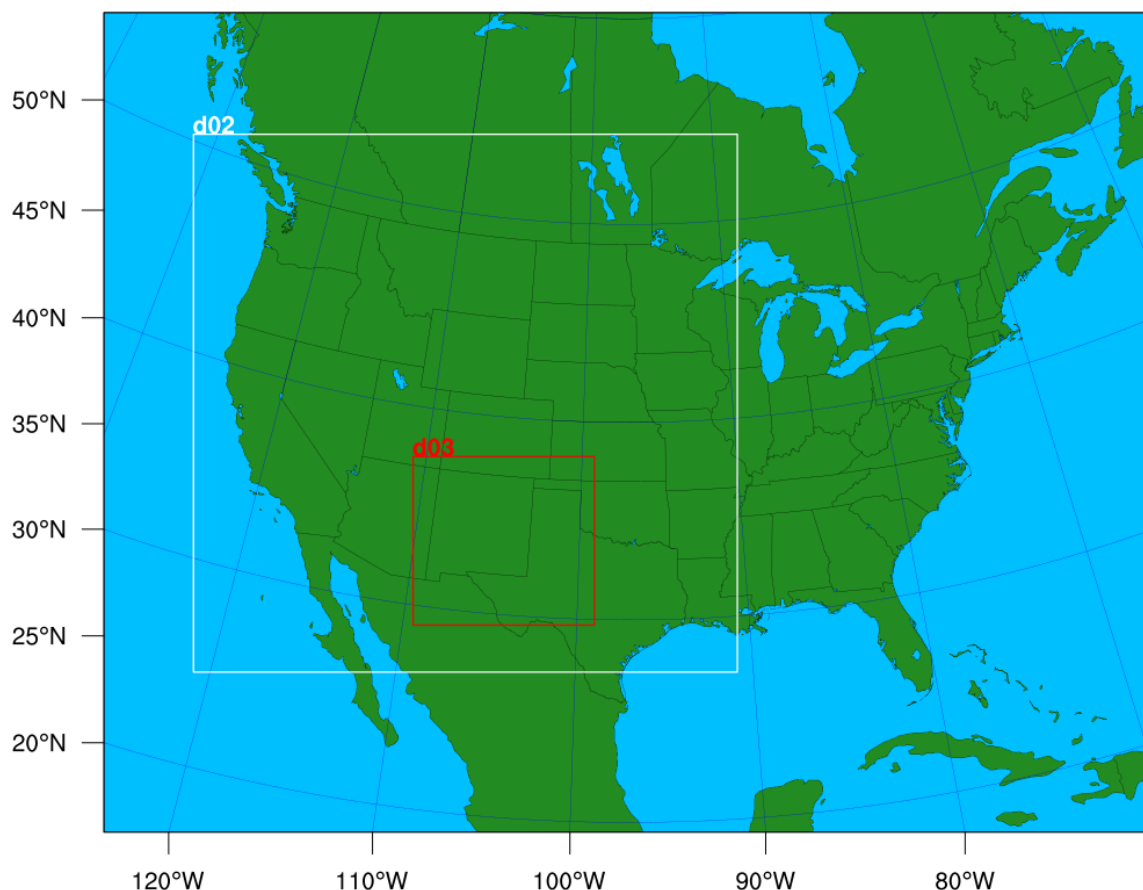


Figure 2-1. WRF 36-km (outer extent), 12-km (d02) and 4-km (d03) modeling domains used in the NM OAI Study.

2.3 WRF Model Configuration

WPS and WRF version 4.2 were used for this modeling analysis. Previous studies utilizing WRF at high resolution over New Mexico, such as the WRAP WestJumpAQMS, WAQS, SNMOS and EPA modeling platform development, have evaluated different configurations of WRF. Table 2-2 presented later in this section summarizes the WRF configurations used in the NM OAI Study and compares it to the WRF configuration used in the WRAP-WAQS 2014 and EPA 2014/2015/2016 WRF modeling. Preliminary analysis of WRAP-WAQS 2014 WRF 12 km model performance in New Mexico showed superior summertime precipitation performance compared to EPA's 2014 WRF modeling.²³ Therefore, the NM OAI Study WRF application was set to match the WRF physics configuration options used by WRAP-WAQS 2014 WRF modeling, except where noted below.

The NM OAI Study 36/12-km WRF/PGM grid configuration (e.g., horizontal domains and vertical layer structure) was designed to be identical to the WRAP-WAQS 2014

²³ https://www.wrapair2.org/pdf/NM_OAI_Study_Webinar1_2020-05-28.pdf

WRF/PGM grid configuration in order to facilitate the use of data between the two studies.

2.3.1 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, 2015 and 2016 WRF modeling also used 35 vertical layers up to a 50 mb height. Table 2-1 displays the 36-vertical layer structure used in the WRAP-WAQS 2011/2014 WRF modeling that was also adopted for the NM OAI Study WRF 2014 36/12/4-km modeling.

2.3.2 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).

Figure 2-2 shows 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 new 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.

For the NM OAI Study 2014 36/12/4-km WRF modeling, we used the new hybrid vertical coordinate system and a new version of the WRFCAMx processor that has been updated to use WRF’s hybrid vertical coordinate. The hybrid vertical coordinate system and use of 4-km New Mexico domain are the two biggest differences between the NM OAI Study and WRAP-WAQS 2014 WRF modeling. The WRAP-WAQS 2014 WRF/CAMx modeling did not use the hybrid vertical coordinate system in WRF because at the time it was not supported in the WRFCAMx processor.

Table 2-1. WRF 36 level vertical layer structure for the NM OAI study. This is the same WRF layer structure as used in WAQS 2011/2014/2016 and EPA 2016 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	

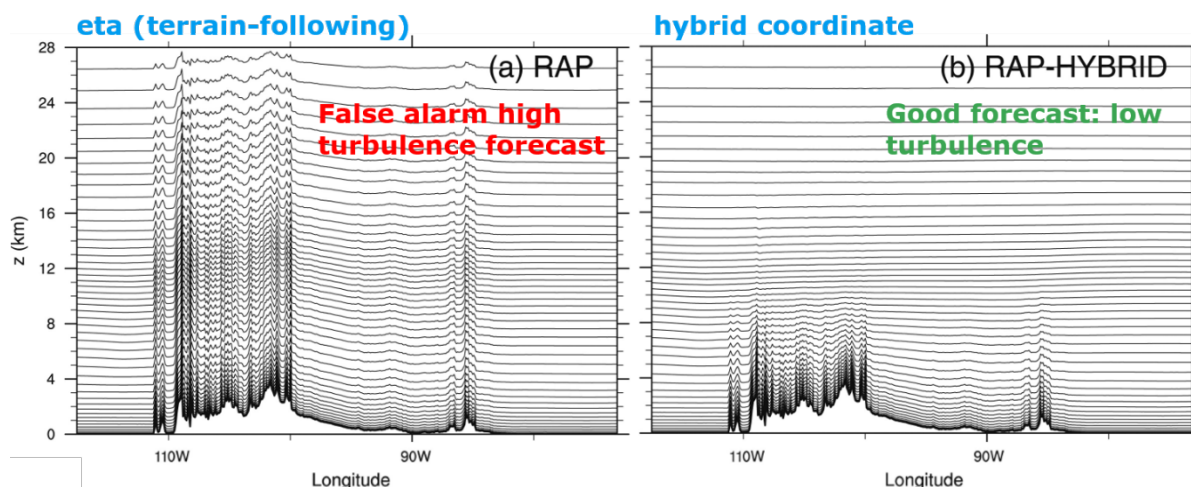


Figure 2-2. Cross-sections of layer interface heights over the Rocky Mountains for the eta (left panel) and hybrid (right panel) vertical coordinates for the WRF-Based Rapid Refresh (RAP) model. Adapted from Park et al., (2018).

2.3.3 Topographic Inputs

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

2.3.4 Vegetation Type and Land Use Inputs

Vegetation type and land use information used 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 was employed.

2.3.5 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 2-2, both the WRAP-WAQS 2014 and EPA 2014/2015/2016 12-km WRF modeling used the 12-km resolution North American Mesoscale Forecast System (NAM²⁴) analysis fields for IC/BC and analysis nudging (i.e., FDDA).

The NM OAI Study applied WRF with two different analysis fields that were evaluated for their performance against meteorological variables as well as their effect on CAMx ozone model performance. Both the NAM and the ~30-km resolution European Center for Medium-Range Weather Forecasting (ECMWF) Re-Analysis (ERA5²⁵) dataset analysis

²⁴ <https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/north-american-mesoscale-forecast-system-nam>

²⁵ <https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era5>

fields were used for IC/BC and FDDA in the two NM OAI Study WRF sensitivity simulations. 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 that is important for ozone modeling in New Mexico. 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 results using the WRF/ERA meteorological inputs produced superior ozone performance than when WRF/NAM inputs were used so the SNMOS ended up using the WRF/ERA meteorological inputs.²⁶

The ERA5 is a fairly new analysis fields product that has not been used in WRF modeling as extensively as the ERA fields. We conducted WRF and PGM sensitivity modeling using the NAM and ERA5 analysis fields to determine which configuration provides the best meteorological inputs and best ozone model performance. The ERA5 fields were 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 FDDA (on the 36/12-km domains) to guide the model to better match the observations.

2.3.6 Time Integration

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

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

Where dx is the grid cell size in km, F_{map} 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 $F_{map} = 1.08$, 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 was used with a maximum timestep of 180s.

2.3.7 Diffusion Options

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

²⁶ <https://www.wrapair2.org/SNMOS.aspx>

2.3.8 Lateral Boundary Conditions

Lateral boundary conditions was specified from the initialization dataset (i.e., either NAM or ERA5) on the 36-km WRF domain with continuous updates nested from each “parent” domain to its “child” domain, using one-way nesting (feedback=0).

2.3.9 Top and Bottom Boundary Conditions

The implicit Rayleigh dampening for the vertical velocity was 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.

2.3.10 Sea Surface Temperature Inputs

The water temperature data for the WRF application was taken from the Fleet Numerical Meteorology and Oceanography Center (FNMOC)²⁷. 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.

2.3.11 Four Dimensional Data Assimilation (FDDA)

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

2.3.12 New Lightning Data Assimilation

More recently, the assimilation of lightning data in WRF simulations has shown to improve the locations and amounts of convective precipitation. The use of lightning 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 was not used in the NM OAI Study 2014 WRF modeling for several 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 within the budget; (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); and (4) the lightning detection data assimilation algorithm has not been implemented in the latest versions of WRF so its use would limit the use of other model options.

2.3.13 PBL and LSM Physics Options

As used in the WRAP-WAQS 2014 WRF modeling, the YSU Planetary Boundary Layer (PBL) and Noah Land Surface Model (LSM) physics options were used in the NM OAI

²⁷<https://www.usno.navy.mil/FNMOC>

Study 2014 36/12/4-km WRF modeling. Previous WRF sensitivity modeling for the intermountain west 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 2-2). The WRAP-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.

2.3.14 Remaining WRF Physics Options

Table 2-2 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 WRAP-WAQS 2014 and EPA 2014/2015/2016 WRF modeling. Our comparison of 2014 WRAP-WAQS and 2014 EPA WRF modeling for summertime precipitation performance in New Mexico found that the WRAP-WAQS WRF meteorological model performance was better than EPA WRF for most variables. Therefore, we used the same microphysics and cumulus schemes for the NM OAI Study as used in 2014 WRAP-WAQS (Thompson and Multi-Scale Kain-Fritsch, respectively) and most of the same other physics options (Table 2-2).

Table 2-2. NM OAI Study 2014 WRF model configuration and comparison with the WRF configuration used in the WRAP-WAQS 2014 and EPA 2014/2015/2016 WRF modeling.

WRF Option	NM OAI Study	2014 WRAP-WAQS	2014 EPA
Horizontal Domains	36/12/4-km	36/12/4-km	12-km
Vertical Coordinate	Hybrid Sigma	Sigma	Sigma
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	36/12-km NAM & ERA5	36/12-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

2.3.15 Application Methodology

The WRF model was executed in 5.5-day blocks initialized at 12Z every five days. Model results were 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.

2.4 WRF Model Evaluation

Quantitative and qualitative evaluations of the NM OAI Study 2014 WRF 36/12/4-km simulation meteorological performance was conducted for both the WRF/NAM and WRF/ERA5 applications. The quantitative evaluations compare integrated surface hourly meteorological observations with WRF predictions matched by time and location and included the calculation of model performance statistical metrics that were compared against performance benchmarks. The qualitative evaluations compared time series plots of modeled wind speed and wind direction to the observations at specific sites. The qualitative evaluation also compared spatial plots of WRF precipitation estimates against spatial maps of precipitation analysis fields based on observations. The evaluation focuses on the meteorological model performance within the 4-km New Mexico domain.

2.4.1 Quantitative Evaluation Using METSTAT

A quantitative model performance evaluation of the NM OAI Study 2014 WRF modeling was conducted using the publicly available METSTAT software (Ramboll Environ, 2015) evaluation tool. Output from the WRF meteorological model was compared against meteorological observations for sites located in New Mexico. This was carried out both graphically and statistically to evaluate model performance for surface winds, temperatures and humidity. 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.

2.4.1.1 Quantitative Statistics

The quantitative analysis was 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):

$$M_o = \frac{1}{IJ} \sum_{j=1}^J \sum_{i=1}^I o_j^i \quad (5-1)$$

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):

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

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)**:

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

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)**:

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

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 $\pm 180^\circ$.

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)**:

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

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.

2.4.1.2 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.

2.4.1.3 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 2-3 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 compared 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 2-3. 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	$\leq \pm 0.5$ K	$\leq \pm 2.0$ K	$\leq \pm 1.0$ K	$\leq \pm 1.0$ 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	$\leq \pm 1.0$ g/kg	$\leq \pm 0.8$ g/kg	$\leq \pm 1.0$ g/kg	$\leq \pm 1.0$ 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	$\leq \pm 0.5$ m/s	$\leq \pm 1.5$ m/s	(not addressed)	$\leq \pm 1.5$ 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	$\leq \pm 10$ degrees	(not addressed)	(not addressed)	$\leq \pm 10$ degrees
Wind Dir. Error	≤ 30 degrees	≤ 55 degrees	(not addressed)	≤ 55 degrees

The output from the 2014 WRF 4-km domain was 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 was used. These metrics were 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 were 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.

2.4.1.4 Surface Wind Speed Performance

Figure 2-3 displays the WRF/NAM and WRF/ERA5 wind speed soccer plot that compares monthly measures of wind speed bias and error across surface monitoring sites in New Mexico with the simple and complex benchmarks. The monthly wind speed performance of the two WRF simulations are remarkably similar with both having near zero bias that achieves the simple benchmark ($\leq \pm 0.5$ m/s). The error (RMSE) for the two WRF simulations falls between the simple and complex benchmarks (i.e., between 2.0 and 2.5 m/s) for all four months (May through August).

2.4.1.5 Surface Wind Direction Performance

The monthly wind direction bias and error statistics for the two WRF simulations are also nearly identical with bias values of ~ 5 degrees that achieves the $\leq \pm 5$ degree simple benchmark and error statistics that falls between the 30 degree simple and 50 degree complex benchmarks (Figure 2-4).

2.4.1.6 Surface Temperature Performance

There are differences in the two WRF simulations temperature performance and more differences in the monthly values than seen for winds (Figure 2-5). The WRF/ERA5 simulations has a near zero temperature bias in May and June with the bias and error achieving the simple benchmark for both months. The WRF/NAM has a warm bias for May and June that straddle the simple benchmark upper bound ($+0.5$ K). The two WRF simulations have similar Jul and August performance that have a warm bias of ~ 1.0 K that fails to achieve the simple benchmark. For both WRF simulations, the temperature bias is right at but mostly within the 2.0 K simple benchmark.

2.4.1.7 Surface Humidity Performance

The WRF/ERA5 clearly has better surface humidity performance than WRF/NAM (Figure 2-6). For July and August, the WRF/NAM has a wet bias in July and August of ~ 1.5 g/kg so fails to achieve the simple ($\leq \pm 0.8$ g/kg) and complex ($\leq \pm 1.0$ g/kg) bias benchmarks. The WRF/ERA5 also has a wet bias for July and August that is not as large as WRF/NAM as it is right at the simple benchmark (~ 1.0 g/kg) but achieving the complex benchmark. The WRF/ERA5 also has better humidity error performance in July and August, although both simulations achieve the error performance benchmarks.

The two WRF simulations have better humidity performance in May and June that achieves the simple benchmark, albeit with a moist bias. May is the best performing month with nearly identical humidity model performance with a bias of ~ 0.6 g/kg and error of ~ 0.9 g/kg. In June, the WRF/ERA5 humidity performance is slightly better than WRF/NAM.

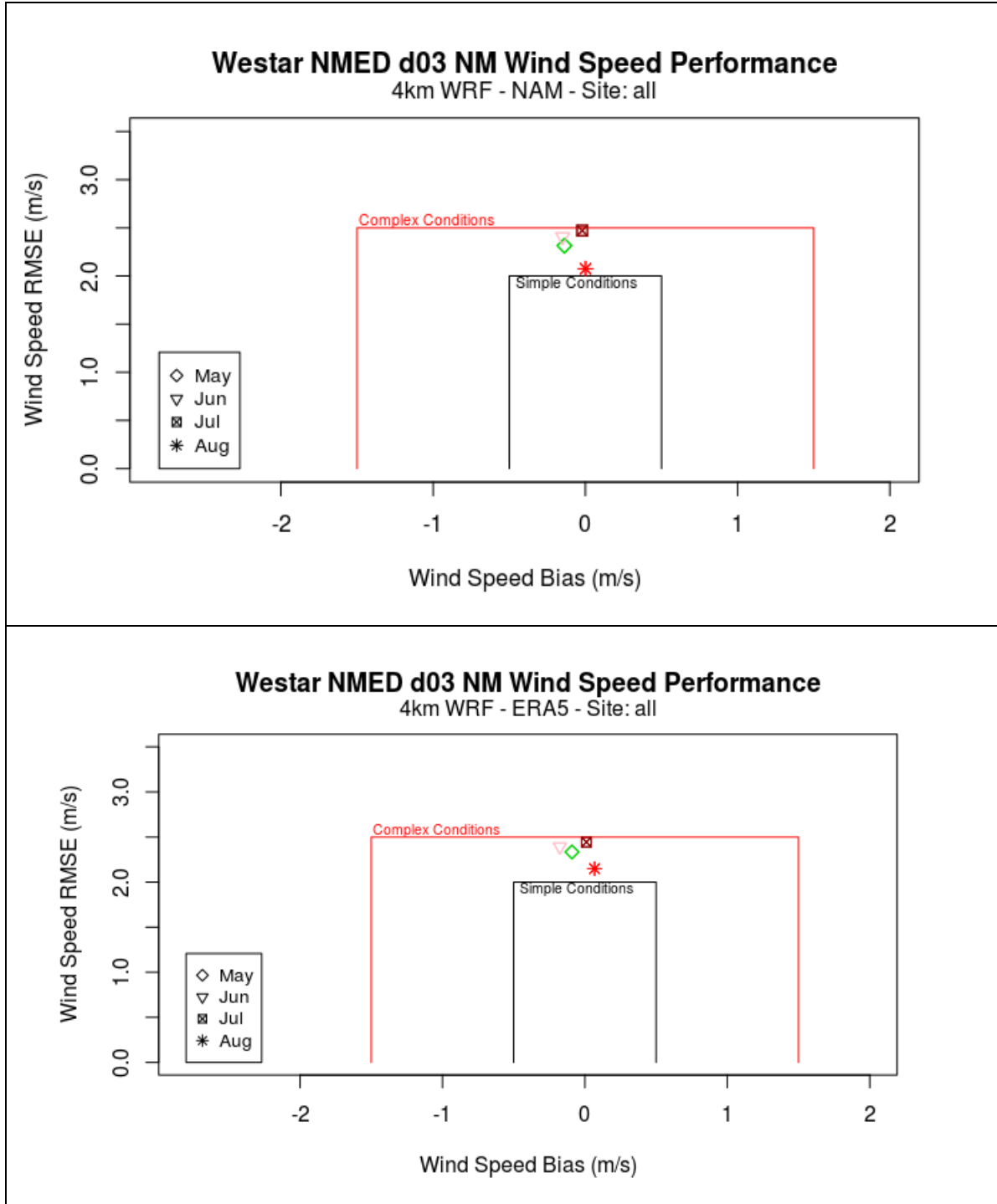


Figure 2-3. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface wind speed (m/s) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

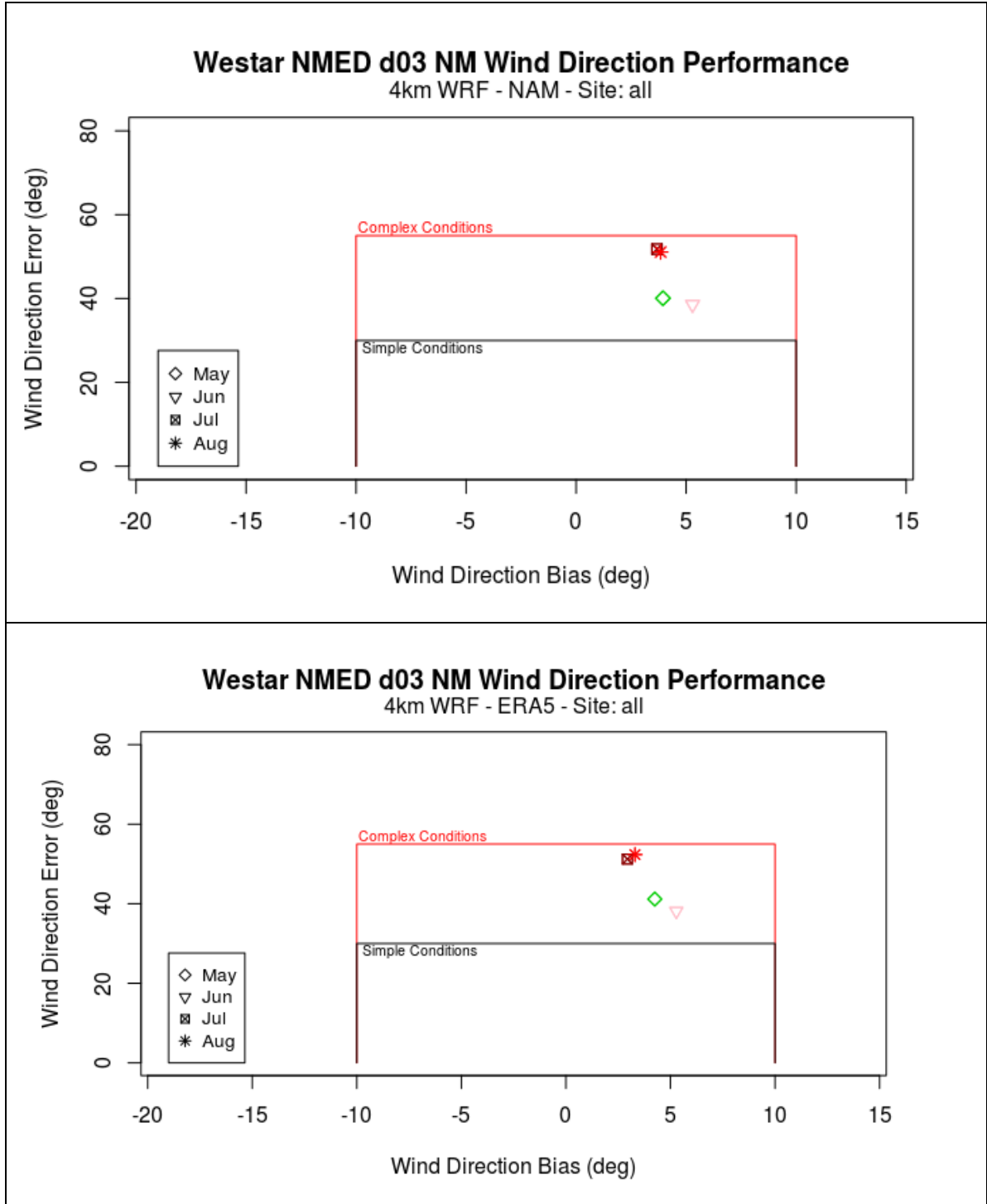


Figure 2-4. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface wind direction (degrees) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

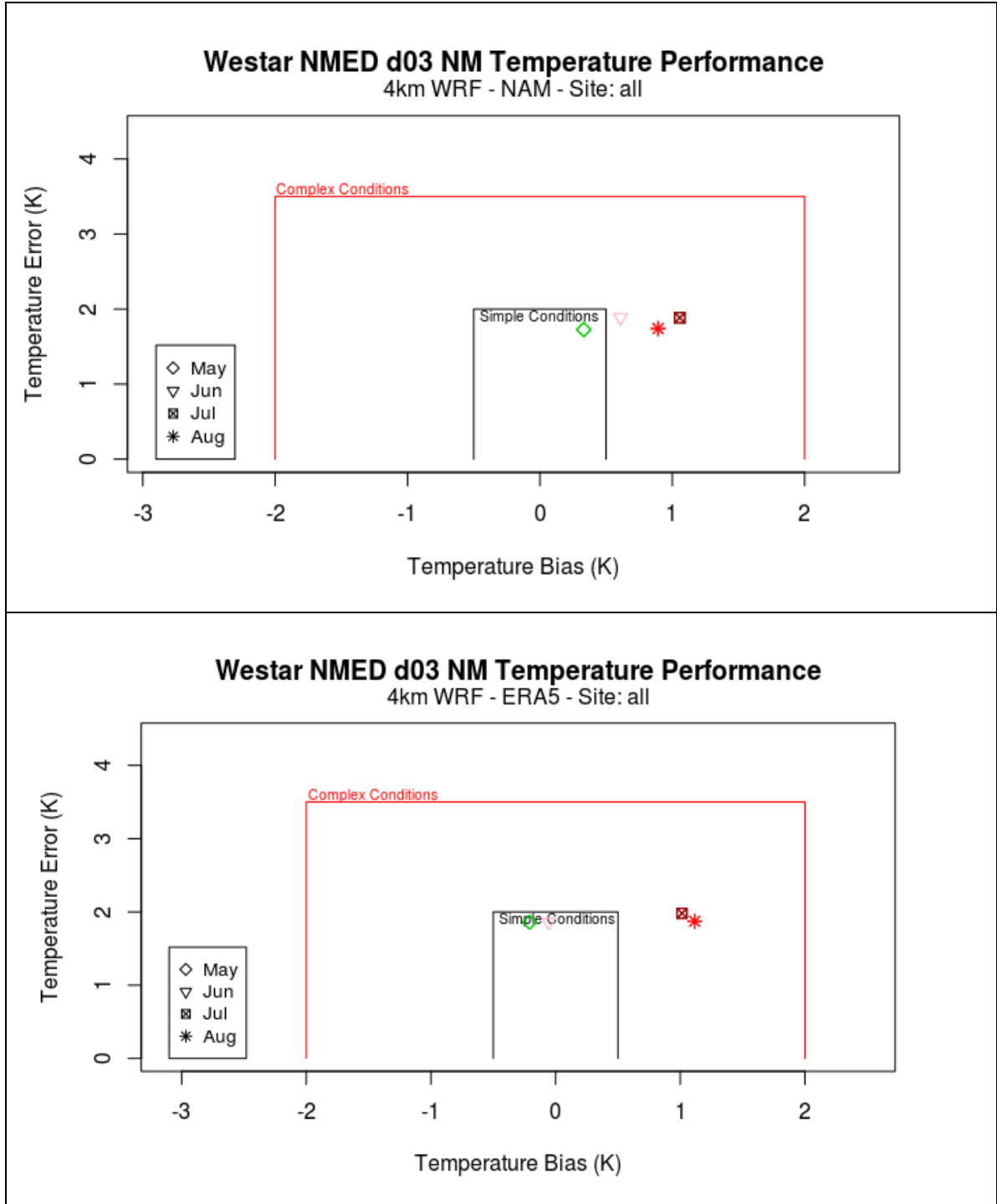


Figure 2-5. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface temperature (K) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

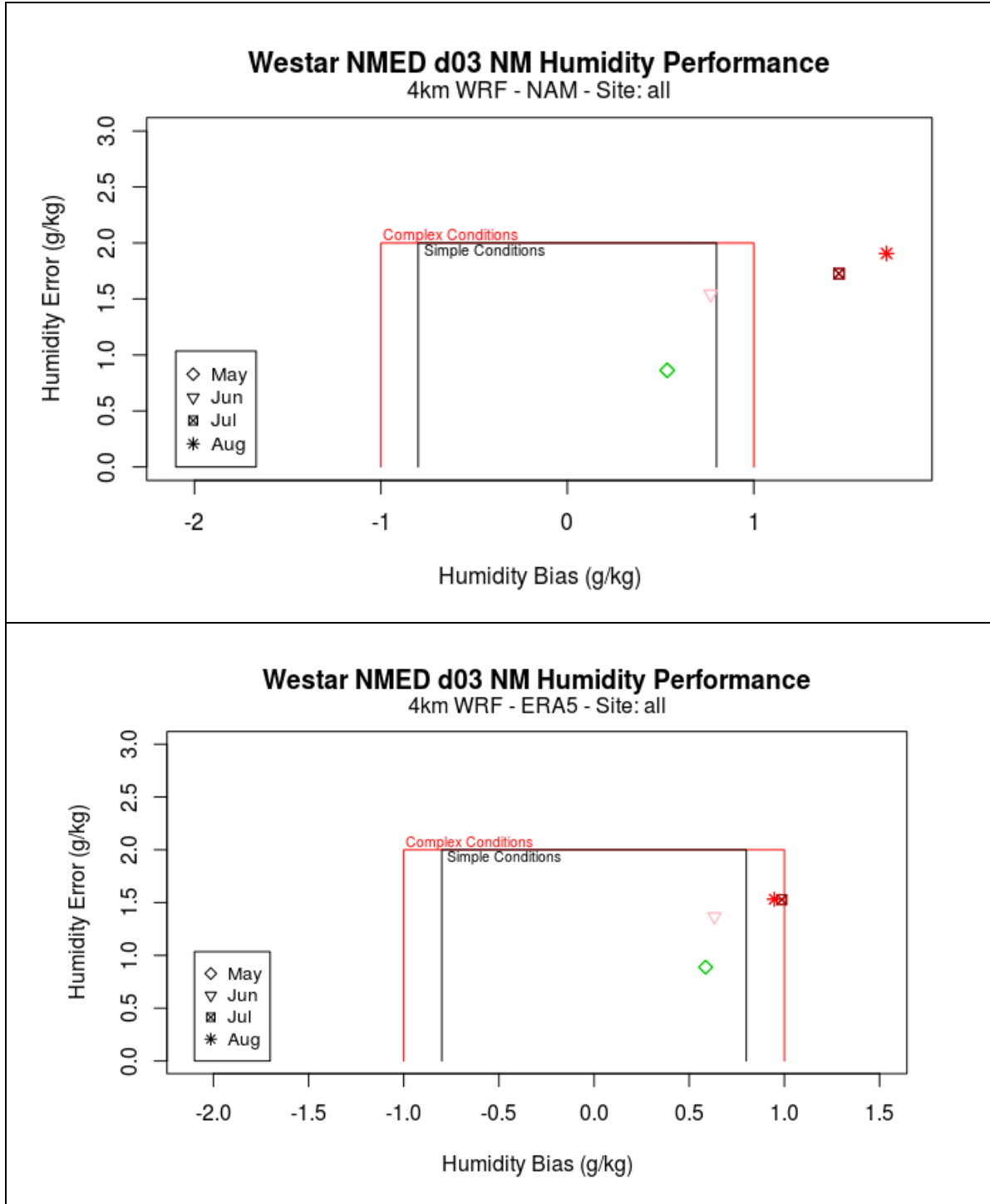


Figure 2-6. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface humidity (g/kg) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

2.4.1.8 Example Site-Specific Humidity Performance

METSTAT was used to evaluate the two WRF simulations for surface meteorological performance for each site in New Mexico. Figures 2-7 and 2-8 show example humidity model performance time series and soccer plots at the Las Cruces International Airport that is 8 miles west of the City of Las Cruces in Dona Ana County. In May, the two WRF simulations have nearly identical daily humidity performance at Las Cruces with a slight overestimation bias that is approximately 0.5 g/kg (Figure 2-7). In June, the humidity performance of the two WRF simulations at Las Cruces start to deviate from each other so by mid-June the WRF/NAM starts to have a large humidity overestimation bias that is as high as 4 g/kg; both simulations have large swings in variations in humidity bias. During the second half of June through July and August the WRF/NAM humidity bias tends to range from 0 to 3 g/kg, while the WRF/ERA5 bias ranges from -1 to +1.5 g/kg. These variations are likely due to the occurrence of monsoonal convective activity that can be very spotty and are also very difficult phenomena for a meteorological model to accurately reproduce.

The soccer plot of monthly humidity model performance at Las Cruces (Figure 2-8) shows that the WRF/ERA5 is clearly performing better with all months achieving the simple benchmark with a slight moist bias of from 0.2 to 0.6 g/kg. The WRF/NAM May humidity performance also achieves the simple benchmark and is nearly identical to WRF/ERA5, but for June, July and August the WRF/NAM monthly humidity performance at Las Cruces has a moist bias of from 1.5 to 2.1 g/kg that fails to achieve the benchmarks ($\leq \pm 1.0$ g/kg).

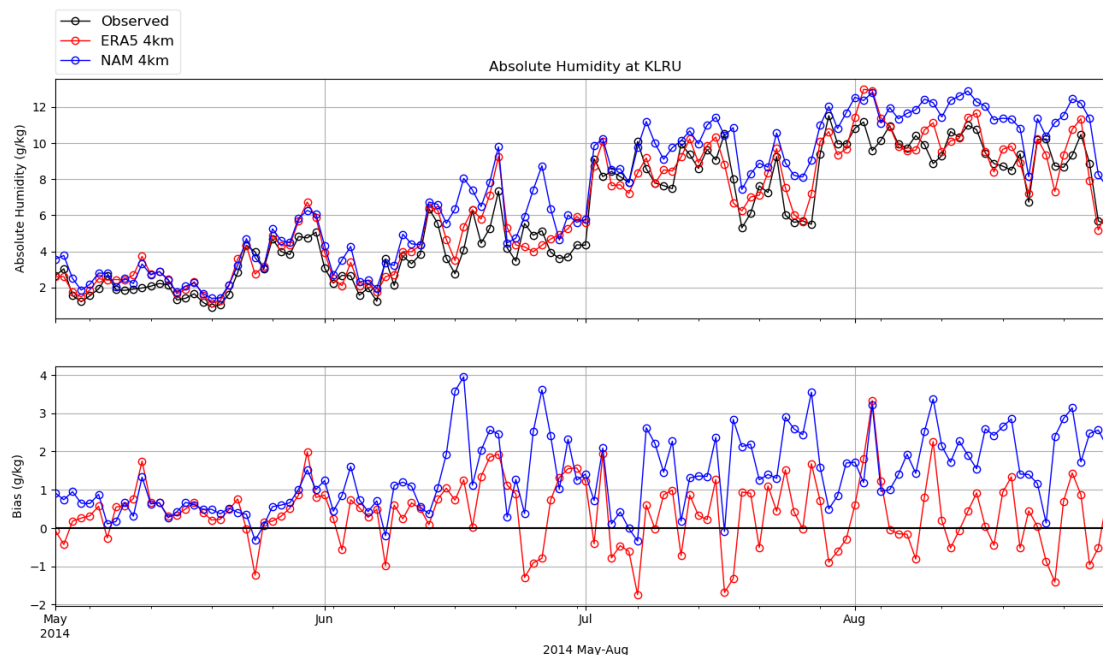


Figure 2-7. Time series plot of predicted and observed (black) daily humidity (g/kg) at Las Cruces International Airport for the WRF/ERA5 (red) and WRF/NAM (blue) simulations.

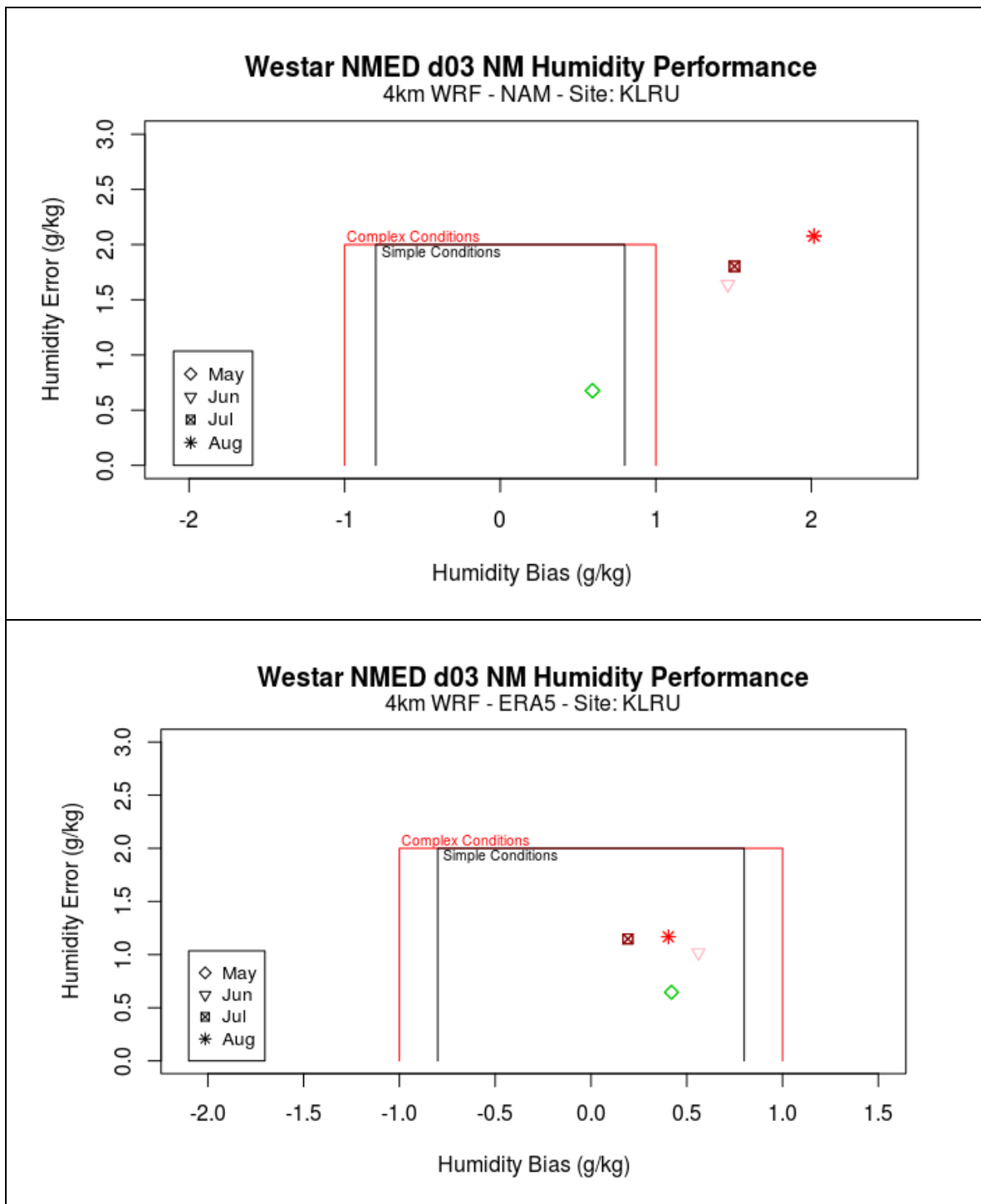


Figure 2-8. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface humidity (g/kg) model performance at Las Cruces International Airport against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

2.4.2 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 (PRISM²⁸) is used to generate the precipitation analysis fields (Daly et al., 2008). The PRISM interpolation method of observed precipitation reflect, 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 (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.

Figure 2-9 compares the PRISM May monthly total precipitation across the 4-km New Mexico domain with the WRF/NAM and WRF/ERA5 model estimates. The PRISM and WRF estimate May precipitation amounts over New Mexico are similar with all three estimating little precipitation in the west and small amounts in the central eastern portion of New Mexico. However, neither WRF simulation reproduces the PRISM precipitation in the southeast corner of the 4-km domain in West Texas near Midland. And the WRF/NAM greatly overstates the PRISM precipitation over the Texas panhandle, with WRF/ERA5 just having a slight overstatement in this region.

The June monthly precipitation comparisons are provided in Figure 2-10. Both models have reasonable June monthly precipitation over New Mexico that is very light. And PRISM and the two WRF simulations agree with the much higher precipitation over the Texas panhandle, with WRF/ERA5 performing better than WRF/NAM that has an overestimation bias.

There is much more observed and estimated precipitation over New Mexico in July 2014 (Figure 2-11). WRF/NAM overestimates the July monthly precipitation over northeast New Mexico in July, with WRF/ERA5 having an overestimation bias in most northerly Texas. But both WRF simulations have a dry bias for monthly precipitation over the remainder of New Mexico.

WRF/ERA5 does a better job at reproducing the locations and magnitudes of the August monthly PRISM precipitation than WRF/NAM (Figure 2-12). WRF/NAM overstates the August precipitation in central-south New Mexico.

²⁸ <http://prism.oregonstate.edu/>

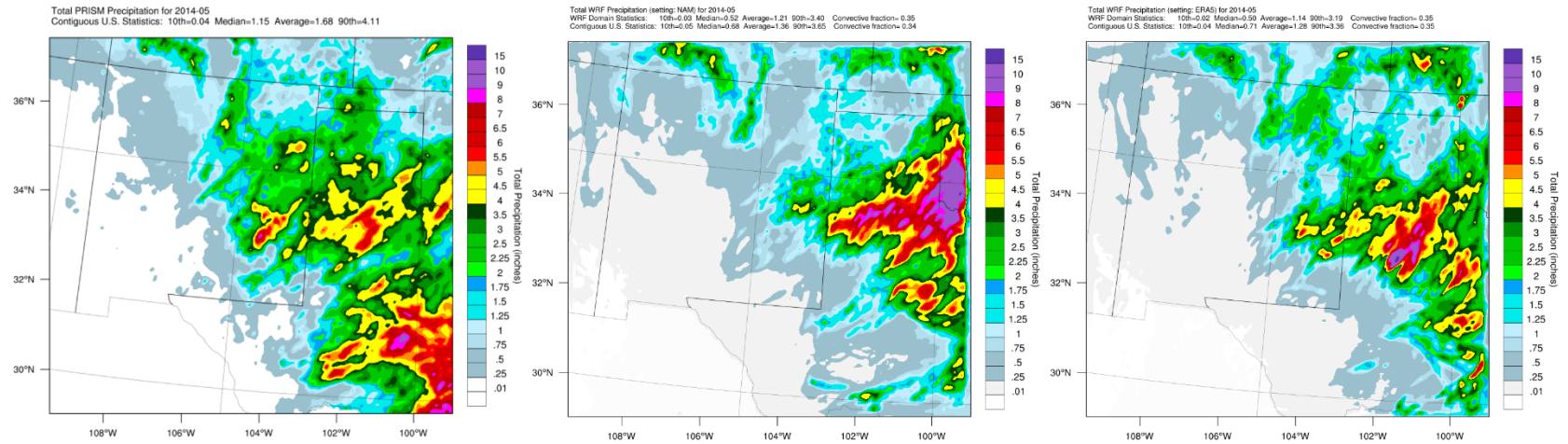


Figure 2-9. May monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).

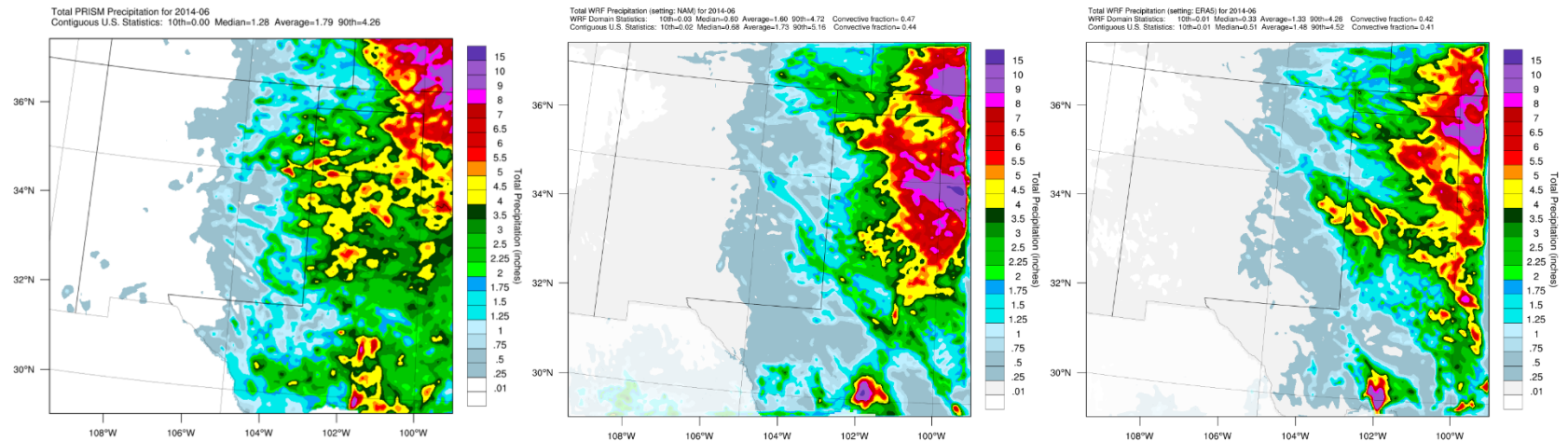


Figure 2-10. June monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).

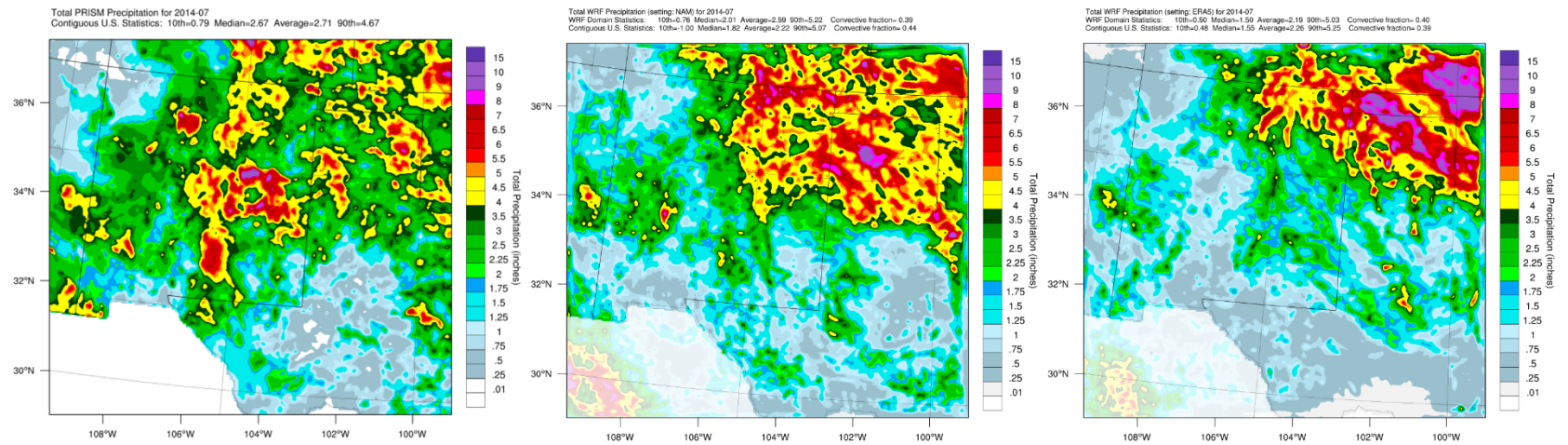


Figure 2-11. July monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).

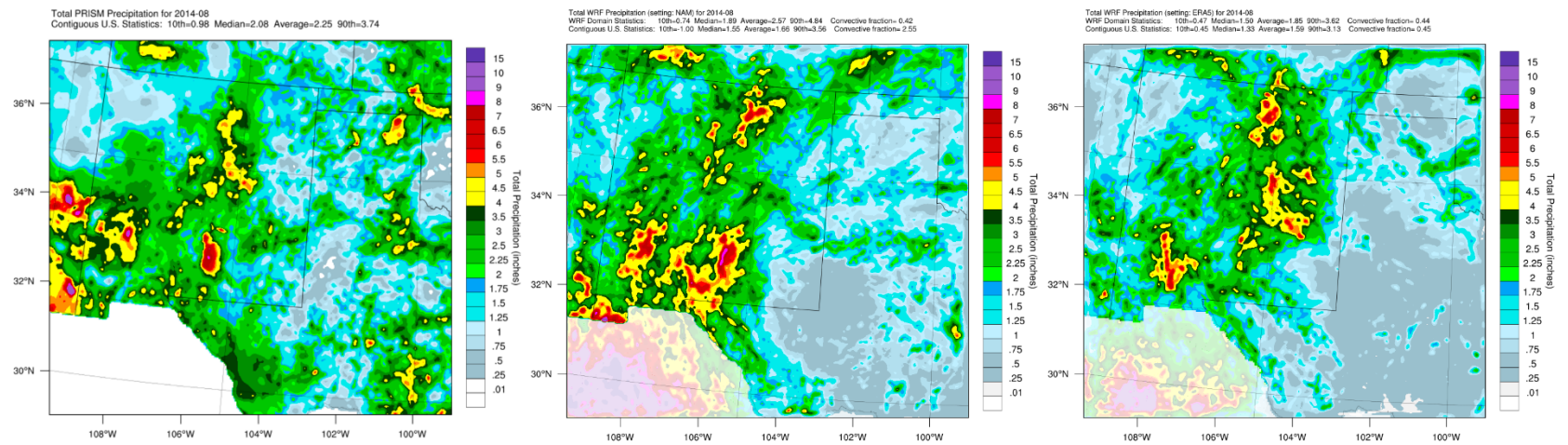


Figure 2-12. June monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).

2.4.3 Conclusions of 2014 WRF Model Performance

The model performance of both WRF simulations is reasonable and very similar for most meteorological variables (e.g., winds and temperature). This is in contrast to the WRAP-WAQS and EPA WRF 2014 simulations that had very different performance characteristics over New Mexico.²⁹ The biggest difference in the performance of the two WRF simulations was for humidity and precipitation. The WRF/NAM simulation had a moist bias for June-August that is likely partly associated with overactive convective precipitation that was greater in WRF/NAM than WRF/ERA5. It is unclear whether the WRF/NAM overstated precipitation is due to overactive convective events when they occur, or having events occur when they are not observed.

From the meteorological model performance evaluation, it is not possible to determine which set of WRF meteorological inputs will produce better ozone model performance when used as meteorological inputs for CAMx. There are variations in spatial and temporal model performance that are difficult to estimate what effects they will have on ozone concentrations. Furthermore, there may be meteorological inputs (e.g., level of mixing) that are more important for ozone modeling than the parameters we have data to evaluate the meteorological model for (i.e., winds, temperature, humidity and precipitation). Although it appears that WRF/NAM overstates the monthly precipitation, if that does not occur on high ozone days it may not matter to the ozone model performance.

CAMx was run for a portion of the summer of 2014 episode with meteorological inputs based on both the WRF/NAM and WRF/ERA5 simulations and the ozone estimates compared to determine which meteorological inputs performed best so were selected for use in the final CAMX 2014 36/12/4-km base case simulation. The meteorological diagnostic sensitivity tests using the CAMx photochemical model are described in Chapter 5.

²⁹ https://www.wrapair2.org/pdf/NM_OAI_Study_Webinar1_2020-05-28.pdf

3. BOUNDARY CONDITION INPUTS

The Boundary Conditions (BCs) for the CAMx most outer 36-km 36US modeling domain lateral boundaries were based on output from a 2014 simulation of the GEOS-Chem global chemistry conducted by WRAP for their 2014v2 modeling platform.

3.1 WRAP 2014 GEOS-Chem Modeling

The WRAP-WAQS 20914v1 36/12-km CAMx and CMAQ base case simulations used BCs based on EPA's 2014 GEOS-Chem simulation that was used in EPA's 2014 modeling platform used in the 2014 National Air Toxics Assessment (NATA³⁰). The CAMx and CMAQ 2014v1 base case simulation and sensitivity modeling found that the BCs based on EPA's 2014 GEOS-Chem caused year-long ozone overestimation bias throughout the western U.S.³¹ Thus, WRAP conducted their own 2014 GEOS-Chem simulation using newer version of the model with updated emissions that resulted in much better CAMx ozone model performance without the systematic ozone over-prediction bias.³² Table 3-1 presents the WRAP 2014 GEOS-Chem model configuration.

Table 3-1. 2014 GEOS-Chem simulation model configuration used by WRAP whose output is used to define the 2014 day-specific diurnally varying BC inputs for the NM OAI Study photochemical modeling.

Science Options	WRAP 2014 GEOS-Chem Base Case
Version	Version 12.2.0 (release date: 2019-02-19)
Vertical Grid Mesh	72 Layers
Chemistry mechanism	GEOS-Chem standard chemistry with complex SOA option ³³ .
Horizontal Grids	2x2.5 degree (Nx, Ny = 144, 91)
Initial Conditions	6-month spin-up; starting from provided initial conditions for standard chemistry
Meteorology	2014 GEOS-FP meteorology
Photolysis mechanism	Default (FAST-J)
Advection Scheme	Default (TPCORE)
Cloud convection scheme	On / Relaxed Arakawa-Schubert
Planetary Boundary Layer mixing	On / non-local scheme implemented by Lin and McElroy
Dry deposition scheme	Default (Wesely)
Chemistry Solver	Default (FLEXCHEM)
Parallelization	Open Multi-Processing (OMP)

³⁰ <https://www.epa.gov/national-air-toxics-assessment>

³¹ http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx

³² https://www.wrapair2.org/pdf/WRAP_Shake-Out_Phase-III_Update_RTOWG_2019-09-10v3a.pptx

³³ We recommend turning off semivolatile primary organic aerosol (POA) chemistry and isoprene SOA reactions via the volatility-based scheme (VBS) [Pye et al., 2010] to avoid risk of double-counting in the complex SOA chemistry scheme. For more information, see <http://maraisresearchgroup.co.uk/Publications/GC-v11-02-SOA-options.pdf>

3.2 2014 GEOS-Chem Model Evaluation

The results of the WRAP 2014 GEOS-Chem simulation and CAMx sensitivity modeling using the new BCs can be found on the WAQS-WRAP2014v2 model evaluation webpage³⁴. Relevant for the NM OAI Study is the fact that this updated 2014 GEOS-Chem BCs do lead to better CAMx model performance for ozone concentrations and corrects a persistent year-long ozone overestimation bias observed with the previous 2014 GEOS-Chem simulation conducted by EPA and used in the EPA 2014 modeling platform. The NM OAI Study evaluated the use of the WRAP 2014 GEOS-Chem BCs for CAMx modeling at several sites in New Mexico and found good ozone performance that achieved ozone model performance goals.³⁵ Thus, the WAQS-WRAP 2014v2 BC inputs based on the WRAP 2014 GEOS-Chem simulation were used as is for the NM OAI Study.

³⁴ http://views.cira.colostate.edu/iwdw/docs/WRAP_WAQS_2014v2_MPE.aspx

³⁵ https://www.wrapair2.org/pdf/NM_OAI_Study_Webinar1_2020-05-28.pdf

4. 2014 EMISSION INPUTS

4.1 Available Emissions Inventory Datasets

The emissions inventories for the CAMx 2014 36/2/4-km base case modeling were based on the WRAP-WAQS 2014v2 emissions inventory. Within the 36-km 36US North American and 12-km 12WUS2 western U.S. domains, the WRAP-WAQS CAMx 2014v2 base case emission inputs were used without any changes.

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

4.2 Development of CAMx Emission Inputs

CAMx emission inputs were 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 was operated using version 6 revision 4 of the Carbon Bond chemical mechanism (CB6r4) (Yarwood et al., 2010).

The 2014 base case (May to August) 4-km New Mexico domain CAMx emission inputs were based on the WRAP-WAQS 2014v2 emissions that rely on the 2014NEIv2 with updates provide by the western states. The New Mexico emissions from the 2014v2 database were reviewed and updated by the NMED. The 2014v2 emissions for New Mexico and portions of surrounding states within the 4-km New Mexico domain were processed by the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (UNC, 2015). SMOKE version 4.7 was used, which is the current version of SMOKE that was released in October 2019.³⁶

4.2.1 Day-Specific On-Road Mobile Source Emissions

The 2014 on-road mobile source emission inputs for the 4-km New Mexico domain were generated using the SMOKE-MOVES emissions model. SMOKE-MOVES used a 2014 mobile source emission factor (EF) lookup table generated by the Motor Vehicle Emission Simulator (MOVES2014³⁷) model (EPA, 2014a,b,c). The SMOKE-MOVES default county-level 2014 vehicle activity data for New Mexico was 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], speed, etc.) to generate 2014 day-specific hourly gridded on-road mobile source emission inputs for CAMx and the 4-km New Mexico domain.

³⁶ <https://www.cmascenter.org/smoke/>

³⁷ <http://www.epa.gov/oms/models/moves/#user>

4.2.2 Point Source Emissions

2014 point source emissions were based on the WRAP-WAQS 2014v2 emissions inventory. The 2014v2 New Mexico point source emissions were reviewed and updated by NMED. Point sources were 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 SO₂ emissions were used for the 2014 base case emissions scenario. The VOC, CO and PM emissions for point sources with CEM data were based on the annual emissions 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 for hours with missing CEM data is inappropriate for PGM modeling since the goal is to obtain an accurate estimate of emissions. 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 were converted to the LCC coordinate system used in the modeling. Non-CEM point sources were 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 were processed using SMOKE using the default temporal (e.g., monthly, day-of-week and hourly) and speciation profiles.

4.2.3 Area and Non-Road Source Emissions

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

4.2.4 Episodic Biogenic Emissions

Biogenic emissions were 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 were used for the 36-km 36US, and 4-km New Mexico modeling domains. Note that the BEIS biogenic emissions were used in the 12-km 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 had better Organic Aerosol (OA)

performance³⁸ 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.

Table 4-1 summarizes MEGAN v3.1 biogenic VOC (BVOC) and soil NO_x emissions by month for the 4-km New Mexico domain. Biogenic emissions are controlled by ambient environmental variables, most notably temperature and light. Increases in temperature normally lead to increased BVOC emissions because of higher biological activity as evident in the Table 4-1.

Table 4-1. 2014 base case biogenic emissions summary by month (in short tons per day) for the 4-km New Mexico domain.

Month	NO _x (in tons/day)	BVOC (in tons/day)
May	1,131	4,139
Jun	1,415	8,902
Jul	1,666	10,248
Aug	1,323	11,438

4.2.5 Wildfires, Prescribed Burns, Agricultural Burns

2014 emissions from open-land burning including wildfires, prescribed burns and agricultural burning were based on the WRAP-WAQS 2014v2 emissions inventory. The WRAP Fire and Smoke Work Group (FSWG³⁹) 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 was used without any changes.

4.2.6 Other Natural Emissions

Lightning NO_x (LNO_x), and windblown dust (WBD) emissions were generated for the 4-km domain using special CAMx processors and WRF 2014 meteorological data. Oceanic emissions such as sea salt spray aerosol (SSA) and dimethyl sulphide (DMS) were not generated for the 4-km New Mexico domain since this domain does not include any ocean within it. However, the LNO_x, WBD and oceanic emissions for the 36-km and 12km were based on the WRAP-WAQS 2014v2 emissions and were included in the modeling.

4.2.7 QA/QC of Emissions Processing and Emissions Merging

The emissions for the 4-km New Mexico domain were processed by major source category in several different processing “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) were performed for each stream of emissions processing and in each step following the procedures developed by

³⁸ http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx

³⁹ <https://www.wrapair2.org/FSWG.aspx>

WRAP (Adelman, 2004). SMOKE includes advanced quality assurance features that include error logs when emissions are dropped or added. In addition, the following visual displays were generated:

- 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.
- QA information 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 were written to generate the CAMx-ready two-dimensional day and domain-specific hourly speciated gridded emission inputs. The point source and fire, emissions were then processed into the day-specific hourly speciated emissions in the CAMx-ready point source format.

For the 36/12-km domains the model-ready emissions from the WRAP/WAQS 2014v2 modeling platform were used in this study.

The resultant CAMx model-ready emissions were 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.

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

CAMx includes a Plume-in-Grid (PiG) sub-model that 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 were selected for treatment by the subgrid-scale PiG module when their emissions rate were 5 tons per day or larger.

4.2.9 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 were 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 illustrates where the inventories may be deficient and provide a reality check of the inventories.

State inventory summaries prepared prior to the emissions processing were 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 compared reports generated with SMOKE to target these specific areas of the processing. For speciation, the inventory state import totals were compared against the same state totals with the speciation matrix applied.

4.2.10 Summary of Emissions for 4-km New Mexico Domain

This section presents 2014 base case anthropogenic emissions summary for the 4-km New Mexico domain. The emissions were processed by major source category in several different “streams” of emissions modeling. Each stream of emissions modeling generates a pre-merged CAMx-ready emissions model input with all pre-merged emissions inputs merged together to generate the final CAMx-ready two-dimensional gridded low-level (layer 1) and point source emission inputs. Table 4-2 lists an example of separate streams of emissions modeling by source category that are used.

Table 4-2. New Mexico 4-km domain emissions processing categories.

Country/Region	Sector	Description
US Anthro	afdust_adj	Area fugitive dust
	ag	Agricultural ammonia sources
	nonpt	Other nonpoint sources
	np_oilgas_wrap	Non-point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)
	np_oilgas	Non-point Oil and Gas
	nonroad	Non-road mobile
	rail	Locomotive
	onroad	On-road mobile
	ptegu	EGU point sources
	ptnonipm	Non-EGU point sources
	pt_oilgas_wrap	Point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)
	pt_oilgas_wrap	Point Oil and Gas
	rwc	Residential Wood Combustion
Mexico Anthro	onroad_mex	Mexico onroad mobile
	othar	Mexico area
	othpt	Mexico point sources
Natural	MEGAN	Biogenic
	LtNOx	Lightning Nox
	AG fire	Ag Fire
	RX fire	Prescribed Fire
	WF fire	Wild Fire
	Ptfire_othna	Mexico fire
	WBD	Windblown Dust

Table 4-3 summarizes criteria air pollutant emissions in episode average short tons per day by source category for the 4-km New Mexico domain. These data represent the model-ready emissions input to the CAMx air quality model for the 2014 base case. Generally, emissions are summarized from the SMOKE reports generated by the SMKMRG program. There are a couple of exceptions to this general approach, fugitive dust and EGU sources. The fugitive dust emissions were adjusted after SMOKE processing to account for fugitive dust correction factors that are derived from the Biogenic Emission Landuse Database version 4 (BELD4). The correction factors are necessary to account for dust removal due to local vegetation scavenging so are not

transported downwind. Model-ready emissions for EGU and Mexico point sources were obtained from WRAP/WAQS 2014 platform so were summarized for the 4-km domain outside of SMOKE.

Table 4-3. 2014 base case anthropogenic emissions summary (episode average short tons per day) by source category for the 4-km New Mexico domain.

Country/ Category	Source Category	CO	NH ₃	NO _x	PM _{2.5}	PM ₁₀	SO ₂	VOC
US Anthro	Area fugitive dust	0.0	0.0	0.0	253.3	1,788.2	0.0	0.0
	Agricultural ammonia sources	0.0	764.7	0.0	0.0	0.0	0.0	43.4
	Non-point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)	237.7	0.0	157.8	4.4	4.4	11.3	567.3
	Remaining Non-point Oil and Gas	286.8	0.0	311.7	6.9	6.9	30.0	1,642.5
	Residential Wood Combustion	7.0	0.1	0.1	0.5	0.5	0.0	1.2
	Other nonpoint sources	141.3	1.5	28.5	9.3	13.4	4.5	213.2
	On-road mobile	1,476.2	6.0	444.5	13.2	20.1	1.7	150.6
	Locomotive	22.9	0.1	122.7	2.9	3.1	0.1	6.2
	Non-road mobile	570.3	0.2	133.4	9.0	9.4	0.3	73.2
	EGU point sources	89.2	3.4	210.6	12.9	17.8	160.0	5.0
	Point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)	89.9	0.0	114.7	1.4	1.4	23.8	56.1
	Remaining Point Oil and Gas	113.8	0.1	205.2	3.2	3.3	27.1	48.4
	Non-EGU point sources	74.4	4.9	47.5	11.4	32.5	49.3	24.4
Mexico Anthro	Mexico area	19.9	33.2	42.2	5.8	15.7	1.7	103.3
	Mexico onroad mobile	356.3	0.6	98.4	1.5	2.6	1.4	34.4
	Mexico point sources	28.4	0.7	20.2	4.8	5.7	16.4	8.3

Figure 4-1 presents pie charts showing the two main ozone precursor (VOCs and NO_x) emissions from anthropogenic sources by source category for New Mexico and portion of surrounding states within the 4-km domain. Point and nonpoint oil and gas sectors account for majority of NO_x emissions followed by on-road mobile and EGU sources. In New Mexico, oil and gas sources are the largest anthropogenic VOC emitters and accounts for nearly 80% of 4-km domain VOC emissions.

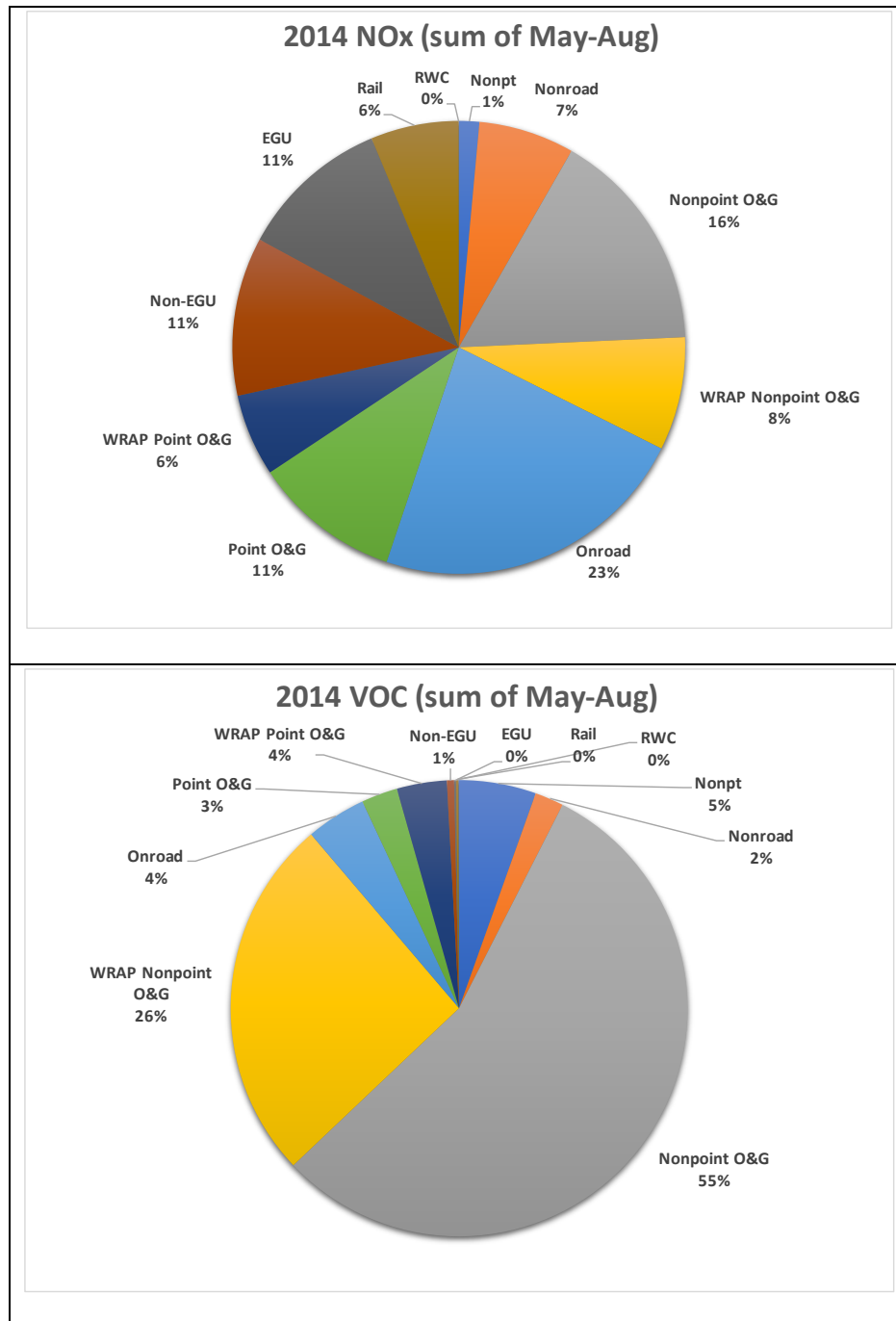


Figure 4-1. New Mexico 2014 base case anthropogenic NOx and VOC emissions by source category.

Figure 4-2 displays spatial maps of NO_x and VOC anthropogenic emissions from the oil and gas sector across the 4-km New Mexico domain. Top panel shows emission maps for non-point O&G sources while bottom panel shows point O&G sources. The San Juan and Permian basins are clearly visible on the emissions map and confirm correct spatial allocation of oil and gas emissions. Figure 4-3 shows emission maps for on-road mobile (top panel), rail (middle panel) and non-point sources including non-road equipment (bottom panel).

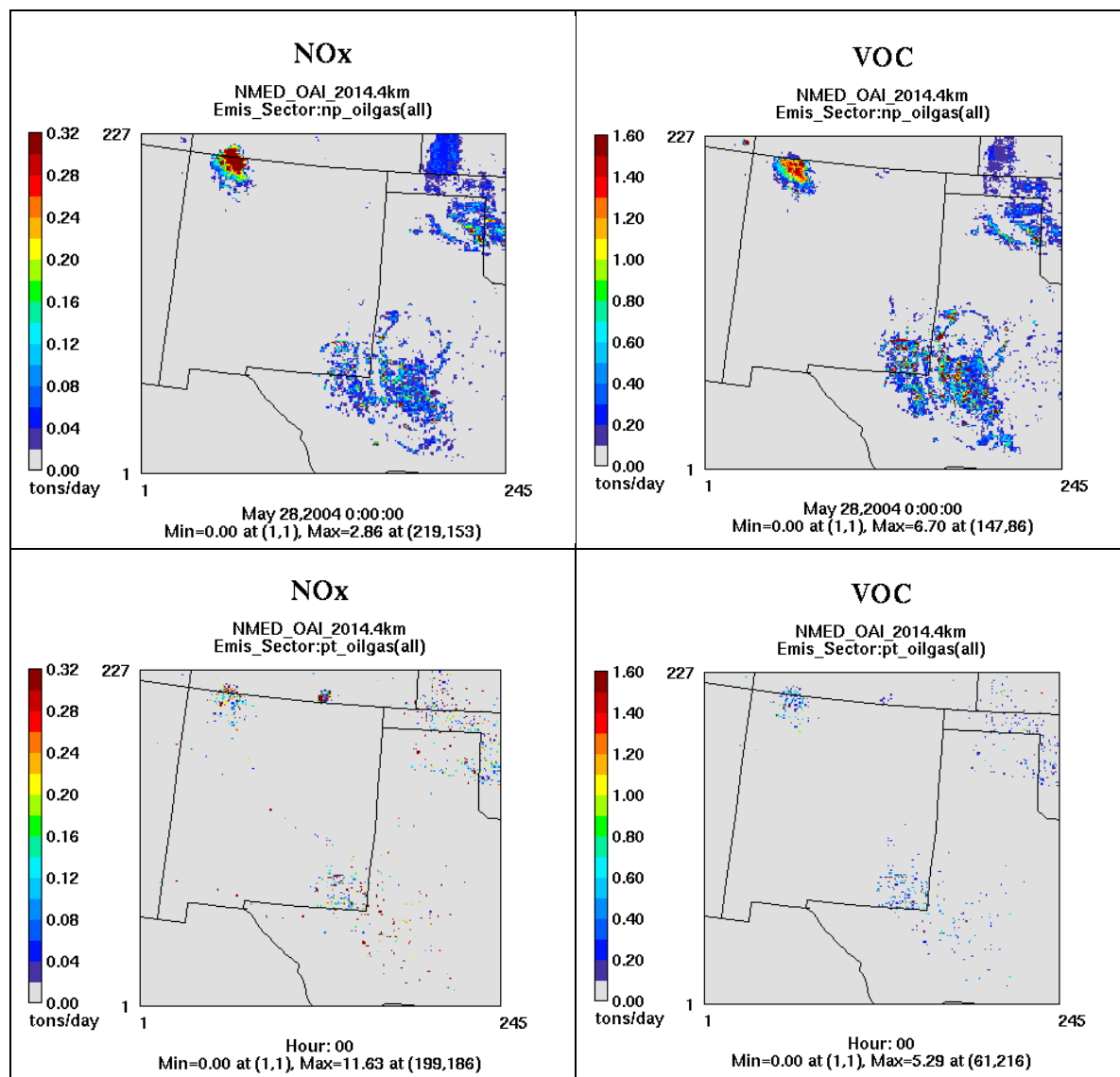


Figure 4-2. Spatial distribution of the non-point (top) and point (bottom) source oil and gas NO_x (left) and VOC (right) emissions (episode avg tons per day) for New Mexico 4-km domain.

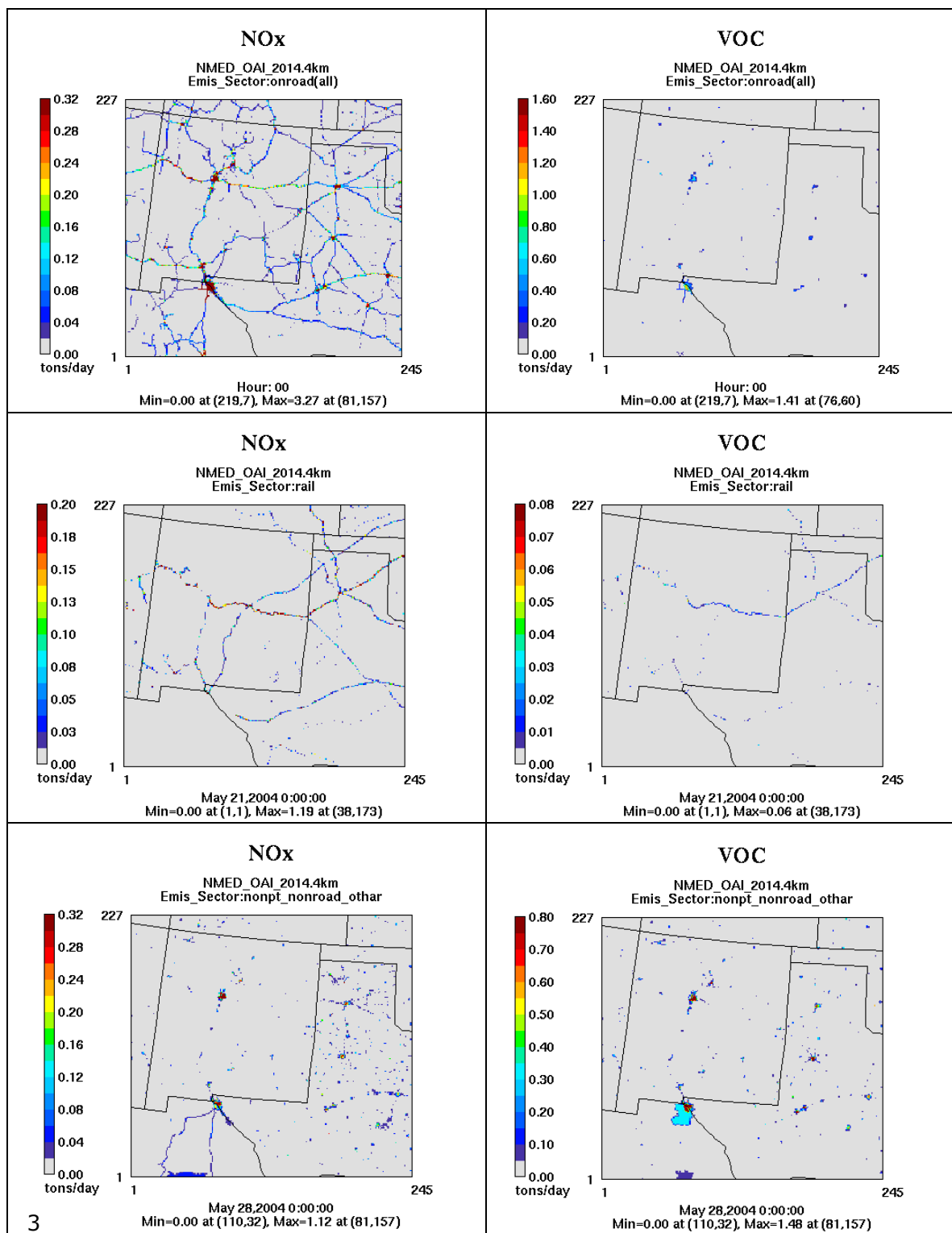


Figure 4-3. Spatial distribution of on-road (top), rail (middle) and non-point/non-road equipment (bottom) NOx (left) and VOC (right) emissions (episode avg tons per day) for New Mexico 4-km domain.

5. DIAGNOSTIC SENSITIVITY TESTS

Several CAMx diagnostic sensitivity tests were conducted to evaluate alternative meteorological inputs based on the 2014 36/12/4-km WRF meteorological model simulations discussed in Chapter 2. To develop the CAMx meteorological inputs, the WRF model output data must first be processed by the WRFCAMx processor.

5.1 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 (Kv) that define the rate and depth of vertical mixing in CAMx. Steps in the WRFCAMx processing are as follows:

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

Several options are available in WRFCAMx to derive vertical turbulent exchange coefficient (also known as: Kv, Kz or vertical diffusivity) fields from WRF output. 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 WRFCAMx processing was performed to generate two sets of Kv profiles using two different Kv options in WRFCAMx, the CMAQ-like and YSU Kv profile options.

5.1.1 *Treatment of Minimum Kv*

The CAMx Kv_patch pre-processor program sets the minimum Kv value to 0.1 to 1.0 m²/s in the lowest 100 m of the atmosphere depending on the amount urban land use category in a grid cell. This is done to account for the urban heat island effect that enhances vertical mixing through-out the day and night.

5.1.2 *Layer Collapsing Strategy*

WRF was run with 36 vertical levels (35 vertical layers) as shown in Table 2-1. For the NM OAI Study, a layer collapsing strategy was employed that reduced the 35 WRF vertical layers to 25 layers in CAMx, which reduces the CAMx run time by about a third. Table 5-1 displays the WRF to CAMx layer collapsing strategy. This is the same layer collapsing study employed by WRAP-WAQS.

Table 5-1. WRF to CAMx vertical layer collapsing strategy used in the NM OAI Study.

CAMx Layers	WRF Layers	WRF hybrid eta	WRF Pressure (mb)	Height (m)
	0	1.0000	1000.0	0
	1	0.9985	998.6	12
1	2	0.9970	997.2	24
	3	0.9950	995.3	40
2	4	0.9930	993.4	56
	5	0.9910	991.5	72
3	6	0.9880	988.6	97
	7	0.9850	985.8	121
4	8	0.9800	981.0	162
5	9	0.9700	971.5	243
6	10	0.9600	962.0	326
7	11	0.9500	952.5	409
	12	0.9400	943.0	492
8	13	0.9300	933.5	577
9	14	0.9100	914.5	747
10	15	0.8900	895.5	921
11	16	0.8700	876.5	1098
12	17	0.8400	848.0	1369
13	18	0.8000	810.0	1742
14	19	0.7600	772.0	2130
15	20	0.7200	734.0	2533
16	21	0.6800	696.0	2954
17	22	0.6400	658.0	3393
18	23	0.6000	620.0	3854
19	24	0.5500	572.5	4463
	25	0.5000	525.0	5115
20	26	0.4500	477.5	5816
	27	0.4000	430.0	6576
21	28	0.3500	382.5	7408
	29	0.3000	335.0	8328
22	30	0.2500	287.5	9360
	31	0.2000	240.0	10541
23	32	0.1500	192.5	11930
	33	0.1000	145.0	13630
24	34	0.0600	107.0	15355
	35	0.0270	75.7	17205
25	36	0.0000	50.0	19260

5.2 CAMx Meteorological Diagnostic Sensitivity Tests

Four separate CAMx 2014 36/12/4-km diagnostic sensitivity tests were conducted for the first portion of the summer 2014 modeling episode that spanned May 15 to June 4, 2014. The purpose of the four meteorological inputs CAMx sensitivity tests was to identify the optimal meteorological inputs for the final CAMx 2014 base case simulation. The four sets of CAMx simulations were based on the WRF/NAM and WRF/ERA5 2014 36/12/4-km simulations described in Chapter 2 processed by WRFCAMx to generate two sets of vertical mixing coefficient (Kv) as described above:

1. WRF/NAM with CMAQ Kv
2. WRF/NAM with YSU Kv
3. WRF/ERA5 with CMAQ Kv
4. WRF/ERA5 with YSU Kv

Ozone model predictions from each sensitivity test were compared with observed ozone concentrations in New Mexico. Figures 5-1 and 5-2 summarize the normalized mean bias (NMB) and error (NME) for each site in New Mexico during the modeling period. The statistics presented in these figures were calculated using a 60 ppb cutoff value relative to observed MDA8 ozone concentrations to understand the performance of each sensitivity test when ozone concentrations are most relevant to the NAAQS. Figure 5-1 shows that the NMB is generally within $\pm 10\%$ (colored grey) at almost all sites (note that the NMB performance goal is $\pm 5\%$ and criteria is $\pm 15\%$). All of the sensitivity simulations have an under-prediction bias for observed ozone greater than 60 ppb at sites in the southern portion of the domain such that for one or two sites have a bias even lower than -10% (i.e., colored bright green). The WRF/NAM with CMAQ Kv sensitivity test has slightly better performance than the others with less underestimation bias (e.g., all sites but one are within $\pm 10\%$ compared to two sites for the other tests). Figure 5-2 shows that the NME is also generally within the performance goal (less than 15%) in all cases, with the southern portions of NM showing the largest errors but still within the performance criteria (less than 25%). The figure shows that CAMx using the WRF/NAM inputs tends to have slightly lower error and better ozone performance than when the WRF/ERA5 meteorological inputs are used.

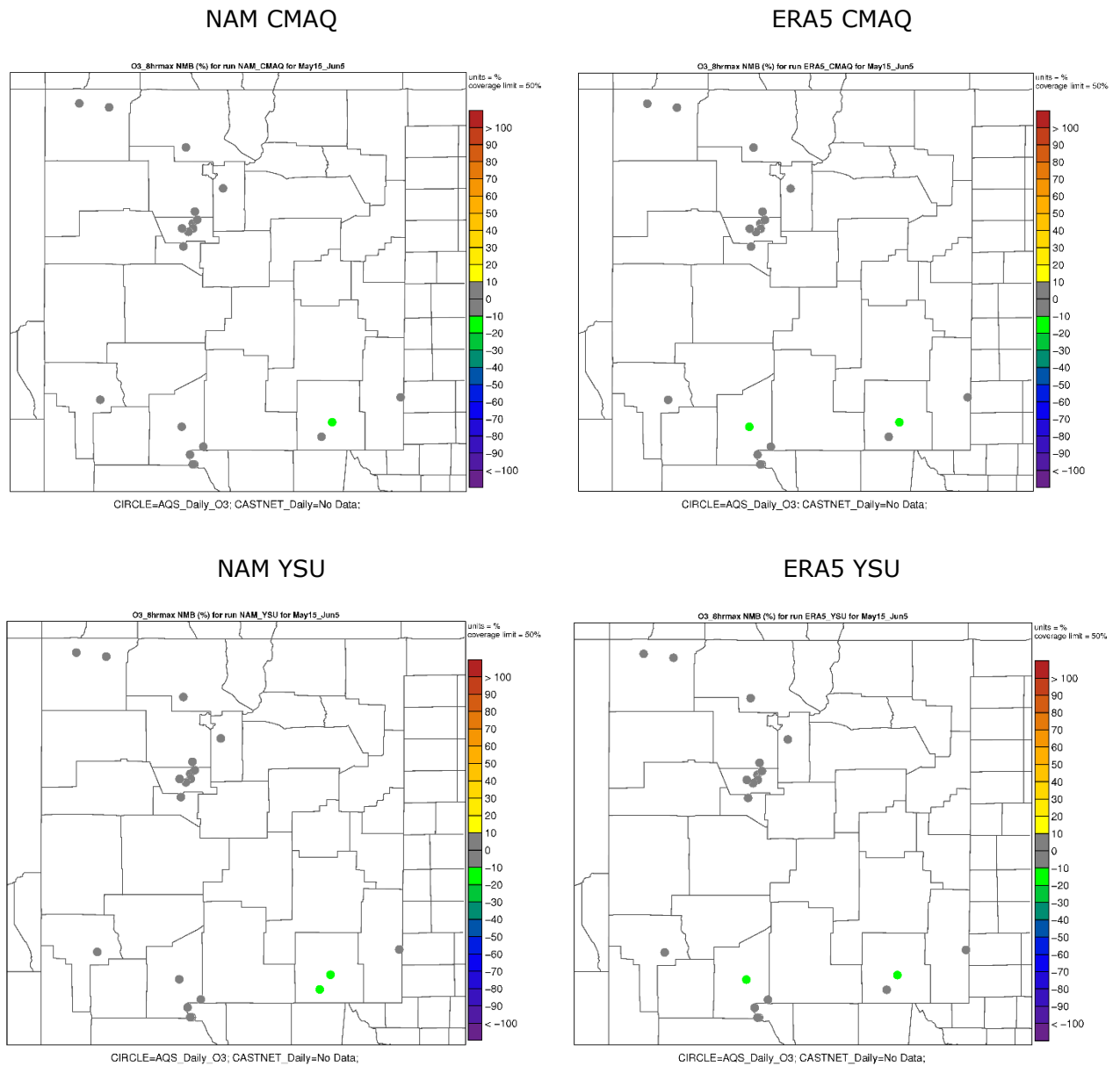


Figure 5-1. Comparison of sensitivity tests NMB with 60 ppb cutoff spatial plots over NM.

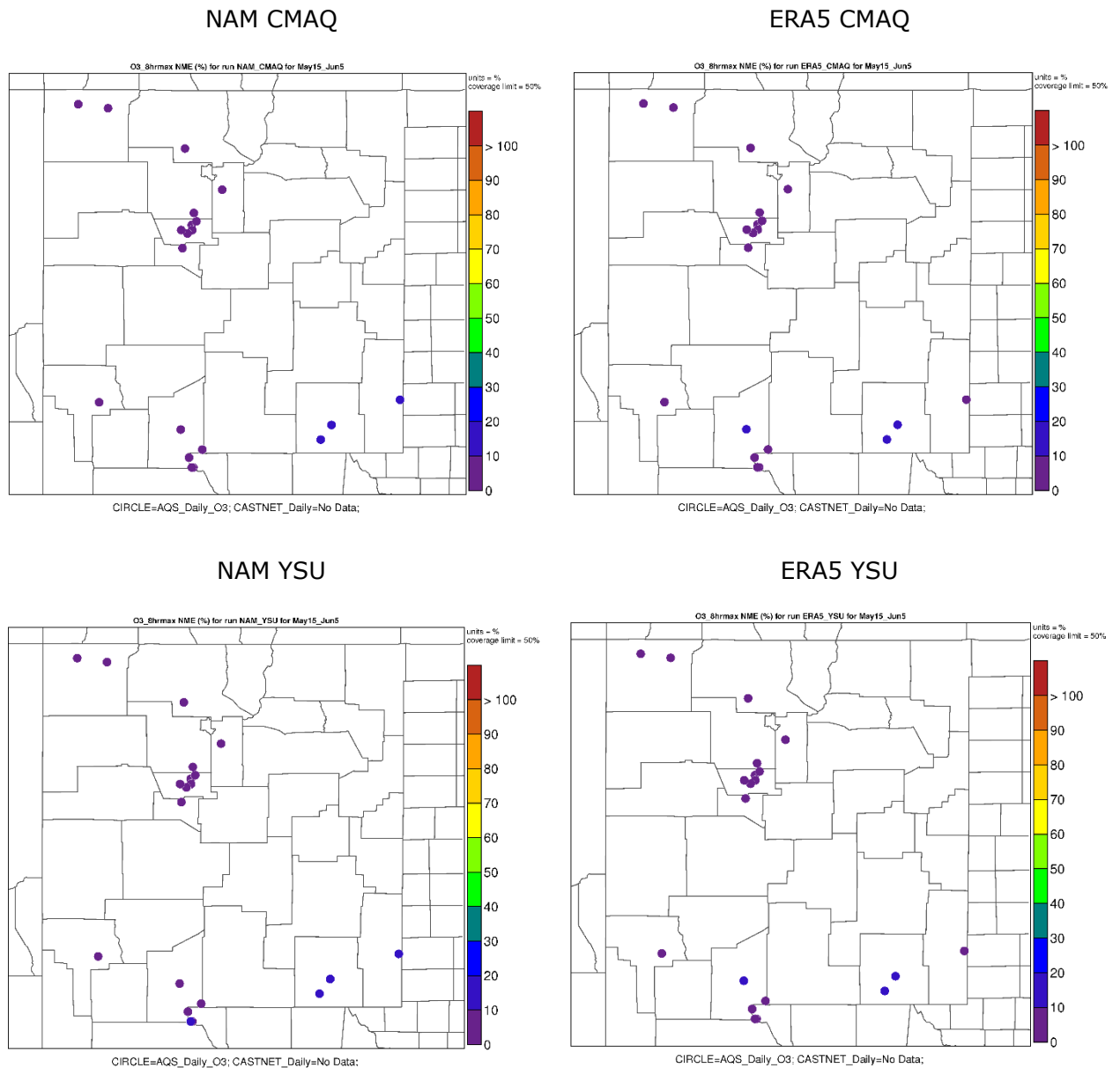


Figure 5-2. Comparison of sensitivity tests NME with 60 ppb cutoff spatial plots over NM.

Figure 5-3 presents soccer plots of bias and error for observed ozone above 60 ppb and all four CAMx sensitivity tests. This figure plots site-specific bias versus error with performance lines in the shape of a soccer goal, when the site-specific bias and error symbol falls within the soccer goal area (i.e., the red box) it is easy to see when the ozone performance goals are achieved. The figure shows that all sites have NMB and NME that fall within the performance criteria for bias ($\leq \pm 15\%$) and error ($\leq 25\%$), with most sites having an underestimation bias of the high (> 60 ppb) observed ozone concentrations. The CAMx simulations with the WRF/NAM meteorological inputs has slightly better performance than when the WRF/ERA5 inputs are used as more sites fall within the performance soccer goal area. Comparison between the NAM cases indicate that the test with CMAQ Kv has slightly smaller errors relative to the test with YSU Kv.

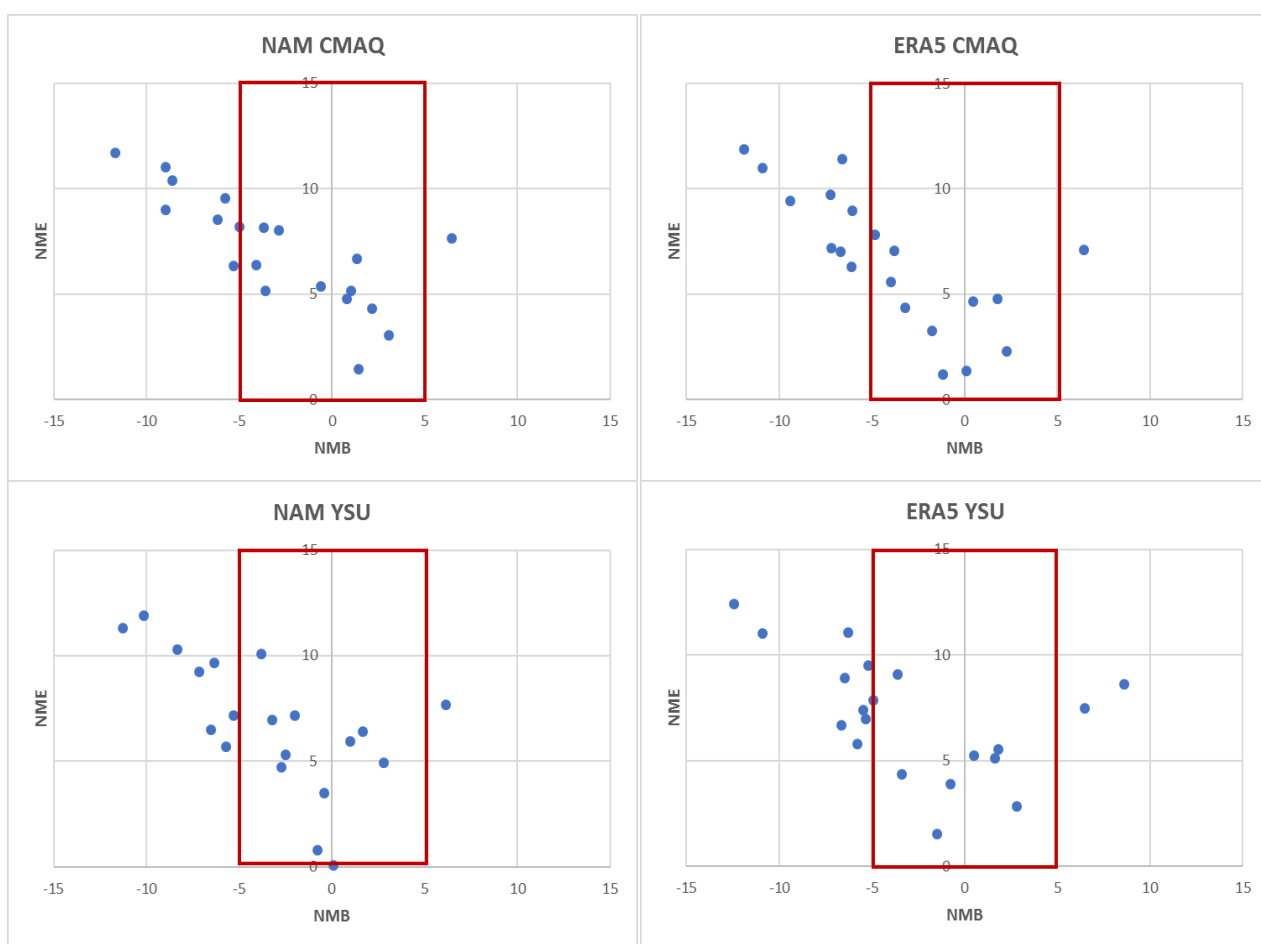


Figure 5-3. Comparison of sensitivity tests soccer plots with 60 ppb cutoff. Red rectangle indicates the performance goal soccer area.

Figures 5-4 to 5-7 present time series of predicted and observed MDA8 ozone concentrations for selected sites in Dona Ana, Eddy and Sandoval counties. At the Solano Road site in Dona Ana County the time series shows that the observed peak ozone concentration on May 29 is matched very well by the CAMx WRF/NAM sensitivity tests, while the CAMx WRF/ERA5 sensitivity test under-predicts by approximately 10 ppb (Figure 5-4). At the Desert View site, which is also in Dona Ana County, all four CAMx sensitivity tests underestimate the high observed ozone on May 28-29, but the CAMx WRF/NAM tests perform slightly better than the CAMx WRF/ERA5 test (Figure 5-5). At the Carlsbad site in Eddy County all test cases under-predict the high ozone concentration from May 27 to May 31 (Figure 5-6). For the site in Sandoval county (Figure 5-7) all four CAMx sensitivity tests track the daily variations of the observed MDA8 ozone including getting the timing and values of the observed ozone peak on May 29, but the CAMx WRF/NAM with CMAQ Kv test exhibits the lowest biases.

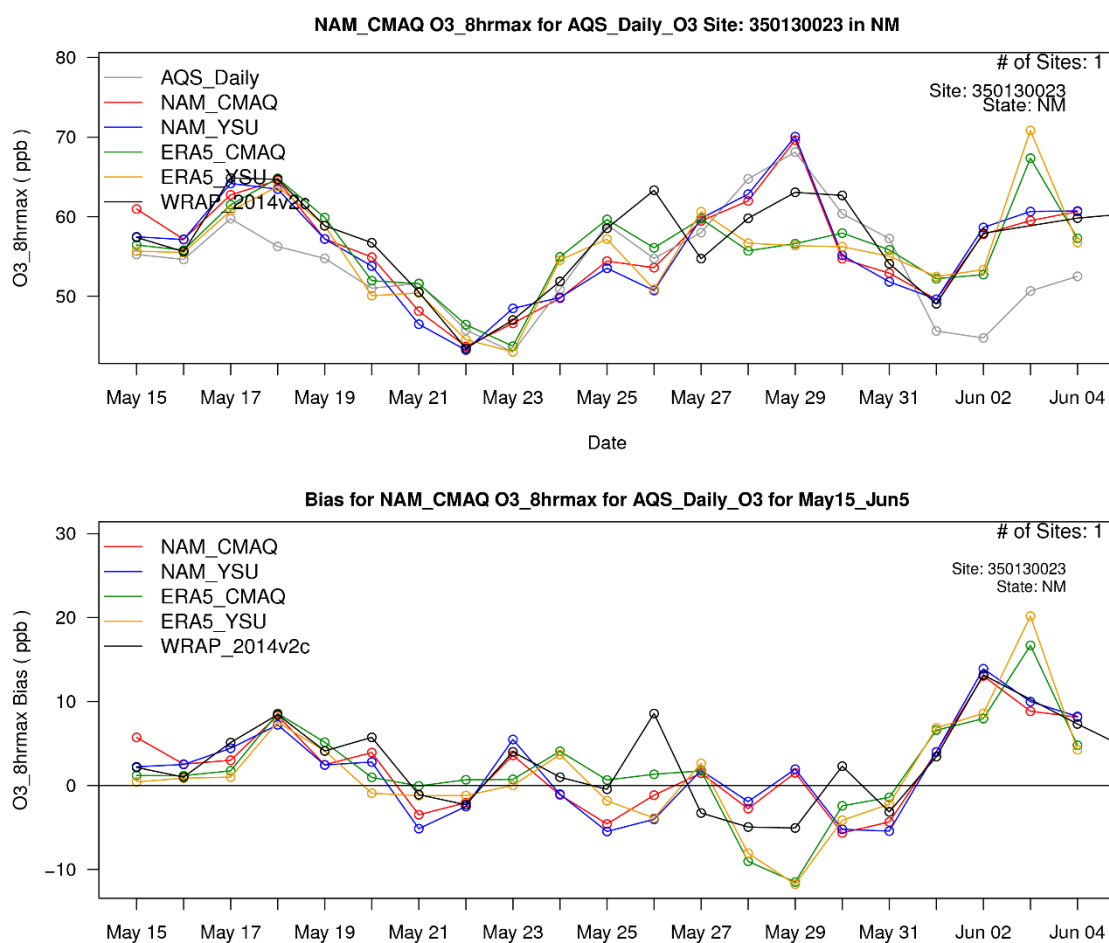


Figure 5-4. Timeseries comparison of sensitivity tests with observations (top) and bias (bottom) at Solano Road site, Dona Ana County

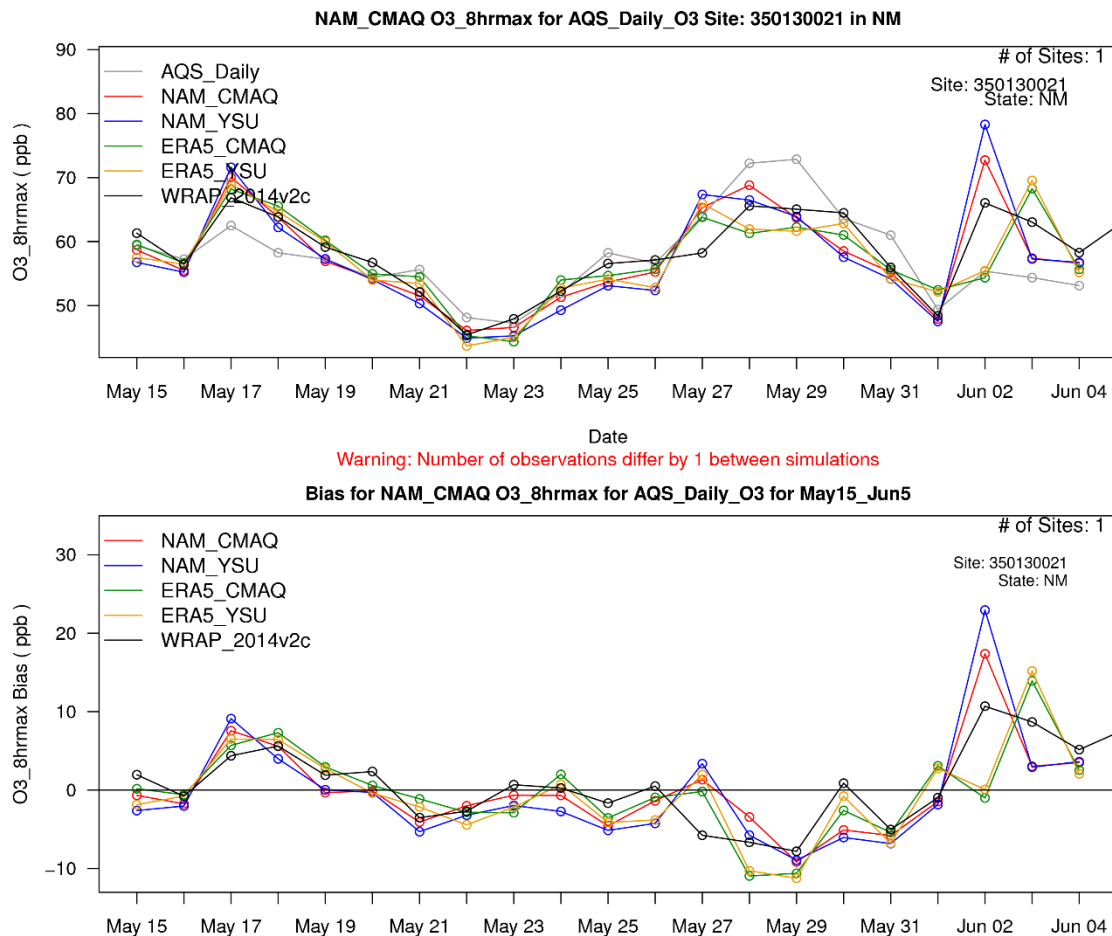


Figure 5-5. Timeseries comparison of sensitivity tests with observations (top) and bias (bottom) at Desert View site, Dona Ana County

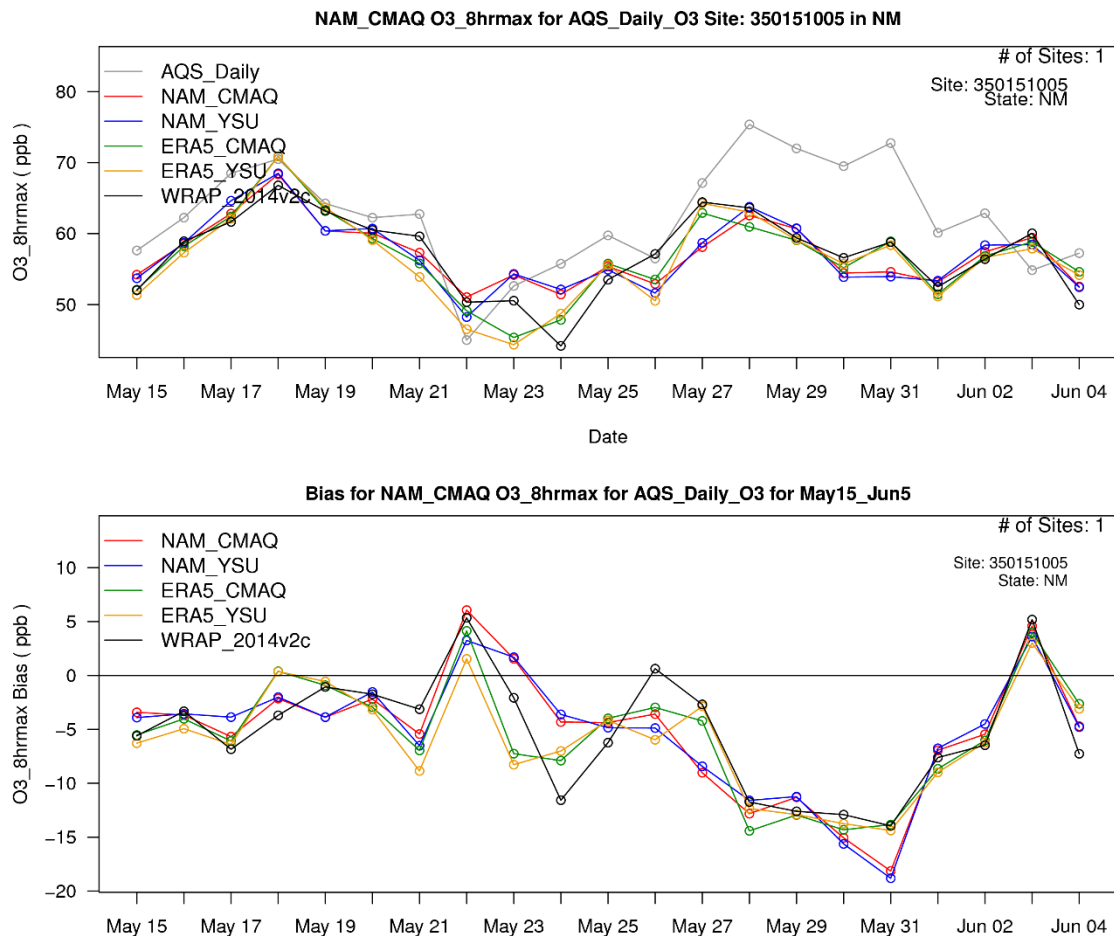


Figure 5-6. Timeseries comparison of sensitivity tests with observations (top) and bias (bottom) at Carlsbad site, Eddy County

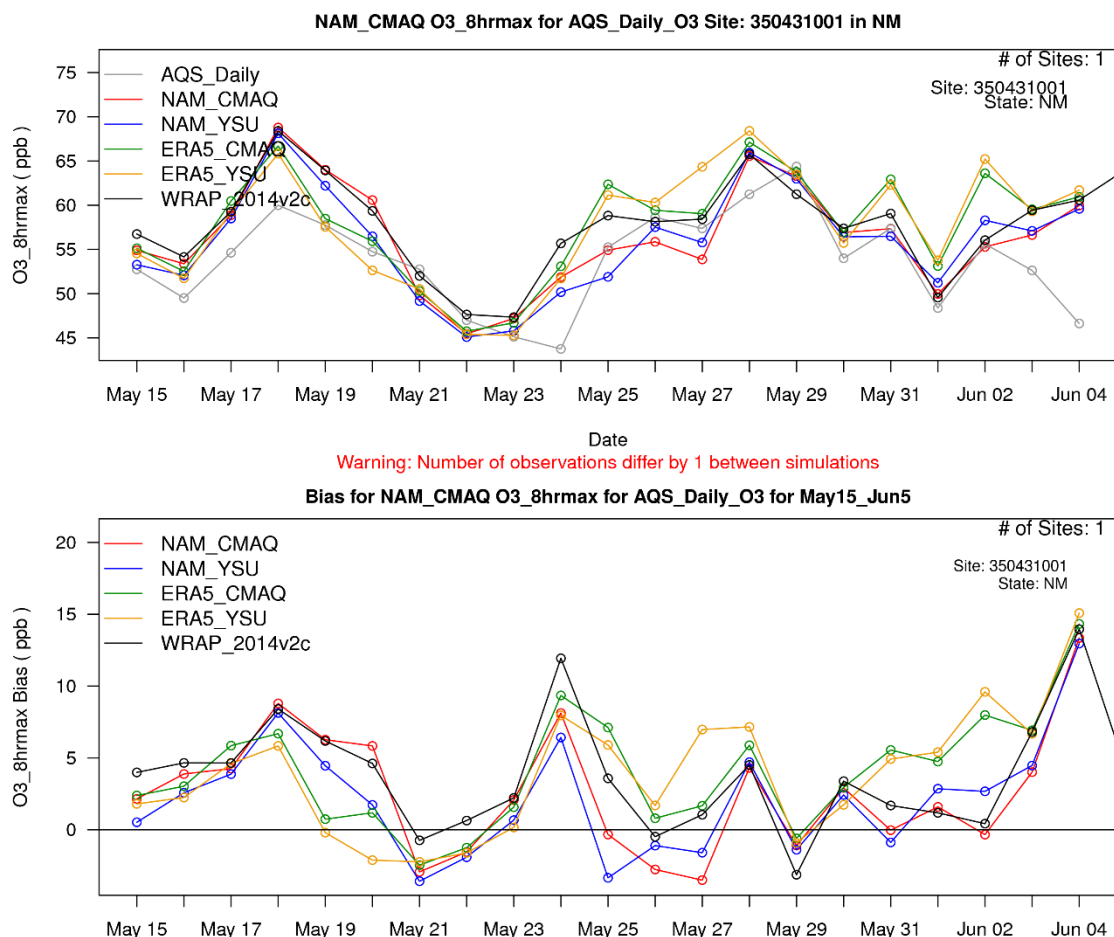


Figure 5-7. Timeseries comparison of sensitivity tests with observations (top) and bias (bottom) at Albuquerque site, Sandoval County

5.3 Summary CAMx Diagnostic Sensitivity Tests

All four of the CAMx meteorological sensitivity cases have biases and errors well within the performance criteria and in most cases even within the more stringent performance goals. For the modeled episode, the differences in performance among all the cases considered are relatively minor. On some sites and days, CAMx using the WRF/NAM meteorology tends to capture peak ozone concentrations better than when the WRF/ERA5 meteorology is used. Note that the sensitivity tests were performed on a period in late spring (May to June) when ozone concentrations exceed the NAAQS, however they may not reflect the observed precipitation biased observed in the WRF MPE for the period of June to August. Also, the WRF performance showed that precipitation biases could occur over northeast NM where there are no ozone monitors so CAMx model performance is unknown in that region. Based on the results presented here, the final CAMx 2014 base case model configuration will use the WRF/NAM with CMAQ Kv treatment meteorological inputs.

6. FINAL MODEL BASE CASE CONFIGURATION

This section summarizes the final CAMx base case model configuration for the summer of 2014 modeling of New Mexico that includes the meteorological, emissions, and air quality inputs as well as CAMx option and configuration. The modeling procedures used in the NM OAI Study modeling are consistent with EPA's latest ozone modeling guidance documents (EPA, 2018d) and past modeling studies of the western U.S. and followed the procedures laid out in the NM OAI Study modeling protocol (WESTAR and Ramboll, 2020a).

6.1 Meteorological Inputs

Procedures for WRF meteorological modeling for the NM OAI Study 2014 36/12/4-km applications are described in Chapter 2. Chapter 5 describes the CAMx diagnostic sensitivity tests using four different meteorological inputs that were based on two 2014 WRF simulations (WRF/NAM and WRF/ERA5) that were processed to generate CAMx inputs using two different two vertical mixing (Kv) options in the WRFCAMx processor (CMAQ-like and YSU). Although the ozone model performance for the four CAMx meteorological sensitivity tests were similar, the CAMx simulation using the WRF/NAM with CMAQ-like vertical mixing coefficients inputs was selected based on the best ozone model performance.

6.2 Emission Inputs

The 36-km and 12-km emissions used in the NM OAI Study CAMx 2014 base case simulation were based on the WRAP-WAQS 2014v2 emissions. Chapter 4 describes the updates to the WRAP-WAQS 2014v2 emissions for New Mexico and the development of the emission inputs for the New Mexico 4-km domain.

6.3 Photochemical Model Inputs

6.3.1 PGM Science Configuration and Input Configuration

This section describes the final CAMx 2014 base case configuration and science options used in the NM OAI Study ozone modeling. Table 6-1 summarizes the CAMx configuration and option used, with more details provided below.

6.3.1.1 PGM Model Versions

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

6.3.1.2 PGM Grid Nesting Strategy

CAMx was operated using the 36/12/4-km nested grid structure shown in Figure 1-10 using two-way grid nesting for all simulations.

6.3.1.3 Initial and Boundary Conditions

Boundary Conditions (BCs) for the CAMx most outer 36-km 36US modeling domain lateral boundaries were based on output from a 2014 simulation of the GEOS-Chem global chemistry conducted by WRAP for their 2014v2 modeling platform. A zero-gradient top BC was specified where the concentrations above the top of CAMx are assumed to be the same as in the top layer of CAMx.

CAMx was started on May 1, 2016 using the 36/12/4-km domains that allowed the model over two-weeks to initialize the model and wash out the initial concentrations 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) was used for horizontal transport along with the spatially varying (Smagorinsky) horizontal diffusion approach. K-theory was used for vertical diffusion using the CMAQ-like Kv profiles from the WRFCAMx processing of the WRF/NAM output. The CB6r4 gas-phase chemical mechanism was selected because it includes the very latest chemical kinetic rates with halogen chemistry that affects ozone levels over the ocean. The latest aerosol mechanism was used in CAMx along with the standard wet and dry deposition schemes. The Plume-in-Grid module was used to treat the near-source chemistry and dispersion of major NO_x emissions sources in the New Mexico 4-km domain for sources with greater than 5 tons per day NO_x emissions.

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

Science Options	CAMx	Comment
Model Codes	CAMx v7.0	Latest version of CAMx made publicly available May 2020 (www.camx.com)
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). Layer collapsing from 35 vertical layers in WRF
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 lateral boundaries
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	Point sources with NO _x emission s greater than 5 tons per day
Chemistry		
Gas Phase Chemistry	CB6r4	Latest chemical reactions and kinetic rates with halogen chemistry (Yarwood et al., 2010)
Meteorological Processor	WRF-CAMx	Compatible with CAMx v7.0
Horizontal Diffusion	Spatially varying	K-theory with Kh grid size dependence
Vertical Diffusion	CMAQ-like Kv	Evaluated 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 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 are accurate enough for air quality planning in New Mexico. 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 includes 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 was performed following the procedures outlined in the previous Chapters.

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.

For the NM OAI Study we conducted an operational MPE for MDA8 ozone focusing on ozone model performance within the state of New Mexico. We also conducted some elements of a diagnostic evaluation as described in Chapter 5.

7.3 Overview of Evaluation of CAMx 2014 Base Case Procedures

This section provides an overview of the approach, procedures and tools used the procedures for evaluating the performance of the CAMx model focusing on ozone in New Mexico.

7.3.1 Photochemical Model Evaluation Methodology

The CAMx model performance evaluations will follow the procedures recommended in the EPA’s latest photochemical modeling guidance (EPA, 2018d), some elements of EPA MPE Checklist (EPA, 2015a,b), and procedures discussed by Boylan and Russell (2006), Simon, Baker and Phillips (2012) and Emery and co-workers (2016).

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 ($\leq \pm 15\%$) and error ($\leq 35\%$). 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 helping interpret 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. In this Chapter we 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

There are two main ozone monitoring networks operating in New Mexico in 2014:

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 (AQS⁴⁰) database throughout the U.S. Typical surface measurements at the ground level routine AIRS monitoring stations include ozone, NO₂, NO_x and CO.

CASTNet Monitoring Network: The Clean Air Status and Trends Network (CASTNet⁴¹) 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 three more CASTNet sites in the 4-km New Mexico modeling domain: Mesa Verde in Colorado, Petrified Forest in Arizona and Palo Duro in Texas.

7.3.4 Atmospheric Model Evaluation Tool (AMET)

The Atmospheric Model Evaluation Tool (AMET⁴²) (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 were 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 v1.3⁴³ is pertinent for AMET v1.4.

⁴⁰ <https://www.epa.gov/aqs>

⁴¹ <https://www.epa.gov/castnet>

⁴² <https://www.cmascenter.org/amet/>

⁴³ <https://www.cmascenter.org/help/documentation.cfm>

7.4 Ozone Evaluation Across the 4-km New Mexico Domain

Figure 7-1 shows the scatter plots of predicted and observed MDA8 ozone concentrations across AQS and CASTNet sites. The AQS sites (Figure 7-1, left) represent mainly the urban locations and whereas CASTNET (Figure 7-1, right) represent monitoring sites that are more rural. Most of the observation-model pair dots in the scatter plots appear to lie along the 1:1 line with very few outliers. The center of the AQS MDA8 ozone scatter plot lies slightly above the 1:1 line of perfect agreement indicating a slight overestimation bias. These scatter plots also displays the Normalized Mean Bias (NMB) and Error (NME) metrics. The average NMB for all MDA8 ozone concentrations and across all AQS sites shows an average overestimation bias of 6.2%, which is slightly higher than the bias performance goal ($\leq \pm 5\%$) but within the bias performance criteria ($\leq \pm 15\%$). The NME for MDA8 ozone across all AQS sites in the 4-km domain is 10.9%, which is well within the error performance goal ($\leq 15\%$).

The average MDA8 ozone NMB at all CASTNet sites is 0.1% which is very low and quite good ozone performance well within the bias performance goal. The MDA8 ozone NME across the CASTNet sites is also very good at 7.9%.

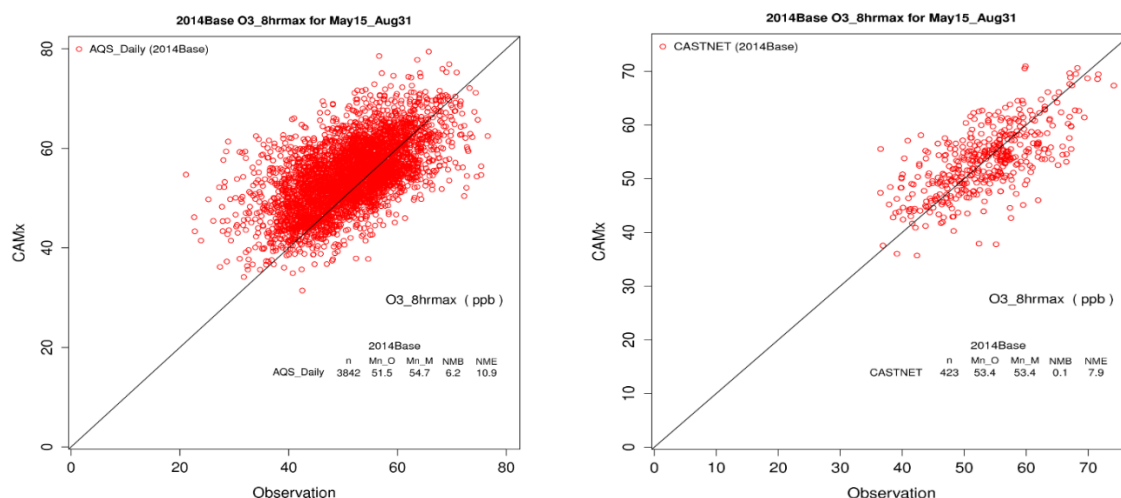


Figure 7-1. Scatter plot of predicted and observed MDA8 ozone across the AQS and CASTNET monitoring sites within the 4-km New Mexico domain during the modeling period (May 15-Aug 31, 2014) for the CAMx 2014 base case simulations.

Figure 7-2 displays the spatial distribution of the AQS and CASTNet site-specific NMB for the modeling period and for all MDA8 ozone (left) and MDA8 ozone when the observed ozone is above a 60 ppb cut-off (here after referred as MDA8_above60). Throughout the domain, the model NMB for all MDA8 ozone achieved the ozone bias performance goal ($\leq \pm 5\%$) at majority of the sites (i.e., symbols colored grey). At few sites, the model showed an overprediction (yellow color) in predicting all MDA8 ozone concentrations. With one exception for a site colored orange in El Paso, the sites with the overestimation bias are colored bright yellow that indicates bias in the +5% to +15% range so achieve the ozone bias performance criteria.

For MDA8_above60 (Figure 7-2, right panel) for most sites in the 4-km domain the NMB symbols are colored grey indicating that they achieve the ozone bias performance goal. Several sites are colored bright green that indicates an underestimation bias that are unable to achieve bias performance goal ($\leq \pm 5\%$) but is within the ozone bias performance criteria ($\leq \pm 15\%$) so the bias is between -5% and -15%.

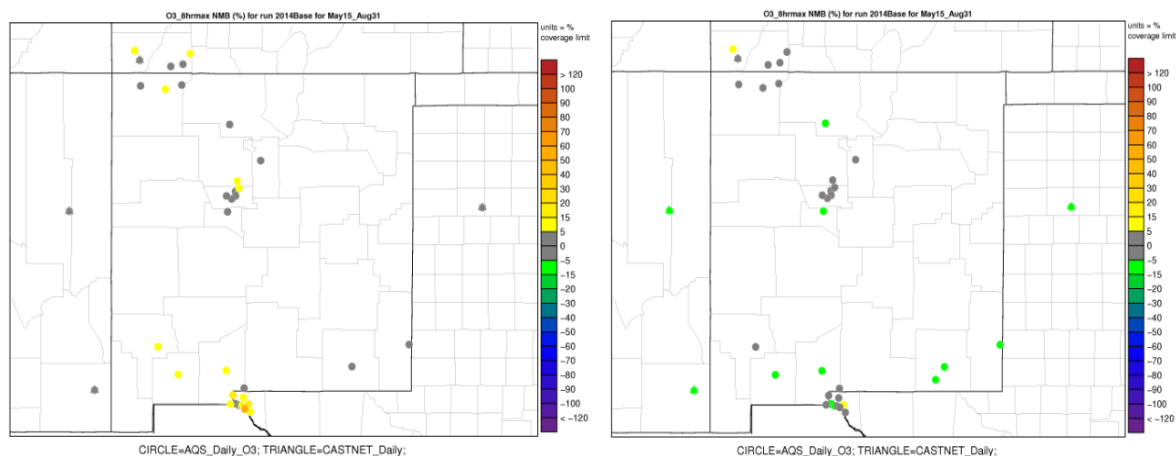


Figure 7-2. Spatial distribution of CAMx 2014 base case simulation period (May15-Aug 31) site-specific Normalized Mean Bias within the 4-km domain for MDA8 O3 (left) and MDA8 O3 above 60ppb cut-off (right).

7.5 Ozone Evaluation Across New Mexico

In this section we evaluated the modeled MDA8 ozone and MDA8_above60 ozone in the state of New Mexico at all AQS monitoring sites using scatter, soccer and spatial overlay plots. Figure 7-3 presents scatter plots of MDA8 and MDA8_above60 ozone modeled and observation paired concentrations, it indicate that the modeled values are close to the observations as majority of them lie along and in the vicinity of 1:1 line. The domain wide all AQS sites MPE statistics of MDA8 and MDA8_above60 ozone NMB (5.0%, -4.3%) and NME (9.8%, 8.0%) metrics are within the ozone performance goals (i.e., $NMB < \pm 5\%$ and $NME < 15\%$).

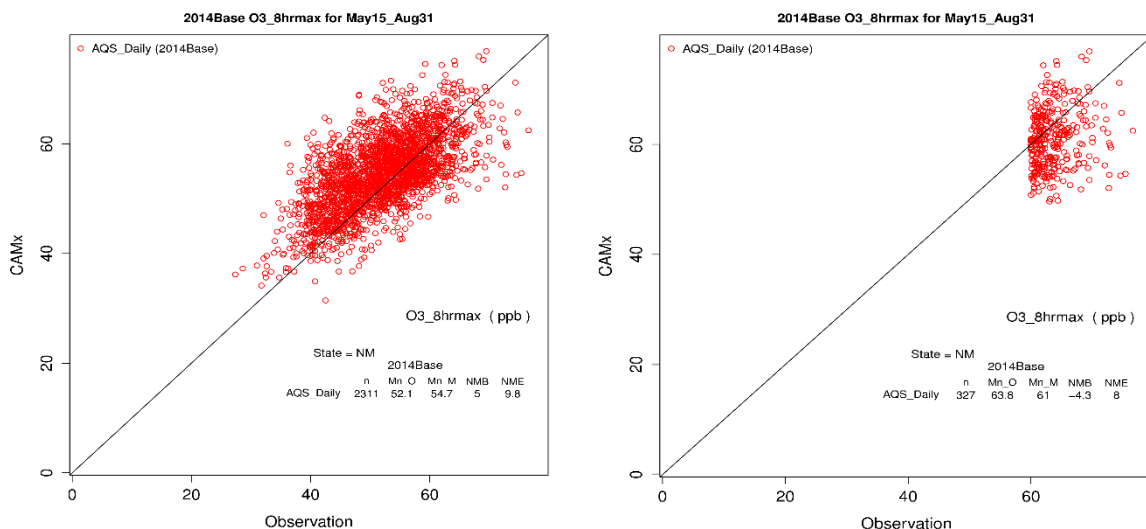


Figure 7-3. Scatter plots of predicted and observed MDA8 ozone (left) and MDA8 ozone when observed value is above 60 ppb cut-off (right) across the AQS monitoring sites in New Mexico during modeling period (May15-Aug 31) for the CAMx 2014 base case simulations.

Figure 7-4 displays the monthly soccer plot for sites in New Mexico and for MDA8 (left) and MDA8_above60 (right) ozone concentrations with the inner rectangle being the performance goal (NMB<±5% and NME<15%) and the outer rectangle being the performance criteria (NMB<±15% and NME<25%). Considering all MDA8 ozone data with no cut-off (i.e., Figure 7-4 left panel), the model is overestimating in the months of July and August achieving the performance criteria but not the performance goals. The months of May and June achieve the performance goals.

Considering the ozone data with 60 ppb cut-off (i.e., Figure 7-4 right panel), the model achieves the ozone performance goals in June, July and August months with an underestimation bias. In May, the underestimation bias for MDA8_above60 is lower than -5% so fails to achieve the bias performance goal, but does achieve the performance criteria. Overall, the soccer plots indicate that the model captures the observed MDA8 and MDA8-above60ppb ozone concentrations well during each month of the summer of 2014

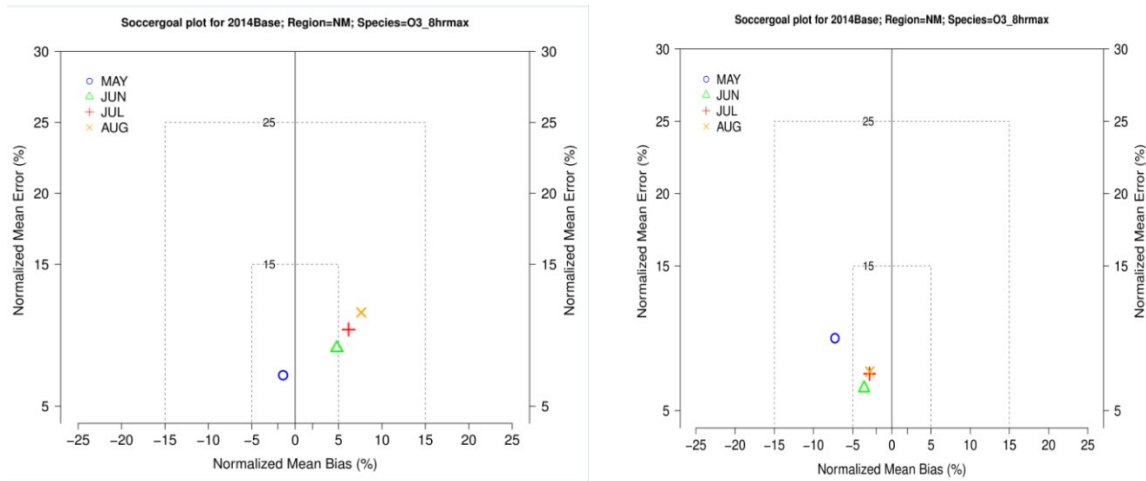


Figure 7-4. Soccer plots of MDA8 ozone (left) and MDA8 ozone when observed value is above a 60 ppb cut-off (right) with monthly average NMB and NME values across sites in New Mexico. The dashed lines represents the performance goals and criteria.

As shown in site-specific spatial NMB plot for New Mexico sites in Figure 7-5, the overestimation of MDA8 ozone (considering all values) that fails to achieve the bias performance goal occurs mainly at southern sites along with three other northerly sites (Bloomfield, North Valley and Foothills). The underestimation of MDA8_{above60} that fails to achieve the bias performance goal occurs primarily at southern sites along with two more northerly sites (Coyote Ranger and Los Lunas).

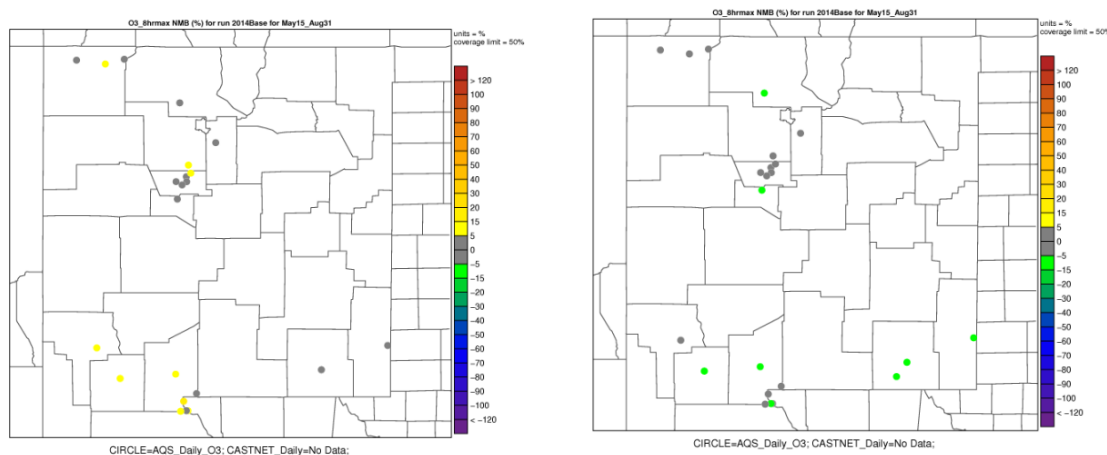


Figure 7-5. Spatial distribution of site-specific Normalized Mean Bias for sites in New Mexico and the CAMx 2014 May-August base case simulation for all MDA8 ozone data (left) and MDA8 ozone with observed value above a 60 ppb cut-off (right).

7.6 Ozone Evaluation in New Mexico Subregions

As shown in the New Mexico ozone performance above, and discussed in the conceptual model in Chapter 1, there are three distinct large regions of ozone formation conditions in New Mexico, each with their own subregional variations: northern New Mexico that shares ozone attributes of other sites in other states in the Four Corners region, Bernalillo County that has many of the attributes of the northern New Mexico sites only also including the presence of a major city; and sites in southern New Mexico. The ozone MPE is conducted separately for each of these major subregions in New Mexico. Table 7-2 shows the AQS sites available in the New Mexico with ozone data during 2014 that are categorized into northern New Mexico (blue), Bernalillo County (yellow) and south New Mexico (orange) subregions. The NMB and NME values shown in Table 7-3 are averaged across all sites in these regions and color coded based on the performance benchmarks for both MDA8 ozone and MDA8above60: green if achieve the performance goal; yellow if falling between the performance goal and criteria; and red if fails to achieve the performance criteria. Both northern and Bernalillo County regions achieve the ozone bias and error performance goal for both MDA8 ozone concentrations without and with an observed MDA8 ozone 60 ppb cut-off threshold. The southern region has NMB that fall between the ozone bias performance goal and criteria due to either a too high overestimation bias (all MDA8 data) or too low underestimation bias (MDA8_above60ppb). Although the bias just barely falls outside of the performance goal.

Table 7-2. AQS monitoring sites categorized into subregions of southern New Mexico (orange), Bernalillo County (yellow) and southern New Mexico (blue).

Site ID	Site Name	County	Latitude	Longitude
350130022	Santa Teresa	Dona Ana	31.79	-106.68
350130017	Sunland Park Yard	Dona Ana	31.80	-106.56
350130021	Desert View	Dona Ana	31.80	-106.58
350130008	La Union	Dona Ana	31.93	-106.63
350130020	Chaparral	Dona Ana	32.04	-106.41
350290003	Deming Airport	Luna	32.26	-107.72
350130023	Solano	Dona Ana	32.32	-106.77
350151005	Carlsbad	Eddy	32.38	-104.26
350171003	Chino Copper Smelter	Grant	32.69	-108.13
350250008	Hobbs Jefferson	Lea	32.73	-103.12
350610008	Los Lunas	Valencia	34.81	-106.74
350010029	South Valley	Bernalillo	35.02	-106.66
350010024	South East Heights	Bernalillo	35.06	-106.58
350010032	Westside	Bernalillo	35.06	-106.76
350010023	Del Norte	Bernalillo	35.13	-106.59
350011012	Foot Hills	Bernalillo	35.19	-106.51
350431001	Bernalillo	Sandoval	35.30	-106.55
350490021	Santa Fe Airport	Santa Fe	35.62	-106.08
350390026	Coyote Ranger District	Rio Arriba	36.19	-106.70
350450009	Bloomfield	San Juan	36.74	-107.98
350451005	Sub Station	San Juan	36.80	-108.47
350450018	Navajo Lake	San Juan	36.81	-107.65

Table 7-3. Region specific NMB and NME values for MDA8 Ozone and MDA8 Ozone when Observed Value is above 60 ppb.

Region	MDA8 O3		MDA8 _above60	
	NMB (%)	NME (%)	NMB (%)	NME (%)
North NM	4.3	9.1	0	6.4
Bernalillo	4.3	9.4	-2.8	7.1
South NM	5.8	10.5	-6.1	8.5

7.7 Ozone Evaluation at Individual New Mexico Monitoring Sites

Table 7-4 contain individual AQS site MDA8 ozone model performance statistics for the CAMx 2014 base case simulation from May 15 to Aug 31, 2014. Among the 22 sites in the state, 13 sites (59%) achieve the bias performance goal (green color, $NMB \leq \pm 5\%$) and 8 sites (36%) exceeded the bias performance goal but achieve the bias performance criteria (orange color, $NMB \leq \pm 15\%$) leaving only one site (La Union in Dona Ana County) whose NMB fails to achieve the bias performance goal. With the exception of the Carlsbad monitor whose MDA8 ozone has a slight underestimation bias (NMB of -1.1%), all sites have a positive NMB when compared to all ozone observations indicating an overestimation bias, with just La Union having an NMB so large (17.4%) that it fails to achieve the ozone bias performance criteria. Also shown in Table 7-4 is the Fractional Bias (FB) whose results are similar to the NMB with just the La Union having a FB (16.4%) that fails to achieve the bias performance criteria.

In terms of NME, all sites achieve the error performance criteria and all sites except for two sites (La Union and Foot Hills) achieve the error performance goal ($NME \leq 15\%$). The results for the Fractional Error (FE) are similar to NME. Overall based on the average NMB and NME values at each site the model appeared to perform well during the modeling period.

Although not color-coded, the correlation (r) performance criteria (> 0.50) for MDA8 ozone is achieved at all monitoring sites. However, the correlation performance goal (> 0.75) is only achieved at one site.

Table 7-4. CAMx 2014 base case model performance statistics for MDA8 Ozone concentrations by monitoring site for summer (May15-Aug) modeling period.

Site ID	Site Name	N	Avg Obs	Avg Mod	MB	ME	NMB	NME	FB	FE	r
350010023	Del Norte	107	54.0	54.9	0.9	4.4	1.7	8.2	1.8	8.3	0.657
350010024	SE Heights	107	53.8	55.4	1.6	4.5	3.1	8.3	3.1	8.3	0.662
350010029	S Valley	108	53.8	55.4	1.6	4.2	3.1	7.7	3.1	7.7	0.69
350010032	Westside	109	54.2	54.8	0.6	4.3	1.1	7.9	1.1	7.9	0.632
350011012	Foot Hills	107	50.4	57.2	6.9	7.6	13.6	15.1	13.0	14.3	0.571
350130008	La Union	108	47.4	55.6	8.2	8.8	17.4	18.6	16.4	17.4	0.72
350130017	Sunland Park	109	50.3	54.8	4.5	6.1	9.0	12.1	9.1	11.8	0.702
350130020	Chaparral	100	52.3	54.8	2.5	4.9	4.8	9.4	5.0	9.2	0.73
350130021	Desert View	108	54.0	55.7	1.7	4.8	3.2	8.9	3.5	8.7	0.717
350130022	Santa Teresa	83	50.5	54.6	4.2	5.3	8.2	10.5	8.1	10.2	0.769
350130023	Solano	108	51.0	54.0	3.1	4.8	6.1	9.4	6.0	9.1	0.727
350151005	Carlsbad	97	53.7	53.1	-0.6	4.9	-1.1	9.0	-0.2	9.0	0.702
350171003	Chino Smelter	105	47.2	51.5	4.3	5.6	9.1	12.0	9.0	11.7	0.693
350250008	Hobbs Jefferson	105	52.9	54.1	1.1	5.1	2.1	9.6	3.0	9.7	0.586
350290003	Deming Airport	108	49.2	52.2	3.0	4.4	6.2	9.0	6.2	8.9	0.745
350390026	Coyote Ranger	105	52.4	54.2	1.7	5.1	3.3	9.8	3.5	9.8	0.55
350431001	Bernalillo	93	52.6	56.9	4.3	5.5	8.1	10.5	7.9	10.2	0.63
350450009	Bloomfield	109	51.6	55.4	3.7	5.3	7.2	10.3	6.9	10.0	0.62
350450018	Navajo Lake	80	54.1	55.3	1.2	3.8	2.2	7.0	2.0	6.9	0.681
350451005	Sub Station	104	54.1	54.8	0.7	4.2	1.4	7.9	1.0	7.9	0.705
350490021	Santa Fe Airport	107	52.8	54.8	2.0	4.6	3.8	8.7	3.8	8.6	0.591
350610008	Los Lunas	107	53.8	54.3	0.4	4.0	0.8	7.5	0.9	7.5	0.633

Similar to Table 7-4, Table 7-5 contain the individual AQS site performance statistics for MDA8 ozone with predicted and observed pairs when the observed value is above a 60 ppb cut-off threshold. Out of the 22 sites, 16 sites (73%) achieve the bias performance goal and the remainder 6 sites (27%) fall between the bias performance goal and criteria. Overall, all the sites showed a consistent slight under-prediction indicating that the model was unable to predict all of the observed ozone peak concentrations. The NME for all sites achieved the ozone error performance goal. The results for FB and FE are consistent with NMB and NME. Almost all of the correlation coefficients fail to achieve the performance criteria for MDA8_above60ppb, although the

sample size for the site-specific MDA8_above60ppb statistics is very small for some sites so the statistics are less meaningful.

Table 7-5. 2014 Base Case model performance statistics of MDA8 Ozone with an observed ozone 60 ppb cut-off by monitoring site for summer (May 15-Aug) modeling period.

Site ID	Site names	N	Avg Obs	Avg Mod	MB	ME	NMB	NME	FB	FE	r
350010023	Del Norte	26	62.2	59.8	-2.4	4.8	-3.9	7.7	-4.2	7.9	-0.167
350010024	SE Heights	20	62.8	61.3	-1.5	4.4	-2.4	7.0	-2.7	7.1	0.31
350010029	South Valley	18	63.0	61.3	-1.8	4.1	-2.8	6.6	-3.1	6.7	0.333
350010032	Westside	21	62.5	60.4	-2.1	4.5	-3.4	7.2	-3.8	7.4	0.045
350011012	Foot Hills	6	62.0	63.2	1.2	4.0	2.0	6.5	1.8	6.4	-0.23
350130008	La Union	7	65.2	64.2	-1.0	4.4	-1.6	6.8	-1.7	6.9	0.128
350130017	Sunland Park	15	64.9	62.6	-2.3	4.9	-3.6	7.6	-3.8	7.8	-0.041
350130020	Chaparral	18	65.4	62.3	-3.0	5.1	-4.7	7.8	-5.1	8	0.565
350130021	Desert View	25	66.2	62.8	-3.4	5.7	-5.1	8.7	-5.4	8.9	0.221
350130022	Santa Teresa	9	64.9	65.0	0.1	4.1	0.1	6.3	0	6.1	0.39
350130023	Solano	11	63.9	59.8	-4.1	4.1	-6.5	6.5	-6.7	6.7	0.807
350151005	Carlsbad	22	65.8	57.7	-8.1	8.1	-12.3	12.3	-13.0	13	0.283
350171003	Chino Smelter	9	63.3	62.7	-0.6	2.2	-1.0	3.4	-1.0	3.4	0.595
350250008	Hobbs Jefferson	20	64.2	57.8	-6.3	7.1	-9.9	11.0	-10.4	11.5	-0.251
350290003	Deming Airport	4	62.2	59.1	-3.1	5.2	-5.0	8.3	-5.4	8.6	0.118
350390026	Coyote Ranger	13	64.3	60.8	-3.5	3.9	-5.4	6.1	-5.7	6.4	0.432
350431001	Bernalillo	11	61.4	63.8	2.4	4.3	3.8	7.0	3.5	6.8	0.117
350450009	Bloomfield	10	62.7	64.3	1.6	3.1	2.5	5.0	2.3	5	0.624
350450018	Navajo Lake	10	62.9	62.5	-0.4	3.8	-0.6	6.1	-0.9	6.1	0.177
350451005	Sub Station	11	62.6	64.6	2.1	4.8	3.3	7.6	2.8	7.4	0.457
350490021	Santa Fe Airport	12	62.9	61.8	-1.1	4.2	-1.7	6.7	-2.1	7	0.373
350610008	Los Lunas	17	62.9	58.8	-4.1	4.7	-6.5	7.5	-6.9	7.9	0.167

Time series of predicted and observed MDA8 ozone concentrations at five representative sites (Bloomfield, Coyote Ranger, South Valley, Desert View and Carlsbad) are shown in Figure 7-6 to Figure 7-10. Time series sites for all sites are contained in Appendix A. Each time series plot consists of two panels: an upper panel that shows the predicted (blue) and observed (red) daily MDA8 ozone concentrations

from May 15 to August 31, 2014; and a bottom panel that shows the difference (i.e., daily bias) in the daily predicted and observed MDA8 ozone concentrations. At the Bloomfield monitor in San Juan County in northern New Mexico, the predicted and observed MDA8 ozone concentrations match each other remarkably well in May and June and into the first part of July. However, by mid-July the model estimates a series of three mini ozone episodes at the end of July, beginning of August and mid-August that are not reflected in the observations.

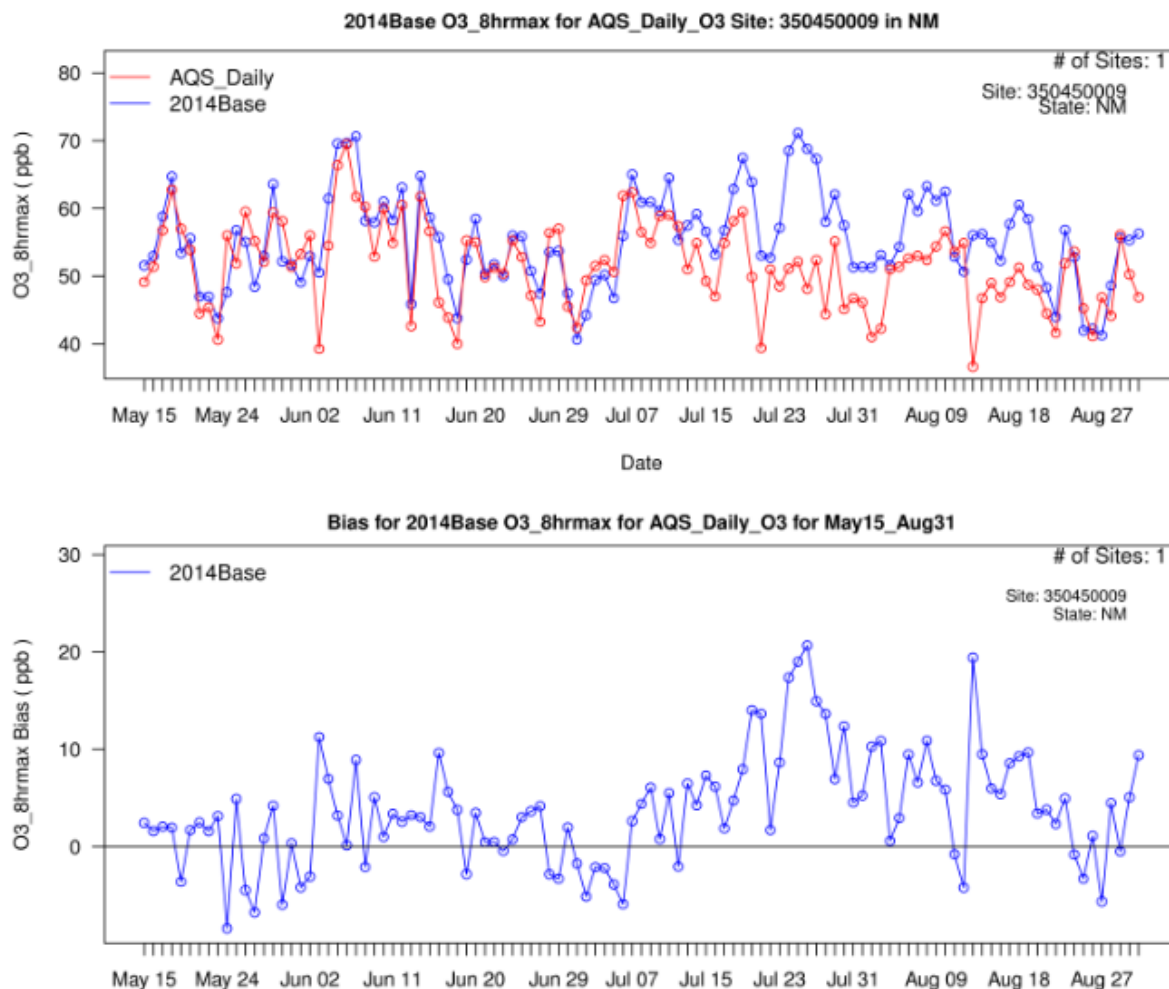


Figure 7-6. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at Bloomfield monitoring site (Site ID: 350450009).

The MDA8 ozone times series Coyote Ranger District site in Rio Arriba County shown in Figure 7-7 shares many of the same characteristics seen at Bloomfield. Extremely good daily MDA8 ozone performance is seen in May and June and the beginning of July. A third of the way into July, however, the model starts to exhibit an ozone overestimation bias with ozone peaks that are 10-20 ppb greater than observed, although better daily ozone performance is seen at Coyote Ranger District the end of August.

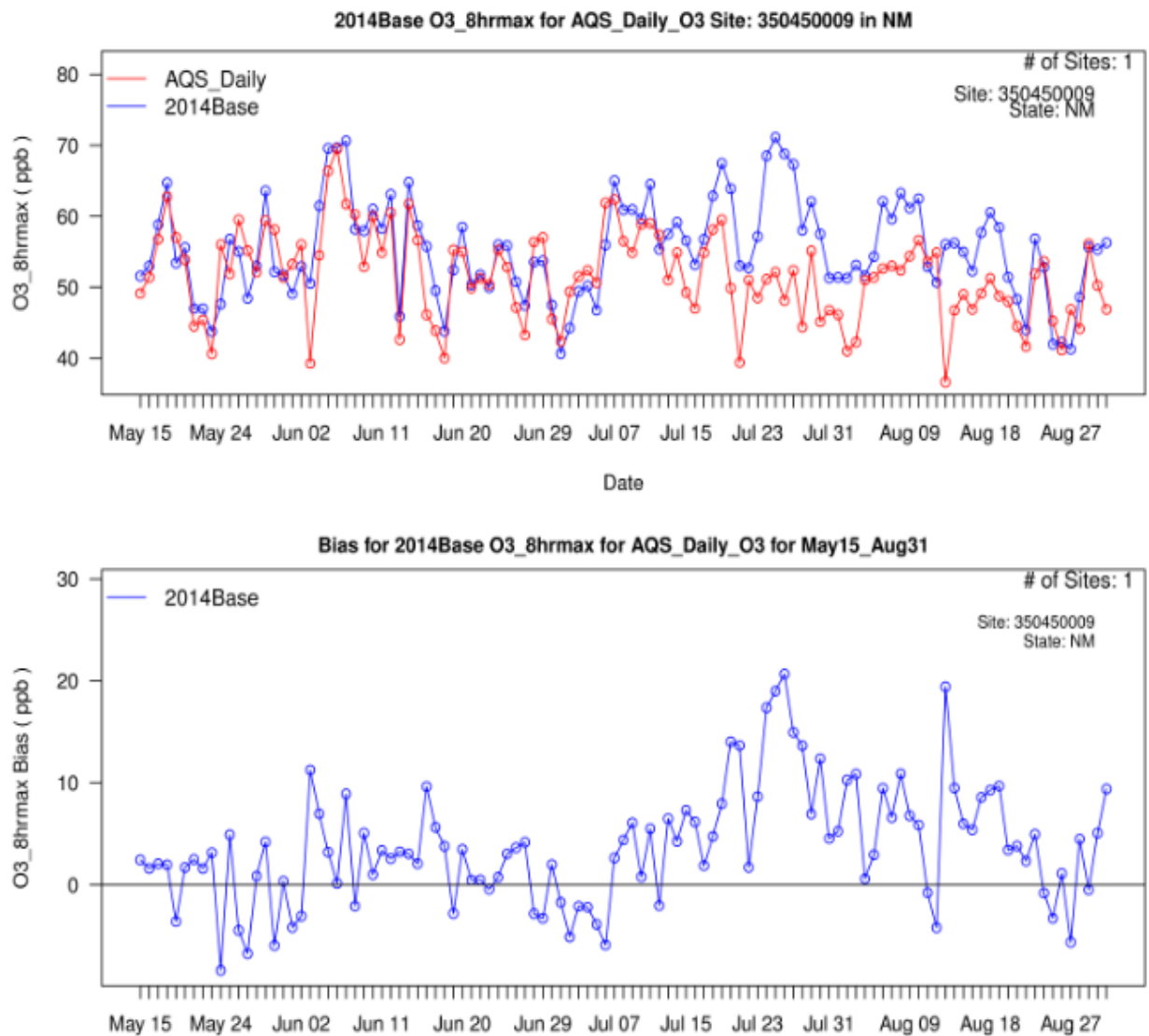


Figure 7-7. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at Coyote Ranger monitoring site (Site ID: 350390026).

The ozone time series at the South Valley site in Bernalillo County is fairly good throughout the May to August episode (Figure 7-8). The daily bias is almost always within $\pm 10\%$ and usually lower than that. The July-August systematic ozone estimation seen at the two northern New Mexico sites is not present, although there is a hint of that phenomena in mid-August.

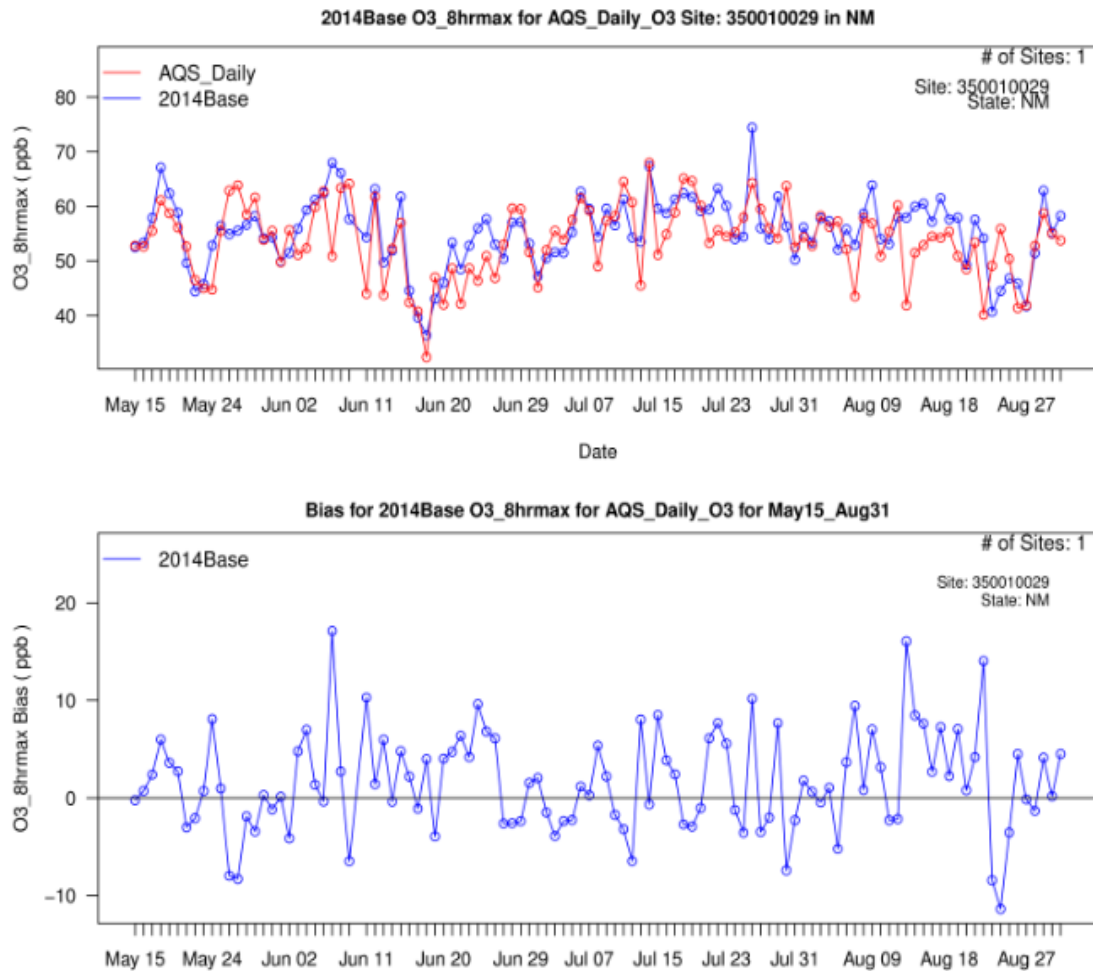


Figure 7-8. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at South Valley monitoring site (Site ID: 350010029).

The observed high MDA8 ozone concentrations at the Desert View monitoring site in Dona Ana County occur as ozone spikes that are a day or two in duration (Figure 7-9). In general, the model follows the observed daily variation on the observed MDA8 ozone concentrations well except for not capturing the observed ozone spikes during May, June and the first part of July. However, for the second half of July and in August the model does a good job in reproducing the observed ozone spikes at Desert View.

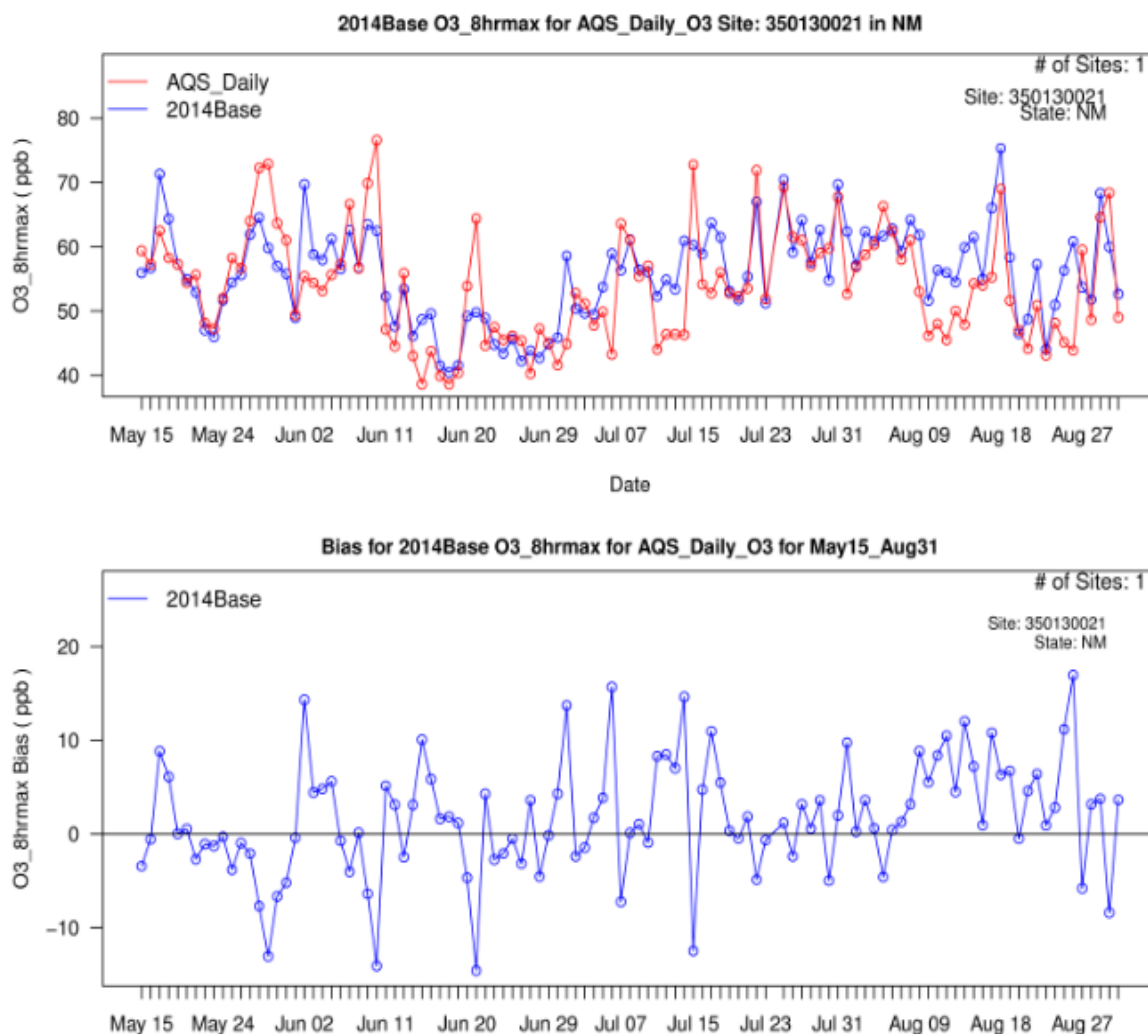


Figure 7-9. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at Desert View monitoring site (Site ID: 350130021).

The observed MDA8 ozone episode during May 29 to June 1 at the Carlsbad site in Eddy County in southeast New Mexico is completely missed by the model (Figure 7-10). Better performance is seen the remainder of the modeling period, although the model misses high ozone periods the end of July and early August. There is also a lot of missing observed data in August, which is unfortunate given the potential presence of high observed ozone during this period based on the data at Desert View.

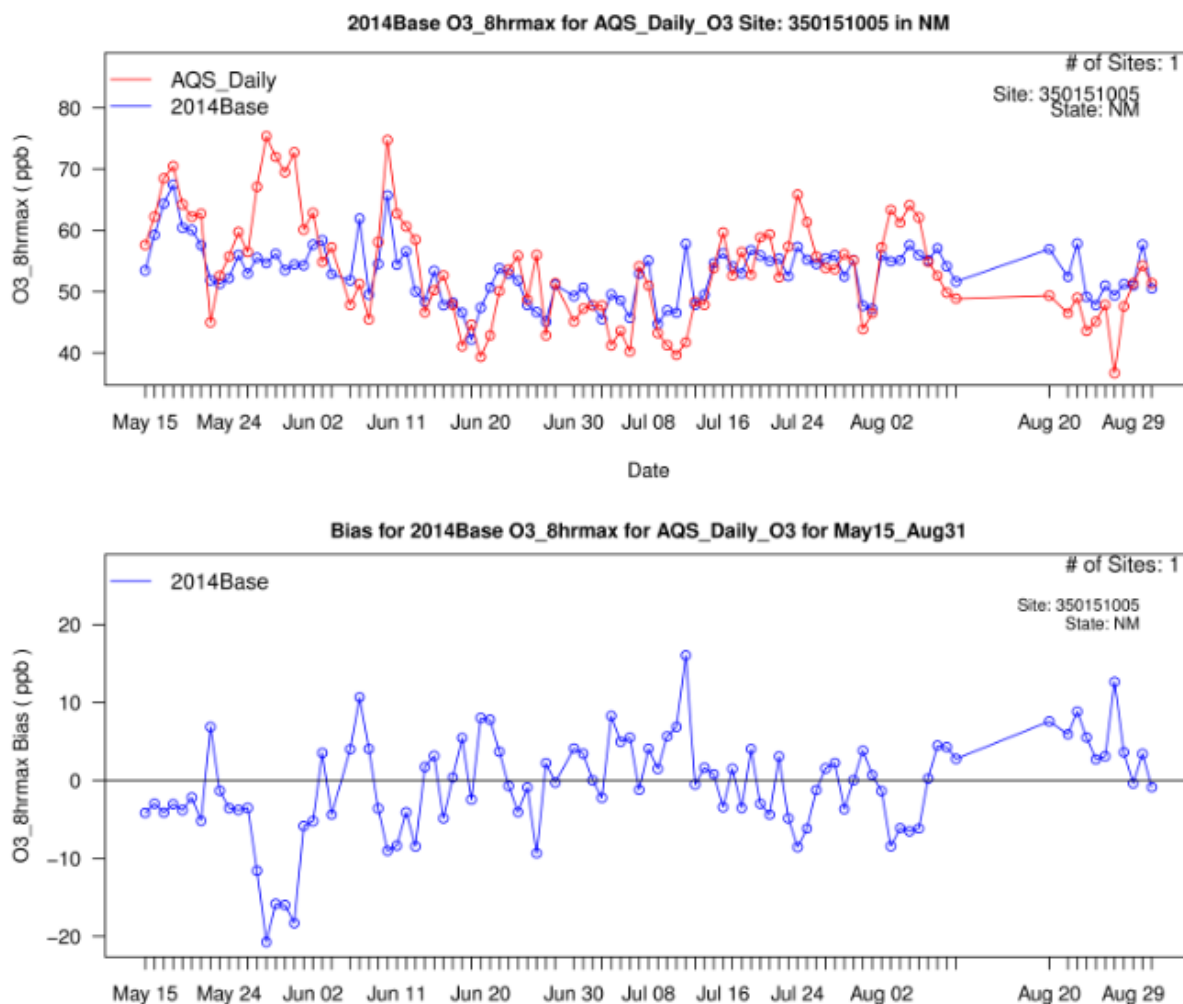


Figure 7-10. Time series of predicted and observed MDA8 ozone concentrations (ppb; top) and daily bias (ppb; bottom) at Carlsbad monitoring site (Site ID: 350151005).

7.8 Ozone Performance Related to Future Year Ozone Projections

EPA's ozone modeling guidance (EPA, 2018d) recommends making future year ozone design value projections using the relative changes in the future year to base year modeled MDA8 ozone concentrations for the 10 highest base year modeled MDA8 ozone concentrations. Thus, the model performance of the CAMx 2014 base case simulation for the 10 highest modeled ozone concentrations is of particular importance. In this

section we examine this issue for three sites: Bloomfield in San Juan County; Desert View in Dona Ana County; and Carlsbad in Eddy County.

7.8.1 Bloomfield Top 10 Ozone Performance

Table 7-2 displays the CAMx 2014 base case 36 highest modeled MDA8 ozone days at Bloomfield with concurrent observed MDA8 ozone, and the bias presented as concentration and percent. The observed top 20 highest MDA8 ozone concentrations are colored yellow, with the darker yellow indicating an observed top 10 MDA8 ozone concentration day. The 10 highest modeled MDA8 ozone concentrations at Bloomfield are also top 20 observed MDA8 ozone days for 6 of the 10 days; the top 10 observed MDA8 ozone concentration days occurring on 5 of the top 10 modeled ozone days. So, there is a good overlap of the top 10 modeled and top 20 observed highest MDA8 ozone days at Bloomfield.

The red shading on the bias percent in Table 7-2 indicates days in the top 10 modeled ozone days whose daily bias exceeds $\pm 10\%$. An alternative future year ozone design value projection approach to the EPA-recommended modeled top 10 MDA8 ozone days is to use the top 10 modeled ozone days that meet a model performance requirement, such as within $\pm 10\%$ of the observed value. With a 10% MPE criteria projection approach, the additional days used to replace those whose bias exceeds $\pm 10\%$ (i.e., shaded red) are colored blue in Table 7-2. Under the 10% MPE criteria projection approach, the 10 modeled days used in the projection all overlap with the top 20 observed ozone days and 7 of the days are a top 10 observed MDA8 ozone day.

This analysis indicates that the model performance on the modeled top 10 days used for making ozone projections at Bloomfield is quite reasonable and has good overlap with the observed highest ozone days.

Table 7-6. Predicted and observed MDA8 ozone concentrations (ppb) at Bloomfield for CAMx 2014 base case for modeled ranked 36 highest MDA8 ozone concentrations.

Bloomfield	Obs	Prd	Bias	%
7/25/2014	52.1	71.1	19.0	36.4%
6/7/2014	61.7	70.6	8.9	14.4%
6/6/2014	69.5	69.7	0.2	0.2%
6/5/2014	66.4	69.6	3.2	4.8%
7/26/2014	48.1	68.8	20.7	42.9%
7/24/2014	51.1	68.5	17.4	34.0%
7/19/2014	59.5	67.5	8.0	13.4%
7/27/2014	52.4	67.3	14.9	28.5%
7/7/2014	62.4	65.0	2.6	4.2%
6/14/2014	61.8	64.8	3.0	4.9%
5/18/2014	62.8	64.7	2.0	3.1%
7/11/2014	59.0	64.5	5.5	9.3%
7/20/2014	49.9	63.9	14.0	28.1%
5/29/2014	59.4	63.6	4.2	7.1%
8/8/2014	52.4	63.3	10.9	20.8%
6/12/2014	60.5	63.1	2.6	4.3%
7/18/2014	58.1	62.9	4.7	8.2%
8/10/2014	56.6	62.5	5.9	10.4%
8/6/2014	52.6	62.1	9.5	18.0%
7/29/2014	55.1	62.1	6.9	12.6%
6/4/2014	54.5	61.5	7.0	12.8%
8/9/2014	54.4	61.2	6.8	12.5%
6/10/2014	60.0	61.0	1.0	1.7%
7/9/2014	54.9	60.9	6.1	11.1%
7/8/2014	56.5	60.9	4.4	7.8%
8/18/2014	51.3	60.5	9.3	18.1%

7.8.2 Desert View Top 10 Ozone Performance

The evaluation of the CAMx 2014 base case for the top 10 modeled MDA8 ozone concentrations at Desert View is shown in Table 7-3. 7 of the top 10 modeled MDA8 ozone concentrations are also top 20 observed ozone days, with 5 of those days also being in the top 10 observed ozone days. Thus, there is good overlap between the highest modeled and observed ozone days at Desert View. 5 of the top 10 modeled ozone days have daily bias that does not meet a within $\pm 10\%$ performance criteria. Imposing a within $\pm 10\%$ performance criteria for selecting the top 10 modeled ozone days results in all 10 days overlapping with observed days in the top 20 of the observed distribution with 7 of those days being top 10 observed ozone days.

Table 7-7. Predicted and observed MDA8 ozone concentrations (ppb) at Desert View for CAMx 2014 base case for modeled ranked 36 highest MDA8 ozone concentrations.

Desert View	Obs	Prd	Bias	%
8/18/2014	69.0	75.3	6.3	9.1%
5/17/2014	62.5	71.3	8.8	14.1%
7/25/2014	69.3	70.4	1.2	1.7%
6/2/2014	55.4	69.7	14.3	25.8%
7/31/2014	67.7	69.7	2.0	2.9%
8/29/2014	64.6	68.3	3.7	5.8%
7/22/2014	71.9	67.0	-4.9	-6.8%
8/17/2014	55.3	66.0	10.8	19.5%
5/28/2014	72.3	64.5	-7.7	-10.7%
5/18/2014	58.3	64.3	6.1	10.4%
8/8/2014	61.0	64.2	3.2	5.2%
7/27/2014	61.0	64.1	3.1	5.2%
7/17/2014	52.8	63.7	10.9	20.7%
6/9/2014	69.9	63.5	-6.4	-9.2%
8/6/2014	62.4	62.8	0.4	0.7%
7/29/2014	59.0	62.6	3.6	6.1%
6/7/2014	66.6	62.6	-4.0	-6.1%
6/10/2014	76.6	62.5	-14.1	-18.4%
8/1/2014	52.6	62.4	9.7	18.5%
8/3/2014	58.8	62.3	3.6	6.1%
5/27/2014	64.0	61.9	-2.1	-3.3%
8/9/2014	53.0	61.8	8.8	16.7%
8/5/2014	66.3	61.7	-4.6	-6.9%
8/15/2014	54.3	61.5	7.2	13.2%
7/18/2014	56.0	61.5	5.5	9.8%
6/5/2014	55.6	61.2	5.6	10.0%

7.8.3 Carlsbad Top 10 Ozone Performance

6 of the top 10 modeled ozone days at Carlsbad occur during observed top 20 ozone days, 4 of those days within the top 10 of the observed ozone distribution (Table 7-4). Five of the modeled top 10 ozone days have bias that does not achieve the within $\pm 10\%$ criteria. When imposing the within $\pm 10\%$ performance criteria for the top 10 modeled ozone days, 7 of those days overlap with observed top 20 days.

Table 7-8. Predicted and observed MDA8 ozone concentrations (ppb) at Carlsbad for CAMx 2014 base case for modeled ranked 36 highest MDA8 ozone concentrations.

Carlsbad	Obs	Prd	Bias	%
5/18/2014	70.5	67.5	-3.0	-4.3%
6/10/2014	74.8	65.7	-9.0	-12.1%
5/17/2014	68.5	64.4	-4.1	-6.0%
6/7/2014	51.3	61.9	10.7	20.8%
5/19/2014	64.3	60.5	-3.8	-5.9%
5/20/2014	62.3	60.1	-2.2	-3.5%
5/16/2014	62.3	59.3	-3.0	-4.8%
6/3/2014	54.9	58.4	3.5	6.5%
8/23/2014	49.0	57.9	8.9	18.1%
7/12/2014	41.8	57.8	16.1	38.5%
6/2/2014	62.9	57.7	-5.2	-8.3%
8/30/2014	54.3	57.7	3.4	6.3%
8/5/2014	64.1	57.6	-6.5	-10.1%
5/21/2014	62.8	57.6	-5.2	-8.2%
7/24/2014	65.9	57.3	-8.5	-13.0%
8/8/2014	52.6	57.1	4.5	8.5%
8/20/2014	49.4	57.0	7.6	15.4%
7/19/2014	52.8	56.8	4.1	7.7%
6/12/2014	60.7	56.6	-4.1	-6.7%
7/16/2014	59.7	56.3	-3.4	-5.7%
5/29/2014	72.0	56.2	-15.8	-22.0%
5/25/2014	59.8	56.0	-3.8	-6.3%
8/6/2014	62.1	56.0	-6.2	-9.9%
7/28/2014	53.7	55.9	2.3	4.2%
8/2/2014	57.3	55.9	-1.3	-2.4%
7/20/2014	58.9	55.9	-3.0	-5.1%

8. SUMMARY AND CONCLUSIONS

The evaluation of the NM OAI Study CAMx 2014 base case simulation focused on Maximum Daily 8-hour Average (MDA8) ozone model performance across all sites in the 4-km New Mexico domain, across all sites within New Mexico, within three subregions in New Mexico (northern, Bernalillo County, and southern) and at individual sites in New Mexico. When examining MDA8 ozone performance across groups of sites, the CAMx 2014 base case always achieves the ozone performance criteria and usually achieves the ozone performance goals. When examining MDA8 ozone performance across all observations, the model tended to have an ozone overestimation tendency but still always achieved the bias performance criteria ($\leq \pm 15\%$) and usually achieved the bias performance goal ($\leq \pm 5\%$). When comparing the model's ability to reproduce the highest observed ozone concentrations greater than 60 ppb, the model still always achieved the bias performance criteria and usually achieved the bias performance goal, albeit with an underestimation tendency. The MDA8 ozone error essentially always achieves the performance goal whether examining all ozone observations or just those observations greater than 60 ppb. More specifically:

- Across the 4-km New Mexico domain for all ozone observations, the Normalized Mean Bias (NMB) for the AQS network was 6.2% that achieves the bias performance criteria but not the bias performance goal. However, across the more rural CASTNet network the NMB (0.1%) is near zero achieving the performance goal.
- With New Mexico, the NMB achieves the performance goal whether using all ozone data (5.0%) or just ozone data when the observed ozone is greater than 60 ppb (-4.3%).
- Similar performance attributes are seen in the New Mexico subregional evaluation whether using all data or the 60 ppb ozone cut-off with the NMB in the northern New Mexico (4.3% and 0.0%) and Bernalillo County (4.3% and -2.8%) subregions achieving the bias performance goal. However, the NMB in the southern New Mexico region (5.8% and -6.1%) just barely falls outside of the performance goal region, but achieves the performance criteria.
- At individual monitoring sites using all ozone data the NMB achieves the bias performance criteria at all sites but one (La Union) with a majority of the sites (13 of 22 or 59%) also achieving the bias performance goal.
- The time series of predicted and observed MDA8 ozone concentrations shows that the model has very good agreement and tracks the day-to-day variations of the observed ozone in the northern New Mexico and Bernalillo County sites for the first half of the May-August 2014 modeling period. The second half of the modeling period the model generally has an ozone overestimation tendency at the northern New Mexico sites.
- Time series at the southern New Mexico show that the model has difficulty in reproducing the observed daily ozone spikes in the first half of the modeling period, but does a better job in reproducing the daily observed high ozone concentrations in the second half of the episode.

An evaluation of the model performance for the top 10 modeled ozone days that are used for making future year ozone projections reveals that they are also high observed ozone days over half of the time.

In conclusion, the NM OAI Study CAMx 2014 base case ozone model performance within New Mexico is as good or better than most recent PGM applications (e.g., WRAP-WAQS, EPA 2016v1 and Denver ozone SIP) and appears to be a reliable PGM modeling platform for evaluating emission reduction strategies for reducing ozone concentrations in New Mexico.

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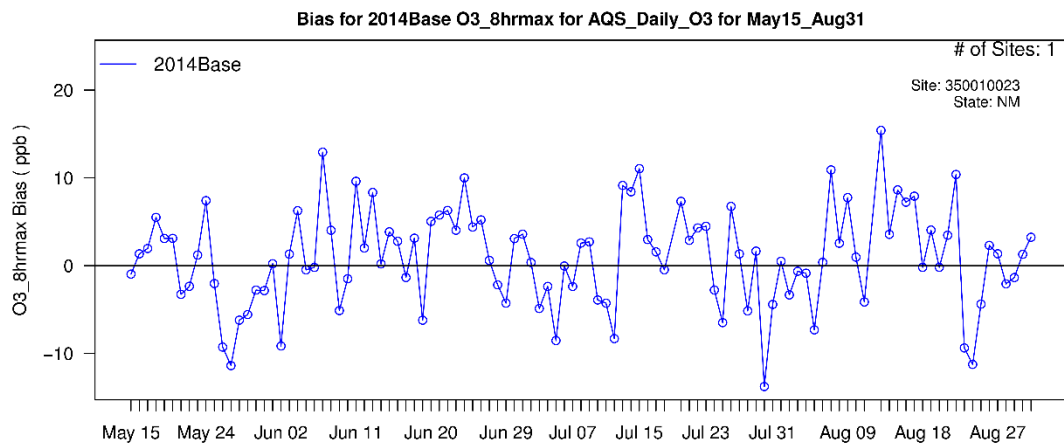
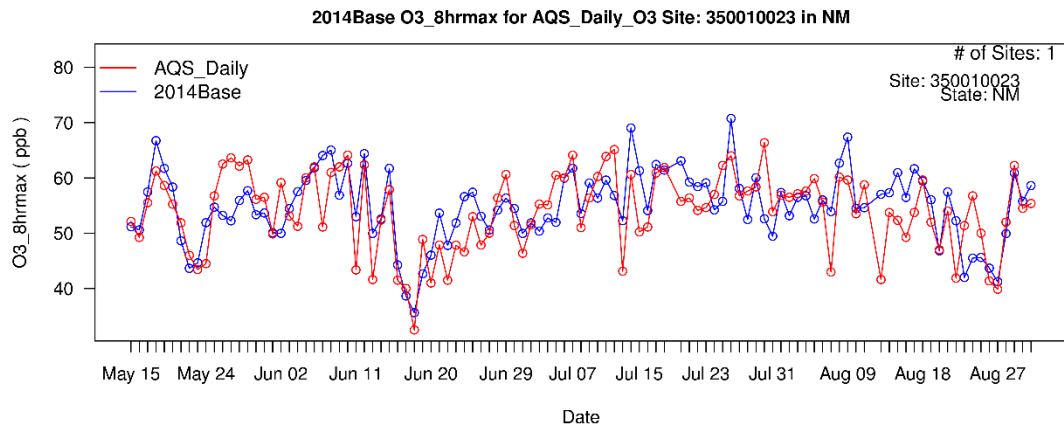
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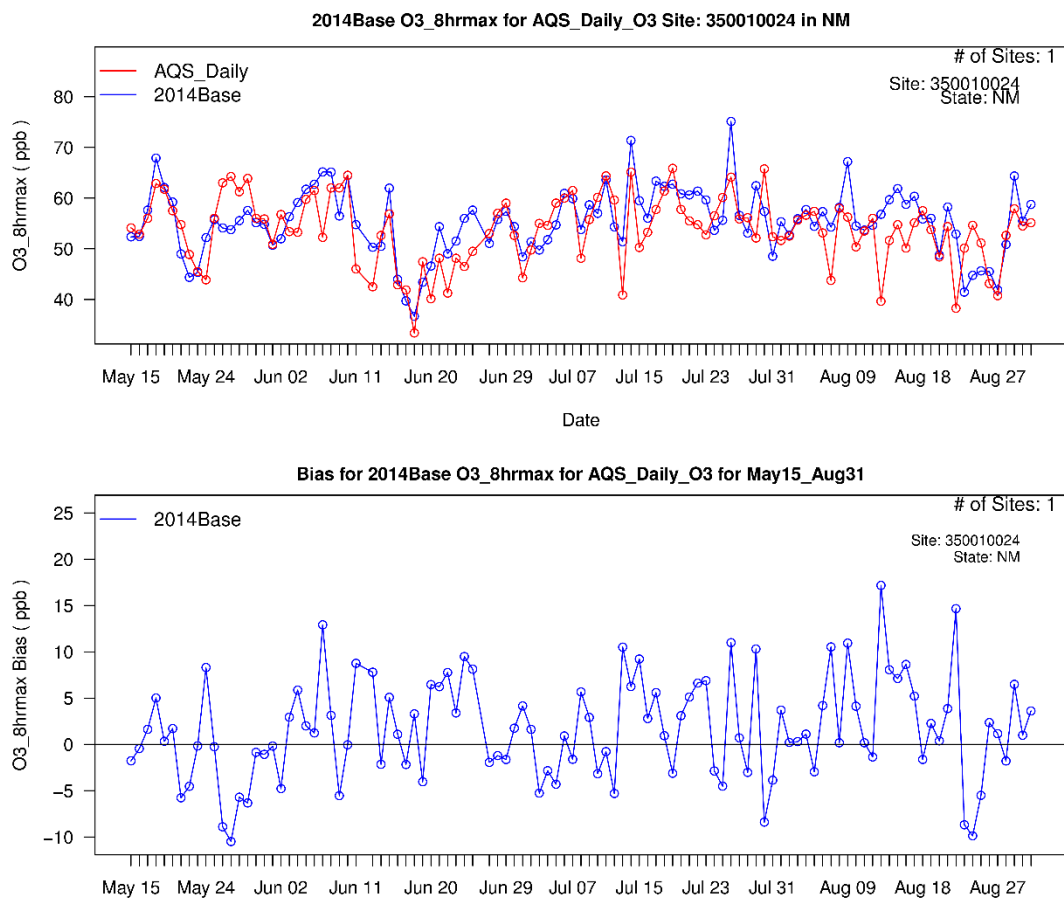
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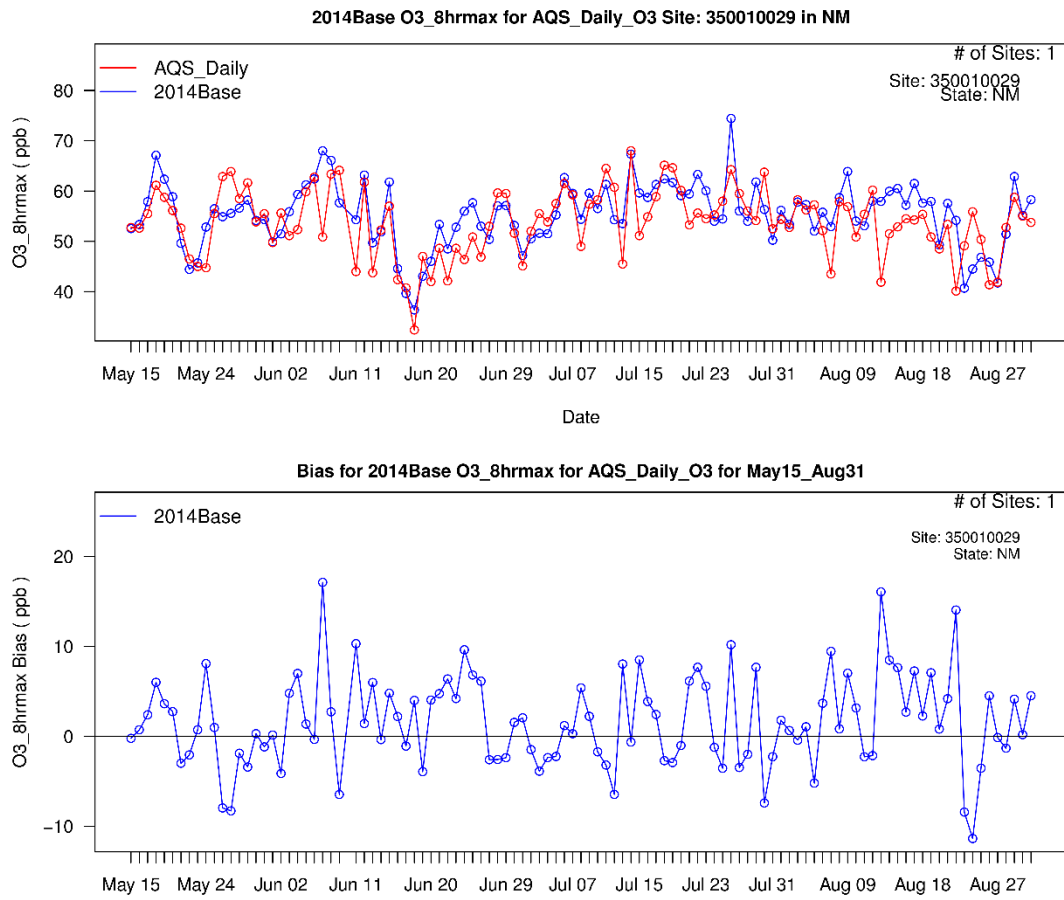
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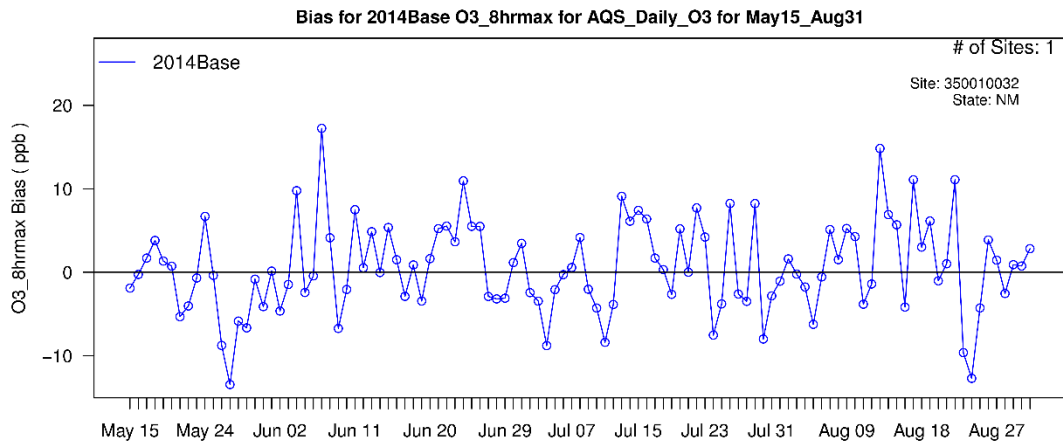
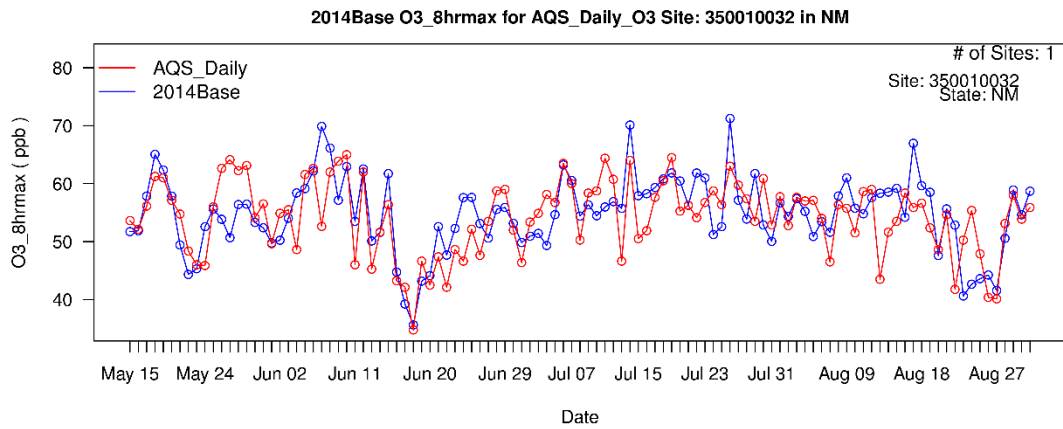
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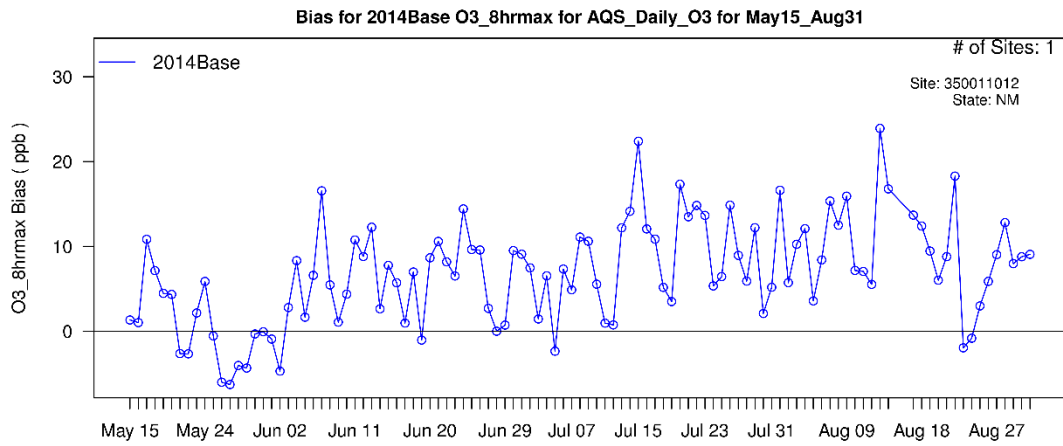
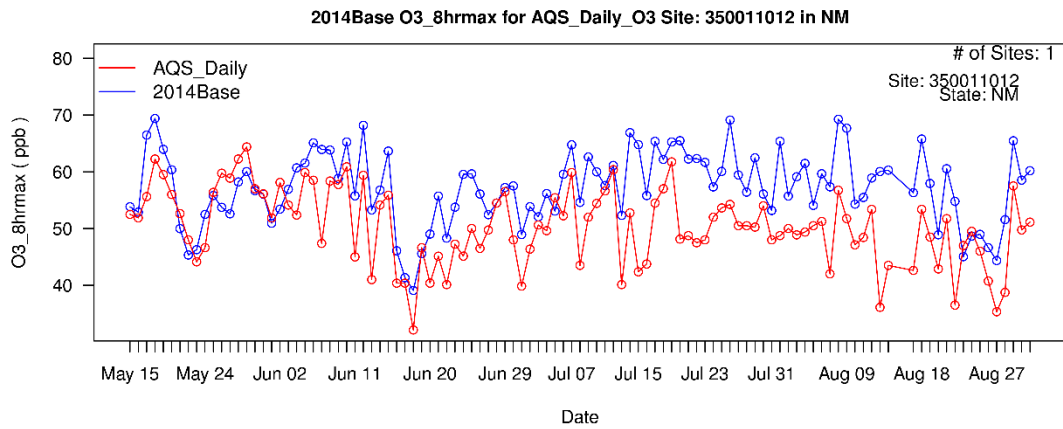
Time Series of Predicted and Observed MDA8 Ozone Concentrations at Sites in New Mexico

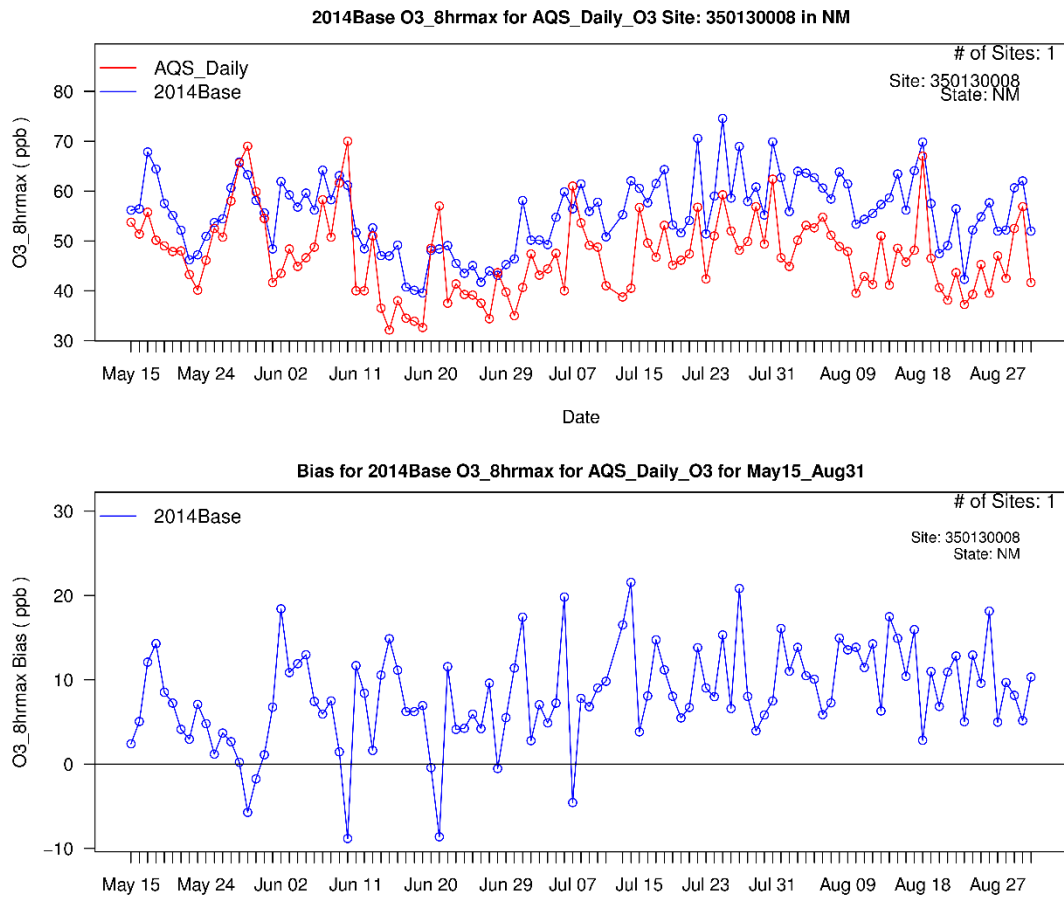


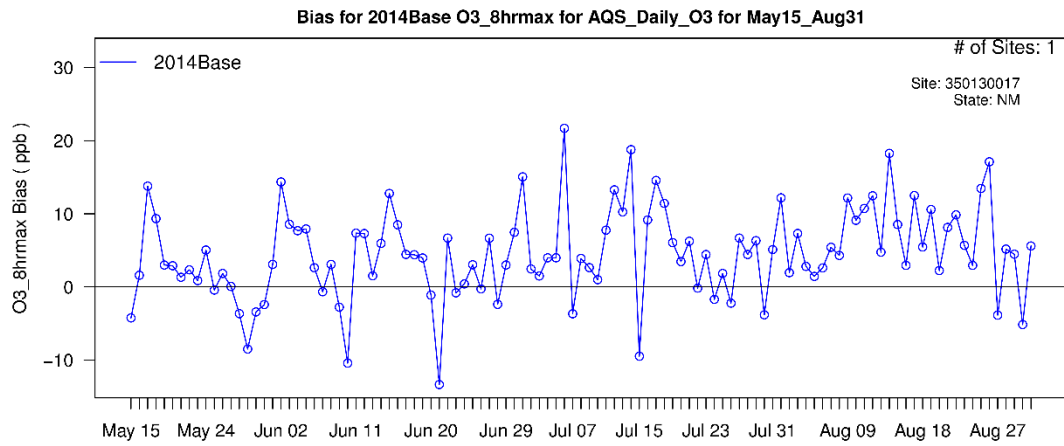
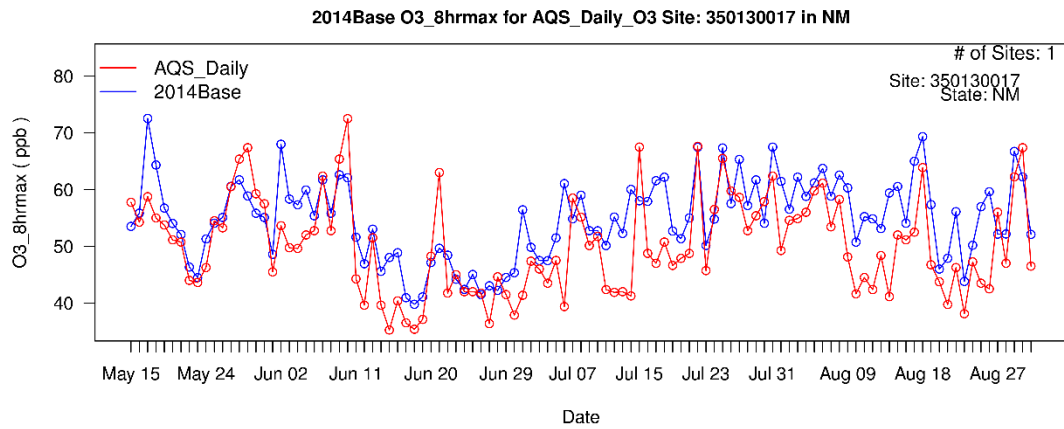


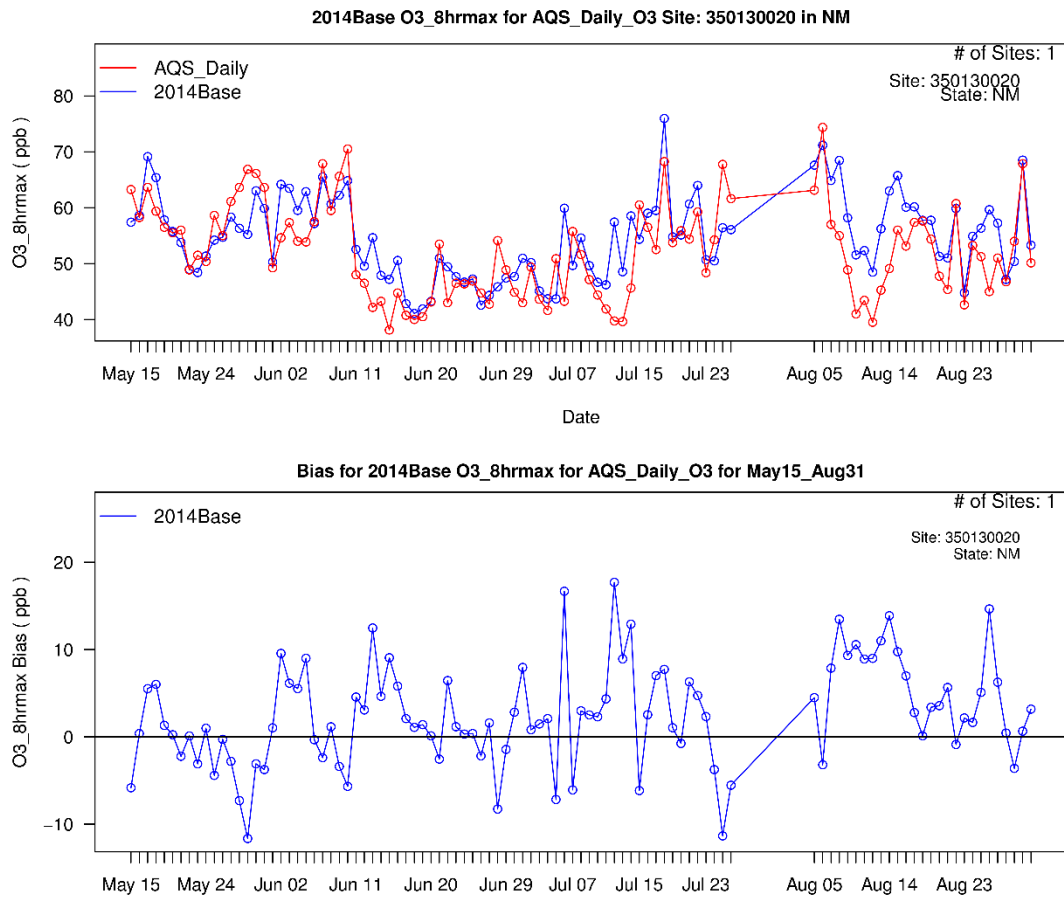


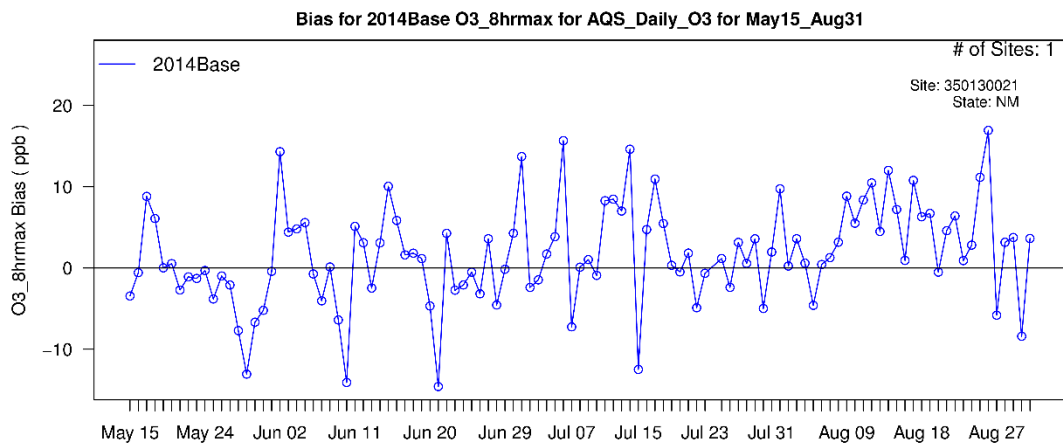
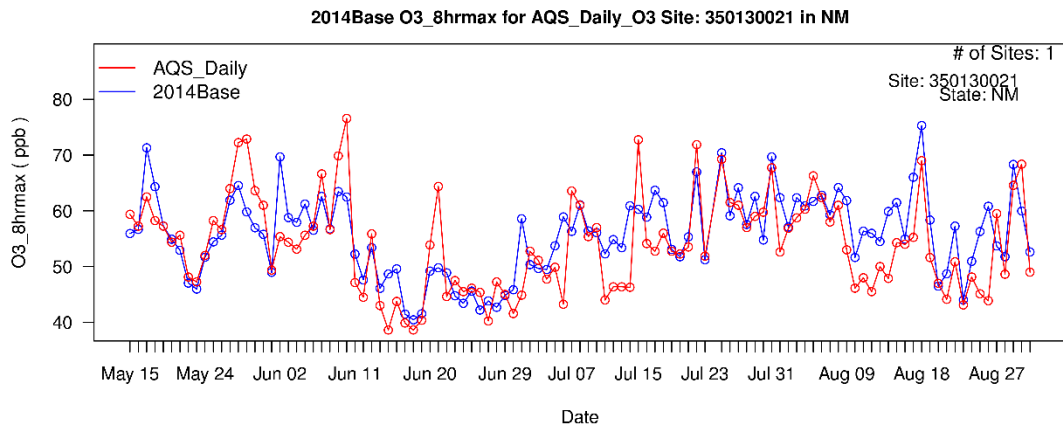


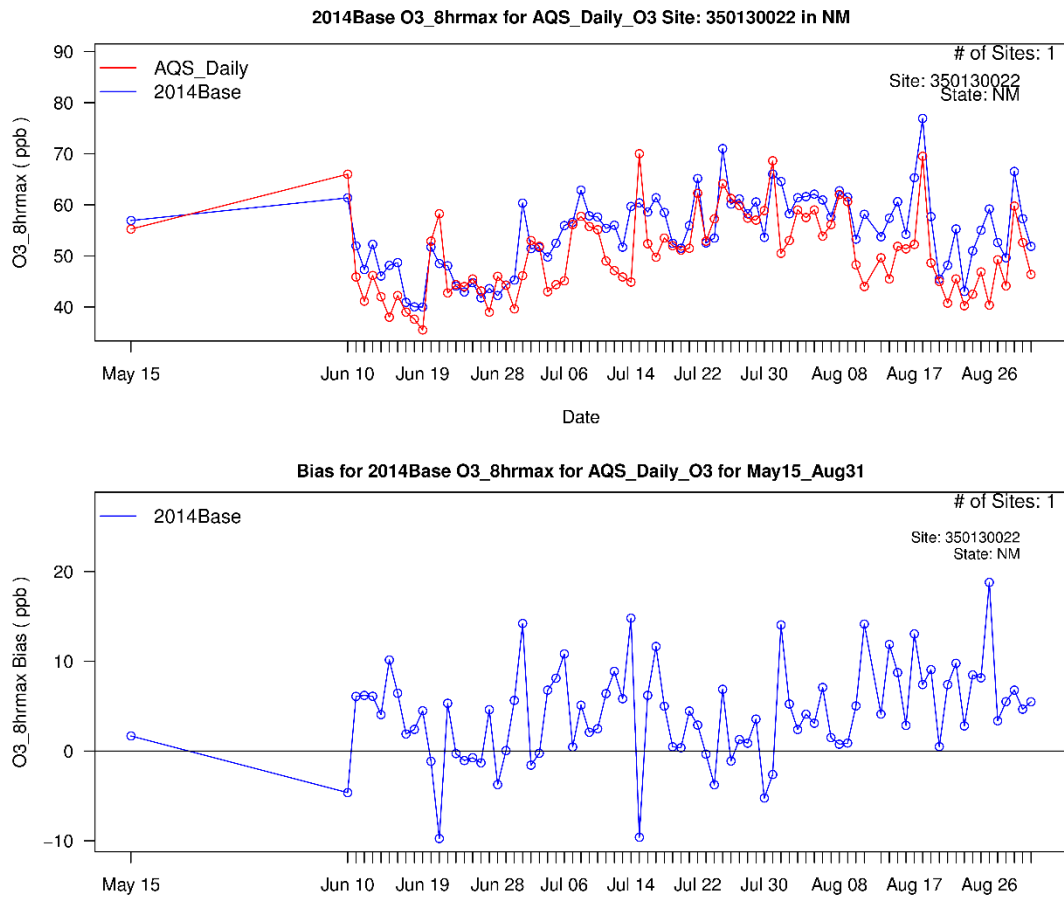


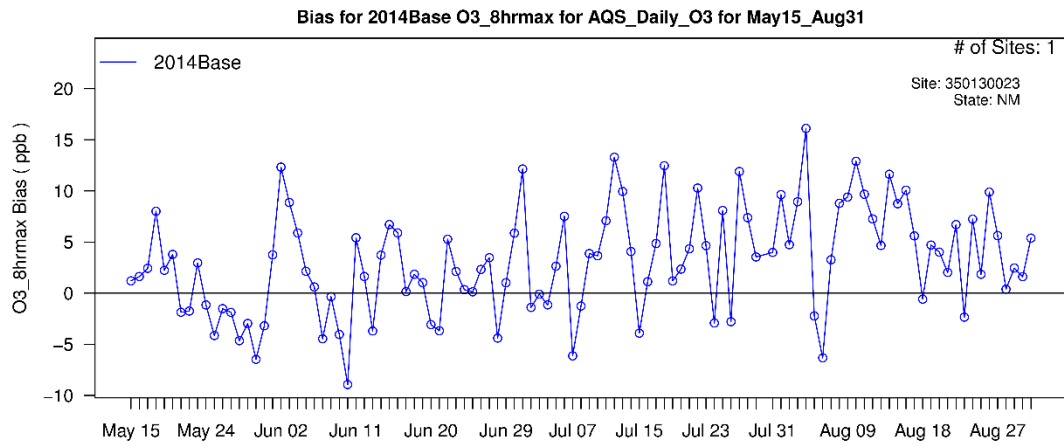
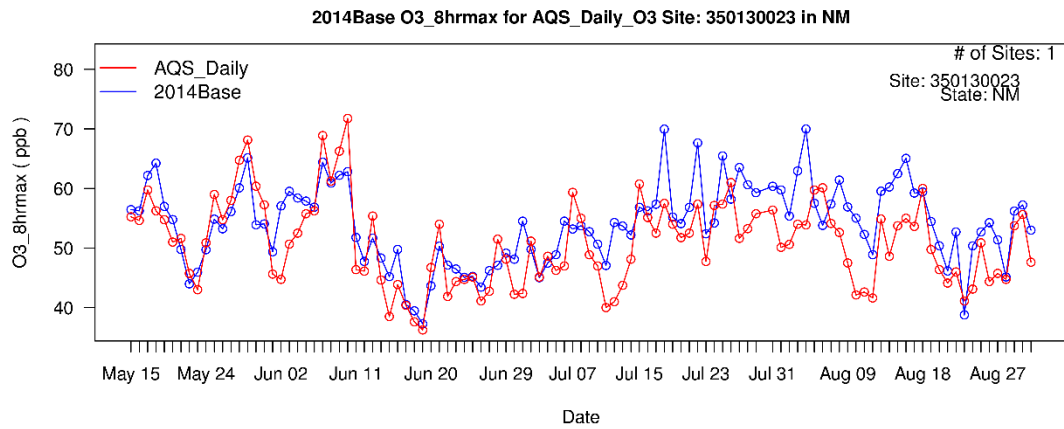


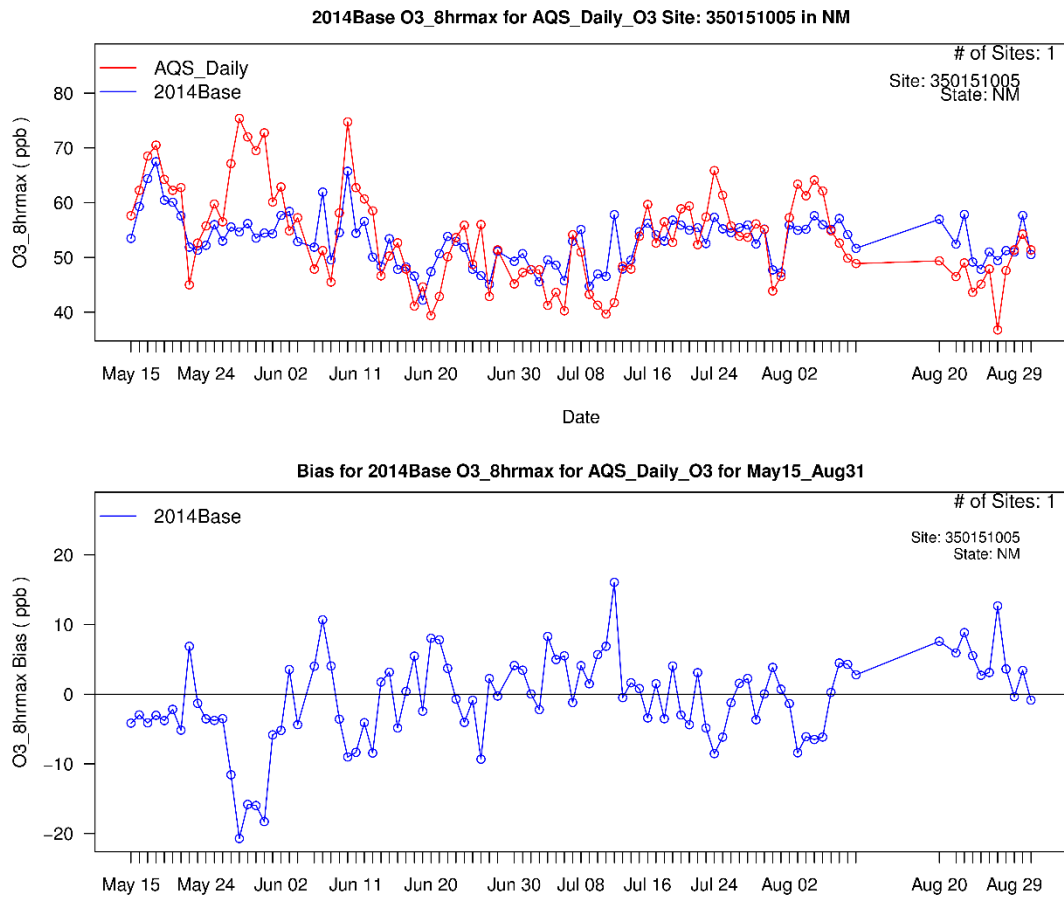


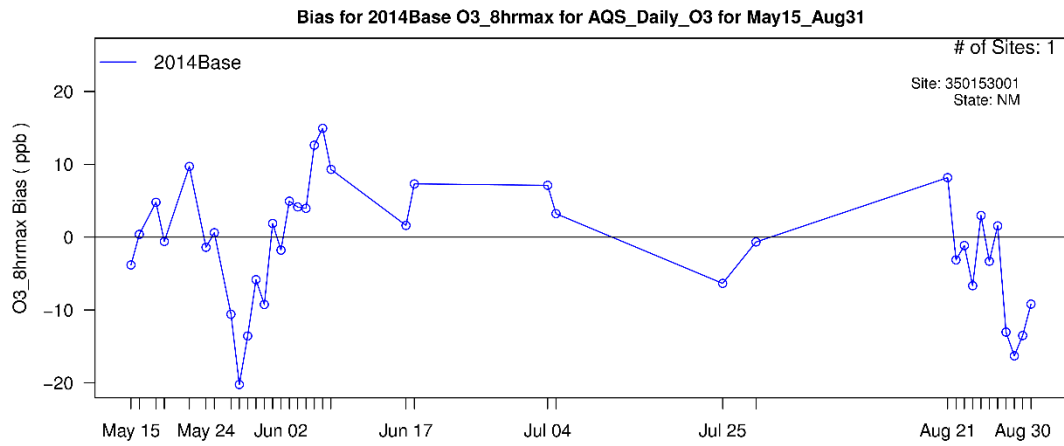
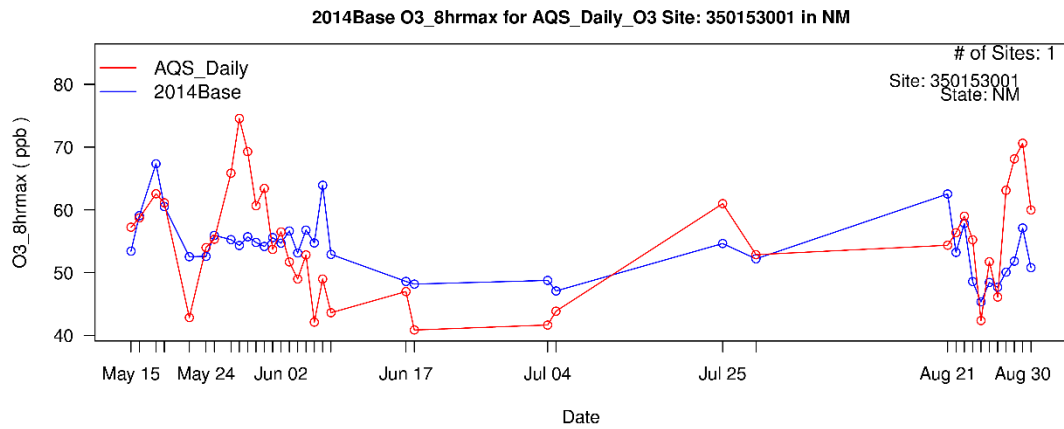


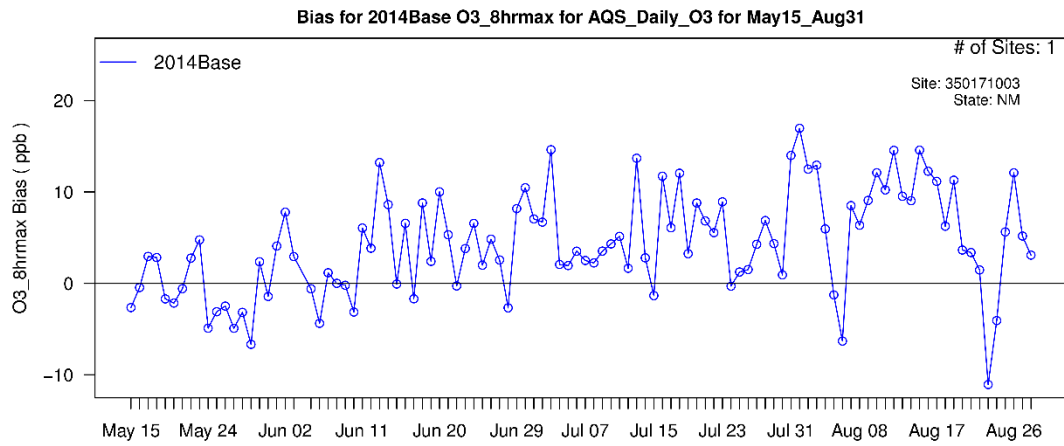
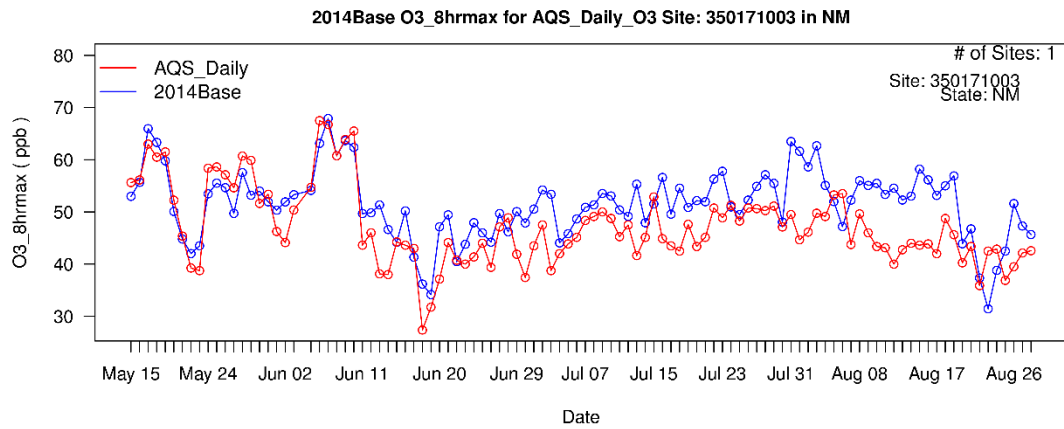


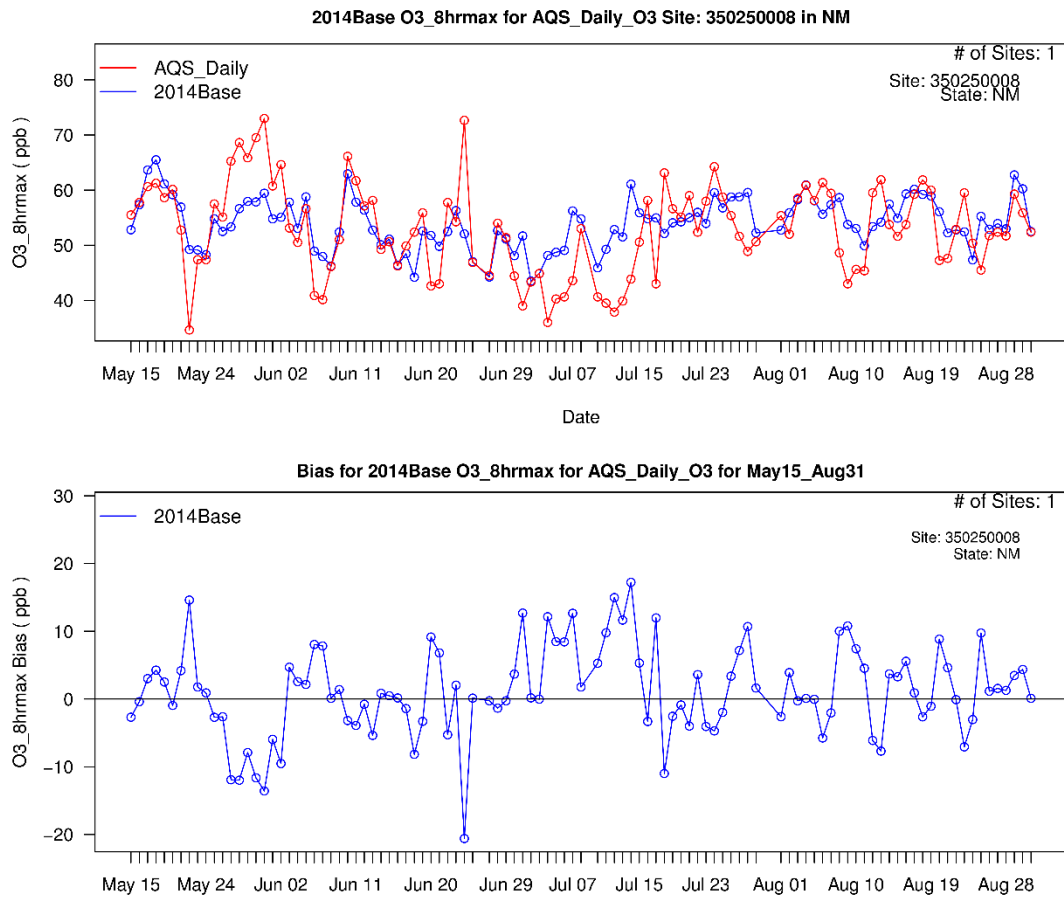


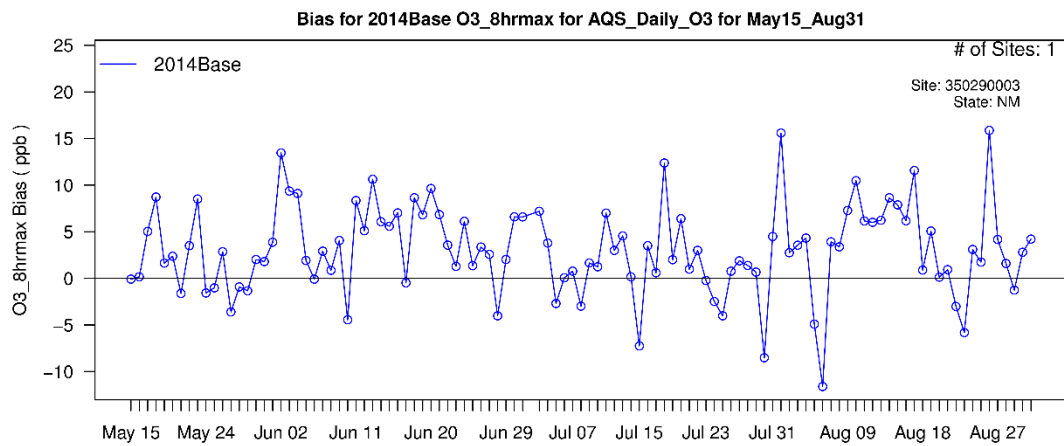
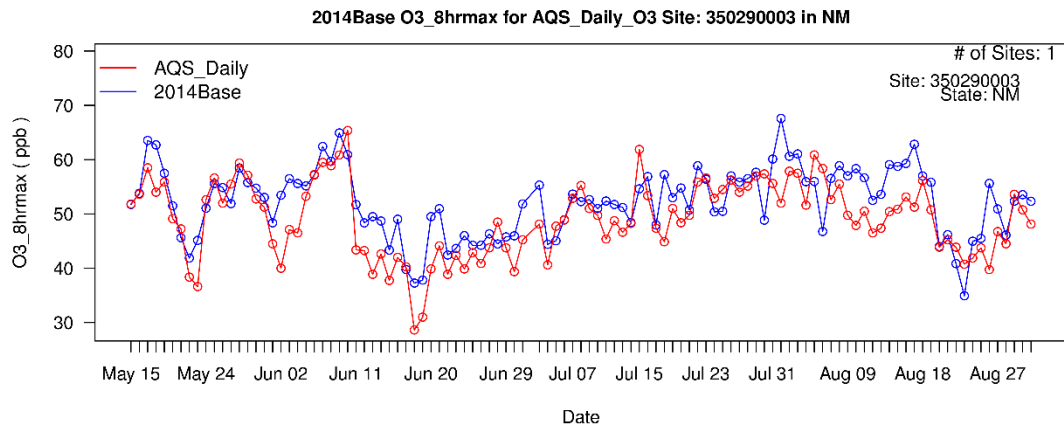


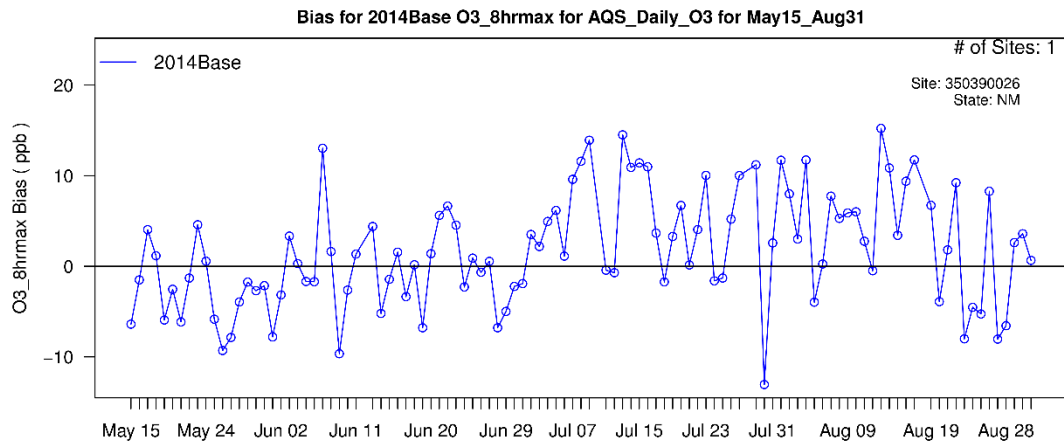
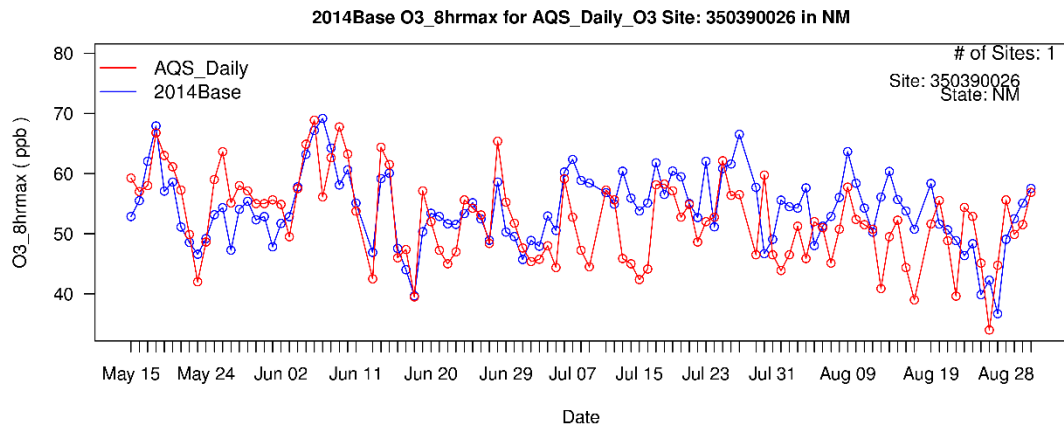


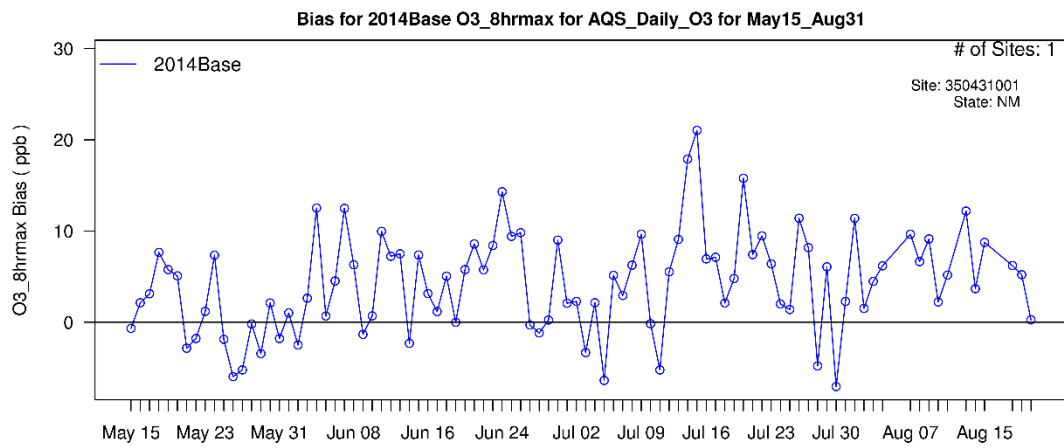
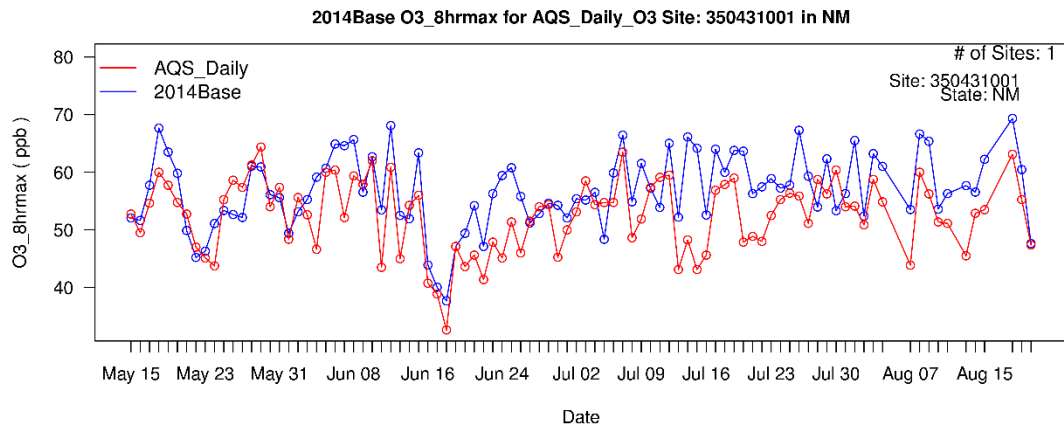


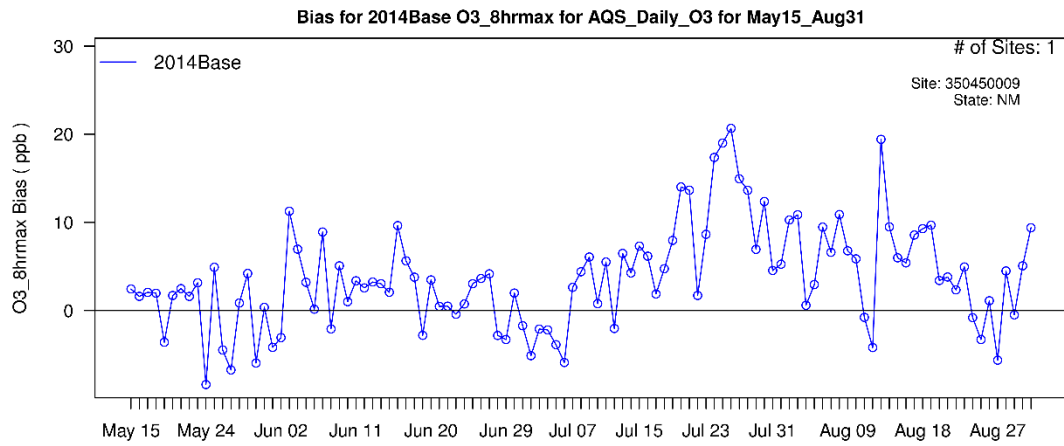
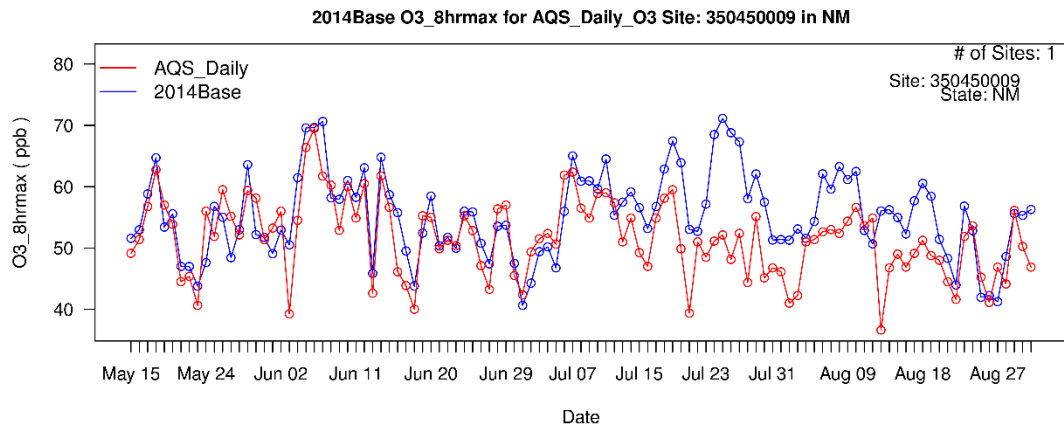


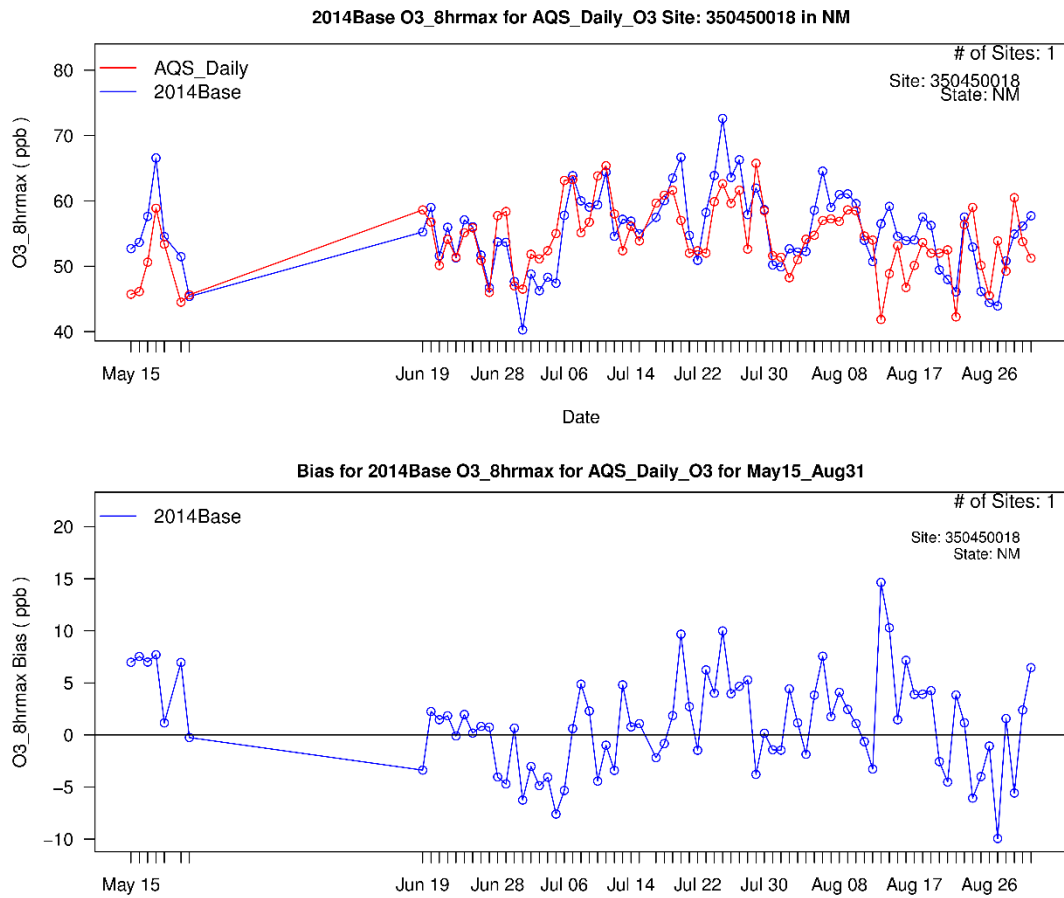


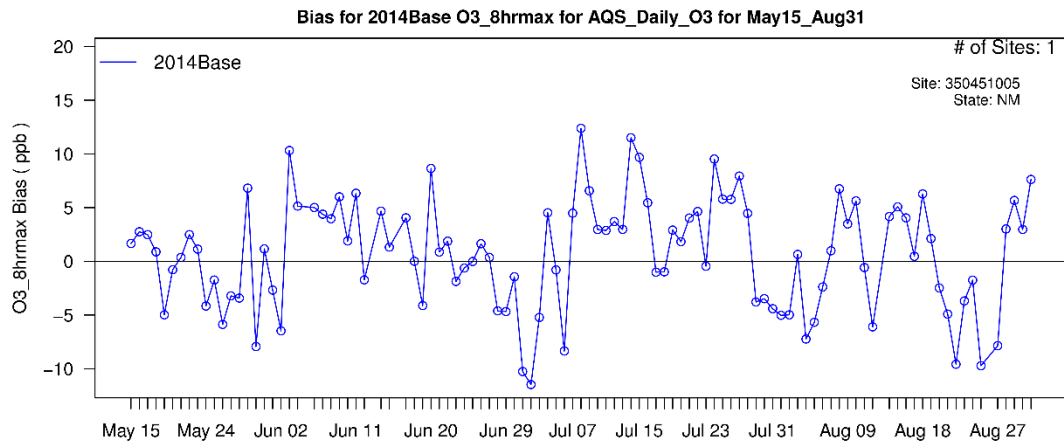
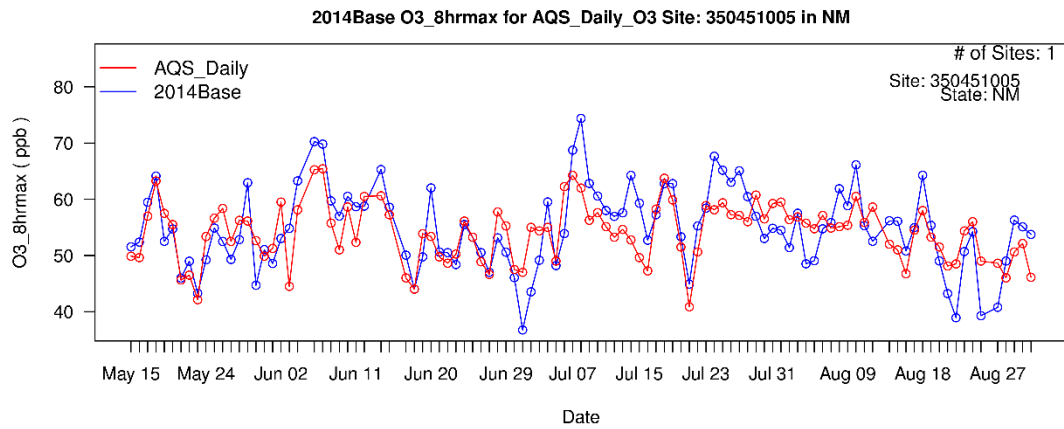


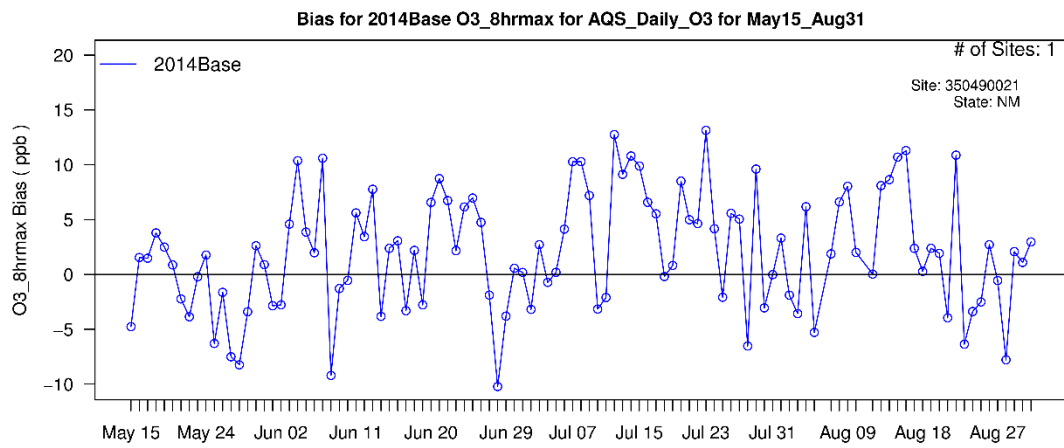
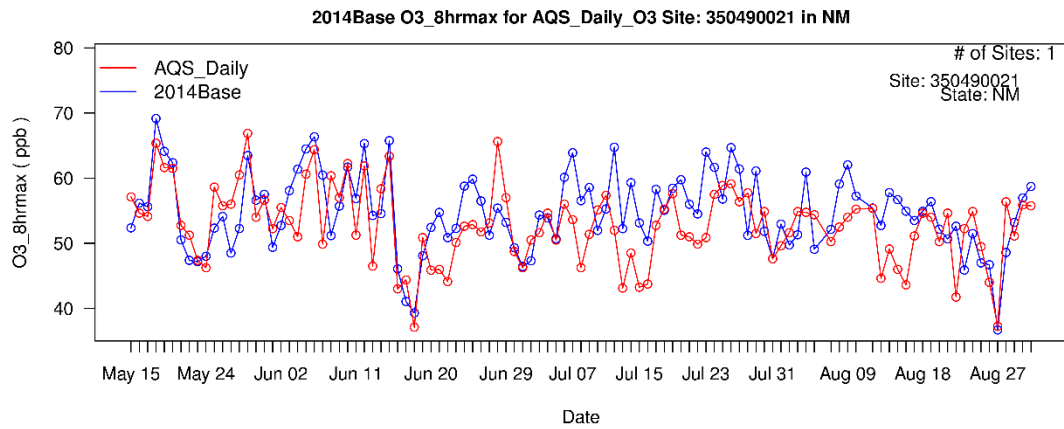


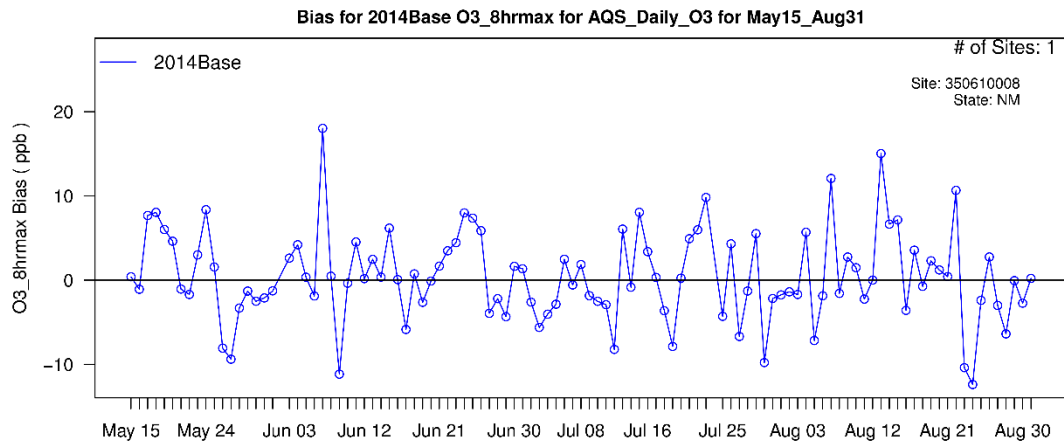
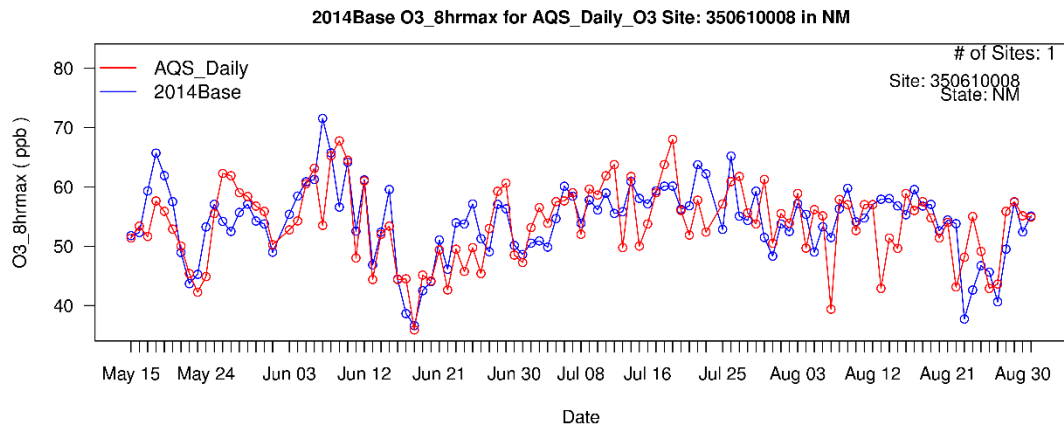












May 2021

NEW MEXICO OZONE ATTAINMENT INITIATIVE PHOTOCHEMICAL MODELING STUDY – DRAFT FINAL AIR QUALITY TECHNICAL SUPPORT DOCUMENT



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CONTENTS

ACRONYMS and ABBREVIATIONS	xiv
1. INTRODUCTION	1
1.1 NM OAI Photochemical Modeling Study Genesis	1
1.2 Overview of NM OAI Study Modeling Approach	4
1.2.1 WRAP-WAQS 2014 PGM Platform Development	4
1.2.2 Episode Selection	5
1.2.3 Model Selection	5
1.2.4 Domain Selection	5
1.2.5 Base and Future Year Emissions Data	8
1.2.6 Initial and Boundary Conditions Development	8
1.2.7 Diagnostic Sensitivity Analyses	8
1.2.8 Model Performance Evaluation	8
1.2.9 2028 Future Year Base and Control Strategy Modeling	9
1.2.10 Future Year Source Apportionment Modeling	9
2. 2014 WRF METEOROLOGICAL MODELING	10
2.1 WRF Meteorological Model	10
2.2 WRF Horizontal Modeling Domain	10
2.3 WRF Model Configuration	10
2.3.1 Vertical Coordinate	12
2.3.2 Topographic Inputs	12
2.3.3 Vegetation Type and Land Use Inputs	12
2.3.4 Atmospheric Data Inputs	12
2.3.5 New Lightning Data Assimilation	13
2.3.6 PBL and LSM Physics Options	13
2.3.7 Remaining WRF Physics Options	13
2.3.8 Application Methodology	14
2.4 WRF Model Evaluation	14
2.4.1 Quantitative Evaluation Using METSTAT	14
2.4.2 Qualitative Evaluations for Precipitation Using PRISM Data	20
2.4.3 Conclusions of 2014 WRF Model Performance	22
3. BOUNDARY CONDITION INPUTS	23
3.1 WRAP 2014 GEOS-Chem Modeling	23
3.2 2014 GEOS-Chem Model Evaluation	24
4. 2014 AND 2028 EMISSION INPUTS	25
4.1 Summary of Emissions Used in 2014 and 2028 Modeling	25
4.2 Development of CAMx 2014 Base Case Emission Inputs	25
4.2.1 Day-Specific On-Road Mobile Source Emissions	25
4.2.2 Point Source Emissions	26
4.2.3 Area and Non-Road Source Emissions	26
4.2.4 Episodic Biogenic Emissions	26
4.2.5 Wildfires, Prescribed Burns, Agricultural Burns	28
4.2.6 Other Natural Emissions	30
4.2.7 2014 Emission Results	30
4.3 Development of CAMx 2028 Emission Scenarios	35

4.3.1	2028 Base Case New Mexico Oil and Gas Emissions	36
4.4	Summary of 2014 and 2028 Base Case Emissions	40
4.5	2028 New Mexico Oil and Gas Control Strategy	45
5.	DIAGNOSTIC SENSITIVITY TESTS	49
5.1	WRFCAMx Processing of 2014 WRF Output	49
5.2	CAMx Meteorological Diagnostic Sensitivity Tests	49
5.3	Summary of CAMx Diagnostic Sensitivity Tests	59
6.	2014 BASE CASE MODELING AND MODEL PERFORMANCE EVALUATION	60
6.1	Final CAMx 2014v2 Base Case Configuration	60
6.2	Ozone Model Performance Goals and Criteria	62
6.3	Spatial Ozone Model Performance	62
6.4	Scatter Plots of MDA8 Ozone	66
6.5	MDA8 Ozone Time Series	68
6.6	Summary Ozone Model Performance Statistics in New Mexico	71
6.7	Conclusions of 2014 Base Case Modeling and Model Performance Evaluation	74
7.	2028 BASE CASE MODELING AND OZONE DESIGN VALUE PROJECTIONS	76
7.1	EPA Recommended Ozone Design Value Projection Procedure	76
7.1.1	Ozone DV Unmonitored Area Analysis (UAA)	77
7.2	2028 Base Case Ozone DVF Projections at Monitoring Sites	77
7.3	2028 Base Case Ozone DVF Unmonitored Area Analysis	79
7.4	2014v2 and 2028 MDA8 Ozone Concentrations	84
7.4.1	Daily 2014v2 and 2028 Base Case MDA8 Ozone Concentrations	84
7.4.2	Comparison of Episode Maximum MDA8 and SMAT UAA Ozone DVF Differences	89
8.	2028 OIL AND GAS CONTROL STRATEGY MODELING AND OZONE DESIGN VALUE PROJECTIONS	90
8.1	2028 Ozone Design Value Comparisons	90
8.1.1	Ozone Design Values at the Monitoring Sites	90
8.1.2	2028 O&G Control Strategy Ozone DVF Unmonitored Area Analysis	93
8.2	2028 Base Case and 2028 O&G Control Strategy MDA8 Ozone Concentrations	96
8.2.1	Daily 2014v2 and 2028 Base Case MDA8 Ozone Concentrations	96
8.3	Conclusions of the 2028 Base and 2028 O&G Control Strategy Modeling	101
9.	SENSITIVITY OF PROJECTED 2028 OZONE DESIGN VALUES TO CURRENT YEAR OZONE DESIGN VALUES	102
9.1	2028 Ozone Design Value Sensitivity Analysis using DVC ₂₀₁₅₋₂₀₁₉	102
9.2	2028 Ozone Design Value Sensitivity Analysis using DVC ₂₀₁₇₋₂₀₁₉	103
10.	2028 SOURCE SECTOR APCA OZONE SOURCE APPORTIONMENT MODELING	105
10.1	Versions of Ozone Source Apportionment	105
10.2	2028 Source Sector APCA Ozone Source Apportionment Specifications	106
10.2.1	2028 O&G Control Strategy Emissions Scenario	106

10.2.2	Definition of Source Groups	106
10.3	2028 Source Sector APCA Ozone Source Apportionment Modeling Results	109
10.3.1	Source Sector Contributions to Projected 2028 Ozone DVFs	109
10.3.2	Source Sector Contributions to Modeled MDA8 Ozone Concentrations	134
10.3.3	International Anthropogenic Emissions Contributions to Projected 2028 ozone DVFs	152
11.	2028 VOC AND NOX SENSITIVITY OSAT OZONE SOURCE APPORTIONMENT MODELING	158
11.1	2028 OSAT Ozone Source Apportionment Design	158
11.2	Spatial Distribution of VOC/NO _x Ozone Formation Sensitivity	159
11.2.1	Percent NO _x Sensitive Ozone on May 17, 2014	160
11.2.2	Percent NO _x Sensitive Ozone on May 26, 2014	162
11.2.3	Percent NO _x Sensitive Ozone on May 28, 2014	162
11.2.4	Percent NO _x Sensitive Ozone on June 5, 2014	165
11.2.5	Percent NO _x Sensitive Ozone on July 12, 2014	165
11.2.6	Percent NO _x Sensitive Ozone on July 24, 2014	165
11.2.7	Percent NO _x Sensitive Ozone on July 26, 2014	169
11.2.8	Percent NO _x Sensitive Ozone on August 14, 2014	169
11.2.9	Percent NO _x Sensitive Ozone due to New Mexico Anthropogenic Emissions	169
11.3	Analysis of VOC/NO _x Ozone Formation Sensitivity at Monitoring Sites in New Mexico	174
11.3.1	VOC/NO _x Sensitivity at Substation in San Juan County	174
11.3.2	VOC/NO _x Sensitivity at South East Heights in Bernalillo County	177
11.3.3	VOC/NO _x Sensitivity at Desert View in Doña Ana County	177
11.3.4	VOC/NO _x Sensitivity at Carlsbad in Eddy County	182
12.	SUMMARY AND CONCLUSIONS	185
12.1	Summary of CAMx 2014 36/12/4-km Photochemical Model Platform Development	185
12.2	Summary of 2028 Ozone Modeling Results and Ozone Design Value Projections	185
12.3	Sensitivity of 2028 Ozone Design Value Projections to Current Year Ozone Design Value	186
12.4	2028 Source Sector APCA Ozone Source Apportionment Modeling	187
12.5	2028 VOC/NO _x Sensitivity OSAT Ozone Source Apportionment Modeling	187
13.	REFERENCES	188

TABLE OF TABLES

Table 1-1.	Ozone design values (ppm) at sites in New Mexico from 2010 to 2019. Red above the 75 ppb 2008 NAAQS, yellow above 2015 70 ppb NAAQS and green within 95% of the 2015 NAAQS.	3
Table 1-2.	Lambert Conformal Conic (LCC) projection parameters for the NM OAI Study 36/12/4 modeling domains.	7

Table 1-3.	Grid definitions for CAMx NM OAI Study 2014 36/12/4-km modeling domains.	7
Table 2-1.	WRF 36 level vertical layer structure for the NM OAI study. This is the same WRF layer structure as used in WAQS 2011/2014/2016 and EPA 2016 WRF modeling.	11
Table 2-2.	NM OAI Study 2014 WRF model configuration and comparison with the WRF configuration used in the WRAP-WAQS 2014 and EPA 2014/2015/2016 WRF modeling.	14
Table 3-1.	2014 GEOS-Chem simulation model configuration used by WRAP whose output is used to define the 2014 day-specific diurnally varying BC inputs for the NM OAI Study photochemical modeling.	23
Table 4-1.	2014 biogenic emissions (tons/month) in the 4-km NM domain estimated by MEGAN3.1 and BEIS3.7.	26
Table 4-2.	2014 fire emissions summary (tons/month) by fire type for the 4-km NM domain	29
Table 4-3.	2014 base case anthropogenic emissions summary (episode average short tons per day) by source category for the 4-km New Mexico domain.	31
Table 4-4.	Comparison of WRAP OGWG 2014 and 2023 New Mexico O&G emissions used in the 2014v2 and 2028OTBa2 scenarios with the NM OAI study 2028 base case New Mexico O&G emissions based on BLM forecast.	38
Table 4-5.	Comparison of WRAP OGWG 2014 and 2023 NO _x and VOC New Mexico O&G emissions with the NM OAI Study 2028 base case.	39
Table 4-6.	Summary of total emissions (tons/year) in New Mexico for the 2014 base case emissions scenario.	40
Table 4-7.	Summary of total emissions (tons/year) in New Mexico for the 2028 base case emissions scenario.	41
Table 4-8.	Percent differences in total New Mexico emissions between the 2014 and 2028 emission scenarios.	41
Table 4-9.	New Mexico NO _x and VOC O&G emissions (tons per year) for the 2028 Base Case and 2028 NM O&G control strategy.	45
Table 5-1.	WRF to CAMx vertical layer collapsing strategy used in the NM OAI Study.	50
Table 6-1.	Final CAMx model configuration for the 2014v2 base case simulation in NM OAI Study.	61
Table 6-2.	Recommended ozone benchmarks for photochemical model statistics (Source: Emery et al., 2016).	62
Table 6-3.	Bias and error MDA8 ozone performance statistics for the original CAMx 2014 base case and the three subregions of New Mexico calculated with and without using an observed MDA8 ozone 60 ppb cutoff.	71

Table 6-4.	Bias and error MDA8 ozone performance statistics for the revised CAMx 2014v2 base case and the three subregions of New Mexico calculated with and without using an observed MDA8 ozone 60 ppb cutoff.	72
Table 6-5.	Bias MDA8 ozone performance statistics with and without an observed ozone cutoff for each site in New Mexico and the original CAMx 2014 base case simulation.	73
Table 6-6.	Bias MDA8 ozone performance statistics with and without an observed ozone cutoff for each site in New Mexico and the revised CAMx 2014v2 base case simulation.	74
Table 7-1.	Current year DVC ₂₀₁₂₋₂₀₁₆ and projected 2028 Base Case ozone DVFs at New Mexico monitoring sites within the 4-km NM domain.	78
Table 7-2.	Current year DVC ₂₀₁₂₋₂₀₁₆ and projected 2028 Base Case ozone DVFs at monitoring sites within the 4-km NM domain but outside of New Mexico.	79
Table 8-1.	Observed ozone DVC ₂₀₁₂₋₂₀₁₆ and projected 2028 ozone DVFs for the 2028 Base Case and 2028 O&G Control strategy and differences in the 2028 ozone DVFs (DVF _{Cntl} – DVF _{Base}).	91
Table 8-2.	Observed ozone DVC ₂₀₁₂₋₂₀₁₆ and projected 2028 ozone DVFs for the 2028 Base Case and 2028 O&G Control strategy and differences in the 2028 ozone DVFs (DVF _{Cntl} – DVF _{Base}).	92
Table 9-1.	Projected 2028 ozone DVFs for the 2015-2019 current year design value DVC ₂₀₁₅₋₂₀₁₉ sensitivity analysis.	103
Table 9-2.	Projected 2028 ozone DVFs for the 2017-2019 current year design value DV ₂₀₁₇₋₂₀₁₉ sensitivity analysis.	104
Table 10-1.	Reduction in 2028 ozone DVF due to the elimination of emissions from 7 Source Sectors in New Mexico.	111
Table 10-2.	Reduction in 2028 ozone DVF due to the elimination of emissions from 7 Source Sectors in United States.	132
Table 10-3.	Percent contribution of New Mexico Source Sectors to All United Source Sectors reduction in 2028 ozone DVF.	133
Table 10-4.	Projected 2028 ozone DVFs for the 2028 O&G Control Strategy (2028OGCS) and 2028 no international anthropogenic emissions (2028INTL) scenarios using the DVC ₂₀₁₂₋₂₀₁₆ current year ozone DVC.	153
Table 10-5.	Projected 2028 ozone DVFs for the 2028 O&G Control Strategy (2028OGCS) and 2028 no international anthropogenic emissions (2028INTL) scenarios using the DVC ₂₀₁₅₋₂₀₁₉ current year ozone DVC.	154
Table 10-6.	Projected 2028 ozone DVFs for the 2028 O&G Control Strategy (2028OGCS) and 2028 no international anthropogenic emissions (2028INTL) scenarios using the DVC ₂₀₁₇₋₂₀₁₉ current year ozone DVC.	155

TABLE OF FIGURES

Figure 1-1.	NM OAI Study 2014 36/12/4-km PGM and emissions modeling domains.	6
Figure 1-2.	4-km New Mexico modeling domain for PGM and emissions modeling, with locations of New Mexico ozone monitors that were operating during some portion of 2014.	7
Figure 2-1.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface wind speed (m/s) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	16
Figure 2-2.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface wind direction (degrees) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	17
Figure 2-3.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface temperature (K) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	18
Figure 2-4.	Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface humidity (g/kg) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).	19
Figure 2-5.	July monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).	21
Figure 2-6.	August monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).	21
Figure 4-1.	Spatial distribution of NO _x (top panel) and VOC (bottom panel) biogenic emissions (episode average tons per day) in the 4-km NM domain estimated by MEGAN3.1 (left) and BEIS3.7 (right).	28
Figure 4-2.	Spatial distribution of agricultural fires, prescribed fires, wildfires and Mexico fires (clockwise starting from top left) NO _x emissions (episode avg tons per day) for New Mexico 4-km domain.	30
Figure 4-3.	New Mexico 2014 base case anthropogenic NO _x and VOC emissions by source category.	32
Figure 4-4.	Spatial distribution of the non-point (top) and point (bottom) source oil and gas NO _x (left) and VOC (right) emissions (episode avg tons per day) for New Mexico 4-km domain.	33
Figure 4-5.	Spatial distribution of on-road (top), rail (middle) and non-point/non-road equipment (bottom) NO _x (left) and VOC (right) emissions (episode avg tons per day) for New Mexico 4-km domain.	34
Figure 4-6.	Example Petroleum and Natural Gas Industry schematic.	37

Figure 4-7.	Comparison of 2014 and 2028 New Mexico NO _x emissions by source sector.	42
Figure 4-8.	Comparison of 2014 and 2028 New Mexico NO _x emissions by source sector.	42
Figure 4-9.	Distribution of New Mexico NO _x emissions across source sectors for the 2014 (top) and 2028 (bottom) base cases.	43
Figure 4-10.	Distribution of New Mexico VOC emissions across source sectors for the 2014 (top) and 2028 (bottom) base cases.	44
Figure 4-11.	Comparison of 2028 Base Case and 2028 NM O&G control strategy NO _x emissions for the Non-Point (top) and Point (bottom) source sectors and the Permian (left) and San Juan (right) basins.	46
Figure 4-12.	Comparison of 2028 Base Case and 2028 NM O&G control strategy VOC emissions for the Non-Point (top) and Point (bottom) source sectors and the Permian (left) and San Juan (right) basins.	47
Figure 4-13.	Differences in 2028 O&G Control Strategy and 2028 Base Case oil and gas NO _x (top) and VOC (bottom) emissions for the Non-Point (left) and Point (right) source sectors.	48
Figure 5-1.	Comparison of sensitivity tests NMB with 60 ppb cutoff spatial plots over NM.	53
Figure 6-1.	Normalized Mean Bias (NMB) for MDA8 ozone concentrations for the revised 2014v2 (top) and original 2014 (bottom) CAMx base case simulations with no ozone cutoff.	64
Figure 6-2.	Normalized Mean Bias (NMB) for MDA8 ozone concentrations for the revised 2014v2 (top) and original 2014 (bottom) CAMx base case simulations with an observed 60 ppb ozone cutoff.	65
Figure 6-3.	Scatter plots of predicted and observed MDA8 ozone concentrations for AQS (top) and CASTNet (bottom) monitoring sites within the 4-km New Mexico domain and the revised 2014v2 (left) and original 2014 (right) CAMx base case simulations.	67
Figure 6-4.	Time series of predicted and observed (red) MDA8 ozone at Desert View in Doña Ana County for the CAMx revised 2014v2 (blue) and original 2014 (green) CAMx base case simulations.	68
Figure 6-5.	Time series of predicted and observed (red) MDA8 ozone at South East Heights in Bernalillo County for the CAMx revised 2014v2 (blue) and original 2014 (green) CAMx base case simulations.	69
Figure 6-6.	Time series of predicted and observed (red) MDA8 ozone at Sub Station in San Juan County for the CAMx revised 2014v2 (blue) and original 2014 (green) CAMx base case simulations.	70
Figure 7-1.	SMAT UAA current year ozone DVC ₂₀₁₂₋₂₀₁₆ and projected 2028 future year ozone DVF for the 2028 Base Case using spatial interpolation with concentration gradients.	81

Figure 7-2.	SMAT UAA current year ozone $DVC_{2012-2016}$ (top) and projected 2028 future year ozone DVF for the 2028 Base Case using spatial interpolation without concentration gradients.	82
Figure 7-3.	Differences between SMAT UAA current year ozone $DVC_{2012-2016}$ and projected 2028 future year ozone DVF for the 2028 Base Case using spatial interpolation with (top) and without (bottom) concentration gradients.	83
Figure 7-4.	CAMx estimated MDA8 ozone concentrations (ppb) on May 17, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).	86
Figure 7-5.	CAMx estimated MDA8 ozone concentrations (ppb) on June 5, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).	86
Figure 7-6.	CAMx estimated MDA8 ozone concentrations (ppb) on July 12, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).	87
Figure 7-7.	CAMx estimated MDA8 ozone concentrations (ppb) on July 24, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).	87
Figure 7-8.	CAMx estimated MDA8 ozone concentrations (ppb) on July 26, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).	88
Figure 7-9.	CAMx estimated MDA8 ozone concentrations (ppb) on August 14, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).	88
Figure 7-10.	Differences in episode maximum MDA8 ozone concentrations (top) and SMAT UAA ozone DVs (bottom) between the 2014v2 and 2028 CAMx Base Case simulations.	89
Figure 8-1.	SMAT UAA spatial distribution of projected 2028 ozone DVF_{Base} (top) and DVF_{Cntrl} (bottom).	94
Figure 8-2.	Differences in SMAT UAA projected 2028 ozone DVFs (ppb) for the 2028 Base Case and 2028 O&G Control Strategy ($DVF_{Cntrl} - DVF_{Base}$) running SMAT without (top) and with (bottom) using modeled concentration gradients in the $DVC_{2012-2016}$ spatial interpolation.	95
Figure 8-3.	CAMx estimated MDA8 ozone concentrations (ppb) on May 17, 2014 for the 2028 Base Case (left), 2028 O&G Control Strategy Case (middle) and their difference (right).	98
Figure 8-4.	CAMx estimated MDA8 ozone concentrations (ppb) on June 5, 2014 for the 2028 Base Case (left), 2028 O&G Control Strategy (middle) and their difference (right).	98
Figure 8-5.	CAMx estimated MDA8 ozone concentrations (ppb) on July 12, 2014 for the 2028 Base Case (left), 2028 O&G Control Strategy (middle) and their difference (right).	99

Figure 8-6.	CAMx estimated MDA8 ozone concentrations (ppb) on July 24, 2014 for the 2028 Base Case (left), 2028 O&G Control Strategy (middle) and their difference (right).	99
Figure 8-7.	CAMx estimated MDA8 ozone concentrations (ppb) on July 26, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).	100
Figure 8-8.	CAMx estimated MDA8 ozone concentrations (ppb) on August 14, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).	100
Figure 10-1.	Source regions used in the 2028 Source Sector APCA ozone source apportionment simulation.	108
Figure 10-2.	Locations of ozone monitoring sites within the 4-km New Mexico modeling domain.	109
Figure 10-3.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Navajo Lake in San Juan County.	112
Figure 10-4.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Bloomfield in San Juan County.	113
Figure 10-5.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Substation in San Juan County.	114
Figure 10-6.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Coyote Ranger District in Rio Arriba County.	115
Figure 10-7.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Southeast Heights in Bernalillo County.	116
Figure 10-8.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Westside in Bernalillo County.	117
Figure 10-9.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at South Valley in Bernalillo County.	118
Figure 10-10.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Foothills in Bernalillo County.	119
Figure 10-11.	Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Santa Fe in Santa Fe County.	120
Figure 10-12.	Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Bernalillo in Sandoval County.	121

Figure 10-13. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Desert View in Doña Ana County in southern New Mexico.	122
Figure 10-14. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Santa Teresa in Doña Ana County in southern New Mexico.	123
Figure 10-15. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Chaparral in Doña Ana County in southern New Mexico.	124
Figure 10-16. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Solano in Doña Ana County in southern New Mexico.	125
Figure 10-17. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Carlsbad in Eddy County in southeastern New Mexico.	126
Figure 10-18. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Hobbs in Lea County in southeastern New Mexico.	127
Figure 10-19. Reduction in 2028 ozone DVF due to removal of New Mexico Source Sector emissions for: (a) EGU Point; (b) Non-EGU Point; (c) On-Road Mobile; and (d) Non-Road Mobile.	129
Figure 10-20. Reduction in 2028 ozone DVF due to removal of New Mexico Source Sector emissions for: (a) Non-Point O&G; (b) Point O&G; and (c) Other Anthropogenic.	130
Figure 10-21. Episode maximum daily MDA8 ozone contributions from Source Sectors in New Mexico for: (a) EGU Point; (b) Non-EGU Point; (c) On-Road Mobile; and (d) Non-Road Mobile.	135
Figure 10-22. Episode maximum daily MDA8 ozone contributions from Source Sectors in New Mexico for: (a) Non-Point O&G; (b) Point O&G; (c) Other Anthropogenic; and (d) Fires.	136
Figure 10-23. Episode maximum MDA8 ozone contributions from Source Sectors in Texas for EGU Point (top left), Fires (top middle), Natural (top right), Non-EGU Point (middle left), Non-Road (middle middle), O&G Non-Point (middle right), On-Road (bottom left), Other Anthropogenic (bottom middle) and O&G Point (bottom right) from the 2028 O&G Control Strategy emissions scenario.	138
Figure 10-24. Episode maximum MDA8 ozone contributions from Source Sectors in Colorado for EGU Point (top left), Fires (top middle), Natural (top right), Non-EGU Point (middle left), Non-Road (middle middle), O&G Non-Point (middle right), On-Road (bottom left), Other Anthropogenic (bottom middle) and O&G Point (bottom right) from the 2028 O&G Control Strategy emissions scenario.	139
Figure 10-25. Episode maximum MDA8 ozone contributions from Source Sectors in United States for EGU Point (top left), Fires (top middle), Natural	

(top right), Non-EGU Point (middle left), Non-Road (middle middle), O&G Non-Point (middle right), On-Road (bottom left), Other Anthropogenic (bottom middle) and O&G Point (bottom right) from the 2028 O&G Control Strategy emissions scenario.	140
Figure 10-26. Episode maximum MDA8 ozone contributions from: (a) International Anthropogenic Emissions within CAMx 36/12/4-km domains; (b) BCs due to International Anthropogenic Emissions (BC_{Intl}); (c) BCs due to Natural sources ($BC_{Natural}$); and (d) BCs due to U.S. Anthropogenic Emissions (BC_{US}).	141
Figure 10-27. Contributions of all Source Groups to total MDA8 ozone concentrations at Navajo Lake for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).	143
Figure 10-28. Contributions of New Mexico Source Groups to MDA8 ozone concentrations from New Mexico at Navajo Lake for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).	144
Figure 10-29. Contributions of all Source Groups to total MDA8 ozone concentrations at Foothills for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).	145
Figure 10-30. Contributions of New Mexico Source Groups to MDA8 ozone concentrations from New Mexico at Foothills for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).	146
Figure 10-31. Contributions of all Source Groups to total MDA8 ozone concentrations at Desert View for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).	148
Figure 10-32. Contributions of New Mexico Source Groups to MDA8 ozone concentrations at Desert View for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).	149
Figure 10-33. Contributions of all Source Groups to total MDA8 ozone concentrations at Carlsbad for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).	150
Figure 10-34. Contributions of New Mexico Source Groups to MDA8 ozone concentrations at Carlsbad for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).	151
Figure 10-35. SMAT UAA ozone design values (ppb) for the current year ozone DVC (left) and projected 2028 ozone DVF for the 2028 O&G Control Strategy (right) using current year DVCs based on 2012-2016 (top), 2015-2019 (middle) and 2017-2019 (bottom) ozone design values.	156
Figure 10-36. SMAT UAA ozone design values (ppb) for the projected 2028 ozone DVF from the 2028 No International Anthropogenic Emissions scenario (left) and differences in 2028 ozone DVFs between the 2028 No International Emissions and 2028 O&G Control Strategy scenarios (right) using current year DVCs based on 2012-2016 (top), 2015-2019 (middle) and 2017-2019 (bottom) ozone design values.	157

Figure 11-1.	2028 MDA8 ozone (left) and Percent NO _x Sensitive Ozone (right) on May 17, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO _x Sens for all emissions; (d) %NO _x Sens for all anthropogenic emissions; and (f) %NO _x Sens for New Mexico anthropogenic emissions.	161
Figure 11-2.	2028 MDA8 ozone (left) and Percent NO _x Sensitive Ozone (right) on May 26, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO _x Sens for all emissions; (d) %NO _x Sens for all anthropogenic emissions; and (f) %NO _x Sens for New Mexico anthropogenic emissions.	163
Figure 11-3.	2028 MDA8 ozone (left) and Percent NO _x Sensitive Ozone (right) on May 28, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO _x Sens for all emissions; (d) %NO _x Sens for all anthropogenic emissions; and (f) %NO _x Sens for New Mexico anthropogenic emissions .	164
Figure 11-4.	2028 MDA8 ozone (left) and Percent NO _x Sensitive Ozone (right) on June 5, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO _x Sens for all emissions; (d) %NO _x Sens for all anthropogenic emissions; and (f) %NO _x Sens for New Mexico anthropogenic emissions .	166
Figure 11-5.	2028 MDA8 ozone (left) and Percent NO _x Sensitive Ozone (right) on July 12, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO _x Sens for all emissions; (d) %NO _x Sens for all anthropogenic emissions; and (f) %NO _x Sens for New Mexico anthropogenic emissions.	167
Figure 11-6.	2028 MDA8 ozone (left) and Percent NO _x Sensitive Ozone (right) on July 24, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO _x Sens for all emissions; (d) %NO _x Sens for all anthropogenic emissions; and (f) %NO _x Sens for New Mexico anthropogenic emissions.	168
Figure 11-7.	2028 MDA8 ozone (left) and Percent NO _x Sensitive Ozone (right) on July 26, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO _x Sens for all emissions; (d) %NO _x Sens for all anthropogenic emissions; and (f) %NO _x Sens for New Mexico anthropogenic emissions.	171
Figure 11-8.	2028 MDA8 ozone (left) and Percent NO _x Sensitive Ozone (right) on August 14, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO _x Sens for all emissions; (d)	

%NO _x Sens for all anthropogenic emissions; and (f) %NO _x Sens for New Mexico anthropogenic emissions.	172
Figure 11-9. Spatial distribution of Percent NO _x Sensitive Ozone due to New Mexico anthropogenic emissions across the 4-km New Mexico domain for 15 days of relatively higher MDA8 ozone concentrations.	173
Figure 11-10. Bar Chart of daily O ₃ V (blue) and O ₃ N (red) contributions across the 10 days used by SMAT and pie chart of ozone contributions averaged across the 10 SMAT days for all Source Categories and Source Regions and the Substation monitor in San Juan County.	175
Figure 11-11. O ₃ V and O ₃ N contributions averaged across the 10 SMAT days at Substation for all anthropogenic emissions (top) and New Mexico anthropogenic emissions (bottom).	176
Figure 11-12. Bar Chart of daily O ₃ V (blue) and O ₃ N (red) contributions across the 10 days used by SMAT and pie chart of ozone contributions averaged across the 10 SMAT days for all Source Categories and Source Regions and the South East Heights monitor in Bernalillo County.	178
Figure 11-13. O ₃ V and O ₃ N contributions averaged across the 10 SMAT days at South East Heights monitoring site for all anthropogenic emissions (top) and New Mexico anthropogenic emissions (bottom).	179
Figure 11-14. Bar Chart of daily O ₃ V (blue) and O ₃ N (red) contributions across the 10 days used by SMAT and pie chart of ozone contributions averaged across the 10 SMAT days for all Source Categories and Source Regions and the Desert View monitor in Doña Ana County.	180
Figure 11-15. O ₃ V and O ₃ N contributions averaged across the 10 SMAT days at Desert View monitoring site for all anthropogenic emissions (top) and New Mexico anthropogenic emissions (bottom).	181
Figure 11-16. Bar Chart of daily O ₃ V (blue) and O ₃ N (red) contributions across the 10 days used by SMAT and pie chart of ozone contributions averaged across the 10 SMAT days for all Source Categories and Source Regions and the Carlsbad monitor in Eddy County.	183
Figure 11-17. O ₃ V and O ₃ N contributions averaged across the 10 SMAT days at Carlsbad monitoring site for all anthropogenic emissions (top) and New Mexico anthropogenic emissions (bottom).	184

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
AQTSD	Air Quality Technical Support Document
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
DV	Ozone Design Value
DVC	Current Year Ozone Design Value
DVF	Future Year Ozone Design Value
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
ERA5	ECMWF global hourly meteorological forecasts at 30-km
ERG	Eastern Research Group
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
LCC	Lambert Conformal Conic 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 Department
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
O&G	Oil and Gas
PAVE	Package for Analysis and Visualization
PBL	Planetary Boundary Layer
PGM	Photochemical Grid Model
PM	Particulate Matter
PPB	Parts Per Billion
PPM	Parts Per Million
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
SMAT	Software for Modeled Attainment Test
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 is a draft final Air Quality Technical Support Document (AQTSD) for the New Mexico (NM) Ozone Attainment Initiative (OAI) Photochemical Modeling Study (“NM OAI Study”). The NM OAI Study has developed a 2014 base year photochemical grid model (PGM) modeling platform and conducted 2028 future year modeling for a Base Case and an Oil and Gas (O&G) Control Strategy scenario that implemented proposed controls on 2028 New Mexico O&G sources. The New Mexico Environmental Department (NMED) has contracted with a team consisting of Western States Air Resources Council (WESTAR) and Ramboll US Corporation (Ramboll) to conduct the NM OAI Study.

The NM OAI Study leverages the 2014 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 covering New Mexico and adjacent regions. The NM OAI Study AQTSD documents the 2014 base case, 2028 future year base case and 2028 NM O&G control strategy modeling and includes a summary of the development of the 2014 PGM modeling platform with more details found on the NM OAI Study Website¹ and reports:

- New Mexico Ozone Attainment Initiative Photochemical Modeling Study – Draft Modeling Protocol (Ramboll and WESTAR, 2020a).²
- New Mexico Ozone Attainment Initiative Photochemical Modeling Study – Draft Work Plan (Ramboll and WESTAR, 2020b).³
- New Mexico Ozone Attainment Initiative Photochemical Modeling Study – 2014 Modeling Platform Development and Model Evaluation (Ramboll and WESTAR2020c).⁴
- New Mexico Ozone Attainment Initiative Photochemical Modeling Study – Revised 2014v2 Base Case and Model Performance Evaluation (Ramboll and WESTAR, 2021).⁵

Although the WESTAR/Ramboll team conducted the 2014 base year and 2028 base and O&G Control Strategy future year modeling, the implementation of the proposed NMED O&G ozone precursor control strategy in the 2028 O&G emissions was conducted by Eastern Research Group (ERG) under separate contract with NMED so is not documented in this report.

1.1 NM OAI Photochemical Modeling Study 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

¹ <https://www.wrapair2.org/NMOAI.aspx>

² https://www.wrapair2.org/pdf/NM_OAI_Modeling_Protocol_v5.pdf.

³ https://www.wrapair2.org/pdf/NM_OAI_Work_Plan_v2.pdf

⁴ https://www.wrapair2.org/pdf/NM_OAI_2014_BaseCase_MPE_v3.pdf

⁵ <https://www.wrapair2.org/NMOAI.aspx>

is within 95% of the ozone NAAQS (74-3-5.3, NMSA 1978⁶). 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 Maximum Daily Average 8-hour (MDA8) ozone concentrations. Table 1-1 lists the observed ozone DVs at New Mexico monitoring sites from 2010 to 2019. The DVs are color-coded when they exceed the 75 ppb 2008 ozone NAAQS (red), 70 ppb 2015 ozone NAAQS (yellow) and within 95% of the 70 ppb ozone NAAQS (green, i.e., ≥ 67 ppb). In more recent years, the ozone DVs have exceeded the 70 ppb 2015 ozone NAAQS at several sites in southern New Mexico (e.g., in Doña Ana and Eddy Counties). In particular, the 2017-2019 ozone DVs are particularly high and even exceeded the 75 ppb 2008 ozone NAAQS at three sites in southern New Mexico (colored red in Table 1-1).

⁶ <https://law.justia.com/codes/new-mexico/2017/chapter-74/article-2/section-74-2-5.3/>

Table 1-1. Ozone design values (ppm) at sites in New Mexico from 2010 to 2019. Red above the 75 ppb 2008 NAAQS, yellow above 2015 70 ppb NAAQS and green within 95% of the 2015 NAAQS.

AQS Site ID	Local Site Name	County Name	2008-2010	2009-2011	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
350010023	Del Norte HS	Bernalillo	0.064	0.066	0.068	0.070	0.068	0.066	0.065	0.067	0.070	0.070
350010024	SE Heights	Bernalillo	0.066	0.068	0.070	0.070	0.068					
350010027	Westside	Bernalillo	0.067	0.068	0.071	0.071						
350010029	South Valley	Bernalillo	0.066	0.067	0.069	0.070	0.067	0.066	0.065	0.065	0.066	0.067
350010032	Westside	Bernalillo			0.070	0.070	0.067					
350011012	Foothills	Bernalillo	0.068	0.070	0.074	0.072	0.067	0.064	0.064	0.067	0.069	0.071
350011013	North Valley	Bernalillo	0.067	0.068	0.069	0.069						
350130008	La Union	Doña Ana	0.064	0.062	0.065	0.067	0.067	0.066	0.066	0.068	0.068	0.070
350130017	Sunland Park	Doña Ana	0.064	0.065	0.068	0.067	0.067					
350130020	Chaparral	Doña Ana	0.066	0.067	0.067	0.069	0.068	0.067	0.066	0.068	0.071	0.073
350130021	Desert View	Doña Ana	0.070	0.069	0.072	0.072	0.072	0.072	0.072	0.072	0.074	0.077
350130022	Santa Teresa	Doña Ana	0.067	0.066	0.070	0.075	0.074	0.072	0.068	0.072	0.074	0.076
350130023	Solano	Doña Ana	0.063	0.063	0.065	0.065	0.065	0.065	0.065	0.066	0.067	0.070
350151005	Carlsbad City	Eddy	0.067	0.068	0.071	0.071	0.071	0.069	0.067	0.068	0.074	0.079
350153001	Carlsbad Caverns	Eddy									0.071	
350171003	Chino Copper	Grant	0.063	0.065	0.067	0.063	0.062					
350250008	Hobbs Jefferson	Lea	0.059	0.061	0.061	0.066	0.065	0.067	0.066	0.067	0.070	0.071
350290003	Deming Airport	Luna	0.057	0.058	0.064	0.067	0.066					
350390026	Coyote Ranger District	Rio Arriba							0.064	0.065	0.067	0.067
350431001	Bernalillo	Sandoval	0.060	0.061	0.061	0.063	0.063	0.065	0.064	0.065	0.068	0.068
350439004	Pueblo of Jemez	Sandoval		0.062								
350450009	Bloomfield	San Juan	0.060	0.061	0.067	0.068	0.067	0.064	0.062	0.064	0.069	0.068
350450018	Navajo Lake	San Juan			0.071	0.071	0.068	0.067	0.066	0.068	0.070	0.069
350451005	Substation	San Juan	0.063	0.063	0.067	0.068	0.066	0.063	0.062	0.064	0.069	0.069
350490021	Santa Fe Airport	Santa Fe	0.063	0.062	0.065	0.066	0.066	0.064	0.063	0.063	0.066	0.066
350610008	Los Lunas	Valencia			0.067	0.070	0.069	0.066	0.064	0.065	0.067	0.068

To address the high observed ozone concentrations in New Mexico, the NMED has embarked on an Ozone Attainment Initiative (OAI⁷) 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) for the NM OAI Study and the NM OAI Study PGM modeling was awarded to a contracting team of WESTAR and Ramboll.

⁷ <https://www.env.nm.gov/air-quality/o3-initiative/>

1.2 Overview of NM OAI Study Modeling Approach

The procedures used for the NM OAI Study photochemical modeling were described in a detailed Modeling Protocol dated May 19, 2020 (Ramboll and WESTAR, 2020a). A description of the tasks and schedule for completing the NM OAI Study is contained in a Work Plan (Ramboll and WESTAR, 2020b) with presentations, results and reports posted to the NM OAI Study webpage⁸ as they are produced. One objective of the study was to evaluate a proposed regulation to control ozone precursor emissions from oil and gas (O&G) development sources in New Mexico. The original future year emissions scenario in the NM OAI Study was 2023, when the proposed O&G rule would not be fully implemented. Thus, the future year to be modeled was changed to 2028 in a December 2020 Contract Amendment from NMED to the WESTAR/Ramboll team.

The NM OAI Study is conducting PGM modeling by enhancing the WRAP-WAQS 2014v2 36/12-km PGM modeling platform⁹ with the addition of a new 4-km grid resolution domain covering New Mexico and surrounding areas, especially the O&G production regions in the Permian and San Juan Basins. The NM OAI Study PGM modeling is performing 2014 base year modeling and model performance evaluation. 2028 future year modeling was also conducted. The NM OAI Study PGM modeling is being conducted in accordance with EPA's guidance for ozone State Implementation Plan (SIP) ozone attainment demonstration modeling (EPA, 2018).

1.2.1 WRAP-WAQS 2014 PGM Platform Development

The WRAP-WAQS developed an annual 2014 PGM modeling platform to address air quality issues in the western states. An initial WRAP-WAQS 2014v1 PGM modeling platform was developed in 2019 for the CAMx and CMAQ PGMs that is documented in a webpage¹⁰ on the Intermountain West Data Warehouse (IWDW). Additional diagnostic sensitivity tests were conducted to address several model performance issues culminating in the WRAP-WAQS 2014v2 36/12-km CAMx modeling database that was used as the starting point for the NM OAI Study CAMx summer of 2014 36/12/4-km modeling database. The development of the WRAP-WAQS 2014v2 PGM database and model performance evaluation is available in a webpage¹¹ on the IWDW.

The WRAP-WAQS 2014v2 CAMx platform used a 36/12-km grid resolution domain structure with meteorological inputs based on the WAQS 2014 36/12-km WRF meteorological model simulation (Bowden, Talgo and Adelman, 2016¹²). The 2014 emissions were based on the 2014 National Emissions Inventory (2014NEI¹³) with updates from western states¹⁴. Boundary Condition (BC) inputs were based on a WRAP 2014 GEOS-Chem model simulation.

Because the NM OAI Study requires a 4-km modeling domain for New Mexico, new summer of 2014 36/12/4-km WRF meteorological modeling was conducted, as

⁸ <https://www.wrapair2.org/NMOAI.aspx>

⁹ <http://views.cira.colostate.edu/wiki#WAQS-2014-Modeling-Platform>

¹⁰ http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx

¹¹ https://views.cira.colostate.edu/iwdw/docs/WRAP_WAQS_2014v2_MPE.aspx

¹² http://views.cira.colostate.edu/wiki/Attachments/Modeling/WAQS_2014_WRF_MPE_January2016.pdf

¹³ <https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data>

¹⁴

https://www.wrapair2.org/pdf/WRAP%20Regional%20Haze%20SIP%20Emissions%20Inventory%20Review%20Documentation_for_Docket%20Feb2019.pdf

described in Chapter 2, that was used to develop 36/12/4-km meteorological inputs for CAMx. The NM OAI Study defined their 36/12-km domains to match WRAP-WAQS 2014v2 36/12-km domains so the WRAP-WAQS 2014v2 36/12-km emission and some other inputs (e.g., BCs) can be used directly in the NM OAI Study PGM modeling. Figure 1-1 shows the 36/12/4-km modeling domains used for the NM OAI Study PGM modeling with the 4-km grid resolution New Mexico domain shown in Figure 1-2.

1.2.2 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 that can be leveraged for the NM OAI Study. Details on the episode selection are contained in Chapter 3 of the NM OAI Study Modeling Protocol (Ramboll and WESTAR, 2020a).

1.2.3 Model Selection

Details on the rationale for model selection are provided in Chapter 2 of the NM OAI Study Modeling Protocol (Ramboll and WESTAR, 2020a). The Weather Research Forecast (WRF) prognostic meteorological model was selected. Emissions modeling was conducted using the Sparse Matric Operator Kernel Emissions (SMOKE) model for most source categories. The Model of Emissions of Gases and Aerosols from Nature (MEGAN v3.1) was used initially for biogenic emissions in the 4-km domain for the original CAMx 2014 Base Case, but was ultimately replaced by biogenic emission based on the BEIS v3.7 model in the final CAMx 2014v2 base case. There are special processors for fires, windblown dust (WBD), lightning NO_x (LNO_x) and oceanic sea salt (NaCl) and Dimethyl Sulfide (DMS) emissions that were used. The 2014 version of the Motor Vehicle Emissions Simulator (MOVES2014b) on-road mobile source emissions model was used with SMOKE-MOVES and WRF meteorological data to generate on-road mobile source emissions for the 4-km New Mexico modeling domain.

The Comprehensive Air-quality Model with extensions (CAMx) photochemical grid model (PGM) was used because it supports two-way grid nesting, was used in the WRAP-WAQS regional haze modeling, contains a well-vetted ozone source apportionment tool and has a rich and successful history of successful application to the region.

1.2.4 Domain Selection

The NM OAI Study modeling is using the same 36-km 36US and 12-km 12WUS2 domains as used in the WRAP-WAQS 2014 modeling platform. A new 4-km New Mexico domain was added to the 36/12-km domain structure. Figure 1-1 displays the 36/12/4-km domain structure with Figure 1-1 showing the 4-km New Mexico domain. New WRF 2014 36/12/4-km meteorological modeling was conducted to generate finer scale 4-km meteorological conditions for the New Mexico domain and consistent meteorology among the 36/12/4-km domains. The domains use a Lambert Conformal Conic (LCC) projection using the parameters given in Table 1-2 with the definitions of the extent of the 36/12/4-km domains given in Table 1-3. CAMx was run using the 36/12/4-km domain structure shown in Figure 1-1 using two-way interactive grid nesting.

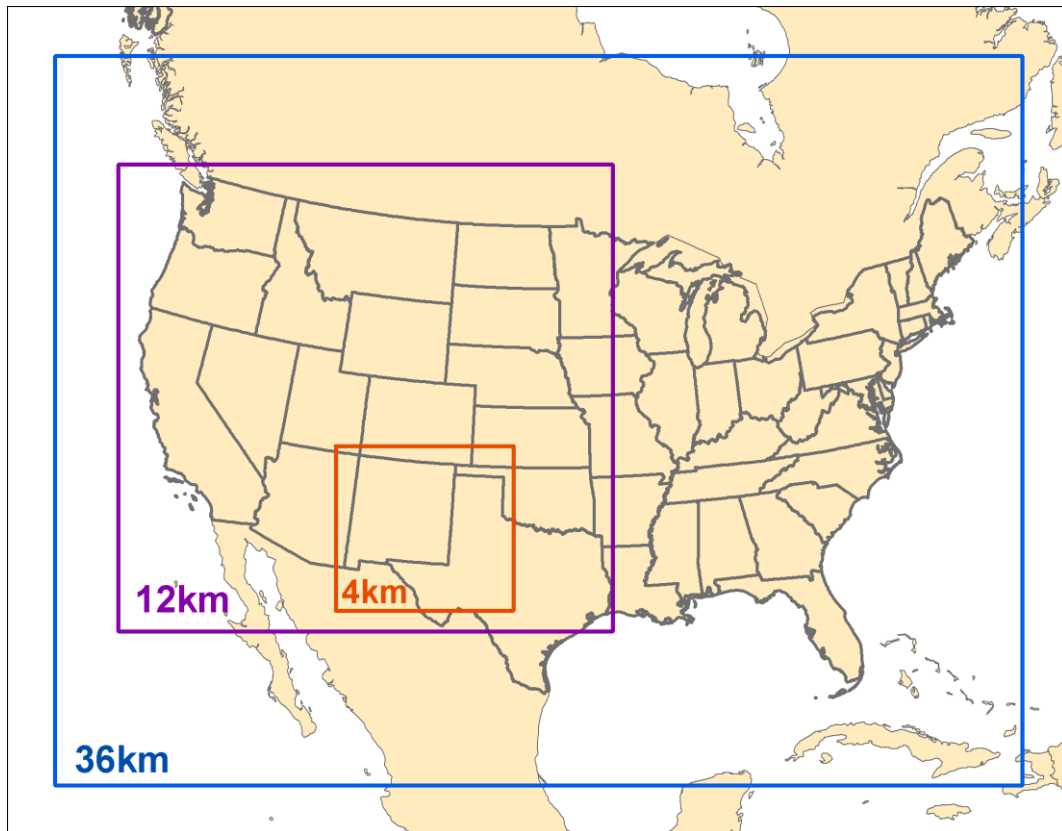


Figure 1-1. NM OAI Study 2014 36/12/4-km PGM and emissions modeling domains.

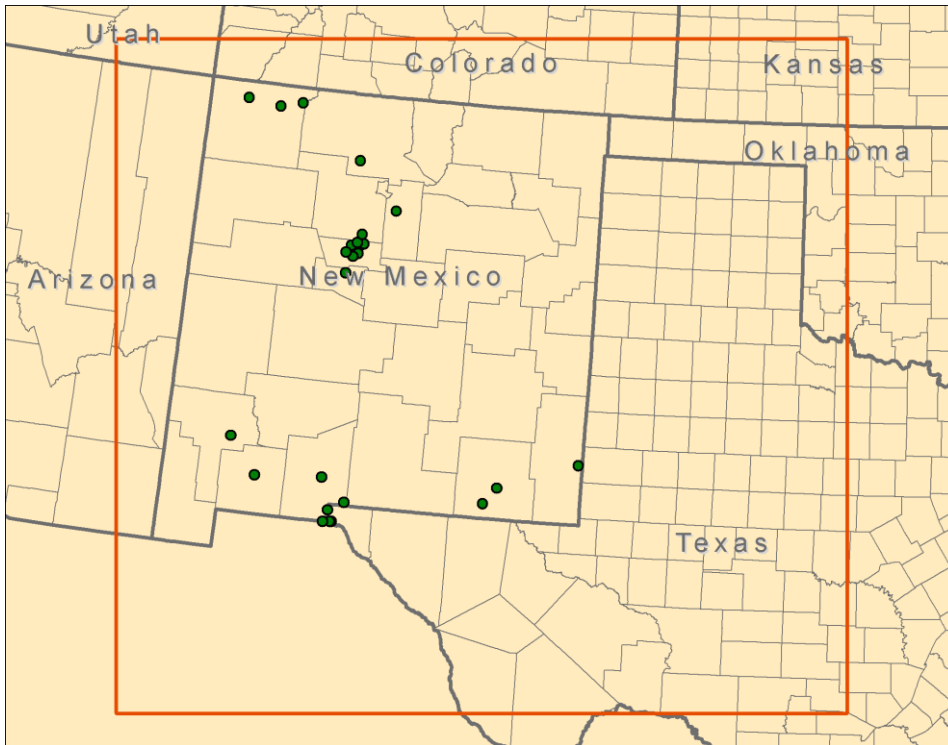


Figure 1-2. 4-km New Mexico modeling domain for PGM and emissions modeling, with locations of New Mexico ozone monitors that were operating during some portion of 2014.

Table 1-2. 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 1-3. 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

1.2.5 Base and Future Year Emissions Data

The 2014 base year emissions data were based on the WRAP-WAQS 2014v2 emissions that were in turn based on the 2014NEIv2 with updates from western states. New emissions were generated for natural emission sources (e.g., biogenic and LNO_x). 2028 emissions were based on the WRAP 2028 On-the-Books (2028OTBa2) emissions scenario with updated 2028 O&G emissions for New Mexico and using actual 2014 fires instead of Representative Baseline fires as used in the WRAP 2028OTBa2 scenario. The development of the 2014 and 2028 emission scenarios are discussed in Chapter 4.

1.2.6 Initial and Boundary Conditions Development

The first two-weeks of May were run 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 washed out the influence of the initial concentrations (IC) before elevated ozone concentrations occur in New Mexico.

Boundary conditions (BC) for the outer 36-km 36US domain were 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. The top BC was based on a zero-gradient assumption where concentrations above the top of the model (above 50 mb, or ~19-km above sea level) are assumed to be the same as in the top vertical layer of CAMx.

Due to uncertainties in projecting future year international emissions, the CAMx BCs based on the 2014 GEOS-Chem global model simulation were held constant for the 2028 modeling. This is likely a conservative estimate of 2028 BCs.

Chapter 3 provides a summary of the development of the 2014 CAMx BC inputs with more details in Ramboll and WESTAR (2020c) and on the WRAP-WAQS 2014v2 modeling website.

1.2.7 Diagnostic Sensitivity Analyses

The NM OAI Study conducted four diagnostic sensitivity tests for the CAMx 2014 36/12/4-km base case that compared the CAMx ozone performance for four alternative meteorological inputs. The NM OAI Study conducted two WRF 2014 36/12/4-km WRF simulations that used different analysis fields as input. The two 2014 36/12/4-km WRF outputs were processed with WRFCAMx using two different options for vertical turbulent exchange (i.e., vertical mixing) coefficients (Kv). This resulted in four different CAMx meteorological inputs that were evaluated using CAMx diagnostic sensitivity tests that are summarized in Chapter 5 with details provided in Ramboll and WESTAR (2020c).

1.2.8 Model Performance Evaluation

The NM OAI Study CAMx 2014 36/12/4-km base case simulation Model Performance Evaluation (MPE) followed EPA's MPE recommendations in their ozone modeling guidance (EPA, 2018) and other sources (e.g., Simon, Baker and Phillips, 2012; Emery et al., 2016). The CAMx 2014 36/12/4-km base case simulation MPE focused on ozone model performance within the 4-km New Mexico domain, and especially within New Mexico. Two CAMx 2014 base case simulations were performed and subjected to an MPE. An original CAMx 2014 base case simulation used CAMx v7.0 and biogenic

emissions in the 4-km NM domain based on the MEGAN v3.1 model whose evaluation is documented in NM OAI Study 2014 platform development and 2014 base case modeling report (Ramboll and WESTAR, 2020c). A revised 2014v2 base case was conducted using CAMx v7.1 and biogenic emissions based on the BEIS v3.7, whose results are documented in an Addendum to the 2014 base case modeling report (Ramboll and WESTAR, 2021).

1.2.9 2028 Future Year Base and Control Strategy Modeling

2028 future year ozone modeling was conducted using the WRAP 2028OTBa2 emissions scenario with updated 2028 O&G emissions in New Mexico and using 2014 actual fires instead of the Representative Baseline fires used in the 2028OTBa2 scenario. These fire inventories were prepared for the WRAP Fire and Smoke Work Group and are documented in a report (Air Sciences, 2020) and presentation.¹⁵ A CAMx 2028 future year 36/12/4-km base case simulation was conducted using CAMx v7.1 and used to project 2028 future year ozone design values (DVs). The procedures to calculate projected ozone DVs followed EPA's latest guidance (EPA, 2018). These procedures use the modeling results in a relative fashion to scale the current year observed 2012-2016 8-hour ozone design values (i.e., $DVC_{2012-2016}$) to project 2028 future year ozone Design Values (DVs). 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 (SMAT¹⁶) tool that includes the recommended procedures in the latest EPA guidance for projecting ozone DVs.

The NM OAI Study also conducted future year modeling for a 2028 O&G Control Strategy that implemented controls on ozone precursors from O&G sources within the San Juan and Permian Basins. The WESTAR/Ramboll team provided the 2028 NM O&G emissions to ERG who, under separate contract to NMED, implemented the proposed NM O&G ozone precursor control strategy in the 2028 NM O&G emissions and provided them to WESTAR/Ramboll for ozone modeling. This report does not document the implementation of the NM O&G ozone precursor control strategy as that was not performed by WESTAR/Ramboll.

1.2.10 Future Year Source Apportionment Modeling

The NM OAI Study also is conducting future year ozone source apportionment modeling for the 2028 O&G Control Strategy scenario using the CAMx ozone source apportionment tool. The CAMx 2028 Source Sector APCA ozone source apportionment modeling examined the ozone contributions of several major anthropogenic emission source sectors in New Mexico and other states as well as contributions of International anthropogenic emissions on ozone concentrations in New Mexico and is discussed in Chapter 9. CAMx 2028 VOC/NO_x Sensitivity OSAT ozone source apportionment modeling was also conducted to examine the level of VOC sensitive versus NO_x sensitive ozone formation in New Mexico and is discussed in Chapter 10.

¹⁵ https://www.wrapair2.org/pdf/FireEIandFutureScenariosResults_to_regional_planners_20200520.pptx

¹⁶ <https://www.epa.gov/scram/photochemical-modeling-tools>

2. 2014 WRF METEOROLOGICAL MODELING

The NM OAI Study conducted WRF meteorological modeling for the summer of 2014 to generate CAMx meteorological inputs for the 36/12/4-km horizontal domain structure shown in Figure 1-1.

2.1 WRF 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 was used in the NM OAI Study.

This chapter summarizes the application and evaluation of the WRF meteorological model to generate 2014 36/12/4-km meteorological inputs for CAMx photochemical grid modeling with more details provided in Chapter 2 of Ramboll and WESTAR (2020c).

2.2 WRF Horizontal Modeling Domain

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

2.3 WRF Model Configuration

WRF version 4.2 was used for this modeling analysis. The NM OAI Study 36/12-km WRF/PGM grid configuration (e.g., horizontal domains and vertical layer structure) was designed to be identical to the WRAP-WAQS 2014 WRF/PGM grid configuration in order to facilitate the use of data between the two studies. A 4-km domain was added covering New Mexico and adjacent regions.

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, 2015 and 2016 WRF modeling also used 35 vertical layers up to a 50 mb height.

Table 2-1 displays the 36-vertical layer structure used in the WRAP-WAQS 2011/2014 WRF modeling that was also adopted for the NM OAI Study WRF 2014 36/12/4-km modeling.

Table 2-1. WRF 36 level vertical layer structure for the NM OAI study. This is the same WRF layer structure as used in WAQS 2011/2014/2016 and EPA 2016 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	

2.3.1 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).

For the NM OAI Study 2014 36/12/4-km WRF modeling, we used the new hybrid vertical coordinate system and a new version of the WRFCAMx processor that has been updated to use WRF’s hybrid vertical coordinate. The hybrid vertical coordinate system and use of 4-km New Mexico domain are the two biggest differences between the NM OAI Study and WRAP-WAQS 2014 WRF modeling. The WRAP-WAQS 2014 WRF/CAMx modeling did not use the hybrid vertical coordinate system in WRF because at the time it was not supported in the WRFCAMx processor.

2.3.2 Topographic Inputs

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

2.3.3 Vegetation Type and Land Use Inputs

Vegetation type and land use information used 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 was employed.

2.3.4 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. The NM OAI Study conducted two WRF simulations that used two different analysis fields that were evaluated for their performance against meteorological variables as well as their effect on CAMx ozone model performance. Both the 12-km resolution North American Model (NAM) and the ~30-km resolution European Center for Medium-Range Weather Forecasting (ECMWF) Re-Analysis (ERA5¹⁷) dataset analysis fields were used for IC/BC and FDDA in the two WRF 2014 36/12/4-km sensitivity simulations.

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

¹⁷ <https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era5>

The effects of the two 2014 WRF simulations on CAMx ozone performance was evaluated in diagnostic sensitivity simulations and the best performing configuration selected as the final CAMx meteorological inputs, as described in Chapter 5.

2.3.5 New Lightning Data Assimilation

More recently, the assimilation of lightning data in WRF simulations has shown to improve the locations and amounts of convective precipitation. The use of lightning 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 algorithm was not used in the NM OAI Study 2014 WRF modeling 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 within the budget; (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); and (4) most importantly, the lightning detection data assimilation algorithm has not been implemented in the latest versions of WRF so its use would limit the use of other model new options, such as the hybrid vertical coordinate system.

2.3.6 PBL and LSM Physics Options

As used in the WRAP-WAQS 2014 WRF modeling, the YSU Planetary Boundary Layer (PBL) and Noah Land Surface Model (LSM) physics options were used in the NM OAI Study 2014 36/12/4-km WRF modeling. Previous WRF sensitivity modeling for the intermountain west 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 (EPA, 2019).

2.3.7 Remaining WRF Physics Options

Table 2-2 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 WRAP-WAQS 2014 and EPA 2014/2015/2016 WRF modeling. Our comparison of 2014 WRAP-WAQS and 2014 EPA WRF modeling for summertime precipitation performance in New Mexico found that the WRAP-WAQS WRF meteorological model performance was better than EPA WRF for most variables. Therefore, we used the same microphysics and cumulus schemes for the NM OAI Study as used in 2014 WRAP-WAQS (Thompson and Multi-Scale Kain-Fritsch, respectively) and most of the same other physics options (see Table 2-2).

Table 2-2. NM OAI Study 2014 WRF model configuration and comparison with the WRF configuration used in the WRAP-WAQS 2014 and EPA 2014/2015/2016 WRF modeling.

WRF Option	NM OAI Study	2014 WRAP-WAQS	2014 EPA
Horizontal Domains	36/12/4-km	36/12/4-km	12-km
Vertical Coordinate	Hybrid Sigma	Sigma	Sigma
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	36/12-km NAM & ERA5	36/12-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

2.3.8 Application Methodology

The WRF model was executed in 5.5-day blocks initialized at 12Z every five days. Model results were 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.

2.4 WRF Model Evaluation

Quantitative and qualitative evaluations of the NM OAI Study 2014 WRF 36/12/4-km simulation meteorological performance was conducted for both the WRF/NAM and WRF/ERA5 applications. The quantitative evaluations compare integrated surface hourly meteorological observations with WRF predictions matched by time and location and included the calculation of model performance statistical metrics that were compared against performance benchmarks. The qualitative evaluations compared time series plots of modeled wind speed and wind direction to the observations at specific sites. The qualitative evaluation also compared spatial plots of WRF precipitation estimates against spatial maps of precipitation analysis fields based on observations.

2.4.1 Quantitative Evaluation Using METSTAT

METSTAT was used to evaluate the WRF/NAM and WRF/ERA model performance against observed surface meteorological observations of wind speed and direction, temperature and mixing ratio (humidity). Figure 2-1 displays the WRF/NAM and WRF/ERA5 wind speed soccer plot that compares monthly measures of wind speed bias and error across surface monitoring sites in New Mexico with the simple and complex performance benchmarks. The monthly wind speed performance of the two WRF simulations are remarkably similar with both having near zero bias that achieves the simple benchmark ($\leq \pm 0.5$ m/s). The error (RMSE) for the two WRF simulations falls between the simple

and complex benchmarks (i.e., between 2.0 and 2.5 m/s) for all four months (May through August).

The monthly wind direction bias and error statistics for the two WRF simulations are also nearly identical with bias values of ~ 5 degrees that achieves the $\leq \pm 5$ degree simple benchmark and error statistics that falls between the 30 degree simple and 50 degree complex benchmarks (Figure 2-2).

There are differences in the two WRF simulations temperature performance and more differences in the monthly values than seen for winds (Figure 2-3). The WRF/ERA5 simulations has a near zero temperature bias in May and June with the bias and error achieving the simple benchmark for both months. The WRF/NAM has a warm bias for May and June that straddle the simple benchmark upper bound ($+0.5$ K). The two WRF simulations have similar July and August performance that have a warm bias of ~ 1.0 K that fails to achieve the simple benchmark. For both WRF simulations, the temperature bias is right at, but mostly within, the 2.0 K simple benchmark.

The WRF/ERA5 clearly has better surface humidity performance than WRF/NAM (Figure 2-4). For July and August, the WRF/NAM has a wet bias in July and August of ~ 1.5 g/kg so fails to achieve the simple ($\leq \pm 0.8$ g/kg) and complex ($\leq \pm 1.0$ g/kg) bias benchmarks. The WRF/ERA5 also has a wet bias for July and August that is not as large as WRF/NAM as it is right at the simple benchmark (~ 1.0 g/kg) but achieving the complex benchmark. The WRF/ERA5 also has better humidity error performance in July and August, although both simulations achieve the error performance benchmarks.

The two WRF simulations have better humidity performance in May and June that achieves the simple benchmark, albeit with a moist bias. May is the best performing month with nearly identical humidity model performance with a bias of ~ 0.6 g/kg and error of ~ 0.9 g/kg. In June, the WRF/ERA5 humidity performance is slightly better than WRF/NAM.

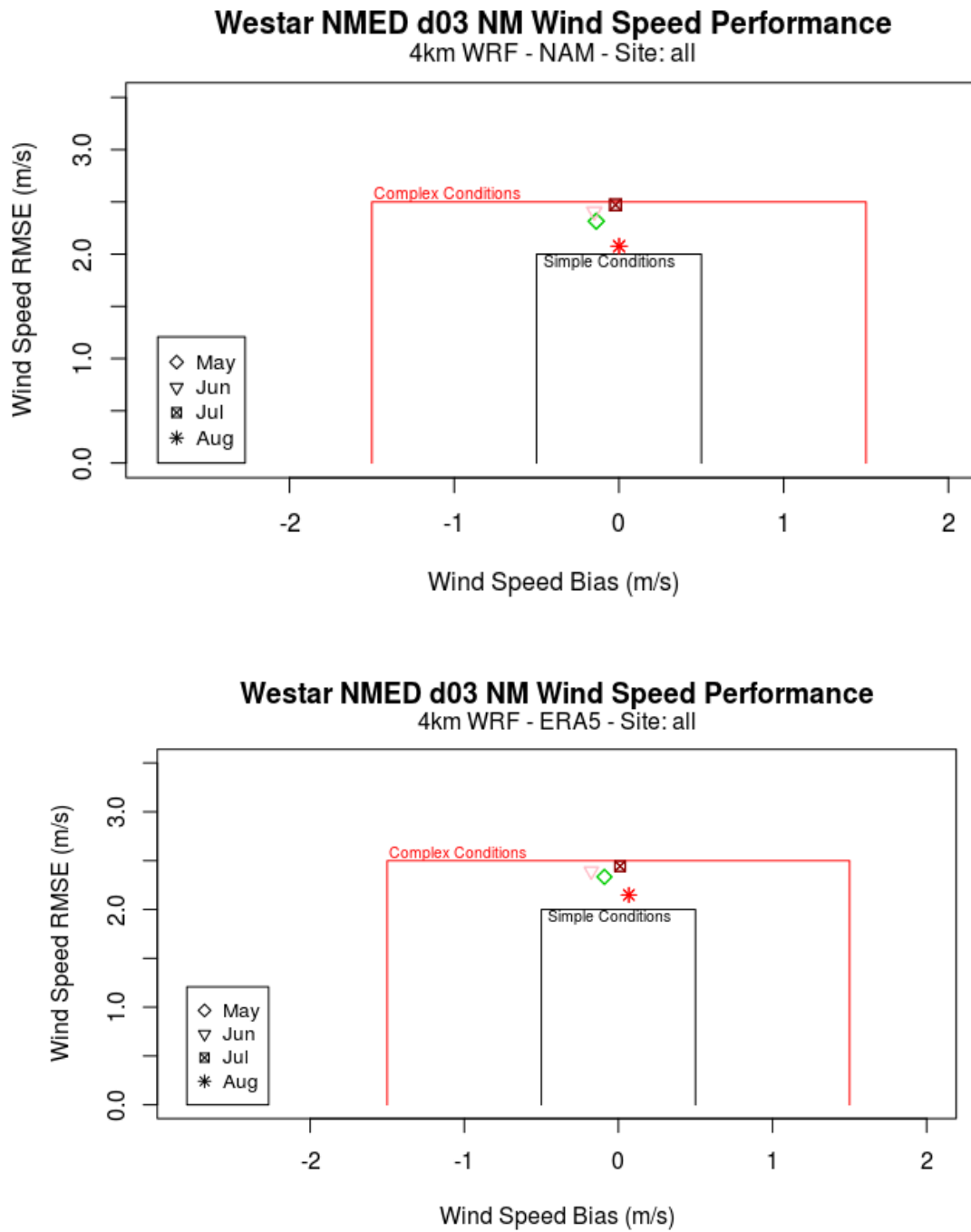


Figure 2-1. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface wind speed (m/s) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

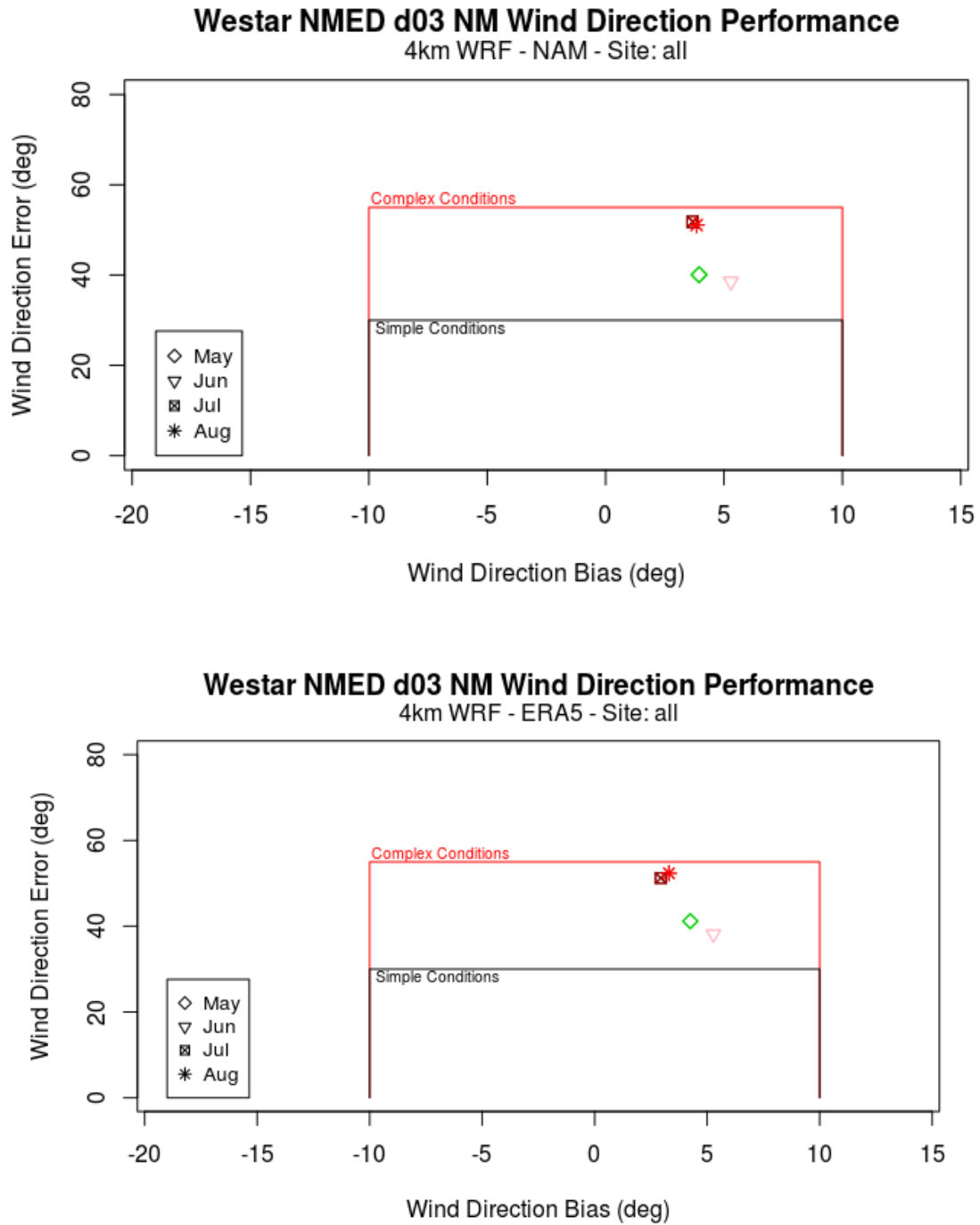


Figure 2-2. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface wind direction (degrees) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

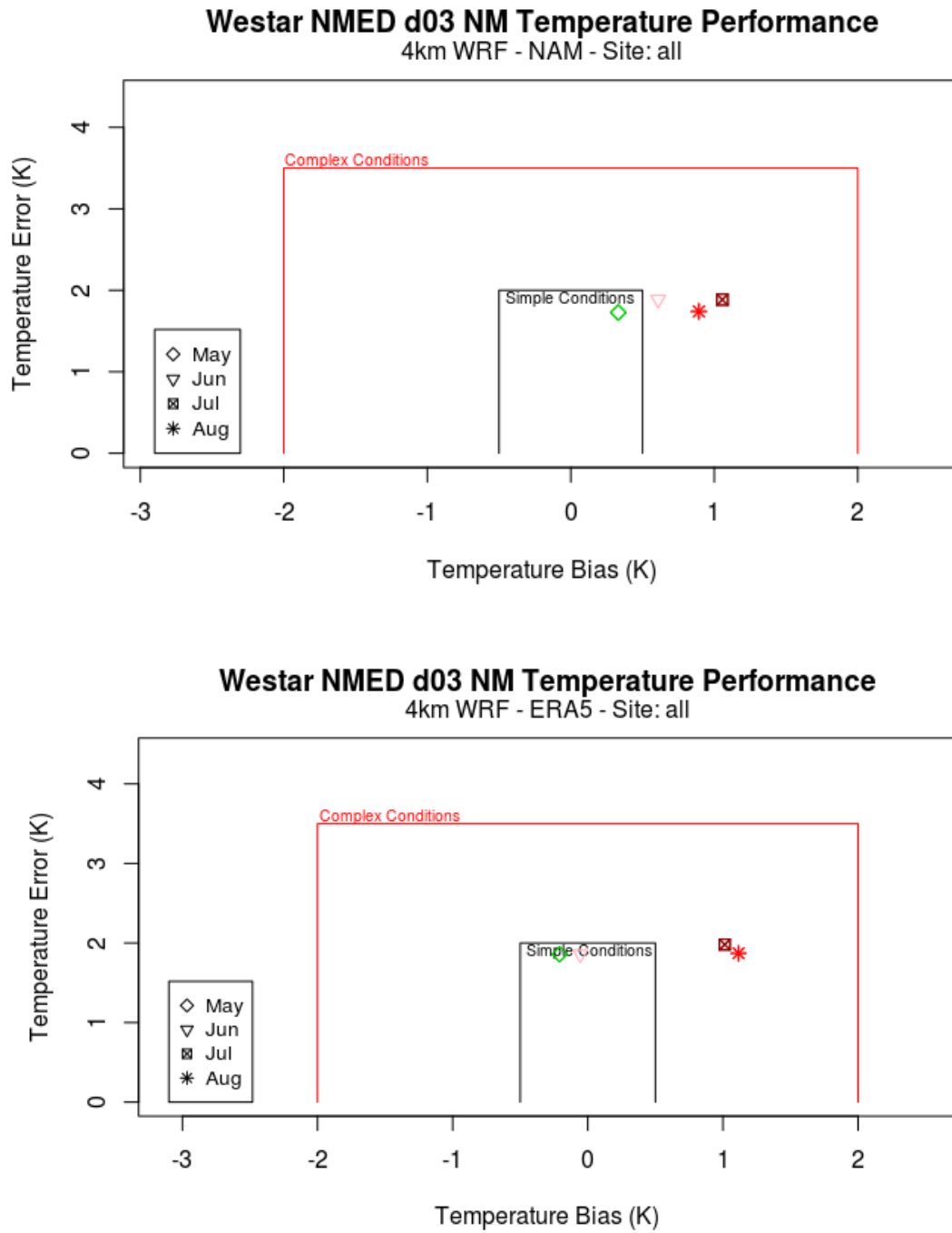


Figure 2-3. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface temperature (K) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

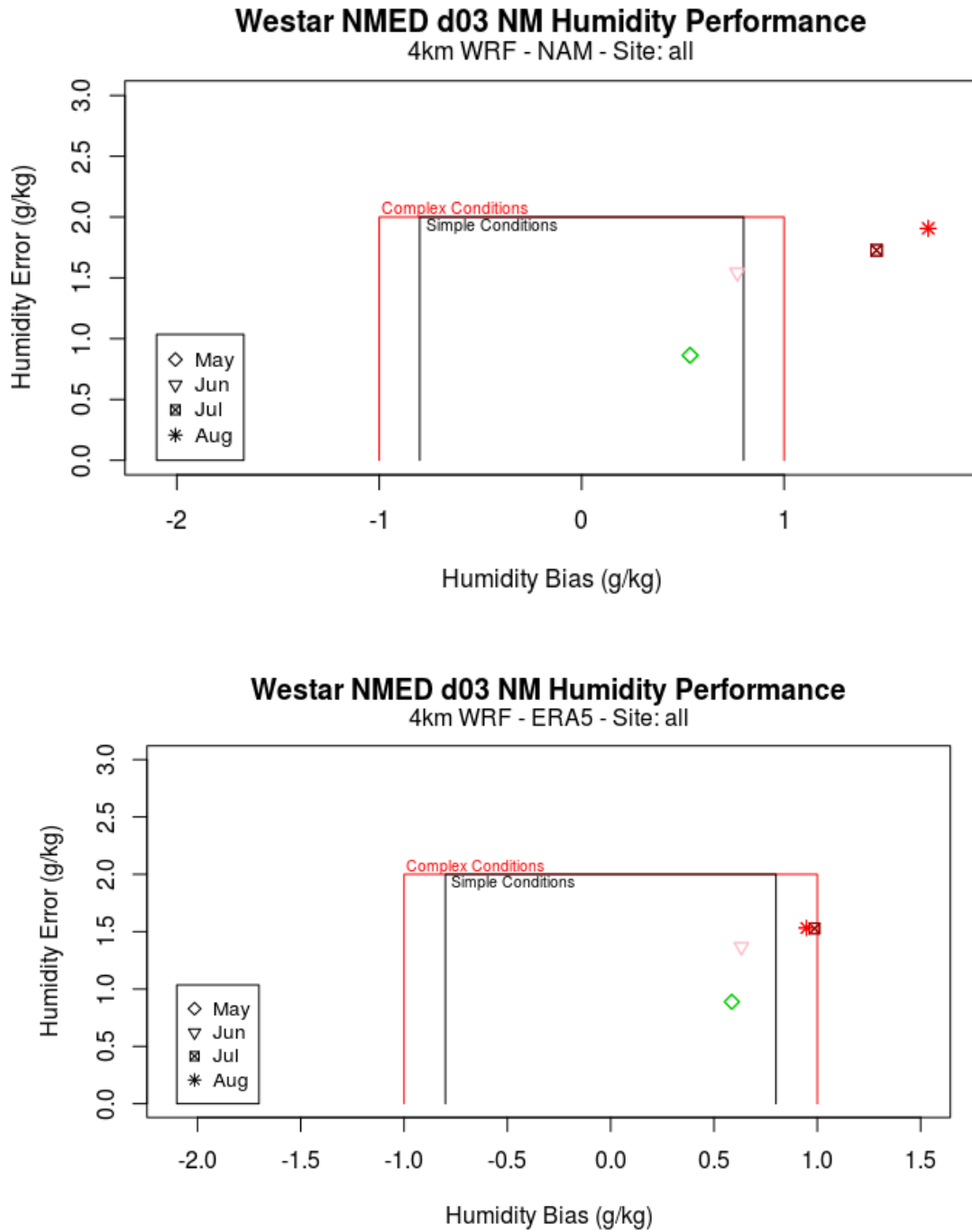


Figure 2-4. Soccer plot comparing WRF/NAM (top) and WRF/ERA5 (bottom) surface humidity (g/kg) model performance against the Simple and Complex Benchmarks for monthly RMSE (y-axis) and Mean Bias (x-axis).

2.4.2 Qualitative Evaluations for Precipitation 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 (PRISM¹⁸) is used to generate the precipitation analysis fields (Daly et al., 2008). The PRISM interpolation method of observed precipitation reflects, 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 (DEM) grid cell, and stations entering the regression are assigned weights based primarily on the physiographic similarity of the station to the grid cell.

Figures 2-5 and 2-6 compares the PRISM monthly total precipitation across the 4-km New Mexico domain with the WRF/NAM and WRF/ERA5 model estimates for, respectively, July and August. Results for other months can be found in Ramboll and WESTAR (2020c). WRF/NAM overestimates the July monthly precipitation over northeast New Mexico, with WRF/ERA5 having an overestimation bias in most northerly Texas. But both WRF simulations have a dry bias for monthly precipitation over the remainder of New Mexico.

WRF/ERA5 does a better job at reproducing the locations and magnitudes of the August monthly PRISM precipitation than WRF/NAM (Figure 2-6). WRF/NAM overstates the August precipitation in central-south New Mexico.

¹⁸ <http://prism.oregonstate.edu/>

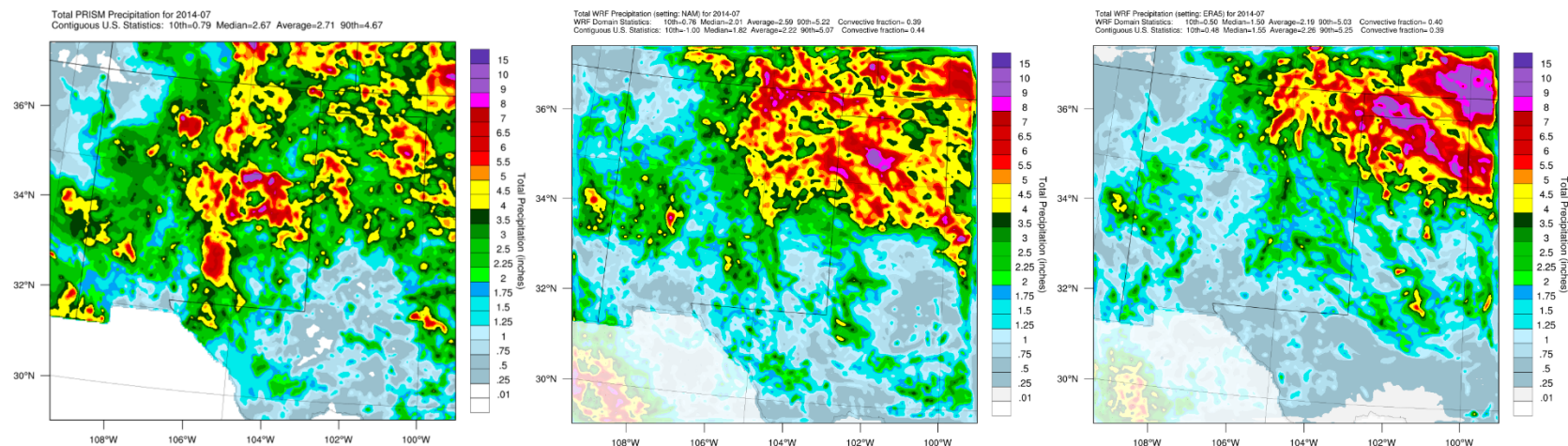


Figure 2-5. July monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).

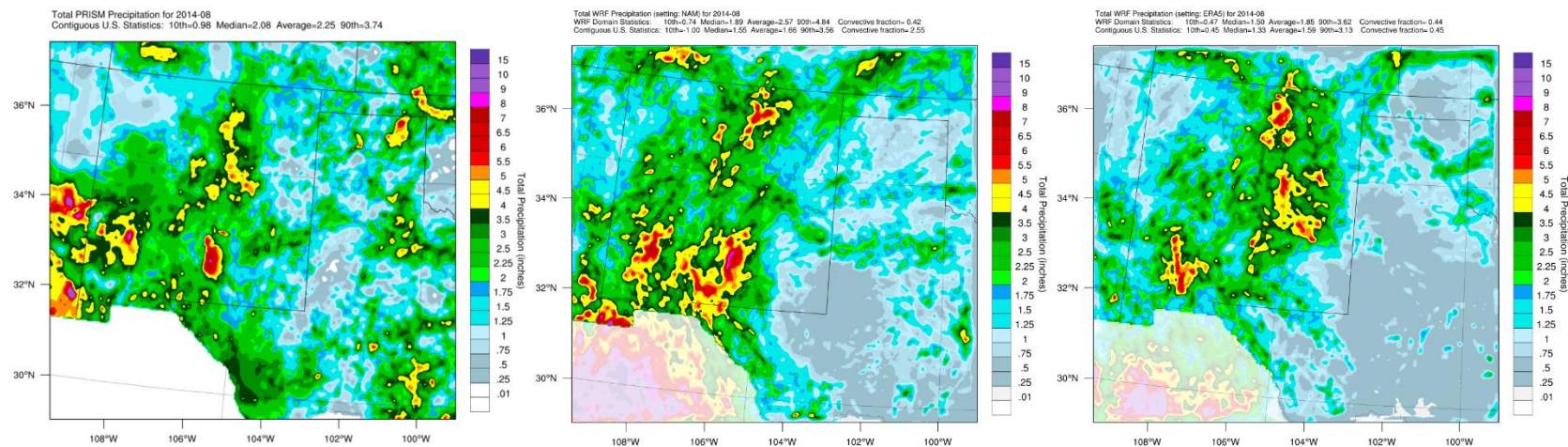


Figure 2-6. August monthly precipitation amounts from PRISM based on observations (left) and predicted by WRF/NAM (middle) and WRF/ERA5 (right).

2.4.3 Conclusions of 2014 WRF Model Performance

The model performance of the WRF/NAM and WRF/ERA5 simulations are reasonable and very similar for most meteorological variables (e.g., winds and temperature). This is in contrast to the WRAP-WAQS and EPA WRF 2014 simulations that had very different performance characteristics over New Mexico.¹⁹ The biggest difference in the performance of the two WRF simulations was for humidity and precipitation. The WRF/NAM simulation had a moist bias for June-August that is likely partly associated with overactive convective precipitation that was greater in WRF/NAM than WRF/ERA5. It is unclear whether the WRF/NAM overstated precipitation is due to overactive convective events when they occur, or having events occur when they are not observed.

From the meteorological model performance evaluation, it is not possible to determine which set of WRF meteorological inputs will produce better ozone model performance when used as meteorological inputs for CAMx. There are variations in spatial and temporal model performance that are difficult to estimate what effects they will have on ozone concentrations. Furthermore, there may be meteorological inputs (e.g., level of mixing) that are more important for ozone modeling than the parameters we have observed data to evaluate the meteorological model for (i.e., winds, temperature, humidity and precipitation). Although it appears that WRF/NAM overstates the monthly precipitation if that does not occur on high ozone days it may not matter to the ozone model performance.

CAMx was run for a portion of the summer of 2014 episode with meteorological inputs based on both the WRF/NAM and WRF/ERA5 simulations and the ozone estimates compared to determine which meteorological inputs performed best so were selected for use in the final CAMX 2014 36/12/4-km base case simulation. The meteorological diagnostic sensitivity tests using the CAMx photochemical model are described in Chapter 5.

¹⁹ https://www.wrapair2.org/pdf/NM_OAI_Study_Webinar1_2020-05-28.pdf

3. BOUNDARY CONDITION INPUTS

The Boundary Conditions (BCs) for the CAMx most outer 36-km 36US modeling domain lateral boundaries were based on output from a 2014 simulation of the GEOS-Chem global chemistry conducted by WRAP for their 2014v2 modeling platform.

3.1 WRAP 2014 GEOS-Chem Modeling

The WRAP-WAQS 2014v1 36/12-km CAMx and CMAQ base case simulations used BCs based on EPA's 2014 GEOS-Chem simulation that was used in EPA's 2014 modeling platform used in the 2014 National Air Toxics Assessment (NATA²⁰). The CAMx and CMAQ 2014v1 base case simulation and sensitivity modeling found that the BCs based on EPA's 2014 GEOS-Chem caused year-long ozone overestimation bias throughout the western U.S.²¹ Thus, WRAP conducted their own 2014 GEOS-Chem simulation using a newer version of the model and with updated emissions that resulted in much better CAMx ozone model performance without the systematic ozone over-prediction bias.²² Table 3-1 presents the WRAP 2014 GEOS-Chem model configuration.

Table 3-1. 2014 GEOS-Chem simulation model configuration used by WRAP whose output is used to define the 2014 day-specific diurnally varying BC inputs for the NM OAI Study photochemical modeling.

Science Options	WRAP 2014 GEOS-Chem Base Case
Version	Version 12.2.0 (release date: 2019-02-19)
Vertical Grid Mesh	72 Layers
Chemistry mechanism	GEOS-Chem standard chemistry with complex SOA option ²³ .
Horizontal Grids	2x2.5 degree (Nx, Ny = 144, 91)
Initial Conditions	6-month spin-up; starting from provided initial conditions for standard chemistry
Meteorology	2014 GEOS-FP meteorology
Photolysis mechanism	Default (FAST-J)
Advection Scheme	Default (TPCORE)
Cloud convection scheme	On / Relaxed Arakawa-Schubert
Planetary Boundary Layer mixing	On / non-local scheme implemented by Lin and McElroy
Dry deposition scheme	Default (Wesely)
Chemistry Solver	Default (FLEXCHEM)
Parallelization	Open Multi-Processing (OMP)

²⁰ <https://www.epa.gov/national-air-toxics-assessment>

²¹ http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx

²² https://www.wrapair2.org/pdf/WRAP_Shake-Out_Phase-III_Update_RTOWG_2019-09-10v3a.pptx

²³ We recommend turning off semivolatile primary organic aerosol (POA) chemistry and isoprene SOA reactions via the volatility-based scheme (VBS) [Pye et al., 2010] to avoid risk of double-counting in the complex SOA chemistry scheme. For more information, see <http://maraisresearchgroup.co.uk/Publications/GC-v11-02-SOA-options.pdf>

3.2 2014 GEOS-Chem Model Evaluation

The results of the WRAP 2014 GEOS-Chem simulation and CAMx sensitivity modeling using the new BCs can be found on the WAQS-WRAP2014v2 model evaluation webpage²⁴. Relevant for the NM OAI Study is the fact that this updated 2014 GEOS-Chem BCs do lead to better CAMx model performance for ozone concentrations and corrects a persistent year-long ozone overestimation bias that occurred using the previous 2014 GEOS-Chem simulation conducted by EPA and used in the EPA 2014 modeling platform. The NM OAI Study evaluated the use of the WRAP 2014 GEOS-Chem BCs for CAMx modeling at several sites in New Mexico and found good ozone performance that achieved ozone model performance goals.²⁵ Thus, the WAQS-WRAP 2014v2 BC inputs based on the WRAP 2014 GEOS-Chem simulation were used “as is” for the NM OAI Study.

²⁴ http://views.cira.colostate.edu/iwdw/docs/WRAP_WAQS_2014v2_MPE.aspx

²⁵ https://www.wrapair2.org/pdf/NM_OAI_Study_Webinar1_2020-05-28.pdf

4. 2014 AND 2028 EMISSION INPUTS

4.1 Summary of Emissions Used in 2014 and 2028 Modeling

The emissions inventories for the CAMx 2014 36/2/4-km base case modeling were based on the WRAP-WAQS 2014v2 emissions inventory. Within the 36-km 36US North American and 12-km 12WUS2 western U.S. domains, the WRAP-WAQS CAMx 2014v2 base case emission inputs were used without any changes.

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

For the NM OAI Study future year 2028 Base Case and 2028 New Mexico O&G Control Strategy, the emissions were based on the WRAP 2028OTBa2 emissions inventory with updated New Mexico O&G emissions and use of 2014 actual fires instead of the Representative Baseline fires. The 2028OTBa2 CAMx-ready emission inputs for the 36/12-km domains were used “as is”, substituting the 2014v2 actual 2014 fires for the Representative Baseline fires. For the 4-km NM domain, the 2028OTBa2 emissions were processed using SMOKE, with the new 2028 New Mexico (NM) oil and gas (O&G) emissions substituted for the NM O&G emissions used in the 2028OTBa2 emissions scenario.

The NM OAI Study 2028 O&G Control Strategy scenario used the exact same emissions as the NM OAI Study 2028 Base Case, only the controlled 2028 O&G emissions were used in New Mexico. The 2028 NM O&G Control Strategy oil and gas emissions were provided by ERG under separate contract to NMED.

4.2 Development of CAMx 2014 Base Case Emission Inputs

The CAMx 2014 base case emission inputs for the 36/12-km domains were based on the WRAP 2014v2 CAMx model-ready emission inputs and were used “as is.” For the 4-km NM domain, the New Mexico emissions from the 2014v2 database were reviewed and updated by the NMED. The 2014v2 emissions for New Mexico and portions of surrounding states within the 4-km New Mexico domain were then processed by the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (UNC, 2015). SMOKE version 4.7 was used, which was released in October 2019.²⁶

4.2.1 Day-Specific On-Road Mobile Source Emissions

The 2014 on-road mobile source emission inputs for the 4-km New Mexico domain were generated using the SMOKE-MOVES emissions model. SMOKE-MOVES used a 2014 mobile source emission factor (EF) lookup table generated by the Motor Vehicle Emission Simulator (MOVES2014²⁷) model (EPA, 2014a,b,c). The SMOKE-MOVES default county-level 2014 vehicle activity data for New Mexico was 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 (see Chapter 2) and 2014 county-level activity data (e.g., vehicle miles travelled

²⁶ <https://www.cmascenter.org/smoke/>

²⁷ <https://www.epa.gov/moves/moves-onroad-technical-reports#moves2014>

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

4.2.2 Point Source Emissions

2014 point source emissions were based on the WRAP-WAQS 2014v2 emissions inventory. The 2014v2 New Mexico point source emissions were reviewed and updated by NMED. Point sources were 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 SO₂ emissions were used for the 2014 base case emissions scenario. The VOC, CO, and PM emissions for point sources with CEM data were based on the annual emissions data in the 2014v2 inventory temporally allocated to each hour of the year using the CEM hourly heat input.

4.2.3 Area and Non-Road Source Emissions

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

4.2.4 Episodic Biogenic Emissions

Two different CAMx 2014 base case simulations were conducted using two different biogenic emission inputs within the 4-km NM domain. The first CAMx 2014 base case 4-km domain biogenic emissions were generated using Version 3.1 of the MEGAN biogenic emissions model. MEGAN v3.1 is a new version of MEGAN and comes with a Leaf Area Index (LAI) database that defines the vegetative biomass and type that when combined with temperature and light dependent emission factors produces biogenic VOC emissions using the day-specific hourly gridded WRF meteorology. However, the new LAI data in MEGAN v3.1 were missing for urban areas producing “holes” in the biogenic VOC emission inputs. Thus, revised CAMx 2014v2 base case 4-km NM biogenic emission inputs used the BEIS v3.7 biogenic emissions model. BEIS3.7 is the most recent version of BEIS released by EPA in October 2020. BEIS3.7 uses updated biomass and emissions factors, and the Biogenic Emissions Landcover Database version 5 (BELD5). Table 4-1 compares the biogenic NO_x and VOC emissions by month (in tons/month) for the 4-km NM domain and the two biogenic models. The BEIS NO_x emissions are substantially lower than MEGAN, and VOC emissions are mostly lower except early summer month showing slightly higher emissions with BEIS. Figure 4-1 displays the spatial distributions of emissions in the 4-km NM domain expressed as episode average tons per day. The BEIS NO_x and VOC emissions are mostly lower than MEGAN throughout the domain. The missing biogenic VOC emissions in urban areas (e.g., El Paso/Juarez) using MEGAN v3.1 is also evident in the spatial maps.

Table 4-1. 2014 biogenic emissions (tons/month) in the 4-km NM domain estimated by MEGAN3.1 and BEIS3.7.

Tons/month		MEGAN	BEIS	% Diff (BEIS-MEGAN)
NO_x	May	35,050	10,602	-69.8%
	Jun	42,445	13,134	-69.1%
	Jul	51,639	12,838	-75.1%
	Aug	41,002	11,923	-70.9%
VOC	May	128,323	159,809	24.5%
	Jun	267,055	256,379	-4.0%
	Jul	317,697	251,562	-20.8%
	Aug	354,570	216,032	-39.1%

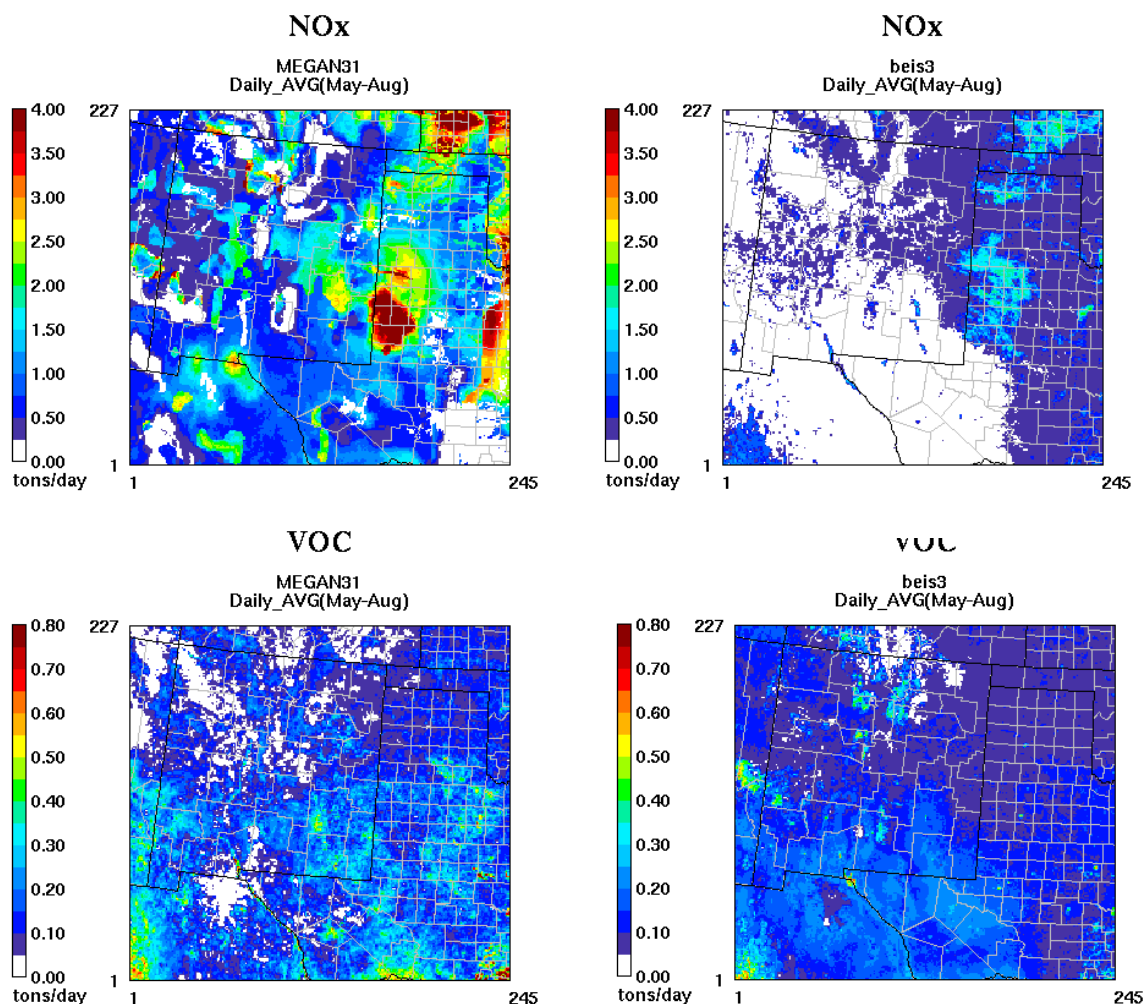


Figure 4-1. Spatial distribution of NO_x (top panel) and VOC (bottom panel) biogenic emissions (episode average tons per day) in the 4-km NM domain estimated by MEGAN3.1 (left) and BEIS3.7 (right).

4.2.5 Wildfires, Prescribed Burns, Agricultural Burns

2014 emissions from open-land burning including wildfires, wildland prescribed burns and agricultural burning were based on the WRAP-WAQS 2014v2 emissions inventory. The WRAP Fire and Smoke Work Group (FSWG²⁸) processed the 2014NEIv2 Bluesky/SMARTFIRE fire emissions for the U.S. and classified them as either wildfires (WF), wildland prescribed burns (Rx) or agricultural burning (Ag) and made other updates for the 2014v2 inventory. The 2014NEIv2 fire emissions for Mexico and Canada were used without any changes. Table 4-2 displays NO_x and VOC emissions by month and fire type within the 4-km NM domain. Figure 4-2 displays spatial maps of NO_x emissions from 2014 summer fires for the 4-km NM domain. Emissions are expressed as episode average tons per day per grid cell. We see some hotspots on the wildfires plot in New Mexico and Arizona near the western boundary of the 4-km domain.

²⁸ <https://www.wrapair2.org/FSWG.aspx>

Table 4-2. 2014 fire emissions summary (tons/month) by fire type for the 4-km NM domain

Tons/month	Pollutant	Ag fires	Prescribed fires	Wildfires	Mexico fires
NO _x	May	36	90	597	49
	Jun	11	81	1,056	32
	Jul	18	13	332	8
	Aug	18	69	39	2
VOC	May	60	617	6,663	92
	Jun	18	736	17,641	187
	Jul	29	82	4,985	40
	Aug	28	1,376	371	13

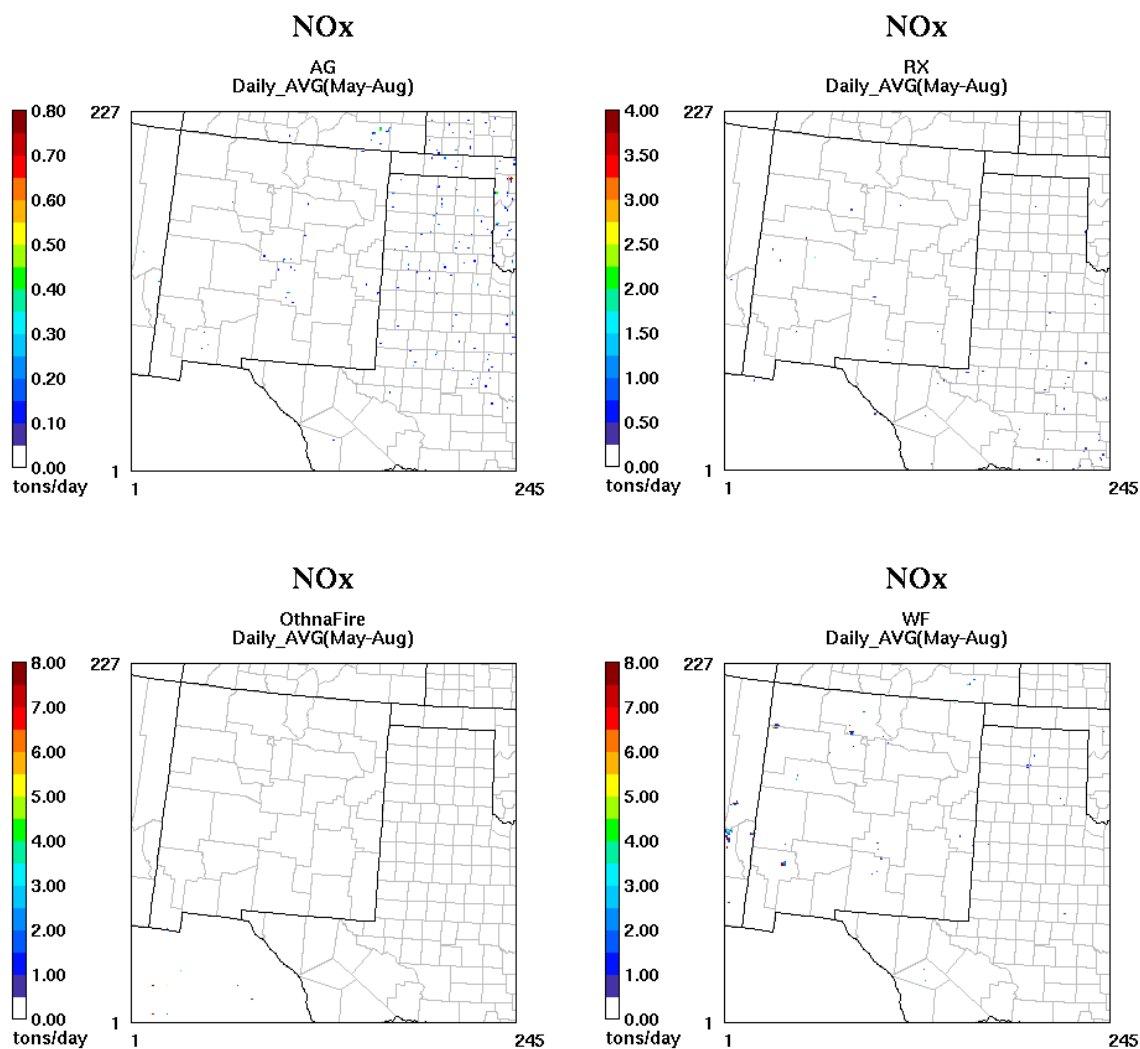


Figure 4-2. Spatial distribution of agricultural fires, prescribed fires, wildfires and Mexico fires (clockwise starting from top left) NO_x emissions (episode avg tons per day) for New Mexico 4-km domain.

4.2.6 Other Natural Emissions

Lightning NO_x (LNO_x), and windblown dust (WBD) emissions were generated for the 4-km domain using special CAMx processors and WRF 2014 meteorological data. Oceanic emissions such as sea salt spray aerosol (SSA) and dimethyl sulphide (DMS) were not generated for the 4-km New Mexico domain since this domain does not include any ocean within it. However, the LNO_x, WBD and oceanic emissions for the 36-km and 12km were based on the WRAP-WAQS 2014v2 emissions and were included in the modeling.

4.2.7 2014 Emission Results

Table 4-3 summarizes the 2014 criteria air pollutant emissions in episode average short tons per day by source category for the 4-km New Mexico domain. These data represent the model-ready emissions input to the CAMx air quality model for the 2014

base case. Mostly, emissions are summarized from the SMOKE reports generated by the SMKMRG program. There are a couple of exceptions to this general approach, fugitive dust and EGU sources. The fugitive dust emissions were adjusted after SMOKE processing to account for fugitive dust correction factors that are derived from the Biogenic Emission Landuse Database version 4 (BELD4). The correction factors are necessary to account for dust removal due to local vegetation scavenging so are not transported downwind. Model-ready emissions for EGU and Mexico point sources were obtained from WRAP/WAQS 2014 platform so were summarized for the 4-km domain outside of SMOKE.

Table 4-3. 2014 base case anthropogenic emissions summary (episode average short tons per day) by source category for the 4-km New Mexico domain.

Country/ Category	Source Category	CO	NH ₃	NO _x	PM _{2.5}	PM ₁₀	SO ₂	VOC
US Anthro	Area fugitive dust	0.0	0.0	0.0	253.3	1,788.2	0.0	0.0
	Agricultural ammonia sources	0.0	764.7	0.0	0.0	0.0	0.0	43.4
	Non-point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)	237.7	0.0	157.8	4.4	4.4	11.3	567.3
	Remaining Non-point Oil and Gas	286.8	0.0	311.7	6.9	6.9	30.0	1,642.5
	Residential Wood Combustion	7.0	0.1	0.1	0.5	0.5	0.0	1.2
	Other nonpoint sources	141.3	1.5	28.5	9.3	13.4	4.5	213.2
	On-road mobile	1,476.2	6.0	444.5	13.2	20.1	1.7	150.6
	Locomotive	22.9	0.1	122.7	2.9	3.1	0.1	6.2
	Non-road mobile	570.3	0.2	133.4	9.0	9.4	0.3	73.2
	EGU point sources	89.2	3.4	210.6	12.9	17.8	160.0	5.0
	Point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)	89.9	0.0	114.7	1.4	1.4	23.8	56.1
	Remaining Point Oil and Gas	113.8	0.1	205.2	3.2	3.3	27.1	48.4
	Non-EGU point sources	74.4	4.9	47.5	11.4	32.5	49.3	24.4
Mexico Anthro	Mexico area	19.9	33.2	42.2	5.8	15.7	1.7	103.3
	Mexico on-road mobile	356.3	0.6	98.4	1.5	2.6	1.4	34.4
	Mexico point sources	28.4	0.7	20.2	4.8	5.7	16.4	8.3

Figure 4-3 presents pie charts showing VOCs and NO_x emissions from anthropogenic sources by source category for New Mexico and portion of surrounding states within the 4-km domain. Point and non-point oil and gas sectors account for majority of NO_x emissions followed by on-road mobile and EGU sources. In New Mexico, oil and gas sources are the largest anthropogenic VOC emitters and accounts for nearly 80% of 4-km domain VOC emissions.

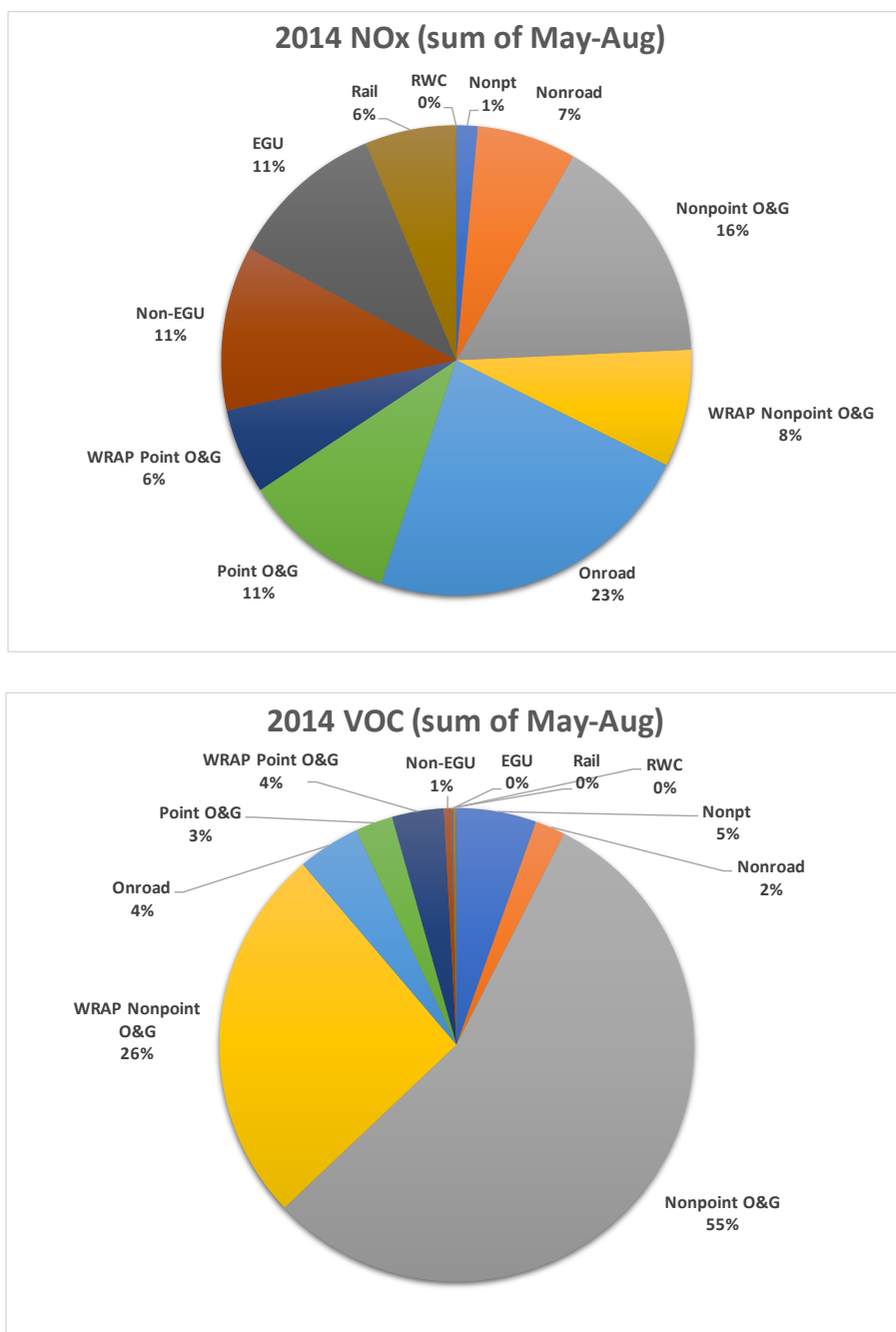


Figure 4-3. New Mexico 2014 base case anthropogenic NO_x and VOC emissions by source category.

Figure 4-4 displays spatial maps of NO_x and VOC anthropogenic emissions from the oil and gas sector across the 4-km New Mexico domain. Top panel shows emission maps for non-point O&G sources while bottom panel shows point O&G sources. The San Juan and Permian basins are clearly visible on the emissions map and confirm correct spatial allocation of oil and gas emissions. Figure 4-5 shows emission maps for on-road mobile (top panel), rail (middle panel) and non-point sources including non-road equipment (bottom panel).

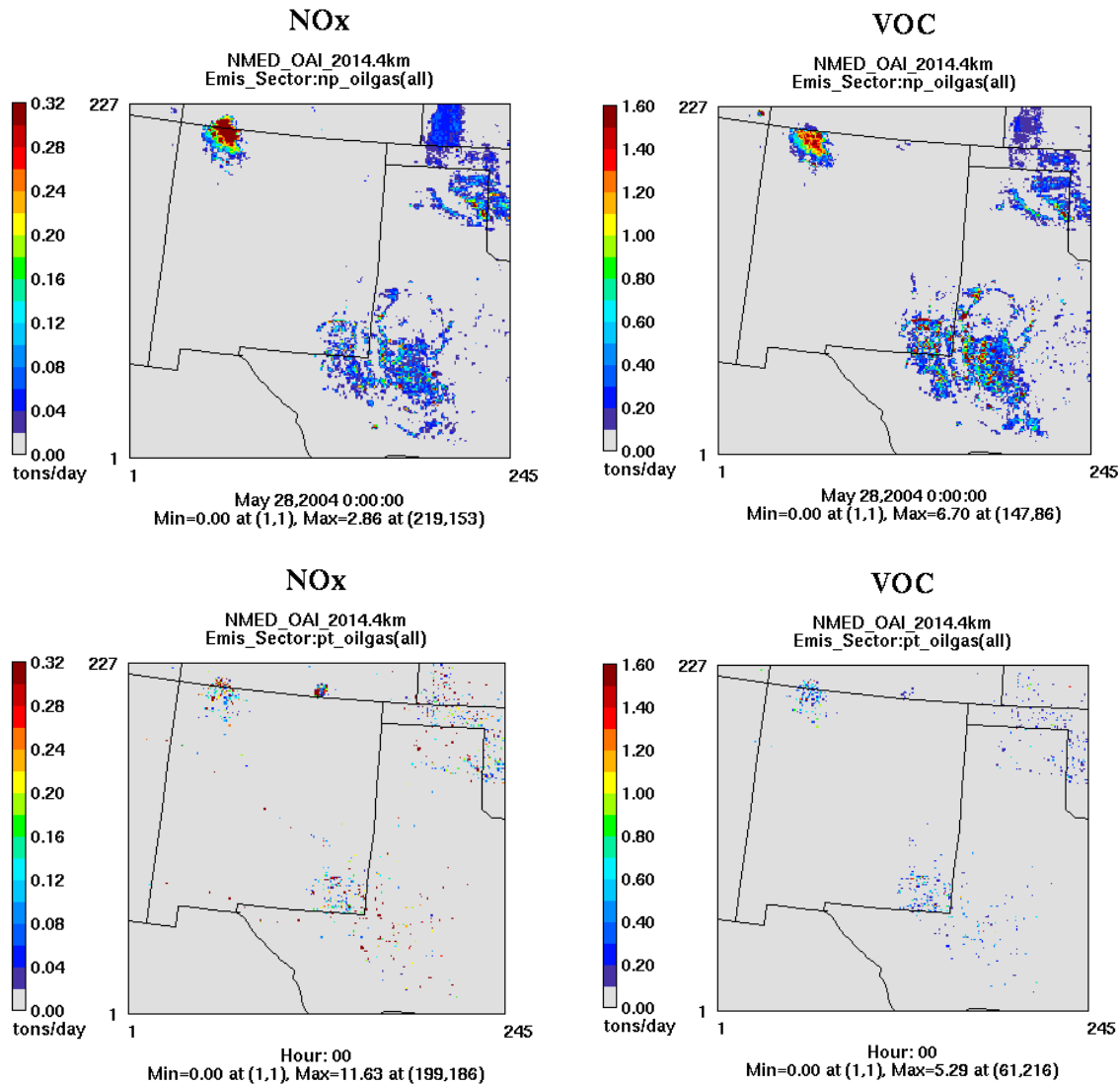


Figure 4-4. Spatial distribution of the non-point (top) and point (bottom) source oil and gas NO_x (left) and VOC (right) emissions (episode avg tons per day) for New Mexico 4-km domain.

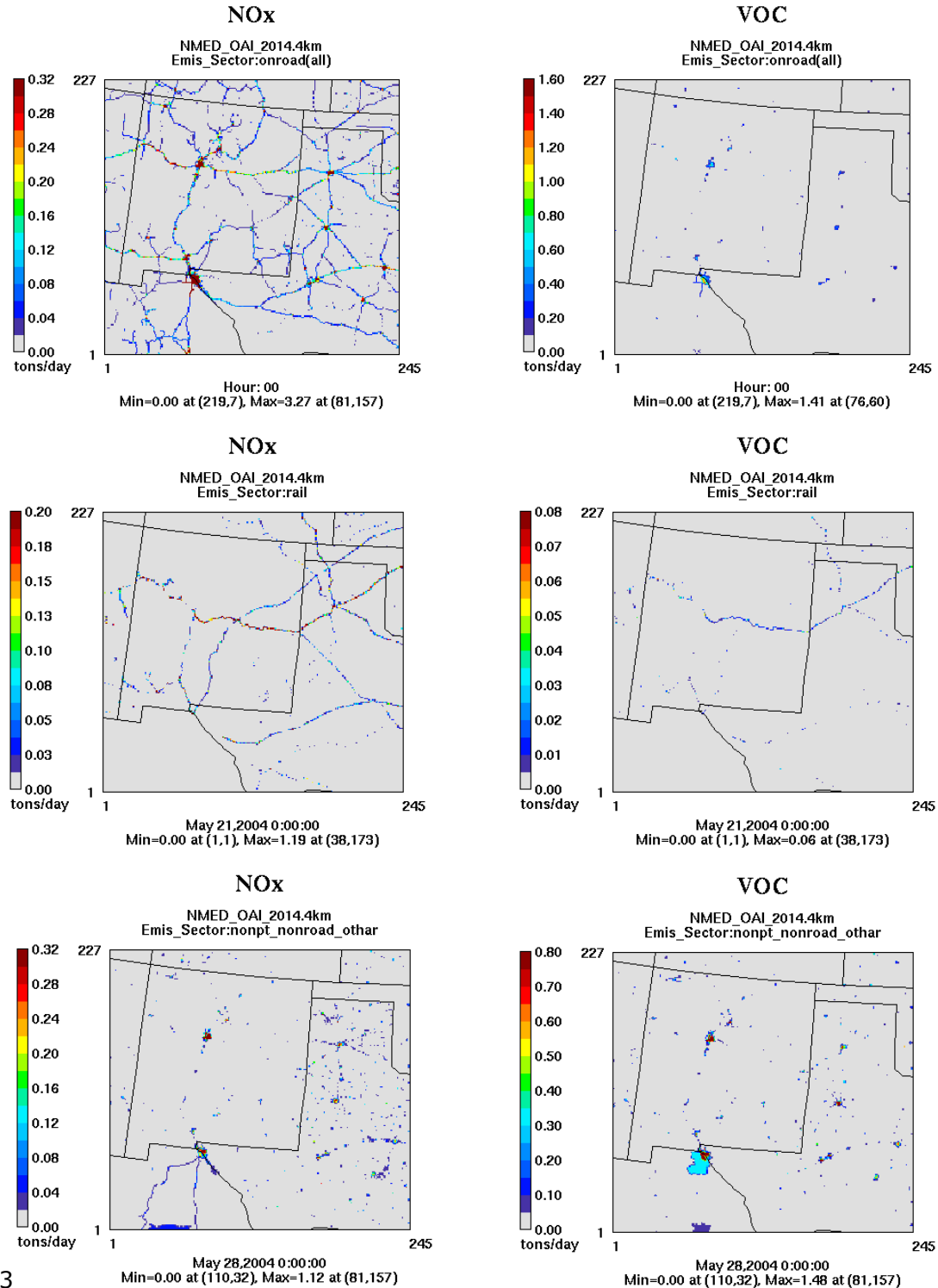


Figure 4-5. Spatial distribution of on-road (top), rail (middle) and non-point/non-road equipment (bottom) NO_x (left) and VOC (right) emissions (episode avg tons per day) for New Mexico 4-km domain.

4.3 Development of CAMx 2028 Emission Scenarios

The NM OAI Study 2028 base case and 2028 O&G Control Strategy emissions were based on the WRAP 2028OTBa2 emissions inventory with updates to NM O&G emissions and using 2014 actual fires. Details on the 2028OTBa2 emission assumptions are contained in the WRAP Representative Baseline (RepBase2) and 2028 On-the-Books (2028OTBa2) CAMx Simulation Run Specification Sheet.²⁹ The original WRAP 2028OTBa emissions scenario used EPA's 2028 emission projections from their 2016v1 modeling platform³⁰ for several source sectors (e.g., non-EGU Point Sources). However, some of EPA's 2028 emission projections were inconsistent with the WRAP 2014v2 emission updates for the western states and there were double counted sources in EPA's 2016v1 platform 2028 emission projections. Thus, WRAP elected to use more source sector emissions from the EPA 2016v1 and WRAP 2014v2 emissions inventories that were vetted by many states resulting in the following source sectors used in the 2028OTBa2 emissions inventory with deviations from the WRAP 2028OTBa2 from the NM OAI Study 2028 base case discussed below (see details in Run Specification Sheet cited in footnote):

- The California Air Resources Board provided 2028 emissions for California and all source sectors.
- 2028 emissions for Electrical Generating Units (EGU) for fossil-fueled EGUs in WRAP states were reviewed in detail by the individual states starting from the results of the WRAP EGU Analysis Project.³¹ 2028 emissions for Non-fossil-fueled EGU in the WRAP region and all EGUs outside of the WRAP region were based on EPA's 2016v1 modeling platform 2028 projections.
- 2028 O&G emissions for New Mexico were based on new estimates developed in the NM OAI Study as described later in this chapter. 2028 O&G emissions for other non-New Mexico WRAP region O&G basins are based on the WRAP projections out to 2023 (Ramboll, 2020a). The EPA 2016v1 platform 2016 O&G emissions were used for non-WRAP states. The 2028OTBa2 O&G emissions were reviewed in detail by WRAP region states to eliminate duplications and update sources as needed.
- Non-EGU Point Source emissions for the WRAP states were reviewed in detail by the individual states starting from the WRAP 2014v2 emissions, while the EPA 2016v1 platform emissions for 2016 were used for non-WRAP states.
- The SMOKE-MOVES model with 2014 meteorology, 2028 vehicle activity and 2028 MOVES2014 Emissions Factor Look-Up tables were used to generate 2028 on-road mobile source emissions by either WRAP³² for the 12-km domain or the NM OAI Study for the 4-km domain.
- 2028 Non-road emissions were based on 2028 estimates by WRAP in the Mobile Source Emissions Inventory Projection Project for the WRAP region and EPA's 2028 estimates for the non-WRAP states.

²⁹

https://views.cira.colostate.edu/docs/iwdw/platformdocs/WRAP_2014/EmissionsSpecifications_WRAP_RepBase2_and_2028_OTBa2_RegionalHazeModelingScenarios_Sept30_2020.pdf

³⁰ <https://www.epa.gov/air-emissions-modeling/2016v1-platform>

³¹ <https://www.wrapair2.org/EGU.aspx>

³² WRAP Mobile Source Emissions Inventory Projections Project

- WRAP region 2014v2 and EPA 2016v1 emissions were used for the Non-Point source sector in the 2028OTBa2 emissions scenario.
- The NM OAI Study 2028 fires were based on the WRAP region 2014v2 actual fire estimates.
- Natural emissions (biogenic, lighting NO_x, windblown dust and oceanic) were the same as used in the WRAP 2014v2, RepBase2 and 2028OTBa2 emission scenarios

4.3.1 2028 Base Case New Mexico Oil and Gas Emissions

A circa 2028 forecast oil and gas (O&G) emission inventory was developed for New Mexico for use in the NM OAI Study 2028 Base Case emission scenario. The basis of the forecast O&G emission inventory is circa 2028 O&G activity estimates provided by BLM³³ and emissions and emission per unit of O&G activity from the future year WRAP Oil and Gas Working Group (OGWG) emission inventory (Ramboll, 2020a). The WRAP OGWG developed 2023 future year O&G emissions for 7 of the WRAP states.

The 2028 New Mexico O&G emission inventory includes wellsite, gathering, and processing subsectors, which are items 1, 5, and 6 in Figure 4-6. Item 1 are On-Shore Petroleum and Natural Gas Production is referred to as “wellsite” sources; emissions from wellsite sources are classified as nonpoint sources. Item 2 are Gathering and Boosting sources. Item 6 consists of Gas Processing Plants are collectively referred to as “midstream” sources; emissions from midstream sources are classified as point sources. The classification of well-site emissions as nonpoint and midstream emissions as point sources is consistent with other O&G emission inventory classifications used in prior studies, such as the BLM Colorado Air Resource Management Modeling Study (CARMMS)³⁴.

³³ Email communication from BLM Staff (Forrest Cook) to Ramboll (John Grant). September 15, 2020.

³⁴ <https://www.blm.gov/programs/natural-resources/soil-air-water/air/colorado>

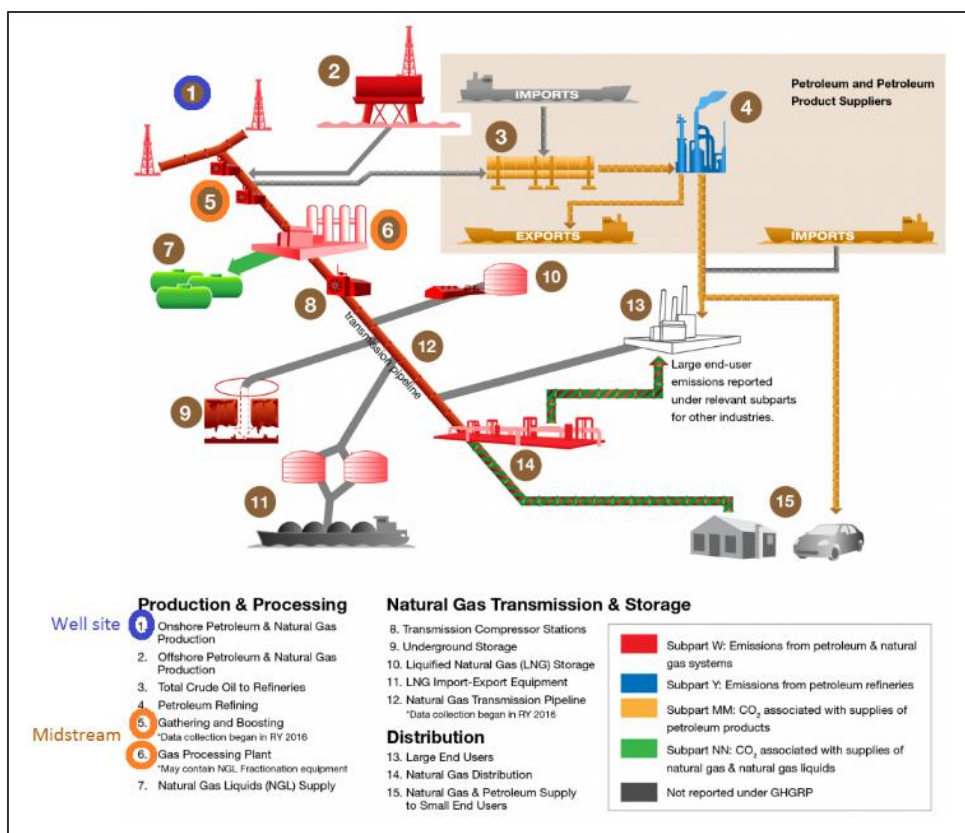


Figure 4-6. Example Petroleum and Natural Gas Industry schematic³⁵.

The BLM O&G forecast factors were used to project New Mexico O&G emissions to 2028. Table 4-4 compares the New Mexico O&G VOC and NO_x activity for the WRAP 2014 and 2023 scenarios with the NM OAI Study 2028 base case activity based on BLM forecasts. With the exception of spud count, the 2028 NM O&G activity is greater than 2014.

A comparison of the WRAP OGWG 2014 and 2023 New Mexico O&G emissions with the 2028 values from the NM OAI Study are given in Table 4-5. Across New Mexico, 2028 O&G NO_x and VOC emissions are, respectively, 29% and 15% higher than in 2014. In the Permian Basin, New Mexico 2028 O&G NO_x emissions are 64% higher than 2014, with VOC emissions 19% higher. The 2028 and 2014 New Mexico O&G emissions in the San Juan Basin are more comparable, with 2028 NO_x and VOC emissions, respectively, 1% and 10% higher than 2014.

³⁵ Source: <https://www.epa.gov/ghgreporting/ghgrp-and-oil-and-gas-industry>, accessed in April 2020.

Table 4-4. Comparison of WRAP OGWG 2014 and 2023 New Mexico O&G emissions used in the 2014v2 and 2028OTBa2 scenarios with the NM OAI study 2028 base case New Mexico O&G emissions based on BLM forecast.

Activity Metric	WRAP OGWG		BLM Forecast
	2014	2023	Circa- 2028
Permian Basin (NM)			
Oil Production (million bbl)	119	276	166
Gas Production (BCF)	508	1,190	790
Well Count	28,615	27,335	40,478
Spud Count	1,178	651	794
San Juan Basin (NM)			
Oil Production (million bbl)	6	7	7
Gas Production (BCF)	713	440	1,138
Well Count	21,687	19,604	23,073
Spud Count	146	64	94
Las Vegas-Raton Basin (NM)			
Oil Production (million bbl)	0	0	0
Gas Production (BCF)	24	24	20
Well Count	835	835	835
Spud Count	0	0	0
Sierra Grande Uplift (NM)			
Oil Production (million bbl)	0	0	0
Gas Production (BCF)	0.02	0.02	0.27
Well Count	1	1	8
Spud Count	34	34	0.4

Table 4-5. Comparison of WRAP OGWG 2014 and 2023 NO_x and VOC New Mexico O&G emissions with the NM OAI Study 2028 base case.

Pollutant	WRAP OGWG		NMED OAI EI
	2014	2023	2028
New Mexico State Total			
NO _x	81,188	93,719	104,955
VOC	185,269	226,032	213,073
Permian , NM			
NO _x	35,251	52,074	57,922
VOC	97,977	149,609	116,896
San Juan , NM			
NO _x	44,730	39,789	45,200
VOC	86,567	75,670	95,500
Estancia Basin , NM			
NO _x	113	645	645
VOC	5	26	26
Orogrande Basin , NM			
NO _x	541	548	548
VOC	28	30	29
Raton , NM			
NO _x	8	8	6
VOC	646	646	600
Pedregosa Basin , NM			
NO _x	262	373	373
VOC	6	9	9
Basin-And-Range Province , NM			
NO _x	261	261	261
VOC	10	11	11
Sierra Grande Uplift , NM			
NO _x	23	23	0
VOC	31	31	2

4.4 Summary of 2014 and 2028 Base Case Emissions

Tables 4-6 through 4-8 summarizes the total emissions in New Mexico for the 2014 and 2028 base case emission scenarios and their differences. Graphical comparisons of the changes in NO_x and VOC emissions between 2014 and 2028 base cases are shown in, respectively, Figures 4-7 and 4-8. And the distribution of NO_x and VOC emissions across source sectors are shown in Figures 4-9 and 4-10, respectively. Total NO_x emissions in New Mexico are estimated to be reduced by -28% between 2014 and 2028 with the largest reductions coming from on-road mobile (-72%), EGU point (-69%) and non-road mobile (-51%) source sectors (Table 4-6 and Figure 4-7). These NO_x emission reductions were offset somewhat by increases in O&G point (+40%) and non-point (+36%) source sectors. Although there are large reductions in on-road (-61%) and non-road (-49%) mobile source VOC emissions between 2014 and 2028 base cases, the total reduction in New Mexico VOC emissions between 2014 and 2028 is only -6% because non-point O&G dominates (~75%; Figure 4-10) anthropogenic VOC emissions in New Mexico and they are only reduced by -5%.

Table 4-6. Summary of total emissions (tons/year) in New Mexico for the 2014 base case emissions scenario.

Category	CO	NH ₃	NO _x	PM _{2.5}	PMC	SO ₂	VOC
Fugitive Dust	0	0	0	31,152	188,801	0	0
Agricultural	0	28,774	0	0	0	0	2,825
Non-Point	23,039	262	5,934	1,561	794	937	28,621
Non-Road	77,821	13	7,334	548	40	18	9,397
O&G Non-Point	76,949	0	45,476	1,362	0	4,129	321,608
On-Road	246,144	939	75,861	2,194	1,042	252	26,275
O&G Point	23,458	0	31,125	436	0	8,623	40,744
EGU Point	11,309	422	43,071	1,507	650	11,911	429
Non-EGU Point	5,479	54	3,829	592	1,577	308	2,043
Rail	3,527	11	20,114	490	52	12	1,033
RWC	1,375	10	23	93	0	4	214
Total	469,102	30,485	232,766	39,935	192,956	26,194	433,188

Table 4-7. Summary of total emissions (tons/year) in New Mexico for the 2028 base case emissions scenario.

Category	CO	NH ₃	NO _x	PM _{2.5}	PMC	SO ₂	VOC
Fugitive Dust	0	0	0	31,152	188,801	0	0
Agricultural	0	28,774	0	0	0	0	2,825
Non-Point	23,039	262	5,934	1,561	794	937	28,621
Non-Road	69,460	15	3,618	244	24	11	4,767
O&G Non-Point	106,267	0	61,987	1,989	0	21,789	304,635
On-Road	111,251	821	21,610	688	1,178	143	10,311
O&G Point	37,205	0	43,480	706	55	11,912	53,212
EGU Point	7,173	301	13,389	1,292	755	3,385	256
Non-EGU Point	5,479	54	4,126	592	1,577	639	2,043
Rail	3,845	12	14,493	300	11	14	603
RWC	1,375	10	23	93	0	4	214
Total	365,093	30,248	168,661	38,617	193,195	38,834	407,488

Table 4-8. Percent differences in total New Mexico emissions between the 2014 and 2028 emission scenarios.

Category	CO	NH ₃	NO _x	PM _{2.5}	PMC	SO ₂	VOC
Fugitive Dust				0%	0%		
Agricultural		0%					0%
Non-Point	0%	0%	0%	0%	0%	0%	0%
Non-Road	-11%	17%	-51%	-56%	-41%	-37%	-49%
O&G Non-Point	38%		36%	46%	-98%	428%	-5%
On-Road	-55%	-13%	-72%	-69%	13%	-43%	-61%
O&G Point	59%		40%	62%		38%	31%
EGU Point	-37%	-29%	-69%	-14%	16%	-72%	-40%
Non-EGU Point	0%	0%	8%	0%	0%	107%	0%
Rail	9%	9%	-28%	-39%	-78%	9%	-42%
RWC	0%	0%	0%	0%	0%	0%	0%
Total	-22%	-1%	-28%	-3%	0%	48%	-6%

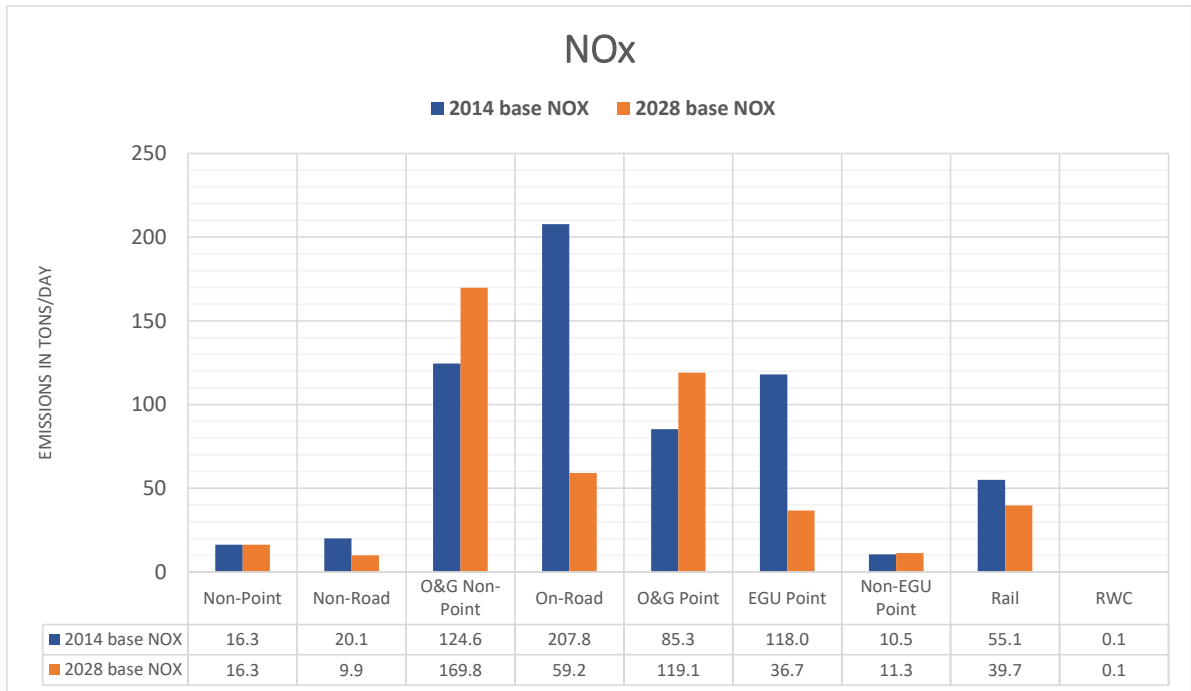


Figure 4-7. Comparison of 2014 and 2028 New Mexico NO_x emissions by source sector.

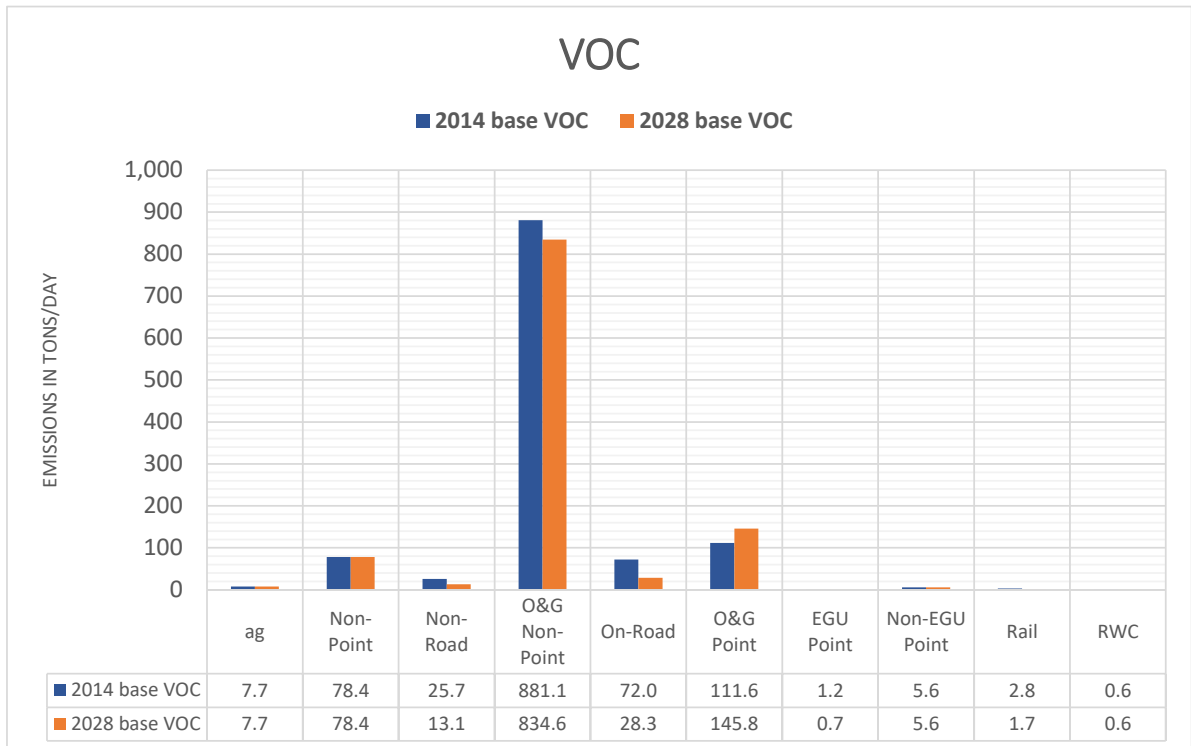


Figure 4-8. Comparison of 2014 and 2028 New Mexico NO_x emissions by source sector.

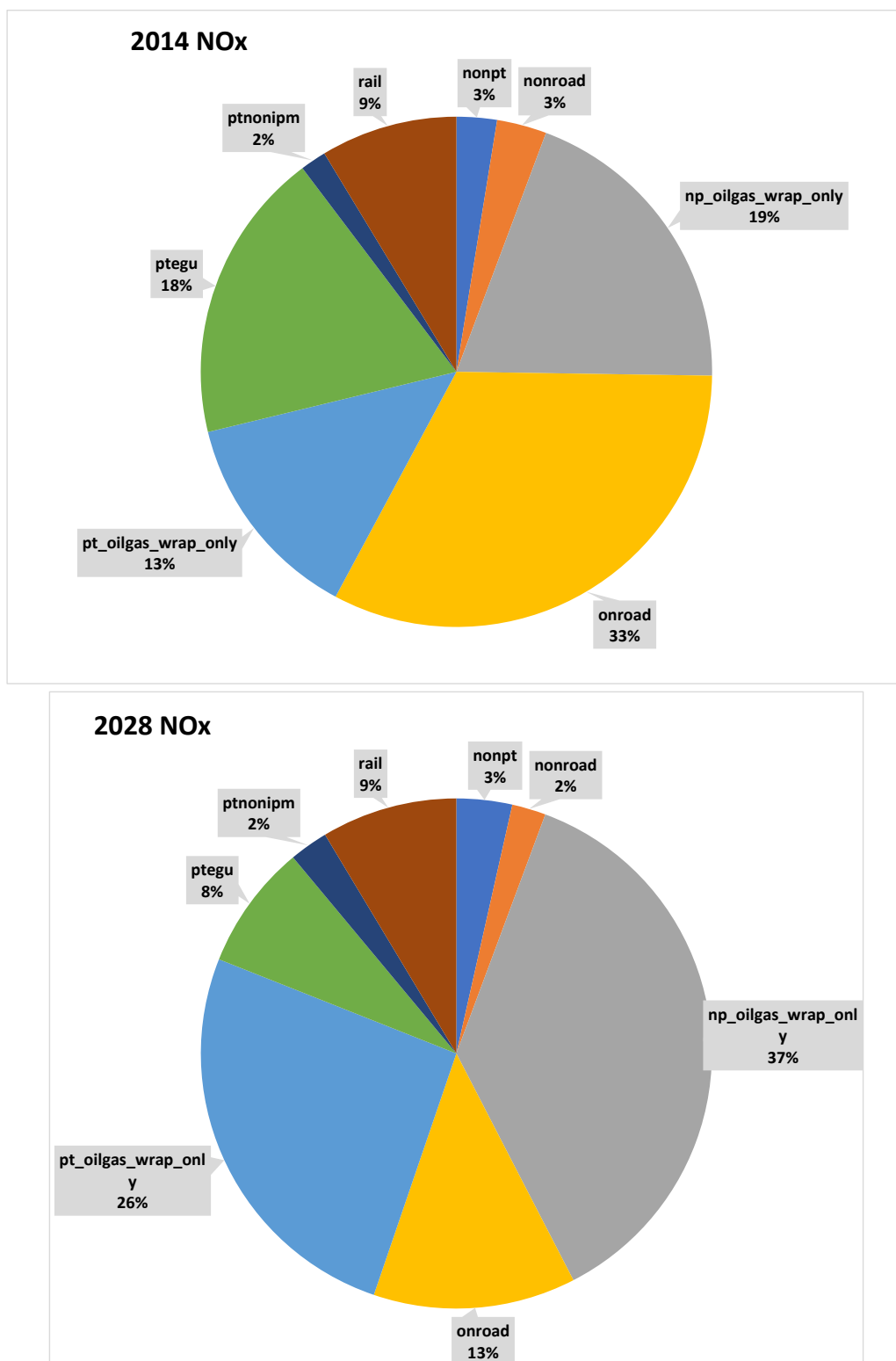


Figure 4-9. Distribution of New Mexico NO_x emissions across source sectors for the 2014 (top) and 2028 (bottom) base cases.

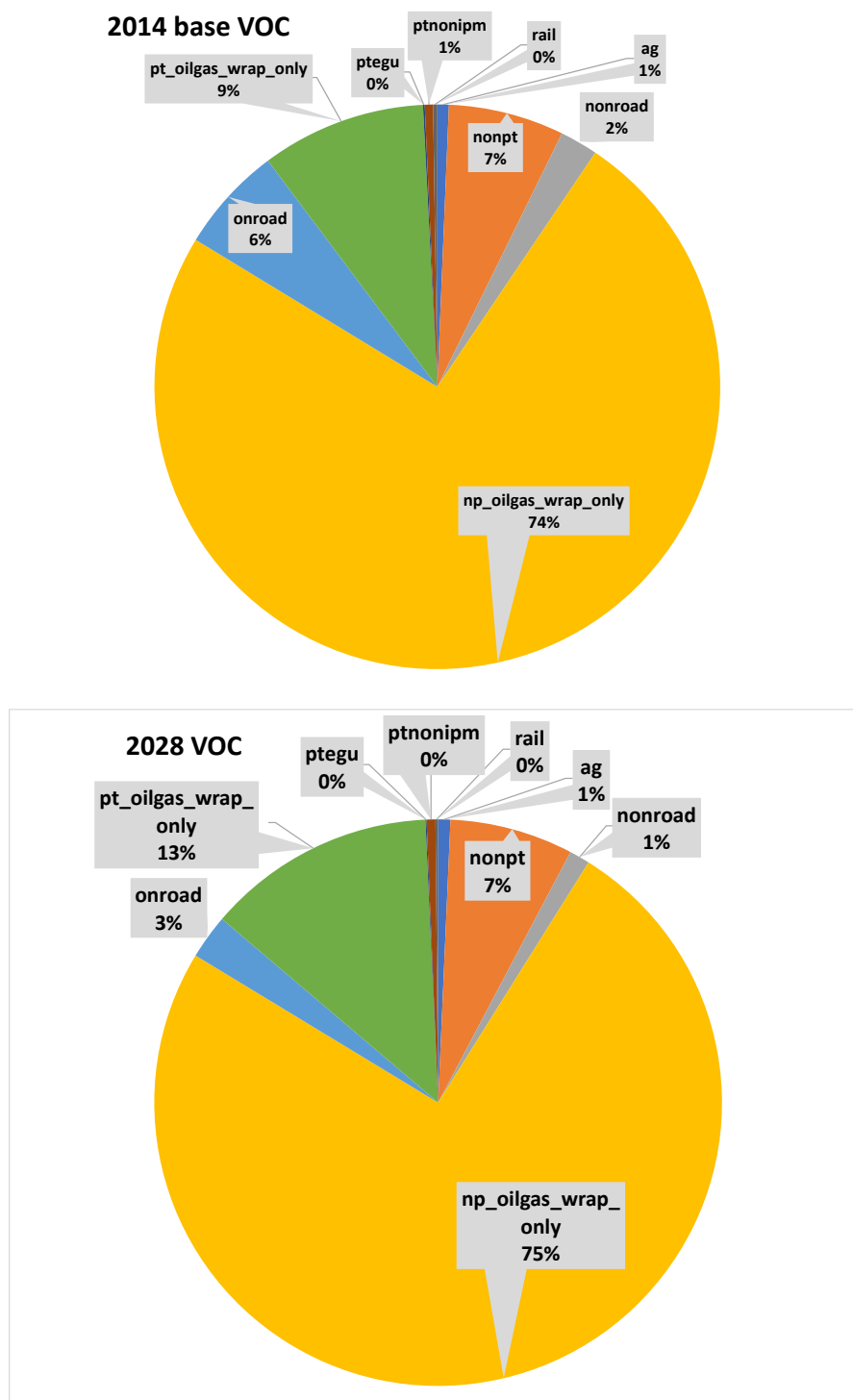


Figure 4-10. Distribution of New Mexico VOC emissions across source sectors for the 2014 (top) and 2028 (bottom) base cases.

4.5 2028 New Mexico Oil and Gas Control Strategy

The WESTAR/Ramboll Team provided the New Mexico 2028 O&G base case emissions to the NMED. The Eastern Research Group (ERG) under separate contract with NMED implemented the emission controls in the 2028 NM O&G emissions based on their interpretation of the proposed New Mexico "Ozone Precursor Rule for Oil and Natural Gas Sector."³⁶ The 2028 O&G Control Strategy reduced O&G emissions in 7 counties in New Mexico.

The 2028 NM O&G controlled emissions were processed by SMOKE and substituted for the 2028 NM O&G Base Case emissions to create the 2028 O&G Control Strategy emissions scenario. The only difference between the NM OAI Study 2028 Base Case and 2028 O&G Control Strategy were the controls on O&G emissions in New Mexico as implemented by ERG.

Table 4-9 displays the New Mexico state-wide O&G emissions for the 2028 Base Case and 2028 O&G Control Strategy. State-wide O&G NO_x emissions are reduced approximately -45% with similar reductions from both the Point and Non-Point source sectors. State-wide O&G VOC emission reductions are reduced approximately -50% with more reductions coming from the Non-Point (-53%) than Point (-35%) source sectors.

Table 4-9. New Mexico NO_x and VOC O&G emissions (tons per year) for the 2028 Base Case and 2028 NM O&G control strategy.

Source Sector	NO _x Emissions (TPY)			VOC Emissions (TPY)		
	Base	Control	Diff	Base	Control	Diff
Non-Point	61,245	33,144	-46%	181,252	85,564	-53%
Point	41,066	22,872	-44%	30,340	19,608	-35%
Total	102,311	56,016	-45%	211,592	105,172	-50%

Figures 4-11 and 4-12 display the changes in, respectively, NO_x and VOC emissions in the Permian and San Juan Basins between the 2028 base and 2028 control cases. In the Permian Basin, O&G NO_x emissions are estimated to be reduced by approximately 21,000 TPY (64%). In the San Juan Basin, O&G NO_x emissions are estimated to be reduced by approximately 25,000 TPY (44%). 2028 VOC O&G emissions in the Permian and San Juan Basins are estimated to be reduced by approximately 53,000 TPY each (-46% and -55% reduction, respectively).

Figure 4-13 shows the spatial distribution of the differences Non-Point and Point O&G NO_x and VOC emissions between the 2028 Base Case and 2028 O&G Control Strategy scenario. The O&G emission reductions are restricted to the New Mexico portions of the San Juan and Permian Basins.

³⁶ <https://www.env.nm.gov/new-mexico-methane-strategy/wp-content/uploads/sites/15/2020/07/Draft-Ozone-Precursor-Rule-for-Oil-and-Natural-Gas-Sector-Version-Date-7.20.20.pdf>

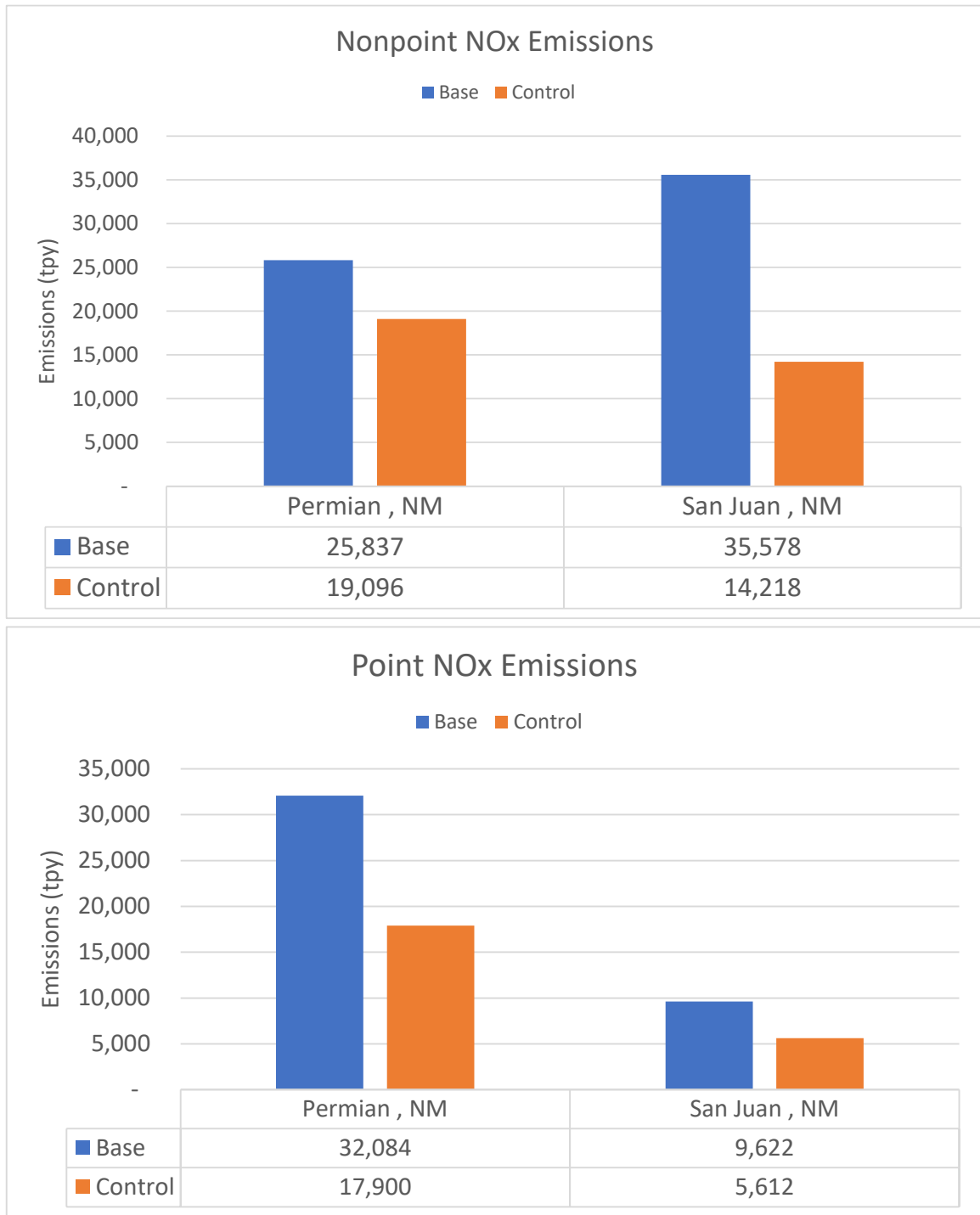


Figure 4-11. Comparison of 2028 Base Case and 2028 NM O&G control strategy NO_x emissions for the Non-Point (top) and Point (bottom) source sectors and the Permian (left) and San Juan (right) basins.

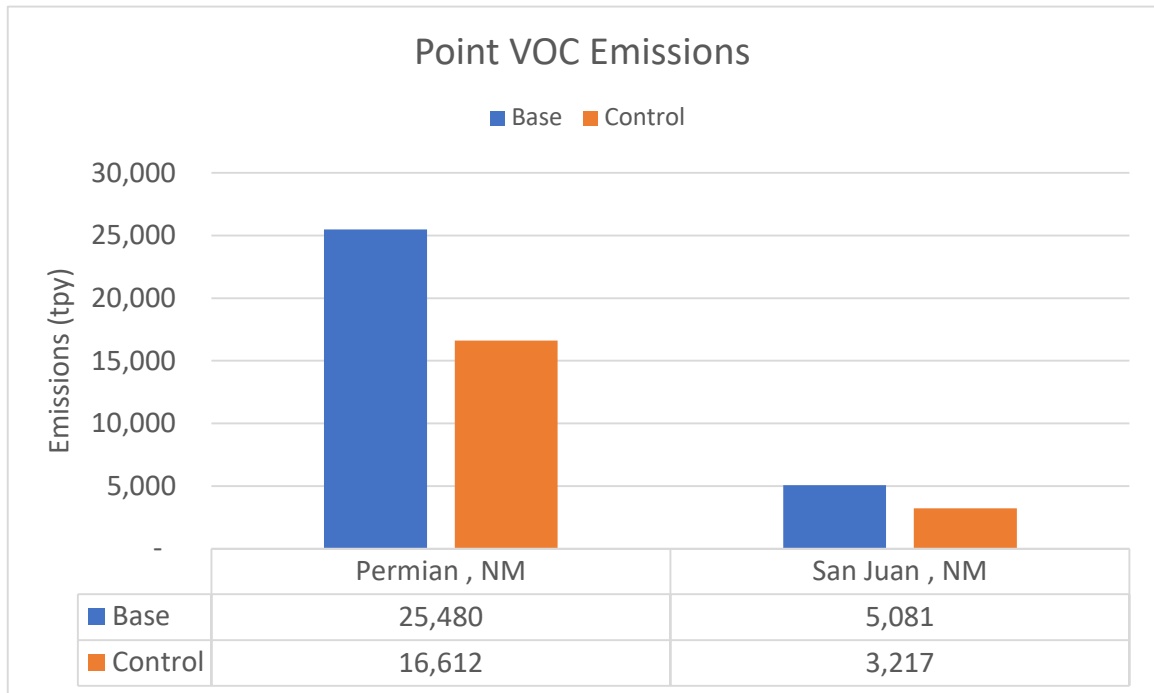
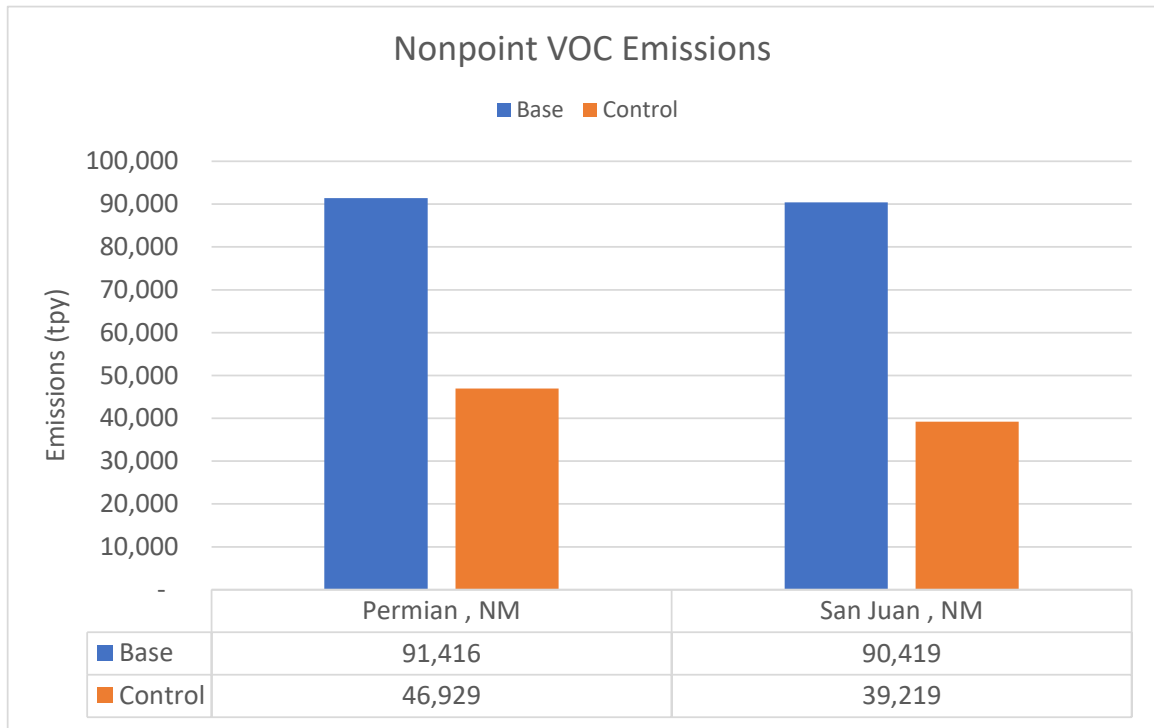


Figure 4-12. Comparison of 2028 Base Case and 2028 NM O&G control strategy VOC emissions for the Non-Point (top) and Point (bottom) source sectors and the Permian (left) and San Juan (right) basins.

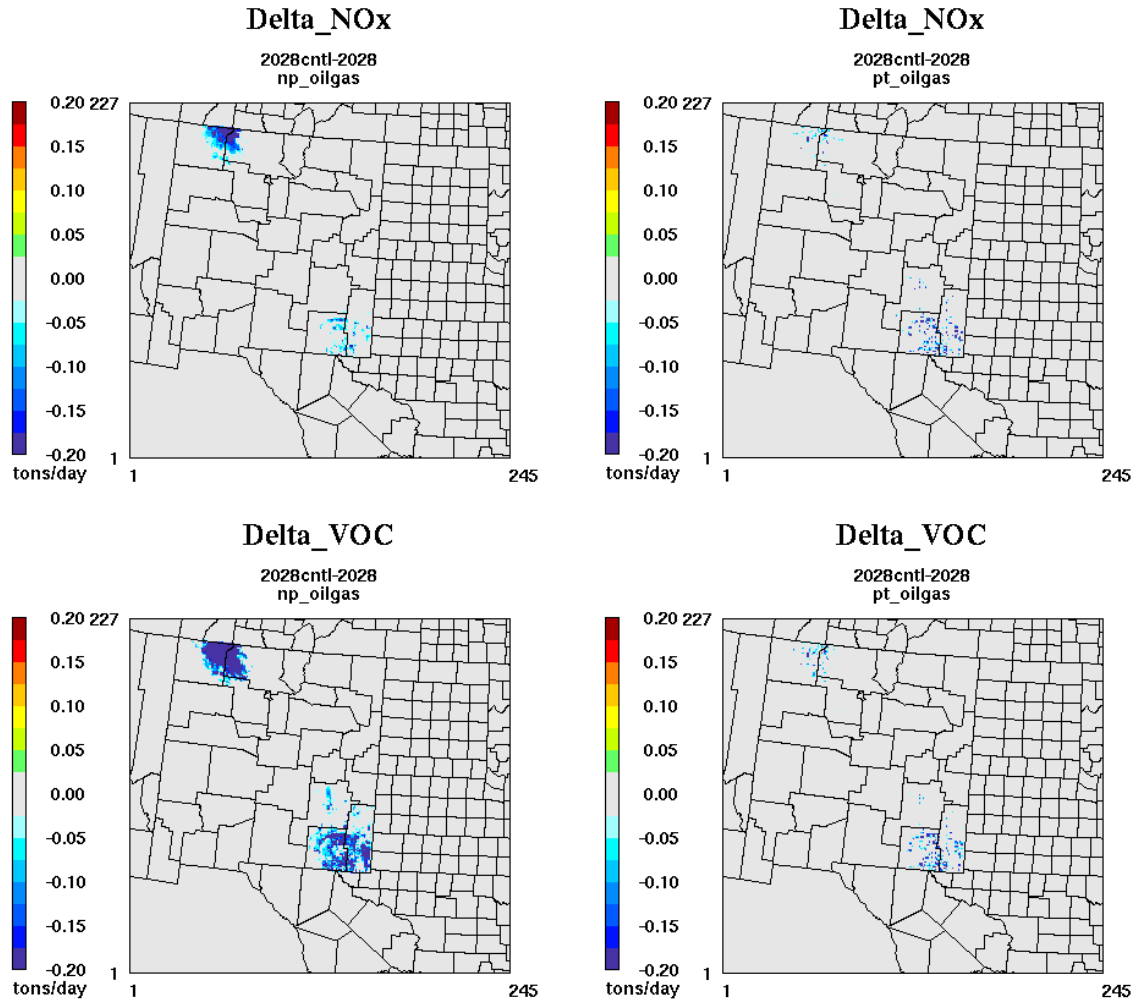


Figure 4-13. Differences in 2028 O&G Control Strategy and 2028 Base Case oil and gas NO_x (top) and VOC (bottom) emissions for the Non-Point (left) and Point (right) source sectors.

5. DIAGNOSTIC SENSITIVITY TESTS

Several CAMx diagnostic sensitivity tests were conducted to evaluate the effects that alternative meteorological inputs have on ozone concentrations.

5.1 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 that define the rate and depth of vertical mixing in CAMx. Several options are available in WRFCAMx to derive vertical turbulent exchange coefficient (also known as Kv or vertical diffusivity) fields from WRF output. The Kv fields are diagnosed from wind, temperature, and Planetary Boundary Layer (PBL) parameters in WRFCAMx. For this application, the WRFCAMx processing was performed to generate two sets of Kv profiles using two different Kv options in WRFCAMx, the CMAQ-like and YSU Kv profile options.

The CAMx Kv_patch pre-processor program was used to set the minimum Kv value to 0.1 to 1.0 m²/s in the lowest 100 m of the atmosphere depending on the amount urban land use category in a grid cell. This is done to account for the urban heat island effect that enhances vertical mixing through-out the day and night.

WRF was run with 36 vertical levels (35 vertical layers) as shown in Table 2-1. For the NM OAI Study, a layer collapsing strategy was employed that reduced the 35 WRF vertical layers to 25 layers in CAMx, which reduces the CAMx run time by about a third. Table 5-1 displays the WRF to CAMx layer collapsing strategy. This is the same layer collapsing study employed by WRAP-WAQS 2014 modeling platform.

5.2 CAMx Meteorological Diagnostic Sensitivity Tests

Four separate CAMx 2014 36/12/4-km diagnostic sensitivity tests were conducted for the first portion of the summer 2014 modeling episode that spanned May 15 to June 4, 2014. The purpose of the four meteorological inputs CAMx sensitivity tests was to identify the optimal meteorological inputs for the final CAMx 2014 base case simulation. The four sets of CAMx simulations were based on the WRF/NAM and WRF/ERA5 2014 36/12/4-km simulations described in Chapter 2 processed by WRFCAMx to generate two sets of vertical mixing coefficient (Kv) as described above:

1. WRF/NAM with CMAQ Kv
2. WRF/NAM with YSU Kv
3. WRF/ERA5 with CMAQ Kv
4. WRF/ERA5 with YSU Kv

Table 5-1. WRF to CAMx vertical layer collapsing strategy used in the NM OAI Study.

CAMx Layers	WRF Layers	WRF hybrid eta	WRF Pressure (mb)	Height (m)
	0	1.0000	1000.0	0
	1	0.9985	998.6	12
1	2	0.9970	997.2	24
	3	0.9950	995.3	40
2	4	0.9930	993.4	56
	5	0.9910	991.5	72
3	6	0.9880	988.6	97
	7	0.9850	985.8	121
4	8	0.9800	981.0	162
5	9	0.9700	971.5	243
6	10	0.9600	962.0	326
7	11	0.9500	952.5	409
	12	0.9400	943.0	492
8	13	0.9300	933.5	577
9	14	0.9100	914.5	747
10	15	0.8900	895.5	921
11	16	0.8700	876.5	1098
12	17	0.8400	848.0	1369
13	18	0.8000	810.0	1742
14	19	0.7600	772.0	2130
15	20	0.7200	734.0	2533
16	21	0.6800	696.0	2954
17	22	0.6400	658.0	3393
18	23	0.6000	620.0	3854
19	24	0.5500	572.5	4463
	25	0.5000	525.0	5115
20	26	0.4500	477.5	5816
	27	0.4000	430.0	6576
21	28	0.3500	382.5	7408
	29	0.3000	335.0	8328
22	30	0.2500	287.5	9360
	31	0.2000	240.0	10541
23	32	0.1500	192.5	11930
	33	0.1000	145.0	13630
24	34	0.0600	107.0	15355
	35	0.0270	75.7	17205
25	36	0.0000	50.0	19260

Figures 5-1 and 5-2 summarize the CAMx MDA8 ozone normalized mean bias (NMB) and error (NME) statistical performance metrics for each site in New Mexico and the four WRF meteorological inputs sensitivity tests. The statistics presented in these figures were calculated using a 60 ppb cutoff value relative to observed MDA8 ozone concentrations to understand the performance of each sensitivity test when ozone concentrations are most relevant to the NAAQS. Figure 5-1 shows that the NMB is generally within $\pm 10\%$ (colored grey) at almost all sites (note that the NMB performance goal is within $\pm 5\%$ and performance criteria is within $\pm 15\%$). All of the sensitivity simulations have an under-prediction bias for observed ozone greater than 60 ppb at sites in the southern portion of the domain such that for one or two sites have a bias even lower than -10% (i.e., colored bright green). The WRF/NAM with CMAQ Kv sensitivity test has slightly better performance than the others with less underestimation bias (e.g., all sites but one are within $\pm 10\%$ compared to two sites for the other tests). Figure 5-2 shows that the NME is also generally within the performance goal (less than 15%) in all cases, with the southern portions of NM showing the largest errors but still within the performance criteria (less than 25%). The figure shows that CAMx using the WRF/NAM inputs tends to have slightly lower error and better ozone performance than when the WRF/ERA5 meteorological inputs are used.

Figure 5-3 presents soccer plots of bias and error for observed ozone above 60 ppb and all four CAMx sensitivity tests. This figure plots site-specific bias versus error with performance lines in the shape of a soccer goal, when the site-specific bias and error symbol falls within the soccer goal area (i.e., the red box) it is easy to see when the ozone performance goals are achieved. The figure shows that all sites have NMB and NME that fall within the performance criteria for bias ($\leq \pm 15\%$) and error ($\leq 25\%$), with most sites having an underestimation bias of the high (> 60 ppb) observed ozone concentrations. The CAMx simulations with the WRF/NAM meteorological inputs has slightly better performance than when the WRF/ERA5 inputs are used as more sites fall within the performance goal area. Comparison between the NAM cases indicate that the CAMx sensitivity test with CMAQ Kv has slightly smaller errors relative to the test with YSU Kv.

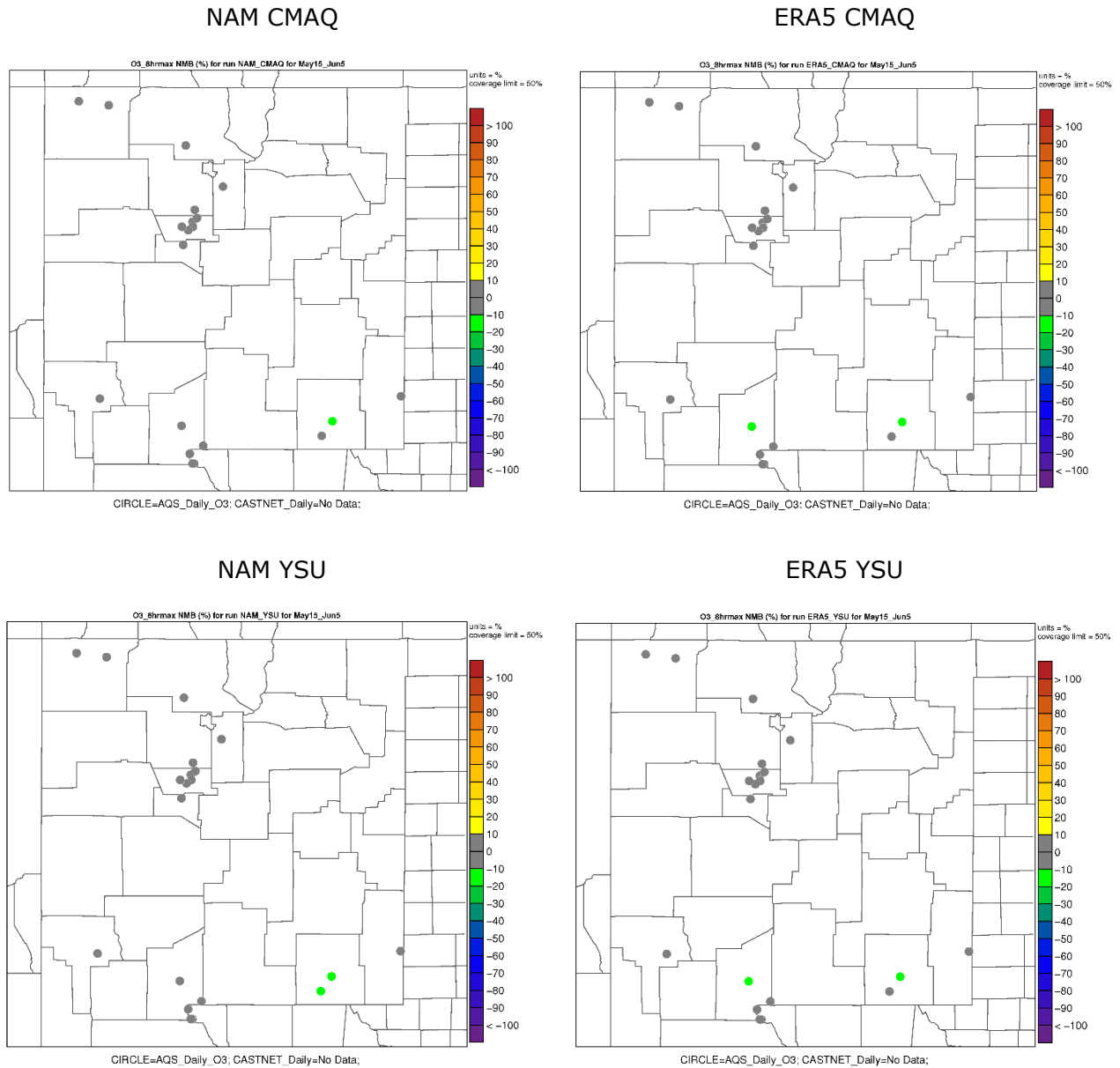


Figure 5-1. Comparison of sensitivity tests NMB with 60 ppb cutoff spatial plots over NM.

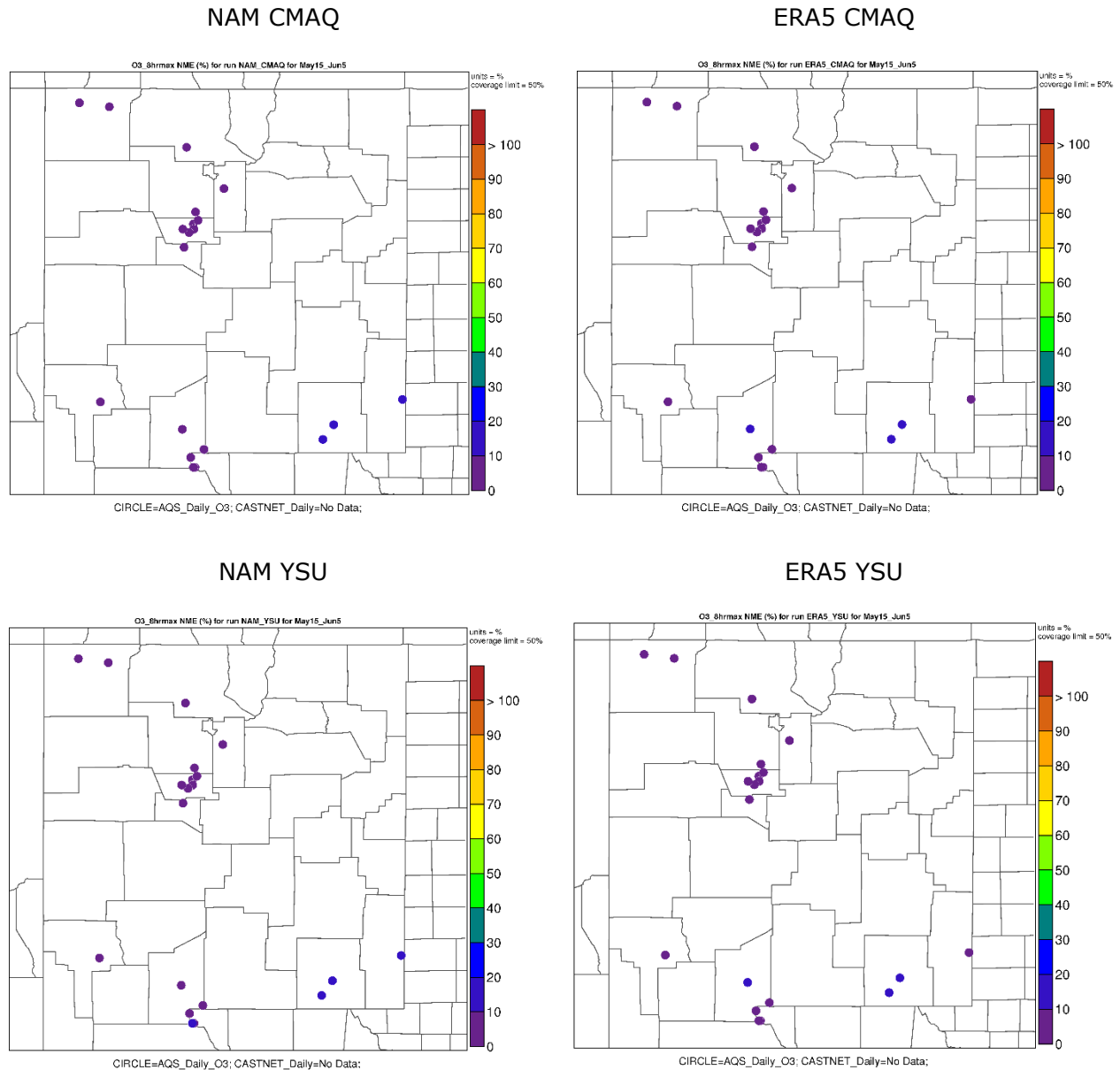


Figure 5-2. Comparison of sensitivity tests NME with 60 ppb cutoff spatial plots over NM.

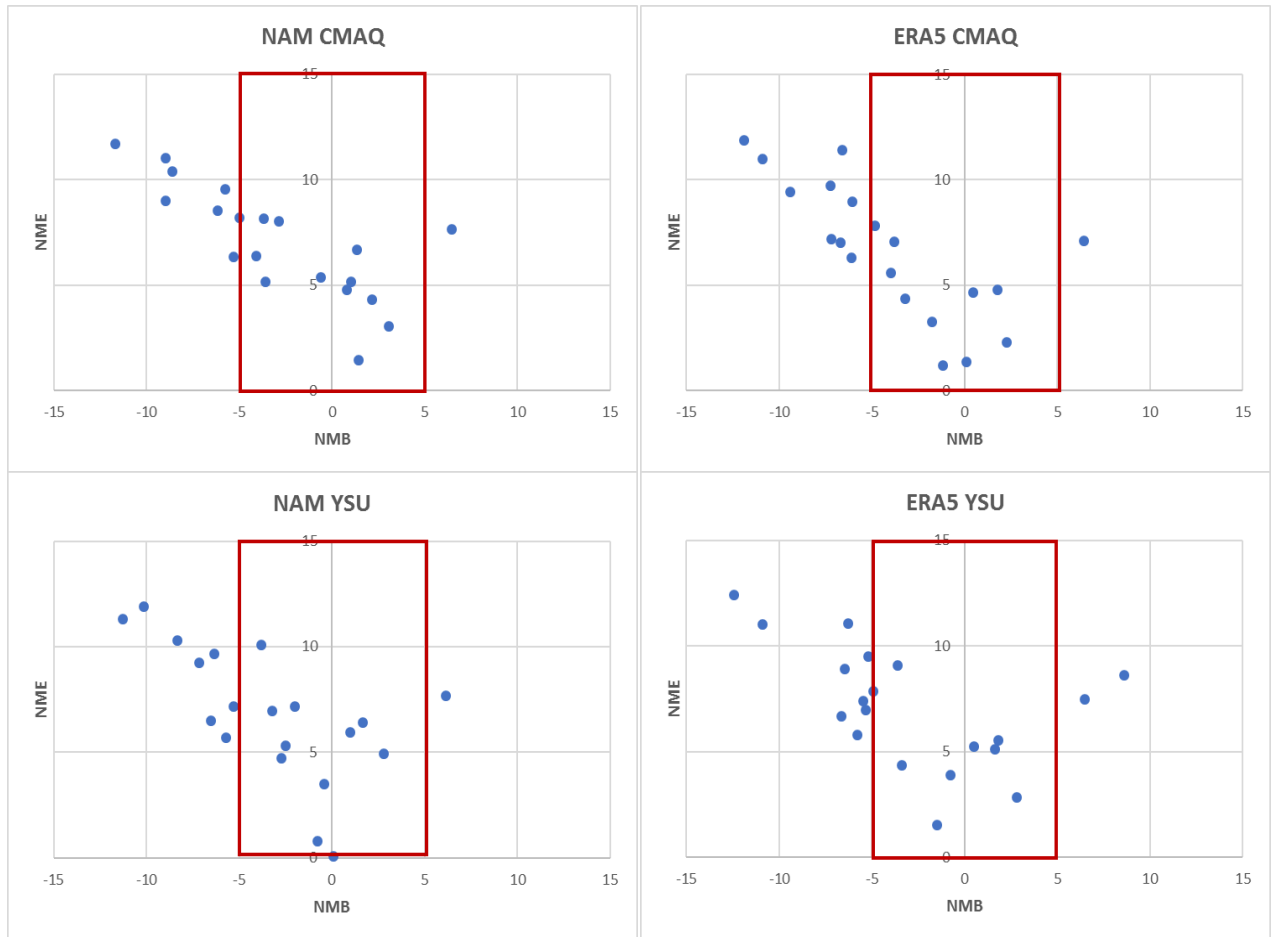


Figure 5-3. Comparison of sensitivity tests soccer plots with 60 ppb cutoff. Red rectangle indicates the performance goal soccer area.

Figures 5-4 to 5-7 present time series of predicted and observed MDA8 ozone concentrations for selected sites in Doña Ana, Eddy and Sandoval counties. At the Solano Road site in Doña Ana County the time series shows that the observed peak ozone concentration on May 29 is matched very well by the CAMx WRF/NAM sensitivity tests, while the CAMx WRF/ERA5 sensitivity test under-predicts by approximately 10 ppb (Figure 5-4). At the Desert View site, which is also in Doña Ana County, all four CAMx sensitivity tests underestimate the high observed ozone on May 28-29, but the CAMx WRF/NAM tests perform slightly better than the CAMx WRF/ERA5 test (Figure 5-5). At the Carlsbad site in Eddy County all test cases under-predict the high ozone concentration from May 27 to May 31 (Figure 5-6). For the site in Sandoval county (Figure 5-7) all four CAMx sensitivity tests track the daily variations of the observed MDA8 ozone including getting the timing and values of the observed ozone peak on May 29, but the CAMx WRF/NAM with CMAQ Kv test exhibits the lowest biases.

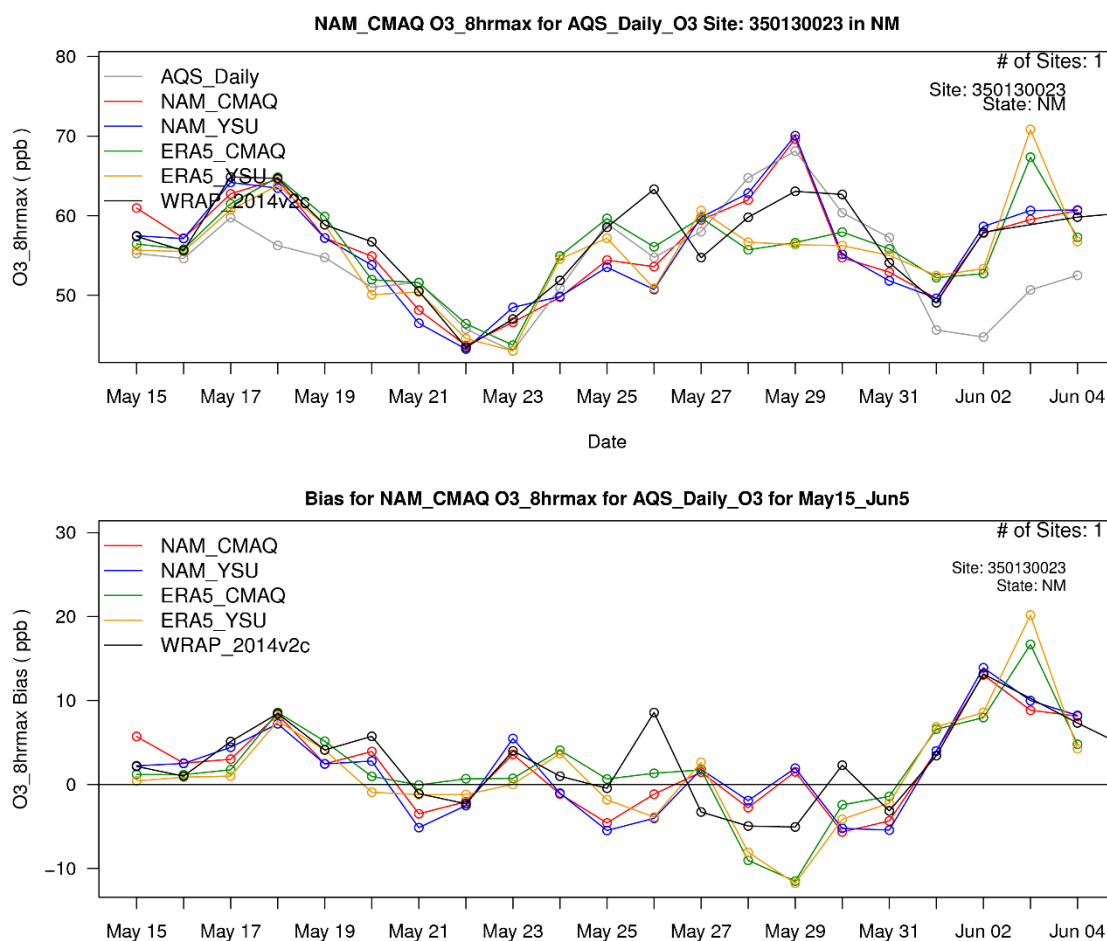


Figure 5-4. Timeseries comparison of sensitivity tests with observations (top) and bias (bottom) at Solano Road site in Doña Ana County

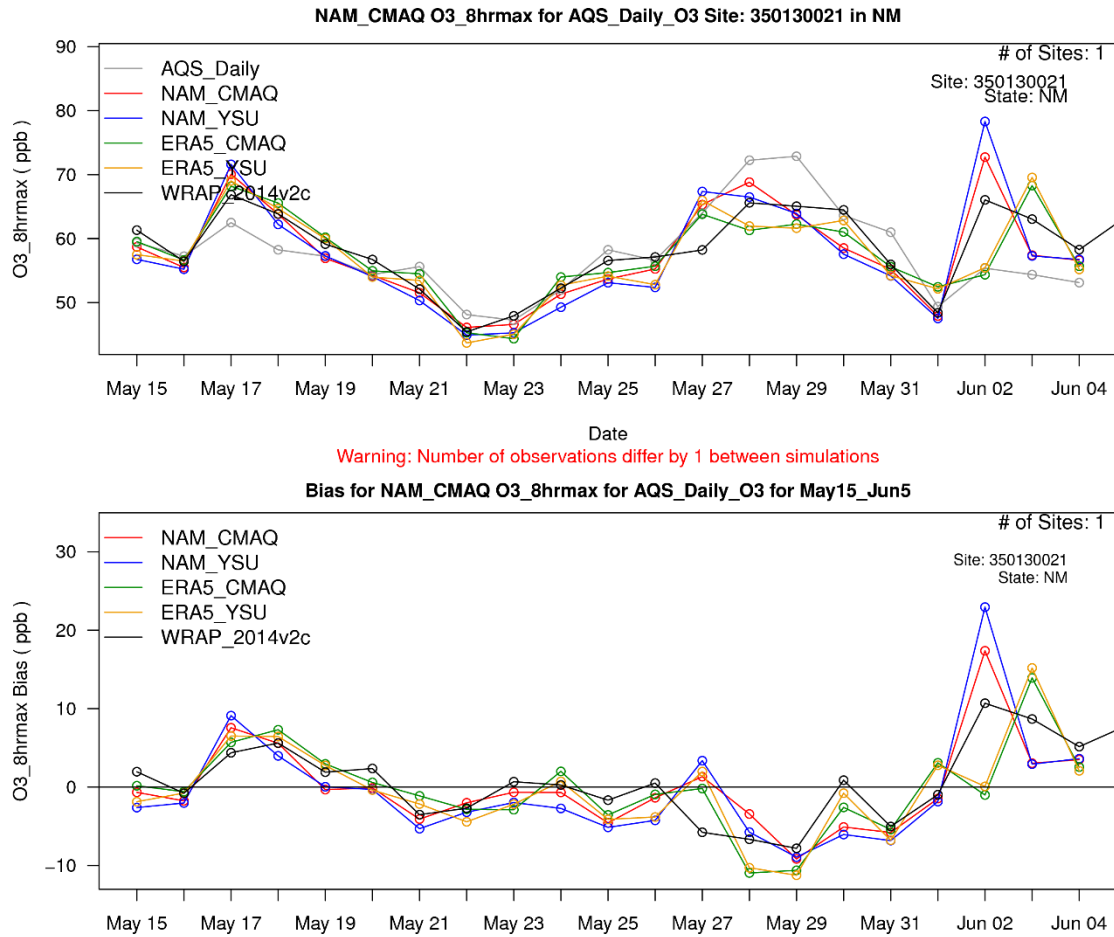


Figure 5-5. Timeseries comparison of sensitivity tests with observations (top) and bias (bottom) at Desert View site in Doña Ana County

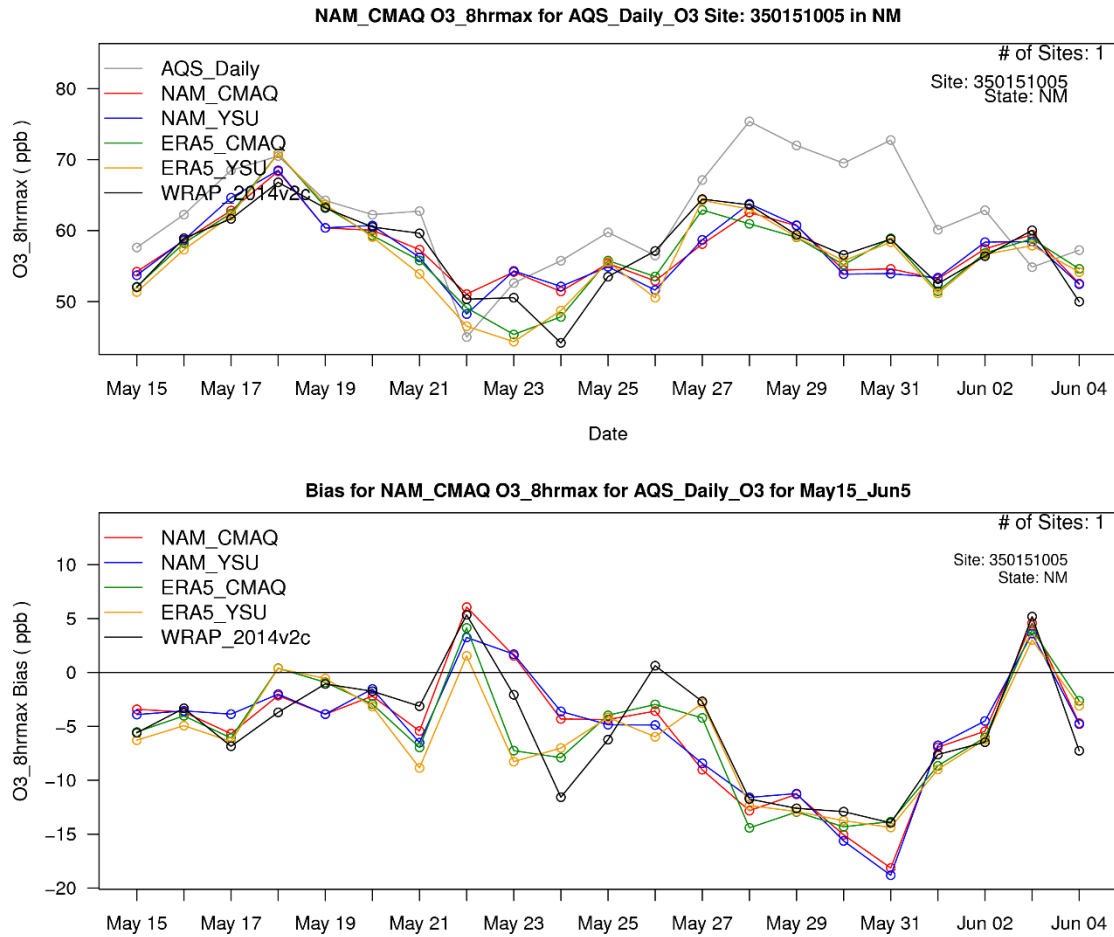


Figure 5-6. Timeseries comparison of sensitivity tests with observations (top) and bias (bottom) at Carlsbad site in Eddy County

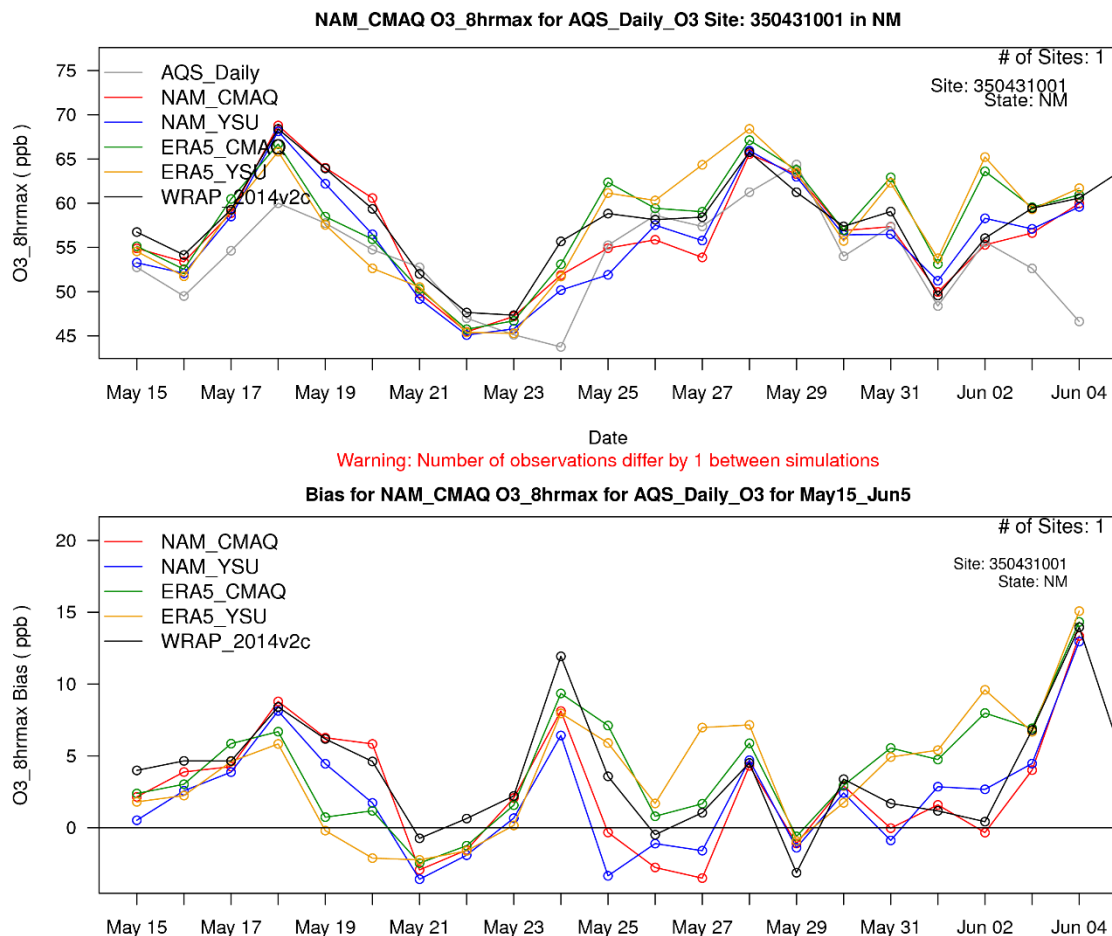


Figure 5-7. Timeseries comparison of sensitivity tests with observations (top) and bias (bottom) at Albuquerque site in Sandoval County

5.3 Summary of CAMx Diagnostic Sensitivity Tests

All four of the CAMx meteorological sensitivity cases have biases and errors well within the performance criteria and in most cases even within the more stringent performance goals. For the modeled episode, the differences in performance among all the cases considered are relatively minor. On some sites and days, CAMx using the WRF/NAM meteorology tends to capture peak ozone concentrations better than when the WRF/ERA5 meteorology is used. Based on the results presented here, the final CAMx 2014 base case model configuration used the WRF/NAM with CMAQ Kv treatment meteorological inputs.

6. 2014 BASE CASE MODELING AND MODEL PERFORMANCE EVALUATION

The NM OAI Study conducted two CAMx 2014 36/12/4-km base case simulations. The original 2014 base case simulation used CAMx v7.0 and biogenic emissions in the 4-km based on the MEGAN v3.1 model and is documented in Ramboll and WESTAR (2020c). There were errors in the CAMx v7.0 source apportionment algorithms that did not significantly affect the CAMx v7.0 2014 base case ozone estimates but would affect planned future year ozone source apportionment modeling. So, a second CAMx 2014v2 base case simulation was performed using CAMx v7.1 that had corrections to the ozone source apportionment algorithms. The revised CAMx v7.1 2014v2 base case simulation also updated the biogenic emissions in the 4-km domain using the BEIS v3.7 biogenic emissions model. The MEGAN v3.1 biogenic model used in the first CAMx v7.0 2014 base case was missing leaf area index (LAI) data for urban areas so produced zero biogenic VOC emissions for the urban land use type. The development of New Mexico-specific urban LAI inputs was beyond the resource and time constraints of the study, so BEIS biogenic emissions were used for the revised 2014v2 CAMx base case simulation. Details on the CAMx 2014v2 final base case simulation and model performance are provided in Ramboll and WESTAR (2021) with a summary provided below.

6.1 Final CAMx 2014v2 Base Case Configuration

The final CAMx meteorological inputs were based on the WRF/NAM simulations using the CMAQ-like Kv profiles as described in Chapters 2 and 5.

The 2014 emissions used in the 36-km and 12-km domains were the same as the WRAP-WAQS 2014v2 emissions. For the 4-km New Mexico domain, the WRAP 2014v2 emissions were processed by the SMOKE emissions model to generate the gridded hourly speciated emissions for CAMx. Chapter 4 describes the updates to the WRAP-WAQS 2014v2 emissions for New Mexico and the development of the emission inputs for the New Mexico 4-km domain.

Table 6-1 summarizes the CAMx configuration and options used for the CAMx 2014v2 base case simulation. Version 7.1 (v7.1) of CAMx released in January 2021 was used in the final 2014v2 base case simulation. CAMx was operated using the 36/12/4-km nested grid structure shown in Figure 1-1 using two-way grid nesting for all simulations. Boundary Conditions (BCs) for the CAMx most outer 36-km 36US modeling domain lateral boundaries were based on output from a 2014 simulation of the GEOS-Chem global chemistry conducted by WRAP for their 2014v2 modeling platform. CAMx was started on May 1, 2016 using the 36/12/4-km domains that allowed the model over two-weeks to initialize the model and wash out the initial concentrations before the first high ozone day on May 17, 2014.

Other CAMx model options and setup are defined in Table 6-1. The PPM advection solver (Colella and Woodward, 1984) was used for horizontal transport along with the spatially varying (Smagorinsky) horizontal diffusion approach. K-theory was used for vertical diffusion using the CMAQ-like Kv profiles from the WRF/CAMx processing of the WRF/NAM output. The CB6r4 gas-phase chemical mechanism was selected because it includes the very latest chemical kinetic rates with halogen chemistry that affects ozone levels over the ocean. The latest aerosol mechanism was used in CAMx along with the

standard wet and dry deposition schemes. The Plume-in-Grid module was used to treat the near-source chemistry and dispersion of major NO_x emissions sources in the New Mexico 4-km domain for sources with greater than 5 tons per day NO_x emissions.

Table 6-1. Final CAMx model configuration for the 2014v2 base case simulation in NM OAI Study.

Science Options	CAMx	Comment
Model Codes	CAMx v7.1	Latest version of CAMx at time of study released in January 2020 (www.camx.com)
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). Layer collapsing from 35 vertical layers in WRF
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 lateral boundaries
Emissions		
Baseline Emissions Processing	SMOKE, SMOKE-MOVES2014, BEIS v3.7	WRAP/WAQS 2014v2 emissions
Sub-grid-scale Plumes	Plume-in-Grid for major NO _x sources in New Mexico	Point sources with NO _x emission s greater than 5 tons per day
Chemistry		
Gas Phase Chemistry	CB6r4	Latest chemical reactions and kinetic rates with halogen chemistry (Yarwood et al., 2010)
Meteorological Processor	WRF-CAMx	Compatible with CAMx v7.0
Horizontal Diffusion	Spatially varying	K-theory with Kh grid size dependence
Vertical Diffusion	CMAQ-like Kv	Evaluated 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)

6.2 Ozone Model Performance Goals and Criteria

Emery and co-workers (2016) analyzed almost 100 PGM model applications and developed a set of PGM model performance goals and criteria based on the variability in the past PGM model performance. “Goals” indicate statistical values that approximately 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. The CAMx revised 2014v2 and original 2014 base case simulations ozone model performance statistics for normalized mean bias (NMB) and normalized mean error (NME) are compared against the ozone model performance goals and criteria developed by Emery et al., (2016) that are given in Table 6-2.

Table 6-2. Recommended ozone 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

6.3 Spatial Ozone Model Performance

Figures 6-1 and 6-2 display the spatial distribution of bias (NMB) performance at monitoring sites in the 4-km NM domain for the revised 2014v2 and original 2014 CAMx base case simulation with and without using a 60 ppb observed ozone cutoff concentrations (i.e., only include predicted and observed MDA8 ozone pairs in the statistics when the observed MDA8 ozone is greater than 60 ppb). When the symbols are grey, they achieve the within ±5% ozone bias Performance Goal and when the symbols are the brightest green or yellow colors they are within the ozone bias Performance Criteria (i.e., between ±5% and ±15%).

With the exception of one monitoring site in El Paso, the NMB at all of the ozone sites in the 4-km domain achieve the ozone Performance Criteria using no cutoff in both CAMx base case simulations, although some sites have an overestimation bias greater than 5% Performance Goal (Figure 6-1). The CAMx 2014v2 and 2014 base case ozone bias performance looks nearly identical with the only noticeable differences being two sites (one in Doña Ana County and one in Luna County) that achieve the ozone bias Performance Goal in the revised 2014v2 CAMx base case (i.e., are colored grey in Figure 6-1, top) but have bias between the 5% and 15% in the original CAMx base case (Figure 6-1, bottom) so fall between the Performance Goal and Criteria (i.e., are colored bright yellow).

Whereas the CAMx base cases tend to have a small ozone overestimation bias when no observed ozone 60 ppb cutoff is used, when using a 60 ppb observed ozone cutoff both base cases tend to have a small underestimation bias (Figure 6-2). With one exception, when using the cutoff all sites achieve the ozone Performance Criteria and many sites achieve the ozone bias Performance Goal. The bias performance of the two base case simulations are nearly identical. The one exception is the Carlsbad site in Eddy County that is between the Performance Goal and Criteria (i.e., between -5% and -15%) in the

original 2014 base case (Figure 3-2, bottom), but has a NMB between -15% and -20% in the revised 2014v2 base case so fails to achieve the ozone bias Performance Criteria (Figure 3-2, top).

We also compared the spatial model performance of the two base cases for error (NME) and correlation (r), but the spatial maps were identical so did not provide any relevant information on the relative performance of the two base case simulations.

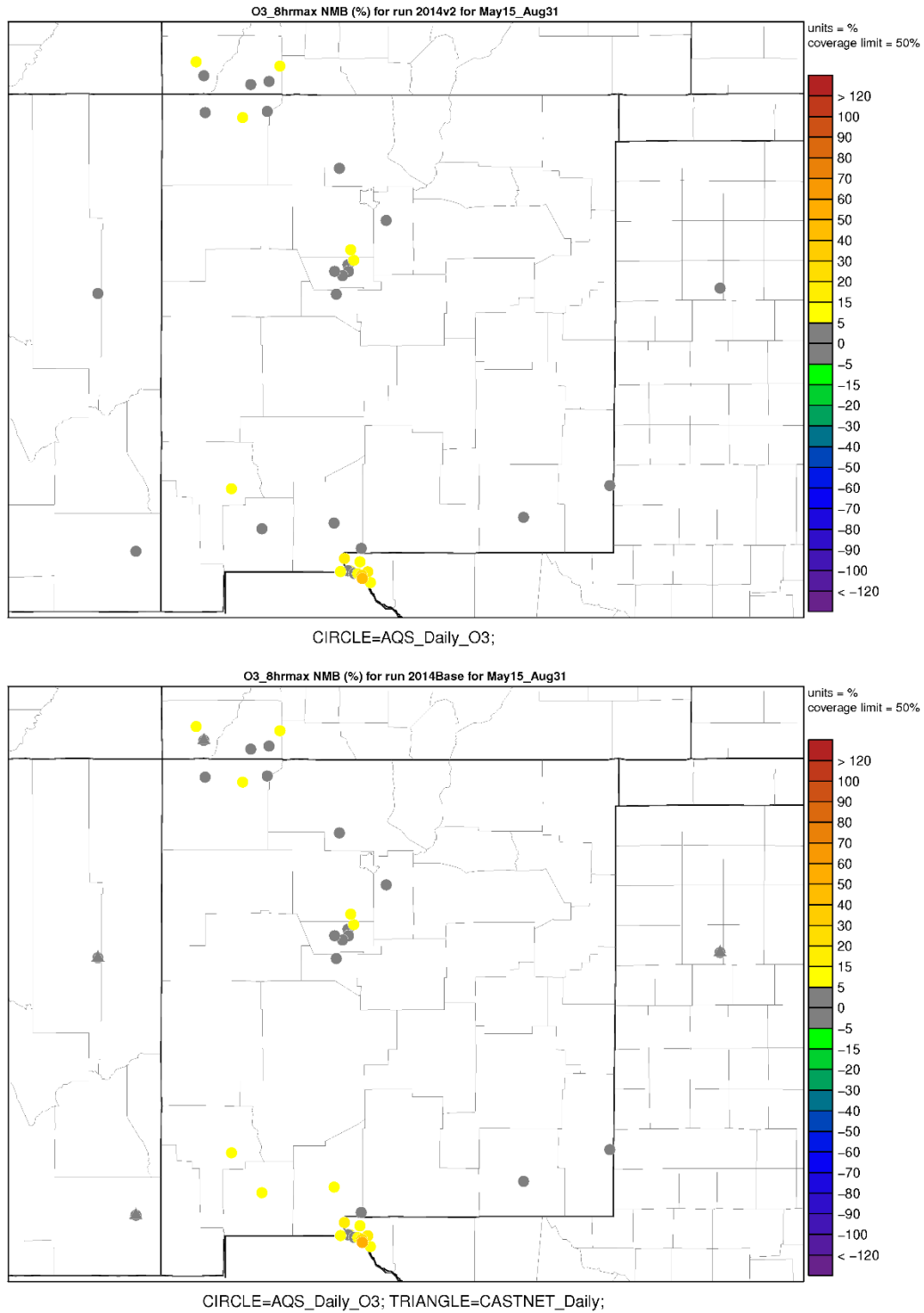


Figure 6-1. Normalized Mean Bias (NMB) for MDA8 ozone concentrations for the revised 2014v2 (top) and original 2014 (bottom) CAMx base case simulations with no ozone cutoff.

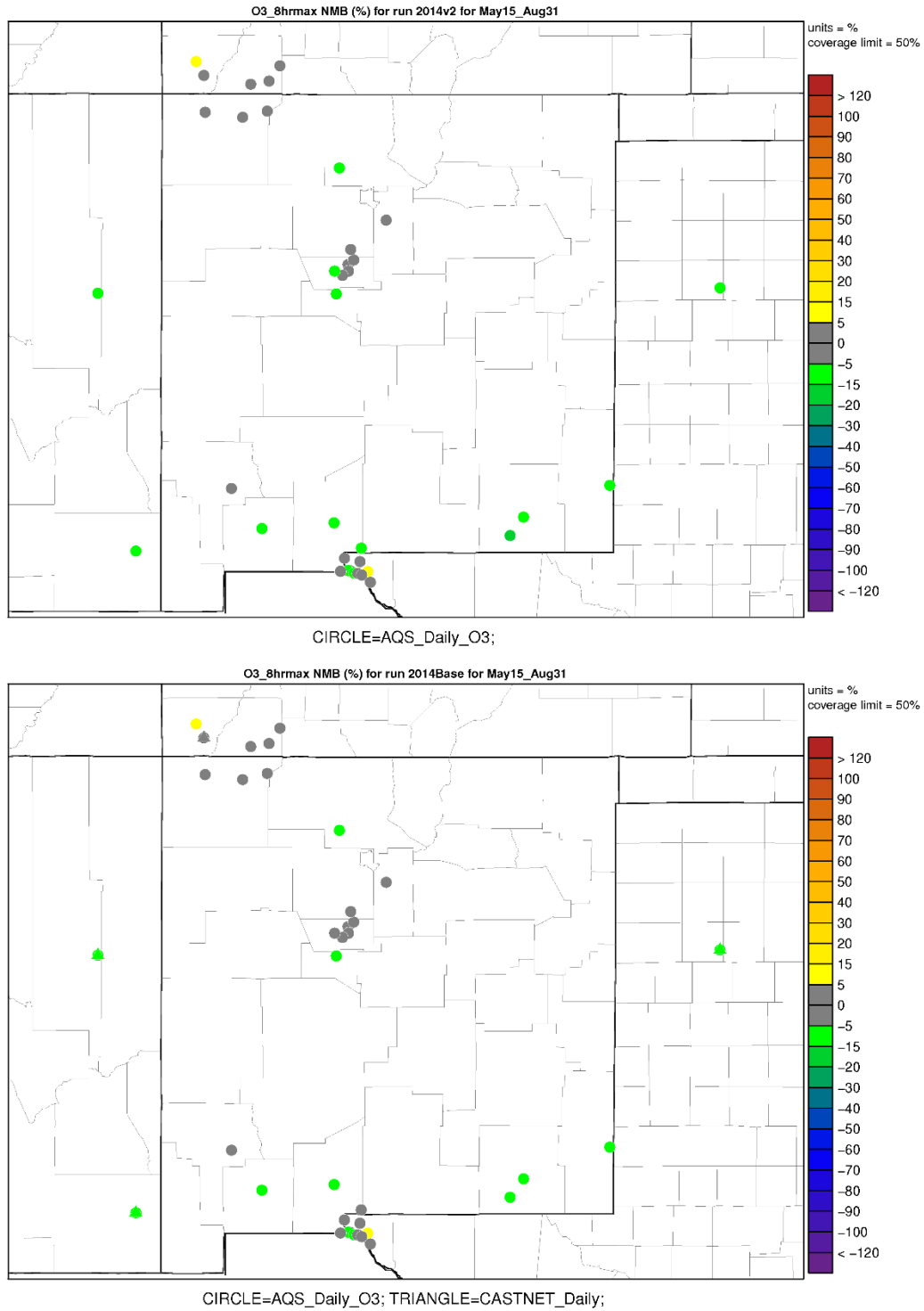


Figure 6-2. Normalized Mean Bias (NMB) for MDA8 ozone concentrations for the revised 2014v2 (top) and original 2014 (bottom) CAMx base case simulations with an observed 60 ppb ozone cutoff.

6.4 Scatter Plots of MDA8 Ozone

Figure 6-3 display scatter plots and summary statistics of MDA8 ozone across AQS or CASTNet sites in the 4-km domain for the revised 2014v2 and original 2014 CAMx base case simulations. The 2014v2 and 2014 MDA8 scatter plots look identical with the MDA8 performance at the AQS sites exhibiting a slight MDA8 ozone overestimation bias as indicated by the center density of the scatterplot being slightly above the 1:1 line of perfect agreement. This is in contrast to the CASTNet MDA8 scatterplots that are centered on the 1:1 line of perfect agreement so the two base case simulations are less biased.

The AQS performance statistics across the 4-km domain for the May-August 2014 modeling period show that the 2014v2 and 2014 MDA8 ozone performance is not exactly identical with the revised 2014v2 base case having a NMB of 4.4% that achieves the ozone bias Performance Goal, whereas the original 2014 base case has a NMB of 6.2% that falls between the ozone bias Performance Goal and Criteria. The 2014v2 NME (10.6%) is also slightly better than the original 2014 base case (10.9%).

Both CAMx base case simulations exhibit extremely good MDA8 ozone model performance across the CASTNet sites in the 4-km domain with near zero bias (-1.4% and +0.1%) and errors (8.1% and 7.9%) that are almost half the ozone error Performance Goal (<15%).

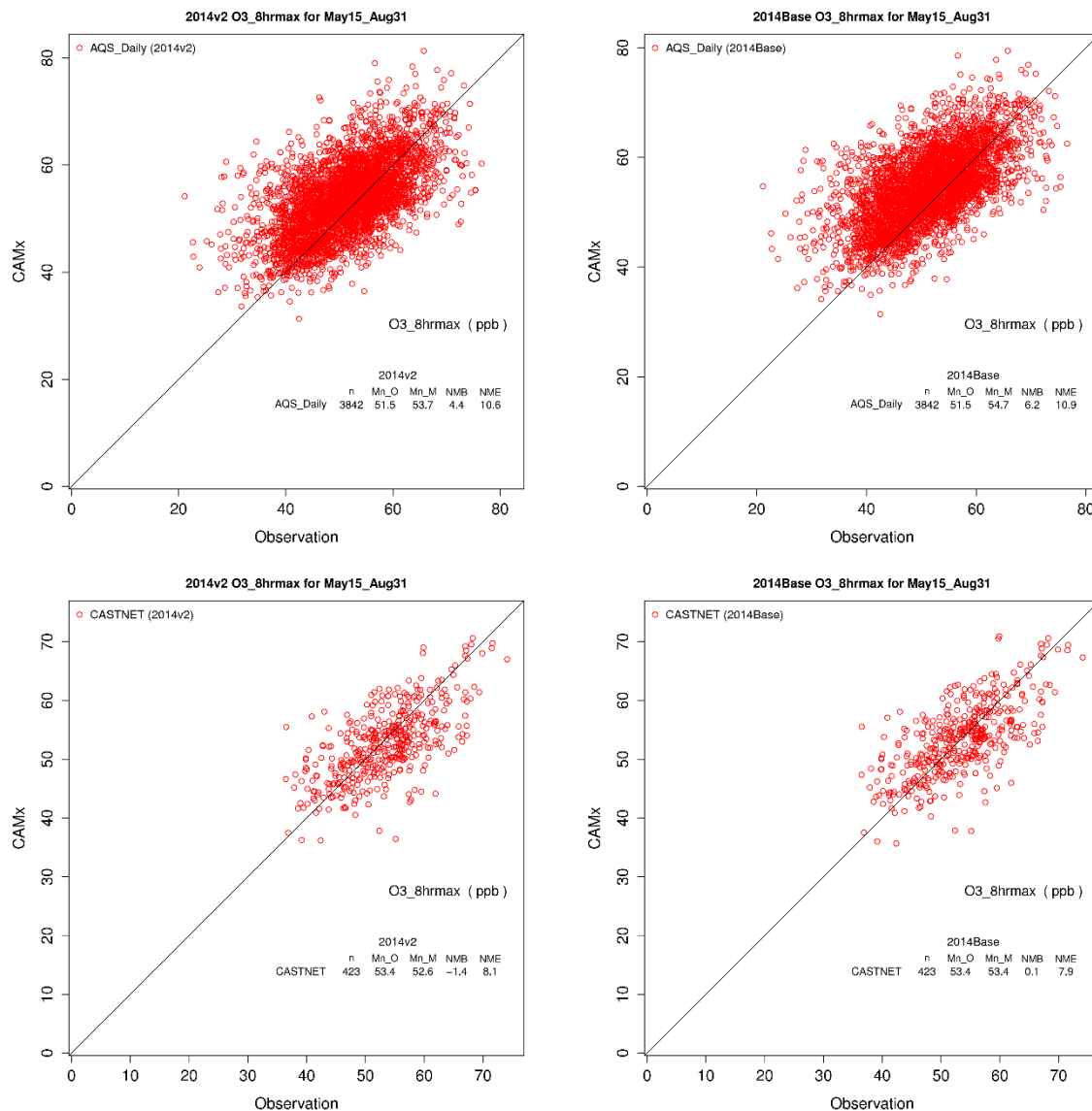


Figure 6-3. Scatter plots of predicted and observed MDA8 ozone concentrations for AQS (top) and CASTNet (bottom) monitoring sites within the 4-km New Mexico domain and the revised 2014v2 (left) and original 2014 (right) CAMx base case simulations.

6.5 MDA8 Ozone Time Series

Example predicted and observed MDA8 ozone time series at selected sites are presented below, with time series at all sites contained in the Appendix in Ramboll and WESTAR (2021). Figure 6-4 displays MDA8 ozone time series at the Desert View monitoring site in Doña Ana County in southern New Mexico. The CAMx MDA8 ozone predictions for the revised 2014v2 (blue) and original 2014 (green) base case simulations are almost on top of each other. In general, when they are a little different the revised 2014v2 MDA8 ozone is slightly lower, although that is not always the case as seen in the MDA8 ozone peaks in early June, mid-July, and end of August.

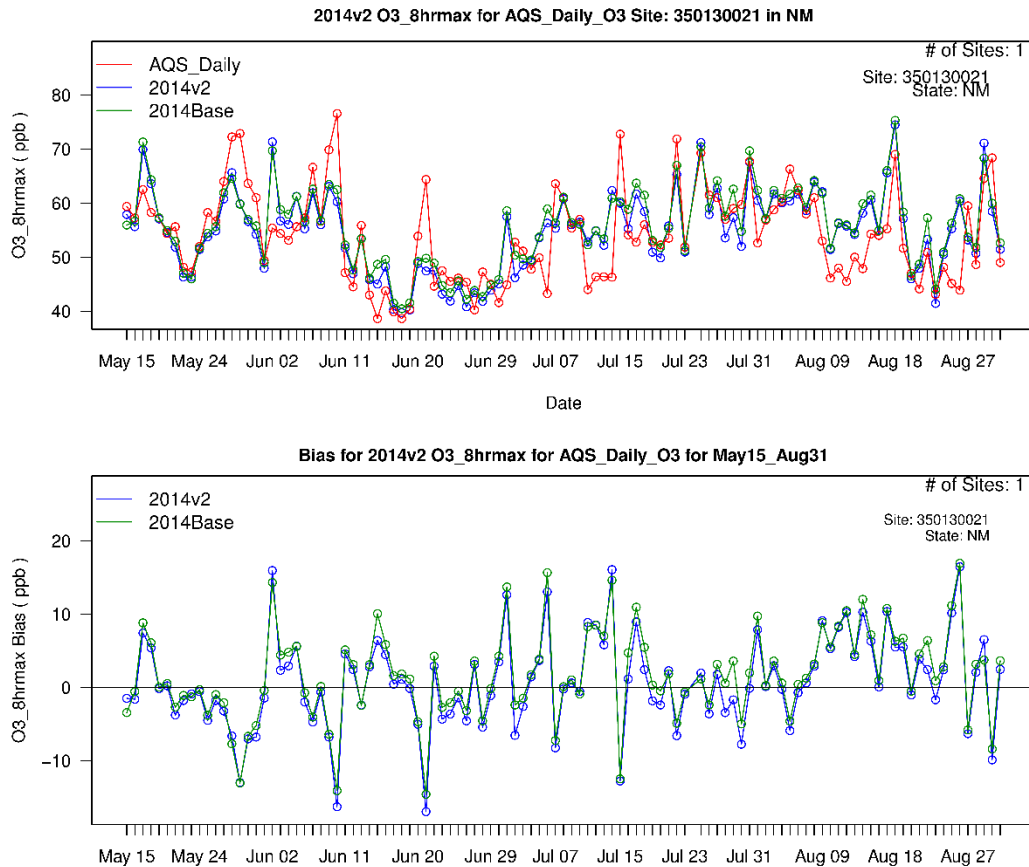


Figure 6-4. Time series of predicted and observed (red) MDA8 ozone at Desert View in Doña Ana County for the CAMx revised 2014v2 (blue) and original 2014 (green) CAMx base case simulations.

The MDA8 ozone time series comparison for the South East Heights monitoring site in Bernalillo County is shown in Figure 6-5. With the exception of a period in early July where the revised 2014v2 base case has a larger underestimation bias compared to the original 2014 base case, the two CAMx base case simulations are predicting nearly identical MDA8 ozone concentrations at this site.

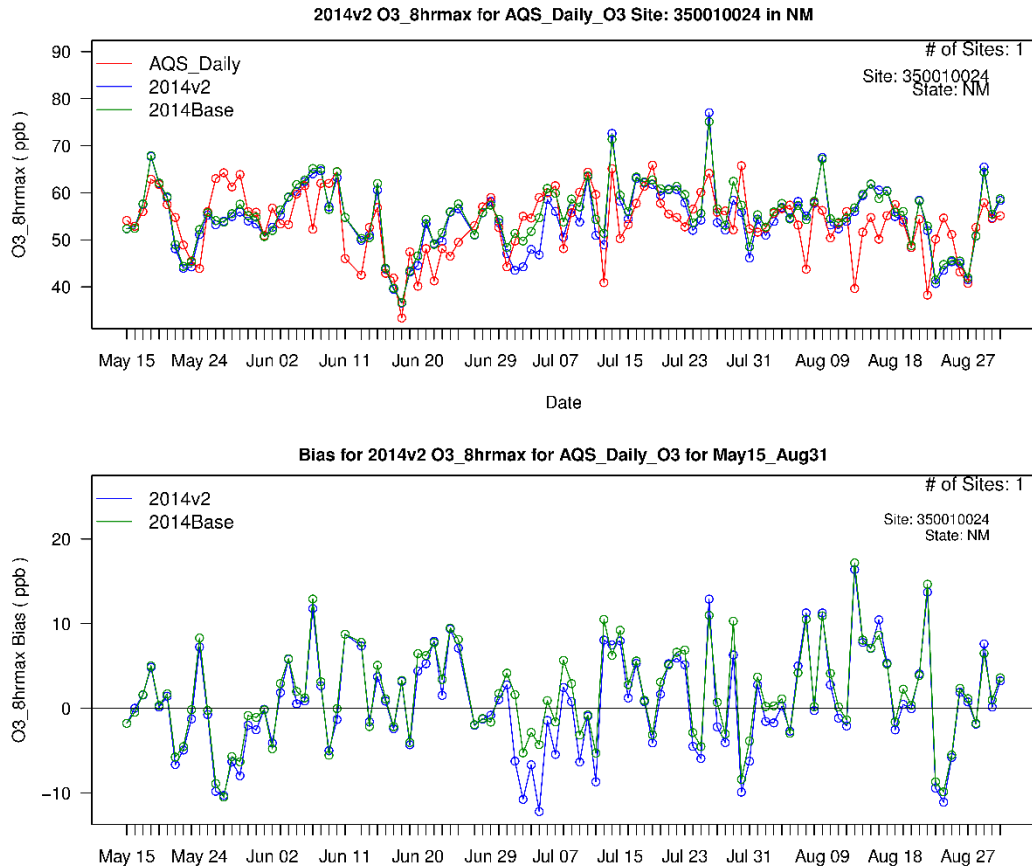


Figure 6-5. Time series of predicted and observed (red) MDA8 ozone at South East Heights in Bernalillo County for the CAMx revised 2014v2 (blue) and original 2014 (green) CAMx base case simulations.

The ozone time series at the Substation monitoring site in San Juan County is shown in Figure 6-6. Both CAMx base cases track the observed MDA8 ozone concentrations very well at the Substation monitoring site. Most of the time, the predicted MDA8 ozone are on top or nearly on top of each other and when different the revised 2014v2 MDA8 ozone is a little lower than the original CAMx 2014 base case.

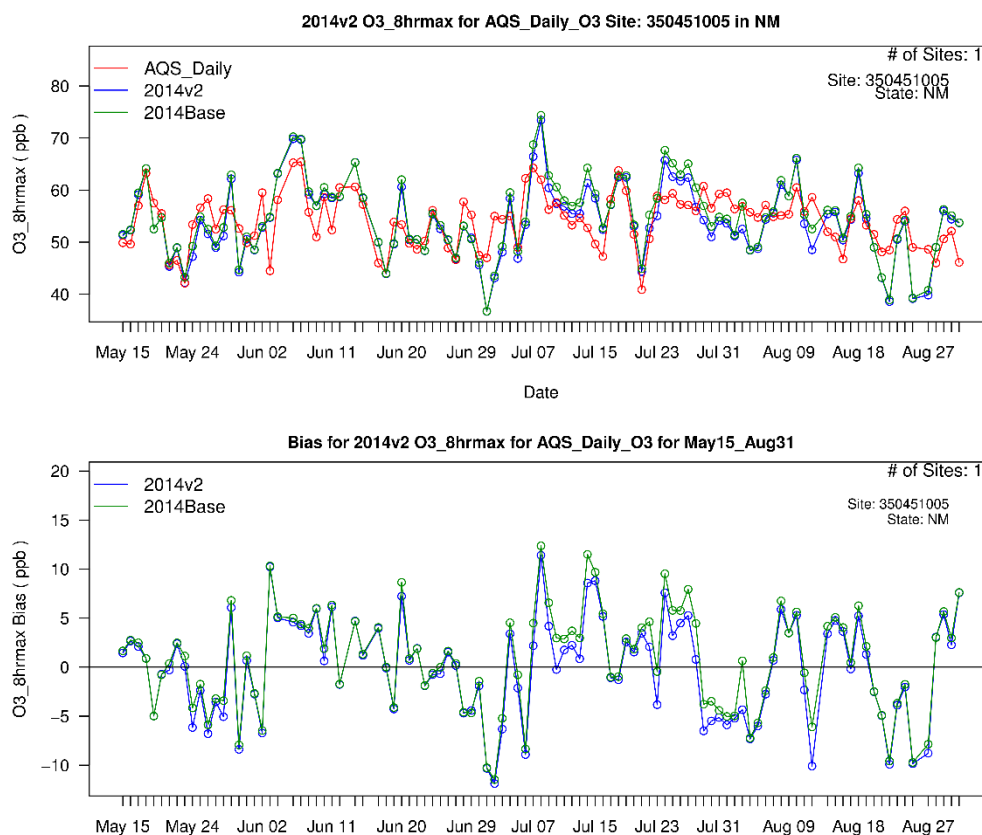


Figure 6-6. Time series of predicted and observed (red) MDA8 ozone at Sub Station in San Juan County for the CAMx revised 2014v2 (blue) and original 2014 (green) CAMx base case simulations.

6.6 Summary Ozone Model Performance Statistics in New Mexico

Ozone model performance statistics were calculated for three geographic regions in New Mexico. The central region was defined as all monitoring sites within Bernalillo County with the southern and northern regions defined as sites, respectively, south and north of Bernalillo County.

Tables 6-3 and 6-4 display the bias and error MDA8 ozone performance statistics with and without the observed MDA8 ozone 60 ppb cutoff for the three New Mexico subregions and the, respectively, original 2014 and revised 2014v2 CAMx base case simulations. The bias and error MDA8 ozone performance statistics are colored green when they achieve the Performance Goal, yellow when they lie between the Performance Goal and Criteria and red when they fail to achieve the Performance Criteria. The CAMx 2014 and 2014v2 base case performance statistics within the three New Mexico subregions are very good and very similar with the bias for the revised 2014v2 base case being 1-2 percentage points lower than the original 2014 CAMx base case simulation. Using no cutoff, when CAMx has a slight ozone overestimation tendency, the revised 2014v2 exhibits better performance statistics than the original 2014 base case. For example, the bias in the southern New Mexico region in original 2014 base case (5.8%) fails to achieve the ozone bias Performance Goal due to too high ozone overestimation, but achieves the ozone bias Performance Goal in the revised 2014v2 base case (3.5%). On the other hand, when an observed ozone 60 ppb cutoff is used the model tends to underestimate ozone a little so the revised 2014v2 base case ozone model performance is degraded a little compared to the original 2014 base case. For example, for the southern New Mexico subregion the original CAMx 2014 base case has a -6.1% NMB that is -7.8% for the revised CAMx 2014v2 base case, both of these NMB ozone performance statistics fall between the ozone bias Performance Goal and Criteria.

Table 6-3. Bias and error MDA8 ozone performance statistics for the original CAMx 2014 base case and the three subregions of New Mexico calculated with and without using an observed MDA8 ozone 60 ppb cutoff.

Region	Nocutoff		Withcutoff	
	NMB(%)	NME(%)	NMB(%)	NME(%)
North NM	4.3	9.1	0	6.4
Bernalillo	4.3	9.4	-2.8	7.1
South NM	5.8	10.5	-6.1	8.5

Table 6-4. Bias and error MDA8 ozone performance statistics for the revised CAMx 2014v2 base case and the three subregions of New Mexico calculated with and without using an observed MDA8 ozone 60 ppb cutoff.

Region	Nocutoff		Withcutoff	
	NMB(%)	NME(%)	NMB(%)	NME(%)
North NM	2.6	8.6	-1.0	6.6
Bernalillo	2.6	9.6	-4.3	8.5
South NM	3.5	10.2	-7.8	9.9

Tables 6-5 and 6-6 contain the bias performance statistics with and without a cutoff for each monitoring site in New Mexico and the, respectively, original CAMx 2014 and revised CAMx 2014v2 base case simulations. When not using the observed ozone cutoff, the original 2014 base case has 59% of the sites achieving the ozone bias Performance Goal with 36% of the sites falling between the Performance Goal and Criteria and one site failing to achieve the ozone bias Performance Criteria due to a 17.4% overestimation bias. The revised 2014v2 base case bias with no cutoff has 68% of the sites achieving the Performance Goal, 27% falling between the Performance Goal and Criteria and one site right at (15.0%) the Performance Criteria.

When an observed ozone cutoff is used, the number of sites achieving the ozone bias Performance Goal is flipped between the two base cases with 68% of the sites achieving the Performance Goal for the original 2014 base case and 59% of the sites achieving the Performance Goal for the revised 2014v2 base case with the remainder of the sites falling between the ozone bias Performance Goal and Criteria.

Table 6-5. Bias MDA8 ozone performance statistics with and without an observed ozone cutoff for each site in New Mexico and the original CAMx 2014 base case simulation.

2014Base (with MEGAN)			
SiteID	SiteNames	NMB No Cutoff	NMB 60 ppb Cutoff
350010023	Del Norte	1.7	-3.9
350010024	South East Heights	3.1	-2.4
350010029	South Valley	3.1	-2.8
350010032	Westside	1.1	-3.4
350011012	Foot Hills	13.6	2.0
350130008	La Union	17.4	-1.6
350130017	Sunland Park Yard	9.0	-3.6
350130020	Chaparral	4.8	-4.7
350130021	Desert View	3.2	-5.1
350130022	Santa Teresa	8.2	0.1
350130023	Solano	6.1	-6.5
350151005	Carlsbad	-1.1	-12.3
350171003	Chino Copper	9.1	-1.0
350250008	Hobbs Jefferson	2.1	-9.9
350290003	Deming Airport	6.2	-5.0
350390026	Coyote Ranger	3.3	-5.4
350431001	Bernalillo	8.1	3.8
350450009	Bloomfield	7.2	2.5
350450018	Navajo Lake	2.2	-0.6
350451005	Sub Station	1.4	3.3
350490021	Santa Fe Airport	3.8	-1.7
350610008	Los Lunas	0.8	-6.5

Table 6-6. Bias MDA8 ozone performance statistics with and without an observed ozone cutoff for each site in New Mexico and the revised CAMx 2014v2 base case simulation.

2014v2 (with BEIS)			
SiteID	SiteNames	NMB No Cutoff	NMB 60 ppb Cutoff
350010023	Del Norte	0.5	-4.9
350010024	South East Heights	1.3	-3.6
350010029	South Valley	0.9	-4.4
350010032	Westside	-1.0	-5.4
350011012	Foot Hills	11.9	0.8
350130008	La Union	15.0	-3.0
350130017	Sunland Park Yard	7.4	-4.1
350130020	Chaparral	2.8	-5.8
350130021	Desert View	1.4	-6.3
350130022	Santa Teresa	5.8	-1.8
350130023	Solano	3.9	-8.2
350151005	Carlsbad	-4.3	-14.5
350171003	Chino Copper	7.0	-1.8
350250008	Hobbs Jefferson	-1.2	-12.6
350290003	Deming Airport	3.8	-8.6
350390026	Coyote Ranger	1.2	-5.6
350431001	Bernalillo	6.4	3.3
350450009	Bloomfield	6.0	1.7
350450018	Navajo Lake	0.5	-3.6
350451005	Sub Station	-0.1	2.2
350490021	Santa Fe Airport	1.5	-2.5
350610008	Los Lunas	-1.7	-9.0

6.7 Conclusions of 2014 Base Case Modeling and Model Performance Evaluation

The evaluation of the NM OAI Study CAMx original 2014 and revised 2014v2 base case simulations focused on MDA8 ozone model performance across all sites within New Mexico, within three subregions in New Mexico (northern, Bernalillo County, and southern) and at individual sites in New Mexico. When examining MDA8 ozone performance across groups of sites, both CAMx 2014 base cases always achieves the ozone Performance Criteria and usually achieves the ozone Performance Goals. Except for one site (La Union in Doña Ana County) both CAMx base cases also achieve the ozone Performance Criteria at all monitoring sites and achieve the ozone Performance Goals as a majority of the sites in New Mexico. When examining MDA8 ozone performance across all observations, the model tended to have an ozone overestimation tendency but still always achieved the bias performance criteria ($\leq \pm 15\%$) and usually achieved the bias performance goal ($\leq \pm 5\%$). When comparing the model's ability to reproduce the highest observed ozone concentrations greater than 60 ppb, the model still always achieved the bias performance criteria and usually achieved the bias performance goal, albeit with an underestimation tendency. The

MDA8 ozone error essentially always achieves the performance goal whether examining all ozone observations or just those observations greater than 60 ppb.

In conclusion, the NM OAI Study original CAMx 2014 and revised CAMx 2014v2 base case simulations ozone model performance within New Mexico is as good or better than most recent PGM applications (e.g., WRAP-WAQS, EPA 2016v1 and Denver ozone SIP) and appears to be a reliable PGM modeling platform for evaluating emission reduction strategies for reducing ozone concentrations in New Mexico.

7. 2028 BASE CASE MODELING AND OZONE DESIGN VALUE PROJECTIONS

A CAMx v7.1 2028 36/12/4-km Base Case model simulation was conducted using the WRF/NAM meteorological, 2014 Boundary Conditions (BCs) and 2028 base case emission inputs described in, respectively, Chapters 2, 3 and 4. The CAMx 2028 base case simulation used the same model configuration as used in the CAMx v7.1 2014v2 revised base case simulations presented in Chapter 6 only with the 2028 Base Case anthropogenic emissions.

The CAMx 2014v2 and 2028 Base Case simulations were used to make 2028 future-year ozone design value (DVF) projections.

7.1 EPA Recommended Ozone Design Value Projection Procedure

EPA recommends using photochemical grid model (PGM) modeling results in a relative fashion to scale the observed current year ozone design value (DVC) to estimate the future year ozone design value (DVF). The model derived scaling factors are called Relative Response Factors (RRF) and are the ratio of future (2028) to base (2014v2) year ozone modeling results averaged over the 10 highest base year base case modeled Maximum Daily 8-hour Average (MDA8) ozone concentrations near the monitor:

$$RRF = \sum \text{Model}_{2028} / \sum \text{Model}_{2014}$$

$$DVF = DVC \times RRF$$

EPA guidance recommends that the DVC is calculated as the average of three-years of ozone design values (DV) centered on the base modeling year, which is 2014 in this case:

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

By near the monitor, EPA guidance recommends that the highest modeled base year MDA8 ozone is selected within a 3x3 array of grid cells centered on the monitor. 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.

EPA guidance recommends using the 10 highest modeled base year MDA8 ozone concentrations days with MDA8 ozone greater than 60 ppb in the RRFs. If there are less than 10 modeled days with base year MDA8 ozone greater than 60 ppb, EPA guidance states that RRFs can still be calculated as long as there are at least 5 days with ozone greater than 60 ppb.

EPA has codified their recommended ozone DVF projection approach in the Software for the Modeled Attainment Test (SMAT³⁷). The SMAT tool was used to make 2028 ozone DVF projections in the NM OAI Study. The default SMAT specification were used except

³⁷ <https://www.epa.gov/scram/photochemical-modeling-tools>

that the minimum number of days needed to calculate an RRF was lowered from 5 to 4 in order to obtain 2028 ozone DV projections at all sites in New Mexico.

7.1.1 Ozone DV Unmonitored Area Analysis (UAA)

SMAT includes an unmonitored area analysis (UAA) that examines projected future year ozone DVFs away from the monitoring sites. The first step in the UAA is the spatial interpolation of the monitor-based ozone DVCs (DVC₂₀₁₂₋₂₀₁₆) across the domain being analyzed, which is the 4-km New Mexico domain in this case. The SMAT spatial interpolation of the monitoring site ozone DVC can be performed with and without using the modeled ozone concentration gradients. As shown below, the SMAT UAA analysis was run for the NM OAI Study 2028 base case ozone DVC projections with and without using the modeled concentration gradients. We recommend using the interpolation without the modeled concentration gradients because of the influence of fires on UAA interpolated ozone DVCs that are uncertain, unverifiable, and not regulatory relevant.

The SMAT UAA procedure for projecting the spatially interpolated ozone DVCs is the same as used at the monitor described above, only instead of using the modeling results in the in a 3x3 array of grid cells with the highest 2014 modeled MDA8 ozone to define near the monitor, the value at the grid cell is used (i.e., 1x1 array).

7.2 2028 Base Case Ozone DVF Projections at Monitoring Sites

Table 7-1 displays the current year DVC₂₀₁₂₋₂₀₁₆ and projected 2028 ozone DVFs at monitoring sites in New Mexico for the 2028 Base Case simulation and their differences. There are two sites in Doña Ana County with current year DVC₂₀₁₂₋₂₀₁₆ above the 70 ppb 2015 ozone NAAQS, Desert View (72.0 ppb) and Santa Teresa (71.3 ppb). However, it should be noted that measured ozone concentrations in Southern New Mexico have been higher in more recent years, as shown in Table 1-1. This issue is examined in a DVC sensitivity analysis presented in Chapter 9.

The 2028 Base Case ozone DVFs at monitoring sites in northern New Mexico are projected to be -2.2 ppb to -5.6 ppb lower than the observed DVC₂₀₁₂₋₂₀₁₆. For the northern New Mexico sites, Navajo Lake has the highest ozone DVC₂₀₁₂₋₂₀₁₆ (67.0 ppb) and 2028 Base Case projected DVF (64.8) and is the site with the lowest reduction between the DVC and DVF (-2.2 ppb).

The current observed DVC₂₀₁₂₋₂₀₁₆ in Bernalillo County range from 65.0 to 68.0 ppb and are projected to be reduced by -4.4 ppb to -5.9 ppb by 2028 with all 2028 Base Case projected ozone DVFs in Bernalillo County below 63 ppb.

The current ozone DVC₂₀₁₂₋₂₀₁₆ at the southern New Mexico sites range from 62.0 to 72.0 ppb and are reduced by -2.0 ppb to -6.3 ppb in the 2028 Base Case. The sites in Doña Ana County have the largest ozone DV reductions between 2014 and 2028 (-4.7 to -6.3 ppb). While those monitoring sites in southeast New Mexico have the lowest ozone DVF reduction between 2014 and 2028 Base Cases, -2.3 ppb at Carlsbad and -2.0 ppb at Hobbs in, respectively, Eddy and Lea Counties. The lower reductions in 2028 Base Case ozone DVFs at the two southeastern New Mexico sites are due to increased oil and gas emissions in the Permian Basin between 2014 and 2028 that offset the effects due to emission reductions from other source sectors, such as mobile sources (see Chapter 4).

Table 7-1. Current year DVC₂₀₁₂₋₂₀₁₆ and projected 2028 Base Case ozone DVF_s at New Mexico monitoring sites within the 4-km NM domain.

AQS_ID	2012-2016 DVC (ppb)	2028 Base DVF Base (ppb)	Difference 2028 DVF minus DVC ₂₀₁₂₋₁₆ (ppb)	Site Name	State	County
Northern New Mexico						
350390026	64.0	60.8	-3.2	Coyote Ranger District	NM	Rio Arriba
350431001	64.0	58.4	-5.6	Bernalillo (E Avenida)	NM	Sandoval
350450009	64.3	61.0	-3.3	Bloomfield	NM	San Juan
350450018	67.0	64.8	-2.2	Navajo Lake	NM	San Juan
350451005	63.7	60.8	-2.9	Substation	NM	San Juan
350490021	64.3	60.6	-3.7	Santa Fe Airport	NM	Santa Fe
Bernalillo County						
350010023	66.3	60.9	-5.4	Del Norte HS	NM	Bernalillo
350010024	68.0	62.3	-5.7	South East Heights	NM	Bernalillo
350010029	66.0	61.0	-5.0	South Valley	NM	Bernalillo
350010032	67.0	62.6	-4.4	Westside	NM	Bernalillo
350011012	65.0	59.1	-5.9	Foothills	NM	Bernalillo
Southern New Mexico						
350130008	66.3	60.0	-6.3	La Union	NM	Doña Ana
350130017	67.0	61.9	-5.1	Sunland Park City Yard	NM	Doña Ana
350130020	67.0	62.3	-4.7	Chaparral	NM	Doña Ana
350130021	72.0	67.0	-5.0	Desert View	NM	Doña Ana
350130022	71.3	66.1	-5.2	Santa Teresa	NM	Doña Ana
350130023	65.0	60.3	-4.7	Solano	NM	Doña Ana
350151005	69.0	66.7	-2.3	Carlsbad	NM	Eddy
350171003	62.0	59.0	-3.0	Chino Copper Smelter	NM	Grant
350250008	66.0	64.0	-2.0	Hobbs Jefferson	NM	Lea
350290003	66.0	62.7	-3.3	Deming Airport	NM	Luna
350610008	66.3	62.2	-4.1	Los Lunas (Los Lentos)	NM	Valencia

The current year DVC₂₀₁₂₋₂₀₁₆ and projected 2028 Base Case ozone DVFs at monitoring sites within the 4-km NM domain but outside of New Mexico are shown in Table 7-2. The El Paso UTEP site is the only site in Table 7-2 that has a DVC₂₀₁₂₋₂₀₁₆ that exceeds (71.0 ppb) the 2015 ozone NAAQS. Design values at monitoring sites in El Paso are projected to go down between -3.2 ppb to -5.2 ppb with projected 2028 Base Case ozone DVFs ranging from 62.5 ppb to 66.2 ppb.

The sites in Arizona and Colorado have current year DVC₂₀₁₂₋₂₀₁₆ that are 68 ppb or lower and are reduced from -1.6 ppb to -5.2 ppb with the smallest reductions occurring in La Plata County, Colorado and the largest reductions occurring in El Paso.

Table 7-2. Current year DVC₂₀₁₂₋₂₀₁₆ and projected 2028 Base Case ozone DVFs at monitoring sites within the 4-km NM domain but outside of New Mexico.

AQS_ID	2012-2016 DVC (ppb)	2028 Base DVF Base (ppb)	Difference 2028 DVF minus DVC ₂₀₁₂₋₁₆ (ppb)	Site Name	State	County
Arizona, Colorado and Texas						
40038001	68.0	64.0	-4.0	Chiricahua NM	AZ	Cochise
40170119	66.7	61.9	-4.8	Petrified Forest	AZ	Navajo
80677001	67.7	66.1	-1.6	UTE 1	CO	La Plata
80677003	66.7	64.4	-2.3	UTE 3	CO	La Plata
80830006	63.0	59.7	-3.3	Cortez - Health Dept	CO	Montezuma
80830101	66.0	62.4	-3.6	Mesa Verde NP	CO	Montezuma
481410029	61.0	58.0	-3.0	Ivanhoe	TX	El Paso
481410037	71.0	66.2	-4.8	El Paso UTEP	TX	El Paso
481410044	67.7	62.5	-5.2	El Paso Chamizal	TX	El Paso
481410055	62.7	59.2	-3.5	Ascarate Park SE	TX	El Paso
481410057	66.5	63.3	-3.2	Socorro Hueco	TX	El Paso
481410058	68.0	63.4	-4.6	Skyline Park	TX	El Paso
483819991	66.7	62.4	-4.3	Palo Duro	TX	Randall

7.3 2028 Base Case Ozone DVF Unmonitored Area Analysis

SMAT was run using output the 2014v2 and 2028 Base Case CAMx simulations to obtain the spatial distribution of interpolated current year ozone DVC₂₀₁₂₋₂₀₁₆ and projected 2028 ozone DVF throughout the 4-km NM domain using the Unmonitored Area Analysis (UAA) feature. SMAT UAA was run with and without using modeled concentration gradients in the spatial interpolation of the observed ozone DVC₂₀₁₂₋₂₀₁₆ at the monitoring sites to each grid cell in the 4-km NM domain.

Figure 7-1 displays the spatial distribution of the SMAT UAA ozone DVC₂₀₁₂₋₂₀₁₆ and DVF across the 4-km NM domain calculated using CAMx modeled ozone concentrations gradients in the spatial interpolation of the DVC₂₀₁₂₋₂₀₁₆. Although the highest DVC₂₀₁₂₋₂₀₁₆ at a monitoring site is 72.0 ppb at Desert View, using modeled concentration

gradients produces an interpolated $DVC_{2012-2016}$ as high as 89.5 ppb that occurs in Arizona on the border with New Mexico that is reduced to 84.0 ppb for the maximum 2028 Base Case UAA DVF. These high MDA8 ozone concentrations in eastern Arizona and southwestern New Mexico are due to elevated ozone concentrations from wildfire emissions that are used in the SMAT UAA $DVC_{2012-2016}$ spatial interpolation when the option to use modeled concentration gradients is selected. Because they occur away from any monitoring sites, whether actual elevated ozone occurred in these wildfire ozone plumes is not known. Away from these wildfire ozone plumes, the SMAT UAA $DVC_{2012-2016}$ range from 60 to 71 ppb that are reduced to the 50 to 65 ppb range in for the SMAT UAA 2028 ozone DVF with small patches in the 65-71 ppb range scattered across New Mexico.

The SMAT UAA ozone $DVC_{2012-2016}$ and 2028 Base Case projections obtained without using the modeled concentrations gradients are shown in Figure 7-2. When doing the SMAT UAA spatial interpolation of the $DVC_{2012-2016}$ without including the concentrations gradients the ozone $DVC_{2012-2016}$ across the 4-km NM modeling domain are constrained by the $DVC_{2012-2016}$ values at the monitoring sites (i.e., Tables 7-1 and 7-2), which range from 61.4 to 71.0 ppb (10 ppb range; Figure 7-2). This is in contrast when the modeled concentrations gradients are used in the SMAT UAA interpolation and the $DVC_{2012-2016}$ range from 58.2 to 89.5 ppb across the domain (31 ppb range; Figure 7-1).

Figure 7-3 displays a spatial map of the differences in ozone $DVC_{2012-2016}$ and 2028 base case DVF ($DVF - DVC$) from the SMAT UAA with the top panel shown the differences with and the bottom panel showing the differences without using the modeled spatial gradients in the interpolation. Using the modeled concentration gradients in the interpolation has a significant effect on the DVC/DVFs, but has little effect on the differences in the SMAT UAA DVF and DVC. In fact, the only perceptible change in the ozone DVF and DVC differences is near the location of the modeled wildfire ozone plume in eastern Arizona.

The largest differences in current year ozone DVC and the 2028 Base Case DVF occurs in the eastern part of the domain with reductions of -4 to -11 ppb that are coming in from east Texas where there are larger emission reductions due to larger population centers. Over most of New Mexico, there are small reductions in the -1 to -4 ppb range with reductions in the -4 to -6 ppb range near Albuquerque. However, within the Permian and San Juan Basins there are small areas of ozone DVF increases with the largest increase of +3 ppb.

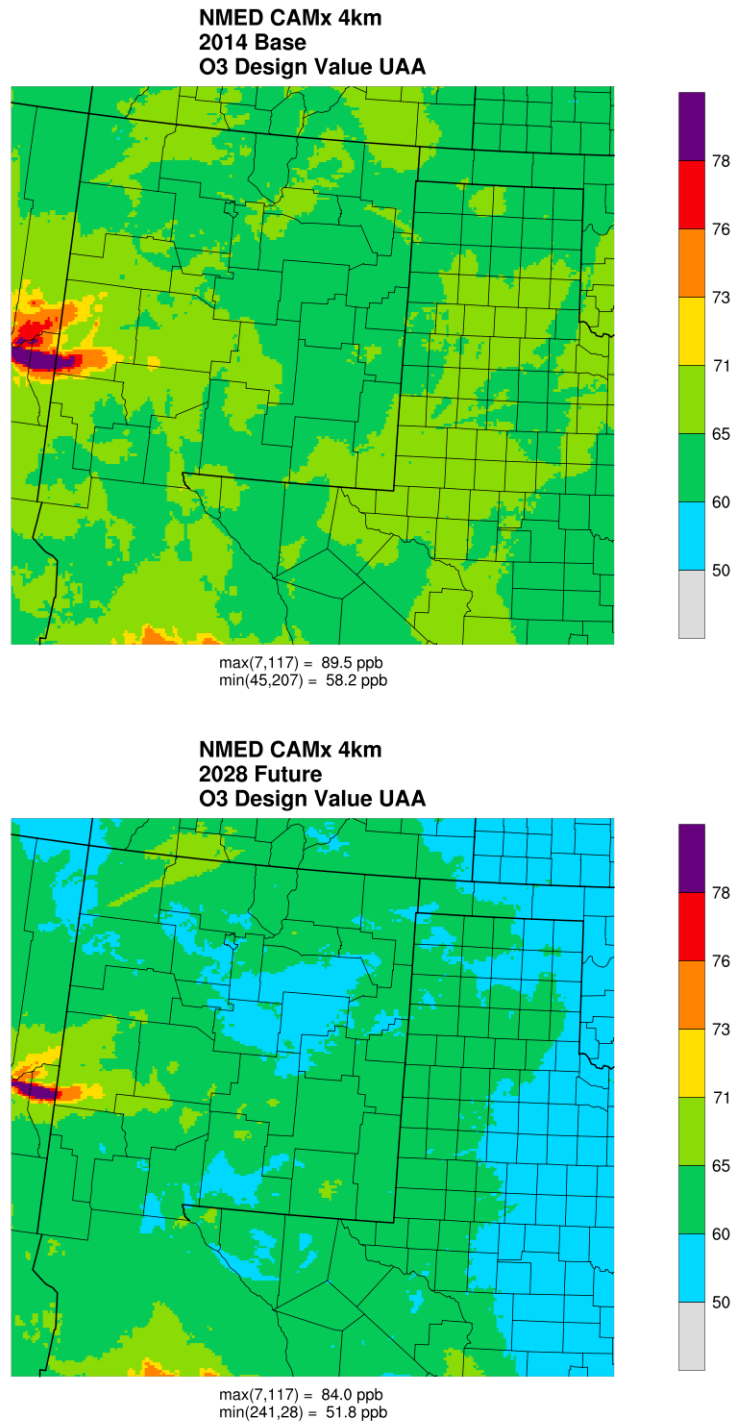


Figure 7-1. SMAT UAA current year ozone DVC₂₀₁₂₋₂₀₁₆ and projected 2028 future year ozone DVF for the 2028 Base Case using spatial interpolation with concentration gradients.

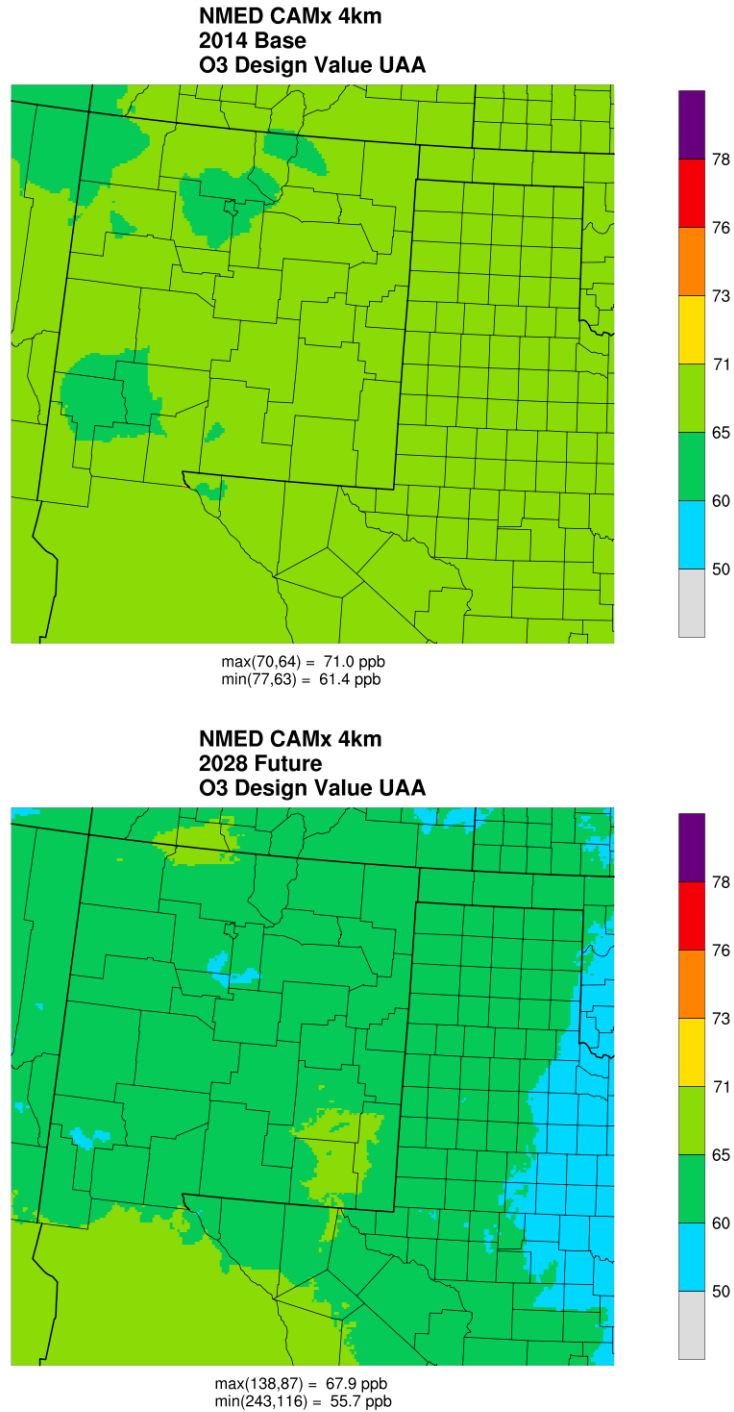


Figure 7-2. SMAT UAA current year ozone DVC₂₀₁₂₋₂₀₁₆ (top) and projected 2028 future year DVF for the 2028 Base Case using spatial interpolation without concentration gradients.

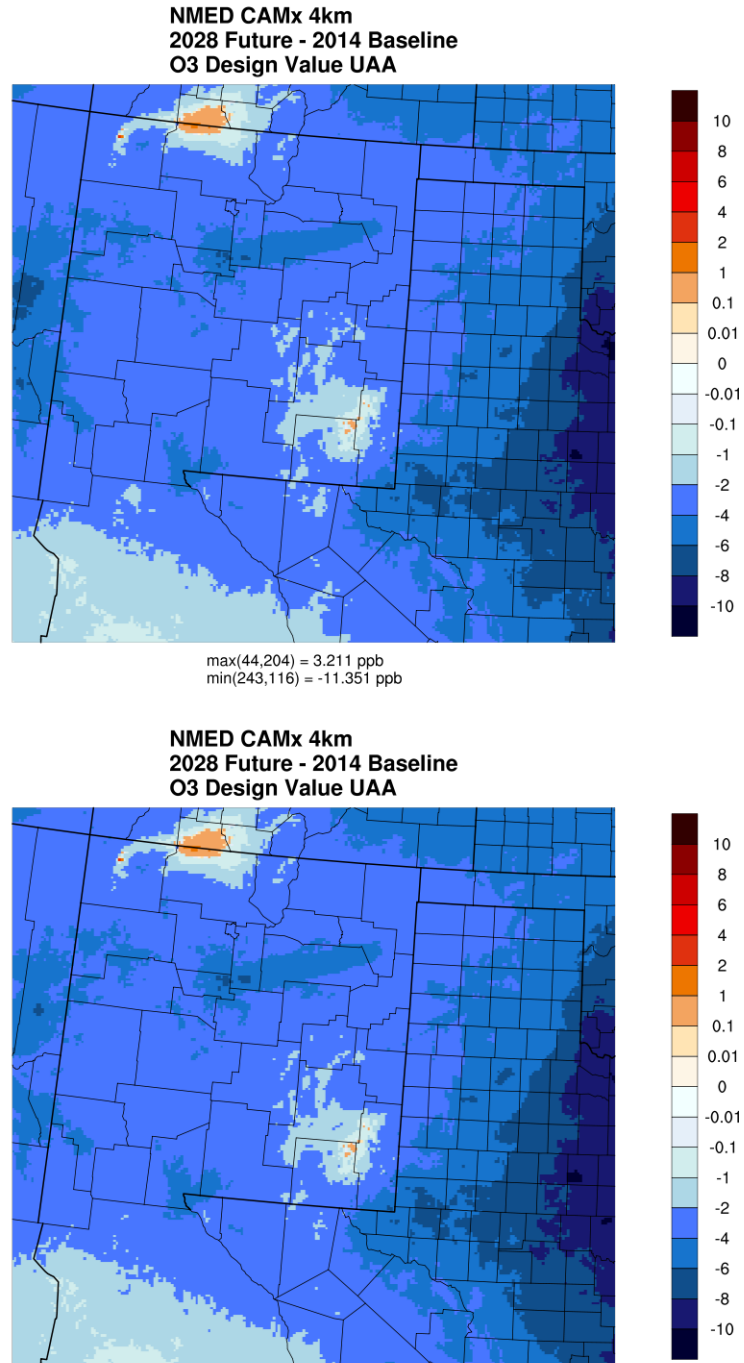


Figure 7-3. Differences between SMAT UAA current year ozone DVC₂₀₁₂₋₂₀₁₆ and projected 2028 future year ozone DVF for the 2028 Base Case using spatial interpolation with (top) and without (bottom) concentration gradients.

7.4 2014v2 and 2028 MDA8 Ozone Concentrations

In this section we present spatial maps of daily MDA8 ozone and the differences in MDA8 ozone for the 2014v2 and 2028 Base Case CAMx simulations for six example days. MDA8 ozone concentration and difference plots were generated for all ~100 days of the modeling episode, most of which were fairly low ozone concentration days so are of less interest.

7.4.1 Daily 2014v2 and 2028 Base Case MDA8 Ozone Concentrations

Figures 7-4 through 7-9 display example spatial maps of MDA8 ozone concentrations for the CAMx 2014v2 and 2028 Base Case simulations and their differences for six example days.

The most prominent features in the estimated MDA8 ozone concentrations on May 17, 2014 are locations of very high (> 80 ppb) ozone concentrations in eastern Arizona and southwest New Mexico (Figure 7-4). These high ozone concentrations have a signature of ozone from wildfires with the largest being an ozone plume being transported into western New Mexico from a wildfire in eastern Arizona. Although there are no ozone monitors located in the center of these model-estimated highly elevated ozone plumes, the Chino Copper Smelter site in Grant County is within the edge of the plume where the model estimates MDA8 ozone concentrations in the 65-71 ppb range that match the observed concentrations at this site extremely well for the May-June 2014 portion of the episode (see Appendix A in Ramboll and WESTAR, 2020c; 2021). Over most of New Mexico, the 2028 Base Case has lower MDA8 ozone concentrations with reductions as high as -11 ppb in southwest Torrance County. However, the 2028 Base Case has MDA8 ozone increases in the San Juan and Permian Basins with a maximum MDA8 ozone increase of +5 ppb in Eddy County.

On June 5, 2014, the 2014v2 Base Case has CAMx-estimated MDA8 ozone concentrations in the 65-71 ppb range in northwest New Mexico and in Doña Ana County with even a small location of MDA8 ozone exceeding the 2015 ozone NAAQS in the northeast corner of San Juan County and a modeled peak MDA8 ozone concentration of 72.9 ppb occurring in El Paso just over the border from Doña Ana County (Figure 7-5). Although the emission changes from 2014v2 to 2028 reduce the intrusion of elevated ozone entering Doña Ana County from El Paso, the elevated ozone in northwest New Mexico is increased. The area of estimated MDA8 ozone in San Juan County that is above the 2015 ozone NAAQS is larger in the 2028 Base Case than the 2014v2 Base Case and stretches into Rio Arriba County with a peak ozone value of 74 ppb in Colorado at the border with New Mexico. As shown in the MDA8 ozone difference plot in Figure 7-5, increases in MDA8 ozone concentrations in the 2028 Base Case are due to increased O&G emissions within the Permian and San Juan Basins.

Although the 2014v2 and 2028 Base Case estimated MDA8 ozone on July 12, 2014 is well below the NAAQS (mostly < 60 ppb with small pockets in the 60-65 ppb range), the 2028 Base Case has increases MDA8 ozone in the San Juan and Permian Basins with a maximum increase of +11.4 ppb (Figure 7-6). The maximum decrease in MDA8 ozone is -7.6 ppb near Albuquerque.

On July 24, 2014, the CAMx 2014v2 Base Case estimates elevated MDA8 ozone concentrations in northwest New Mexico with values even exceeding the 2015 ozone

NAAQS in San Juan County and a peak value of 74.7 ppb in Colorado at the border with New Mexico (Figure 7-7). The 2028 Base Case has lower ozone than the 2014v2 Base Case across New Mexico with only small areas of ozone increases. The area of MDA8 ozone in San Juan County that was above the 2015 ozone NAAQS in the 2014v2 Base Case is reduced to below the NAAQS in the 2028 Base Case, although the peak MDA8 ozone in Colorado at the border of New Mexico still exceeds the NAAQS (71.3 ppb).

The CAMx 2014v2 Base Case estimates a high peak MDA8 ozone concentration of 78.4 ppb in Albuquerque with several additional areas of high ozone above the NAAQS occurring in other northern New Mexico Counties on July 26, 2014 (Figure 7-8). Although the 2028 Base Case has reduced almost all of the areas with 2014v2 MDA8 ozone above the NAAQS, there is still an estimate ozone peak above the NAAQS (72.3 ppb) just west of Albuquerque in northeast Cibola County. Ozone increases are seen in the Permian and San Juan Basins on July 26 with the highest increase of +5.7 ppb occurring in the San Juan Basin.

An ozone peak of 74.1 ppb occurs on August 14 on the border of Doña Ana County and El Paso with ozone in excess of the NAAQS stretching into Doña County (Figure 7-9). The emission reductions in the 2028 Base Case appear reduce the estimated ozone in Doña County to below the NAAQS, although the peak ozone (71.2 ppb) just over the border in El Paso still exceeds the NAAQS. Ozone increases in the Permian and San Juan Basins are mostly less than +1 ppb and fairly isolated on this day.

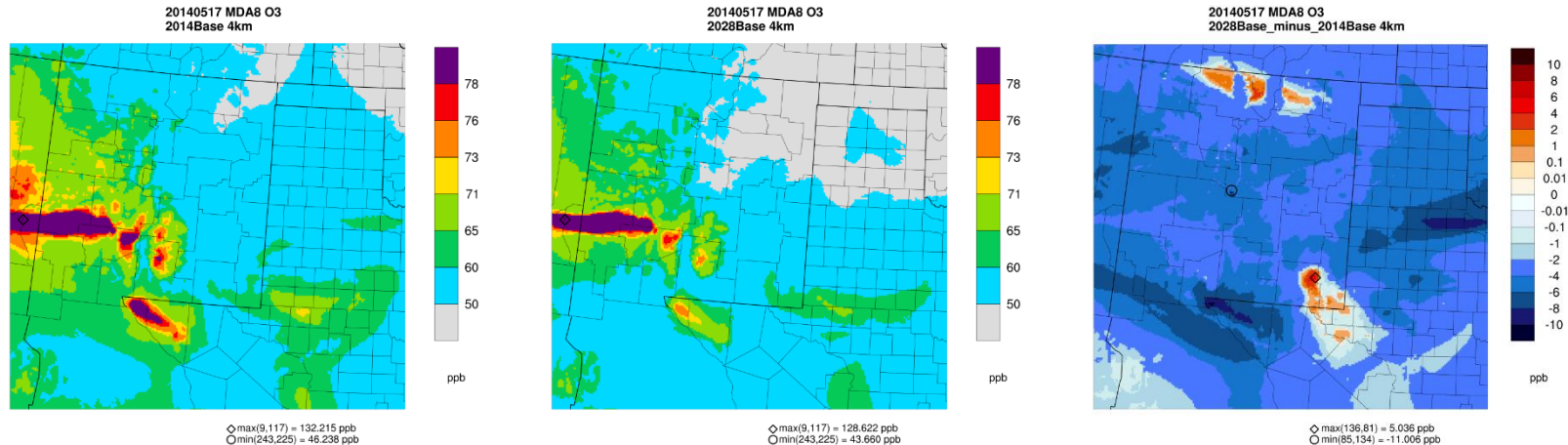


Figure 7-4. CAMx estimated MDA8 ozone concentrations (ppb) on May 17, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).

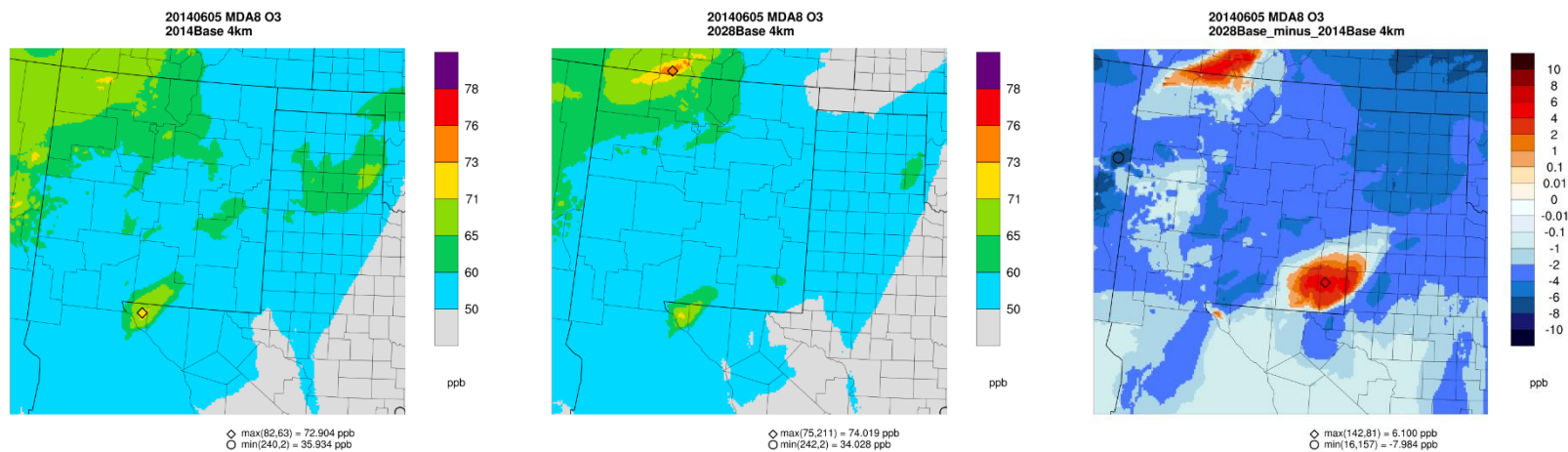


Figure 7-5. CAMx estimated MDA8 ozone concentrations (ppb) on June 5, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).

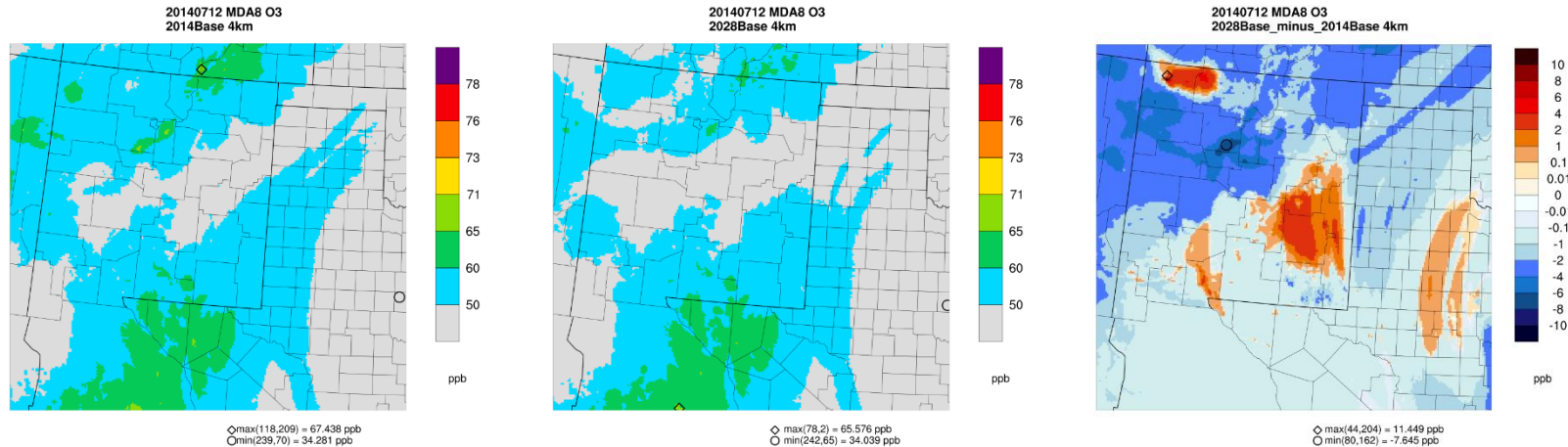


Figure 7-6. CAMx estimated MDA8 ozone concentrations (ppb) on July 12, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).

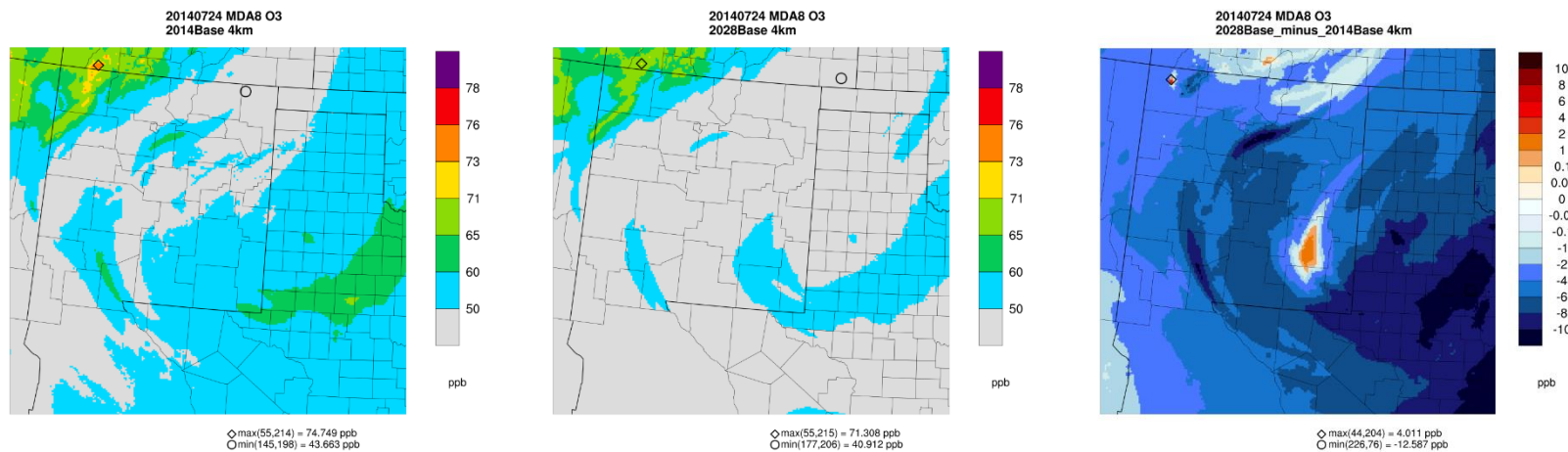


Figure 7-7. CAMx estimated MDA8 ozone concentrations (ppb) on July 24, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).

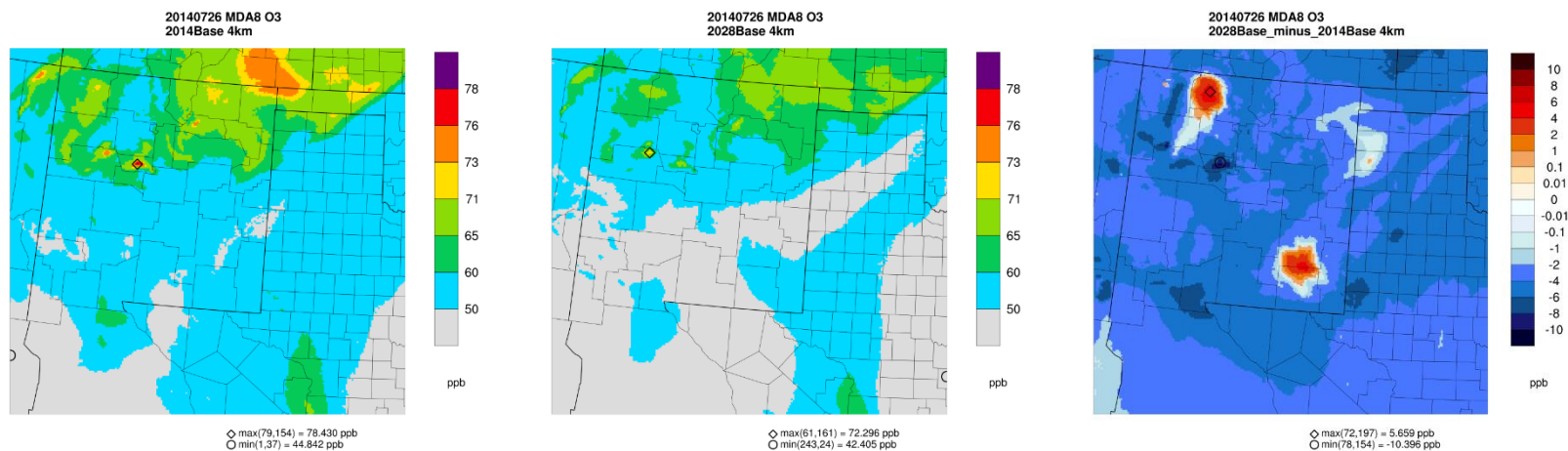


Figure 7-8. CAMx estimated MDA8 ozone concentrations (ppb) on July 26, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).

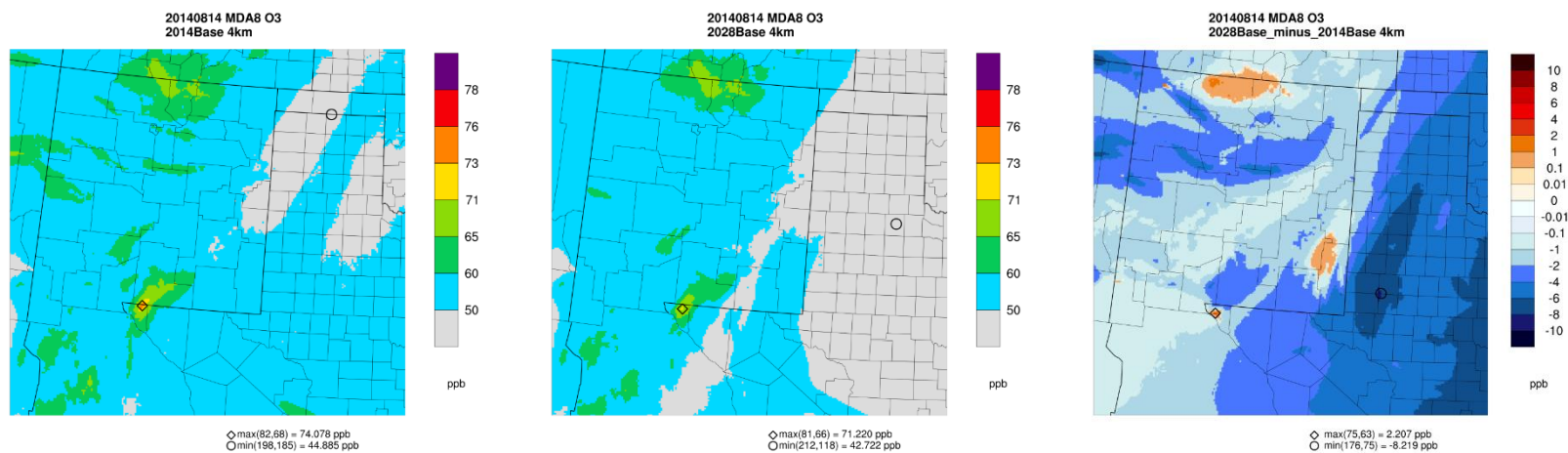


Figure 7-9. CAMx estimated MDA8 ozone concentrations (ppb) on August 14, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).

7.4.2 Comparison of Episode Maximum MDA8 and SMAT UAA Ozone DVF Differences

Figure 7-10 compare the differences in episode maximum MDA8 ozone concentrations and SMAT UAA ozone DVs between the 2014v2 and 2028 Base Case simulations (the SMAT UAA ozone DV differences are without using concentration gradients and was shown previously in the bottom panel of Figure 7-3). Not surprisingly, since the SMAT UAA DVs represents an average across several modeling days, the episode maximum MDA8 ozone differences have higher changes than the SMAT UAA ozone differences with a maximum increase of +5 ppb vs. +3 ppb and maximum decrease of -12 ppb vs. -11 ppb for the, respectively, episode maximum MDA8 ozone and UAA DVs. The largest decreases occur in Albuquerque and in southern Doña Ana County on the border with El Paso. The largest increases in ozone occur in the San Juan and Permian Basin.

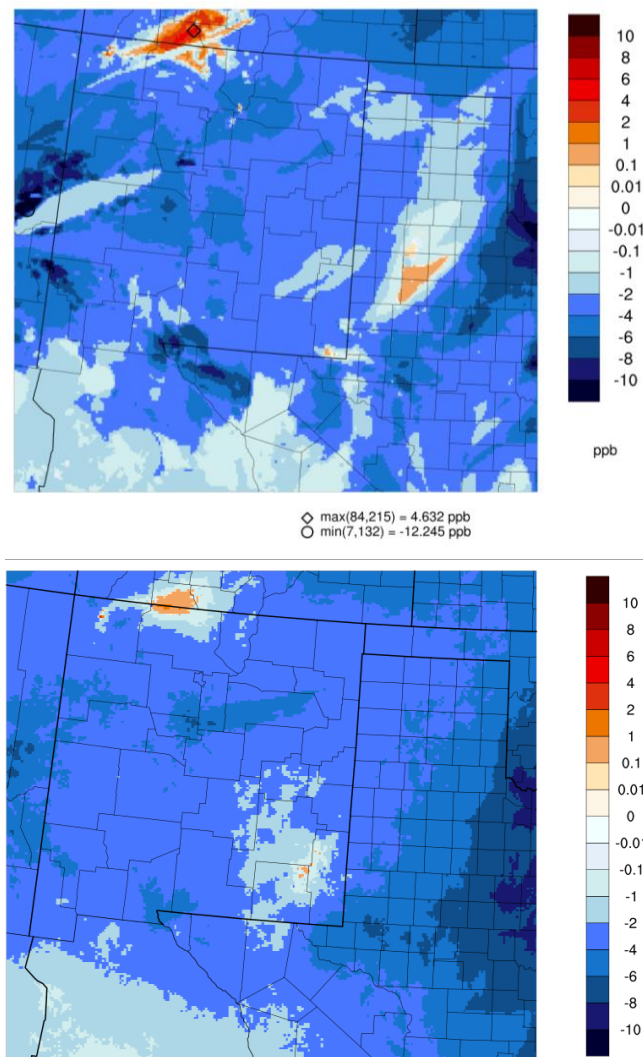


Figure 7-10. Differences in episode maximum MDA8 ozone concentrations (top) and SMAT UAA ozone DVs (bottom) between the 2014v2 and 2028 CAMx Base Case simulations.

8. 2028 OIL AND GAS CONTROL STRATEGY MODELING AND OZONE DESIGN VALUE PROJECTIONS

The implementation of the proposed New Mexico oil and gas (O&G) ozone precursor control strategy reduces VOC and NO_x emissions in the New Mexico portions of the San Juan and Permian Basins, as discussed in Section 4.5. Most of the O&G emission reduction in the San Juan Basin occur in northeastern San Juan and northwestern Rio Arriba Counties. While most of the emission reductions in the Permian Basin occur in Eddy and Lea Counties.

8.1 2028 Ozone Design Value Comparisons

The same procedures as used to project 2028 ozone DVFs for the CAMx 2028 Base Case (DVF_{Base}) were used to project the 2028 ozone DVFs for the 2028 O&G Control Strategy scenario (DVF_{Cntl}). These procedures start with an observed current year design value that is an average of 3 design values over 5-years (DVC₂₀₁₂₋₂₀₁₆) that is scaled by Relative Response Factors (RRFs) based on the ratio of the 2028 O&G Control Strategy over the 2014v2 Base Case CAMx ozone results to obtained a projected 2028 ozone DVF_{Cntl} for the 2028 O&G Control Strategy.

8.1.1 Ozone Design Values at the Monitoring Sites

Table 8-1 list the current year ozone DVC₂₀₁₂₋₂₀₁₆ and the projected 2028 ozone DVFs for the 2028 Base Case and 2028 O&G Control Strategy and the differences in the two 2028 ozone DVFs (DVF_{Cntl} – DVF_{Base}).

At monitoring sites in northern New Mexico, the 2028 ozone DVF_{Base} values are estimated to be reduced by -0.2 to -1.5 ppb due to the 2028 O&G Control Strategy with the largest reductions occurring at the Navajo Lake (-1.5 ppb) and Substation (-1.2 ppb) monitoring sites in San Juan County. After implementation of the 2028 O&G Control Strategy, the projected 2028 ozone DVF_{Cntl} in northern New Mexico range from 58.1 to 63.3 ppb.

Although not as close to the 2028 O&G emission reductions, the 2028 projected ozone DVF_{Cntl} in Bernalillo County see benefits of the 2028 O&G Control Strategy with ozone DVF reductions of -0.2 to -0.5 ppb. After implementation of the 2028 O&G Control Strategy, the projected 2028 ozone DVF_{Cntl} range from 58.8 to 62.1 ppb in Bernalillo County.

The 2028 ozone DVF reductions due to the 2028 O&G Control Strategy at the southern New Mexico monitoring sites range from -0.2 to -0.7 ppb with the largest reductions occurring at the Hobbs (-0.7 ppb) and Carlsbad (-0.3 ppb) monitoring sites in, respectively, Eddy and Lea Counties that lie within the Permian Basin. The other monitoring sites in southern New Mexico are farther away from the Permian Basin so have much more modest reductions in ozone DVFs (-0.1 to -0.2 ppb) due to the controls on oil and gas sources. After implementation of the 2028 O&G Control Strategies, the projected 2028 ozone DVF_{Cntl} at southern New Mexico sites range from 58.9 ppb to 66.8 ppb.

Table 8-1. Observed ozone DVC₂₀₁₂₋₂₀₁₆ and projected 2028 ozone DVFs for the 2028 Base Case and 2028 O&G Control strategy and differences in the 2028 ozone DVFs (DVF_{Cntl} – DVF_{Base}).

AQS_ID	2012-16	Projected 2028 DVF			Site Name	State	County
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base			
Northern New Mexico							
350390026	64.0	60.8	60.0	-0.8	Coyote Ranger District	NM	Rio Arriba
350431001	64.0	58.4	58.1	-0.3	Bernalillo (E Avenida)	NM	Sandoval
350450009	64.3	61.0	60.2	-0.8	Bloomfield	NM	San Juan
350450018	67.0	64.8	63.3	-1.5	Navajo Lake	NM	San Juan
350451005	63.7	60.8	59.6	-1.2	Substation	NM	San Juan
350490021	64.3	60.6	60.4	-0.2	Santa Fe Airport	NM	Santa Fe
Bernalillo County							
350010023	66.3	60.9	60.7	-0.2	Del Norte HS	NM	Bernalillo
350010024	68.0	62.3	62.0	-0.3	South East Heights	NM	Bernalillo
350010029	66.0	61.0	60.5	-0.5	South Valley	NM	Bernalillo
350010032	67.0	62.6	62.1	-0.5	Westside	NM	Bernalillo
350011012	65.0	59.1	58.8	-0.3	Foothills	NM	Bernalillo
Southern New Mexico							
350130008	66.3	60.0	59.8	-0.2	La Union	NM	Doña Ana
350130017	67.0	61.9	61.8	-0.1	Sunland Park City Yard	NM	Doña Ana
350130020	67.0	62.3	62.2	-0.1	Chaparral	NM	Doña Ana
350130021	72.0	67.0	66.8	-0.2	Desert View	NM	Doña Ana
350130022	71.3	66.1	66.0	-0.1	Santa Teresa	NM	Doña Ana
350130023	65.0	60.3	60.2	-0.1	Solano	NM	Doña Ana
350151005	69.0	66.7	66.4	-0.3	Carlsbad	NM	Eddy
350171003	62.0	59.0	58.9	-0.1	Chino Copper Smelter	NM	Grant
350250008	66.0	64.0	63.3	-0.7	Hobbs Jefferson	NM	Lea
350290003	66.0	62.7	62.5	-0.2	Deming Airport	NM	Luna
350610008	66.3	62.2	62.0	-0.2	Los Lunas (Los Lentos)	NM	Valencia

Table 8-2 list the observed ozone DVC₂₀₁₂₋₂₀₁₆ and projected 2028 ozone DVFs for monitoring sites outside of New Mexico but within the 4-km NM modeling domain. There are small reductions in projected ozone DVFs in Arizona (0.0 and -0.1 ppb) and El Paso, Texas (0.0 to -0.2 ppb) due to the New Mexico 2028 O&G Control Strategy. However, there are more substantial reductions in projected 2028 ozone DVFs at sites in La Plata (-0.7 and -0.9 ppb) and Montezuma (-0.5 ppb) counties in southwestern Colorado that are adjacent to the New Mexico portion of the San Juan Basin where some of the 2028 O&G Control Strategy emission reductions occur.

Table 8-2. Observed ozone DVC₂₀₁₂₋₂₀₁₆ and projected 2028 ozone DVFs for the 2028 Base Case and 2028 O&G Control strategy and differences in the 2028 ozone DVFs (DVF_{Cntl} – DVF_{Base}).

AQS_ID	2012-16	Projected 2028 DVF			Site Name	State	County
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base			
Arizona, Colorado and Texas							
40038001	68.0	64.0	63.9	-0.1	Chiricahua NM	AZ	Cochise
40170119	66.7	61.9	61.9	0.0	Petrified Forest	AZ	Navajo
80677001	67.7	66.1	65.2	-0.9	UTE 1	CO	La Plata
80677003	66.7	64.4	63.7	-0.7	UTE 3	CO	La Plata
80830006	63.0	59.7	59.2	-0.5	Cortez - Health Dept	CO	Montezuma
80830101	66.0	62.4	61.9	-0.5	Mesa Verde NP	CO	Montezuma
481410029	61.0	58.0	57.9	-0.1	Ivanhoe	TX	El Paso
481410037	71.0	66.2	66.1	-0.1	El Paso UTEP	TX	El Paso
481410044	67.7	62.5	62.4	-0.1	El Paso Chamizal	TX	El Paso
481410055	62.7	59.2	59.1	-0.1	Ascarate Park SE	TX	El Paso
481410057	66.5	63.3	63.2	-0.1	Socorro Hueco	TX	El Paso
481410058	68.0	63.4	63.4	0.0	Skyline Park	TX	El Paso
483819991	66.7	62.4	62.2	-0.2	Palo Duro	TX	Randall

8.1.2 2028 O&G Control Strategy Ozone DVF Unmonitored Area Analysis

The SMAT Unmonitored Area Analysis (UAA) was applied to estimate the spatial distribution of projected 2028 ozone DVF_{Cntrl} throughout the 4-km NM modeling domain. Figure 8-1 displays the spatial distribution of the SMAT UAA ozone DVFs for the 2028 Base Case and 2028 O&G Control Strategy where the SMAT UAA was applied without using concentration gradients in the spatial interpolation of the $DVC_{2012-2016}$. Within New Mexico, the projected 2028 DVF_{Base} tends to be mostly in the 60-71 ppb range, with a few small locations with the values dropping below 60 ppb. The highest ozone concentrations (65-71 ppb) in New Mexico for the 2028 ozone DVF_{Base} occur in the San Juan and Permian Basin as indicated by the lighter green shading (Figure 8-1, top panel). When the O&G Control Strategy is applied, the ozone DVF_{Cntrl} in the San Juan Basin is lower (i.e., in the 60-65 ppb with the light green shading completely gone) and the area of ozone DVF_{Base} in the 65-71 ppb range is greatly reduced for the ozone DVF_{Cntrl} case.

Figure 8-2 shows a spatial map of the differences in SMAT UAA projected 2028 ozone DVFs between the 2028 Base Case and 2028 O&G Control Strategy ($DVF_{Cntrl} - DVF_{Base}$) where the top and bottom panels represent ozone DVF differences without and with using the modeled concentration gradients in the SMAT UAA spatial interpolation. As shown in Chapter 7, use of concentration gradients has a large effect on the projected 2028 ozone DVFs, but it has no material effect on the differences in the ozone DVFs for the two 2028 emission scenarios as the plots appear almost identical.

Within the Permian Basin, the 2028 O&G Control Strategy reduces the ozone DVF by -0.5 to -1.5 ppb with most of the largest reductions (-1.0 to -1.5 ppb) occurring in Lea County. The 2028 O&G Control Strategy has a larger effect on the 2028 ozone DVF in the San Jun Basin with reductions of -1.0 to -3.0 ppb with the largest reductions (-2.0 to -3.0 ppb) straddling the New Mexico/Colorado state line at Rio Arriba/Archuleta Counties.

There are also isolated grid cells of SMAT UAA ozone DVF increases in the Permian and San Juan Basins due to the 2028 O&G Control Strategy. These ozone DVF increases appear to be several isolated 4-km grid cells and are likely due to highly localized ozone increases at the locations of O&G point source NO_x emission reductions due to the O&G Control Strategy. Most (e.g., 90-95%) fresh emissions of oxides of nitrogen (NO_x) are in the form of nitric oxide (NO) that is converted fairly quickly to nitrogen dioxide (NO_2). The $NO-O_3$ titration reaction ($NO + O_3 \rightarrow NO_2 + O_2$) occurs very quickly and can locally deplete ozone concentrations due to the fresh NO emissions while forming NO_2 that can form ozone further downwind during photochemistry. This can result in localized ozone increases when NO_x emissions are reduced in high NO_x emission areas, such as large urban areas or within NO_x point source plumes. The so called “ NO_x Disbenefits” effects (i.e., local ozone increases due to NO_x emission reductions) has been verified in numerous measurement and modeling studies and has been one reason that in the past Los Angeles was more likely to have higher ozone on weekend days than weekdays because of the lower morning NO_x emissions on weekend days (the “weekend effect”). Over the years as NO_x emissions have been controlled, the effects of “ NO_x Disbenefits” has been lessening but can still occur in major urban areas and in NO_x point source plumes.

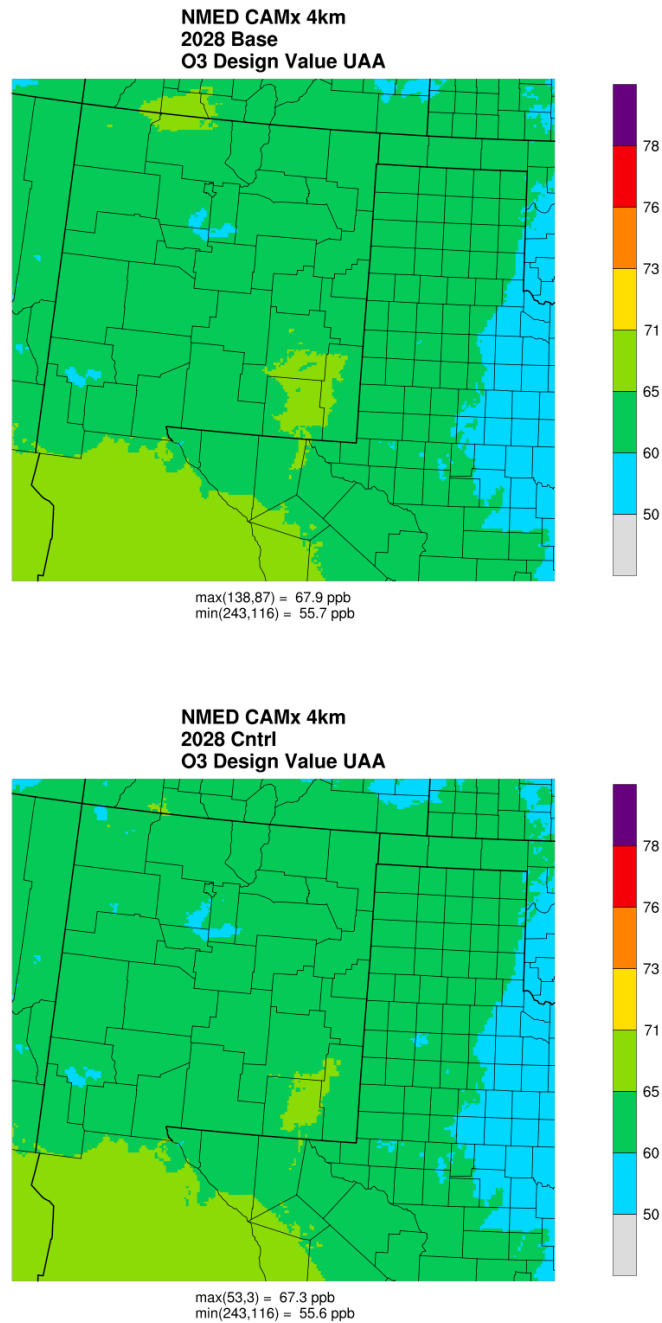


Figure 8-1. SMAT UAA spatial distribution of projected 2028 ozone DVF_{Base} (top) and DVF_{Cntrl} (bottom).

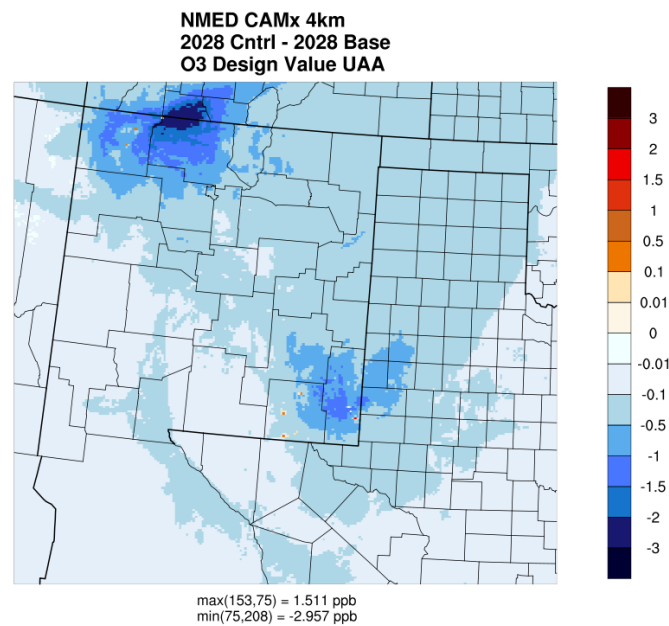
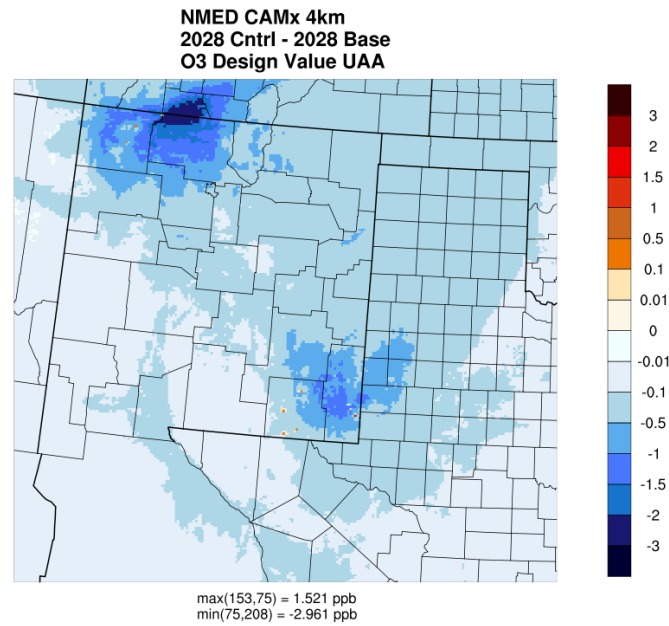


Figure 8-2. Differences in SMAT UAA projected 2028 ozone DVFs (ppb) for the 2028 Base Case and 2028 O&G Control Strategy ($DVF_{Cntrl} - DVF_{Base}$) running SMAT without (top) and with (bottom) using modeled concentration gradients in the DVC₂₀₁₂₋₂₀₁₆ spatial interpolation.

8.2 2028 Base Case and 2028 O&G Control Strategy MDA8 Ozone Concentrations

In this section we present spatial maps of modeled MDA8 ozone and the differences in MDA8 ozone for the 2028 Base Case and O&G Control Strategy emission scenarios for several example days.

8.2.1 Daily 2014v2 and 2028 Base Case MDA8 Ozone Concentrations

Figures 8-3 through 8-8 display example spatial maps of MDA8 ozone concentrations and their differences for the two CAMx 2028 emission scenarios for the same six days that were used to compare the 2014v2 and 2028 Base Case results that were presented in Figures 7- through 7-9. However, in the MDA8 difference plots for the two 2028 emission scenarios, a finer scale is used to better illustrate the 2028 MDA8 ozone differences due to the implementation of the O&G Control Strategy in 2028.

As discussed in Chapter 7, CAMx estimates very high MDA8 ozone concentrations on May 17, 2014 that are due to emissions from wildfires (Figure 8-3). The 2028 O&G Control Strategy scenario reduces the MDA8 ozone within the San Juan and Permian Basins by from -1 to -3 ppb on May 17th, with ozone reductions of -0.1 to -0.5 ppb spanning the area between the two Basins. There are areas of MDA8 ozone increases around the western edges of the O&G control area in the San Juan Basin with ozone increases as high as +1.4 ppb.

On June 5, 2014, the 2028 Base Case has CAMx-estimated MDA8 ozone concentrations in excess of the 70 ppb 2015 ozone NAAQS in northeast San Juan and northwest Rio Arriba Counties with a peak MDA8 ozone of 74 ppb on the border with and just inside of Colorado (Figure 8-4). The 2028 O&G Control Strategy is very effectively reducing these high MDA8 ozone exceedances in the San Juan Basin with ozone reductions of up to -4.6 ppb that reduce the MDA8 ozone to below the 2015 ozone NAAQS in San Juan and Rio Arriba Counties. MDA8 ozone is also reduced in the Permian Basin, although not nearly as great as in the San Juan Basin on this day. There are very small areas of ozone increases due to the 2028 O&G Control Strategy within New Mexico that are less than 0.1 ppb, although they are as high as 0.4 ppb near the Four Corners location.

The 2028 Base Case MDA8 ozone on July 12, 2014 in New Mexico is mostly below 60 ppb (blue) with some isolated areas slightly above that (green; Figure 8-5). The 2028 O&G Control Strategy results in MDA8 ozone reductions of more than -0.5 ppb over large areas expanding out of the two O&G Basins with reductions as high as -4.6 ppb in the San Juan Basin and as high as -1.0 to -1.5 ppb reduction in the Permian Basin. In the Permian Basin in the southeast corner of New Mexico, there are ozone increases due to the 2028 O&G Control Strategy that appear to be mostly in the +0.1 to +0.5 ppb range, with a peak increase of +1.6 ppb.

Elevated MDA8 ozone concentrations approaching, but below, the 2015 ozone NAAQS are estimated to occur in San Juan County on July 24, 2014 with a peak value of 71.3 ppb that is above the NAAQS occurring right across the border in Colorado (Figure 8-6). Although the 2028 O&G Control Strategy reduces the MDA8 ozone on this day across wide areas of New Mexico, with ozone reductions as high as -2.8 ppb in the Permian Basin, there are estimated increases in MDA8 ozone in San Juan County. These MDA8 ozone increases in San Juan County due to the 2028 O&G Control Strategy and are as high as +6.4 ppb. These increased in MDA8 ozone concentrations in San Juan County

due to the 2028 O&G Control Strategy are sufficient to increase the MDA8 ozone concentration in one grid cell to 71.0 ppb, which exceeds the 2015 ozone NAAQS.

On July 26th there are patches of elevated MDA8 ozone in the 2028 Base Case in the 65-71 ppb range in northern New Mexico with a peak MDA8 ozone concentration of 72.3 ppb in the northeast corner of Cibola County that exceeds the ozone NAAQS (Figure 8-7). The 2028 O&G Control Strategy reduces the MDA8 ozone Peak in Cibola County by -0.4 ppb to 71.9 ppb, which still exceeds the NAAQS. The 2028 O&G Control Strategy results in reductions in MDA8 ozone concentrations in excess of -3.0 ppb in the San Juan and Permian Basins with a maximum reduction of -5.4 ppb. The ozone reductions in the San Juan Basin are sufficient to reduce MDA8 ozone concentrations that were in the 65-71 ppb range in the 2028 Base Case to below 65 ppb.

On August 14, 2014, there are small areas of MDA8 ozone concentrations in the 65-71 ppb range in New Mexico on the northern border with Colorado and in southern border in Doña Ana County with the domain-wide peak ozone of 71.2 ppb just over the border from Doña Ana County in El Paso (Figure 8-8). The 2028 O&G Control Strategy has little effects on the MDA8 ozone peak in El Paso that remains at 71.2 ppb. The 2028 O&G Control Strategy reduces MDA8 ozone in the San Juan and Permian Basins by as much as -1.8 ppb; the ozone reductions in San Juan County reduce the size of the elevated ozone in the 65-71 ppb range. There are also areas of ozone increases to the west and northeast of the San Juan Basin due to the 2028 O&G Control Strategy that are as much as +1.6 ppb.

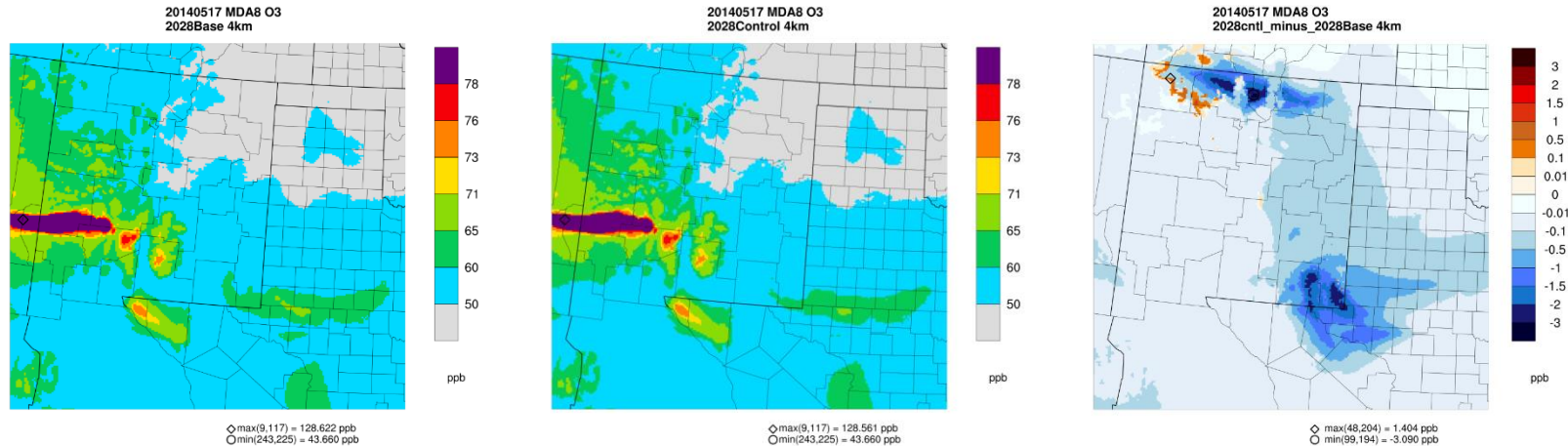


Figure 8-3. CAMx estimated MDA8 ozone concentrations (ppb) on May 17, 2014 for the 2028 Base Case (left), 2028 O&G Control Strategy Case (middle) and their difference (right).

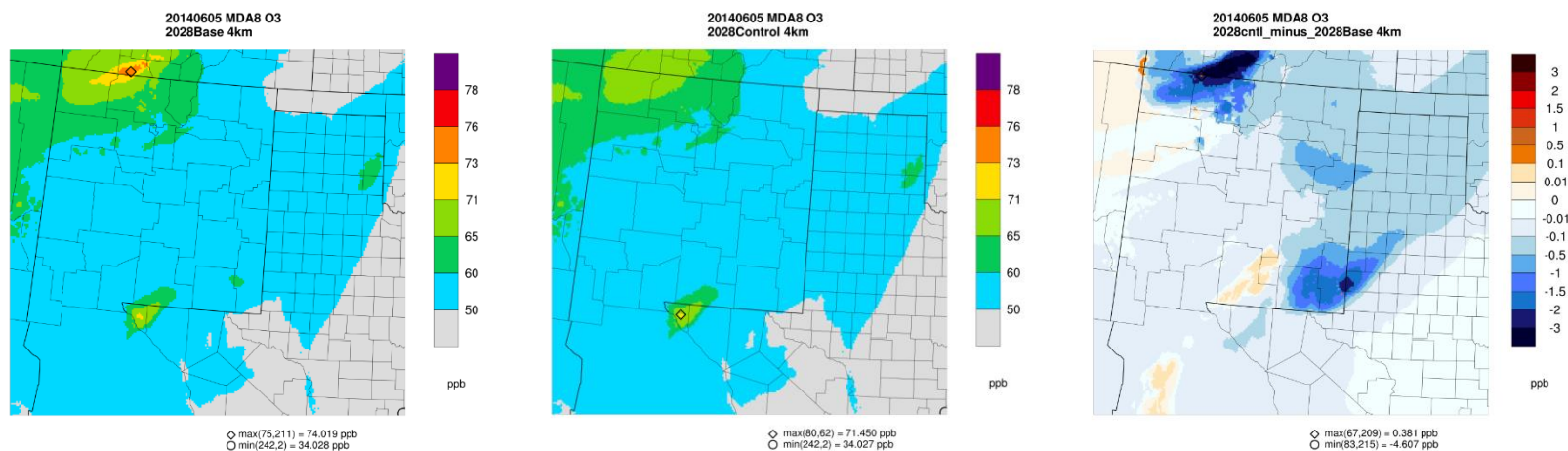


Figure 8-4. CAMx estimated MDA8 ozone concentrations (ppb) on June 5, 2014 for the 2028 Base Case (left), 2028 O&G Control Strategy (middle) and their difference (right).

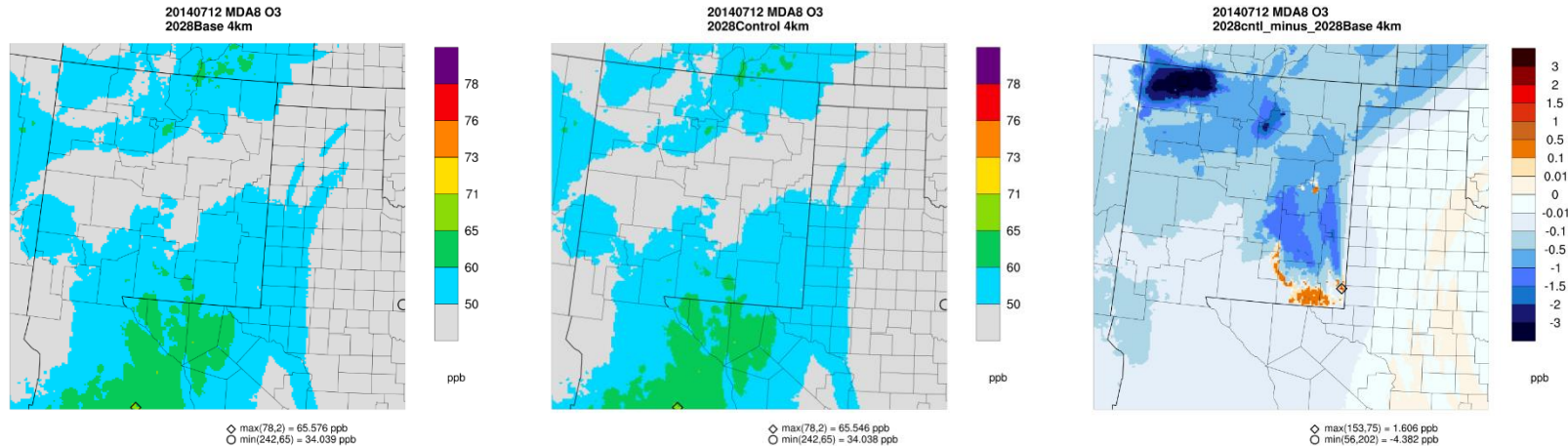


Figure 8-5. CAMx estimated MDA8 ozone concentrations (ppb) on July 12, 2014 for the 2028 Base Case (left), 2028 O&G Control Strategy (middle) and their difference (right).

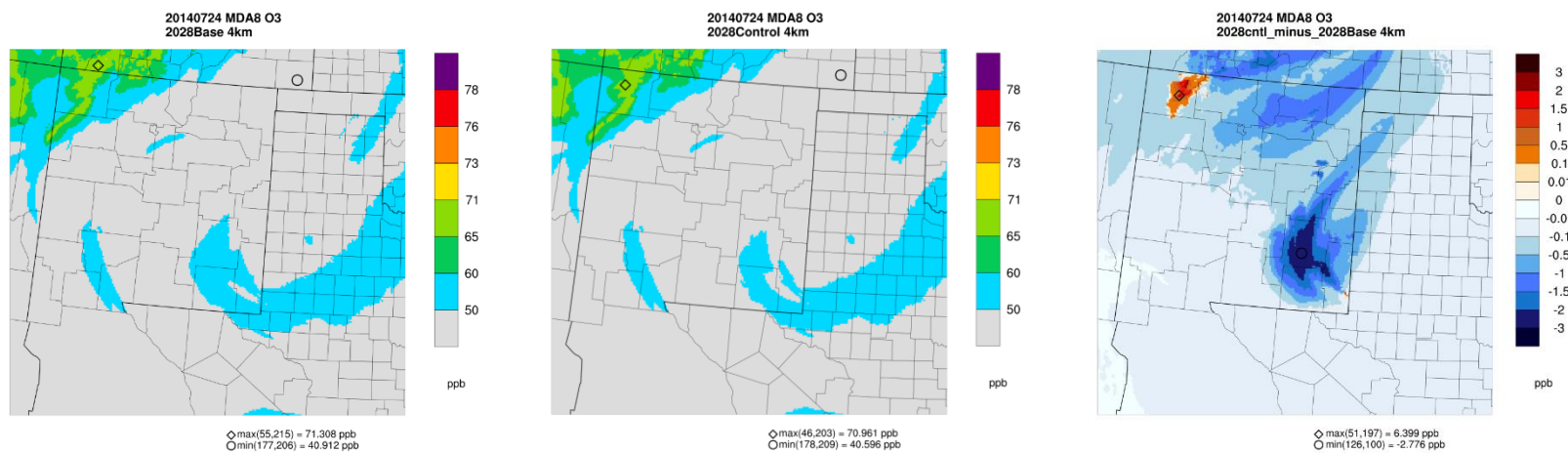


Figure 8-6. CAMx estimated MDA8 ozone concentrations (ppb) on July 24, 2014 for the 2028 Base Case (left), 2028 O&G Control Strategy (middle) and their difference (right).

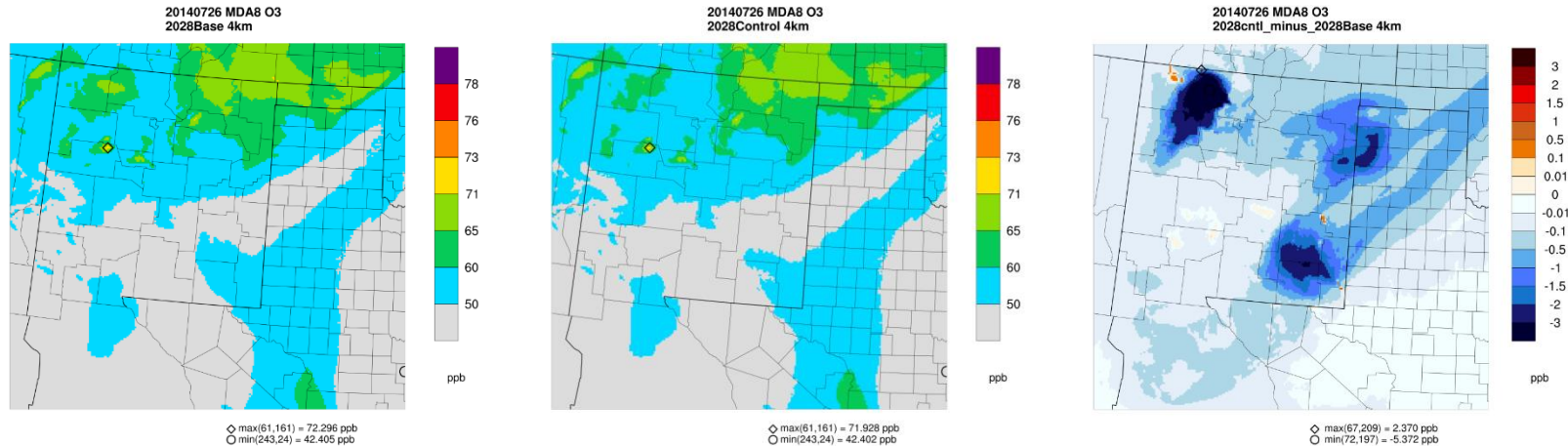


Figure 8-7. CAMx estimated MDA8 ozone concentrations (ppb) on July 26, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).

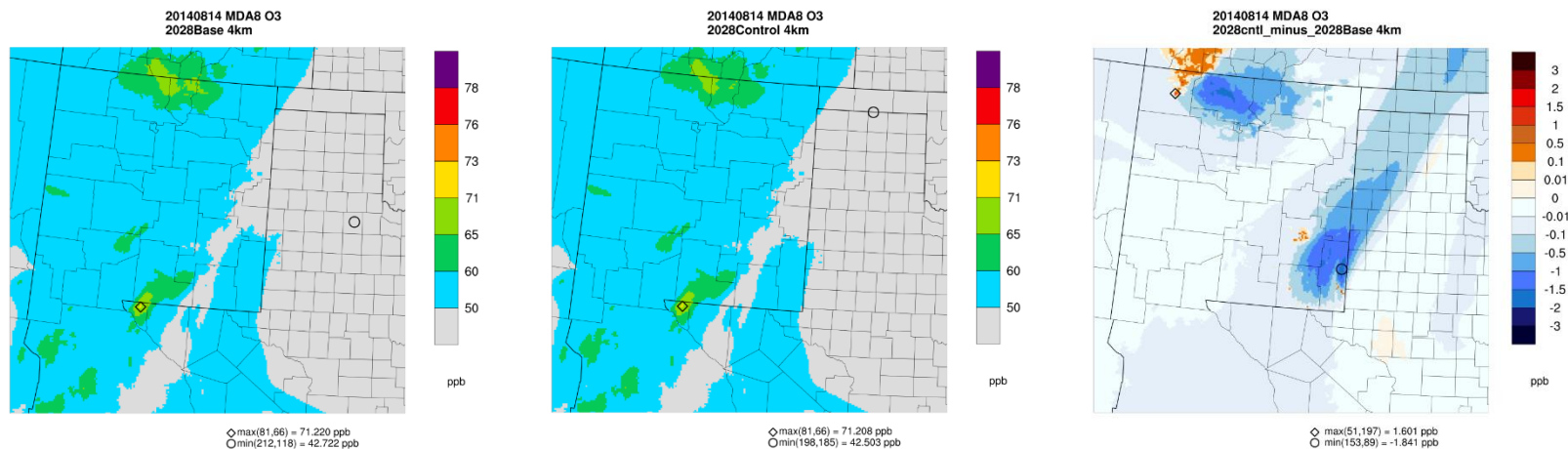


Figure 8-8. CAMx estimated MDA8 ozone concentrations (ppb) on August 14, 2014 for the 2014v2 Base Case (left), 2028 Base Case (middle) and their difference (right).

8.3 Conclusions of the 2028 Base and 2028 O&G Control Strategy Modeling

The O&G Control Strategy results in wide areas of reductions in 2028 Base Case MDA8 ozone concentrations and SMAT UAA projected 2028 ozone DVFs across large portions of New Mexico, with the largest ozone reductions occurring in the San Juan and Permian Basins. There are also areas of increases in MDA8 ozone and SMAT UAA projected 2028 ozone DVFs due to the O&G Control Strategy that usually occur in isolated locations within and near the San Juan and Permian Basin. The ozone increases in the SMAT UAA projected DVFs across New Mexico due to the O&G Control Strategy occur in a few isolated grid cells in the San Juan and Permian Basins; the projected 2028 ozone DVFs at all the monitoring sites saw only ozone reductions with no ozone increases due to the O&G Control Strategy. The size of the areas and magnitudes of the ozone reductions due to the 2028 O&G Control Strategy scenario were much greater than the ozone increases.

Using the current year ozone design value from 2012-2016 ($DVC_{2012-2016}$), the projected 2028 ozone DVFs for both the 2028 Base Case and 2028 O&G Control Strategy are below the 70 ppb 2015 ozone NAAQS with the highest values for the 2028 Base and O&G Control Cases occurring at the Desert View (67.0 and 66.8 ppb) monitoring site in Doña Ana County and the Carlsbad (66.7 and 66.4 ppb) monitoring site in Eddy County. However, as noted in Chapter 1 (Table 1-1), more recent observed DVs at Desert View and Carlsbad are much higher than the observed current year $DVC_{2012-2016}$ used in the 2028 ozone DVF projections presented in Chapters 7 and 8. The sensitivity of the choice of current year DVC on the projected 2028 ozone DVFs is analyzed in Chapter 9.

9. SENSITIVITY OF PROJECTED 2028 OZONE DESIGN VALUES TO CURRENT YEAR OZONE DESIGN VALUES

Following EPA photochemical grid modeling guidance ozone projection procedures, the projected 2028 future year ozone design values (DVs) were below the 70 ppb 2015 ozone NAAQS at all monitoring sites in New Mexico. EPA's guidance uses as a starting point for the future year ozone projections an average of three current year design values centered on the base modeling year (i.e., $DVC_{2012-2016}$). However, at many sites in New Mexico, the current year $DVC_{2012-2016}$ is lower than the most recent 2017-2019 ozone design values ($DV_{2017-2019}$). For example, at the Desert View site in Doña Ana County the most recent $DV_{2017-2019}$ is 77 ppb that is 5 ppb higher than the $DVC_{2012-2016}$ (72.0 ppb). And the most recent $DV_{2017-2019}$ at the Carlsbad site in Eddy County (79 ppb) is 7.7 ppb higher than the $DVC_{2012-2016}$ (71.3 ppb) used in the 2028 ozone DVF projections presented in Chapters 7 and 8.

In this Chapter we examine the sensitivity of the 2028 ozone DVF projections to the observed current year ozone design value (DVC) used as the starting point for the 2028 ozone DVF projections. Instead of using the $DVC_{2012-2016}$ as the starting point for the 2028 ozone DVF projections, we use the average of three ozone design values from 2015-2019 5-year period (i.e., $DVC_{2015-2019}$) and also conduct 2028 ozone DVF projections using the latest ozone $DV_{2017-2019}$ as the DVC. Note that we are still using the CAMx 2014v2 Base Case modeling results for the denominator of the RRFs used to make the 2028 ozone DVF projections that will not account for the changes in emissions between 2014 and the more current years that affect the magnitude of the ozone $DVC_{2015-2019}$ and $DV_{2017-2019}$. This includes emission reductions from mobile sources as well as emission increases from O&G sources. Thus, the 2028 ozone DVF projection sensitivity analysis to base year ozone DVC has uncertainties and will likely overstate 2028 ozone DVFs in and near the Permian Basin where the more current year O&G emissions are higher than they were in 2014 and understate the DVFs in areas not affected by O&G emissions from the Permian Basin.

9.1 2028 Ozone Design Value Sensitivity Analysis using $DVC_{2015-2019}$

Table 9-1 presents the current year ozone design value from 2015-2019 ($DVC_{2015-2019}$) and the projected 2028 ozone DVFs using the $DVC_{2015-2019}$ as the ozone projection DVC starting point. The $DVC_{2015-2019}$ are higher than the EPA-recommended (EPA, 2018) $DVC_{2012-2016}$ used as the ozone DVF projection starting point in Chapters 7 and 8. For example, there are four monitoring sites with $DVC_{2015-2019}$ above the NAAQS with Desert View (74.3 ppb), Santa Teresa (74.0 ppb), and Carlsbad (73.7 ppb) having $DVC_{2015-2019}$ of, respectively, 2.3, 2.7 and 4.7 ppb higher than the corresponding $DVC_{2012-2016}$. Note that the $DVC_{2015-2019}$ at Carlsbad Caverns NP (71.0 ppb) also exceeds the NAAQS, however it was not in operation for the $DVC_{2012-2016}$ period and the $DVC_{2015-2019}$ is based on just 3-years of data (2016-2018), so is actually based on just one design value, $DV_{2016-2018}$.

The 2028 projected ozone DVFs for the 2028 Base Case using the current year DVC₂₀₁₅₋₂₀₁₉ has one monitoring site that exceeds the 2015 ozone NAAQS, 71.2 ppb at Carlsbad. The next highest 2028 ozone DVFs for the 2028 Base Case are 69.3 ppb at Carlsbad Caverns NP and 69.1 ppb at Desert View.

The emissions controls in the 2028 O&G Control Strategy are sufficient to reduce the 2028 Base Case ozone DVF at Carlsbad (71.2 ppb) to below the ozone NAAQS (70.9 ppb) when DVC₂₀₁₅₋₂₀₁₉ current year design value is used in the 2028 ozone DVF projections.

Table 9-1. Projected 2028 ozone DVFs for the 2015-2019 current year design value DVC₂₀₁₅₋₂₀₁₉ sensitivity analysis.

AQS_ID	2015-19	Projected 2028 DVF			Site Name	County
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base		
350010023	69.0	63.4	63.1	-0.3	Del Norte HS	Bernalillo
350010029	66.0	61.0	60.5	-0.5	South Valley	Bernalillo
350011012	69.0	62.7	62.4	-0.3	Foothills	Bernalillo
350130008	68.7	62.1	62.0	-0.1	La Union	Doña Ana
350130020	70.7	65.7	65.7	0.0	Chaparral	Doña Ana
350130021	74.3	69.1	68.9	-0.2	Desert View	Doña Ana
350130022	74.0	68.6	68.5	-0.1	Santa Teresa	Doña Ana
350130023	67.7	62.9	62.7	-0.2	Solano	Doña Ana
350151005	73.7	71.2	70.9	-0.3	Carlsbad	Eddy
350153001	71.0	69.3	69.3	0.0	Carlsbad Caverns NP	Eddy
350250008	69.3	67.2	66.5	-0.7	Hobbs Jefferson	Lea
350390026	66.3	63.0	62.2	-0.8	Coyote Ranger Dist	Rio Arriba
350431001	67.0	61.2	60.9	-0.3	Bernalillo (E Avenida)	Sandoval
350450009	67.0	63.6	62.8	-0.8	Bloomfield	San Juan
350450018	69.0	66.7	65.2	-1.5	Navajo Lake	San Juan
350451005	67.3	64.2	62.9	-1.3	Substation	San Juan
350490021	65.0	61.2	61.0	-0.2	Santa Fe Airport	Santa Fe
350610008	66.7	62.6	62.3	-0.3	Los Lunas (Los Lentes)	Valencia

9.2 2028 Ozone Design Value Sensitivity Analysis using DVC₂₀₁₇₋₂₀₁₉

Table 9-2 shows the results of the 2028 ozone DVF projection current year ozone design value sensitivity analysis using the latest 2017-2019 ozone design value as the starting point for the 2028 ozone projections. There are three monitors in New Mexico with DV₂₀₁₅₋₂₀₁₉ above the NAAQS: Desert View (77.0 ppb), Santa Teresa (76.0 ppb) and Carlsbad (79 ppb). These DV₂₀₁₇₋₂₀₁₉ values are, respectively, 5.0, 4.7 and 10.0 ppb higher than the DVC₂₀₁₂₋₂₀₁₆ used as the

ozone projection starting point in the 2028 ozone DVF projections presented in Chapters 7 and 8.

For the 2028 Base Case, there are two sites with projected 2028 ozone DVFs in the DV₂₀₁₇₋₂₀₁₉ current year design value sensitivity test that have DVF values above the 2015 ozone NAAQS: 71.6 ppb at Desert View and 76.4 ppb at Carlsbad. The 76.0 ppb DV₂₀₁₇₋₂₀₁₉ at Santa Teresa is reduced to 70.5 ppb under the 2028 Base Case so attains the ozone NAAQS.

The projected 2028 ozone DVF using the DV₂₀₁₇₋₂₀₁₉ as the current year DVC under the O&G Control Strategy are 71.4 ppb at Desert View and 76.0 at Carlsbad so still exceed the 2015 ozone NAAQS. In fact, the Carlsbad 76.0 ppb ozone DVF even exceeds the 2008 ozone NAAQS.

Table 9-2. Projected 2028 ozone DVFs for the 2017-2019 current year design value DV₂₀₁₇₋₂₀₁₉ sensitivity analysis.

AQS_ID	2017-19	Projected 2028 DVF			Site Name	County
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base		
350010023	70.0	64.3	64.0	-0.3	Del Norte HS	Bernalillo
350010029	67.0	61.9	61.4	-0.5	South Valley	Bernalillo
350011012	71.0	64.5	64.2	-0.3	Foothills	Bernalillo
350130008	70.0	63.3	63.2	-0.1	La Union	Doña Ana
350130020	73.0	67.8	67.8	0.0	Chaparral	Doña Ana
350130021	77.0	71.6	71.4	-0.2	Desert View	Doña Ana
350130022	76.0	70.5	70.3	-0.2	Santa Teresa	Doña Ana
350130023	70.0	65.0	64.8	-0.2	Solano	Doña Ana
350151005	79.0	76.4	76.0	-0.4	Carlsbad	Eddy
350250008	71.0	68.9	68.1	-0.8	Hobbs Jefferson	Lea
350390026	67.0	63.6	62.8	-0.8	Coyote Ranger Dist	Rio Arriba
350431001	68.0	62.1	61.8	-0.3	Bernalillo (E Avenida)	Sandoval
350450009	68.0	64.6	63.7	-0.9	Bloomfield	San Juan
350450018	69.0	66.7	65.2	-1.5	Navajo Lake	San Juan
350451005	69.0	65.8	64.5	-1.3	Substation	San Juan
350490021	66.0	62.2	62.0	-0.2	Santa Fe Airport	Santa Fe
350610008	68.0	63.8	63.5	-0.3	Los Lunas (Los Lentes)	Valencia

10. 2028 SOURCE SECTOR APCA OZONE SOURCE APPORTIONMENT MODELING

Ozone source apportionment modeling was conducted to determine the contributions of Source Sectors within New Mexico to 2028 ozone concentrations and projected future year ozone design values (DVF) under the 2028 New Mexico oil and gas (O&G) control strategy emissions scenario. The Anthropogenic Precursor Culpability Assessment (APCA) version of the CAMx ozone source apportionment tool was used and the modeling also obtained contributions from Colorado, Texas and the remainder of U.S. states as well as international anthropogenic emissions.

10.1 Versions of Ozone Source Apportionment

CAMx includes two ozone source apportionment tools: the Ozone Source Apportionment Technology (OSAT) and the Anthropogenic Precursor Culpability Assessment (APCA). Both use tagged tracer species that track ozone formation from VOC (V_i) and NO_x ($\text{NIT}_i + \text{RGN}_i$) emissions from each user-specified Source Group (i). A Source Group can consist of a Source Region and/or Source Category. A typical OSAT/APCA application will use a Source Region map that divides the modeling domain into geographic regions and separate emission files of different Source Categories are provided as input to CAMx; ozone source apportionment is obtained for Source Groups that are defined as the intersection of the Source Regions with the Source Categories (e.g., on-road mobile sources from New Mexico). The ozone source apportionment tool runs in parallel to the CAMx host model and extracts information on ozone formation and assigns it to the user-defined Source Groups.

There are 10 reactive tracers used to track ozone formation for each user-defined Source Group as follows:

V_i	VOC emissions
NIT_i	Nitric oxide (NO) and nitrous acid (HONO) emissions
RGN_i	Nitrogen dioxide (NO_2), nitrate radical (NO_3) and dinitrogen pentoxide (N_2O_5)
TPN_i	Peroxy acetyl nitrate (PAN), analogues of PAN and peroxy nitric acid (PNA)
NTR_i	Organic nitrates (RNO_3)
HN3_i	Gaseous nitric acid (HNO_3)
O3N_i	Ozone formed under NO_x sensitive conditions
O3V_i	Ozone formed under VOC sensitive conditions
OON_i	Odd-oxygen in NO_2 formed from O3N_i
OOV_i	Odd-oxygen in NO_2 formed from O3V_i

For each time step and grid cell, when ozone is formed in the host model OSAT determines whether the ozone formation was more VOC sensitive or NO_x sensitive and apportions the ozone formed to Source Groups based on the relative contribution of the limiting precursor to the total precursor (e.g., under VOC sensitive conditions $V_i / \sum V_i$). APCA differs from OSAT in that it will only allocate ozone formed to natural (e.g., biogenic) emissions Source Groups when the ozone formed is due to natural VOC interacting with natural NO_x. So when ozone is formed due to biogenic VOC emissions interacting with anthropogenic NO_x emissions under VOC sensitive ozone formation conditions, a case OSAT would assign to the natural Source Group O3V_i tracer, APCA redirects the ozone formed to the anthropogenic Source Group O3N_i tracer. APCA was designed to provide more control strategy relevant information than OSAT and is used in identifying ozone contributions in emissions culpability assessments (e.g., CSAPR³⁸). However, OSAT has to be used to obtain information on whether ozone formation is more VOC or NO_x sensitive. Details on the CAMx OSAT and APCA source apportionment tools are provided in Chapter 7 of the CAMx user's guide.³⁹ Since we are running CAMx v7.1, it uses the third version of OSAT3 and corresponding version of APCA.

As the main focus of the 2028 Source Sector ozone source apportionment modeling is to identify the contributions of anthropogenic emission source sectors and regions to elevated MDA8 ozone concentrations in New Mexico, the APCA version of ozone source apportionment tool was used.

10.2 2028 Source Sector APCA Ozone Source Apportionment Specifications

Details on the design and specifications of the 2028 Source Sector APCA ozone source apportionment simulate are provide below.

10.2.1 2028 O&G Control Strategy Emissions Scenario

The 2028 Source Sector APCA ozone source apportionment was conducted using the 2028 New Mexico O&G Control Strategy emissions scenario.

10.2.2 Definition of Source Groups

The 2028 Source Sector APCA ozone source apportionment simulation used a Source Region map to define geographic regions of emission areas to be tracked. Separate source contributions were also obtained for 9 emission Source Categories as well as contributions due to Boundary Conditions (BCs) around the lateral edges of the 36-km grid resolution domain.

10.2.2.1 Boundary Conditions

The CAMx v7 source apportionment tool has a new capability to provide separate contributions due to stratified BCs. Typically, these stratifications will be different source sectors from outside of the CAMx modeling domain. WRAP conducted 2014 GEOS-Chem modeling for a base case (BASE), a 2014 GEOS-Chem no

³⁸ <https://www.epa.gov/csapr>

³⁹ http://www.camx.com/files/camxusersguide_v7-10.pdf

international anthropogenic emissions case (i.e., Zero-out Rest of World or ZROW) and a no global anthropogenic emissions case (i.e., just natural emissions). Output from the three 2014 GEOS-Chem runs were processed to generate lateral BCs for the CAMx 36-km 36US1 North America modeling domain that contained: (1) the contributions of international anthropogenic emissions (BC_{Intl}); (2) the contributions of U.S. anthropogenic emissions (BC_{US}); and (3) the contributions of natural sources ($BC_{Natural}$). Details on the WRAP 2014 GEOS-Chem base, ZROW and Natural modeling are contained in a Run Specification Sheet⁴⁰ and the WRAP/WAQS 2014v2 model performance evaluation webpage.⁴¹

This results in the 2028 Source Sector APCA ozone source apportionment simulation tracking ozone contributions from three Source Groups for the lateral boundaries ($BC_{Natural}$, BC_{Intl} and BC_{US}). Contributions due to the top BC concentration as well as Initial Concentrations (IC) were also separately tracked resulting in 5 Source Groups used to track the contributions of BC and IC.

10.2.2.2 Source Regions

Five source regions were used in the 2028 Source Sector APCA ozone source apportionment simulation as shown in Figure 10-1:

1. New Mexico;
2. Texas;
3. Colorado;
4. Remainder U.S. states plus coastal water out to 200 nautical miles (nmi) from the U.S. coast; and
5. International, which included Mexico, Canada and waters off their coasts plus waters more than 200 nmi off the U.S. coast.

⁴⁰ https://views.cira.colostate.edu/docs/iwdw/platformdocs/WRAP_2014/Run_Spec_WRAP_2014_Task1-7_NAT-ZROW_v4.pdf

⁴¹ https://views.cira.colostate.edu/iwdw/docs/WRAP_WAQS_2014v2_MPE.aspx

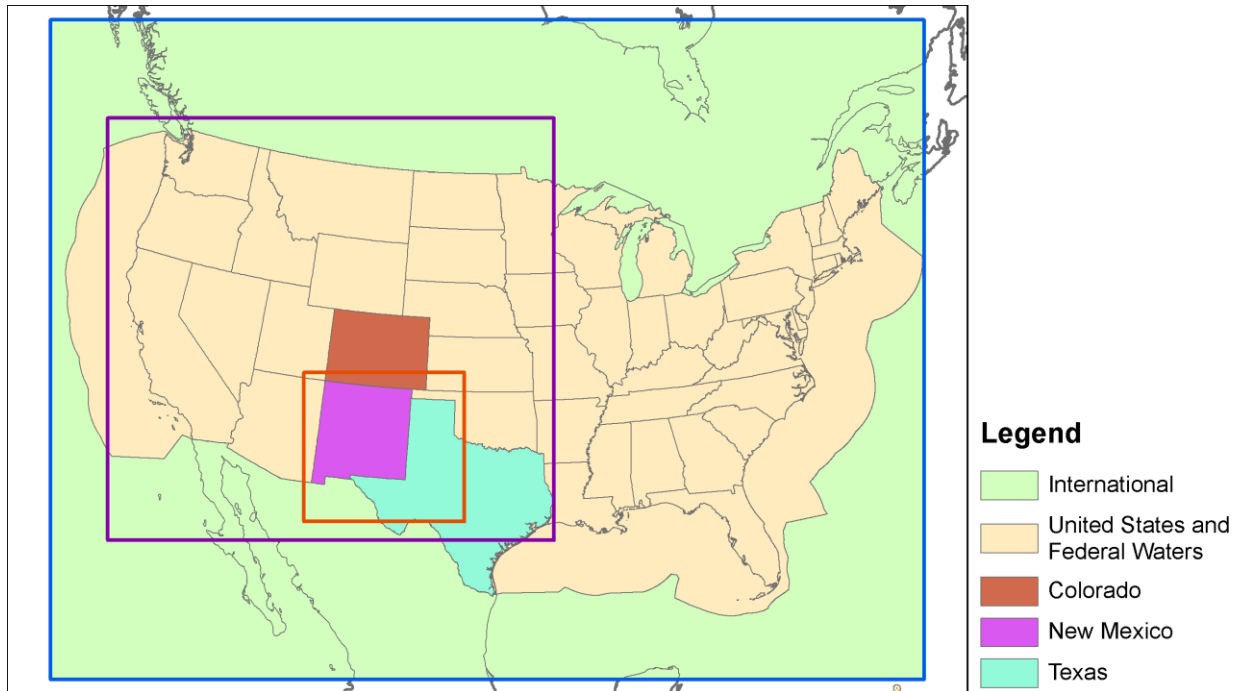


Figure 10-1. Source regions used in the 2028 Source Sector APCA ozone source apportionment simulation.

10.2.2.3 Source Categories

The emissions inventory was divided up into 9 Source Categories in the 2028 Source Sector APCA ozone source apportionment modeling as follows:

1. Natural (biogenic, lightning NO_x, windblown dust and oceanic [sea salt and dimethyl sulfide]);
2. Fires (U.S. wildfires, wildland prescribed burns and agricultural burning and other [Mexico/Canada] fires);
3. Oil and gas point sources (surrogate for midstream O&G);
4. Oil and gas non-point sources (surrogate for upstream O&G);
5. EGU point;
6. Non-EGU point;
7. On-road mobile;
8. Non-road mobile; and
9. Remainder anthropogenic.

Since the APCA version of the CAMx ozone source apportionment tool is being utilized, Natural emissions has to be the first Source Category so APCA knows which Source Category is uncontrollable.

10.2.2.4 Source Groups

With 5 Source Regions and 9 Source Categories, plus 5 Source Groups for IC/BC, there is a total of 50 Source Groups that separate ozone source contributions are obtained ($50 = 5 \times 9 + 5$).

10.3 2028 Source Sector APCA Ozone Source Apportionment Modeling Results

The 2028 Source Sector APCA ozone source apportionment modeling results were analyzed to obtain the contributions of the different Source Sectors within New Mexico to projected future year 2028 ozone design values (DVs) as well as contributions to Maximum Daily Average 8-hour (MDA8) ozone concentrations. The 2028 ozone DVF and modeled MDA8 ozone concentrations were analyzed at the monitoring sites as well as across the 4-km New Mexico domain. Figure 10-2 shows the locations of the monitoring sites within the 4-km New Mexico domain.

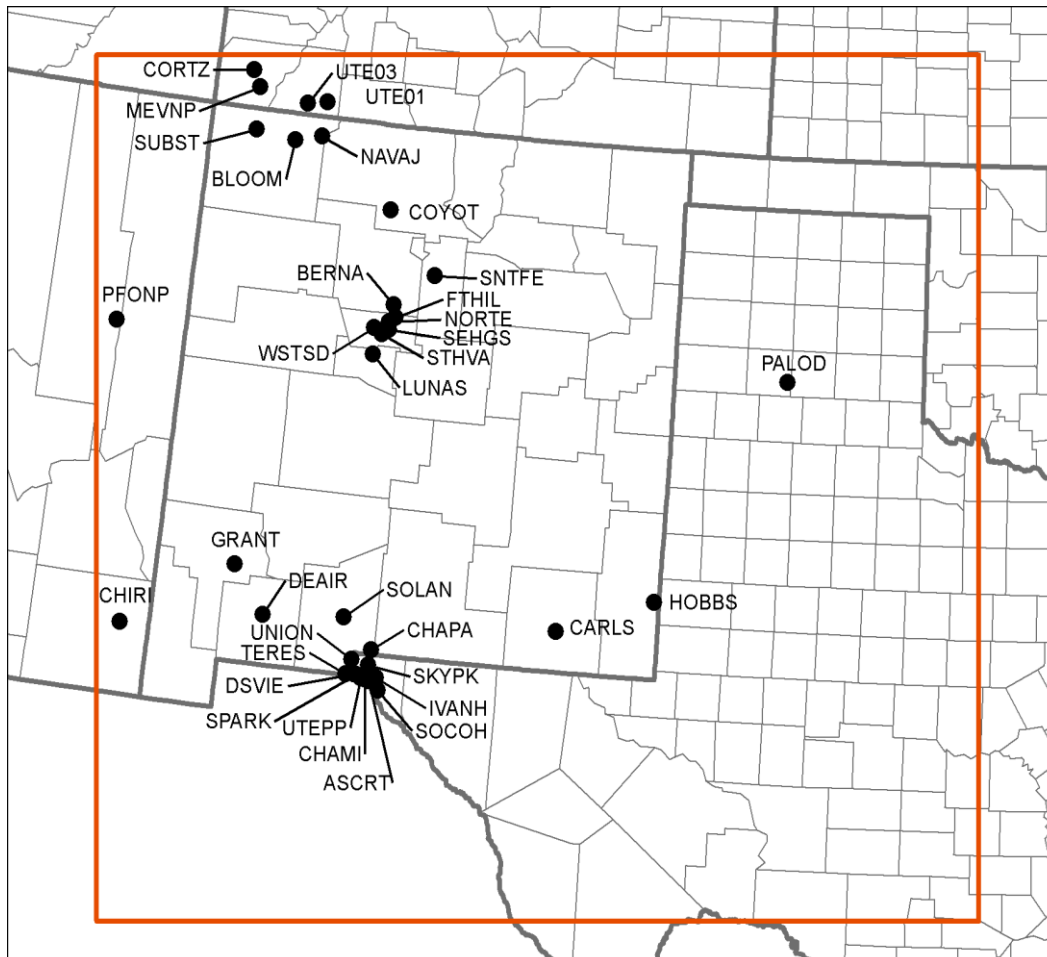


Figure 10-2. Locations of ozone monitoring sites within the 4-km New Mexico modeling domain.

10.3.1 Source Sector Contributions to Projected 2028 Ozone DVFs

In this section, the contributions of Source Sector emissions within New Mexico and the entire United States to future year projected 2028 ozone design values (DVF) at New Mexico monitoring sites and across the 4-km New Mexico domain are analyzed.

10.3.1.1 New Mexico Source Sector 2028 Ozone DVF Contributions

Table 10-1 displays the current year 2012-2016 DVC, the projected 2028 ozone DVF for the 2028 O&G Control Scenario and the reductions in the 2028 ozone DVF due to the removal of anthropogenic emissions in New Mexico for each of the 7 anthropogenic emissions Source Sectors at all monitoring sites in New Mexico. The incremental ozone contributions in the 2028 ozone DVF due to New Mexico emissions from the 7 Source Sectors are shown for several New Mexico monitoring sites in Figures 10-3 through 10-18.

At the three monitoring sites in San Juan County, New Mexico emissions from EGU and O&G Source Sectors contribute the most to the 2028 ozone DVF (Table 10-1). The largest ozone contribution is 3.1 ppb for the New Mexico EGU Source Sector at the SUBST site (Figure 10-5) due to its close proximity to the Four Corners Power Plant (FCPP) that is assumed to have Units 4 and 5 operating in 2028. The EGU ozone contributions fall off with distance from the FCPP as seen at the BLOOM (1.9 ppb; Figure 10-4), NAVAJ (1.7 ppb; Figure 10-3) and COYOT (0.5 ppb; Figure 10-6) monitoring sites. New Mexico O&G Point contributes 0.2 to 0.9 ppb and O&G Non-Point contributes 0.5 to 2.1 ppb to 2028 ozone DVFs at the four northern New Mexico monitoring sites in San Juan and Rio Arriba Counties. All other Source Sectors have contributions of 0.5 ppb or less at the northern New Mexico sites.

Sites in Central New Mexico include those in Bernalillo County (Figures 10-7 through 10-10) as well as two sites in neighboring counties (Figures 10-11 and 10-12). Ozone concentrations in Bernalillo County are highly influenced by emissions from Albuquerque, which is by far the largest city in New Mexico. So, Source Sectors associated with population centers (e.g., on-road, non-road and other anthropogenic) tend to have the highest contributions to the 2028 ozone DVFs at these sites. Although they have different magnitudes of ozone contributions, the rankings of the Source Sector contributions are very similar at the Bernalillo County sites with Other Anthropogenic being highest followed by On-Road and Non-Road mobile with the other four Source Sectors being half or less of the top three Source Sectors. On-Road mobile is the highest followed by Other Anthropogenic and Non-Road at the Santa Fe (Figure 10-11) and Sandoval County (Figure 10-12) sites, with all other Source Sector contributions being much lower.

Sites in the southern New Mexico (Figures 10-13 through 10-18) include those in southern Doña Ana County on the border with Texas that tend to have mostly small contributions from New Mexico Source Sectors with the exception of EGU (0.7 to 0.9 ppb), due to the close proximity of the Rio Grande Power Plant to some of the sites, and On-Road mobile (0.4-0.5 ppb) due to population centers along I-25 (e.g., Sunland Park, Santa Teresa, etc.). The Solano monitor (Figure 10-16) has higher ozone contributions due to On-Road (1.2 ppb) and Non-Road (0.7 ppb) mobile sources because of the higher mobile emissions from the City of Las Cruces, which is the second largest city in New Mexico.

New Mexico emissions from the O&G Point and Non-Point Sources sectors have the highest ozone contribution at the Carlsbad (0.5 and 0.5 ppb) and Hobbs (0.9 and 1.1 ppb) monitoring sites in southeastern New Mexico (Figures 10-17 and 10-18). These two southeastern New Mexico monitors are essentially within the Permian Basin. The contribution of On-Road to the 2028 ozone DVF at Carlsbad and Hobbs sites is 0.3 ppb, with all other Source Sector contributions being lower.

Table 10-1. Reduction in 2028 ozone DVF due to the elimination of emissions from 7 Source Sectors in New Mexico.

AQS_ID	Site_ID	DVC	DVF	O&GPT	O&GNP	EGU	NonEGU	OnRoad	NonRoad	OAnth
Northern New Mexico										
350390026	COYOT	64.0	60.0	-0.2	-0.5	-0.5	0.0	-0.2	-0.1	0.0
350450009	BLOOM	64.3	60.2	-0.7	-1.4	-1.9	0.0	-0.4	-0.1	-0.1
350450018	NAVAJ	67.0	63.3	-0.9	-2.1	-1.7	-0.1	-0.4	-0.2	-0.1
350451005	SUBST	63.7	59.6	-0.6	-1.5	-3.1	-0.1	-0.5	-0.2	-0.2
Central New Mexico										
350010023	NORTE	66.3	60.7	-0.2	-0.3	-0.5	-1.0	-2.7	-2.0	-3.6
350010024	SEHGS	68.0	62.0	-0.2	-0.3	-0.5	-1.1	-2.5	-1.9	-3.2
350010029	STHVA	66.0	60.5	-0.3	-0.5	-0.5	-1.0	-2.2	-1.7	-2.4
350010032	WSTSD	67.0	62.1	-0.2	-0.4	-0.4	-0.4	-1.6	-1.2	-1.8
350011012	FTHIL	65.0	58.8	-0.2	-0.3	-0.5	-0.7	-2.5	-2.0	-3.0
350431001	BERNA	64.0	58.1	-0.1	-0.2	-0.4	-0.4	-2.1	-1.5	-1.9
350490021	SNTFE	64.3	60.4	-0.2	-0.3	-0.2	-0.3	-1.2	-0.7	-0.8
Southern New Mexico										
350130008	UNION	66.3	59.8	-0.2	-0.2	-0.7	0.0	-0.5	-0.3	-0.1
350130017	SPARK	67.0	61.8	-0.2	-0.2	-0.9	0.0	-0.4	-0.2	-0.2
350130020	CHAPA	67.0	62.2	-0.1	-0.1	-0.3	0.0	-0.2	-0.1	-0.1
350130021	DSVIE	72.0	66.8	-0.2	-0.3	-0.9	-0.1	-0.5	-0.3	-0.2
350130022	TERES	71.3	66.0	-0.3	-0.3	-0.7	-0.1	-0.5	-0.3	-0.2
350130023	SOLAN	65.0	60.2	-0.2	-0.2	-0.2	-0.2	-1.2	-0.7	-0.3
350151005	CARLS	69.0	66.4	-0.5	-0.5	-0.2	-0.1	-0.3	-0.2	-0.1
350171003	GRANT	62.0	58.9	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
350250008	HOBBS	66.0	63.3	-0.9	-1.1	-0.2	0.0	-0.3	-0.2	-0.1
350290003	DEAIR	66.0	62.5	-0.2	-0.1	-0.2	0.0	-0.6	-0.4	0.0

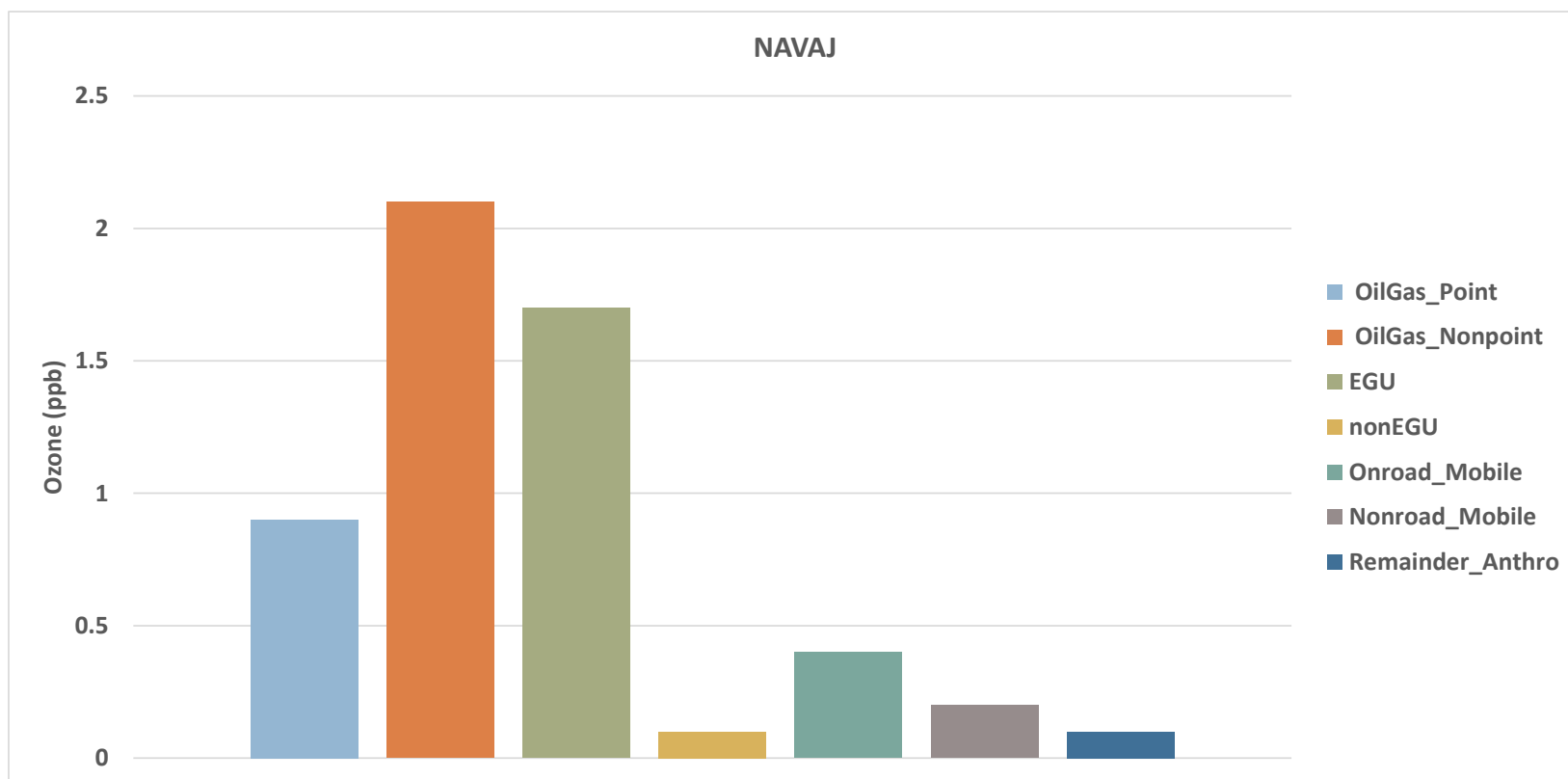


Figure 10-3. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Navajo Lake in San Juan County.

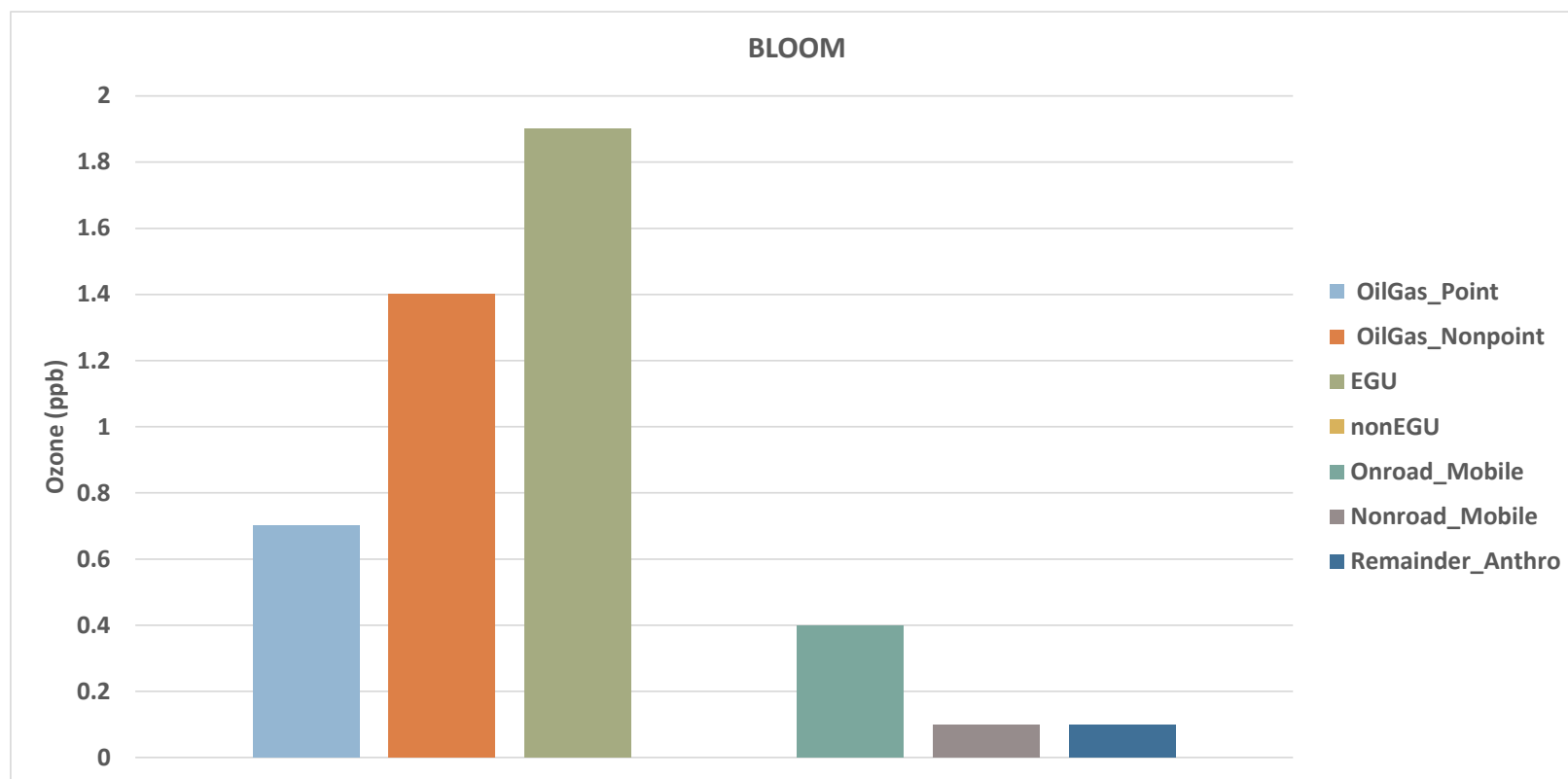


Figure 10-4. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Bloomfield in San Juan County.

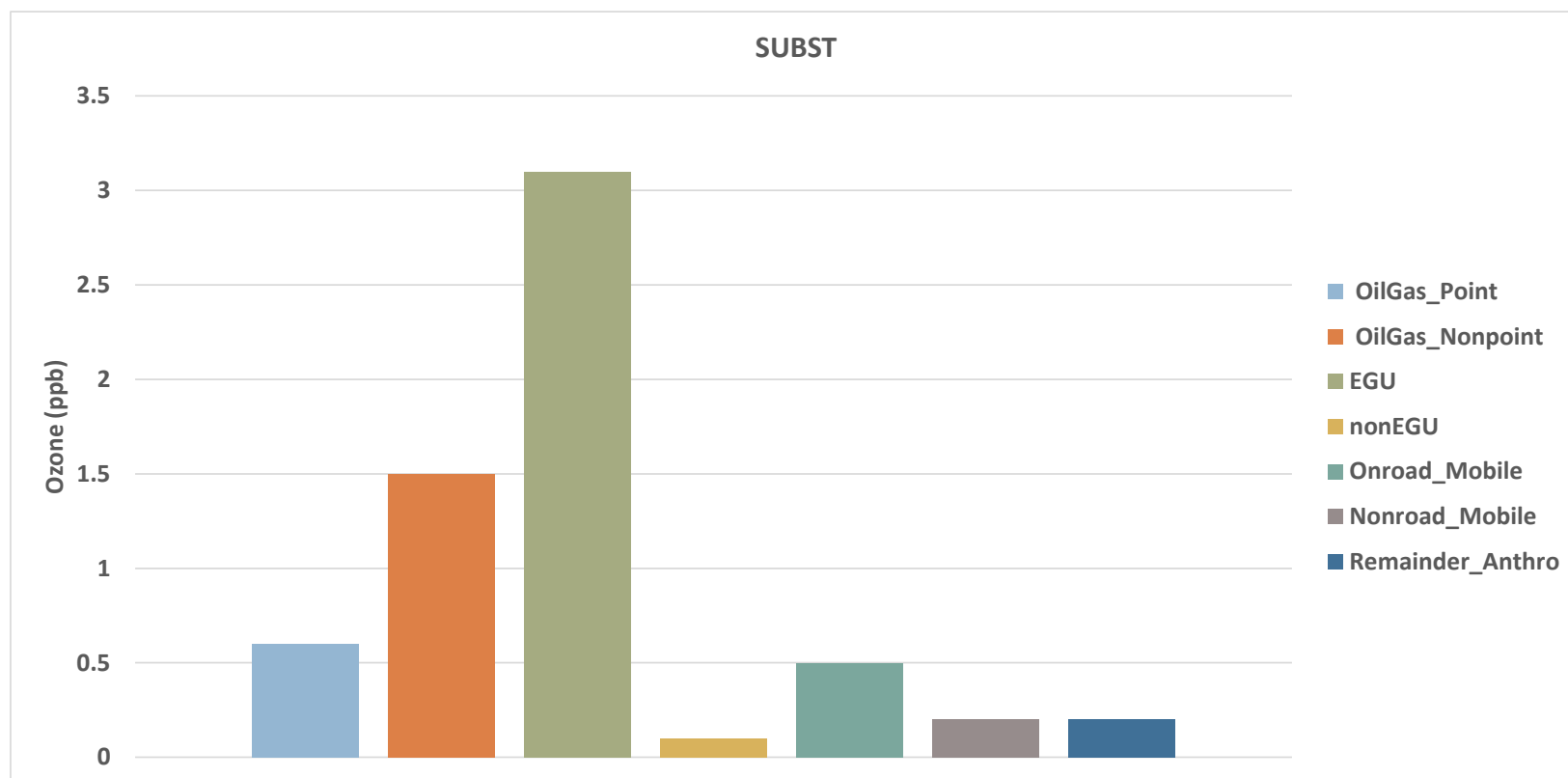


Figure 10-5. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Substation in San Juan County.

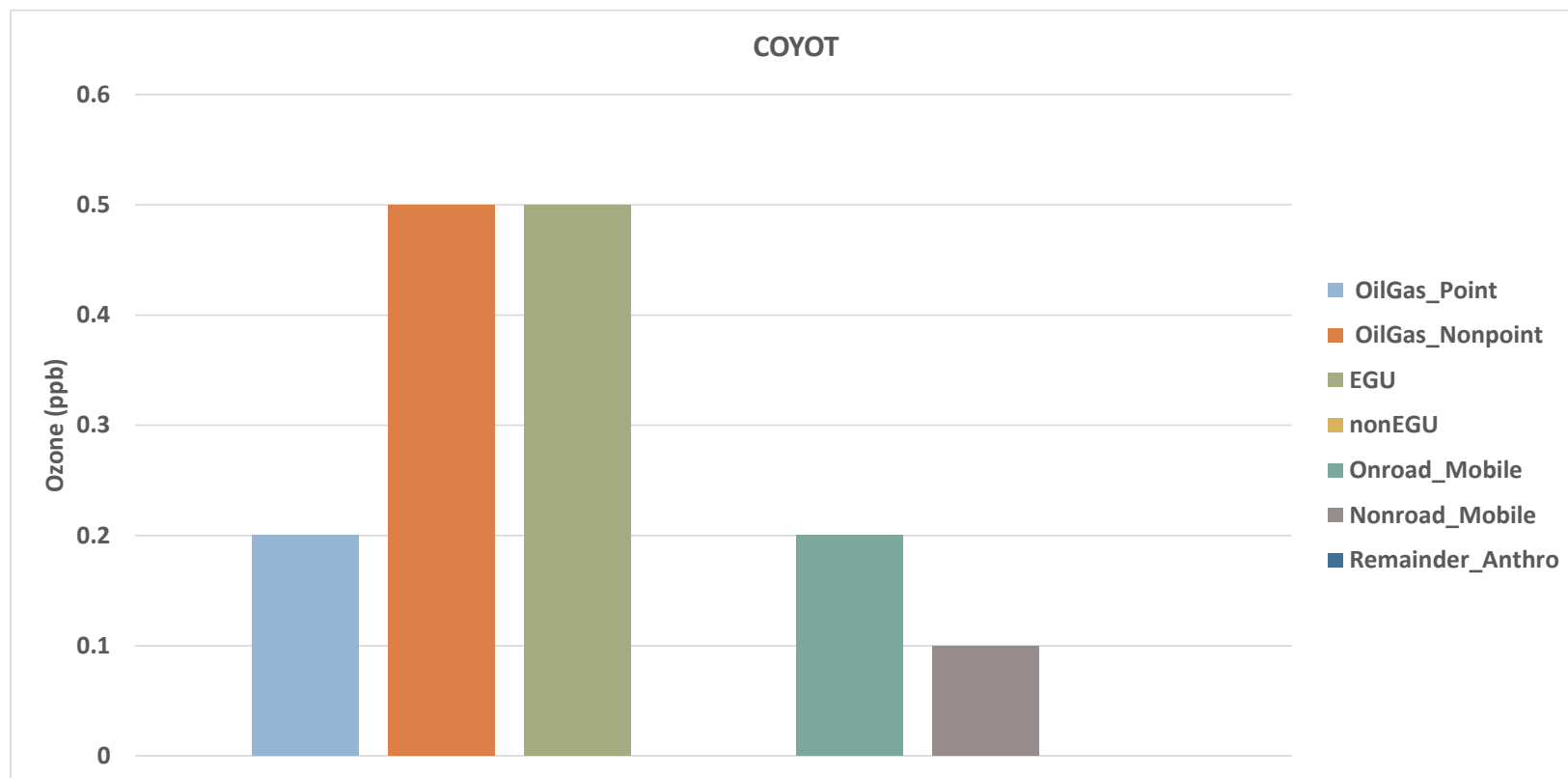


Figure 10-6. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Coyote Ranger District in Rio Arriba County.

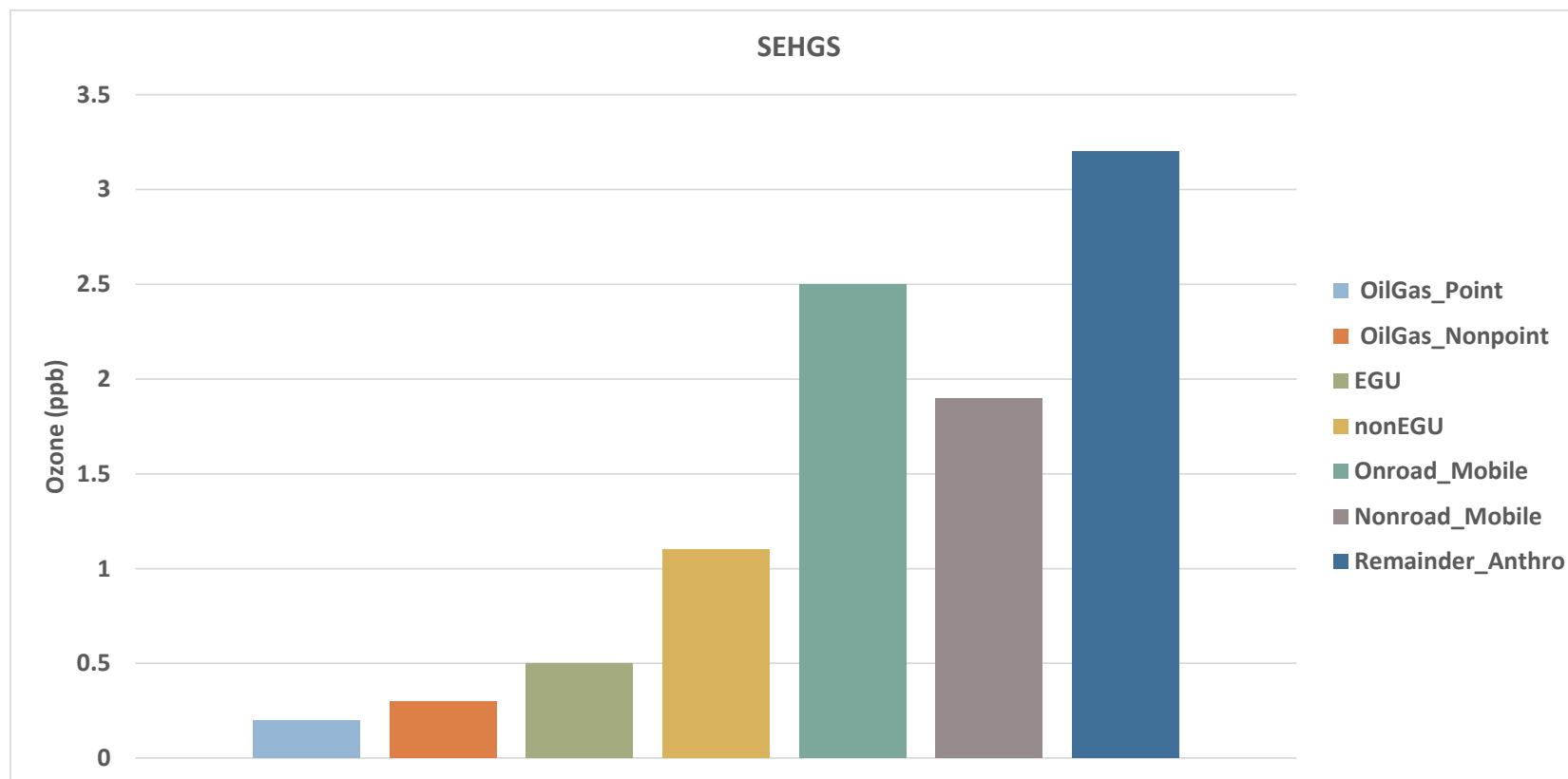


Figure 10-7. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Southeast Heights in Bernalillo County.

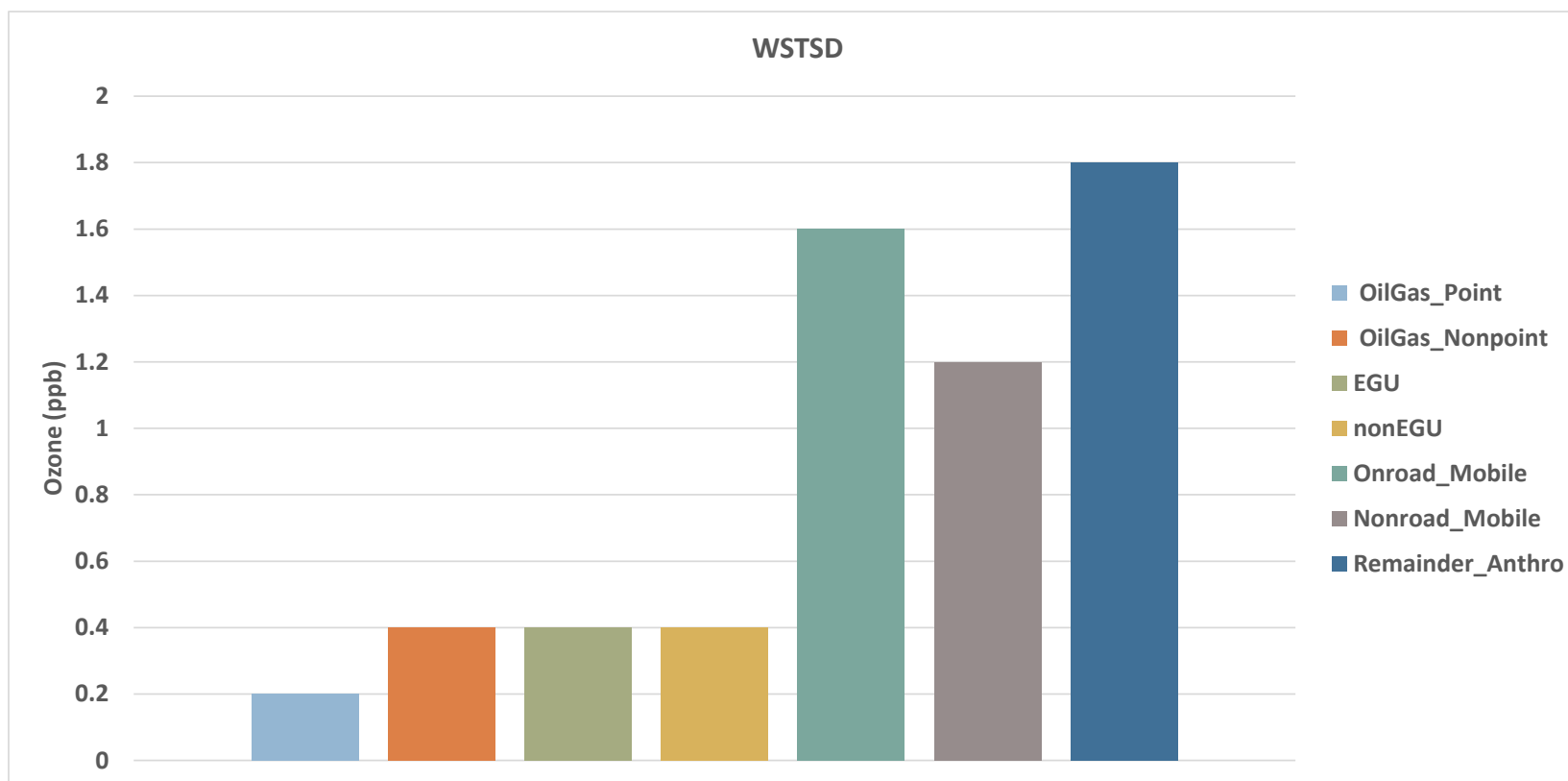


Figure 10-8. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Westside in Bernalillo County.

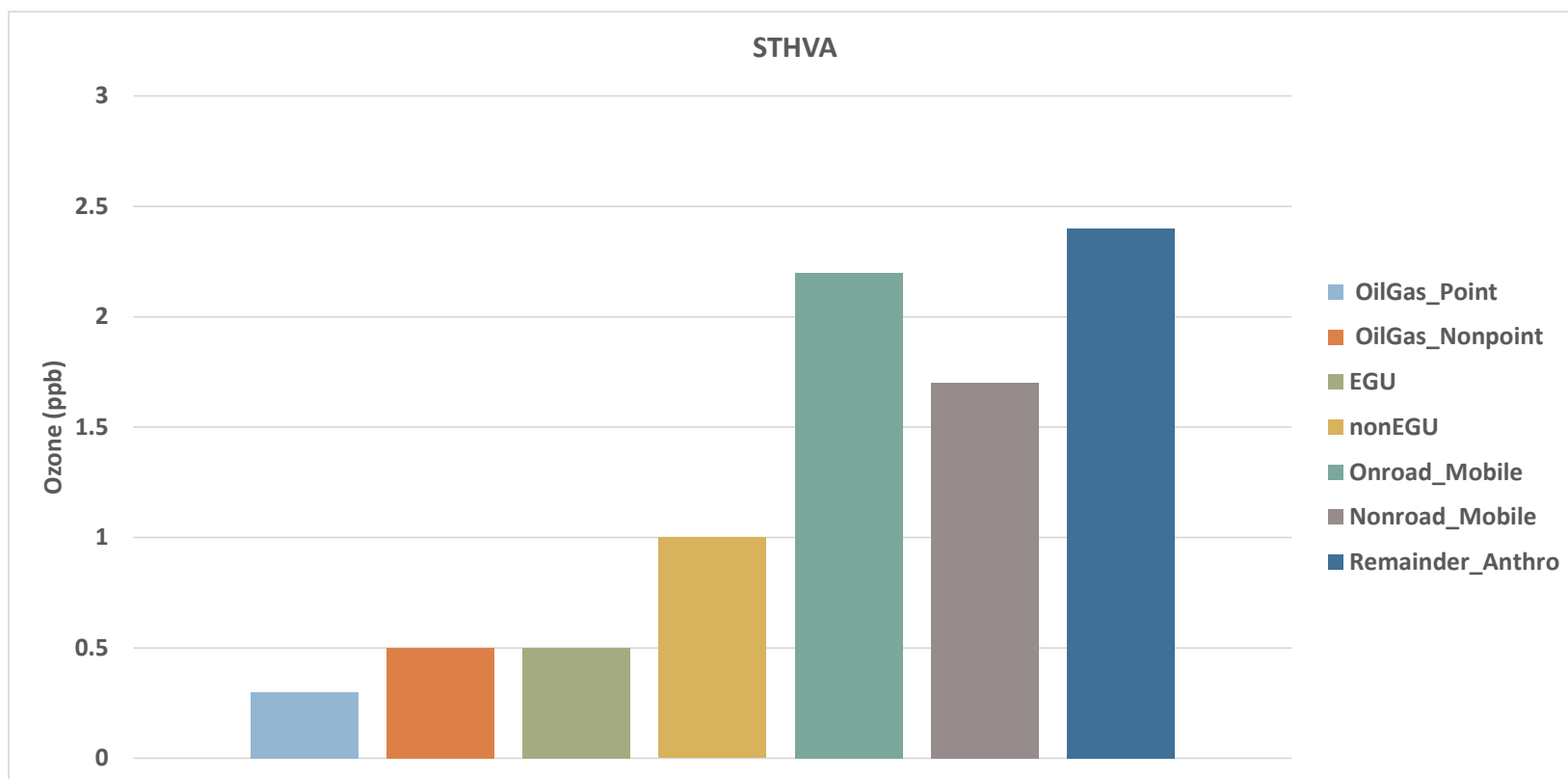


Figure 10-9. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at South Valley in Bernalillo County.

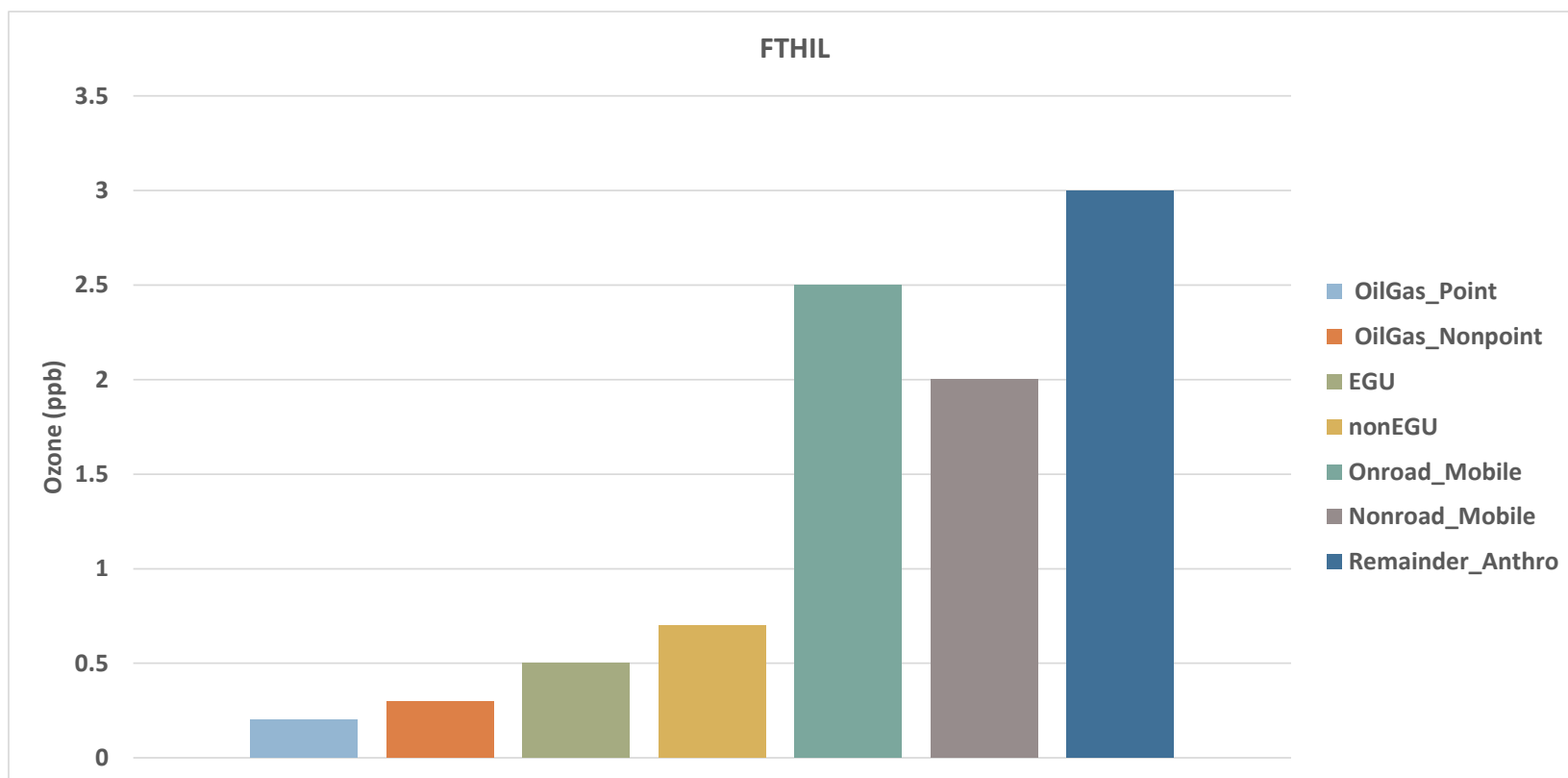


Figure 10-10. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Foothills in Bernalillo County.

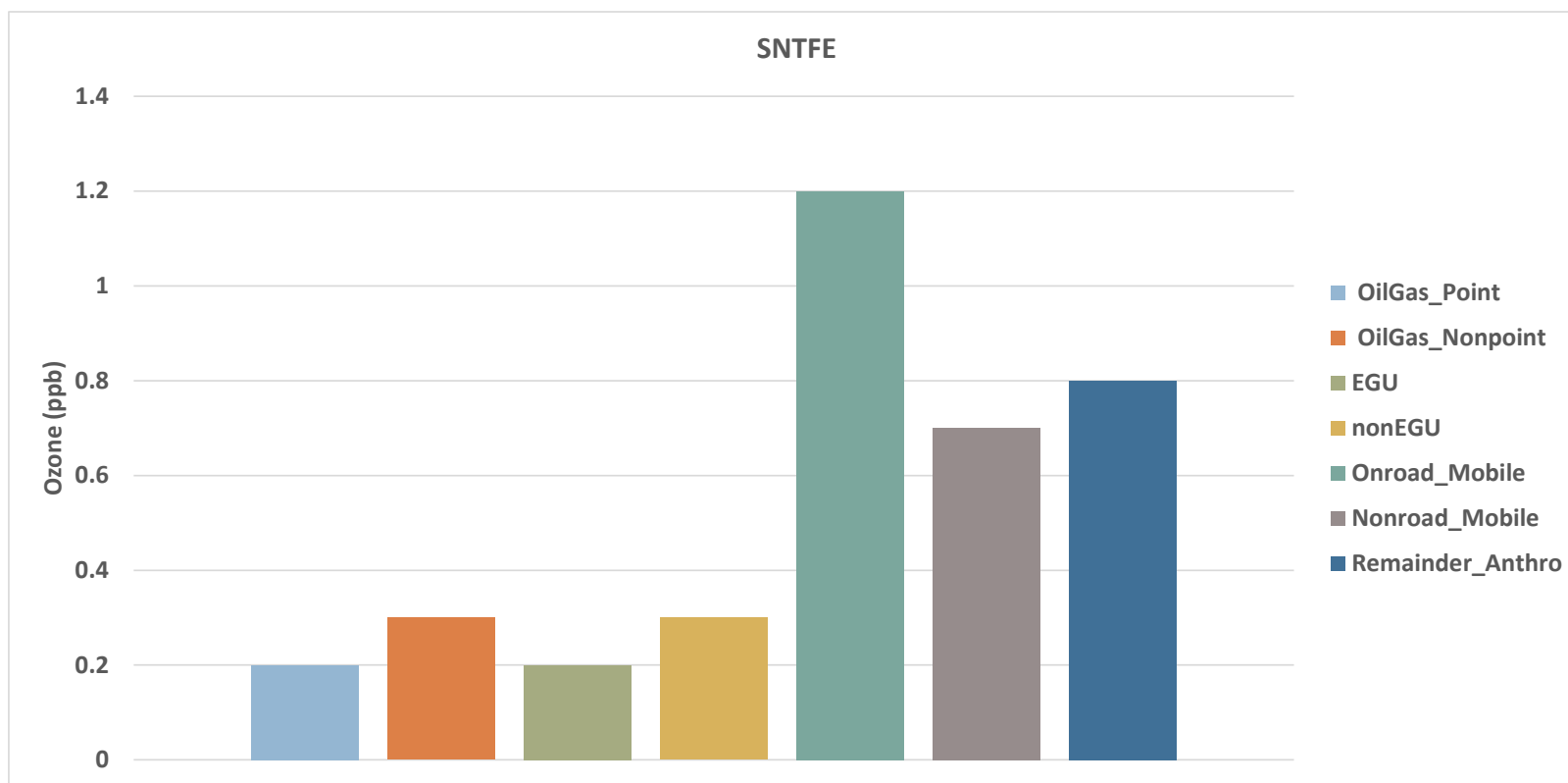


Figure 10-11. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Santa Fe in Santa Fe County.

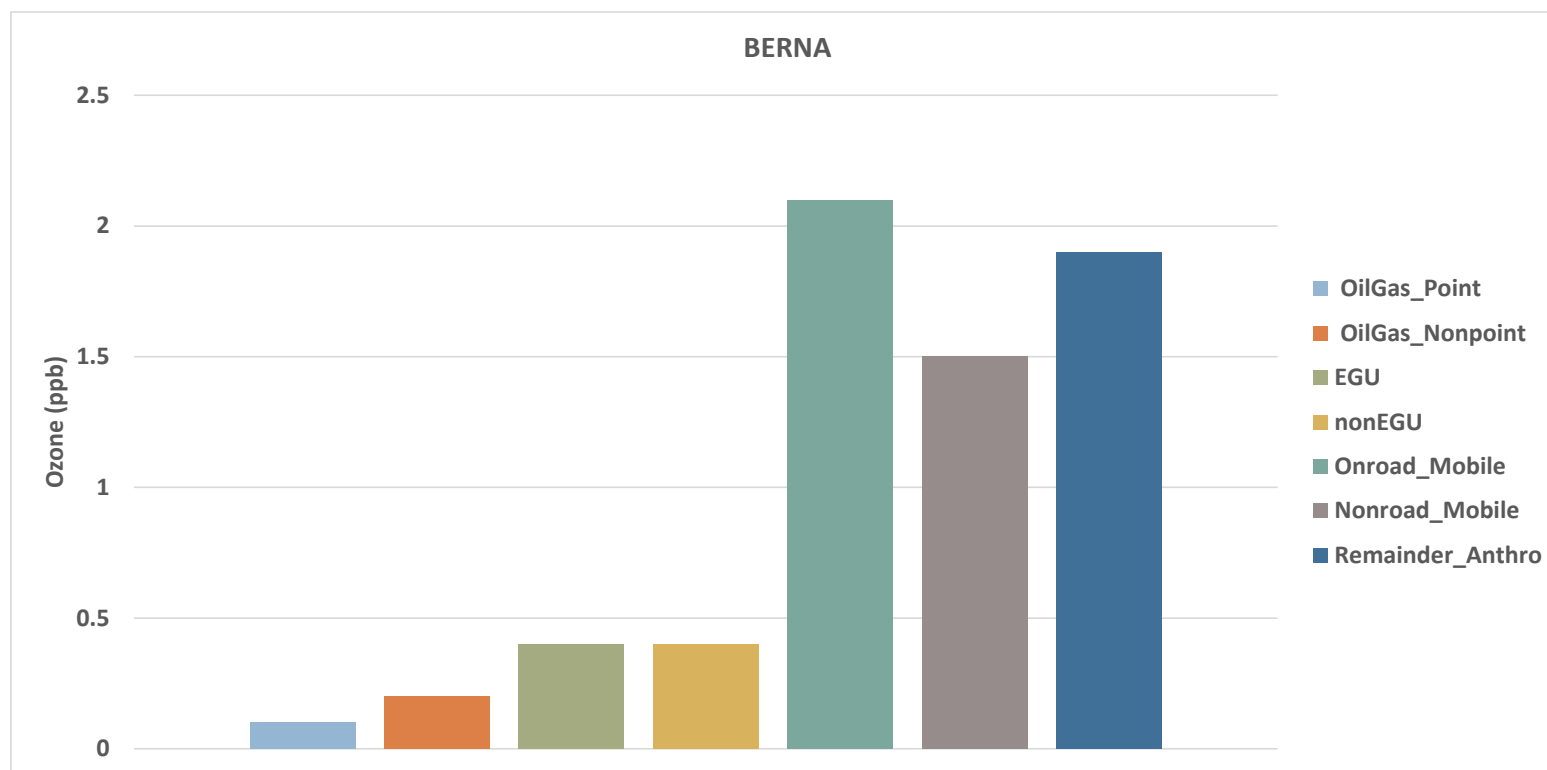


Figure 10-12. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Bernalillo in Sandoval County.

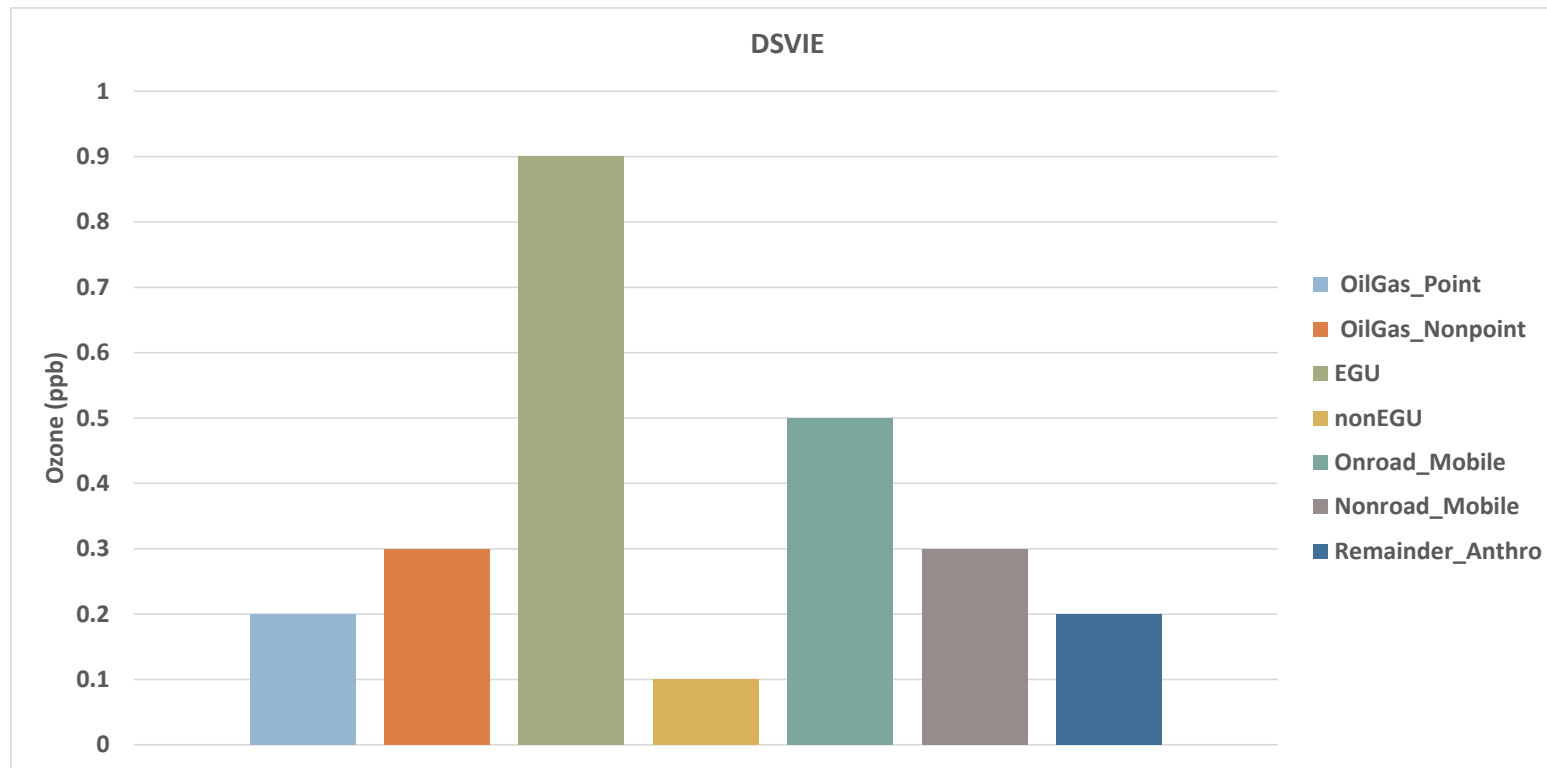


Figure 10-13. Contributions of New Mexico anthropogenic emissions from 7 Source Sectors to projected 2028 ozone DVFs at Desert View in Doña Ana County in southern New Mexico.

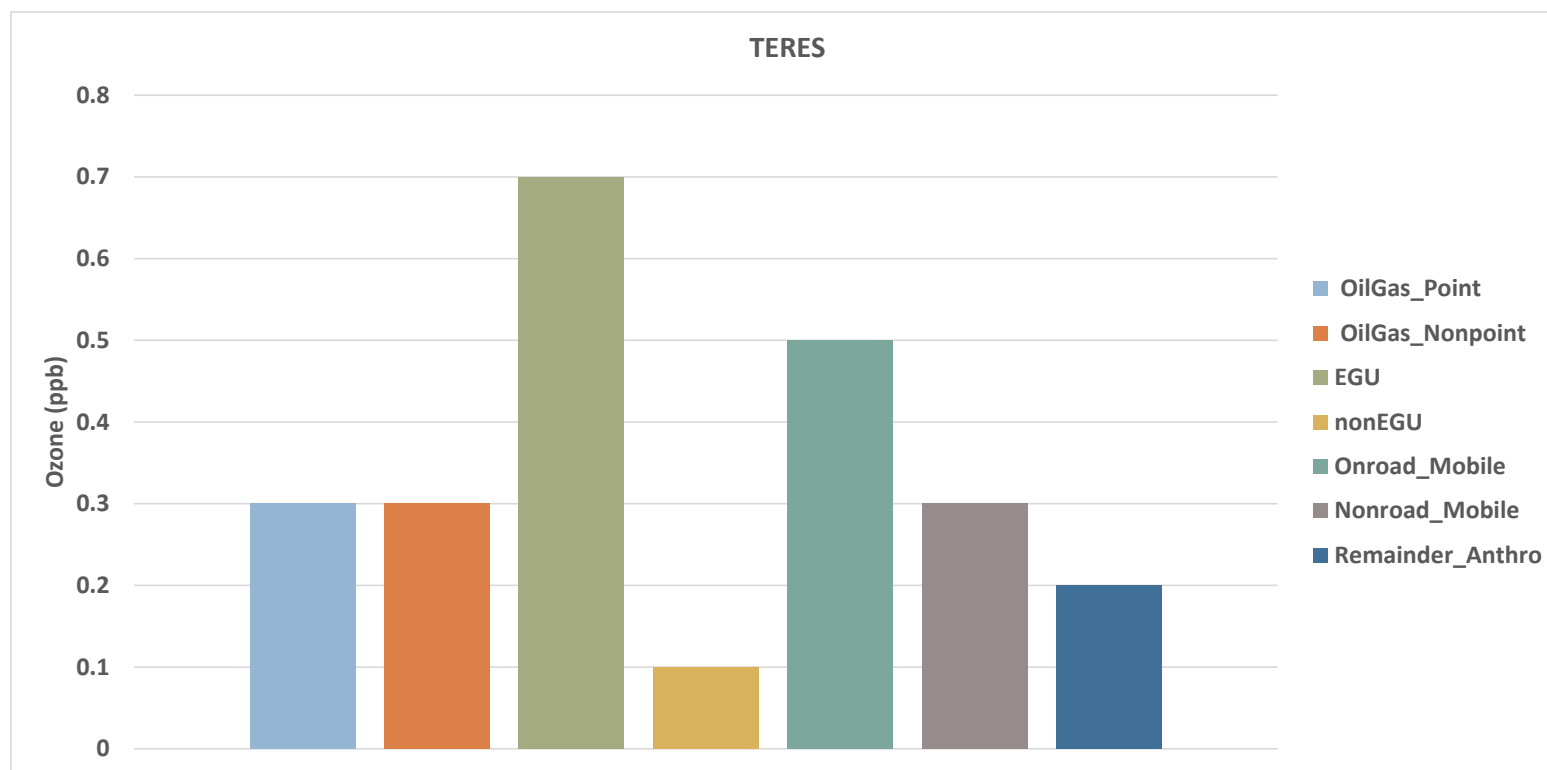


Figure 10-14. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Santa Teresa in Doña Ana County in southern New Mexico.

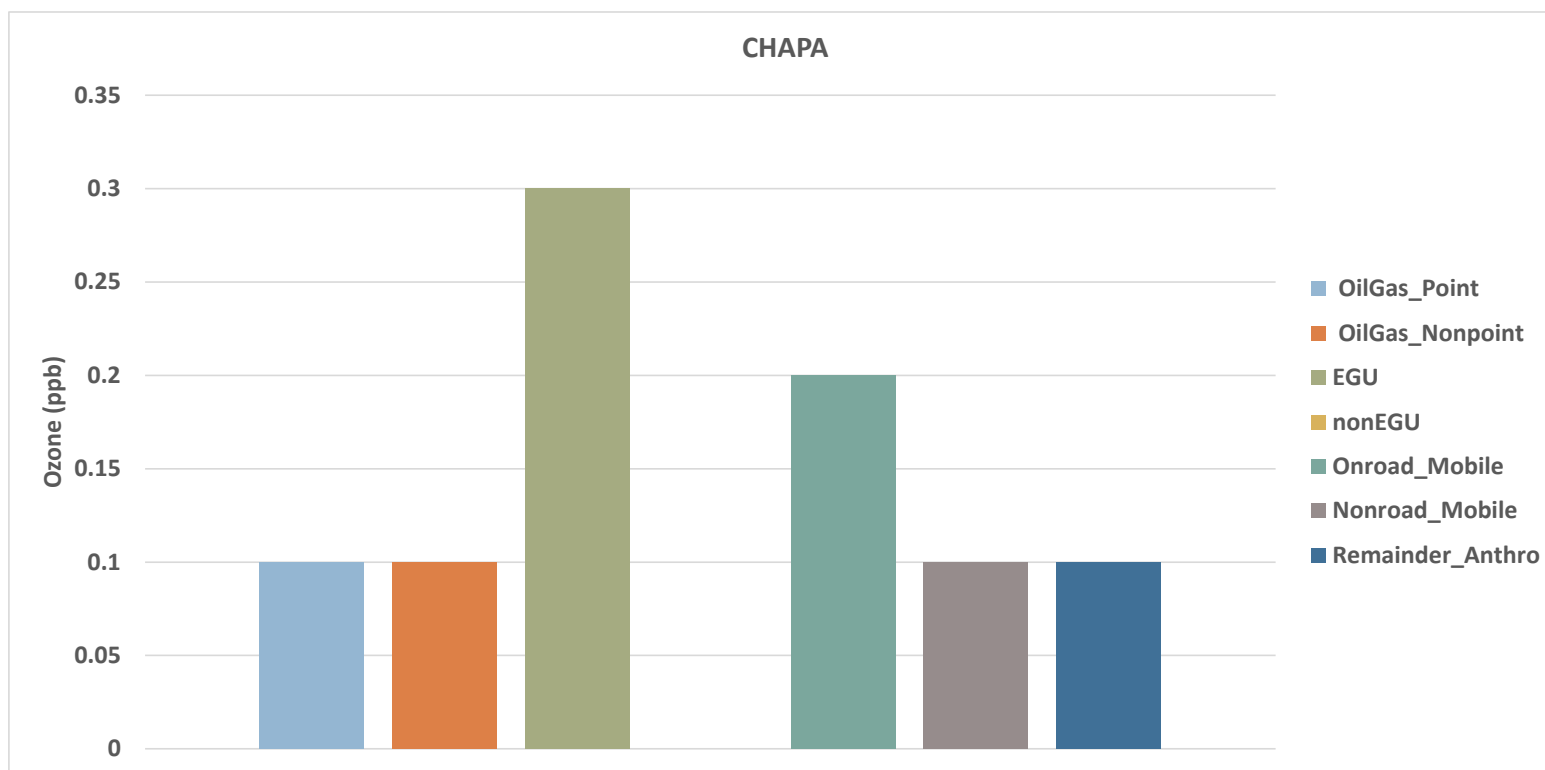


Figure 10-15. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Chaparral in Doña Ana County in southern New Mexico.

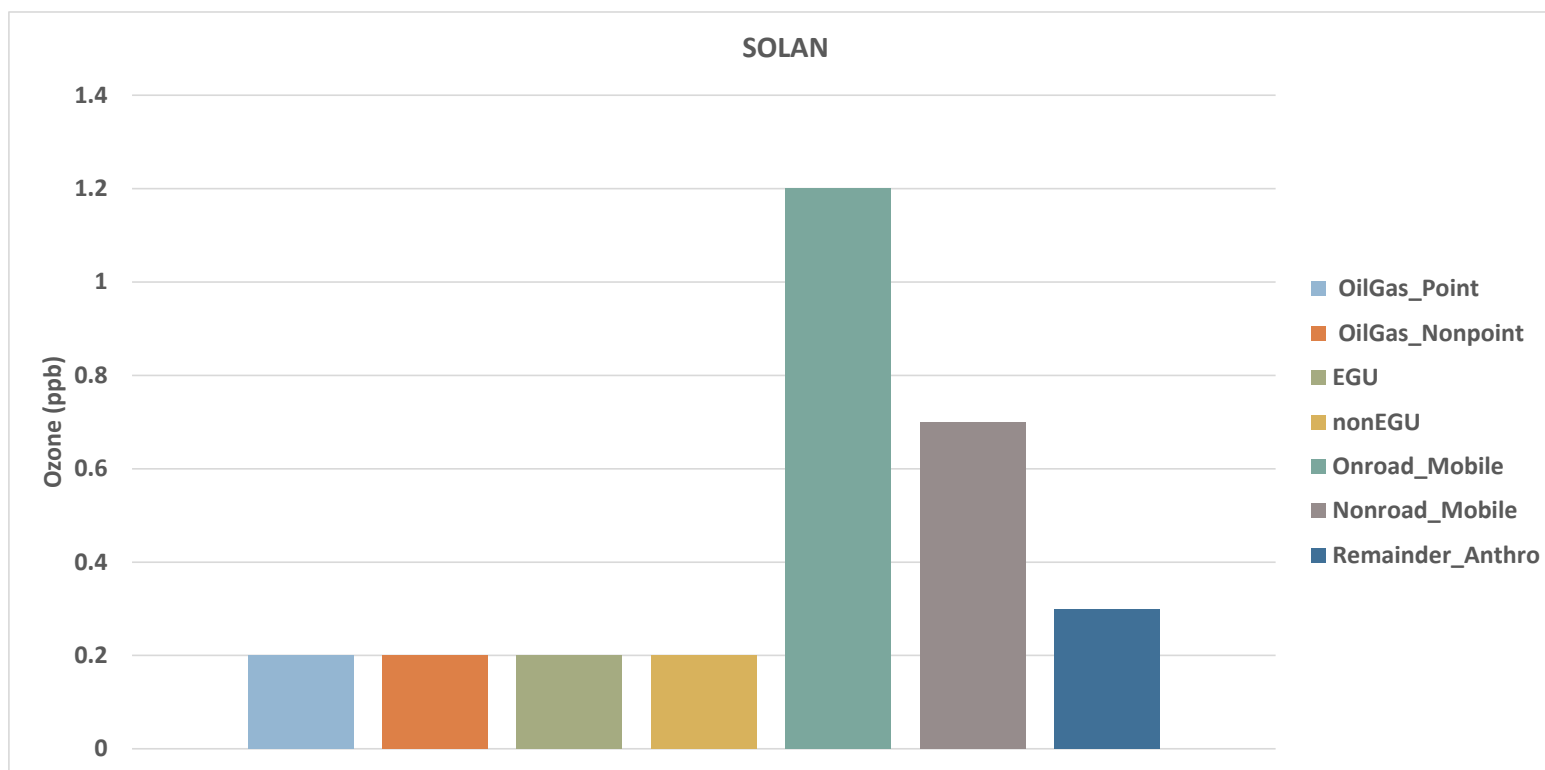


Figure 10-16. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Solano in Doña Ana County in southern New Mexico.

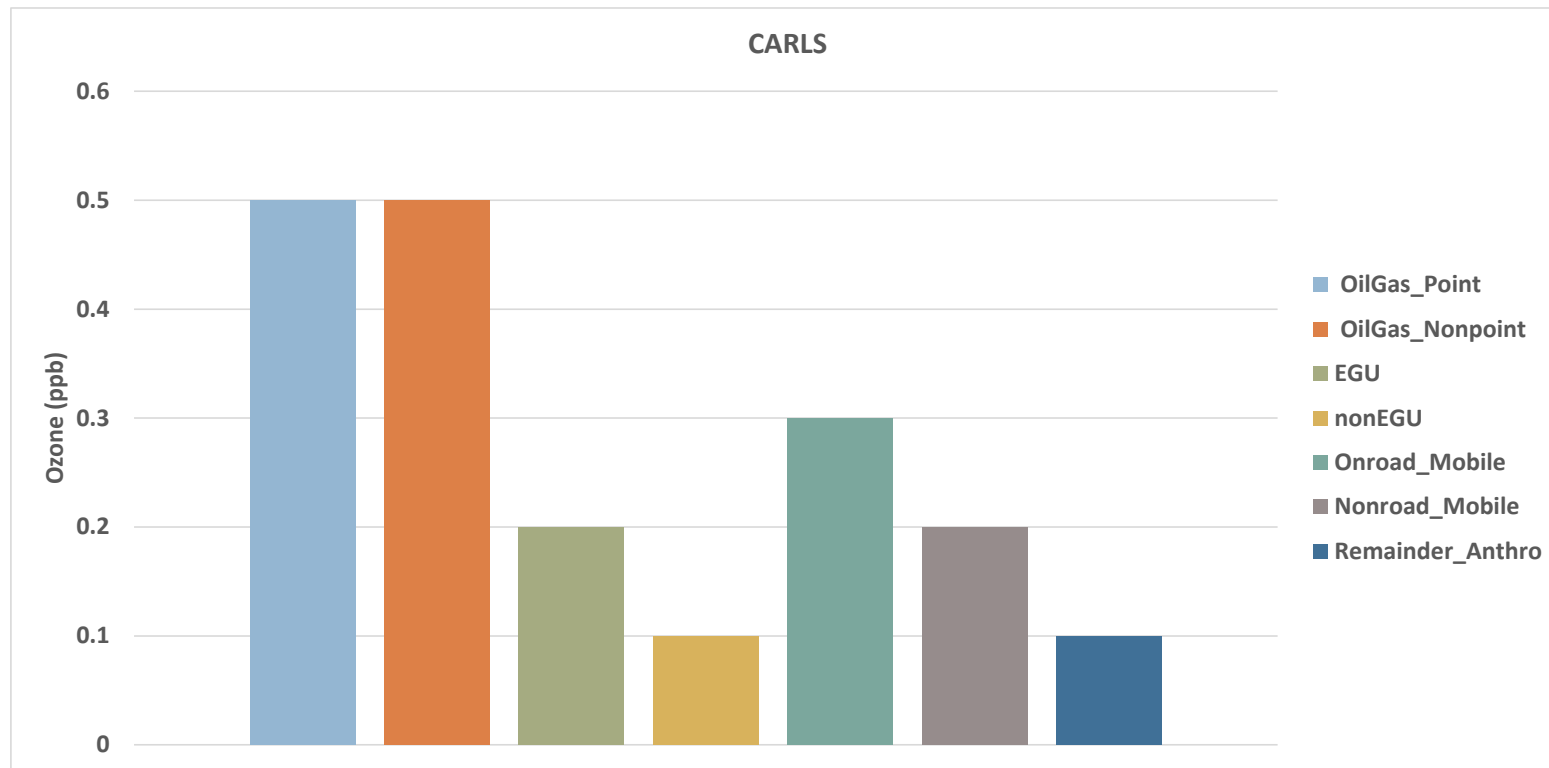


Figure 10-17. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Carlsbad in Eddy County in southeastern New Mexico.

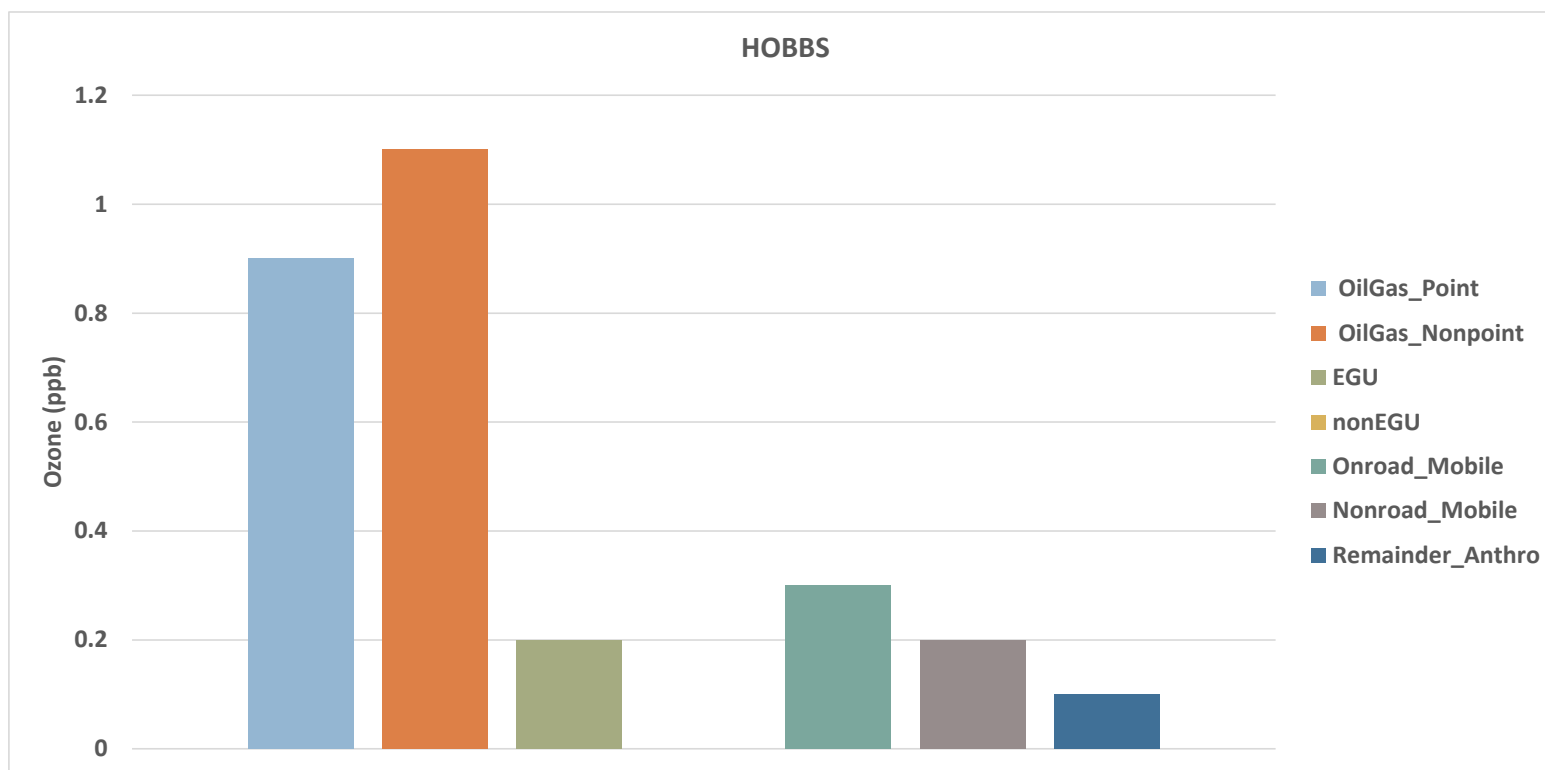


Figure 10-18. Contributions of New Mexico anthropogenic emissions for 7 Source Sectors to projected 2028 ozone DVFs at Hobbs in Lea County in southeastern New Mexico.

The SMAT Unmonitored Area Analysis (UAA) feature was used to estimate the spatial distribution 2028 ozone DVFs across the 4-km New Mexico domain for the 2028 O&G Control Scenario without New Mexico emissions from each of the 7 anthropogenic emission Source Sectors. Figures 10-19 and 10-20 display the reduction in 2028 ozone DVFs across the New Mexico 4-km domain due to the removal of New Mexico emissions for the 7 Source Sectors. Removing New Mexico EGU emissions reduces the 2028 ozone DVF by as much as 3.1 ppb in San Juan County with ozone reductions of 0.1 to 1.0 ppb in the upper half of New Mexico and from Doña Ana to Lea Counties in southern New Mexico (Figure 10-19a). The removal of New Mexico Non-EGU Point emissions results in a reduction of 1.3 ppb in eastern Bernalillo County and reductions of 0.1 to 1.0 in adjacent counties, with little effect over the rest of New Mexico away from Bernalillo County (Figure 10-19b).

New Mexico On-Road mobile contributes as much as 2.6 ppb to the 2028 ozone DVF with reductions of 1-2 ppb stretching from Albuquerque to Santa Fe and in Las Cruces (Figure 10-19c). New Mexico Non-Road mobile contributes as much as 2.1 ppb in Bernalillo County (Figure 10-19d).

New Mexico Non-Point O&G has large (> 2 ppb) contributions to the 2028 ozone DVF in the San Juan and Permian Basins (Figure 10-20a). Whereas, New Mexico Point O&G contributes as much as 1-2 ppb in the Permian Basin but less than 1 ppb in the San Juan Basin (Figure 10-20b). The Other Anthropogenic Source Sector contributions has a similar distribution as the two mobile Source Sectors with the highest ozone contributions centered on Bernalillo County (Figure 10-20c).

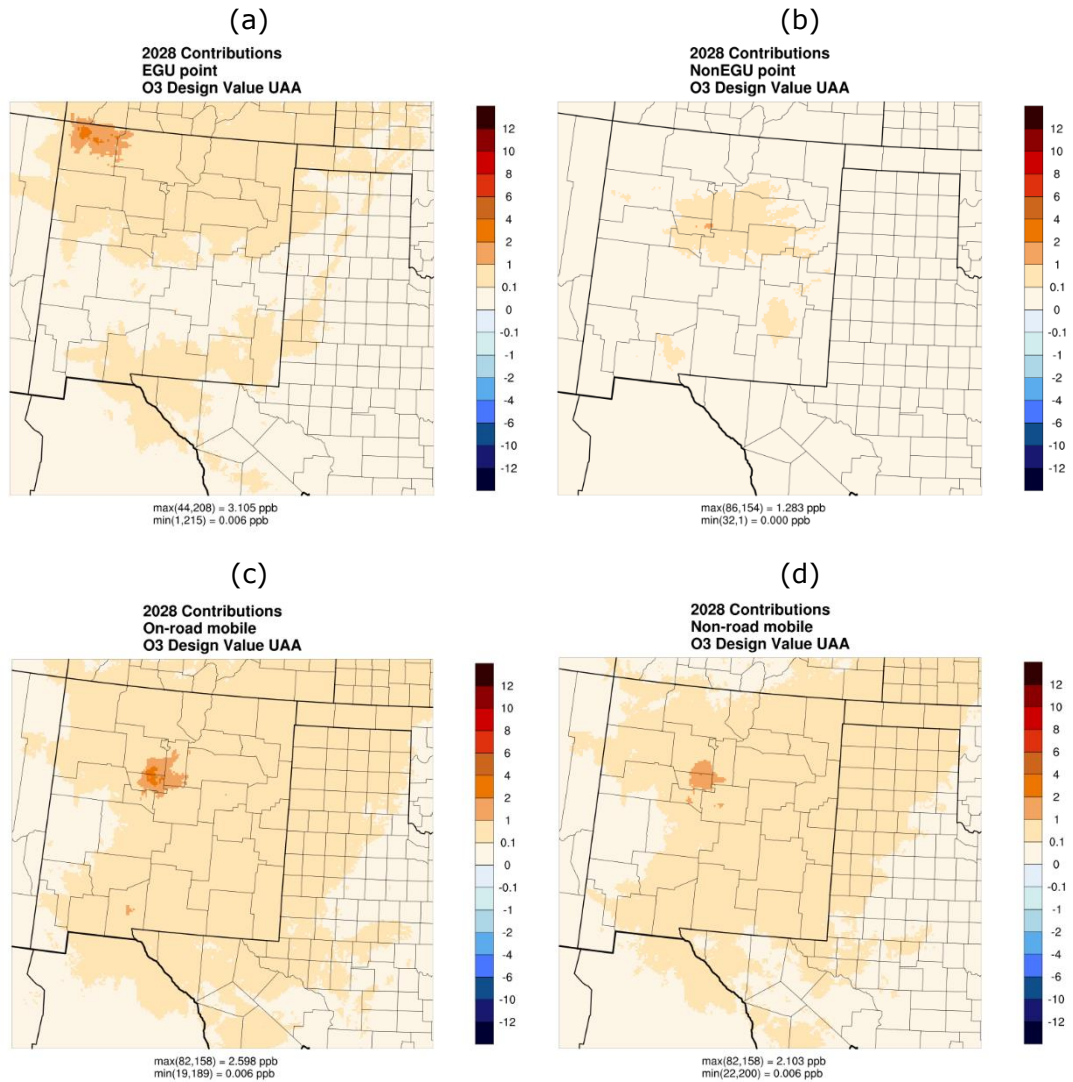


Figure 10-19. Reduction in 2028 ozone DVF due to removal of New Mexico Source Sector emissions for: (a) EGU Point; (b) Non-EGU Point; (c) On-Road Mobile; and (d) Non-Road Mobile.

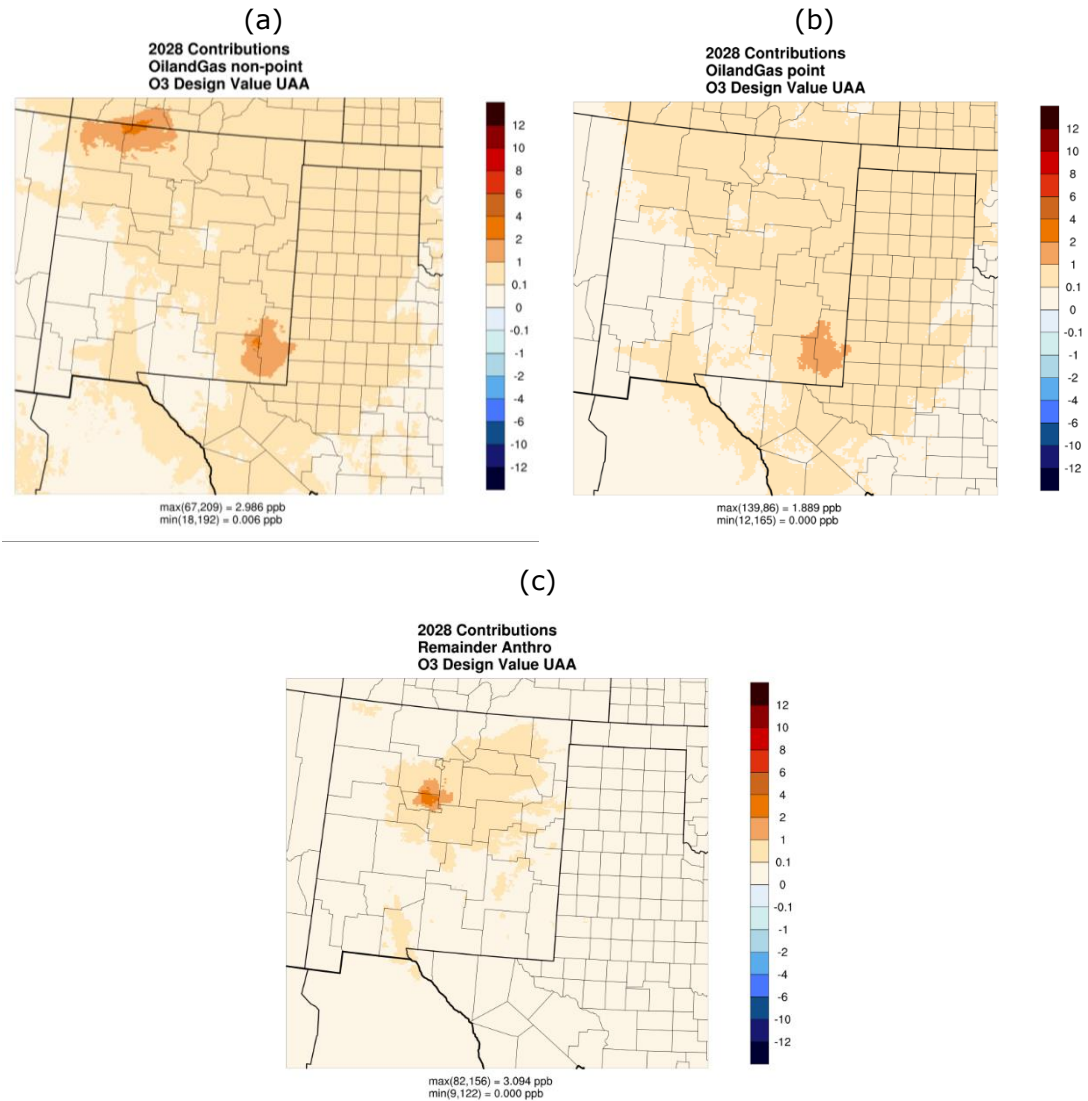


Figure 10-20. Reduction in 2028 ozone DVF due to removal of New Mexico Source Sector emissions for: (a) Non-Point O&G; (b) Point O&G; and (c) Other Anthropogenic.

10.3.1.2 United States Source Sector 2028 Ozone DVF Contributions

Table 10-2 displays the reductions in 2028 ozone DVFs due to the elimination of Source Sector emissions throughout the United States. Table 10-3 shows the percent of the all U.S. Source Sector ozone reduction that was due to just the Source Sector emissions in New Mexico (i.e., the percent the ozone reductions in Table 10-1 are of the ozone reductions in Table 10-2). At the three San Juan County sites, O&G non-point contributes the most (2-3 ppb) with approximately 60-78% coming from O&G non-point sources in New Mexico. Oil and gas point contributes 1.1 to 1.3 ppb at the three San Juan County sites with 55-69% coming from sources in New Mexico. The U.S. EGU Source Sector contributes 2.0 to 3.6 ppb to the 2028 ozone DVF at the three San Juan County sites with a vast majority (~85%) coming from New Mexico. On the other hand, the U.S. On-Road (1.7 ppb) and Non-Road (1.2 ppb) contribution at the three San Juan County sites comes mostly from outside of New Mexico (10-30%).

For sites in Bernalillo County in central New Mexico, 40% to 86% of the U.S. Source Sector contributions come from sources within New Mexico. The largest U.S. Source Sector contributions are for On-Road (3-4 ppb) and Non-Road (2-3 ppb) for which 60-70% of the contribution is due to sources from New Mexico.

At the Doña Ana County monitoring sites, approximately 25% (13-38%) of the U.S. O&G and 22-50% of the U.S. EGU Source Sector is from New Mexico. However, only 9-17% of the U.S. On-Road ozone contribution is from New Mexico sources with the exception of Solano that has 44% of the U.S. on-road mobile ozone contribution due to New Mexico on-road emissions. .

The Carlsbad and Hobbs monitors in southeast New Mexico have approximately half of their U.S. O&G ozone contributions from New Mexico sources, with only ~20% of U.S. mobile contribution coming from New Mexico.

The Grant monitor in southwest New Mexico has almost no ozone contributions from sources in New Mexico.

Table 10-2. Reduction in 2028 ozone DVF due to the elimination of emissions from 7 Source Sectors in United States.

AQS_ID	Site_ID	DVC	DVF	O&GPT	O&GNP	EGU	NonEGU	On-Road	Non-Road	OAnth
Northern New Mexico										
350390026	COYOT	64.0	60.0	-0.5	-0.9	-0.8	-0.7	-1.5	-1.0	-0.7
350450009	BLOOM	64.3	60.2	-1.1	-2.1	-2.3	-0.7	-1.7	-1.1	-0.6
350450018	NAVAJ	67.0	63.3	-1.3	-2.7	-2.0	-0.8	-1.7	-1.2	-0.8
350451005	SUBST	63.7	59.6	-1.1	-2.5	-3.6	-0.8	-1.7	-1.2	-0.7
Central New Mexico										
350010023	NORTE	66.3	60.7	-0.5	-0.7	-1.1	-1.7	-3.9	-3.0	-4.2
350010024	SEHGS	68.0	62.0	-0.5	-0.7	-1.0	-1.7	-3.6	-2.8	-3.7
350010029	STHVA	66.0	60.5	-0.6	-0.9	-1.0	-1.6	-3.3	-2.5	-2.9
350010032	WSTSD	67.0	62.1	-0.4	-0.7	-0.9	-1.0	-2.7	-2.0	-2.4
350011012	FTHIL	65.0	58.8	-0.5	-0.7	-1.1	-1.4	-3.8	-3.0	-3.7
350431001	BERNA	64.0	58.1	-0.4	-0.6	-0.8	-1.1	-3.4	-2.5	-2.6
350490021	SNTFE	64.3	60.4	-0.5	-0.7	-0.7	-0.7	-2.0	-1.4	-1.3
Southern New Mexico										
350130008	UNION	66.3	59.8	-0.8	-0.9	-1.6	-1.5	-3.2	-2.3	-1.5
350130017	SPARK	67.0	61.8	-0.7	-1.0	-1.8	-1.5	-3.0	-2.1	-1.7
350130020	CHAPA	67.0	62.2	-0.6	-0.8	-1.3	-1.4	-2.3	-1.7	-1.3
350130021	DSVIE	72.0	66.8	-0.8	-1.1	-1.8	-1.6	-3.1	-2.2	-1.8
350130022	TERES	71.3	66.0	-0.8	-1.1	-1.6	-1.5	-2.9	-2.1	-1.5
350130023	SOLAN	65.0	60.2	-0.7	-1.0	-0.9	-1.1	-2.7	-1.8	-1.1
350151005	CARLS	69.0	66.4	-0.8	-1.1	-0.5	-0.8	-1.3	-0.9	-0.7
350171003	GRANT	62.0	58.9	-0.2	-0.3	-0.4	-0.7	-1.3	-1.0	-0.7
350250008	HOBBS	66.0	63.3	-1.6	-2.2	-0.7	-0.6	-1.4	-1.0	-0.7
350290003	DEAIR	66.0	62.5	-0.4	-0.5	-0.6	-0.7	-1.7	-1.2	-0.7

Table 10-3. Percent contribution of New Mexico Source Sectors to All United Source Sectors reduction in 2028 ozone DVF.

AQS_ID	Site_ID	O&GPT	O&GNP	EGU	NonEGU	On-Road	Non-Road	OAnth
Northern New Mexico								
350390026	COYOT	40%	56%	63%	0%	13%	10%	0%
350450009	BLOOM	64%	67%	83%	0%	24%	9%	17%
350450018	NAVAJ	69%	78%	85%	13%	24%	17%	13%
350451005	SUBST	55%	60%	86%	13%	29%	17%	29%
Central New Mexico								
350010023	NORTE	40%	43%	45%	59%	69%	67%	86%
350010024	SEHGS	40%	43%	50%	65%	69%	68%	86%
350010029	STHVA	50%	56%	50%	63%	67%	68%	83%
350010032	WSTSD	50%	57%	44%	40%	59%	60%	75%
350011012	FTHIL	40%	43%	45%	50%	66%	67%	81%
350431001	BERNA	25%	33%	50%	36%	62%	60%	73%
350490021	SNTFE	40%	43%	29%	43%	60%	50%	62%
Southern New Mexico								
350130008	UNION	25%	22%	44%	0%	16%	13%	7%
350130017	SPARK	29%	20%	50%	0%	13%	10%	12%
350130020	CHAPA	17%	13%	23%	0%	9%	6%	8%
350130021	DSVIE	25%	27%	50%	6%	16%	14%	11%
350130022	TERES	38%	27%	44%	7%	17%	14%	13%
350130023	SOLAN	29%	20%	22%	18%	44%	39%	27%
350151005	CARLS	63%	45%	40%	13%	23%	22%	14%
350171003	GRANT	0%	0%	0%	0%	8%	10%	0%
350250008	HOBBS	56%	50%	29%	0%	21%	20%	14%
350290003	DEAIR	50%	20%	33%	0%	35%	33%	0%

10.3.2 Source Sector Contributions to Modeled MDA8 Ozone Concentrations

The contributions of the Source Sector emissions to the absolute CAMx modeling results 2028 daily MDA8 ozone concentrations are analyzed in this section. We first present spatial maps of the episode maximum MDA8 ozone contributions across the 4-km New Mexico domain for each Source Region. The contributions of all and New Mexico Source Sectors to MDA8 ozone concentrations are then presented at four example New Mexico monitoring sites for the 10 days used to make the 2028 ozone DVF projections (i.e., the 10 SMAT days). Finally, the spatial maps of New Mexico and all United States Source sector contributions to daily MDA8 ozone concentrations are presented for six example days during the May-August 2014 modeling episode.

10.3.2.1 Episode Maximum Source Sector MDA8 Ozone Contributions by Source Region

Figures 10-21 and 10-22 display the episode maximum MDA8 ozone contributions due to Source Sector emissions from New Mexico. The maximum New Mexico EGU MDA8 ozone contribution is 10.9 ppb and occurs at the location of the Four Corners Power Plan in San Juan County (Figure 10-21a). Elevated ozone due to emissions from New Mexico EGUs is also seen in Lea County at the location of the Hobbs, Cunningham and Maddox EGUs and in southern Doña Ana County at the location of the Rio Grande EGU (Figure 10-21a). The highest New Mexico Non-EGU Point source contribution is 3.1 ppb in eastern Bernalillo County with the Non-EGU Point contribution mostly less than 1 ppb away from Bernalillo County (Figure 10-21b). The maximum New Mexico On-Road (4.7 ppb) and Non-Road (4.0 ppb) ozone contributions both occur in Albuquerque, with a secondary ozone maximum occurring in Las Cruces (Figure 10-21c and d). The On-Road ozone spatial patterns follow the major freeways, including east-west I-40 and north-south I-25, with even I-10 evident in Luna County in southwest New Mexico (Figure 10-21c).

The highest New Mexico O&G Non-Point (7.6 ppb) and O&G Point (5.4 ppb) both occur at the same location in the Permian Basin (Figure 10-22a and b). The O&G Non-Point ozone contributions exceed 5 ppb over large portions of the Permian and San Juan Basins (Figure 10-22a). The O&G Point source ozone contributions are lower, exceeding 3 ppb over large portions of the Permian Basin with much lower ozone contributions in the San Juan Basin (Figure 10-22b). The Other Anthropogenic ozone contribution has a bull's eye centered on Albuquerque with a maximum of 6.2 ppb (Figure 10-22c). Fires are highly episodic with four distinct fire ozone plumes present in New Mexico with episode maximum exceeding 20 ppb (Figure 10-22d).

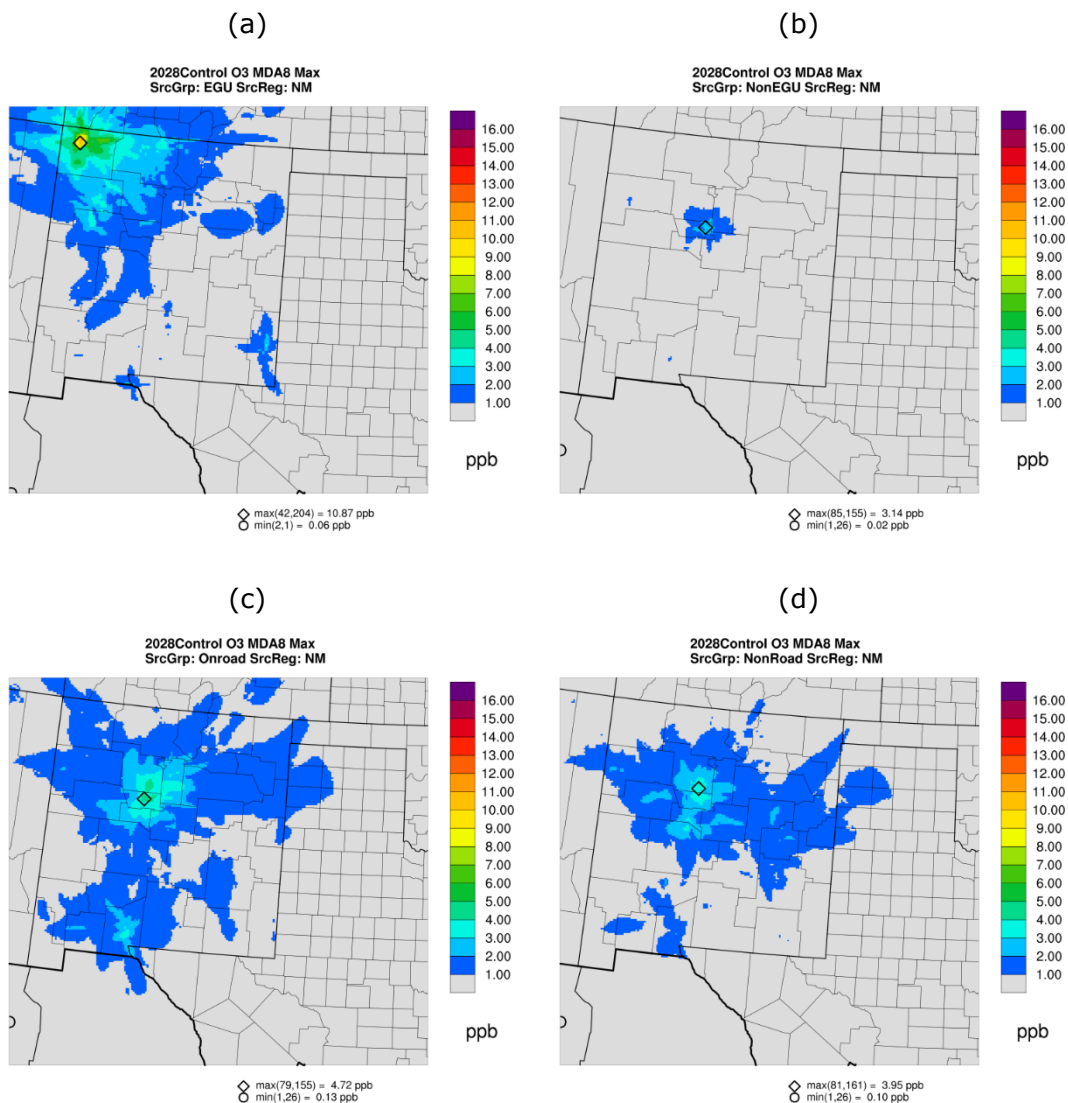


Figure 10-21. Episode maximum daily MDA8 ozone contributions from Source Sectors in New Mexico for: (a) EGU Point; (b) Non-EGU Point; (c) On-Road Mobile; and (d) Non-Road Mobile.

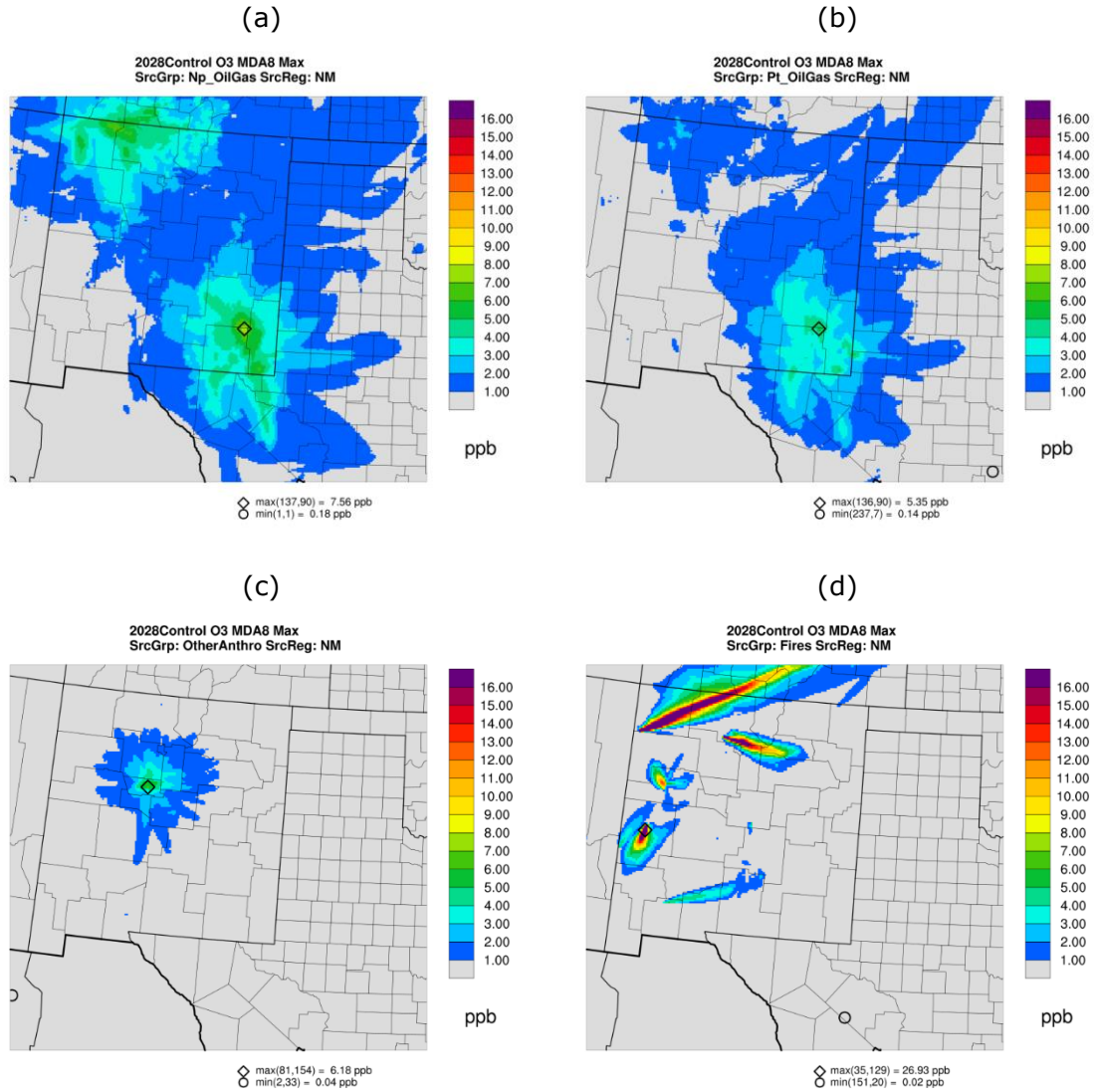


Figure 10-22. Episode maximum daily MDA8 ozone contributions from Source Sectors in New Mexico for: (a) Non-Point O&G; (b) Point O&G; (c) Other Anthropogenic; and (d) Fires.

Figure 10-23 displays the episode maximum MDA8 ozone contributions due to emissions from Texas for 9 Source Sectors (7 anthropogenic Source Sectors plus fires and natural). The presence of EGUs in the Texas Panhandle is clearly evident (e.g., 1,100 MW Tolk coal EGU) that produce ozone in excess of 2 ppb entering eastern New Mexico (Figure 10-23, top left). Elevated ozone due to Texas Non-EGU Point, On-Road, Non-Road, and Other Anthropogenic is seen in El Paso with elevated ozone concentrations entering Doña Ana County. The Texas anthropogenic Source Sector that contributes the most to ozone in New Mexico is O&G. Texas O&G Non-Point (Figure 10-23, middle right) produces ozone above 4 ppb in Lea County and ozone in excess of 2 ppb as far north as Santa Fe and San Miguel Counties. Within the New Mexico portion of the Permian Basin, the maximum Texas O&G Non-Point ozone contribution exceeds 3 ppb and the maximum Texas O&G Point contribution exceeds 2 ppb.

The Colorado Source Sector with the largest contribution to New Mexico ozone concentrations is O&G Non-Point that has a peak ozone contribution in the 4-km domain of 7 ppb that occurs in Colorado just north of the border of San Juan and Rio Arriba Counties (Figure 10-24, middle right). Colorado O&G Non-Point contributes ozone in excess of 4 ppb in the northern portion of the two northwest New Mexico counties and ozone in excess of 1.5-2.0 ppb stretching south to Bernalillo County. Other Colorado anthropogenic emissions Source Sectors contribute ozone in excess of 0.5 ppb across large portions of New Mexico with O&G Point contributing ozone in excess of 1 ppb in San Juan County.

The highest Source Sector ozone contributions in the 4-km New Mexico domain due to all emissions in the U.S. are shown in Figure 10-25. The peak U.S. EGU ozone contribution is 11.5 ppb at the same locations as the New Mexico EGU peak ozone contribution with most of the U.S. EGU contribution at this location due to the FCPP in New Mexico (10.9 ppb, see Figure 10-21a). In addition to the EGU ozone hotspots in the Texas panhandle discussed above (Figure 10-23), there are also all U.S. EGU ozone hotspots in eastern Arizona at the locations of the Springerville and Coronado Generating Stations (Figure 10-25, top left). The U.S. On-Road, Non-Road and Other Anthropogenic ozone contributions (Figure 10-25) look similar to the New Mexico alone ozone contributions (Figures 10-21 and 10-22) with the addition of an incremental ozone concentrations across the 4-km domain due to the U.S. Source Sector emissions from outside New Mexico.

The peak U.S. O&G Non-Point ozone contribution is 10.5 ppb (Figure 10-25, middle right) and occurs at the same location in Colorado on the border with New Mexico as where the Colorado O&G Non-Point peak ozone (7.0 ppb) occurred (Figure 10-24, middle right). The additional 4.5 ppb ozone comes mainly from New Mexico O&G Non-Point emissions (Figure 10-22a). Ozone due to U.S. O&G Non-Point exceeds 8 ppb in the New Mexico portions of the San Juan and Permian Basins. Ozone due to U.S. O&G Point sources exceeds 4 ppb over a wide area in the Permian Basin, whereas U.S. O&G Point rarely exceeds 4 ppb in the San Juan Basin.

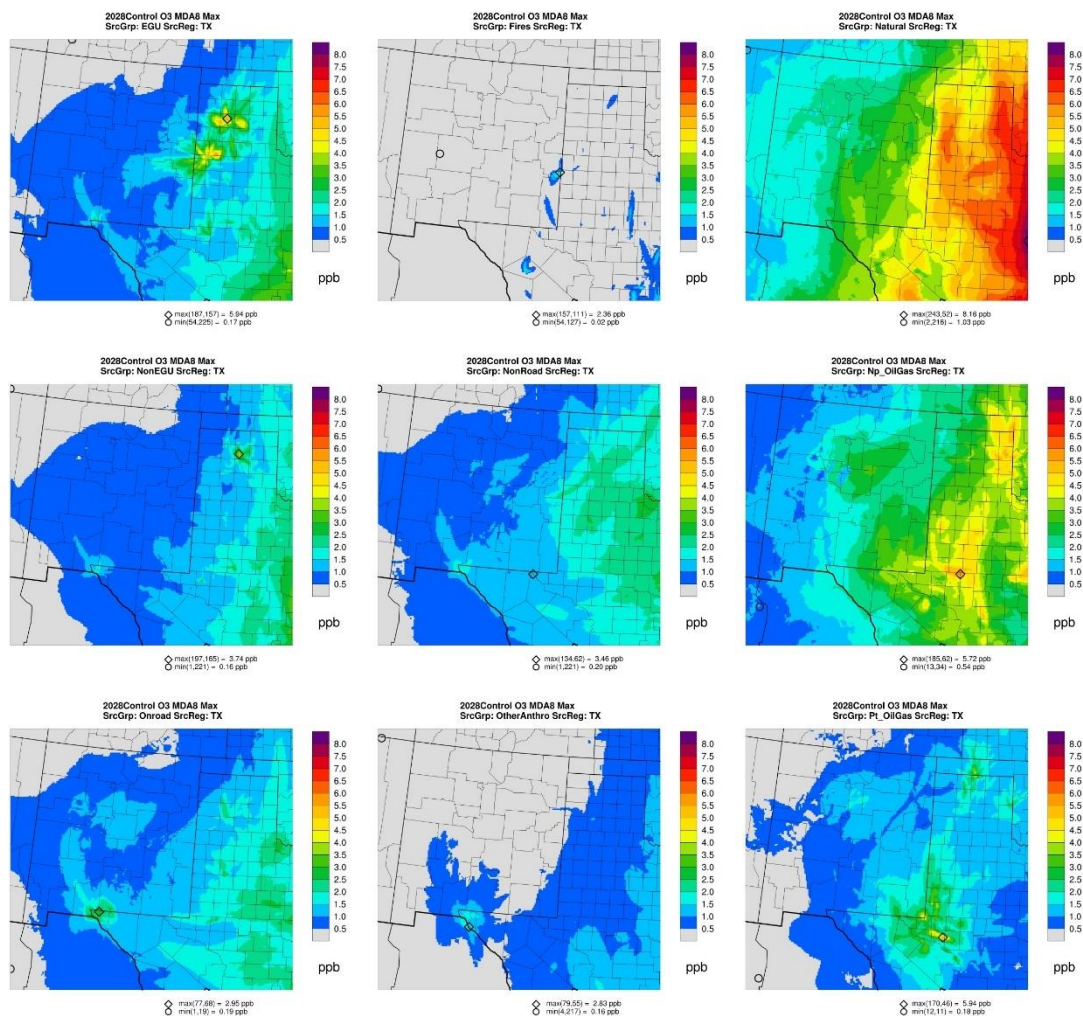


Figure 10-23. Episode maximum MDA8 ozone contributions from Source Sectors in Texas for EGU Point (top left), Fires (top middle), Natural (top right), Non-EGU Point (middle left), Non-Road (middle middle), O&G Non-Point (middle right), On-Road (bottom left), Other Anthropogenic (bottom middle) and O&G Point (bottom right) from the 2028 O&G Control Strategy emissions scenario.

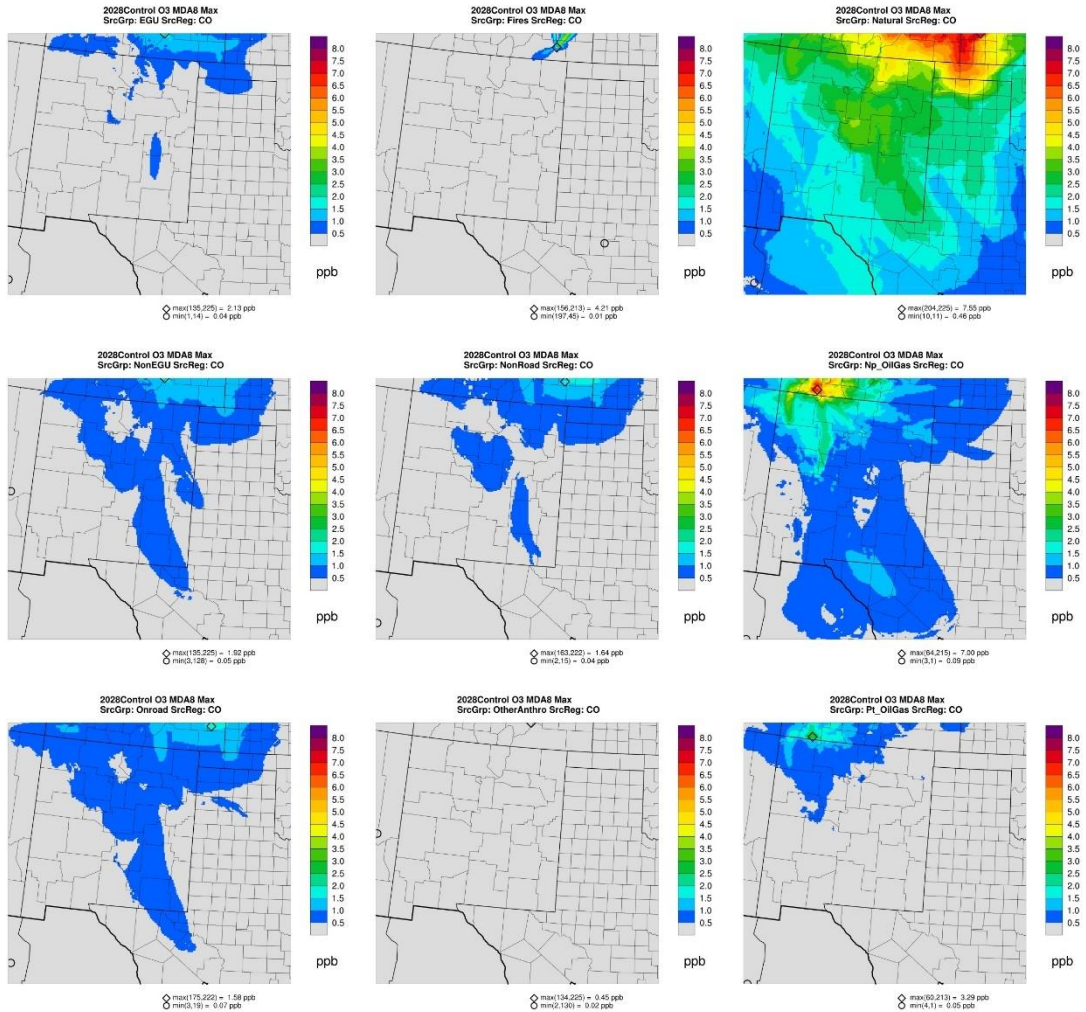


Figure 10-24. Episode maximum MDA8 ozone contributions from Source Sectors in Colorado for EGU Point (top left), Fires (top middle), Natural (top right), Non-EGU Point (middle left), Non-Road (middle middle), O&G Non-Point (middle right), On-Road (bottom left), Other Anthropogenic (bottom middle) and O&G Point (bottom right) from the 2028 O&G Control Strategy emissions scenario.

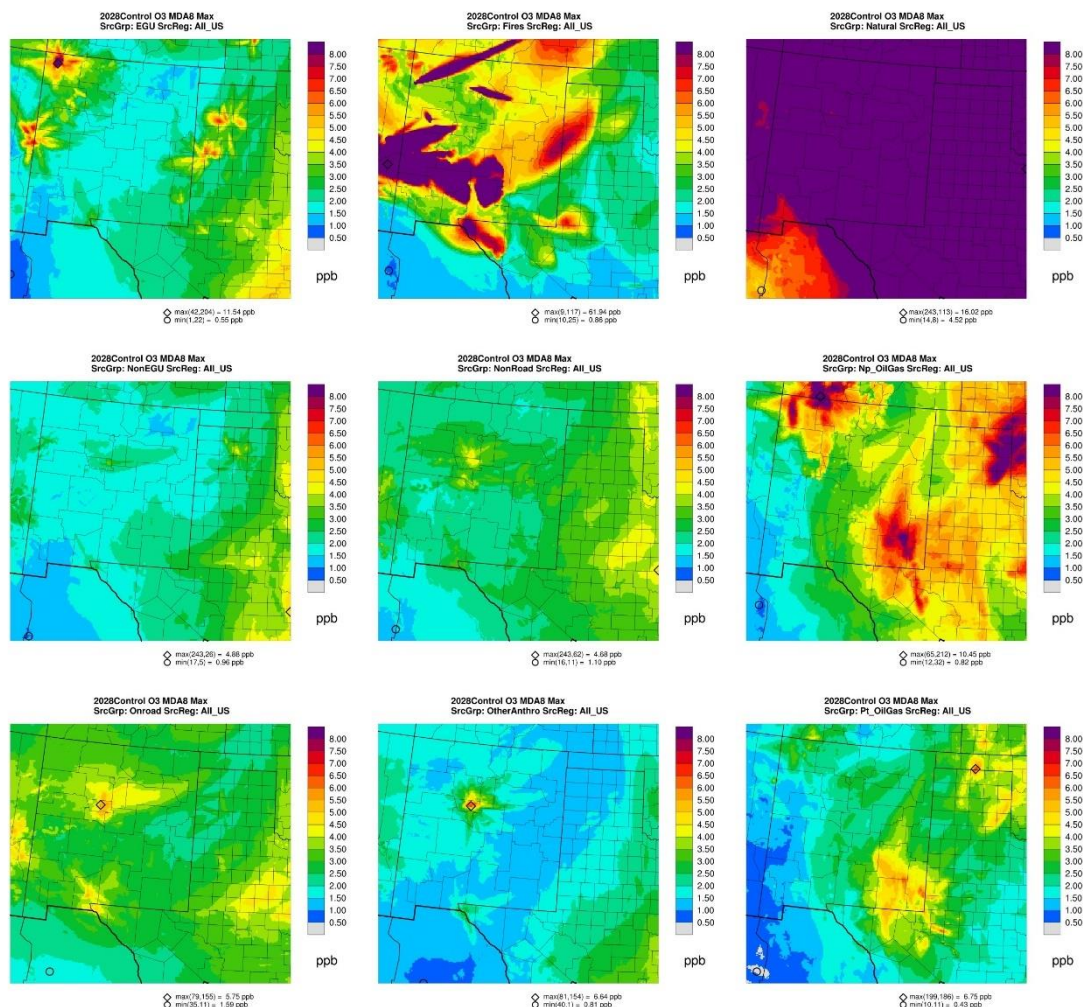


Figure 10-25. Episode maximum MDA8 ozone contributions from Source Sectors in United States for EGU Point (top left), Fires (top middle), Natural (top right), Non-EGU Point (middle left), Non-Road (middle middle), O&G Non-Point (middle right), On-Road (bottom left), Other Anthropogenic (bottom middle) and O&G Point (bottom right) from the 2028 O&G Control Strategy emissions scenario.

The top two panels in Figure 10-26 display the episode maximum MDA8 ozone contributions due to international anthropogenic emissions that are either within the CAMx 36/12/4-km modeling domain (i.e., mainly from in-domain Mexico emissions) or coming through the BCs (BC_{Intl}) from international emissions from outside of the CAMx modeling domains that were generated from 2014 GEOS-Chem simulations. The in-domain international anthropogenic emissions contribute high ozone concentrations in southern New Mexico with values exceeding 16 ppb stretching into Doña Ana, Luna and Otero Counties. The southeastern half of New Mexico has ozone contributions in excess of 8 ppb due to in-domain international emissions. Although the ozone peaks are not as high as the in-domain international anthropogenic emissions, the BC_{Intl} ozone contributions exceed 10 ppb across all of New Mexico and are as high as 13 ppb

(Figure 10-26b). The BC_{Natural} ozone contributions is as high as 49 ppb in San Juan County (Figure 10-26c), while the BC_{US} ozone contributions ranges from 3-4 ppb across New Mexico (Figure 10-26d).

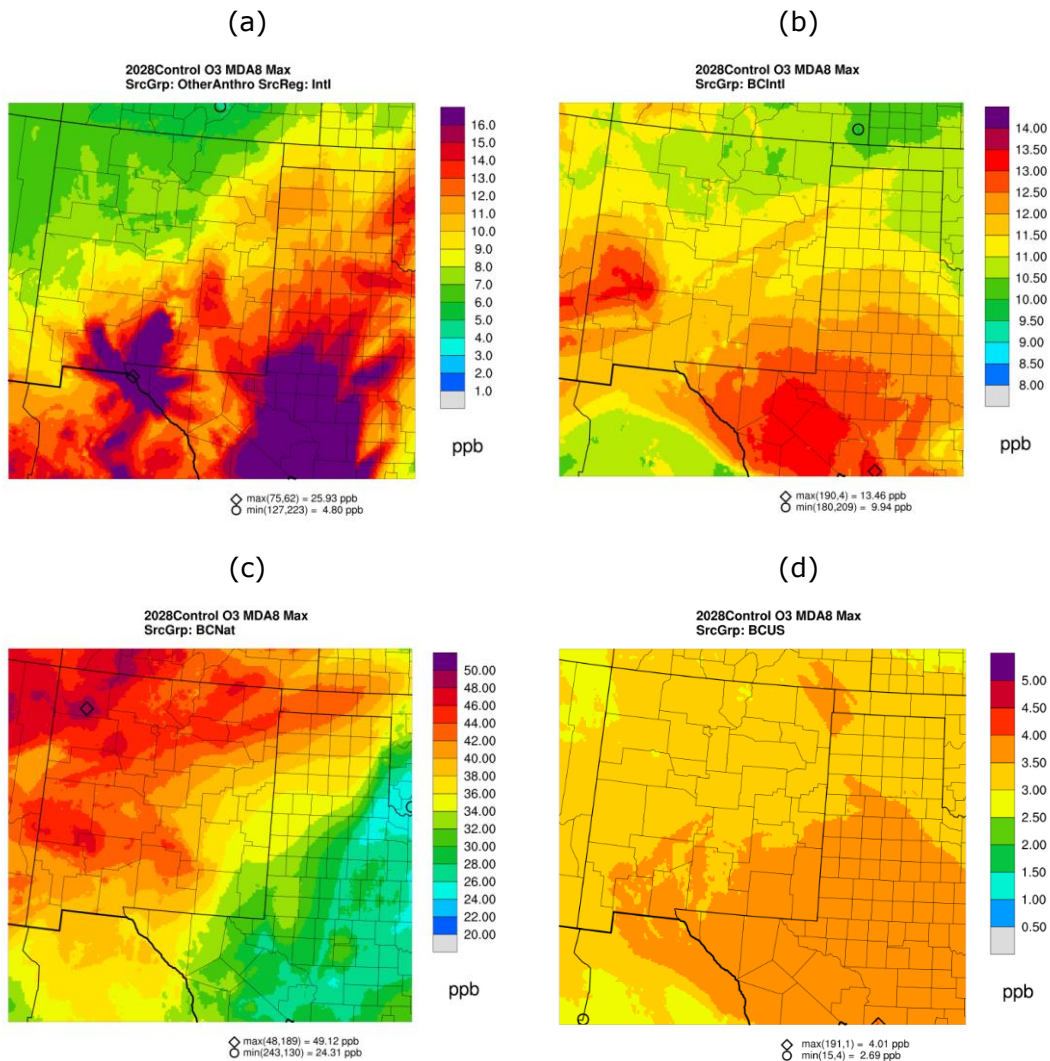


Figure 10-26. Episode maximum MDA8 ozone contributions from: (a) International Anthropogenic Emissions within CAMx 36/12/4-km domains; (b) BCs due to International Anthropogenic Emissions (BC_{Intl}); (c) BCs due to Natural sources (BC_{Natural}); and (d) BCs due to U.S. Anthropogenic Emissions (BC_{US}).

10.3.2.2 Source Sector Ozone Contributions to MDA8 Ozone Concentrations on Modeled High Ozone Days

The daily CAMx 2028 Source Sector APCA ozone source apportionment modeling results were extracted at the locations of the New Mexico ozone monitoring sites and loaded into an Excel Dashboard to visualize the source contributions using stacked bar, pie and tree charts. The Dashboard displays modeled 2028 MDA8 ozone concentrations at a user-selected monitoring site in groups of 10 high ozone days, and the average across the 10 days. These 10 days include the 10 days used in the SMAT 2028 ozone DVF projections, as well as the modeled 2028 first and second highest group of 10 days.

Figures 10-27 through 10-34 display results from the Dashboard for 5 monitoring sites representing different locations in New Mexico. Figures 10-27 and 10-28 display the modeled 2028 ozone results at the Navajo Lake monitor in northwest New Mexico for the 10 SMAT days. The top panel in Figure 10-27 shows stacked bar charts of daily MDA8 ozone contributions by Source Region and BCs for the 10 SMAT days at Navajo Lake. The total MDA8 ozone concentrations are 60-70 ppb and the BCs (grey bar) contribute by far the most with contributions ranging from 26 to 60 ppb. The New Mexico contribution ranges from near zero to 10.9 ppb. The bottom panel in Figure 10-27 shows a Tree Chart and breaks down each Source Region's contribution by Source Category averaged across the 10 SMAT days at Navajo Lake. The Natural category dominates the BC contribution followed by the BC International Anthropogenic Emissions category.

Figure 10-28 focuses on contributions due to emissions from New Mexico Source Categories to MDA8 ozone on the 10 SMAT days at Navajo Lake showing day by day results in the top panel and a pie chart of New Mexico contributions averaged across the 10 days in the bottom panel. For the Navajo Lake site, New Mexico O&G Non-Point is always the largest contributor (38% on average) followed by EGU (29% on average) and then O&G Point (16% on average). Next most important is either On-Road or Natural, depending on the day (6-7% on average). The other two San Juan County sites have higher EGU contributions, with EGU being the highest New Mexico Source Category accounting for 50% and 32% of the New Mexico ozone contribution at, respectively, Substation and Bloomfield.

Figures 10-29 and 10-30 show ozone contribution results for the 10 SMAT days at the Foothills monitoring site and represents typical contributions for sites in Bernalillo County. There is a wide-range of variation in the New Mexico ozone contribution to the 10 SMAT days at Foothills, from near zero to 15 ppb. BCs contribute the most, 27 to 47 ppb. The remaining U.S. and in-domain international emissions also contribute a fair amount. The three most important New Mexico Source Categories contributing to modeled MDA8 ozone at Foothills averaged across the 10 SMAT days are Other Anthropogenic (27%), On-Road (35%) and Non-Road (20%) (Figure 10-30).

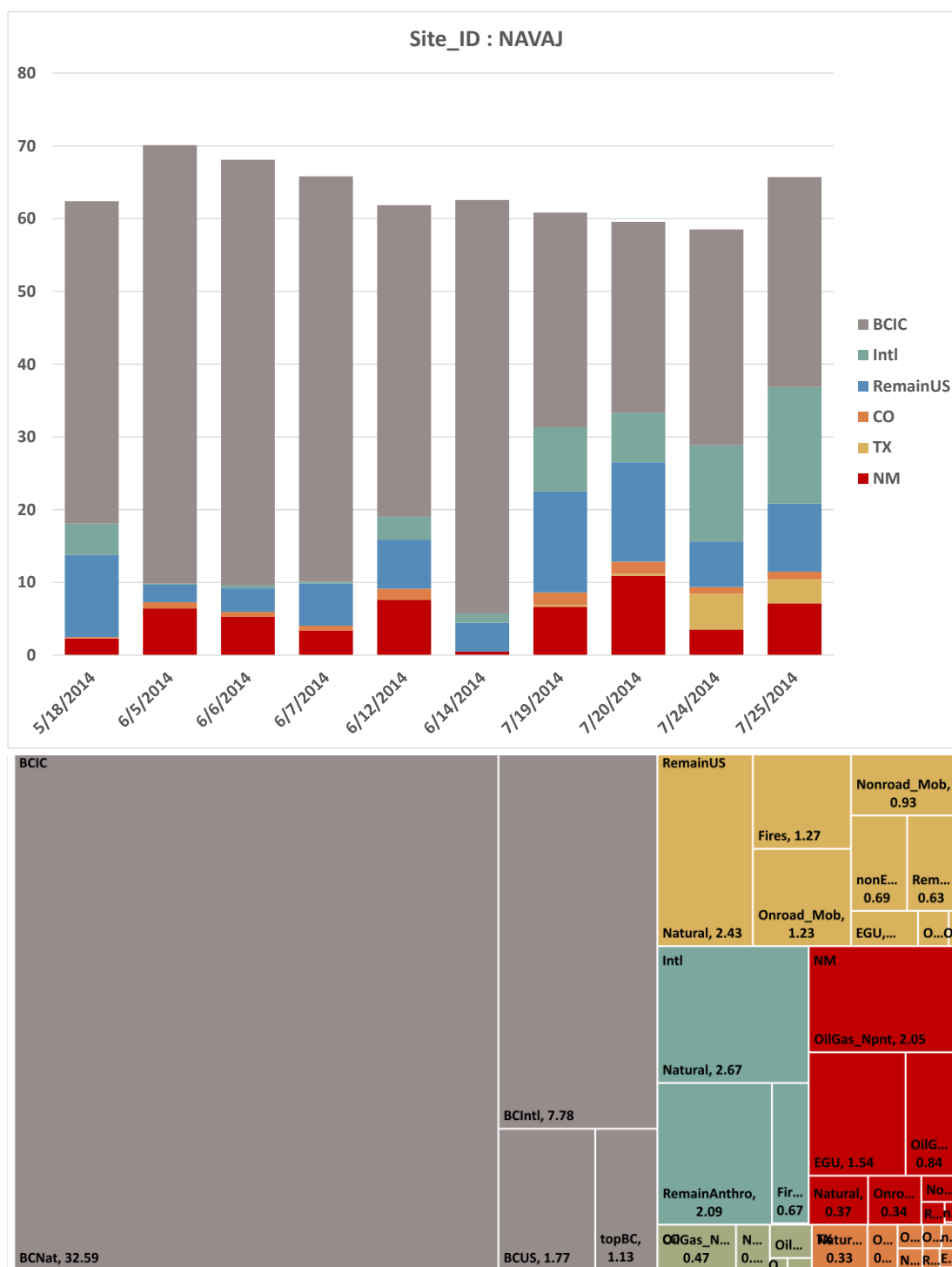


Figure 10-27. Contributions of all Source Groups to total MDA8 ozone concentrations at Navajo Lake for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).

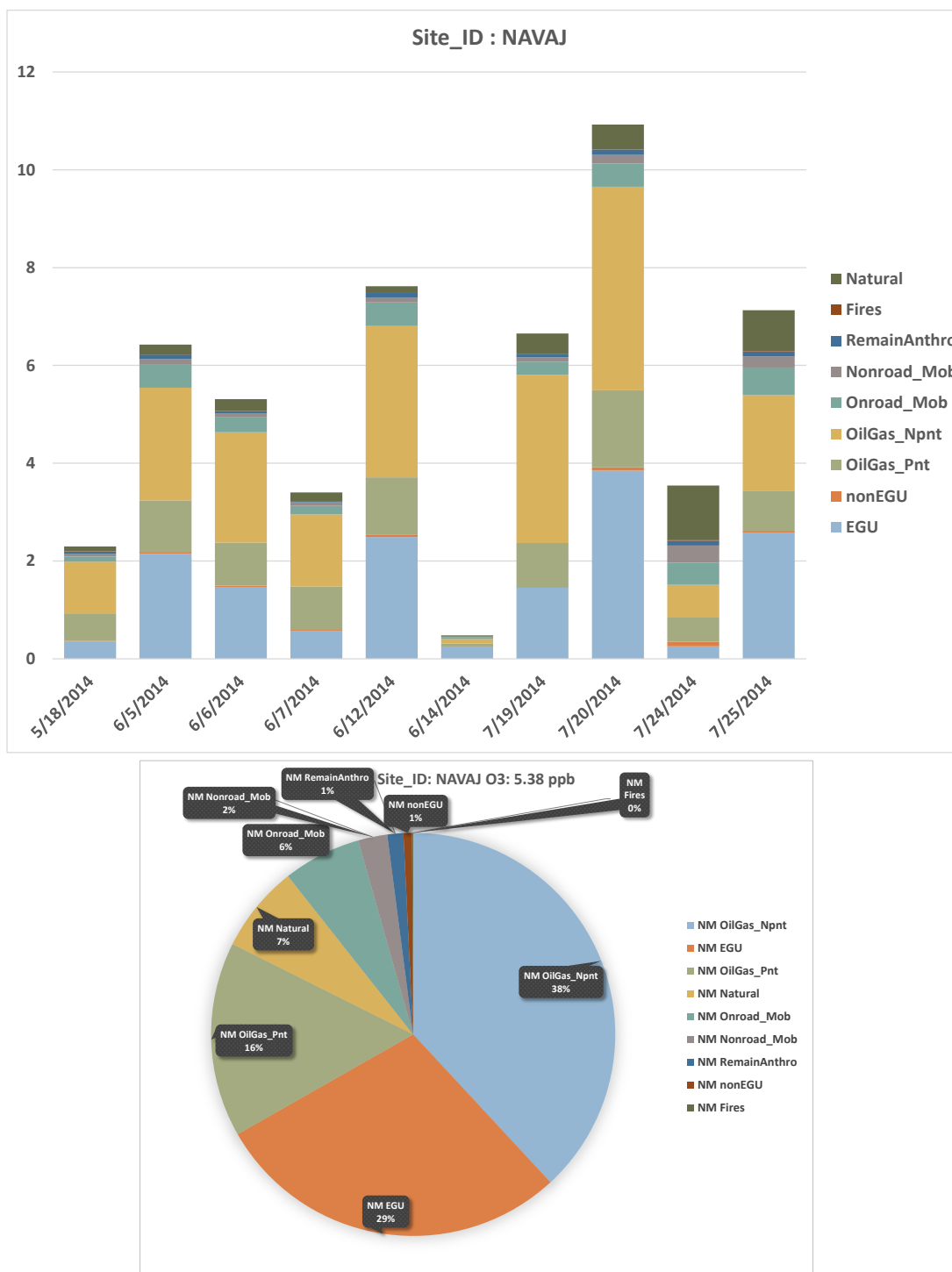


Figure 10-28. Contributions of New Mexico Source Groups to MDA8 ozone concentrations from New Mexico at Navajo Lake for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).

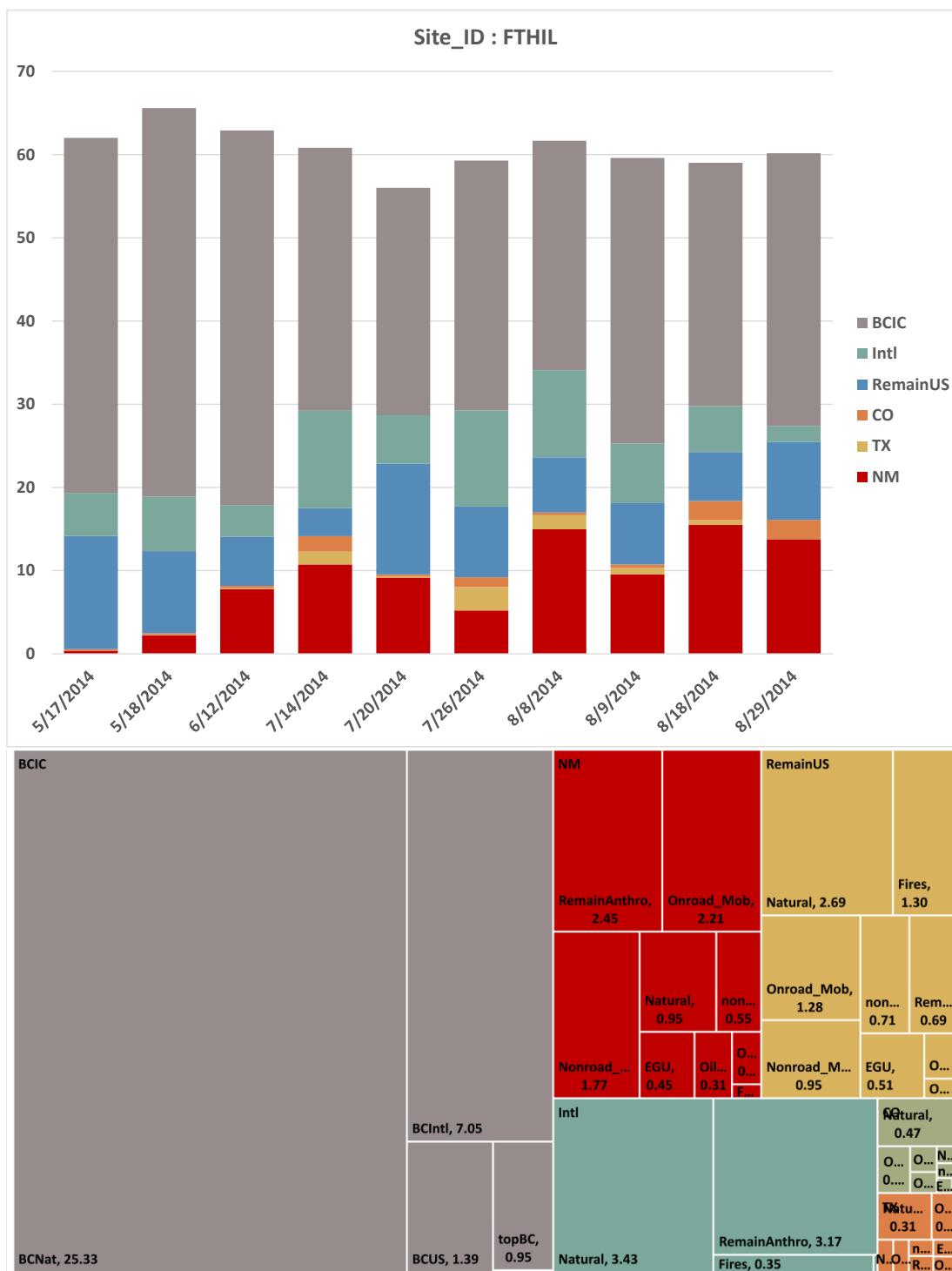


Figure 10-29. Contributions of all Source Groups to total MDA8 ozone concentrations at Foothills for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).

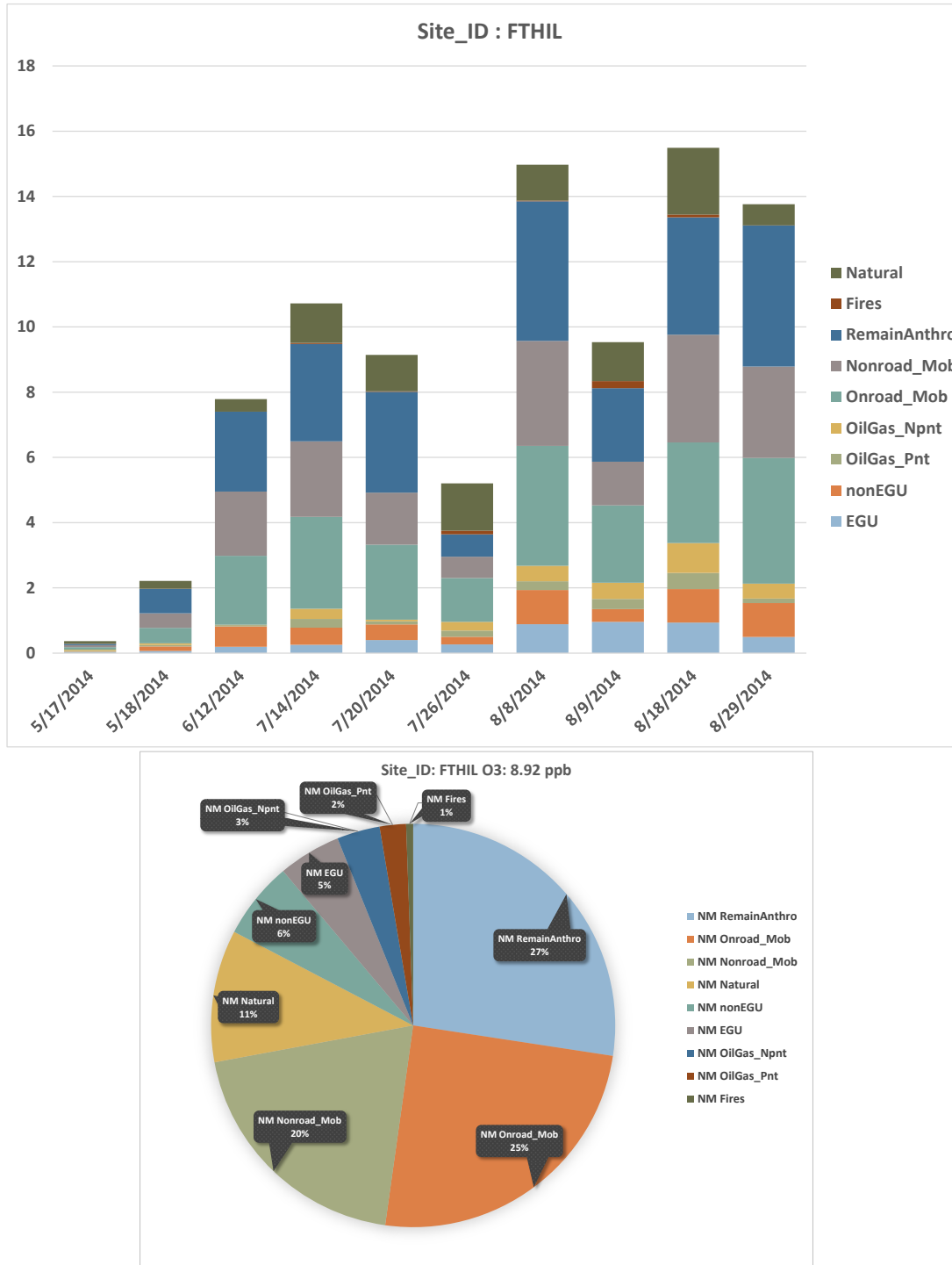


Figure 10-30. Contributions of New Mexico Source Groups to MDA8 ozone concentrations from New Mexico at Foothills for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).

Ozone contributions for the 10 SMAT days at the Desert View monitor in Doña Ana County are shown in Figures 10-31 and 10-32. BCs from outside the 36-km North American domain is the largest contributor (45% on average), followed by in-domain international emissions (27%), Remainder US (14%) and Texas (8%). Emissions from New Mexico only contribute 4% of the total ozone averaged across the 10 SMAT days at Desert View. International anthropogenic emissions from BCs (5.8 ppb) and in-domain (i.e., Mexico) sources (13.0 ppb) contribute a combined 18.8 ppb (30%) of the average ozone across the 10 SMAT days at Desert View (Figure 10-31, bottom). As shown in Figure 10-32, the contributions from sources in New Mexico contribute from 1.3 to 4.4 ppb to the total MDA8 ozone on the 10 SMAT days, with an average contribution of 2.8 ppb. The largest New Mexico contributing Source Sector is EGU (29%), followed by Natural (18%), On-Road (15%) with 10% contribution coming from Non-Road and Remaining Anthropogenic (Figure 10-32, bottom).

Figures 10-33 and 10-34 displays the 10 SMAT day ozone contributions at the Carlsbad monitoring site. BC and in-domain international emissions contribute the most to ozone at Carlsbad. There is a lot of variation in the day-to-day contributions from New Mexico (0.2 to 5 ppb) with an average contribution of 2.0 ppb. Similar results are seen for Texas (0.5 to 9 ppb with an average of 2.5 ppb). Non-Point O&G and then Point O&G are the two largest anthropogenic Source Sector contributors from both New Mexico and Texas.

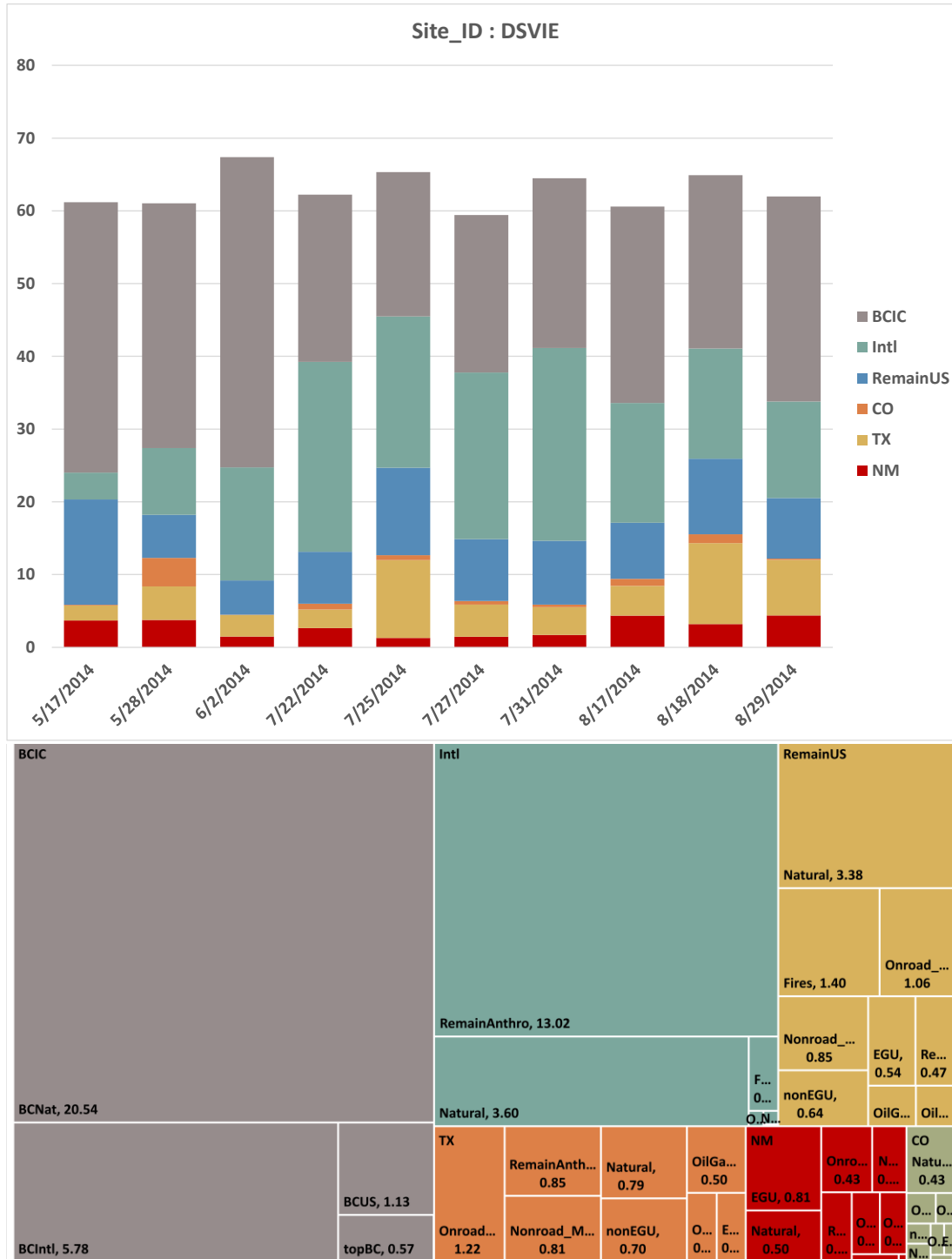


Figure 10-31. Contributions of all Source Groups to total MDA8 ozone concentrations at Desert View for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).

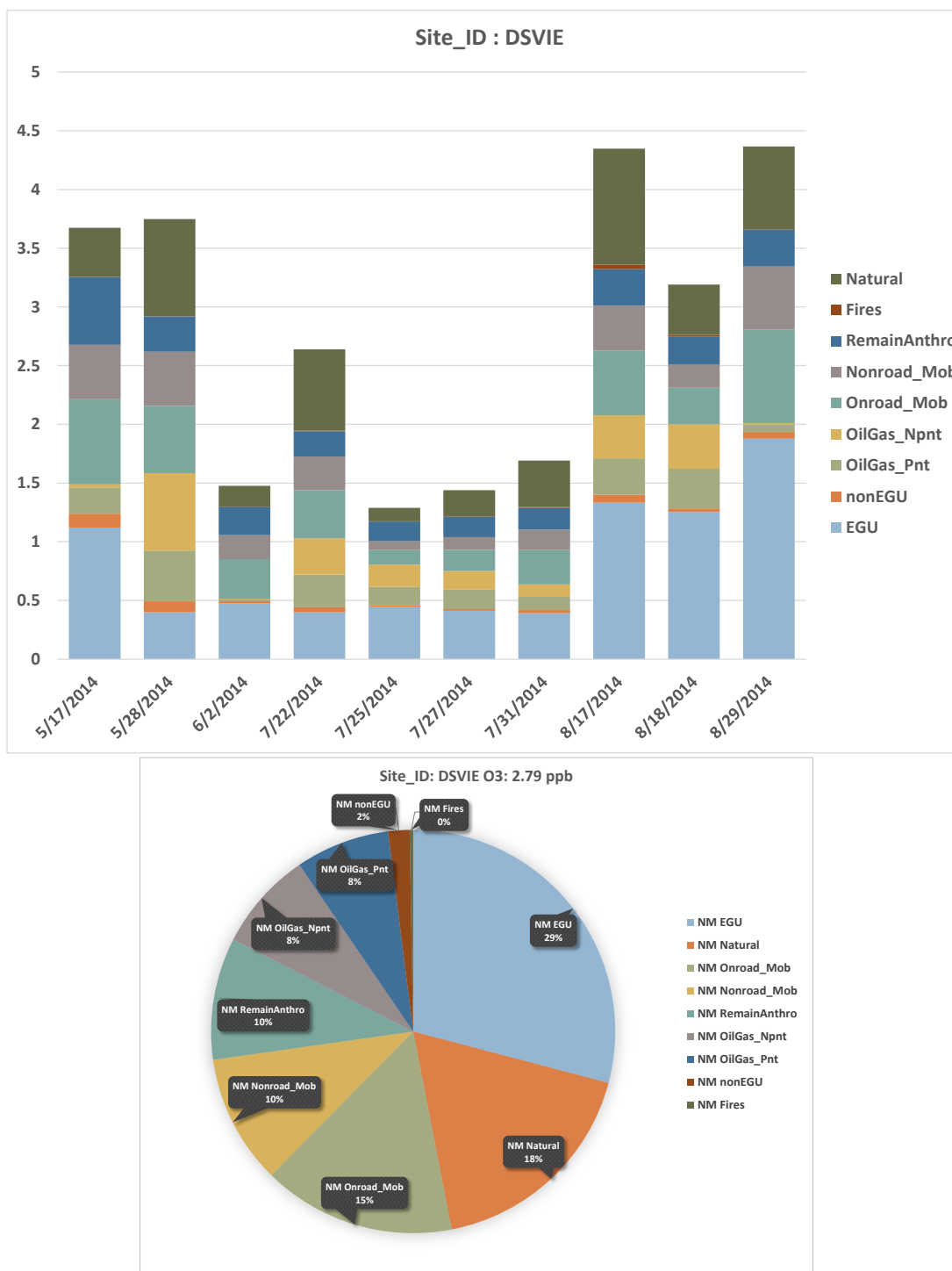


Figure 10-32. Contributions of New Mexico Source Groups to MDA8 ozone concentrations at Desert View for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).

NMED Exhibit 17

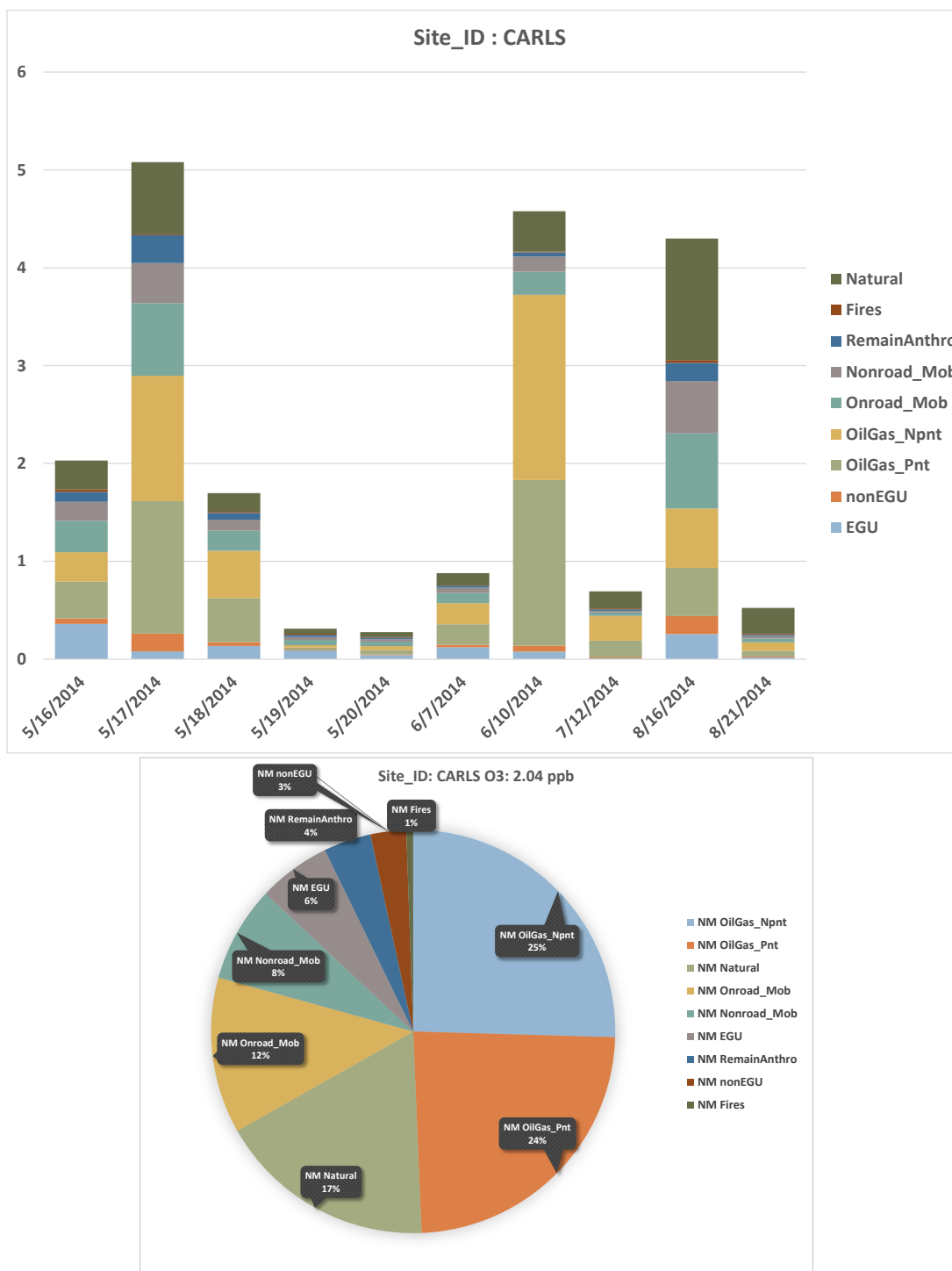


Figure 10-34. Contributions of New Mexico Source Groups to MDA8 ozone concentrations at Carlsbad for the 10 high SMAT ozone days (top) and average across the 10 SMAT days (bottom).

10.3.3 International Anthropogenic Emissions Contributions to Projected 2028 ozone DVFs

The SMAT ozone DVF projection tool was run using the CAMx 2028 O&G Control Strategy output with the contributions of international anthropogenic emissions removed. The ozone concentrations due to the BC_{Intl} and in-domain international emissions (i.e., Mexico, Canada and CMV_{Intl}) were removed from the CAMx 2028 O&G Control Strategy output and SMAT was run to obtain projected 2028 ozone DVFs without any contributions of international anthropogenic emissions. SMAT was run using three different current year ozone design values: $DVC_{2012-2016}$, $DVC_{2015-2019}$ and $DVC_{2017-2019}$ using the same procedures as used in the 2028 ozone DVF projection DVC sensitivity analysis discussed in Chapter 9. Tables 10-4 through 10-6 display the projected 2028 ozone DVFs for the 2028 O&G Control Strategy and 2028 no international anthropogenic emissions scenarios using the three sets of DVCs.

The elimination of the international anthropogenic emissions reduces the projected 2028 ozone DVFs by 13 to 25 ppb with the smallest reductions at the northern and largest reductions at the southern sites in New Mexico. For all DVC scenarios, the projected 2028 ozone DVFs at all monitoring sites in New Mexico are below the 2015 70 ppb ozone NAAQS when ozone contributions due to international anthropogenic emissions are removed. The highest projected 2028 ozone DVF under the no international anthropogenic emissions scenario is 52.8 ppb at the Carlsbad monitoring site when the $DVC_{2017-2019}$ current year design value is used in the 2028 ozone DVF projection.

Figure 10-35 displays the spatial distribution of the current year ozone DVC and the projected 2028 ozone DVF for the 2028 O&G Control Strategy using the SMAT UAA tool and the three definitions of DVCs. Using the $DVC_{2012-2016}$ and $DVC_{2015-2019}$, the SMAT projected 2028 ozone DVFs are all below the 2015 ozone NAAQS under the 2028 O&G Control Strategy emissions scenario. However, when the $DVC_{2017-2019}$ is used, the SMAT UAA estimates projected 2028 ozone DVFs in excess of the 2015 ozone NAAQS across all of Eddy County in southeast New Mexico.

The spatial distribution of the projected 2028 ozone DVF with no international anthropogenic emissions and its differences with the 2028 O&G Control Strategy 2028 ozone DVF using the three DVC definitions are shown in Figure 10-36. The removal of the international anthropogenic emission contributions reduces the 2028 ozone DVFs in New Mexico by 10-30 ppb. The highest 2028 ozone DVF in the 4-km New Mexico domain are 52.5, 55.2 and 56.4 ppb for the, respectively, $DVC_{2012-2016}$, $DVC_{2015-2019}$ and $DVC_{2017-2019}$ current year design value sensitivity scenarios, which are well below the 2015 70 ppb ozone NAAQS.

Table 10-4. Projected 2028 ozone DVFs for the 2028 O&G Control Strategy (2028OGCS) and 2028 no international anthropogenic emissions (2028INTL) scenarios using the DVC₂₀₁₂₋₂₀₁₆ current year ozone DVC.

AQS_ID	2012-16 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS-INTL (ppb)	Site Name	County
350010023	66.3	60.7	47.2	-13.5	Del Norte HS	Bernalillo
350010024	68.0	62.0	48.5	-13.5	South East Heights	Bernalillo
350010029	66.0	60.5	47.1	-13.4	South Valley	Bernalillo
350010032	67.0	62.1	48.5	-13.6	Westside	Bernalillo
350011012	65.0	58.8	45.7	-13.1	Foothills	Bernalillo
350130008	66.3	59.8	39.9	-19.9	La Union	Doña Ana
350130017	67.0	61.8	38.4	-23.4	Sunland Park	Doña Ana
350130020	67.0	62.2	39.6	-22.6	Chaparral	Doña Ana
350130021	72.0	66.8	42.6	-24.2	Desert View	Doña Ana
350130022	71.3	66.0	42.2	-23.8	Santa Teresa	Doña Ana
350130023	65.0	60.2	41.5	-18.7	Solano	Doña Ana
350151005	69.0	66.4	46.1	-20.3	Carlsbad	Eddy
350171003	62.0	58.9	43.0	-15.9	Chino Copper Smelt	Grant
350250008	66.0	63.3	44.9	-18.4	Hobbs Jefferson	Lea
350290003	66.0	62.5	43.3	-19.2	Deming Airport	Luna
350390026	64.0	60.0	47.4	-12.6	Coyote Ranger Dist	Rio Arriba
350431001	64.0	58.1	44.4	-13.7	Bernalillo (E Avenida)	Sandoval
350450009	64.3	60.2	46.4	-13.8	Bloomfield	San Juan
350450018	67.0	63.3	50.2	-13.1	Navajo Lake	San Juan
350451005	63.7	59.6	48.5	-11.1	Substation	San Juan
350490021	64.3	60.4	47.9	-12.5	Santa Fe Airport	Santa Fe
350610008	66.3	62.0	47.5	-14.5	Los Lunas (Los Lentos)	Valencia

Table 10-5. Projected 2028 ozone DVFs for the 2028 O&G Control Strategy (2028OGCS) and 2028 no international anthropogenic emissions (2028INTL) scenarios using the DVC₂₀₁₅₋₂₀₁₉ current year ozone DVC.

AQS_ID	2015-19 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS–INTL (ppb)	Site Name	County
350010023	69.0	63.1	49.2	-13.9	Del Norte HS	Bernalillo
350010029	66.0	60.5	47.1	-13.4	South Valley	Bernalillo
350011012	69.0	62.4	48.5	-13.9	Foothills	Bernalillo
350130008	68.7	62.0	41.3	-20.7	La Union	Doña Ana
350130020	70.7	65.7	41.8	-23.9	Chaparral	Doña Ana
350130021	74.3	68.9	43.9	-25.0	Desert View	Doña Ana
350130022	74.0	68.5	43.8	-24.7	Santa Teresa	Doña Ana
350130023	67.7	62.7	43.3	-19.4	Solano	Doña Ana
350151005	73.7	70.9	49.2	-21.7	Carlsbad	Eddy
350153001	71.0	69.3	44.1	-25.2	Carlsbad NP	Eddy
350250008	69.3	66.5	47.1	-19.4	Hobbs Jefferson	Lea
350390026	66.3	62.2	49.1	-13.1	Coyote Ranger Dist	Rio Arriba
350431001	67.0	60.9	46.5	-14.4	Bernalillo (E Avenida)	Sandoval
350450009	67.0	62.8	48.3	-14.5	Bloomfield	San Juan
350450018	69.0	65.2	51.7	-13.5	Navajo Lake	San Juan
350451005	67.3	62.9	51.2	-11.7	Substation	San Juan
350490021	65.0	61.0	48.4	-12.6	Santa Fe Airport	Santa Fe
350610008	66.7	62.3	47.8	-14.5	Los Lunas (Los Lentos)	Valencia

Table 10-6. Projected 2028 ozone DVFs for the 2028 O&G Control Strategy (2028OGCS) and 2028 no international anthropogenic emissions (2028INTL) scenarios using the DVC₂₀₁₇₋₂₀₁₉ current year ozone DVC.

AQS_ID	2017-19 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS-INTL (ppb)	Site Name	County
350010023	70.0	64.0	49.9	-14.1	Del Norte HS	Bernalillo
350010029	67.0	61.4	47.8	-13.6	South Valley	Bernalillo
350011012	71.0	64.2	49.9	-14.3	Foothills	Bernalillo
350130008	70.0	63.2	42.1	-21.1	La Union	Doña Ana
350130020	73.0	67.8	43.1	-24.7	Chaparral	Doña Ana
350130021	77.0	71.4	45.5	-25.9	Desert View	Doña Ana
350130022	76.0	70.3	45.0	-25.3	Santa Teresa	Doña Ana
350130023	70.0	64.8	44.7	-20.1	Solano	Doña Ana
350151005	79.0	76.0	52.8	-23.2	Carlsbad	Eddy
350250008	71.0	68.1	48.3	-19.8	Hobbs Jefferson	Lea
350390026	67.0	62.8	49.6	-13.2	Coyote Ranger Dist	Rio Arriba
350431001	68.0	61.8	47.2	-14.6	Bernalillo (E Avenida)	Sandoval
350450009	68.0	63.7	49.1	-14.6	Bloomfield	San Juan
350450018	69.0	65.2	51.7	-13.5	Navajo Lake	San Juan
350451005	69.0	64.5	52.5	-12.0	Substation	San Juan
350490021	66.0	62.0	49.1	-12.9	Santa Fe Airport	Santa Fe
350610008	68.0	63.5	48.7	-14.8	Los Lunas (Los Lentos)	Valencia

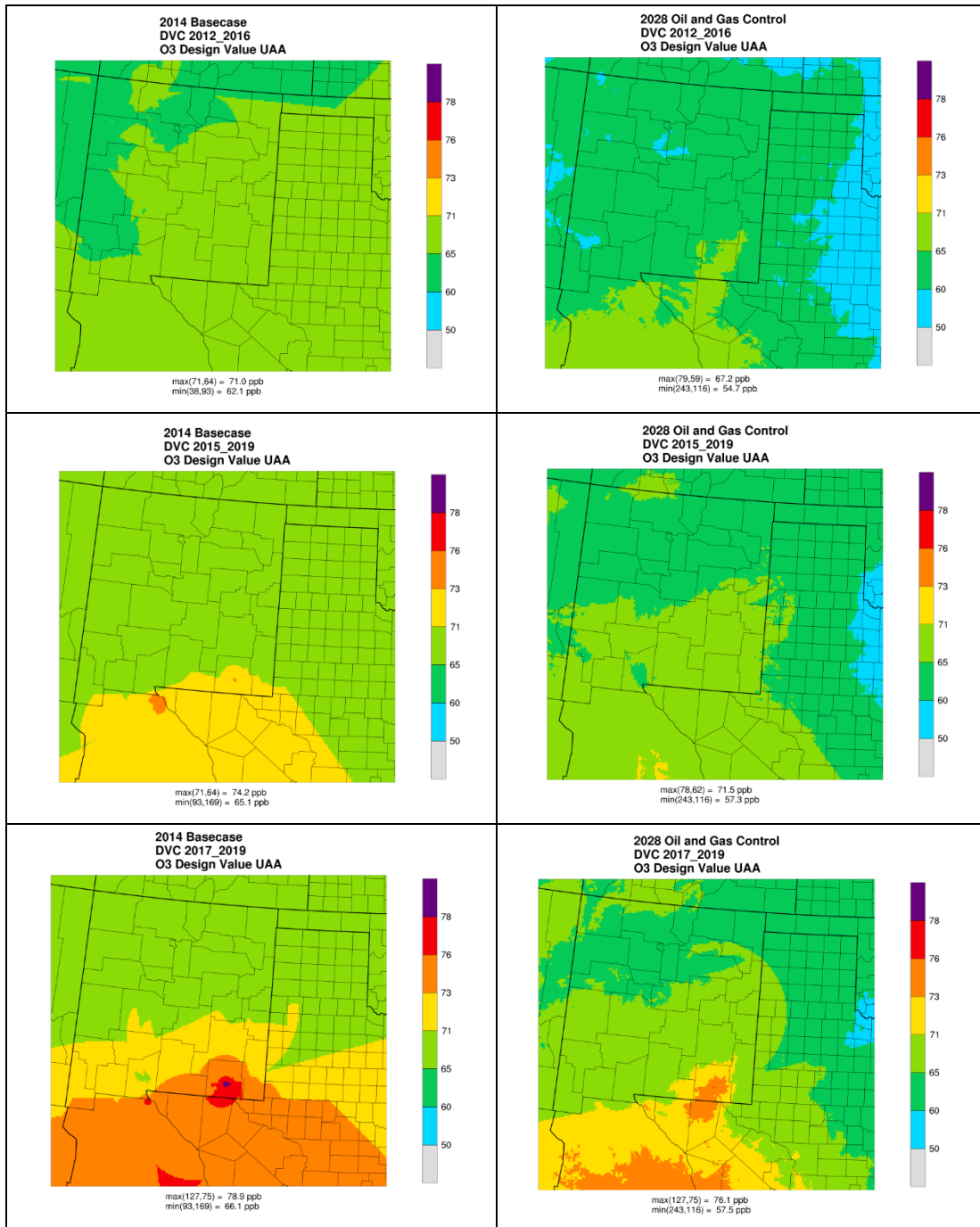


Figure 10-35. SMAT UAA ozone design values (ppb) for the current year ozone DVC (left) and projected 2028 ozone DVC for the 2028 O&G Control Strategy (right) using current year DVCs based on 2012-2016 (top), 2015-2019 (middle) and 2017-2019 (bottom) ozone design values.

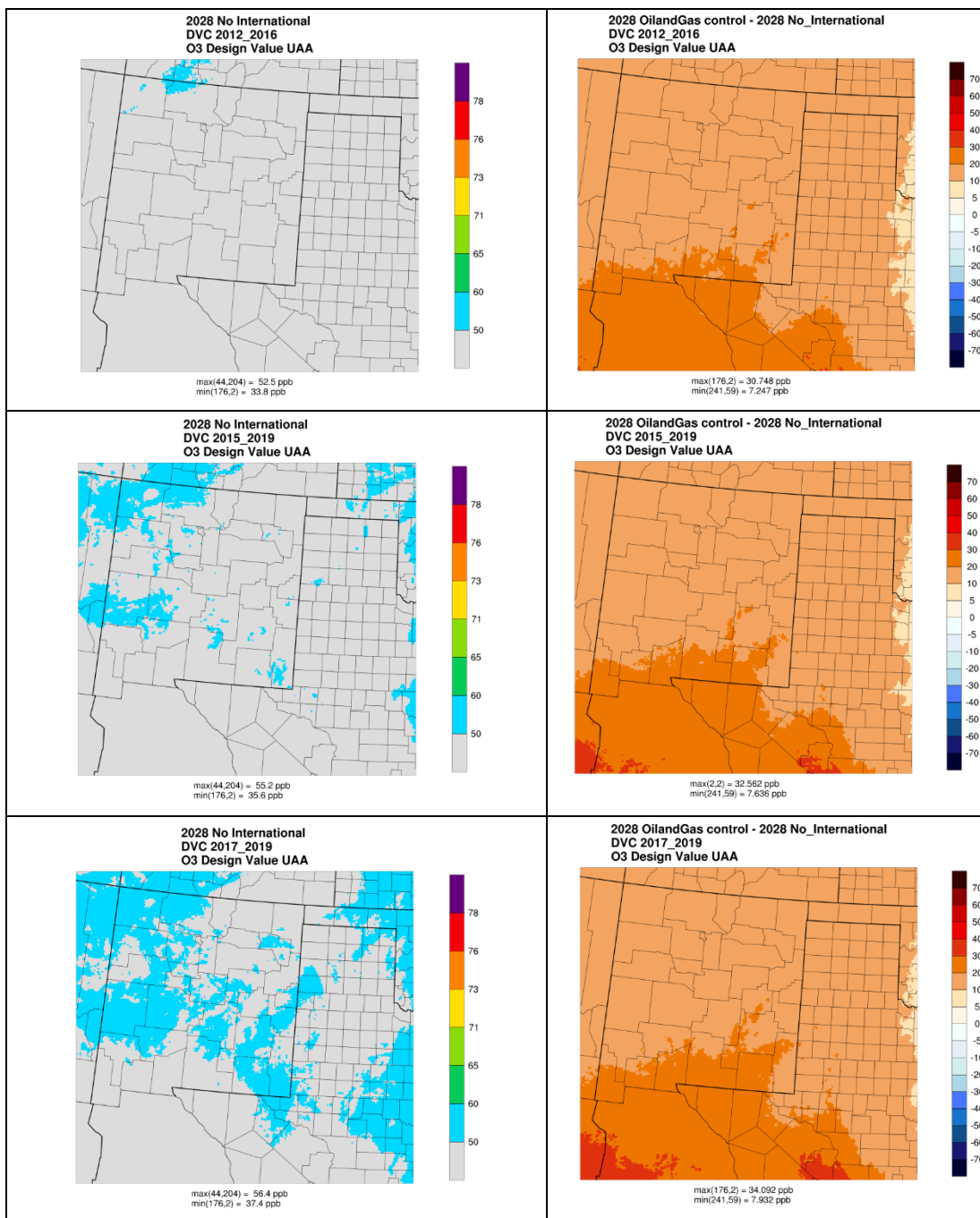


Figure 10-36. SMAT UAA ozone design values (ppb) for the projected 2028 ozone DVF from the 2028 No International Anthropogenic Emissions scenario (left) and differences in 2028 ozone DVFs between the 2028 No International Emissions and 2028 O&G Control Strategy scenarios (right) using current year DVCs based on 2012-2016 (top), 2015-2019 (middle) and 2017-2019 (bottom) ozone design values.

11. 2028 VOC AND NOX SENSITIVITY OSAT OZONE SOURCE APPORTIONMENT MODELING

A second CAMx 2028 ozone source apportionment model simulation was performed to estimate whether ozone formation that leads to elevated ozone concentrations in New Mexico occurs under conditions that are more sensitive to VOC or NO_x emissions. The VOC/NO_x emissions sensitivity ozone source apportionment simulation used the Ozone Source Apportionment Technology (OSAT) version of the CAMx ozone source apportionment tools. As discussed in Section 10.1, when using OSAT, the relative amounts of the O3V and O3N ozone source apportionment tracers provide an indication of whether ozone formation is more sensitive to VOC or NO_x emissions.

11.1 2028 OSAT Ozone Source Apportionment Design

The CAMx 2028 OSAT VOC/ NO_x sensitivity ozone source apportionment simulation used the 36/12/4-km nested domain structure, summer of 2014 meteorology and the 2028 O&G Control Strategy emissions scenario. The same five Source Regions as used in the 2028 Source Sector APCA ozone source apportionment simulation were used (See Figure 10-1):

1. New Mexico;
2. Texas;
3. Colorado;
4. Remainder U.S. states plus coastal water out to 200 nautical miles (nmi) of the U.S. coast; and
5. International, which include Mexico, Canada and waters off their coasts, plus waters more than 200 nmi off the U.S. coast.

Three Source Categories were specified in the 2028 OSAT ozone source apportionment modeling:

1. Anthropogenic emissions;
2. Fires; and
3. Natural emissions.

Fires include U.S. wildfires (WF), wildland prescribed burns (Rx) and agricultural burning (Ag), and other fires from Mexico and Canada. Natural emissions include biogenic, lightning NO_x (LNO_x), windblown dust (WBD) and oceanic (sea salt and DMS) sources.

With 5 Source Regions and 3 Source Categories, plus separate Source Groups for Initial Concentrations (IC) and Boundary Conditions (BC), that results in a total of 17 Source Groups for which separate ozone source contributions will be obtained in the 2028 OSAT ozone source apportionment modeling ($17 = 5 \times 3 + 2$).

11.2 Spatial Distribution of VOC/NO_x Ozone Formation Sensitivity

The sensitivity of ozone formation to VOC and NO_x emissions is obtained for each of the 15 emission Source Groups that consist of emissions from 3 source categories (i.e., anthropogenic, fires and natural) emitting from 5 Source Regions. The percent contribution of NO_x sensitive ozone formation metric is used to display the ozone formation sensitivity that is defined as follows:

$$\text{Percent NO}_x \text{ Sensitive Ozone (\%NO}_x\text{Sens)} = 100 \times \sum \text{O3N}_i / \sum (\text{O3V}_i + \text{O3N}_i)$$

Where the sum is performed over the 15 different emissions Source Groups (i) that consist of the three emission Source Categories emitting from the 5 Source Regions. The Percent VOC Sensitive Ozone will be 100 minus the Percent NO_x Sensitive Ozone metric.

Note that the O3V and O3N tracers for the IC and BC Source Groups are not used in the Percent NO_x Sensitive Ozone metric since they were defined from the 2014 simulation of the 2014 GEOS-Chem global chemistry model and the CAMx GEOS2CAMx processor arbitrarily assigns half of the GEOS-Chem total ozone to the O3V and O3N tracers each so do they not have accurate information on whether such IC/BC ozone concentrations are more VOC or NO_x sensitive.

Spatial displays of the Percent NO_x Sensitive Ozone metric were generated for Maximum Daily Average 8-hour (MDA8) ozone concentrations and several combinations of Source Groups for each day of the May-August 2014 modeling episode. When presenting the Percent NO_x Sensitive Ozone metric for a combination of Source Groups, it is also important to know the total MDA8 ozone due to the same combination of Source Groups in order to interpret the significance of the %NO_xSens metric; if the MDA8 ozone concentrations due to the combination of Source Groups is very small (e.g., < 0.01 ppb), whether the ozone formed was more sensitive to VOC or NO_x emissions is inconsequential. Spatial maps across the New Mexico 4-km modeling domains were generated for total MDA8 ozone and Percent NO_x Sensitive Ozone for the following combinations of Source Groups:

- All emissions based Source Groups (i.e., anthropogenic, fires and natural emissions emitted from the 5 Source Regions in the CAMx modeling domain).
- All anthropogenic emissions based Source Groups across the CAMx modeling domain.
- The New Mexico anthropogenic emissions Source Group.

The Percent NO_x Sensitive Ozone for the New Mexico anthropogenic emissions Source Group provides information on whether New Mexico VOC or NO_x emissions may be more important to ozone formation.

Figures 11-1 through 11-8 display the total MDA8 ozone and Percent NO_x Sensitive ozone metric for eight example days during the episode that tended to have relatively higher ozone concentrations and included the six example days displayed in previous Chapters.

11.2.1 Percent NO_x Sensitive Ozone on May 17, 2014

Figure 11-1 displays the 2028 OSAT source apportionment results for the May 17, 2014 day that was dominated by ozone concentrations from a fire in eastern Arizona that caused modeled elevated ozone concentrations in southwestern New Mexico. Figure 11-1a displays the MDA8 ozone concentrations from all Source Groups, including IC/BC, and is the modeled total MDA8 ozone on this day. The modeled peak MDA8 ozone on May 17th is 129 ppb and occurs within the fire ozone plume in eastern Arizona. The Percent NO_x Sensitive Ozone due to all emissions based source groups indicates ozone formation across the 4-km NM domain is more NO_x sensitive than VOC sensitive with the color scale going from green (%NO_xSens > 65%) to red/orange (%NO_xSens > 85%) (Figure 11-1b). Although, it is interesting to note that at the locations of the higher total MDA8 ozone concentrations, the amount of %NO_xSens ozone is less, with the lowest value (%NO_xSens = 64%) occurring at the same location as the peak modeled MDA8 ozone concentration in eastern Arizona.

Figure 11-1c and d show the MDA8 ozone and %NO_xSens metric for all anthropogenic emissions on May 17th, with the anthropogenic emissions %NO_xSens metric being mostly orange and red (%NO_xSens > 90%), indicating mostly NO_x sensitive ozone formation. There are areas of high MDA8 ozone due to anthropogenic emissions in west Texas (peak of 23 ppb) where %NO_xSens ozone is a little lower (80-90%), as well as a small area on the Colorado side of the San Juan Basin with lower %NO_xSens metric. Figure 11-1e and f show the MDA8 ozone and %NO_xSens metric for New Mexico anthropogenic emissions on May 17th. The highest contribution of New Mexico anthropogenic emissions to MDA8 ozone is 9 ppb and occurs in the Permian Basin with ozone formation being very NO_x sensitive (%NO_xSens > 85%). The lowest New Mexico NO_x sensitive ozone is in the San Juan Basin with a minimum value of 32%, indicating a VOC sensitive ozone formation value of 68% (Figure 11-1f). The New Mexico anthropogenic emissions ozone contribution in the San Juan Basin is less than 3 ppb (Figure 11-1e).

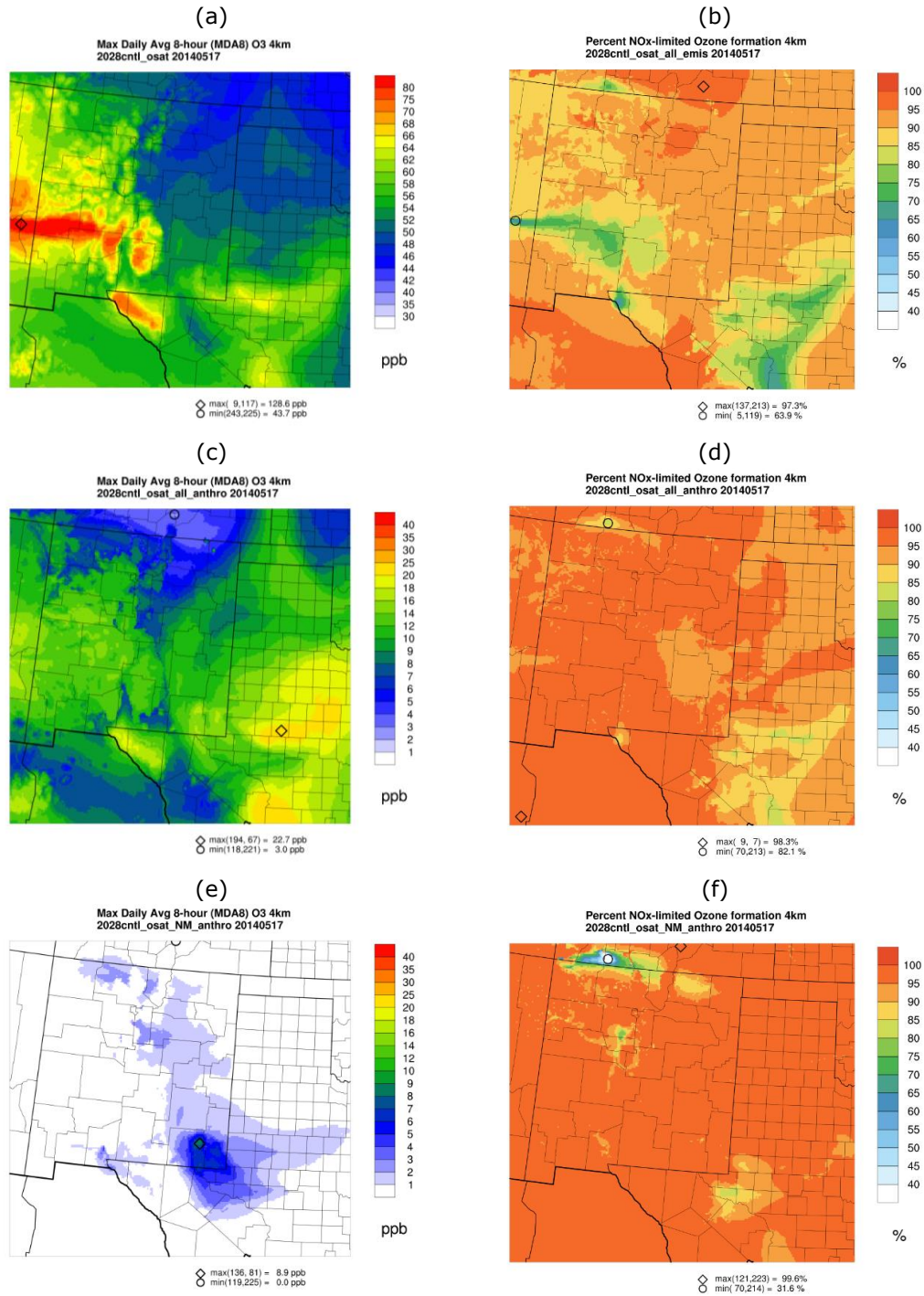


Figure 11-1. 2028 MDA8 ozone (left) and Percent NO_x Sensitive Ozone (right) on May 17, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO_xSens for all emissions; (d) %NO_xSens for all anthropogenic emissions; and (f) %NO_xSens for New Mexico anthropogenic emissions.

11.2.2 Percent NO_x Sensitive Ozone on May 26, 2014

On May 26th, the peak modeled MDA8 ozone concentrations is 58 ppb and occurs in San Juan County (Figure 11-2a). Ozone formation from all emissions is mostly NO_x sensitive across New Mexico (Figure 11-2b). Although the lowest %NO_xSens due to all emissions on May 26 (68%) occurs at the location of the peak MDA8 ozone in San Juan County. When looking at just anthropogenic emissions, the %NO_xSens ozone is mostly greater than 90% across most of New Mexico on May 26th with the exception of San Juan County and stretching south into McKinley County with a %NO_xSens minimum of 69% (Figure 11-2d) occurring at the same location as the modeled 58 ppb peak. The maximum MDA8 ozone due to New Mexico anthropogenic emissions on May 26th is 7 ppb and occurs at the same location as the 58 ppb total MDA8 ozone peak in San Juan County. Ozone formation due to New Mexico emissions at the location of this MDA8 ozone peak in San Juan County is split approximately equally between VOC and NO_x sensitive ozone formation (%NO_xSens = 45%; Figure 11-2f).

11.2.3 Percent NO_x Sensitive Ozone on May 28, 2014

May 28th has elevated ozone concentrations in southern New Mexico, including southern Doña Ana County and the Permian Basin, as well as within the Albuquerque urban plume (Figure 11-3a). Ozone formation across New Mexico due to anthropogenic emission tends to be mostly NO_x sensitive on May 28th with the lowest NO_x sensitive ozone of 73% occurring at almost the exact same location in southern Doña Ana County as the ozone peak (Figure 11-3b). When just looking at the sensitivity of anthropogenic emissions, the %NO_xSens value at the location of the peak in southern Doña Ana County increases from 73% to 81% (Figure 11-3d). Finally, the contributions of New Mexico anthropogenic emissions to the ozone peak in southern Doña Ana County is 2-4 ppb and is very NO_x sensitive (%NO_xSens > 90%) (Figure 11-3e and f). The highest MDA8 ozone due to New Mexico anthropogenic emissions on May 28th is 9 ppb in the Albuquerque urban plume where %NO_xSens is slightly lower than the surrounding areas (85-90%), with the lowest New Mexico anthropogenic emissions %NO_xSens being 75% in a high ozone area in the Permian Basin.

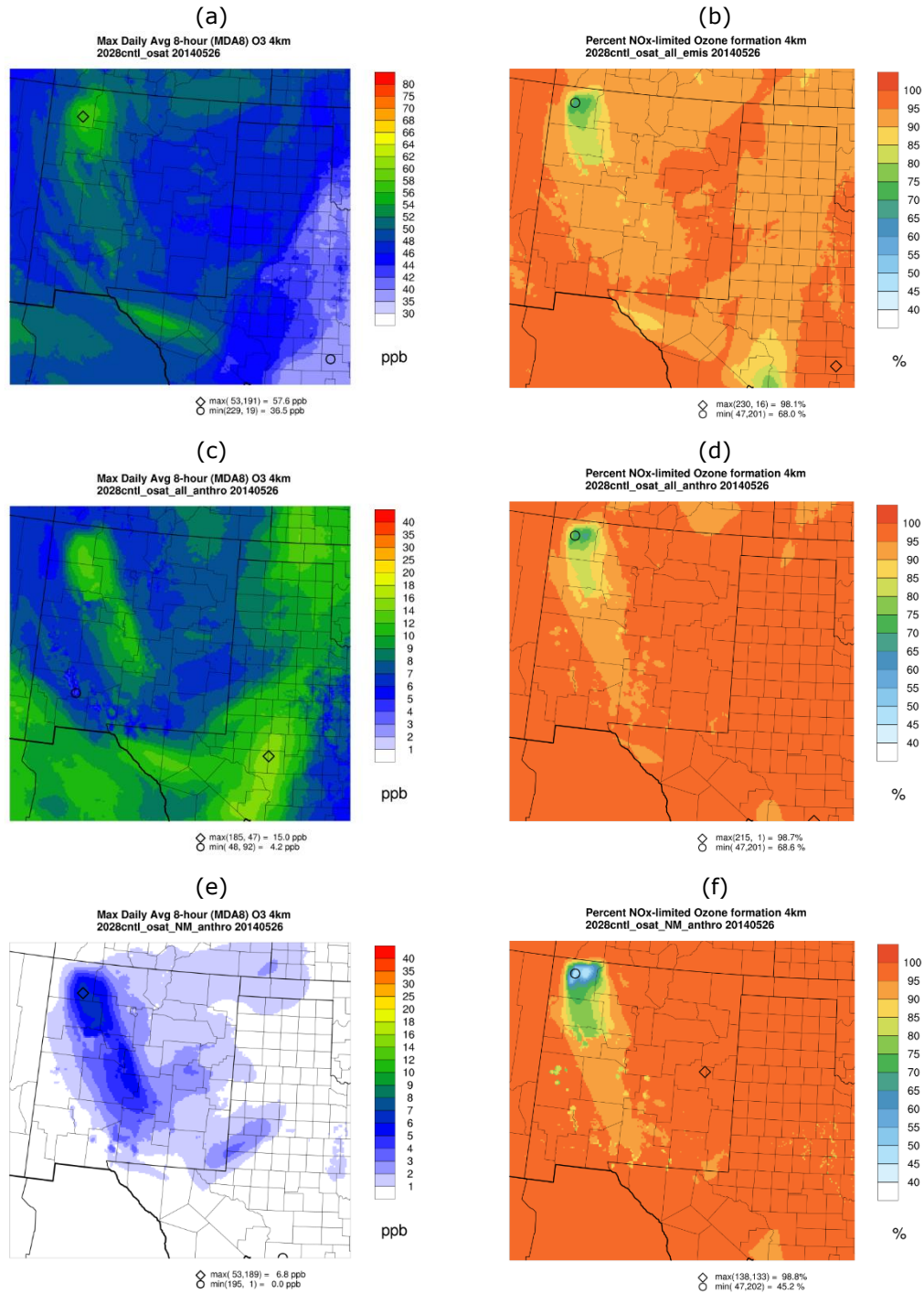


Figure 11-2. 2028 MDA8 ozone (left) and Percent NO_x Sensitive Ozone (right) on May 26, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO_xSens for all emissions; (d) %NO_xSens for all anthropogenic emissions; and (f) %NO_xSens for New Mexico anthropogenic emissions.

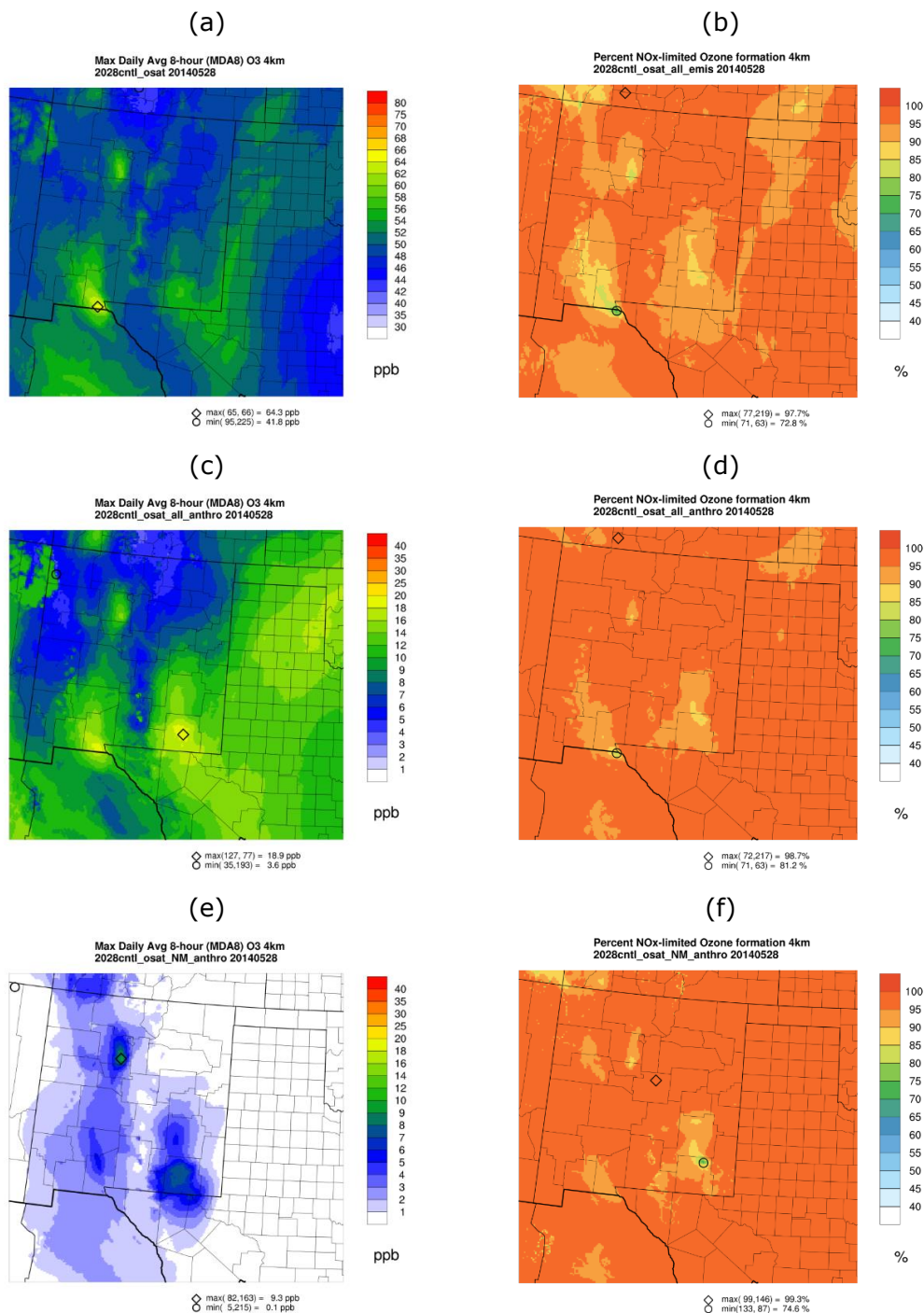


Figure 11-3. 2028 MDA8 ozone (left) and Percent NO_x Sensitive Ozone (right) on May 28, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO_xSens for all emissions; (d) %NO_xSens for all anthropogenic emissions; and (f) %NO_xSens for New Mexico anthropogenic emissions .

11.2.4 Percent NO_x Sensitive Ozone on June 5, 2014

CAMx estimates 2028 high MDA8 ozone concentrations in excess of the 70 ppb ozone NAAQS on June 5, 2014 in the San Juan Basin and El Paso (Figure 11-4a). In these high ozone locations, ozone formation is split approximately 50%/50% between VOC and NO_x sensitive ozone formation conditions (Figure 11-4b). When looking at just anthropogenic emissions, ozone formation tends to be more NO_x sensitive with %NO_xSens ranging from 60-85% in El Paso and 70-85% in San Juan Basin (Figure 11-4d). Ozone from New Mexico anthropogenic emissions is mainly NO_x sensitive in El Paso on June 5th, but in the San Juan Basin there is more VOC sensitive ozone formation with New Mexico anthropogenic emissions ozone contribution ranging from 1 to 4 ppb (Figure 11-4e and f). In particular, there are large areas of blue shaded %NO_xSens ozone in San Juan County due to New Mexico anthropogenic emissions that indicates that New Mexico VOC and NO_x anthropogenic emissions are equally important to ozone formation in San Juan County on this day. On the other hand, ozone formation within the Permian Basin appears to be more NO_x sensitive on June 5th.

11.2.5 Percent NO_x Sensitive Ozone on July 12, 2014

The total MDA8 ozone on July 12th has elevated ozone concentrations entering New Mexico from the south that appears to have originated in Mexico (Figure 11-5a). Ozone formation from anthropogenic emissions on this day is estimated to occur primarily under NO_x sensitive conditions (%NO_xSens of 86% to 100%; Figure 11-5d). Ozone formation from New Mexico anthropogenic emissions is primarily NO_x sensitive on July 12th with a relative larger amount of VOC sensitive ozone in the south where elevated ozone concentrations occur, but New Mexico's anthropogenic emissions ozone contribution is less than 1 ppb (Figure 11-5e and f).

11.2.6 Percent NO_x Sensitive Ozone on July 24, 2014

On July 24th, the peak MDA8 ozone in the 4-km domain is above the NAAQS (71.1 ppb) and occurs in San Juan County (Figure 11-6a). Although ozone formation is primarily NO_x sensitive across the 4-km NM domain, the largest VOC sensitive ozone due to all emissions (23% or %NO_xSens = 77%) occurs at the location of the peak ozone in San Juan County (Figure 11-6b). However, the amount of VOC sensitive ozone at this location due to anthropogenic emissions is 13% (Figure 11-6d), and less than that (~10%) for anthropogenic emission from New Mexico (Figure 11-6f).

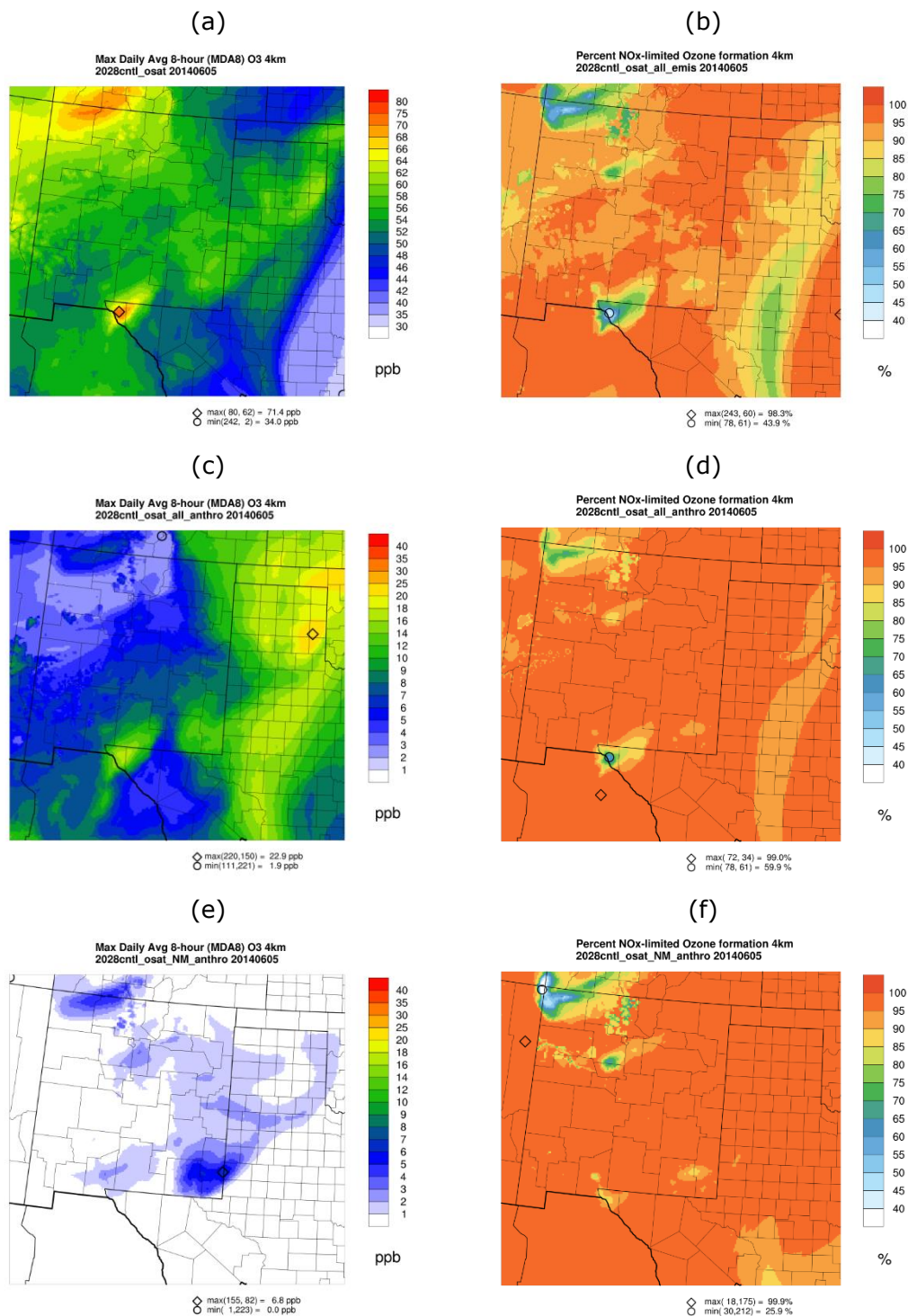


Figure 11-4. 2028 MDA8 ozone (left) and Percent NO_x Sensitive Ozone (right) on June 5, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO_xSens for all emissions; (d) %NO_xSens for all anthropogenic emissions; and (f) %NO_xSens for New Mexico anthropogenic emissions .

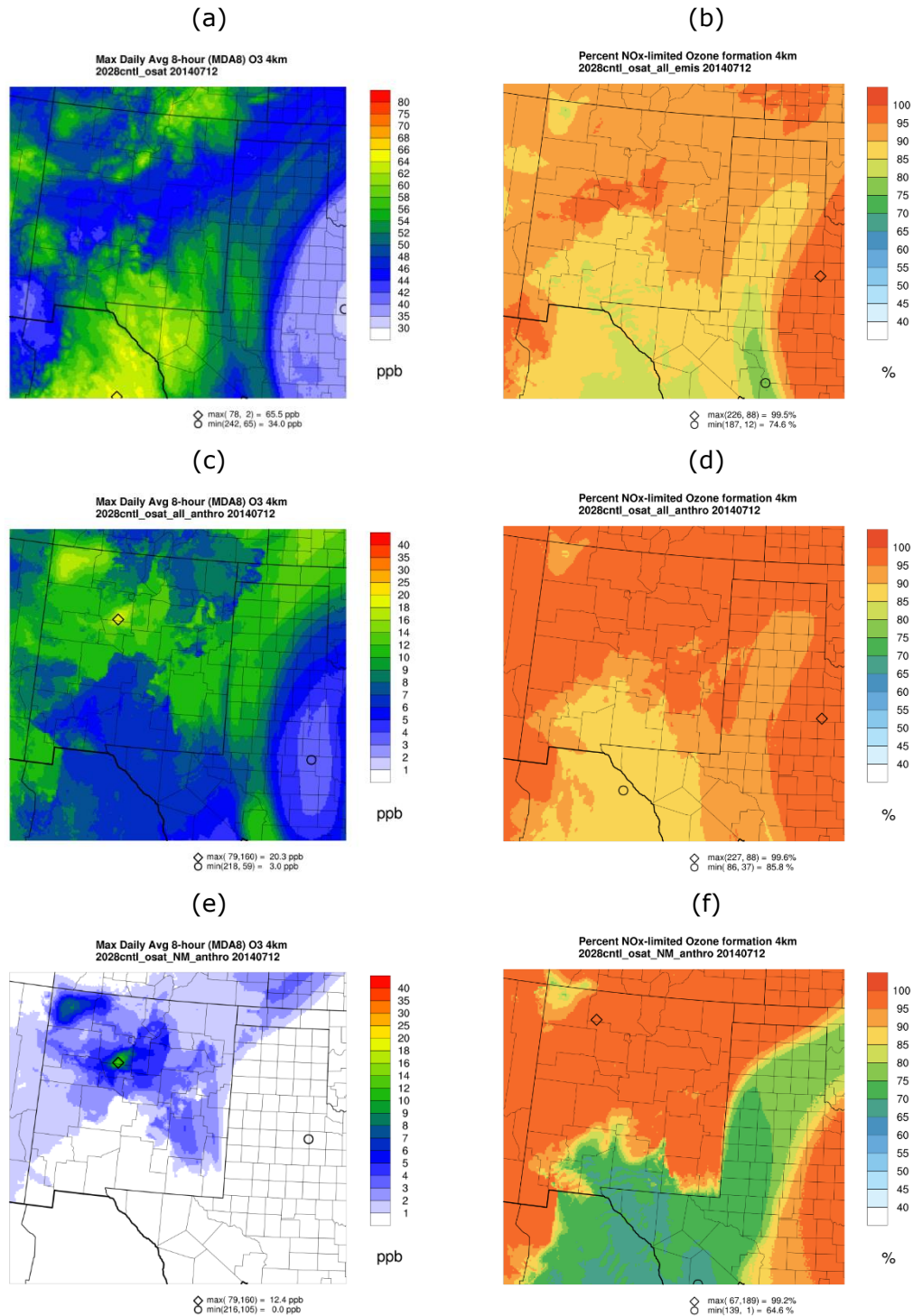


Figure 11-5. 2028 MDA8 ozone (left) and Percent NO_x Sensitive Ozone (right) on July 12, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO_xSens for all emissions; (d) %NO_xSens for all anthropogenic emissions; and (f) %NO_xSens for New Mexico anthropogenic emissions.

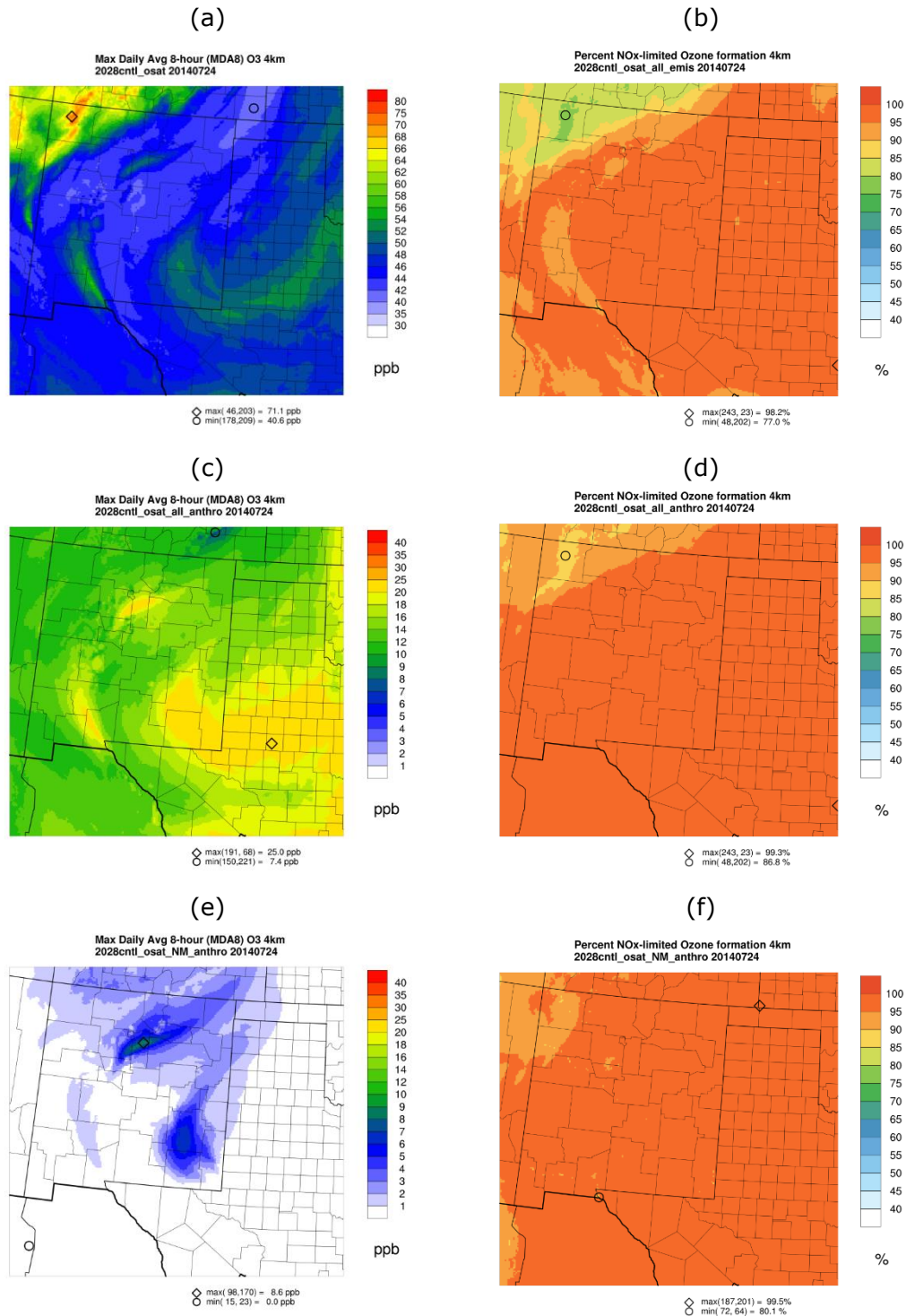


Figure 11-6. 2028 MDA8 ozone (left) and Percent NO_x Sensitive Ozone (right) on July 24, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO_xSens for all emissions; (d) %NO_xSens for all anthropogenic emissions; and (f) %NO_xSens for New Mexico anthropogenic emissions.

11.2.7 Percent NO_x Sensitive Ozone on July 26, 2014

Modeled elevated MDA8 ozone concentrations occur in northern New Mexico on July 26th with a maximum value above the NAAQS (72 ppb) in northeast Cibola County, west of Albuquerque (Figure 11-7a). Ozone formation is primarily NO_x sensitive across northern New Mexico on this day (%NO_xSens > 85%) with the lowest NO_x sensitivity occurring at the location of the 72 ppb ozone peak in Cibola County (78%; Figure 11-7b). However, the NO_x sensitive ozone formation due to anthropogenic emissions at this location is 88% (Figure 11-7d) with a similar value estimated for anthropogenic emission from New Mexico (Figure 11-7f). New Mexico anthropogenic emissions contribute a significant amount (14 ppb) of the 72 ppb ozone peak in northeast Cibola County (Figure 11-7e). Ozone formation due to New Mexico anthropogenic emissions in the San Juan Basin is more VOC sensitive than the rest of New Mexico on July 26th.

11.2.8 Percent NO_x Sensitive Ozone on August 14, 2014

On August 14th there is modeled elevated MDA8 ozone concentrations in northern Rio Arriba County in the San Juan Basin as well as in southern New Mexico with a peak MDA8 ozone in the 4-km domain of 71.2 ppb in El Paso (Figure 11-8a). Although ozone formation is primarily (85-95%) NO_x sensitive across New Mexico on this day, at the locations of the highest MDA8 ozone concentrations, there is relatively more VOC sensitive ozone formation (Figure 11-8b). At the location of the 71.2 ppb ozone peak in El Paso, the CAMx OSAT simulation estimates that ozone formation due to anthropogenic emissions is ~75% NO_x sensitive and ~25% VOC sensitive. Anthropogenic emissions from New Mexico contribute approximately 1 ppb to the ozone peak in El Paso that is primarily formed under NO_x sensitive conditions (Figure 11-8e and f).

11.2.9 Percent NO_x Sensitive Ozone due to New Mexico Anthropogenic Emissions

Figure 11-9 displays the spatial distribution of the Percent NO_x Sensitive Ozone metric due to New Mexico anthropogenic emissions for 15 example days from the May-August 2014 modeling episode, including the 8 days discussed above. As expected, given its mostly rural nature, the CAMx OSAT simulations estimates that ozone formation due to New Mexico anthropogenic emissions is primarily NO_x sensitive. However, there are several locations where ozone formation is estimated to have relatively higher VOC sensitive ozone formation conditions. The San Juan Basin consistently has higher VOC sensitive ozone formation conditions due to New Mexico anthropogenic emissions. Albuquerque also has higher VOC sensitive ozone formation conditions due to New Mexico anthropogenic emissions, and occasionally, ozone formation in the Permian Basin also has relatively higher VOC sensitive ozone formation. As discussed above, the highest MDA8 ozone conditions also have relatively higher VOC sensitive ozone formation conditions. For example, at the location of the relatively high (58 ppb) MDA8 ozone in San Juan County on May 26th the fraction of VOC sensitive ozone is 32% for all emissions, 31% for all anthropogenic emissions and 55% for New Mexico anthropogenic emissions (Figure 11-2). On May 28th the high ozone (64 ppb) in southern Dona Ana County on the border with Texas has a Percent VOC Sensitive Ozone of 27% for all emissions and 19% for all anthropogenic emissions with New Mexico anthropogenic emissions having Percent VOC

Sensitive Ozone for a secondary peak in the Permian Basin of 25% (Figure 11-3). June 5th is a day where there is high MDA8 ozone in the San Juan and Rio Arriba Counties that is approaching the NAAQS that is split approximately equally between VOC and NO_x sensitive ozone (Figure 11-4). On August 14th the modeled ozone peak exceeds the ozone NAAQS in El Paso and ~30% of the ozone was formed under VOC sensitive conditions (Figure 11-8).

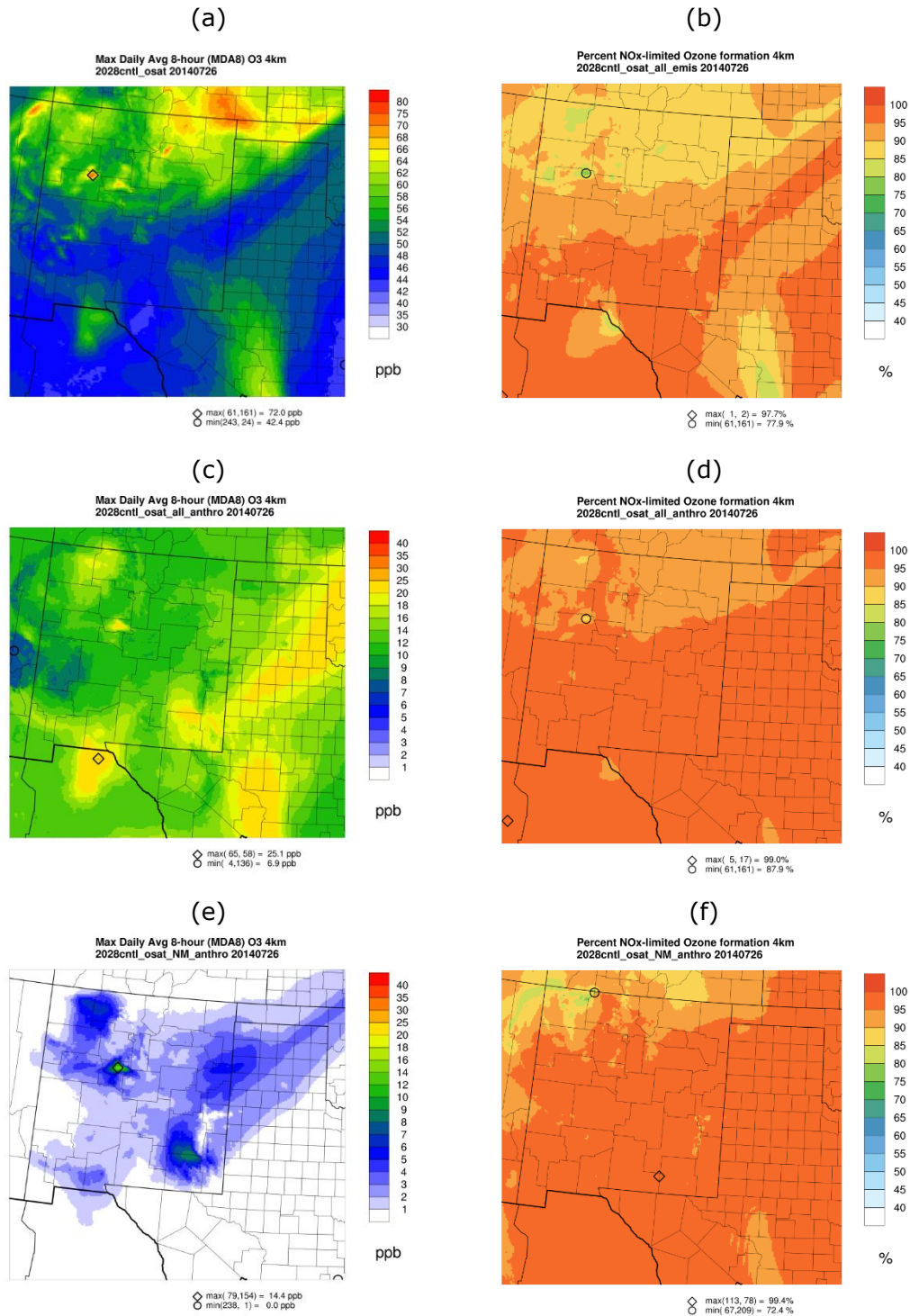


Figure 11-7. 2028 MDA8 ozone (left) and Percent NO_x Sensitive Ozone (right) on July 26, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO_xSens for all emissions; (d) %NO_xSens for all anthropogenic emissions; and (f) %NO_xSens for New Mexico anthropogenic emissions.

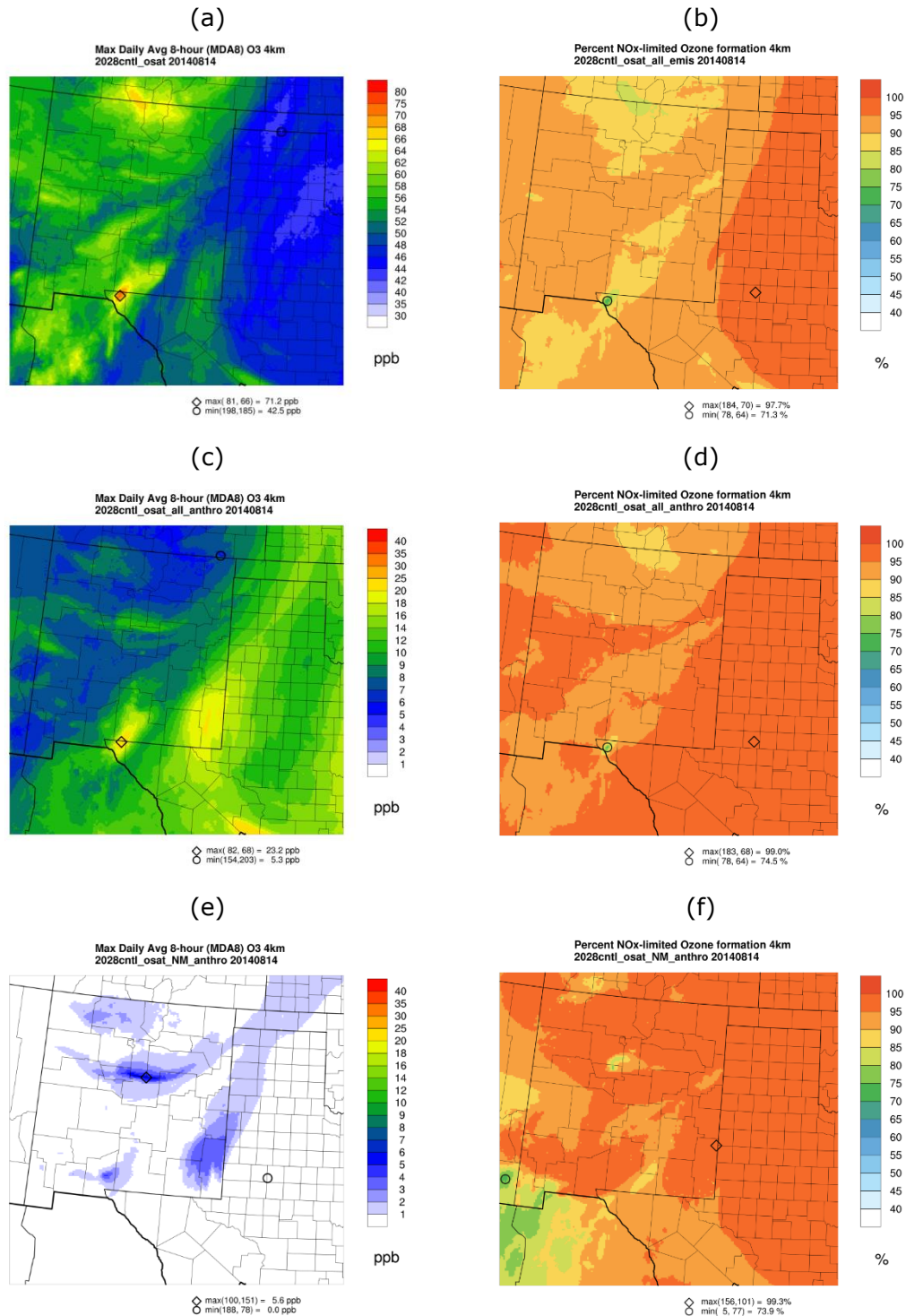


Figure 11-8. 2028 MDA8 ozone (left) and Percent NO_x Sensitive Ozone (right) on August 14, 2014 for: (a) total MDA8 ozone; (c) ozone due to anthropogenic emissions; (e) ozone due to New Mexico anthropogenic emissions; (b) %NO_xSens for all emissions; (d) %NO_xSens for all anthropogenic emissions; and (f) %NO_xSens for New Mexico anthropogenic emissions.

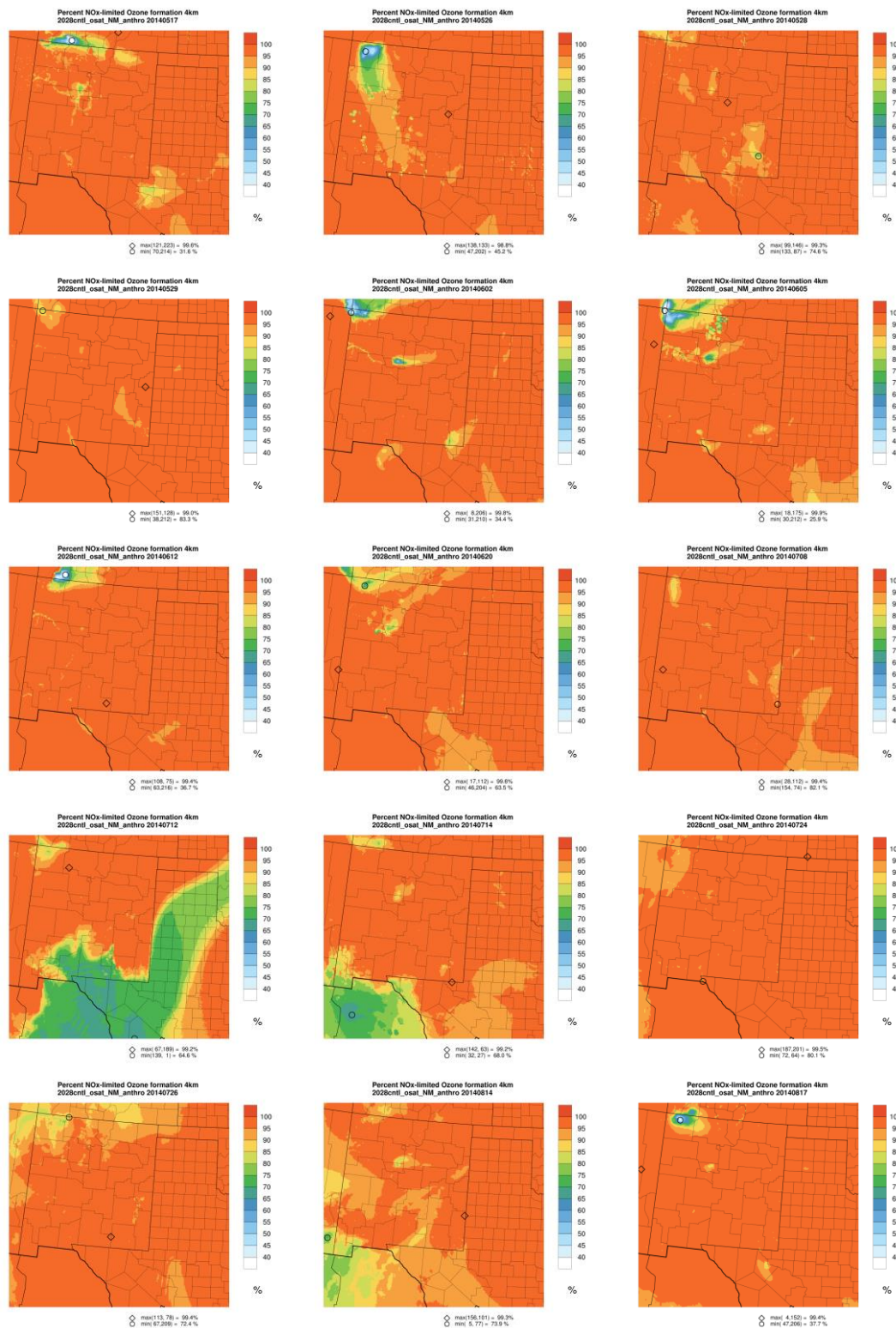


Figure 11-9. Spatial distribution of Percent NO_x Sensitive Ozone due to New Mexico anthropogenic emissions across the 4-km New Mexico domain for 15 days of relatively higher MDA8 ozone concentrations.

11.3 Analysis of VOC/NO_x Ozone Formation Sensitivity at Monitoring Sites in New Mexico

The CAMx 2028 OSAT ozone source apportionment results were extracted at the locations of the New Mexico monitoring sites and loaded into an Excel Dashboard where the source apportionment contributions to daily MDA8 ozone concentrations can be visualized. The Dashboard displays the OSAT source apportionment O3V and O3N results for groups of 10 days and the average across the 10 days for different combinations of the 3 Source Categories and 5 Source regions within the CAMx modeling domain, with examples for several monitoring sites discussed below.

11.3.1 VOC/NO_x Sensitivity at Substation in San Juan County

Figure 11-10 displays the CAMx OSAT results at the Substation site in San Juan County using daily stacked bar charts of O3V and O3N for the 10 days used by SMAT to make the 2028 ozone DVF projections, along with a pie chart of the O3V and O3N results averaged across the 10 SMAT days. The Dashboard can also display results for the highest and second highest 10 modeled MDA8 ozone concentration days from the CAMx 2028 O&G Control Strategy simulation. As discussed in Chapter 7, the 10 SMAT days are selected as the 10 days with the highest modeled MDA8 ozone near the monitor in the CAMx 2014v2 Base Case, so there is a lot of overlap in days between the 10 SMAT days and the 10 highest modeled 2028 MDA8 ozone days.

The displays in Figure 11-10 use warmer colors (e.g., red) for the NO_x sensitive ozone O3N and cooler colors (e.g., blue) for the VOC sensitive ozone O3V. Emissions within the CAMx domain contribute from 6 to 36 ppb to the total MDA8 ozone across the 10 SMAT days at Substation, with a vast majority of the ozone formed being NO_x sensitive, whose daily variation ranges from approximately 70% to 90% of the SMAT 10 days daily MDA8 ozone concentrations due to emissions (Figure 11-10, top). Averaged across the 10 SMAT days, the total MDA8 ozone at Substation is 63.7 ppb with 67% of that due to BCs and the rest (21.1 ppb) due to in-domain emissions, of which 81% is NO_x sensitive and 19% is VOC sensitive (Figure 11-10, bottom). Since Figure 11-10 is for all emissions sources, the region-specific stacked bars and pie slices display the contributions of anthropogenic, fire and natural emissions from all of the Source Regions.

The Dashboard can be used to isolate the amount of VOC and NO_x sensitive ozone from the different Source Categories and Regions used in the CAMx OSAT simulation with two example pie charts averaged across the 10 SMAT days at Substation shown in Figure 11-11. The top pie chart in Figure 11-11 shows ozone contributions averaged across the 10 SMAT days for all anthropogenic emissions and all Source Regions. All emissions in the domain contributed 21.1 ppb to the average of the 10 SMAT days at Substation of which 11.4 is due to the anthropogenic emissions (Figure 11-11, top) so the remainder (9.7 ppb) is due to natural and fire emissions. Of the 11.4 ppb all anthropogenic emissions ozone contribution, 91% was formed under NO_x sensitive and 9% was formed under VOC sensitive conditions. The bottom pie chart in Figure 11-11 shows the contributions to the average of the 10 SMAT days at Substation due to anthropogenic emissions from New Mexico and shows that New Mexico is

contributing 42% of the anthropogenic emissions contribution (4.7 of 11.4 ppb) at Substation with most of that (87%) being NO_x sensitive ozone.

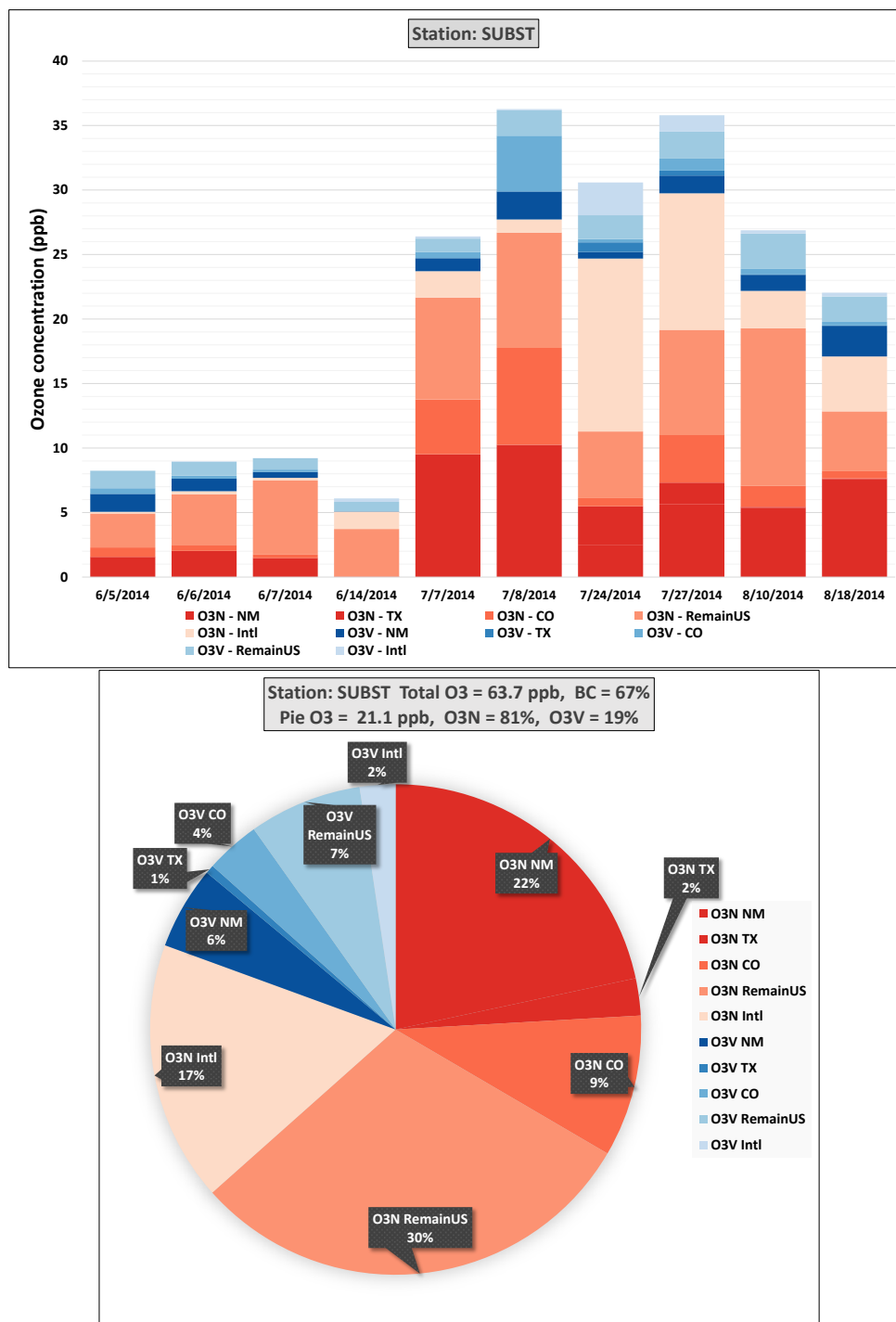


Figure 11-10. Bar Chart of daily O3V (blue) and O3N (red) contributions across the 10 days used by SMAT and pie chart of ozone contributions averaged across the 10 SMAT days for all Source Categories and Source Regions and the Substation monitor in San Juan County.

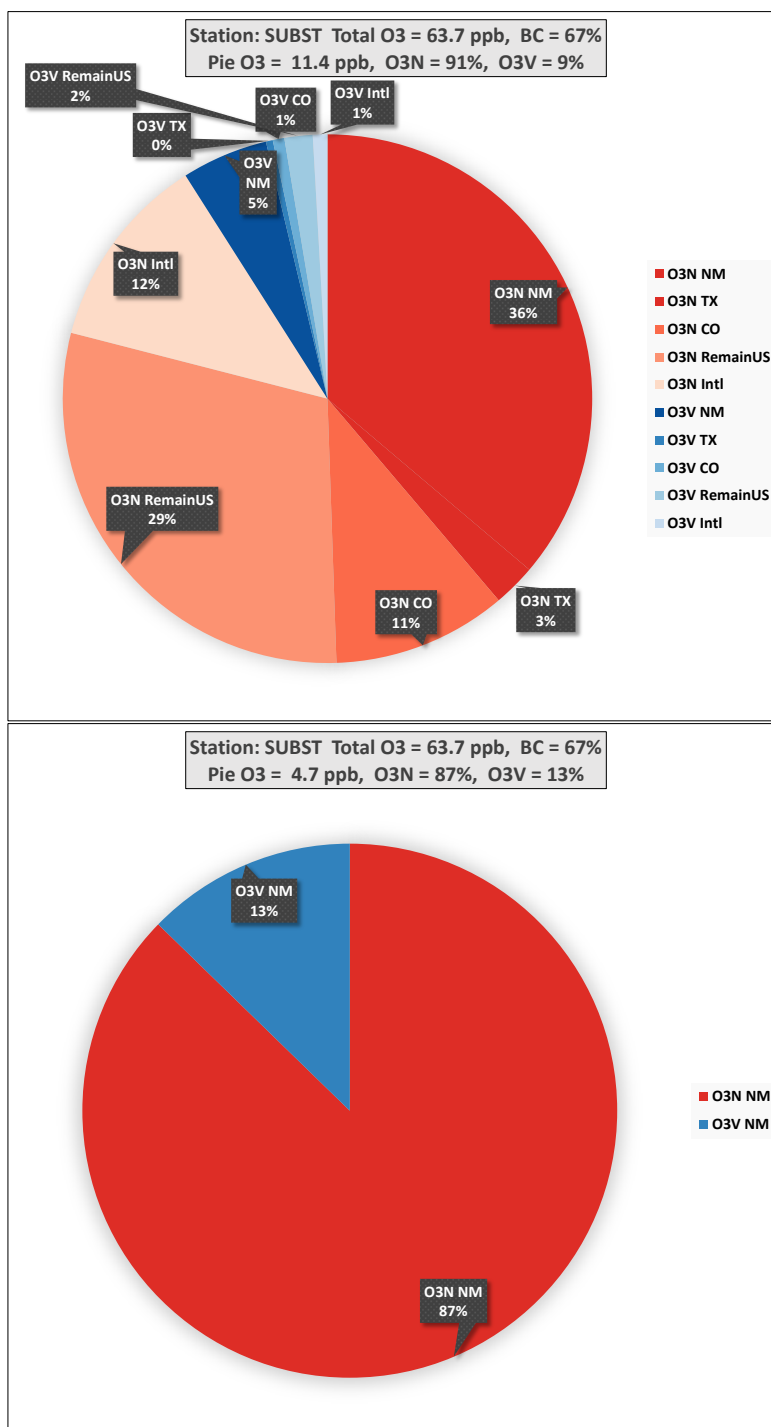


Figure 11-11. O3V and O3N contributions averaged across the 10 SMAT days at Substation for all anthropogenic emissions (top) and New Mexico anthropogenic emissions (bottom).

11.3.2 VOC/NO_x Sensitivity at South East Heights in Bernalillo County

The CAMx OSAT source apportionment results for the 10 SMAT days and all sources at the South East Heights monitoring in Bernalillo County are shown in Figure 11-12. There is a lot of day-to-day variability across the 10 SMAT days with in-domain emissions estimated to contribute from 10 to 40 ppb, with the remainder of the ozone coming from the BCs. On the two lowest in-domain emissions ozone days (June 7 and 8 with 10 and 11 ppb ozone from in-domain emissions), the ozone is almost completely (> 90%) NO_x sensitive, whereas on other days the VOC sensitive ozone can exceed 20% (e.g., August 29). This daily variation in VOC and NO_x sensitivity in Bernalillo County was also seen in the spatial maps (e.g., Figure 11-9). Averaged across the 10 SMAT days at South East Heights, in-domain emission sources contribute 25.4 ppb, of which 87% is NO_x sensitive ozone with the O3N from New Mexico (30%), remainder U.S. (26%) and international (25%) being the highest contributors.

A vast majority (93%) of the 14.5 ppb anthropogenic emissions ozone contribution at South East Heights was formed under NO_x sensitive conditions (Figure 11-12, top) with over half of that coming from New Mexico (7.4 ppb) that was also primarily (92%) NO_x sensitive ozone (Figure 11-13, bottom).

11.3.3 VOC/NO_x Sensitivity at Desert View in Doña Ana County

The CAMx OSAT results for the Desert View monitoring site in Doña Ana County are shown in Figures 11-14 and 11-15. Ozone from Texas and Mexico contributes greatly to ozone levels at Desert View. This includes ozone from El Paso that can have a higher fraction of VOC sensitive ozone (e.g., see Figure 11-4) that is seen on some days in the daily bar charts in Figure 11-14 (e.g., July 24, 2014). Emissions within the CAMx domain contribute 24 to 46 ppb of the daily MDA8 ozone on the 10 SMAT days at Desert View with 14 to 28 ppb of that being anthropogenic in origin. Across all emissions, the average of the 10 SMAT days is 81% NO_x sensitive, with the anthropogenic component of ozone being much more NO_x sensitive (90%) than the natural/fire component (69%). New Mexico anthropogenic emissions contribute 2 ppb (10%; Figure 11-15, bottom) of the 20.9 ppb anthropogenic ozone (Figure 11-15, top) at Desert View with emissions from Mexico contributing approximately half (10.6 ppb) and Texas (3.9 ppb), almost 20%.

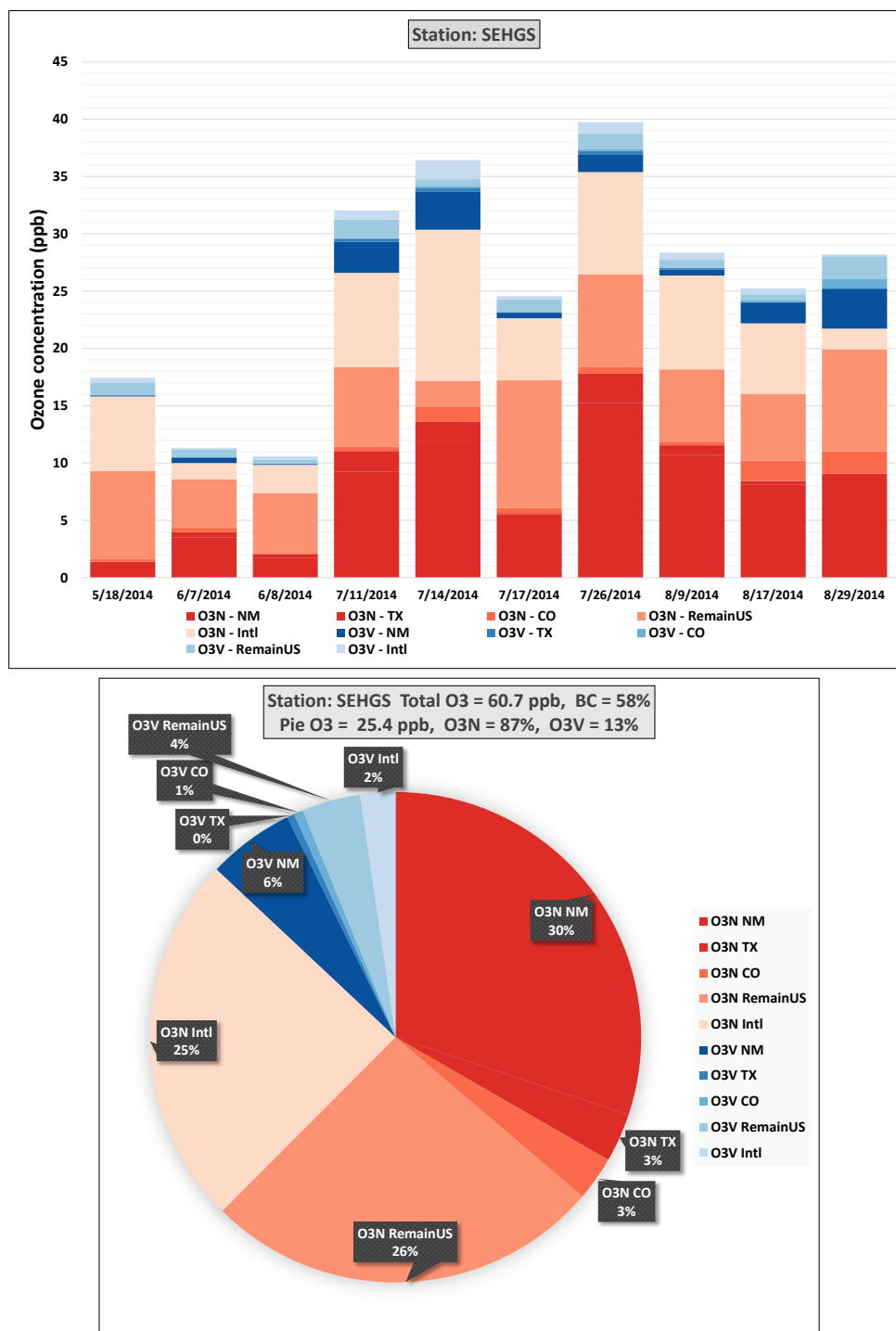


Figure 11-12. Bar Chart of daily O3V (blue) and O3N (red) contributions across the 10 days used by SMAT and pie chart of ozone contributions averaged across the 10 SMAT days for all Source Categories and Source Regions and the South East Heights monitor in Bernalillo County.

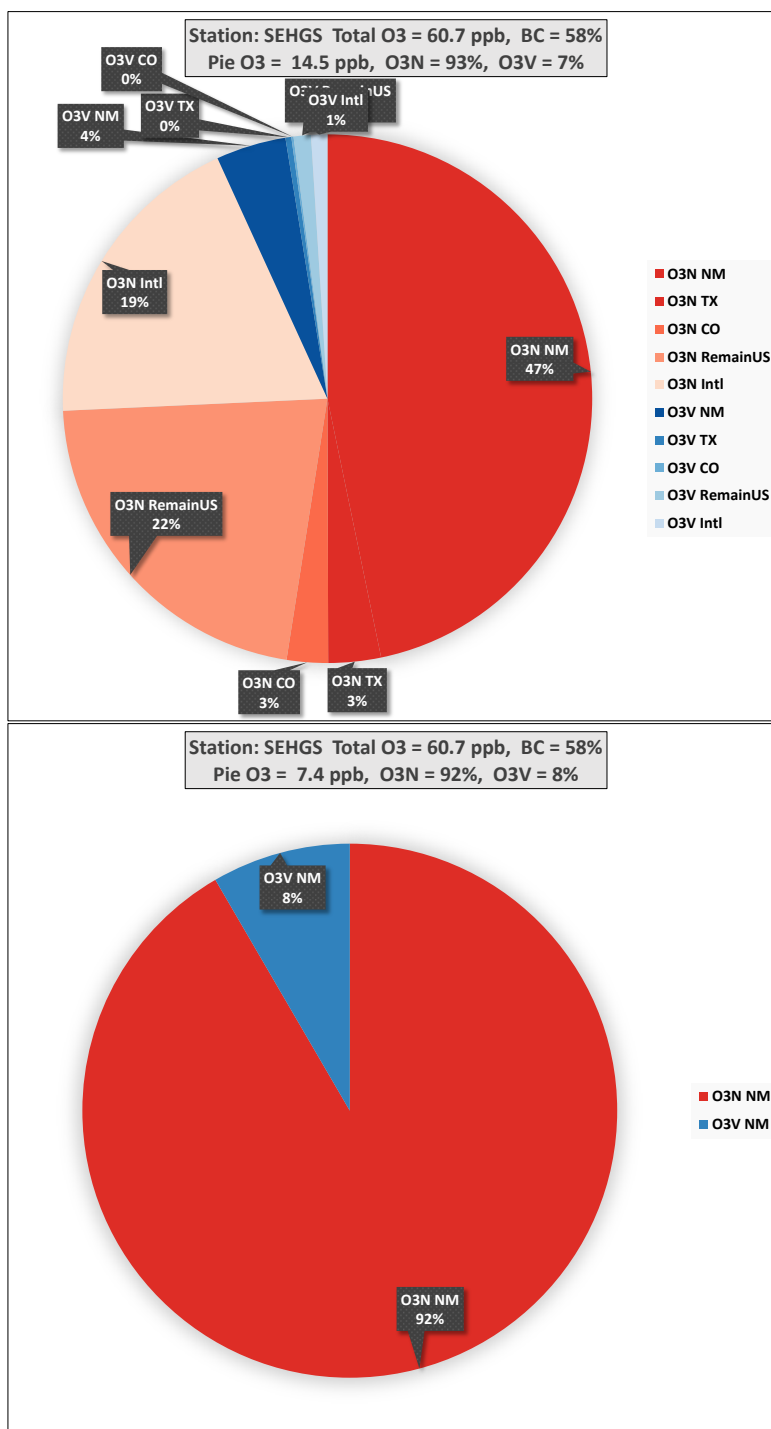


Figure 11-13. O3V and O3N contributions averaged across the 10 SMAT days at South East Heights monitoring site for all anthropogenic emissions (top) and New Mexico anthropogenic emissions (bottom).

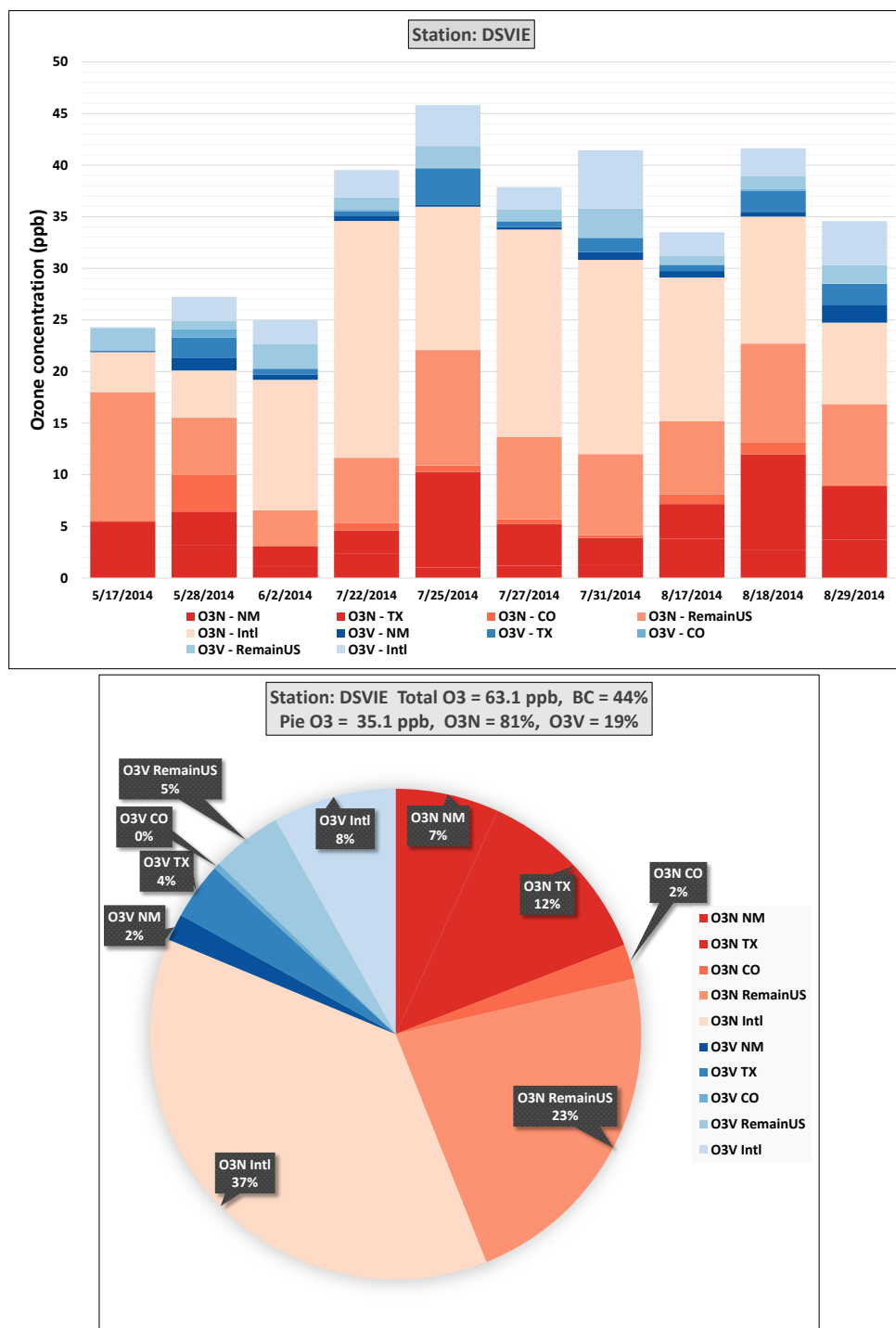


Figure 11-14. Bar Chart of daily O3V (blue) and O3N (red) contributions across the 10 days used by SMAT and pie chart of ozone contributions averaged across the 10 SMAT days for all Source Categories and Source Regions and the Desert View monitor in Doña Ana County.

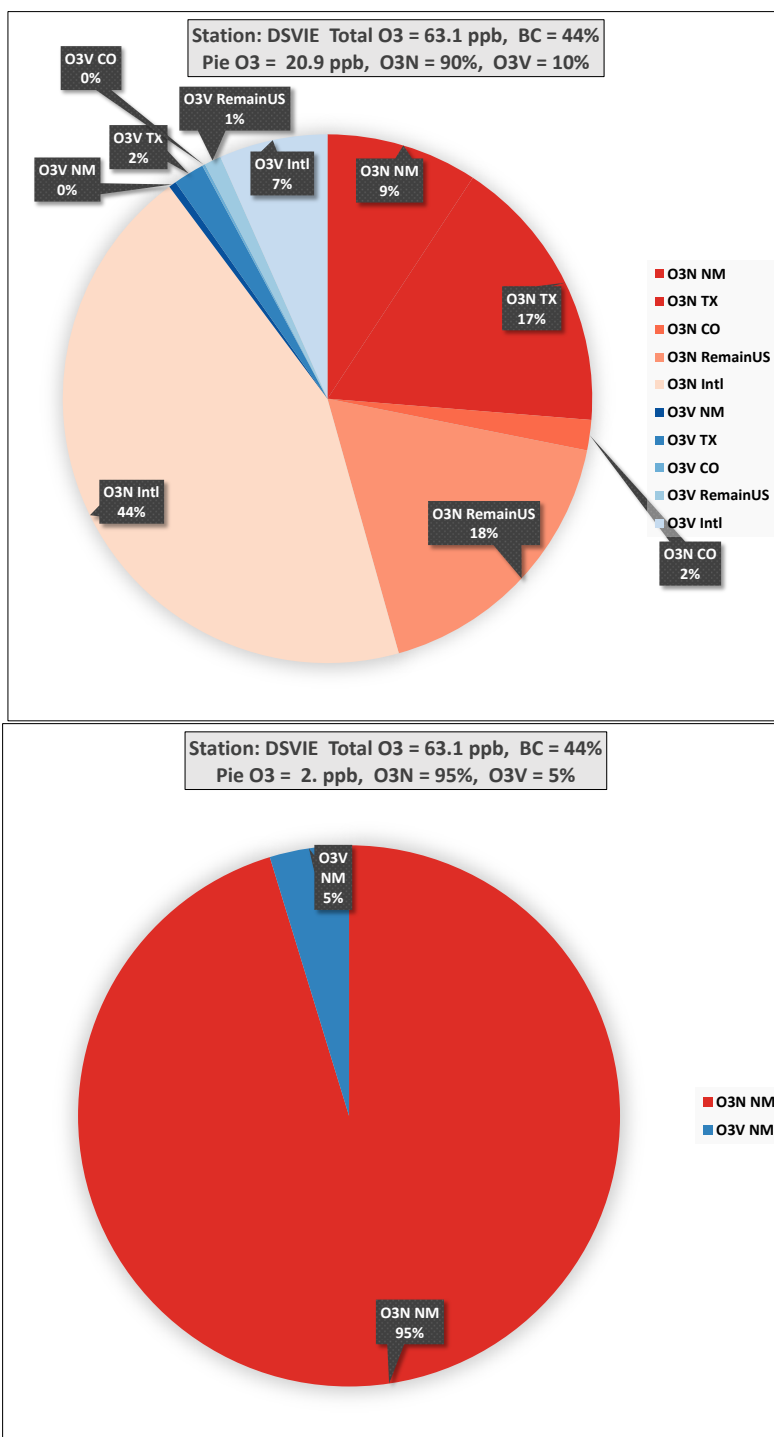


Figure 11-15. O3V and O3N contributions averaged across the 10 SMAT days at Desert View monitoring site for all anthropogenic emissions (top) and New Mexico anthropogenic emissions (bottom).

11.3.4 VOC/NO_x Sensitivity at Carlsbad in Eddy County

Figures 11-16 and 11-17 display the CAMx 2028 OSAT results at the Carlsbad monitor in Eddy County. Across the 10 SMAT days, emissions within the CAMx domain account for 11 to 27 ppb of the daily ozone at Carlsbad (Figure 11-16, top). The model estimates more NO_x sensitive ozone at Carlsbad (91% on average) than Desert View (81% on average). The ozone due to emissions averaged across the 10 SMAT days at Carlsbad is 19.1 ppb that is approximately equally split between anthropogenic (10.0 ppb) and natural/fire (9.1 ppb) sources, with the ozone from the anthropogenic emissions (94%) being more NO_x sensitive than the ozone from the natural/fire emissions (87%). Of the 10 ppb from anthropogenic emissions, almost half (4.7 ppb) is from international emissions with anthropogenic emissions from New Mexico and Texas both contributing 16% (1.6 ppb) each (Figure 11-17).

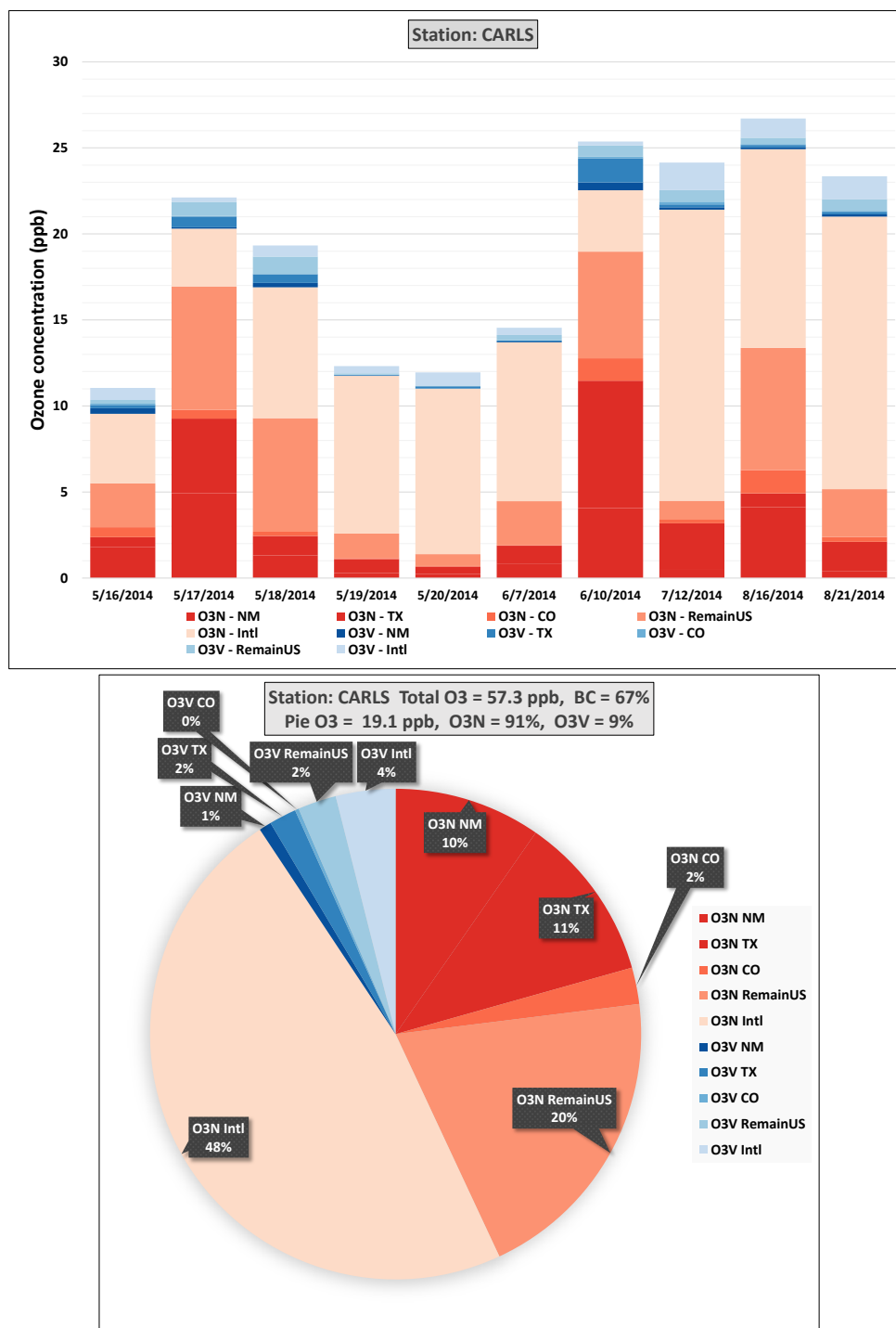


Figure 11-16. Bar Chart of daily O3V (blue) and O3N (red) contributions across the 10 days used by SMAT and pie chart of ozone contributions averaged across the 10 SMAT days for all Source Categories and Source Regions and the Carlsbad monitor in Eddy County.

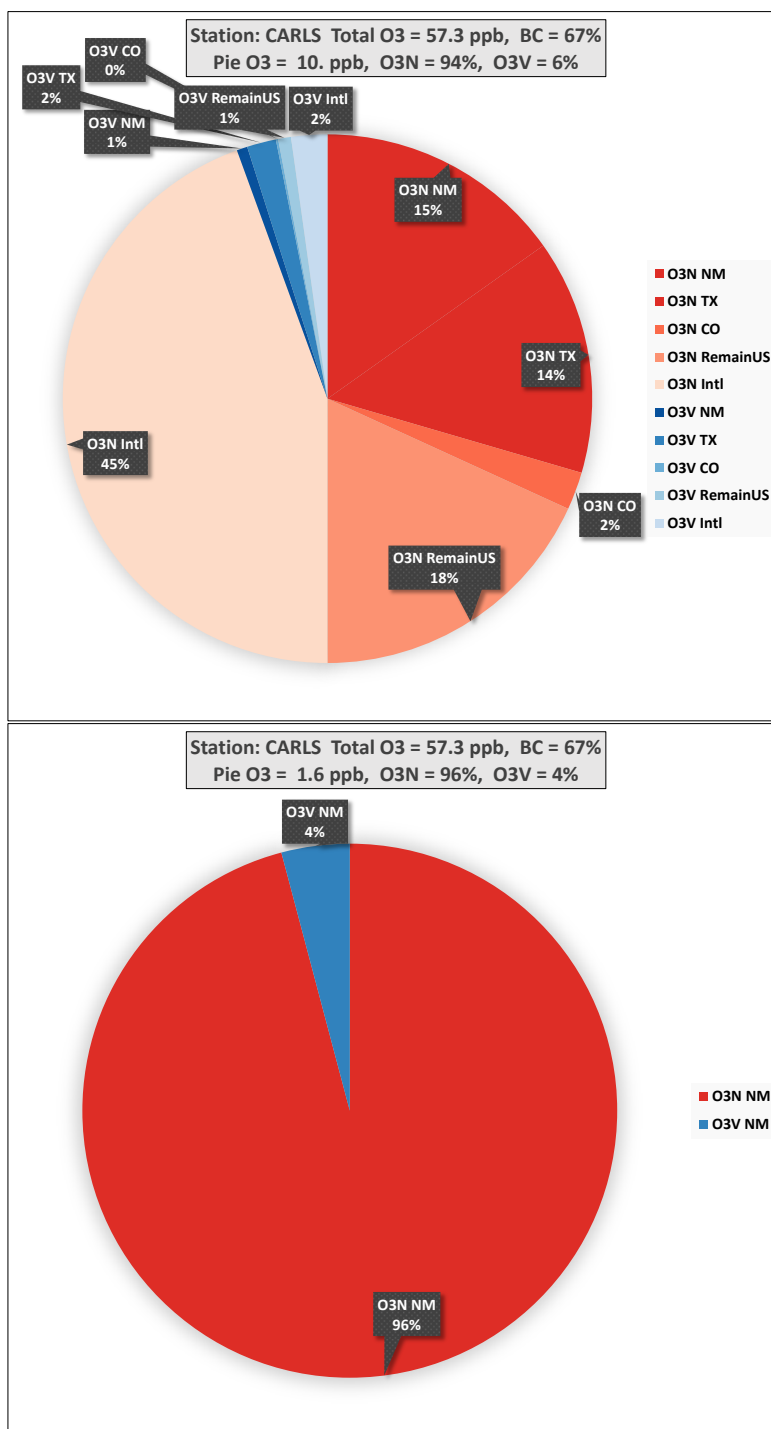


Figure 11-17. O3V and O3N contributions averaged across the 10 SMAT days at Carlsbad monitoring site for all anthropogenic emissions (top) and New Mexico anthropogenic emissions (bottom).

12. SUMMARY AND CONCLUSIONS

12.1 Summary of CAMx 2014 36/12/4-km Photochemical Model Platform Development

A CAMx 2014 36/12/4-km ozone modeling platform was developed with the 4-km domain focused on New Mexico and adjacent states. The CAMx 2014 36/12/4-km modeling platform was based on the Western Regional Air Partnership (WRAP), Western Air Quality Study (WAQS) CAMx 2014 36/12-km modeling platform. WRF meteorological modeling was conducted to generate CAMx meteorological inputs for the 36/12/4-km domains and summer of 2014. A model performance evaluation was conducted that compared CAMx 2014 estimated ozone concentrations with concurrent ozone observations that produced good ozone model performance. A revised CAMx 2014v2 base case was conducted with a newer version of the CAMx model and updated biogenic emissions that also produced very good ozone model performance.

SMOKE emission and CAMx ozone modeling was conducted for a 2014v2 Base Case, a 2028 Base Case and a 2028 O&G Control Strategy that implemented O&G controls on O&G sources in the New Mexico portions of the San Juan and Permian Basins. The proposed New Mexico O&G ozone precursor rule controls were implemented in the 2028 Base Case NM O&G emissions by Eastern Research Group (ERG) under separate contract with NMED.

12.2 Summary of 2028 Ozone Modeling Results and Ozone Design Value Projections

2028 projected future year ozone design values (DVF) were made using the CAMx 2014v2, 2028 Base Case and 2028 O&G Control Strategy modeling results following EPA's latest photochemical modeling guidance (EPA, 2018). EPA's modeling guidance recommends scaling the current year design value (DVC) using a Relative Response Factor (RRF) based on the ratio of the future to current year modeling results (i.e., $RRF = \text{CAMx Ozone}_{2028} / \text{CAMx Ozone}_{2014}$). The guidance recommends using a DVC based on an average of three ozone design values centered on the base modeling year, which in this case is 2014, so design values from 2012-2016 are used (i.e., $DVC_{2012-2016}$). Following EPA's ozone projection approach guidance, all 2028 projected ozone DVFs were below the 2015 ozone NAAQS at all monitoring sites in New Mexico using the $DVC_{2012-2016}$ observed ozone starting point for the projections.

A comparison of the CAMx absolute modeled daily MDA8 ozone concentrations for the 2028 Base Case and 2028 O&G Control Strategy found that the strategy resulted in MDA8 ozone reductions over large areas of New Mexico, with the largest ozone reductions occurring in the San Juan and Permian Basins. However, there were also isolated areas of ozone increases due to the 2028 O&G Control Strategy that usually occurred in or near the San Juan and Permian Basins that are likely due to "NO_x Disbenefits" where NO_x emission reductions can cause localized ozone increases. For at least one day (June 5, 2014) that CAMx 2028 Base Case had a large area with MDA8 ozone concentrations that exceeded the 70 ppb ozone NAAQS in San Juan County, the 2028 O&G Control Strategy was sufficient to reduce the MDA8 ozone concentrations to below the NAAQS. On

another day (July 24, 2014), the “NO_x Disbenefits” of the 2028 O&G Control Strategy was sufficient to increase the MDA8 ozone concentrations in one 4-km grid cell in San Juan County that was below the NAAQS in the 2028 Base Case to right at the threshold for exceeding the NAAQS (71.0 ppb) in the 2028 O&G Control Strategy.

12.3 Sensitivity of 2028 Ozone Design Value Projections to Current Year Ozone Design Value

Given the upward trend in ozone design values in southern New Mexico in recent years (see Table 1-1), the sensitivity of the 2028 future year ozone DVF projections to the current year ozone design value (DVC) was investigated by making 2028 ozone DVF projections using current year design values based on observations from 2015-2019 (i.e., DVC₂₀₁₅₋₂₀₁₉) and 2017-2019 (i.e., DV₂₀₁₇₋₂₀₁₉) instead of the DVC₂₀₁₂₋₂₀₁₆ current year design value recommended in EPA’s ozone modeling guidance (EPA, 2018).

There were four monitoring sites with DVC₂₀₁₅₋₂₀₁₉ exceeding the 70 ppb ozone NAAQS, compared to two using the DVC₂₀₁₂₋₂₀₁₆. The Carlsbad site projected 2028 ozone DVF (71.2 ppb) still exceeded the ozone NAAQS for the 2028 Base Case when the DVC₂₀₁₅₋₂₀₁₉ current year design value was used in the projection. However, the emission reductions in the 2028 O&G Control Strategy were sufficient to bring the projected 2028 ozone DVF at the Carlsbad site (70.9 ppb) to below the ozone NAAQS in the DVC₂₀₁₅₋₂₀₁₉ current year design value sensitivity analysis.

Three monitors exceeded the 70 ppb ozone NAAQS using the most recent ozone design value (DV₂₀₁₇₋₂₀₁₉), but one of the sites that had their DVC₂₀₁₅₋₂₀₁₉ exceeding the NAAQS was no longer in operation in 2017-2019 (i.e., Carlsbad Caverns NP). Two of the sites were still estimated to have projected 2028 ozone DVFs that exceeded the ozone NAAQS for both the 2028 Base Case and 2028 O&G Control Strategy in the DV₂₀₁₇₋₂₀₁₉ current year DVC sensitivity analysis. Under the 2028 O&G Control Strategy, the projected 2028 ozone DVFs at Carlsbad and Desert View were, respectively, 76.0 and 71.4 ppb using the DV₂₀₁₇₋₂₀₁₉ as the current year DVC in the ozone projections.

There were significant increases in O&G emissions within the Permian Basin since 2014 that are not accounted for in the CAMx ozone modeling results in the DVC₂₀₁₅₋₂₀₁₉ and DV₂₀₁₇₋₂₀₁₉ current year design value sensitivity tests. If those additional O&G emissions were included in the CAMx base year base case simulations, the projected 2028 ozone DVFs would be lower in the vicinity of the Permian Basin because of the higher denominator in the RRF projections factors due to higher O&G emissions than occurred in 2014.

EPA recommends using the average of three years of design values for the DVC as it is more stable and has less year-to-year variability than a single design value period (EPA, 2018, pp. 101⁴²). So, the 2028 ozone DVFs projection sensitivity test using the DV₂₀₁₇₋₂₀₁₉ has an additional caveat as it is less stable and more influenced by year-to-year variability in ozone concentrations.

⁴² https://www.epa.gov/sites/production/files/2020-10/documents/o3-pm-rh-modeling_guidance-2018.pdf

12.4 2028 Source Sector APCA Ozone Source Apportionment Modeling

The 2028 O&G Control Strategy Source Sector APCA ozone source apportionment modeling found that approximately half to two-thirds of the ozone on high MDA8 ozone days in New Mexico is due to Boundary Conditions (BCs) that are mainly from international and natural emissions from outside of the CAMx 36-km North America modeling domain. The highest contributing New Mexico Source Sector varied by location. For sites in San Juan County in northwestern New Mexico, EGU and O&G Non-Point sources were the two highest contributing Source Sectors followed by O&G Point sources. For sites in Bernalillo County in the central part of New Mexico, Other Anthropogenic, On-Road and Non-Road were the highest contributing Source Sectors. In Doña Ana County in southern New Mexico, New Mexico EGU and On-Road were the highest contribution Source Sectors. O&G Non-Point and Point sources were the highest contributing New Mexico Source Sectors at the Carlsbad and Hobbs sites in southeastern New Mexico. Texas and Mexico had large contributions to ozone in southern New Mexico, whereas Colorado had large contributions in northwestern New Mexico.

International anthropogenic emissions contributed 13 to 26 ppb to the projected 2028 ozone DVFs at New Mexico sites, with larger international contributions at the southern New Mexico sites. The elimination of the contributions of international anthropogenic emissions reduced the projected 2028 ozone DVFs to below 60 ppb under all scenarios, even when the DVC₂₀₁₇₋₂₀₁₉ was used that produced a projected 2028 ozone DVF at Carlsbad that exceeded both the 2008 and 2015 ozone NAAQS.

12.5 2028 VOC/NO_x Sensitivity OSAT Ozone Source Apportionment Modeling

The 2028 VOC/NO_x Sensitivity OSAT ozone source apportionment simulation found that ozone formation across New Mexico was primarily NO_x sensitive. There were some areas that had relatively higher VOC sensitive ozone formation conditions on some days, including the San Juan Basin, Albuquerque, the Texas part of El Paso, and to a lesser extent, the Permian Basin. There are even days (e.g., June 5th) where elevated MDA8 ozone concentrations in San Juan Basin that approached the ozone NAAQS and ozone formation was approximately evenly split between NO_x and VOC sensitive ozone formation conditions. But overall, ozone formation was more NO_x sensitive than VOC sensitive. The highest modeled ozone concentrations tend to have relatively higher VOC sensitive ozone concentrations. Thus, although ozone formation appears to be mainly NO_x sensitive, VOC controls will also have benefits in reducing some of the highest ozone concentrations in New Mexico.

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New Mexico OAI Study Photochemical Modeling – 1st Monthly Webinar May 2020



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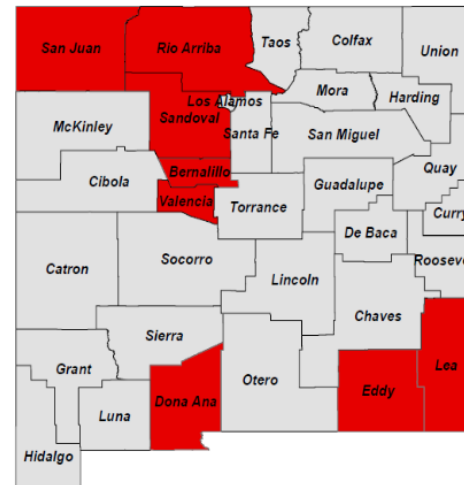
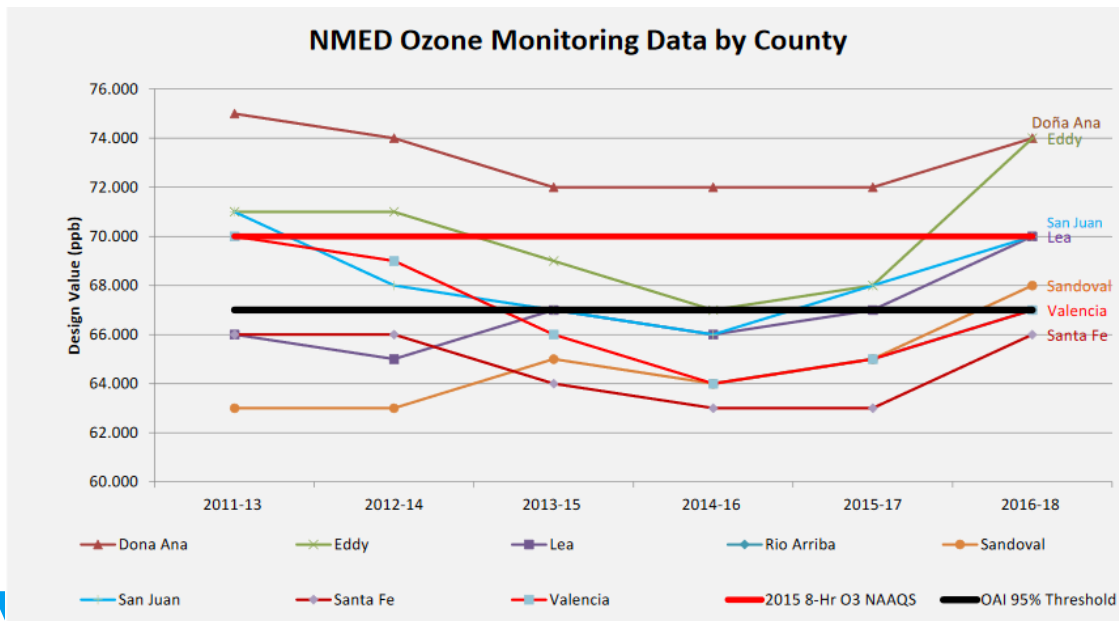
May 28, 2020

Content

- Introduction
- Work Plan
- Evaluation of Existing 2014 WRF and Proposed NM OAI Study WRF Configuration
- Evaluation of 2014 Boundary Conditions (BCs) from WRAP 2014 GEOS-Chem
- Modeling Protocol Overview
- 2014 and 2023 Emissions for New Mexico
- 2014 and 2023 Mobile Source Assumptions and Activity Data for New Mexico
- Next Steps

Introduction

- 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)
- There are 8 counties in New Mexico with measured ozone concentrations within 95% of the 70 ppb 2015 ozone NAAQS
- NMED contracted with WESTAR/Ramboll to conduct 2014 and 2023 photochemical modeling to assess the contributions of sources to and effects of control measures on ozone concentrations

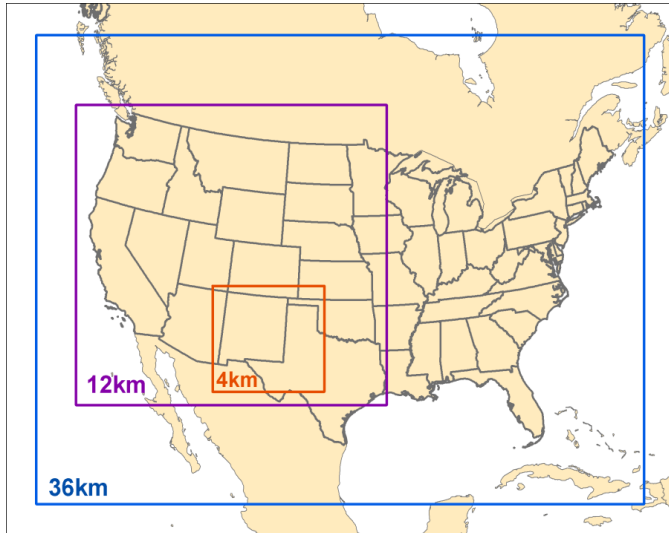


*Parallel planning is occurring for Bernalillo County through the Albuquerque/Bernalillo County Department of Environmental Health

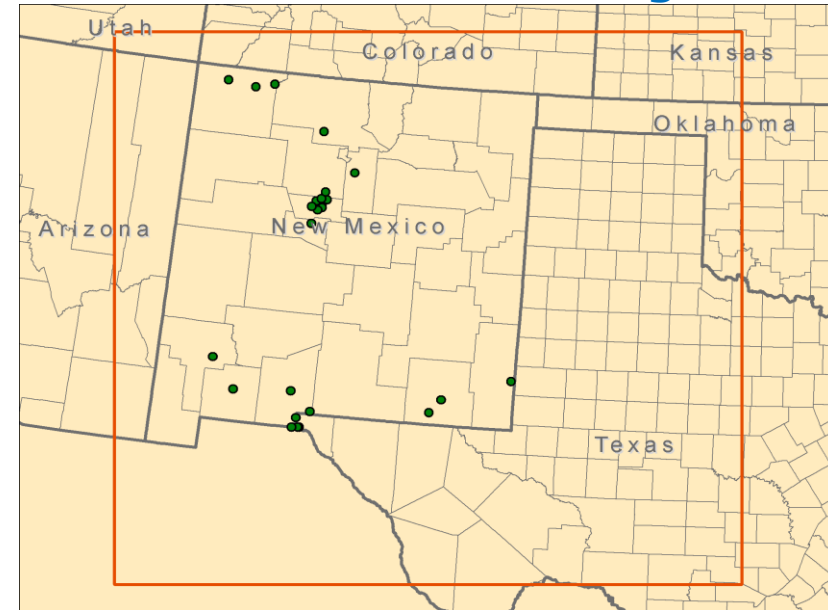
Work Plan (1 of 2)

- Task 1: Development Modeling Protocol/QAPP and Work Plan
 - Modeling Plan provides a roadmap on how the study will be carried, including episode, domain and model selection and current and future year modeling approaches

36/12/4-km Domain Structure



New Mexico 4-km Modeling Domain



- Task 2: WRF Meteorological Modeling
 - Develop CAMx meteorological inputs for May-Aug 2014 and 36/12/4-km domains
- Task 3: Evaluate Boundary Condition Inputs
 - Based on WRAP 2014 GEOS-Chem global chemistry model

Work Plan (2 of 2)

- Task 4: 2014 and 2023 Emissions Development
 - Sources of 2014 and 2023 Emissions
 - Mobile Source Emissions
 - Natural Emissions
 - SMOKE Emissions Modeling
 - 2023 Emission Control Measures
- Task 5: CAMx 2014 Base Case Modeling
 - Model Performance Evaluation
 - Formal 2016 Base Case Modeling and MPE Report on Tasks 2-5
- Task 6: 2023 Future Year CAMx Modeling
 - 2023 Base Case and Future Year Ozone Design Value Projections
 - 2023 Ozone Source Apportionment Modeling
 - 2023 Control Measure Evaluation
- Task 7: Air Quality Technical Support Document (AQTSD)
 - Prepare formal AQTSD documenting the study
 - Transfer Modeling Databases and Results to Intermountain West Data Warehouse (IWDW)
 - Maintain NM OAI Study Webpage on WRAP website throughout the study

Current Schedule

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
	<i>PPT on final approach and project plan</i>	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 Model	<i>PPT on 2014 WAQS and EPA WRF</i>	May 2020
2.2 Additional Met Model	<i>PPT on New WRF 4-km MPE in New Mexico</i>	Jun 2020
2.3 Process Met Data	PGM summer 2014 36/12/4-km met inputs	Jun 2020
3. Boundary Conditions (BC)		
3.1 Evaluate BC Data	<i>PPT on WRAP 2014 GEOS-Chem BCs</i>	Jun 2020
4. Base Year (2014) and Future Year (2023) Emissions		
4.1 2014 and 2023 Emissions for 4-km New Mexico Domain	<i>PPT on sources of 2014 and 2023 New Mexico EI</i>	May 2020
	<i>PPT and tile plots/excel spreadsheets for 2014 and 2023 emissions in the 4-km NM domain</i>	Jun 2020
4.2 Mobile Sources		
4.2.1 Evaluate Mobile EI	<i>PPT on options for 2014/2023 mobile sources</i>	Jun 2020
	<i>PPT on final 2014/2023 mobile source EI</i>	Jun 2020
4.2.3 Prepare Mobile Source Emission Inputs	<i>PPT on 2014/2023 SMOKE-MOVES</i>	Aug 2020
	Model-ready 2014/2023 mobile source inputs	Aug 2020
4.3 Biogenic/Natural Emissions	<i>PPT on biogenic and natural emission modeling</i>	Jul 2020
	Model-ready 2014 natural emissions inputs	Jul 2020
4.4 SMOKE Modeling	<i>PPT on 2014/2023 SMOKE modeling</i>	Aug 2020
	Model-ready 2014/2023 anthropogenic EI inputs	Aug 2020
4.5 FY Emissions Strategies	<i>PPT on FY 2023 SMOKE control/strategies</i>	Aug 2020
	Summary tables/plots for 2023 scenarios	Aug 2020
5. 2014 Base Year (2014) Air Quality Modeling		
	<i>Webinar PPT on final 2014 base case and MPE</i>	Sep 2020
	Draft report on Tasks 2-5, 2014 Base and MPE	Sep 2020
	Final report on Tasks 2-5, 2014 Base and MPE	Oct 2020
	RtC on 2014 base case and MPE report	Oct 2020
6. Future Year (2023) Air Quality Modeling		
6.1 FY PGM Modeling	<i>PPT on 2023 PGM Modeling</i>	Oct 2020
	Difference plots of FY-BY Ozone Concentrations	Oct 2020
6.2 Attainment Test	<i>PPT on 2023 ozone DV projections</i>	Oct 2020
	<i>PPT on FY Source Apportionment Modeling</i>	Nov 2020

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4.1 2014 and 2023 Emissions for 4-km New Mexico Domain	<i>PPT on sources of 2014 and 2023 New Mexico EI</i>	May 2020
	<i>PPT and tile plots/excel spreadsheets for 2014 and 2023 emissions in the 4-km NM domain</i>	Jun 2020
4.2 Mobile Sources		
4.2.1 Evaluate Mobile EI	<i>PPT on options for 2014/2023 mobile sources</i>	Jun 2020
	<i>PPT on final 2014/2023 mobile source EI</i>	Jun 2020
4.2.3 Prepare Mobile Source Emission Inputs	<i>PPT on 2014/2023 SMOKE-MOVES</i>	Aug 2020
	Model-ready 2014/2023 mobile source inputs	Aug 2020
4.3 Biogenic/Natural Emissions	<i>PPT on biogenic and natural emission modeling</i>	Jul 2020
	Model-ready 2014 natural emissions inputs	Jul 2020
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	Difference plots of FY-BY Ozone Concentrations	Oct 2020
6.2 Attainment Test	<i>PPT on 2023 ozone DV projections</i>	Oct 2020
	<i>PPT on FY Source Apportionment Modeling</i>	Nov 2020

Current Webinar Schedule and Content

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 4.3 2014 Natural Emissions Results (e.g., Biogenic, LNOx)	Jul 2020
4.	4.2.3 2014/2023 SMOKE-MOVES for 4-km NM Domain 4.4 2014 & 2023 SMOKE Emissions Modeling Results	Aug 2020
5.	4.5 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

Subtask 2.1: Evaluate Existing 2014 Meteorology and Define NM OAI Study WRF 2014 36/12/4-km Model Configuration

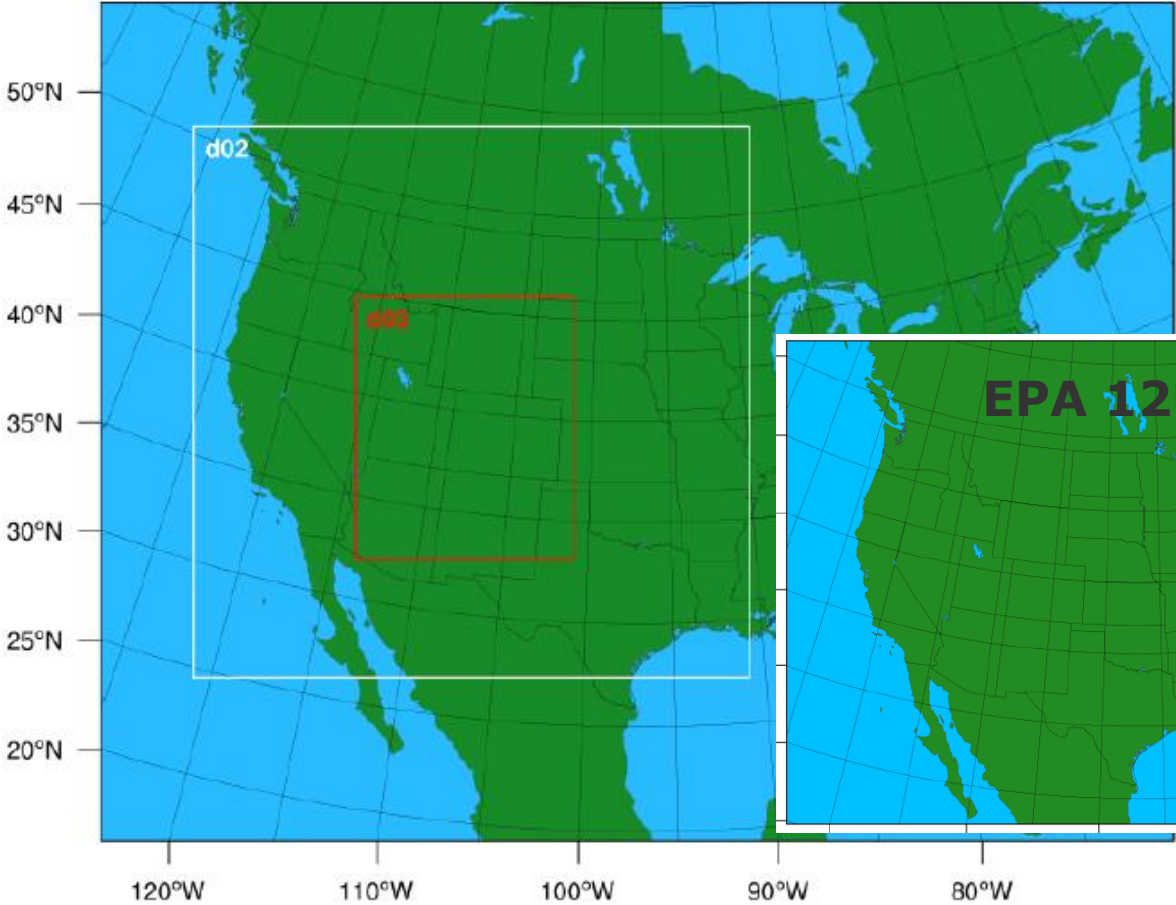


NM OAI vs WAQS vs EPA WRF Configurations

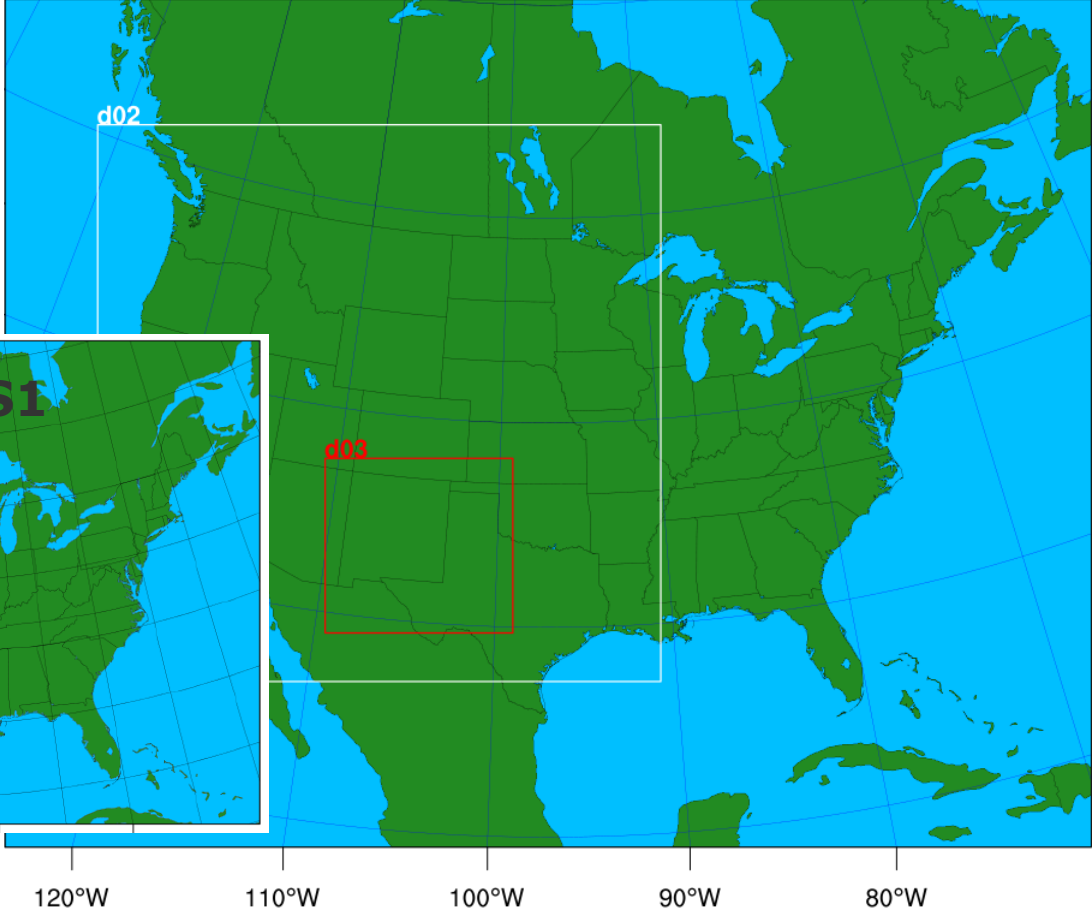
WRF Option	Proposed NM OAI	2014 WAQS	2014/2015 EPA
Vertical Coordinate	hybrid	eta	eta
Domains run	36/12/4-km	36/12/4-km	12-km
Microphysics	Thompson	Thompson	Morrison 2
LW Radiation	RRTMG	RRTMG	RRTMG
SW Radiation	RRTMG	RRTMG	RRTMG
LSM	Noah	Noah	Pleim-Xiu
PBL scheme	YSU	YSU	ACM2
Sfc Layer Physics	MM5 similarity	MM5 similarity	MM5 similarity
Cumulus	36/12/4-km Multi-scale Kain Fritsch	36/12-km Multi-scale Kain Fritsch	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

NM OAI vs WAQS vs EPA WRF Domains

WAQS 36/12/4 km



NM OAI 36/12/4 km



EPA vs WAQS WRF MPE Approach

- Evaluate EPA 12US1 and WAQS 12WUS2 for April-August 2014
 - For both EPA and WAQS, include observation sites within New Mexico only
- Quantitative Evaluation
 - METSTAT – model/obs pairing, bias/error statistics against NCAR ds3505 observations
 - Soccer plots – monthly stats
 - Time series – hourly and daily
 - Plots for all sites in NM, and each individual site within NM
- Qualitative Evaluation
 - PRISM precipitation spatial maps
 - Monthly and daily

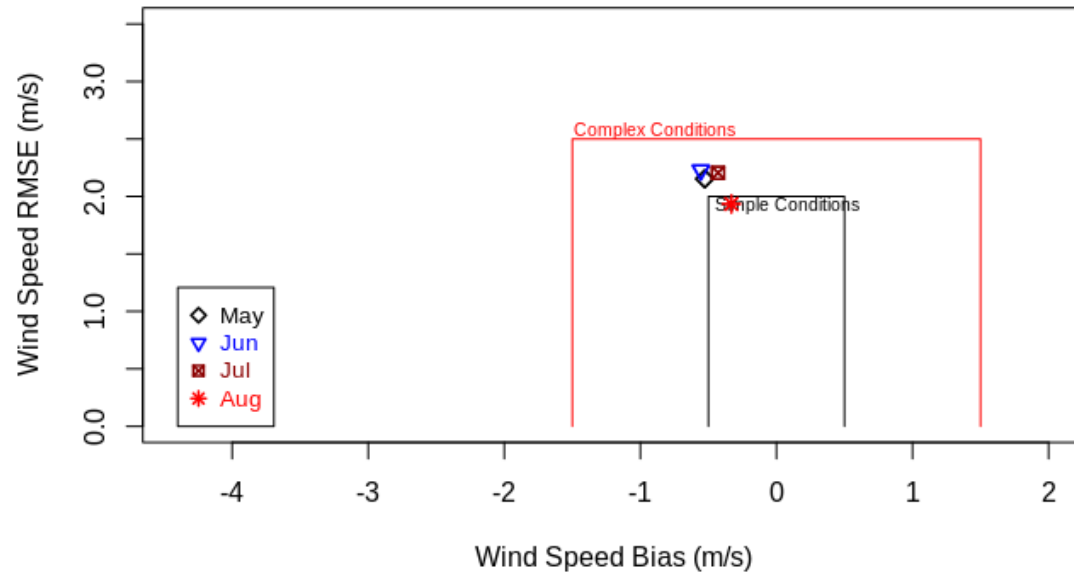
WRF Statistical Benchmarks

Meteorological Variable	Simple Conditions		Complex Conditions	
	Bias	Error	Bias	Error
Temperature	< ±0.5 °C	< 2.0 °C	< ±2.0 °C	< 2.5 °C
Wind Speed	< ±0.5 m/s	< 2.0 m/s (RMSE)	< ±1.5 m/s	< 2.5 m/s (RMSE)
Wind Direction	< ±10 degrees	< 30 degrees	< ±10 degrees	< 50 degrees
Humidity	< ±0.8 g/kg	< 2.0 g/kg	< ±1.0 g/kg	< 2.0 g/kg

Soccer Plots – Wind Speed for all NM sites

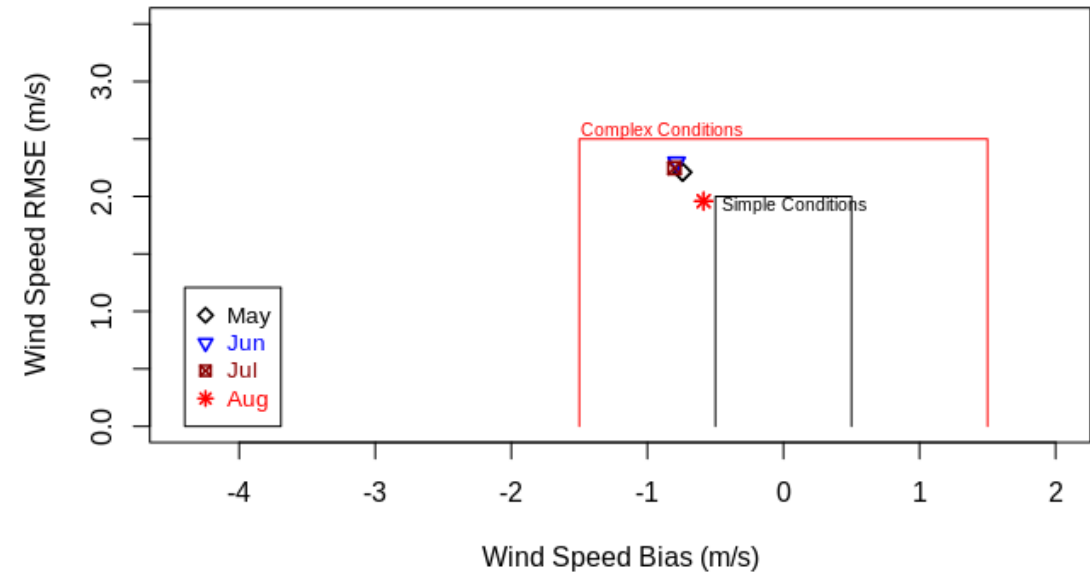
EPA 12 km

EPA WRF d01 NM Wind Speed Performance
2014 - all



WAQS 12 km

WAQS WRF d02 NM Wind Speed Performance
2014 - all



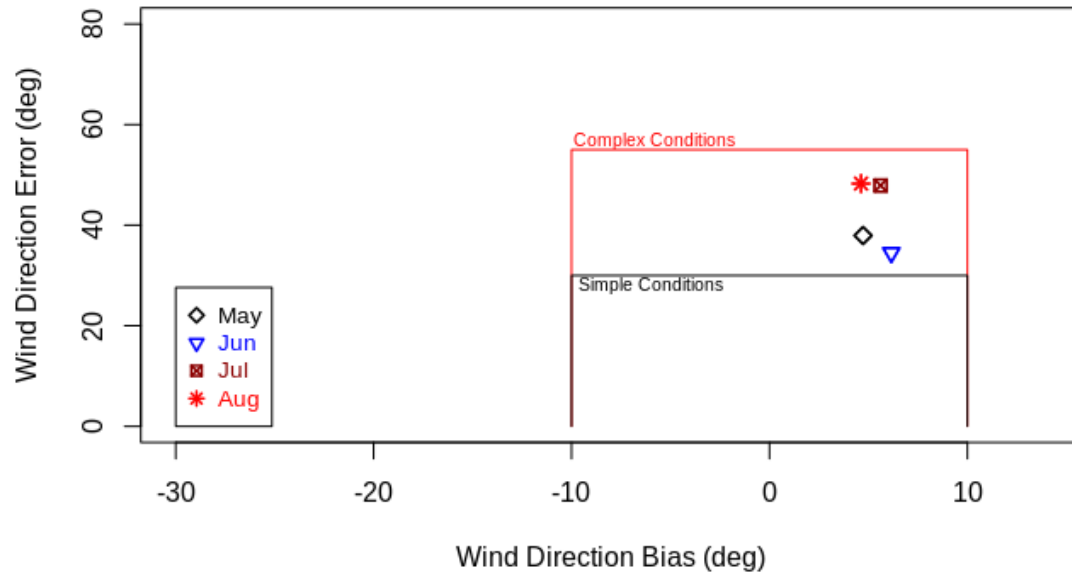
All months within complex conditions goal for both runs

Both runs have underprediction bias for all months; EPA slightly better

Soccer Plots – Wind Direction for all NM sites

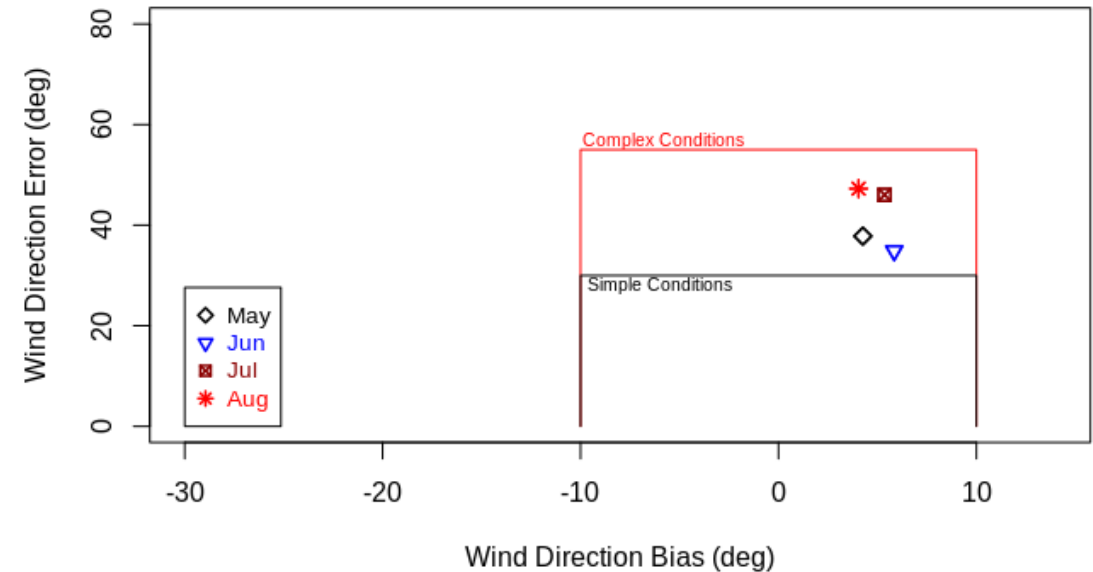
EPA 12 km

EPA WRF d01 NM Wind Direction Performance
2014 - all



WAQS 12 km

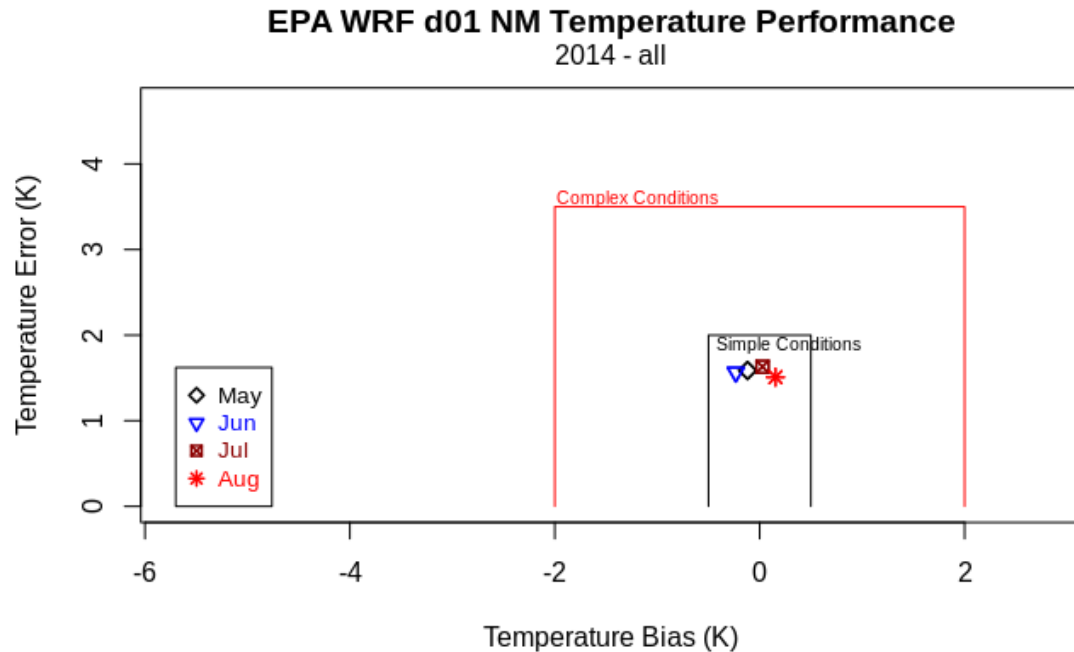
WAQS WRF d02 NM Wind Direction Performance
2014 - all



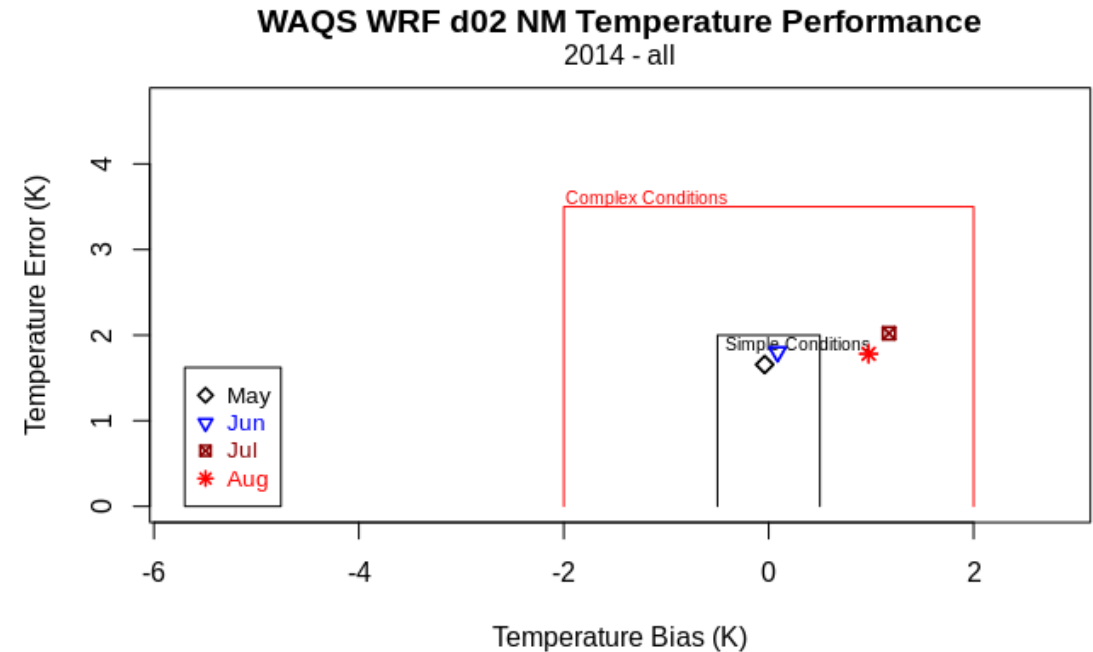
WAQS and EPA performance nearly identical

Soccer Plots – Temperature for all NM sites

EPA 12 km



WAQS 12 km



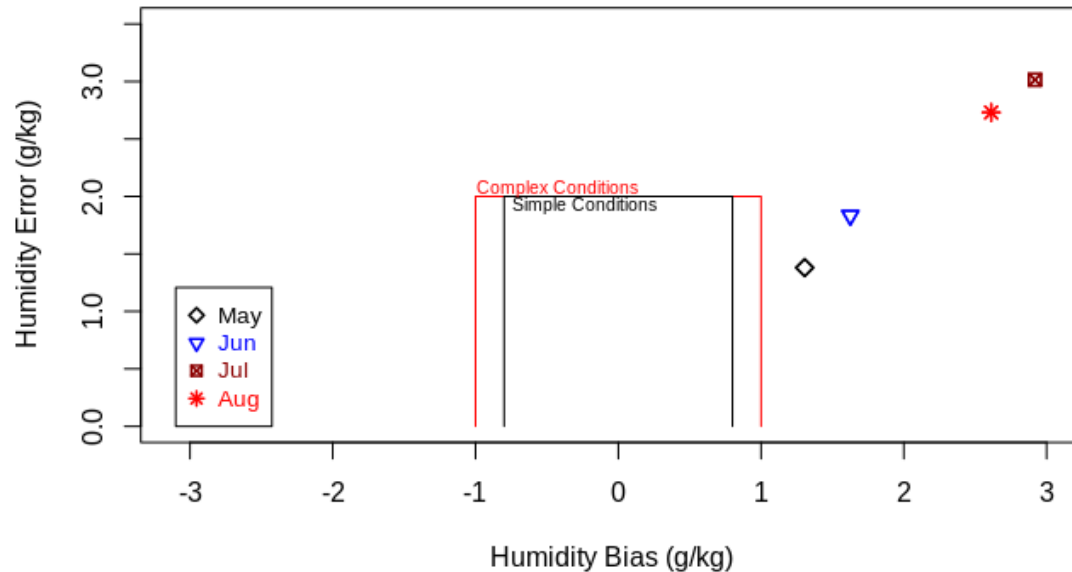
EPA run outperforms WAQS

WAQS temperature poorest for Jul-Aug with warm bias

Soccer Plots – Humidity for all NM sites

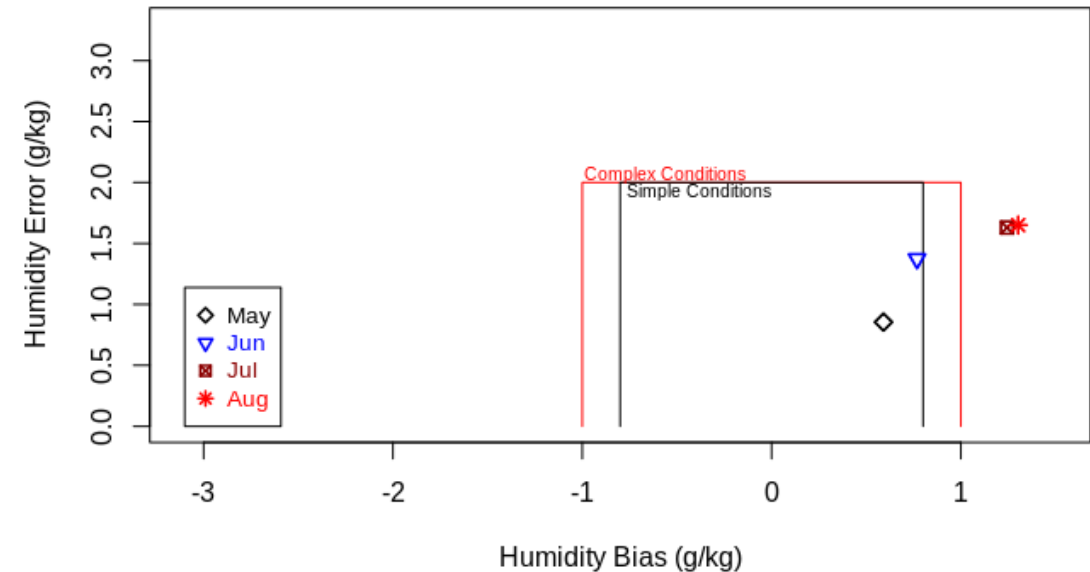
EPA 12 km

EPA WRF d01 NM Humidity Performance
2014 - all



WAQS 12 km

WAQS WRF d02 NM Humidity Performance
2014 - all

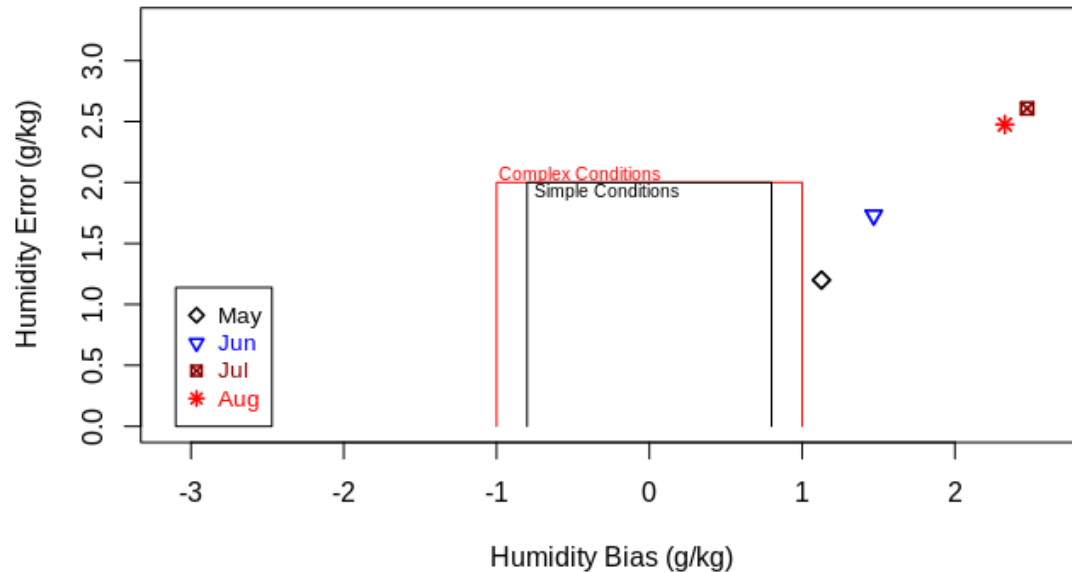


WAQS run outperforms EPA; both runs have positive (wet) bias for all months
EPA performance poorest for Jul-Aug: overactive convection?

Soccer Plots – Humidity for KABQ

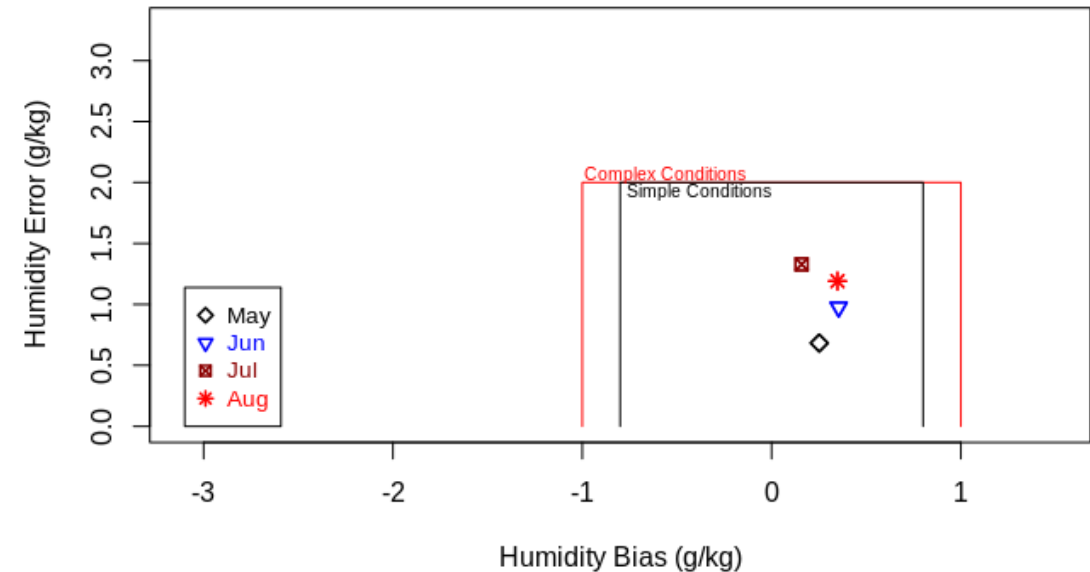
EPA 12 km

EPA WRF d01 NM Humidity Performance
2014 - KABQ



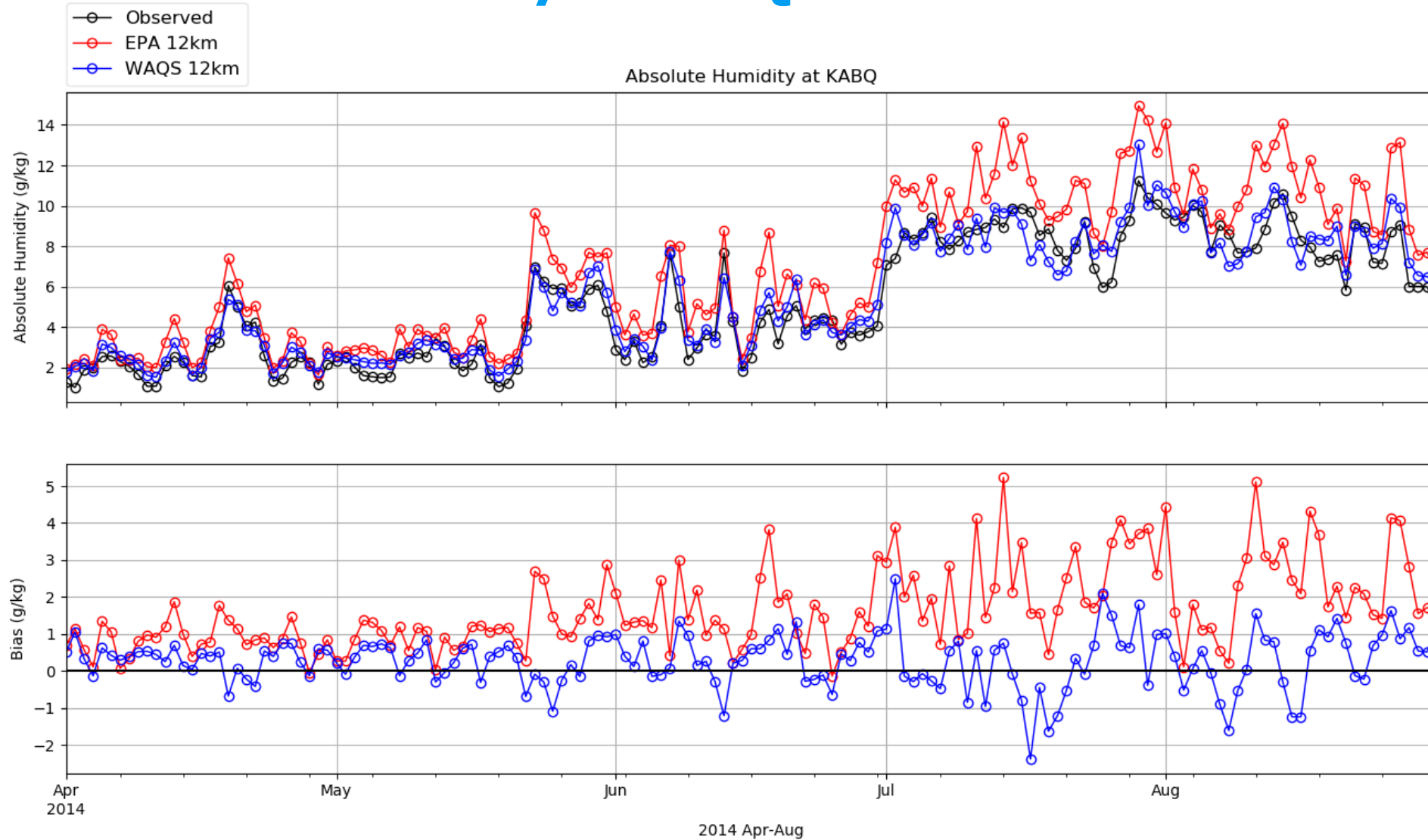
WAQS 12 km

WAQS WRF d02 NM Humidity Performance
2014 - KABQ



WAQS run outperforms EPA; much smaller wet bias for all months

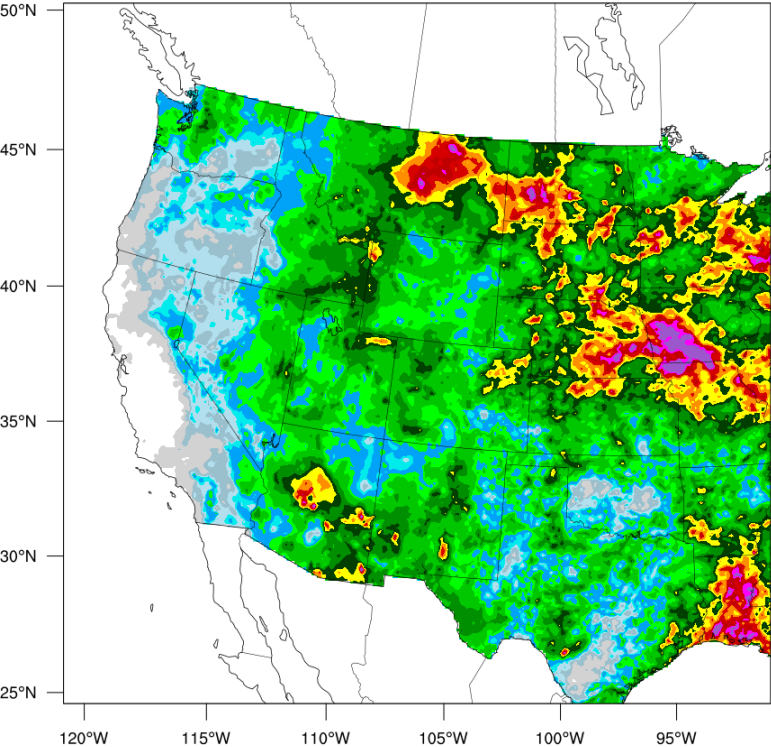
Time Series – Humidity at KABQ



Monthly Precipitation Plots – Aug 2014

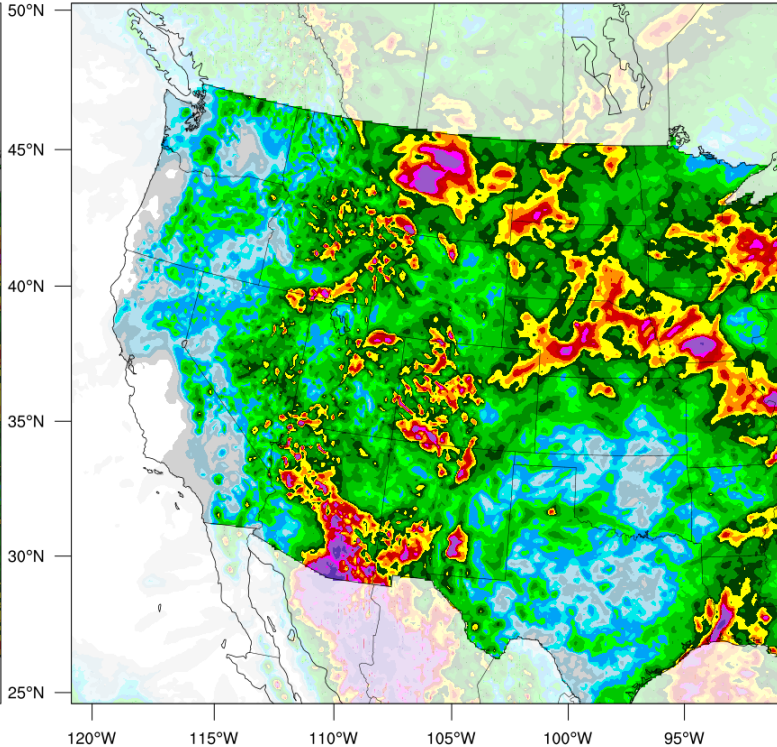
PRISM Obs

Total PRISM Precipitation for 2014-08
Contiguous U.S. Statistics: 10th=0.512 Median=2.358 Average=2.788 90th=5.633



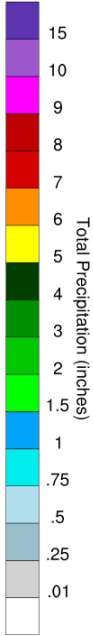
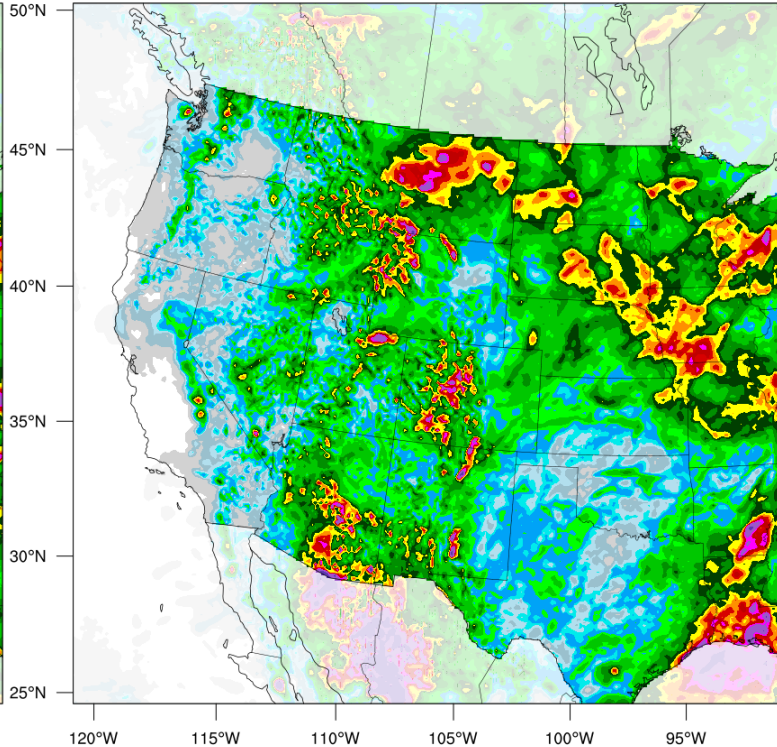
EPA 12 km

Total WRF Precipitation (EPA) for 2014-08
WRF Domain Statistics: 10th=0.02 Median=2.37 Average=2.92 90th=6.12
Contiguous U.S. Statistics: 10th=0.58 Median=2.64 Average=3.06 90th=6.01



WAQS 12 km

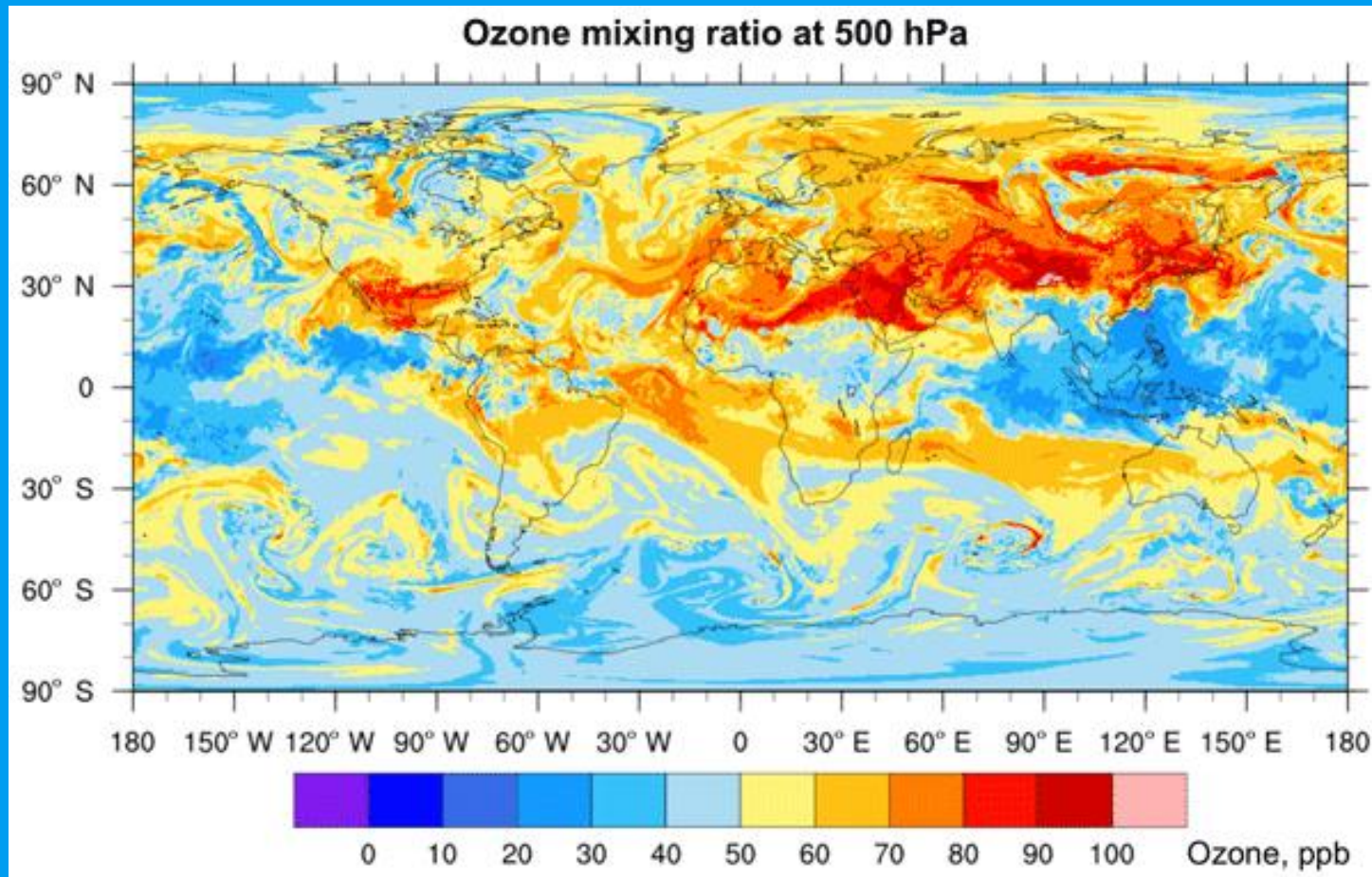
Total WRF Precipitation (WAQS) for 2014-08
WRF Domain Statistics: 10th=0.01 Median=1.88 Average=2.52 90th=5.54
Contiguous U.S. Statistics: 10th=0.39 Median=2.00 Average=2.55 90th=5.47



Existing 2014 WRF MPE Summary and Conclusions

- WRF performance reasonable for both simulations outside of humidity/precipitation
- EPA wet bias in summer months associated with overactive summer convection
- WAQS smaller wet bias
- NM OAI proposed WRF configuration aligns closely with WAQS to avoid overactive summer convection in New Mexico, with these differences
 - Reposition 4 km domain to encompass all of New Mexico
 - Use hybrid vertical coordinate to improve representation of upper troposphere/lower stratosphere
 - Add second simulation driven by ERA5 analysis
 - No observation nudging
- Two NM OAI WRF simulations (WRF/NAM12 and WRF/ERA5) currently running
- Present evaluation of these two simulations in June webinar

Task 3: Evaluate 2014 Boundary Conditions Based on WRAP 2014 GEOS-Chem

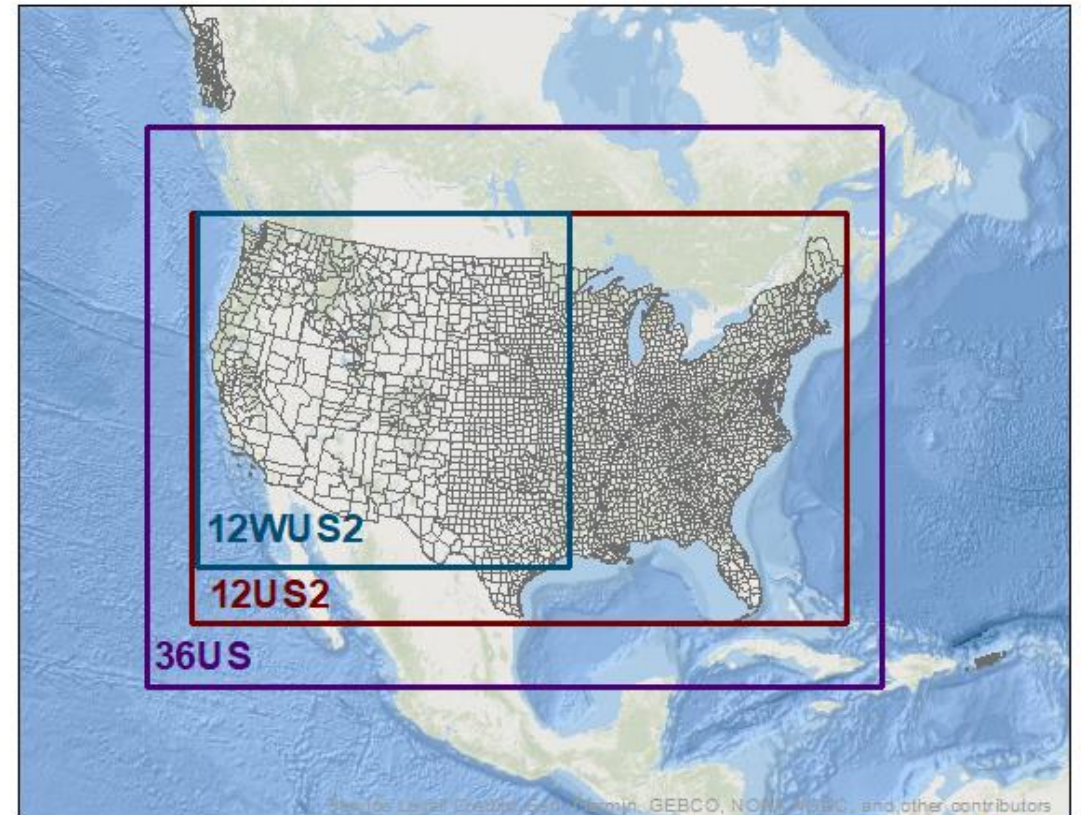


Overview of 2014 BC Evaluation

- Overview of WAQS-WRAP 2014 GEOS-Chem modeling
- Overview of WAQS 2014 Representative Base case Scenario
- Analysis of WAQS 2014 modeling results and BC contributions

Background

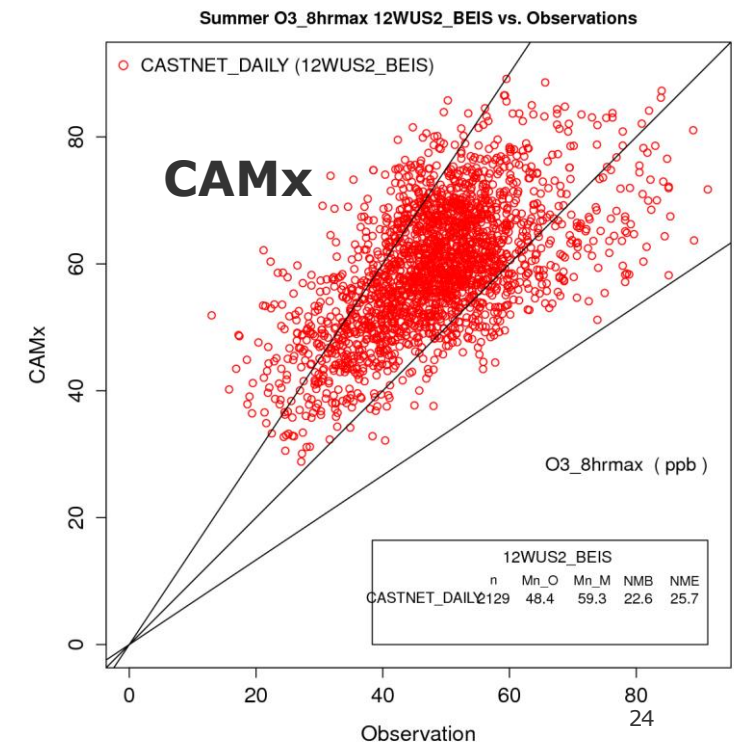
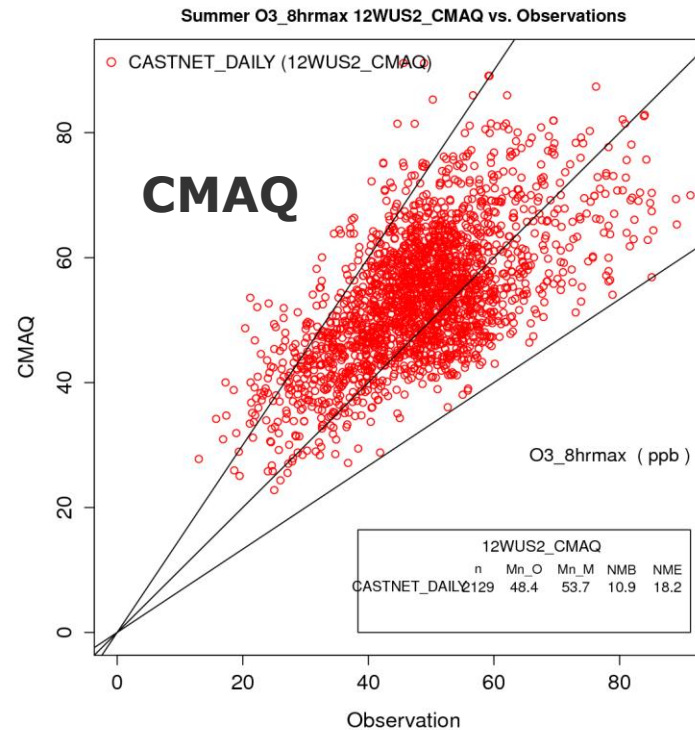
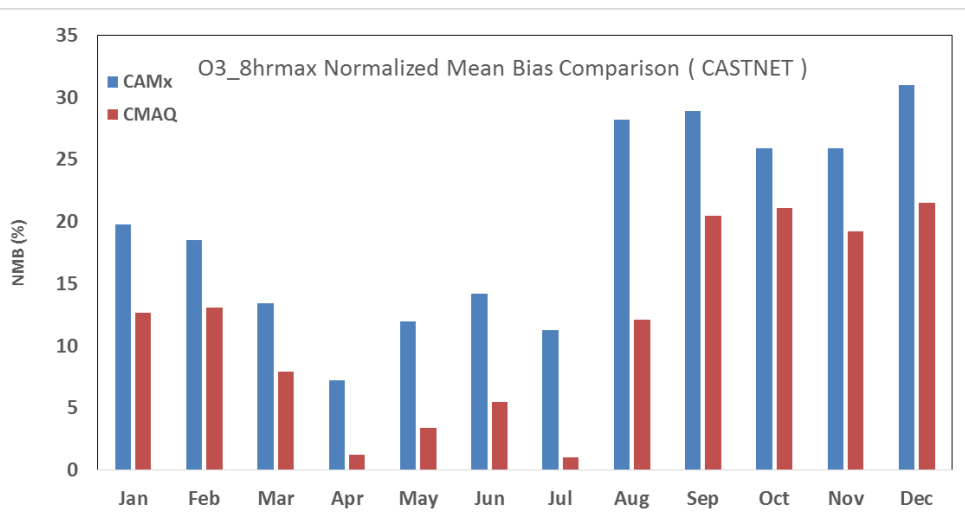
- Phase I and II of WRAP 2014 Shake-Out study developed a 2014v1 PGM modeling platform:
 - 36-km 36US and 12-km 12WUS2 domains
 - CMAQ and CAMx PGMs
 - **EPA 2014 GEOS-Chem BCs**
 - 2014v1 Emissions
 - 2014NEIv2 with western state updates
 - BEIS Biogenic Emissions



RAMBOLL

BCs Based on EPA 2014 GEOS-Chem had issues

- Year-round ozone overestimation bias
 - In both CMAQ and CAMx, but more pronounced in CAMx
- Maybe some SO₄ overestimation, even after eliminating volcano eruptions and DMS emissions



Revised 2014 GEOS-Chem simulation

- WRAP elected to conduct a revised 2014 GEOS-Chem simulation
 - Use updated emissions, newer GEOS-Chem version and other updates as used by EPA and Ramboll in their 2016 GEOS-Chem runs that produced BCs without the large ozone overestimation bias in the CMAQ and CAMx simulations.

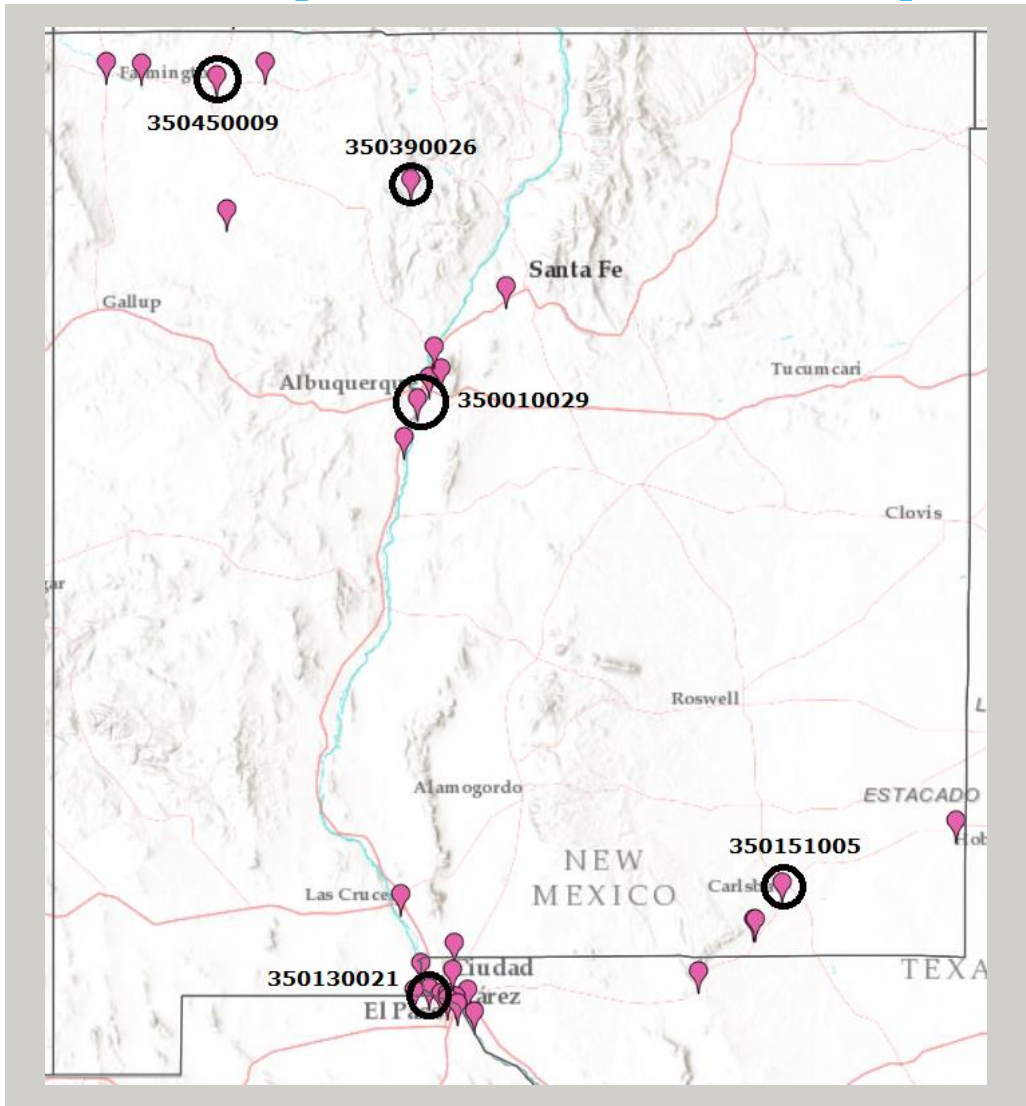
Science Options	WRAP 2014 Basecase	EPA 2014 <u>Basecase</u>	EPRI 2016 Basecase
Version	Version 12.2.0 (2019-02-19)	Version 11-01 (2017-02-01)	Version 11-02r (2018-06-22)
Vertical Grid Mesh	72 Layers	47 Layers	72 Layers
Chemistry mechanism	standard chemistry with complex SOA option	tropospheric chemistry with complex SOA option	standard chemistry with complex SOA option
Horizontal Grids	2x2.5 degree (<u>Nx</u> , Ny = 144, 91)	4x5 degree (<u>Nx</u> , Ny = 72, 46)	2x2.5 degree (<u>Nx</u> , Ny = 144, 91)
Initial Conditions	6-month spin-up	1-year spin-up	6-month spin-up
Meteorology	2014 GEOS-FP meteorology	2014 GEOS-5 meteorology	2016 GEOS-FP meteorology
Photolysis	Default (FAST-J)	Default (FAST-J)	Default (FAST-J)
Advection Scheme	Default (TPCORE)	Default (TPCORE)	Default (TPCORE)
Cloud Convection	On/Relaxed Arakawa-Schubert	On/Relaxed Arakawa-Schubert	On/Relaxed Arakawa-Schubert
PBL	Lin and McElroy	Lin and McElroy	Lin and McElroy
Dry Deposition	Default (<u>Wesely</u>)	Default (<u>Wesely</u>)	Default (<u>Wesely</u>)
Chemistry Solver	Default (FLEXCHEM)	Default (FLEXCHEM)	Default (FLEXCHEM)
Parallelization	Open Multi-Processing (OMP)	Open Multi-Processing (OMP)	Open Multi-Processing (OMP)

Representative Base Case Simulation Description

- WRAP 2014 GEOS-Chem used to derive Boundary conditions for 2014v2 and Representative Baseline (RepBase)
- Two additional GEOS-Chem simulations were performed to separate the Natural, Anthropogenic International and US contributions in the boundary conditions themselves:
 - Natural (NAT) and Zero-Rest-Of-the-World (ZROW)
- RepBase was instrumented in CAMx with source apportionment technology to track the ozone and PM contributions from the following 14 categories including boundary conditions:

Source Group Number	Brief Description
1	Natural Emissions
2	U.S. Wildfires (WF)
3	U.S. Prescribed Burns (Rx)
4	U.S. Agricultural Burning (Ag)
5	U.S. Anthropogenic Emissions (USAnthro)
6	Mexico Anthropogenic Emissions
7	Canada Anthropogenic Emissions
8	Off-Shore Commercial Marine Vessel (CMV) C3 Ocean Going Vessels (OGV) within 200 nautical miles of the coast (i.e., within the Emissions Control Area, ECA)
9	Remainder off-shore anthropogenic emissions that includes CMV C3 OGV outside of the ECA and non-U.S. O&G
10	Boundary Conditions: International contributions (BC_Intl)
11	Boundary Conditions: Natural contributions (BC_Nat)
12	Boundary Conditions: US contributions (BC_US)
13	Initial Conditions contributions
14	Top Boundary Concentrations contributions (top of the model)

Boundary Conditions Analysis Sites



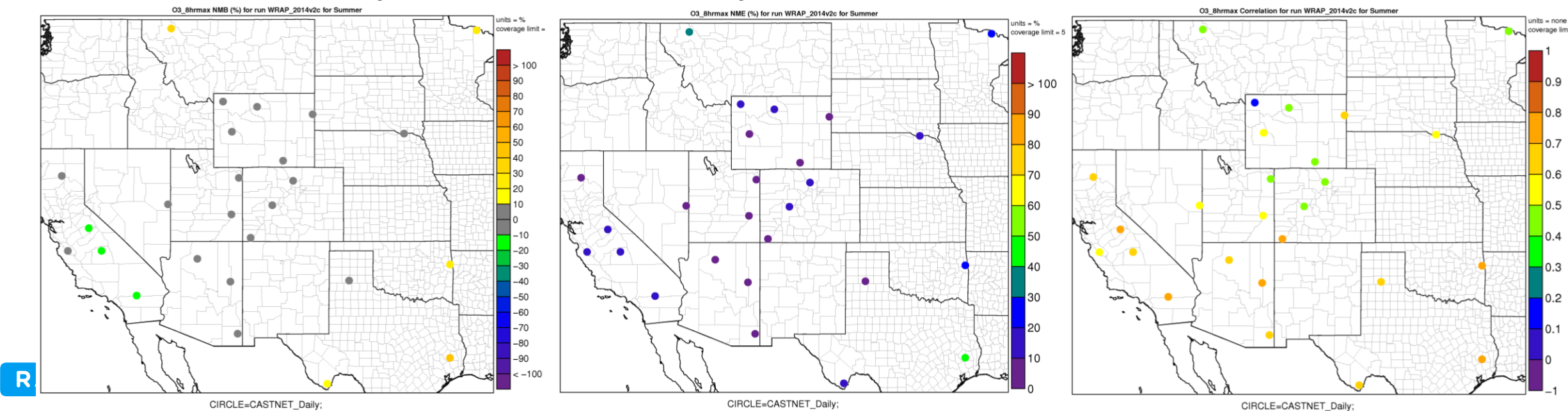
- Compared MDA8 ozone from WRAP Representative Base scenario (RepBase) source apportionment with a few selected and representative AQS sites in NM

Site ID	County	Latitude	Longitude
350450009	San_Juan	36.74	-107.98
350390026	Rio_Arriba	36.19	-106.70
350010029	Bernalillo	35.02	-106.66
350130021	Dona_Ana	31.80	-106.58
350151005	Eddy	32.38	-104.26

Selected Sites Ozone Model Performance

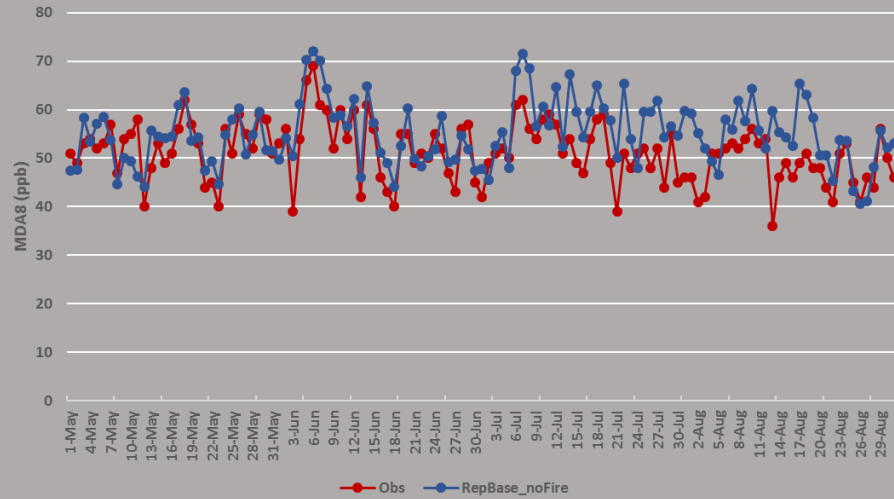
- RepBase does not have year specific emissions and is not meant to represent 2014. Fires contributions have been removed from this analysis
- RepBase statistics indicate performance for scenario in these sites are almost all within the goals for NMB and NME, within criteria for r
- Consistent with 2014v2 AZ, UT, CO ozone **NMB**, **NME** and **r** in the Summer (no CASTNET sites in NM)

Site ID	County	NMB (%)	NME (%)	r
350450009	San_Juan	7.36	10.36	0.63
350390026	Rio_Arriba	3.24	8.62	0.57
350010029	Bernalillo	1.34	8.10	0.66
350130021	Dona_Ana	0.26	8.03	0.72
350151005	Eddy	-4.33	9.45	0.72

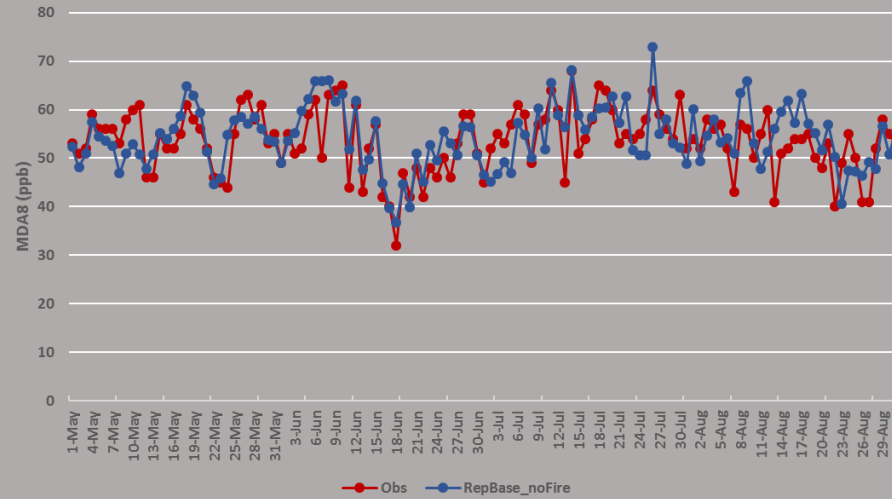


Selected Sites Time Series

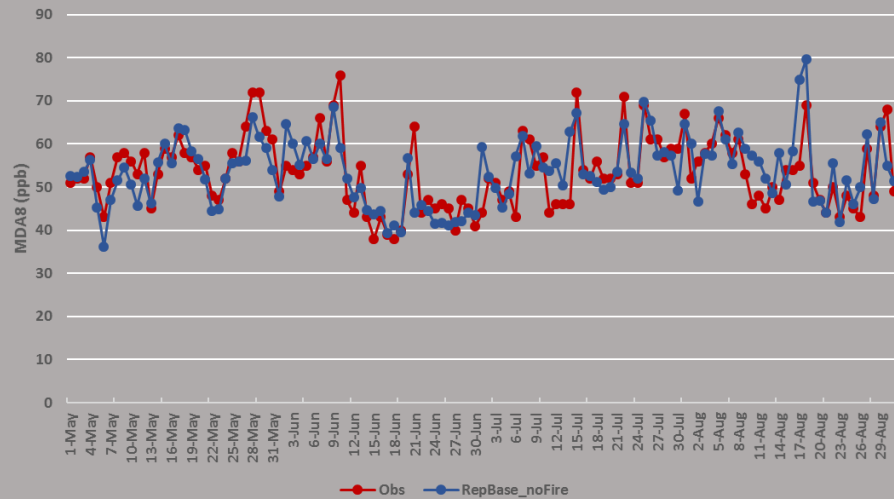
AQS 350450009-San Juan



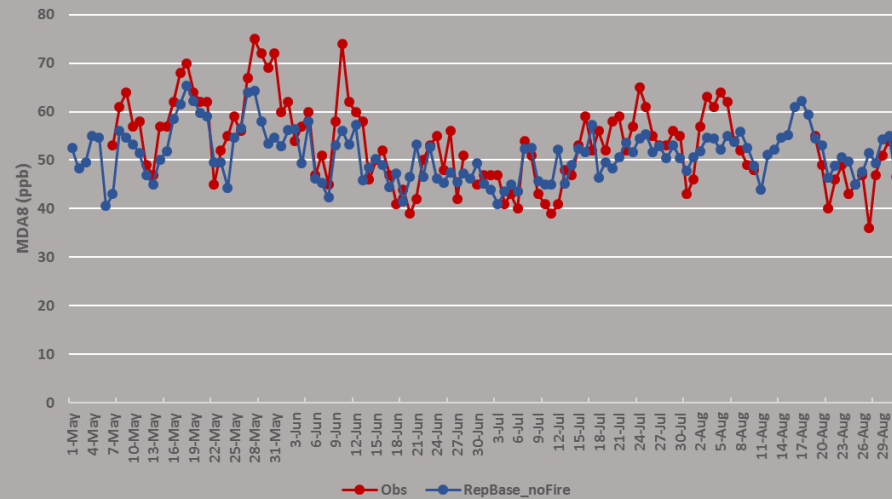
AQS 350010029-Bernalillo



AQS 350130021-Dona Ana

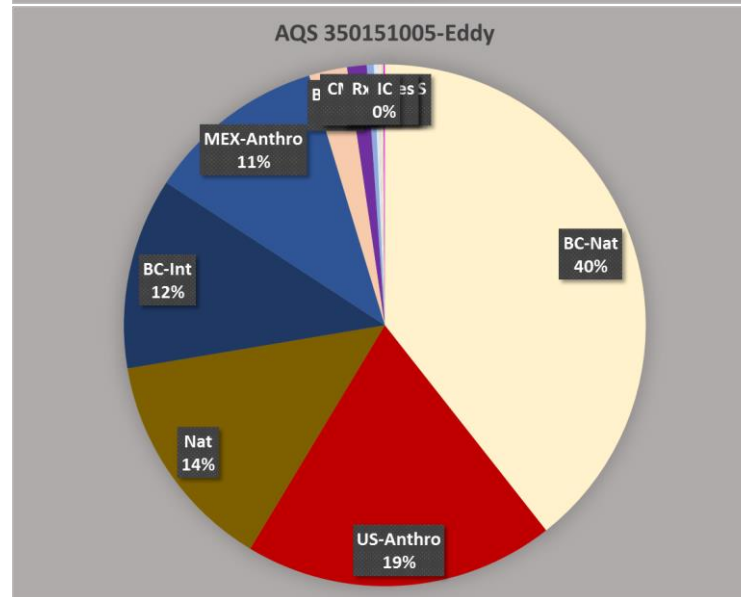
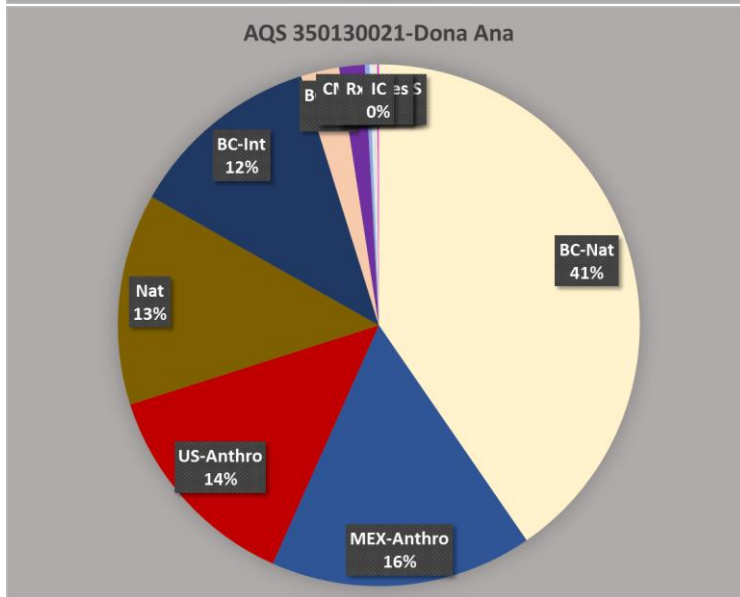
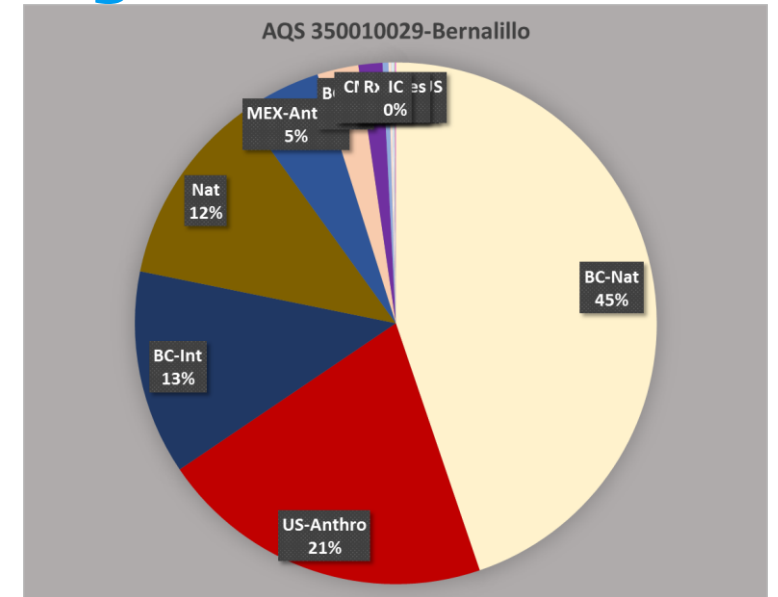
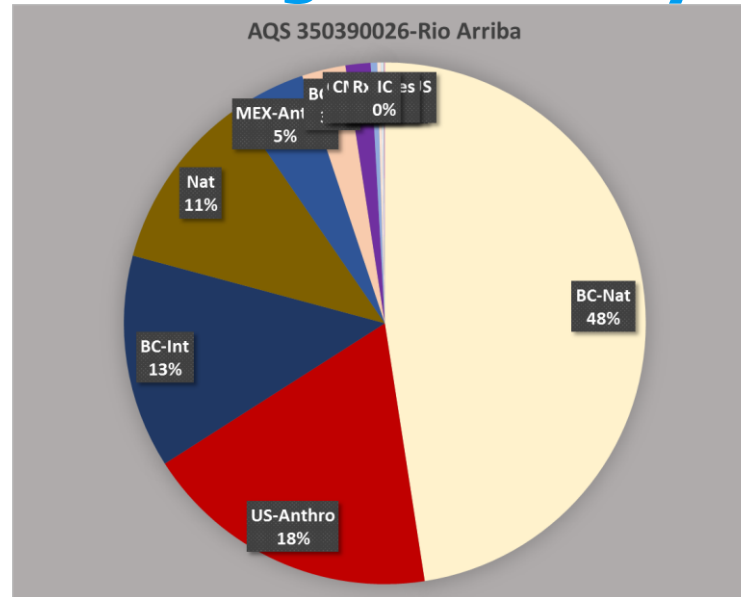
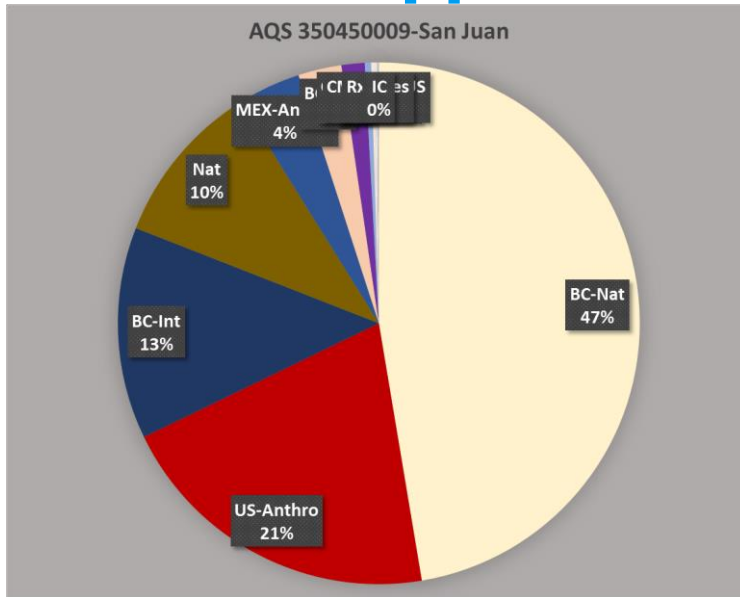


AQS 350151005-Eddy



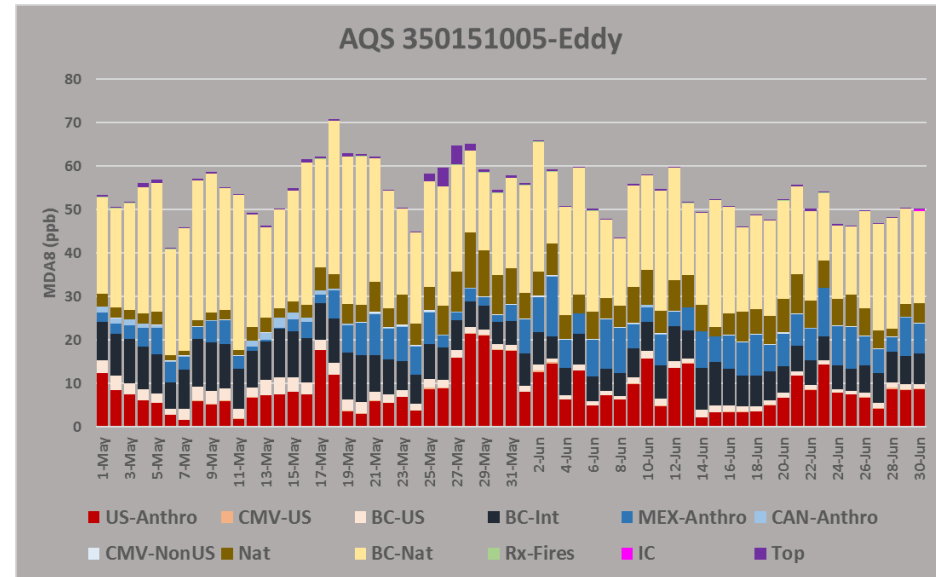
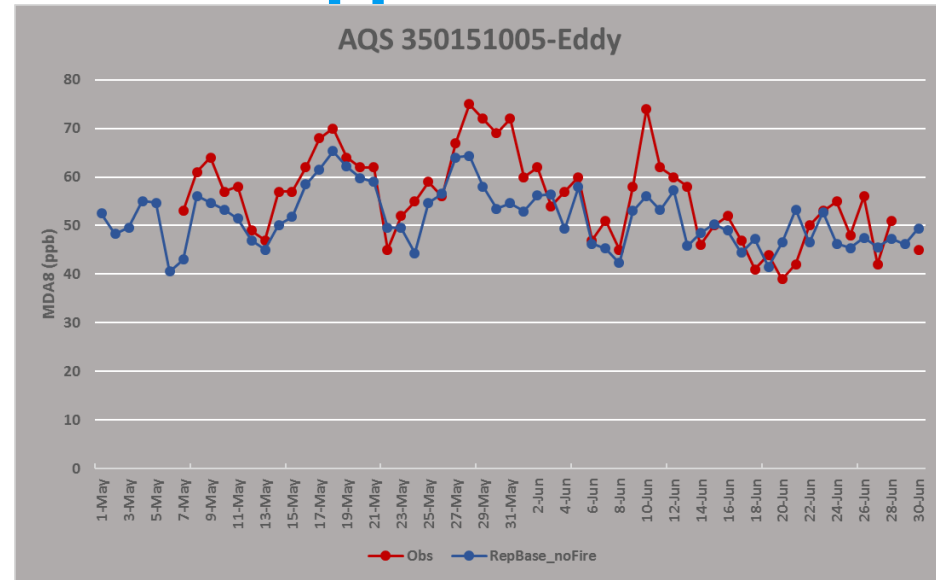
- RepBase statistics and time series suggest that is reasonable to use Source Apportionment results to understand sources of ozone at these sites

Source Apportionment Average over May to August

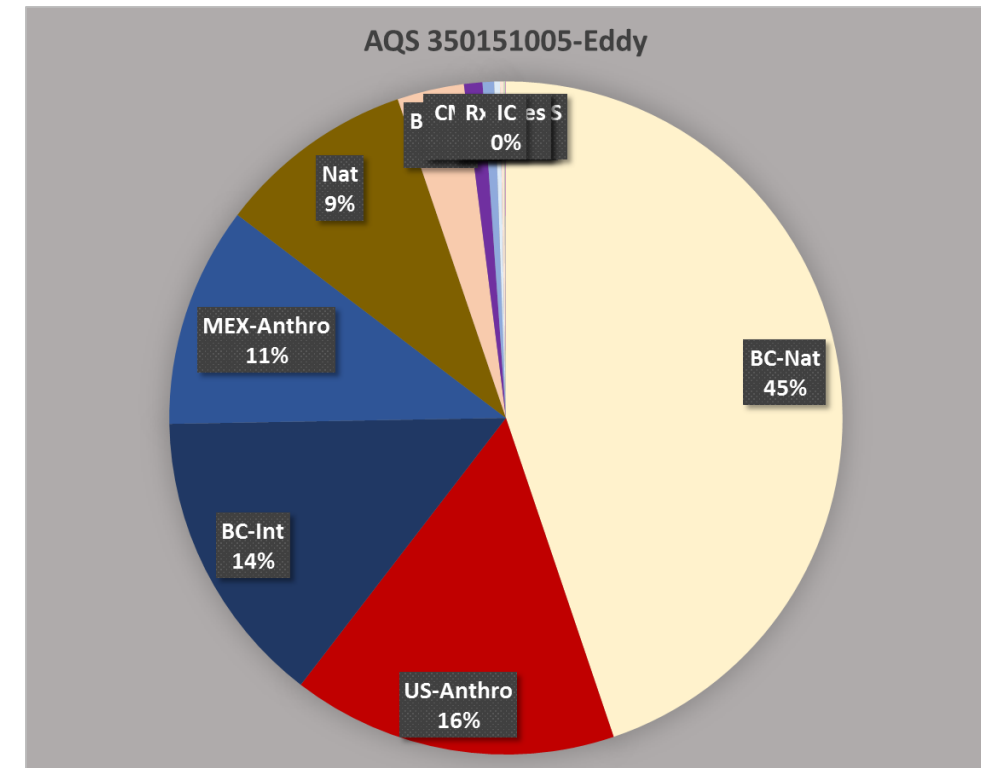


- Natural contribution from the GEOS-Chem Boundary Conditions ~ 40% to 48% of the ozone
- US Anthro ~ 14% to 21%
- International BC ~13%
- Mexican Anthro ~5%. Largest at Dona Ana county at 16%

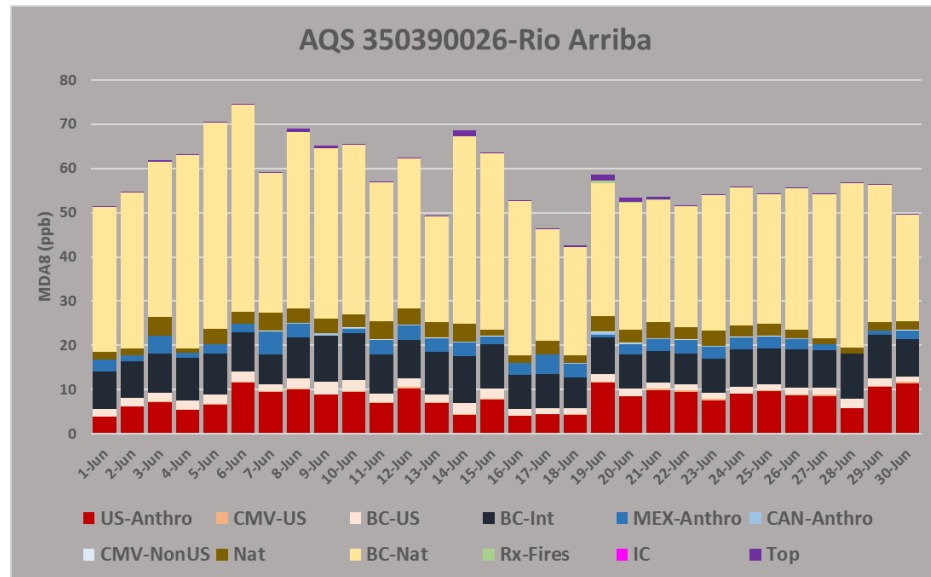
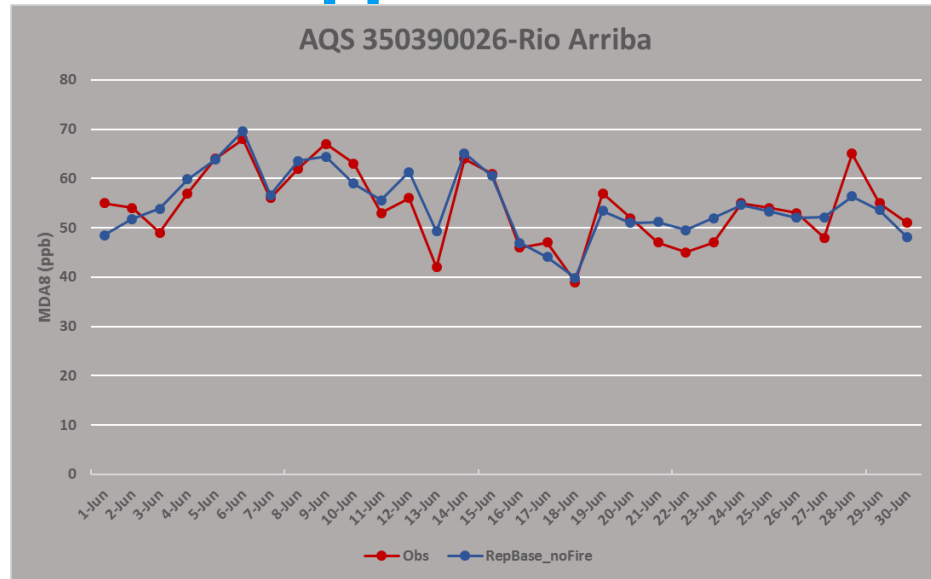
Source Apportionment: Eddy County



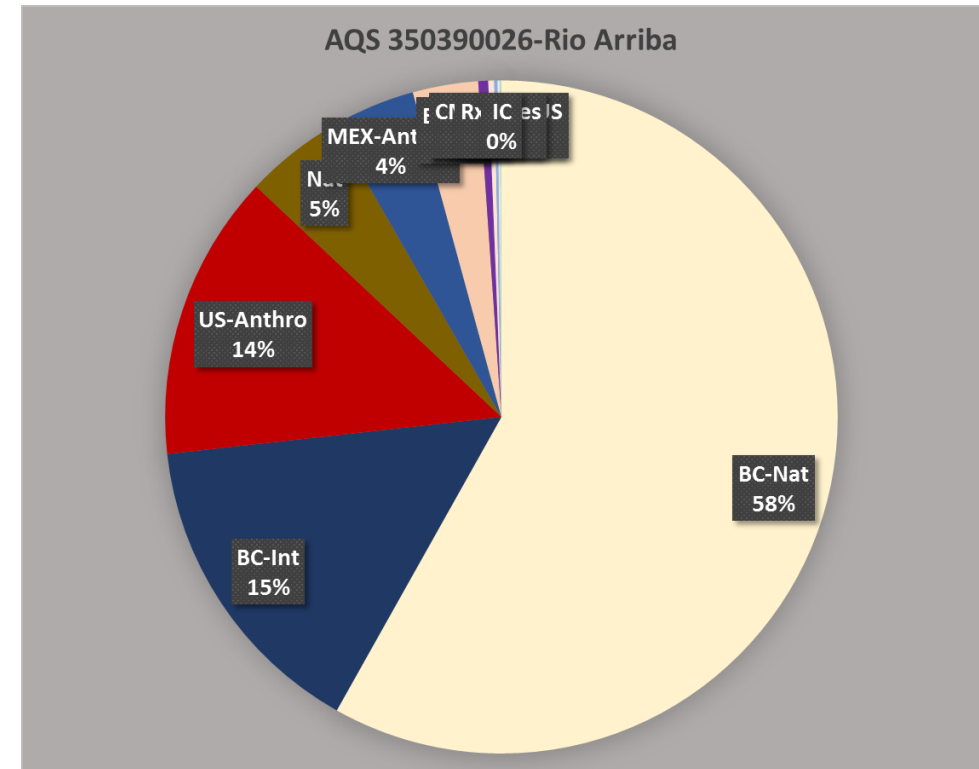
- Obs in Eddy County Site in May-Jun show multiple days with MDA8 > 70 ppb
- US Anthro and International BC contributions show equivalent contributions (16 and 14%)
- Peak on May 25 to 27 has some influence from the top of the model



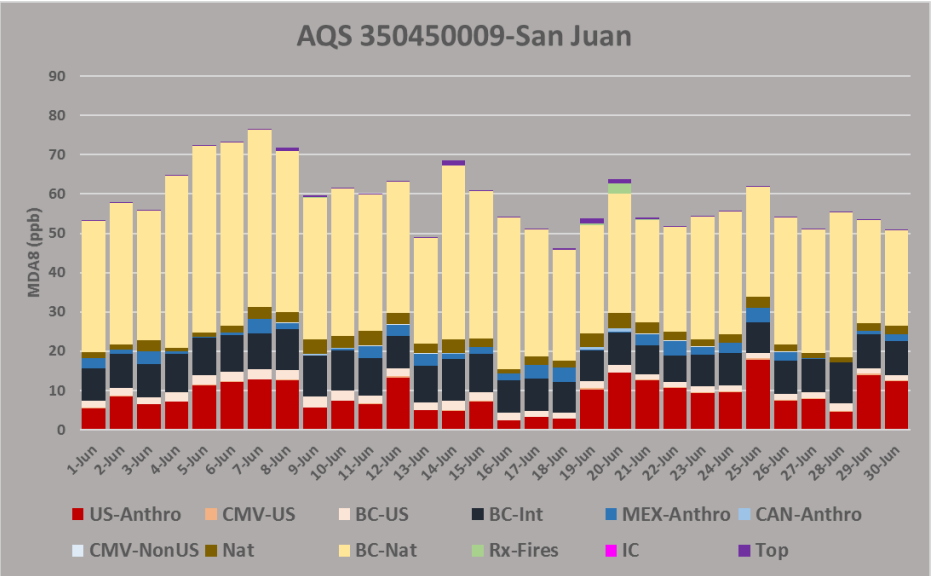
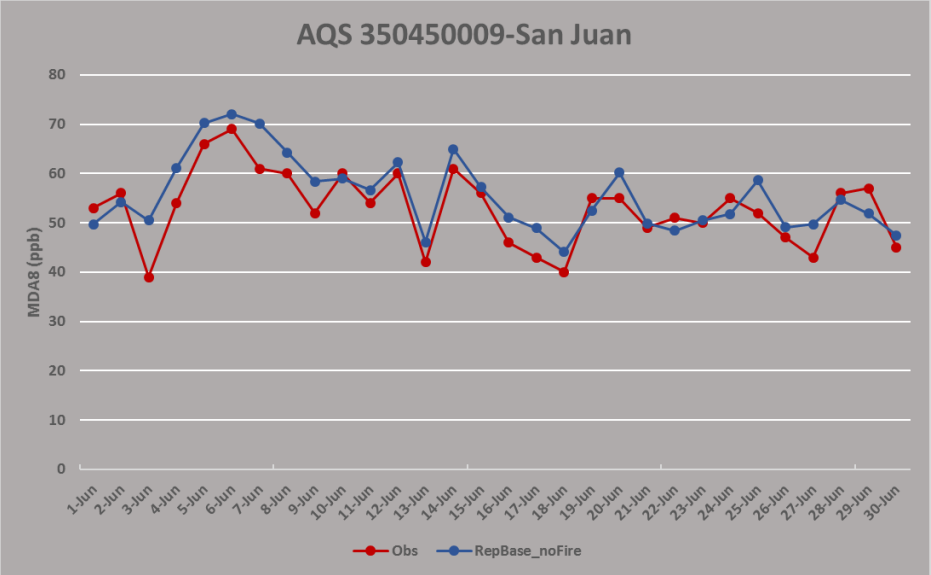
Source Apportionment: Rio Arriba county



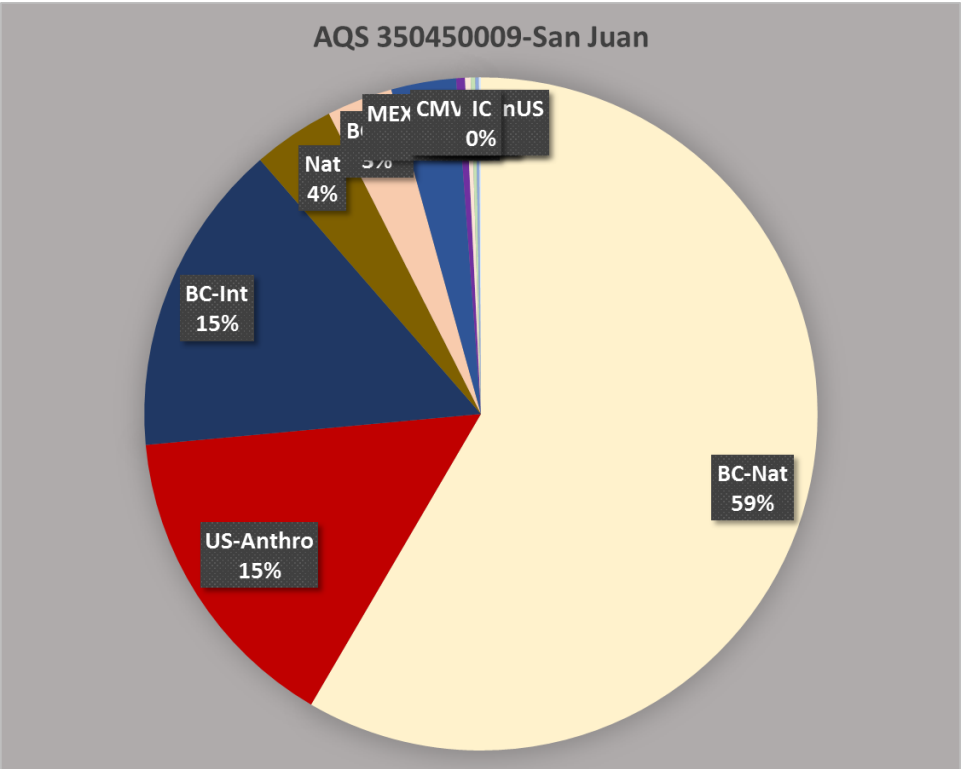
- International BC and US Anthro contributions show equivalent contributions (15 and 14%)
- Peak on June 6 dominated by Natural contributions from the Boundary



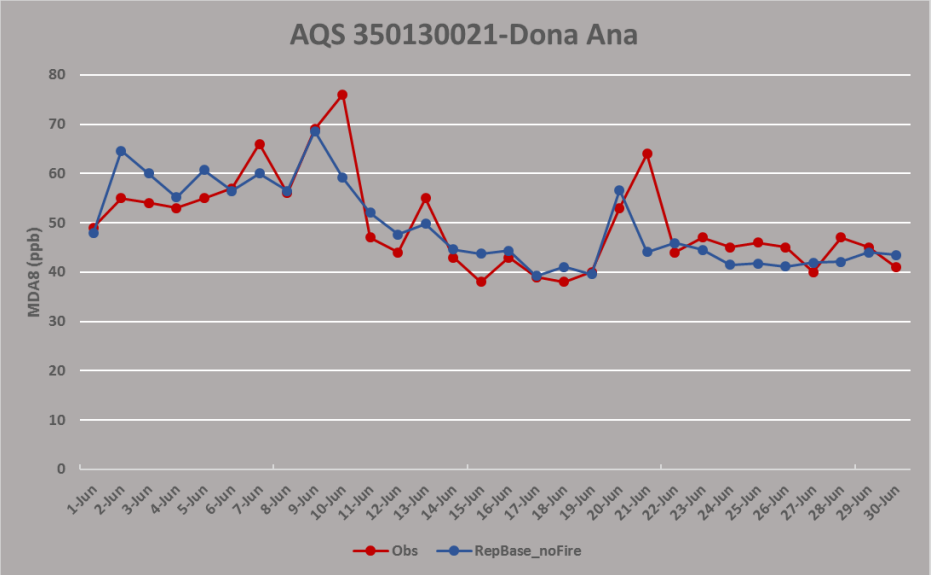
Source Apportionment: San Juan county



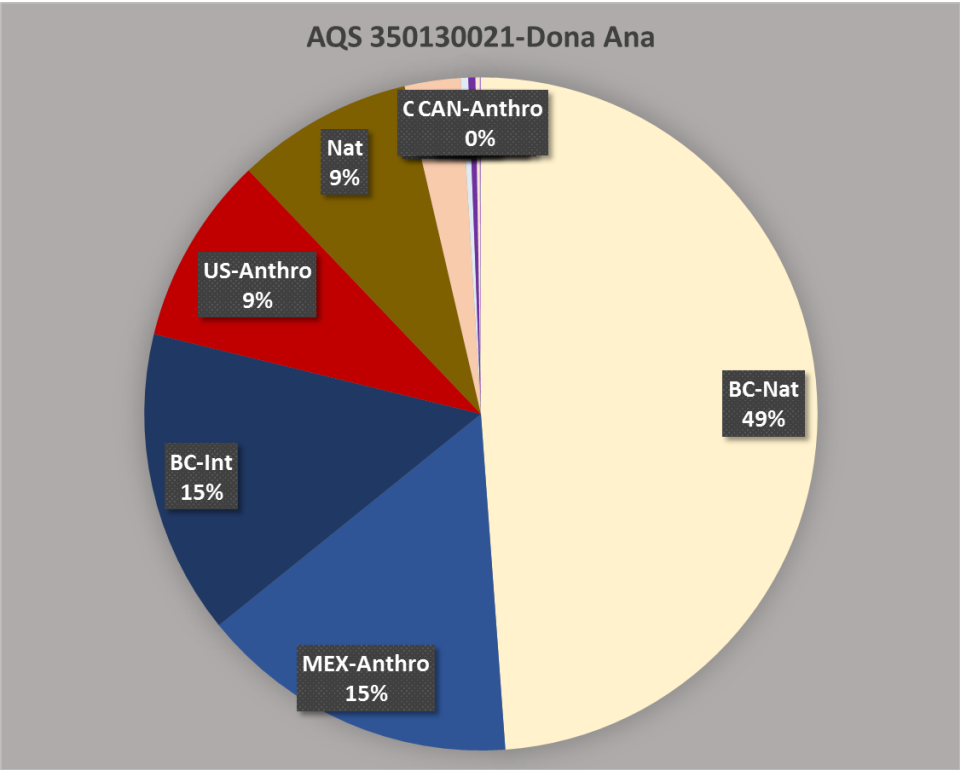
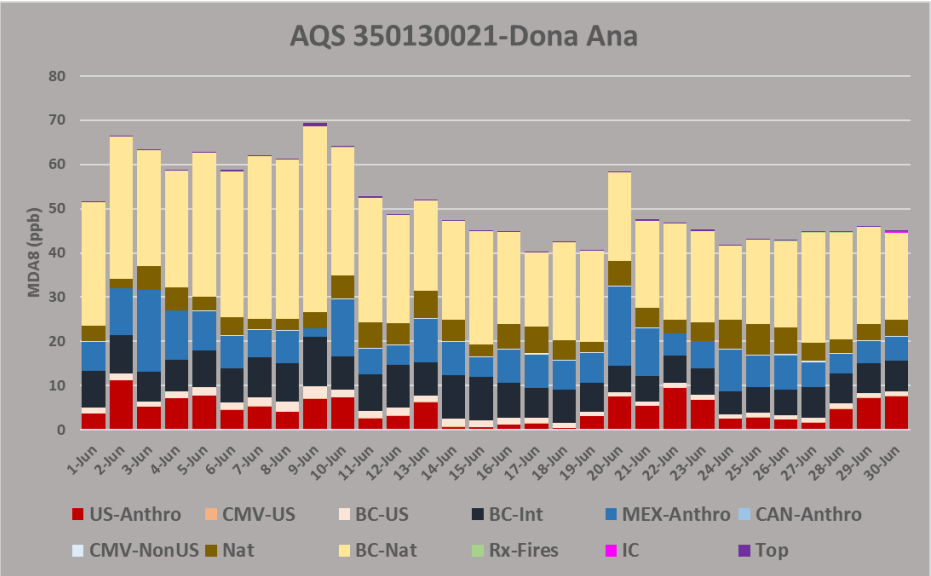
- International BC and US Anthro contributions show equivalent contributions (15%)
- Peak on June 7 dominated by Natural contributions from the Boundary



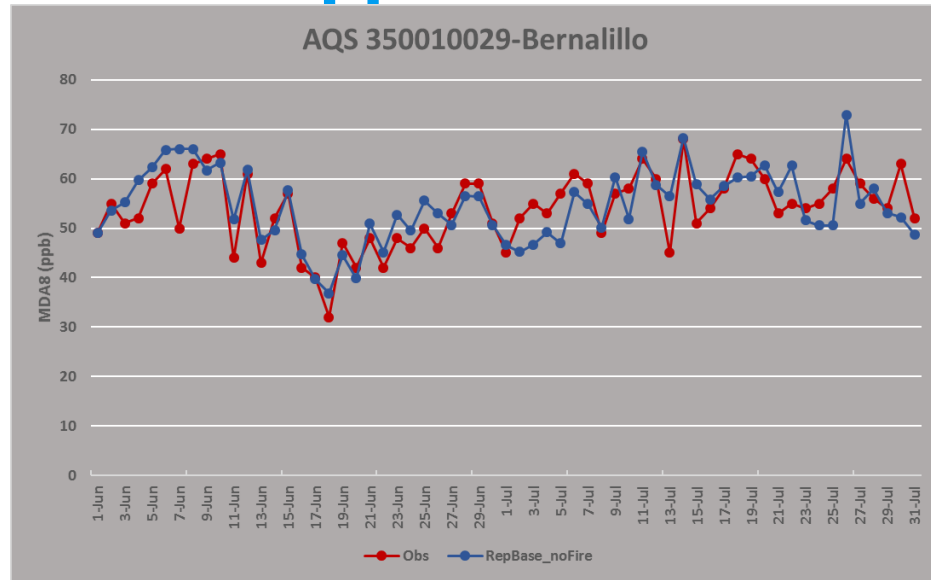
Source Apportionment: Dona Ana county



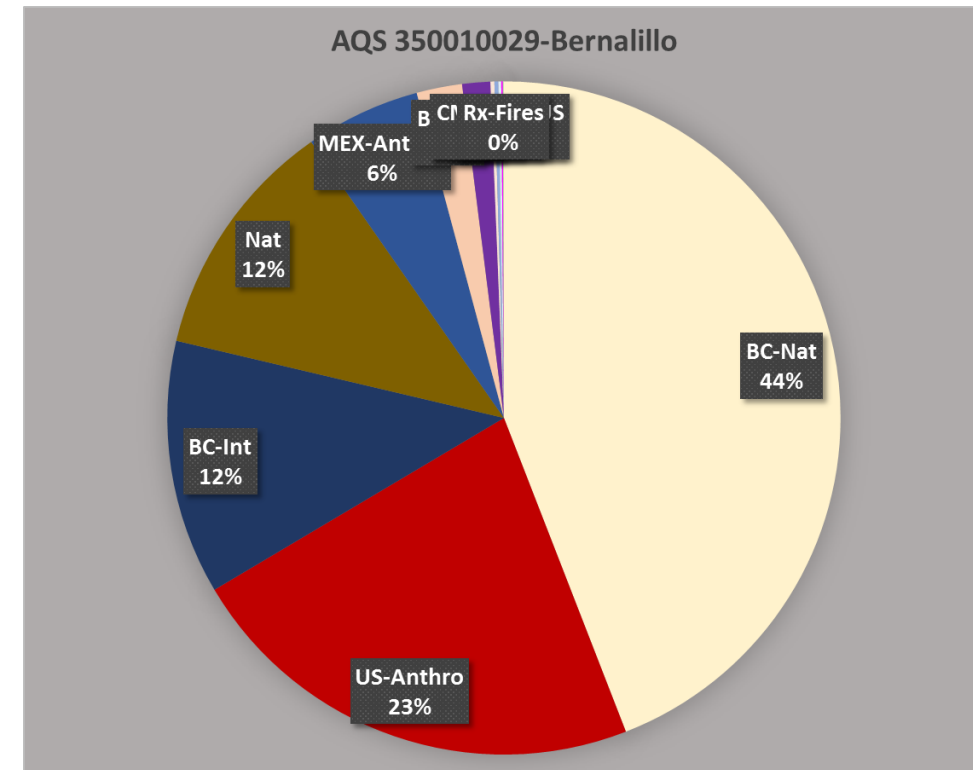
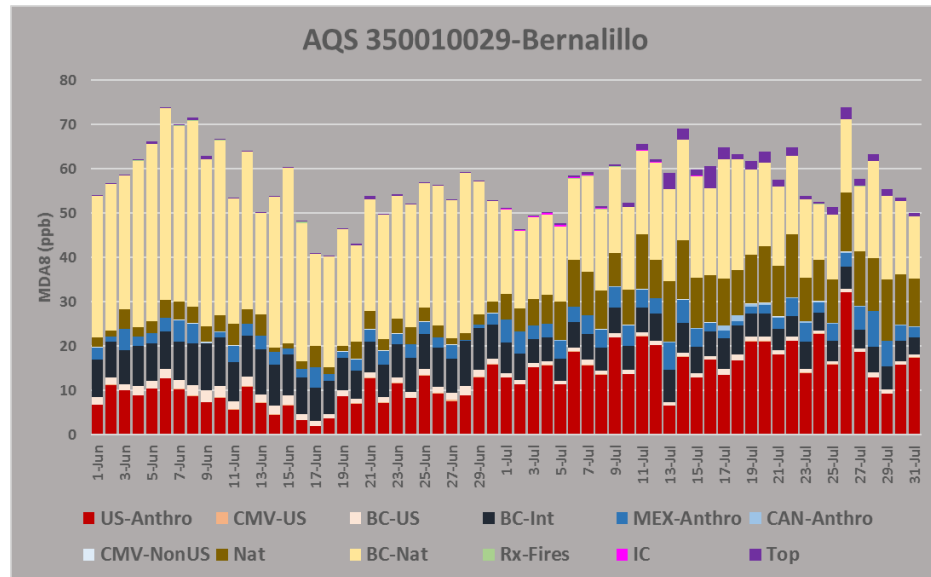
- International BC and Mexican Anthro contributions show equivalent contributions (15%)
- Peak on June 9 dominated by Natural contributions from the Boundary



Source Apportionment: Bernalillo county



- US Anthro is almost twice as large as International BC contributions
- First peak in June has large US and International contributions, second peak in July more dominated by US natural sources



GEOS-Chem Summary of Recent Updates

- WRAP 2014 Base Case used GEOS-Chem version 12.2.0 released 2019-02-19
- Current GC stable version is 12.8.2 released 2020-05-27
- Cumulative updates relevant for ozone :

Feature	Type	Version
Grid independent lightning NOx, biogenic and soil NOx emissions	Science	12.4.0
Updated offline biogenic emissions generated with GC 12.3.0	Science	12.5.0
Small alkyl nitrate chemistry	Science	12.7.0
Ozone deposition to the ocean	Science	12.8.0

http://wiki.seas.harvard.edu/geos-chem/index.php/GEOS-Chem_12#12.8.1

Conclusions: BCs from WRAP 2014 GEOS-Chem

- Initial WRAP 2014v1 CAMx and CMAQ simulations using EPA 2014 GEOS-Chem BCs exhibited large ozone overestimation bias year-round
 - Made it difficult to evaluate other model options (e.g., biogenic emissions)
- WRAP elected to conduct their own 2014 GEOS-Chem using new versions of the model and emission inventories in CAMx 2014v2 and RepBase simulation
 - Much better ozone model performance across the western states
- We more closely examined WRAP CAMx 2014v2 ozone model performance in New Mexico
 - CAMx 2014v2 ozone performance in New Mexico good mostly achieving ozone performance goals
- We examined WRAP CAMx RepBase ozone source apportionment at sites in New Mexico
 - Found approximately 60%-75% of ozone was due to BCs, BCs from natural sources higher (40-50%)
 - Higher BC ozone contribution in northwest than southeast Counties in New Mexico
- Few recent updates to GEOS-Chem could affect ozone but would likely not significantly affect ozone BCs and would affect costs and schedule

Task 1: Overview of Modeling Protocol



Modeling Protocol – 1. Introduction

1.1 New Mexico OAI Project Genesis

1.2 Overview of NM OAI Study Modeling Approach

1.3 Related Studies

1.4 Conceptual Models for High Ozone in New Mexico

1.5 Overview of the Modeling Approach

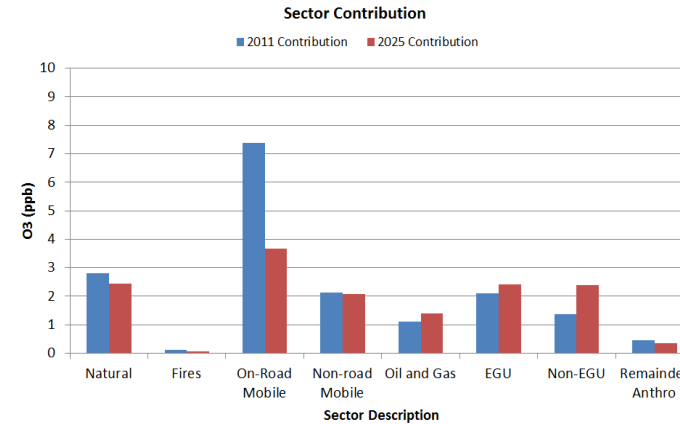
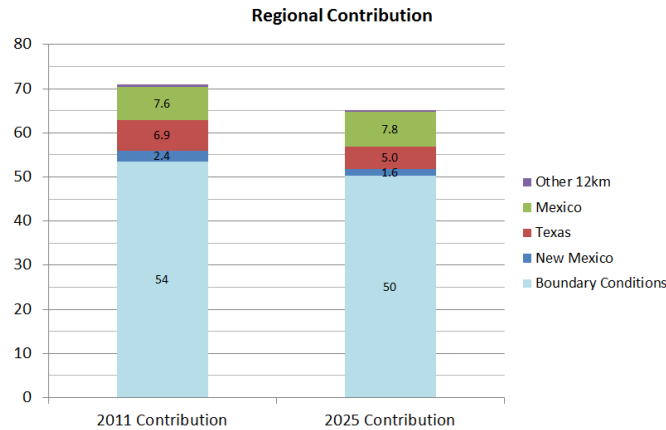
1.6 Project Participants and Contacts

1.7 Communication

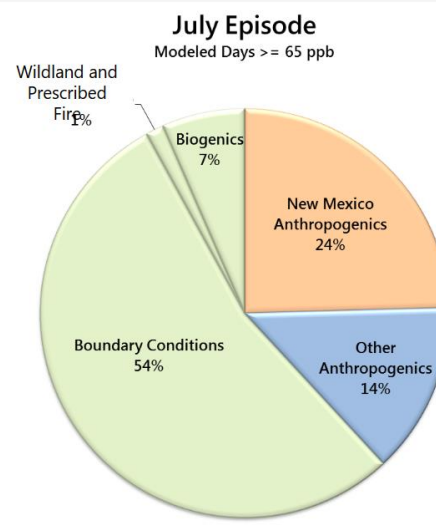
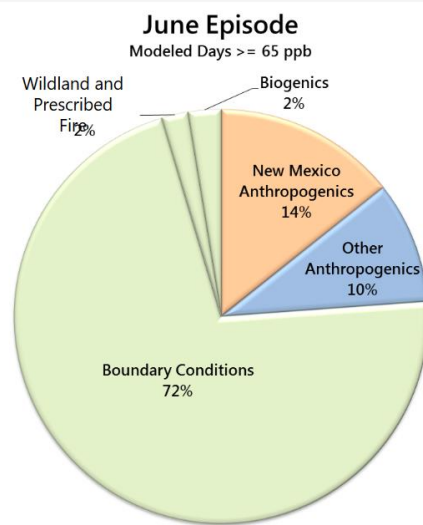
1.8 Schedule

Modeling Protocol – 1. Introduction – 1.3 Related Studies

- Southern New Mexico Ozone Study (SNMOS)
 - Contributions to 2011 and 2025 Ozone Design Values at Desert View (2-3% due to NM)



- City of Albuquerque Ozone Study – Contributions to Ozone in Albuquerque



Modeling Protocol – Model and Episode Selection

2. Model Selection

- Mainly Consistent with WRAP/WAQS 2014v2 and EPA 2016v1 modeling platforms
- CAMx – Photochemical
 - Used in WRAP, SNMOS, EPA, Denver SIP, etc.
- WRF – Meteorological
 - Current state-of-science
- SMOKE – Emissions Processor
 - Most widely used Emissions Model
- MEGAN – Biogenic Emissions
 - Selected over BEIS used in WRAP 2014v2
- GEOS-Chem – Global
 - For 36-km domain Boundary Conditions (BCs)

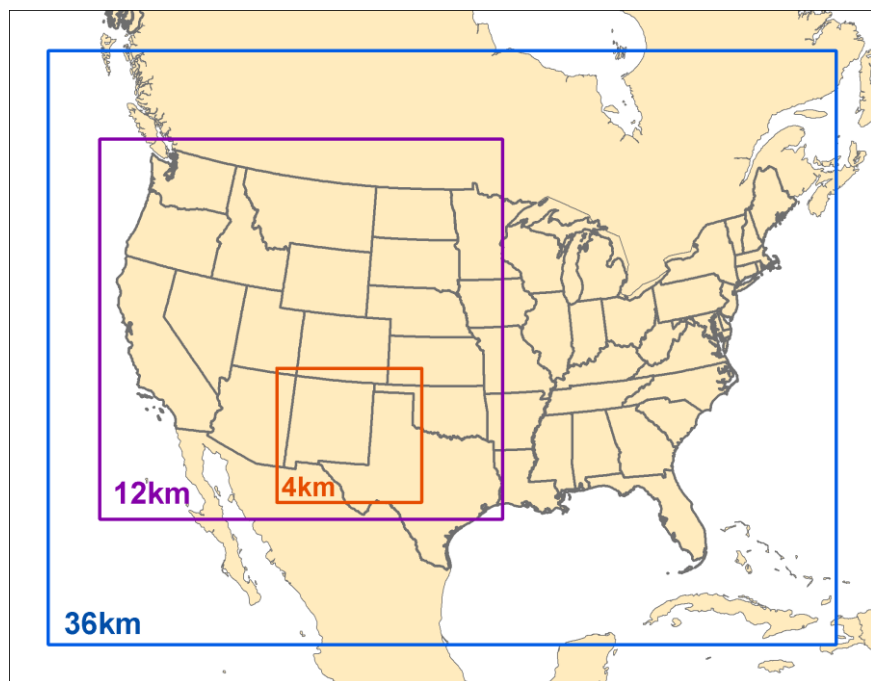
3. Episode Selection – May-Aug 2014

- Need to leverage existing photochemical modeling database so choose between 2014 or 2016
- Select 2014 because:
 - Coincides with an NEI Year
 - Higher quality emissions with updates from western states (WRAP 2014v2)
 - Observed ozone close to ozone DVs
 - 2014 has more ozone exceedance days (8) than 2016 (3)

Modeling Protocol – Domain Selection and WRF Modeling

4. Domain Selection

- 36/12/4-km domains
- 4-km domain include New Mexico and O&G production areas in San Juan and Permian Basin



5. WRF Modeling

WRF Option	NM OAI Study	2014 WAQS	2014/2015 EPA
Vertical Coordinate	Hybrid	eta	eta
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
LSM	Noah	Noah	Pleim-Xiu
PBL scheme	YSU	YSU	ACM2
Sfc Layer Physics	MM5 similarity	MM5 similarity	MM5 similarity
Cumulus	36/12/4-km Multi-scale Kain Fritsch	36/12-km Multi-scale Kain Fritsch	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

Modeling Protocol – 2014 Base Case & Model Performance Evaluation

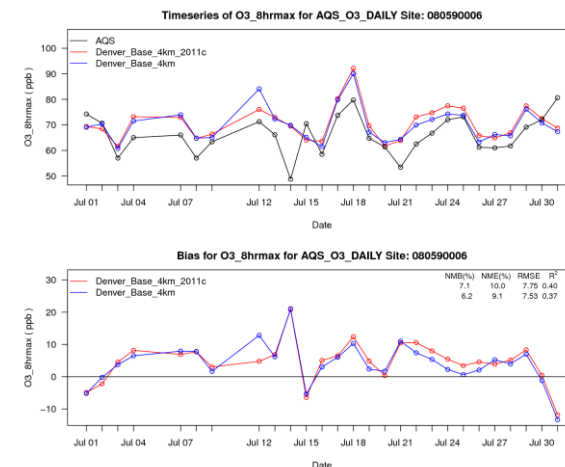
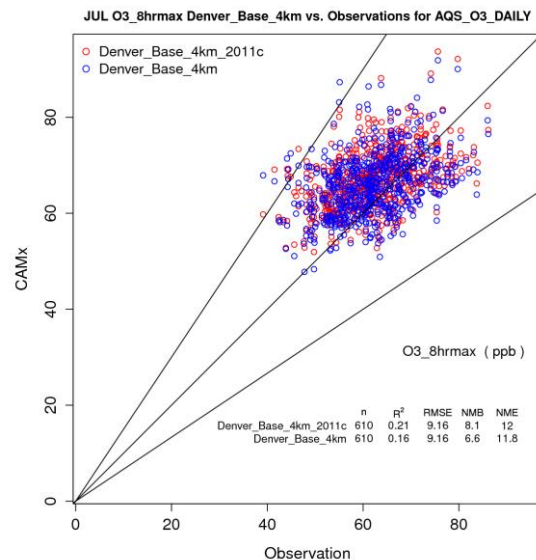
6. CAMx 2014 Inputs Preparation

- CAMx Configuration and Options

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/graupe
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/Model Performance Evaluation

- Focus on ozone performance in NM 4-km Domain
- Ozone Performance Goals and Criteria
 - NMB < 5% & NME < 15%
- AMET evaluation tool
- Diagnostic Sensitivity Tests:
 - WRF/NAM vs. WRF/ERA5
 - YSU vs. CMAQ-like Kv
- MPE Graphical Displays



Modeling Protocol – Future Year Modeling

8. 2023 CAMx Modeling

- EPA 2023fh Emission Projections
- Natural Emissions at 2016 Levels
- 2023 Control Measure Sensitivity Modeling
 - Control assumptions to be provided by NMED
- 2023 Ozone Source Apportionment
 - Design Document to be reviewed by NMED
 - Geographic Regions
 - NM, TX, OK, CO, AZ, CA, Mex, Can
 - Source Sectors
 - 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

9. Ozone Design Value (DV) Projections

- EPA recommended ozone DV projection approach uses the model in a relative sense to scale the observed ozone DVB

$$DVF_{2023} = DVB_{2014} \times RRF$$

$$RRF = \sum \text{MDA8 Ozone}_{2023} / \sum \text{MDA8 Ozone}_{2014}$$

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

10. Quality Assurance Project Plan (QAPP)

- Elements of QAPP built into sections of Modeling Protocol
- QA/QC critical component of all aspects of PGM modeling

11. References

New Mexico 2014 and 2023 Emissions



New Mexico Emissions Data

- 2014 base year anthropogenic emissions inventory for New Mexico will be based on the WAQS 2014v2 emissions
 - NMED will review the WAQS 2014v2 emissions and provide updates as needed
- 2023 anthropogenic emissions will be based on the EPA 2016v1 platform
- Onroad emissions based on SMOKE-MOVES processing with 2014 activity data and day-specific hourly gridded 2014 WRF meteorology
- O&G emissions based on state-of-the-science O&G emissions estimates from the IWDW-WAQS platform

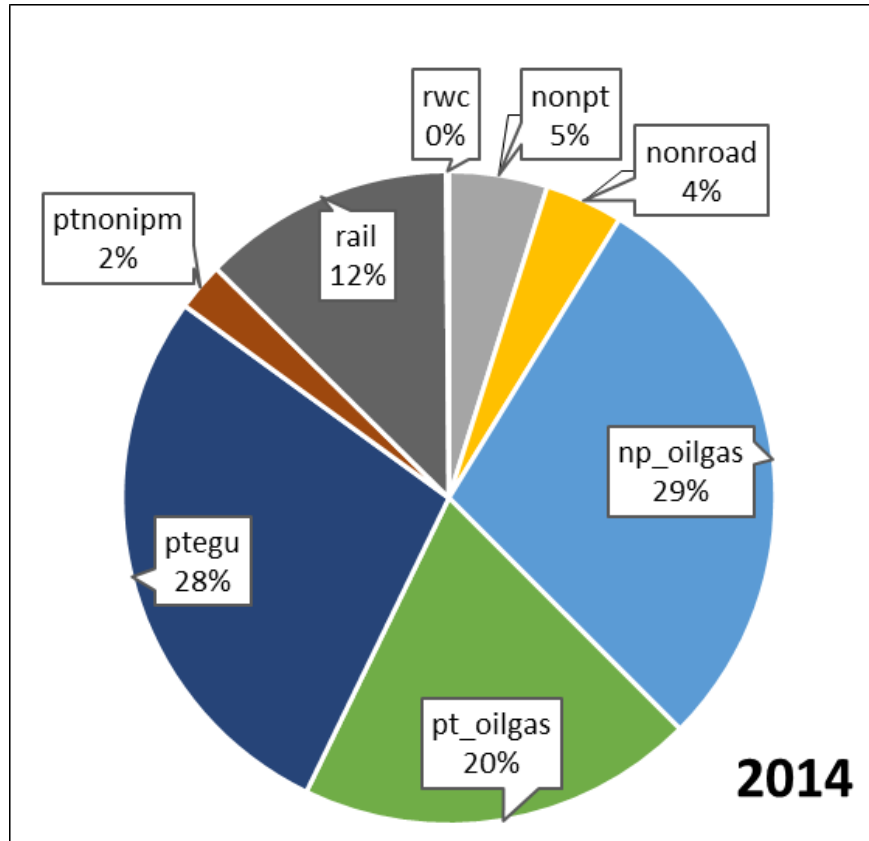
Emission Modeling

Sector Description

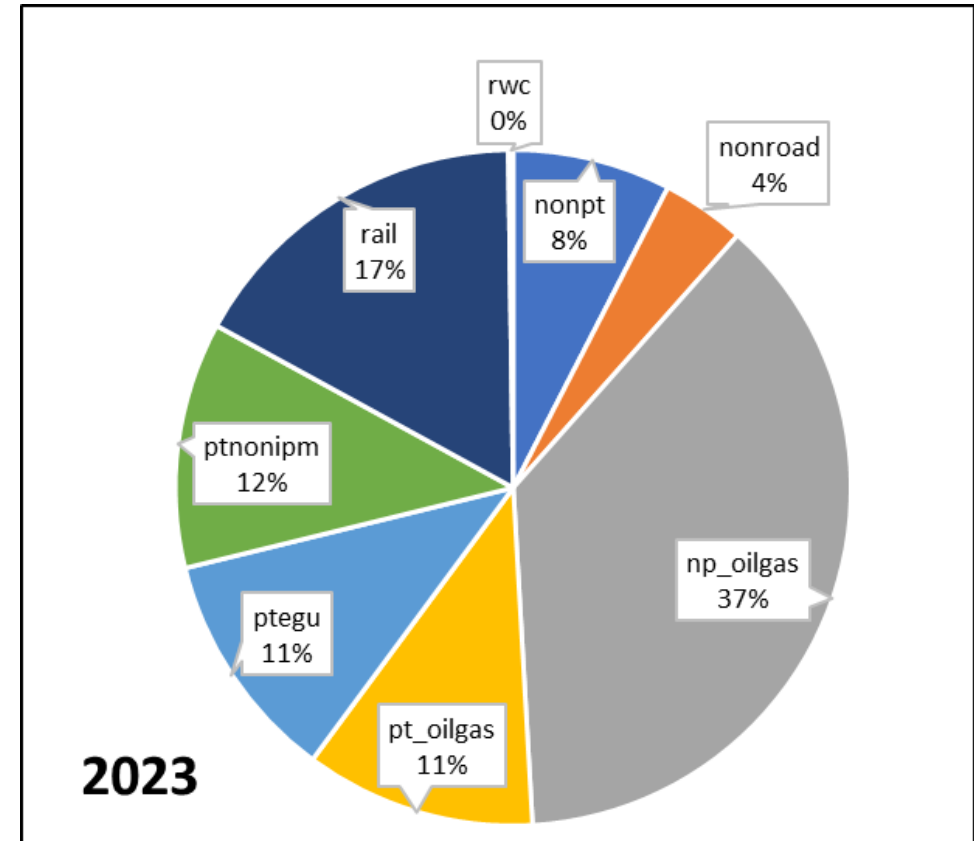
Sector	Description
afdust_adj	Area fugitive dust
ag	Agricultural ammonia sources
cmv_c1c2	Category 1 & 2 Marine Vessels
cmv_c3	Category 3 Marine Vessels
nonpt	Other nonpoint sources
np_oilgas	Non-point Oil and Gas
nonroad	Non-road mobile
onroad	On-road mobile
ptegu	EGU point sources
ptnonipm	Non-EGU point sources
pt_oilgas	Point Oil and Gas
rail	Locomotive
rwg	Residential Wood Combustion

New Mexico Emissions: 2023 vs. 2014 NOx

All anthro source categories except onroad



157,415 TPY

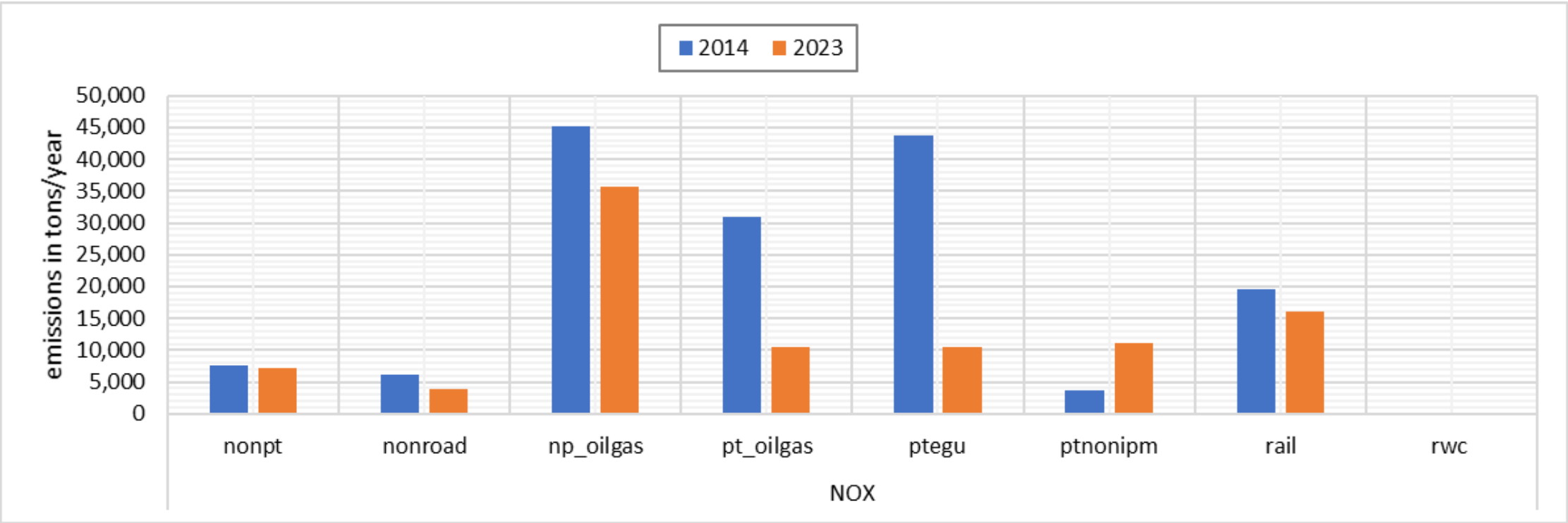


2023

95,157 TPY

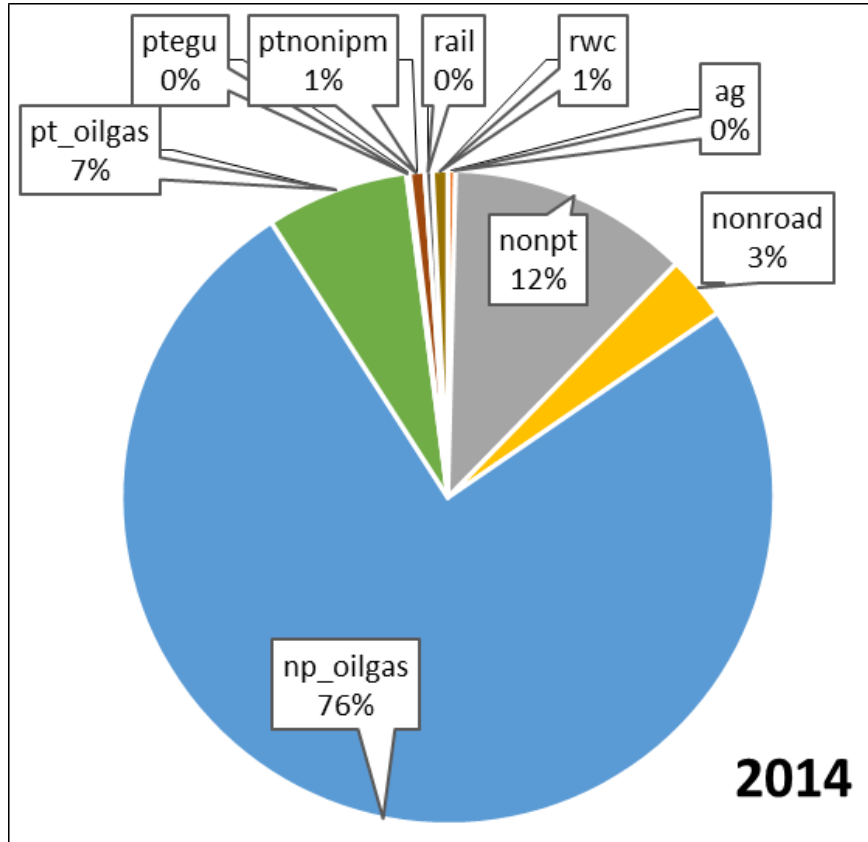
-62,258 TPY (40%) Reduction

New Mexico Emissions: 2023 vs. 2014 NOx by Source Category

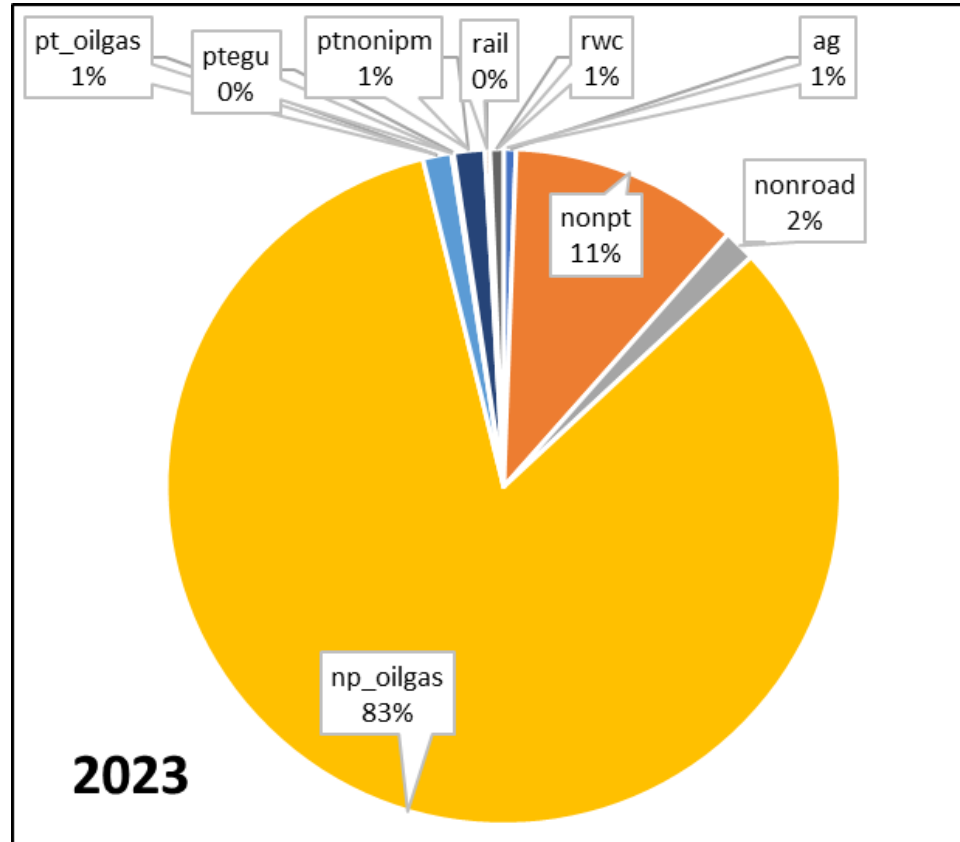


New Mexico Emissions: 2023 vs. 2014 VOC

All anthro source categories except onroad



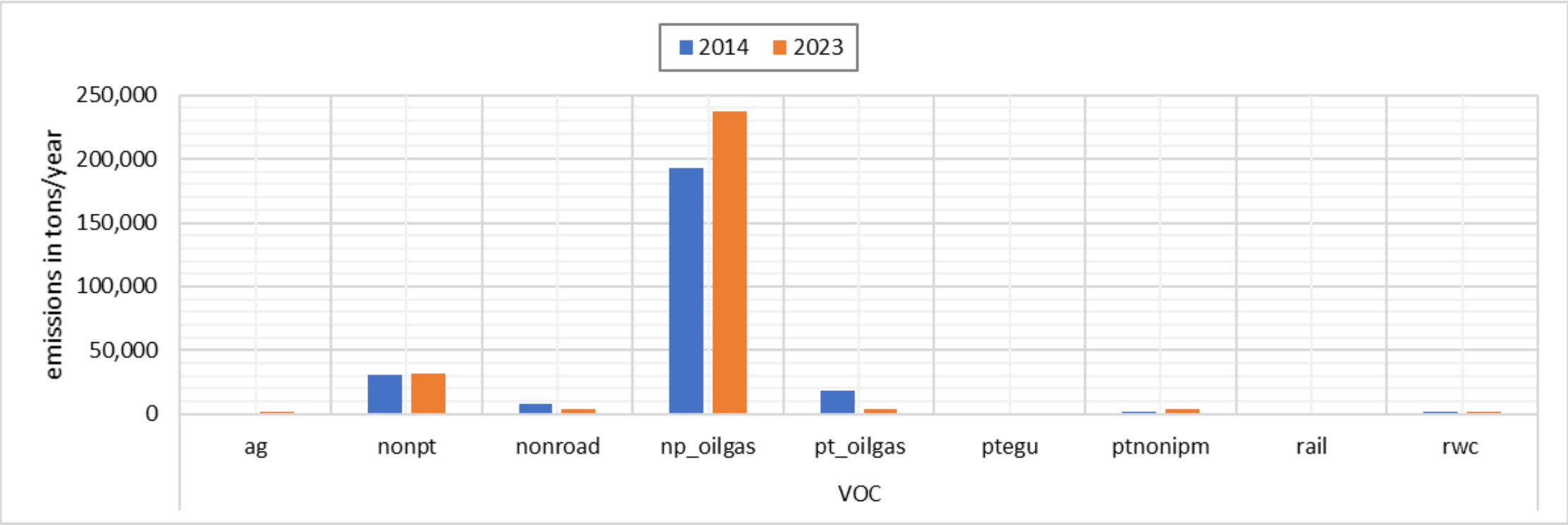
255,765 TPY



285,240 TPY

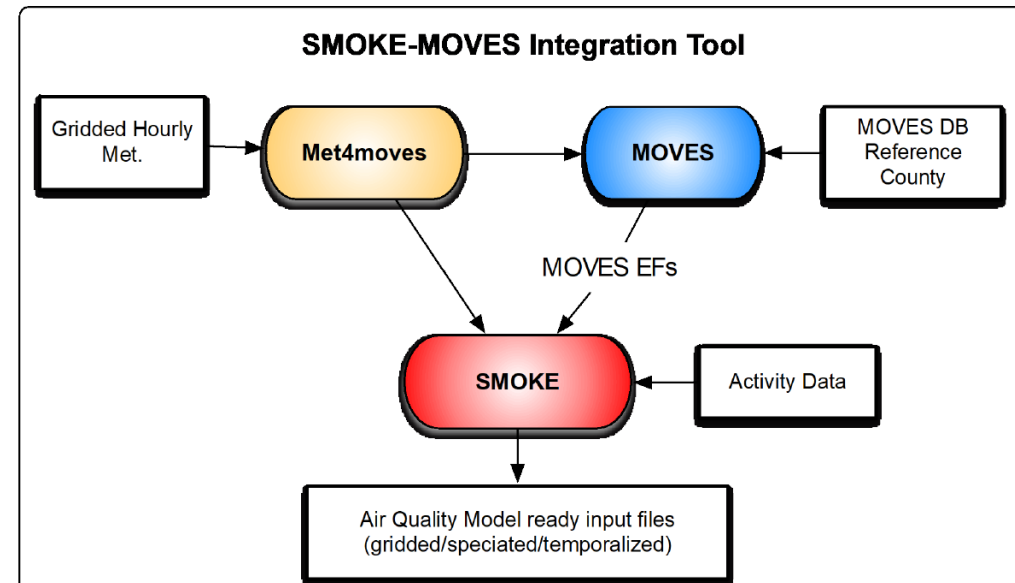
+29,475 TPY (12%) Increase

New Mexico Emissions: 2023 vs. 2014 VOC by Source Category



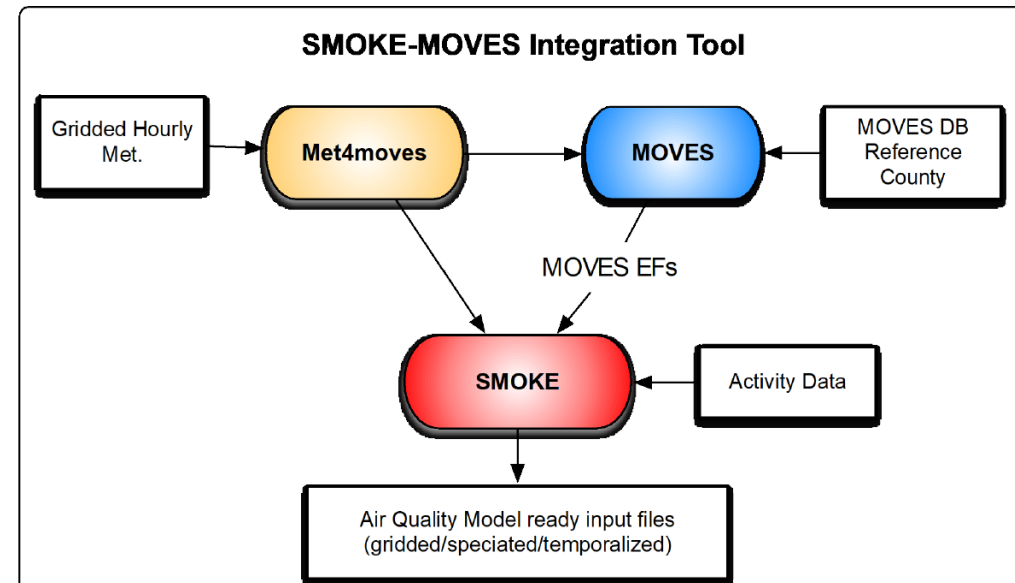
Overview of SMOKE-MOVES Processing

- Requires emission rate “lookup” tables generated by MOVES
 - EPA generated 2014 and 2023 MOVES “lookup” tables for modeling platform
- Uses gridded, hourly, day-specific temperatures
- Emission factors by temperature bin and speed for a series of “representative counties”, to which every other county is mapped



Creating Onroad Emissions using SMOKE-MOVES

- Met4MOVES: Meteorological data preprocessor
- SMOKE processing applies the emission factors to the activity data to compute grid-cell emissions
- Activity Data
 - Vehicle Miles Travelled (VMT)
 - Vehicle Population
 - Extended Idling Hours

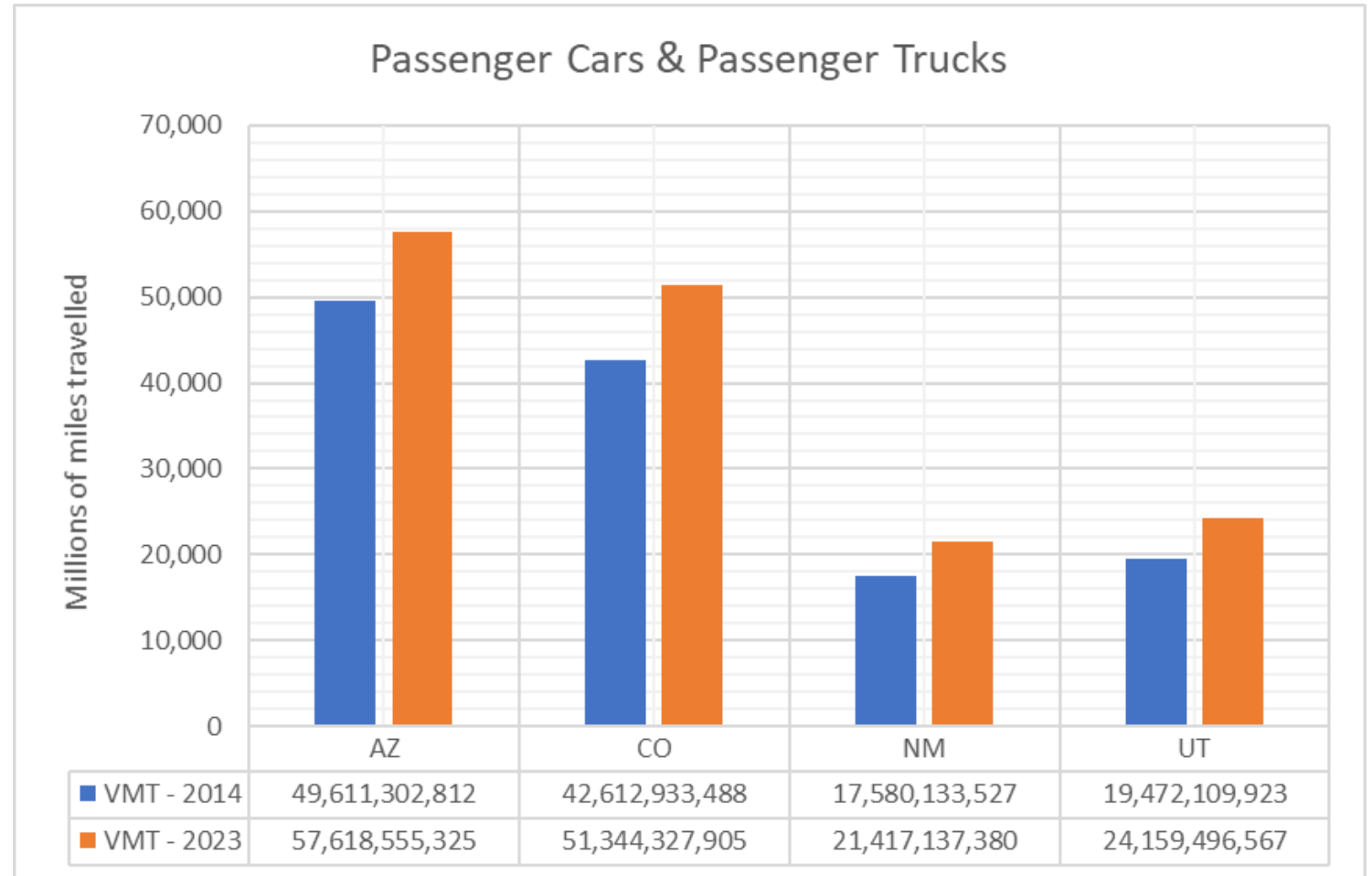


Review of On-Road Mobile Source Activity Data

- Activity data from EPA emission modeling platform
- Developed a spreadsheet tool to assist NMED to review activity data for 13 WRAP states
 - Show 2014 and 2023 population and activity of on-road vehicles
- The tab "Dashboard" shows comparisons of vehicle population and VMT by state, vehicle type, fuel type and road type.
- The tab "Scaling_factor" provides ratio of future year/base year activities by state, vehicle type and fuel type.

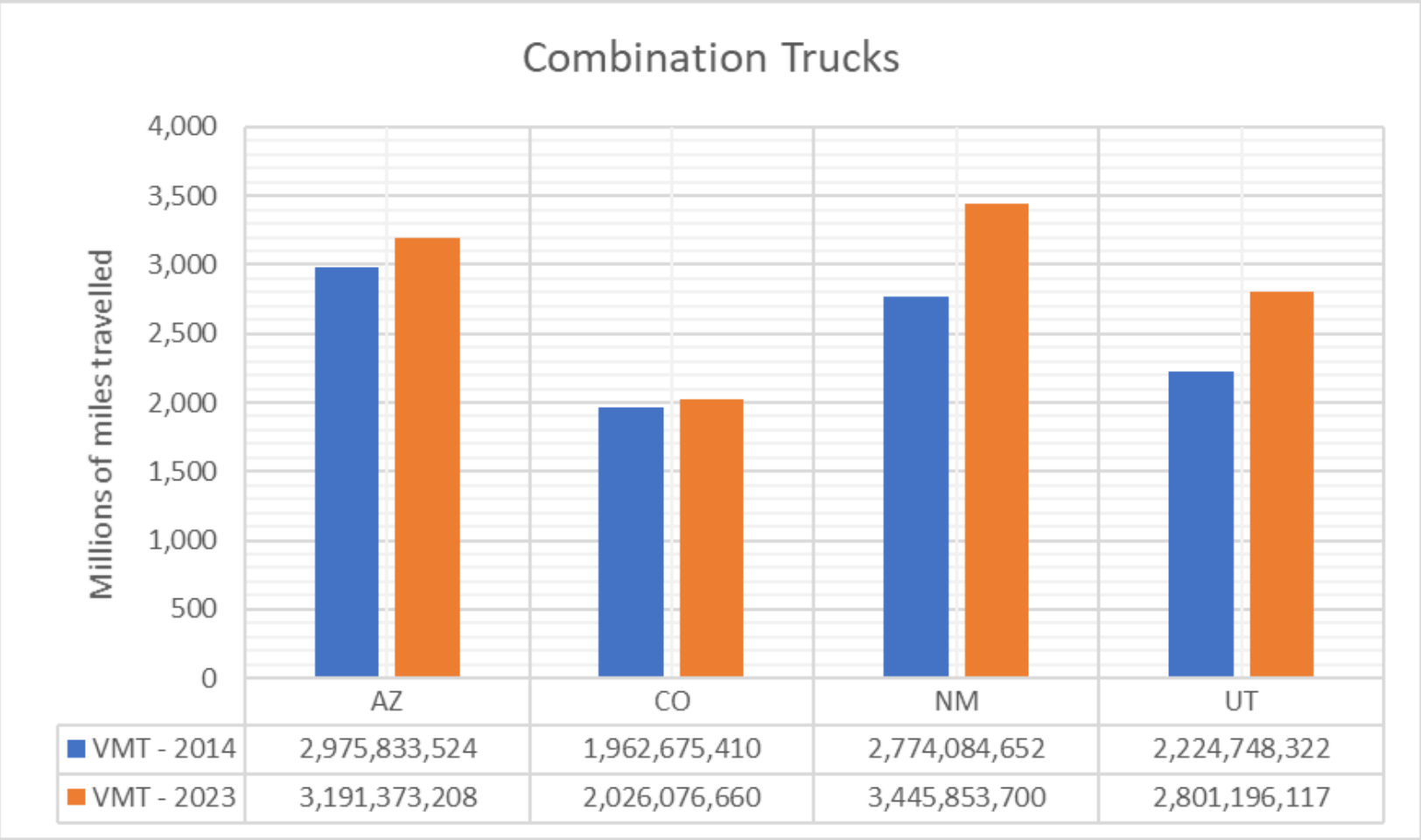
Gasoline Vehicles VMT for NM and Neighboring States

- Gasoline passenger vehicles
- Overall EPA projected 21% VMT increase in 2023 from 2014 for New Mexico



Heavy-Duty Diesel Trucks VMT for NM and Neighboring States

- Heavy-duty diesel truck VMT
- Overall EPA estimated 24% VMT increase in 2023 from 2014



Example Plots that can be Created with the Tool

Color

- Currently selected option which contains Data
- Currently selected option which does not contain Data
- Unselected option which contains Data
- Unselected option which does not contain Data

Symbol

- denotes button is on - used to filter/deselect multiple options in each slicer by a single click
- Click to clear all filters

Year

2014

2023

State

AZ CA CO ID MT

ND NM NV OR SD

UT WA WY

Activity Type

Vehicle Population VMT

Auxiliary Power Usage Hours Extended Idle Usage Hours

FuelType

Diesel

E-85

Electricity

Gasoline

CNG

RoadType

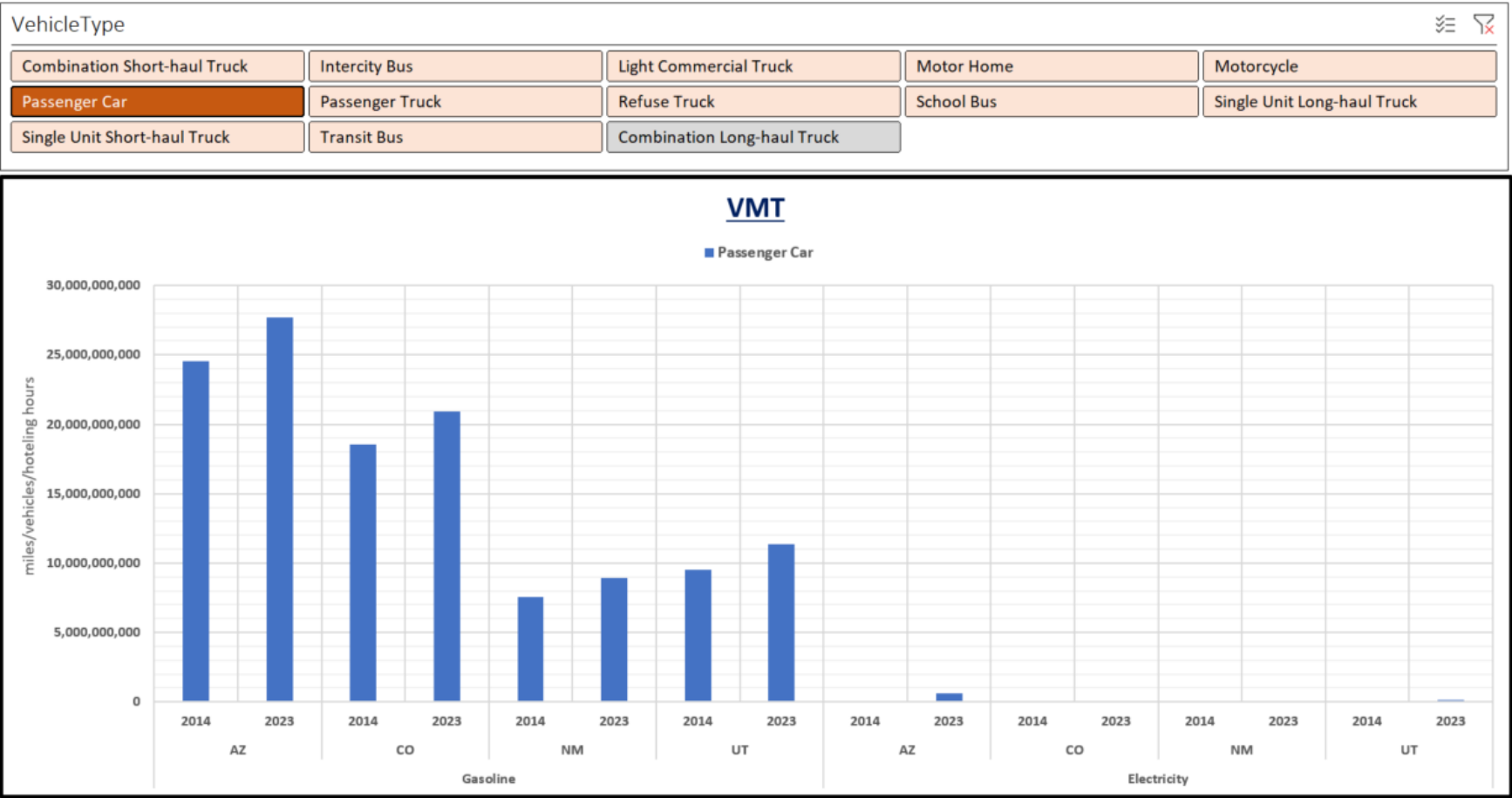
Rural Restricted Access

Rural Unrestricted Access

Urban Restricted Access

Urban Unrestricted Access

Off-Network



**Vehicle population data do not vary by road type. To show vehicle population, select Off-Network under road type.

- Gasoline and Electric Passenger car VMT comparison for 2014 and 2023

Color

- Currently selected option which contains Data
- Currently selected option which does not contain Data
- Unselected option which contains Data
- Unselected option which does not contain Data

Symbol

- denotes button is on - used to filter/deselect multiple options in each slicer by a single click
- Click to clear all filters

Year

2014
2023

State

AZ

CA

CO

ID

MT

ND

NM

NV

OR

SD

UT

WA

WY

Activity Type

Vehicle Population

VTM

Auxiliary Power Usage Hours

Extended Idle Usage Hours

FuelType

Diesel

Gasoline

CNG

E-85

Electricity

RoadType

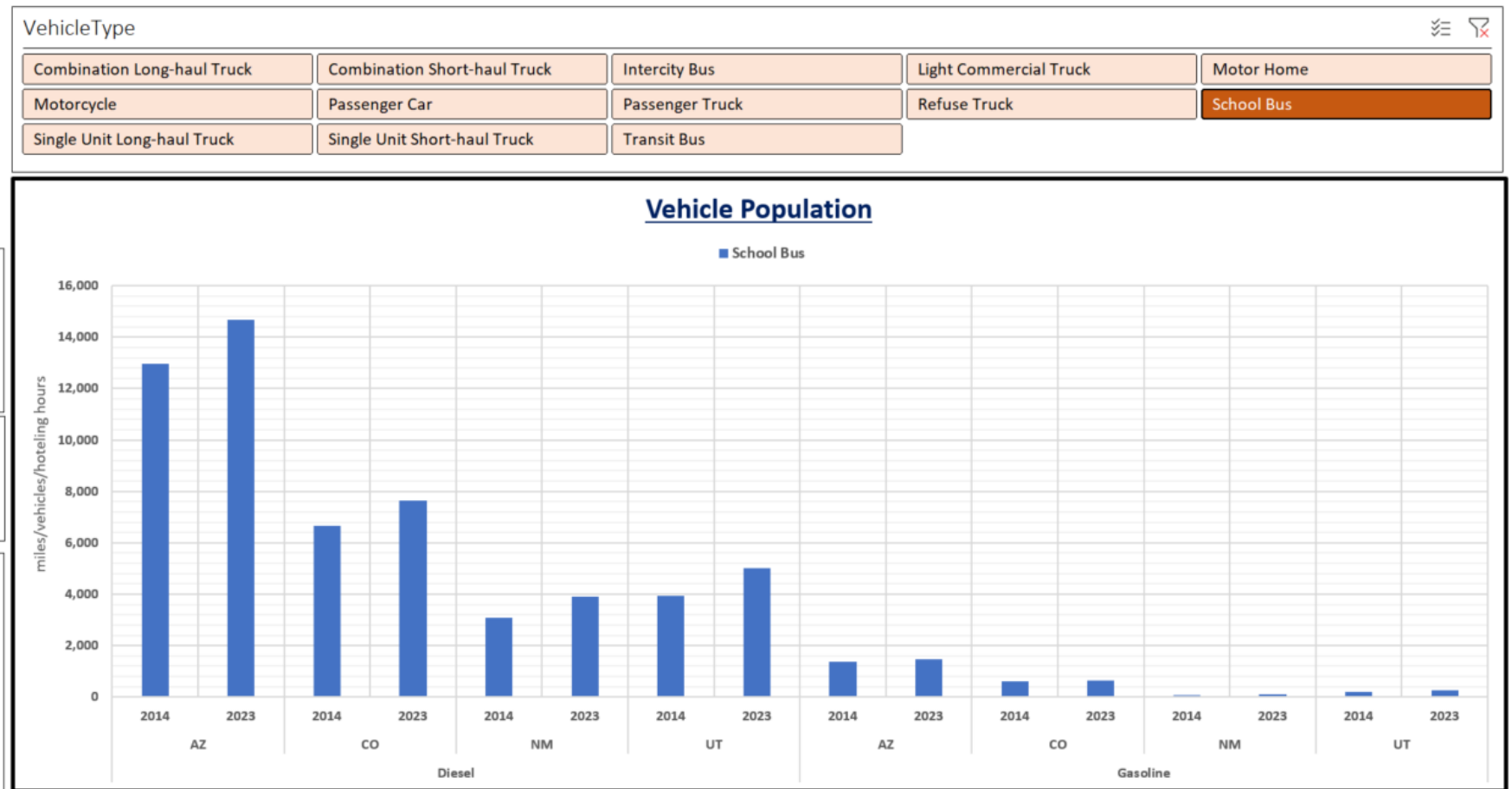
Off-Network

Rural Restricted Access

Rural Unrestricted Access

Urban Restricted Access

Urban Unrestricted Access



**Vehicle population data do not vary by road type. To show vehicle population, select Off-Network under road type.

- School bus population comparison for NM, AZ, UT and CO by fuel type

Color

Currently selected option which contains Data

Currently selected option which does not contain Data

Unselected option which contains Data

Unselected option which does not contain Data

Symbol

denotes button is on - used to filter/deselect multiple options in each slicer by a single click

Click to clear all filters

Year

2014

2023

State

AZ

CA

CO

ID

MT

ND

NM

NV

OR

SD

UT

WA

WY

Activity Type

Auxiliary Power Usage Hours

Extended Idle Usage Hours

Vehicle Population

VMT

FuelType

CNG

Diesel

E-85

Gasoline

Electricity

RoadType

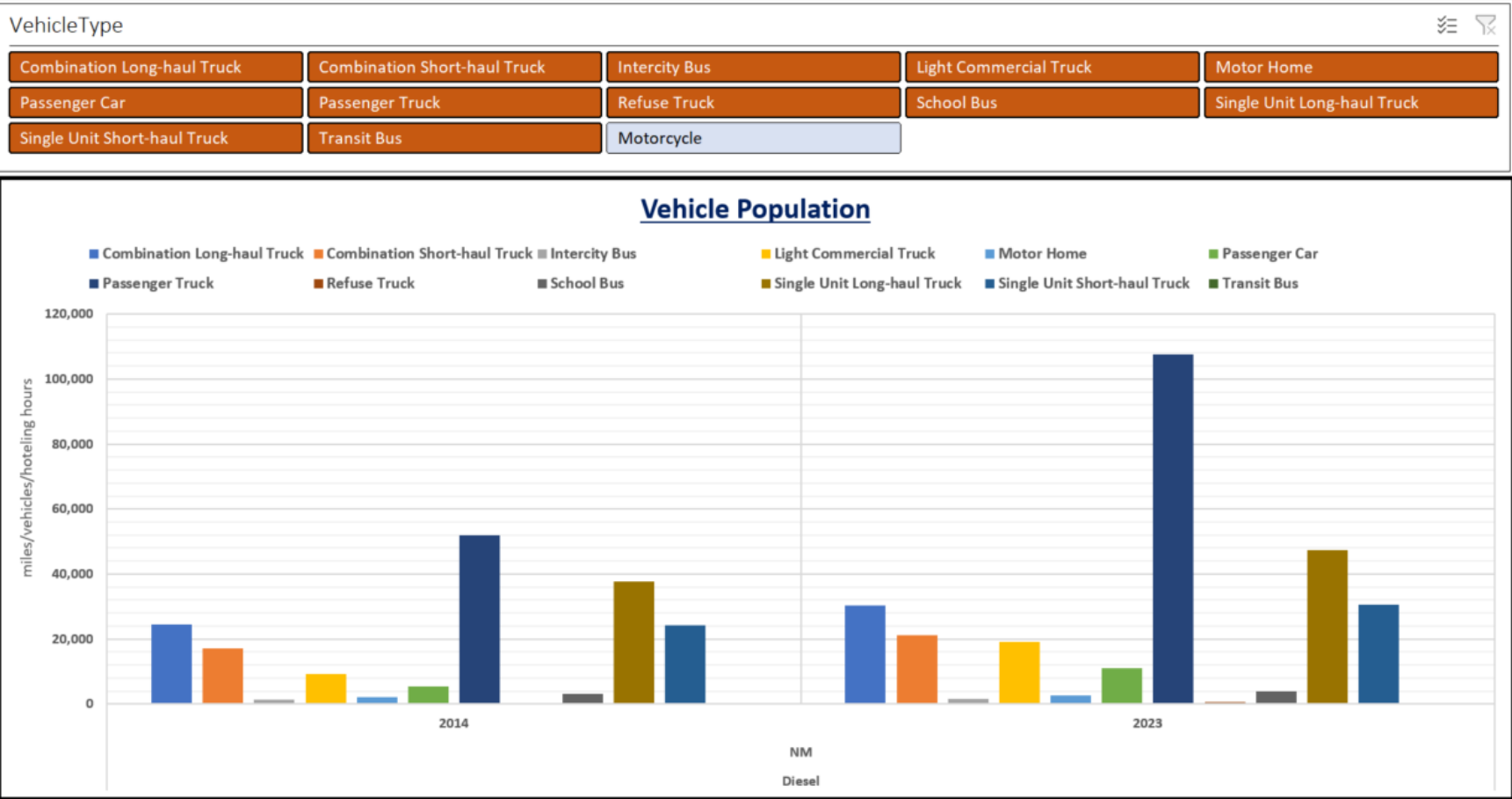
Off-Network

Rural Restricted Access

Rural Unrestricted Access

Urban Restricted Access

Urban Unrestricted Access



Color

- Currently selected option which contains Data
- Currently selected option which does not contain Data
- Unselected option which contains Data
- Unselected option which does not contain Data

Symbol

- denotes button is on - used to filter/deselect multiple options in each slicer by a single click
- Click to clear all filters

Year

2014

2023

State

AZ CA CO ID MT

ND NM NV OR SD

UT WA WY

Activity Type

Auxiliary Power Usage Hours

Extended Idle Usage Hours

Vehicle Population

VMT

FuelType

CNG

Diesel

E-85

Gasoline

Electricity

RoadType

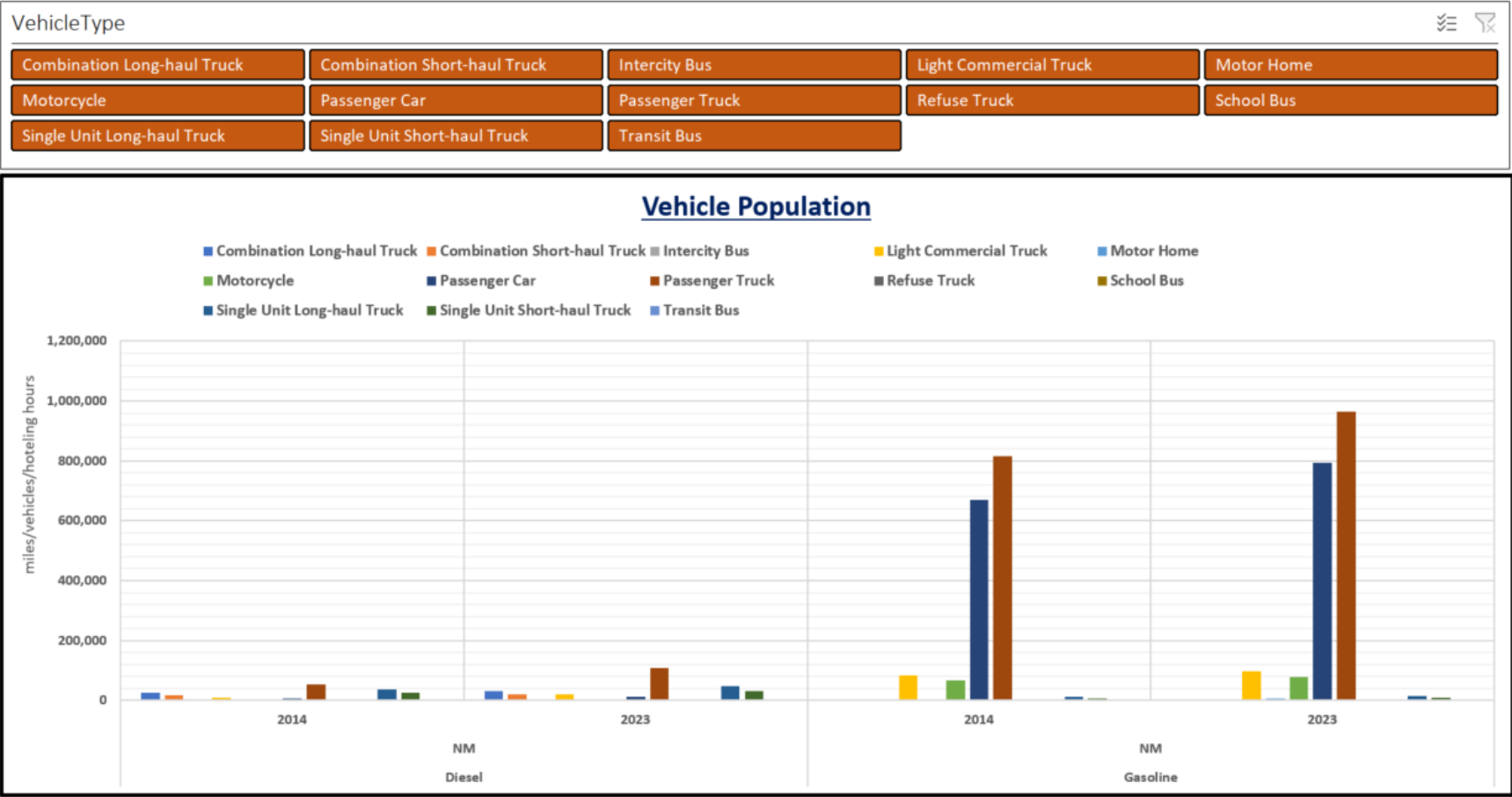
Off-Network

Rural Restricted Access

Rural Unrestricted Access

Urban Restricted Access

Urban Unrestricted Access



Vehicle Population

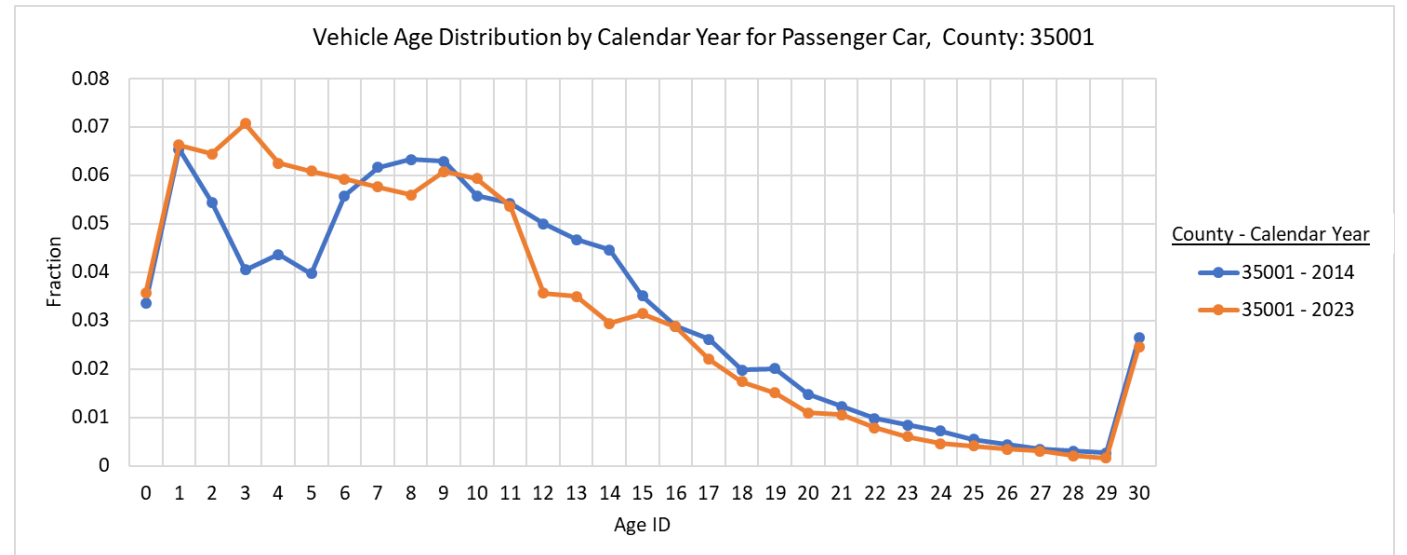
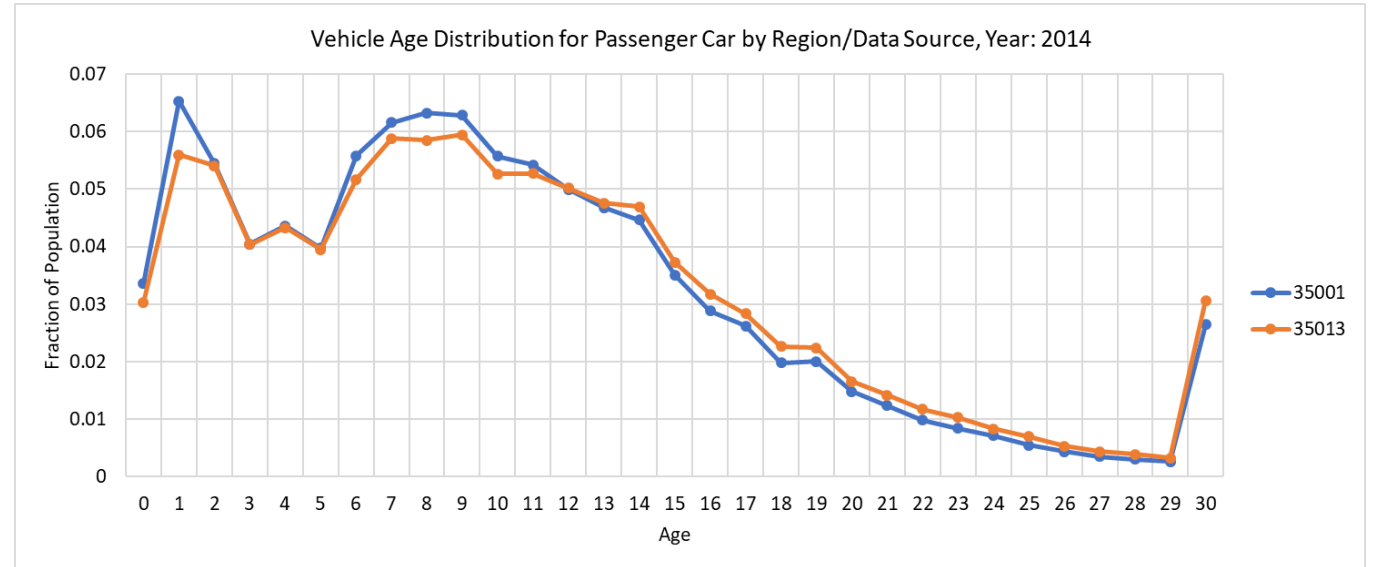
Vehicle Type	2014 NM Diesel	2023 NM Diesel	2014 NM Gasoline	2023 NM Gasoline
Combination Long-haul Truck	~10,000	~10,000	~10,000	~10,000
Combination Short-haul Truck	~10,000	~10,000	~10,000	~10,000
Intercity Bus	~10,000	~10,000	~10,000	~10,000
Light Commercial Truck	~10,000	~10,000	~10,000	~10,000
Motor Home	~10,000	~10,000	~10,000	~10,000
Motorcycle	~10,000	~10,000	~10,000	~10,000
Passenger Car	~10,000	~10,000	~10,000	~10,000
Passenger Truck	~10,000	~10,000	~10,000	~10,000
Refuse Truck	~10,000	~10,000	~10,000	~10,000
School Bus	~10,000	~10,000	~10,000	~10,000
Single Unit Long-haul Truck	~10,000	~10,000	~10,000	~10,000
Single Unit Short-haul Truck	~10,000	~10,000	~10,000	~10,000
Transit Bus	~10,000	~10,000	~10,000	~10,000

**Vehicle population data do not vary by road type. To show vehicle population, select Off-Network under road type.

- NM diesel and gasoline vehicle population by vehicle type

MOVES Inputs: Vehicle Age Distribution

- Vehicle age distribution for passenger cars
- The last bin of age distribution represents vehicles 30 year and older



MOVES Inputs: I&M Coverage

Inspection and Maintenance Coverage (imcoverage table)

Source: MOVES2014b defaults

				Compliance Factor (%)*								
Rep county affected	Calendar Year	Program Test	Range of ModelYears affected	Pollutant_Emissions Process Affected	Passenger Car_Gasoline	Light Commercial Truck_Gasoline	Passenger Truck_Gasoline	Light Commercial Truck_Ethanol	Passenger Car_Ethanol	Passenger Truck_Ethanol	Single Unit Short-haul Truck_Gasoline	Single Unit Short-haul Truck_Ethanol
35001	2014	Exhaust OBD** Check	1996_2012	CO_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				CO_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				NOx_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				NOx_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				THC_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				THC_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
		Evaporative Gas Cap Check	1975_2006	THC_Evap Fuel Vapor Venting							93.1	93.1
			1975_1995	THC_Evap Fuel Vapor Venting								
		Two-mode, 2500 RPM/Idle Test	1975_1995	CO_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				CO_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				THC_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				THC_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
		Evaporative System OBD Check	1996_2012	THC_Evap Fuel Vapor Venting	93.1	93.1	93.1	93.1	93.1	93.1		
			2007_2012	THC_Evap Fuel Vapor Venting							93.1	93.1
	2023	Exhaust OBD Check	1996_2021	CO_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				CO_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				NOx_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				NOx_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				THC_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				THC_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
		Evaporative Gas Cap Check	1975_2006	THC_Evap Fuel Vapor Venting							93.1	93.1
			1975_1995	THC_Evap Fuel Vapor Venting	93.1	93.1	93.1	93.1	93.1	93.1		
		Two-mode, 2500 RPM/Idle Test	1975_1995	CO_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				CO_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				THC_Running Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
				THC_Start Exhaust	93.1	93.1	93.1	93.1	93.1	93.1	93.1	93.1
		Evaporative System OBD Check	1996_2021	THC_Evap Fuel Vapor Venting	93.1	93.1	93.1	93.1	93.1	93.1		
			2007_2021	THC_Evap Fuel Vapor Venting							93.1	93.1

Note: CDBs from 2016v1 and 2014v7.1 platforms did not include local/state IM coverage information. Platforms used MOVES defaults data where available.

MOVES2014b default database includes I/M coverage information only for Rep County 35001, other counties would be assumed to not have I/M program.

*The compliance factor represents the percentage of vehicles within a source type that actually receive the benefits of the program

**On-Board Diagnostics (OBD)

NM OAI Study Next Steps



Next Up in June 2020

- A little ahead of schedule (Task 3 completed month early)
- Need comments from NMED on Modeling Protocol and Work Plan
- Need approval from NMED to proceed with WRAP 2014v2 and EPA 2023 New Mexico emissions and mobile source assumptions
- Task 2.2 WRF modeling simulation will be finished in early June.
 - Conduct MPE and CAMx sensitivity test modeling
- Task 3 Evaluate BC data completed a month ahead of schedule (May instead of Jun)
- Task 4 -- Would like to start 2014 SMOKE and SMOKE-MOVES emissions modeling in June

New Mexico OAI Study Photochemical Modeling – 2nd Monthly Webinar June 2020



WESTAR and Ramboll

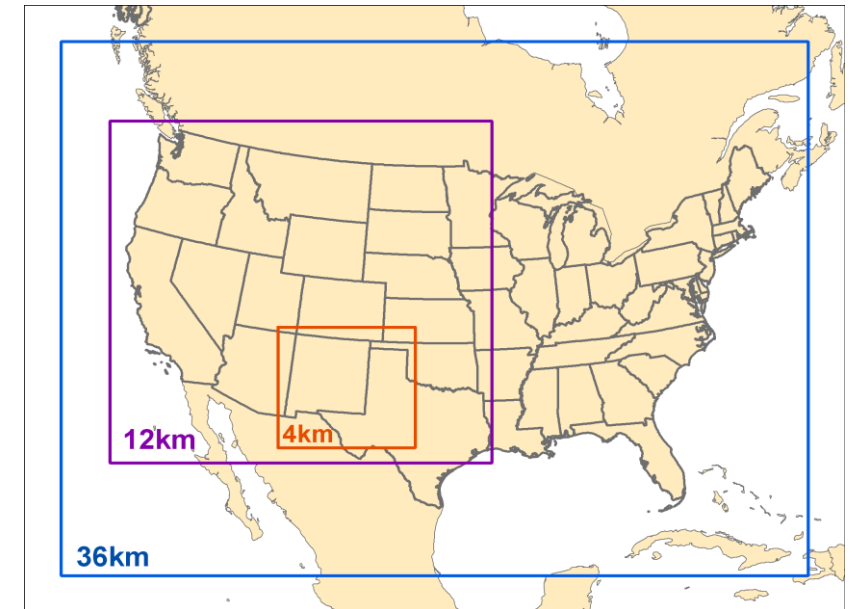
June 26, 2020

Content

- Introduction
- Overview of NMED OAI Modeling Project
- Summary of May 28, 2020 Webinar
- NMED OAI Modeling Study Website
 - <https://www.wrapair2.org/NMOAI.aspx>
- 2014 and 2023 New Mexico Emissions
- 2014 36/12/4-km WRF Meteorological Modeling and Model Evaluation
- Next Steps
- Discussion

Overview of NMED OAI Modeling Study Tasks

- Task 1: Development Modeling Protocol/QAPP and Work Plan -- Completed
- Task 2: WRF Meteorological Modeling -- Completed
- Task 3: Evaluate Boundary Condition Inputs – Completed
- Task 4: 2014 and 2023 Emissions Development
 - Sources of 2014 and 2023 Emissions -- Completed
 - Sources of Mobile Source Emissions -- Completed
 - Natural Emissions; SMOKE Emissions Modeling; 2023 Controls
- Task 5: CAMx 2014 Base Case Modeling
 - Formal 2014 Base Case and MPE Report
- Task 6: 2023 Future Year CAMx Modeling
 - 2023 Base, Source Apportionment and Control Measure Evaluation
- Task 7: Air Quality Technical Support Document (AQTSD)
 - Formal AQTSD; Transfer Data and Results to IWDW



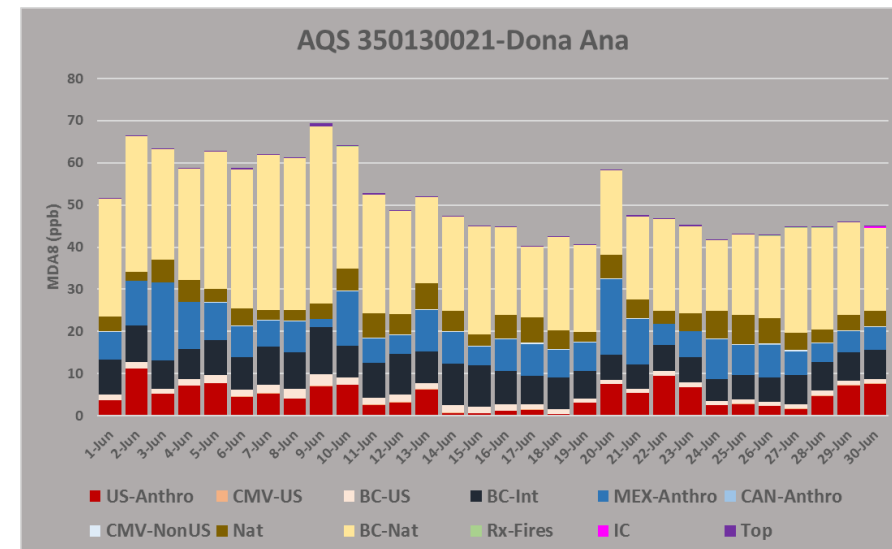
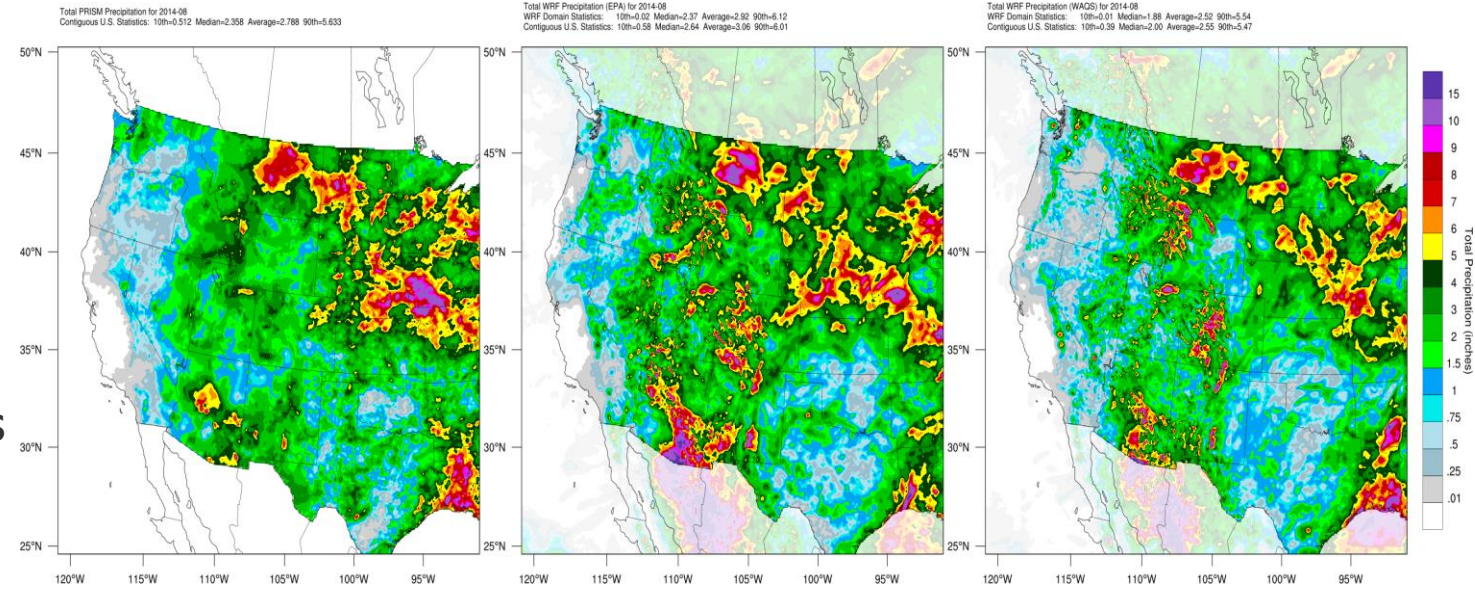
OVERVIEW OF MAY 26, 2020 WEBINAR

PRISM

EPA 12

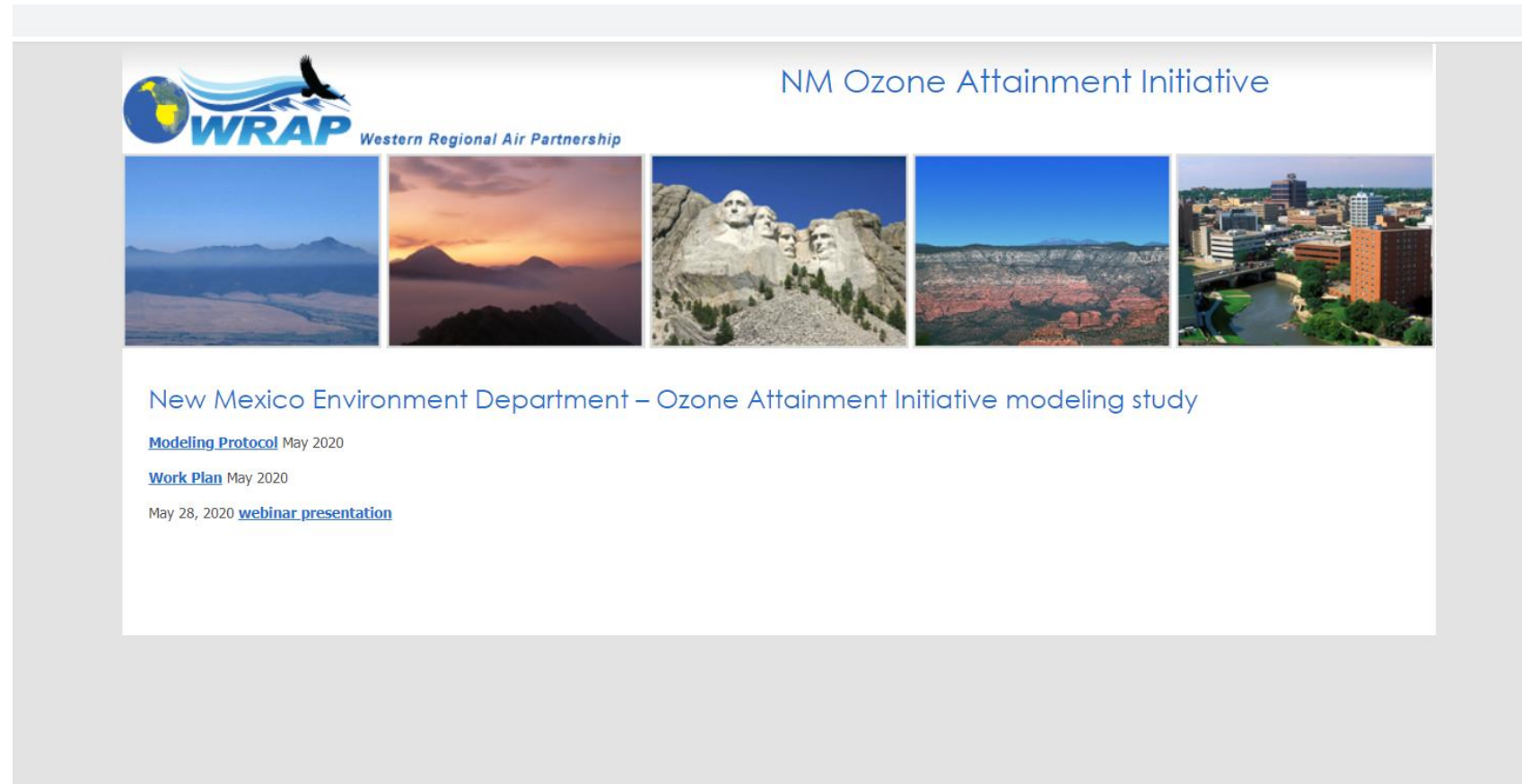
WAQS

- Evaluation of Existing 2014 WRF Meteorological Modeling
 - EPA vs. WAQS 2014 WRF Modeling
 - NMED 2014 WRF following WAQS
- Evaluation of 2014 GEOS-Chem BCs
 - Deemed adequate
- Overview of Modeling Protocol and Work Plan
- 2014 and 2023 New Mexico Emissions
 - Request comments by June 12
- Next Steps



NMED OAI MODELING STUDY WEBSITE

- <https://www.wrapair2.org/NMOAI.aspx>



2014 AND 2023 EMISSIONS



New Mexico Emissions Data

- 2014 anthropogenic emissions are based on the WAQS 2014v2
 - NMED provided information on a piece of equipment missing from the inventory (NOx 94 TPY and VOC 1 TPY)
 - Consistent emissions between Regional Haze and OAI studies
- 2023 anthropogenic emissions are based on the EPA 2016v1 platform
 - NMED updates: some Title V facilities are duplicates in the pt_oilgas and ptnonipm sectors
 - Added Lordsburg Generating Station missing from the 2023 inventory
- On-Road emissions based on SMOKE-MOVES processing with 2014/2023 activity data and day-specific hourly gridded 2014 WRF meteorology
- O&G emissions based on state-of-the-science O&G emissions estimates from the IWDW-WAQS platform

2014 update

facility_name	sector	CO	NOX	PM10	PM25	SO2	VOC
Saunders Gas Plant	pt_oilgas	6	94	0	0	0	1

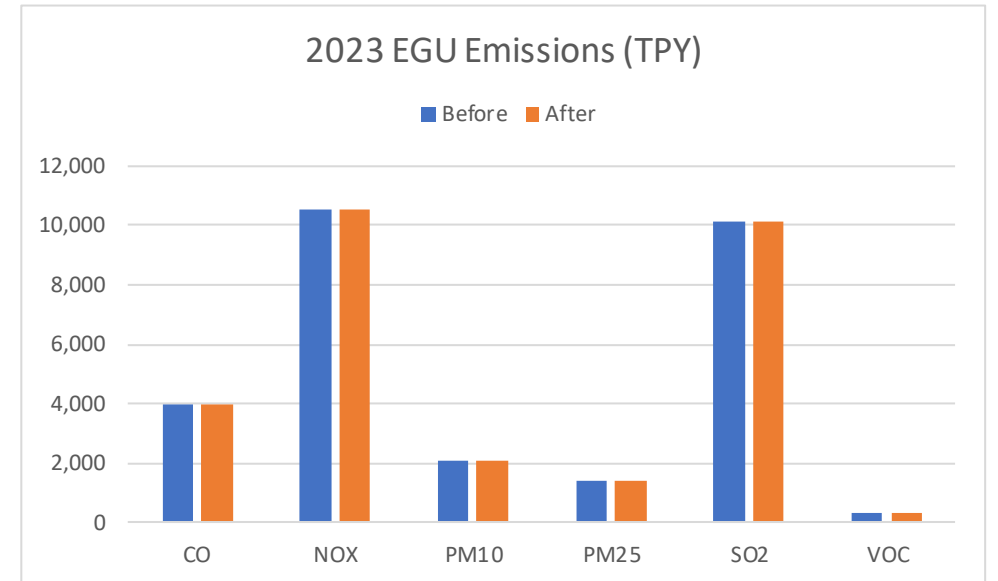
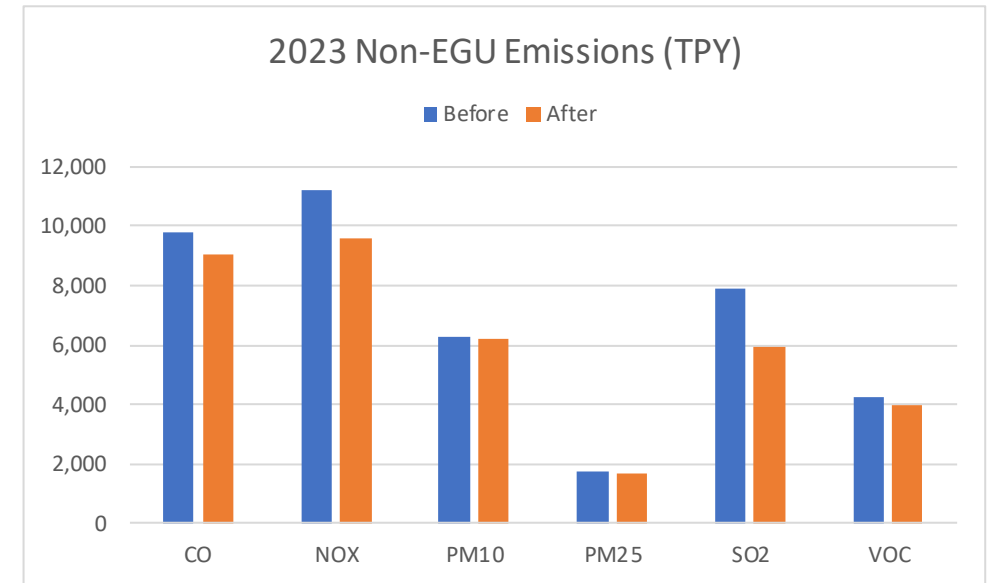
2023 NEW MEXICO EMISSIONS – DUPLICATE EMISSIONS

facility_name	sector	CO	NH3	NOX	PM10	PM25	SO2	VOC
Hope Pump Station	pt_oilgas	48	0	204	0	0	0	10
NuStar Logistics Operation LP - Hope Pump Station	ptnonipm	4	0	101	0	0	0	0
Durango Midstream - Empire Abo Gas Plant - CS	pt_oilgas	142	0	546	20	20	1,184	623
Empire Abo Gas Plant/Compressor Station	ptnonipm	12	0	84	0	0	162	42
Durango Midstream - Maljamar Gas Plant	pt_oilgas	239	0	305	14	14	417	250
Maljamar Gas Plant	ptnonipm	50	0	87	7	7	213	57
DCP - Linam Ranch Gas Plant	pt_oilgas	345	0	547	23	19	300	163
Linam Ranch Gas Plant	ptnonipm	449	0	692	28	28	109	103
DCP - Eunice Gas Plant	pt_oilgas	183	0	526	7	6	1,585	67
DCP Midstream - Eunice Gas Plant	ptnonipm	224	0	606	11	11	1,437	70
Mid-America Pipeline - San Luis Pump Station	pt_oilgas	4	0	8	0	0	0	8
San Luis Pump Station	ptnonipm	2	0	3	0	0	0	1
Huerfano Pump Station	ptnonipm	10	0	25	1	1	0	23
Mid-America Pipeline - Huerfano Pump Station	pt_oilgas	5	0	14	1	1	0	16
Lordsburg Generating Station	ptegu	2	0	3	0	0	0	1

Some O&G sources not classified as O&G and incorrectly placed in Non-EGU Point Source Sector in EPA's 2023fh emission projections so got double counted when EPA 2023 O&G was replaced by WRAP 2023 O&G

2023 NM EMISSIONS UPDATES

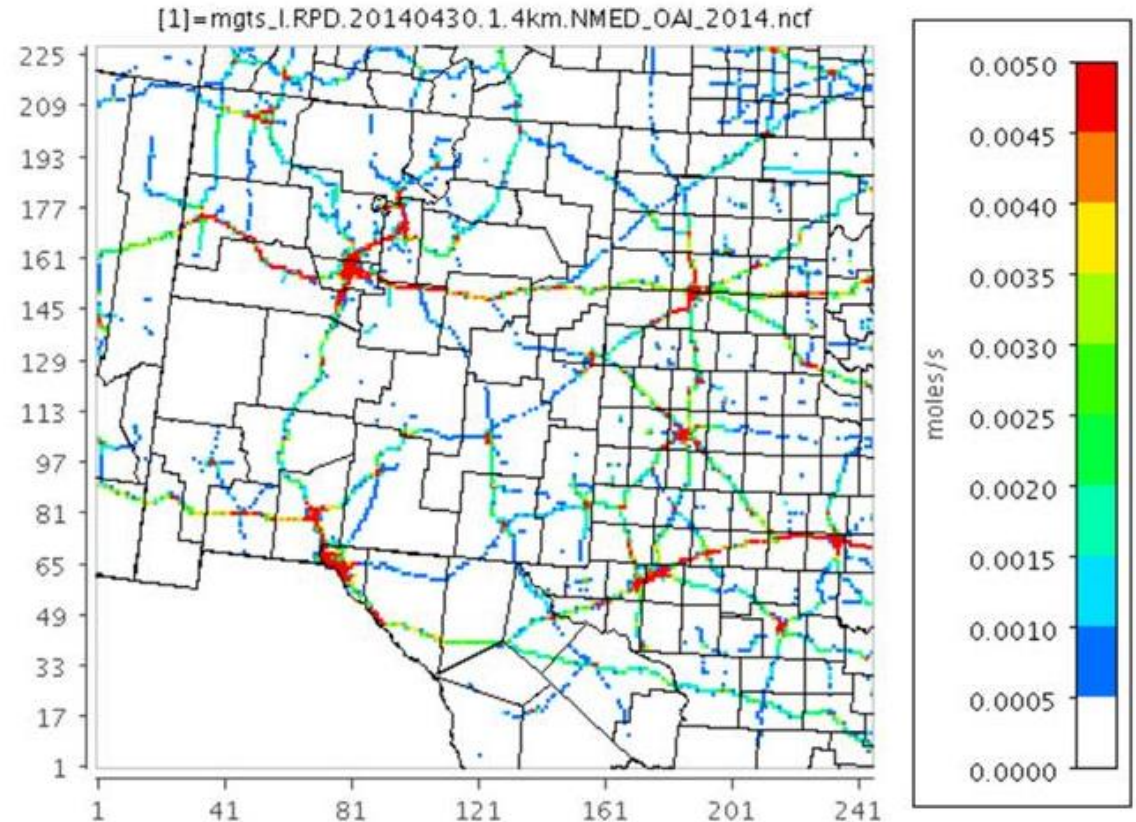
Duplicate Sources						
	CO	NOX	PM10	PM25	SO2	VOC
Ptnonipm	751	1,599	48	48	1,921	297
Original inventory (total emissions)						
	CO	NOX	PM10	PM25	SO2	VOC
Pt_oilgas	38,732	44,062	1,150	1,104	12,864	32,934
Ptnonipm	9,774	11,208	6,273	1,744	7,881	4,232
Ptegu	3,963	10,516	2,040	1,365	10,122	312
Updated total emissions (removing duplicates)						
	CO	NOX	PM10	PM25	SO2	VOC
Pt_oilgas	38,732	44,062	1,150	1,104	12,864	32,934
Ptnonipm	9,023	9,609	6,225	1,696	5,960	3,936
Ptegu	3,965	10,519	2,040	1,365	10,122	312



SMOKE PROCESSING

- SMOKE version 4.7
- Process 4 km emissions using spatial surrogates from EPA's emission modeling platform
- Began processing SMOKE-MOVES with 4-km MCIP data and 2014 MOVES lookup tables
 - rate-per-distance (RPD) (30 mins per day)
 - rate-per-vehicle (RPV) (10 mins per day)
 - rate-per-profile (RPP)
 - rate-per-hour (RPH)

Layer 1 NO2[1]



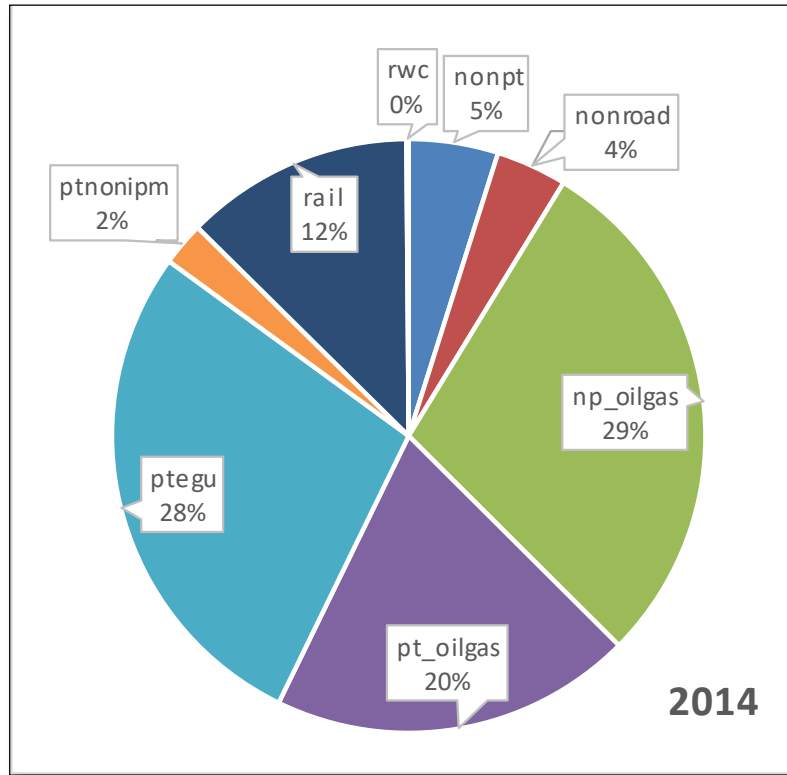
Emission Modeling Sector Description

Separate SMOKE emissions
modeling of each Source
Sector

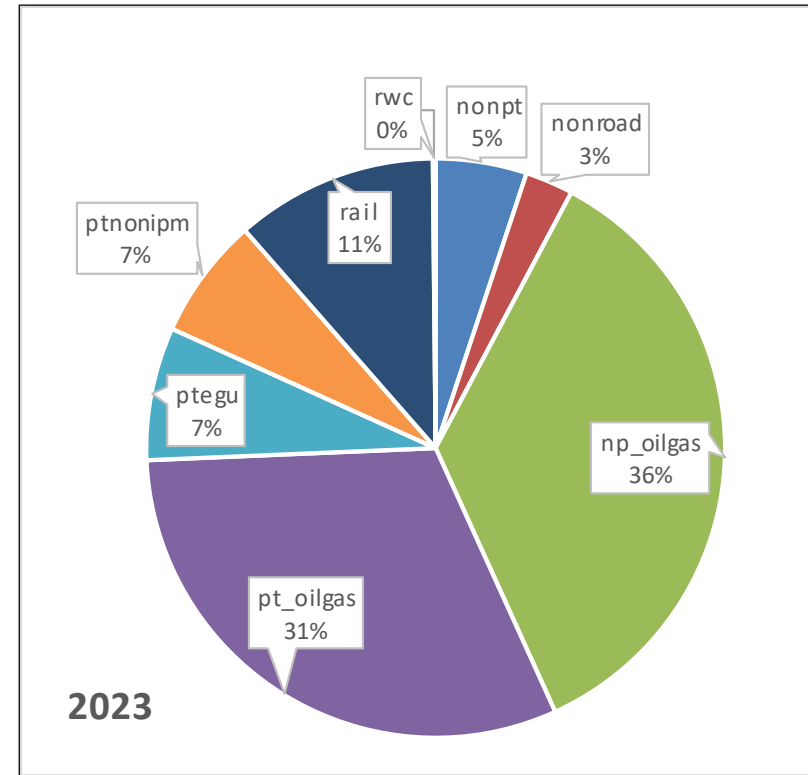
Sector	Description
afdust_adj	Area fugitive dust
ag	Agricultural ammonia sources
cmv_c1c2	Category 1 & 2 Marine Vessels
cmv_c3	Category 3 Marine Vessels
nonpt	Other nonpoint sources
np_oilgas	Non-point Oil and Gas
nonroad	Non-road mobile
onroad	On-road mobile
ptegu	EGU point sources
ptnonipm	Non-EGU point sources
pt_oilgas	Point Oil and Gas
rail	Locomotive
rwc	Residential Wood Combustion

Updated New Mexico Emissions: 2023 vs. 2014 NOx

All anthro source categories except onroad



157,534 TPY

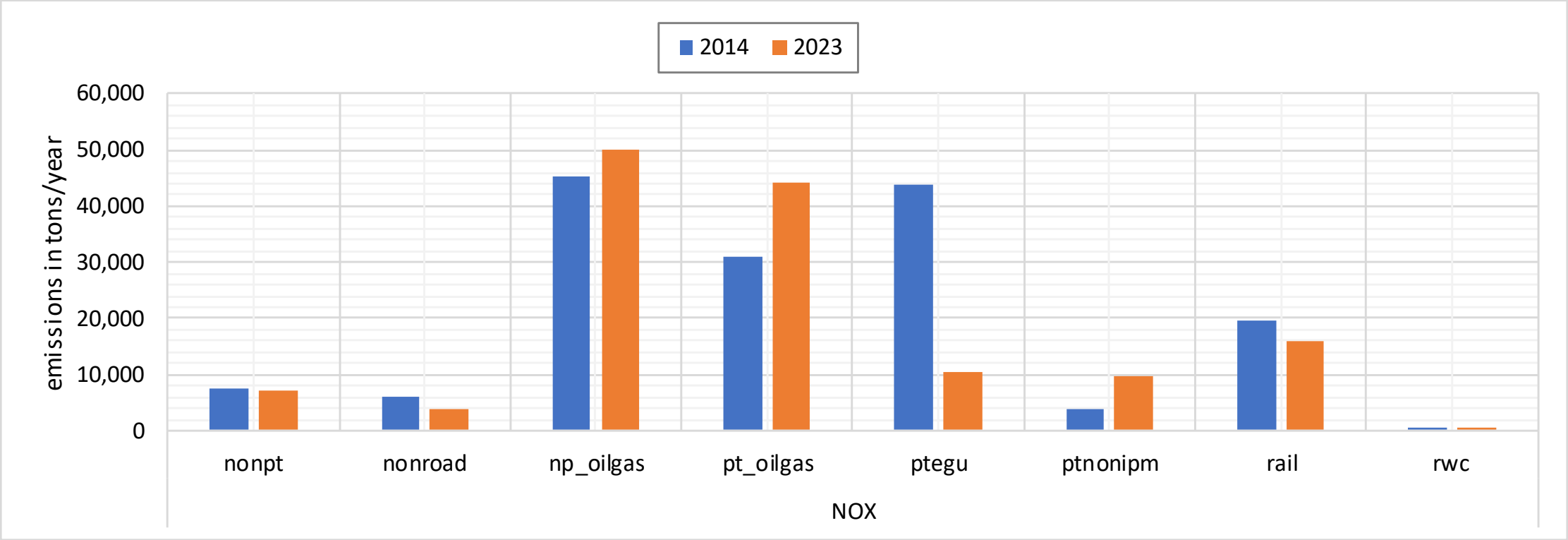


141,606 TPY

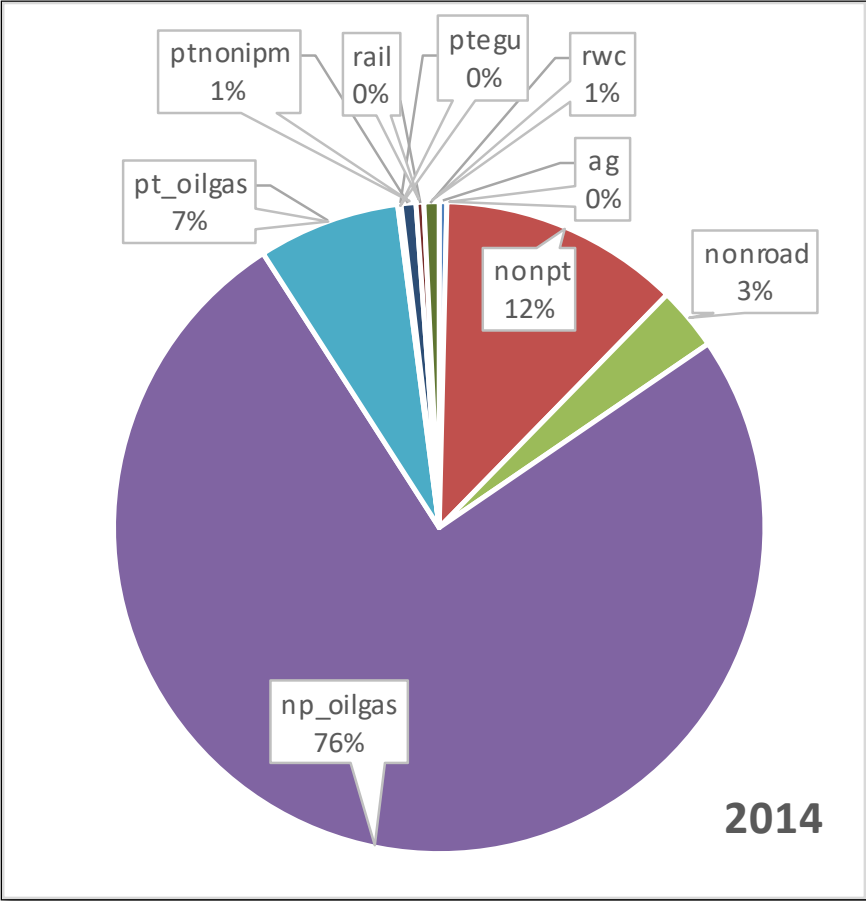


-15,928 TPY (10%) Reduction

Updated New Mexico Emissions: 2023 vs. 2014 NOx by Source Category

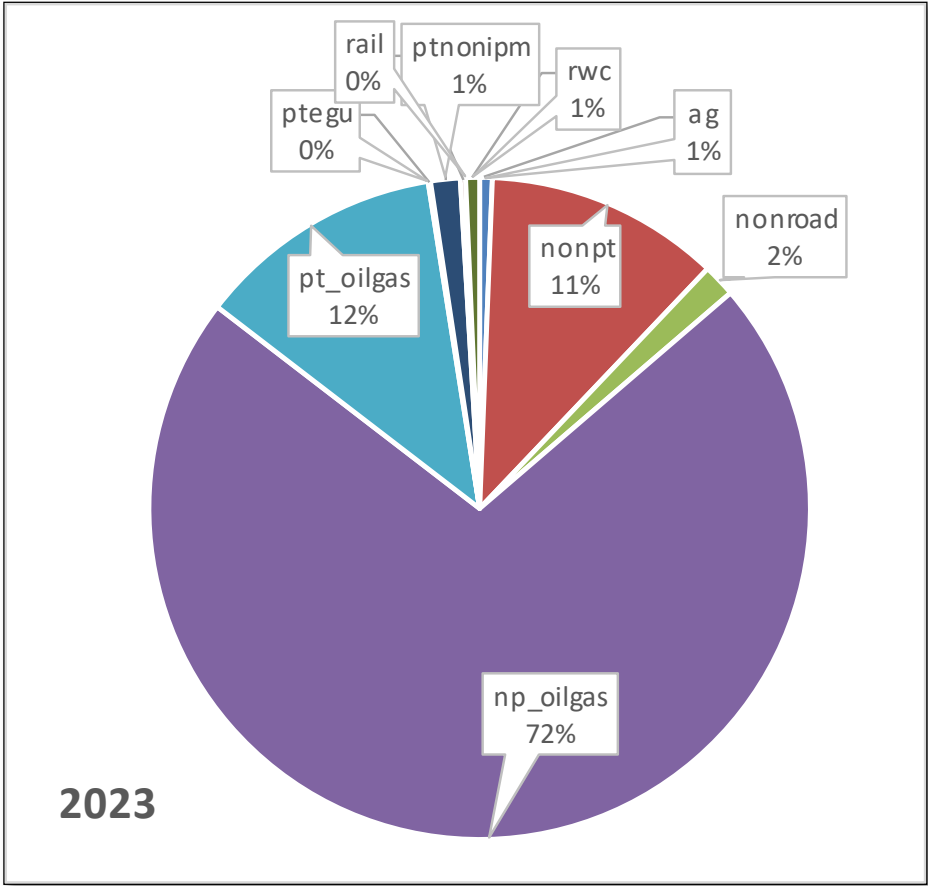


Updated New Mexico Emissions: 2023 vs. 2014 VOC



255,765 TPY

All anthro source categories except onroad



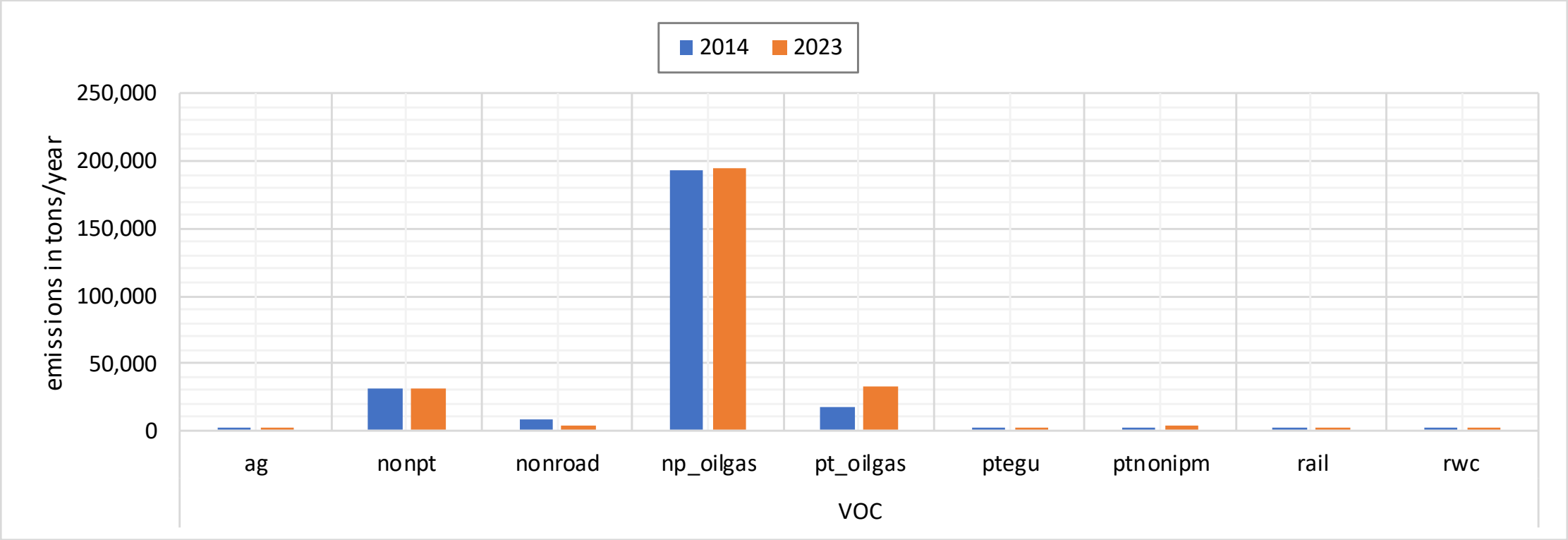
2023

272,492 TPY



+16,727 TPY (7%) Increase

Updated New Mexico Emissions: 2023 vs. 2014 VOC by Source Category



2014 36/12/4-KM WRF METEOROLOGICAL MODELING

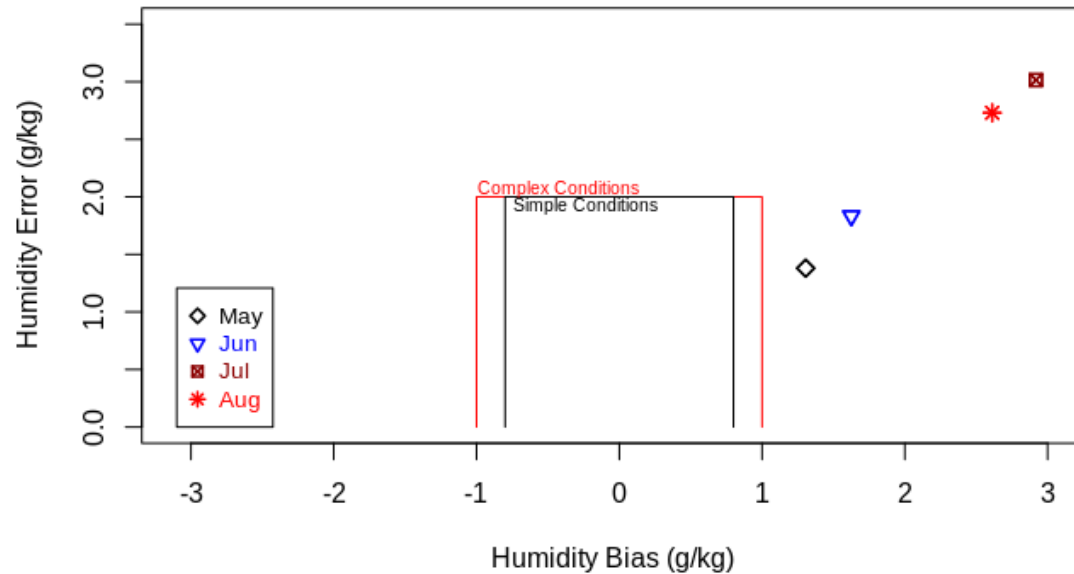


RECAP OF EPA/WAQS WRF EVALUATION

- Evaluated EPA 12US1 and WAQS 12WUS2 for May-August 2014
- EPA wet bias in summer months associated with overactive summer convection
- WAQS smaller wet bias

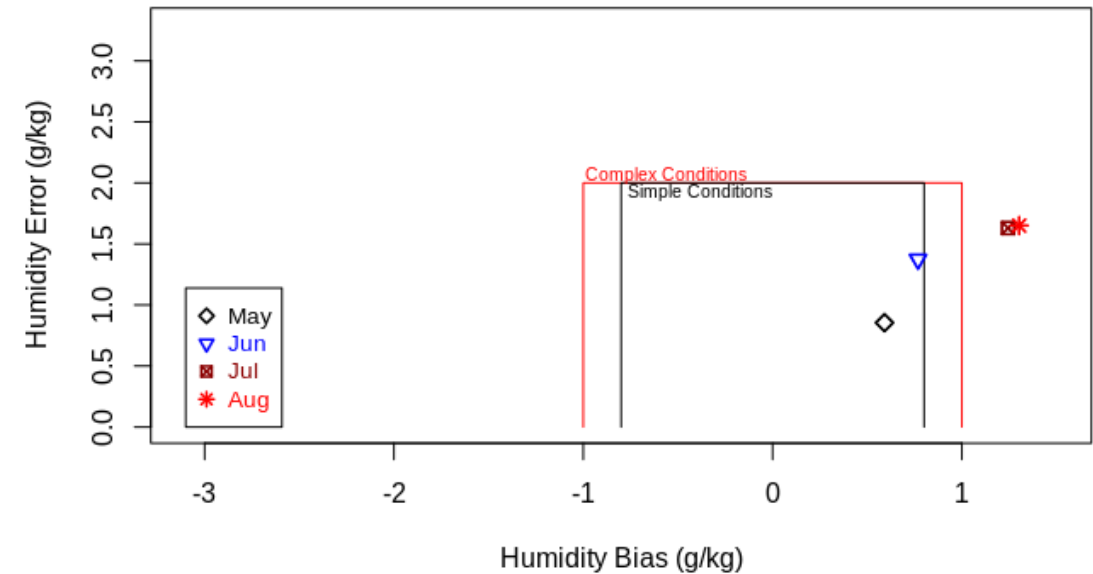
EPA 12 km

EPA WRF d01 NM Humidity Performance
2014 - all



WAQS 12 km

WAQS WRF d02 NM Humidity Performance
2014 - all



RECAP OF NM OAI WRF SETUP AND PROCEDURE

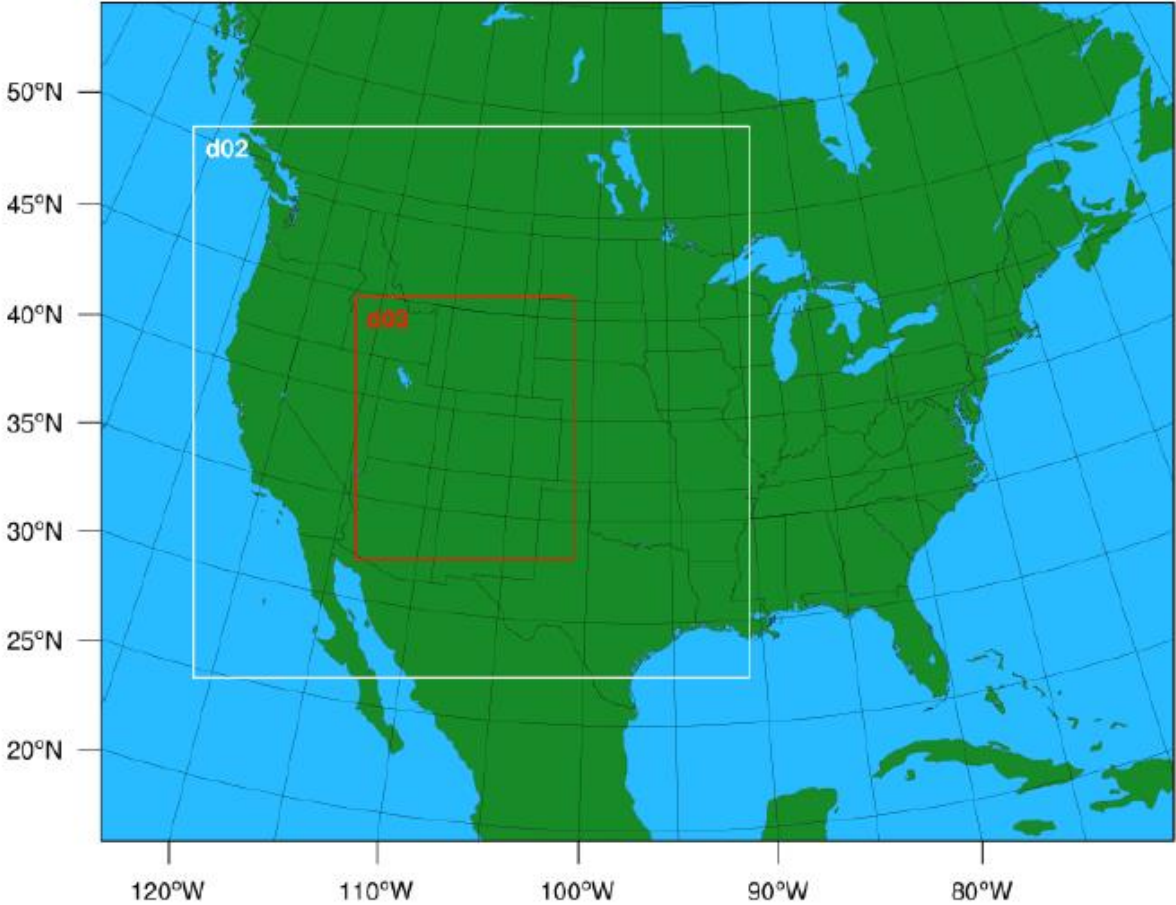
- NM OAI proposed WRF configuration aligns closely with WAQS to reduce overactive summertime convection in New Mexico, with these differences
 - Reposition 4 km domain to encompass all of New Mexico
 - Use hybrid vertical coordinate to improve representation of upper troposphere/lower stratosphere
 - Add second simulation driven by ERA5 analysis
 - No observation nudging
- Two NM OAI WRF simulations (NAM12/ERA5) completed and evaluated
- Present evaluation of these two simulations for this webinar

NM OAI VS WAQS WRF CONFIGURATION

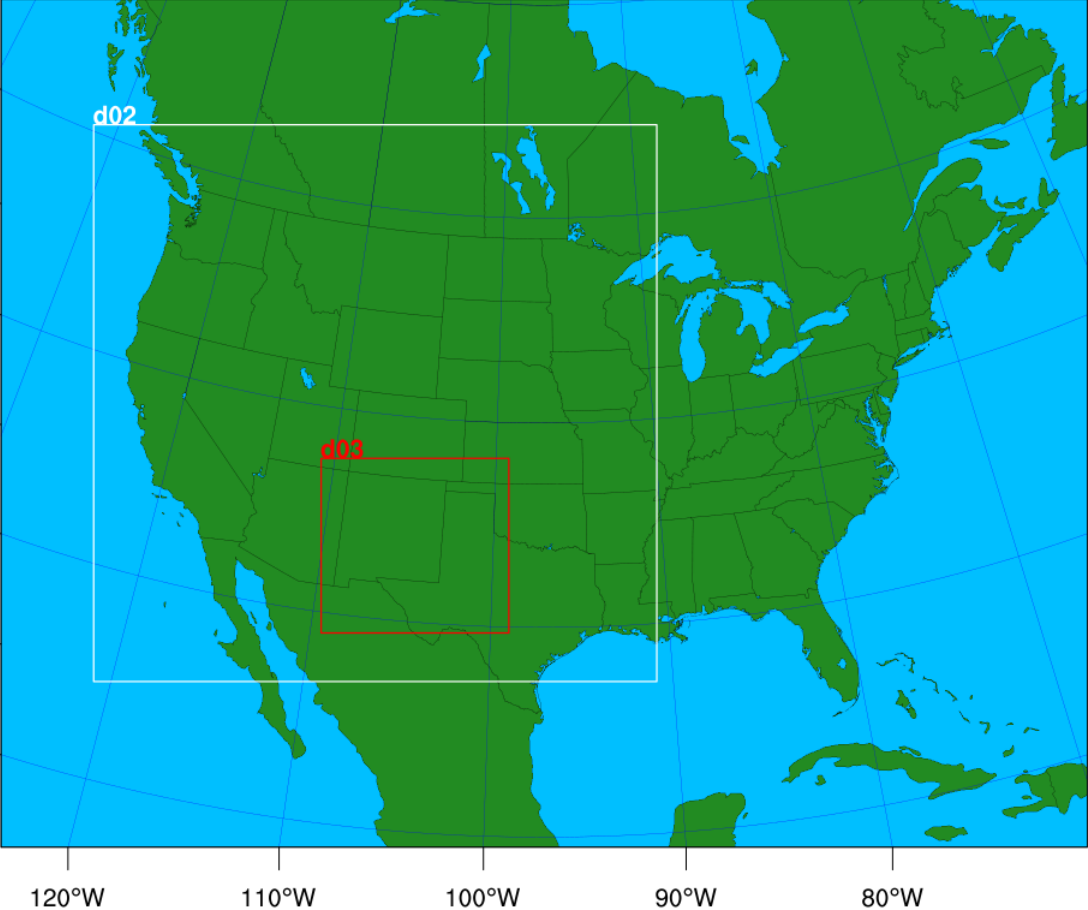
WRF Option	NM OAI	2014 WAQS
Vertical Coordinate	hybrid sigma-pressure	sigma
Domains run	36/12/4-km	36/12/4-km
Microphysics	Thompson	Thompson
LW Radiation	RRTMG	RRTMG
SW Radiation	RRTMG	RRTMG
LSM	Noah	Noah
PBL scheme	YSU	YSU
Sfc Layer Physics	MM5 similarity	MM5 similarity
Cumulus	36/12/4-km Multi-scale Kain Fritsch	36/12-km Multi-scale Kain Fritsch
BC, IC Analysis Nudging Source	12-km NAM/ERA5	12-km NAM
Analysis Nudging Grids	36/12-km	36/12-km
Obs Nudging	None	4-km
Sea Sfc Temp	FNMOCC	FNMOCC

NM OAI VS WAQS WRF DOMAINS

WAQS 36/12/4 km



NM OAI 36/12/4 km



ERA5 VS NAM WRF MPE APPROACH

- Evaluate ERA5 and NAM WRF simulations for May-August 2014
 - ERA5 and NAM analysis field inputs are critical inputs to a WRF simulation as they define initial and boundary conditions (IC and BC) and are used in the Four Dimensional Data Assimilation (FDDA) to continuously nudge the WRF predictions to the analysis fields
 - Evaluation include observation sites within New Mexico only
- Quantitative Evaluation
 - METSTAT – model/obs pairing, bias/error statistics against NCAR ds3505 observations
 - Soccer plots – monthly stats
 - Time series – hourly and daily
 - Plots for all sites in NM, and each individual site within NM
- Qualitative Evaluation
 - PRISM precipitation spatial maps
 - Monthly and daily

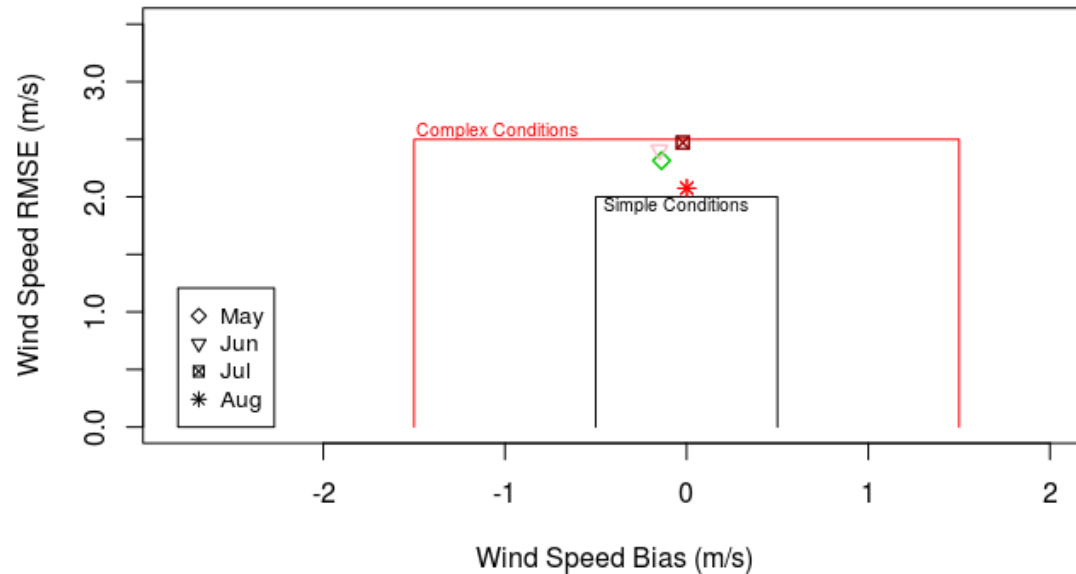
WRF STATISTICAL BENCHMARKS

Meteorological Variable	Simple Conditions		Complex Conditions	
	Bias	Error	Bias	Error
Temperature	< ±0.5 °C	< 2.0 °C	< ±2.0 °C	< 2.5 °C
Wind Speed	< ±0.5 m/s	< 2.0 m/s (RMSE)	< ±1.5 m/s	< 2.5 m/s (RMSE)
Wind Direction	< ±10 degrees	< 30 degrees	< ±10 degrees	< 50 degrees
Humidity	< ±0.8 g/kg	< 2.0 g/kg	< ±1.0 g/kg	< 2.0 g/kg

SOCCKER PLOTS – WIND SPEED FOR ALL NM SITES

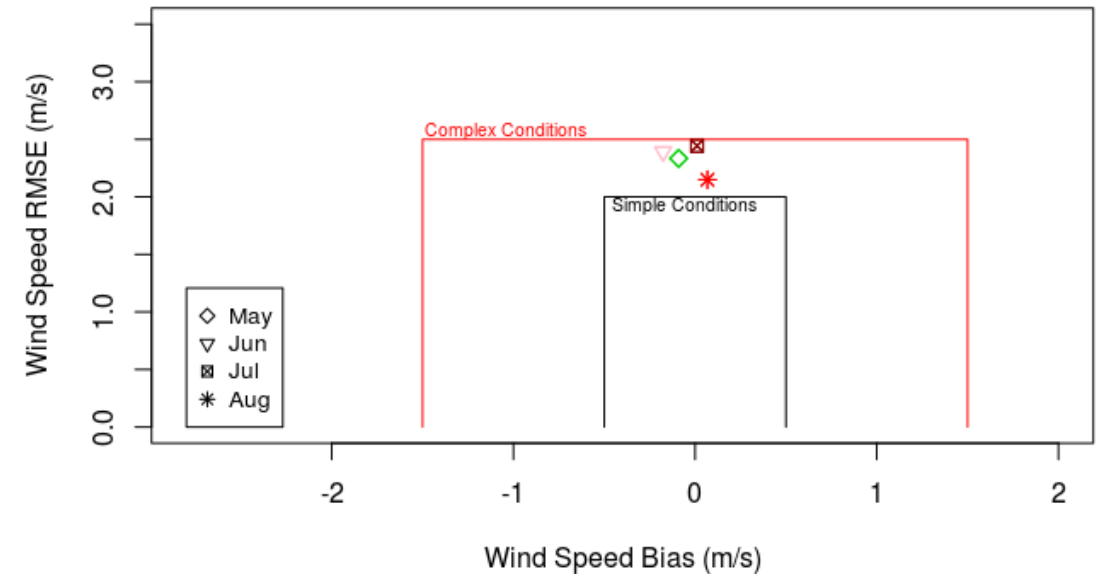
NAM

Westar NMED d03 NM Wind Speed Performance
4km WRF - NAM - Site: all



ERA5

Westar NMED d03 NM Wind Speed Performance
4km WRF - ERA5 - Site: all



All months within complex conditions goal for both runs

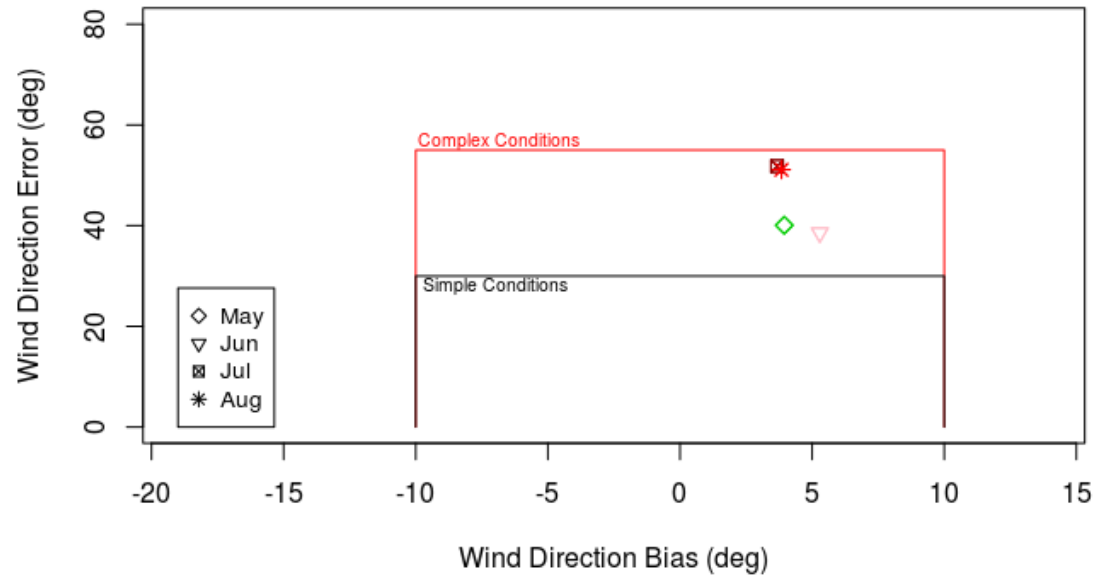
NAM and ERA5 very similar; both runs' RMSE outside simple conditions goal for all months

SOC CER PLOTS – WIND DIRECTION FOR ALL NM SITES

NAM

Westar NMED d03 NM Wind Direction Performance

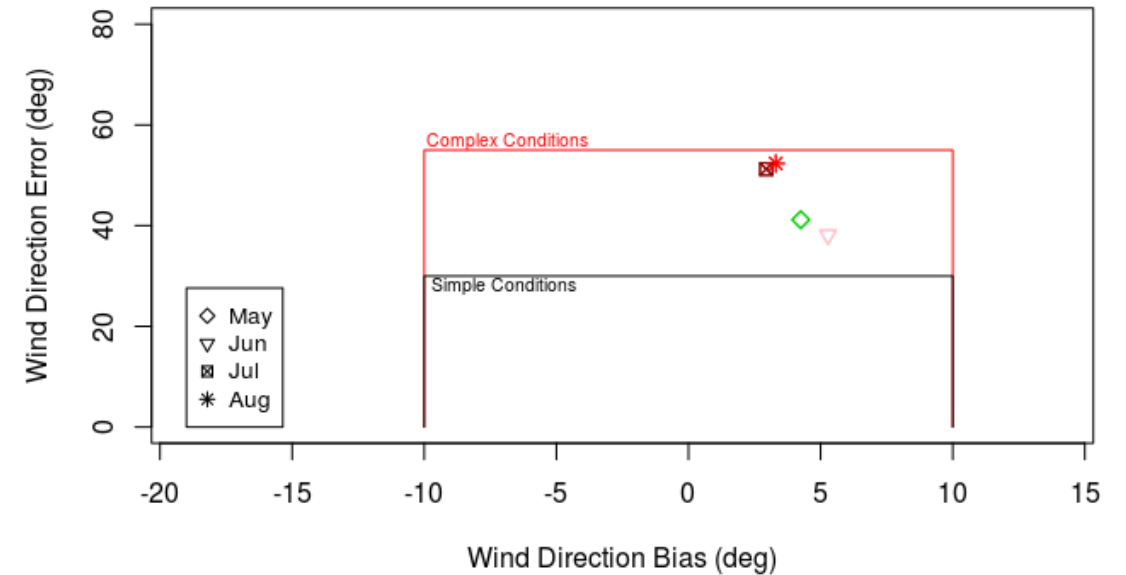
4km WRF - NAM - Site: all



ERA5

Westar NMED d03 NM Wind Direction Performance

4km WRF - ERA5 - Site: all



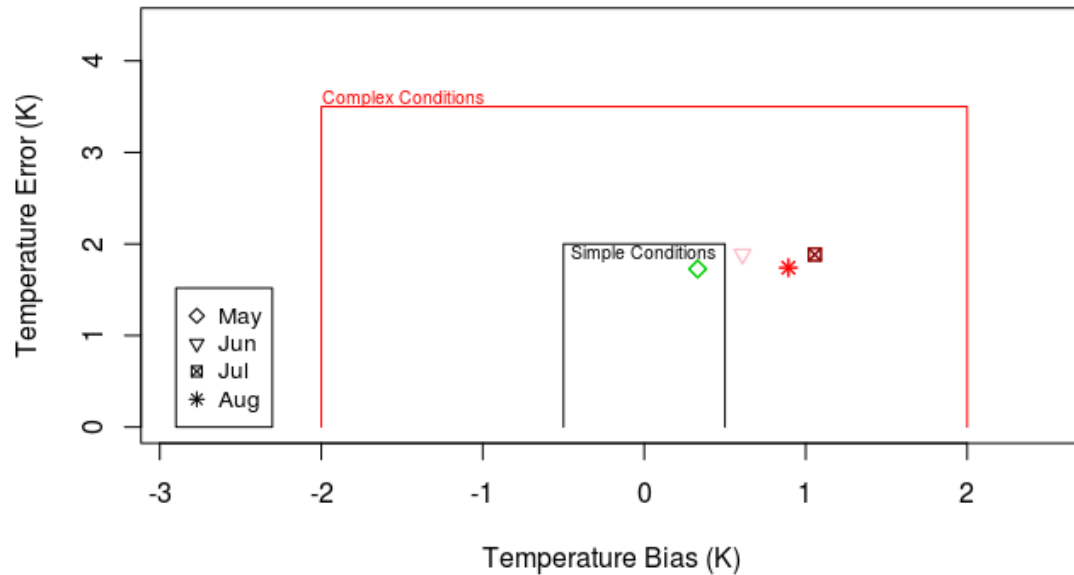
NAM and ERA5 performance nearly identical

SOC CER PLOTS – TEMPERATURE FOR ALL NM SITES

NAM

Westar NMED d03 NM Temperature Performance

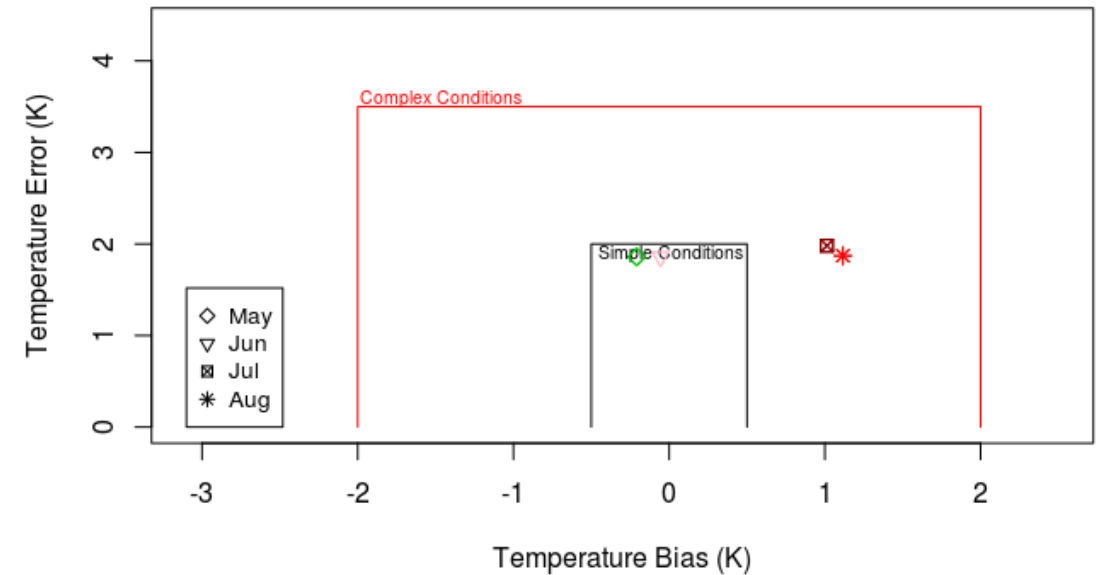
4km WRF - NAM - Site: all



ERA5

Westar NMED d03 NM Temperature Performance

4km WRF - ERA5 - Site: all



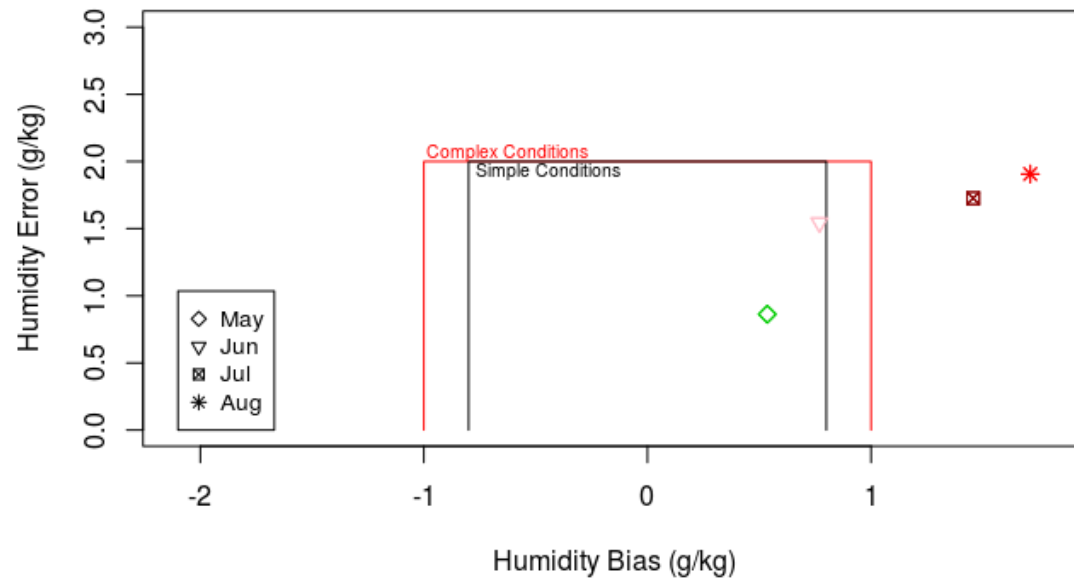
ERA5 run outperforms NAM for May-Jun; similar performance for Jul-Aug

SOCCKER PLOTS – HUMIDITY FOR ALL NM SITES

NAM

Westar NMED d03 NM Humidity Performance

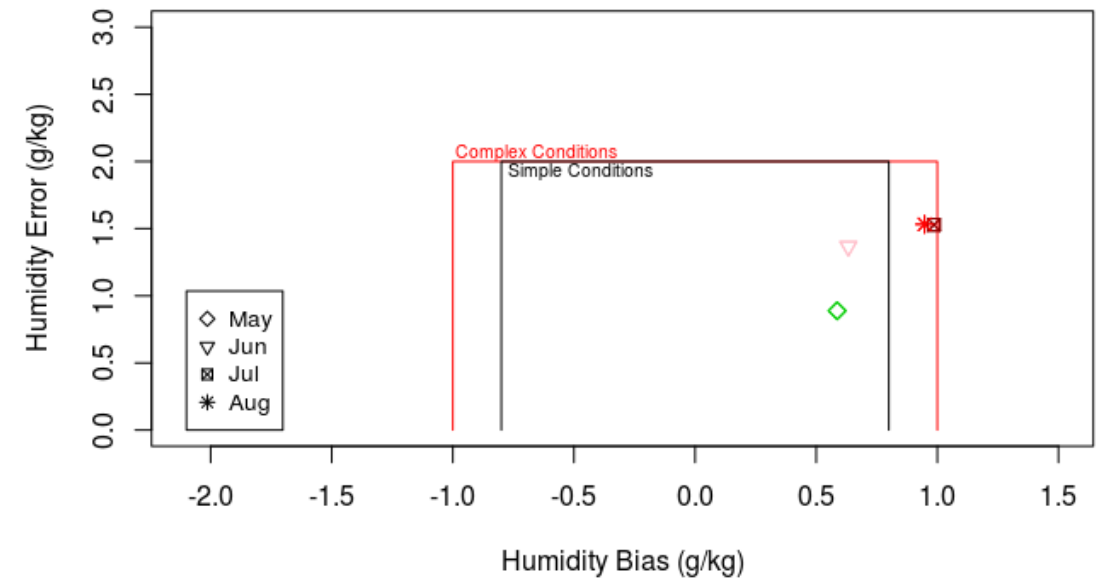
4km WRF - NAM - Site: all



ERA5

Westar NMED d03 NM Humidity Performance

4km WRF - ERA5 - Site: all



ERA5 run outperforms NAM; both runs have positive (wet) bias for all months

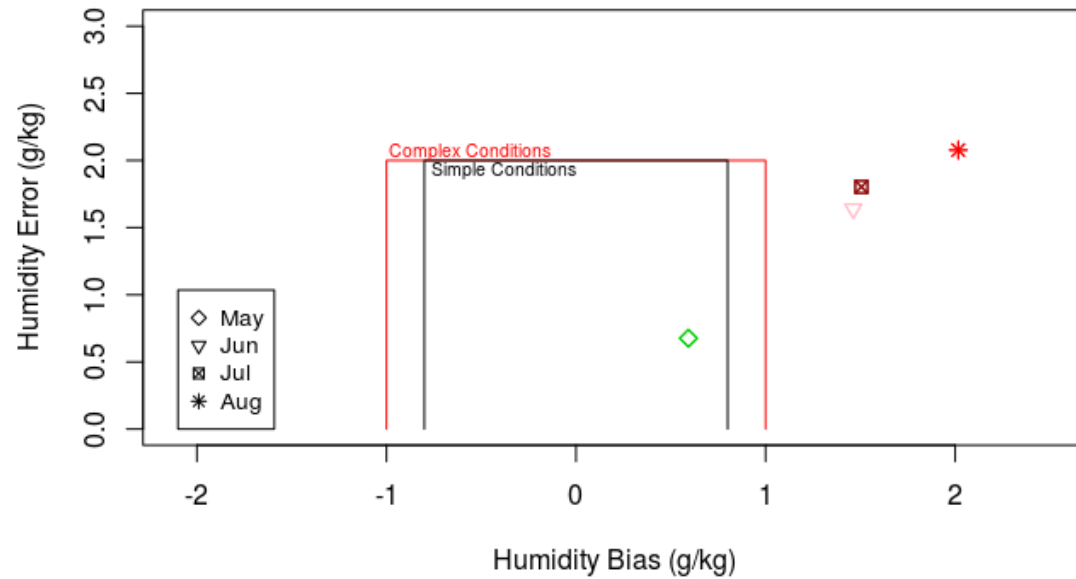
ERA5 considerably better performance for Jul-Aug

SOCGER PLOTS – HUMIDITY FOR KLRU

NAM

Westar NMED d03 NM Humidity Performance

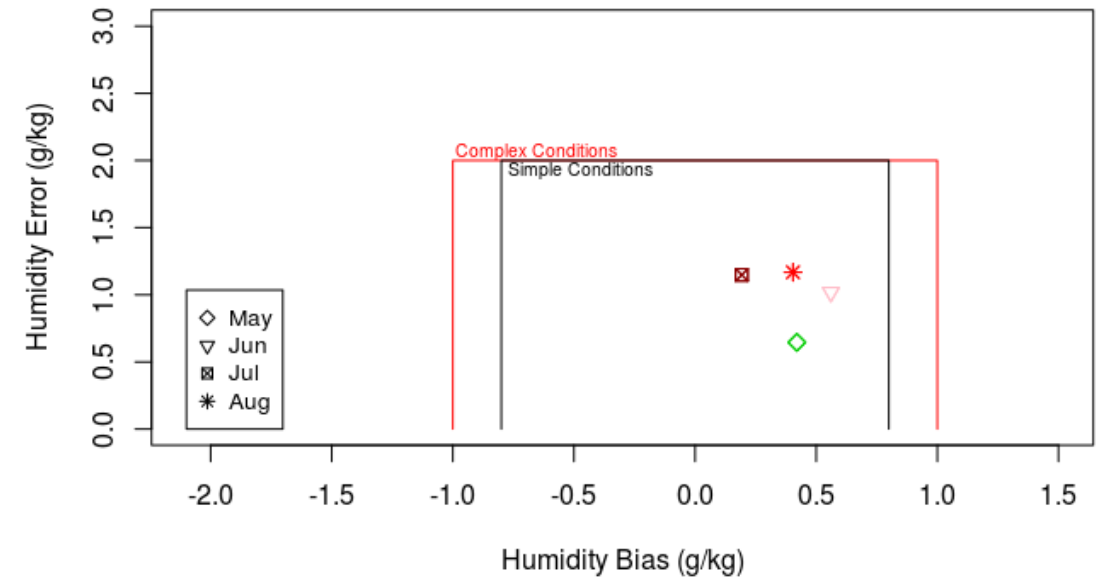
4km WRF - NAM - Site: KLRU



ERA5

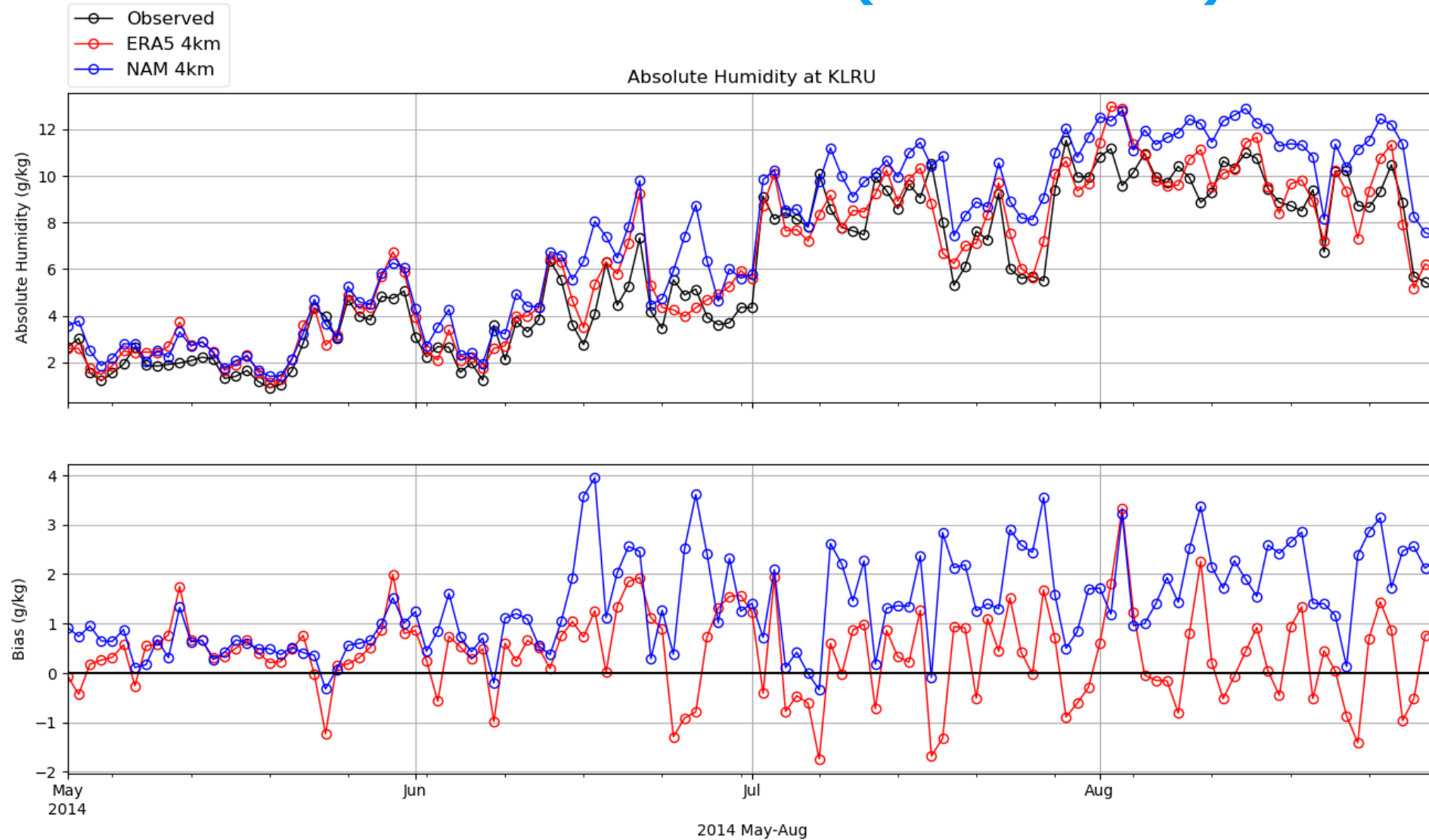
Westar NMED d03 NM Humidity Performance

4km WRF - ERA5 - Site: KLRU



ERA5 run outperforms NAM for all months

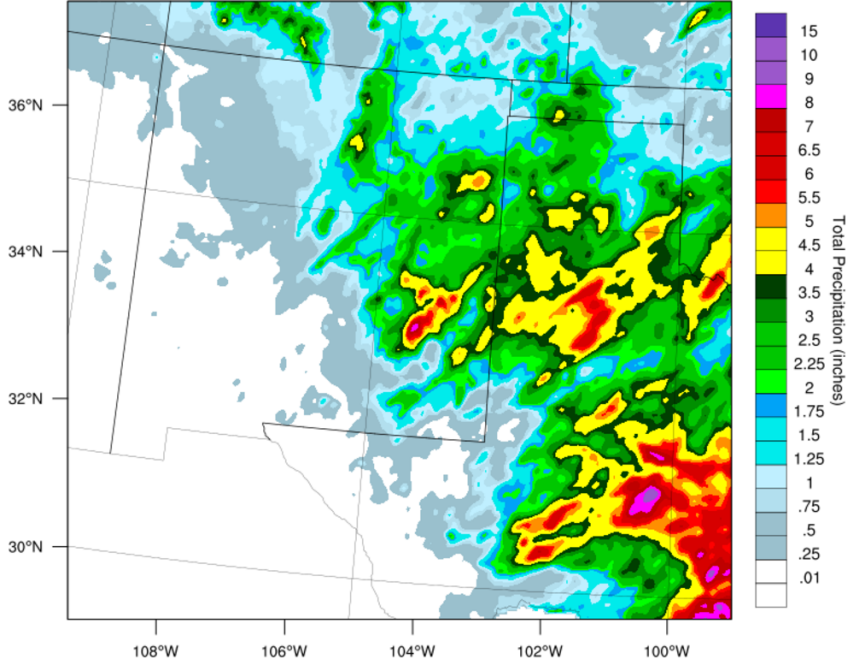
TIME SERIES – HUMIDITY AT KLRU (LAS CRUCES)



MONTHLY PRECIPITATION PLOTS – MAY 2014

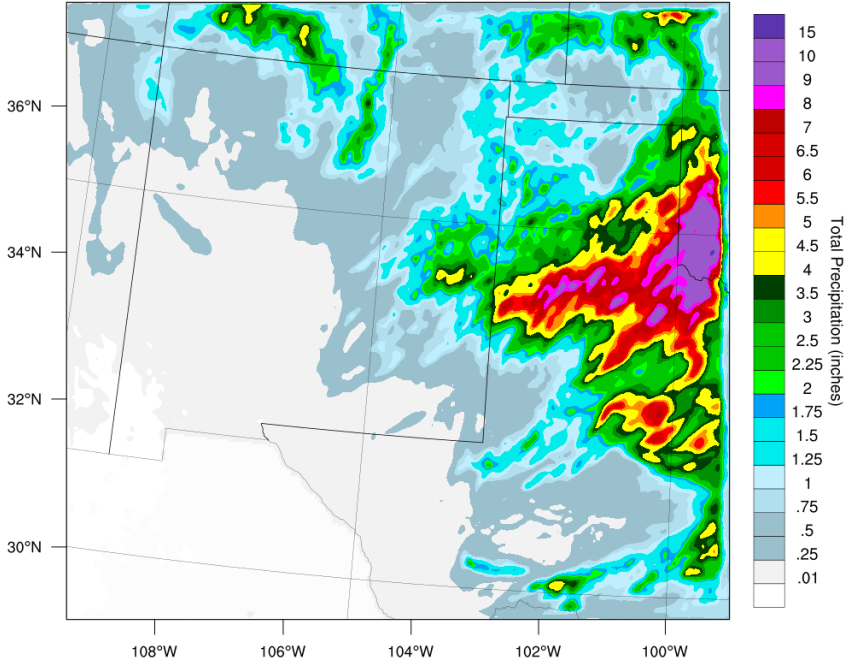
PRISM Obs

Total PRISM Precipitation for 2014-05
Contiguous U.S. Statistics: 10th=0.04 Median=1.15 Average=1.68 90th=4.11



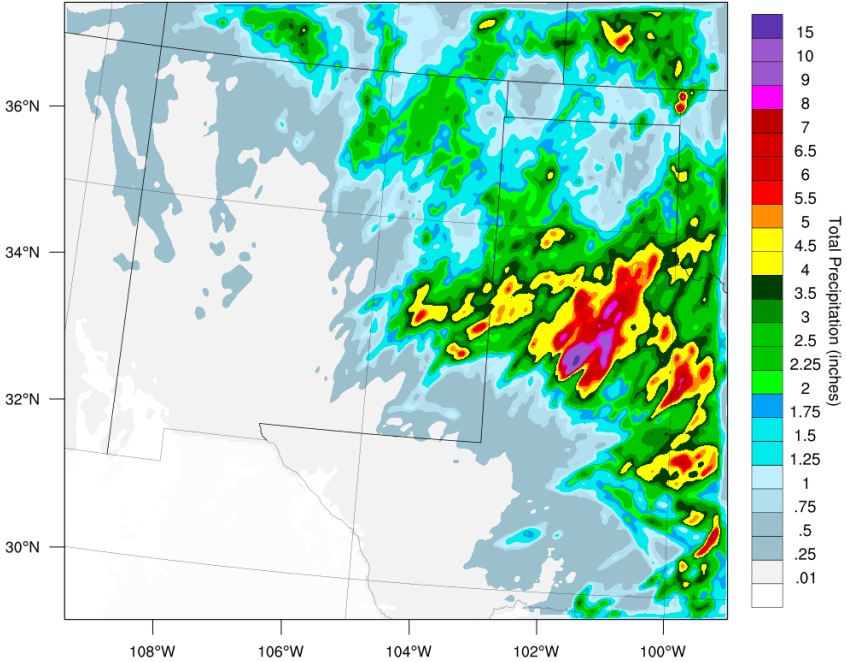
NAM

Total WRF Precipitation (setting: NAM) for 2014-05
WRF Domain Statistics: 10th=0.03 Median=0.52 Average=1.21 90th=3.40 Convective fraction= 0.35
Contiguous U.S. Statistics: 10th=0.05 Median=0.68 Average=1.36 90th=3.65 Convective fraction= 0.34



ERA5

Total WRF Precipitation (setting: ERA5) for 2014-05
WRF Domain Statistics: 10th=0.02 Median=0.50 Average=1.14 90th=3.19 Convective fraction= 0.35
Contiguous U.S. Statistics: 10th=0.04 Median=0.71 Average=1.28 90th=3.36 Convective fraction= 0.35

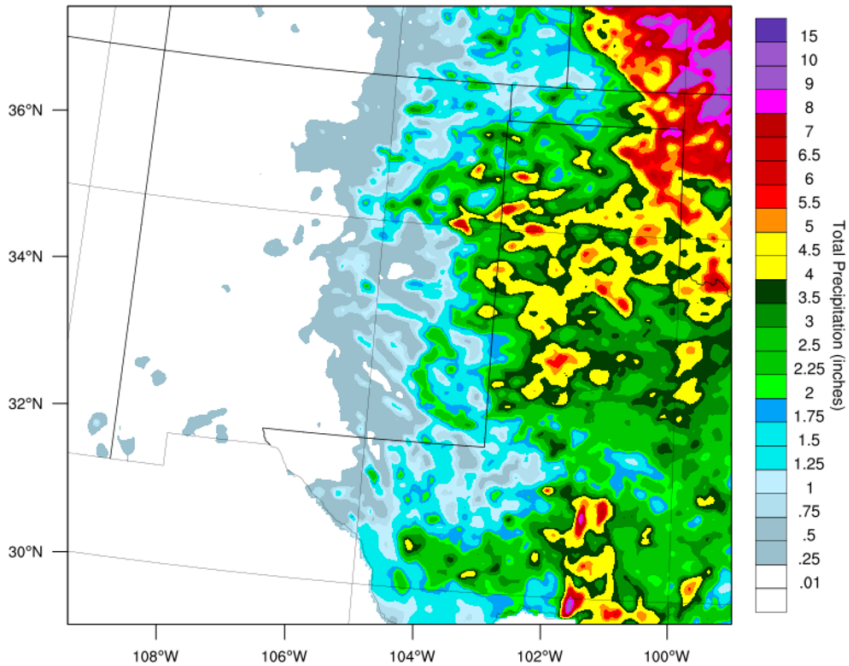


NAM and ERA5 are similar over New Mexico

MONTHLY PRECIPITATION PLOTS – JUNE 2014

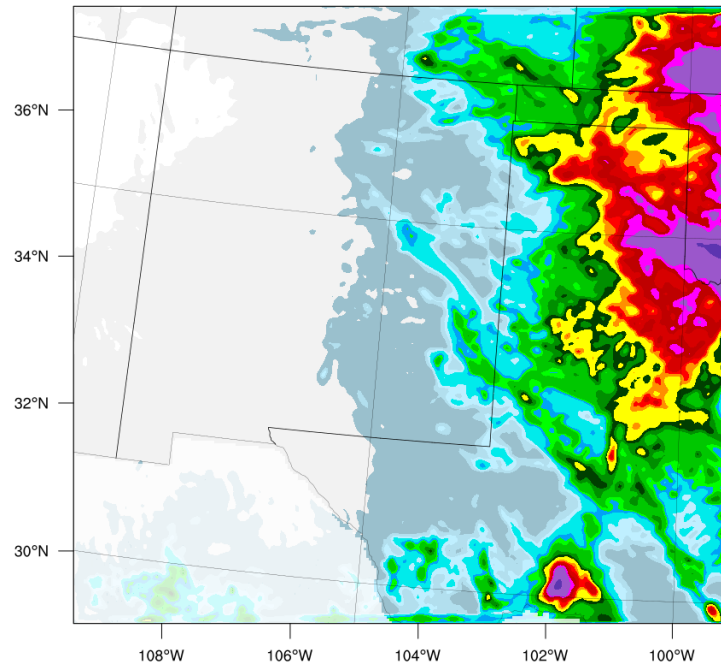
PRISM Obs

Total PRISM Precipitation for 2014-06
Contiguous U.S. Statistics: 10th=0.00 Median=1.28 Average=1.79 90th=4.26



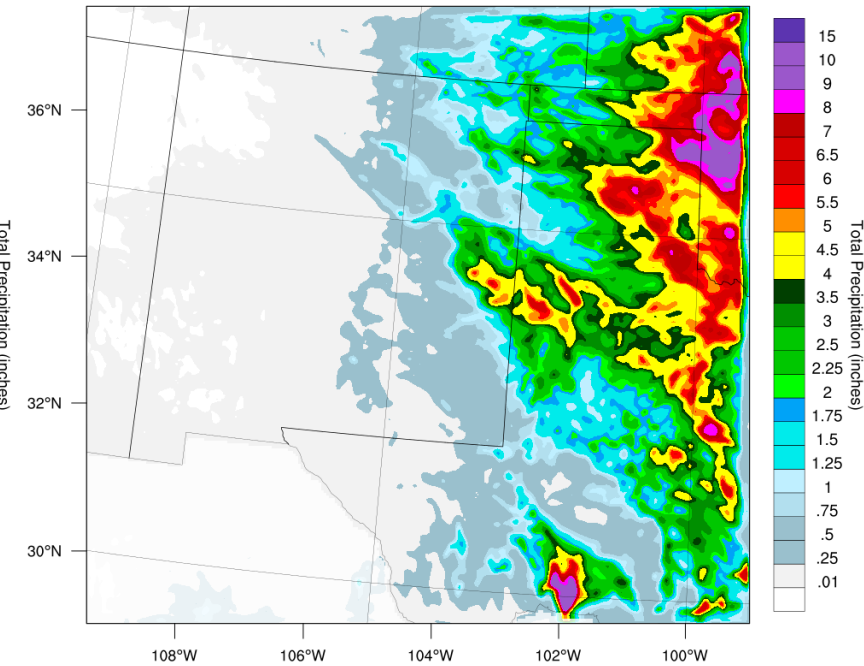
NAM

Total WRF Precipitation (setting: NAM) for 2014-06
WRF Domain Statistics: 10th=0.03 Median=0.60 Average=1.60 90th=4.72 Convective fraction= 0.47
Contiguous U.S. Statistics: 10th=0.02 Median=0.68 Average=1.73 90th=5.16 Convective fraction= 0.44



ERA5

Total WRF Precipitation (setting: ERA5) for 2014-06
WRF Domain Statistics: 10th=0.01 Median=0.33 Average=1.33 90th=4.26 Convective fraction= 0.42
Contiguous U.S. Statistics: 10th=0.01 Median=0.51 Average=1.48 90th=4.52 Convective fraction= 0.41



Both NAM and ERA5 are reasonable over NM; NAM overpredicts over North Texas

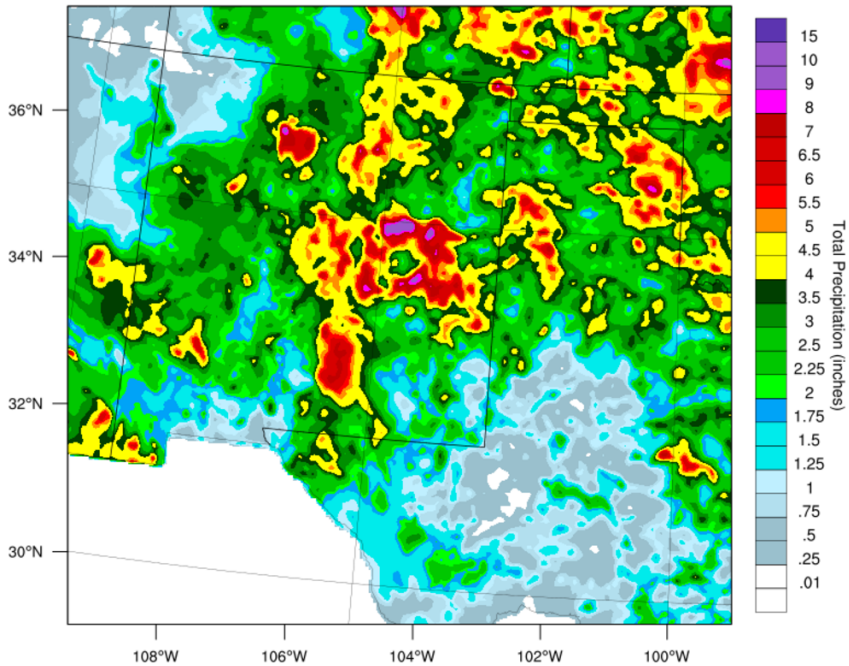
ERA5 slightly better

RAMBOLL

MONTHLY PRECIPITATION PLOTS – JULY 2014

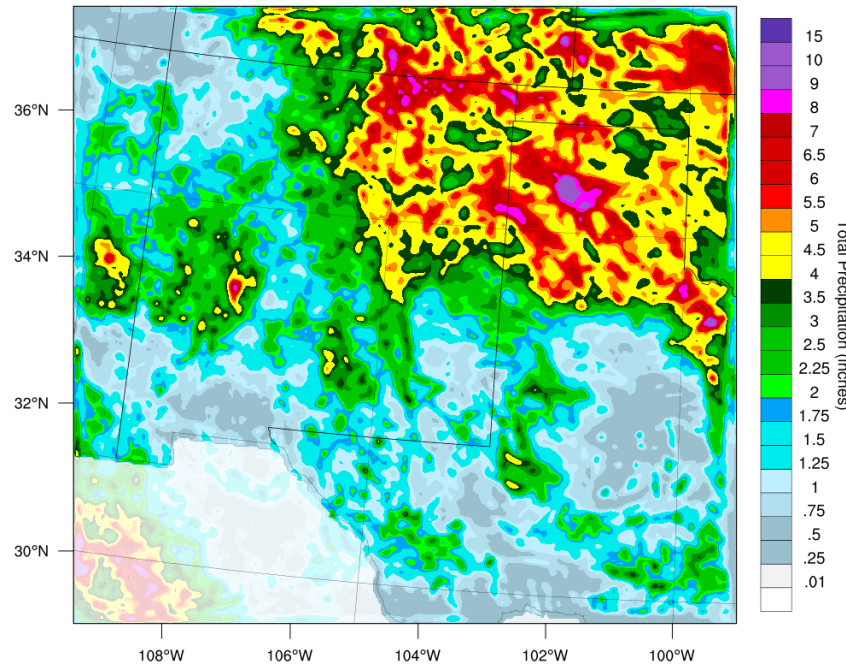
PRISM Obs

Total PRISM Precipitation for 2014-07
Contiguous U.S. Statistics: 10th=0.79 Median=2.67 Average=2.71 90th=4.67



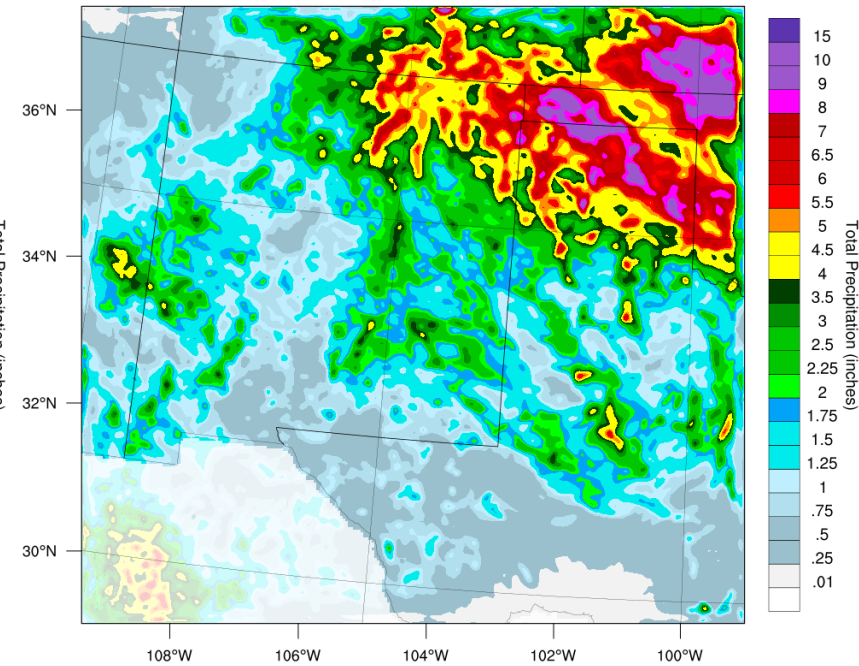
NAM

Total WRF Precipitation (setting: NAM) for 2014-07
WRF Domain Statistics: 10th=0.76 Median=2.01 Average=2.59 90th=5.22 Convective fraction= 0.39
Contiguous U.S. Statistics: 10th=1.00 Median=1.82 Average=2.22 90th=5.07 Convective fraction= 0.44



ERA5

Total WRF Precipitation (setting: ERA5) for 2014-07
WRF Domain Statistics: 10th=0.50 Median=1.50 Average=2.19 90th=5.03 Convective fraction= 0.40
Contiguous U.S. Statistics: 10th=0.48 Median=1.55 Average=2.26 90th=5.25 Convective fraction= 0.39

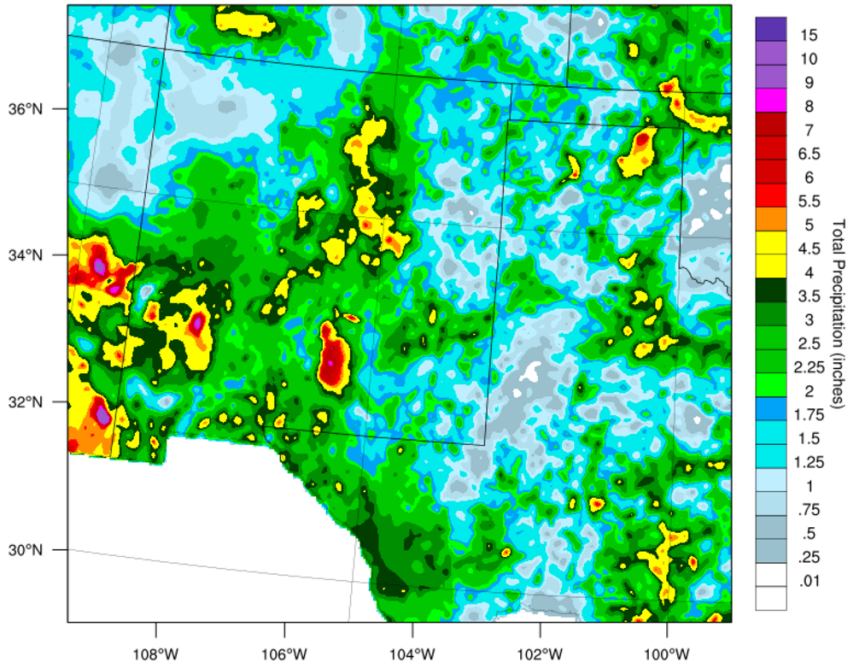


NAM overpredicts over NE New Mexico; both NAM and ERA5 show dry bias elsewhere in NM

MONTHLY PRECIPITATION PLOTS – AUG 2014

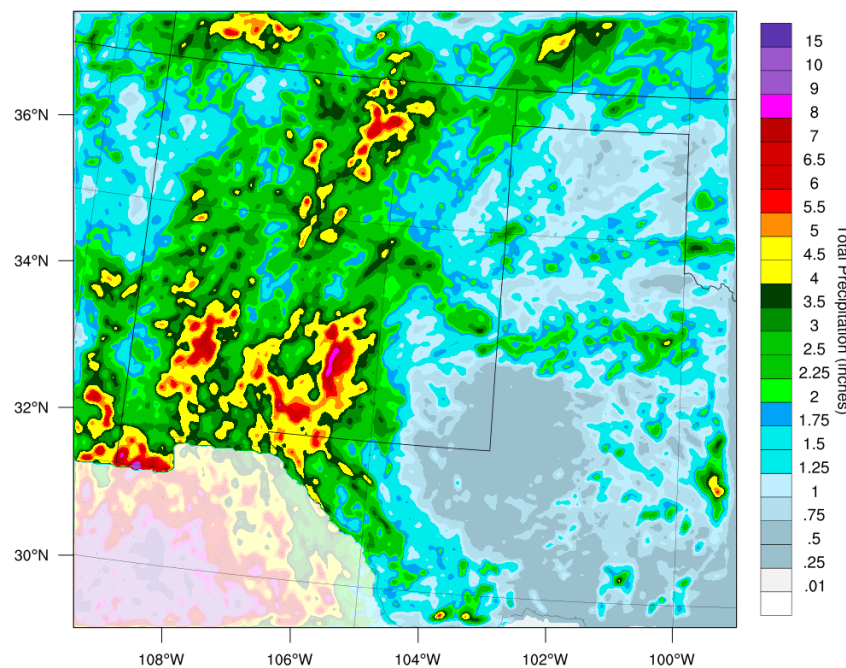
PRISM Obs

Total PRISM Precipitation for 2014-08
Contiguous U.S. Statistics: 10th=0.98 Median=2.08 Average=2.25 90th=3.74



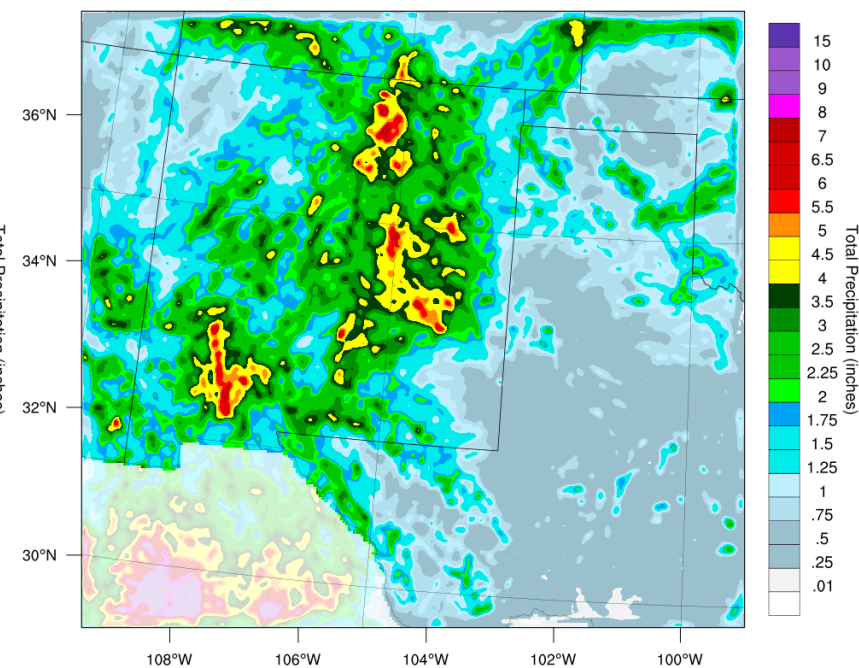
NAM

Total WRF Precipitation (setting: NAM) for 2014-08
WRF Domain Statistics: 10th=0.74 Median=1.89 Average=2.57 90th=4.84 Convective fraction= 0.42
Contiguous U.S. Statistics: 10th=1.00 Median=1.55 Average=1.66 90th=3.56 Convective fraction= 2.55



ERA5

Total WRF Precipitation (setting: ERA5) for 2014-08
WRF Domain Statistics: 10th=0.47 Median=1.50 Average=1.85 90th=3.62 Convective fraction= 0.44
Contiguous U.S. Statistics: 10th=0.45 Median=1.33 Average=1.59 90th=3.13 Convective fraction= 0.45



ERA5 slightly better than NAM in matching location and magnitude of PRISM observations

2014 WRF SUMMARY AND CONCLUSIONS

- WRF performance reasonable for both NAM and ERA5 simulations
- Differences between NAM and ERA5 are smaller in comparison to EPA/WAQS
- NAM wet bias in June-August may be partly associated with overactive summer convection
- ERA5 has smaller wet bias
- Not possible to know which WRF simulation will result in better in CAMx ozone performance
 - Relative performance varies across parameters/seasons/locations
 - Best (or worst) performing WRF days may have small (or large) influence on AQ concentrations
 - Other meteorological variables (vertical diffusion, PBL heights, etc.) may be more important than the ones we can easily evaluate (T, Q, winds, precip)
- Proceed with both WRF simulations through CAMx and select best ozone performance for final CAMx configuration

NM OAI Study Next Steps



Next Up in July 2020

- July 2020: Task 4 -- 2014 and 2023 Emissions
 - 2014 SMOKE-MOVES and SMOKE for 4-km New Mexico Domain
 - 2014 36/12/4-km MEGAN biogenic and LNOx emissions modeling
 - Start 2023 SMOKE modeling
- July 2020: Task 5 – CAMx 2014 36/12/4-km Base Case Modeling
 - CAMx meteorological input sensitivity modeling
 - May 1 – June 16, 2014; 4 configurations: WRF/NAM and WRF/ERA5 using CMAQ/YSU vertical diffusivities (Kv)
 - Start CAMx 2014 36/12/4-km final base case May - August
- July 2020: NMED OAI Webinar
 - 2014 SMOKE Results for 4-km New Mexico domain (Anthro & Natural)
 - CAMx WRF meteorology sensitivity modeling
 - CAMx 2014 36/12/4-km final base case configuration
- Expected progress in August 2020
 - 2014 CAMx base case and MPE Report
 - 2023 Base and Control Strategy SMOKE Modeling and 2023 CAMx base case

DISCUSSION



NEW MEXICO OZONE ATTAINMENT INITIATIVE

2014 and 2023 Emissions, CAMx WRF Sensitivity Tests and Selection of Final Model Configuration

Ralph Morris, Pradeepa Vennam,
Marco Rodriguez, Jeremiah Johnson,
Tejas Shah, Ramboll

Tom Moore and Mary Uhl, WESTAR

NM OAI Study Webinar#3

July 27, 2020



AGENDA – NMED OAI STUDY WEBINAR#3 – JULY 27, 2020

- Welcome and agenda review – Tom and all
- 2014 and 2023 emissions QA, updates and processing – Ramboll
 - 2014 and 2023 Emissions QA and identification of duplicate sources
 - 2014 SMOKE emissions processing and results
 - 2014 natural emissions
- CAMx meteorological sensitivity tests and CAMx final 2014 base case configuration – Ramboll
 - WRF NAM and ERA simulations
 - Ozone evaluation of CAMx four meteorological input sensitivity tests
 - Final CAMx 2014 36/12/4-km base case configuration
- Upcoming schedule, milestones when NMED needs support for EIB process - all

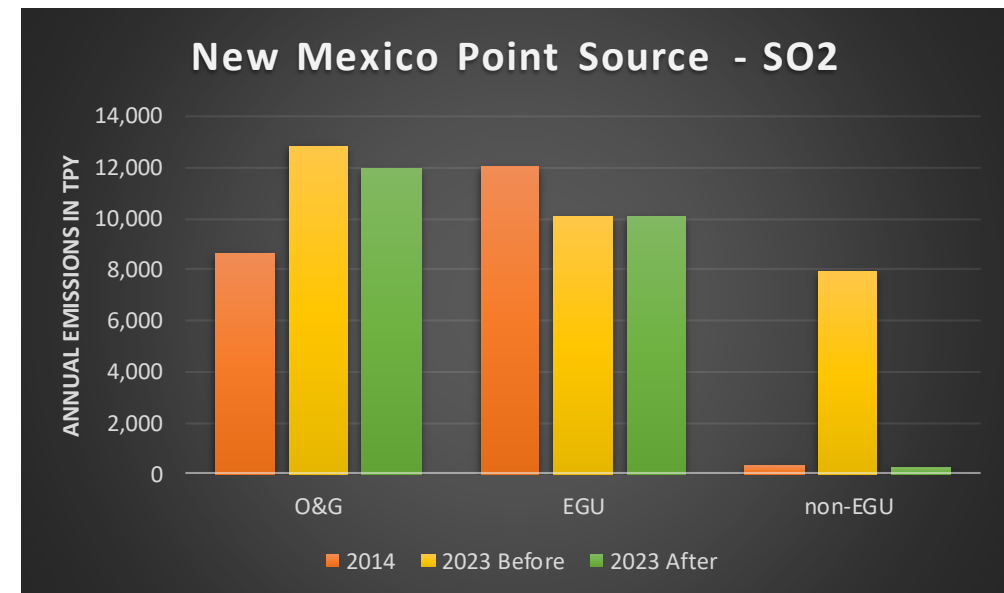
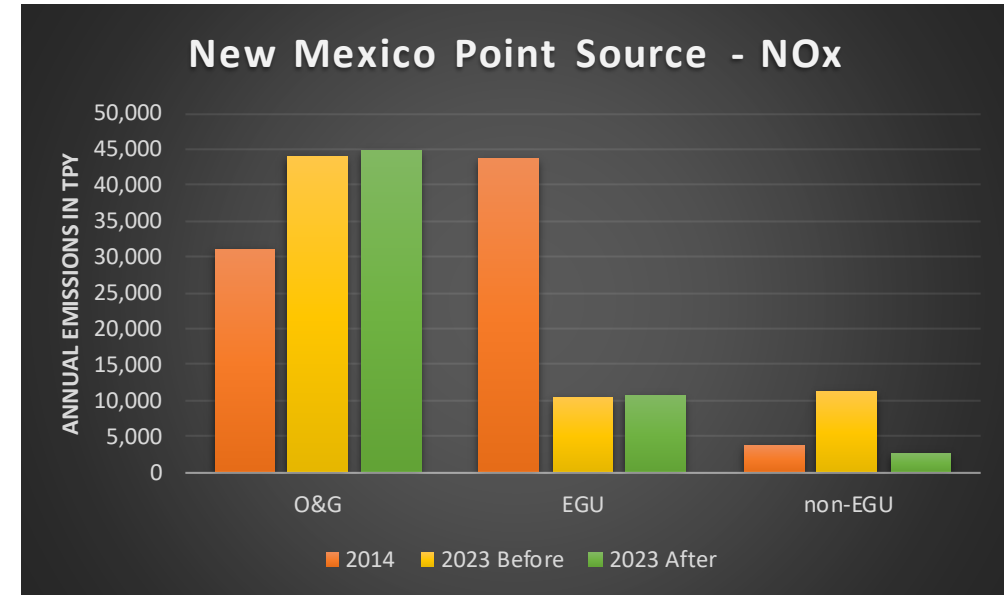
2014 AND 2023 EMISSIONS

NEW MEXICO EMISSIONS DATA

- 2014 anthropogenic emissions are based on the WAQS 2014v2
 - NMED found a generator engine missing in 2014v2 inventory (94 tpy NOx)
 - No double counting of sources in 2014v2 inventory
 - Consistent emissions data between the Regional Haze and OAI studies
- 2023 anthropogenic emissions are based on the EPA 2016v1 platform
 - NMED found some point sources exist in both 2023 point O&G and non-EGU sectors
 - Found double counting of sources in WRAP O&G inventory: Title V and minor point sources
 - Found Lordsburg Generating Station is missing
 - Add two O&G sources: Chaco Gas Plant (NOx 2,053 tpy) and Mountainair CS (NOx 645 tpy)

DUPLICATE POINT SOURCES IN 2023

- NMED identified 21 facilities double counted in 2023 non-EGU and WRAP point O&G inventory
 - Double counted emissions: NOx 8,669 TPY and SO2 7,662 TPY
 - Represents approximately 9% (NOx) and 24% (SO2) of the New Mexico 2023 O&G emissions
- Duplicates in the WRAP O&G inventory: Some sources were present in Title V and minor point O&G sources datasets in the OGWG inventory.
 - Double counted emissions NOx: 1,927 TPY and SO2: 942 TPY



O&G SOURCES
IDENTIFIED IN
NON-EGU
INVENTORY
BASED ON NAICS
CODES

O&G NAICS found in ptnonipm but not duplicate

Duplicates found by EPA/NMED in pt_oilgas and ptnonipm sectors

Duplicates found based on NAICS

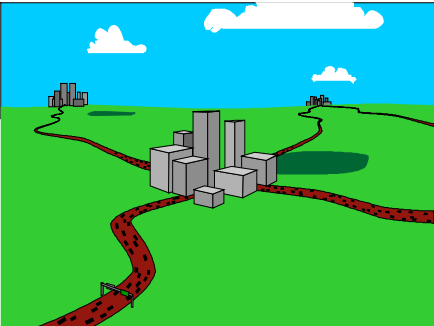


Sum of ann_value					poll							
region_cd	state	facility_name	facility_id	naics	CO	NH3	NOX	PM10	PM25	SO2	VOC	
	8123	CO	OVERLAND PASS - FT LUPTON METER NORTH	14794011	486990						1	
	8123	CO	OVERLAND PASS - FT LUPTON METER SOUTH	14919211	486990						3	
	8123	CO	OVERLAND PASS - FT LUPTON/DJ JUNCTION	14794111	486990						5	
	8123	CO	OVERLAND PASS - GROVER STATION	14794411	486990						10	
	8123	CO	OVERLAND PASS - LILLI METER	16286411	486990						3	
	8123	CO	OVERLAND PASS - LUCERNE METER	14793811	486990						4	
	8123	CO	OVERLAND PASS - LUCERNE/DJ JUNCTION	14919311	486990						7	
	8123	CO	OVERLAND PASS - MEWBOURN METER	14919411	486990						5	
	8123	CO	OVERLAND PASS - MEWBOURN/FT LUPTON	14919511	486990						8	
	8123	CO	OVERLAND PASS - OPPL/DJ JUNCTION & DJ PL	14793911	486990	0	0	1	1	1	9	
	8123	CO	OVERLAND PASS - PAWNEE CREEK	16203211	486990						2	
	35001	NM	Albuquerque Refined Products Terminal	12817711	48691	3	1				22	
	35005	NM	NuStar Logistics Operation LP - Hope Pump St	7565111	48691	4	101	0	0	0	0	
	35015	NM	Artesia Gas Plant	7411811	21112	380	351	11	11	19	73	
	35015	NM	Chaparral Gas Plant	17128911	21112	72	110	3	3	4	133	
	35015	NM	DCP Midstream - Pecos Diamond Gas Plant	7761811	21112	46	59	4	4	0	165	
	35015	NM	Empire Abo Gas Plant/Compressor Station	7584511	21112	12	84	0	0	162	42	
	35015	NM	Oxy - Indian Basin Gas Plant	7905211	21112	29	161	4	4	51	40	
	35025	NM	DCP Midstream - Eunice Gas Plant	5228911	21112	224	606	11	11	1,437	70	
	35025	NM	Denton Gas Plant	8091311	21112	32	26	2	2	952	28	
	35025	NM	Eunice Gas Processing Plant	8092311	21112	357	2,046	22	21	23	72	
	35025	NM	Jal No3 Gas Plant	5226911	21112	382	381	16	16	1,968	266	
	35025	NM	Linam Ranch Gas Plant	8241211	21112	449	692	28	28	109	103	
	35025	NM	Maljamar Gas Plant	5226611	21112	50	87	7	7	213	57	
	35025	NM	Saunders Gas Plant	8241411	21112	116	821	10	10	416	66	
	35025	NM	Targa - Monument Gas Plant	8241311	21112	195	361	17	5	1,953	89	
	35043	NM	San Luis Pump Station	6723811	48699	2	3	0	0		1	
	35043	NM	San Ysidro Pump Station GCP1-1145	6724211	48699	2	9	1	1	1	20	
	35045	NM	Harvest Pipeline - San Juan Gas Plant	7231911	21112	63	527	17	17	1	47	
	35045	NM	Huerfano Pump Station	6735511	48699	10	25	1	1	0	23	
	35045	NM	Kutz Canyon Processing Plant	7230311	21112	603	767	14	14	3	510	
	35045	NM	San Juan River Gas Plant	8091911	21112	92	137	4	4	143	78	
	35045	NM	Val Verde Treatment Plant	7992811	21112	107	139	25	25	43	156	
	38093	ND	Jamestown East Products Terminal	8012911	486910						39	
	46005	SD	NuStar PipeLine Operating Partnership	15648111	486910						41	
	46013	SD	NuStar Pipeline Operating Partnership LP	15646411	486910						73	
	46029	SD	Magellan Pipeline Company	15646511	486910						83	
	46035	SD	NuStar Pipeline Operatng Partnership	15646711	486910	0	0	0	0	0	14	
	46099	SD	Magellan Pipeline Company	15646311	486910	14	9	0	0	0	165	
	46099	SD	NuStar Pipeline Operating Partnership LP	2911811	486910	0	2	0	0	0	17	
	46135	SD	NuStar PipeLine Operating Partnership	15646611	486910						102	
	56025	WY	Casper Gas Plant	17924811	211130	41	0	32	2	2	0	
	56037	WY	Rock Springs Terminal	6939911	486910	0	0	0	0		33	
Grand Total						3,284	0	7,537	199	186	7,500	2,698

INTRODUCTION TO EMISSION PROCESSING

INTRODUCTION TO EMISSION PROCESSING

Start With



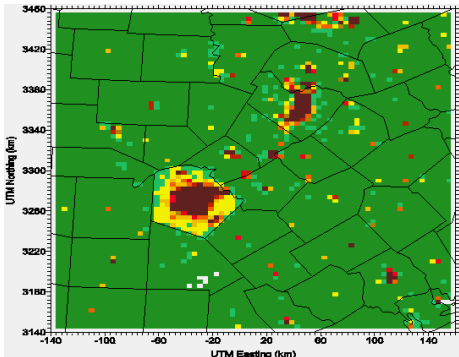
Annual Estimates (tons/year)

County Totals

Criteria Pollutants (NO_x, CO, VOC)



Model Ready



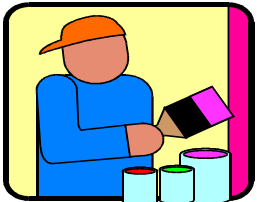
Hourly

Gridded

Speciated

Inventory Components

Total Inventory



Area



Points



Motor
Vehicles



Biogenics

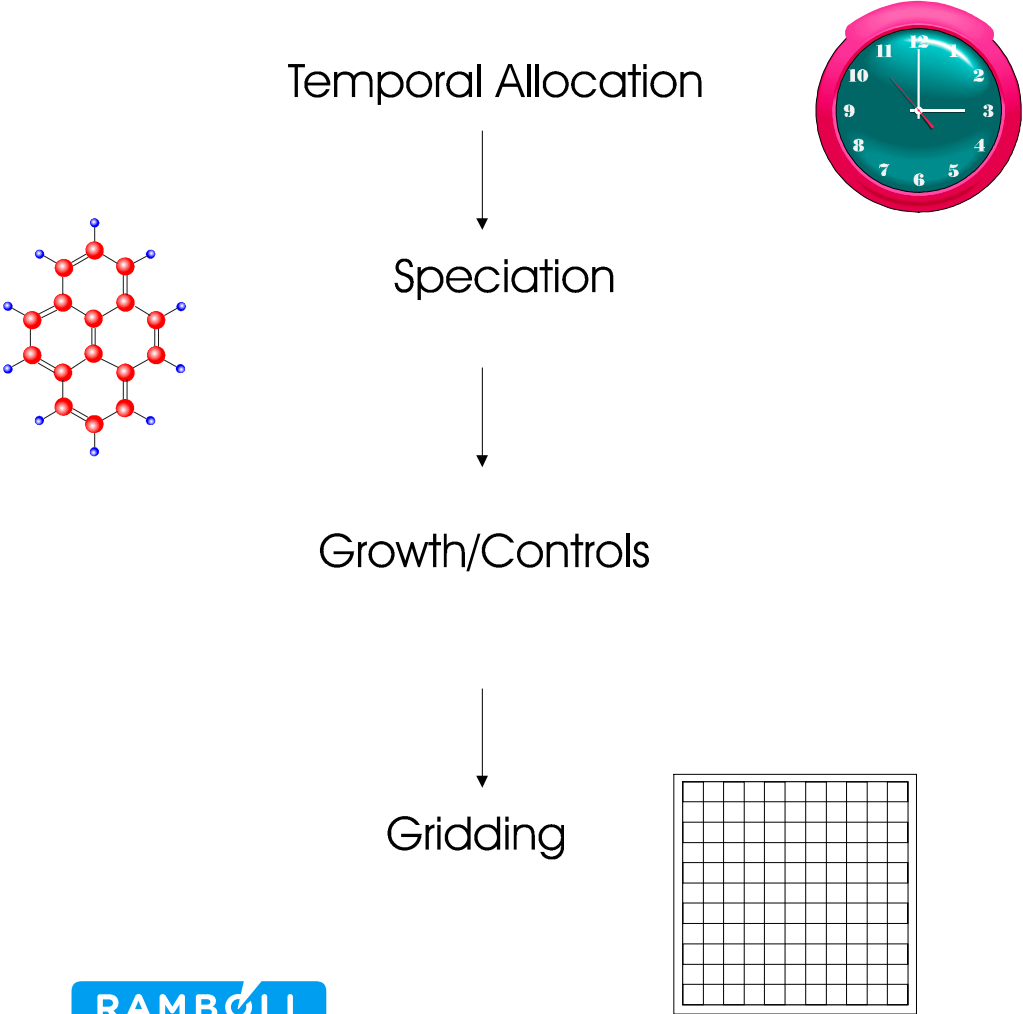
EMISSION PROCESSING STEPS

Merge Components

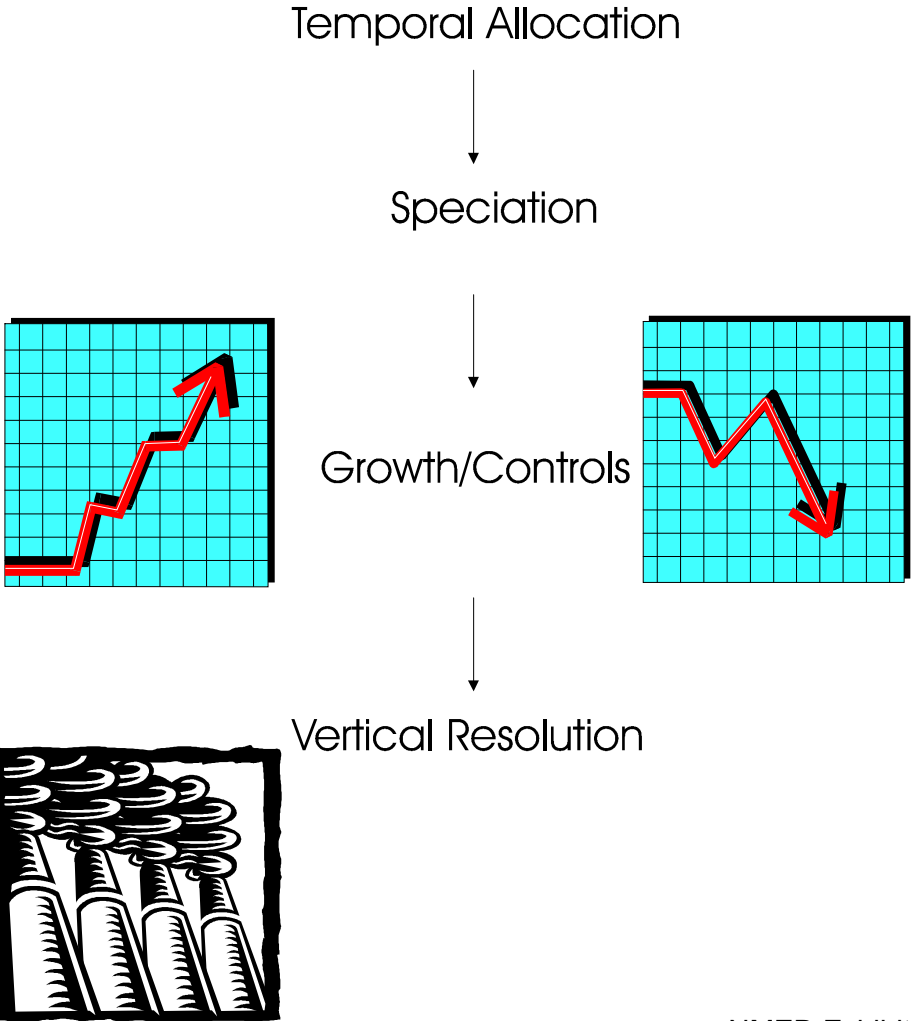
Model Inputs

INTRODUCTION TO EMISSION PROCESSING

Area source emission processing

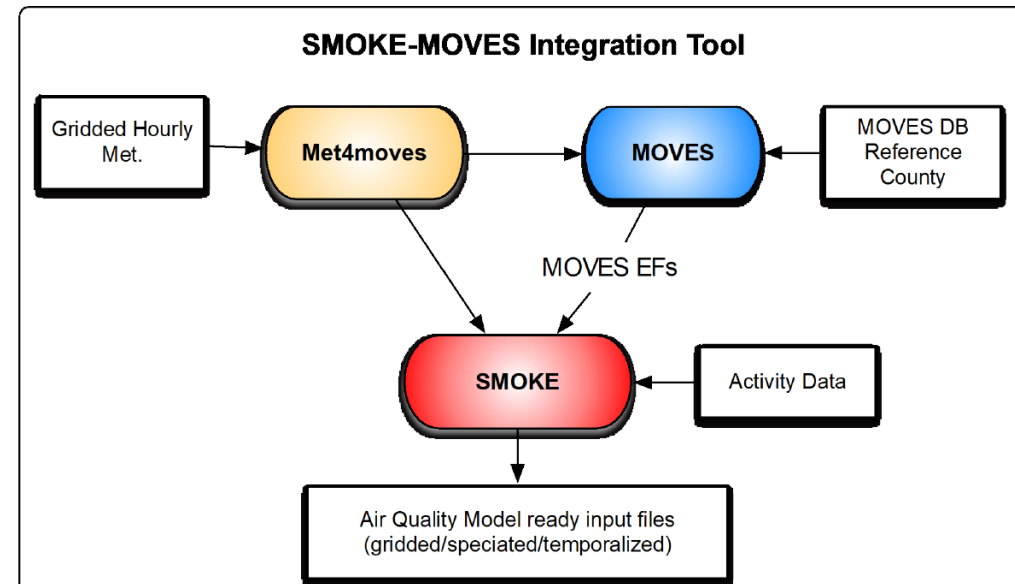


Point source emission processing



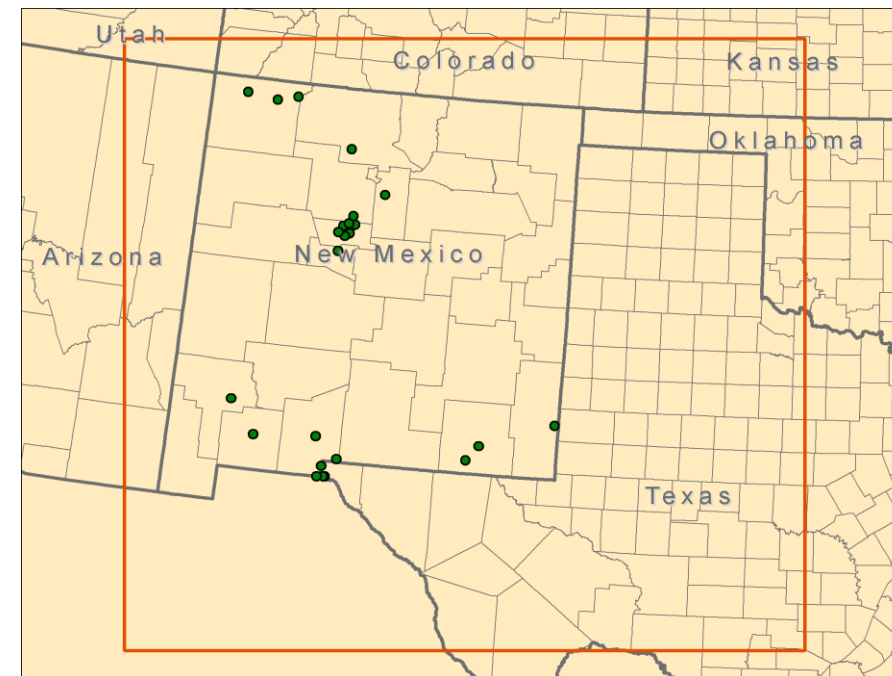
OVERVIEW OF SMOKE-MOVES PROCESSING

- Requires emission rate “lookup” tables generated by MOVES
- Uses gridded, hourly, day-specific temperatures
- SMOKE processing applies the emission factors to the activity data to compute grid-cell emissions



SMOKE PROCESSING OF 2014 EMISSIONS

- SMOKE version 4.7
- Process emissions for 4-km domain
- Spatial surrogates: O&G spatial surrogates are based on 2014 O&G activity data and other 4-km surrogates obtained from EPA's Emission Modeling Platform (EMP).
- Speciation for CB6r4 chemical mechanism in CAMx



SMOKE PROCESSING SECTORS

2014 4-km emissions in average tons/day

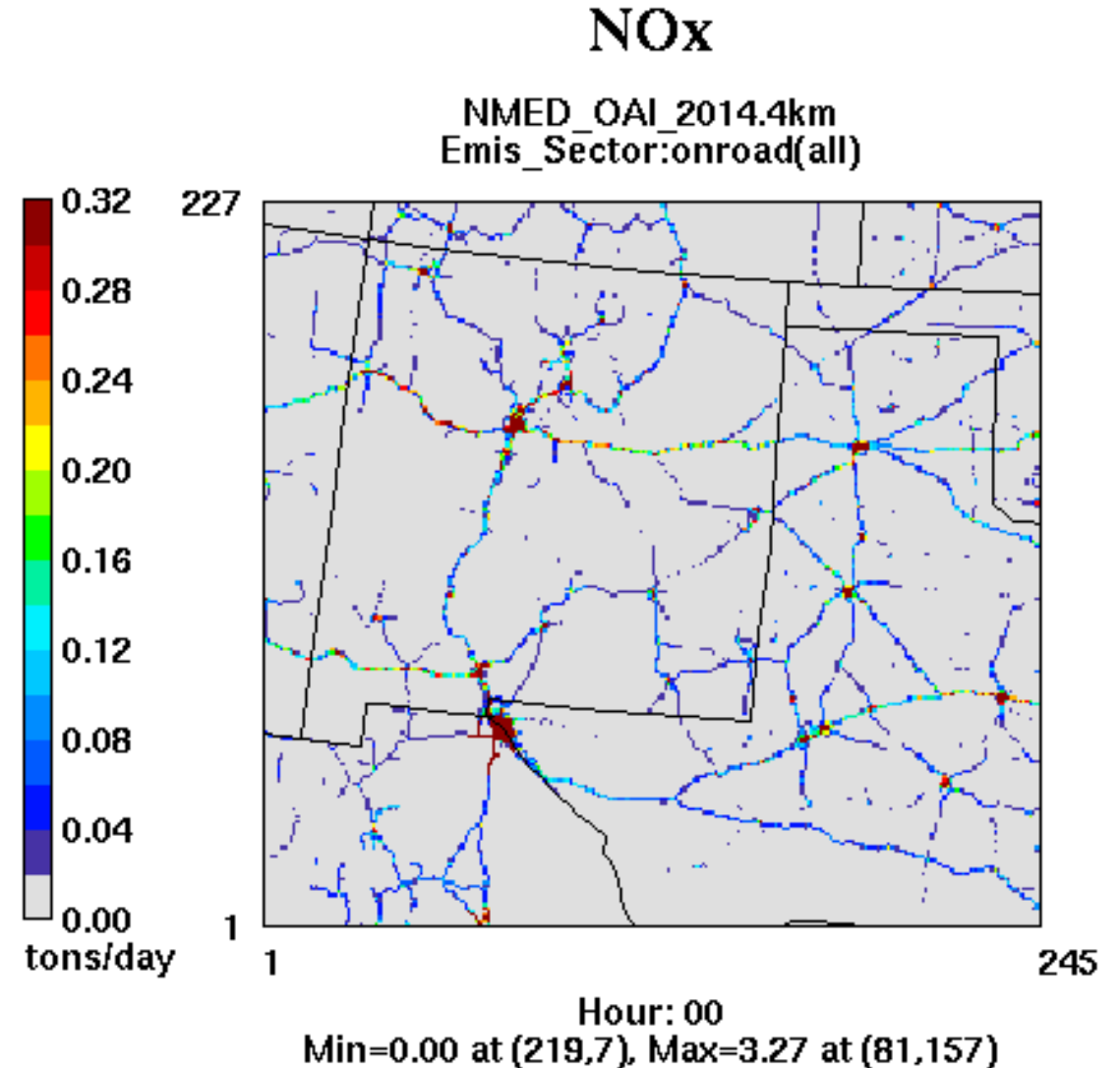
Sector	CO	NOx	VOC
ag	0.0	0.0	43.4
nonpt	141.3	28.5	213.2
nonroad	570.3	133.4	73.2
np_oilgas	286.8	311.7	1,642.5
np_oilgas_wrap_only	237.7	157.8	567.3
onroad	1,476.2	444.5	150.6
onroad_mex	356.3	98.4	34.4
othar	19.9	42.2	103.3
othpt	28.4	20.2	8.3
ptegu	89.2	210.6	5.0
pt_oilgas	113.8	205.2	48.4
pt_oilgas_wrap_only	89.9	114.7	56.1
ptnonipm	74.4	47.5	24.4
rail	22.9	122.7	6.2
rwc	7.0	0.1	1.2
TOTAL	3,513.9	1,937.6	2,977.3



Sector	Description
afdust_adj	- Area fugitive dust
ag	- Agricultural ammonia sources
nonpt	- Other nonpoint sources
np_oilgas_wrap	- Non-point Oil and Gas for 7 WRAP states (CO, MT, NM, ND, SD, UT, WY)
np_oilgas	- Non-point Oil and Gas
nonroad	- Non-road mobile
rail	- Locomotive
onroad	- On-road mobile
ptegu	- EGU point sources
ptnonipm	- Non-EGU point sources
pt_oilgas_wrap	- Point Oil and Gas for 7 WRAP states (CO, MT, NM, ND, SD, UT, WY)
pt_oilgas	- Point Oil and Gas
rwc	- Residential Wood Combustion
onroad_mex	- Mexico onroad mobile
othar	- Mexico area
othpt	- Mexico point sources
MEGAN/BEIS	- Biogenic
LtNOx	- Lightning Nox
AG fire	- Ag Fire
RX fire	- Prescribed Fire
WF fire	- Wild Fire
Ptfire_othna	- Mexico fire
WBD	- Windblown Dust

ONROAD EMISSIONS

- On-road emissions developed using SMOKE-MOVES processing with 2014/2023 activity data and day-specific hourly gridded 2014 WRF meteorology
 - 2014 MOVES lookup tables and 4-km MCIP data
- SMOKE-MOVES processing:
 - rate-per-distance (RPD) (30 mins per day)
 - rate-per-vehicle (RPV) (10 mins per day)
 - rate-per-profile (RPP)
 - rate-per-hour (RPH)

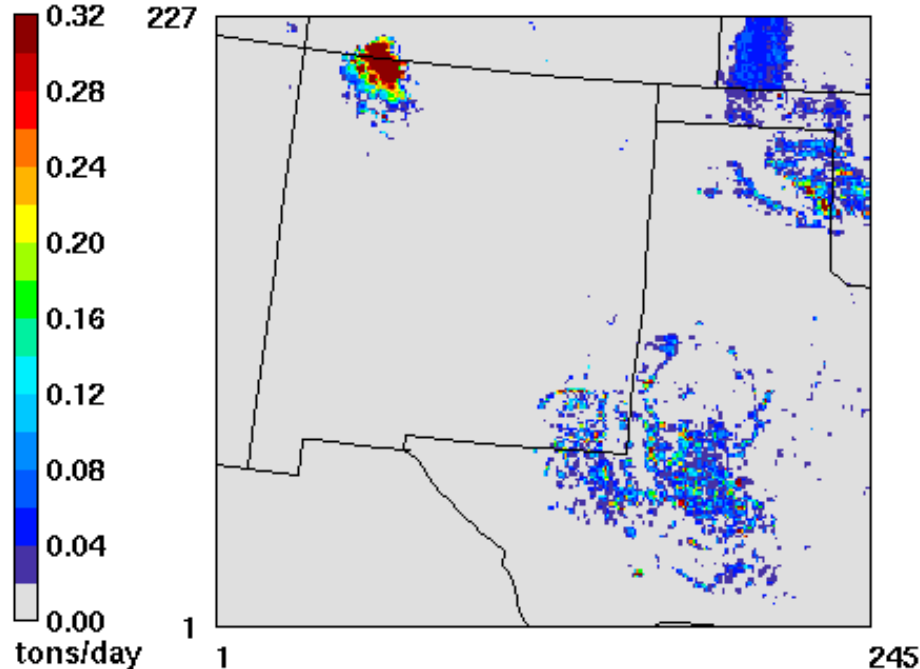


NON-POINT O&G EMISSIONS

Basin-specific speciation profiles

NO_x

NMED_OAI_2014.4km
Emis_Sector:np_oilgas(all)



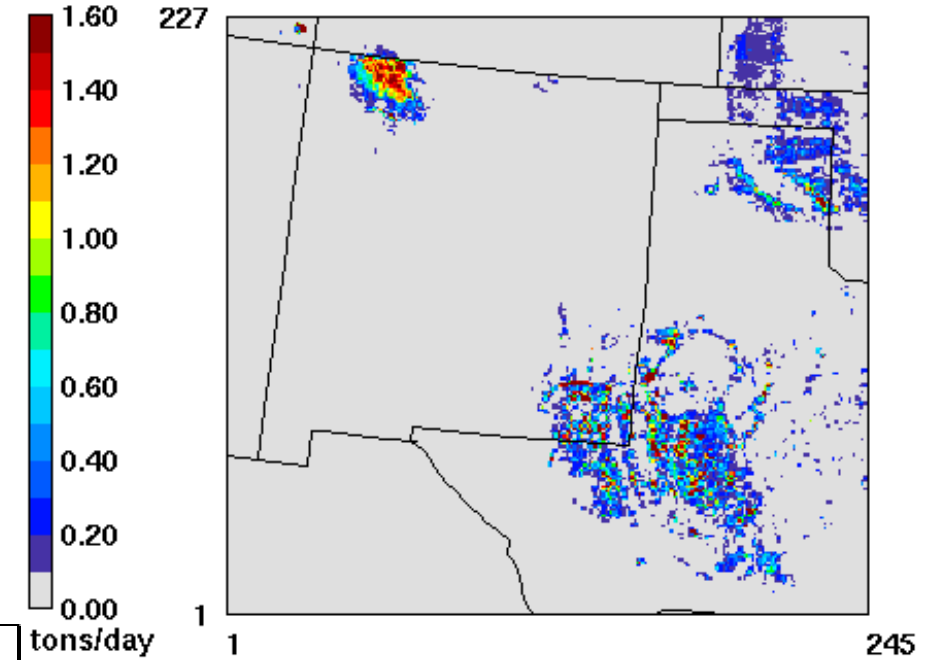
May 28,2004 0:00:00
Min=0.00 at (1,1), Max=2.86 at (219,153)

RAMBOLL

Surrogate	Surrogate Description
688	Gas production at oil wells
689	Gas production at all wells
690	Oil production at all wells
691	Well count - CBM wells
692	Spud count
693	Well count - all wells
694	Oil production at Oil wells
695	Well count - oil wells
696	Gas production at gas wells
697	Oil production at gas wells
698	Well count - gas wells
699	Gas production at CBM wells

VOC

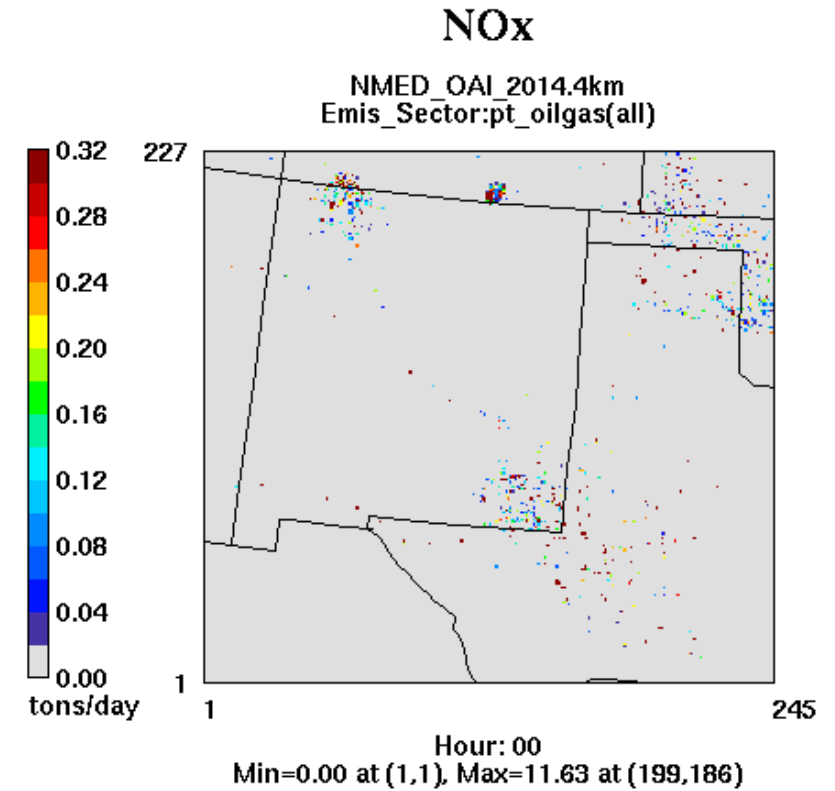
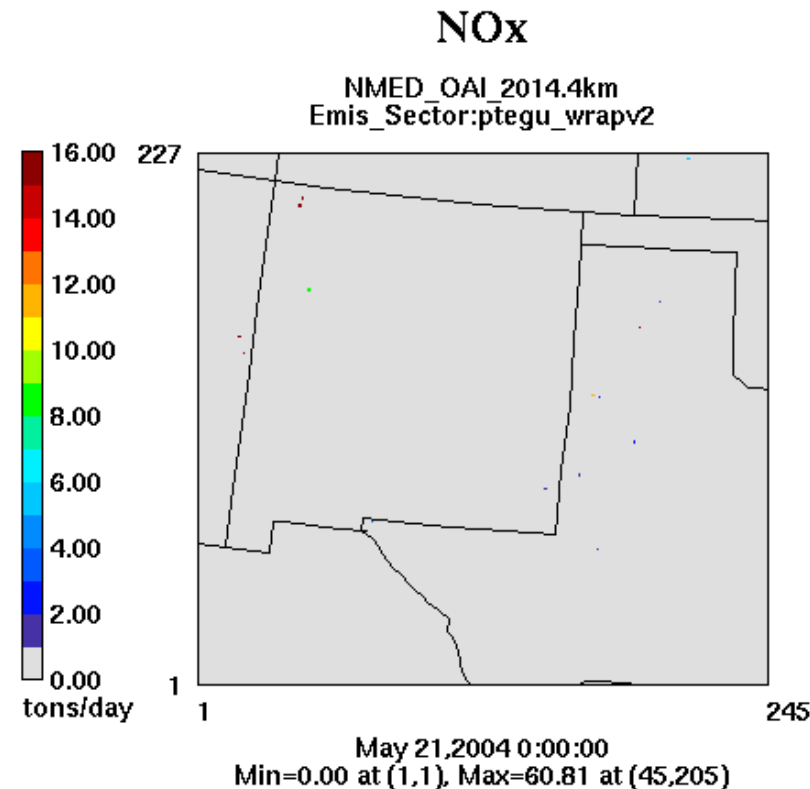
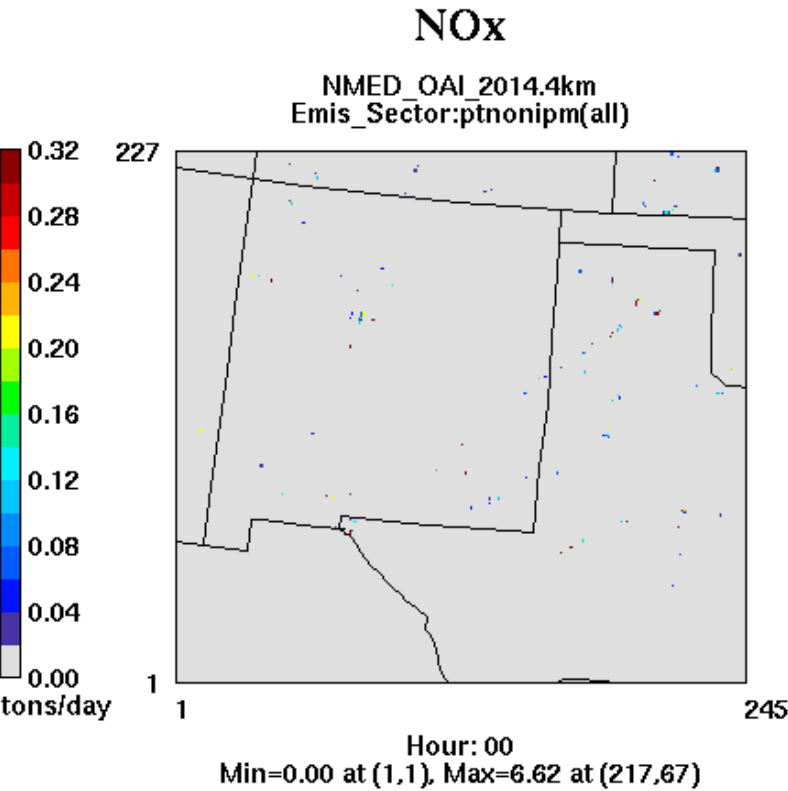
NMED_OAI_2014.4km
Emis_Sector:np_oilgas(all)



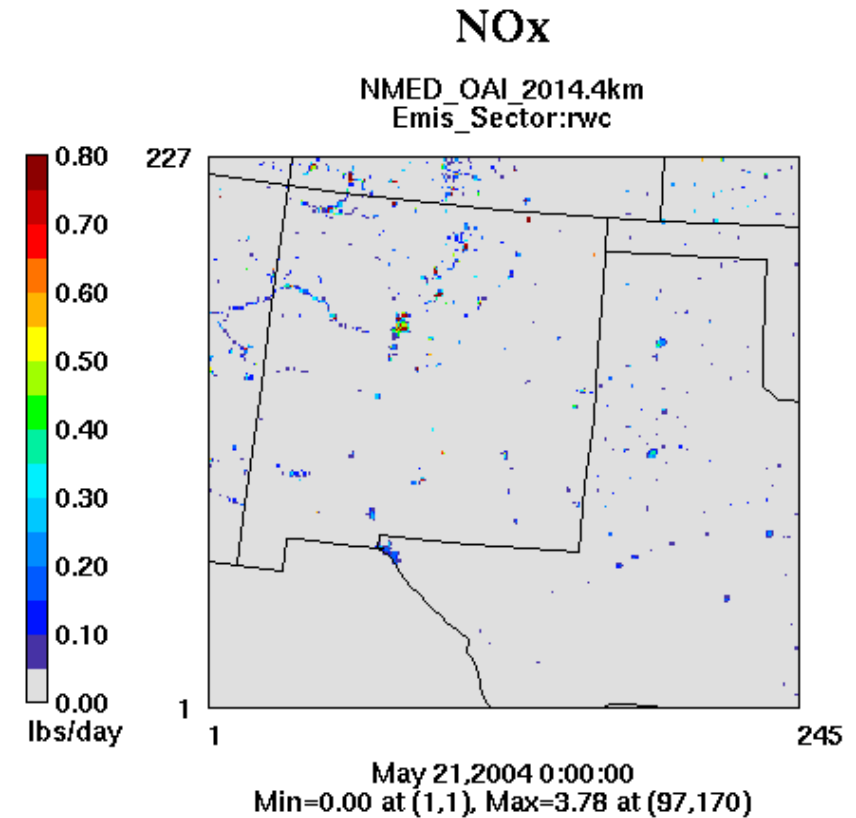
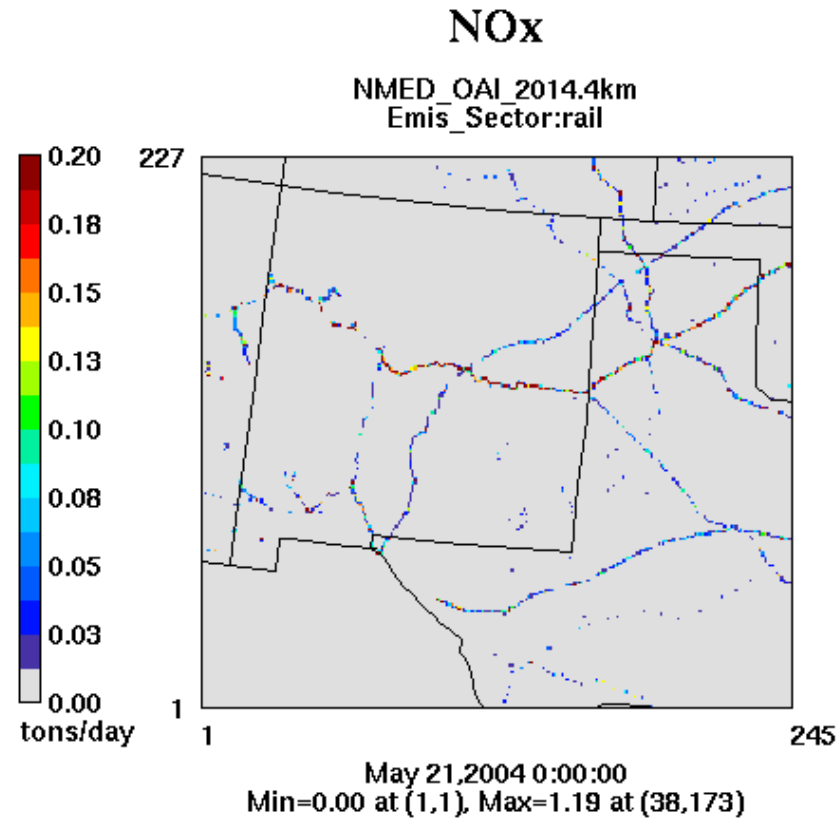
May 28,2004 0:00:00
Min=0.00 at (1,1), Max=6.70 at (147,86)

POINT SOURCE EMISSIONS

Point source processing generates elevated and low-level gridded files. Elevated files contain x/y coordinates for each point source so they are not domain dependent.

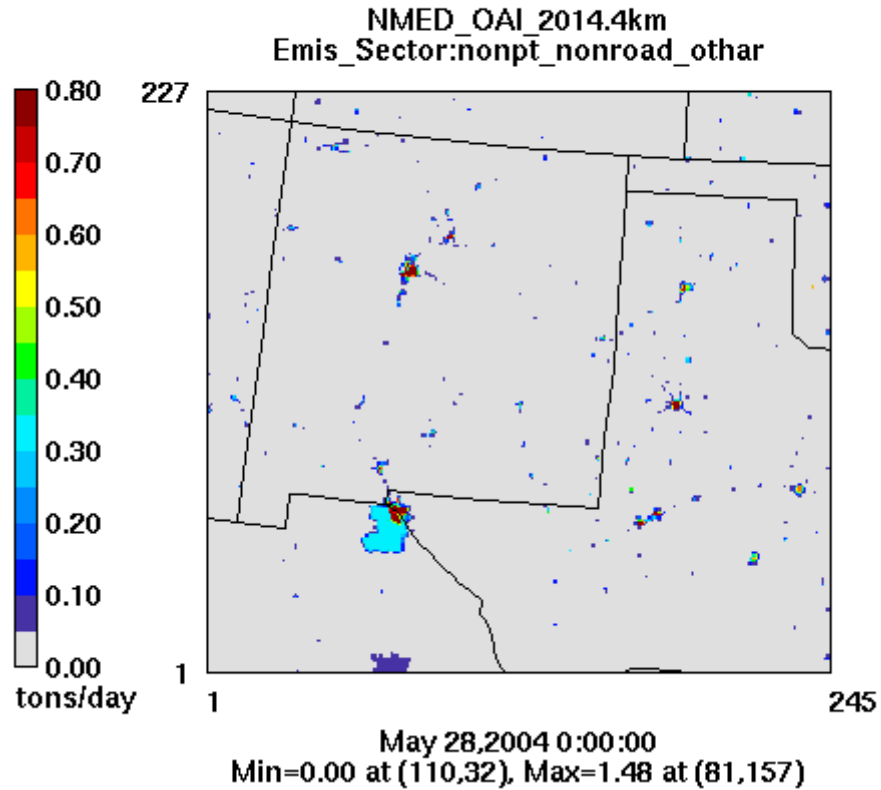


RAIL AND RWC EMISSIONS

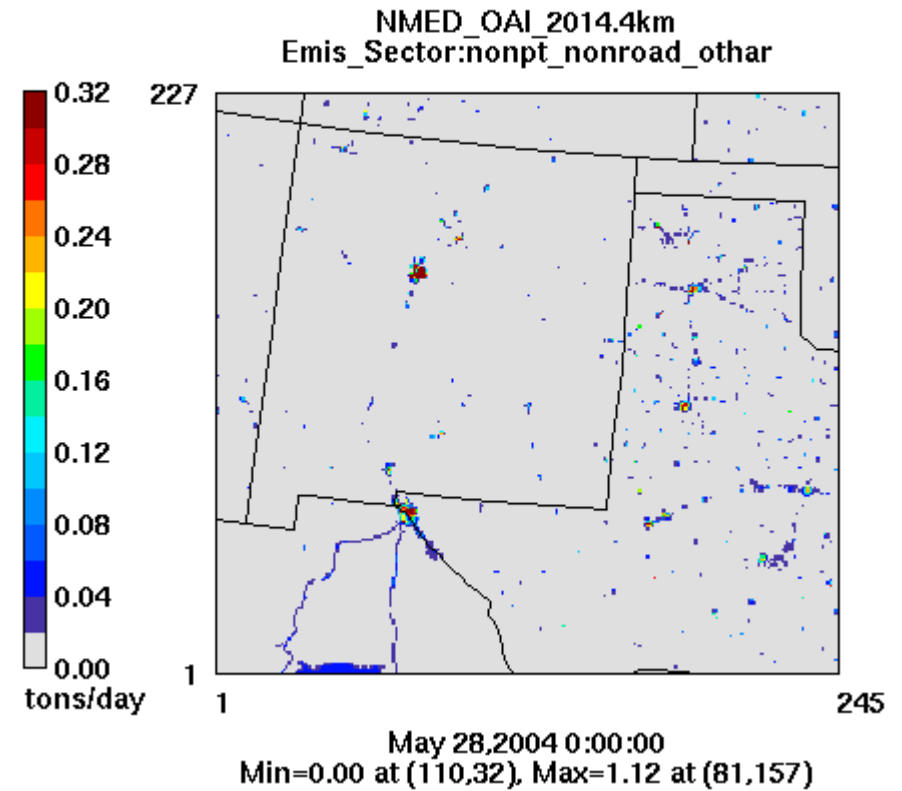


NONPOINT AND NONROAD EMISSIONS

VOC



NOx



NATURAL EMISSIONS

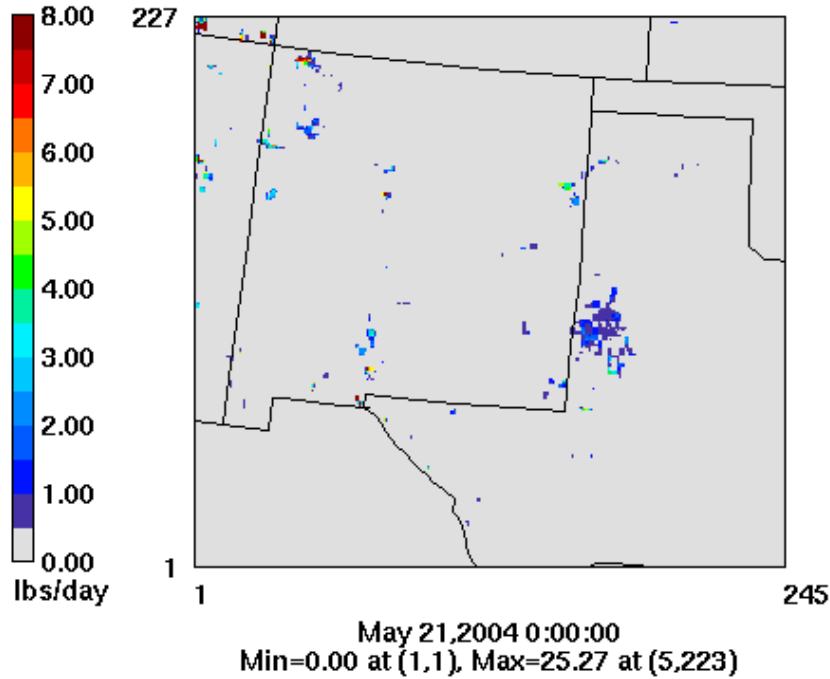
- Lightning NOx: Lightning NOx (LNOx) emissions processor with 2014 WRF meteorological data to generate CAMx-ready emissions
- Oceanic Emissions: OCEANIC emissions processor was used to generate sea salt and dimethyl sulfide (DMS) emissions
- Fire Emissions: Agricultural, prescribed burn and wildfire emissions from WRAP 2014v2 modeling developed by WRAP Smoke and Fire Workgroup
- Windblown dust: CAMx windblown dust (WBD) processor
- Biogenic Emissions: MEGAN or BEIS biogenic emissions model

WINDBLOWN DUST EMISSIONS

	Emissions (tons/day)	
Year	PM2_5	CPRM
2014	20.9	80.2

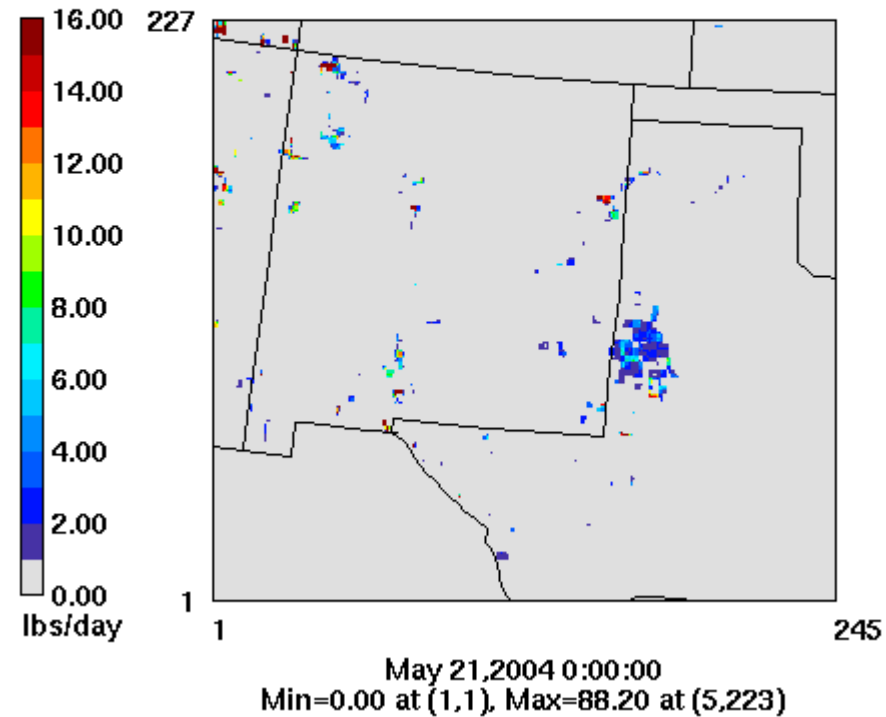
PM25

NMED_OAI_2014.4km
Emis_Sector:WBD



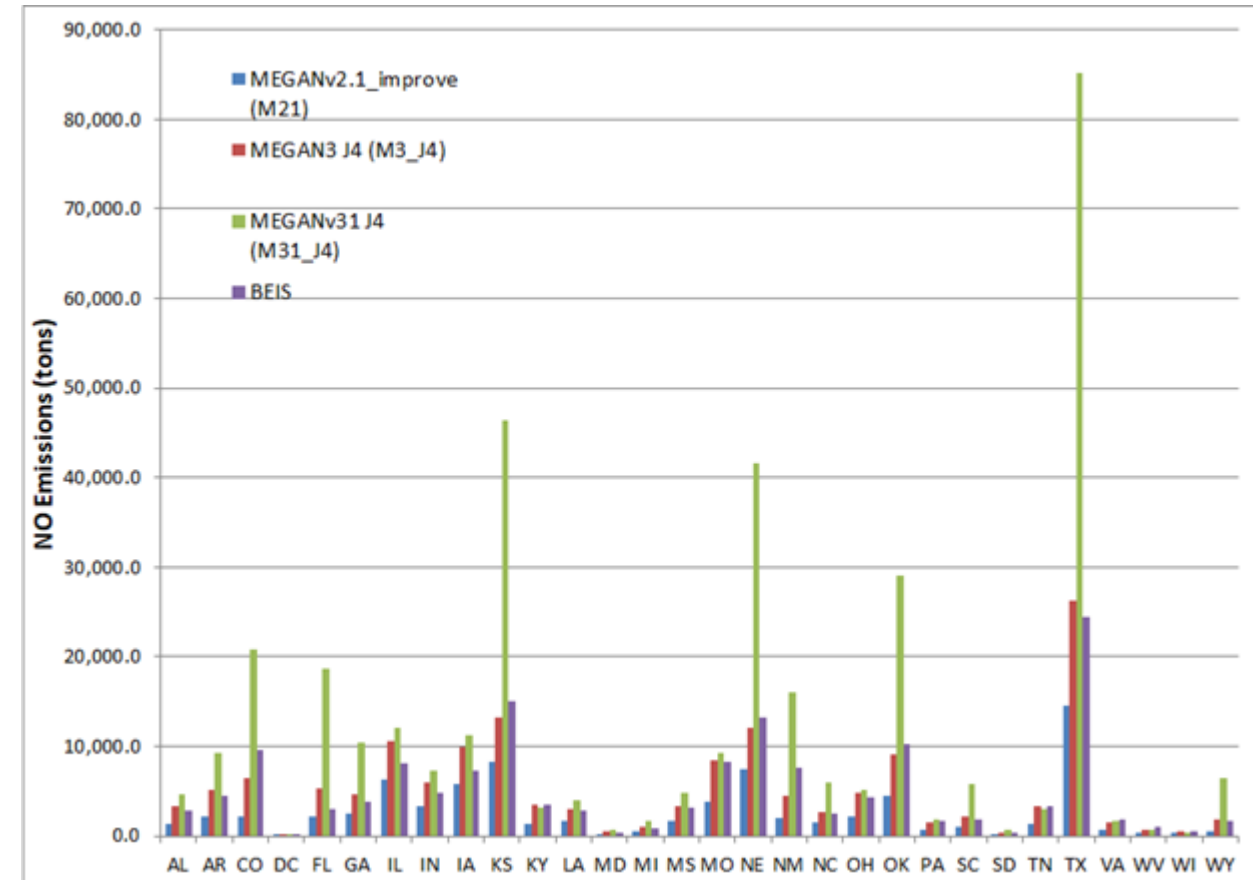
PMC

NMED_OAI_2014.4km
Emis_Sector:WBD



BIOGENIC EMISSIONS

- MEGAN3.1 improvement: Replaced soil NO code (Yienger and Levy approach) used by MEGAN3.0 (and BEIS) with state-of-the-art BDSNP approach. This model was already available to the community in GEOS-chem and WRF-CMAQ but required on-line AQ model.
- Summer soil NO_x (June 1-July 15, 2013 period) for New Mexico estimated using different biogenic models.
- Agricultural regions with high fertilizer application rates have large NO emissions
- Will use MEGAN v3.1 emissions as latest data



Reference: Guenther, A. et al (2018). Final Report For Project 18-005: Next steps for improving Texas biogenic VOC and NO emission estimates. Prepared for Air Quality Research Program (AQRP).

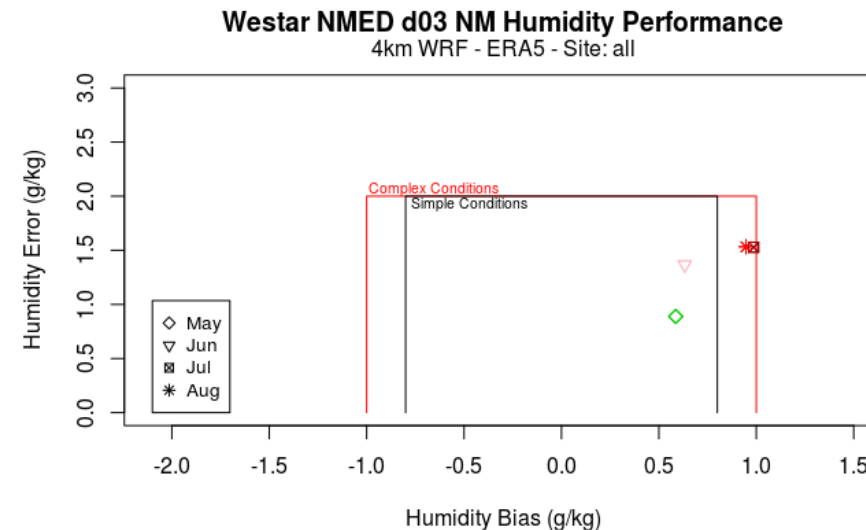
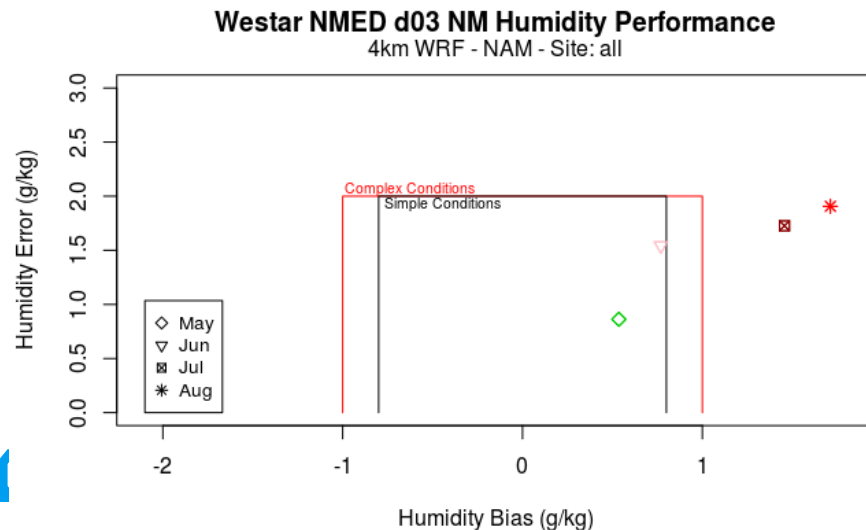
CAMX METEOROLOGICAL SENSITIVITY TESTS AND FINAL CONFIGURATION

OVERVIEW

- Explore CAMx model performance using various WRF simulations presented on June 26, 2020 webinar (WRF sensitivities)
- CAMx model configurations used for WRF sensitivities
- Determine the WRF input and model configuration that best performs on selected period to use for 2014 CAMx base case

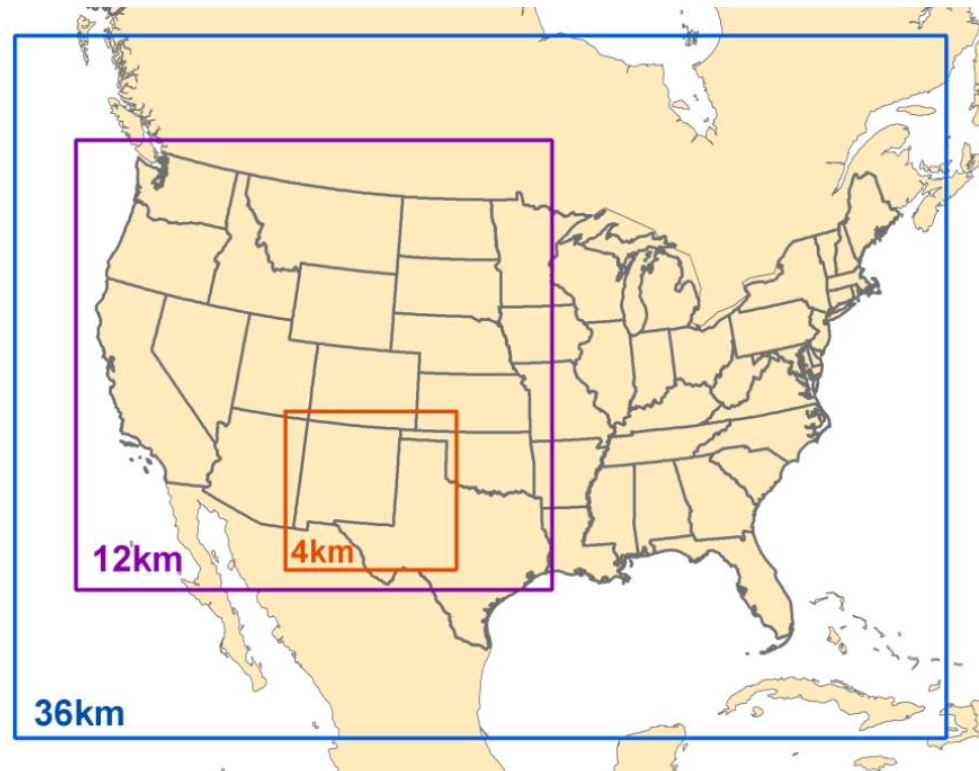
2014 WRF PERFORMANCE SUMMARY (JUNE 26 WEBINAR)

- WRF summer 2014 simulations using NAM and ERA5 analysis fields
 - Analysis fields used for initialization and boundary conditions (BCs) and for 36/12-km four-dimensional data assimilation (FDDA/nudging)
- WRF model performance reasonable for both NAM and ERA5 simulations
 - Surface meteorology (WS, WD, T, Q) and precipitation (PRISM)
- Differences between NAM and ERA5 are smaller in comparison to EPA/WAQS
- NAM wet bias in Jun-Aug may be partly associated with overactive summer convection
 - ERA5 has smaller wet bias



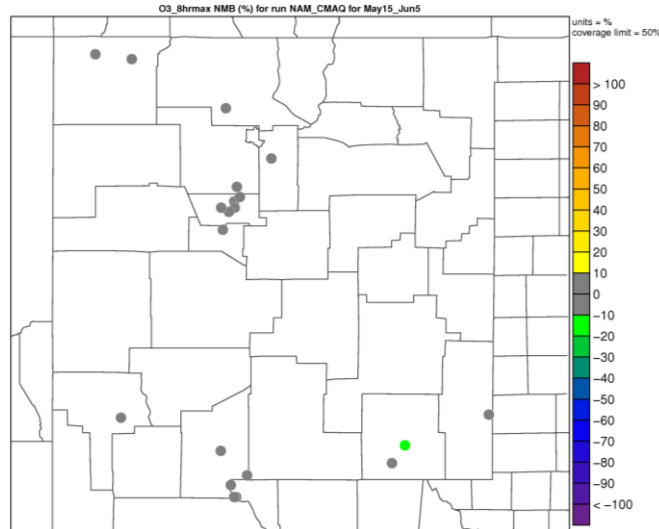
MODELING DOMAIN AND CONFIGURATION

- Performed CAMx simulations using 36/12/4-km nested domains with available WRF met (NAM and ERA5) for selected period: May 15 to Jun 5
- Emissions and other inputs identical on all sensitivities.
- CAMx flexi-nesting used for 4 km domain emissions
- Tested two types of vertical diffusivities (Kv): CMAQ and YSU
- Total of four CAMx sensitivities:
 1. **NAM CMAQ**
 2. **NAM YSU**
 3. **ERA5 CMAQ**
 4. **ERA5 YSU**

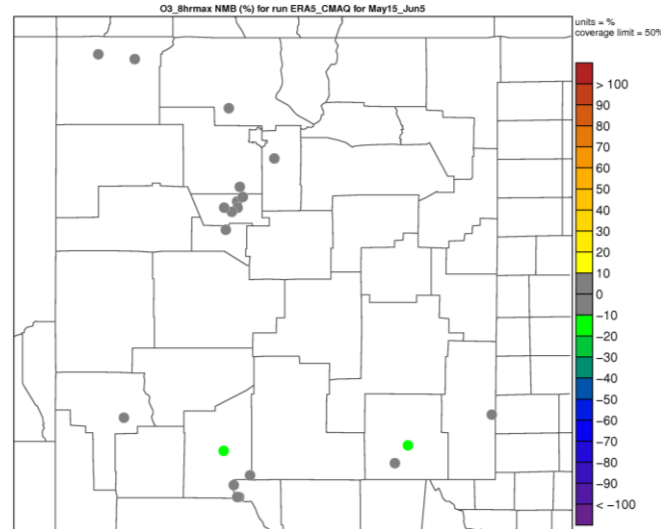


OZONE BIAS COMPARISON: NMB WITH 60 PPB CUT-OFF

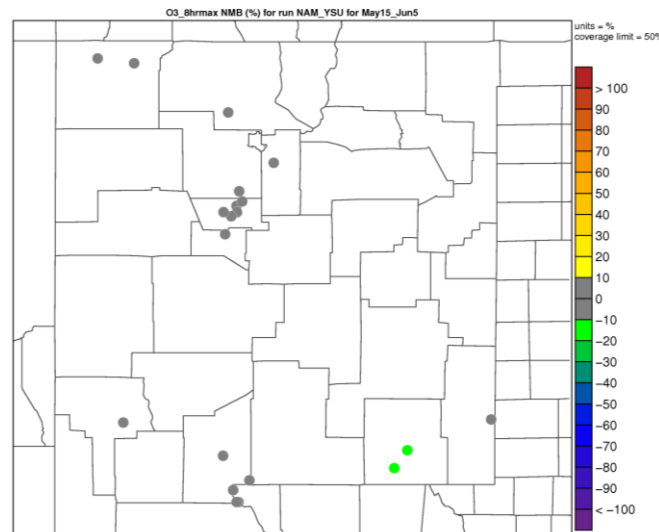
NAM CMAQ



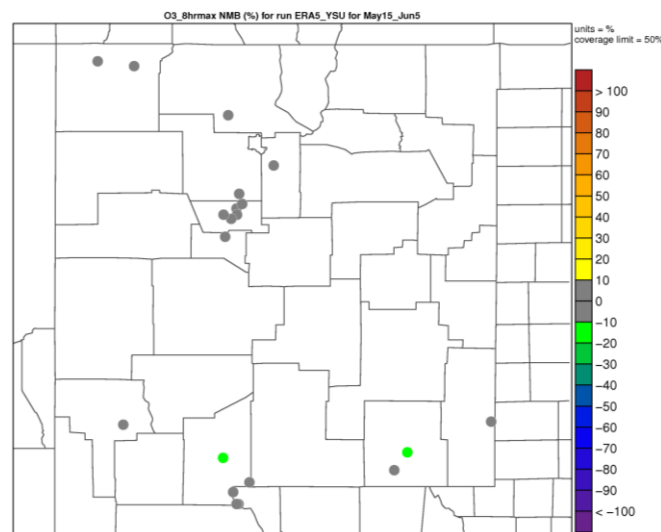
ERA5 CMAQ



NAM YSU



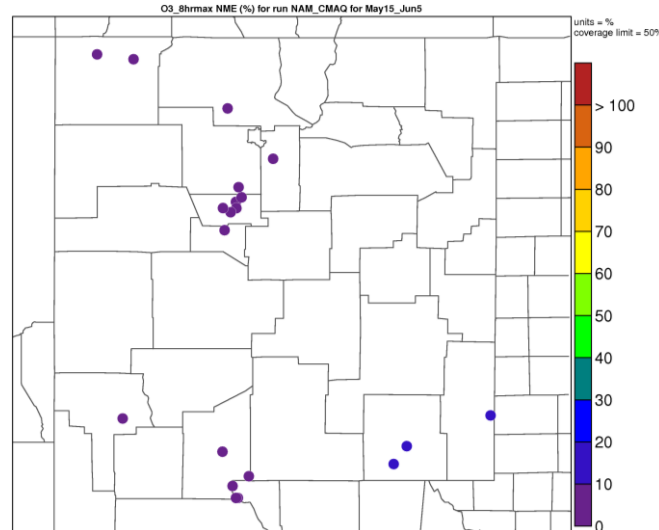
ERA5 YSU



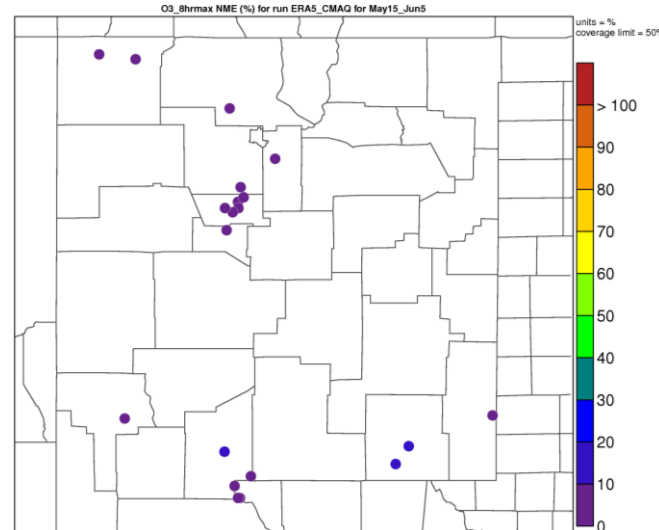
- NMB for all sensitivities generally within Performance Goal
 - Goal: NMB < $\pm 5\%$
 - Criteria: NMB < $\pm 15\%$
- Worst performance occurs in Southern portion of NM
- Based on NMB, NAM CMAQ is the configuration with best performance

OZONE ERROR COMPARISON: NME WITH 60 PPB CUT-OFF

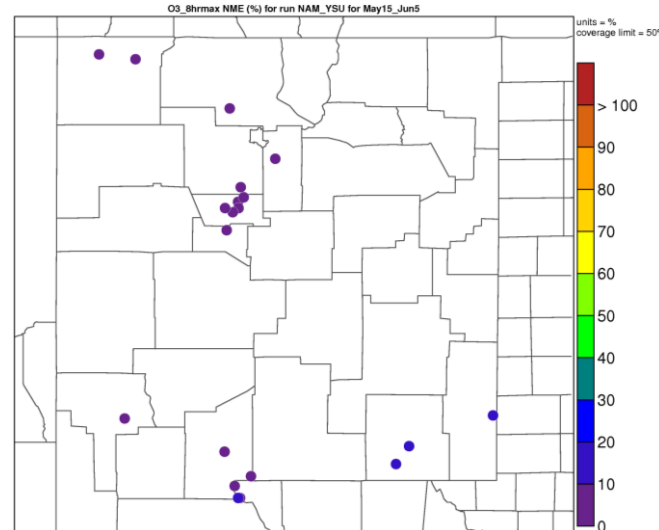
NAM CMAQ



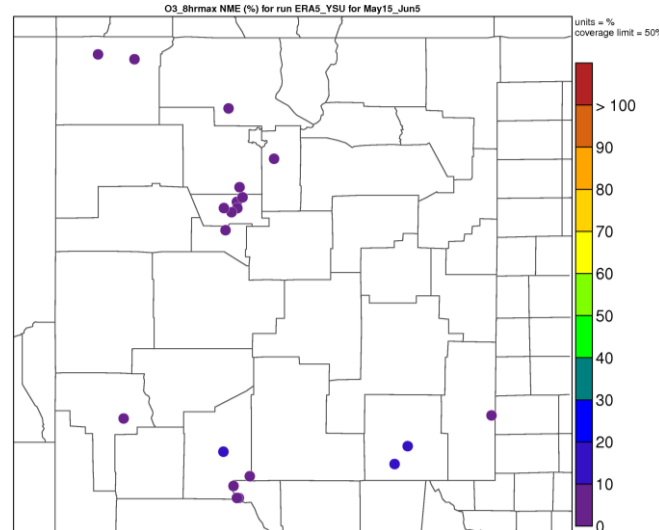
ERA5 CMAQ



NAM YSU

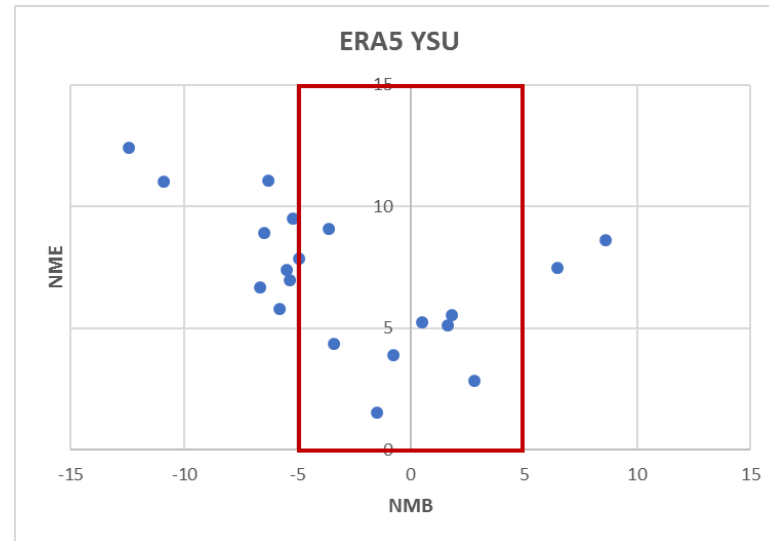
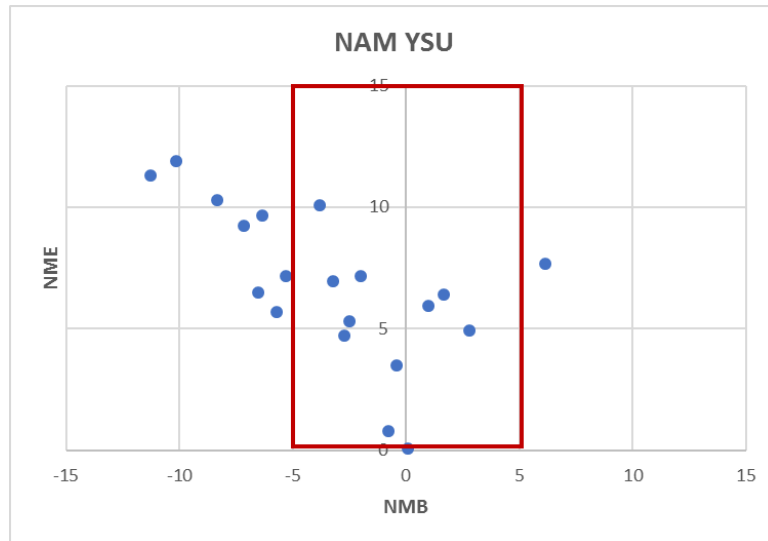
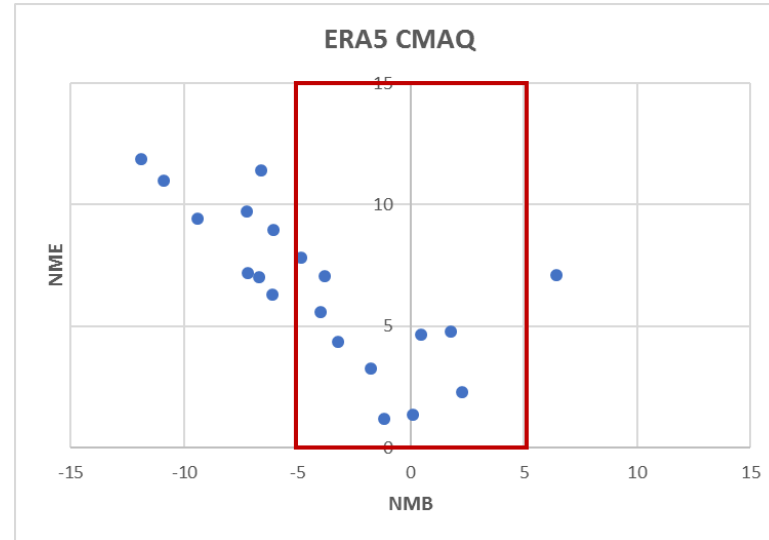
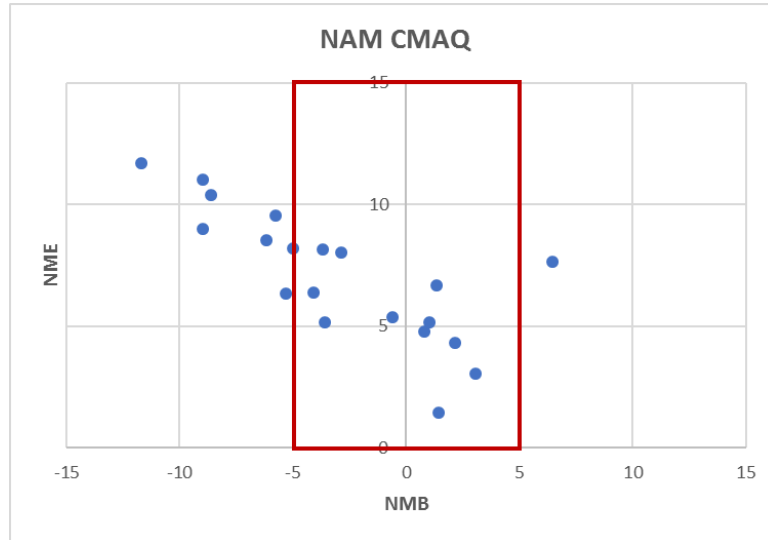


ERA5 YSU



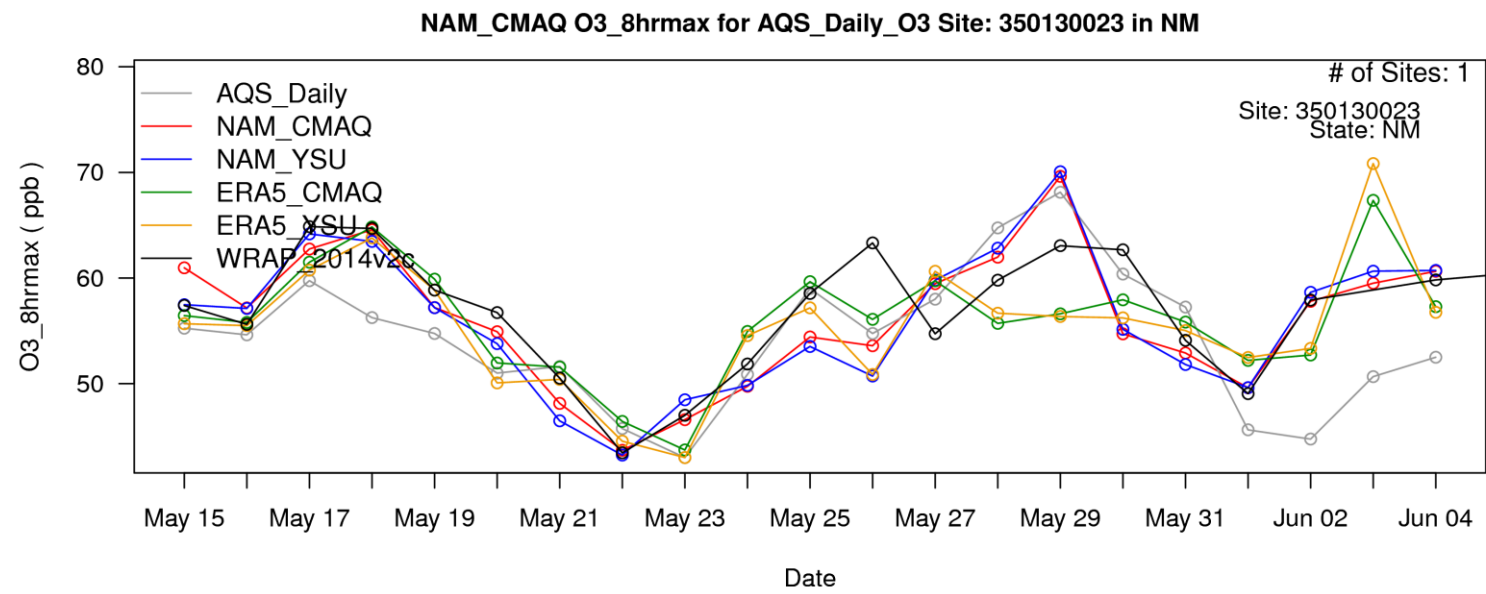
- NME for all sensitivities generally within Performance Goal
 - Goal: $\text{NME} < 15\%$
 - Criteria: $\text{NMB} < 25\%$
- Worst performance occurs in Southern portion of NM
- Based on NME, NAM meteorology is the best performing

SITE-SPECIFIC COMPARISON: SOCCER PLOTS 60 PPB CUT-OFF

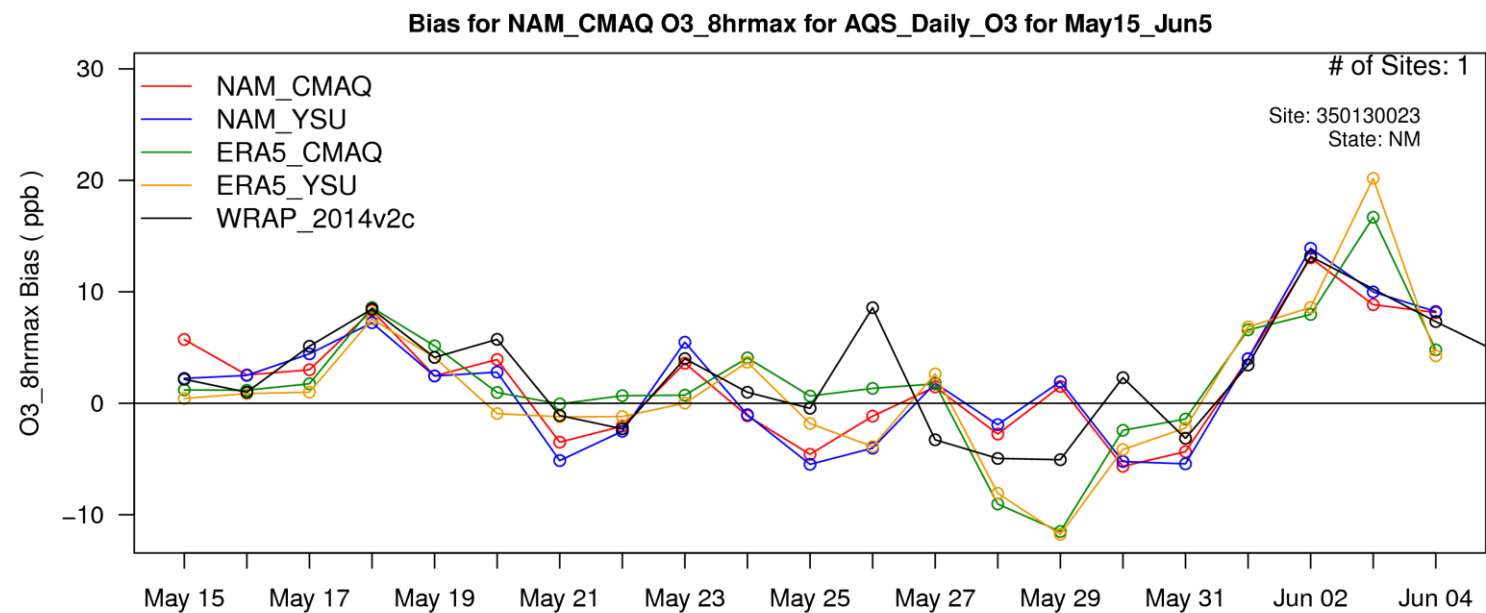


- With a 60 ppb cut-off all sensitivities show CAMx tends to underpredict ozone peaks
- Still all sensitivities within Performance Criteria
- NAM shows slightly better performance than ERA5
 - More sites achieve Performance Goals
- NAM CMAQ shows sites with smaller NME compared to NAM YSU

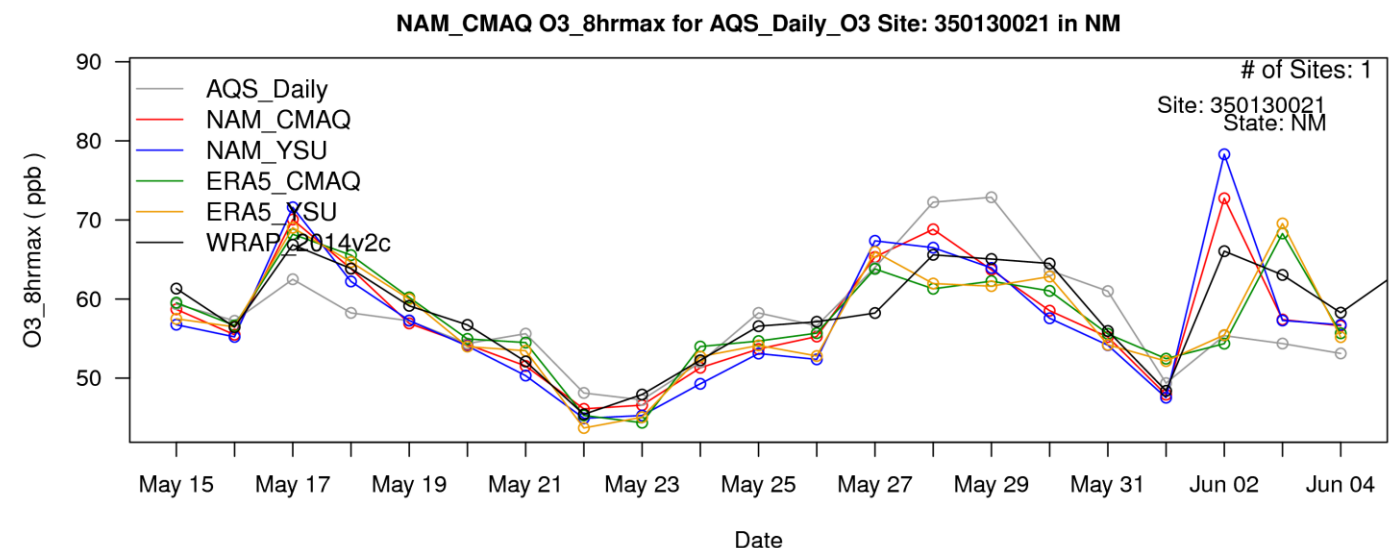
SELECTED SITES TIMESERIES: SOLANO RD (DONA ANA COUNTY)



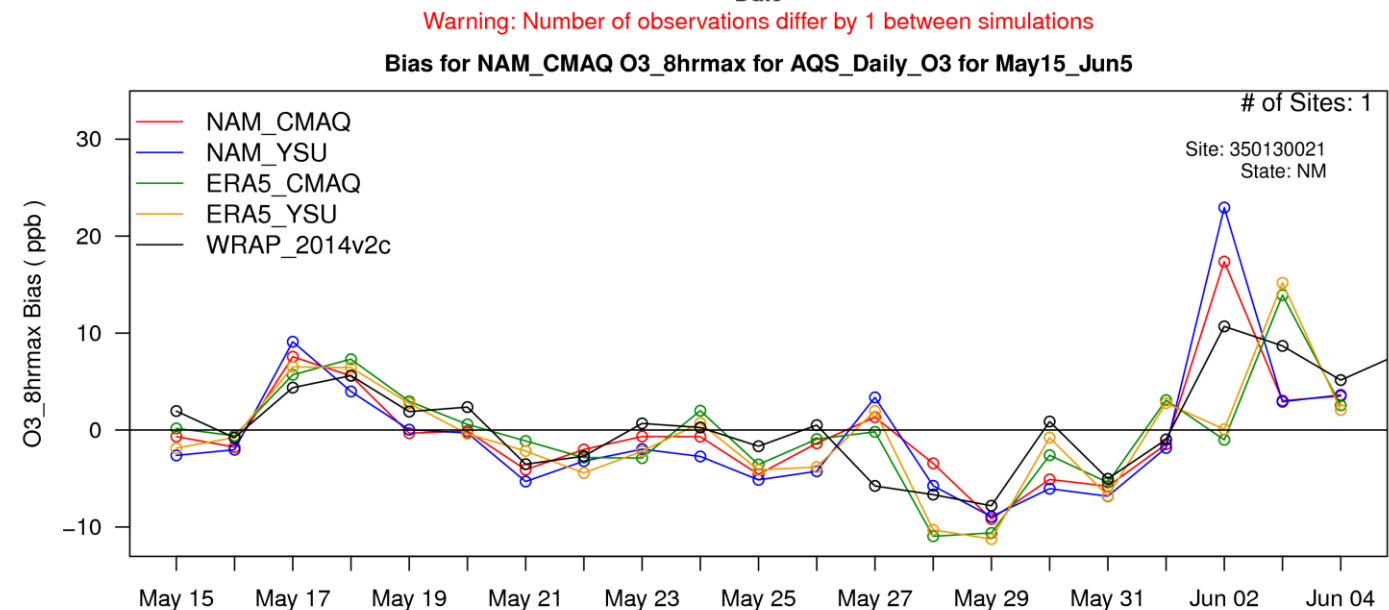
- NAM sensitivities better capture peak on May 29



SELECTED SITES TIMESERIES: DESERT VIEW (DONA ANA COUNTY)

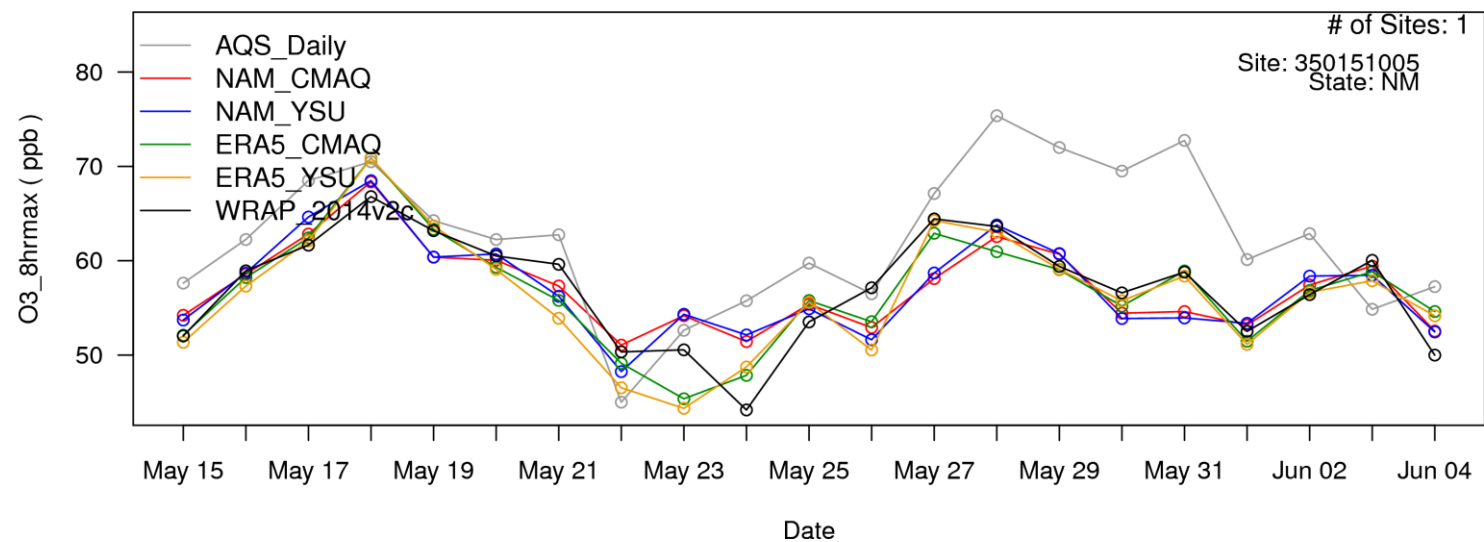


- Underestimate observed peaks May 28-29
- WRF/NAM better than other WRF



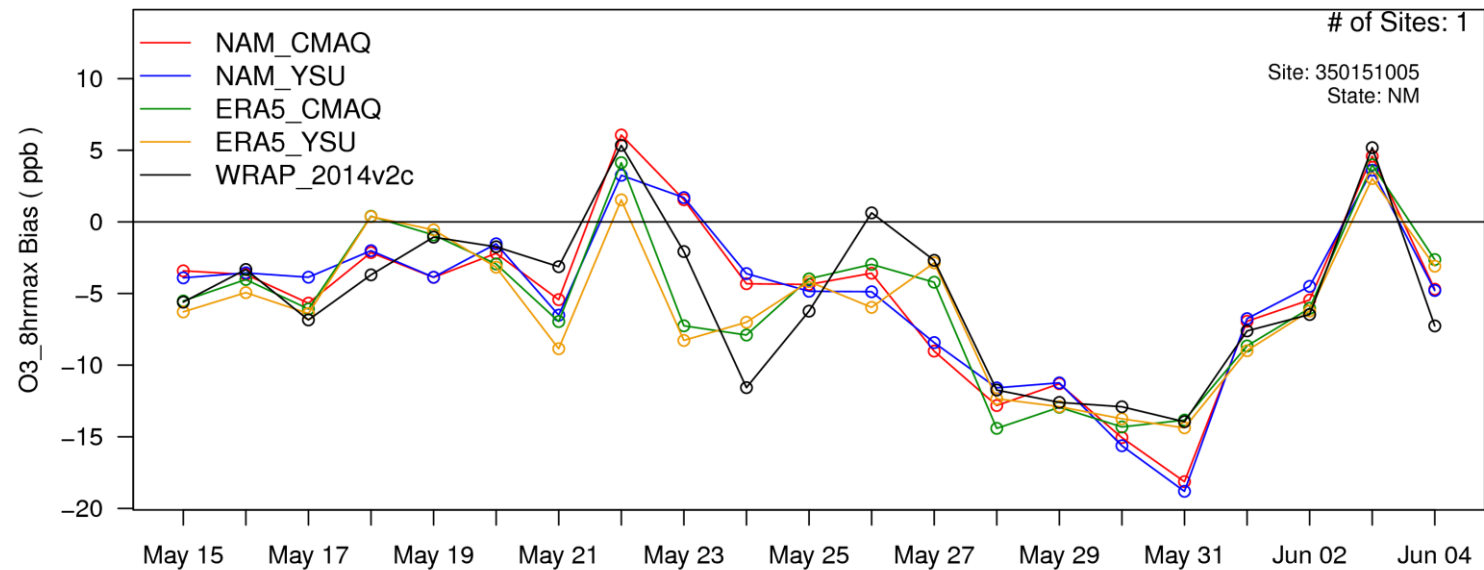
SELECTED SITES TIMESERIES: CARLSBAD (EDDY COUNTY)

NAM_CMAQ O3_8hrmax for AQS_Daily_O3 Site: 350151005 in NM



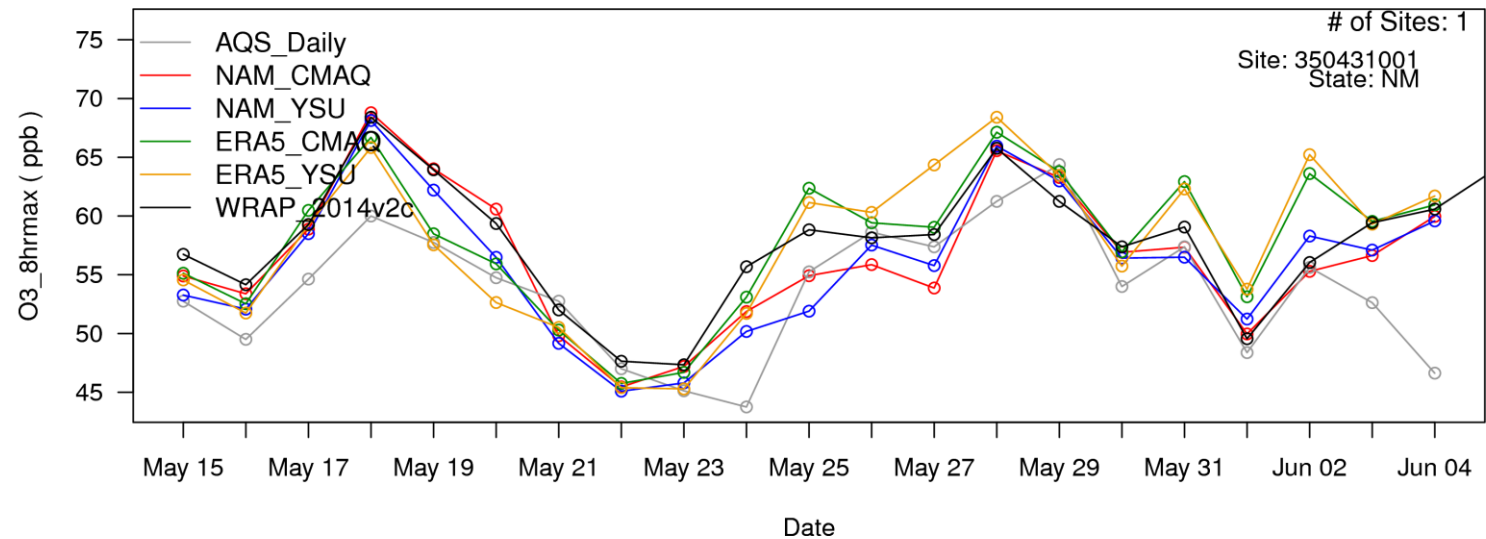
- All sensitivities miss high ozone on May 27 to May 31

Bias for NAM_CMAQ O3_8hrmax for AQS_Daily_O3 for May15_Jun5



SELECTED SITES TIMESERIES: SANDOVAL COUNTY

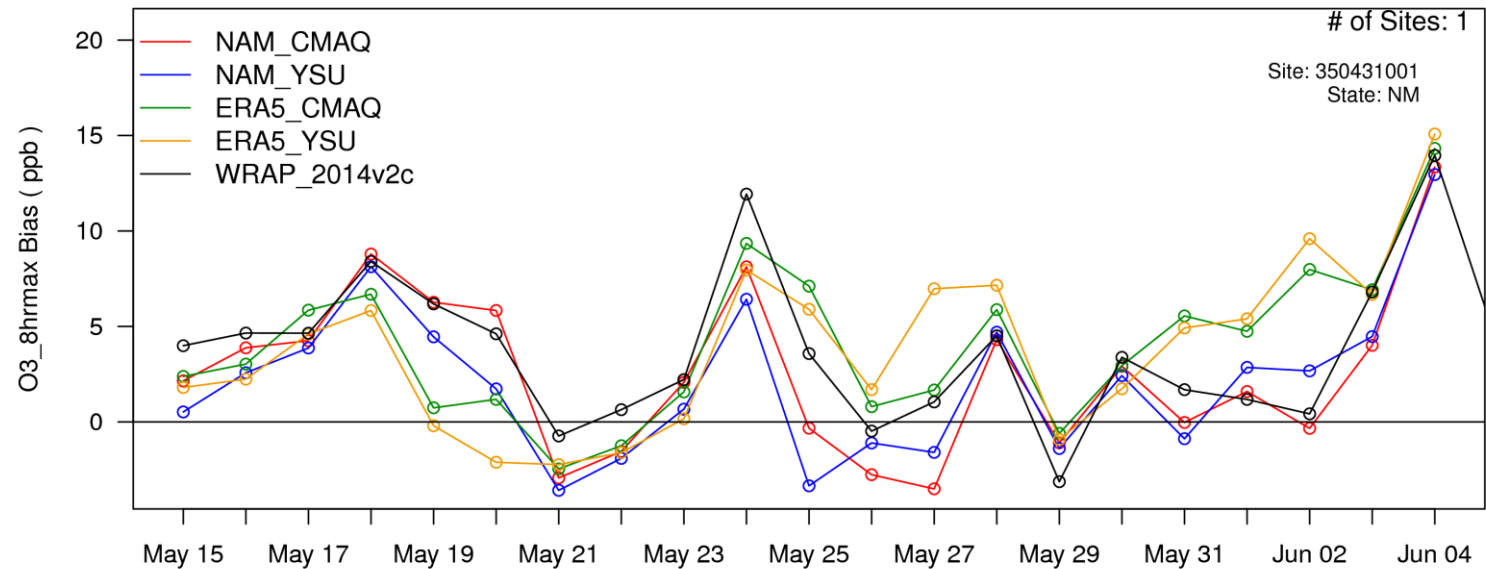
NAM_CMAQ O3_8hrmax for AQS_Daily_O3 Site: 350431001 in NM



- All sensitivities get high ozone on May 29. NAM CMAQ has lower bias

Warning: Number of observations differ by 1 between simulations

Bias for NAM_CMAQ O3_8hrmax for AQS_Daily_O3 for May15_Jun5



CAMX SENSITIVITIES SUMMARY

- All sensitivities have NMB and NME values that are within Performance Criteria, most sites within Performance Goals
- Differences between all sensitivities are relatively small among each other
- NAM meteorology captures peak ozone concentrations better than ERA5
- Caveats:
 - WRF sensitivities run for May-Jun so they may not reflect the observed precipitations biases in WRF for Jun-Aug
 - WRF performance showed that precipitation biases could occur over NE NM where there are no ozone monitors, so performance is unknown there
- NAM with CMAQ Kv treatment selected to simulate 2014 base case based on slightly better performance on NMB

FINAL CAMX 2014 BASE CASE CONFIGURATION

- CAMx summer 2014 36/12/4-km meteorological inputs based on WRF simulation using NAM analysis fields processed with WRFCAMx with CMAQ Kv option
 - Same WRF/NAM configuration as used by WRAP-WAQS CAMx 2014 base case

Science Options	CAMx	Comment
Model Codes	CAMx v7.0 (May 2020)	Latest version of CAMx used in WRAP/WAQS 2014v2 and EPA Haze modeling
<u>Horizontal Grid Mesh</u>	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 1
Boundary Conditions	WRAP 2014 GEOS-Chem	For 36US domain
<u>Emissions</u>		
Baseline Emissions Processing	SMOKE, SMOKE-MOVES2014, MEGAN	WRAP/WAQS 2014v2 emissions; 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 2023 emission years
<u>Chemistry</u>		
Gas Phase Chemistry	CB6r4	Latest chemical reactions and rates with halogen chemistry (Zhang et al., 2010)
Meteorological Processor	WRFCAMx	Compatible with CAMx v7.0
Horizontal Diffusion	Spatially varying	K-theory with Kh grid size dependent
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
<u>Deposition Schemes</u>		
Dry Deposition	Zhang dry deposition scheme	(Zhang et al., 2001; 2003)
Wet Deposition	CAMx -specific formulation	rain/snow/graupel
Numerics		

CURRENT STATUS AND NEXT STEPS

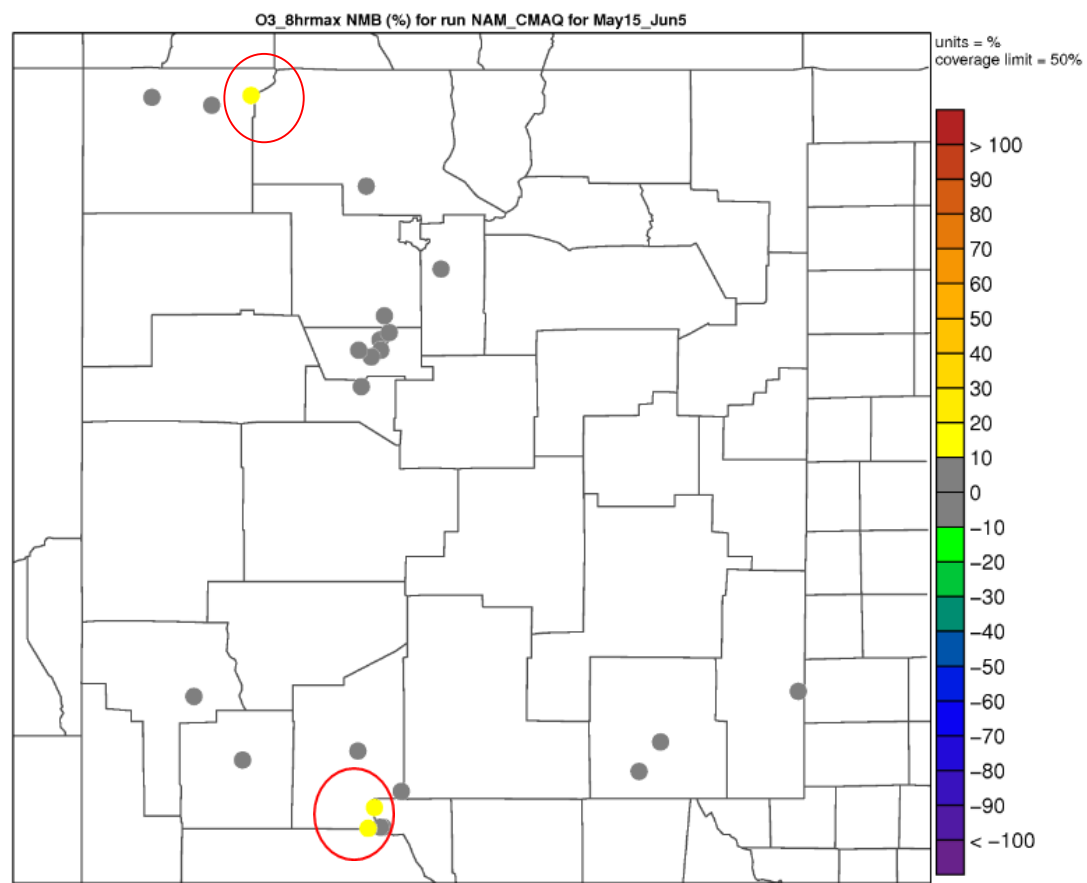
CURRENT STATUS/NEXT STEPS

- CAMx Summer 2014 36/12/4-km base case simulation in August 2020
 - Model Performance Evaluation
 - Task 5 2014 Base Case and MPE Report
- 2023 SMOKE Emissions Processing in August

Webinar Number	Webinar Topics by Task	Date	Status
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	• Done • Done • Done • Done
2.	2.2 Additional Met Modeling 3.1 Evaluate BC Data 4.1 Summary of 2014 and 2023 Emissions	Jun 2020	• Done • Done • Done
3.	4.2.1 Summary of 2014 and 2023 Mobile Source Emissions 4.3 2014 Natural Emissions Results (e.g., Biogenic & LNOx)	Jul 2020	• Done • In Progress
4.	4.2.3 2014 & 2023 SMOKE-MOVES Results 4-km NM Domain 4.4 2014 & 2023 SMOKE Emissions Modeling Results	Aug 2020	• Partly Done • Partly Done
5.	4.5 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	

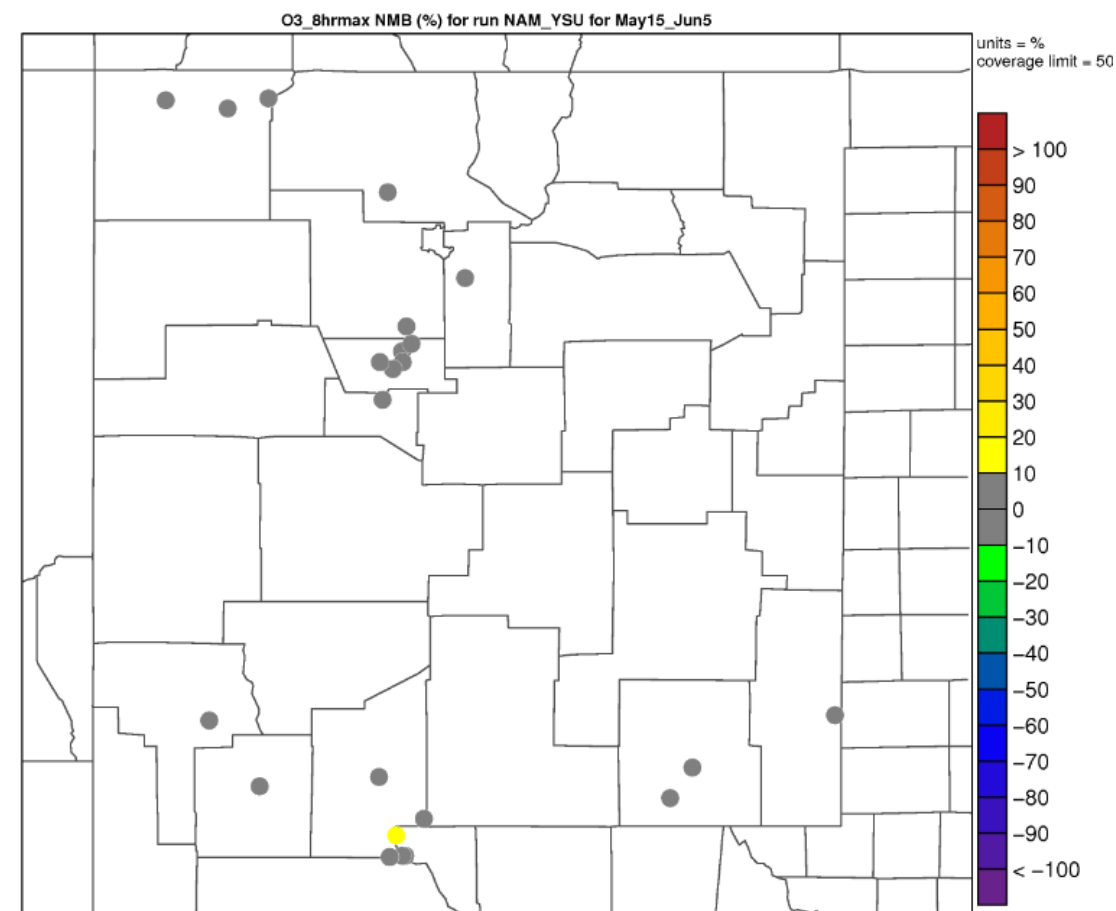
ADDITIONAL SLIDES

NAM_CMAQ with no 60ppb cut-off



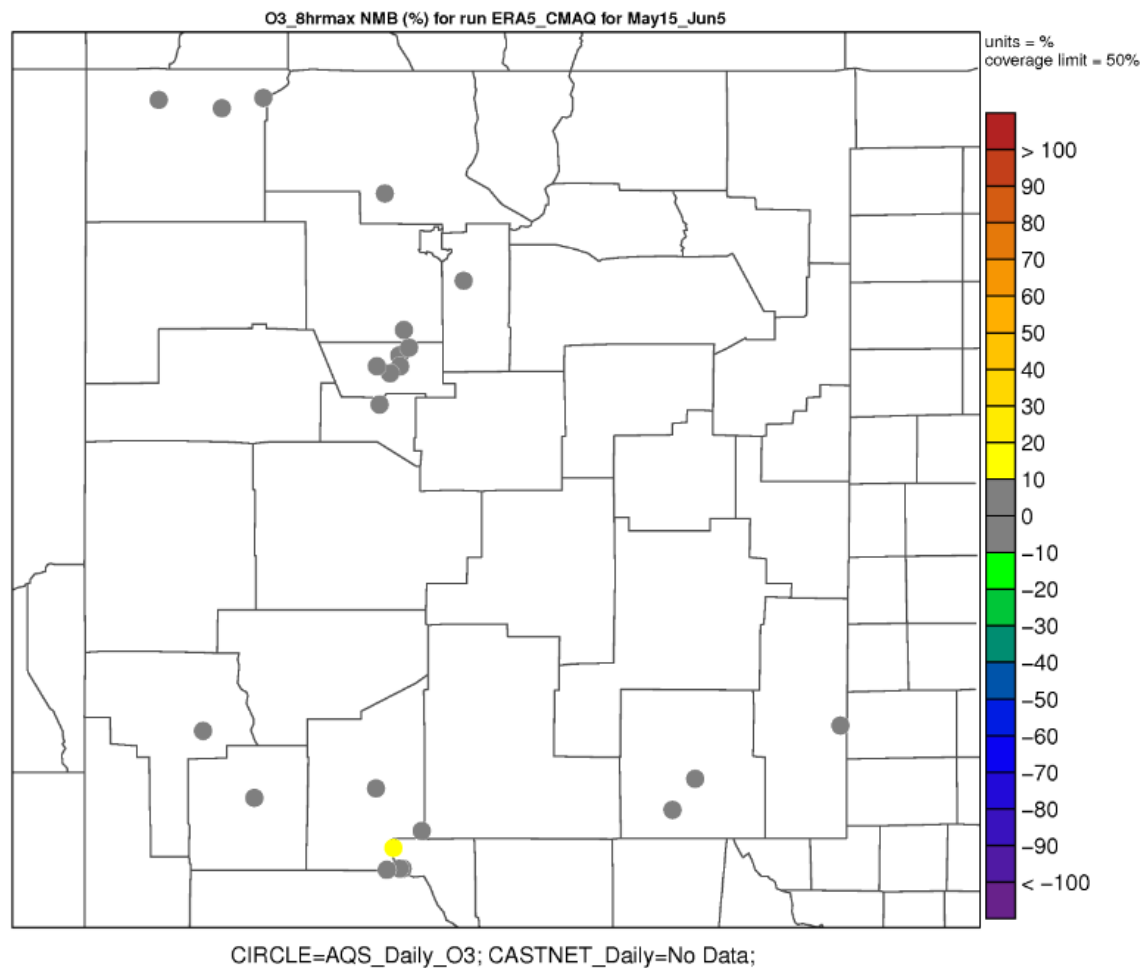
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NAM_YSU with no 60ppb cut-off

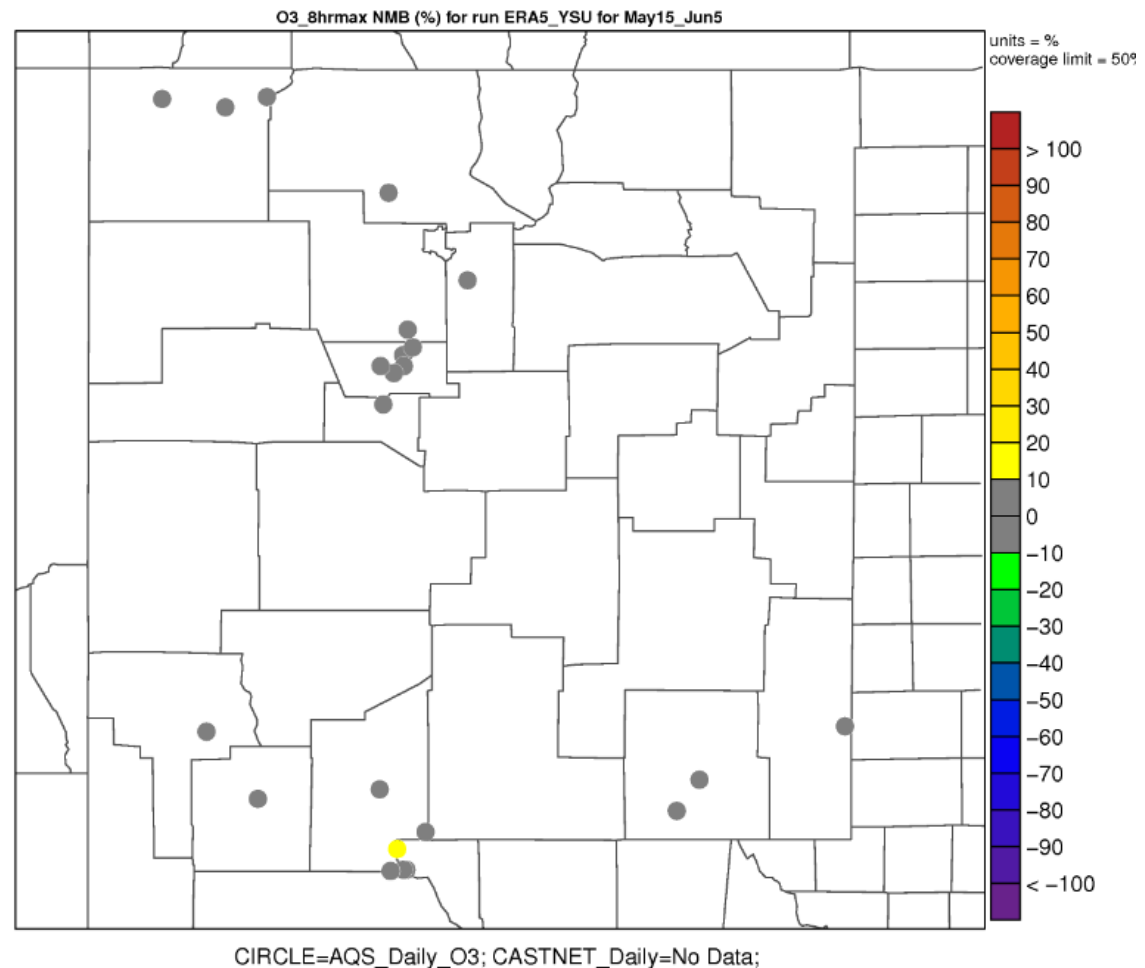


CIRCLE=AQS_Daily_O3; CASTNET_Daily=No Data;

ERA5_CMAQ with no 60ppb cut-off



ERA5_YSU with no 60ppb cut-off



NEW MEXICO OZONE ATTAINMENT INITIATIVE

1. 2014 and 2023 Emissions
2. CAMx 2014 Base and Model Performance
3. 2023 CAMx Modeling Status
4. Next Steps -- Future Year Control Strategy

Ralph Morris, Pradeepa Vennam, Marco Rodriguez, Jeremiah Johnson, Chao-Jung Chien and Tejas Shah, Ramboll

Tom Moore and Mary Uhl, WESTAR

NM OAI Study Webinar #4

August 31, 2020

AGENDA – NMED OAI STUDY WEBINAR#4 – AUGUST 31, 2020

- 2014 and 2023 Emissions
 - o Natural Emissions for 2014
 - o Updates to 2023 Emissions to Remove Duplicates and Other Updates
 - o SMOKE Emissions Modeling for 2014 and 2023
 - o Summary of 2014 and 2023 Emissions
- CAMx 2014 36/12/4-km Base Case Modeling
 - o Final CAMx Configuration for 2014 Base Case
 - o CAMx 2014 Base Case Ozone Model Performance Evaluation
 - o Status of Task 5 2014 Base Case and Model Evaluation Report
- Next Steps

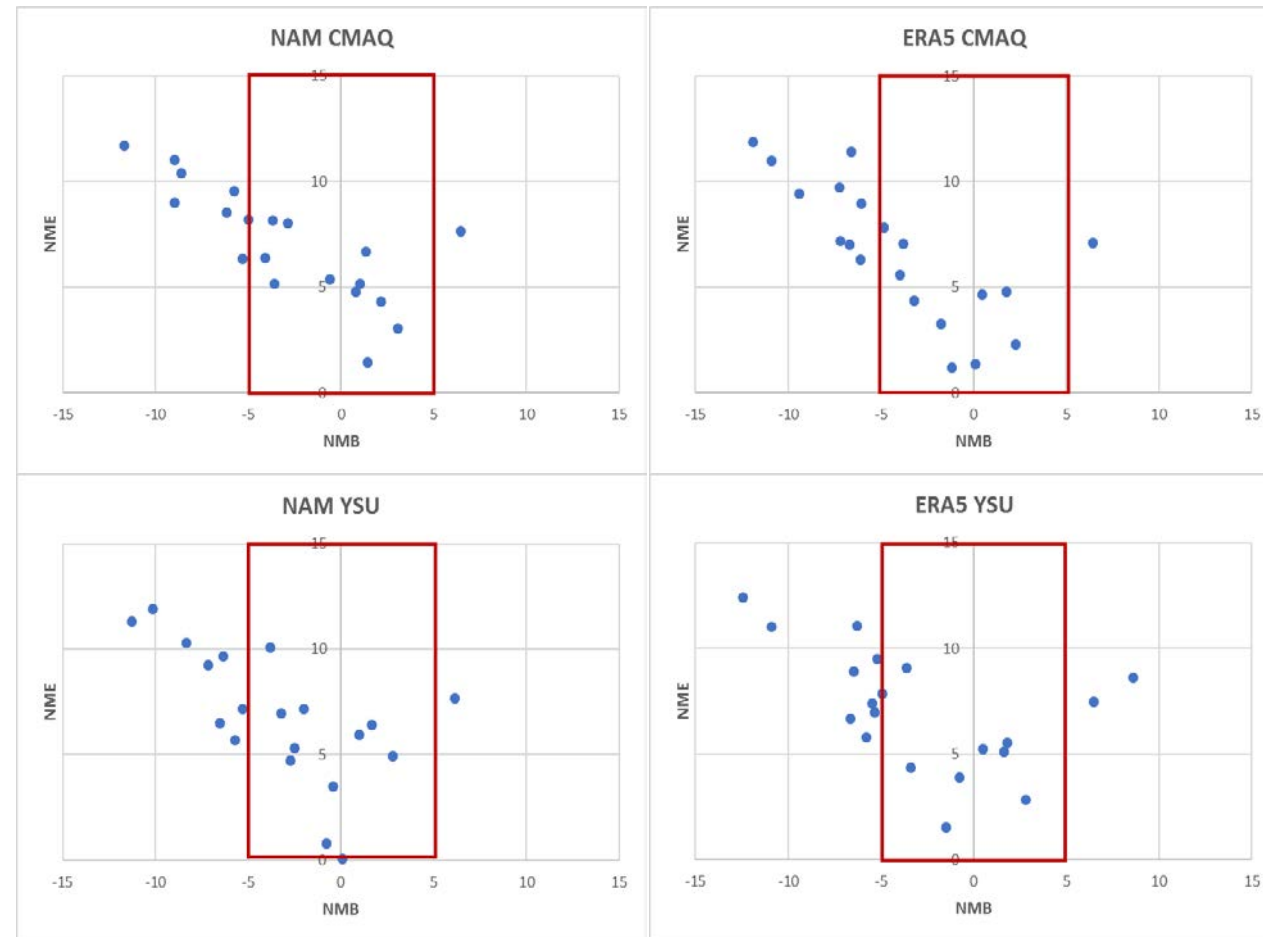
OVERVIEW OF NM OAI PHOTOCHEMICAL MODELING STUDY

- *Task 1: Modeling Protocol, QAPP and Work Plan – Completed May 2020*
- *Task 2: Meteorological Modeling – Completed June 2020*
- *Task 3: Boundary Conditions – Completed June 2020*
- *Task 4: 2014 and 2023 Emissions – 2014 Completed June 2020*
 - *2023 Almost Completed August 2020 – **only 2023 SMOKE-MOVES for 12-km 12WUS2 left***
- *Task 5: CAMx 2014 Base Case and Model Performance Evaluation – Work done August 2020*
 - **Working on Task 5 2014 Base Case and MPE report done in early September**
- **Task 6: Future Year (2023) Modeling**
 - **6.1: CAMx 2023 Base Case Modeling – Set-up ready to start (need 2023 12-km mobile)**
 - **6.2: Model Attainment Test – Not Started**
 - **6.3: Source Apportionment Modeling – Not Started**
 - **6.4: Emissions Sensitivity / Control Modeling – Not Started**
- **Task 7: Technical Support Document and Technology Transfer – Not Started**

PREVIOUS WEBINAR HIGHLIGHTS (JULY 27, 2020)

- 2014 and 2023 Emissions
 - Summary of SMOKE processing
 - Identification & elimination of duplicate sources
 - Preliminary results
- CAMx 2014 Meteorological Sensitivity Runs
 - WRF/NAM and WRF/ERA5 simulations
 - Kv = CMAQ-like and Kv = YSU
 - Four CAMx WRF sensitivity simulations
 - WRF/NAM w/ Kv=CMAQ selected
 - Ozone performance for all four runs close
 - WRF/NAM w/ Kv=CMAQ had slightly lower bias and better performance on some observed ozone peaks

Site-Specific Bias/Error Soccer Plots for Four CAMx WRF Sensitivity Tests



2014 AND 2023 EMISSIONS

NEW MEXICO EMISSIONS DATA

- 2014 anthropogenic emissions are based on the WRAP/WAQS 2014v2
 - o Onroad emissions based on SMOKE-MOVES processing with 2014 activity and WRF meteorology
 - o O&G emissions based on state-of-the-science WRAP OGWG emission estimates
 - o NMED found a generator engine missing in 2014v2 inventory (94 tpy NOx)
 - o Consistent emissions data between the Regional Haze and OAI studies
- 2023 anthropogenic emissions are based on the EPA 2016v1 platform
 - o Like 2014, onroad emissions created using SMOKE-MOVES and O&G emissions based on WRAP OGWG
 - o NMED found duplicate sources between WRAP O&G and EPA non-EGU sectors
 - o Found double counting of NM sources in WRAP O&G inventory: Title V and minor point sources
 - o Updated San Juan Generating Station (NOx 7,059 TPY) and added Lordsburg Generating Station
 - o Updated three O&G sources: Chaco Gas Plant (NOx 2,053 tpy), Carlsbad CS, and Mountainair CS (NOx 645 tpy)

NATURAL EMISSIONS

Remained the same between 2014 and 2023

- Lightning NOx: Lightning NOx (LNOx) emissions processor with 2014 WRF meteorological data to generate CAMx-ready emissions
- Oceanic Emissions: OCEANIC emissions processor was used to generate sea salt and dimethyl sulfide (DMS) emissions
- Fire Emissions: Agricultural, prescribed burn and wildfire emissions from WRAP 2014v2 modeling developed by WRAP Smoke and Fire Workgroup
- Windblown dust: CAMx windblown dust (WBD) processor
- Biogenic Emissions: MEGAN v3.1 biogenic emissions model

MEGAN V3.1 EMISSIONS

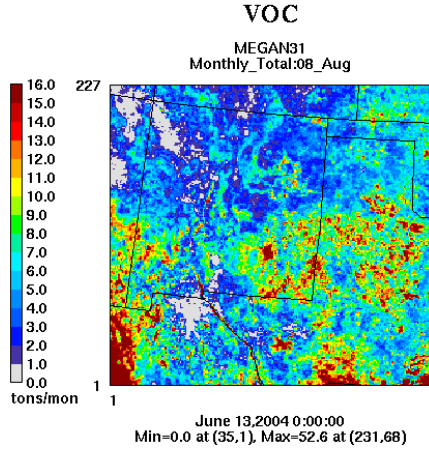
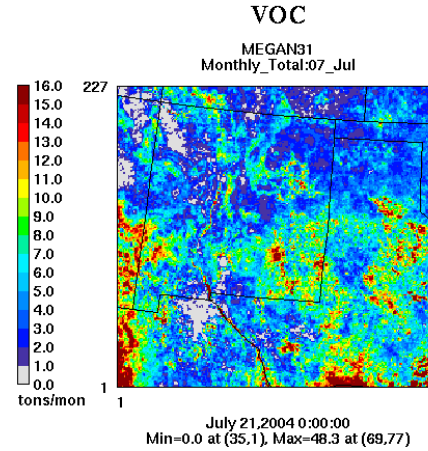
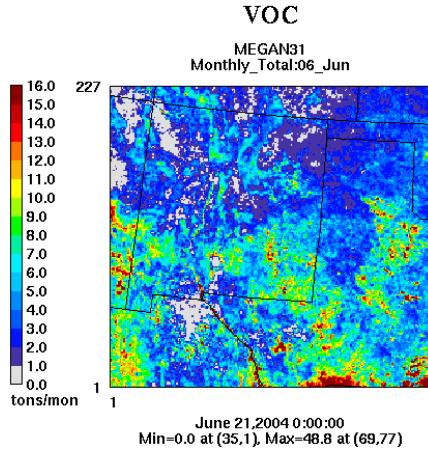
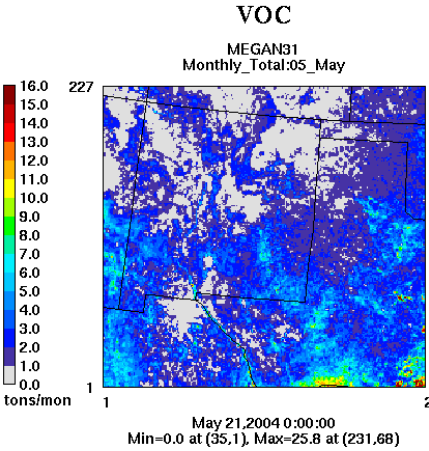
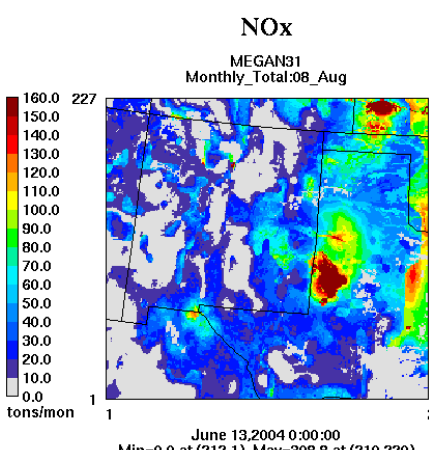
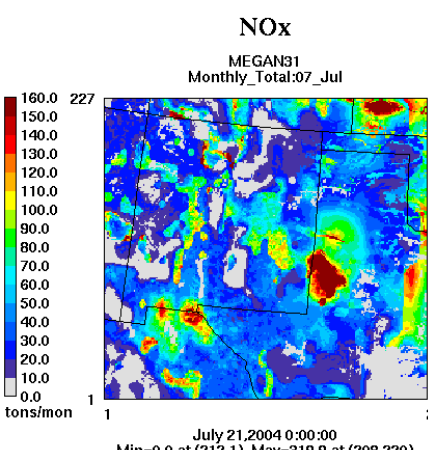
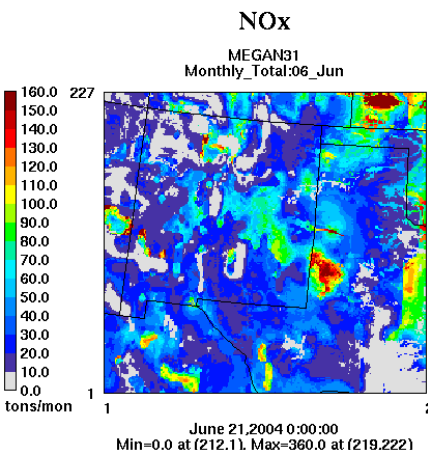
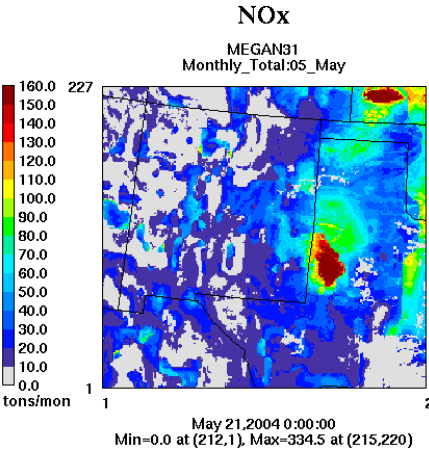
- Soil NOx

May

June

July

August

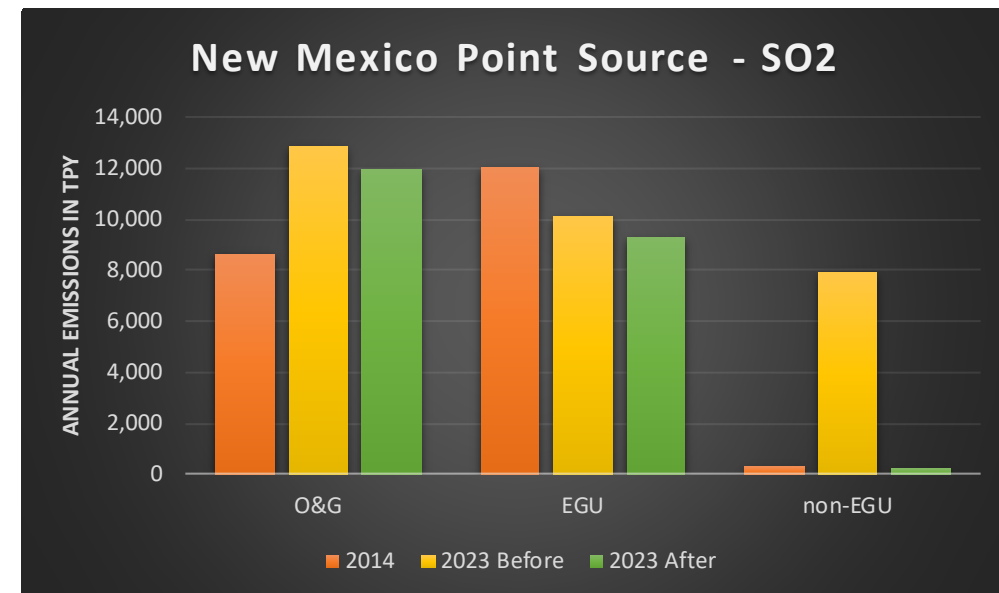
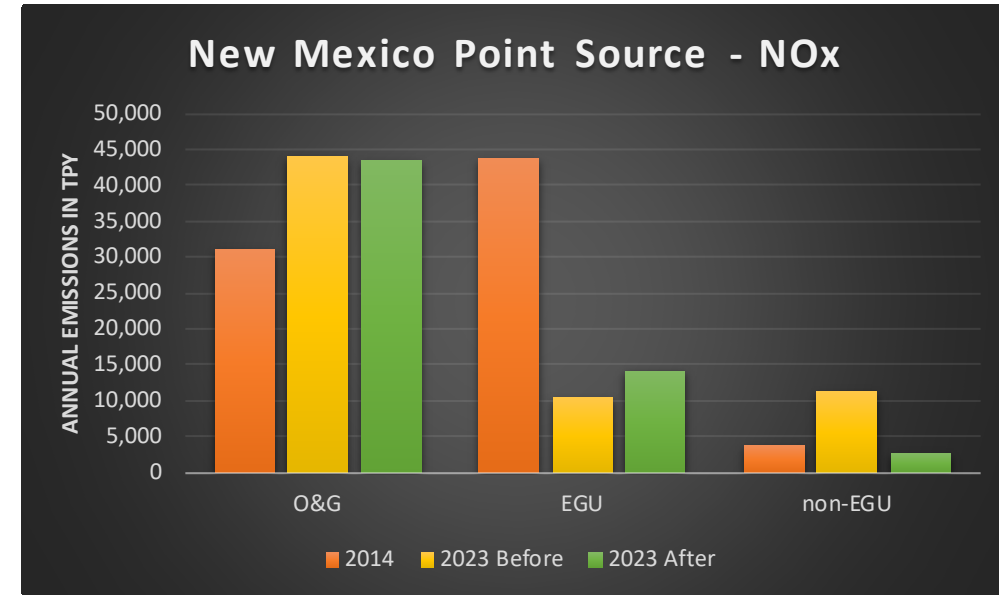


Month	tons/day	
	NOx	VOC
May	1,131	4,139
Jun	1,369	8,615
Jul	1,666	10,248
Aug	1,323	11,438



DUPLICATE POINT SOURCES IN 2023

- NMED identified 21 facilities double counted in 2023 non-EGU and WRAP point O&G inventory
 - Double counted emissions: NOx 8,669 TPY and SO2 7,662 TPY
 - Represents approximately 9% (NOx) and 24% (SO2) of the New Mexico 2023 O&G emissions
- Duplicates in the WRAP O&G inventory: Some sources were present in Title V and minor point O&G sources datasets in the OGWG inventory.
 - Double counted emissions NOx: 1,927 TPY and SO2: 942 TPY



SMOKE PROCESSING SECTORS

US-Anthro

Sector	Description
afdust_adj	- Area fugitive dust
ag	- Agricultural ammonia sources
nonpt	- Other nonpoint sources
np_oilgas_wrap	- Non-point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)
np_oilgas	- Non-point Oil and Gas
nonroad	- Non-road mobile
rail	- Locomotive
onroad	- On-road mobile
ptegu	- EGU point sources
ptnonipm	- Non-EGU point sources
pt_oilgas_wrap	- Point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)
pt_oilgas_wrap	- Point Oil and Gas
rwc	- Residential Wood Combustion



**New Mexico
4-km Domain**

Non-US Anthro & Natural

Sector	Description
onroad_mex	- Mexico onroad mobile
othar	- Mexico area
othpt	- Mexico point sources
MEGAN/BEIS	- Biogenic
LtNOx	- Lightning Nox
AG fire	- Ag Fire
RX fire	- Prescribed Fire
WF fire	- Wild Fire
Ptfire_othna	- Mexico fire
WBD	- Windblown Dust

NEW MEXICO 4-KM DOMAIN EMISSIONS (ANTHRO ONLY)

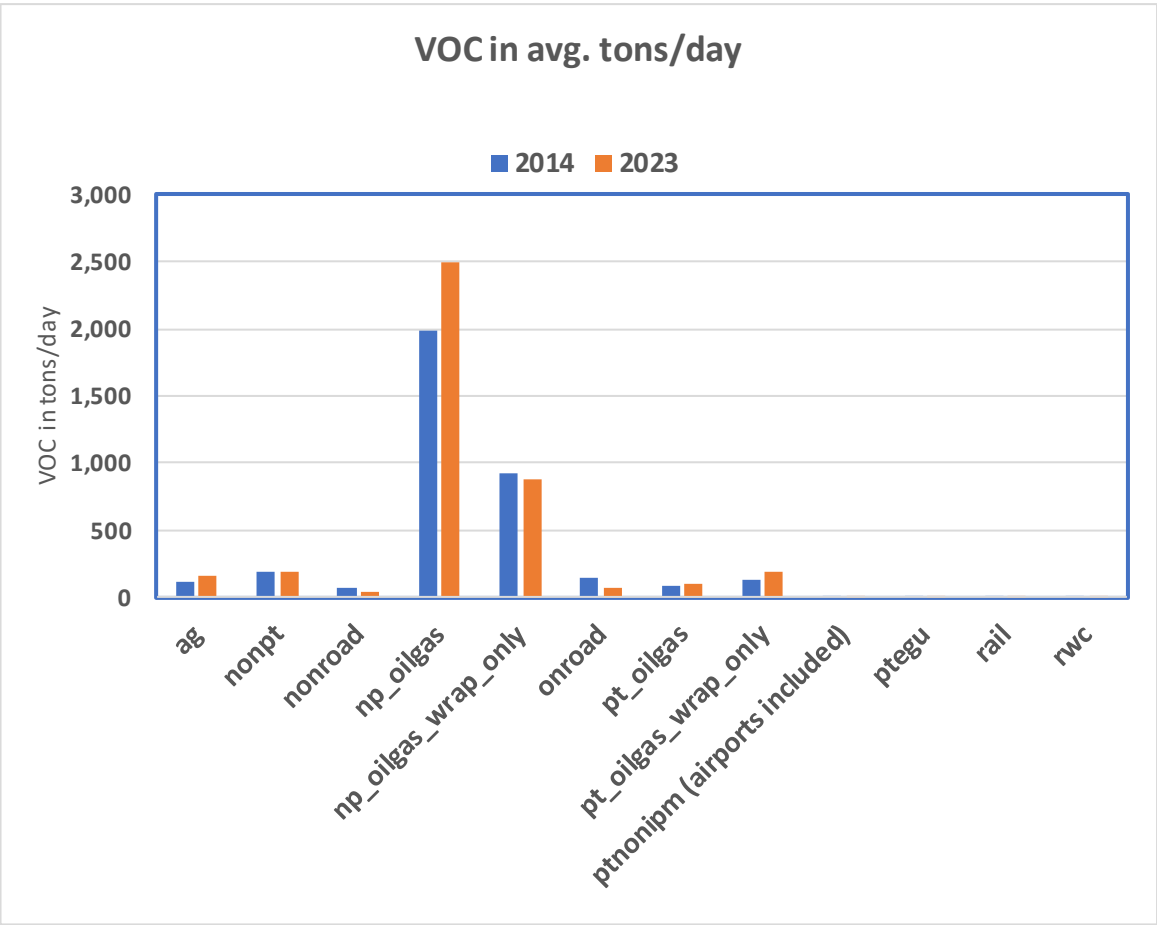
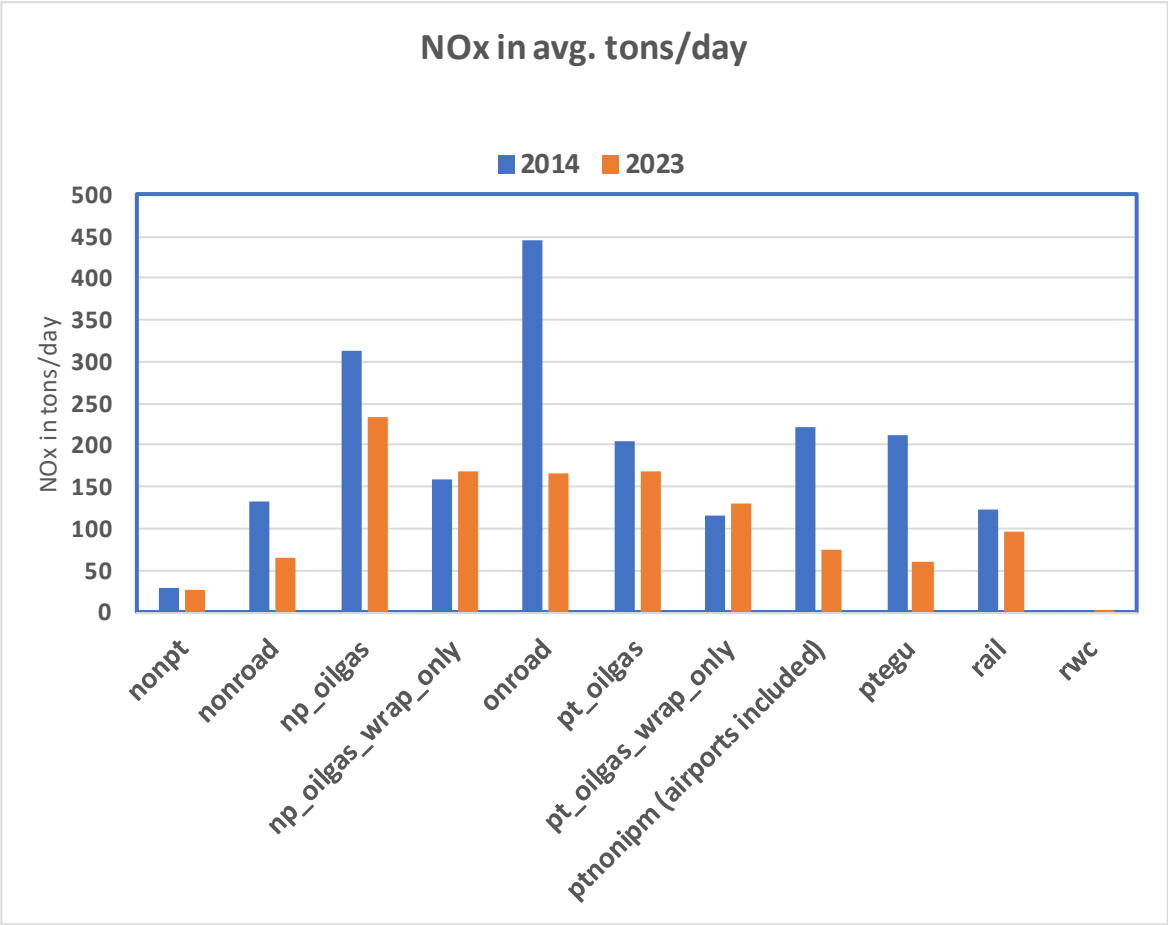
2014 in average tons/day

Sector	CO	NOx	VOC
ag	0.0	0.0	43.4
nonpt	141.3	28.5	213.2
nonroad	570.3	133.4	73.2
np_oilgas	286.8	311.7	1,642.5
np_oilgas_wrap_only	237.7	157.8	567.3
onroad	1,476.2	444.5	150.6
onroad_mex	356.3	98.4	34.4
othar	19.9	42.2	103.3
othpt	28.4	20.2	8.3
ptegu	89.2	210.6	5.0
pt_oilgas	113.8	205.2	48.4
pt_oilgas_wrap_only	89.9	114.7	56.1
ptnonipm	74.4	47.5	24.4
rail	22.9	122.7	6.2
rcw	7.0	0.1	1.2
TOTAL	3,513.9	1,937.6	2,977.3

2023 in average tons/day

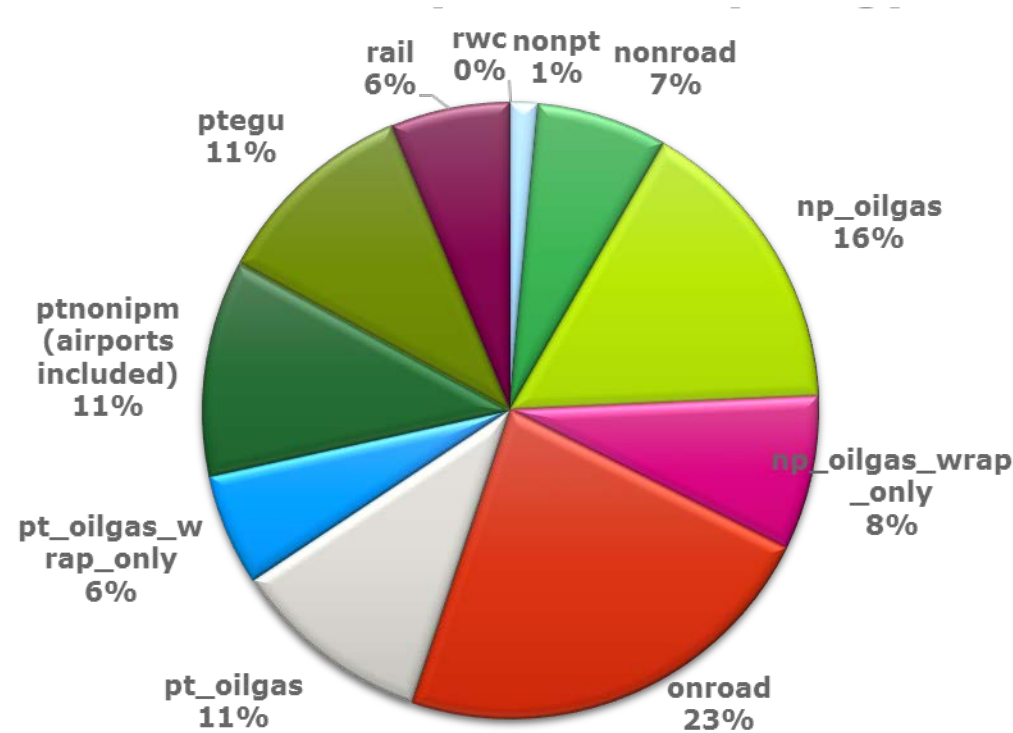
Sector	CO	NOX	VOC
ag	0.0	0.0	65.7
nonpt	141.9	27.3	217.0
nonroad	504.9	64.1	39.3
np_oilgas	298.3	234.3	2,124.5
np_oilgas_wrap_only	267.4	169.0	559.6
onroad	841.8	166.6	0.0
onroad_mex	336.3	98.0	35.0
othar	21.6	44.1	121.8
othpt	32.8	19.1	11.3
ptegu	34.0	60.6	1.6
pt_oilgas	99.0	169.1	57.9
pt_oilgas_wrap_only	111.4	130.5	86.5
ptnonipm	55.9	43.9	20.2
rail	22.1	96.4	4.2
rcw	7.0	0.1	1.1
TOTAL	2,774.2	1,323.1	3,345.6

NEW MEXICO 4-KM EMISSIONS COMPARISON: 2014 VS. 2023



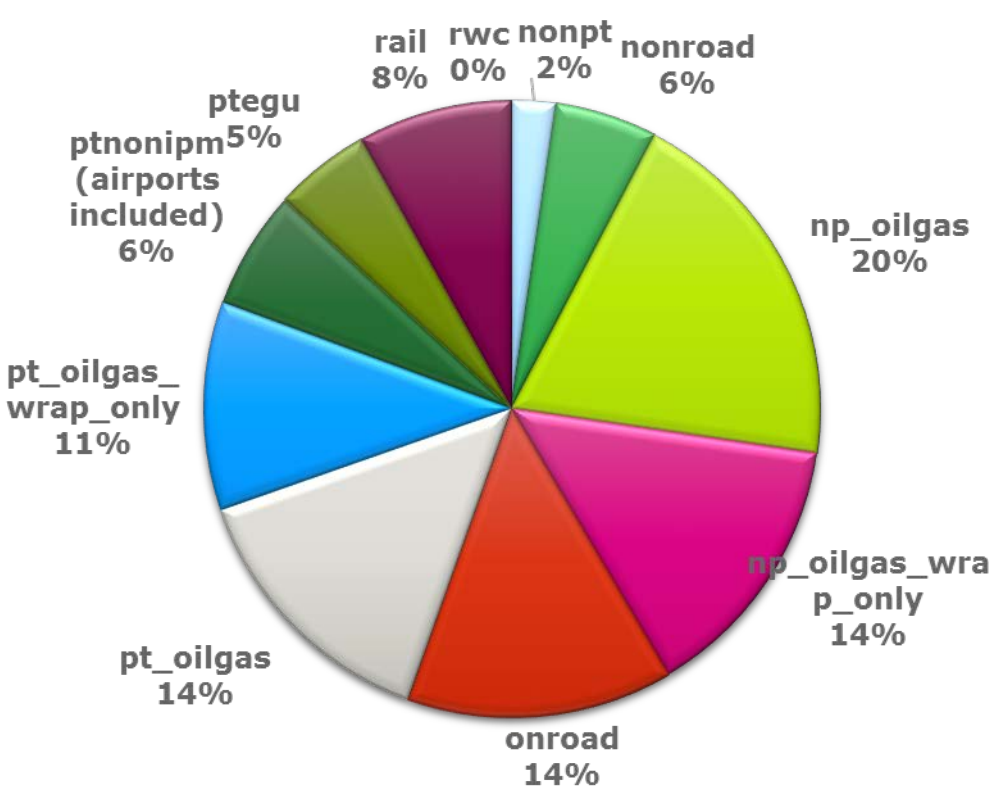
NEW MEXICO 4-KM NOX COMPARISON

2014 NOx



1,938 TPD

2023 NOx

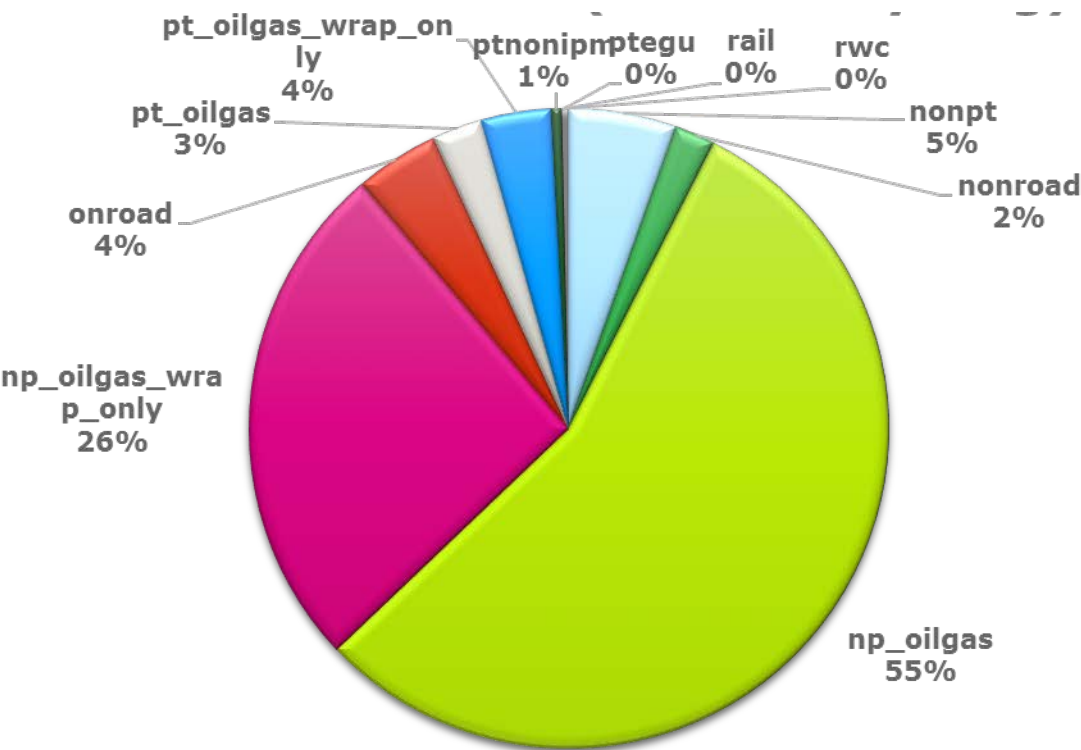


1,323 TPD

-615 TPD (32 %) Reduction

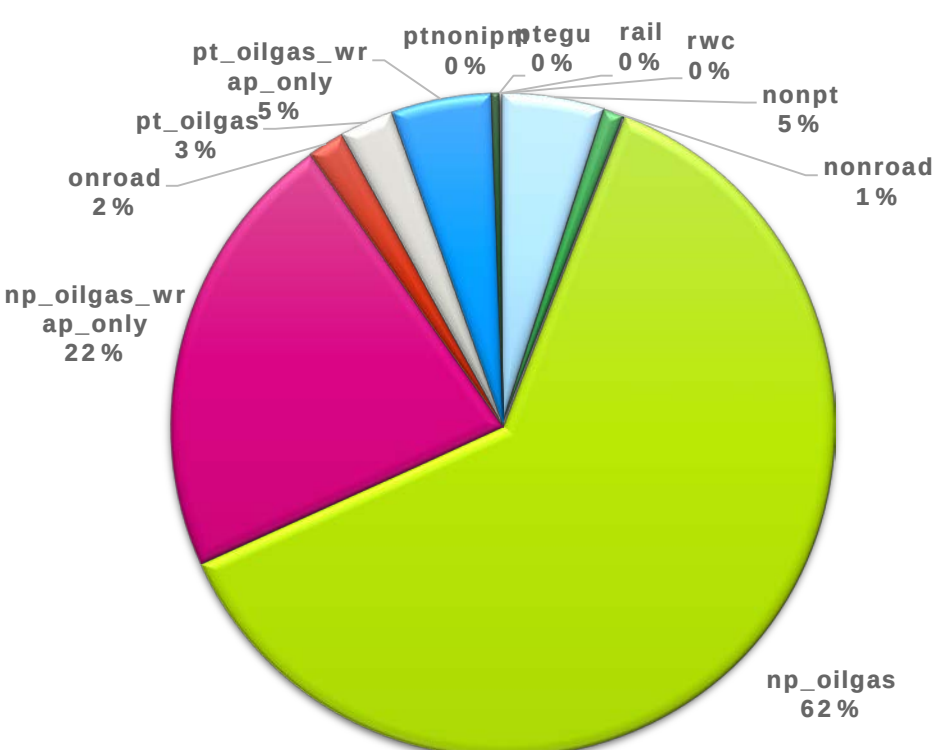
NEW MEXICO 4-KM VOC COMPARISON

2014 VOC



2,977 TPD

2023 VOC



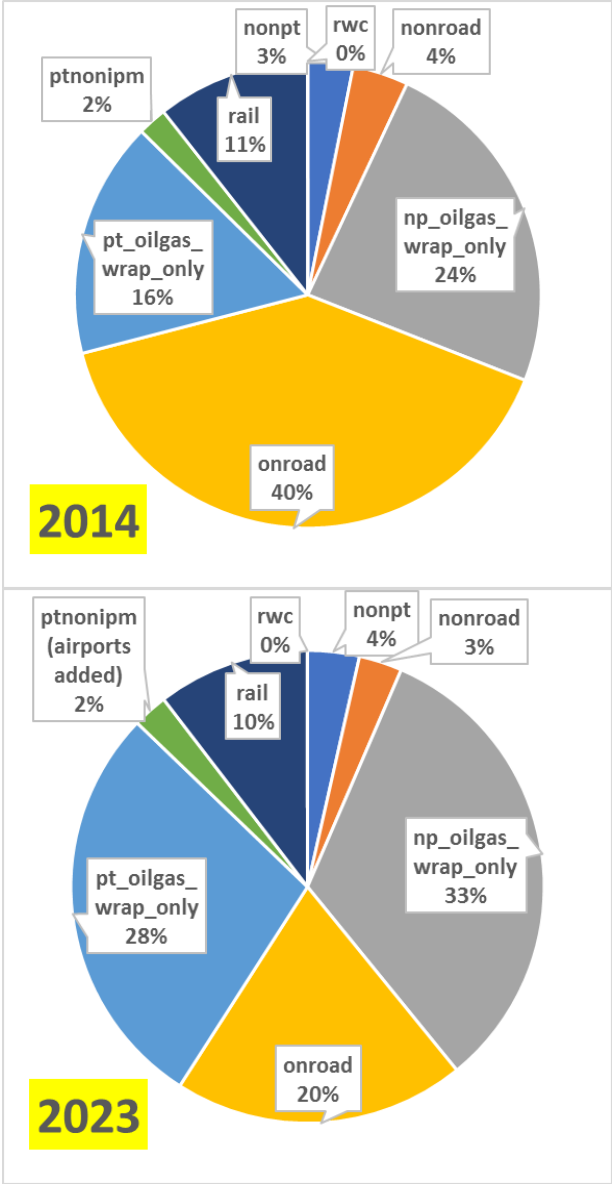
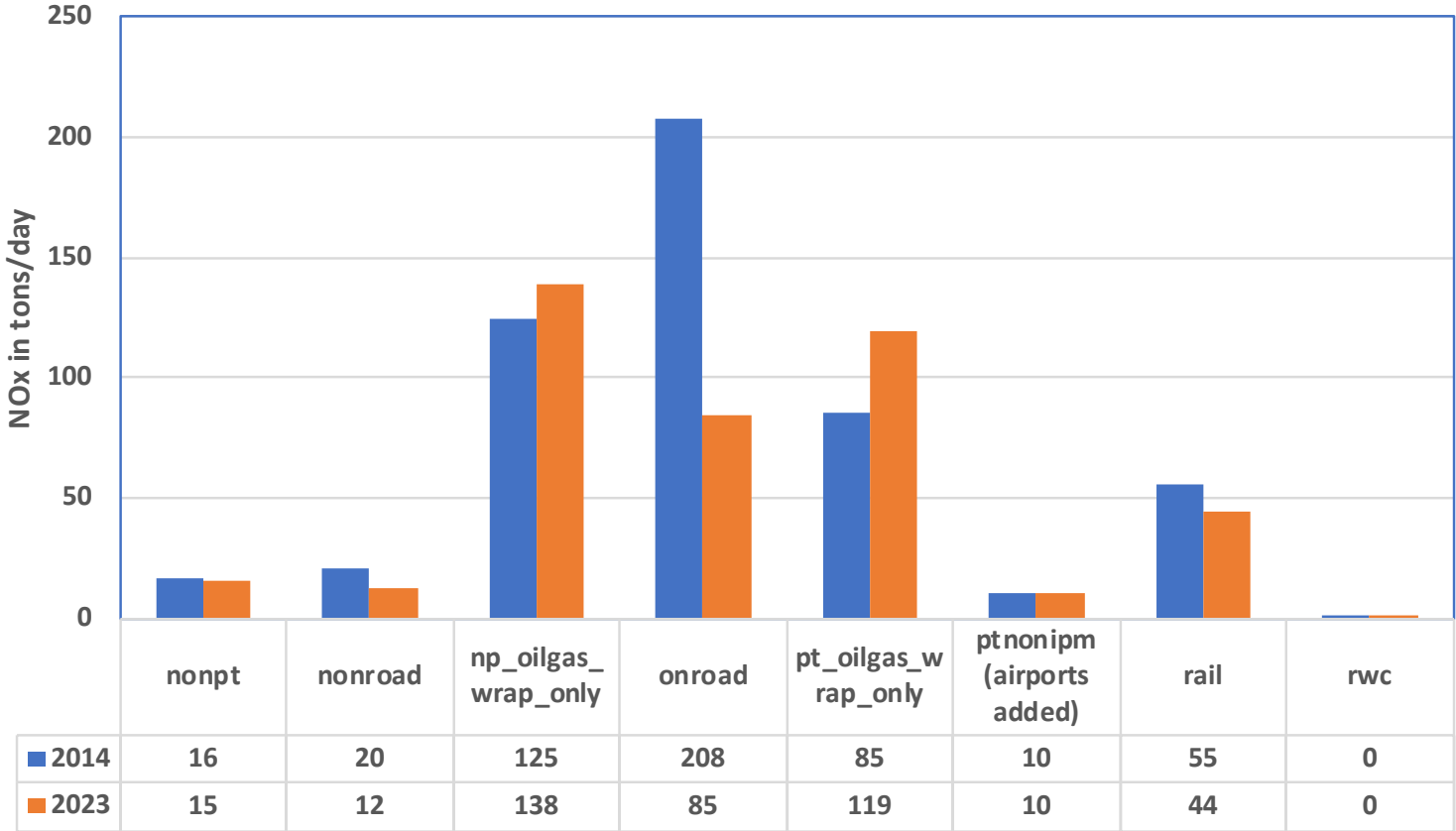
3,346 TPD

+ 369 TPD (12 %) Increase



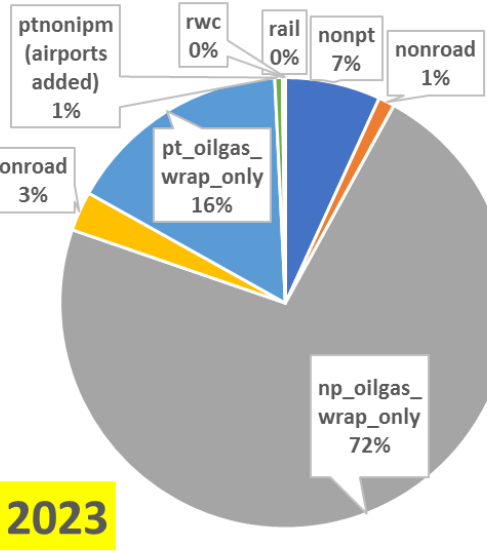
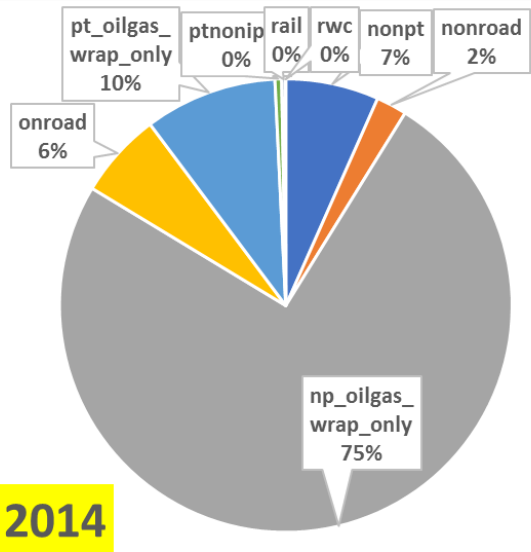
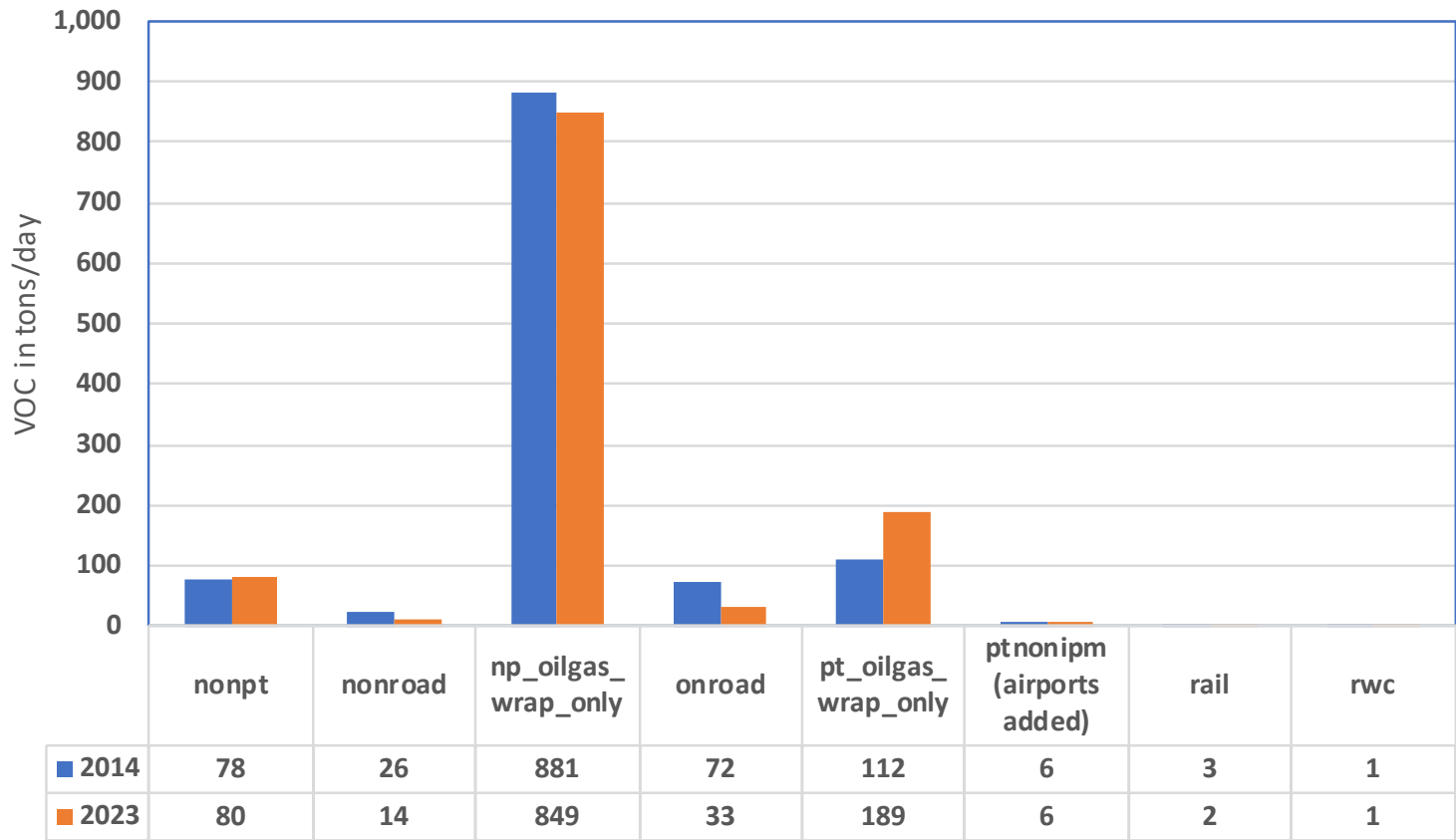
NEW MEXICO NOx SUMMARY

NOx



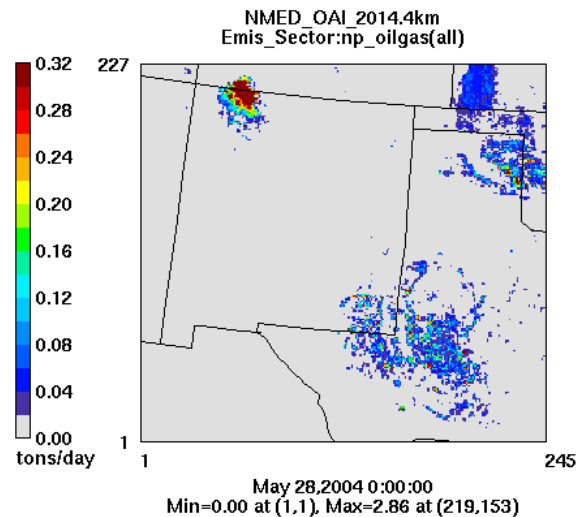
NEW MEXICO VOC SUMMARY

VOC

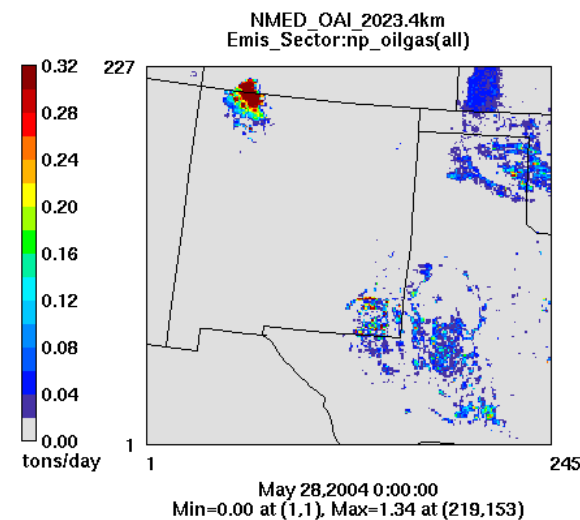


NON-POINT O&G EMISSIONS: NOX

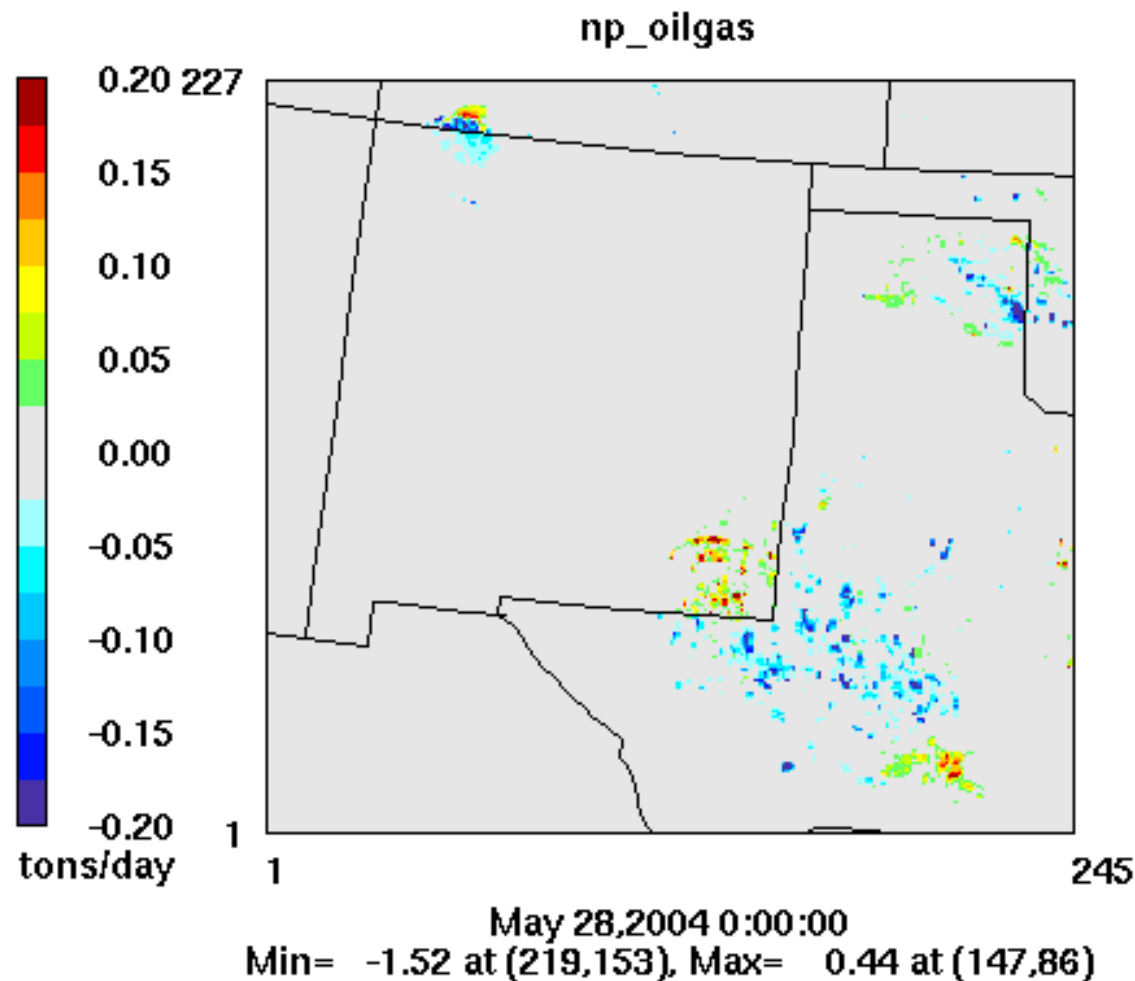
2014



2023

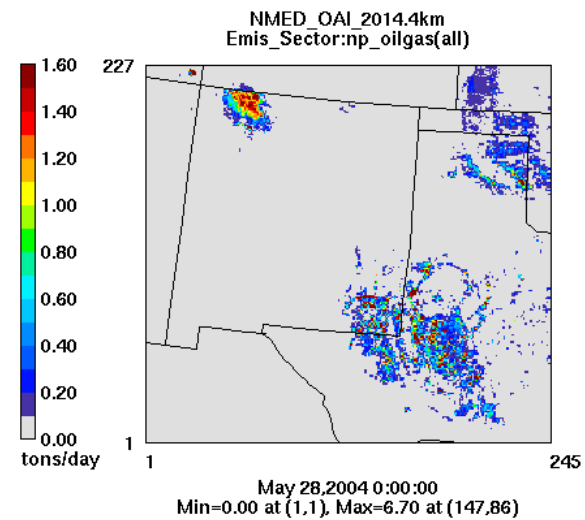


Delta NOx (2023 – 2014)

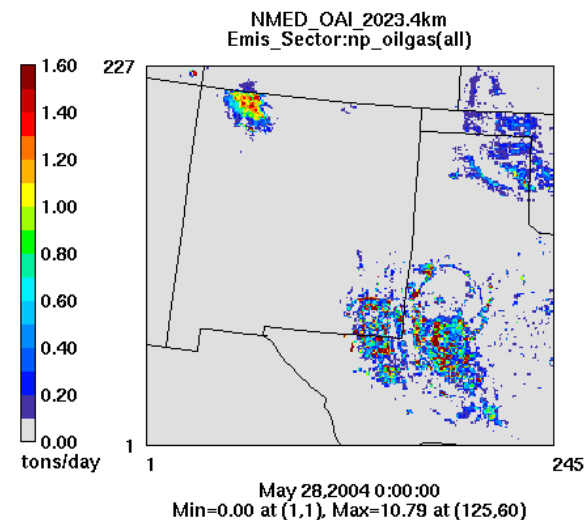


NON-POINT O&G EMISSIONS: VOC

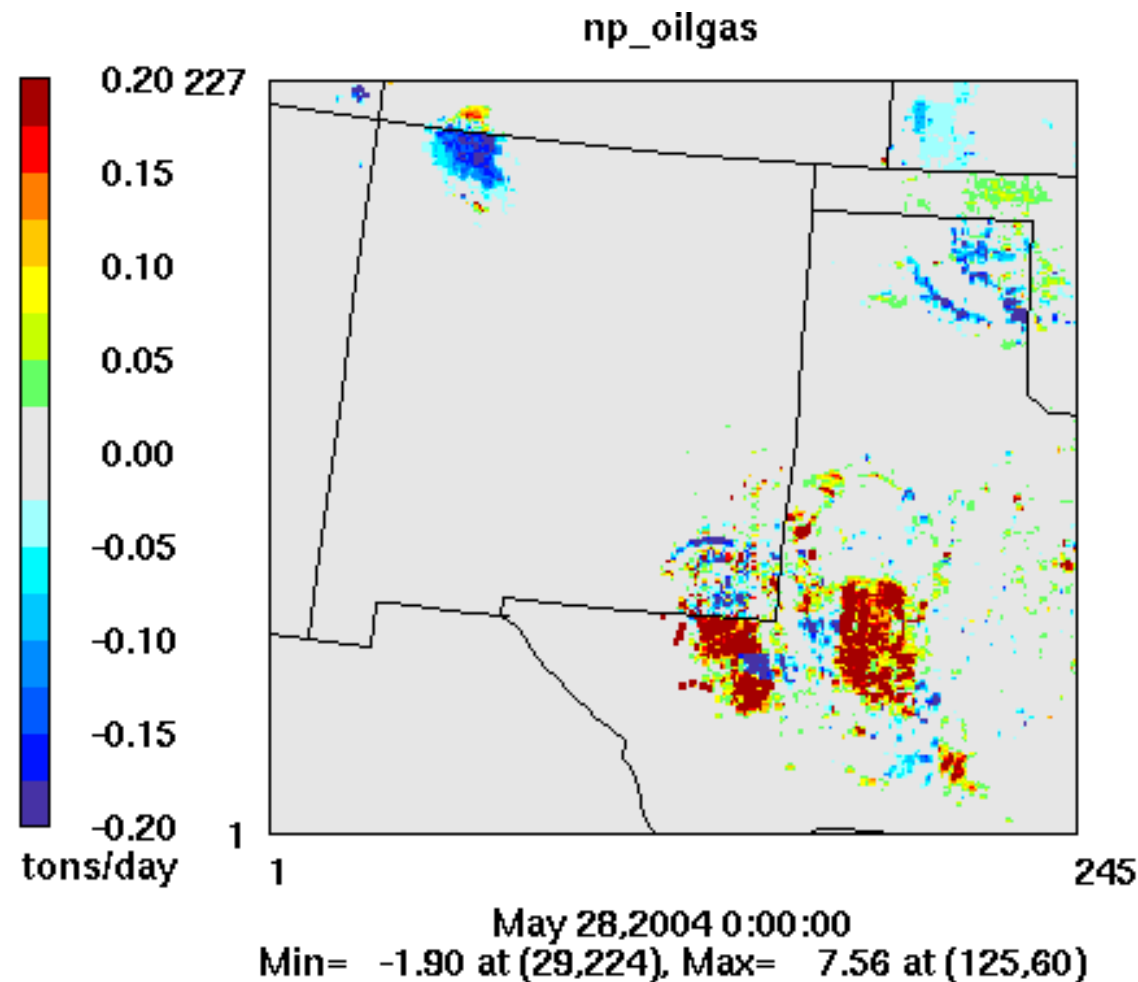
2014



2023

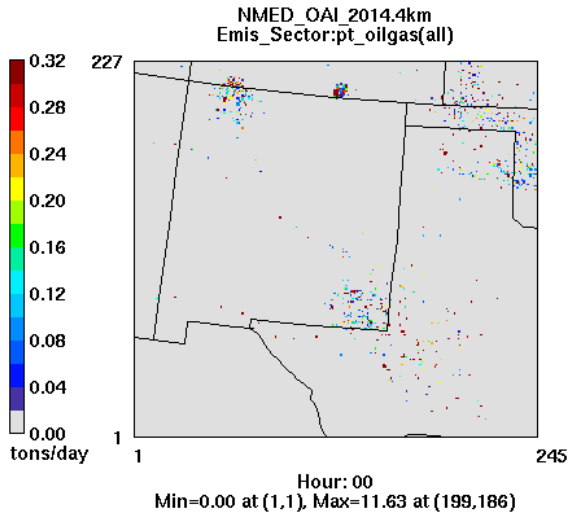


Delta VOC (2023 – 2014)

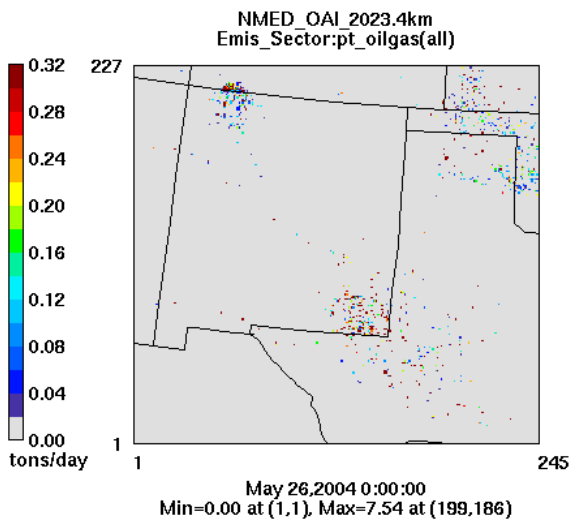


POINT O&G EMISSIONS: NOX

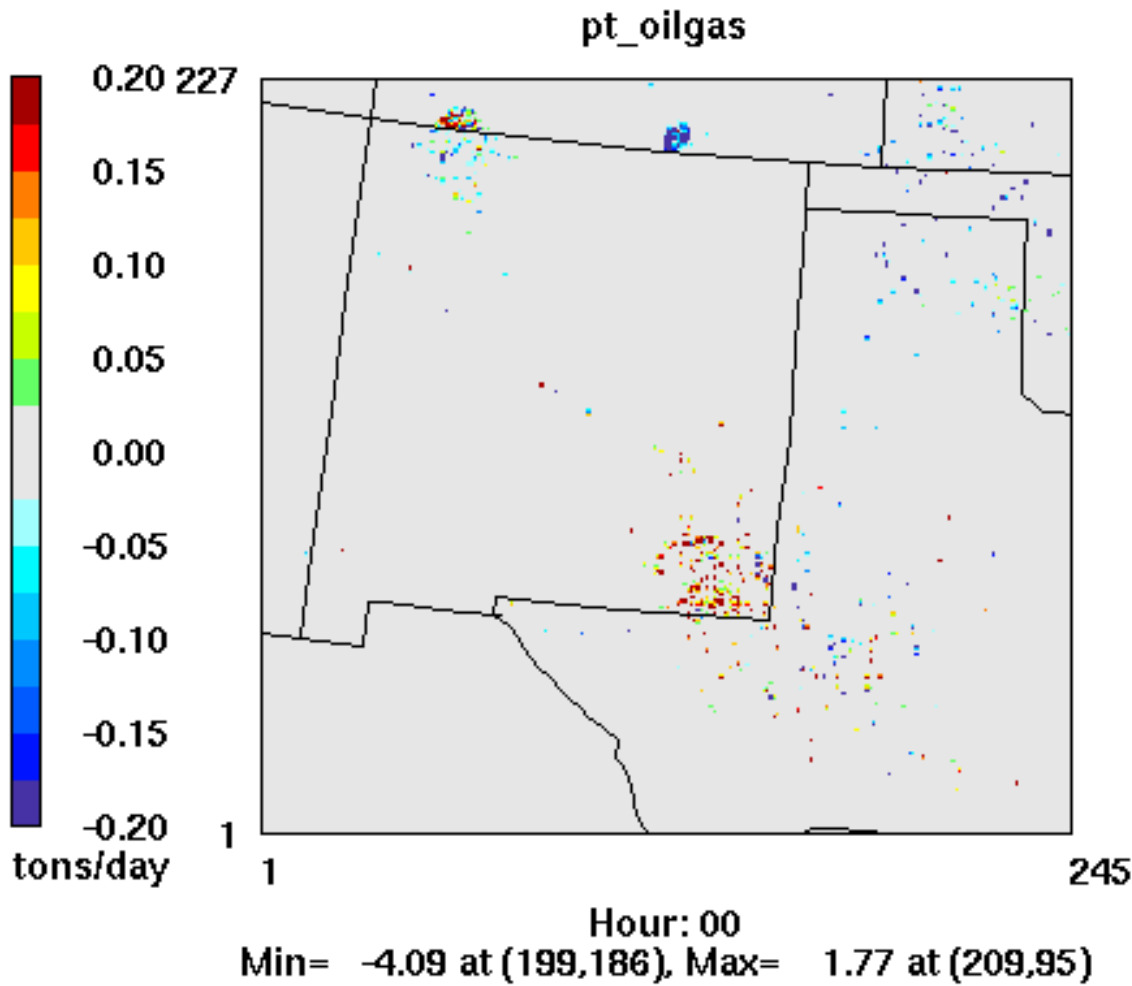
2014



2023

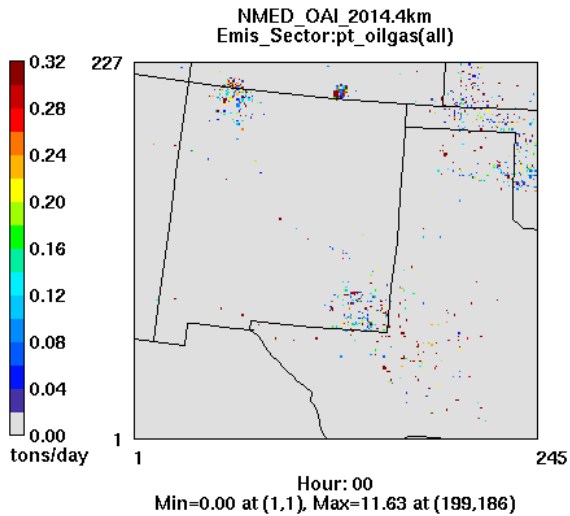


Delta NOx (2023 – 2014)

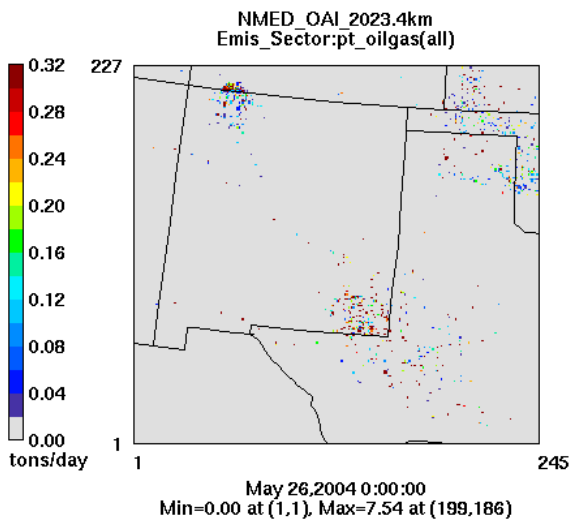


POINT O&G EMISSIONS: VOC

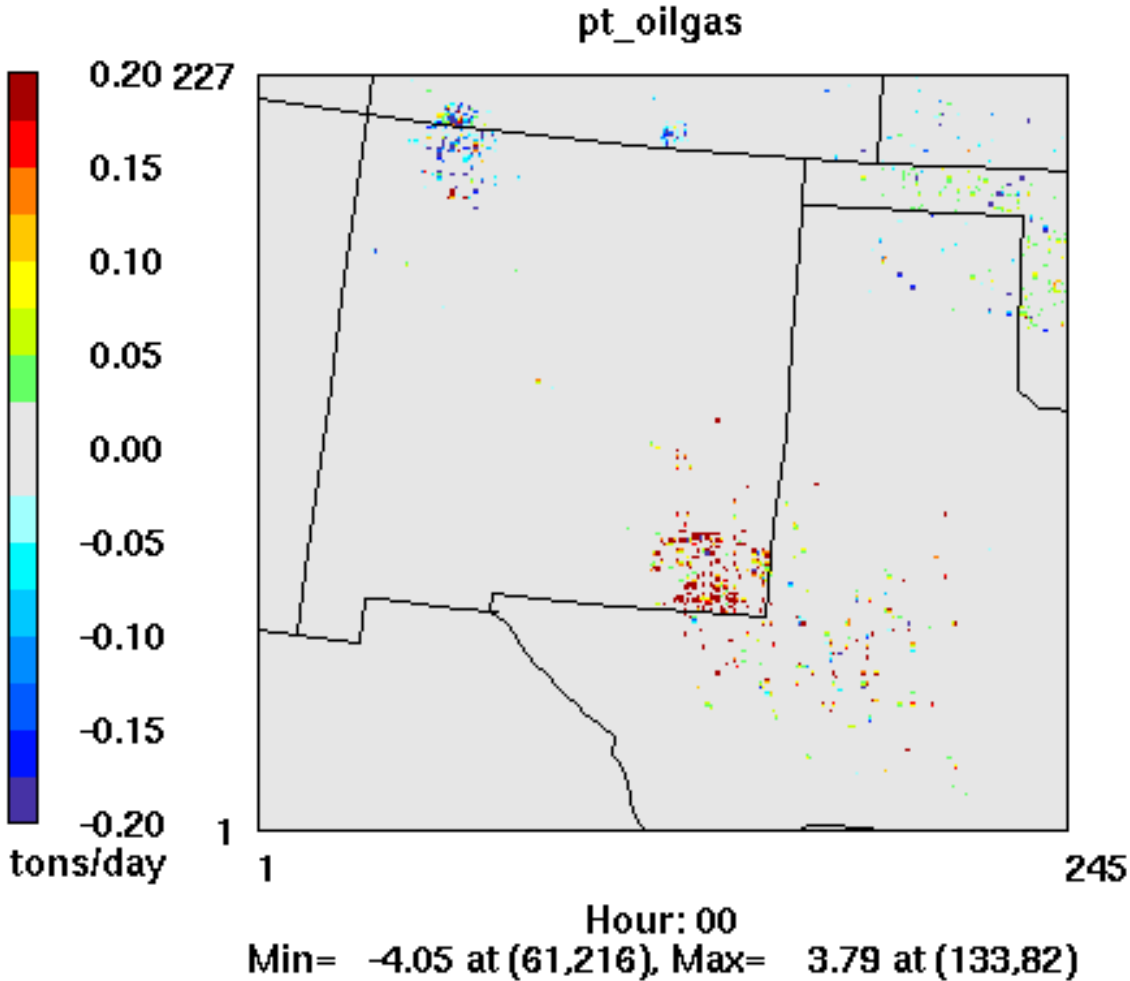
2014



2023

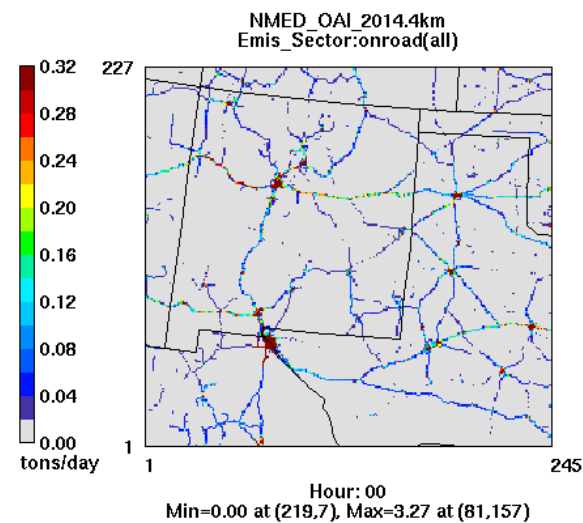


Delta VOC (2023 – 2014)

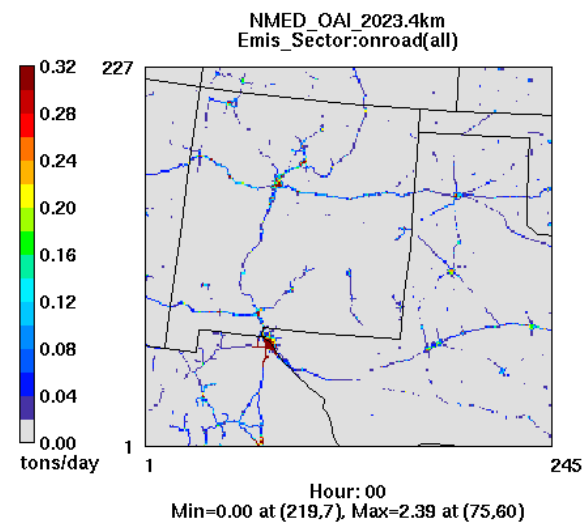


ONROAD EMISSIONS: NOX

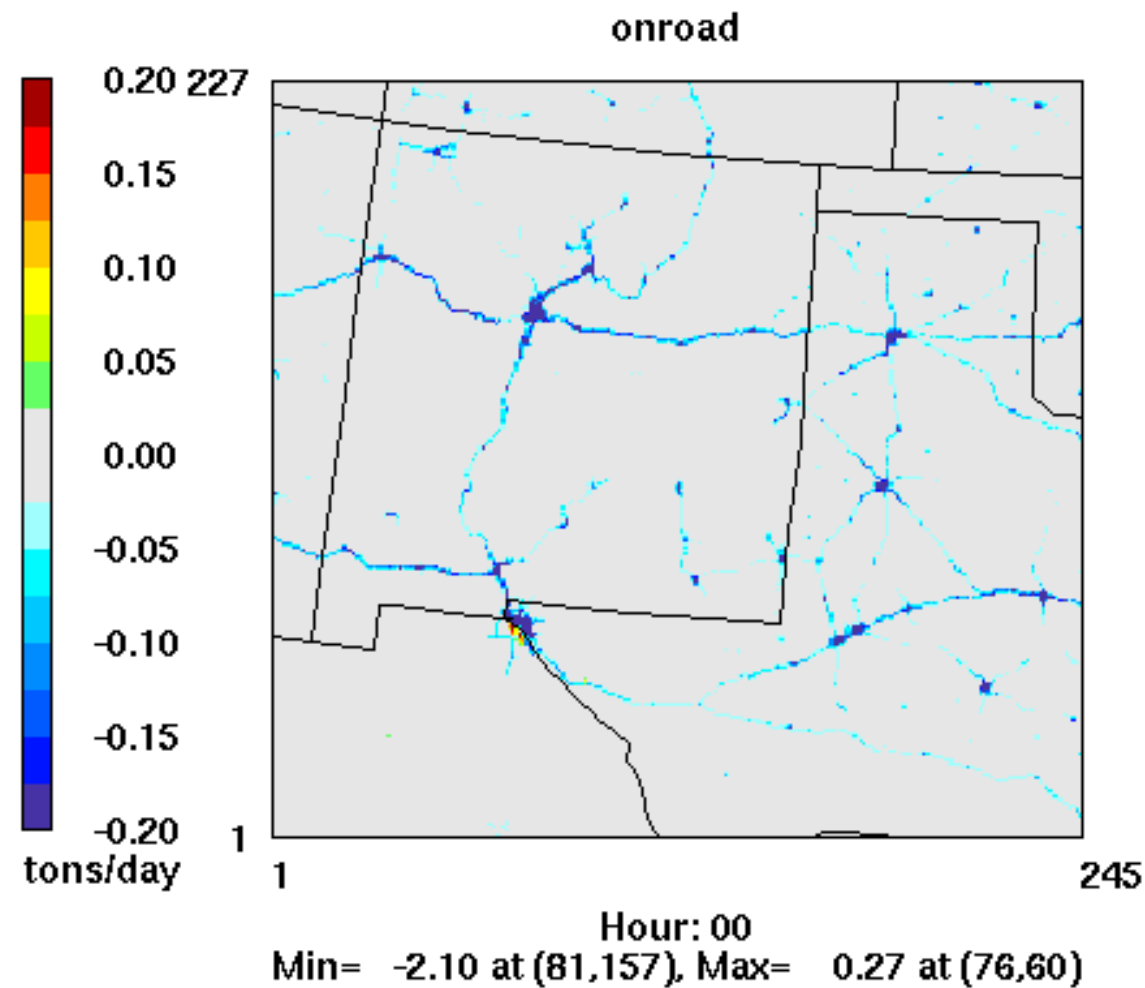
2014



2023

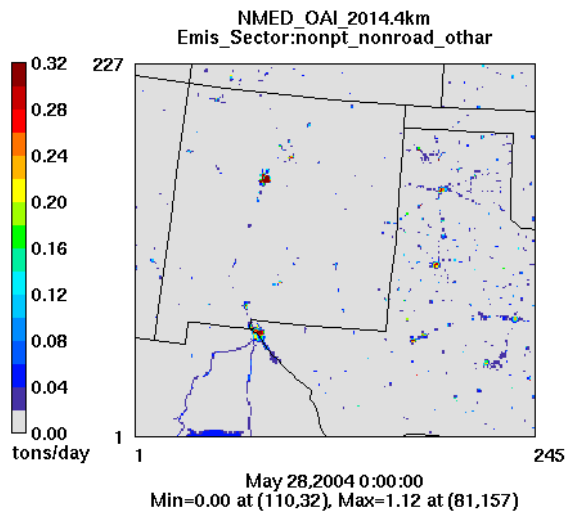


Delta NOx (2023 – 2014)

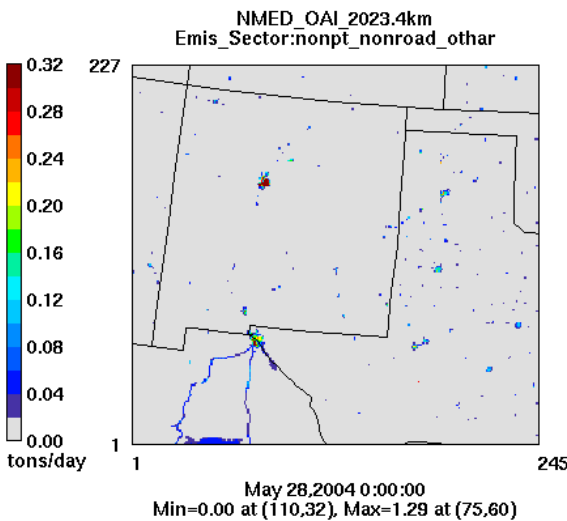


NONPOINT AND NONROAD EMISSIONS: NOX

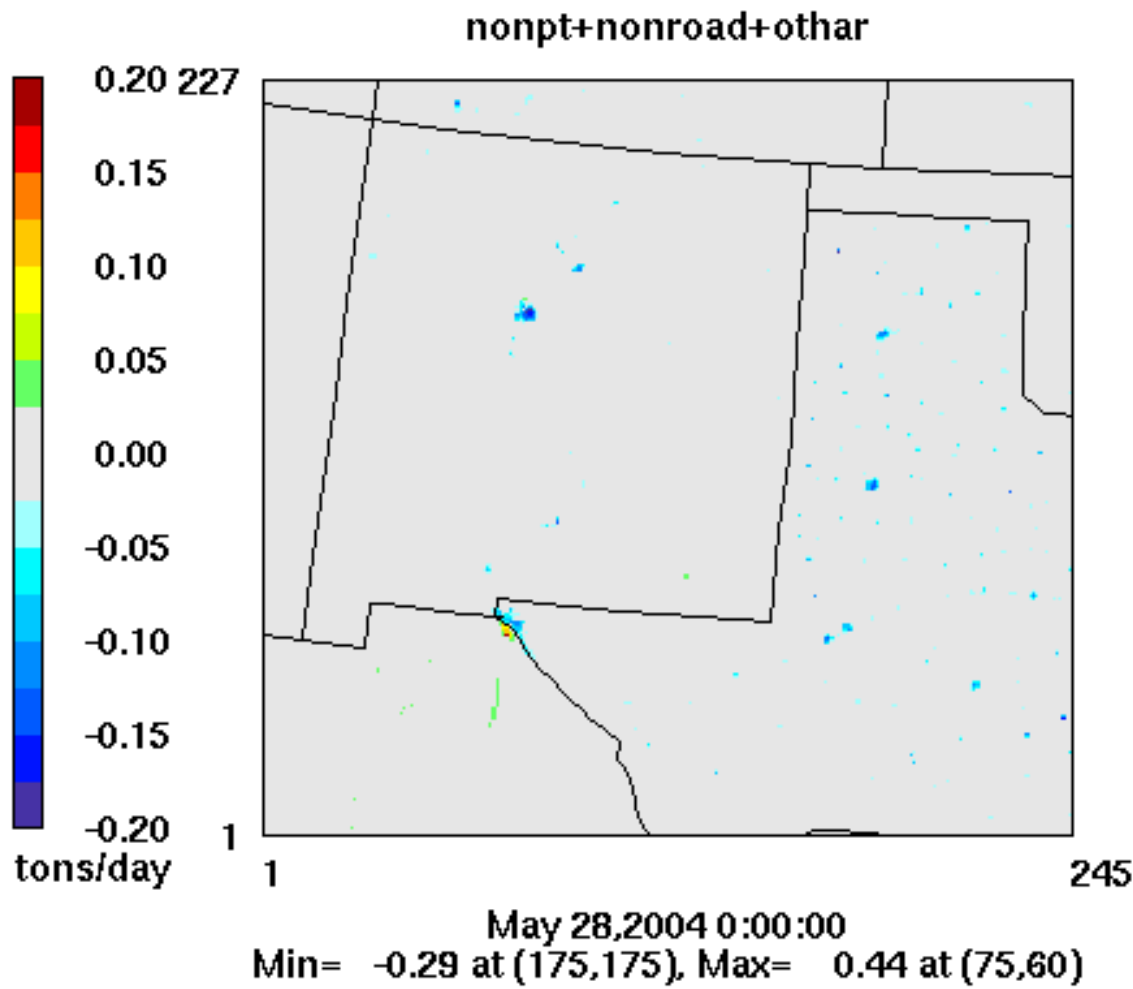
2014



2023

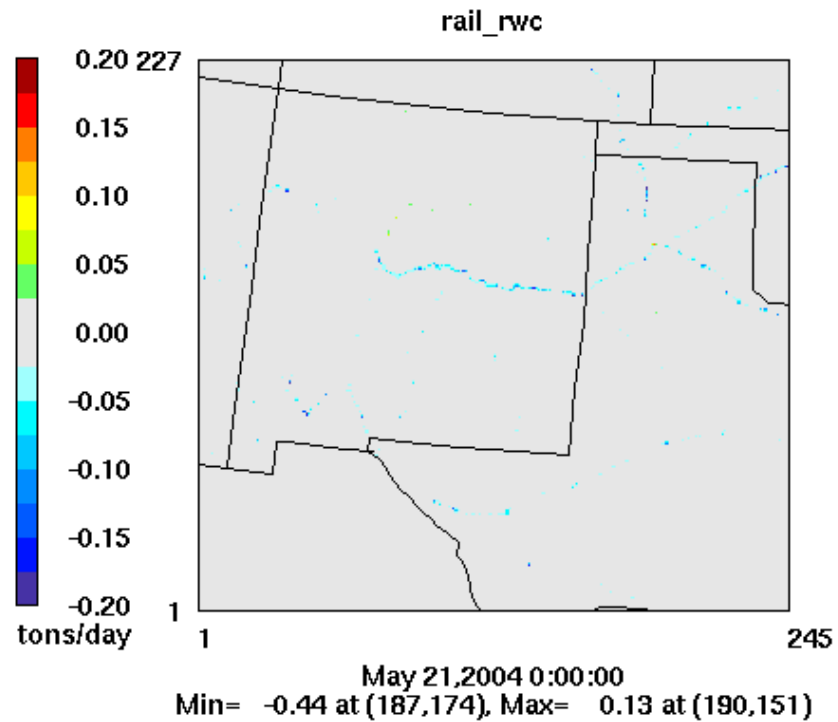


Delta NOx (2023 – 2014)

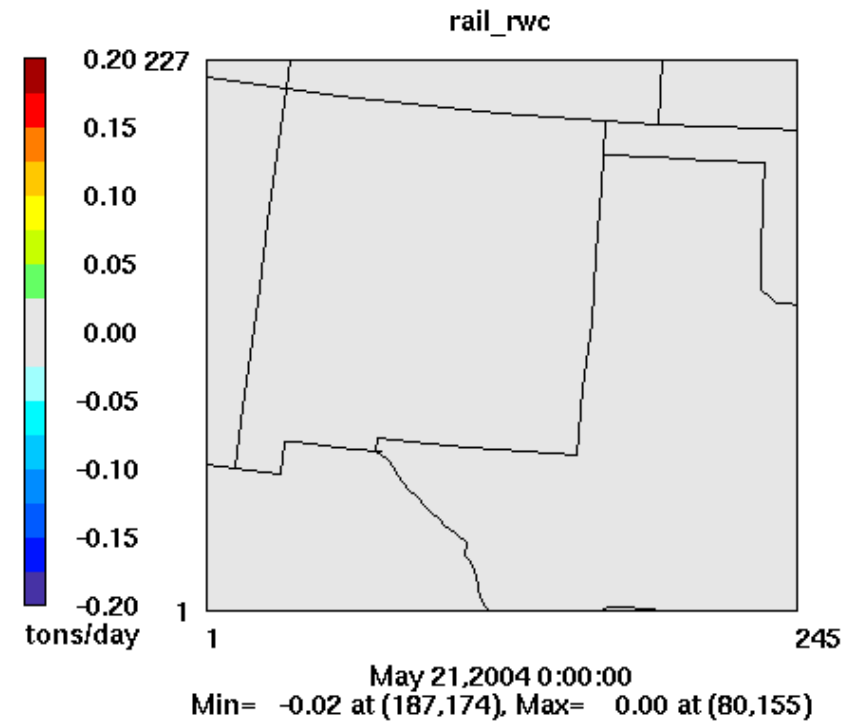


RAIL AND RWC EMISSIONS

Delta NOx (2023 – 2014)



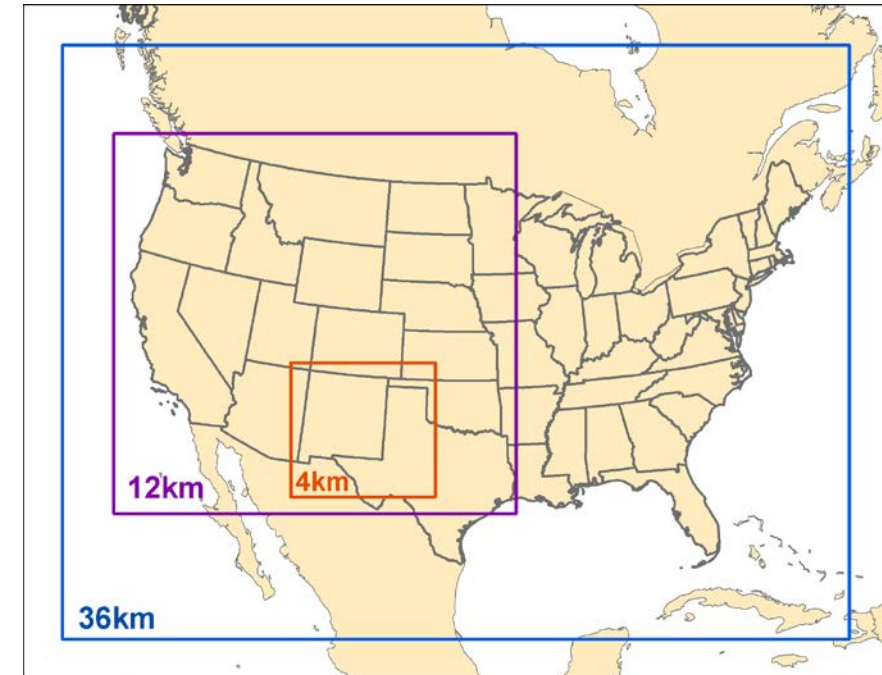
Delta VOC (2023 – 2014)



CAMX 2014 BASE CASE MODELING AND MODEL PERFORMANCE EVALUATION

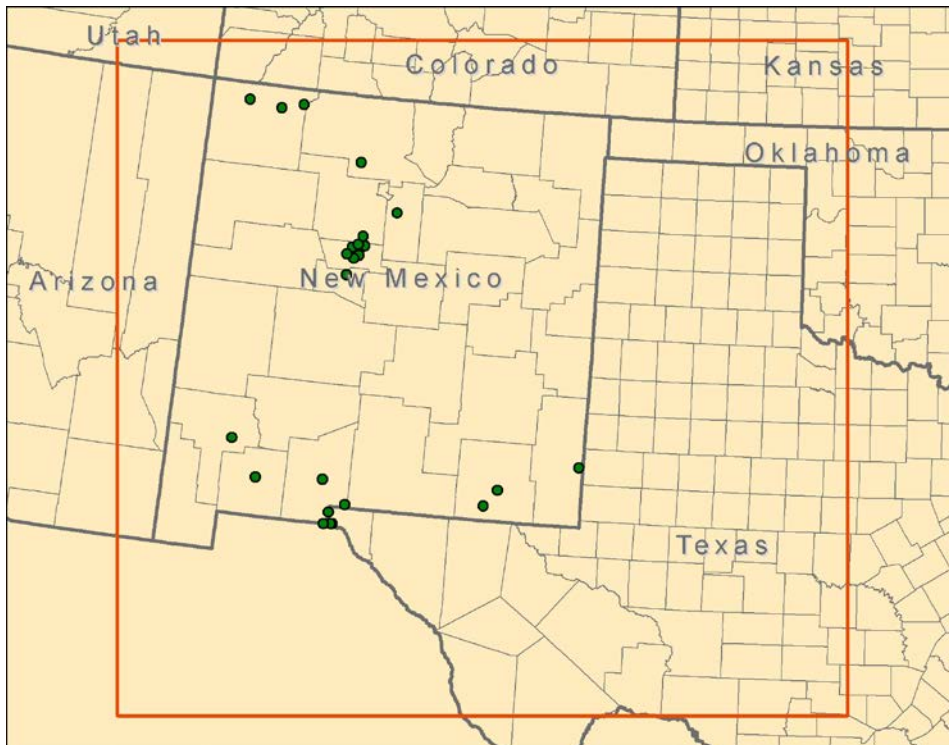
CAMX 2014 BASE CASE – FINAL MODEL CONFIGURATION

- Episode: May-August 2014
 - 16-day spin-up before first high ozone day in NM
 - 68 ppb on May 17
- 36/12/4-km Modeling Domains
 - 36/12-km domains same as WRAP Regional Haze
 - New 4-km New Mexico domain
- Boundary Conditions (BC) from WRAP 2014 GEOS-Chem
- Four Meteorological Diagnostic Sensitivity tests
 - Selected WRF/NAM with Kv=CMAQ
- WRAP 2014v2 base year emissions
 - EPA NEI2014v2 w/ western state updates
- EPA 2016v1 platform 2023fh emissions for Future Year



CAMX CONFIGURATION

- Very similar to WRAP CAMx 36/12-km Regional Haze set-up
 - o Addition of 4-km NM Domain



Science Options	CAMx	Comment
Model Codes	CAMx v7.0	Latest version of CAMx made publicly available May 2020 (www.camx.com)
<u>Horizontal Grid Mesh</u>	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 ~20 m. Model top at 50 mb (~19 km). Layer collapsing from 35 vertical layers in WRF
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 lateral boundaries
<u>Emissions</u>		
Emissions Processing	SMOKE, SMOKE-MOVES2014, MEGAN	WRAP/WAQS 2014v2 emissions and EPA 2023fh for future year
Sub-grid-scale	Plume-in-Grid (PiG)	NOx > threshold
<u>Chemistry</u>		
Gas Phase	CB6r4	(Yarwood et al., 2010)
Meteorological Processor	WRFCAMx	Compatible with CAMx v7.0
Horizontal Diffusion	Spatially varying	K-theory with Kh dependence
Vertical Diffusion	CMAQ-like Kv	Evaluated YSU Kv scheme
Diffusivity Min	Kv-min = 0.1 to 1.0 m ² /s in lowest 100 m	Urban land use fraction
<u>Deposition Schemes</u>		
Dry Deposition	Zhang dry deposition scheme	(Zhang et. al, 2001; 2003)
Wet Deposition	CAMx -specific formulation	rain/snow/graupel
<u>Numerics</u>		
Gas Phase Chemistry Solver	Euler Backward Iterative(EBI)	EBI fast and accurate solver
Vertical Advection	Implicit scheme ate	Emery et al., (2009a,b; 2011)
Horizontal Advection	Piecewise Parabolic	Colella and Woodward (1984)

2014 BASE CASE MPE

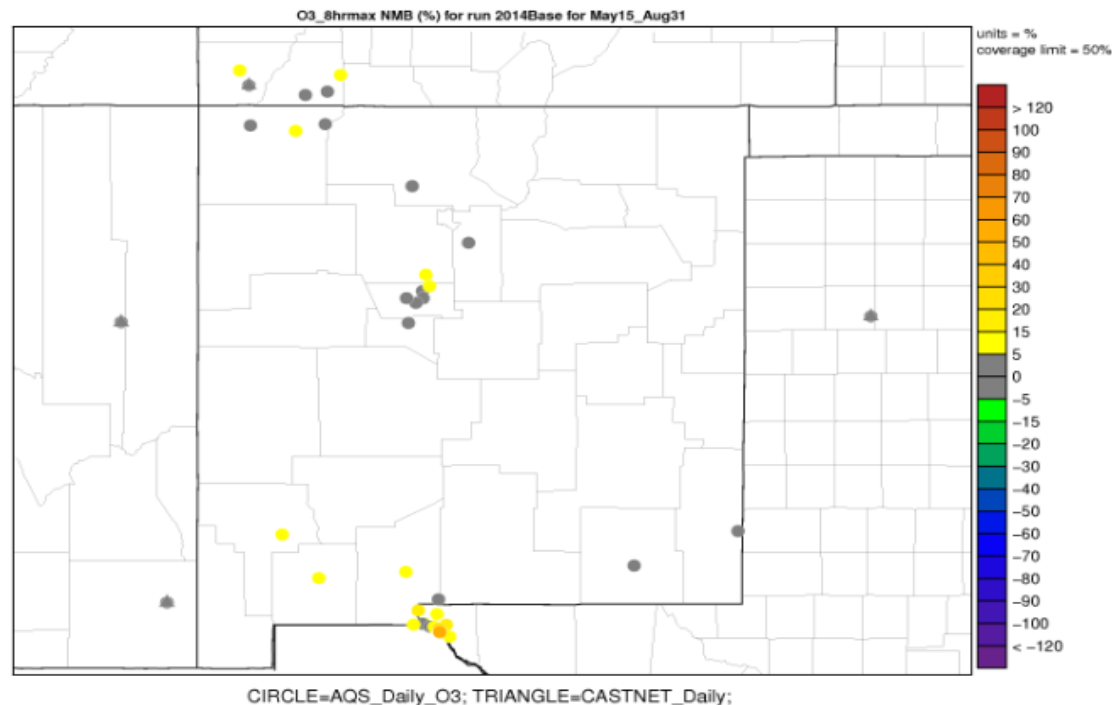
- Used AMETv1.4 MPE tool
- Model evaluated against EPA AQS Surface Air Quality Data for 2014
- Model performance compared with standard PGM goals and criteria values (Emery et al., 2016)
- “Goals” : statistical value that the best model can be expected to achieve
- “Criteria” : statistical value that majority of models have achieved

Species	NMB		NME	
	Goal	Criteria	Goal	Criteria
1-hr & MDA8 Ozone	<±5%	<±15%	<15%	<25%

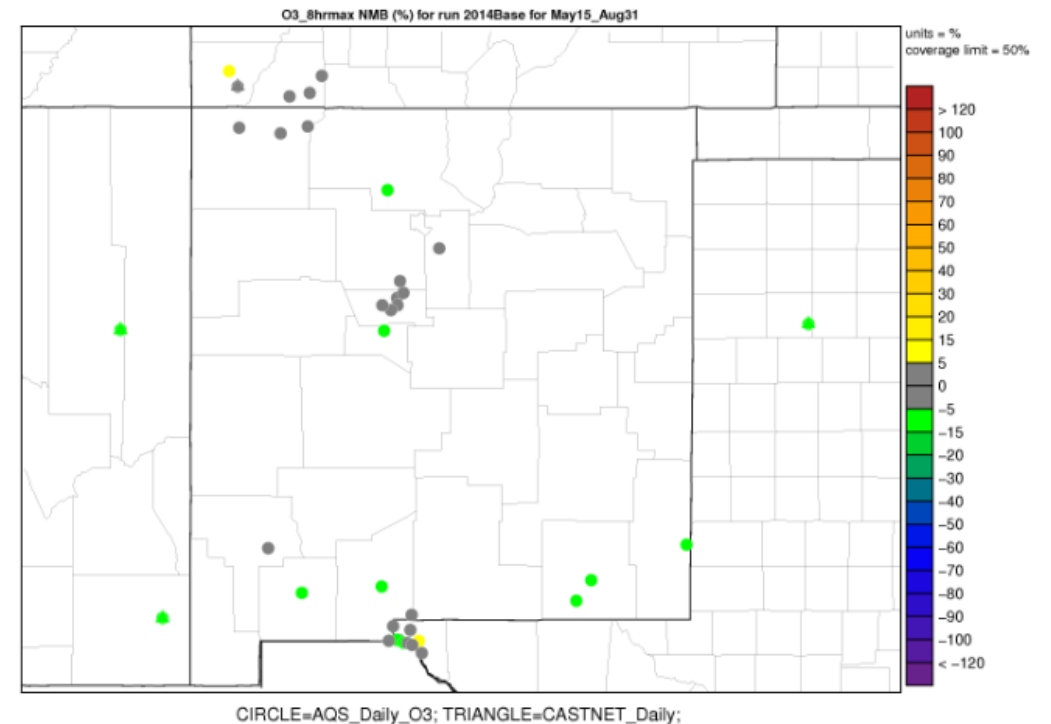
OZONE EVALUATION ACROSS 4KM DOMAIN

- Throughout the domain at most of the sites model is achieving performance goal with $\text{NMB} < \pm 5\%$.
- Few remaining sites are within the performance criteria with $\text{NMB} < \pm 15\%$, where model is overpredicting lower concentrations and underpredicting higher concentrations.

MDA8 O3 no cut-off



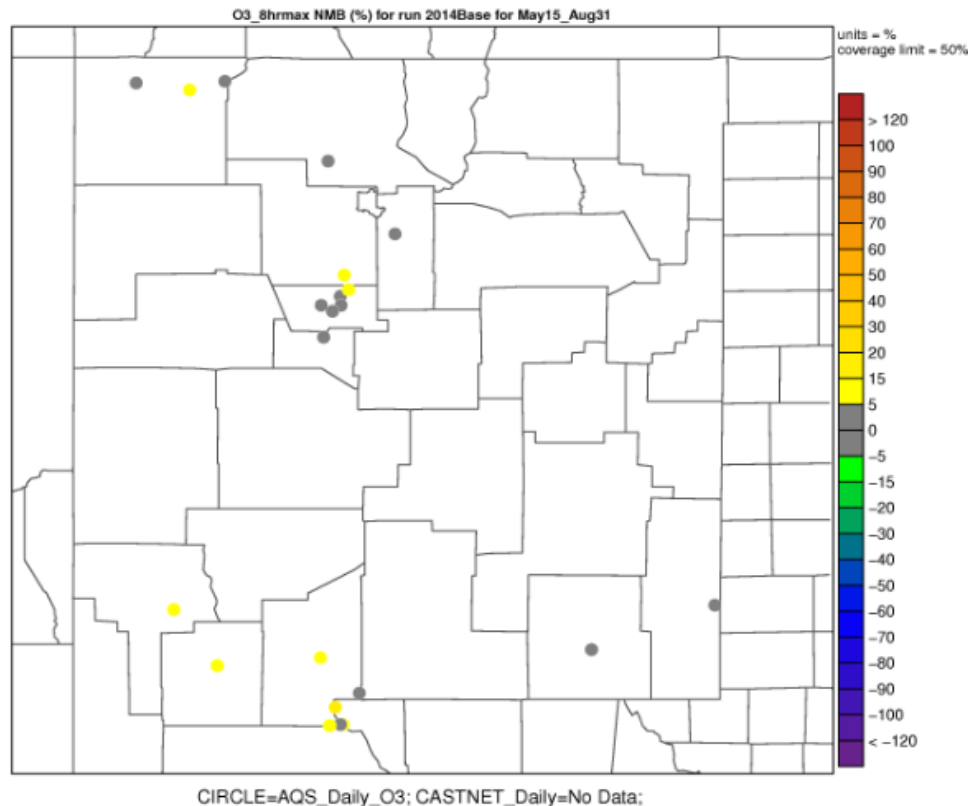
MDA8 O3 with 60 ppb cut-off



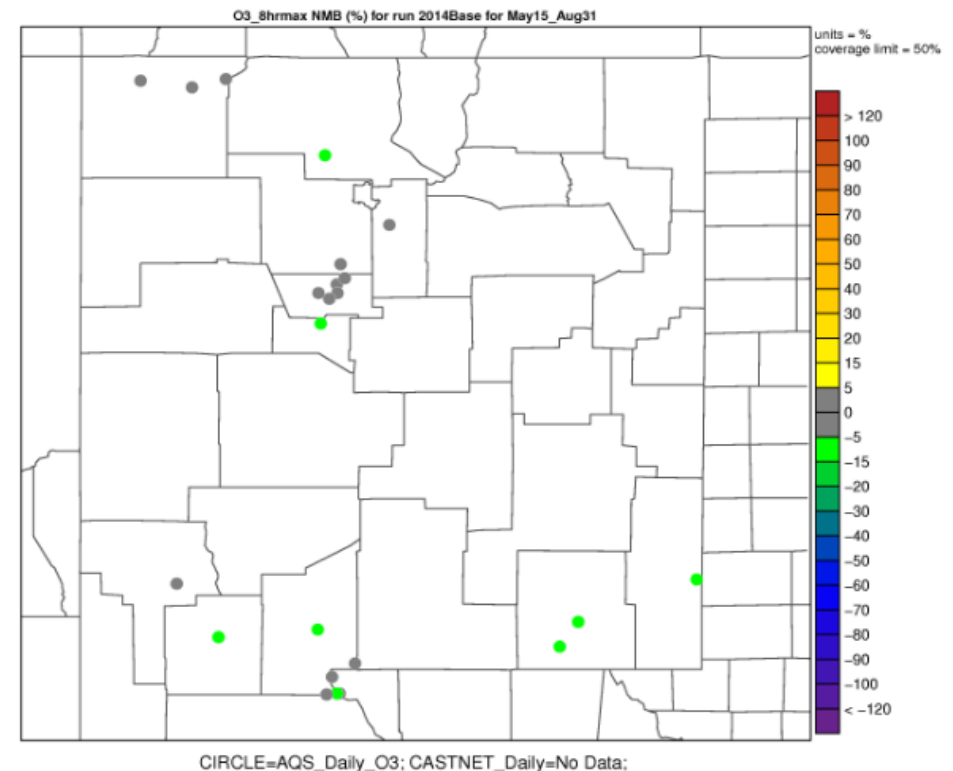
OZONE EVALUATION ACROSS NM DOMAIN

- Overall majority of sites in New Mexico are achieving performance goal ($< \pm 5\%$) and criteria ($< \pm 15\%$)
- Most of the southern New Mexico sites are underpredicting MDA8 concentrations higher than 60 ppb

MDA8 O3 no cut-off



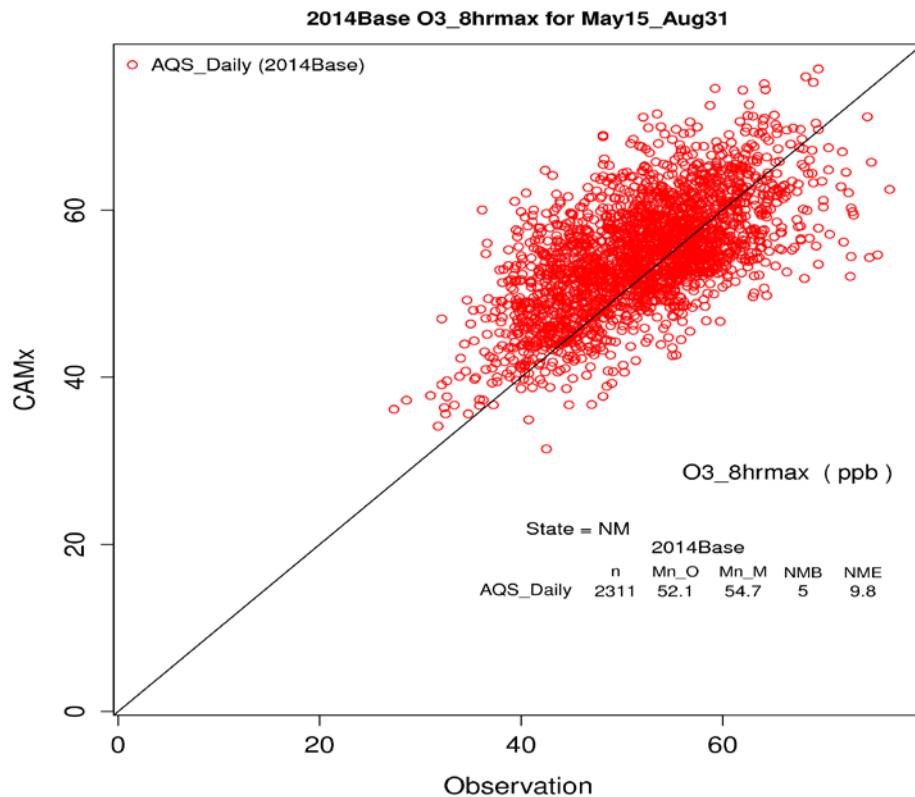
MDA8 O3 with 60 ppb cut-off



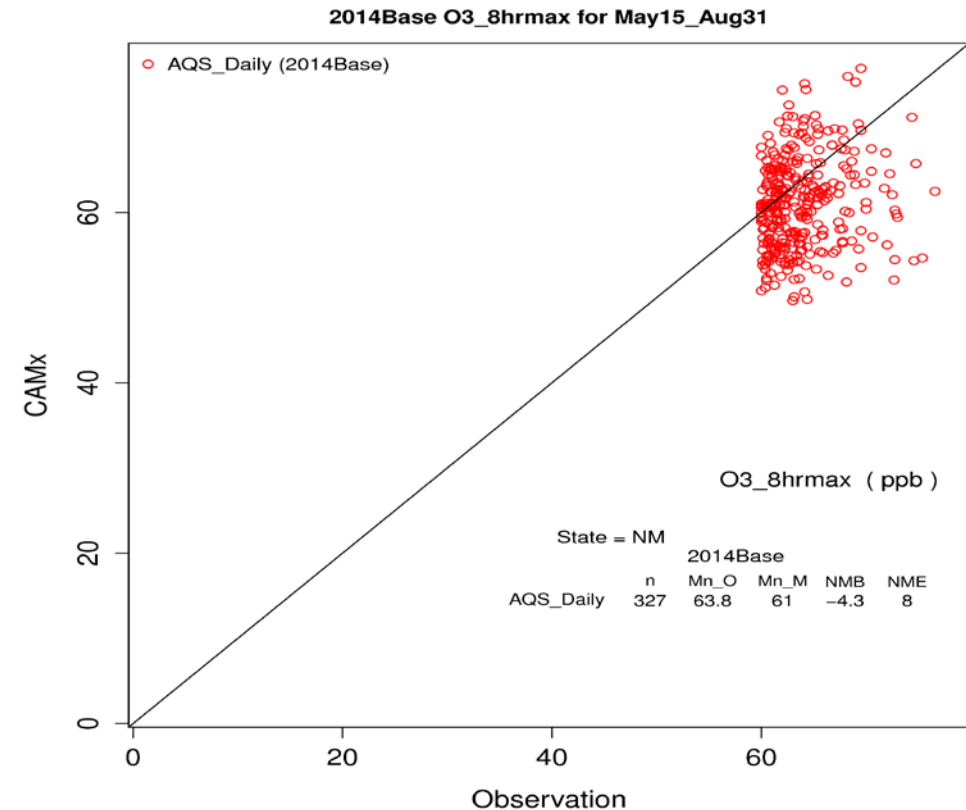
SCATTER PLOTS ACROSS AQS SITES IN NM

Domain wide all AQS sites MPE statistics w/ and w/o 60 ppb cut-off
NMB (5.0%, -4.3%) and NME (9.8%, 8.0%) metrics are within
performance goals (NMB < $\pm 5\%$ and NME < 15%).

MDA8 O3 without cut-off



MDA8 O3 with 60 ppb cut-off

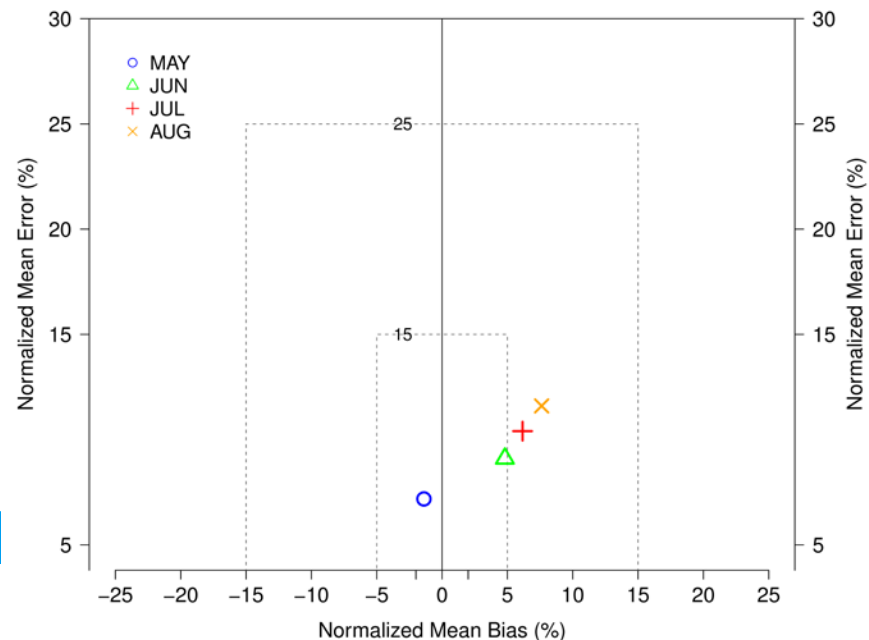


MONTHLY SOCCER PLOT FOR ALL NM AQS SITES

- May only includes only 15 days (i.e., May 15 -30) and has higher underestimation
- Using all ozone data slight overestimation with Jul and Aug bias falling between goal and criteria
- With 60 ppb observed MDA8 ozone cut-off slight underestimation bias that achieved goal in Jun-Jul-Aug
- All monthly average error metrics are within performance goal.

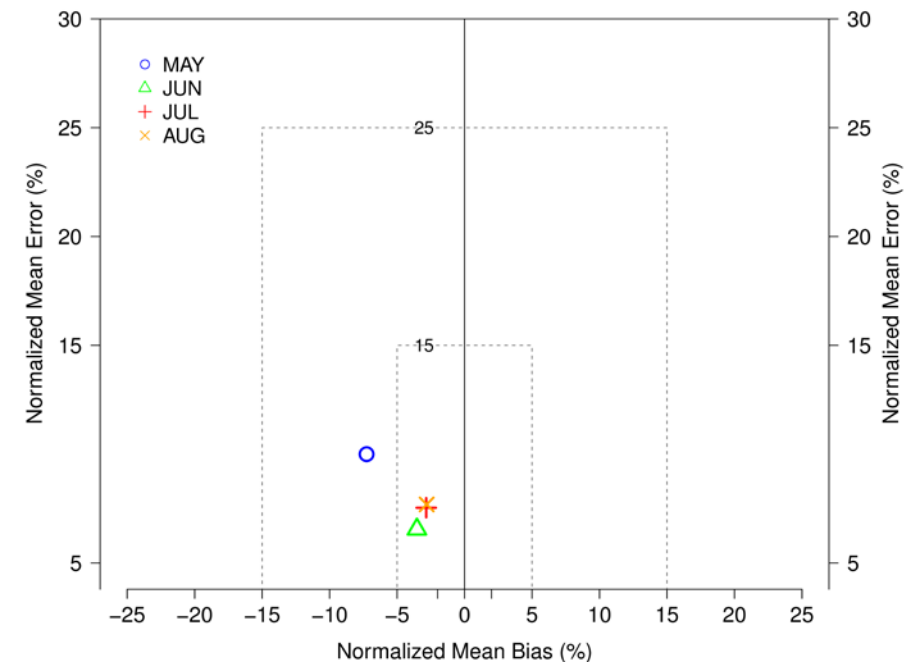
MDA8 O3 without cut-off

Soccergoal plot for 2014Base; Region=NM; Species=O3_8hrmax

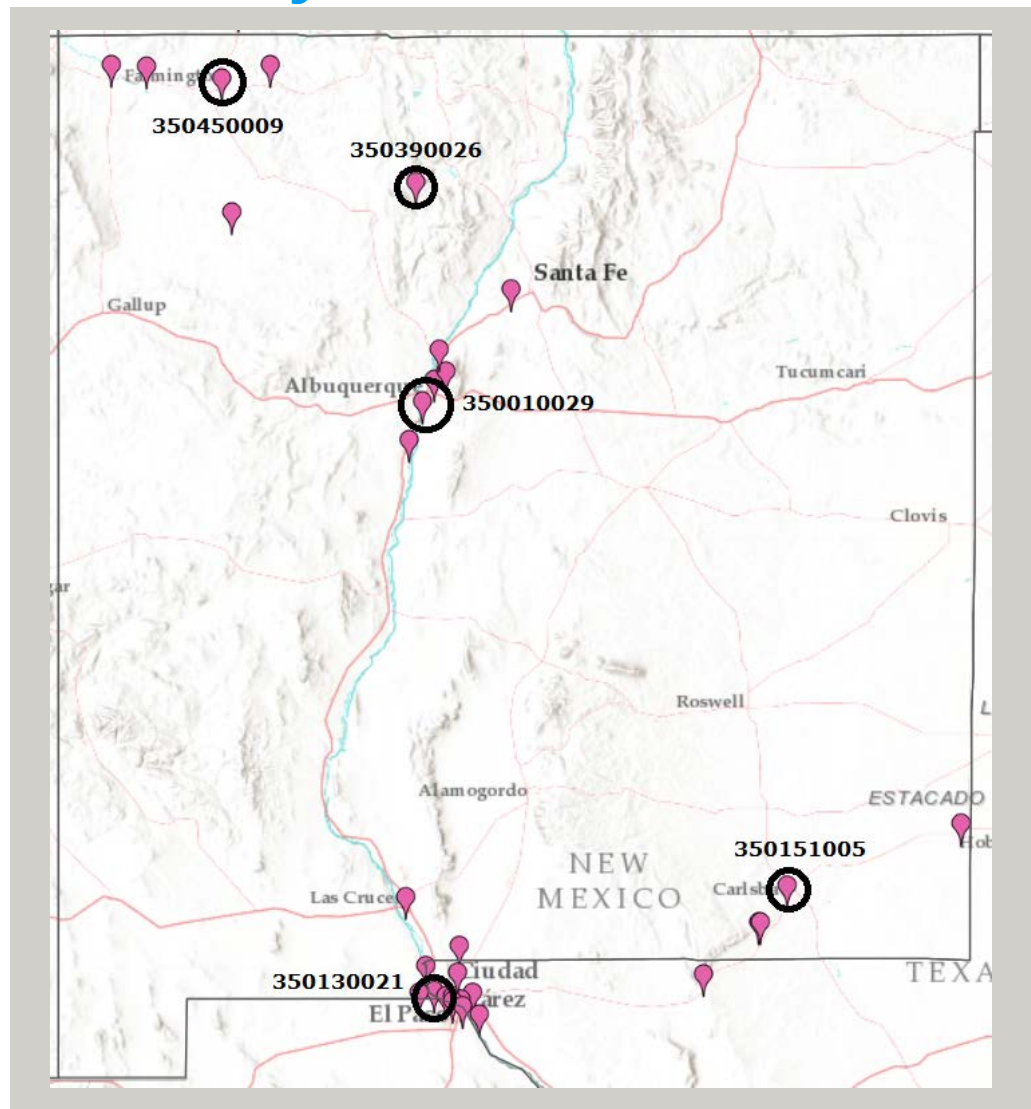


MDA8 O3 with 60 ppb cut-off

Soccergoal plot for 2014Base; Region=NM; Species=O3_8hrmax



NM Analysis Sites

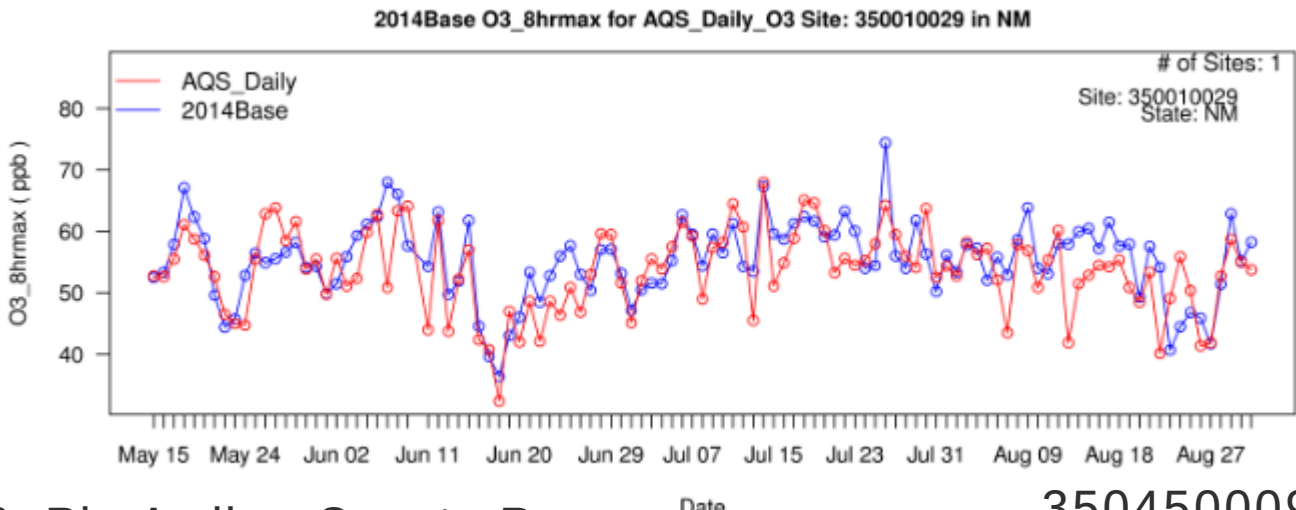


- Compared MDA8 ozone from 2014Base case modeling with a few selected AQS sites in NM

Site ID	Site Name	County	Latitude	Longitude
350450009	Bloomfield	San_Juan	36.74	-107.98
350390026	Coyote Ranger	Rio_Arriba	36.19	-106.70
350010029	South Valley	Bernalillo	35.02	-106.66
350130021	Desert View	Dona_Ana	31.80	-106.58
350151005	Carlsbad	Eddy	32.38	-104.26

OZONE EVALUATION ACROSS NM DOMAIN

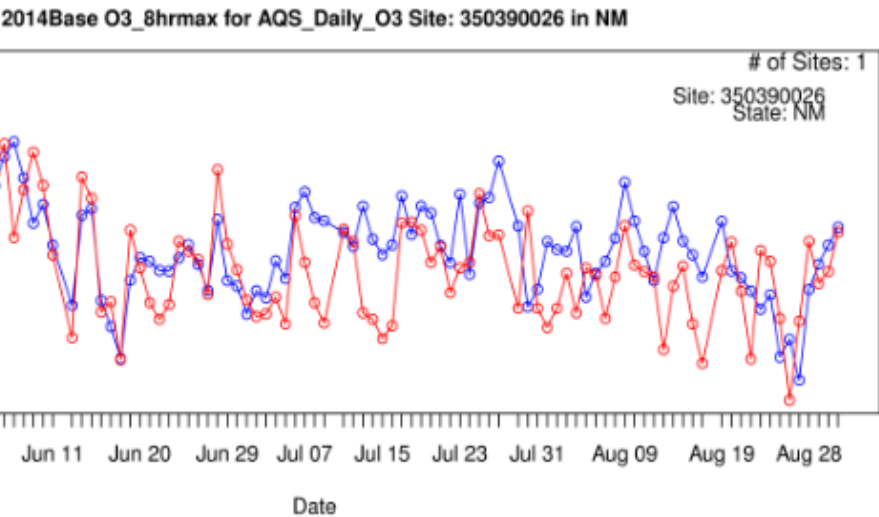
350010029
Bernalillo
South Valley



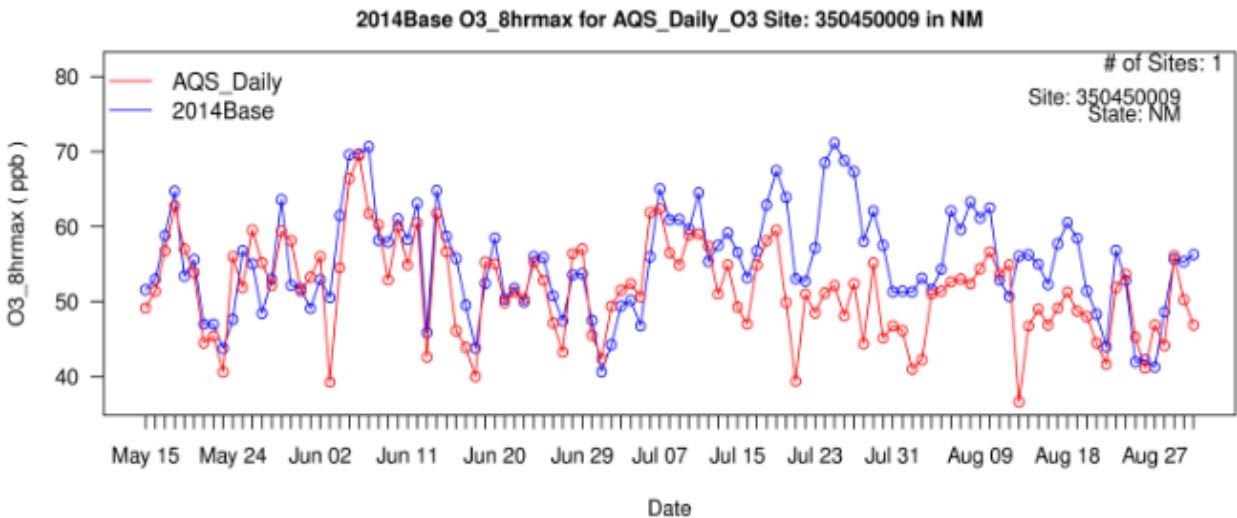
Model performing well at Bernalillo county site.

Model overpredicting lower concentrations at both Rio Arriba and San Juan county sites.

350390026, Rio Arriba, Coyote Ranger

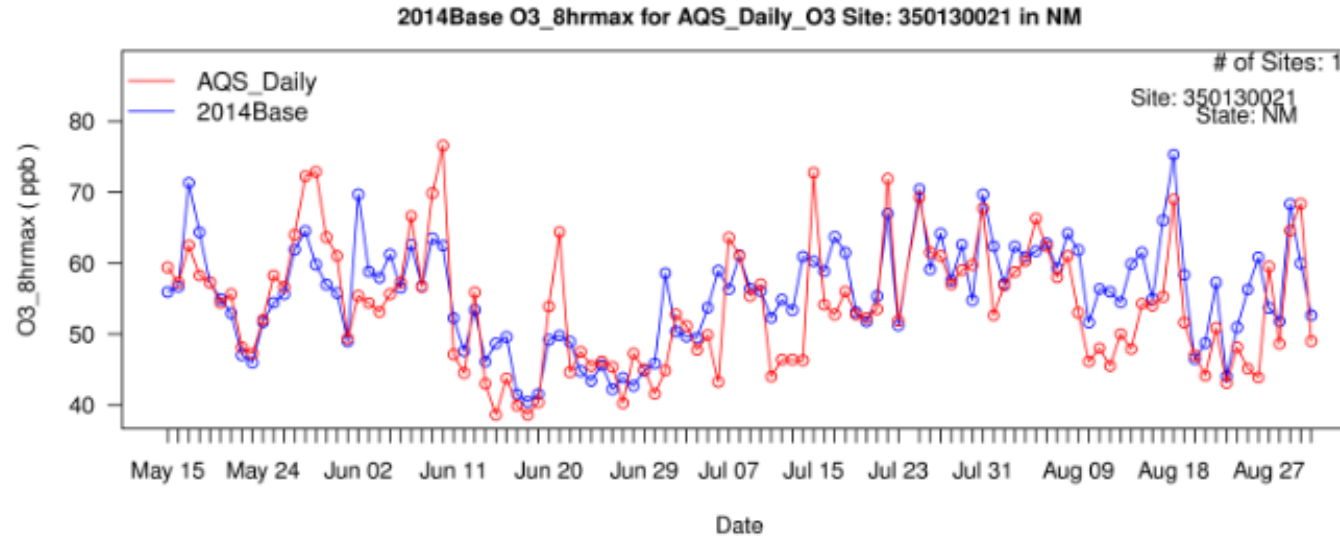


350450009, San Juan, Bloomfield



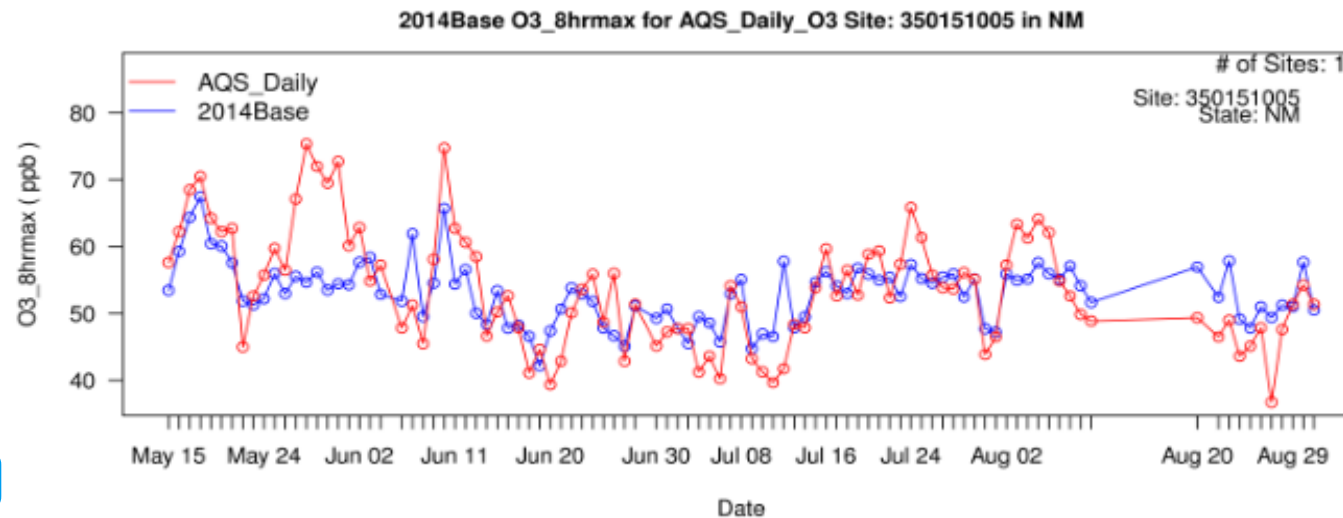
OZONE EVALUATION ACROSS NM DOMAIN

350130021
Dona Ana
Desert View



Model able to predict peaks during August month.

350151005
Eddy
Carlsbad



Model underpredicting the May 27-31st exceedance event.

SITE SPECIFIC METRICS

Site ID	Site Names	NMB No Cut-Off	NMB w/ 60 ppb Cut-Off
350010023	Del Norte	1.7	-3.88
350010024	South East Heights	3.1	-2.37
350010029	South Valley	3.1	-2.79
350010032	Westside	1.1	-3.4
350011012	Foot Hills	13.6	1.98
350130008	La Union	17.4	-1.56
350130017	Sunland Park Yard	9.0	-3.55
350130020	Chaparral	4.8	-4.65
350130021	Desert View	3.2	-5.11
350130022	Santa Teresa	8.2	0.14
350130023	Solano	6.1	-6.47
350151005	Carlsbad	-1.1	-12.3
350171003	Chino Copper Smelter	9.1	-0.99
350250008	Hobbs Jefferson	2.1	-9.87
350290003	Deming Airport	6.2	-5.04
350390026	Coyote Ranger District	3.3	-5.43
350431001	Bernalillo	8.1	3.84
350450009	Bloomfield	7.2	2.47
350450018	Navajo Lake	2.2	-0.61
350451005	Sub Station	1.4	3.28
350490021	Santa Fe Airport	3.8	-1.69
350610008	Los Lunas	0.8	-6.53

	Below Performance Goal	
	Between Performance Goal and Criteria	
	Exceeds Performance Criteria	

NEW MEXICO REGIONAL EVALUATION REGIONS

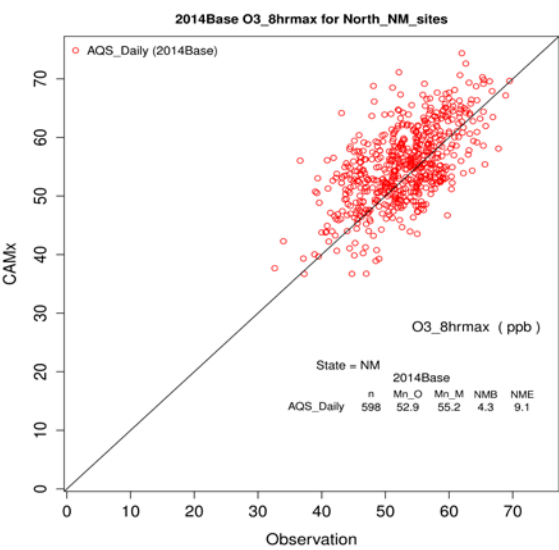
Site ID	Site Name	County	Lat	Lon
350130022	Santa Teresa	Dona Ana	31.79	-106.68
350130017	Sunland Park Yard	Dona Ana	31.80	-106.56
350130021	Desert View	Dona Ana	31.80	-106.58
350130008	La Union	Dona Ana	31.93	-106.63
350130020	Chaparral	Dona Ana	32.04	-106.41
350290003	Deming Airport	Luna	32.26	-107.72
350130023	Solano	Dona Ana	32.32	-106.77
350151005	Carlsbad	Eddy	32.38	-104.26
350171003	Chino Copper Smelter	Grant	32.69	-108.13
350250008	Hobbs Jefferson	Lea	32.73	-103.12
350610008	Los Lunas	Valencia	34.81	-106.74
350010029	South Valley	Bernalillo	35.02	-106.66
350010024	South East Heights	Bernalillo	35.06	-106.58
350010032	Westside	Bernalillo	35.06	-106.76
350010023	Del Norte	Bernalillo	35.13	-106.59
350011012	Foot Hills	Bernalillo	35.19	-106.51
350431001	Bernalillo	Sandoval	35.30	-106.55
350490021	Santa Fe Airport	Santa Fe	35.62	-106.08
350390026	Coyote Ranger District	Rio Arriba	36.19	-106.70
350450009	Bloomfield	San Juan	36.74	-107.98
350451005	Sub Station	San Juan	36.80	-108.47
350450018	Navajo Lake	San Juan	36.81	-107.65

	South NM sites
	Bernalillo county
	North NM sites

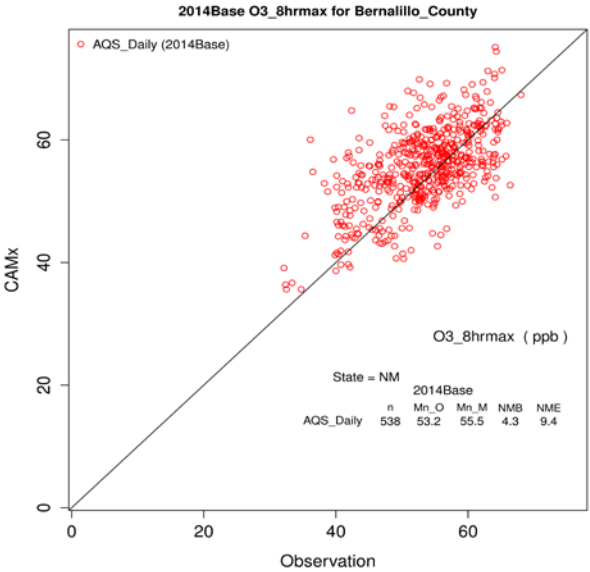
	No Cut-Off		With Cut-Off	
Region	NMB(%)	NME(%)	NMB(%)	NME(%)
North NM	4.3	9.1	0	6.4
Bernalillo	4.3	9.4	-2.8	7.1
South NM	5.8	10.5	-6.1	8.5

REGION BASED SCATTER PLOTS

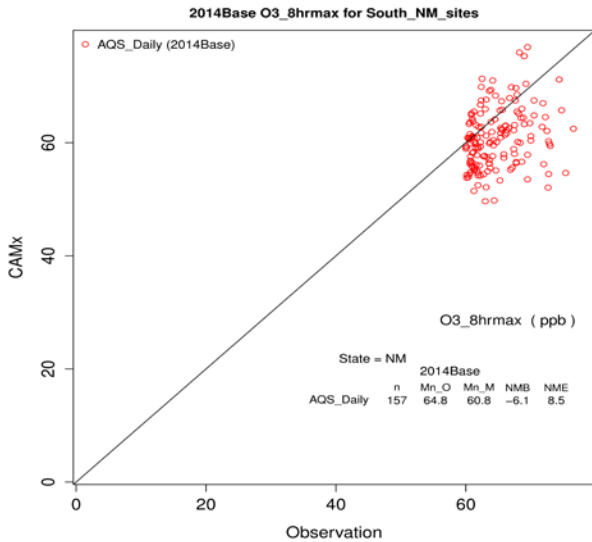
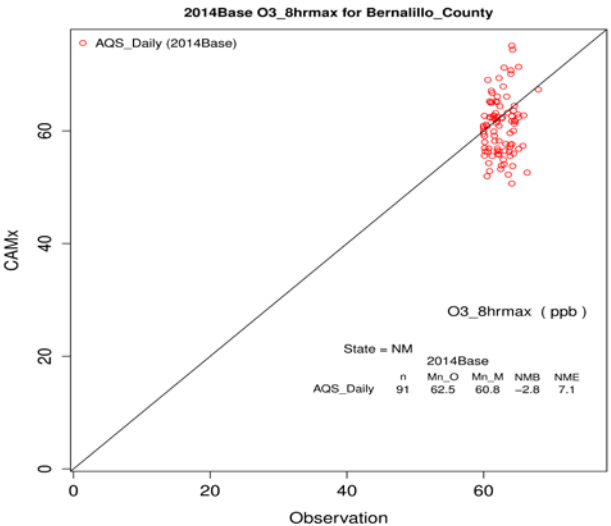
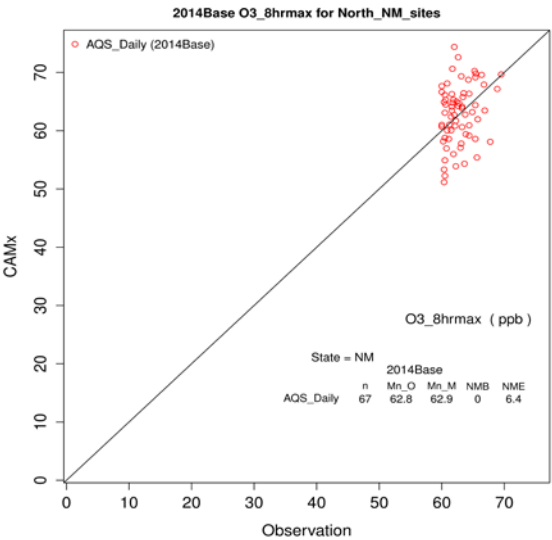
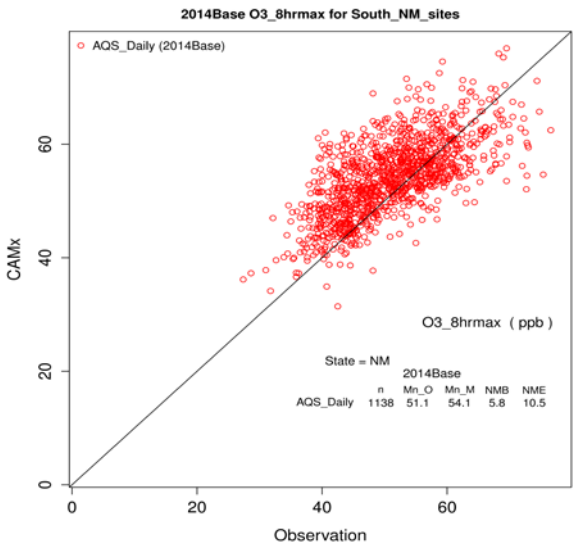
North NM



Bernalillo



South NM



MPE FOR OZONE DESIGN VALUE PROJECTION

- EPA-recommended approach for making future year ozone Design Value (DV) projections uses the PGM base year top 10 highest MDA8 ozone concentrations to develop Relative Response Factors (RRF)
- The RRF is applied to the measured base year (BY) ozone design value (DVb) to project a future year (FY) ozone design value (DVf)

$$\text{RRF} = \sum \text{Model}_{\text{FY}} / \sum \text{Model}_{\text{BY}}$$

$$\text{DVf} = \text{DVb} \times \text{RRF}$$

- The ozone model performance for the 10 highest modeled base year MDA8 ozone is therefore important
 - o An alternative projection approach to the EPA-default is to use the top 10 highest modeled base year MDA8 ozone that meet a MPE requirement (e.g., within $\pm 10\%$)

EVALUATION FOR TOP 10 HIGHEST MODELED MDA8 OZONE

Desert View	Obs	Prd	Bias	%
8/18/2014	69.0	75.3	6.3	9.1%
5/17/2014	62.5	71.3	8.8	14.1%
7/25/2014	69.3	70.4	1.2	1.7%
6/2/2014	55.4	69.7	14.3	25.8%
7/31/2014	67.7	69.7	2.0	2.9%
8/29/2014	64.6	68.3	3.7	5.8%
7/22/2014	71.9	67.0	-4.9	-6.8%
8/17/2014	55.3	66.0	10.8	19.5%
5/28/2014	72.3	64.5	-7.7	-10.7%
5/18/2014	58.3	64.3	6.1	10.4%
8/8/2014	61.0	64.2	3.2	5.2%
7/27/2014	61.0	64.1	3.1	5.2%
7/17/2014	52.8	63.7	10.9	20.7%
6/9/2014	69.9	63.5	-6.4	-9.2%
8/6/2014	62.4	62.8	0.4	0.7%
7/29/2014	59.0	62.6	3.6	6.1%
6/7/2014	66.6	62.6	-4.0	-6.1%
6/10/2014	76.6	62.5	-14.1	-18.4%
8/1/2014	52.6	62.4	9.7	18.5%
8/3/2014	58.8	62.3	3.6	6.1%

Carlsbad	Obs	Prd	Bias	%
5/18/2014	70.5	67.5	-3.0	-4.3%
6/10/2014	74.8	65.7	-9.0	-12.1%
5/17/2014	68.5	64.4	-4.1	-6.0%
6/7/2014	51.3	61.9	10.7	20.8%
5/19/2014	64.3	60.5	-3.8	-5.9%
5/20/2014	62.3	60.1	-2.2	-3.5%
5/16/2014	62.3	59.3	-3.0	-4.8%
6/3/2014	54.9	58.4	3.5	6.5%
8/23/2014	49.0	57.9	8.9	18.1%
7/12/2014	41.8	57.8	16.1	38.5%
6/2/2014	62.9	57.7	-5.2	-8.3%
8/30/2014	54.3	57.7	3.4	6.3%
8/5/2014	64.1	57.6	-6.5	-10.1%
5/21/2014	62.8	57.6	-5.2	-8.2%
7/24/2014	65.9	57.3	-8.5	-13.0%
8/8/2014	52.6	57.1	4.5	8.5%
8/20/2014	49.4	57.0	7.6	15.4%
7/19/2014	52.8	56.8	4.1	7.7%
6/12/2014	60.7	56.6	-4.1	-6.7%
7/16/2014	59.7	56.3	-3.4	-5.7%

Bloomfield	Obs	Prd	Bias	%
7/25/2014	52.1	71.1	19.0	36.4%
6/7/2014	61.7	70.6	8.9	14.4%
6/6/2014	69.5	69.7	0.2	0.2%
6/5/2014	66.4	69.6	3.2	4.8%
7/26/2014	48.1	68.8	20.7	42.9%
7/24/2014	51.1	68.5	17.4	34.0%
7/19/2014	59.5	67.5	8.0	13.4%
7/27/2014	52.4	67.3	14.9	28.5%
7/7/2014	62.4	65.0	2.6	4.2%
6/14/2014	61.8	64.8	3.0	4.9%
5/18/2014	62.8	64.7	2.0	3.1%
7/11/2014	59.0	64.5	5.5	9.3%
7/20/2014	49.9	63.9	14.0	28.1%
5/29/2014	59.4	63.6	4.2	7.1%
8/8/2014	52.4	63.3	10.9	20.8%
6/12/2014	60.5	63.1	2.6	4.3%
7/18/2014	58.1	62.9	4.7	8.2%
8/10/2014	56.6	62.5	5.9	10.4%
8/6/2014	52.6	62.1	9.5	18.0%
7/29/2014	55.1	62.1	6.9	12.6%

Yellow = 20 highest observed MDA8 ozone (dark yellow top 10)

Red = bias greater than $\pm 10\%$

Blue = Added model days using $\pm 10\%$ MPE criteria



CONCLUSIONS CAMX 2015 36 / 12 / 4-KM BASE CASE MPE

- Across all sites in New Mexico ozone performance meets the bias and error Performance Goals
 - Across all observations there is a slight overestimation but still meet bias goal ($\leq \pm 5\%$)
 - Using just observed ozone above a 60 ppb cut-off, the goal is still met with an underestimation bias
- The northern NM and Bernalillo County subregions meet the ozone goals , but southern NM subregion bias falls between the performance goal and criterion
- Example evaluation for 10 highest modeled MDA8 ozone used to make ozone projections using EPA default approach found good overlap with observed highest MDA8 ozone:
 - At Desert View (Dona Ana County) 7 of top 10 modeled days were top 20 observed, 5 top 10 observed
 - At Carlsbad (Eddy County) 6 of top 10 modeled days were top 20 observed; 4 top 10 observed
 - At Bloomfield (San Juan County) 6 of top 10 modeled days were top 20 observed; 5 top 10 observed
- Although there were some periods of questionable model performance (e.g., late July in San Juan County and late May at Carlsbad), overall the model performance was quite reasonable and mostly achieved the performance goals and always achieved the performance criteria

CURRENT STATUS AND NEXT STEPS

CURRENT STATUS / NEXT STEPS

- Close to starting Task 6.1 CAMx 2023 Base Case Simulation
 - o NMED asked us to pause the 2023 modeling on August 26, 2020

Original NM OAI Modeling Study Work Plan Webinar Schedule

Webinar Number	Webinar Topics by Task	Date	Status
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	• Done • Done • Done • Done
2.	2.2 Additional Met Modeling 3.1 Evaluate BC Data 4.1 Summary of 2014 and 2023 Emissions	Jun 2020	• Done • Done • Done
3.	4.2.1 Summary of 2014 and 2023 Mobile Source Emissions 4.3 2014 Natural Emissions Results (e.g., Biogenic & LNOx)	Jul 2020	• Done • Done
4.	4.2.3 2014 & 2023 SMOKE-MOVES Results 4-km NM Domain 4.4 2014 & 2023 SMOKE Emissions Modeling Results 5 CAMx 2014 Base Case and Model Evaluation	Aug 2020	• Done • 12-km SMK-MVS • MPE Report
5.	4.5 FY Emissions Strategy Results 5. 2014 CAMx Base Case Modeling and MPE	Sep 2020	• Need data NMED • Report early Sep
6.	6.1 2023 CAMx Modeling Results 6.2 2023 Ozone Design Value Projections	Oct 2020	• September? • September?
7.	6.3 2023 Control Strategy Results 6.4 2023 Source Apportionment Modeling Results	Nov 2020	• Need data NMED • Not Done

NEXT STEPS

- NMED issues a stop work on 2023 modeling; redirect effort to 2028 modeling
- NMED requests WESTAR/Ramboll provide scope-of-work, cost estimate and schedule for three new tasks:
 - o Develop 2028 base case O&G emissions for New Mexico
 - o Develop CAMx 36/12/4-km 2028 emissions using WRAP 2028OTBa2 database with updated 2028 O&G emissions for New Mexico and run CAMx 2028 36/12/4-km base case simulation
 - o Receive 2028 New Mexico O&G control strategy emissions from NMED and conduct CAMx 2028 36/12/4-km NM O&G control strategy simulation and provide ozone results to NMED

NEW MEXICO OZONE ATTAINMENT INITIATIVE

2014 and 2028 Emissions Development

Tejas Shah, Chao-Jung Chien, Sai Sreedhar Varada, John Grant, Marco Rodriguez,
and Ralph Morris, Ramboll

Tom Moore and Mary Uhl, WESTAR

NM OAI Study Webinar

February 1, 2021

DEVELOPMENT OF 2028 MODELING EMISSIONS

01

Natural Emissions

02

Anthropogenic Emission Data Sources

03

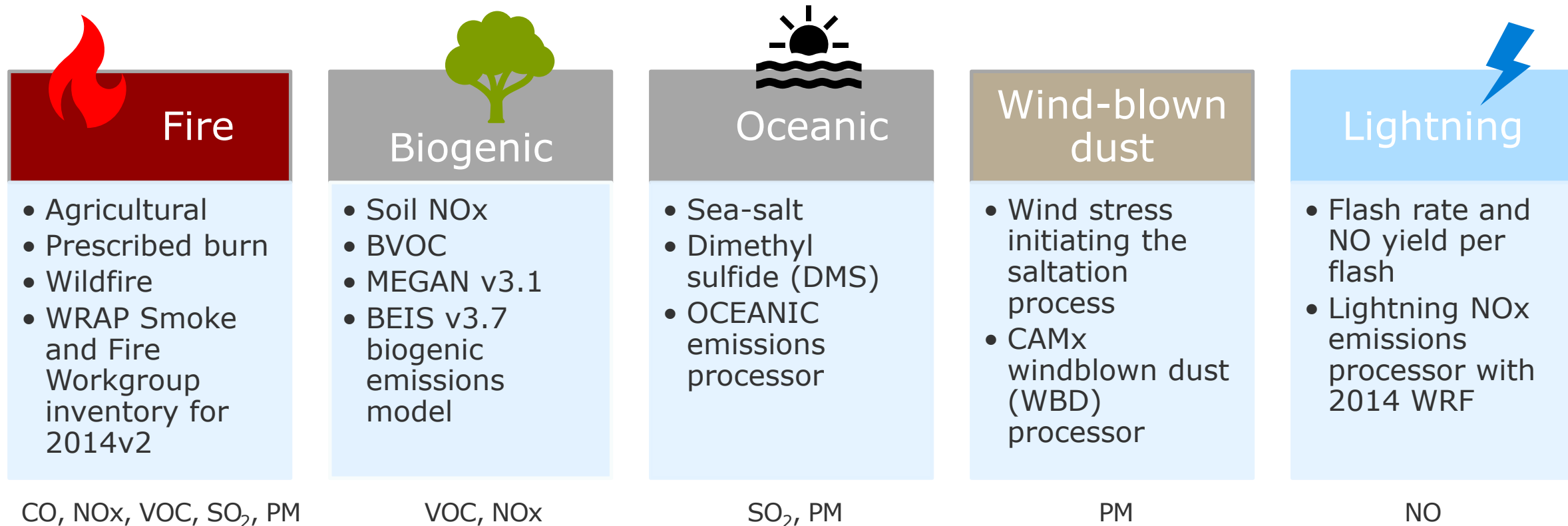
SMOKE Emissions Modeling

04

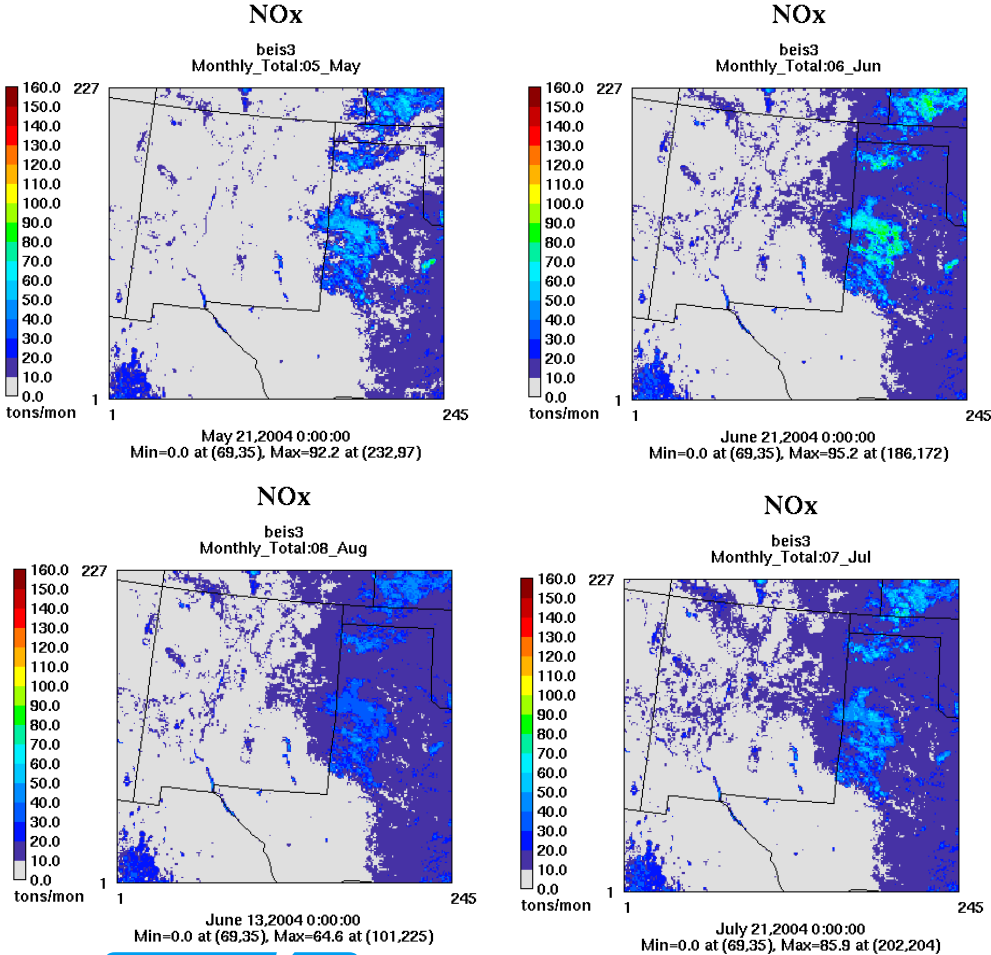
Summary of 2014 and 2028 Emissions

NATURAL EMISSIONS

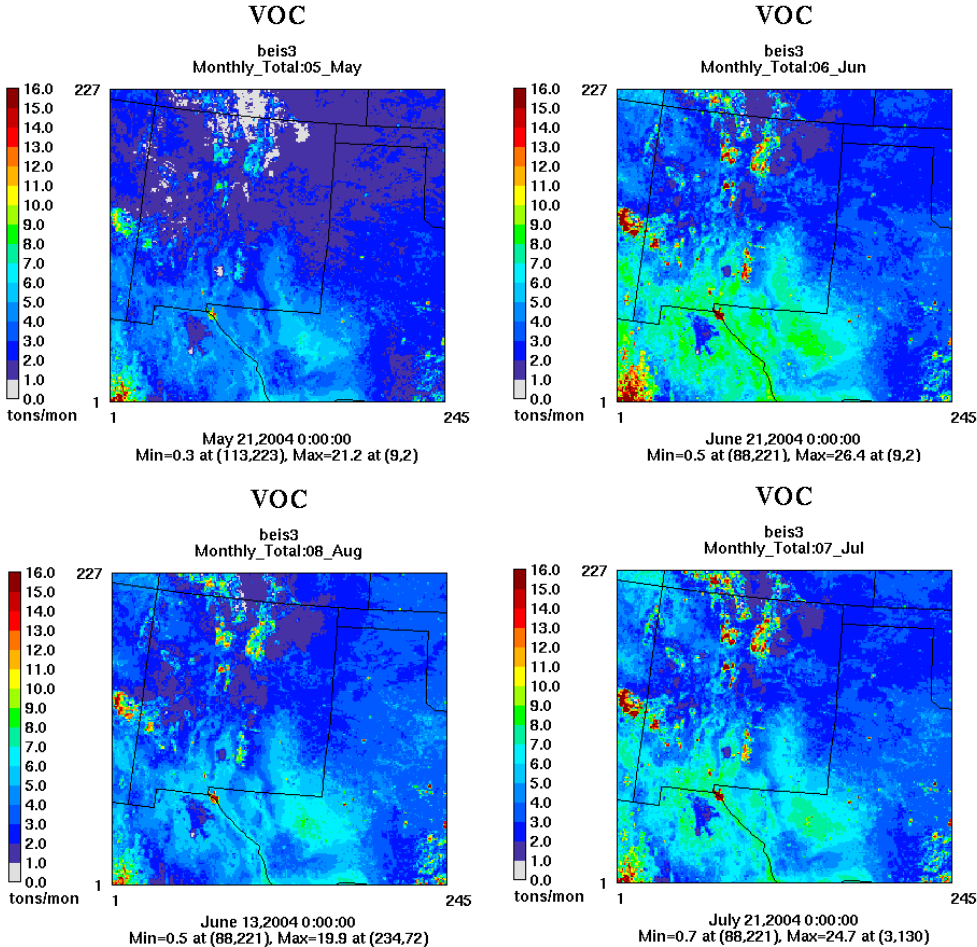
Remained the same between 2014 and 2028



BEIS V3.7 EMISSIONS



Tons/month		MEGAN	BEIS3	Abs Diff	Ratio
				(BEIS3-MEGAN)	(BEIS3/MEGAN)
May	NOX	35,050	10,602	-24,448	0.30
	VOC	128,323	159,809	31,486	1.25
Jun	NOX	42,445	13,134	-29,311	0.31
	VOC	267,055	256,379	-10,676	0.96
Jul	NOX	51,639	12,838	-38,801	0.25
	VOC	317,697	251,562	-66,135	0.79
Aug	NOX	41,002	11,923	-29,079	0.29
	VOC	354,570	216,032	-138,538	0.61



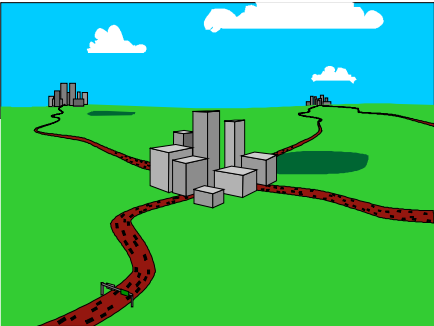
ANTHRO EMISSION DATA SOURCES



- 2014 anthropogenic emissions from 2014v2 scenario of the WRAP/WAQS RH modeling
 - Onroad emissions generated using SMOKE-MOVES processing for the 4-km domain
 - O&G emissions based on state-of-the-science WRAP OGWG emission estimates
 - NMED found a generator engine missing in 2014v2 inventory (94 tpy NO_x)
 - Consistent emissions data between the Regional Haze and OAI studies
- 2028 anthropogenic emissions based on the WRAP/WAQS 2028 on-the-books scenario (2028OTBa2 only with actual 2014 fires)
 - O&G emissions based on inventory developed by Ramboll (presented in Jan 11th meeting)
 - Onroad emissions created using SMOKE-MOVES
 - Fixed double counting of NM sources
 - Updated San Juan Generating Station (NO_x 7,391 TPY) and added Lordsburg Generating Station
 - Updated three O&G sources: Chaco Gas Plant (NO_x 2,053 tpy), Carlsbad CS, and Mountainair CS (NO_x 645 tpy)

EMISSION PROCESSING FOR AQM

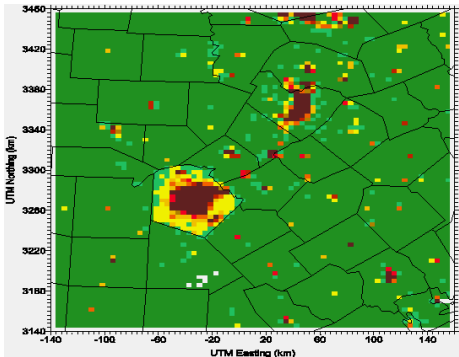
Start With



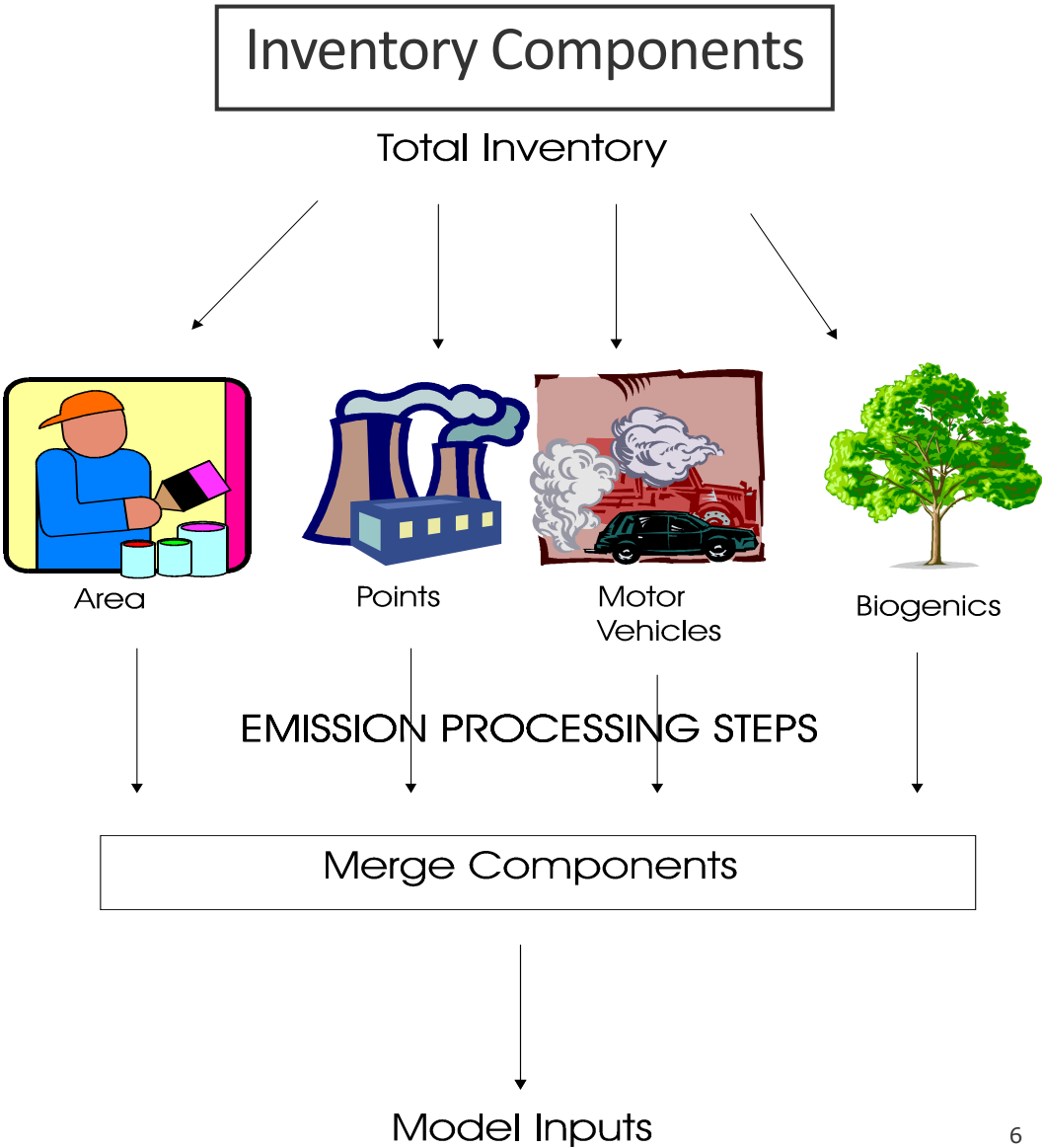
- Annual Estimates (tons/year)
- County Totals
- Criteria Pollutants (NO_x, CO, VOC)



Model Ready



- Hourly
- Gridded
- Speciated

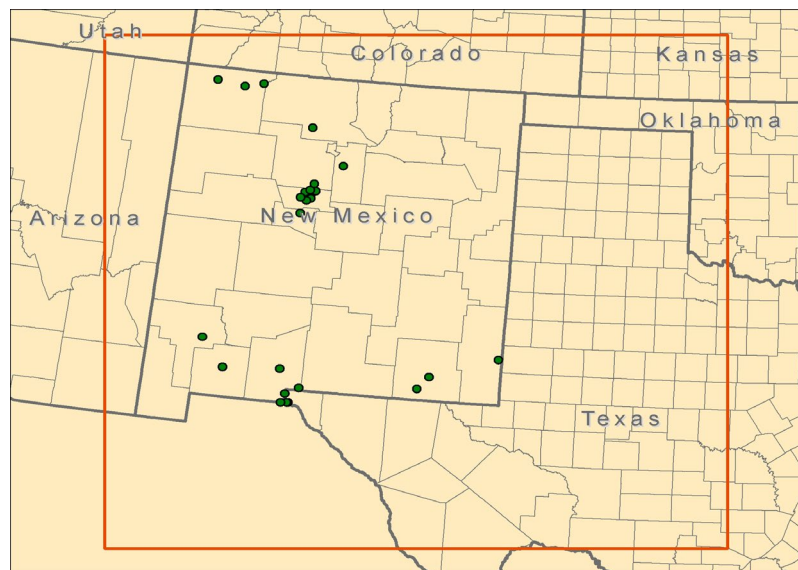


SMOKE PROCESSING SECTORS

US-Anthro



Sector	Description
afdust_adj	- Area fugitive dust
ag	- Agricultural ammonia sources
nonpt	- Other nonpoint sources
np_oilgas_wrap	- Non-point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)
np_oilgas	- Non-point Oil and Gas
nonroad	- Non-road mobile
rail	- Locomotive
onroad	- On-road mobile
ptegu	- EGU point sources
ptnonipm	- Non-EGU point sources
pt_oilgas_wrap	- Point Oil and Gas for 7 WRAP States (CO, MT, NM, ND, SD, UT, WY)
pt_oilgas_wrap	- Point Oil and Gas
rwc	- Residential Wood Combustion



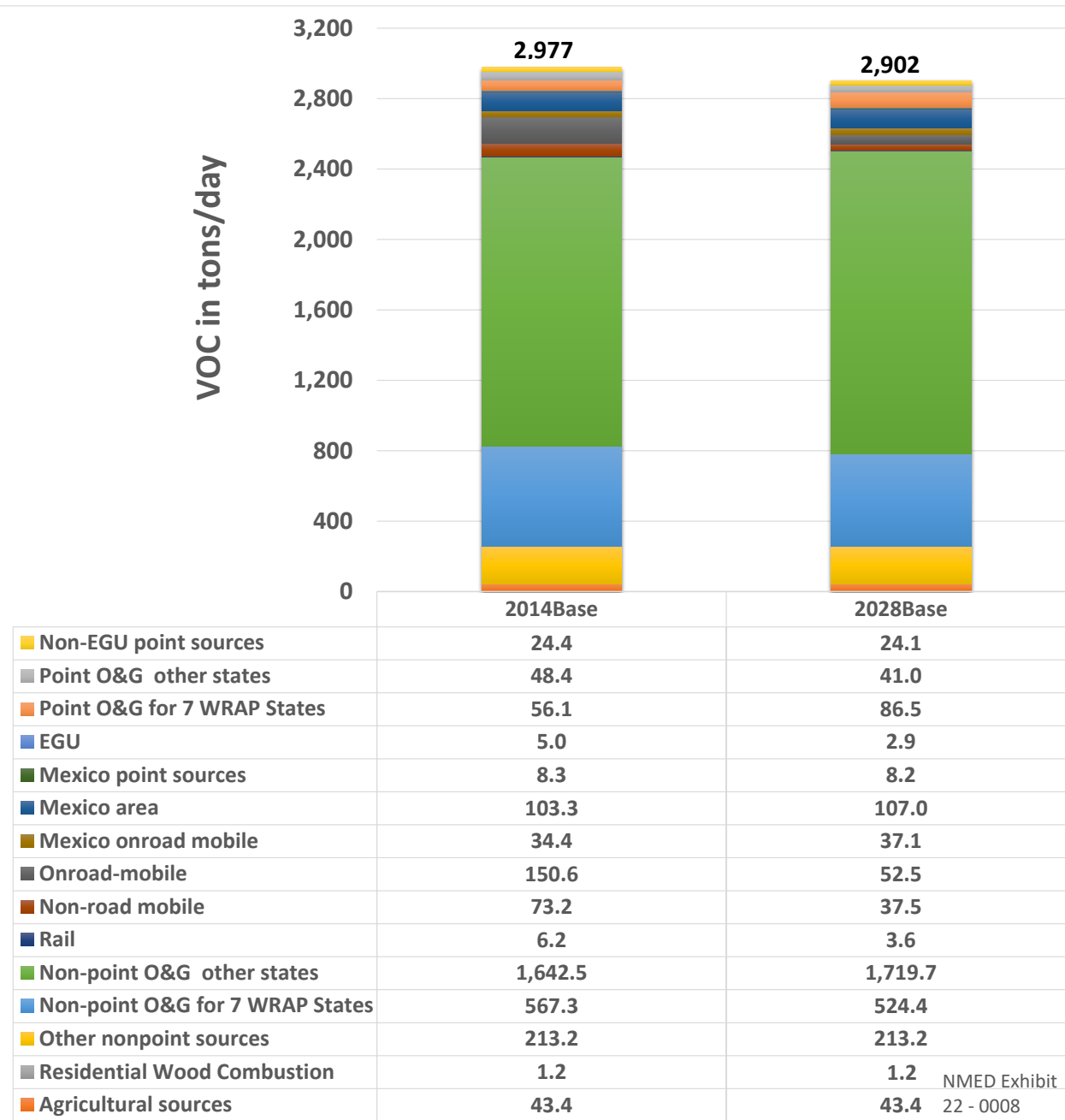
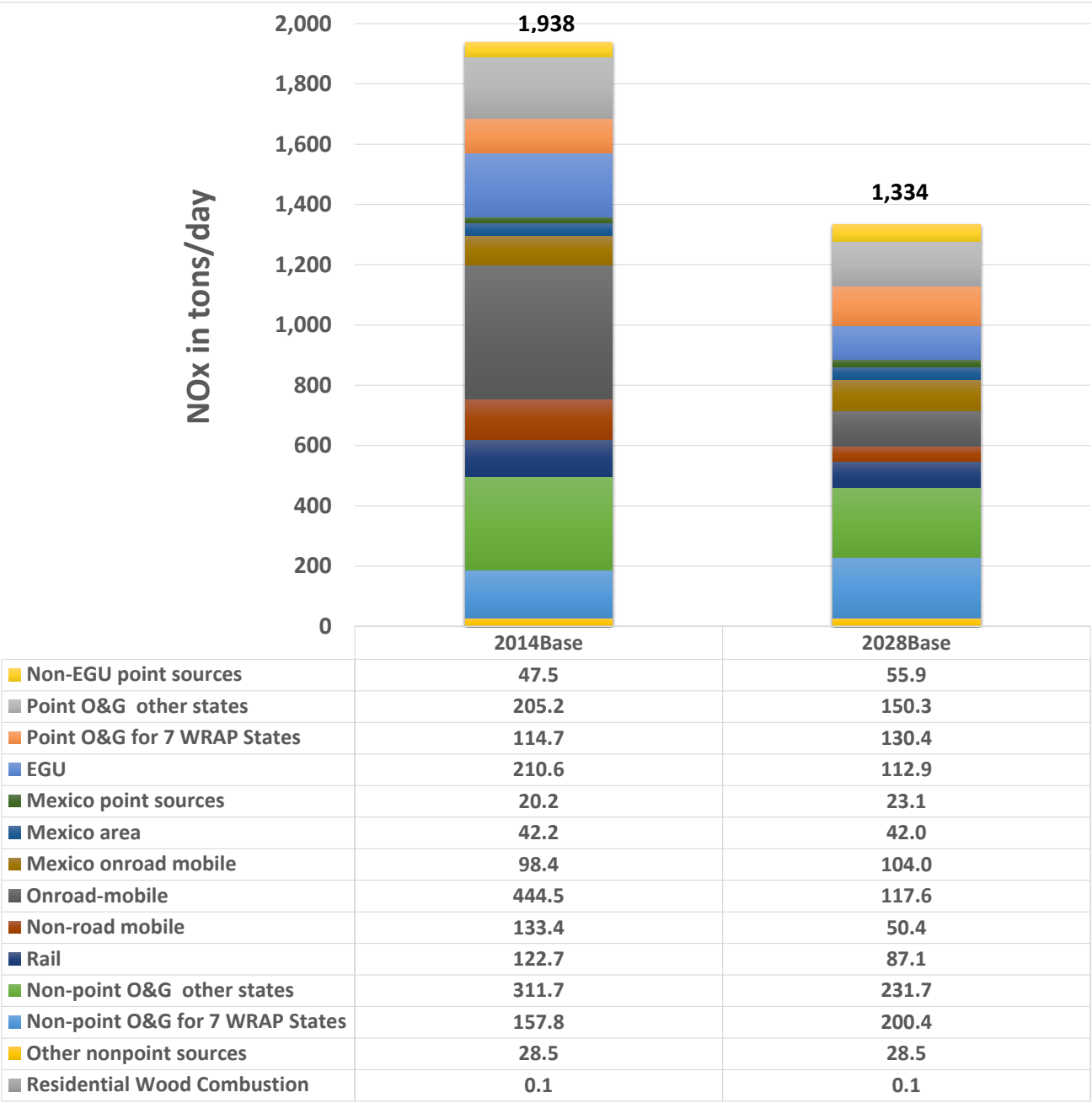
New Mexico 4-km Domain

Non-US Anthro & Natural

Sector	Description
onroad_mex	- Mexico onroad mobile
othar	- Mexico area
othpt	- Mexico point sources
MEGAN/BEIS	- Biogenic
LtNOx	- Lightning Nox
AG fire	- Ag Fire
RX fire	- Prescribed Fire
WF fire	- Wild Fire
Ptfire_othna	- Mexico fire
WBD	- Windblown Dust

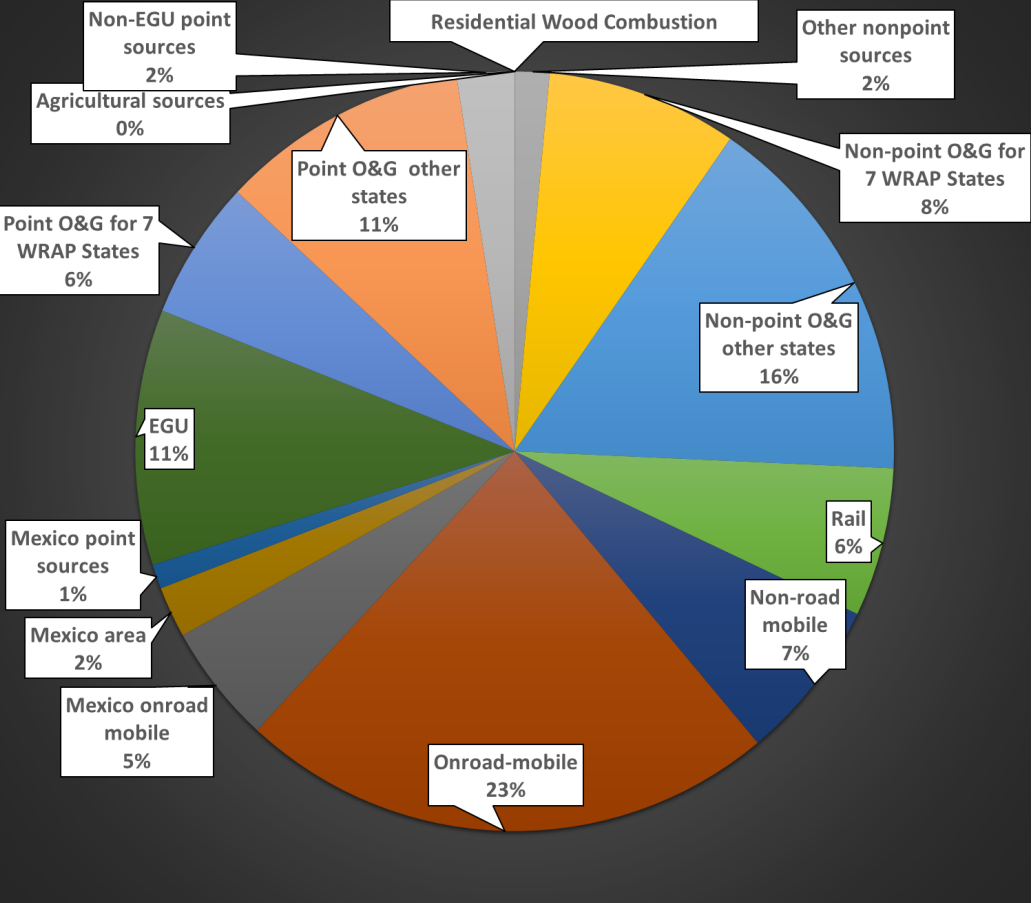


NEW MEXICO 4-KM EMISSIONS COMPARISON:



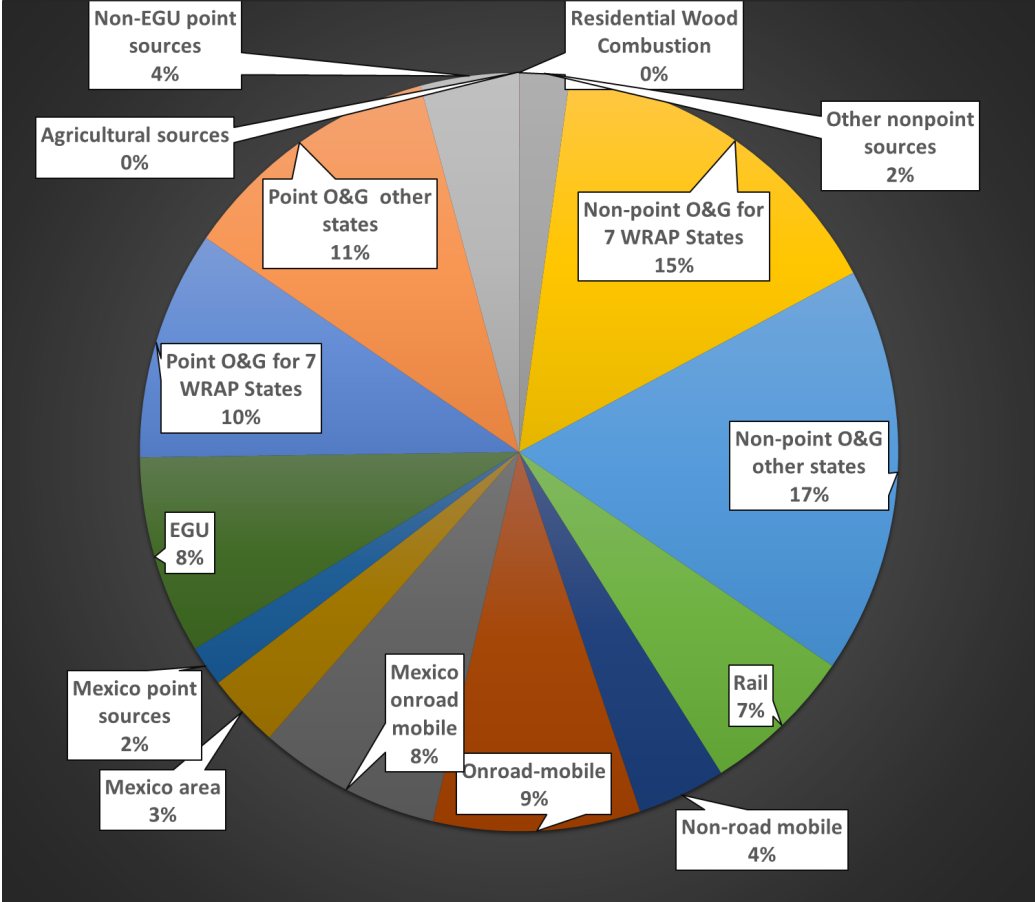
NEW MEXICO 4-KM NOx COMPARISON

2014 NOx



1,938 TPD

2028 NOx

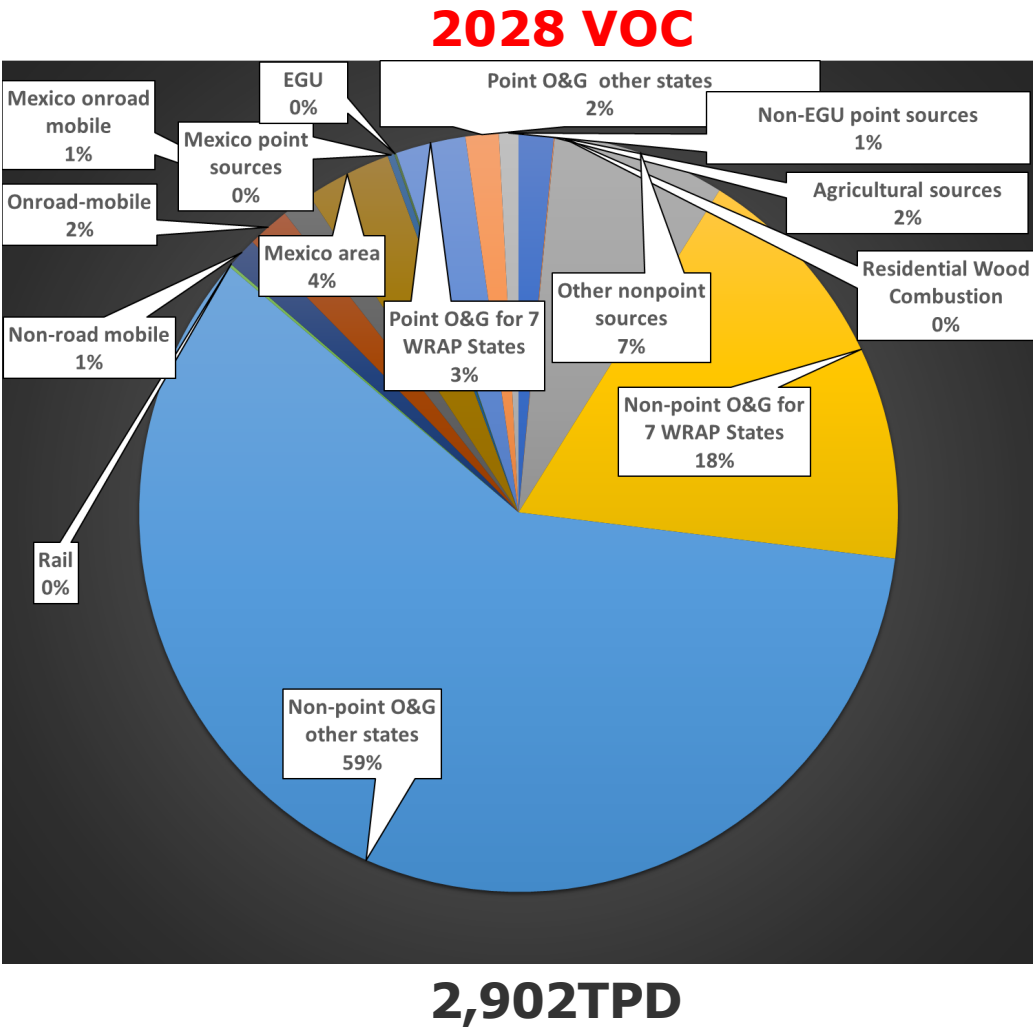
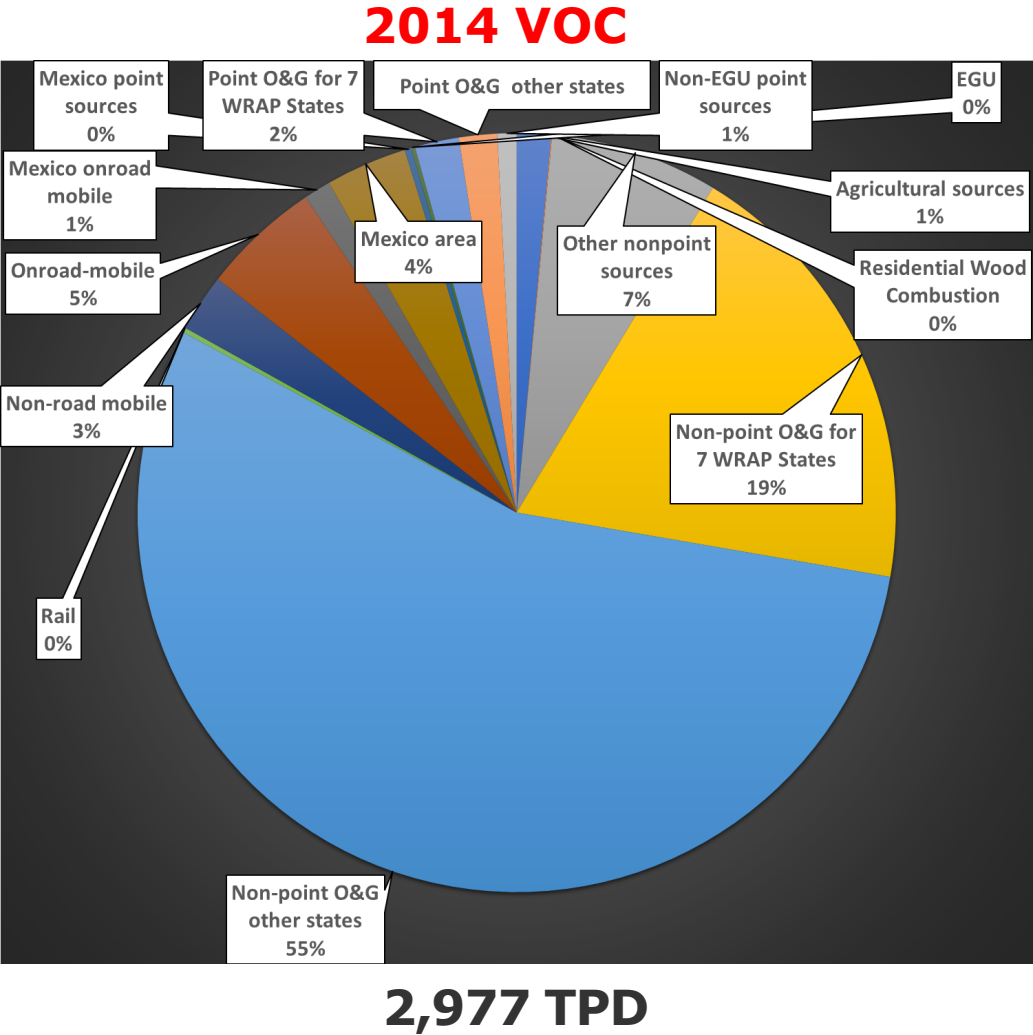


1,334 TPD

-604 TPD (31.1%) Reduction



NEW MEXICO 4-KM VOC COMPARISON



-75 TPD (2.5%) Reduction

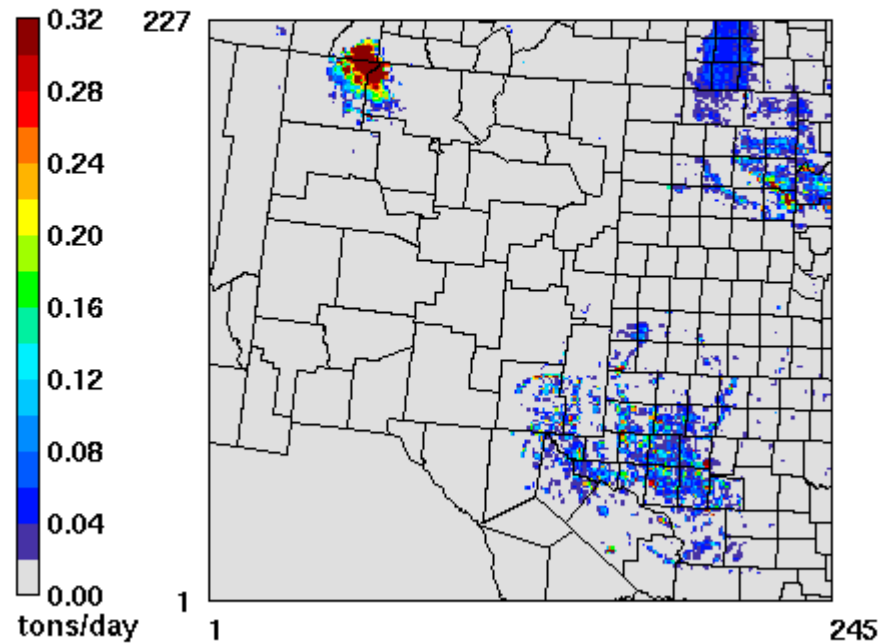


NON-POINT O&G EMISSIONS: NOx

2014

NOx

NMED_OAI_2014
np_oilgas

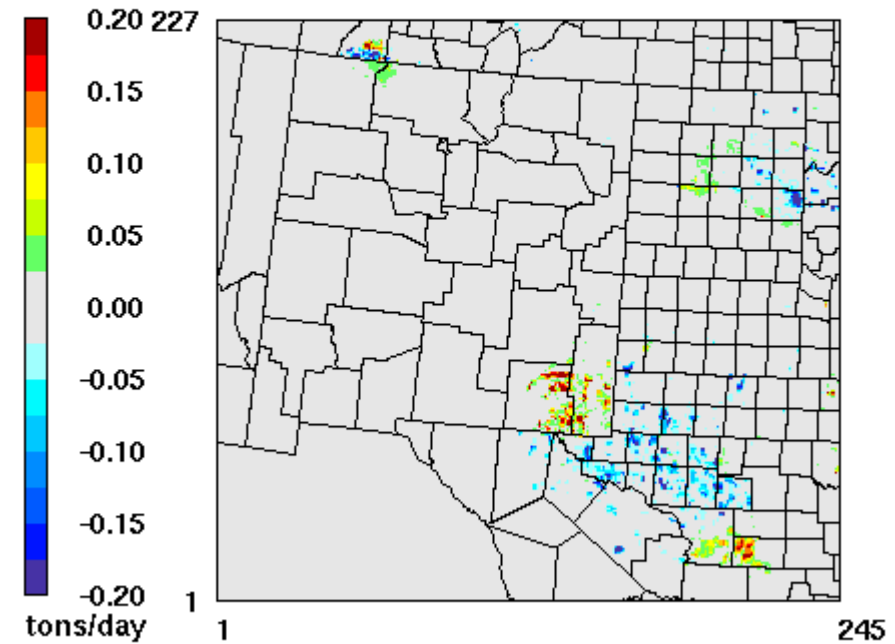


May 28, 2004 0:00:00
Min=0.00 at (1,1), Max=2.86 at (219,153)

Difference plot (2028 – 2014)

Delta_NOx

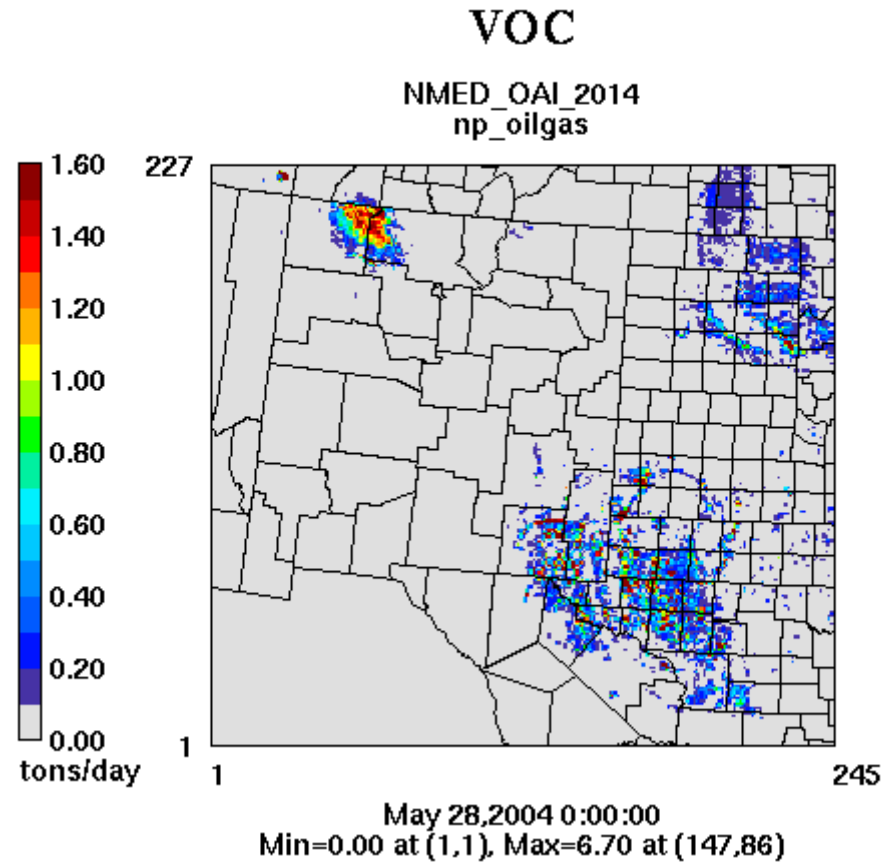
2028-2014
np_oilgas



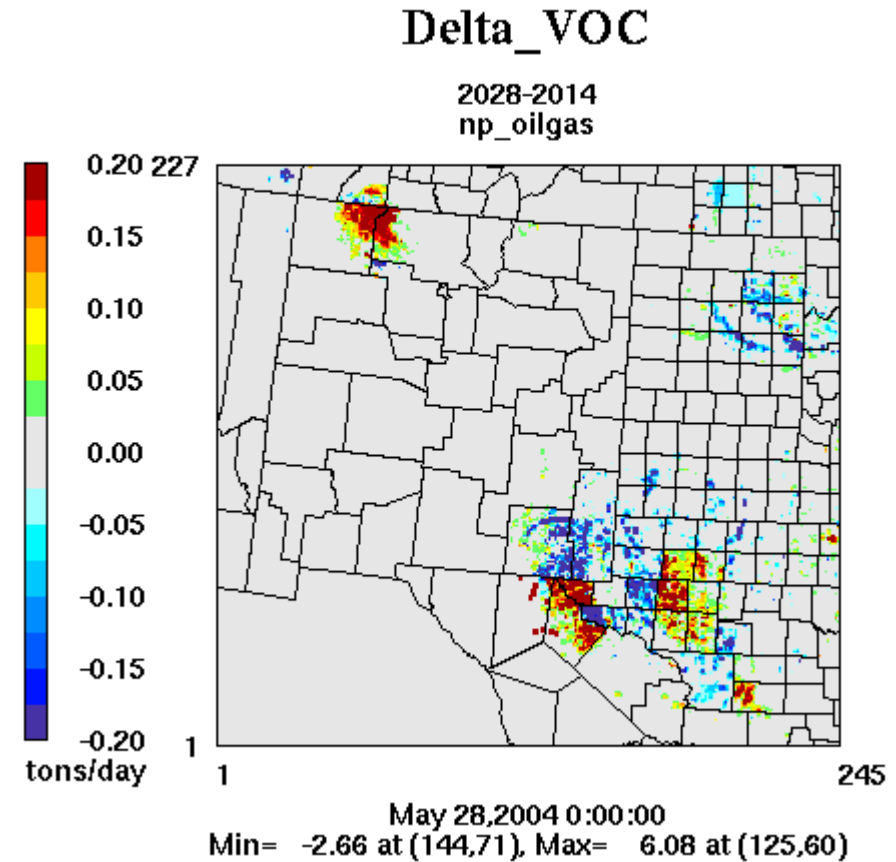
May 28, 2004 0:00:00
Min= -1.32 at (219,153), Max= 0.71 at (147,86)

NON-POINT O&G EMISSIONS: VOC

2014

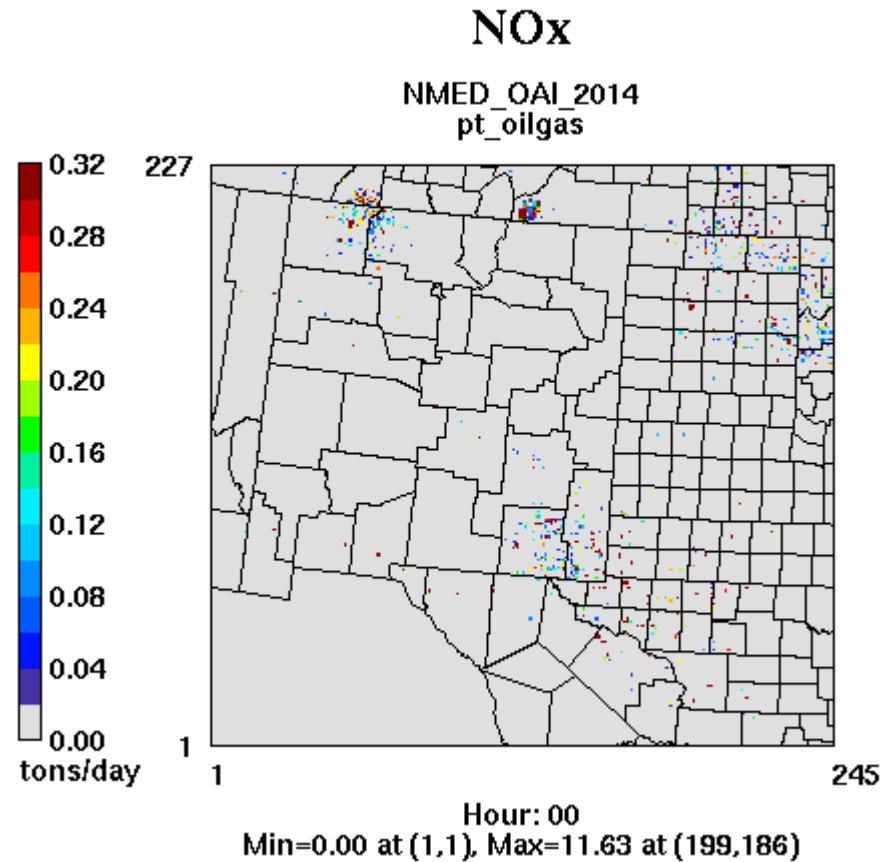


Difference plot (2028 – 2014)

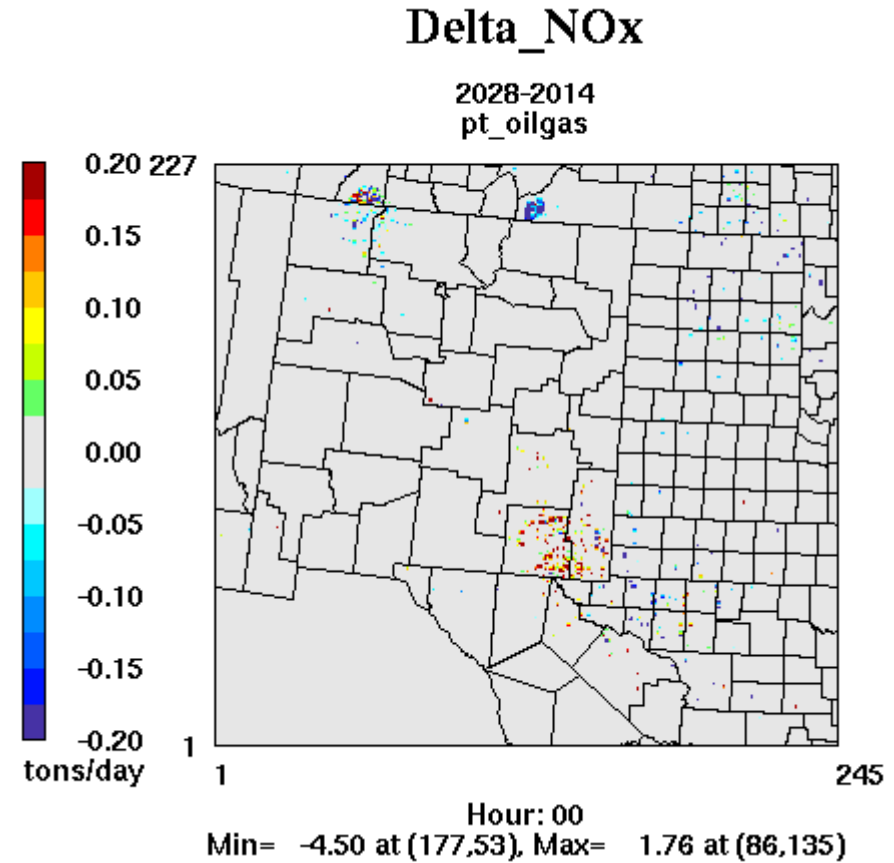


POINT O&G EMISSIONS: NOX

2014

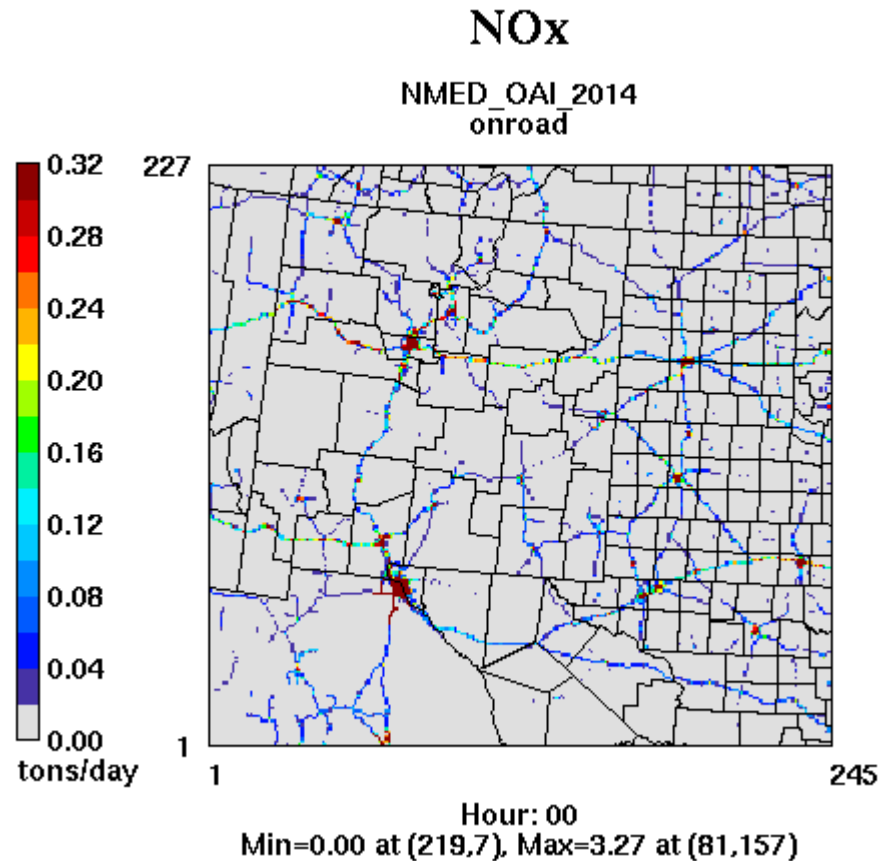


Difference plot (2028 – 2014)

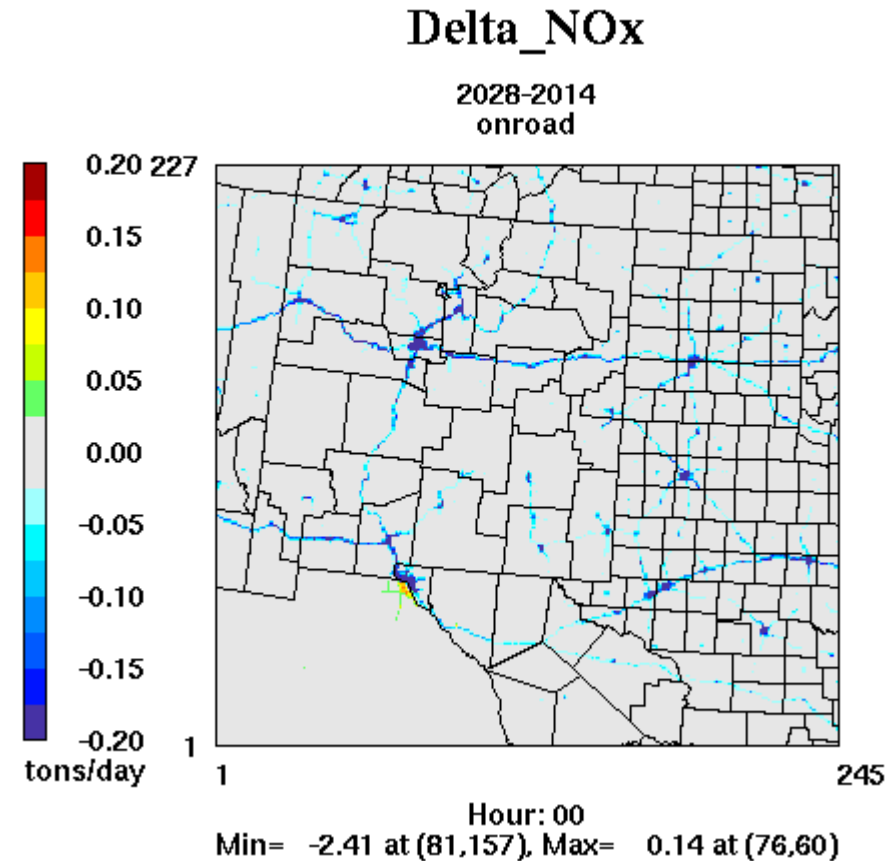


ONROAD EMISSIONS: NOx

2014



Difference plot (2028 – 2014)

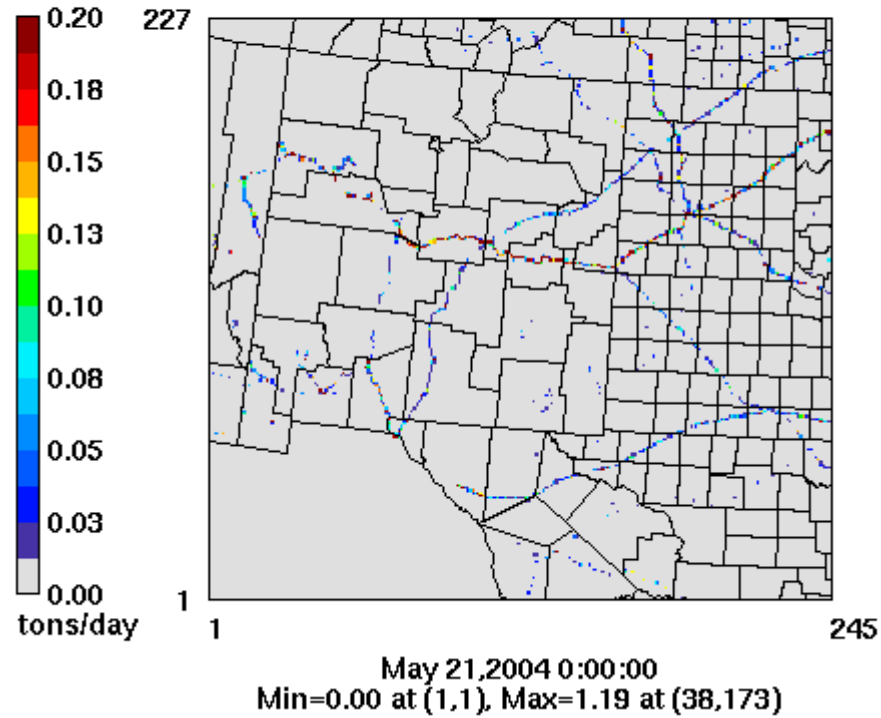


RAIL EMISSIONS: NOx

2014

NOx

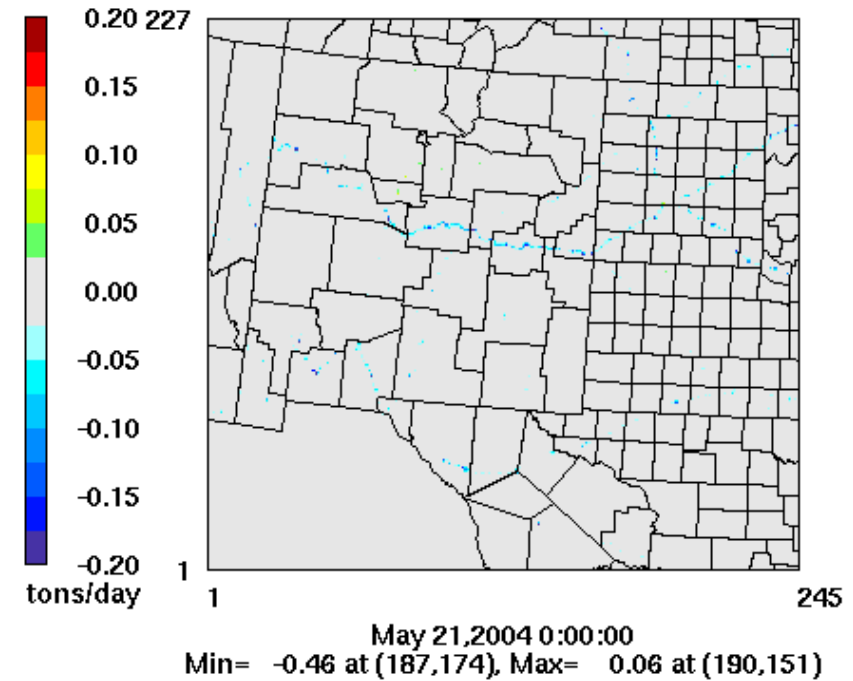
NMED_OAI_2014
rail



Difference plot (2028 – 2014)

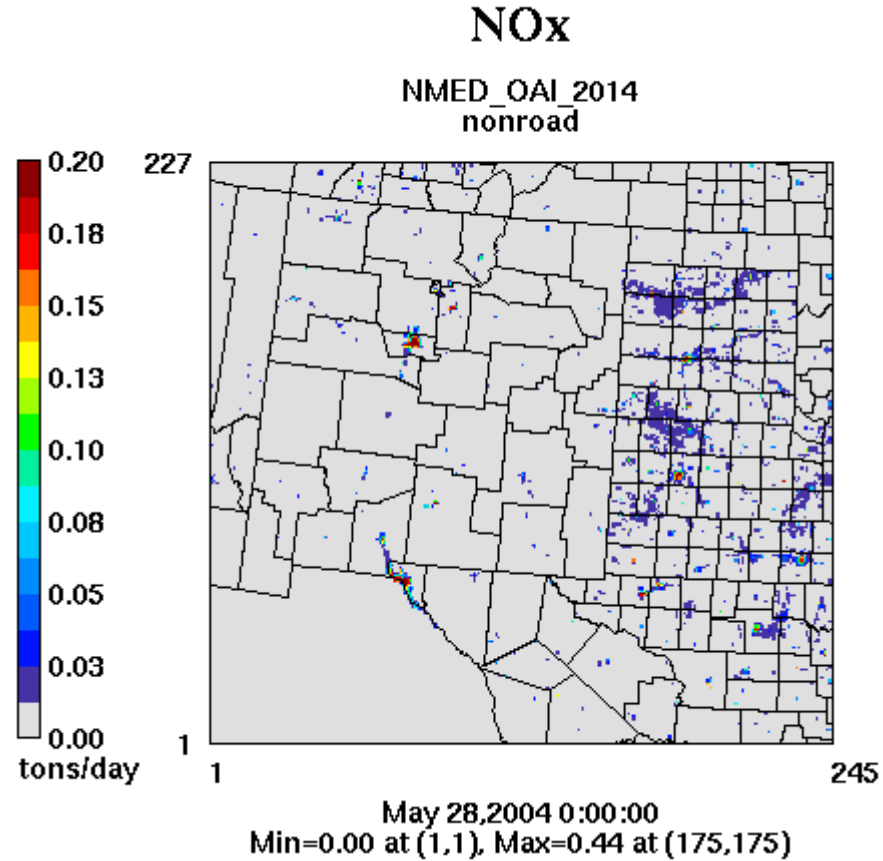
Delta_NOx

2028-2014
rail

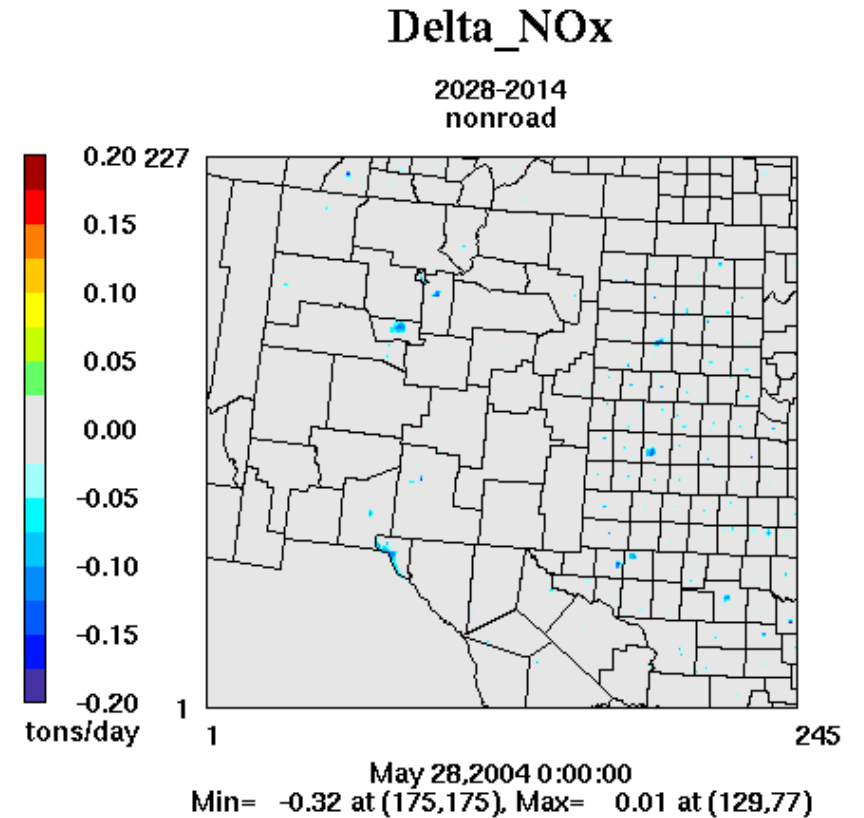


NONROAD EMISSIONS: NOx

2014



Difference plot (2028 – 2014)



CURRENT STATUS AND NEXT STEPS

- Completed 36/12/4-km 2028 emissions with updated 2028 O&G emissions for New Mexico and started CAMx runs
- Process 2028 O&G emissions for NM O&G Control Scenario
- Conduct CAMx 2028 36/12/4-km NM O&G control strategy simulation and provide ozone results to NMED

2028 O&G CONTROL SCENARIO EMISSIONS – PRELIMINARY ANALYSIS

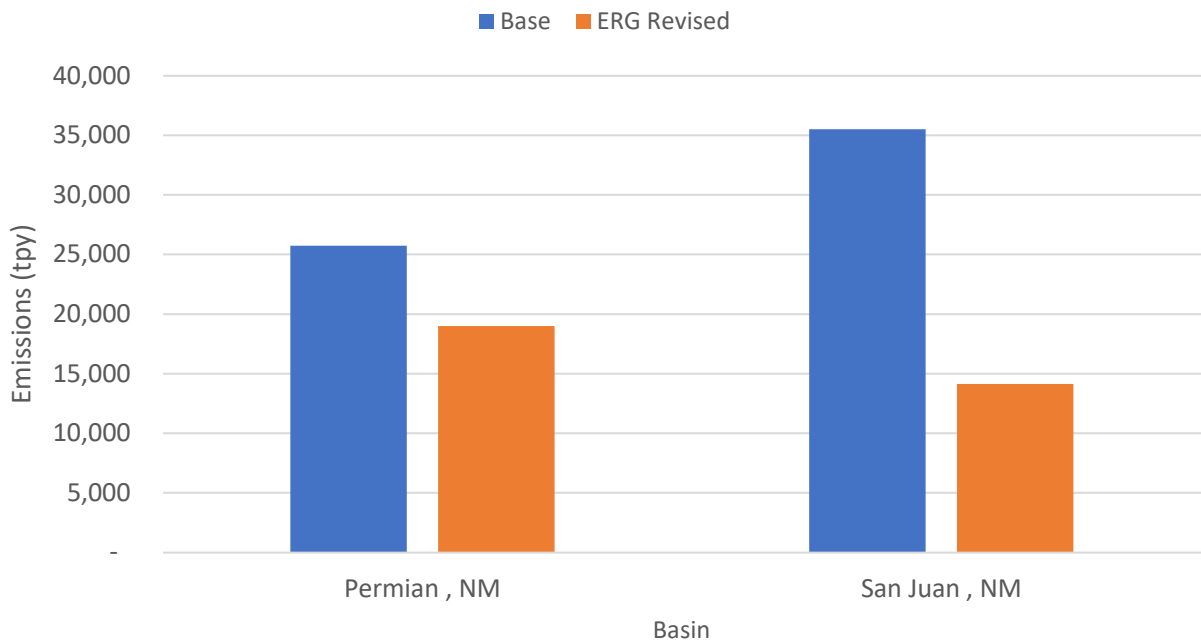
2028 O&G CONTROL SCENARIO EMISSIONS

- ERG provided revised point and nonpoint NM emissions for affected counties/SCCs/pollutants.
- 7 NM counties included in ERG's inventory
 - San Juan Basin (4 counties)
 - Permian Basin (3 counties)
- Bar chart displays by Pollutant, Basin and Source Categories (in tons/year)

NOx	Source	Base	ERG Revised	Change	Percent Change
	Nonpoint	61,245	33,144	(28,101)	-46%
	Point	41,066	22,872	(18,195)	-44%
	Total	102,311	56,015	(46,296)	-45%
VOC	Source	Base	ERG Revised	Change	Percent Change
	Nonpoint	181,252	85,564	(95,688)	-53%
	Point	30,340	19,608	(10,732)	-35%
	Total	211,592	105,173	(106,420)	-50%

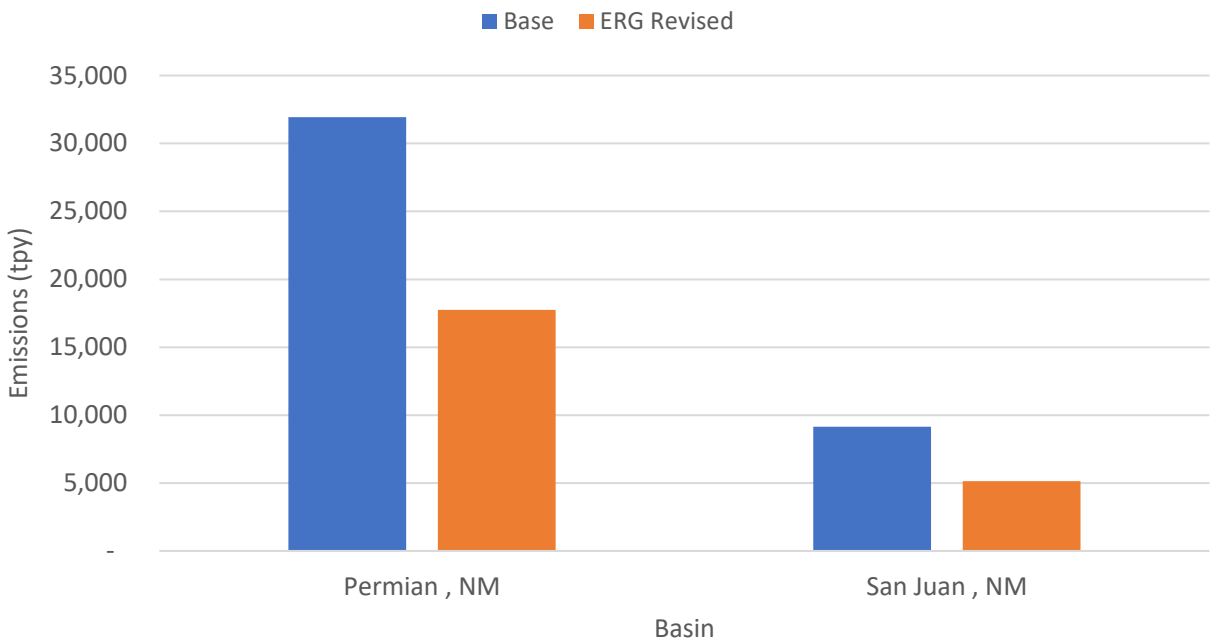
2028 O&G CONTROL SCENARIO NOX EMISSIONS

Nonpoint NOX Emissions



- 26% NOx reduction for Permian
- 60% NOx reduction for San Juan

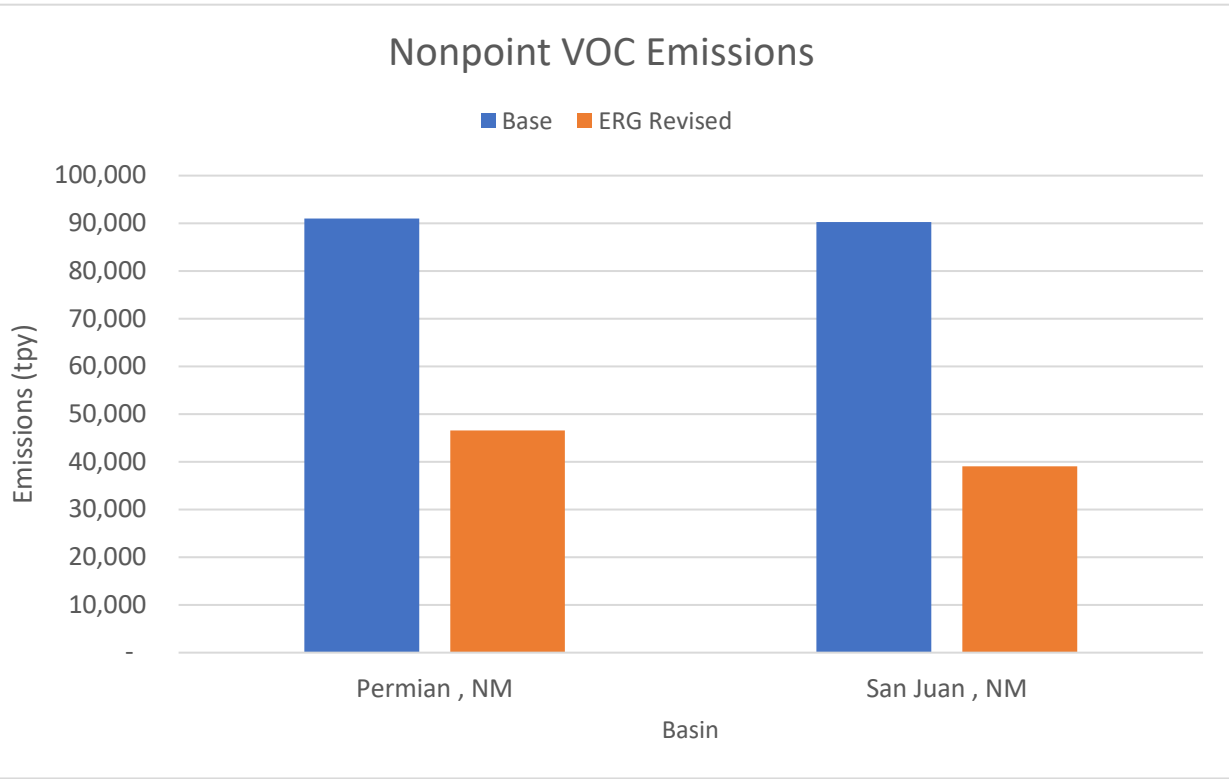
Point NOX Emissions



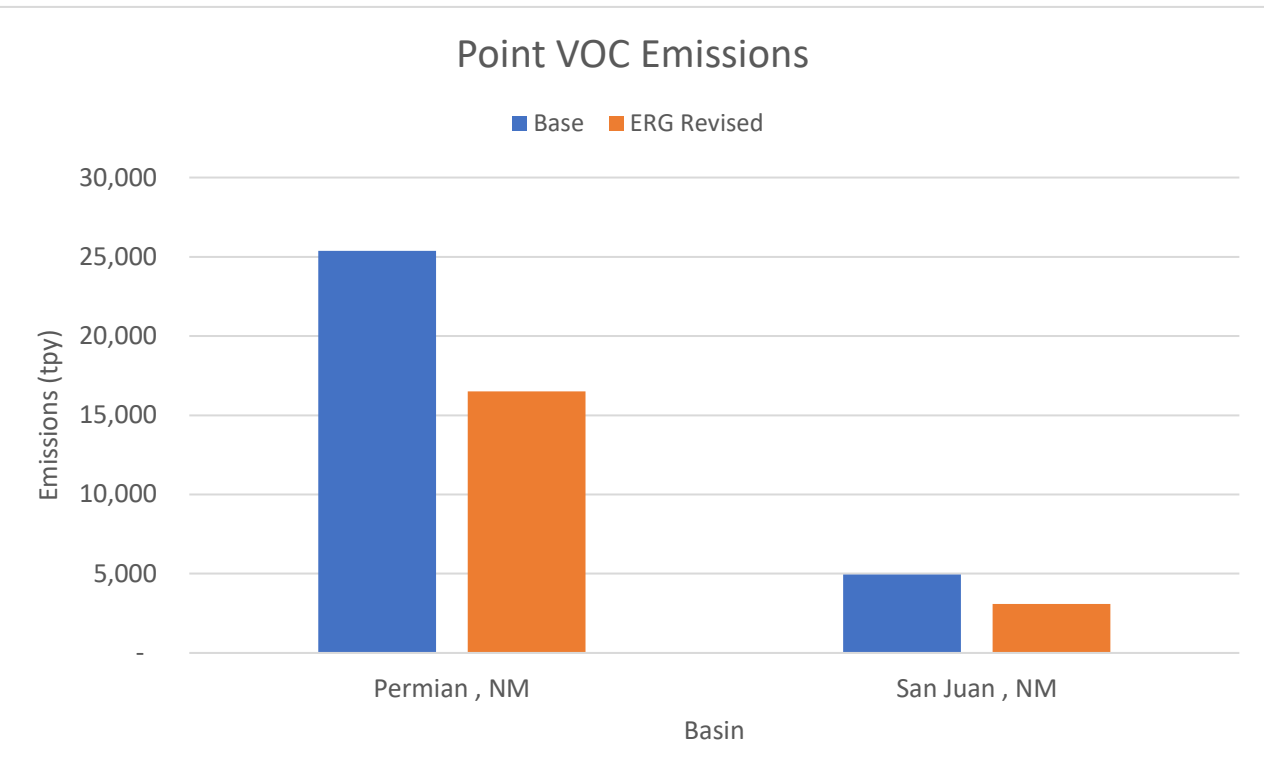
- 44% NOx reduction for Permian
- 44% NOx reduction for San Juan



2028 O&G CONTROL SCENARIO VOC EMISSIONS

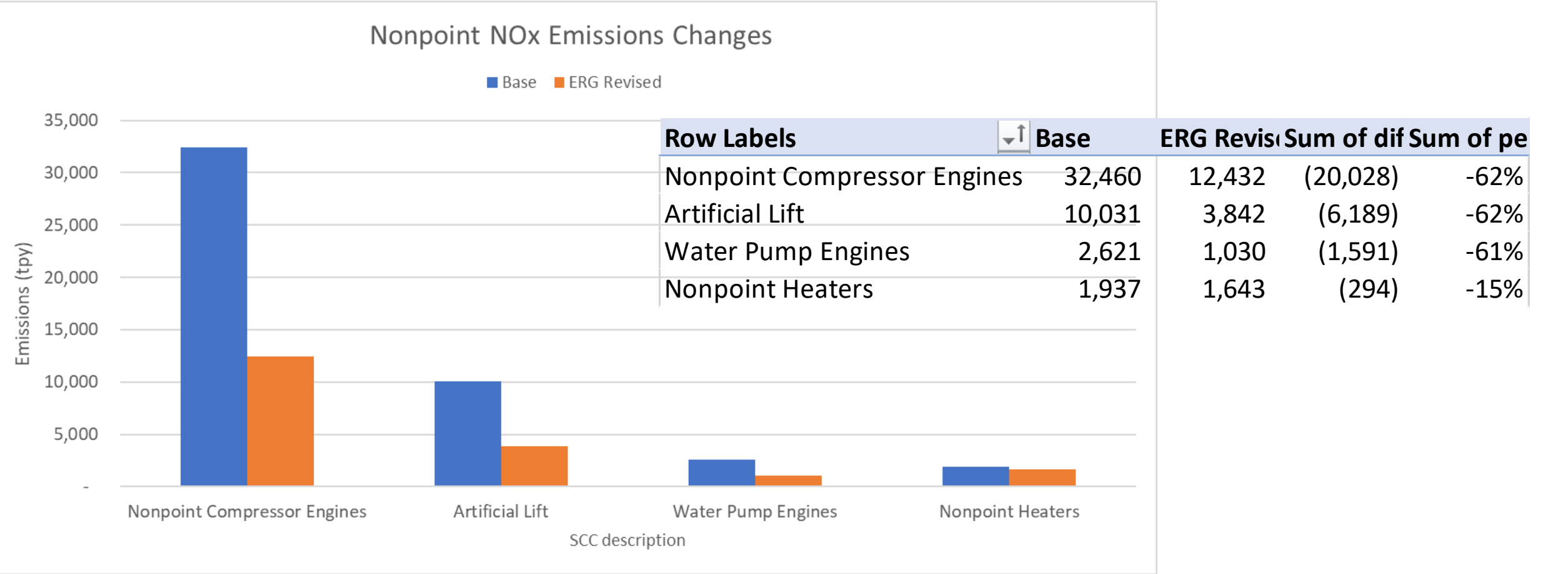


- 49% VOC reduction in Permian
- 57% VOC reduction in San Juan

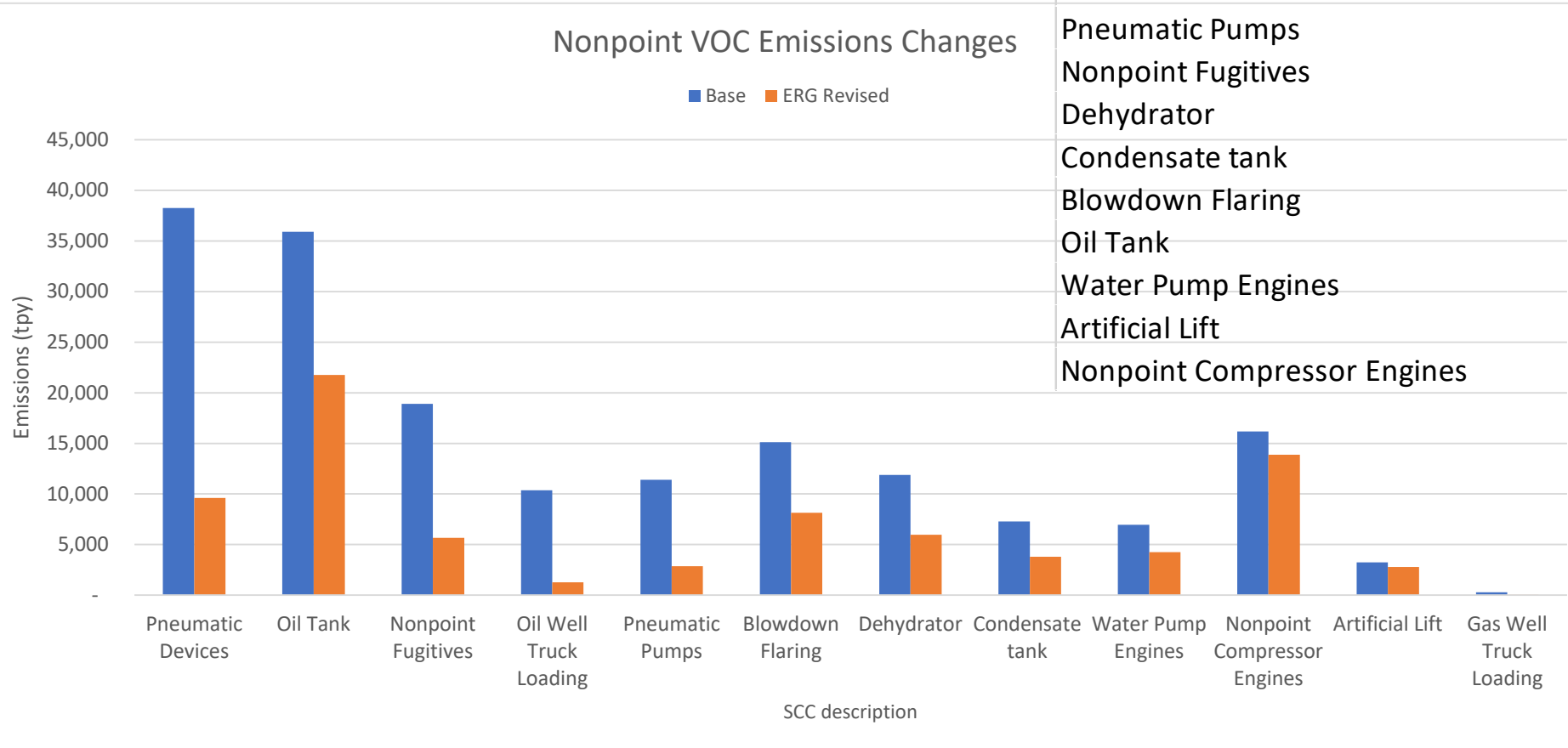


- 35% VOC reduction for Permian
- 38% VOC reduction for San Juan

NONPOINT O&G NOX CHANGE



NONPOINT O&G VOC CHANGE



Row Labels	Base	ERG Revised	Sum of dif	Sum of pe
Oil Well Truck Loading	10,353	1,273	(9,080)	-88%
Gas Well Truck Loading	292	36	(256)	-88%
Pneumatic Devices	38,240	9,598	(28,641)	-75%
Pneumatic Pumps	11,404	2,862	(8,541)	-75%
Nonpoint Fugitives	18,894	5,668	(13,225)	-70%
Dehydrator	11,870	5,964	(5,905)	-50%
Condensate tank	7,289	3,809	(3,480)	-48%
Blowdown Flaring	15,110	8,135	(6,975)	-46%
Oil Tank	35,889	21,747	(14,141)	-39%
Water Pump Engines	6,962	4,252	(2,710)	-39%
Artificial Lift	3,232	2,776	(455)	-14%
Nonpoint Compressor Engines	16,162	13,885	(2,277)	-14%

NEW MEXICO OZONE ATTAINMENT INITIATIVE

Revised 2014v2 Base Case, 2028 Base Case Modeling and 2028 NM O&G Control Strategy

Tejas Shah, Chao-Jung Chien, Sai Sreedhar Varada, John Grant, Marco Rodriguez,
Pradeepa Vennam and Ralph Morris, Ramboll

Tom Moore and Mary Uhl, WESTAR

NM OAI Study Webinar

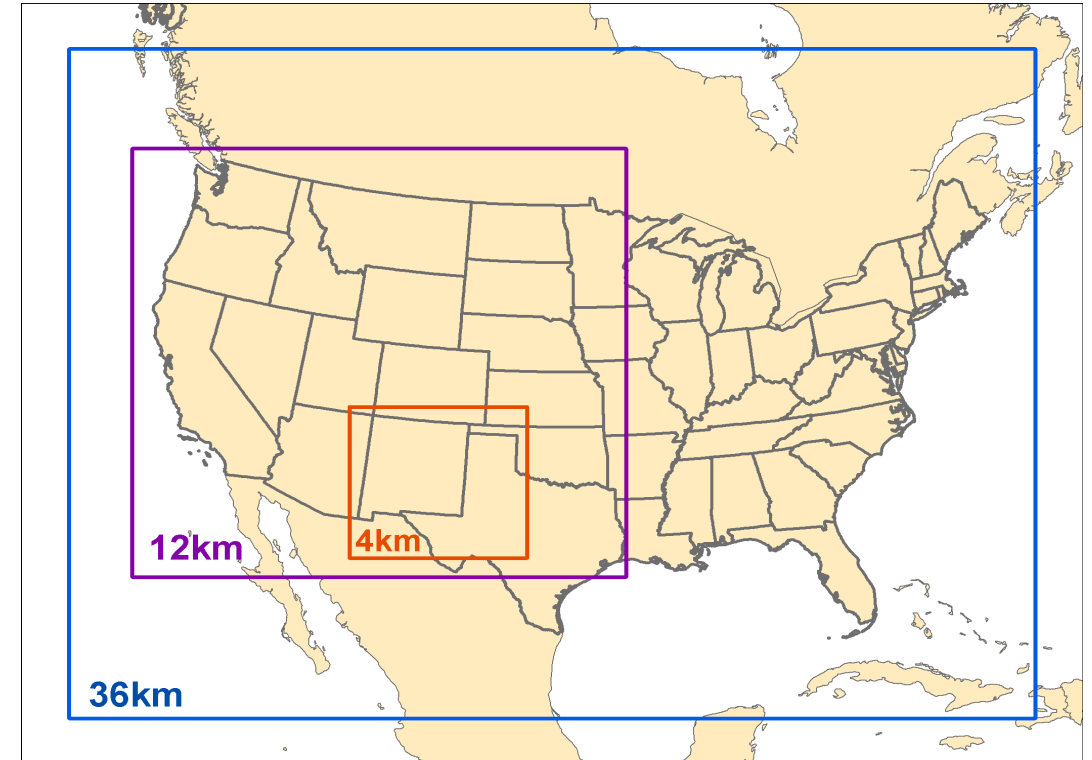
February 10, 2021

REVISED 2014V2 BASE CASE AND 2028 BASE CASE MODELING

- 01** Revised 2014v2 Base Case Modeling
- 02** 2028 Base Case Modeling and Ozone DV Projections
- 03** 2028 New Mexico O&G Control Scenario
- 04** Design of 2028 State/Category APCA Source Apportionment
- 05** Design of 2028 VOC- & NOx-limited OSAT Source Apportionment

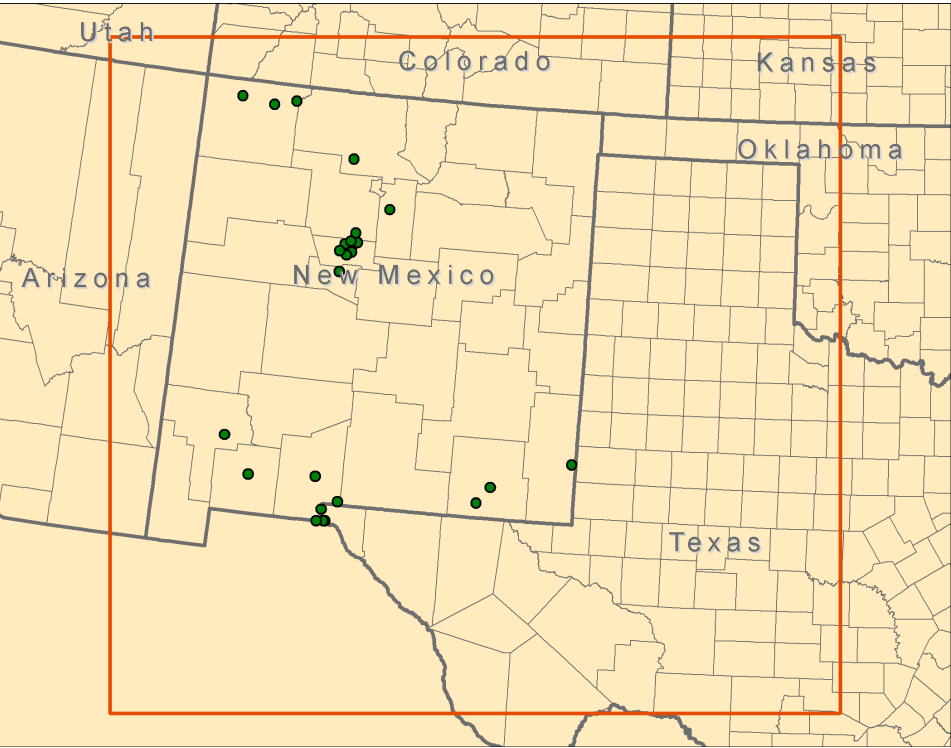
CAMX 2014 NM OAI STUDY MODEL CONFIGURATION

- Episode: May-August 2014
 - 16-day spin-up before first high ozone day in NM
 - 68 ppb on May 17
- 36/12/4-km Modeling Domains
 - 36/12-km domains same as WRAP Regional Haze
 - New 4-km New Mexico domain
- Boundary Conditions (BC) WRAP 2014 GEOS-Chem
- Four Meteorological Diagnostic Sensitivity tests
 - Selected WRF/NAM with Kv=CMAQ
- WRAP 2014v2 base year emissions
 - EPA NEI2014v2 w/ western state updates
- WRAP 2028OTBa2 for future year w/ 2014 actual fires and new 2028 NM O&G



ORIGINAL CAMX CONFIGURATION

- Similar to WRAP CAMx 36/12-km Regional Haze set-up w/ 4-km NM domain added
- Two changes in revised 2014v2 Base Case:
 - Use CAMx v7.1
 - Use BEIS biogenic emissions



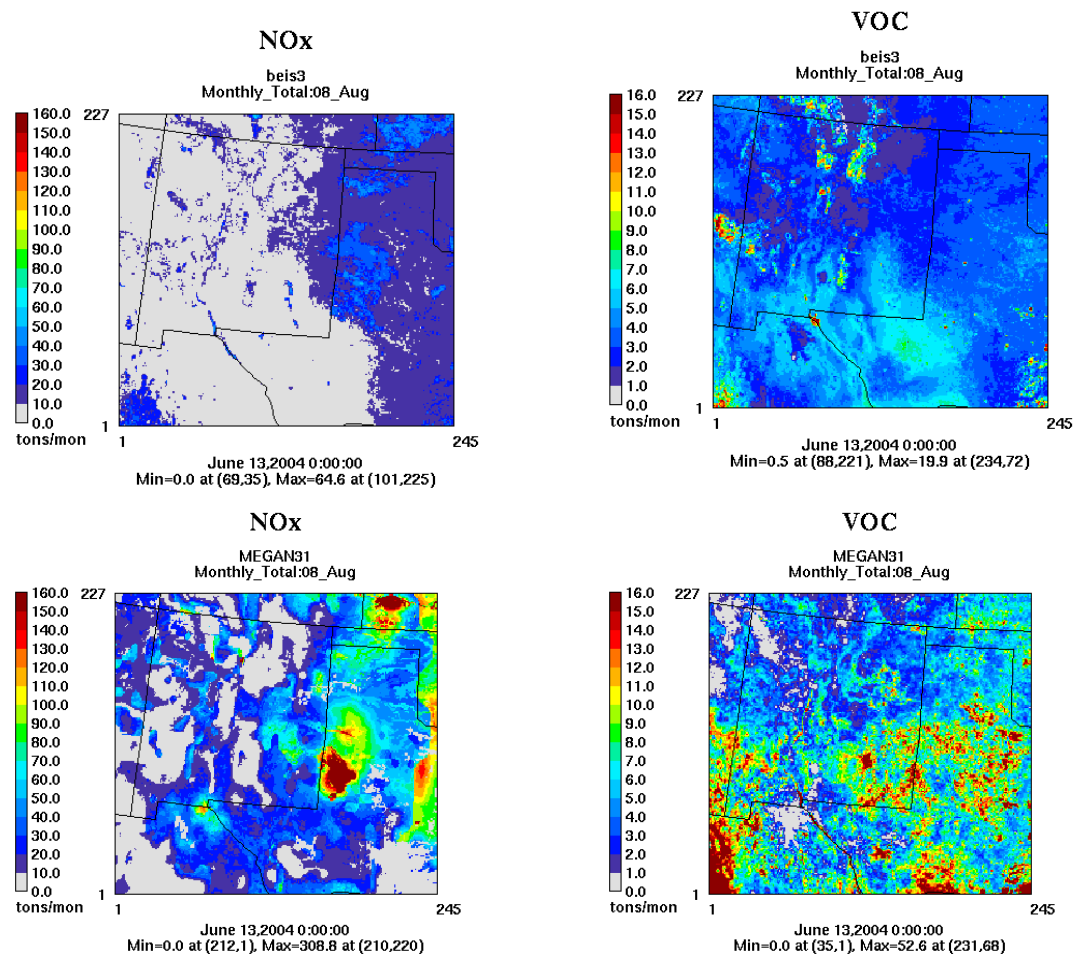
Science Options	CAMx	Comment
Model Codes	CAMx v7.0	Latest version of CAMx made publicly available May 2020 (www.camx.com)
Horizontal Grid Mesh	36/12/4-km	
36-km grid	148 x 112 cells	36US domain
12-km grid	227 x 215 cells	12WUS2 domain. Includes buffer cells
4-km grid	245 x 227 cells	New Mexico 4-km domain. Includes buffer cells
Vertical Grid Mesh	25 vertical layers, defined by WRF	Layer 1 ~20 m. Model top at 50 mb (~19 km). Layer collapsing from 35 vertical layers in WRF
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 lateral boundaries
Emissions		
Emissions Processing	SMOKE, SMOKE-MOVES2014, MEGAN	WRAP/WAQS 2014v2 emissions and EPA 2023fh for future year
Sub-grid-scale	Plume-in-Grid (PiG)	NOx > threshold
Chemistry		
Gas Phase	CB6r4	(Yarwood et al., 2010)
Meteorological Processor	WRFCAMx	Compatible with CAMx v7.0
Horizontal Diffusion	Spatially varying	K-theory with Kh dependence
Vertical Diffusion	CMAQ-like Kv	Evaluated YSU Kv scheme
Diffusivity Min	Kv-min = 0.1 to 1.0 m ² /s in lowest 100 m	Urban land use fraction
Deposition Schemes		4
Dry Deposition	Zhang dry deposition scheme	(Zhang et. al, 2001; 2003)

REVISED CAMx 2014v2 BASE CASE SIMULATION

REVISED CAMX 2014V2 36/12/4-KM BASE CASE AND MPE

- Two changes between original CAMx 36/12/4-km 2014 and revised 2014v2 base cases
 - Use CAMx v7.1 instead of CAMx v7.0
 - Bugs in source apportionment tools in CAMx v7.0 necessitated change
 - Little change expected in ozone results due to model version
 - Switched from MEGAN v3.1 to BEIS biogenic emissions in 4-km domain
 - MEGAN v3.1 very new and turned out to be not ready to run out of the box
 - MEGAN v3.1 missing LAI in urban areas so has zero biogenic emissions unless extra work is performed to do data filling
 - MEGAN v3.1 has much higher (~3x) biogenic NO_x than BEIS, and previous versions of MEGAN
 - WRAP 2014/RepBase/2028 regional haze modeling is using BEIS
 - Denver 2020 Serious ozone SIP used MEGAN but for follow-on 2023 and 2026 modeling switched to BEIS because of zero urban biogenic emissions and biogenic NO_x that seemed high

BEIS V3.7 VS. MEGAN V3.1 BIOGENIC EMISSIONS - AUGUST



BEIS

Tons/month		MEGAN	BEIS3	Abs Diff	Ratio
				(BEIS3-MEGAN)	(BEIS3/MEGAN)
May	NOX	35,050	10,602	-24,448	0.30
	VOC	128,323	159,809	31,486	1.25
Jun	NOX	42,445	13,134	-29,311	0.31
	VOC	267,055	256,379	-10,676	0.96
Jul	NOX	51,639	12,838	-38,801	0.25
	VOC	317,697	251,562	-66,135	0.79
Aug	NOX	41,002	11,923	-29,079	0.29
	VOC	354,570	216,032	-138,538	0.61

MEGAN

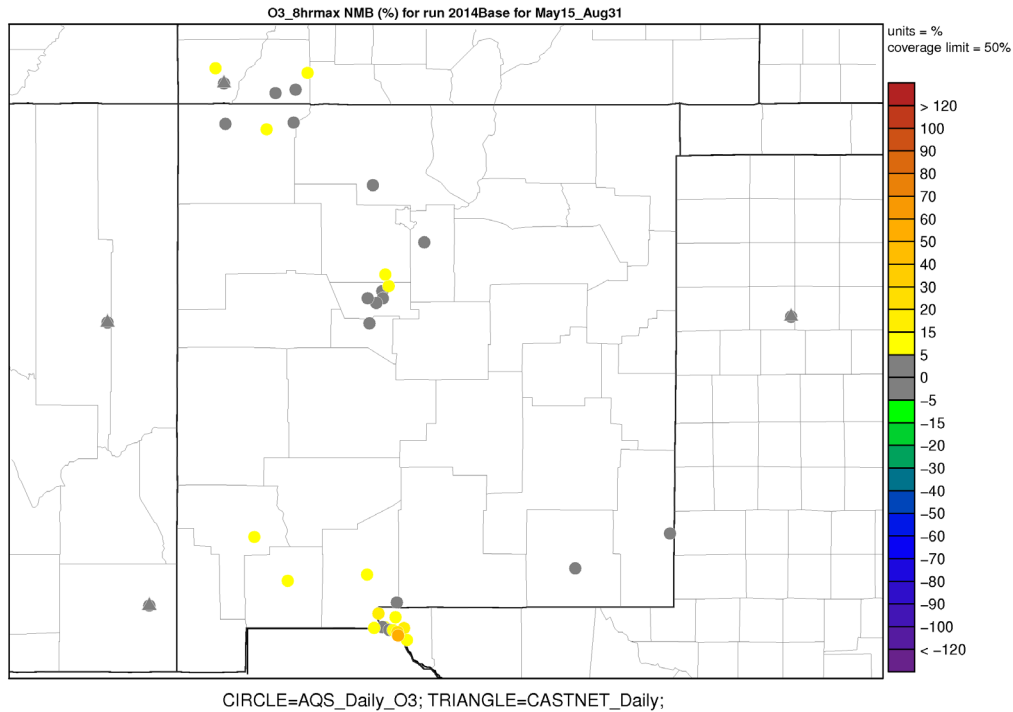
2014 (MEGAN) AND 2014V2 (BEIS) BASE CASE MPE

- Used EPA's AMETv1.4 MPE tool
- Model evaluated against EPA AQS and CASTNet Surface Air Quality Data for 2014
- Model performance compared with standard PGM goals and criteria values (Emery et al., 2016)
- "Goals" - statistical value that the best model can be expected to achieve
- "Criteria" - statistical value that majority of models have achieved

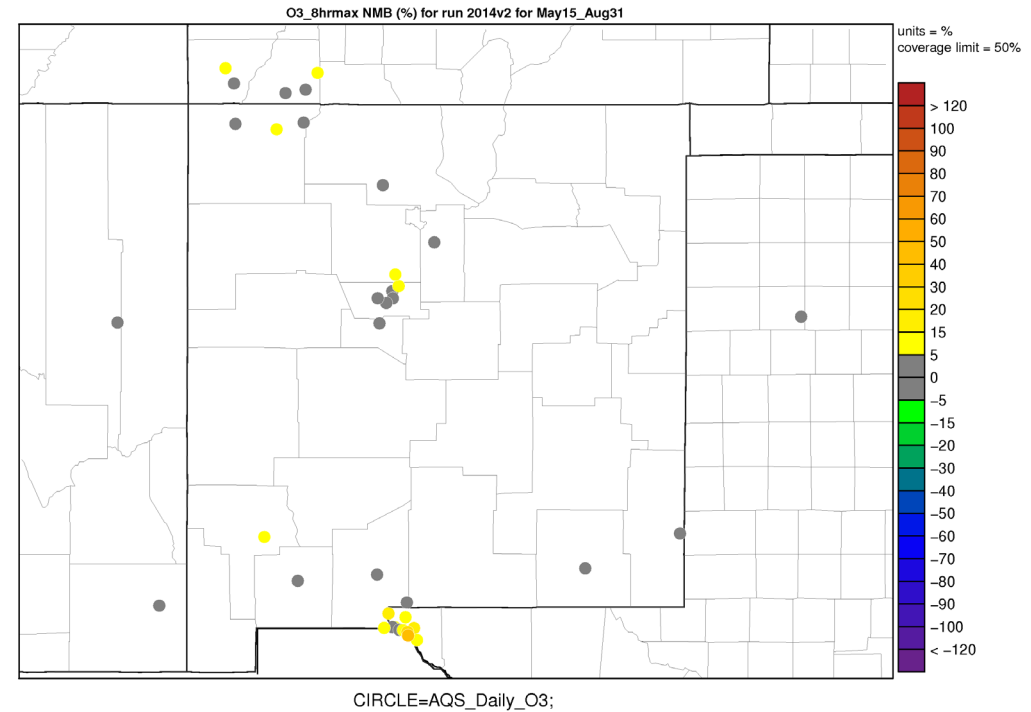
Species	NMB		NME	
	Goal	Criteria	Goal	Criteria
1-hr & MDA8 Ozone	<±5%	<±15%	<15%	<25%

NMB (BIAS) WITHOUT 60 PPB CUTOFF

2014Base (MEGAN)



2014v2 (BEIS)



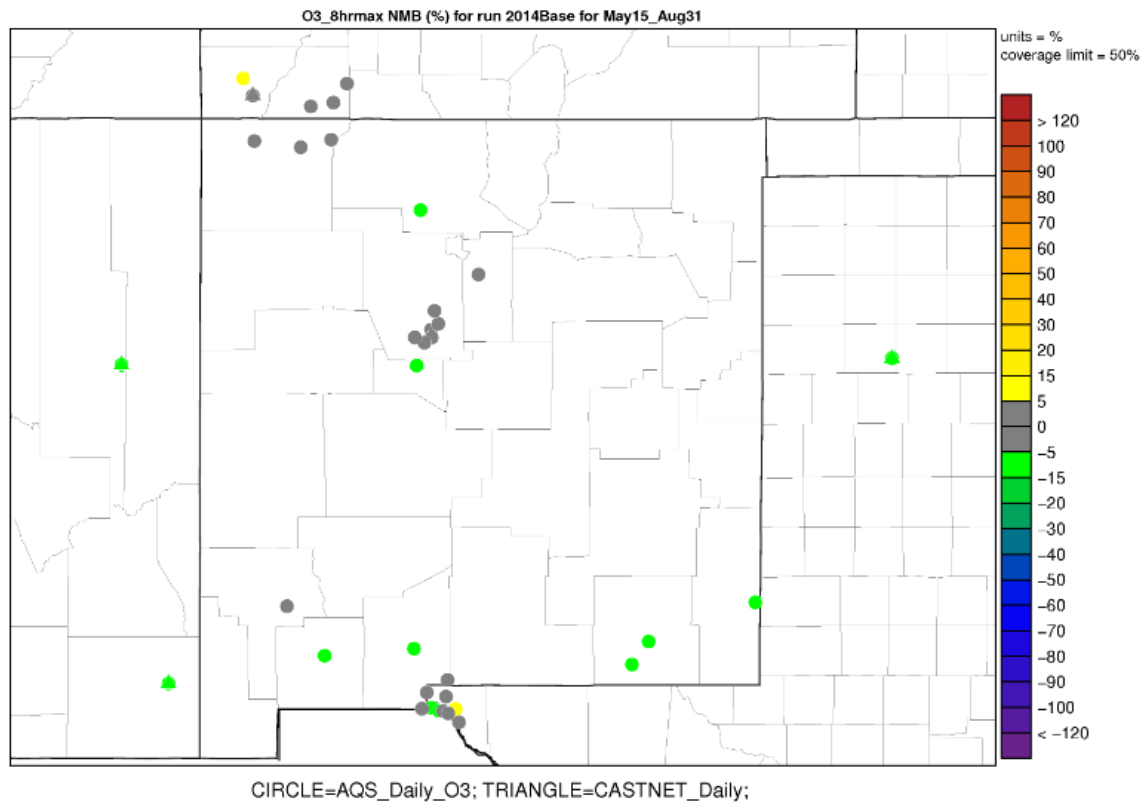
Both 2014 Base and 2014v2 meet ozone Performance Criteria at all sites but one in El Paso



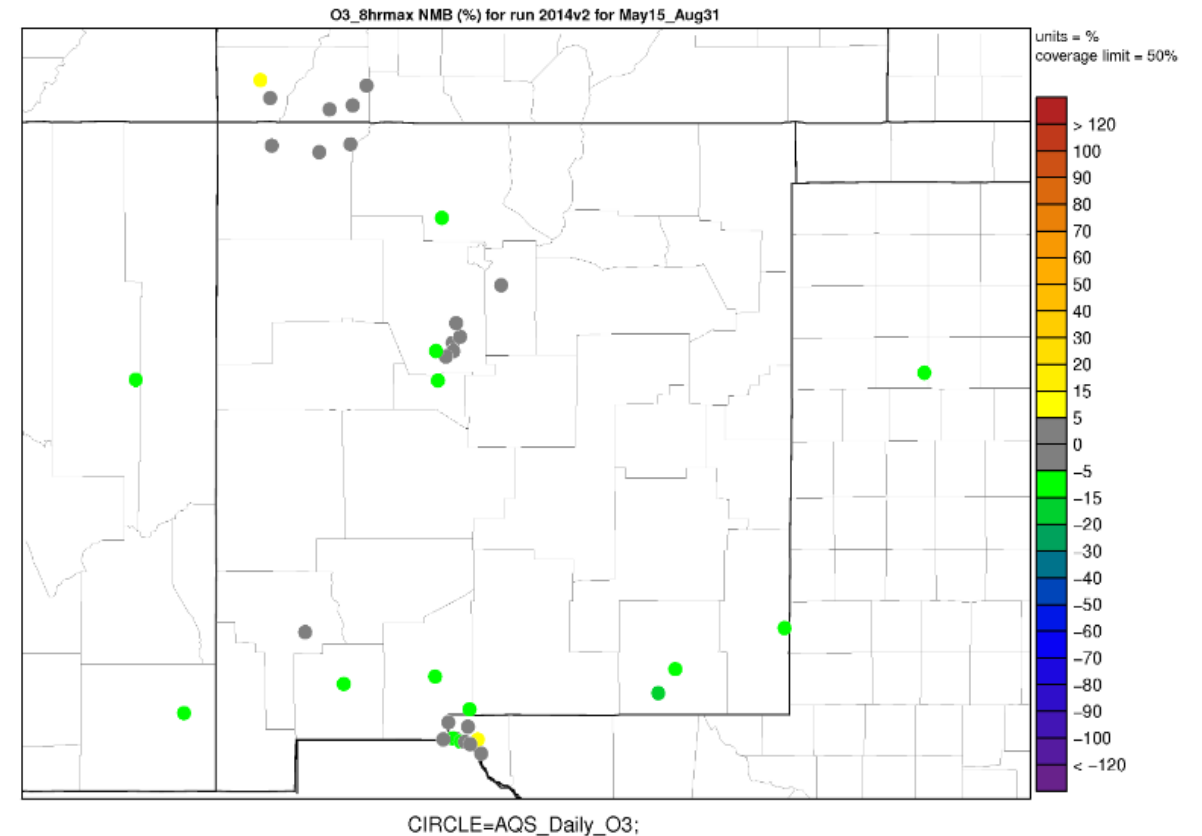
2014v2 has more sites achieving Performance Goals (grey)

NMB (BIAS) WITH 60 PPB CUTOFF

2014Base (MEGAN)

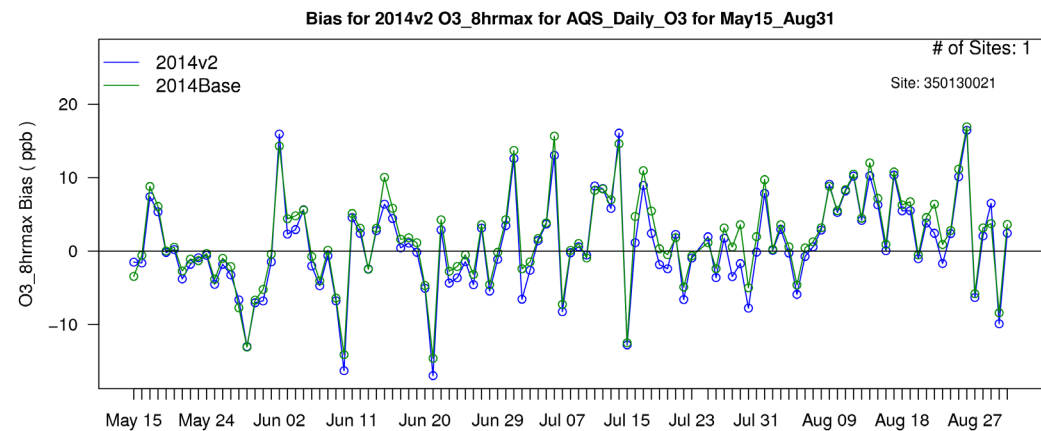
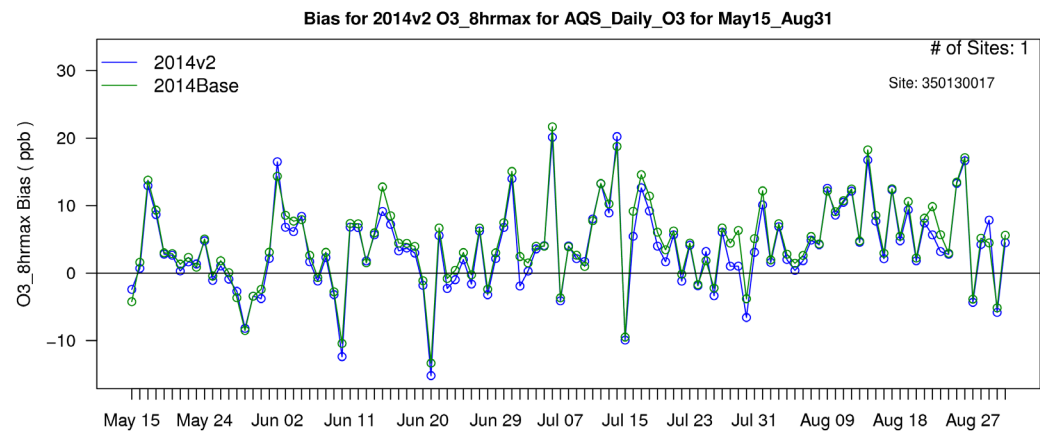
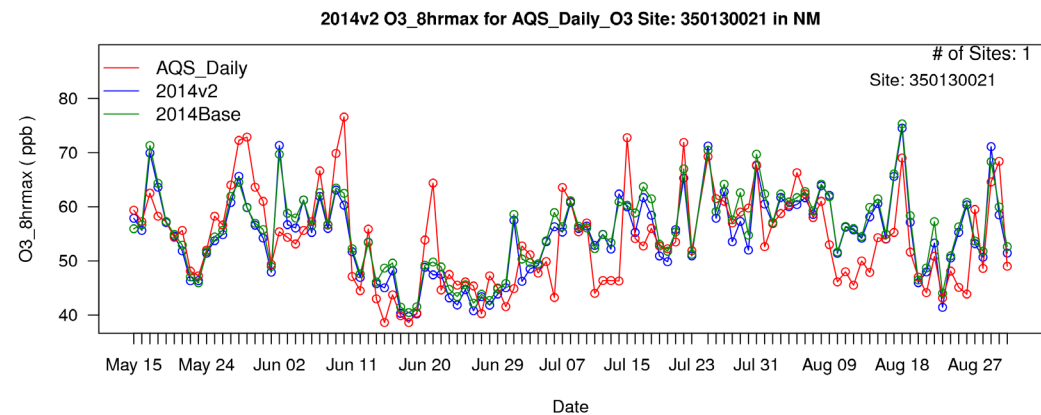
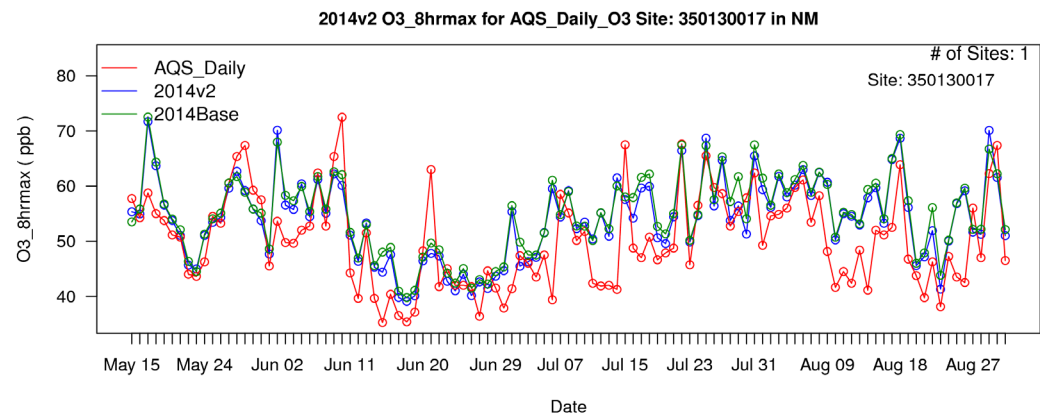


2014v2 (BEIS)

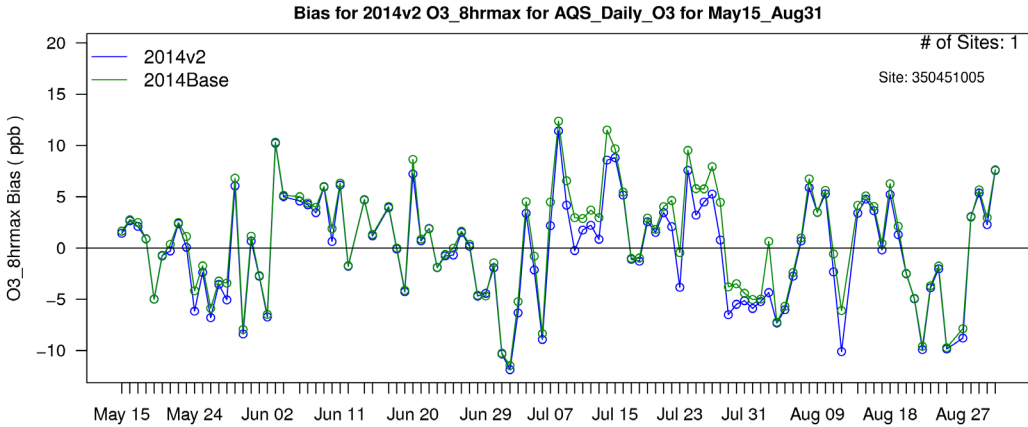
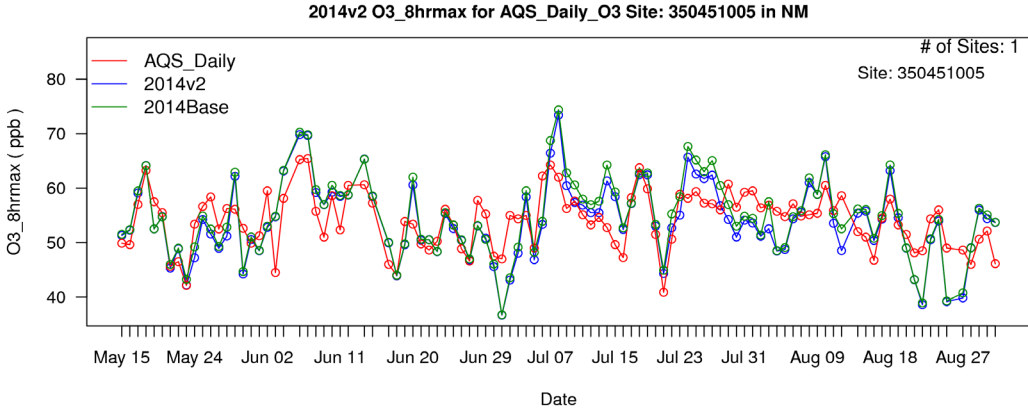
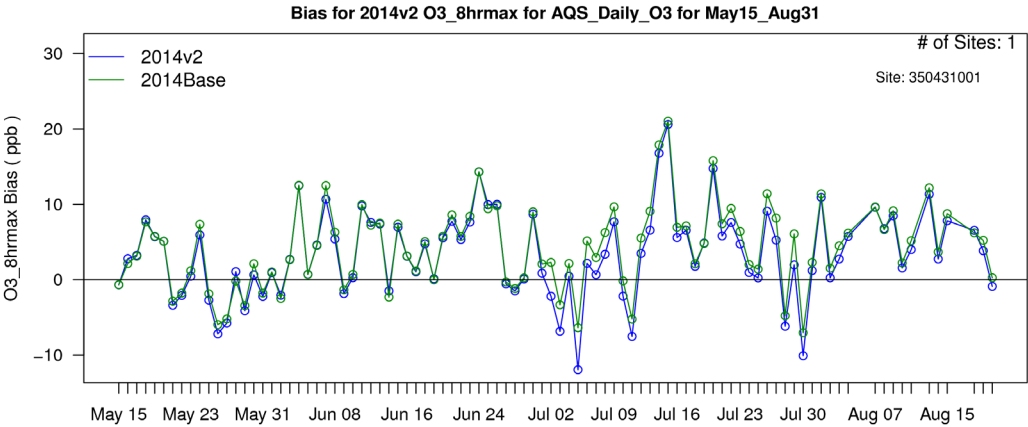
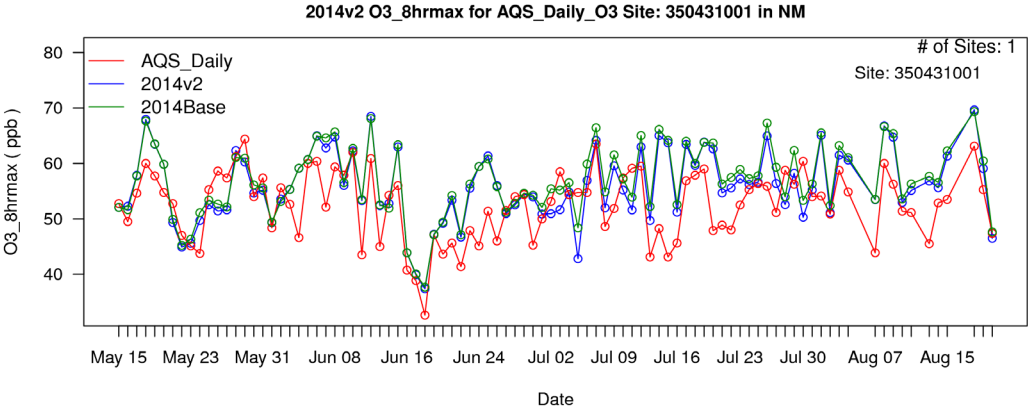


2014v2 larger underestimation at a few sites with 60ppb cutoff compared to 2014Base but still achieves Performance Criteria

SUNLAND PARK AND DESERT VIEW (DONA ANA COUNTY)



BERNALILLO (SANDOVAL CTY) & SUB STATION (SAN JUAN CTY)



OZONE MPE BY NEW MEXICO SUBREGIONS

- Original 2014 Base Case

	Nocutoff		Withcutoff	
Region	NMB(%)	NME(%)	NMB(%)	NME(%)
North NM	4.3	9.1	0	6.4
Bernalillo	4.3	9.4	-2.8	7.1
South NM	5.8	10.5	-6.1	8.5

- Revised 2014v2 Base Case

	Nocutoff		Withcutoff	
Region	NMB(%)	NME(%)	NMB(%)	NME(%)
North NM	2.6	8.6	-1.0	6.6
Bernalillo	2.6	9.6	-4.3	8.5
South NM	3.5	10.2	-7.8	9.9

- Consistent with MEGAN v3.1 having higher NOx emissions than BEIS v3.7, CAMx revised 2014v2 base has slight lower ozone than original 2014 base
 - Also consistent with time series plots
- Results in slight improvement in ozone performance statistics when no cutoff is used
- Results in a slight degradation in ozone performance statistics when 60 ppb observed ozone cutoff is used
- Very similar ozone model performance

OZONE MPE BY NEW MEXICO MONITORING SITE

2014Base (with MEGAN)			
SiteID	SiteNames	NMB No Cutoff	NMB 60 ppb Cutoff
350010023	Del Norte	1.7	-3.9
350010024	South East Heights	3.1	-2.4
350010029	South Valley	3.1	-2.8
350010032	Westside	1.1	-3.4
350011012	Foot Hills	13.6	2.0
350130008	La Union	17.4	-1.6
350130017	Sunland Park Yard	9.0	-3.6
350130020	Chaparral	4.8	-4.7
350130021	Desert View	3.2	-5.1
350130022	Santa Teresa	8.2	0.1
350130023	Solano	6.1	-6.5
350151005	Carlsbad	-1.1	-12.3
350171003	Chino Copper	9.1	-1.0
350250008	Hobbs Jefferson	2.1	-9.9
350290003	Deming Airport	6.2	-5.0
350390026	Coyote Ranger	3.3	-5.4
350431001	Bernalillo	8.1	3.8
350450009	Bloomfield	7.2	2.5
350450018	Navajo Lake	2.2	-0.6
350451005	Sub Station	1.4	3.3
350490021	Santa Fe Airport	3.8	-1.7
350610008	Los Lunas	0.8	-6.5

2014v2 (with BEIS)			
SiteID	SiteNames	NMB No Cutoff	NMB 60 ppb Cutoff
350010023	Del Norte	0.5	-4.9
350010024	South East Heights	1.3	-3.6
350010029	South Valley	0.9	-4.4
350010032	Westside	-1.0	-5.4
350011012	Foot Hills	11.9	0.8
350130008	La Union	15.0	-3.0
350130017	Sunland Park Yard	7.4	-4.1
350130020	Chaparral	2.8	-5.8
350130021	Desert View	1.4	-6.3
350130022	Santa Teresa	5.8	-1.8
350130023	Solano	3.9	-8.2
350151005	Carlsbad	-4.3	-14.5
350171003	Chino Copper	7.0	-1.8
350250008	Hobbs Jefferson	-1.2	-12.6
350290003	Deming Airport	3.8	-8.6
350390026	Coyote Ranger	1.2	-5.6
350431001	Bernalillo	6.4	3.3
350450009	Bloomfield	6.0	1.7
350450018	Navajo Lake	0.5	-3.6
350451005	Sub Station	-0.1	2.2
350490021	Santa Fe Airport	1.5	-2.5
350610008	Los Lunas	-1.7	-9.0

CONCLUSIONS: REVISED CAMX 2014V2 BASE CASE

- With lower biogenic emissions, the CAMx revised 2014v2 base case (BEIS) produces slightly lower ozone concentrations than the original CAMx 2014 base case (MEGAN)
 - Slightly improves ozone performance when overestimated (e.g., when not using ozone cutoff)
 - Slightly degrades ozone performance when underestimated (e.g., when using 60 ppb ozone cutoff)
 - Overall ozone model performance is comparable and basic MPE features nearly identical
- How to document in the NMED OAI Study?
 - 2014 database development and model evaluation report for original CAMx 2014 base case posted to NMED OAI website
 - https://www.wrapair2.org/pdf/NM_OAI_2014_BaseCase_MPE_v3.pdf
 - Ozone performance not appreciably changed

CAMX 2028 BASE CASE RESULTS

SMAT CONFIGURATION

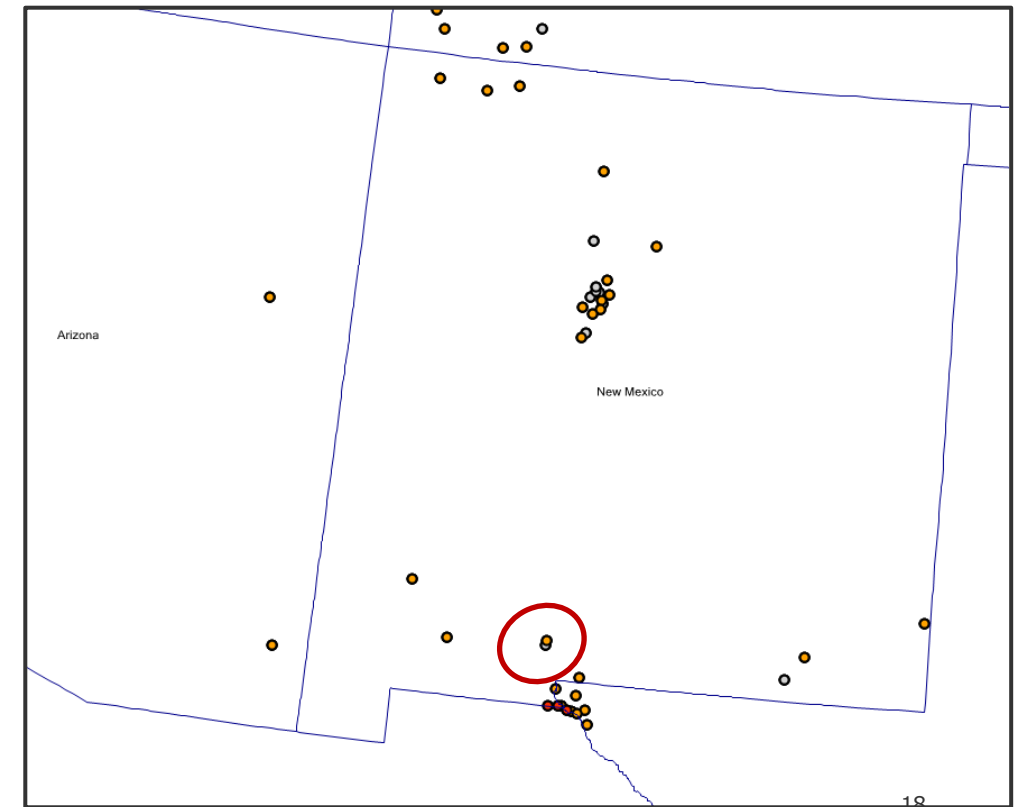
- SMAT run with “default” options except where highlighted:
 - Request spatial field output
 - Ozone DV spatial interpolation performed with and without using concentration gradients
 - Updated SMAT ozone observations file
 - Base year design values calculated centered on 2014 (i.e., 2012-2016)

Option	Main category	Setting	Default	This Study
Desired Output	Project Name			NMED_OAI
	Point Estimates Forecast	Forecast Ozone DV at monitors	Yes	Yes
	Quarterly model data	output used model data file	Yes	Yes
	Spatial Field	Interpolate monitor data to spatial field	No	Yes
	Neighbor File	Spatial Field	No	No
	Actions on run completion	Extract all selected output files	Yes	Yes
	Design Value Periods	output all DV periods	No	No
	Base an Future DV	Output Max DV	No	No
Data Input	Monitor Data	Ozone Data	SMAT_OZONE_MAX4DV_STD7 0_2002_2015.CSV	SMAT_OZONE_MAX4DV_STD7 0_2002_2018.CSV
	Model Data	Baseline File	EPA_test	2014v2.csv
		Forecast File	EPA_test	2028.csv
	Using Model Data	Temporal adjustment at monitor	3x3	3x3
			Max-paired in space	Max-paired in space
Filtering/ Interpolation	Choose Ozone DV	Start Year	2009-2011	2012-2014
		End Year	2011-2013	2014-2016
	Valid ozone monitors	Minimum number of DV	1	1
		Required DV	None selected	None selected
	Default interpolation method	Inverse Distance Weights	Yes	Yes
		check to set max interpolation distance	not checked	not checked
RRF/ Spatial Gradient	RRF setup	Top x modeled ozone days	10	10
		Initial threshold value (ppb)	not checked	not checked
		Minimum number days in baseline above threshold	NA	NA
		Minimum allowable threshold value (ppb)	60	60
		Min number of days above min allowable threshold	5	5
		Enable backstop minimum threshold for spatial fields	not checked	not checked
		subrange first day ozone used in RRF	-	-
		subrange last day ozone used in RRF	-	-
		paired days based on high concentration instead of date	not checked	not checked
	Spatial Gradient Setup	Start Value	1	1
		End Value	5	5

SMAT DESIGN VALUES NEW MEXICO

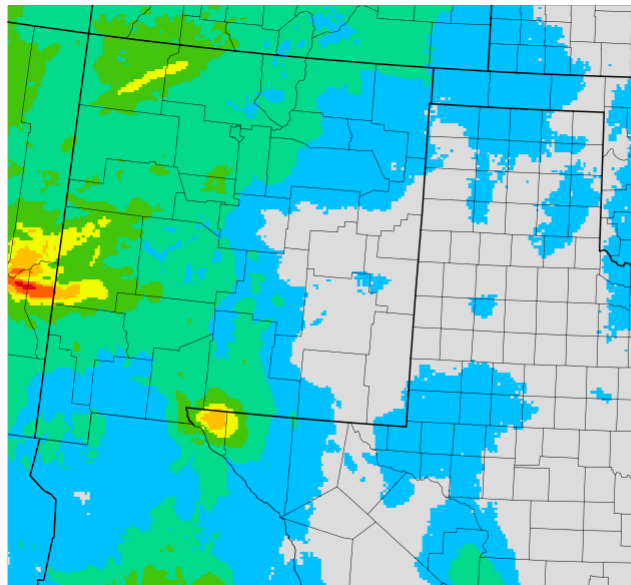
AQS ID	DVC: 2014 (ppb)	DVF: 2028 (ppb)	DVF – DVC (ppb)	County
350010023	66.3	60.9	-5.4	Bernalillo
350010024	68.0	62.3	-5.7	Bernalillo
350010029	66.0	61.0	-5.0	Bernalillo
350010032	67.0	62.6	-4.4	Bernalillo
350011012	65.0	59.1	-5.9	Bernalillo
350130008	66.3	60.0	-6.3	Dona Ana
350130017	67.0	61.9	-5.1	Dona Ana
350130020	67.0	62.3	-4.7	Dona Ana
350130021	72.0	67.0	-5.0	Dona Ana
350130022	71.3	66.1	-5.2	Dona Ana
350130023	65.0	60.3	-4.7	Dona Ana
350151005	69.0	66.7	-2.3	Eddy
350171003	62.0	59.0	-3.0	Grant
350290003	66.0	62.7	-3.3	Luna
350390026	64.0	60.8	-3.2	Rio Arriba
350431001	64.0	58.4	-5.6	Sandoval
350450009	64.3	61.0	-3.3	San Juan
350450018	67.0	64.8	-2.2	San Juan
350451005	63.7	60.8	-2.9	San Juan
350490021	64.3	60.6	-3.7	Santa Fe
350610008	66.3	62.2	-4.1	Valencia

- Only two sites in NM have DV over 71 in the base case period (2012-2016)
 - Desert View and Santa Teresa



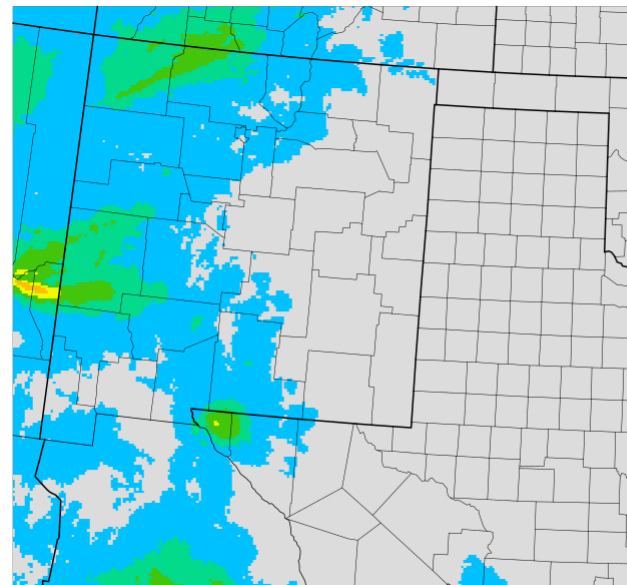
UNMONITORED AREA ANALYSIS USING MODELED GRADIENTS IN 2012-2014 OZONE DV SPATIAL INTERPOLATION

DVC: 2014



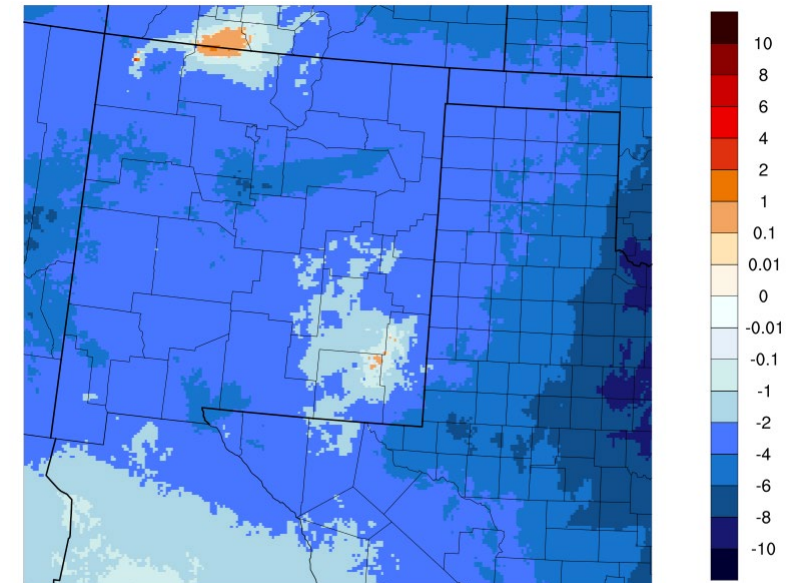
max(7,117) = 77.4 ppb
min(238,27) = 55.2 ppb

DVF: 2018



max(7,117) = 72.6 ppb
min(241,28) = 47.7 ppb

DVF - DVC



UNMONITORED AREA ANALYSIS NOT USING MODELED GRADIENTS IN 2012-2014 OZONE DV SPATIAL INTERPOLATION

DVC: 2014

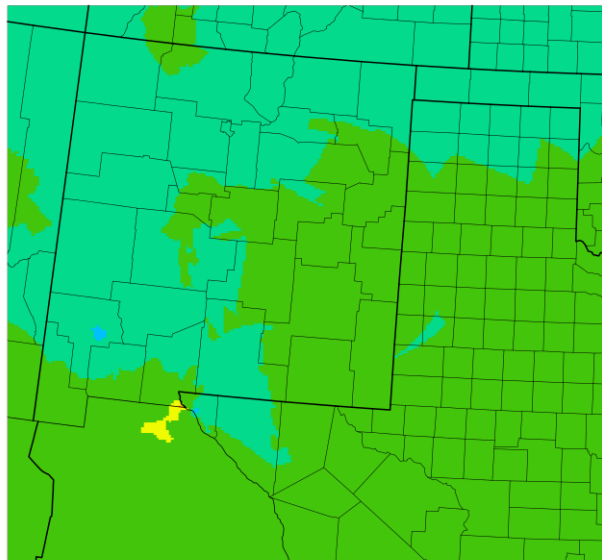
DVF: 2018

DVF - DVC

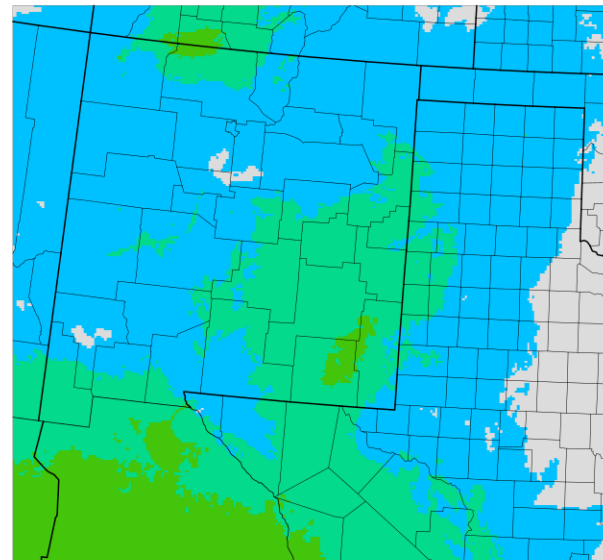
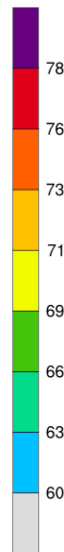
NMED CAMx 4km
2014 Baseline
O3 Design Value UAA

NMED CAMx 4km
2028 Future
O3 Design Value UAA

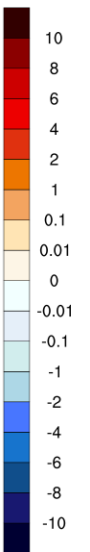
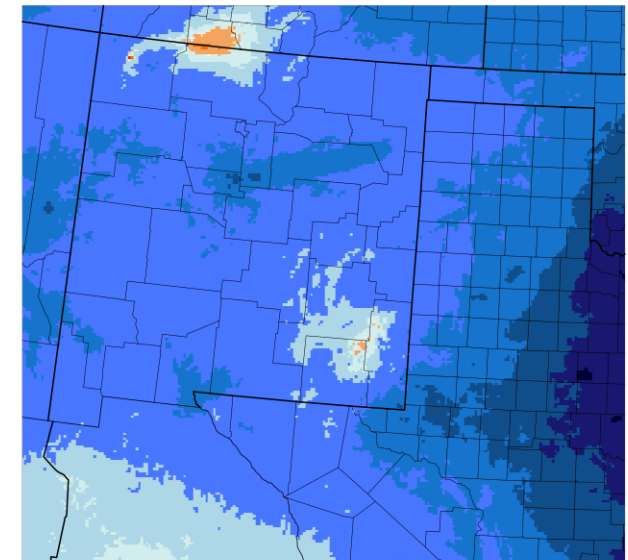
NMED CAMx 4km
2028 Future - 2014 Baseline
O3 Design Value UAA



max(70,64) = 71.0 ppb
min(77,63) = 61.4 ppb



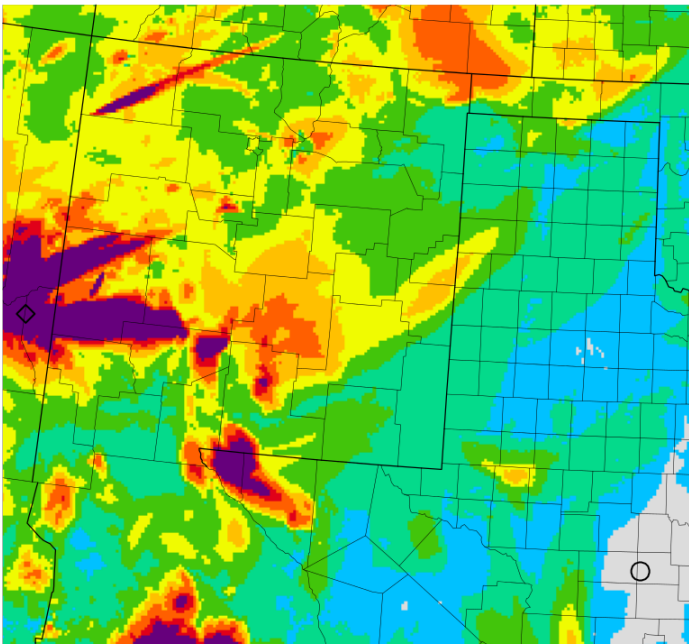
max(138,87) = 67.9 ppb
min(243,116) = 55.7 ppb



MODEL MDA8 RESULTS

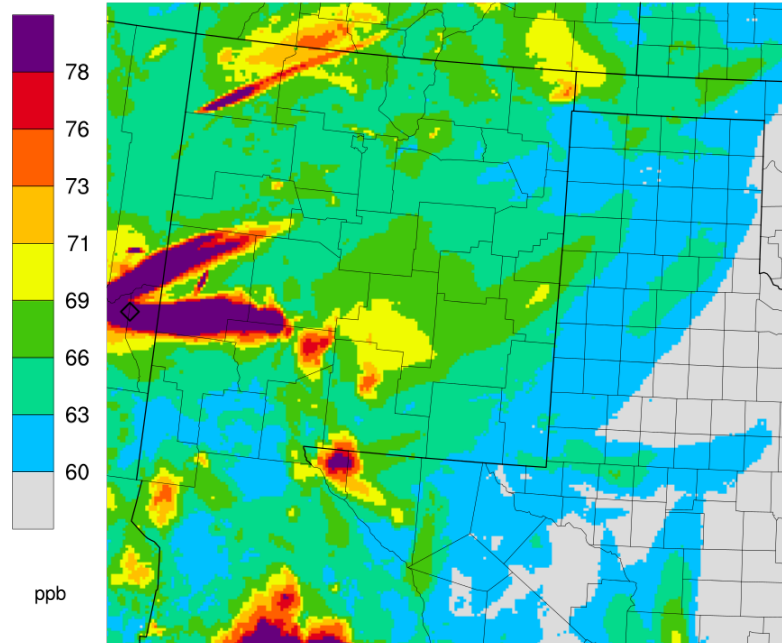
EPISODE MAXIMUM MDA8 AND DIFFERENCE

Max(2014)



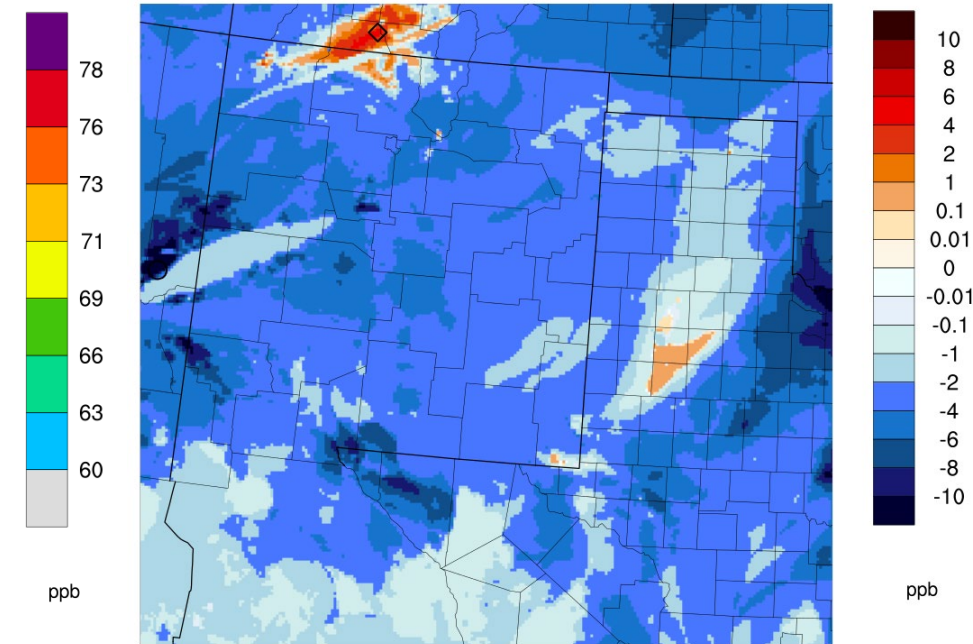
◇ max(9,117) = 132.215 ppb
○ min(224,27) = 57.238 ppb

Max(2028)



◇ max(9,117) = 128.622 ppb
○ min(242,35) = 52.186 ppb

Max(2028) – Max(2014)

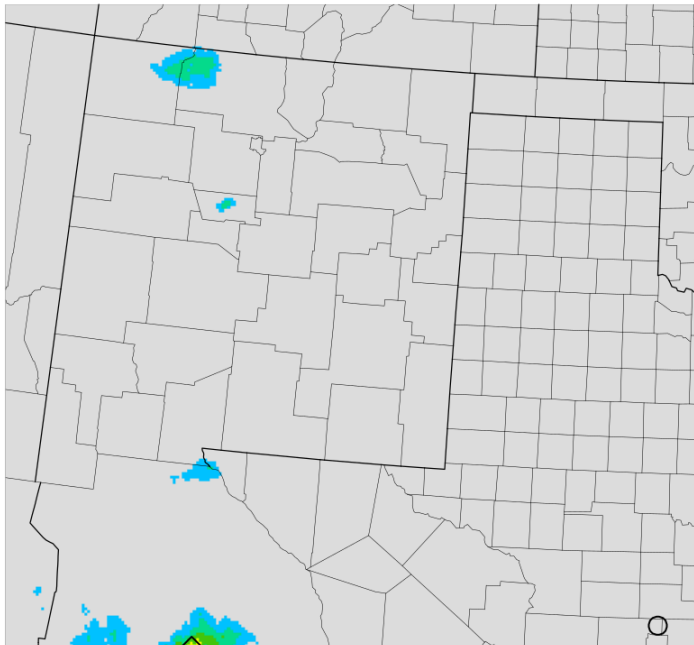


◇ max(84,215) = 4.632 ppb
○ min(7,132) = -12.245 ppb

- Maximum values and differences are unpaired in time.
- High concentrations tend to occur on western part of the domain where there are no monitors

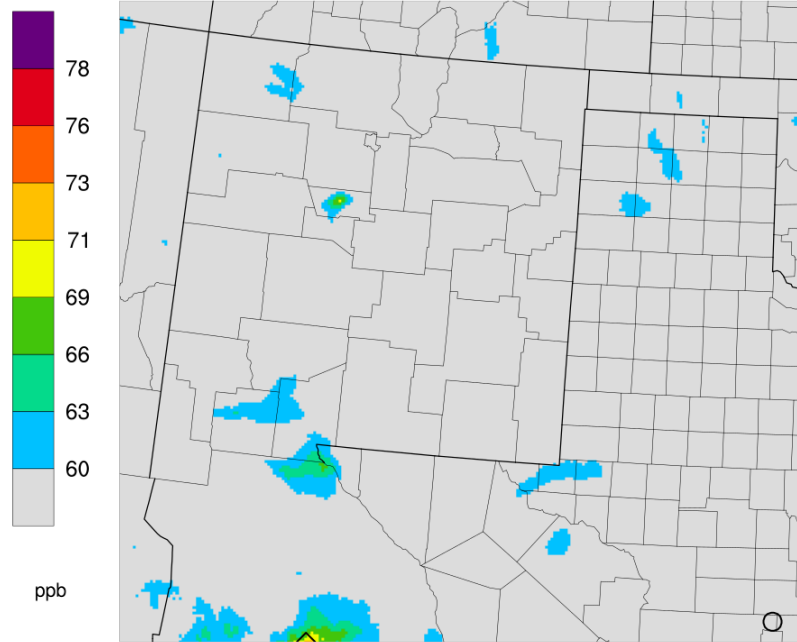
MAXIMUM ONE DAY DIFFERENCE: AUG 17

2028



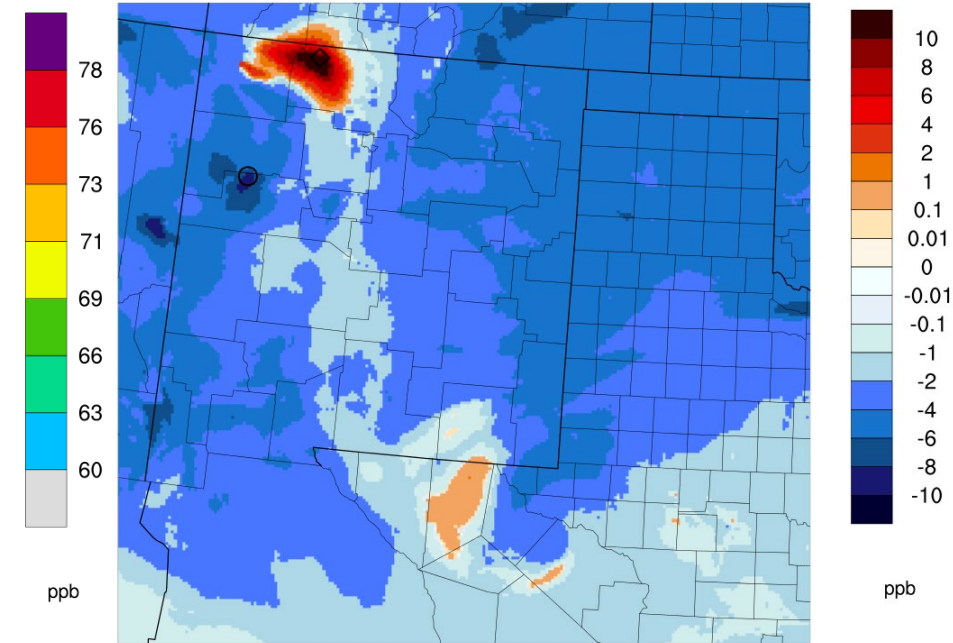
◇ max(66,1) = 70.391 ppb
○ min(229,8) = 40.970 ppb

2014



◇ max(66,1) = 71.637 ppb
○ min(229,8) = 41.865 ppb

2028 - 2014

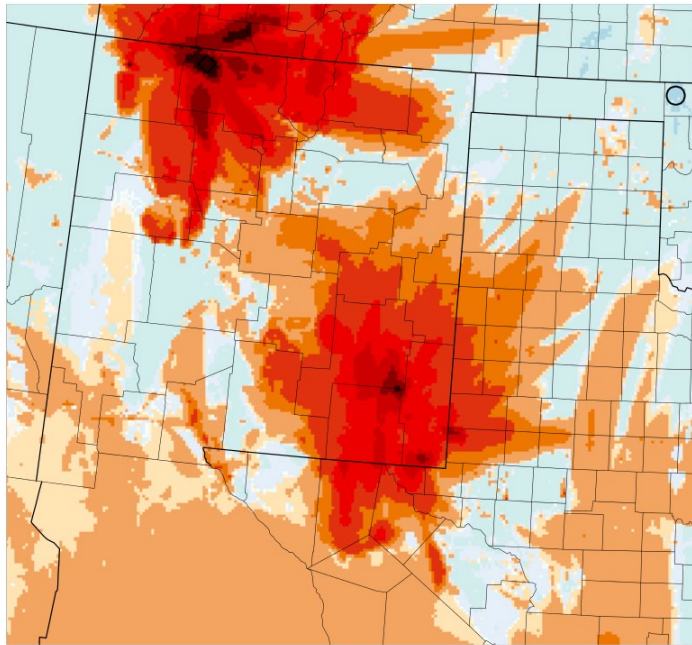


◇ max(71,204) = 12.203 ppb
○ min(46,163) = -9.358 ppb

- Maximum difference (12.2 ppb) occurs in NW part of the domain in a day with low ozone concentrations

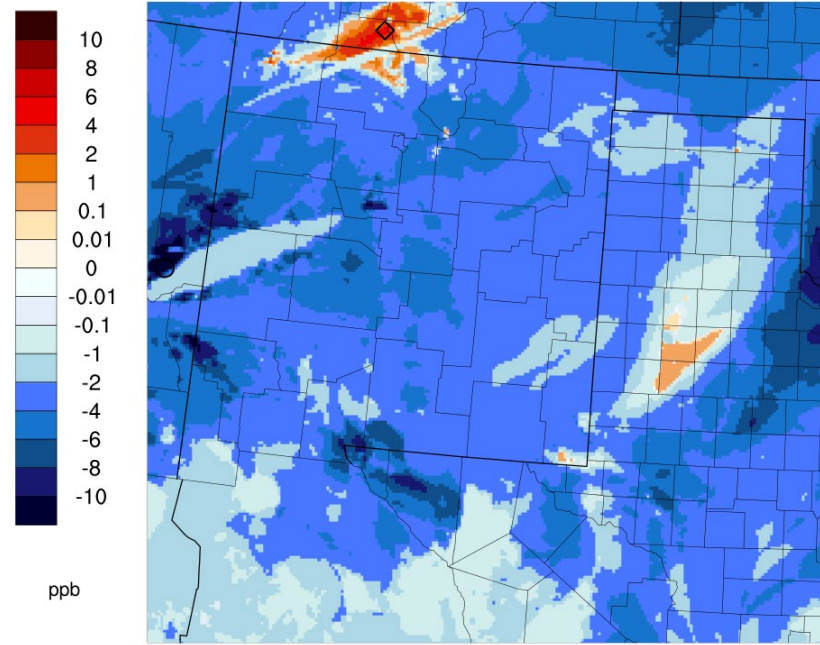
COMPARISON AMONG DIFFERENCES

MAX (DIFF)



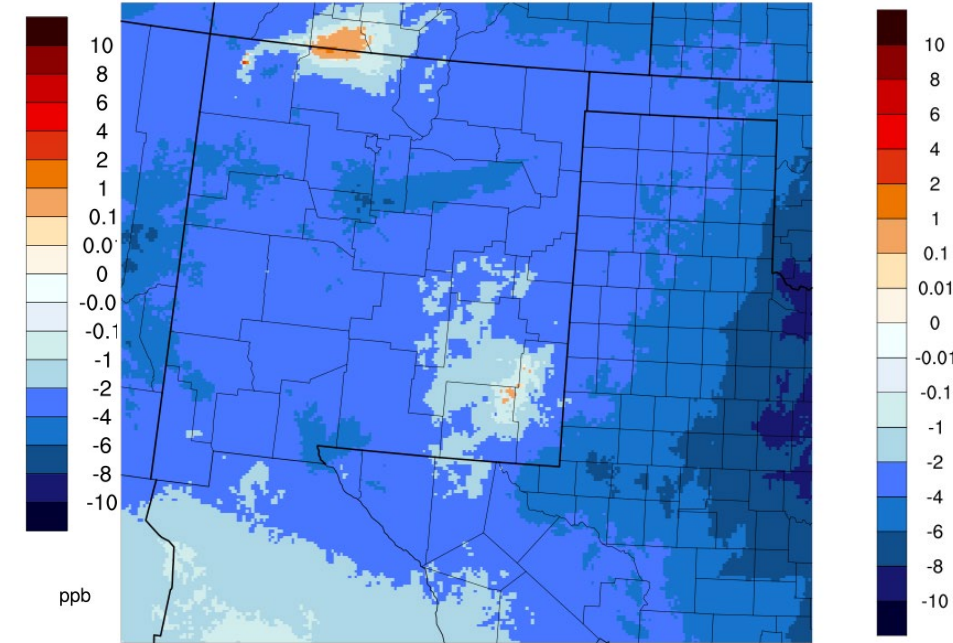
◇ max(71,204) = 12.203 ppb
○ min(235,193) = -1.250 ppb

DIFF (MAX)



◇ max(84,215) = 4.632 ppb
○ min(7,132) = -12.245 ppb

UAA DIFF

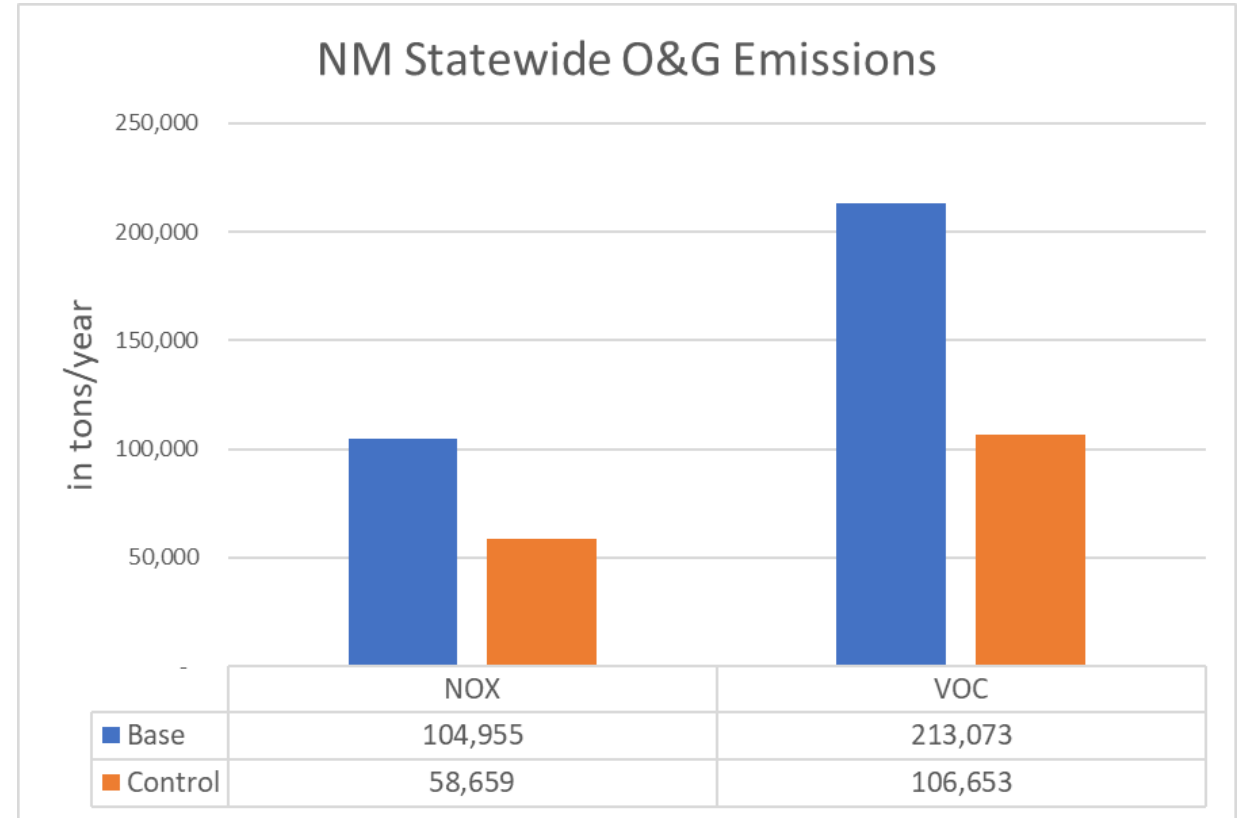


- Feature with increased ozone in 2028 over northern NM appears in all figures

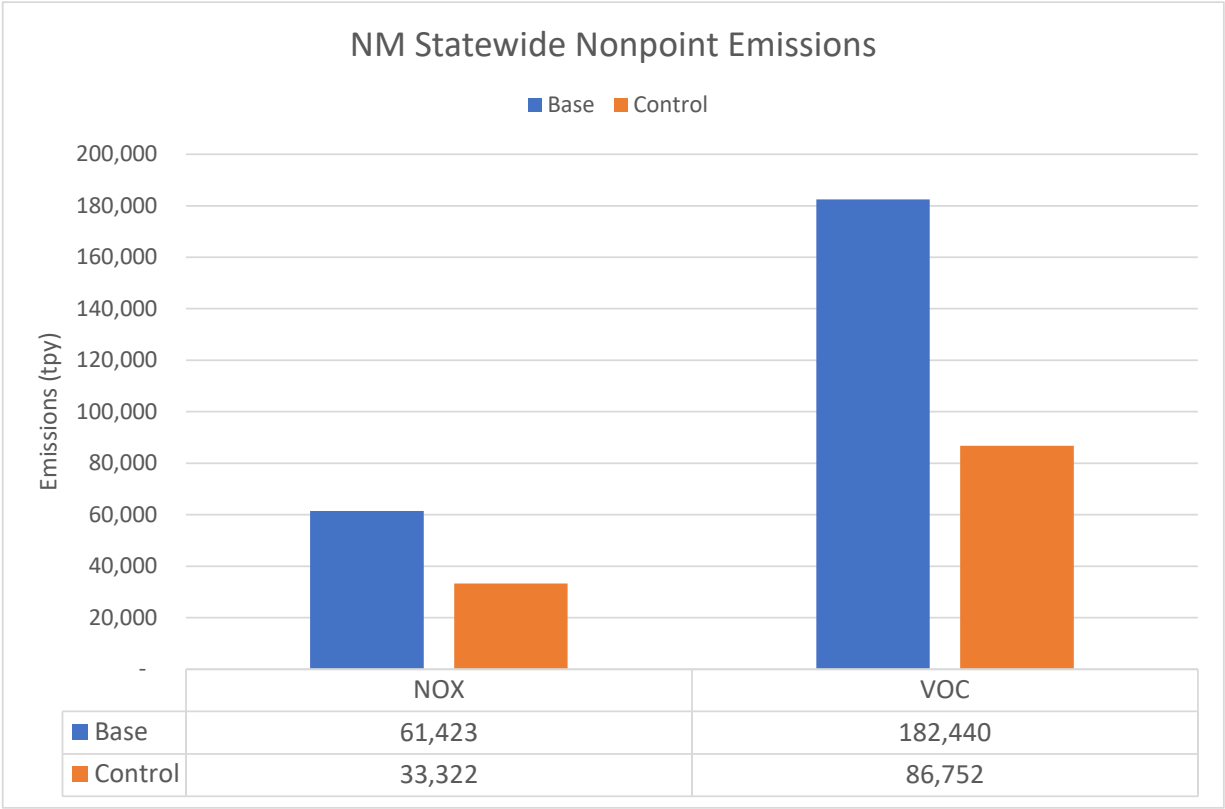
STATUS OF 2028 NEW MEXICO OIL AND GAS (O&G) CONTROL STRATEGY (CS) MODELING

2028 O&G CONTROL SCENARIO EMISSIONS

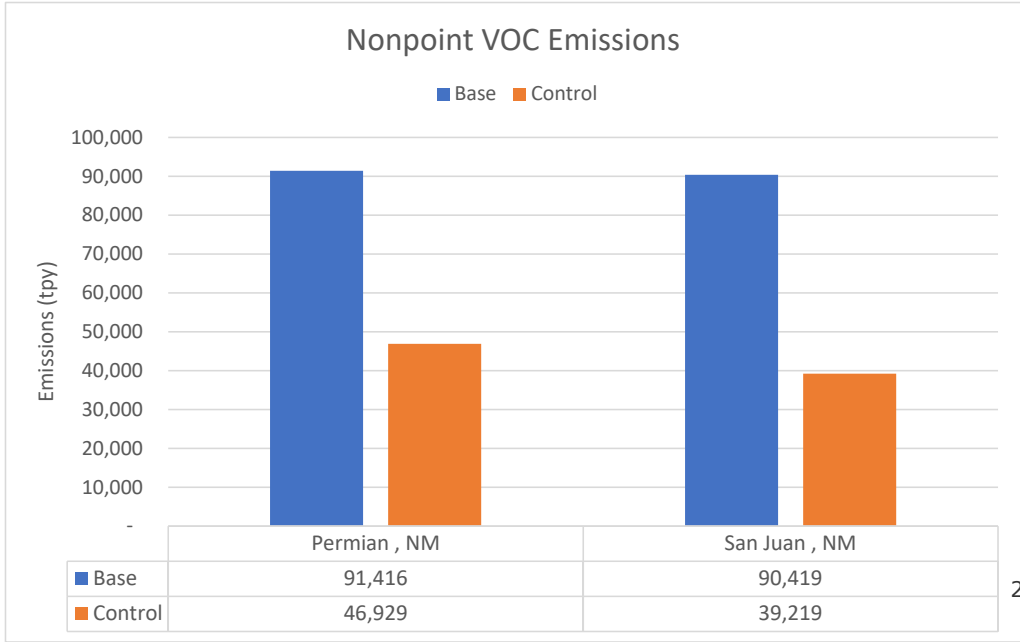
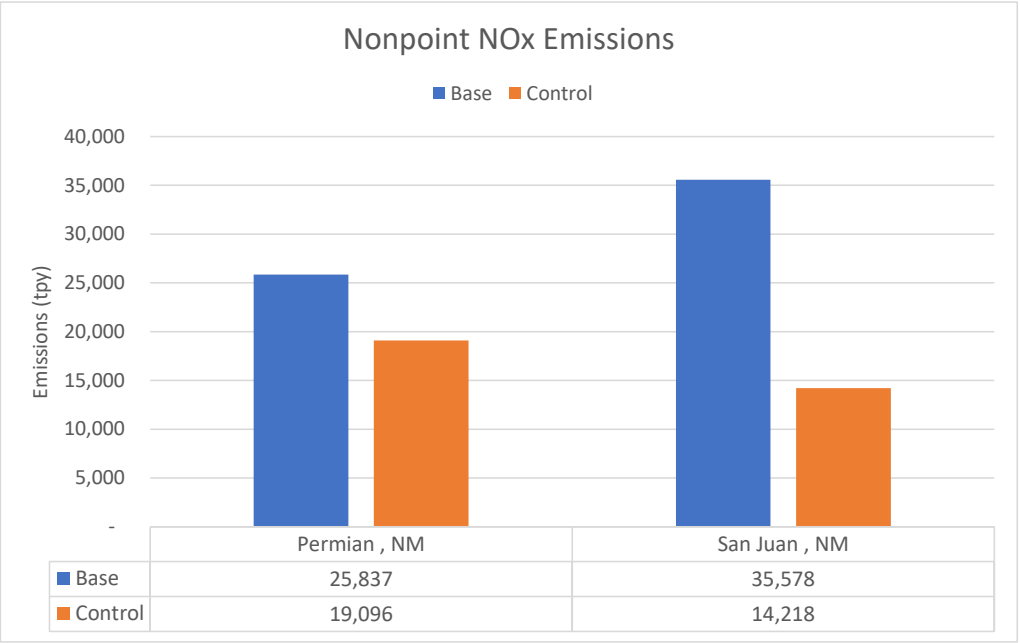
- ERG provided revised point and nonpoint NM emissions for affected counties/SCCs/pollutants.
- 7 NM counties included in ERG's inventory
 - San Juan Basin (4 counties)
 - Permian Basin (3 counties)
- Bar chart display to show comparisons between 2028 Base and Control Scenario O&G emissions for NM
- 44% NO_x and 50% VOC reductions in total O&G emissions



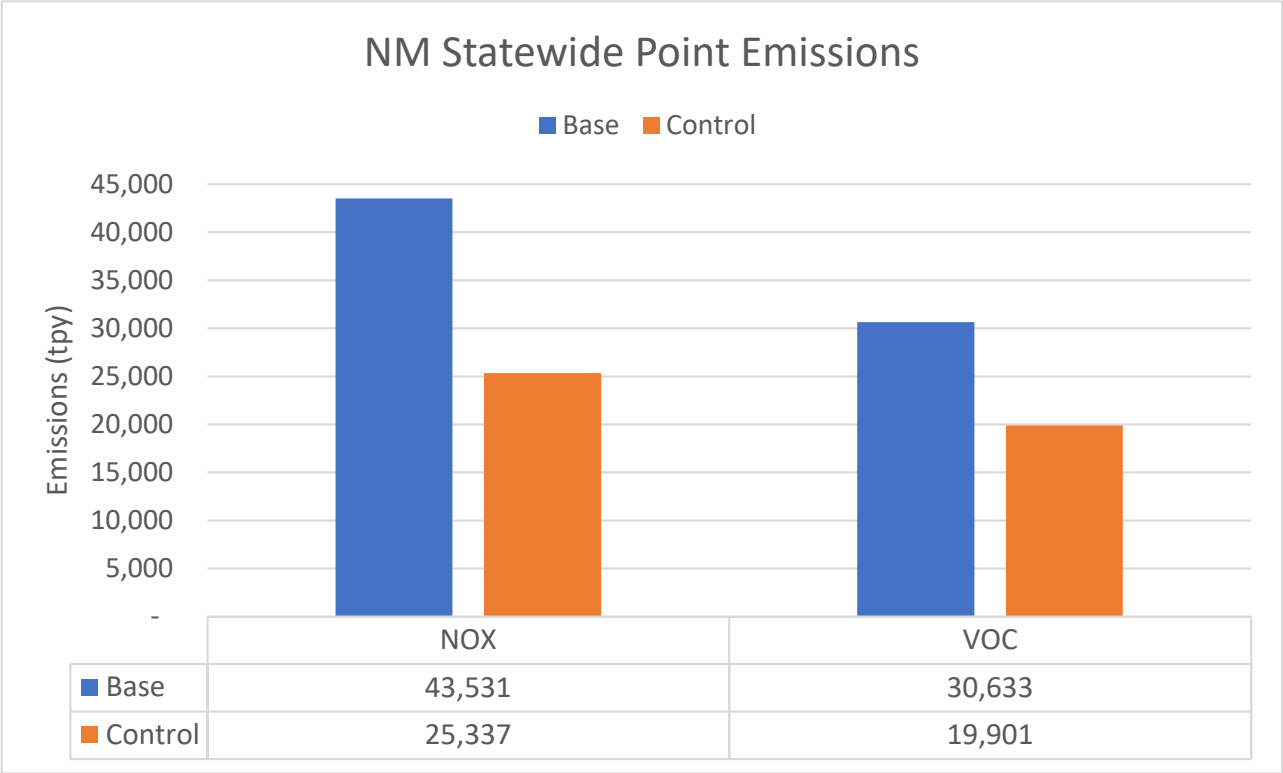
NEW MEXICO NONPOINT O&G



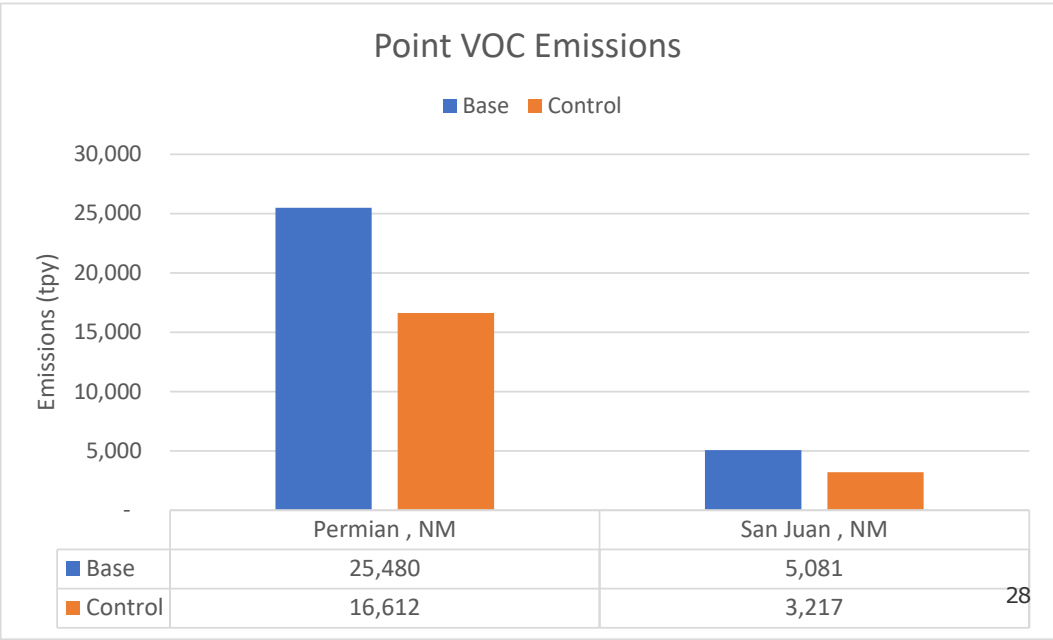
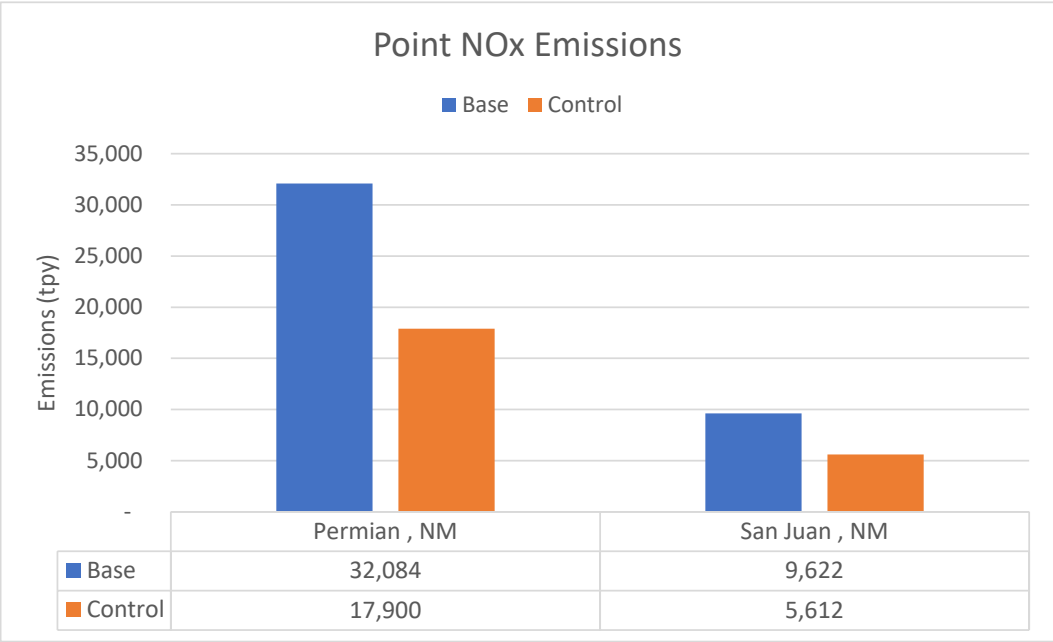
- 46% NOx reduction in nonpoint O&G
- 52% VOC reduction in nonpoint O&G



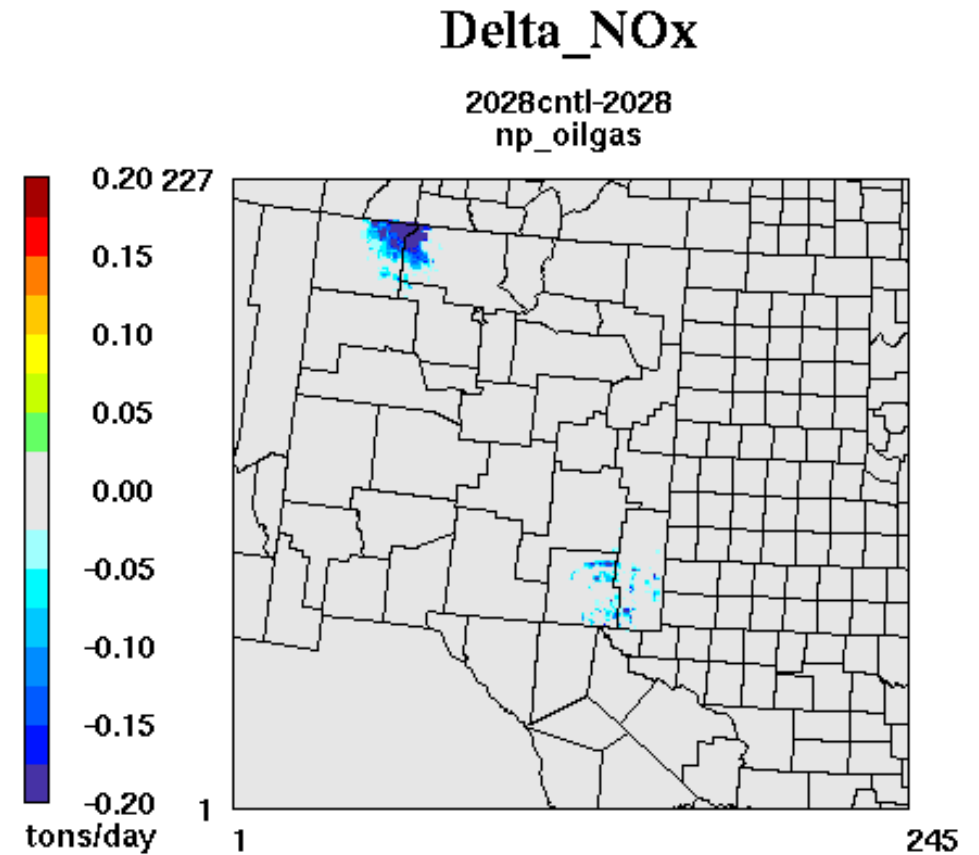
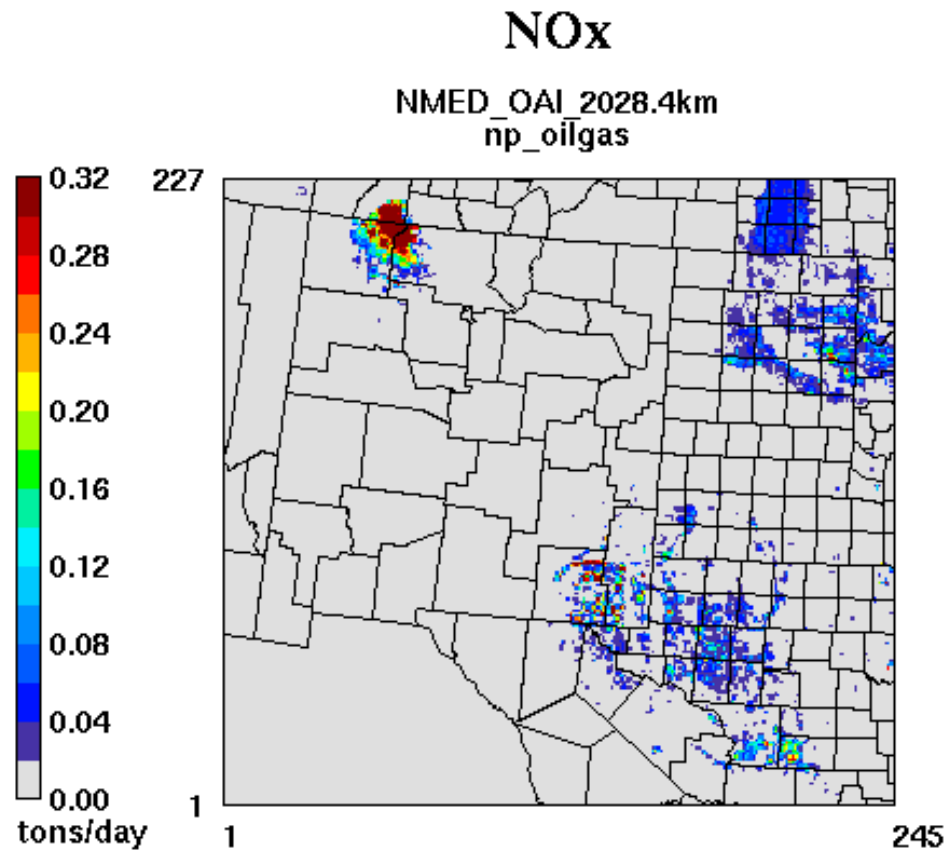
NEW MEXICO POINT O&G



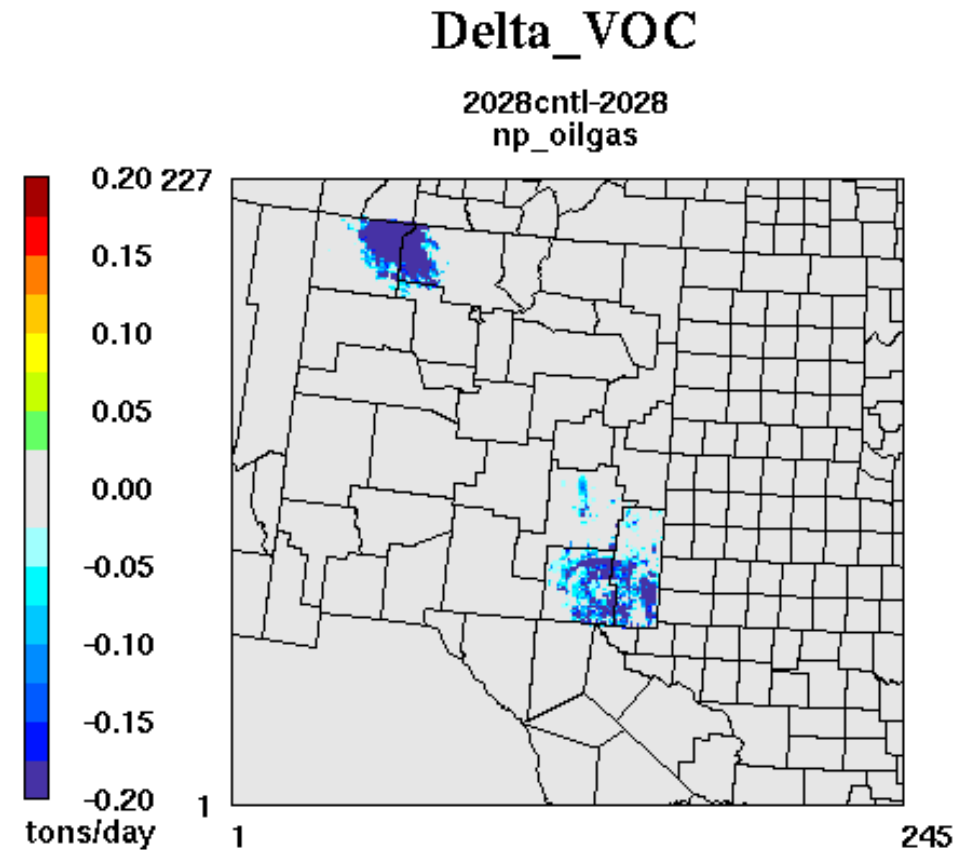
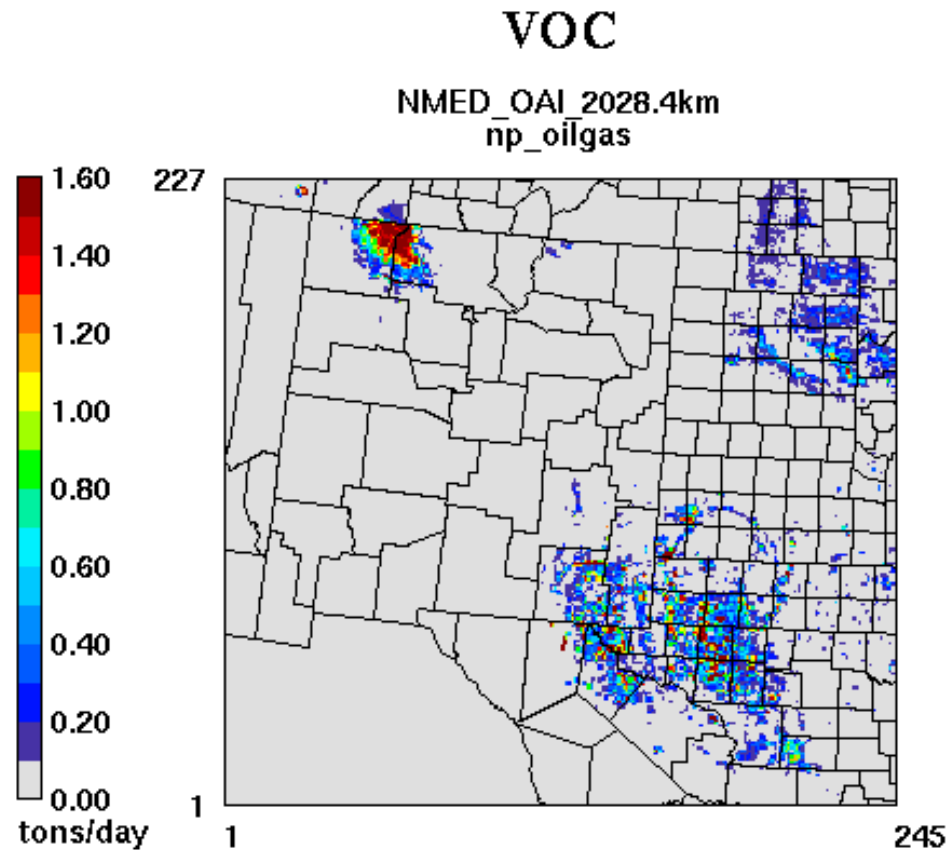
- 42% NOx reduction in point O&G
- 35% VOC reduction in point O&G



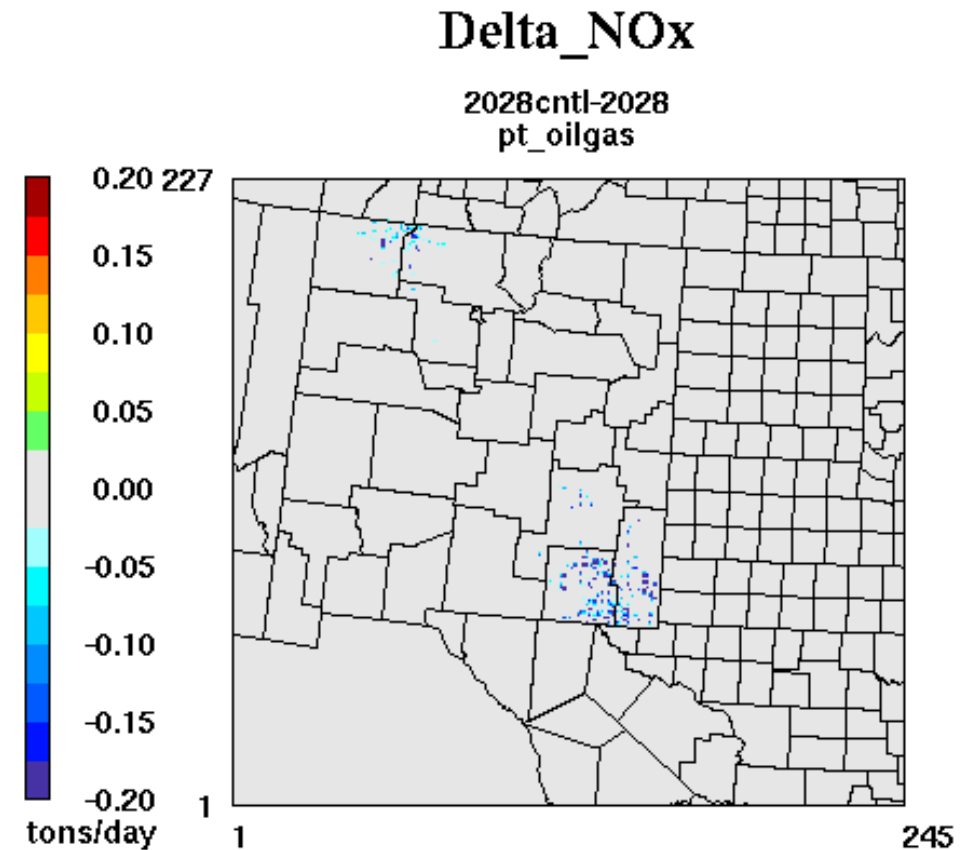
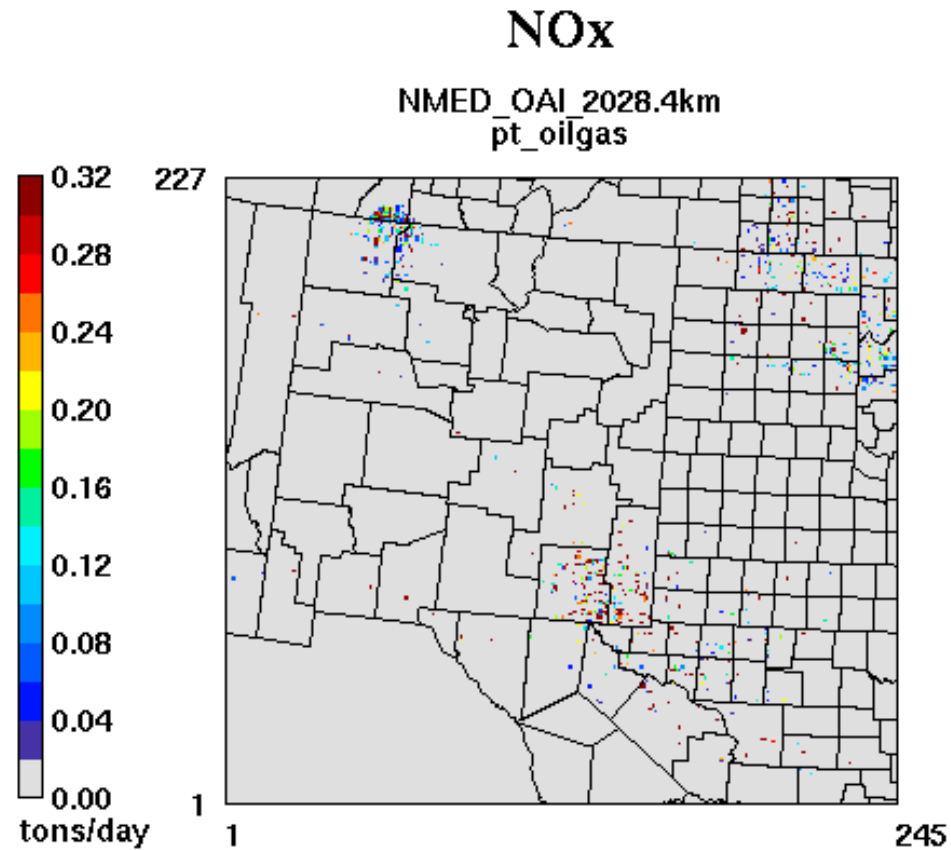
NONPOINT O&G COMPARISON: NOx



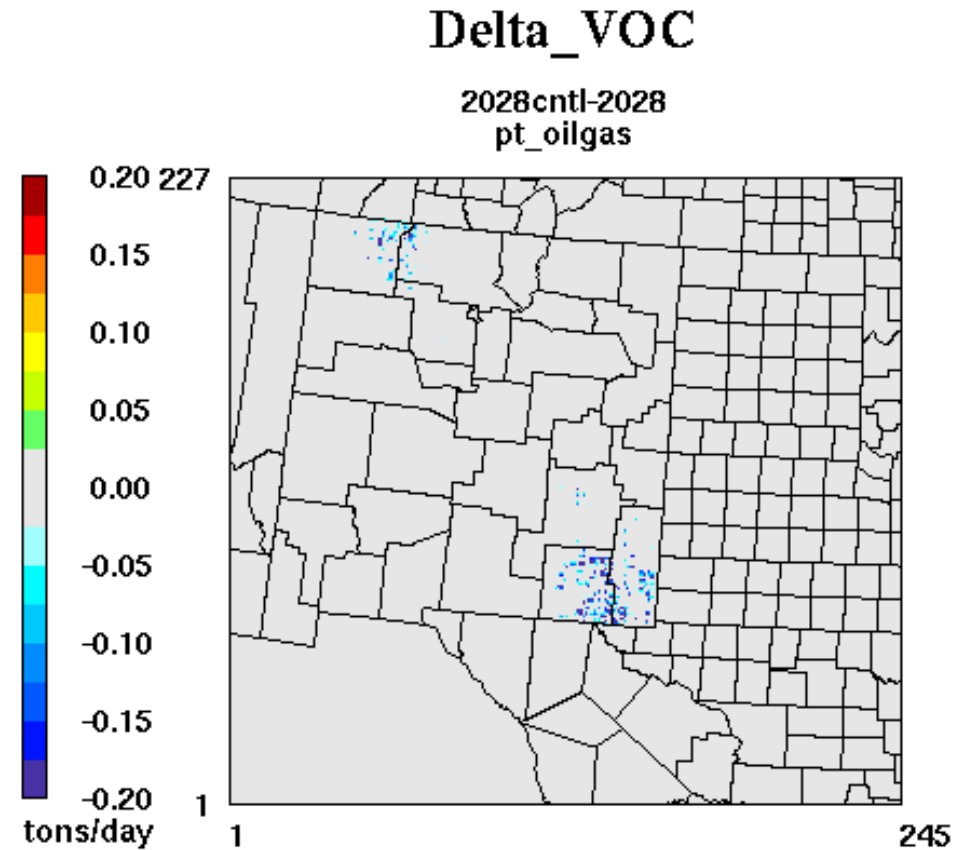
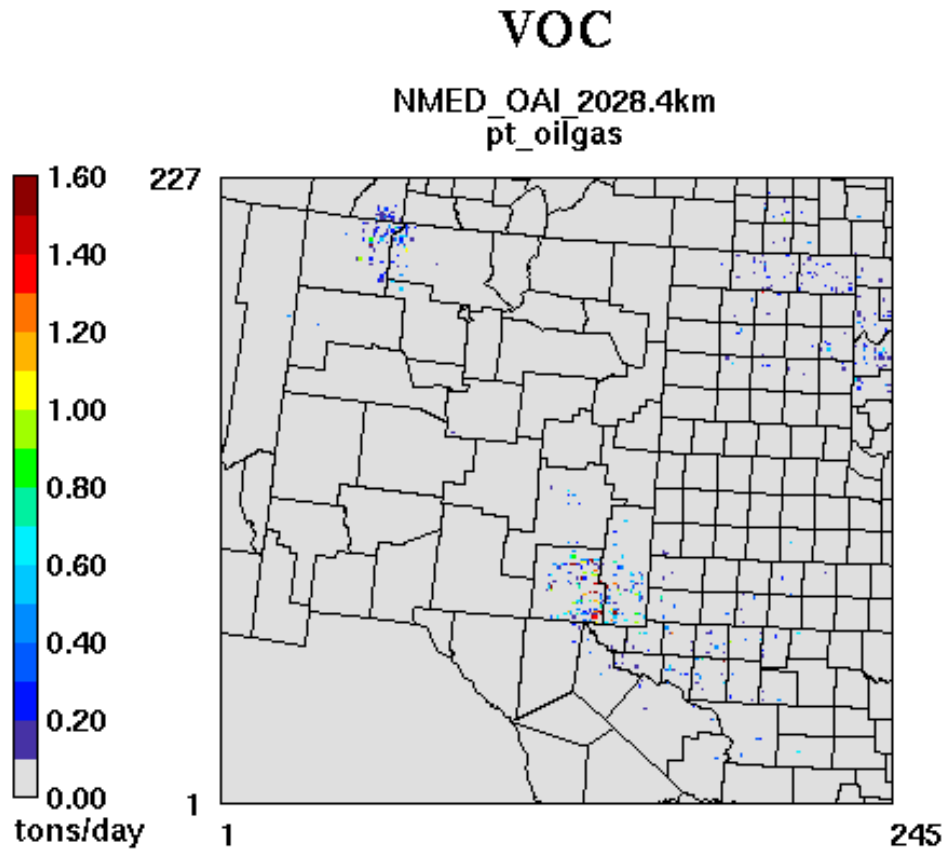
NONPOINT O&G COMPARISON: VOC



POINT O&G COMPARISON: NOx



POINT O&G COMPARISON: VOC



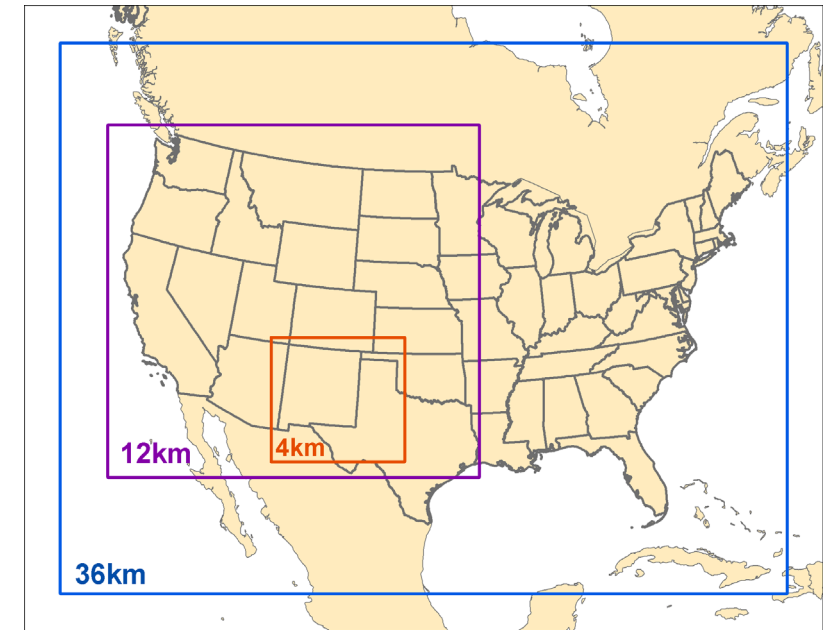
CURRENT STATUS AND NEXT STEPS

- Completed processing of 2028 O&G emissions for New Mexico O&G Control Scenario
- Started 2028 CAMx runs for O&G Control Scenario last Friday (2/5)
- Analyze CAMx outputs and provide ozone results to NMED

DESIGN OF 2028 NM O&G CS SOURCE REGION AND CATEGORY APCA OZONE SOURCE APPORTIONMENT

CAMX 2028 NM O&G CS APCA OZONE SOURCE APPORTIONMENT

- Purpose: To determine contributions of 9 Source Categories within New Mexico and rest of U.S. as well as international anthropogenic emissions to ozone concentrations in New Mexico under the 2028 NM O&G CS emissions scenario.
- Approach:
 - Model: CAMX version 7.1 (released December 2020)
 - Domains: NMED OAI Study 36/12/4-km
 - Period: May – August 2014
 - Boundary Conditions: WRAP 2014 GEOS-Chem
 - Emissions Scenario: WRAP 2028OTBa2 except:
 - Actual 2014 Fire Emissions (U.S. WF, Rx and Ag)
 - 2028 New Mexico Oil and Gas Control Strategy (2028 NM O&G CS)
 - Source Apportionment: Anthropogenic Precursor Culpability Assessment (APCA) version of CAMx ozone source apportionment tool.



CAMX 2028 NM O&G CS APCA OZONE SOURCE APPORTIONMENT

- CAMx Ozone Source Apportionment Technology (OSAT) ozone source apportionment tool:
 - Ozone contributions are obtained for user-defined Source Groups:
 - A Source Group typically consists of a Source Category emitting from a geographic Source Region
 - For example, on-road mobile source emissions from New Mexico
 - OSAT uses reactive tracers for ozone (O3V and O3N) and precursors (e.g., VOC and NOx) and intermediate species (e.g., NO3 and PAN) that run in parallel to the host model
 - When ozone is formed in the host model, OSAT determines whether ozone formation is more VOC-limited or NOx-limited and assigns the ozone formed to Source Groups O3V or O3N based on the relative contribution of the Source Groups' limiting precursor to the total precursor concentration
- CAMx Anthropogenic Precursor Culpability Assessment (APCA) ozone source apportionment tool:
 - APCA differs from OSAT in that it recognizes that natural emissions are not controllable so only allocates ozone to natural emissions Source Groups when it is due to natural NOx interacting with natural VOC
 - When ozone is formed due to natural VOC and anthropogenic NOx under VOC-limited conditions, a case OSAT would assign to the natural Source Group, APCA redirects the ozone formed to the anthropogenic Source Group
 - APCA provides more control-strategy relevant information

CAMX 2028 NM O&G CS APCA OZONE SOURCE APPORTIONMENT

- **Definition of Source Groups**

- Boundary Conditions (BCs) from 2014 GEOS-Chem runs:

- BC_{Intl} - International anthropogenic emissions
- BC_{USA} - U.S. anthropogenic emissions
- BC_{Natural} - Natural sources
- BC_{Top} - BC above the top of domain

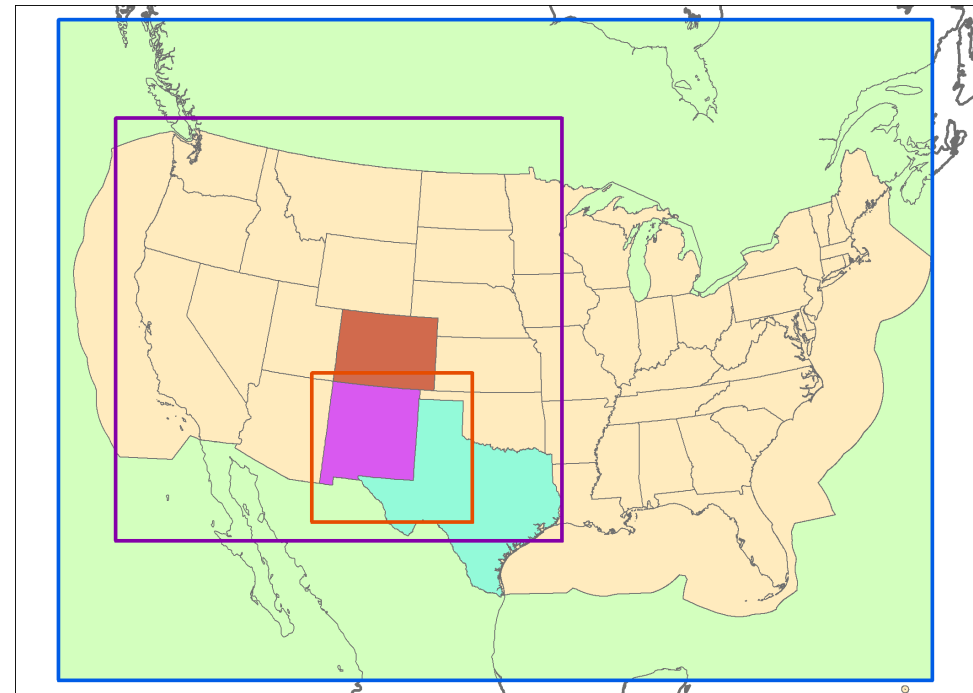
- Source Categories (9):

1. Natural (biogenic, lightning NO_x, etc.);
2. Fires (WF, Rx, Ag, other);
3. Oil and gas point sources (surrogate for midstream);
4. Oil and gas non-point sources (surrogate for upstream);
5. EGU point;
6. Non-EGU point;
7. On-road mobile;
8. Non-road mobile; and
9. Remainder anthropogenic.

- Source Regions (5):

- New Mexico
- Texas
- Colorado
- Remainder U.S.
- International (Mex, Can, CMV > 200 nmi)

- 50 Source Groups (50 = 5 x 9 + 5)



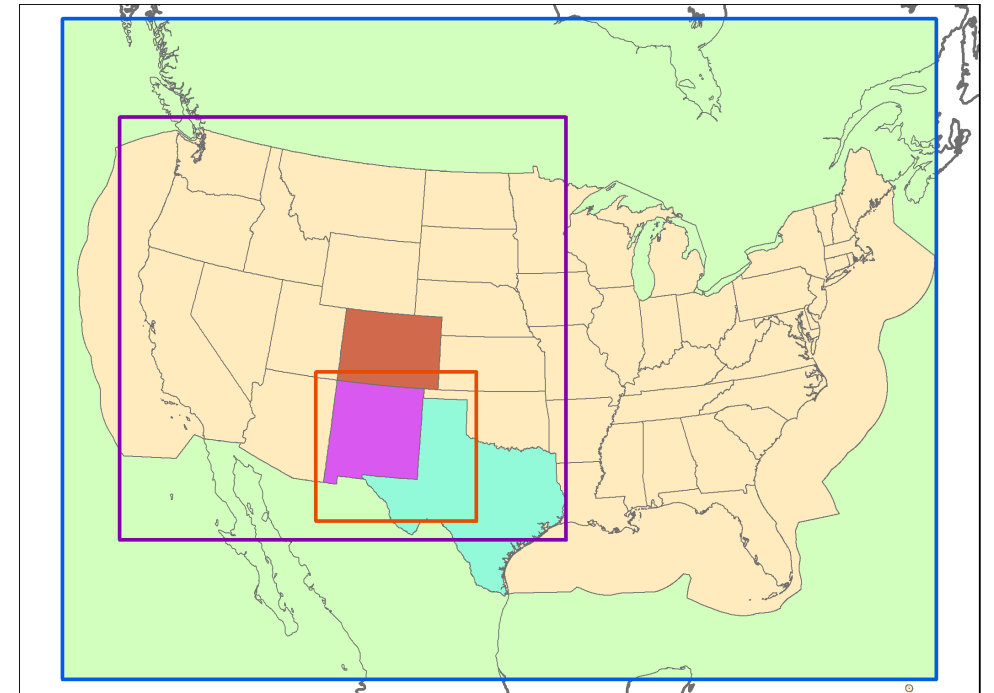
CAMX 2028 NM O&G CS APCA OZONE SOURCE APPORTIONMENT

- Post-Processing of CAMx 2028 NM O&G CS APCA Source Apportionment Results
 - MDA8 Ozone Concentrations at the Monitoring Sites
 - Generate stacked Bar Charts and Pie Charts of source contributions using an Excel Dashboard
 - User select monitoring sites and group of 10 days to display, and stacked bar charts are generated for the 10 days and pie chart for the average of the 10 days (e.g., 10 days used in SMAT for 2028 ozone projections)
 - Spatial maps of MDA8 ozone for Source Categories within New Mexico across 4-km domain
 - Provides a footprint of New Mexico Source Category contributions
 - Other spatial maps of MDA8 ozone (e.g., Source Categories and State across Western U.S.)
 - International Anthropogenic Emission Contributions
 - Run SMAT removing contributions from International anthropogenic emissions (i.e., Mex/Can/CMV + BC_{Intl}) to obtain 2028 ozone DVs w/o International emissions and compare with 2028 NM O&G CS ozone DV projections

DESIGN OF 2028 NM O&G CS OSAT VOC- VS. NOX-LIMITED OZONE SOURCE APPORTIONMENT

CAMX 2028 NM O&G CS OSAT OZONE SOURCE APPORTIONMENT

- Purpose: To estimate relative amount of VOC-Sensitive vs. NOx-sensitive ozone formation within 2028 New Mexico.
- Use the OSAT version of CAMx ozone source apportionment tool
- Definition of Source Groups
 - Source Regions (5):
 - Use same 5 Source Regions as APCA SA run
 - Source Categories (2):
 - Anthropogenic Emissions
 - Natural and Fire Emissions
 - 12 Source Groups (5 x 2 + 2 [IC,BC])
 - Will run faster than CAMx APCA SA Run (50 Source Groups)



CAMX 2028 NM O&G CS OSAT OZONE SOURCE APPORTIONMENT

- Post-processing of CAMx 2028 NM O&G CS OSAT ozone source apportionment results
 - Monitoring site displays
 - Extract Hourly and MDA8 ozone at the monitoring sites and load in Excel Dashboard to display stacked Bar Charts and Pie Charts of IC/BC and VOC-sensitive vs. NOx-sensitive ozone formation contributions
 - Spatial maps across 4-km NM domain depicting fraction of MDA8 ozone formed under VOC-sensitive vs. NOx-sensitive formation conditions:
 - Total MDA8 ozone; BC ozone; O3V ozone; and O3N ozone
 - Ratio of O3V/O3N: When > 1 → more VOC-sensitive and when < 1 → more NOx sensitive
 - Percent NOx-sensitive ozone formation to total ozone without BC (i.e., $100 \times \Sigma O3N / (\Sigma O3N + \Sigma O3V)$)

NEW MEXICO OZONE ATTAINMENT INITIATIVE

Sensitivity of 2028 Ozone Projections to Current Year Ozone Design Values and Preliminary Draft Air Quality Technical Support Document

Marco Rodriguez, Pradeepa Vennam, Jung Chien, John Grant, Tejas Shah and Ralph Morris, Ramboll

Tom Moore and Mary Uhl, WESTAR

NM OAI Study Webinar

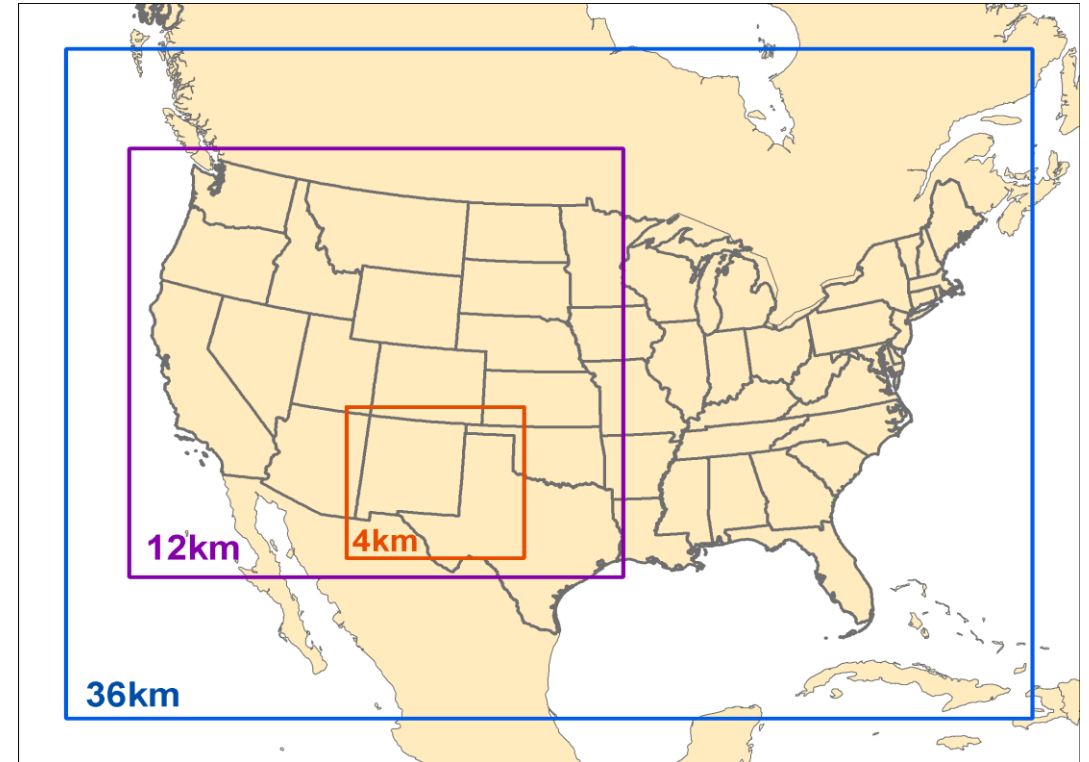
March 12, 2021

SENSITIVITY OF 2028 OZONE PROJECTIONS TO DVC & AQTSD

- 01** Summary of 2028 Base and O&G Control Strategy Ozone Design Value Projections following EPA Guidance (from Feb 24, 2021)
- 02** Sensitivity of 2028 Ozone Projections to Current Year Ozone Design Values ($DVC_{2015-2019}$ and $DV_{2017-2019}$)
- 03** Preliminary Draft Air Quality Technical Support Document (AQTSD)
- 04** Status of 2028 O&G Control Strategy Source Sector APCA Ozone Source Apportionment Modeling
- 05** Status of 2028 O&G Control Strategy VOC/NO_x Sensitivity OSAT Ozone Source Apportionment Modeling

CAMX 2014 NM OAI STUDY MODEL CONFIGURATION

- Episode: May-August 2014
 - 16-day spin-up before first high ozone day in NM
 - 68 ppb on May 17
- 36/12/4-km Modeling Domains
 - 36/12-km domains same as WRAP Regional Haze
 - New 4-km New Mexico domain
- Boundary Conditions (BC) WRAP 2014 GEOS-Chem
- Four Meteorological Diagnostic Sensitivity tests
 - Selected WRF/NAM with Kv=CMAQ
- WRAP 2014v2 base year emissions
 - EPA NEI2014v2 w/ western state updates
- WRAP 2028OTBa2 for future year w/ 2014 actual fires and new 2028 NM O&G



FUTURE YEAR OZONE DESIGN PROJECTION APPROACH

- EPA's Ozone Modeling Guidance (2018) recommends making future year ozone Design Value (DVF) projections using the relative change in modeling results between the base (2014) and future (2028) years to scale the current year ozone design value (DVC)
 - The model derived scaling factors are called Relative Response Factors (RRFs) and are the ratio of the future to current year CAMx modeling results averaged across the 10 highest modeled MDA8 ozone days > 60 ppb in the current (2014) year base case near the monitor:

$$\text{RRF} = \Sigma \text{MDA8 Ozone}_{2028} / \Sigma \text{MDA8 Ozone}_{2014}$$

$$\text{DVF} = \text{RRF} \times \text{DVC}$$

- By "near the monitor," the maximum 2014 modeled MDA8 ozone within a 3x3 array of 4-km grid cells centered on the monitor from the 2014 is used
- If there are not 10 modeled MDA8 ozone days in the 2014 base case > 60 ppb for the RRFs, then you can use less than 10 days, but EPA guidance recommends there be at least 5 days
- EPA recommends that the observed current year design value (DVC) be based on the average of 3 years of ozone DVs over 5-years centered on the base modeling year (2014):

$$\text{DVC}_{2012-2016} = 1/3 \times (\text{DV}_{2012-2014} + \text{DV}_{2013-2015} + \text{DV}_{2014-2016})$$

FUTURE YEAR OZONE DESIGN PROJECTION APPROACH

- EPA has codified their recommended future year ozone DVF projection technique in the Software for Modeled Attainment Test (SMAT)
- SMAT was applied using default settings, with one exception, and the 2014v2 and 2028 Base Case and 2028 O&G Control Strategy CAMx modeling results to obtain projected 2028 ozone DVF projections:
 - Use 3x3 array of 4-km cells centered on monitor for “near the monitor”
 - Use 10 days for RRFs with CAMx 2014 MDA8 ozone > 60 ppb
 - If less than 10 days with MDA8 ozone > 60 ppb use 4 days minimum (exception)
 - Default minimum number of days is 5, needed to relax to pick up Hobbs monitor in Lea County
 - Use current year design value based on average of 3 DVs centered on 2014
 - $DVC_{2012-2016}$
- SMAT Unmonitored Area Analysis (UAA) to obtain 2028 ozone DVF projections throughout 4-km New Mexico modeling domain
 - Recommend use spatial interpolation of monitoring site DVC without using modeled concentration gradients

PROJECTED 2028 OZONE DVFS FOLLOWING EPA GUIDANCE

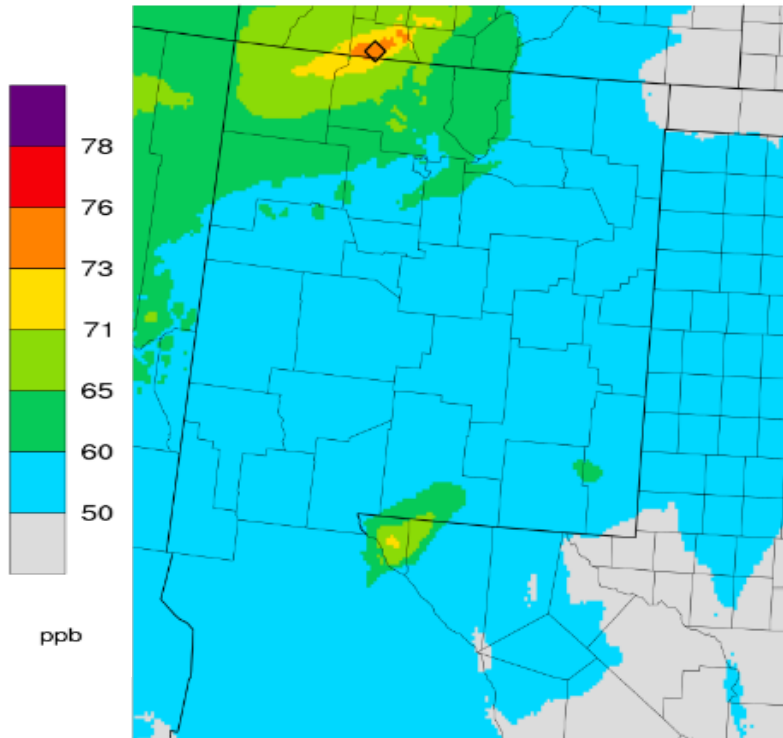
- Two sites have current year DVC₂₀₁₂₋₂₀₁₆ above the 2015 ozone NAAQS:
 - Desert View = 72.0 ppb
 - Santa Teresa = 71.3 ppb
- Using EPA guidance, all sites have 2028 ozone DVF below NAAQS
- 2028 O&G Control Strategy reduces 2028 ozone DVF by:
 - 0.3 to -1.5 ppb North NM Sites
 - 0.2 to -0.5 ppb Bernalillo County
 - 0.1 to -0.3 ppb South NM Sites

AQS_ID	2012-16	Projected 2028 DVF			Site Name	State
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base		
Northern New Mexico						
350390026	64.0	60.8	60.0	-0.8	Coyote Ranger District	NM
350431001	64.0	58.4	58.1	-0.3	Bernalillo (E Avenida)	NM
350450009	64.3	61.0	60.2	-0.8	Bloomfield	NM
350450018	67.0	64.8	63.3	-1.5	Navajo Lake	NM
350451005	63.7	60.8	59.6	-1.2	Substation	NM
350490021	64.3	60.6	60.4	-0.2	Santa Fe Airport	NM
Bernalillo County						
350010023	66.3	60.9	60.7	-0.2	Del Norte HS	NM
350010024	68.0	62.3	62.0	-0.3	South East Heights	NM
350010029	66.0	61.0	60.5	-0.5	South Valley	NM
350010032	67.0	62.6	62.1	-0.5	Westside	NM
350011012	65.0	59.1	58.8	-0.3	Foothills	NM
Southern New Mexico						
350130008	66.3	60.0	59.8	-0.2	La Union	NM
350130017	67.0	61.9	61.8	-0.1	Sunland Park City Yard	NM
350130020	67.0	62.3	62.2	-0.1	Chaparral	NM
350130021	72.0	67.0	66.8	-0.2	Desert View	NM
350130022	71.3	66.1	66.0	-0.1	Santa Teresa	NM
350130023	65.0	60.3	60.2	-0.1	Solano	NM
350151005	69.0	66.7	66.4	-0.3	Carlsbad	NM
350171003	62.0	59.0	58.9	-0.1	Chino Copper Smelter	NM
350250008	66.0	64.0	63.3	-0.7	Hobbs Jefferson	NM
350290003	66.0	62.7	62.5	-0.2	Deming Airport	NM
350610008	66.3	62.2	62.0	-0.2	Los Lunas (Los Lentos)	NM

2028 BASE AND O&G CONTROL MDA8 OZONE ON JUNE 5, 2014

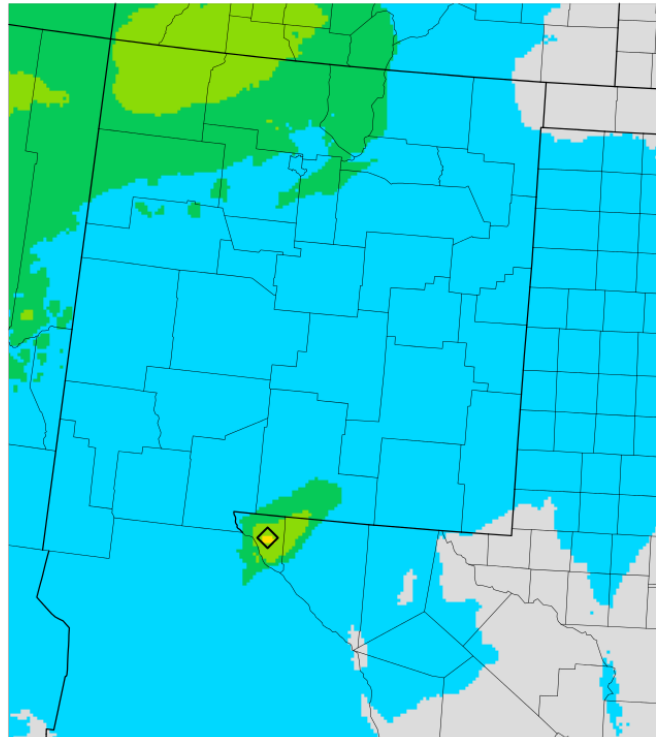
- Day with 2028 Base Case MDA8 ozone above 70 ppb 2015 ozone NAAQS in San Juan County that is reduced to below the NAAQS in 2028 O&G Control Strategy

20140605 MDA8 O3
2028Base 4km



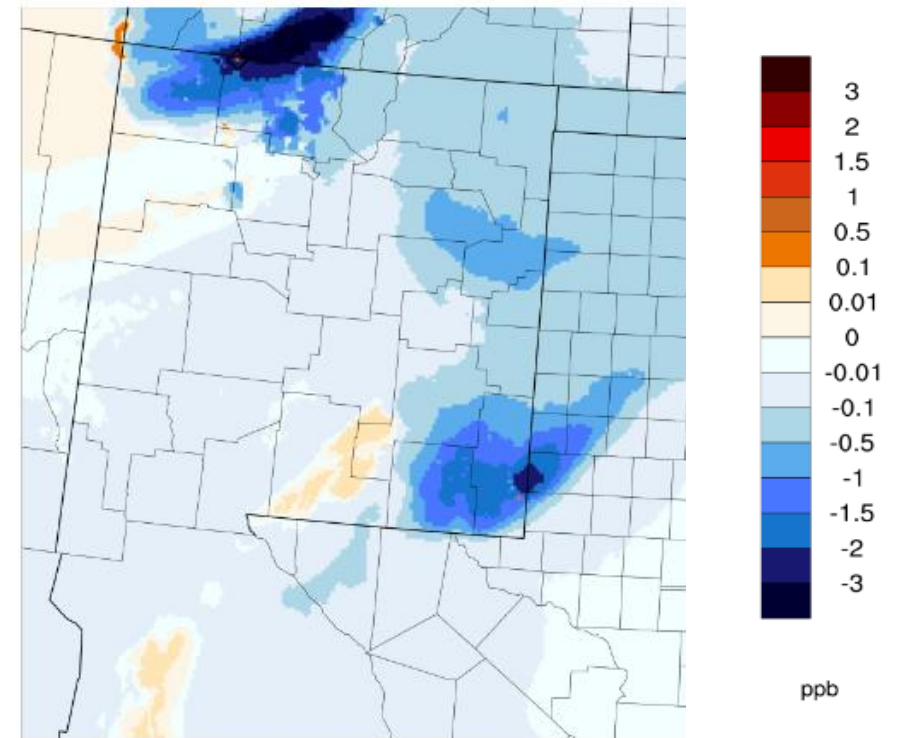
◇ max(75,211) = 74.019
○ min(242,2) = 34.028 p

20140605 MDA8 O3
2028Control 4km



◇ max(80,62) = 71.450
○ min(242,2) = 34.027 p

20140605 MDA8 O3
2028cntl_minus_2028Base 4km

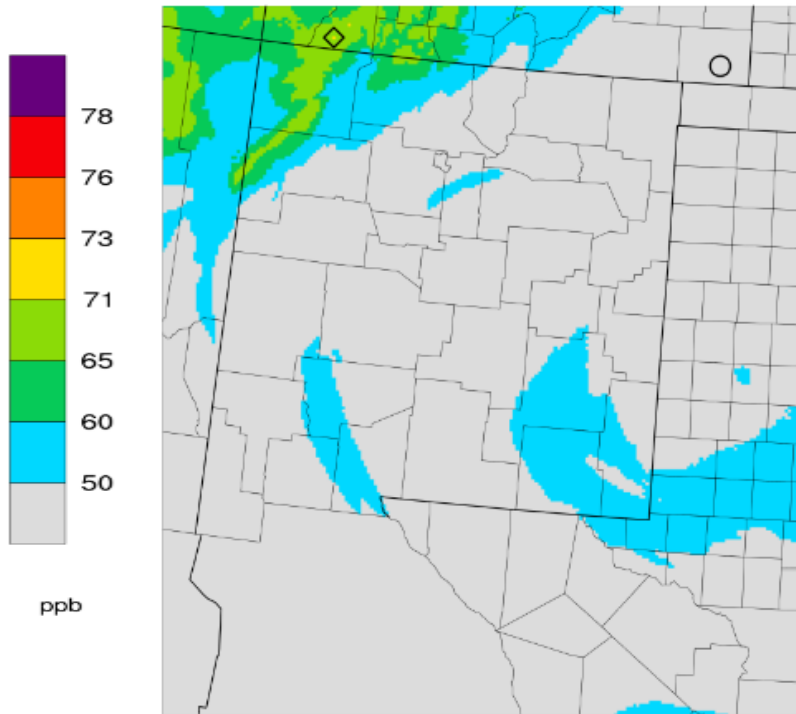


◇ max(67,209) = 0.381 p
○ min(83,215) = -4.607 p

2028 BASE AND O&G CONTROL MDA8 OZONE ON JULY 24, 2014

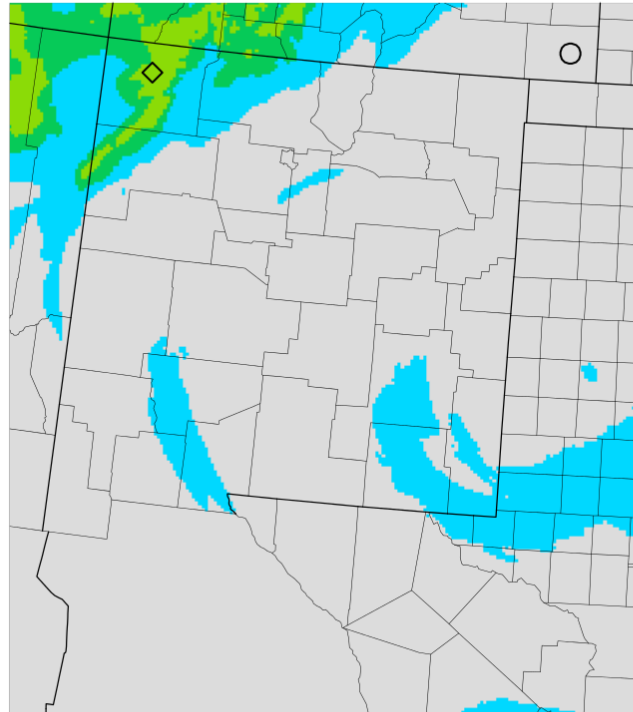
- Day in which NO_x Disbenefits due to 2028 O&G Control Strategy is sufficient to increase a single 4-km grid cell in San Juan County that was below the ozone NAAQS in 2028 Base Case to barely above (71.0 ppb) the 2015 ozone NAAQS in 2028 O&G Control Strategy

20140724 MDA8 O3
2028Base 4km



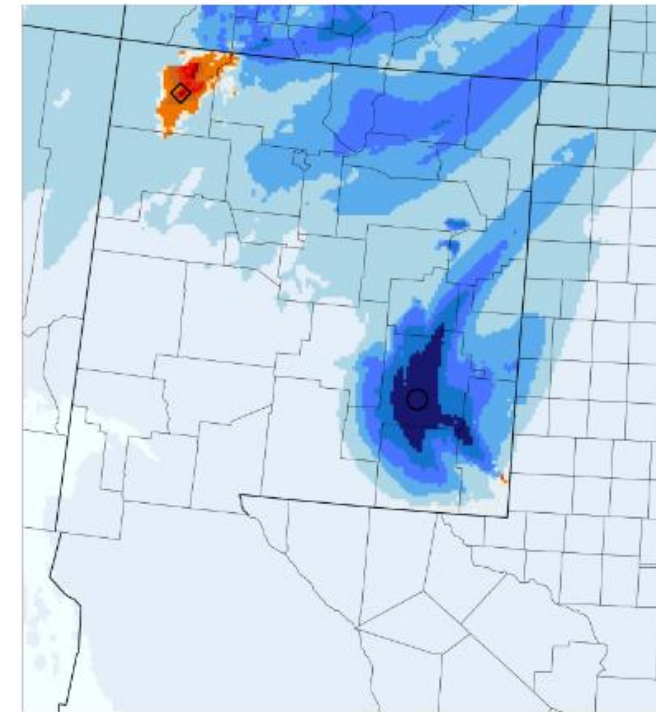
◇ max(55,215) = 71.308
○ min(177,206) = 40.912

20140724 MDA8 O3
2028Control 4km



◇ max(46,203) = 70.961
○ min(178,209) = 40.596

20140724 MDA8 O3
2028cntl_minus_2028Base 4km



◇ max(51,197) = 6.399 ppb
○ min(126,100) = -2.776 ppb

INCREASING OZONE AT NEW MEXICO SITES

Ozone Design Values 2010 to 2019

- More recent years have higher ozone DVs at some New Mexico sites:
 - Red > 75 ppb 2008 NAAQS
 - Yellow > 70 ppb 2015 NAAQS
 - Green > 67 ppb (95th percentile)
- Latest 2017-2019 ozone design value (DV₂₀₁₇₋₂₀₁₉) has 6 sites that exceed the 2015 ozone NAAQS:
 - Carlsbad = 79 ppb
 - Desert View = 77 ppb
 - Santa Teresa = 76 ppb
 - Chaparral = 73 ppb
 - Hobbs = 71 ppb
 - Foothills = 71 ppb

AQS Site ID	Local Site Name	County Name	2008-2010	2009-2011	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
350010023	Del Norte HS	Bernalillo	0.064	0.066	0.068	0.070	0.068	0.066	0.065	0.067	0.070	0.070
350010024	SE Heights	Bernalillo	0.066	0.068	0.070	0.070	0.068					
350010027	Westside	Bernalillo	0.067	0.068	0.071	0.071						
350010029	South Valley	Bernalillo	0.066	0.067	0.069	0.070	0.067	0.066	0.065	0.065	0.066	0.067
350010032	Westside	Bernalillo			0.070	0.070	0.067					
350011012	Foothills	Bernalillo	0.068	0.070	0.074	0.072	0.067	0.064	0.064	0.067	0.069	0.071
350011013	North Valley	Bernalillo	0.067	0.068	0.069	0.069						
350130008	La Union	Dona Ana	0.064	0.062	0.065	0.067	0.067	0.066	0.066	0.068	0.068	0.070
350130017	Sunland Park	Dona Ana	0.064	0.065	0.068	0.067	0.067					
350130020	Chaparral	Dona Ana	0.066	0.067	0.067	0.069	0.068	0.067	0.066	0.068	0.071	0.073
350130021	Desert View	Dona Ana	0.070	0.069	0.072	0.072	0.072	0.072	0.072	0.072	0.074	0.077
350130022	Santa Teresa	Dona Ana	0.067	0.066	0.070	0.075	0.074	0.072	0.068	0.072	0.074	0.076
350130023	Solano	Dona Ana	0.063	0.063	0.065	0.065	0.065	0.065	0.065	0.066	0.067	0.070
350151005	Carlsbad City	Eddy	0.067	0.068	0.071	0.071	0.071	0.069	0.067	0.068	0.074	0.079
350153001	Carlsbad Caverns	Eddy									0.071	
350171003	Chino Copper	Grant	0.063	0.065	0.067	0.063	0.062					
350250008	Hobbs Jefferson	Lea	0.059	0.061	0.061	0.066	0.065	0.067	0.066	0.067	0.070	0.071
350290003	Deming Airport	Luna	0.057	0.058	0.064	0.067	0.066					
350390026	Coyote Ranger District	Rio Arriba							0.064	0.065	0.067	0.067
350431001	Bernalillo Pueblo Of Jemez	Sandoval	0.060	0.061	0.061	0.063	0.063	0.065	0.064	0.065	0.068	0.068
350439004		Sandoval		0.062								
350450009	Bloomfield	San Juan	0.060	0.061	0.067	0.068	0.067	0.064	0.062	0.064	0.069	0.068
350450018	Navajo Lake	San Juan			0.071	0.071	0.068	0.067	0.066	0.068	0.070	0.069
350451005	Substation	San Juan	0.063	0.063	0.067	0.068	0.066	0.063	0.062	0.064	0.069	0.069
350490021	Santa Fe Airport	Santa Fe	0.063	0.062	0.065	0.066	0.066	0.064	0.063	0.063	0.066	0.066
350610008	Los Lunas	Valencia			0.067	0.070	0.069	0.066	0.064	0.065	0.067	0.068

2028 OZONE PROJECTIONS SENSITIVITY ANALYSIS TO DVC

- Given increased ozone concentrations in more recent years, a sensitivity analysis of the 2028 ozone projections to current year ozone design value (DVC) starting point for the projections was conducted
- 2028 ozone DVF projection sensitivity analysis was conducted using two alternative definitions of current year design value (DVC):
 - $DVC_{2015-2019} = (DV_{2015-2017} + DV_{2016-2018} + DV_{2017-2019}) / 3$
 - Consistent with EPA guidance to use average of 3-years of ozone DVs for DVC to modulate year-to-year variability, but centered on 2017 instead of 2014
 - $DV_{2017-2019}$ (the latest design value based on validated data)
- Still using CAMx 2014v2 and 2028 modeling results, so not accounting for changes in emissions from 2014 to 2017-2019 in 2028 ozone projections:
 - Where emissions went down (e.g., mobile source dominated), may understate 2028 ozone DVFs
 - Where emissions went up (e.g., Permian Basin O&G), may overstate 2028 ozone DVFs

2028 OZONE DVF SENSITIVITY TO DVC USING DVC₂₀₁₅₋₂₀₁₉

- Four monitoring sites have 2015-2019 current year DVC₂₀₁₅₋₂₀₁₉ greater than the 2015 ozone NAAQS:
 - Desert View = 74.3 ppb
 - Santa Teresa = 74.0 ppb
 - Carlsbad = 73.7 ppb
 - Carlsbad NP* = 71.0 ppb
- 2028 Base Case has one site with 2028 ozone DVF > NAAQS using DVC₂₀₁₅₋₂₀₁₉:
 - Carlsbad = 71.2 ppb
- 2028 O&G Control Strategy sufficient that all 2028 ozone DVFs are below the NAAQS when using DVC₂₀₁₅₋₂₀₁₉:
 - Carlsbad = 70.9 ppb

AQS_ID	2015-19	Projected 2028 DVF			Site Name	County
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base		
350010023	69.0	63.4	63.1	-0.3	Del Norte HS	Bernalillo
350010029	66.0	61.0	60.5	-0.5	South Valley	Bernalillo
350011012	69.0	62.7	62.4	-0.3	Foothills	Bernalillo
350130008	68.7	62.1	62.0	-0.1	La Union	Dona Ana
350130020	70.7	65.7	65.7	0.0	Chaparral	Dona Ana
350130021	74.3	69.1	68.9	-0.2	Desert View	Dona Ana
350130022	74.0	68.6	68.5	-0.1	Santa Teresa	Dona Ana
350130023	67.7	62.9	62.7	-0.2	Solano	Dona Ana
350151005	73.7	71.2	70.9	-0.3	Carlsbad	Eddy
350153001	71.0	69.3	69.3	0.0	Carlsbad Caverns NP	Eddy
350250008	69.3	67.2	66.5	-0.7	Hobbs Jefferson	Lea
350390026	66.3	63.0	62.2	-0.8	Coyote Ranger Dist	Rio Arriba
350431001	67.0	61.2	60.9	-0.3	Bernalillo (E Avenida)	Sandoval
350450009	67.0	63.6	62.8	-0.8	Bloomfield	San Juan
350450018	69.0	66.7	65.2	-1.5	Navajo Lake	San Juan
350451005	67.3	64.2	62.9	-1.3	Substation	San Juan
350490021	65.0	61.2	61.0	-0.2	Santa Fe Airport	Santa Fe
350610008	66.7	62.6	62.3	-0.3	Los Lunas (Los Lentes)	Valencia

2028 OZONE DVF SENSITIVITY TO DVC USING DV₂₀₁₇₋₂₀₁₉

- Six monitoring sites have DV₂₀₁₇₋₂₀₁₉ greater than the 2015 ozone NAAQS:
 - Carlsbad = 79.0 ppb
 - Desert View = 77.0 ppb
 - Santa Teresa = 76.0 ppb
 - Chaparral = 73.0 ppb
 - Hobbs = 71.0 ppb
 - Foothills = 71.0 ppb
- 2028 Base Case two sites DVF > NAAQS:
 - Carlsbad = 76.4 ppb
 - Desert View = 71.6 ppb
- 2028 O&G Control, both DVF > NAAQS:
 - Carlsbad = 76.0 ppb
 - Desert View = 71.4 ppb

AQS_ID	2017-19	Projected 2028 DVF			Site Name	County
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base		
350010023	70.0	64.3	64.0	-0.3	Del Norte HS	Bernalillo
350010029	67.0	61.9	61.4	-0.5	South Valley	Bernalillo
350011012	71.0	64.5	64.2	-0.3	Foothills	Bernalillo
350130008	70.0	63.3	63.2	-0.1	La Union	Dona Ana
350130020	73.0	67.8	67.8	0.0	Chaparral	Dona Ana
350130021	77.0	71.6	71.4	-0.2	Desert View	Dona Ana
350130022	76.0	70.5	70.3	-0.2	Santa Teresa	Dona Ana
350130023	70.0	65.0	64.8	-0.2	Solano	Dona Ana
350151005	79.0	76.4	76.0	-0.4	Carlsbad	Eddy
350250008	71.0	68.9	68.1	-0.8	Hobbs Jefferson	Lea
350390026	67.0	63.6	62.8	-0.8	Coyote Ranger Dist	Rio Arriba
350431001	68.0	62.1	61.8	-0.3	Bernalillo (E Avenida)	Sandoval
350450009	68.0	64.6	63.7	-0.9	Bloomfield	San Juan
350450018	69.0	66.7	65.2	-1.5	Navajo Lake	San Juan
350451005	69.0	65.8	64.5	-1.3	Substation	San Juan
350490021	66.0	62.2	62.0	-0.2	Santa Fe Airport	Santa Fe
350610008	68.0	63.8	63.5	-0.3	Los Lunas (Los Lentos)	Valencia

PRELIMINARY DRAFT AQTSD

1. Introduction
 2. 2014 WRF Meteorological Modeling
 3. Boundary Condition Inputs
 4. 2014 Emission Inputs
 5. Diagnostic Sensitivity Tests
 6. 2014 Base Case Modeling and Model Performance Evaluation
 7. 2028 Base Case Modeling and Ozone Design Value Projections
 8. 2028 Oil and Gas Control Strategy Modeling and Ozone Design Value Projections
 9. Sensitivity of 2028 Ozone Design Value Projections to Current Year Design Values
 10. Summary and Conclusions
 11. References
- To Come:
10. APCA Source Sector Ozone Source Apportionment Modeling
 11. OSAT VOC/NOx Sensitivity Ozone Source Apportionment Modeling

CAMX 2028 O&G CS APCA OZONE SOURCE APPORTIONMENT

• Definition of Source Groups

○ Boundary Conditions (BCs) from 2014 GEOS-Chem runs:

- BC_{Intl} - International anthropogenic emissions
- BC_{USA} - U.S. anthropogenic emissions
- $BC_{Natural}$ - Natural sources
- BC_{Top} - BC above the top of domain

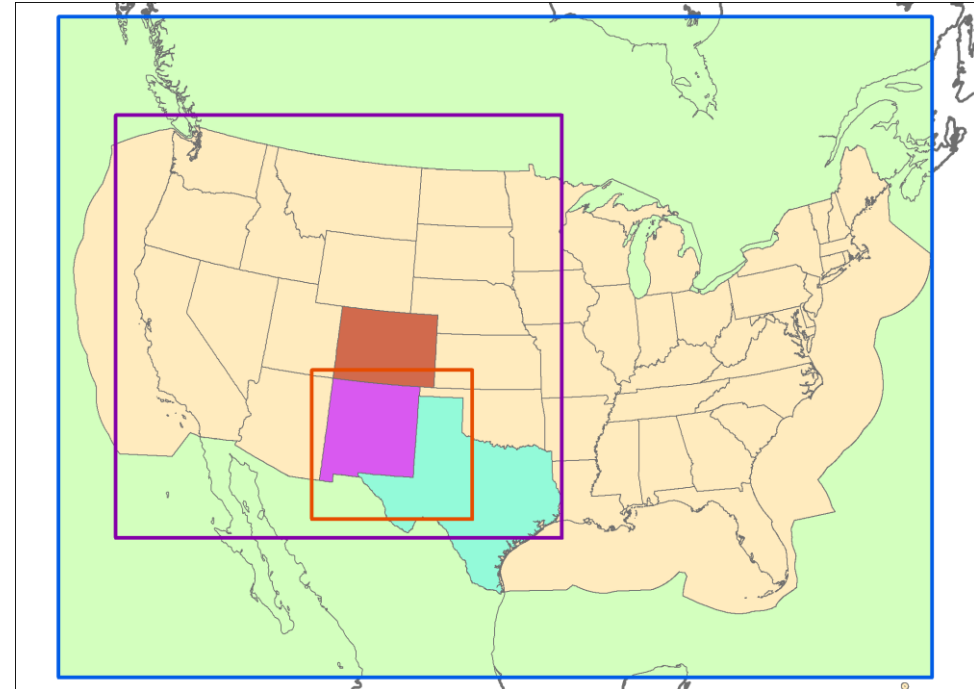
○ Source Categories (9):

1. Natural (biogenic, lightning NO_x, etc.);
2. Fires (WF, Rx, Ag, other);
3. Oil and gas point sources (surrogate for midstream);
4. Oil and gas non-point sources (surrogate for upstream);
5. EGU point;
6. Non-EGU point;
7. On-road mobile;
8. Non-road mobile; and
9. Remainder anthropogenic.

○ Source Regions (5):

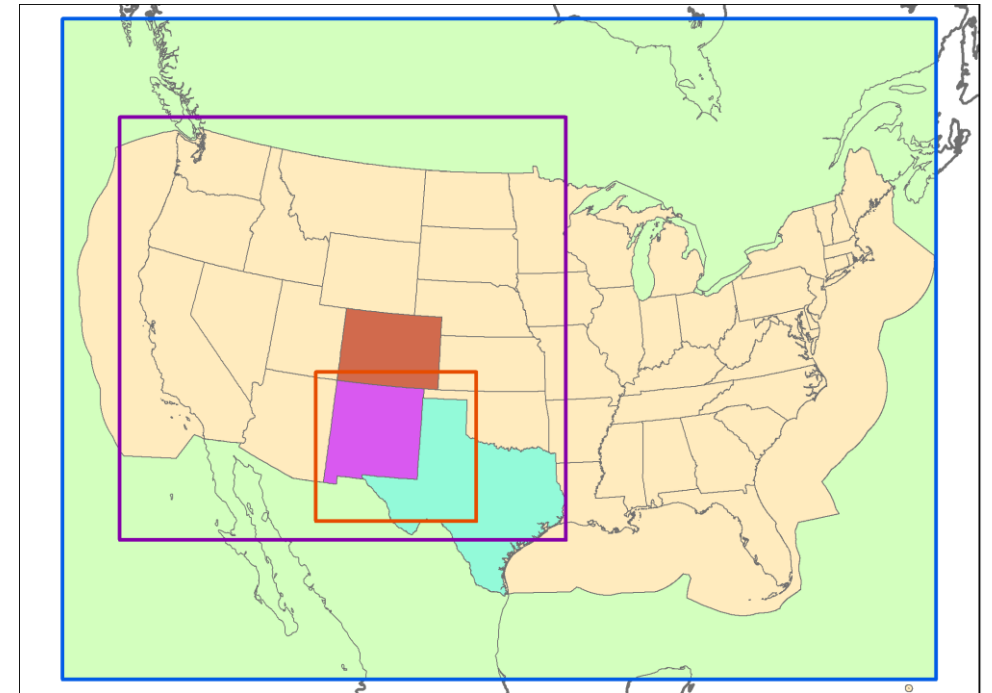
- New Mexico
- Texas
- Colorado
- Remainder U.S.
- International (Mex, Can, CMV > 200 nmi)

○ 50 Source Groups ($50 = 5 \times 9 + 5$)



CAMX 2028 O&G CS OSAT OZONE SOURCE APPORTIONMENT

- Use the OSAT version of CAMx ozone source apportionment tool
 - OSAT O3V and O3N tracers give indication of amount of VOC-limited and NOx-limited ozone formation
- Definition of Source Groups
 - Source Regions (5):
 - Use same 5 Source Regions as APCA SA run
 - Source Categories (3):
 - Anthropogenic Emissions
 - Natural (Biogenic, lightning NOx, WBD, oceanic)
 - Fires (WF, Rx, Ag and other)
 - 17 Source Groups (5 x 3 + 2 [IC,BC])
 - Will run faster than CAMx APCA SA Run (50 Source Groups)



Start March 12, 2021

NEW MEXICO OZONE ATTAINMENT INITIATIVE

2028 Source Sector APCA Ozone Source Apportionment Modeling and Revised Draft Air Quality Technical Support Document

Marco Rodriguez, Pradeepa Vennam, Jung Chien, John Grant, Tejas Shah and Ralph Morris, Ramboll

Tom Moore and Mary Uhl, WESTAR

NM OAI Study Webinar

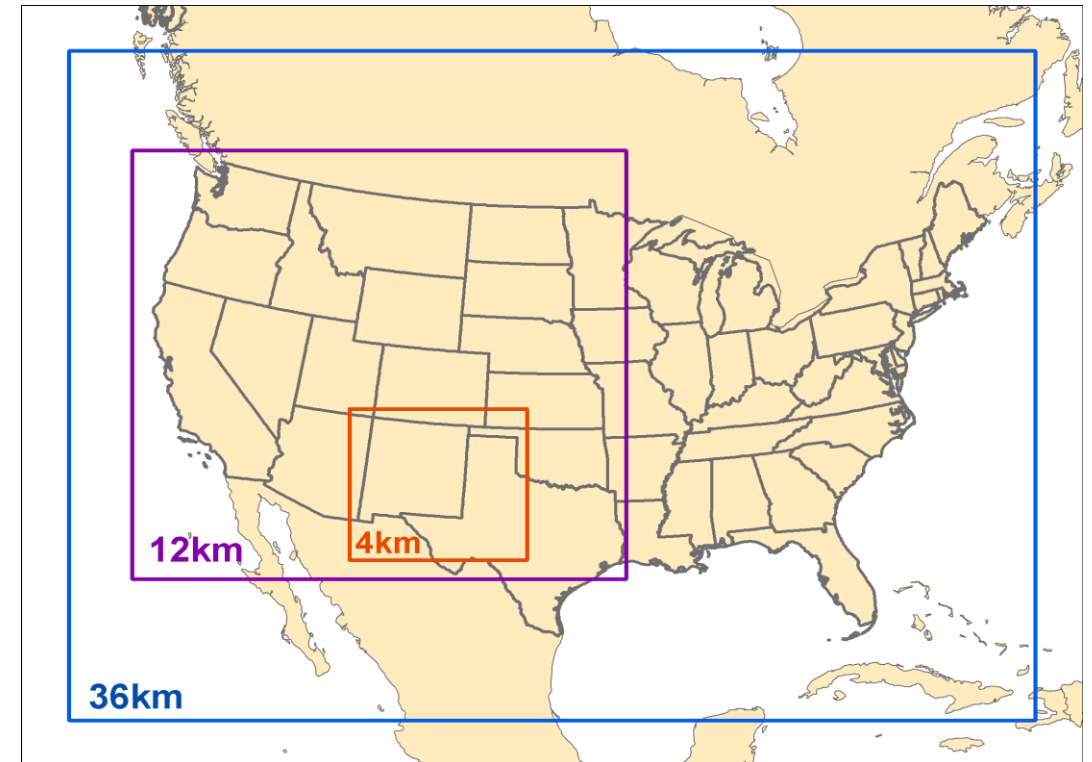
April 2, 2021

2028 SOURCE SECTOR APCA OZONE SOURCE APPORTIONMENT

- 01** Summary of 2028 Ozone Design Value Projections Following EPA Guidance and Sensitivity Analysis to Current Year DVC
- 02** 2028 O&G CS Source Sector APCA Ozone Source Apportionment Modeling Results
- 03** Second Draft Air Quality Technical Support Document (AQTSD)
- 04** Status of 2028 OSAT VOC/NO_x Formation Sensitivity Ozone Source Apportionment Modeling

CAMX 2014 NM OAI STUDY MODEL CONFIGURATION

- Episode: May-August 2014
 - 16-day spin-up before first high ozone day in NM
 - 68 ppb on May 17
- 36/12/4-km Modeling Domains
 - 36/12-km domains same as WRAP Regional Haze
 - New 4-km New Mexico domain
- Boundary Conditions (BC) WRAP 2014 GEOS-Chem
- Four Meteorological Diagnostic Sensitivity tests
 - Selected WRF/NAM with Kv=CMAQ
- WRAP 2014v2 base year emissions
 - EPA NEI2014v2 w/ western state updates
- WRAP 2028OTBa2 for future year w/ 2014 actual fires and new 2028 NM O&G



PROJECTED 2028 OZONE DVFS FOLLOWING EPA GUIDANCE

- Future Year 2028 ozone design value (DVF) projections following EPA guidance using 2012-2016 DVC:
 - $2028 \text{ DVF} = \text{RRF} \times \text{DVC}_{2012-2016}$
- Two sites have current year $\text{DVC}_{2012-2016}$ above the 2015 ozone NAAQS:
 - Desert View = 72.0 ppb
 - Santa Teresa = 71.3 ppb
- Using EPA guidance, all sites have 2028 ozone DVF below NAAQS for both 2028 Base and 2028 O&G Control Strategy:
 - Desert View = 67.0 and 66.8 ppb
 - Santa Teresa = 66.1 and 66.0 ppb

AQS_ID	2012-16	Projected 2028 DVF			Site Name	State
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base		
Northern New Mexico						
350390026	64.0	60.8	60.0	-0.8	Coyote Ranger District	NM
350431001	64.0	58.4	58.1	-0.3	Bernalillo (E Avenida)	NM
350450009	64.3	61.0	60.2	-0.8	Bloomfield	NM
350450018	67.0	64.8	63.3	-1.5	Navajo Lake	NM
350451005	63.7	60.8	59.6	-1.2	Substation	NM
350490021	64.3	60.6	60.4	-0.2	Santa Fe Airport	NM
Bernalillo County						
350010023	66.3	60.9	60.7	-0.2	Del Norte HS	NM
350010024	68.0	62.3	62.0	-0.3	South East Heights	NM
350010029	66.0	61.0	60.5	-0.5	South Valley	NM
350010032	67.0	62.6	62.1	-0.5	Westside	NM
350011012	65.0	59.1	58.8	-0.3	Foothills	NM
Southern New Mexico						
350130008	66.3	60.0	59.8	-0.2	La Union	NM
350130017	67.0	61.9	61.8	-0.1	Sunland Park City Yard	NM
350130020	67.0	62.3	62.2	-0.1	Chaparral	NM
350130021	72.0	67.0	66.8	-0.2	Desert View	NM
350130022	71.3	66.1	66.0	-0.1	Santa Teresa	NM
350130023	65.0	60.3	60.2	-0.1	Solano	NM
350151005	69.0	66.7	66.4	-0.3	Carlsbad	NM
350171003	62.0	59.0	58.9	-0.1	Chino Copper Smelter	NM
350250008	66.0	64.0	63.3	-0.7	Hobbs Jefferson	NM
350290003	66.0	62.7	62.5	-0.2	Deming Airport	NM
350610008	66.3	62.2	62.0	-0.2	Los Lunas (Los Lentos)	NM

INCREASING OZONE AT NEW MEXICO SITES

Ozone Design Values 2010 to 2019

- More recent years have higher ozone DVs at some New Mexico sites:
 - Red > 75 ppb 2008 NAAQS
 - Yellow > 70 ppb 2015 NAAQS
 - Green > 67 ppb (95th percentile)
- Latest 2017-2019 ozone design value (DV₂₀₁₇₋₂₀₁₉) has 6 sites that exceed the 2015 ozone NAAQS
- Conducted sensitivity analysis of 2028 ozone DVF projections to current year DVC
 - DVC₂₀₁₅₋₂₀₁₉
 - DVC₂₀₁₇₋₂₀₁₉

AQS Site ID	Local Site Name	County Name	2008-2010	2009-2011	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
350010023	Del Norte HS	Bernalillo	0.064	0.066	0.068	0.070	0.068	0.066	0.065	0.067	0.070	0.070
350010024	SE Heights	Bernalillo	0.066	0.068	0.070	0.070	0.068					
350010027	Westside	Bernalillo	0.067	0.068	0.071	0.071						
350010029	South Valley	Bernalillo	0.066	0.067	0.069	0.070	0.067	0.066	0.065	0.065	0.066	0.067
350010032	Westside	Bernalillo			0.070	0.070	0.067					
350011012	Foothills	Bernalillo	0.068	0.070	0.074	0.072	0.067	0.064	0.064	0.067	0.069	0.071
350011013	North Valley	Bernalillo	0.067	0.068	0.069	0.069						
350130008	La Union	Dona Ana	0.064	0.062	0.065	0.067	0.067	0.066	0.066	0.068	0.068	0.070
350130017	Sunland Park	Dona Ana	0.064	0.065	0.068	0.067	0.067					
350130020	Chaparral	Dona Ana	0.066	0.067	0.067	0.069	0.068	0.067	0.066	0.068	0.071	0.073
350130021	Desert View	Dona Ana	0.070	0.069	0.072	0.072	0.072	0.072	0.072	0.072	0.074	0.077
350130022	Santa Teresa	Dona Ana	0.067	0.066	0.070	0.075	0.074	0.072	0.068	0.072	0.074	0.076
350130023	Solano	Dona Ana	0.063	0.063	0.065	0.065	0.065	0.065	0.065	0.066	0.067	0.070
350151005	Carlsbad City	Eddy	0.067	0.068	0.071	0.071	0.071	0.069	0.067	0.068	0.074	0.079
350153001	Carlsbad Caverns	Eddy									0.071	
350171003	Chino Copper	Grant	0.063	0.065	0.067	0.063	0.062					
350250008	Hobbs Jefferson	Lea	0.059	0.061	0.061	0.066	0.065	0.067	0.066	0.067	0.070	0.071
350290003	Deming Airport	Luna	0.057	0.058	0.064	0.067	0.066					
350390026	Coyote Ranger District	Rio Arriba							0.064	0.065	0.067	0.067
350431001	Bernalillo Pueblo Of Jemez	Sandoval	0.060	0.061	0.061	0.063	0.063	0.065	0.064	0.065	0.068	0.068
350439004		Sandoval		0.062								
350450009	Bloomfield	San Juan	0.060	0.061	0.067	0.068	0.067	0.064	0.062	0.064	0.069	0.068
350450018	Navajo Lake	San Juan			0.071	0.071	0.068	0.067	0.066	0.068	0.070	0.069
350451005	Substation Santa Fe	San Juan	0.063	0.063	0.067	0.068	0.066	0.063	0.062	0.064	0.069	0.069
350490021	Airport	Santa Fe	0.063	0.062	0.065	0.066	0.066	0.064	0.063	0.063	0.066	0.066
350610008	Los Lunas	Valencia			0.067	0.070	0.069	0.066	0.064	0.065	0.067	0.068

2028 OZONE DVF SENSITIVITY TO DVC₂₀₁₅₋₂₀₁₉ AND DVC₂₀₁₇₋₂₀₁₉

AQS_ID	2015-19	Projected 2028 DVF			Site Name	County
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base		
350010023	69.0	63.4	63.1	-0.3	Del Norte HS	Bernalillo
350010029	66.0	61.0	60.5	-0.5	South Valley	Bernalillo
350011012	69.0	62.7	62.4	-0.3	Foothills	Bernalillo
350130008	68.7	62.1	62.0	-0.1	La Union	Dona Ana
350130020	70.7	65.7	65.7	0.0	Chaparral	Dona Ana
350130021	74.3	69.1	68.9	-0.2	Desert View	Dona Ana
350130022	74.0	68.6	68.5	-0.1	Santa Teresa	Dona Ana
350130023	67.7	62.9	62.7	-0.2	Solano	Dona Ana
350151005	73.7	71.2	70.9	-0.3	Carlsbad	Eddy
350153001	71.0	69.3	69.3	0.0	Carlsbad Caverns NP	Eddy
350250008	69.3	67.2	66.5	-0.7	Hobbs Jefferson	Lea
350390026	66.3	63.0	62.2	-0.8	Coyote Ranger Dist	Rio Arriba
350431001	67.0	61.2	60.9	-0.3	Bernalillo (E Avenida)	Sandoval
350450009	67.0	63.6	62.8	-0.8	Bloomfield	San Juan
350450018	69.0	66.7	65.2	-1.5	Navajo Lake	San Juan
350451005	67.3	64.2	62.9	-1.3	Substation	San Juan
350490021	65.0	61.2	61.0	-0.2	Santa Fe Airport	Santa Fe
350610008	66.7	62.6	62.3	-0.3	Los Lunas (Los Lentos)	Valencia

AQS_ID	2017-19	Projected 2028 DVF			Site Name
	DVC (ppb)	Base (ppb)	Cntl (ppb)	Cntl - Base	
350010023	70.0	64.3	64.0	-0.3	Del Norte HS
350010029	67.0	61.9	61.4	-0.5	South Valley
350011012	71.0	64.5	64.2	-0.3	Foothills
350130008	70.0	63.3	63.2	-0.1	La Union
350130020	73.0	67.8	67.8	0.0	Chaparral
350130021	77.0	71.6	71.4	-0.2	Desert View
350130022	76.0	70.5	70.3	-0.2	Santa Teresa
350130023	70.0	65.0	64.8	-0.2	Solano
350151005	79.0	76.4	76.0	-0.4	Carlsbad
350250008	71.0	68.9	68.1	-0.8	Hobbs Jefferson
350390026	67.0	63.6	62.8	-0.8	Coyote Ranger Dist
350431001	68.0	62.1	61.8	-0.3	Bernalillo (E Avenida)
350450009	68.0	64.6	63.7	-0.9	Bloomfield
350450018	69.0	66.7	65.2	-1.5	Navajo Lake
350451005	69.0	65.8	64.5	-1.3	Substation
350490021	66.0	62.2	62.0	-0.2	Santa Fe Airport
350610008	68.0	63.8	63.5	-0.3	Los Lunas (Los Lentos)

CAMX 2028 O&G CS SOURCE SECTOR APCA OZONE SA

• Definition of Source Groups

○ Boundary Conditions (BCs) from WRAP 2014 GEOS-Chem runs:

- BC_{Intl} - International anthropogenic emissions
- BC_{USA} - U.S. anthropogenic emissions
- $BC_{Natural}$ - Natural sources
- BC_{Top} - BC above the top of domain

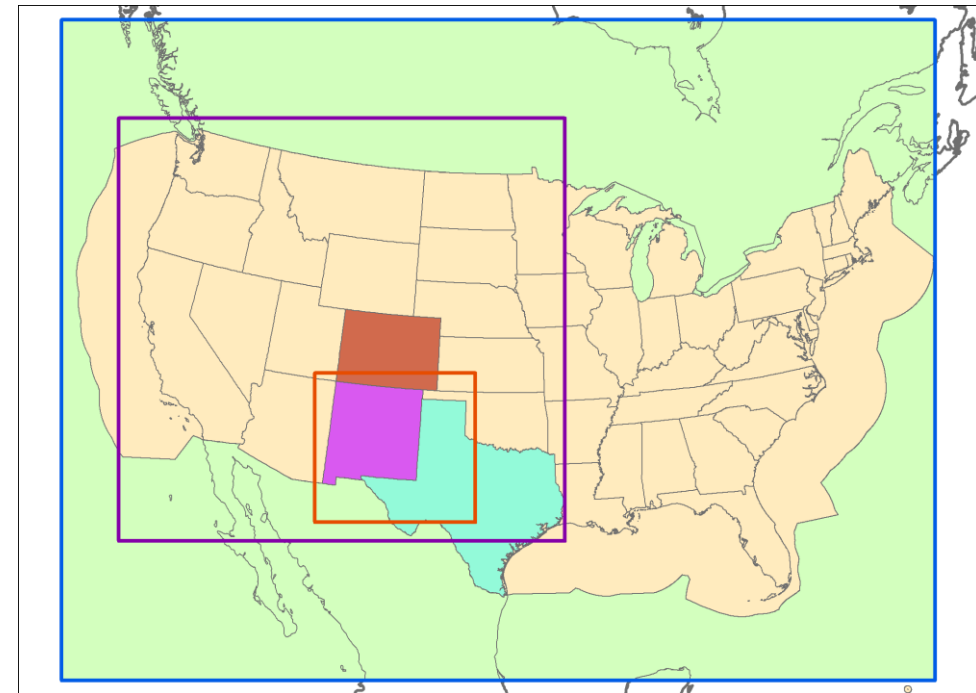
○ Source Categories (9):

1. Natural (biogenic, lightning NO_x, etc.);
2. Fires (WF, Rx, Ag, other);
3. Oil and gas point sources (surrogate for midstream);
4. Oil and gas non-point sources (surrogate for upstream);
5. EGU point;
6. Non-EGU point;
7. On-road mobile;
8. Non-road mobile; and
9. Remainder anthropogenic.

○ Source Regions (5):

- New Mexico
- Texas
- Colorado
- Remainder U.S.
- International (Mex, Can, CMV > 200 nmi)

○ 50 Source Groups ($50 = 5 \times 9 + 5$)



SOURCE SECTOR CONTRIBUTIONS TO 2028 OZONE DVFS

- 1. NEW MEXICO SOURCE SECTOR CONTRIBUTIONS TO 2028 OZONE DVF AT MONITORS**
- 2. SPATIAL DISTRIBUTION OF NEW MEXICO SOURCE SECTOR CONTRIBUTIONS TO 2028 DVFS**
- 3. UNITED STATES SOURCE SECTOR CONTRIBUTIONS TO 2028 OZONE DVF AT MONITORS**

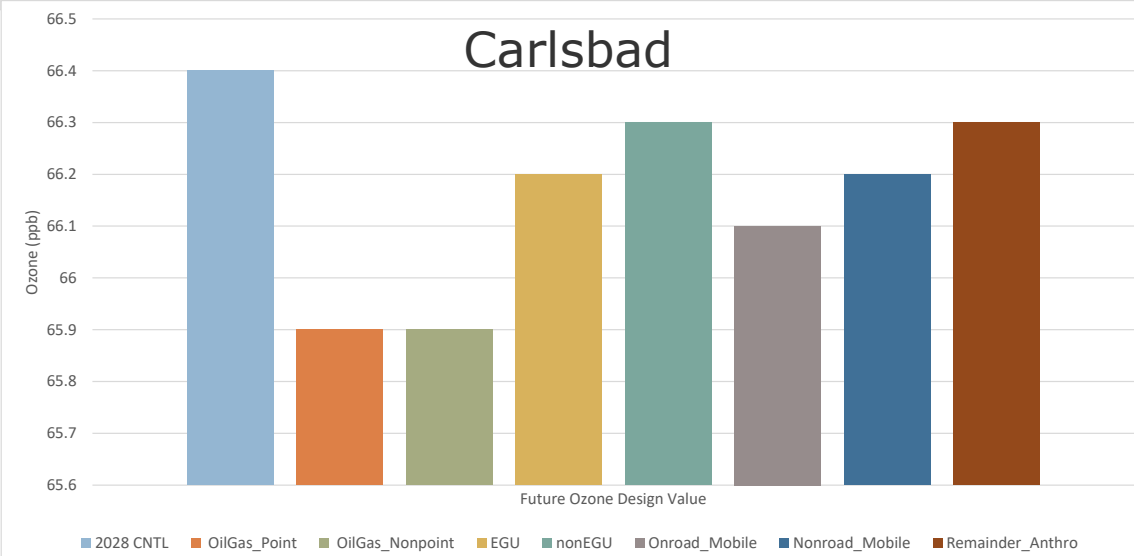
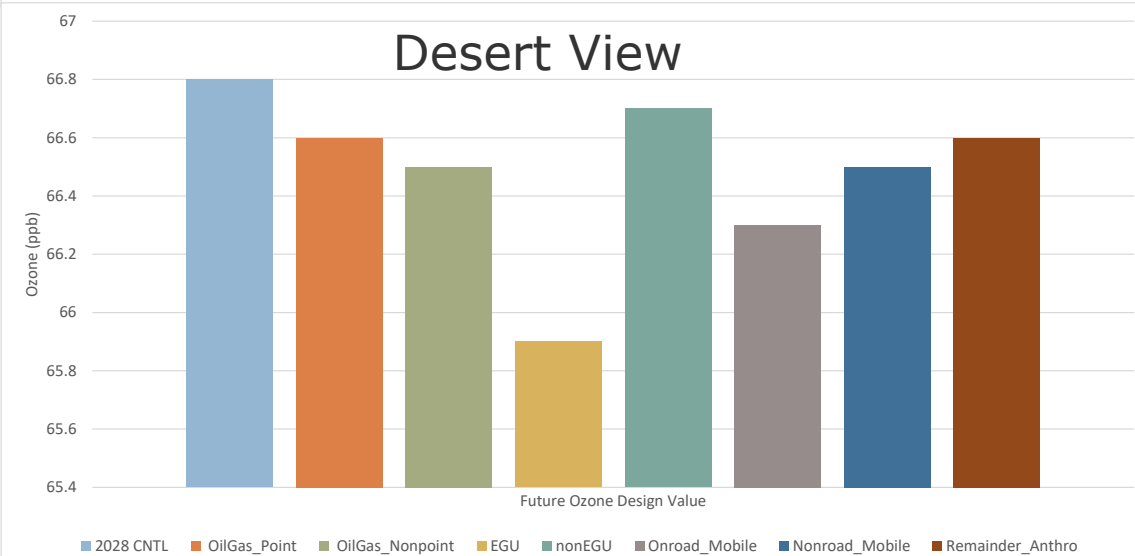
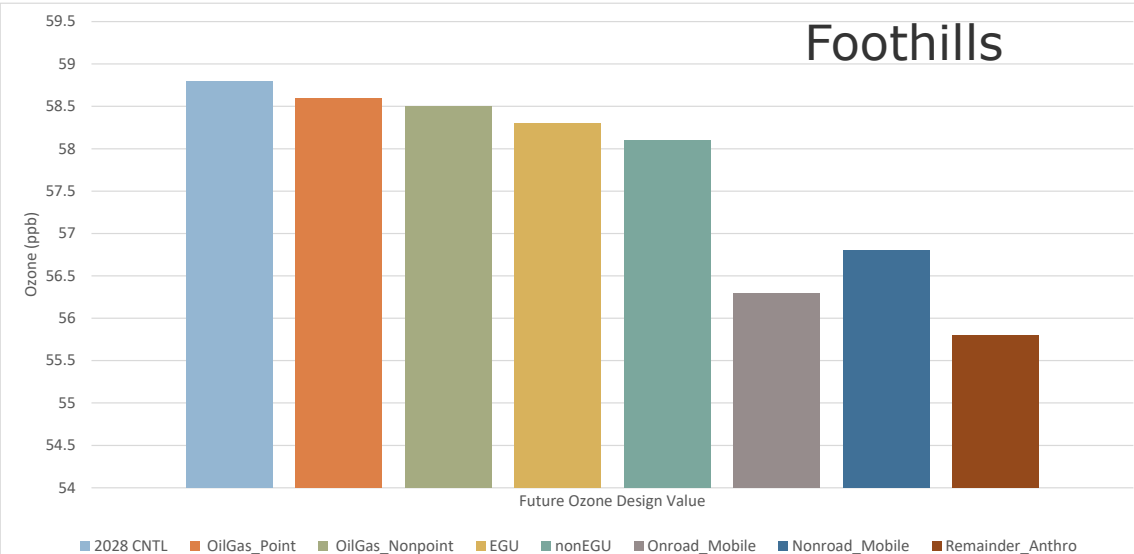
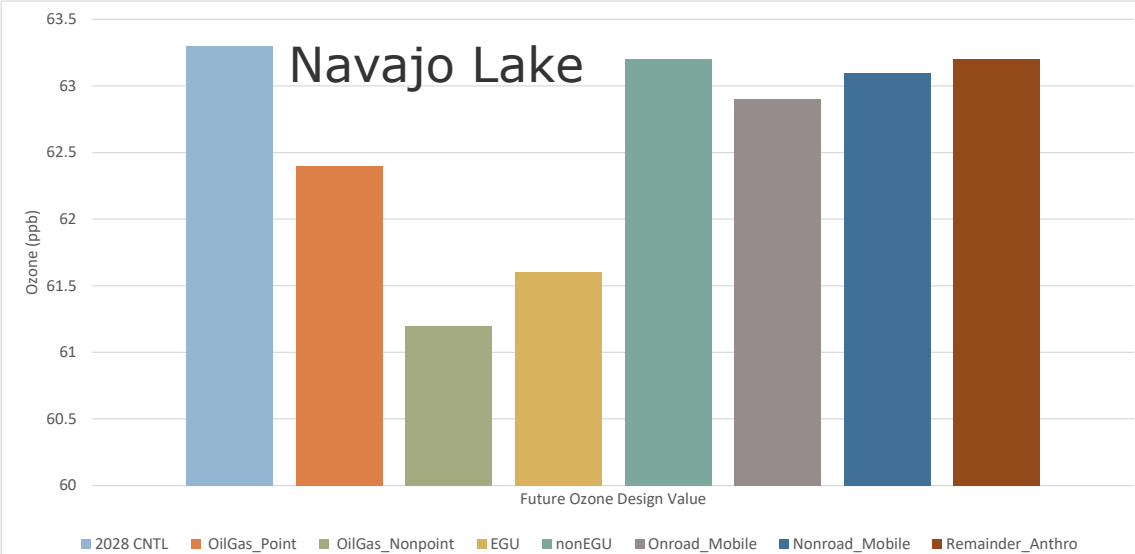
REDUCTIONS 2028 OZONE DVFS NEW MEXICO SOURCE SECTORS

- 2028 ozone DVF Reductions from New Mexico Source Sectors
 - O&G Point: -0.1 to -0.9 ppb
 - O&G Non-Pt: -0.1 to -2.1 ppb
 - EGU Point: 0.0 to -3.1 ppb
 - Non-EGU Pt: 0.0 to -1.1 ppb
 - On-Road: -0.1 to -2.7 ppb
 - Non-Road: -0.1 to -1.9 ppb
 - Other Anthro: 0.0 to -3.6 ppb

AQS_ID	Site_ID	DVC	DVF	O&GPT	O&GNP	EGU	NonEGU	OnRoad	NonRoad	OAnth
350010023	NORTE	66.3	60.7	-0.2	-0.3	-0.5	-1.0	-2.7	-2.0	-3.6
350010024	SEHGS	68.0	62.0	-0.2	-0.3	-0.5	-1.1	-2.5	-1.9	-3.2
350010029	STHVA	66.0	60.5	-0.3	-0.5	-0.5	-1.0	-2.2	-1.7	-2.4
350010032	WSTSD	67.0	62.1	-0.2	-0.4	-0.4	-0.4	-1.6	-1.2	-1.8
350011012	FTHIL	65.0	58.8	-0.2	-0.3	-0.5	-0.7	-2.5	-2.0	-3.0
350130008	UNION	66.3	59.8	-0.2	-0.2	-0.7	0.0	-0.5	-0.3	-0.1
350130017	SPARK	67.0	61.8	-0.2	-0.2	-0.9	0.0	-0.4	-0.2	-0.2
350130020	CHAPA	67.0	62.2	-0.1	-0.1	-0.3	0.0	-0.2	-0.1	-0.1
350130021	DSVIE	72.0	66.8	-0.2	-0.3	-0.9	-0.1	-0.5	-0.3	-0.2
350130022	TERES	71.3	66.0	-0.3	-0.3	-0.7	-0.1	-0.5	-0.3	-0.2
350130023	SOLAN	65.0	60.2	-0.2	-0.2	-0.2	-0.2	-1.2	-0.7	-0.3
350151005	CARLS	69.0	66.4	-0.5	-0.5	-0.2	-0.1	-0.3	-0.2	-0.1
350171003	GRANT	62.0	58.9	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
350250008	HOBBS	66.0	63.3	-0.9	-1.1	-0.2	0.0	-0.3	-0.2	-0.1
350290003	DEAIR	66.0	62.5	-0.2	-0.1	-0.2	0.0	-0.6	-0.4	0.0
350390026	COYOT	64.0	60.0	-0.2	-0.5	-0.5	0.0	-0.2	-0.1	0.0
350431001	BERNA	64.0	58.1	-0.1	-0.2	-0.4	-0.4	-2.1	-1.5	-1.9
350450009	BLOOM	64.3	60.2	-0.7	-1.4	-1.9	0.0	-0.4	-0.1	-0.1
350450018	NAVAJ	67.0	63.3	-0.9	-2.1	-1.7	-0.1	-0.4	-0.2	-0.1
350451005	SUBST	63.7	59.6	-0.6	-1.5	-3.1	-0.1	-0.5	-0.2	-0.2
350490021	SNTFE	64.3	60.4	-0.2	-0.3	-0.2	-0.3	-1.2	-0.7	-0.8
350610008	LUNAS	66.3	62.0	-0.2	-0.3	-0.3	-0.3	-1.1	-1.0	-0.4

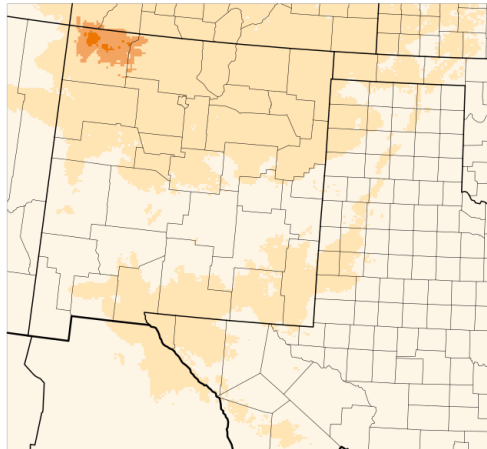
2028 OGCS OZONE DVF & W/ NM SOURCE SECTORS REMOVED

2028 CNTL OilGas_Point OilGas_Nonpoint EGU nonEGU Onroad_Mobile Nonroad_Mobile Remainder_Anthro



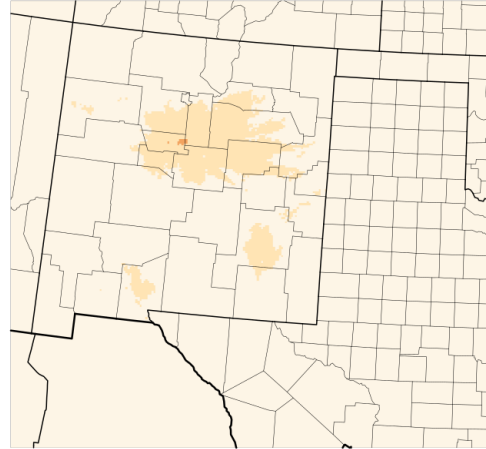
SMAT UAA (DVC₂₀₁₂₋₂₀₁₆) 2028 DVF SOURCE CONTRIBUTIONS

2028 Contributions
EGU point
O3 Design Value UAA



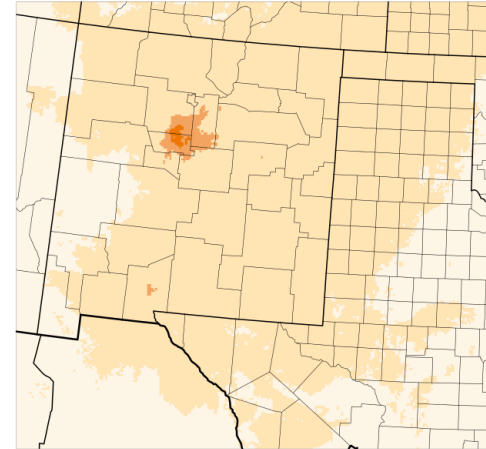
max(44,208) = 3.105 ppb
min(1,215) = 0.006 ppb

2028 Contributions
NonEGU point
O3 Design Value UAA



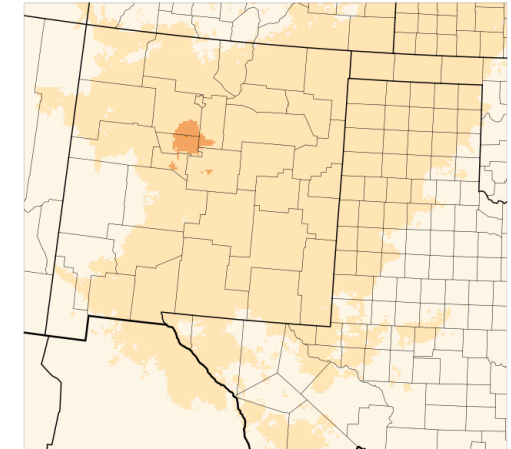
max(86,154) = 1.283 ppb
min(32,1) = 0.000 ppb

2028 Contributions
On-road mobile
O3 Design Value UAA



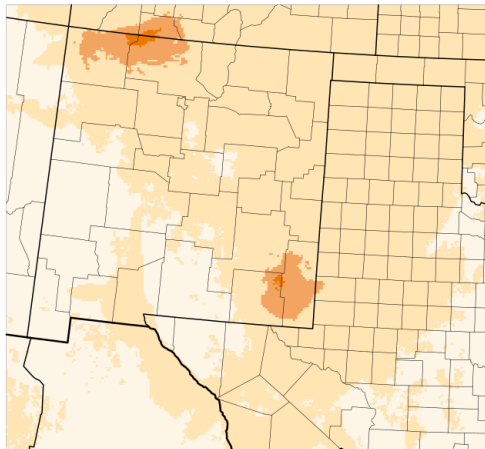
max(82,158) = 2.598 ppb
min(19,189) = 0.006 ppb

2028 Contributions
Non-road mobile
O3 Design Value UAA



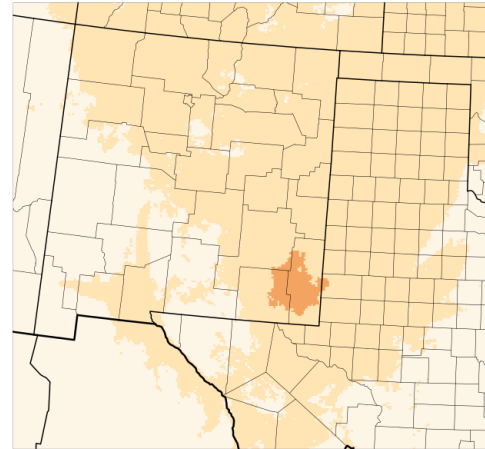
max(82,158) = 2.103 ppb
min(22,200) = 0.006 ppb

2028 Contributions
OilandGas non-point
O3 Design Value UAA



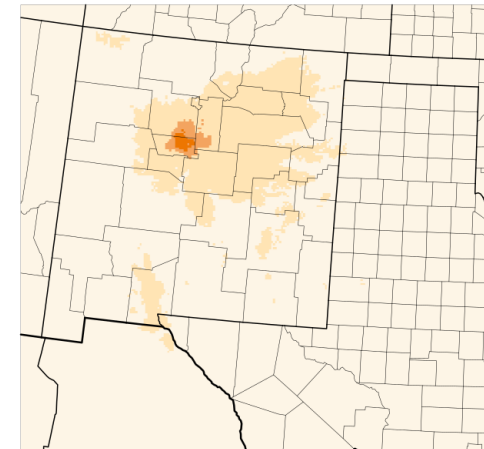
max(67,209) = 2.986 ppb
min(18,192) = 0.006 ppb

2028 Contributions
OilandGas point
O3 Design Value UAA



max(139,86) = 1.889 ppb
min(12,165) = 0.000 ppb

2028 Contributions
Remainder Anthro
O3 Design Value UAA



max(82,156) = 3.094 ppb
min(9,122) = 0.000 ppb



REDUCTIONS 2028 O3 DVFS U.S. ANTHROPOGENIC SOURCE SECTORS

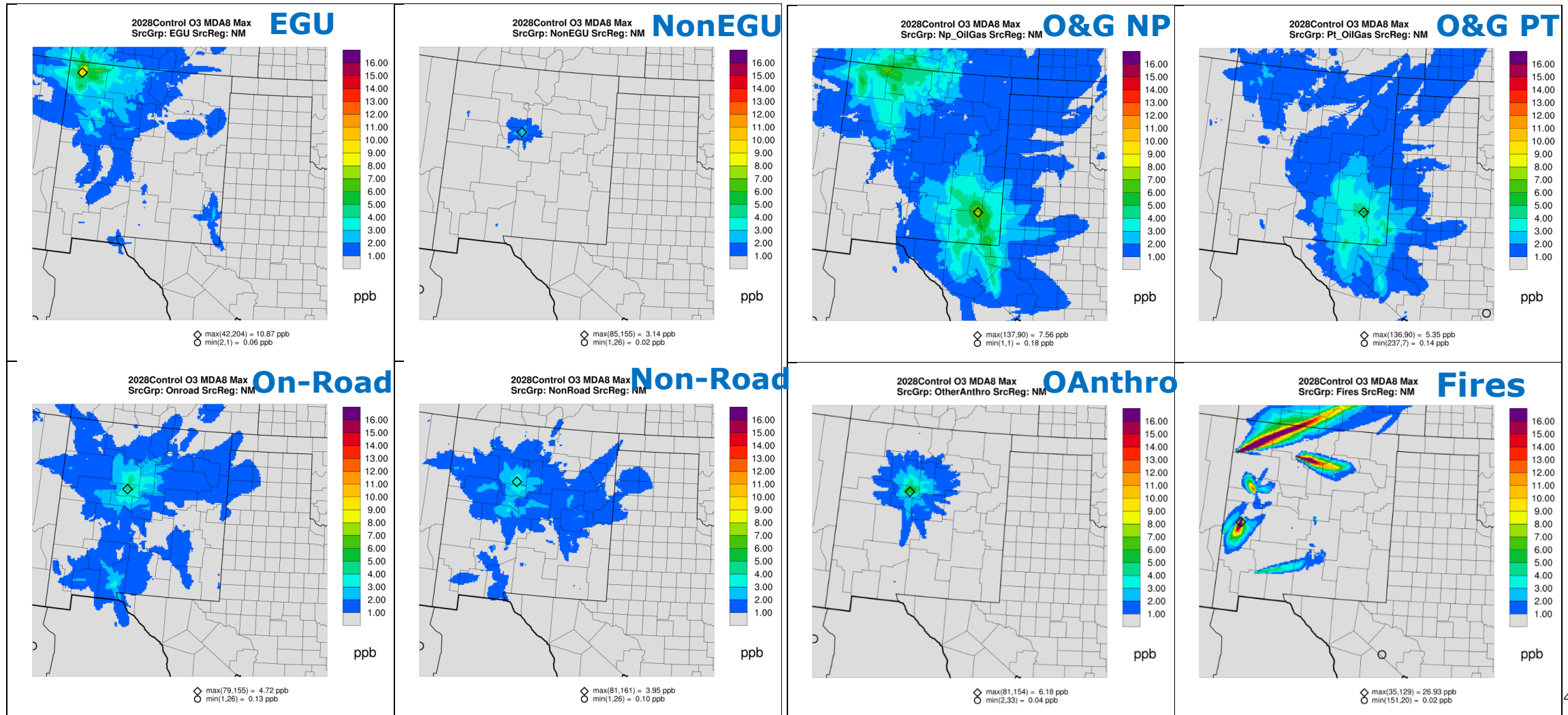
- 2028 ozone DVF Reductions from All U.S. Anthro Source Sectors
 - O&G Point: -0.2 to -1.6 ppb
 - O&G Non-Pt: -0.3 to -2.7 ppb
 - EGU Point: -0.4 to -3.6 ppb
 - Non-EGU Pt: -0.6 to -1.7 ppb
 - On-Road: -1.3 to -3.9 ppb
 - Non-Road: -0.9 to -3.0 ppb
 - Other Anthro: -0.6 to -4.2 ppb

AQS_ID	Site_ID	DVC	DVF	O&GPT	O&GNP	EGU	NonEGU	OnRoad	NonRoad	OAnth
350010023	NORTE	66.3	60.7	-0.5	-0.7	-1.1	-1.7	-3.9	-3.0	-4.2
350010024	SEHGS	68.0	62.0	-0.5	-0.7	-1.0	-1.7	-3.6	-2.8	-3.7
350010029	STHVA	66.0	60.5	-0.6	-0.9	-1.0	-1.6	-3.3	-2.5	-2.9
350010032	WSTSD	67.0	62.1	-0.4	-0.7	-0.9	-1.0	-2.7	-2.0	-2.4
350011012	FTHIL	65.0	58.8	-0.5	-0.7	-1.1	-1.4	-3.8	-3.0	-3.7
350130008	UNION	66.3	59.8	-0.8	-0.9	-1.6	-1.5	-3.2	-2.3	-1.5
350130017	SPARK	67.0	61.8	-0.7	-1.0	-1.8	-1.5	-3.0	-2.1	-1.7
350130020	CHAPA	67.0	62.2	-0.6	-0.8	-1.3	-1.4	-2.3	-1.7	-1.3
350130021	DSVIE	72.0	66.8	-0.8	-1.1	-1.8	-1.6	-3.1	-2.2	-1.8
350130022	TERES	71.3	66.0	-0.8	-1.1	-1.6	-1.5	-2.9	-2.1	-1.5
350130023	SOLAN	65.0	60.2	-0.7	-1.0	-0.9	-1.1	-2.7	-1.8	-1.1
350151005	CARLS	69.0	66.4	-0.8	-1.1	-0.5	-0.8	-1.3	-0.9	-0.7
350171003	GRANT	62.0	58.9	-0.2	-0.3	-0.4	-0.7	-1.3	-1.0	-0.7
350250008	HOBBS	66.0	63.3	-1.6	-2.2	-0.7	-0.6	-1.4	-1.0	-0.7
350290003	DEAIR	66.0	62.5	-0.4	-0.5	-0.6	-0.7	-1.7	-1.2	-0.7
350390026	COYOT	64.0	60.0	-0.5	-0.9	-0.8	-0.7	-1.5	-1.0	-0.7
350431001	BERNA	64.0	58.1	-0.4	-0.6	-0.8	-1.1	-3.4	-2.5	-2.6
350450009	BLOOM	64.3	60.2	-1.1	-2.1	-2.3	-0.7	-1.7	-1.1	-0.6
350450018	NAVAJ	67.0	63.3	-1.3	-2.7	-2.0	-0.8	-1.7	-1.2	-0.8
350451005	SUBST	63.7	59.6	-1.1	-2.5	-3.6	-0.8	-1.7	-1.2	-0.7
350490021	SNTFE	64.3	60.4	-0.5	-0.7	-0.7	-0.7	-2.0	-1.4	-1.3

SOURCE SECTOR CONTRIBUTIONS TO MODELED 2028 OZONE

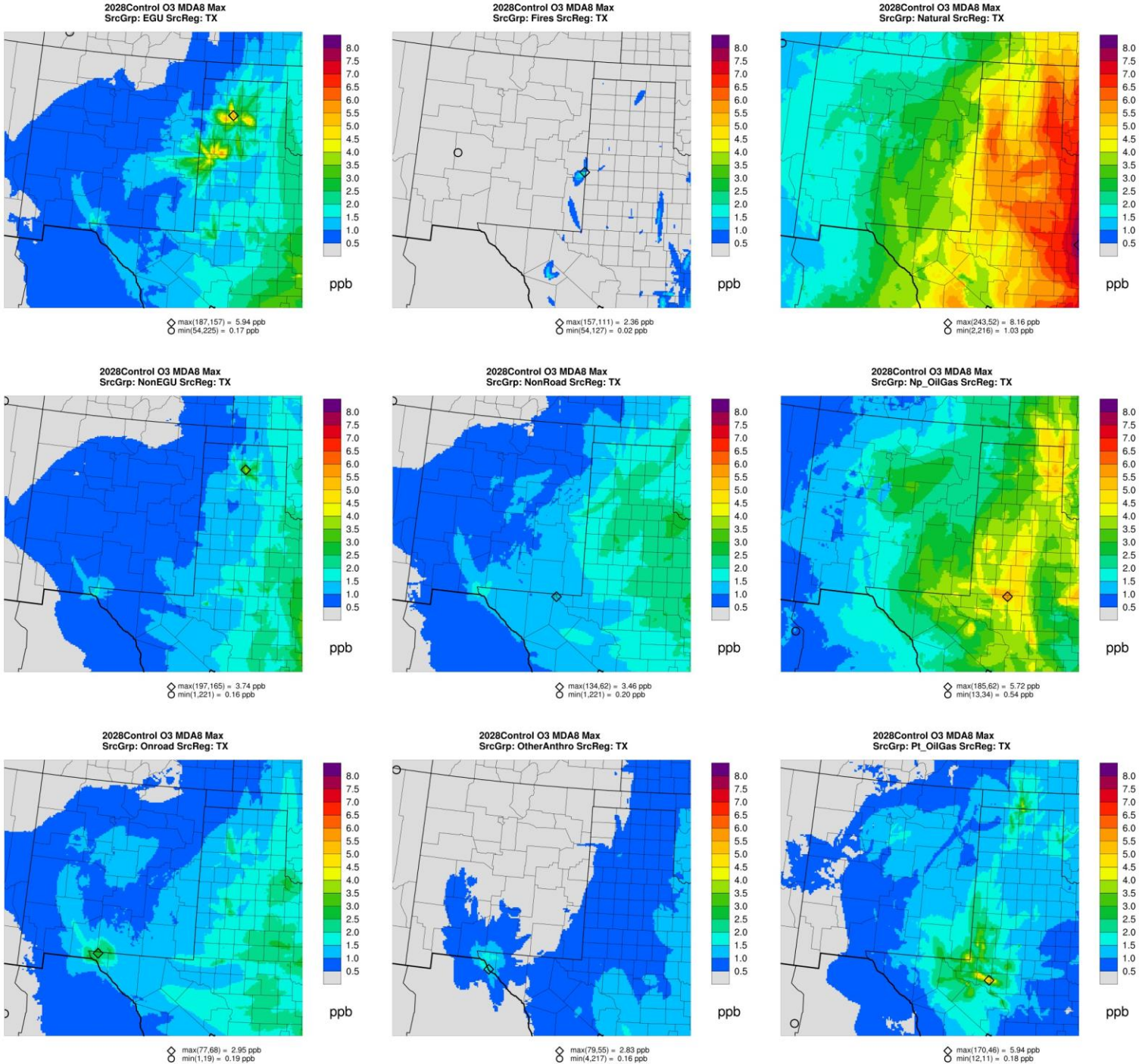
- 1. HIGHEST NEW MEXICO SOURCE SECTOR CONTRIBUTIONS TO DAILY MDA8 OZONE DURING EPISODE**
- 2. DETAILS OF SOURCE SECTOR CONTRIBUTIONS TO MODELED 2028 MDA8 OZONE ON 10 SMAT DAYS USED TO MAKE 2028 OZONE DVF PROJECTIONS**
- 3. SPATIAL DISTRIBUTION OF NEW MEXICO AND ALL UNITED STATES SOURCE SECTOR CONTRIBUTIONS ON SIX EXAMPLE DAYS**

HIGHEST NEW MEXICO SOURCE SECTOR OZONE CONTRIBUTIONS TO MDA8 OZONE DURING EPISODE



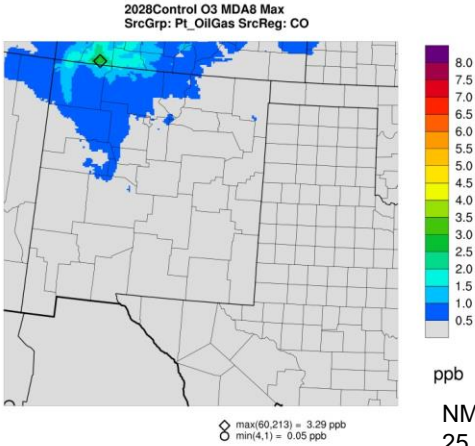
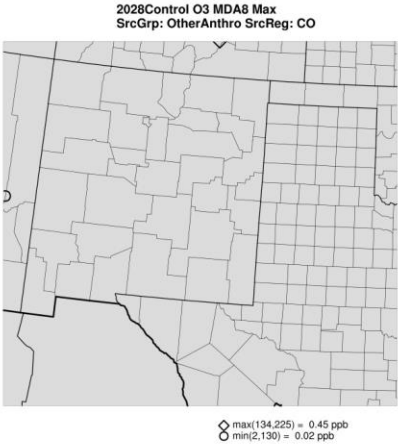
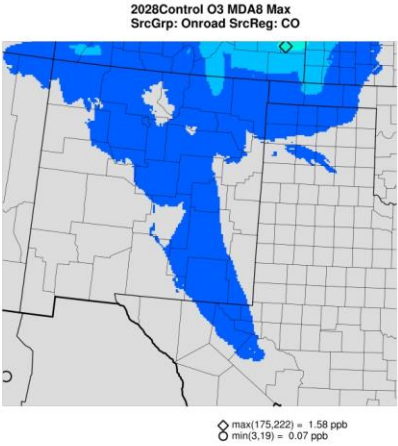
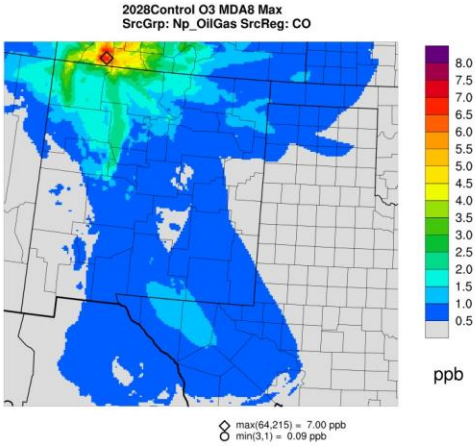
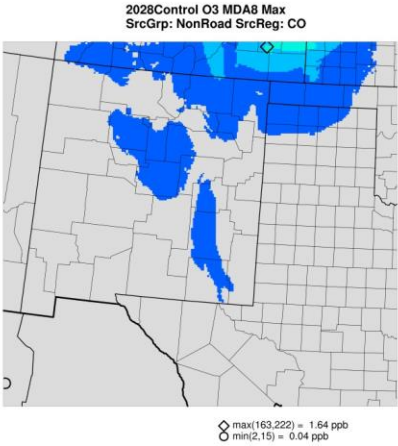
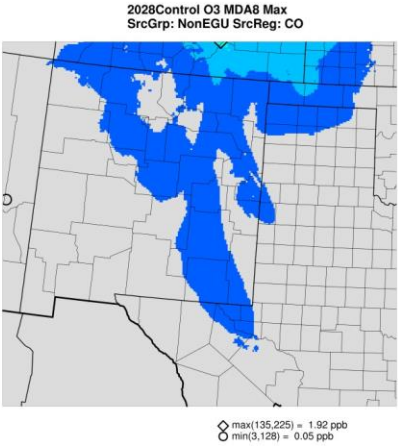
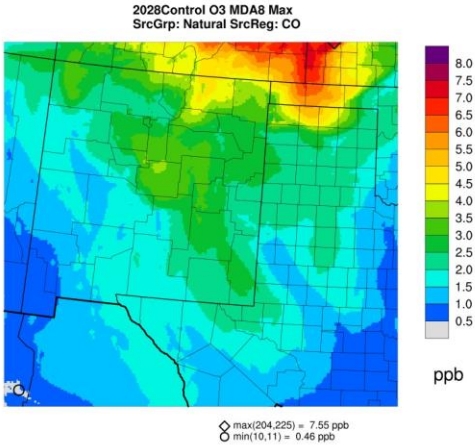
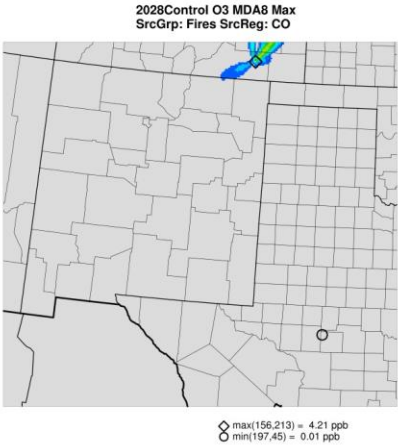
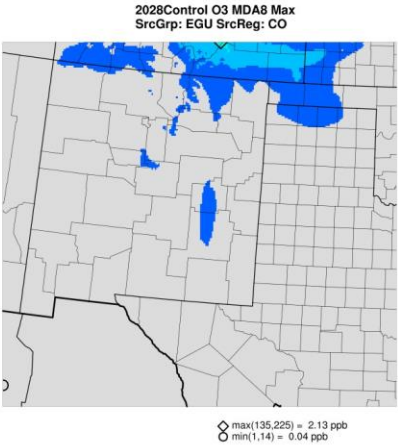
HIGHEST TEXAS SOURCE SECTOR OZONE CONTRIBUTIONS TO MDA8 OZONE DURING EPISODE

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT



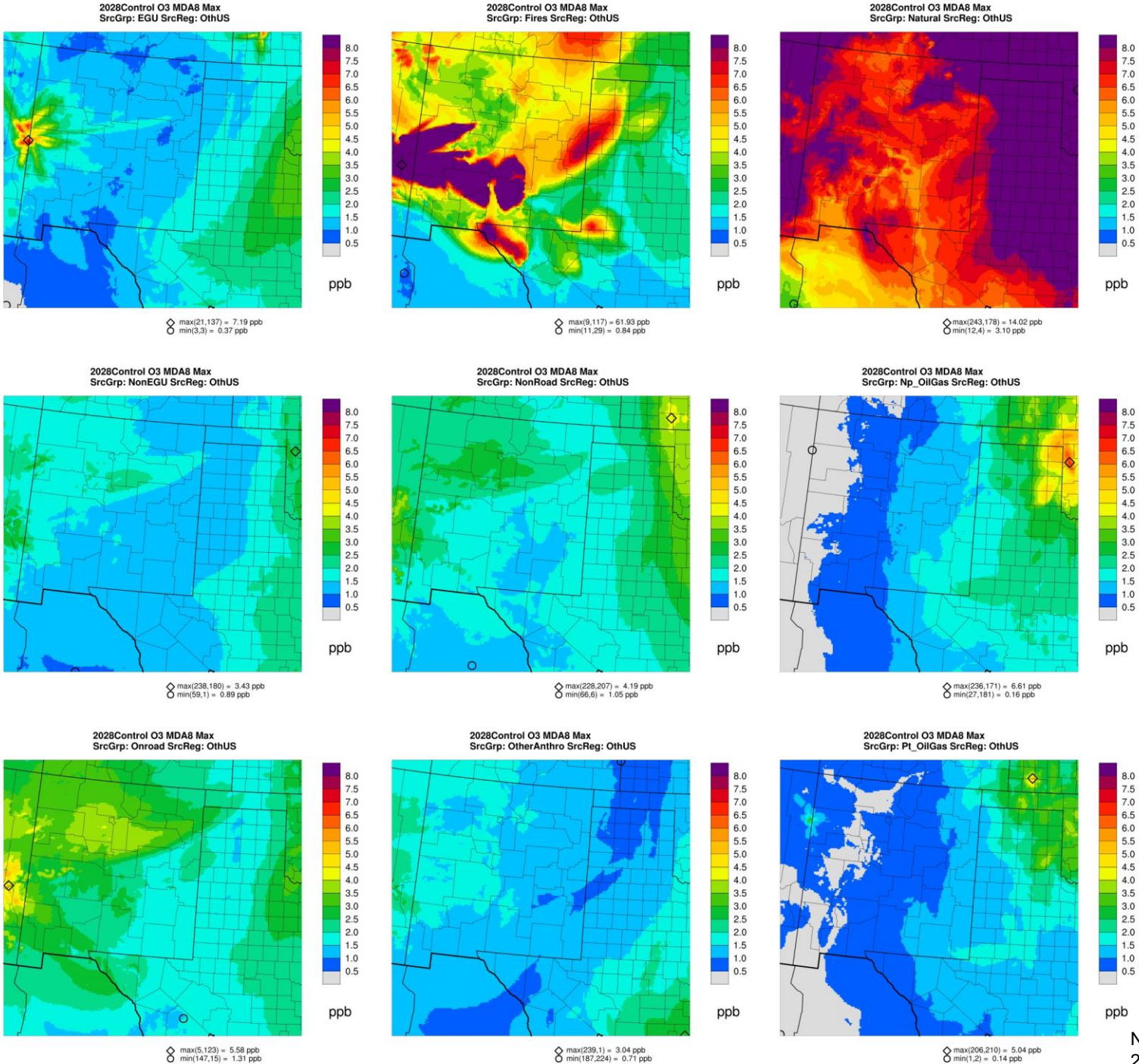
HIGHEST COLORADO SOURCE SECTOR OZONE CONTRIBUTIONS TO MDA8 OZONE DURING EPISODE

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT



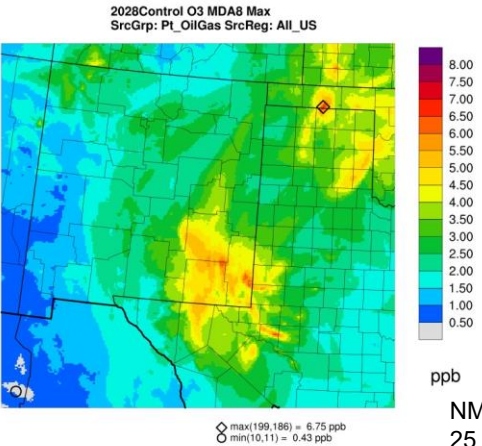
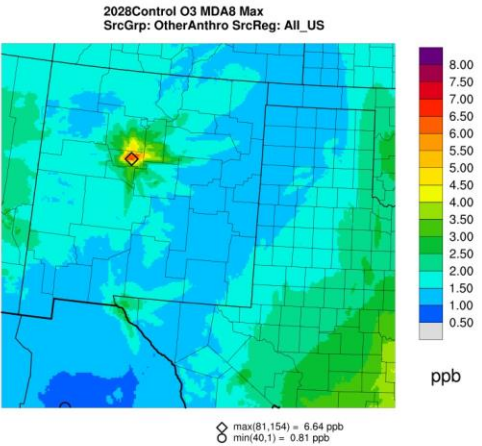
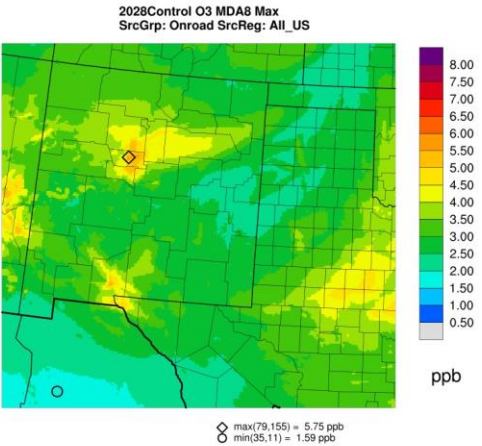
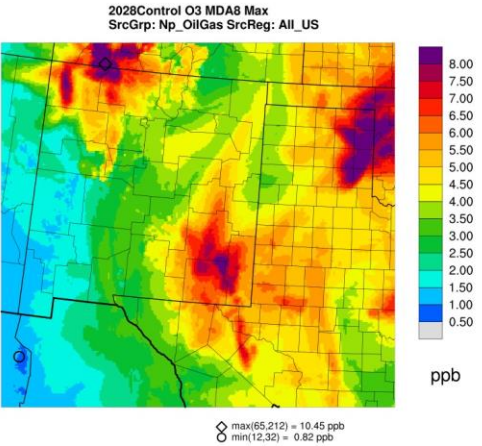
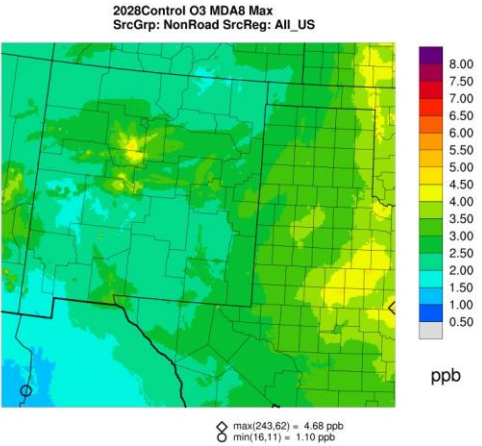
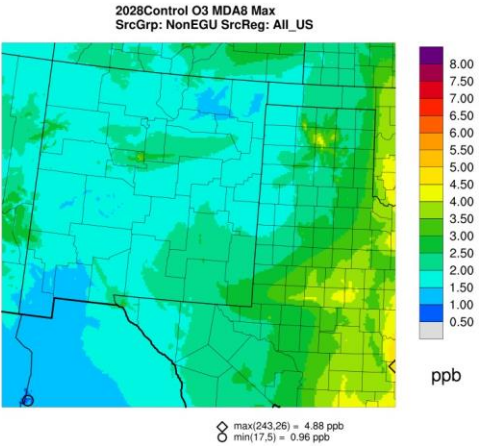
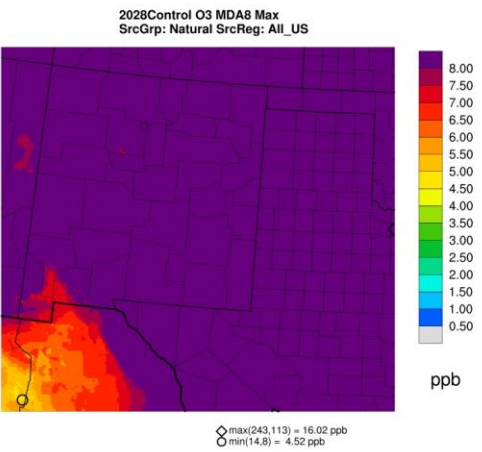
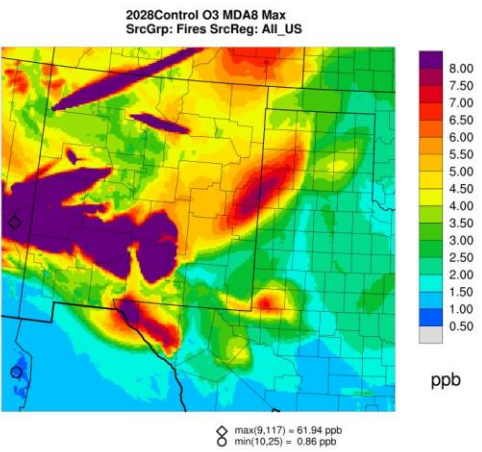
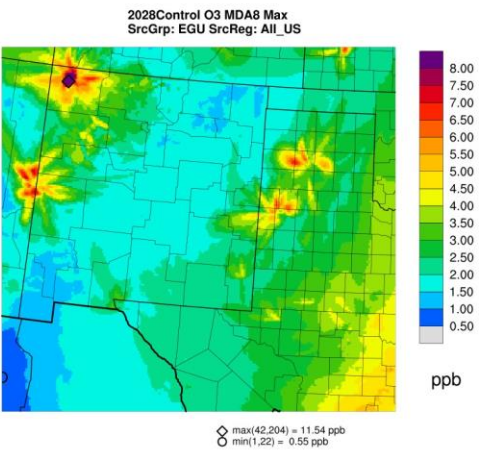
HIGHEST REMAINING U.S. SOURCE SECTOR OZONE CONTRIBUTIONS TO MDA8 OZONE DURING EPISODE (EXCLUDES NM, TX AND CO)

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT



HIGHEST ALL U.S. SOURCE SECTOR OZONE CONTRIBUTIONS TO MDA8 OZONE DURING EPISODE

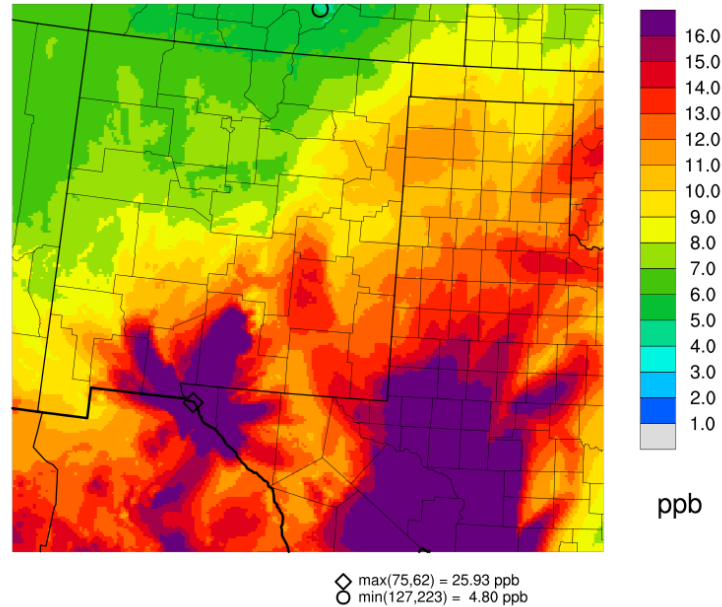
EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT



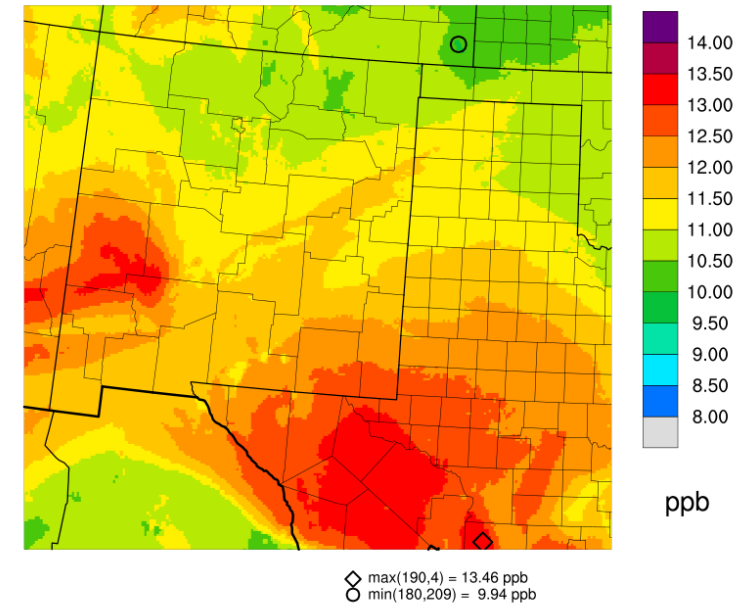
HIGHEST OZONE CONTRIBUTIONS TO MDA8 OZONE DURING EPISODE

- In-Domain International Anthropogenic Emissions (top left)
- Boundary Conditions from International Anthropogenic Emissions (top right)
- Boundary Conditions from Natural Sources (bottom left)
- Boundary Conditions from U.S. Anthropogenic Emissions (bottom right)

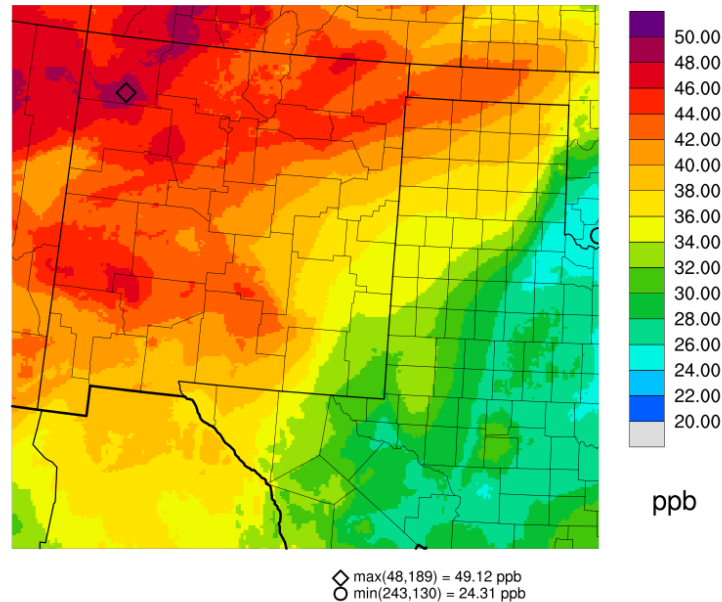
2028Control O3 MDA8 Max
SrcGrp: OtherAnthro SrcReg: Intl



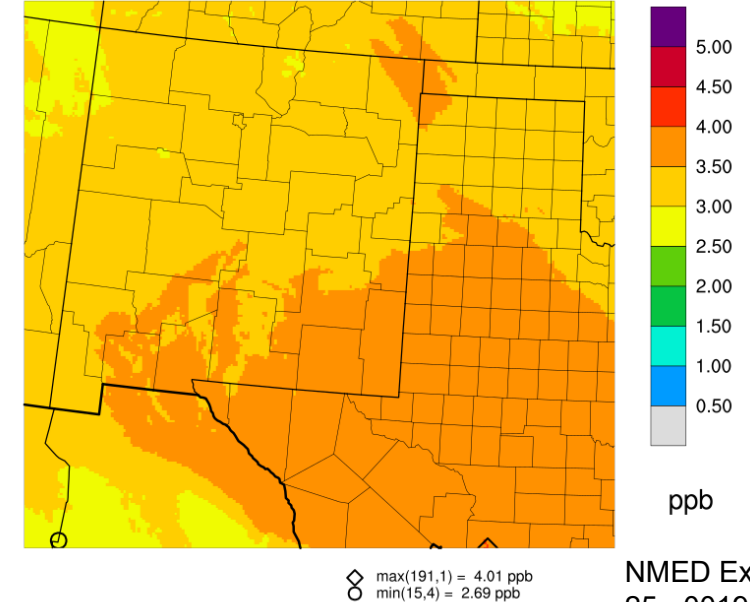
2028Control O3 MDA8 Max
SrcGrp: BCIntl



2028Control O3 MDA8 Max
SrcGrp: BCNat



2028Control O3 MDA8 Max
SrcGrp: BCUS



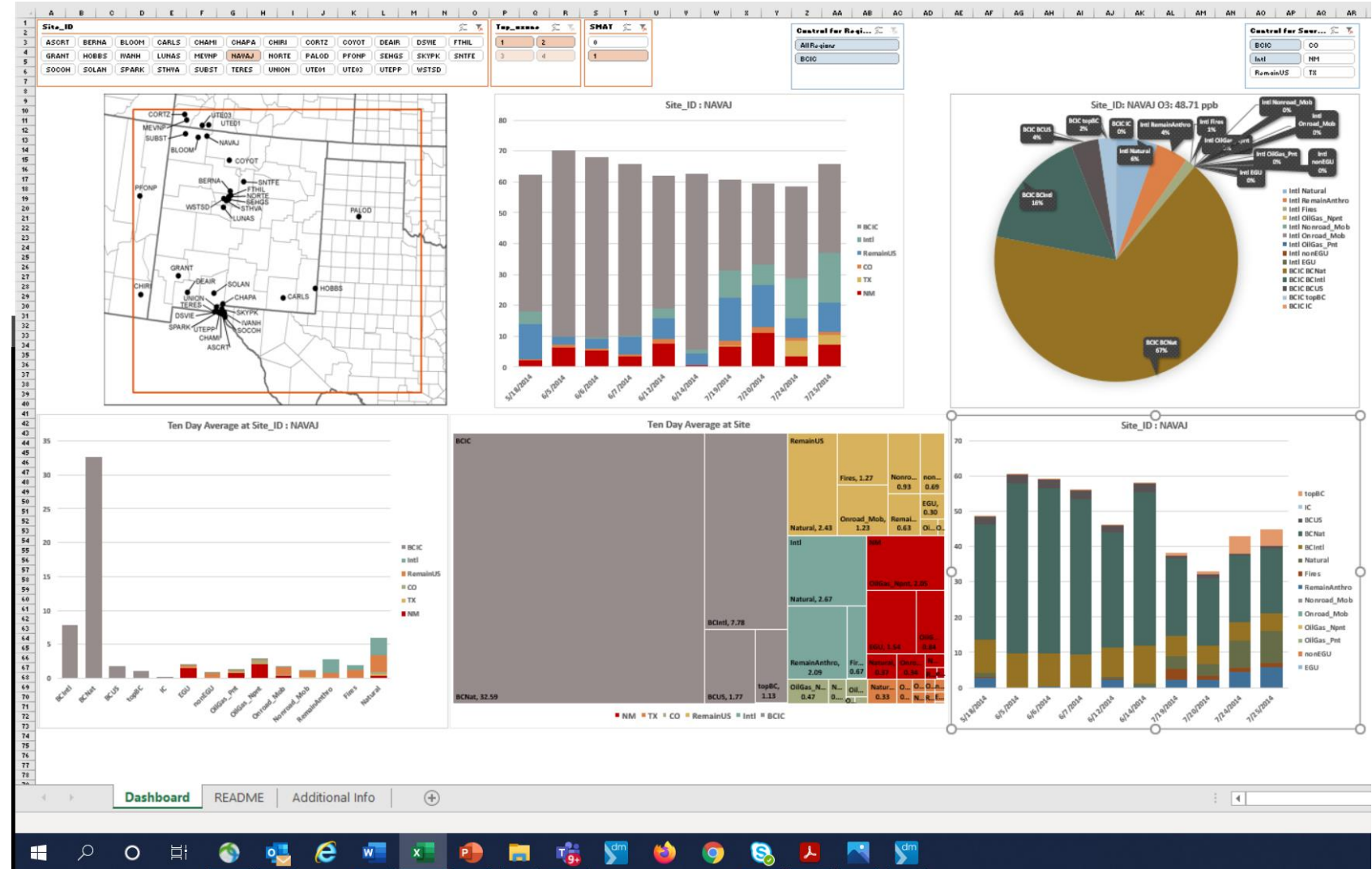
EXCEL DASHBOARD TO DISPLAY 2028 SOURCE SECTOR APCA OZONE SOURCE APPORTIONMENT MDA8 OZONE RESULTS

- User selects:

- Monitoring Site
 - Which 10 days to display
 - SMAT days, 1-10, etc.
- Dashboard Displays:
 - Stacked Bar Chart of MDA8 ozone contributions for 10 days
 - Stacked Bar Chart of Source Sector contributions averaged across 10 days
 - Tree Chart of contributions averaged across 10 days

- Also control source contributions by Source Region:

- BC, Intl, NM, TX, CO and RemainUS
- Dashboard generates stacked Bar Chart for 10 days and Pie Chart averaged across 10 days



NAVAJO LAKE: 10 SMAT DAYS

Contributions from All Sources

Average MDA8 O3

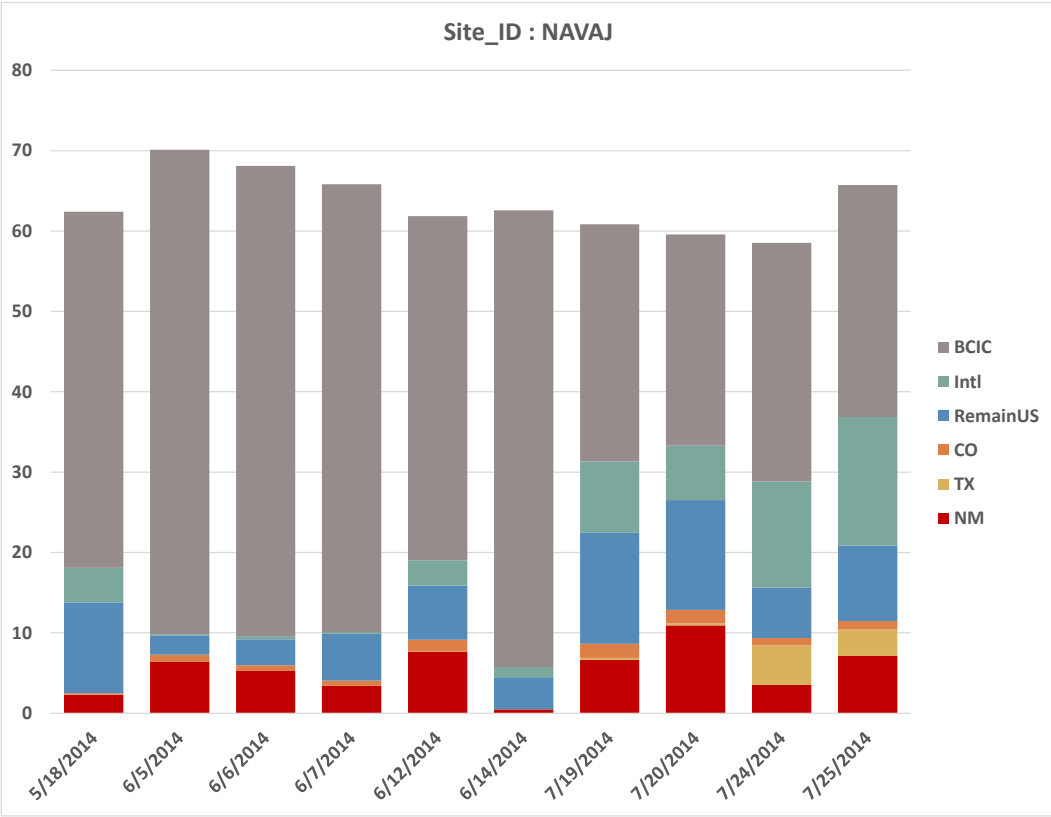
Ozone = 63.6 ppb

BC = 43.3 ppb (68%)

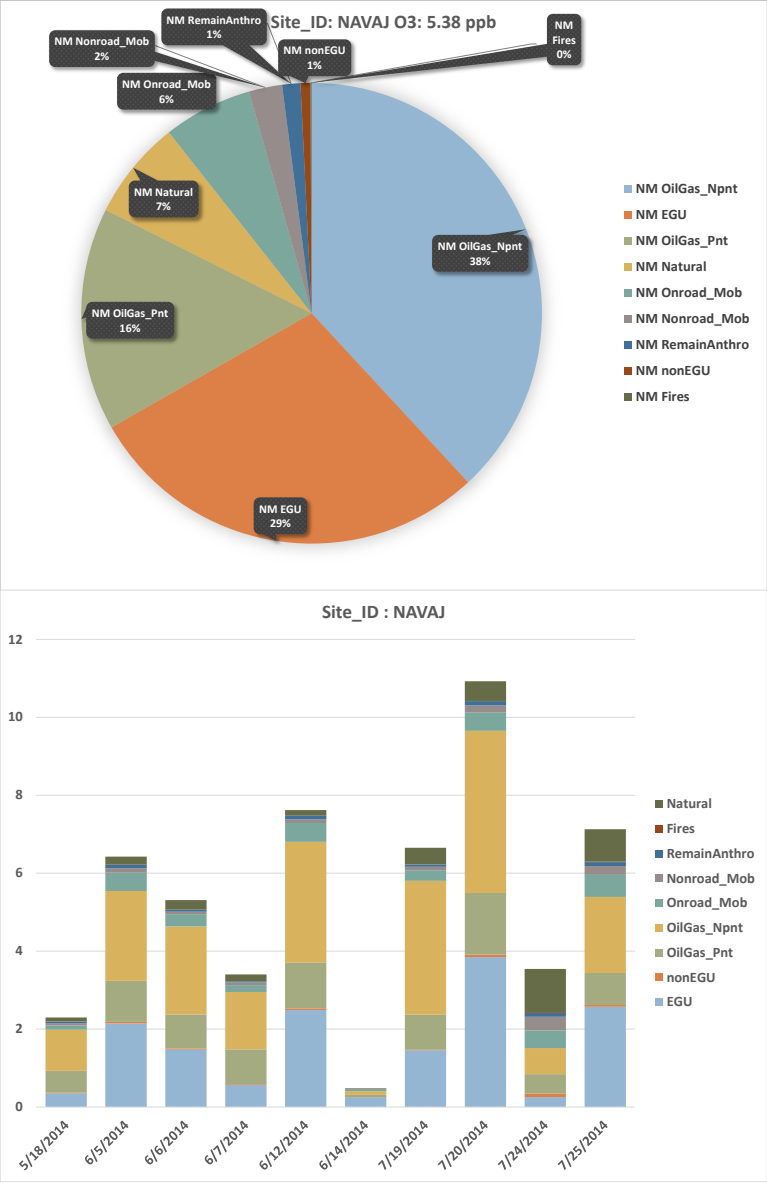
US = 14.8 ppb (23%)

NM = 5.4 ppb (8%)

Intl Ant = 9.9 ppb (16%)



Contributions from New Mexico Sources



FOOTHILLS: 10 SMAT DAYS

Contributions from All Sources

Average MDA8 O3

Ozone = 60.7 ppb

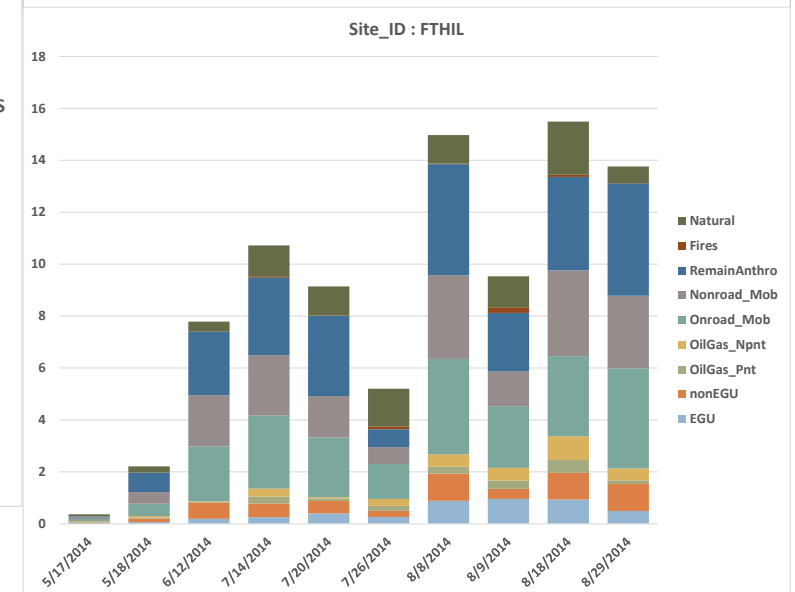
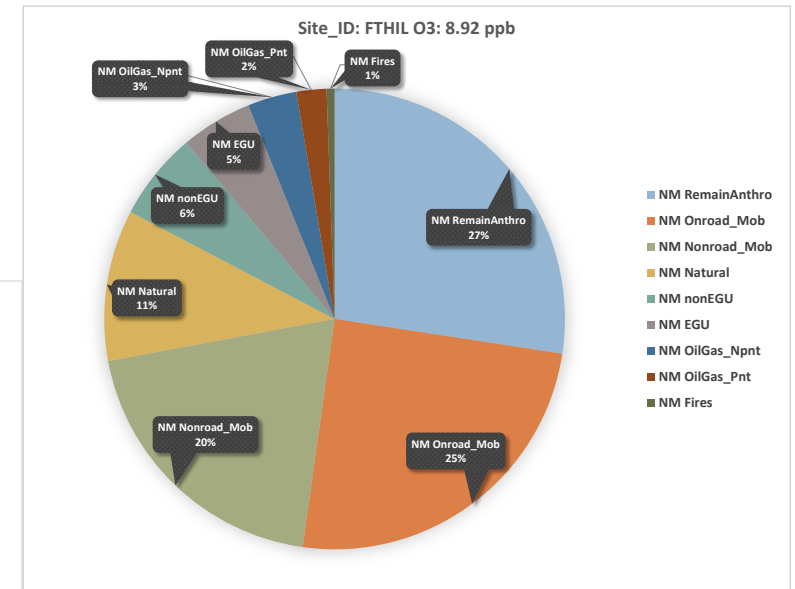
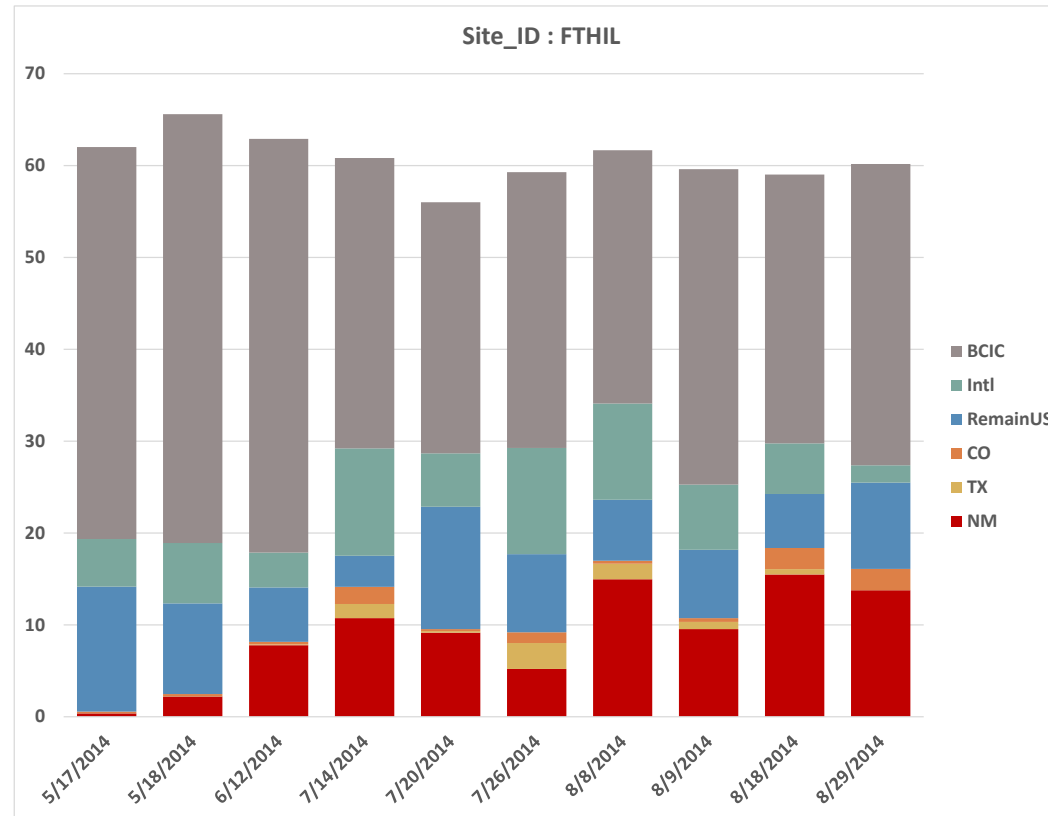
BC = 34.7 ppb (57%)

US = 19.0 ppb (31%)

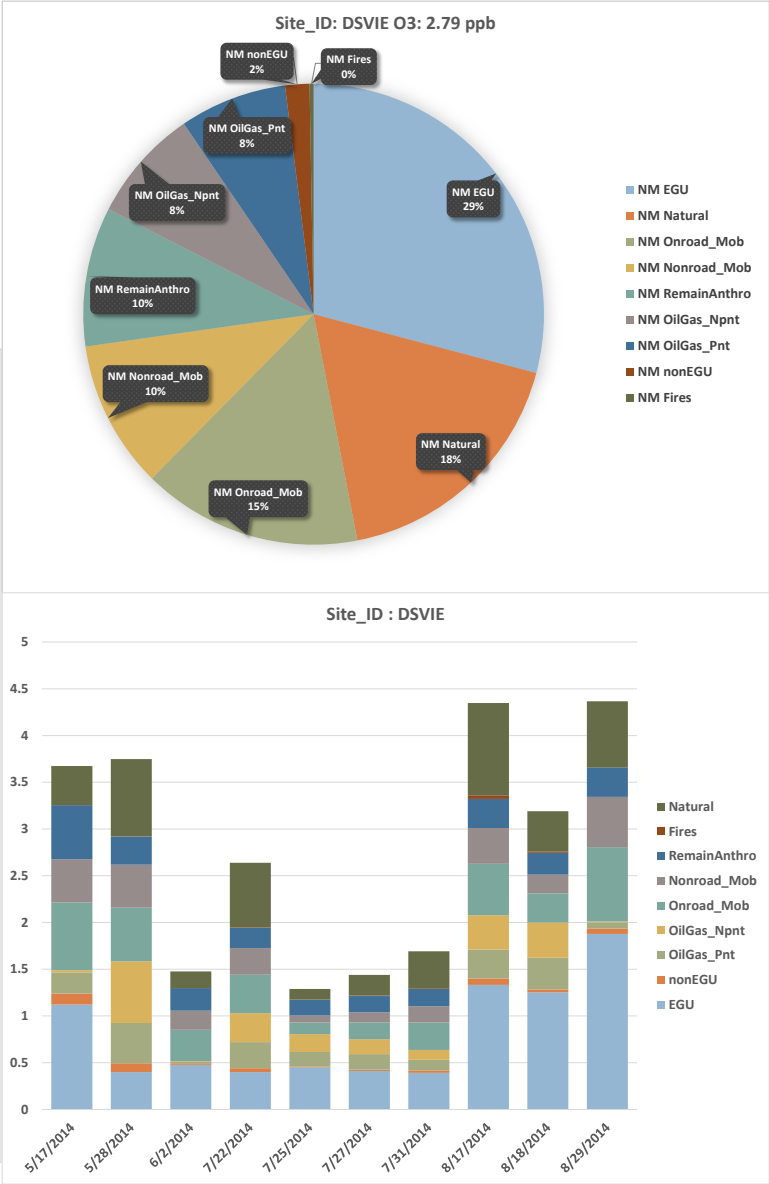
NM = 8.9 ppb (15%)

Intl Ant = 10.2 ppb (17%)

Contributions from New Mexico Sources



Contributions from New Mexico Sources



DESERT VIEW: 10 SMAT DAYS

Contributions from All Sources

Average MDA8 O3

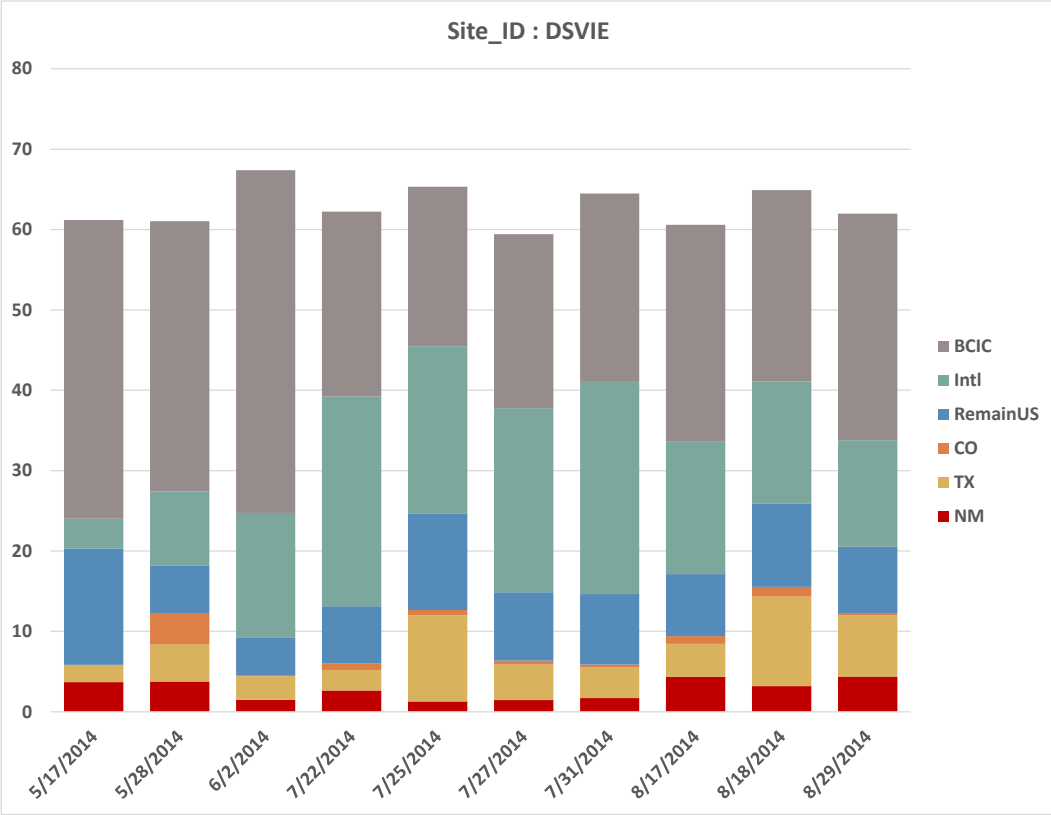
Ozone = 62.9 ppb

BC = 28.0 ppb (45%)

US = 17.9 ppb (28%)

NM = 2.8 ppb (4%)

Intl Ant = 18.8 ppb (30%)



CARLSBAD: 10 SMAT DAYS

Contributions from All Sources

Average MDA8 O3

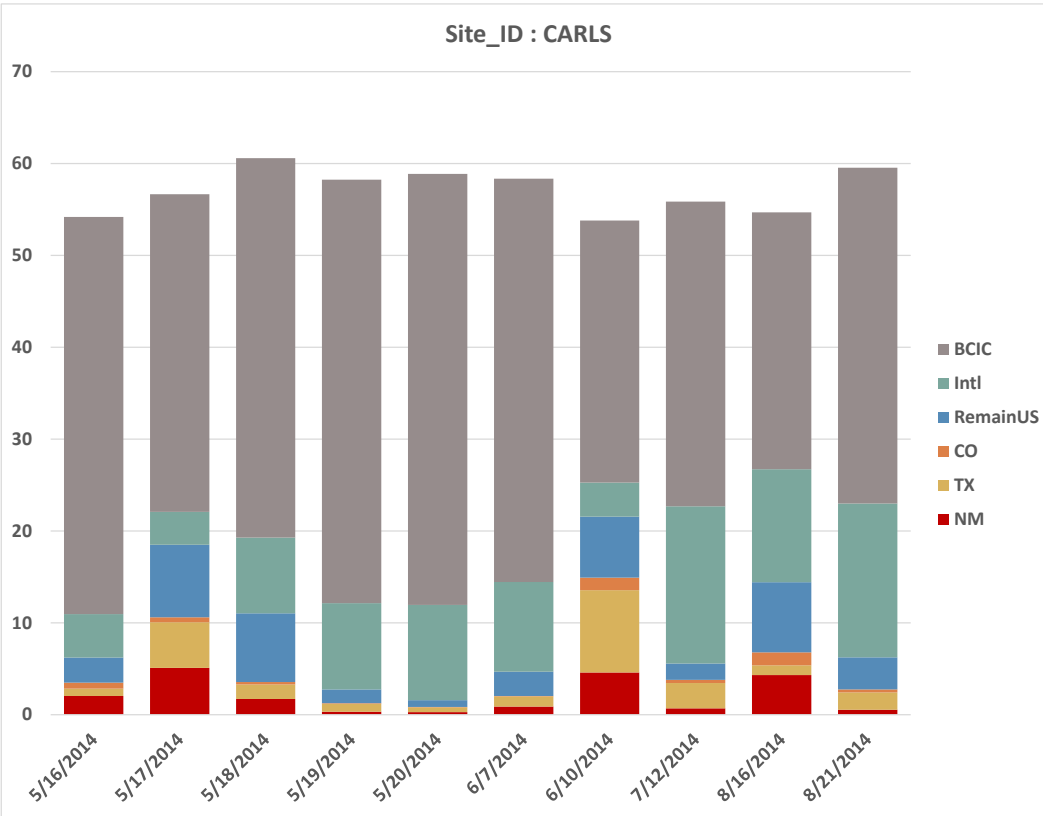
Ozone = 57.1 ppb

BC = 38.2 ppb (67%)

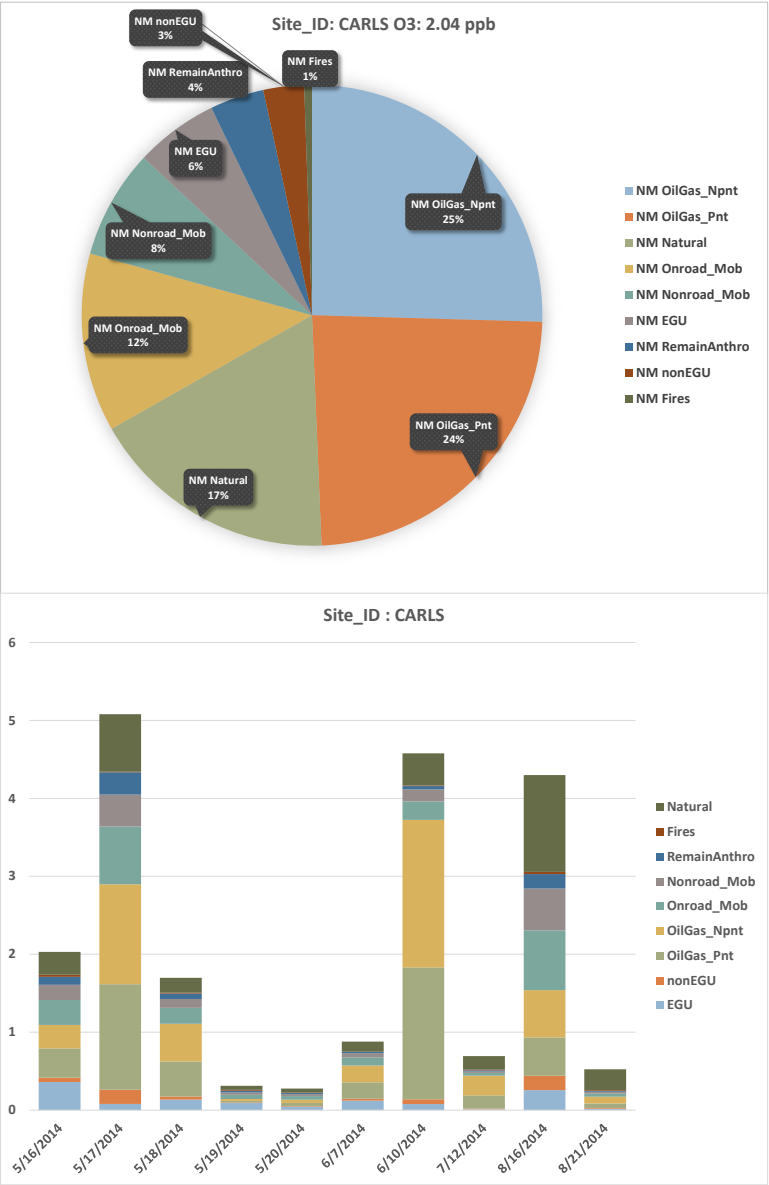
US = 9.3 ppb (16%)

NM = 2.0 ppb (3%)

Intl Ant = 13.4 ppb (23%)



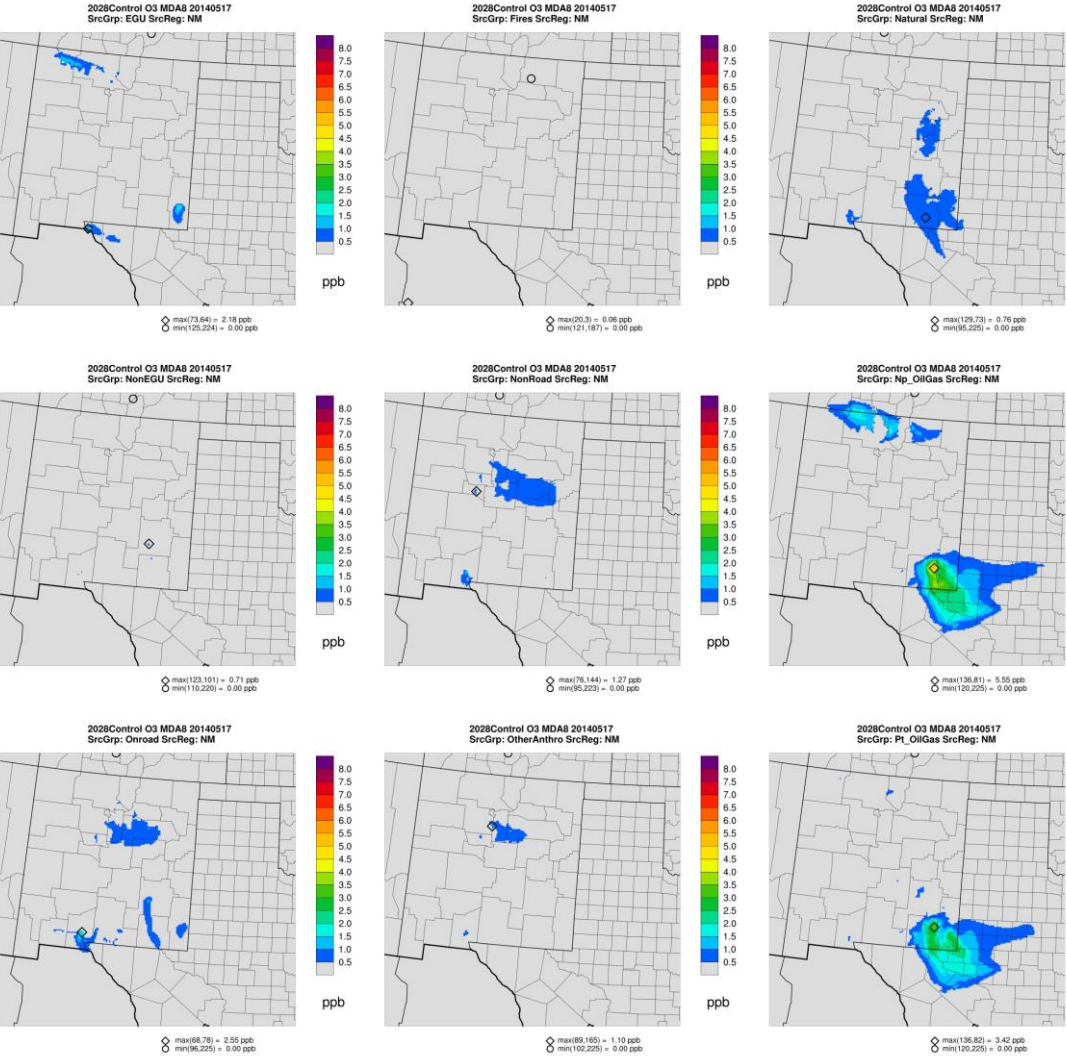
Contributions from New Mexico Sources



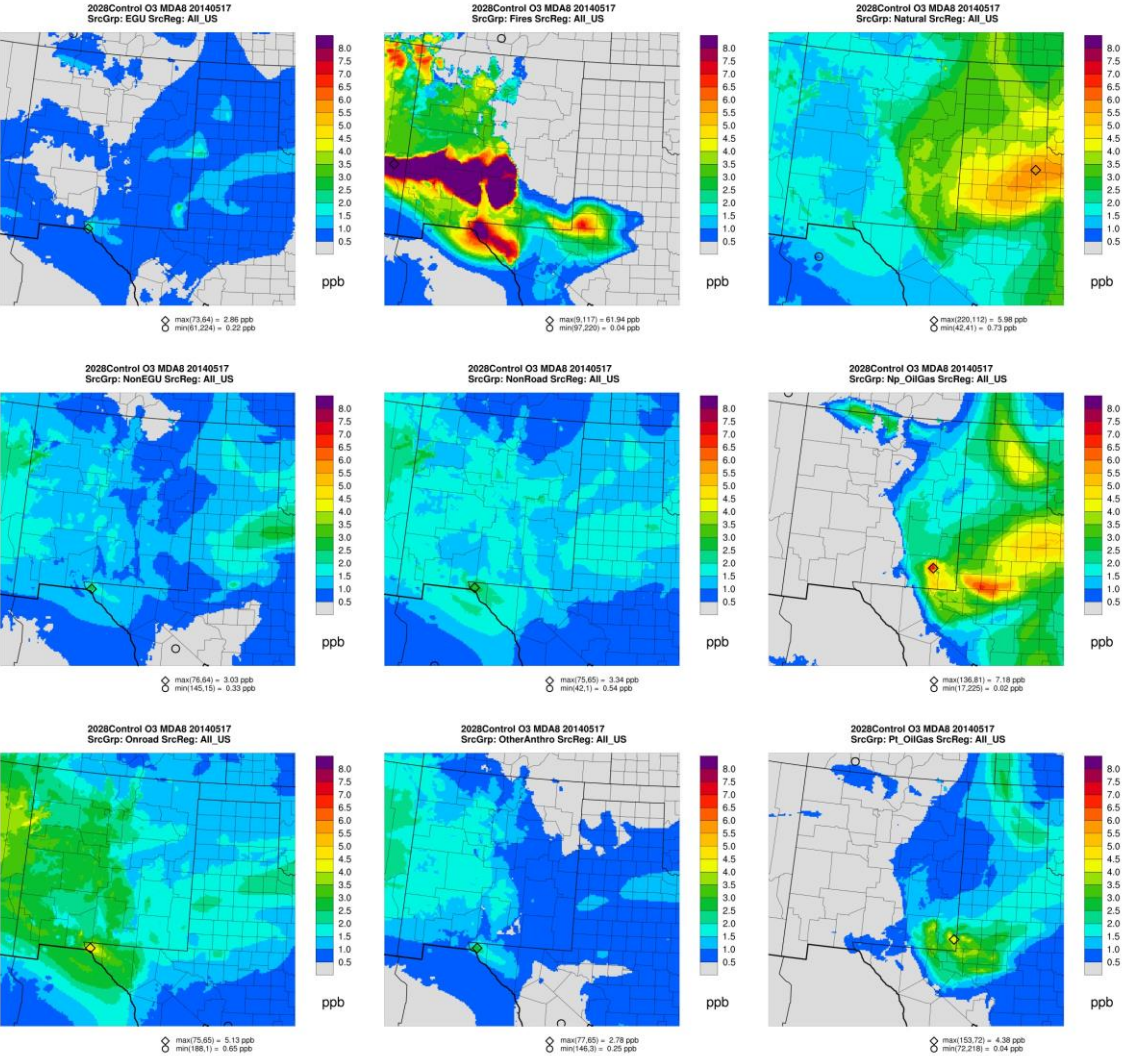
2028 SOURCE SECTOR -- MAY 17, 2014

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT

New Mexico



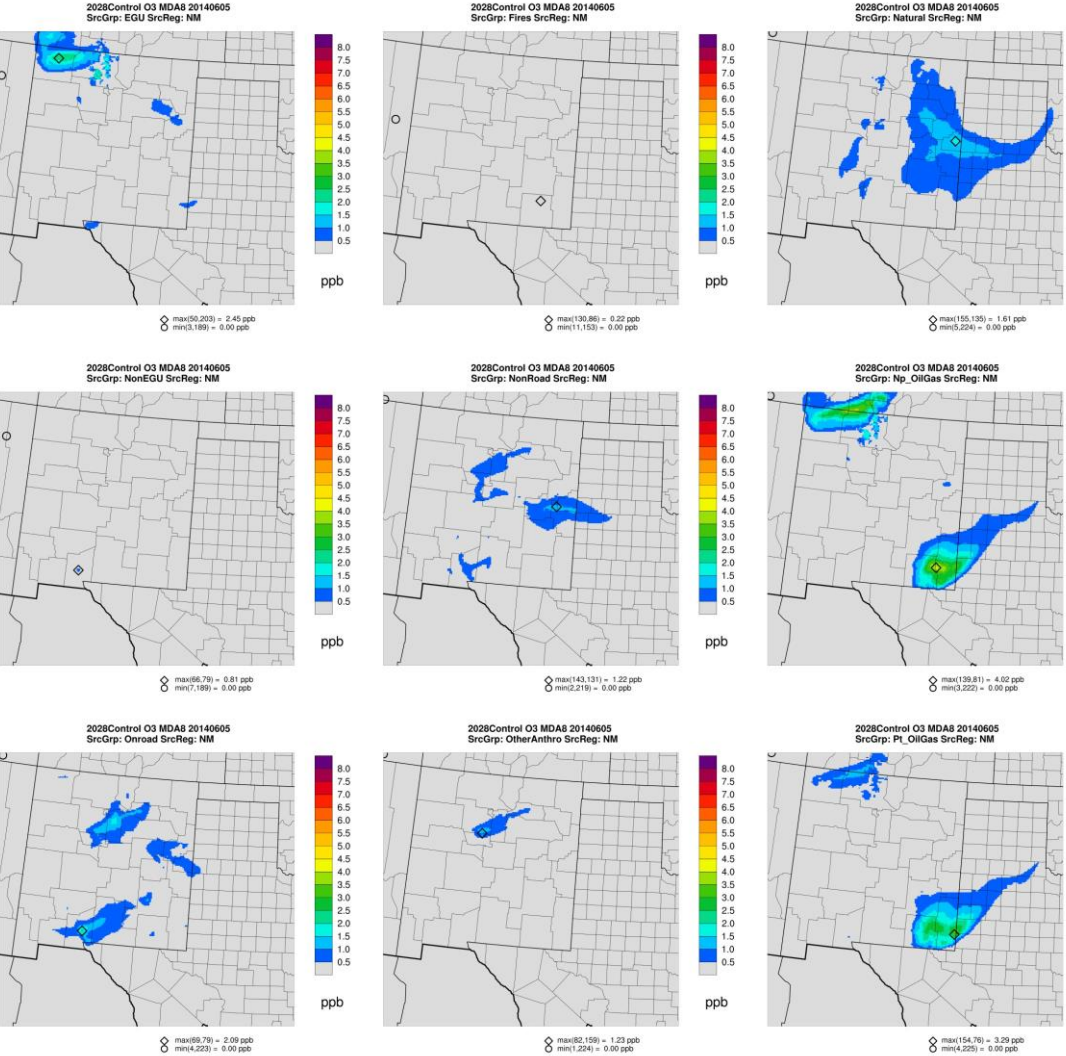
All United States



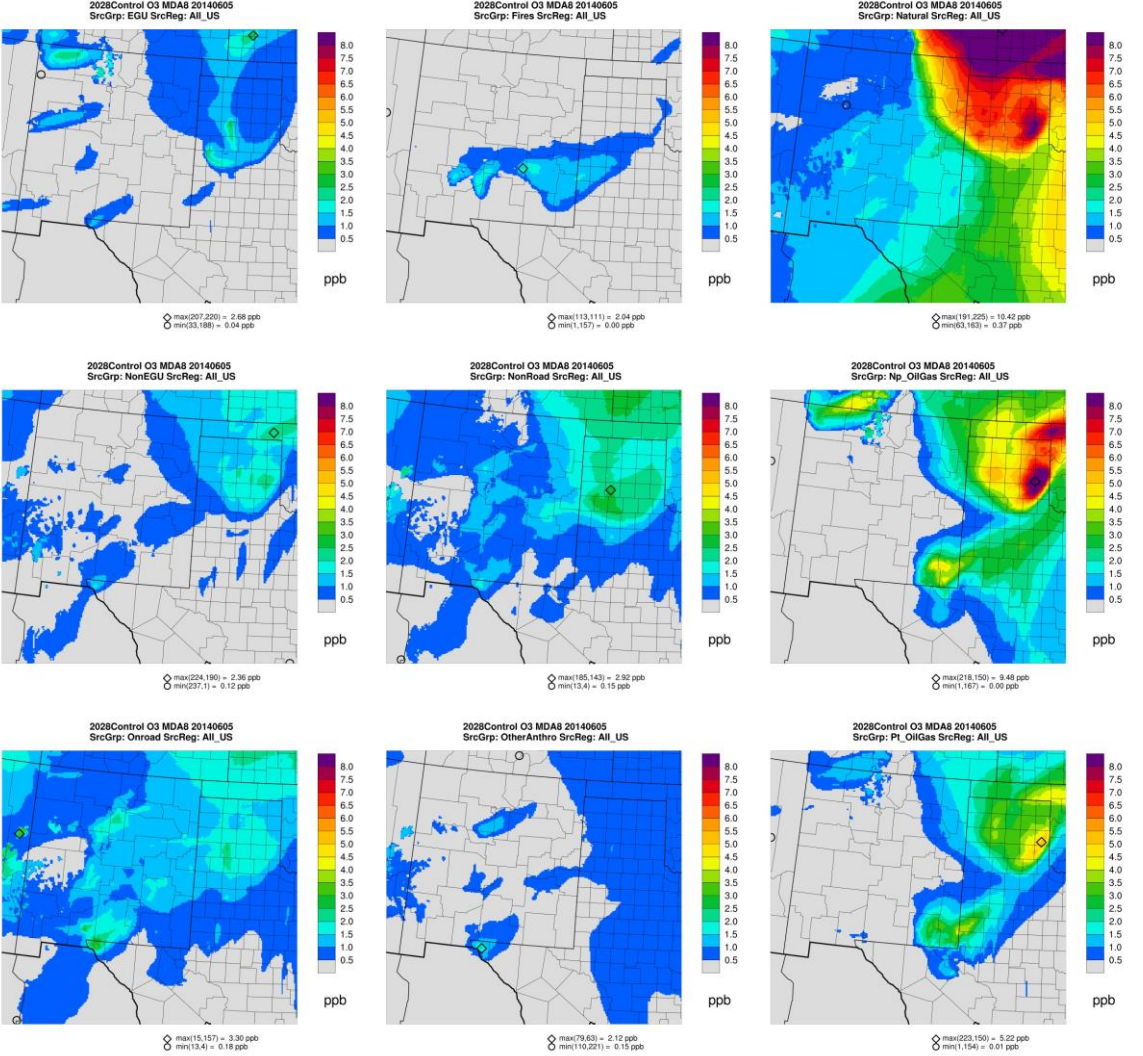
2028 SOURCE SECTOR – JUNE 5, 2014

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT

New Mexico



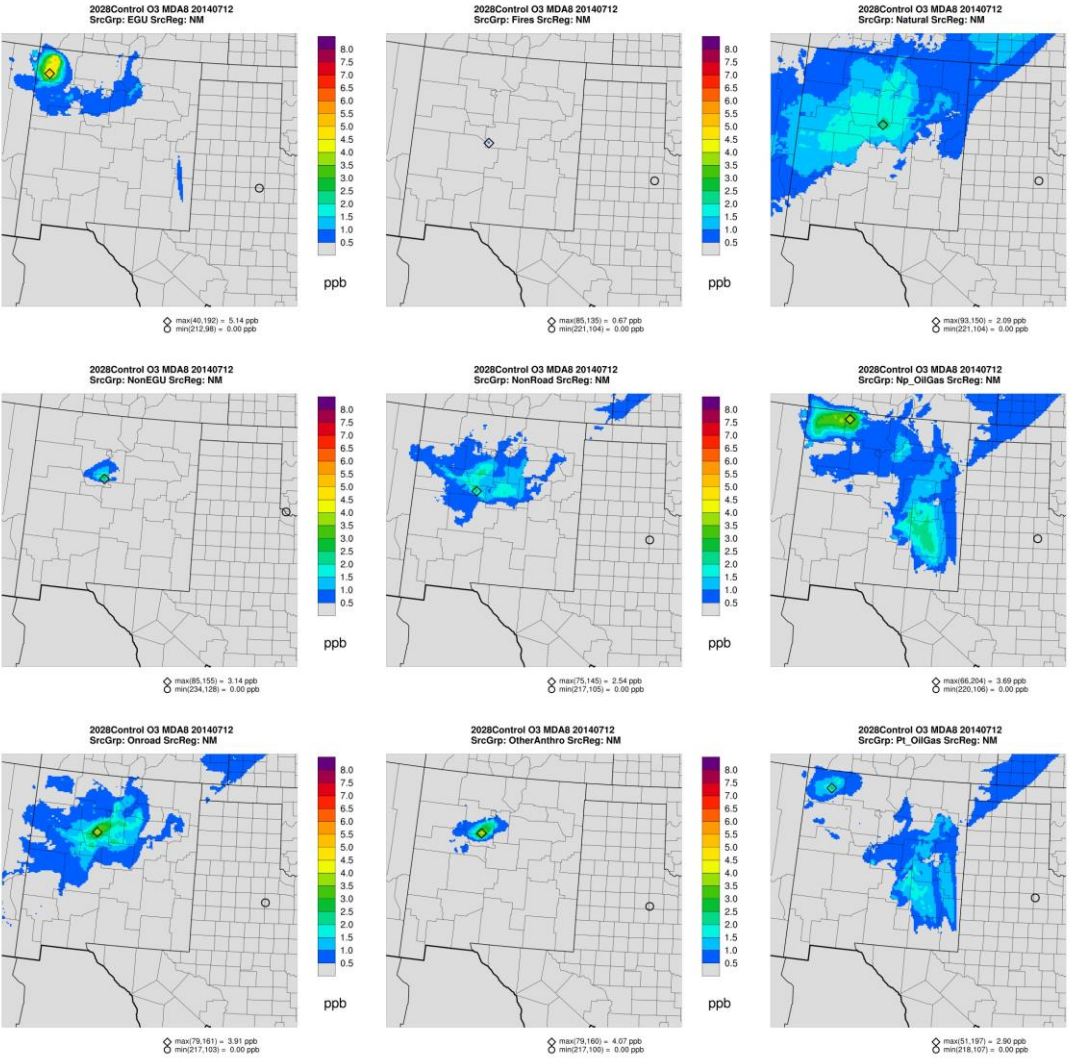
All United States



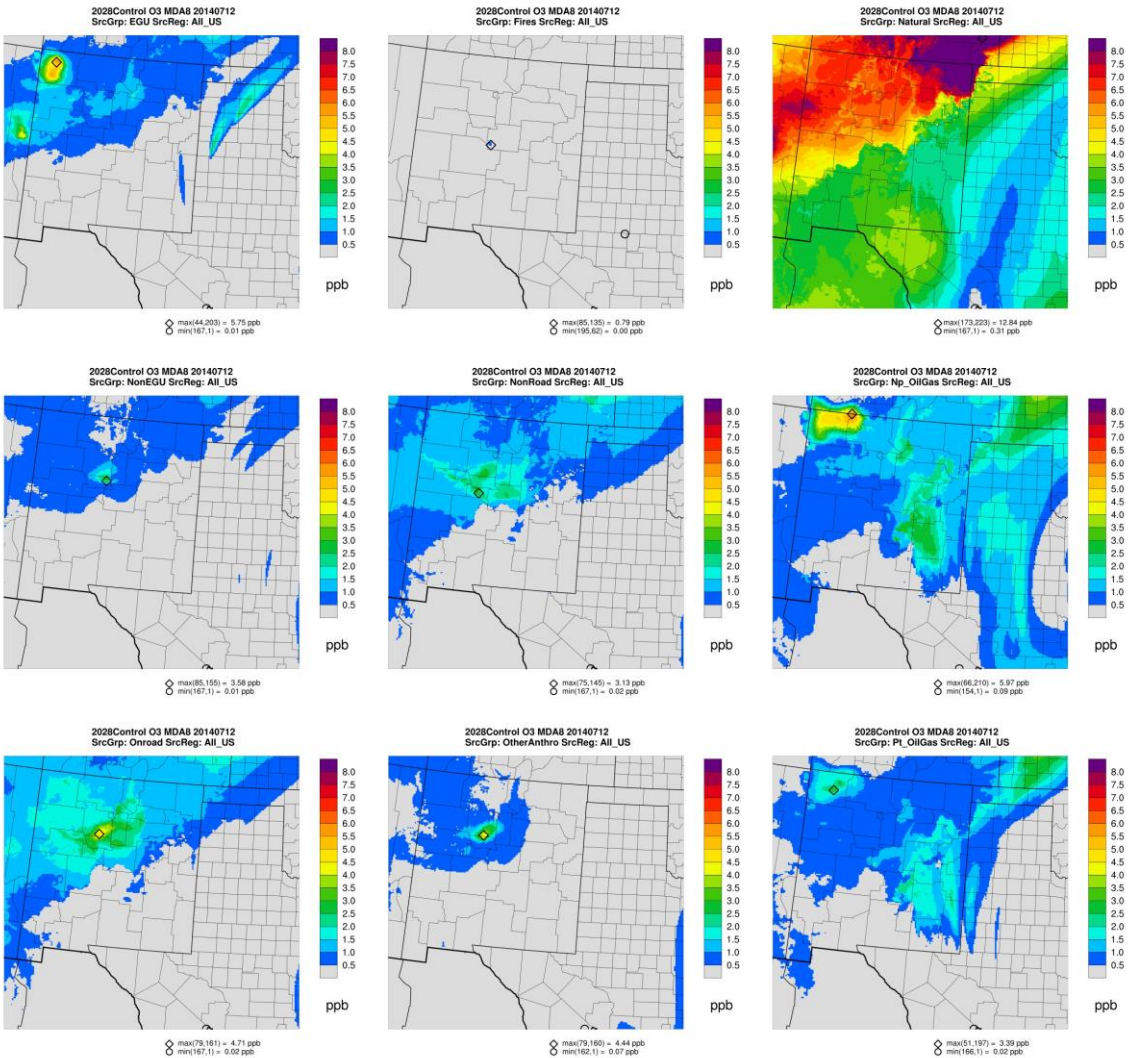
2028 SOURCE SECTOR – JULY 12, 2014

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT

New Mexico

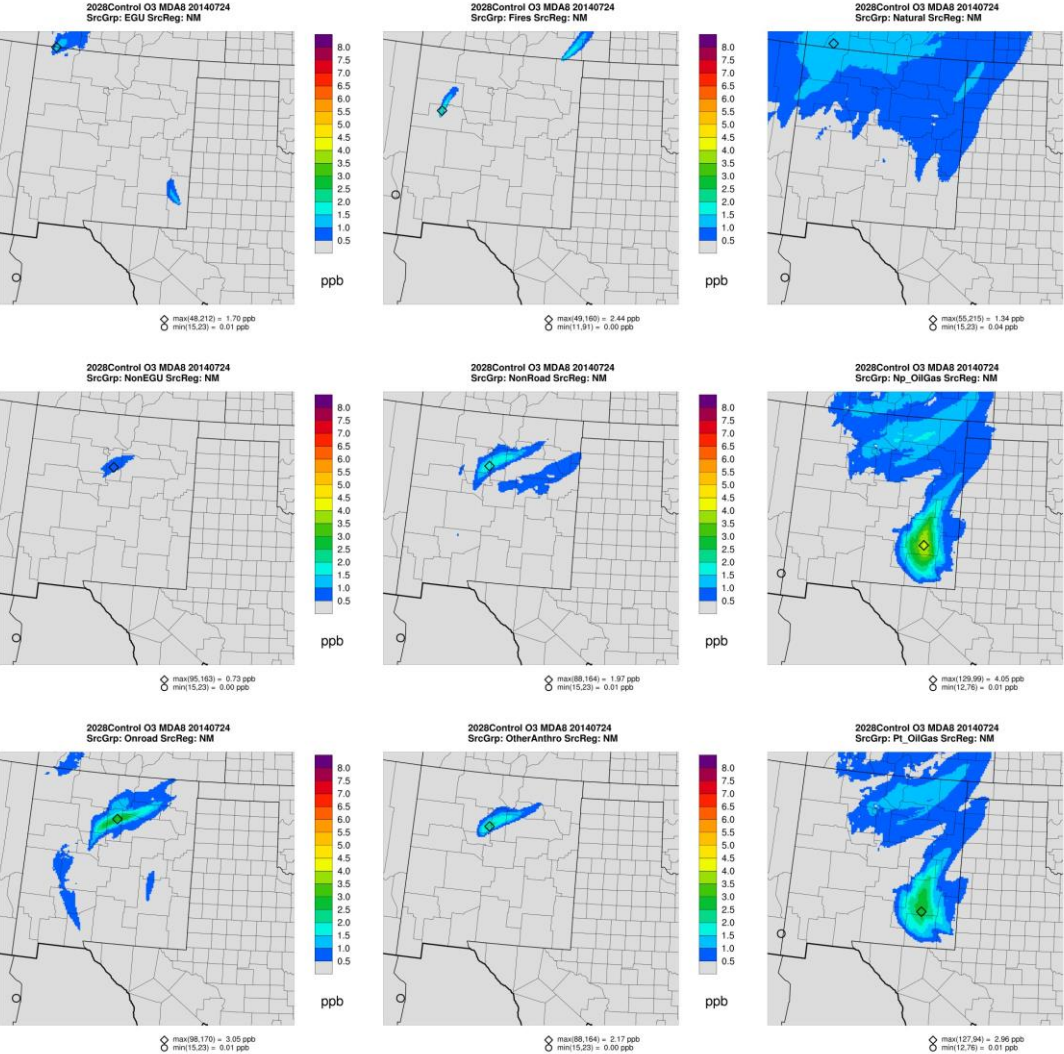


All United States

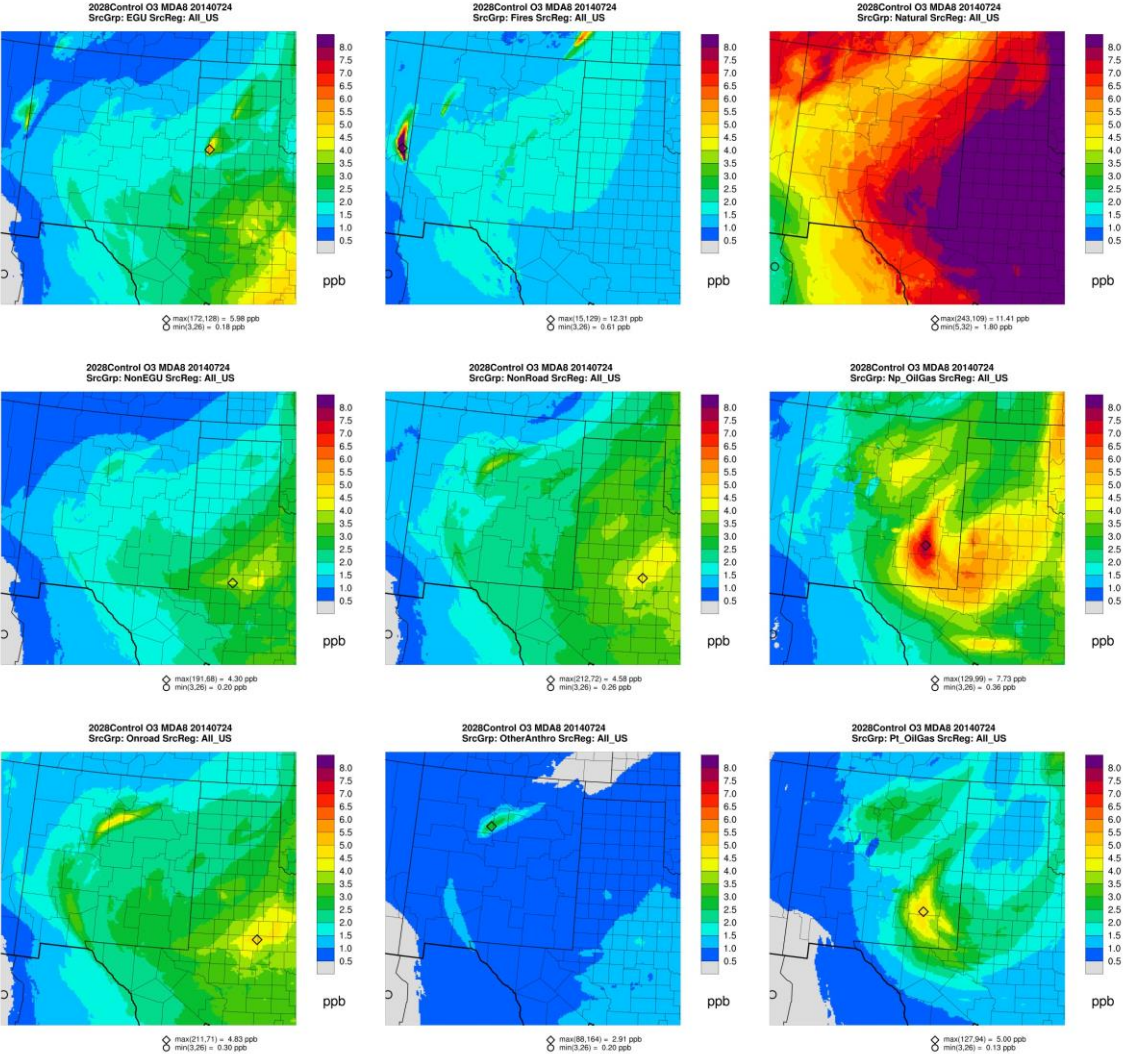


2028 SOURCE SECTOR – JULY 24, 2014

New Mexico



All United States

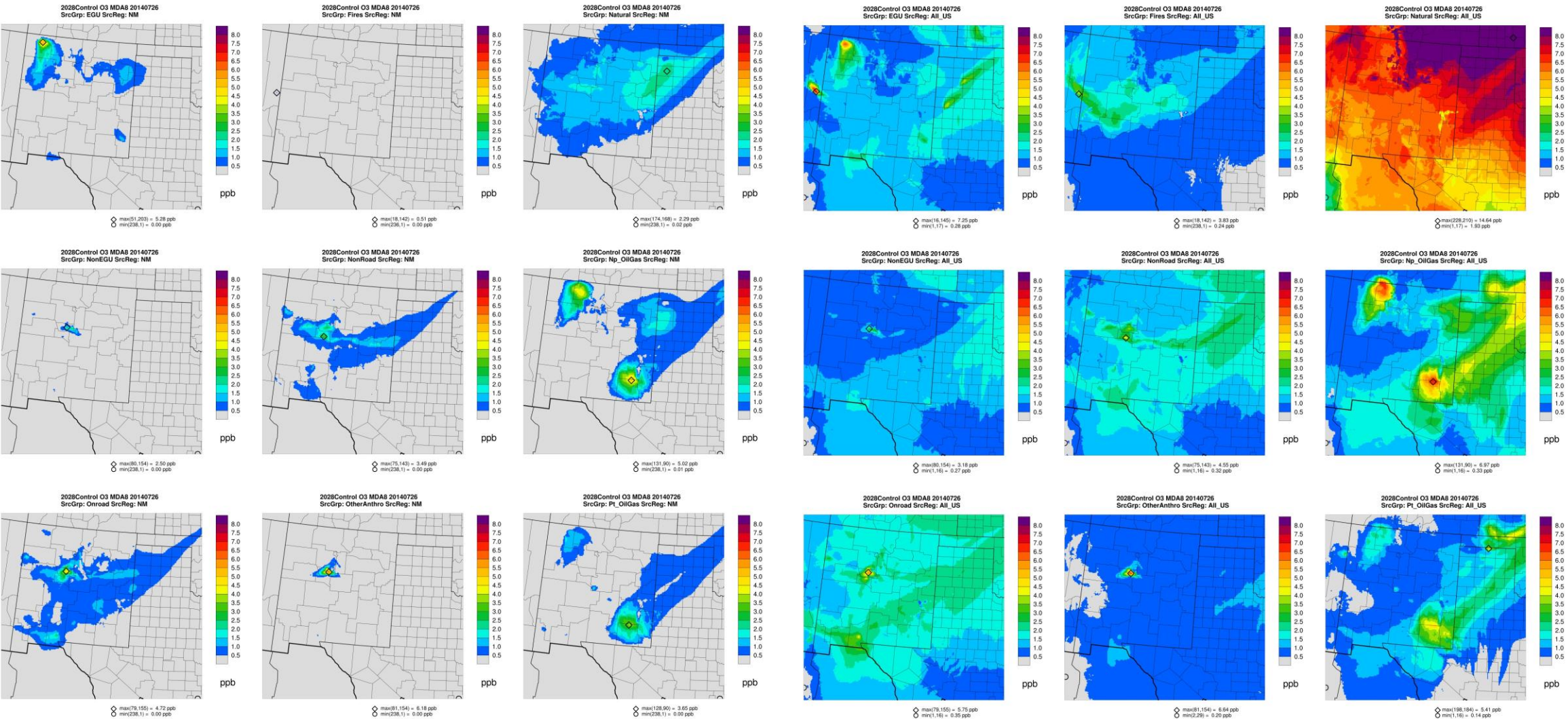


2028 SOURCE SECTOR – JULY 26, 2014

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT

New Mexico

All United States

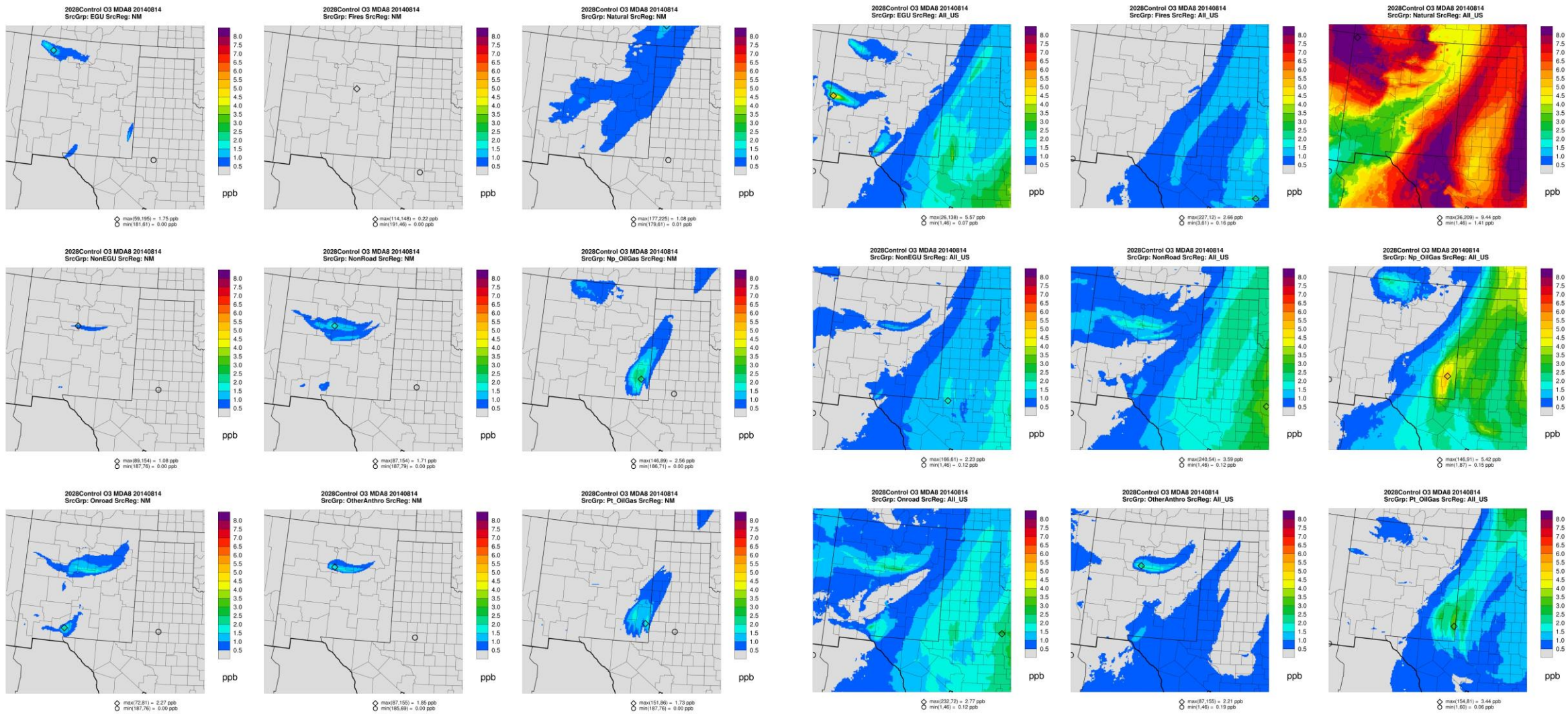


2028 SOURCE SECTOR – AUGUST 14, 2014

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT

New Mexico

All United States



INTERNATIONAL ANTHROPOGENIC EMISSIONS CONTRIBUTIONS

1. CONTRIBUTIONS OF INTERNATIONAL ANTHROPOGENIC EMISSIONS TO PROJECTED 2028 OZONE DVFS AT MONITORING SITES USING THREE DEFINITIONS OF CURRENT YEAR DESIGN VALUES: $DVC_{2012-2016}$, $DVC_{2015-2019}$ AND $DVC_{2017-2019}$
2. CONTRIBUTIONS OF INTERNATIONAL ANTHROPOGENIC EMISSIONS TO SMAT UNMONITORED AREA ANALYSIS PROJECTED 2028 OZONE DVFS ACROSS 4-KM NEW MEXICO DOMAIN USING THREE DEFINITIONS OF CURRENT YEAR DESIGN VALUES: $DVC_{2012-2016}$, $DVC_{2015-2019}$ AND $DVC_{2017-2019}$

2028 OZONE DVF NO INTERNATIONAL ANTHRO EMISSIONS

- 2028 ozone DVF projections using $DVC_{2012-2016}$, $DVC_{2015-2019}$ and $DVC_{2017-2019}$
- Elimination of international anthropogenic emissions reduces 2028 ozone DVF by 13 to 25 ppb
- 2028 ozone DVF w/ no international anthropogenic emissions range from 38 to 53 ppb

2012-14 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS-INTL (ppb)	Site Name
66.3	60.7	47.2	-13.5	Del Norte HS
68.0	62.0	48.5	-13.5	South East Heights
66.0	60.5	47.1	-13.4	South Valley
67.0	62.1	48.5	-13.6	Westside
65.0	58.8	45.7	-13.1	Foothills
66.3	59.8	39.9	-19.9	La Union
67.0	61.8	38.4	-23.4	Sunland Park
67.0	62.2	39.6	-22.6	Chaparral
72.0	66.8	42.6	-24.2	Desert View
71.3	66.0	42.2	-23.8	Santa Teresa
65.0	60.2	41.5	-18.7	Solano
69.0	66.4	46.1	-20.3	Carlsbad
62.0	58.9	43.0	-15.9	Chino Copper Smelt
66.0	63.3	44.9	-18.4	Hobbs Jefferson
66.0	62.5	43.3	-19.2	Deming Airport
64.0	60.0	47.4	-12.6	Coyote Ranger Dist
64.0	58.1	44.4	-13.7	Bernalillo (E Avenida)
64.3	60.2	46.4	-13.8	Bloomfield
67.0	63.3	50.2	-13.1	Navajo Lake
63.7	59.6	48.5	-11.1	Substation
64.3	60.4	47.9	-12.5	Santa Fe Airport
66.3	62.0	47.5	-14.5	Los Lunas (Los Lentos)

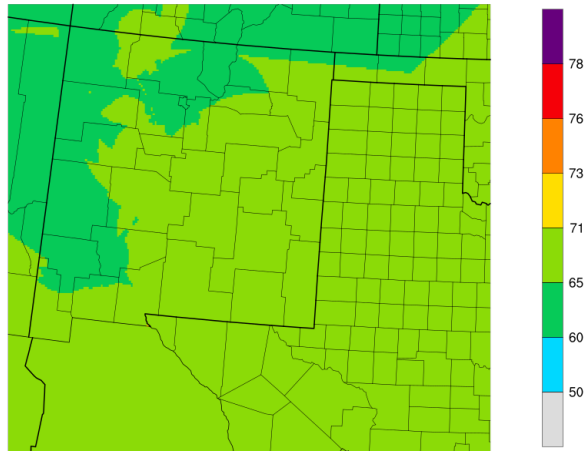
2015-19 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS-INTL (ppb)	Site Name
69.0	63.1	49.2	-13.9	Del Norte HS
66.0	60.5	47.1	-13.4	South Valley
69.0	62.4	48.5	-13.9	Foothills
68.7	62.0	41.3	-20.7	La Union
70.7	65.7	41.8	-23.9	Chaparral
74.3	68.9	43.9	-25.0	Desert View
74.0	68.5	43.8	-24.7	Santa Teresa
67.7	62.7	43.3	-19.4	Solano
73.7	70.9	49.2	-21.7	Carlsbad
71.0	69.3	44.1	-25.2	Carlsbad NP
69.3	66.5	47.1	-19.4	Hobbs Jefferson
66.3	62.2	49.1	-13.1	Coyote Ranger Dist
67.0	60.9	46.5	-14.4	Bernalillo (E Avenida)
67.0	62.8	48.3	-14.5	Bloomfield
69.0	65.2	51.7	-13.5	Navajo Lake
67.3	62.9	51.2	-11.7	Substation
65.0	61.0	48.4	-12.6	Santa Fe Airport
66.7	62.3	47.8	-14.5	Los Lunas (Los Lentos)

2017-19 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS-INTL (ppb)	Site Name
70.0	64.0	49.9	-14.1	Del Norte HS
67.0	61.4	47.8	-13.6	South Valley
71.0	64.2	49.9	-14.3	Foothills
70.0	63.2	42.1	-21.1	La Union
73.0	67.8	43.1	-24.7	Chaparral
77.0	71.4	45.5	-25.9	Desert View
76.0	70.3	45.0	-25.3	Santa Teresa
70.0	64.8	44.7	-20.1	Solano
79.0	76.0	52.8	-23.2	Carlsbad
71.0	68.1	48.3	-19.8	Hobbs Jefferson
67.0	62.8	49.6	-13.2	Coyote Ranger Dist
68.0	61.8	47.2	-14.6	Bernalillo (E Avenida)
68.0	63.7	49.1	-14.6	Bloomfield
69.0	65.2	51.7	-13.5	Navajo Lake
69.0	64.5	52.5	-12.0	Substation
66.0	62.0	49.1	-12.9	Santa Fe Airport
68.0	63.5	48.7	-14.8	Los Lunas (Los Lentos)

SMAT UAA -- DVC (TOP) AND 2028 O&G CONTROL DVF (BOTTOM)

DVC₂₀₁₂₋₂₀₁₆

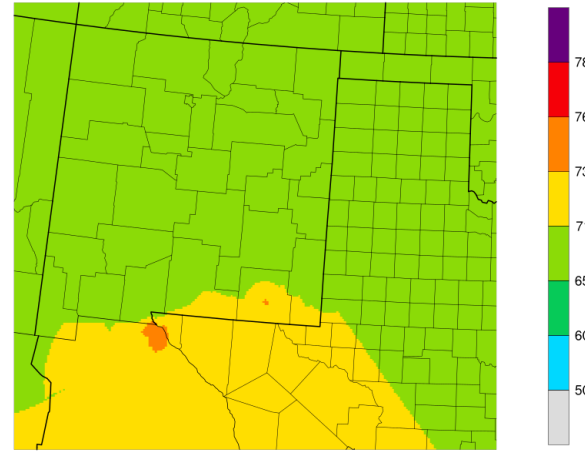
2014 Basecase
DVC 2012_2016
O3 Design Value UAA



max(71,64) = 71.0 ppb
min(93,93) = 62.1 ppb

DVC₂₀₁₅₋₂₀₁₉

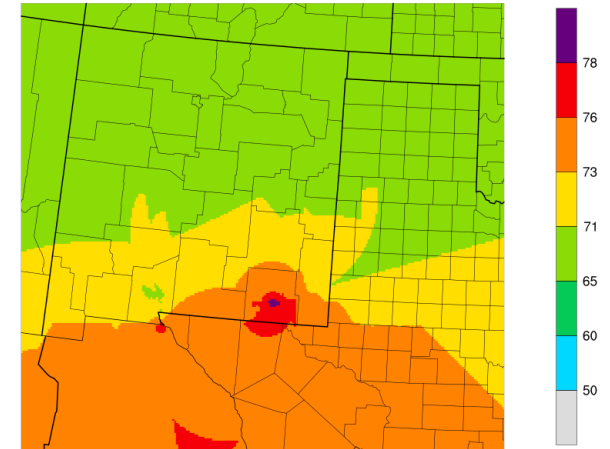
2014 Basecase
DVC 2015_2019
O3 Design Value UAA



max(71,64) = 74.2 ppb
min(93,169) = 65.1 ppb

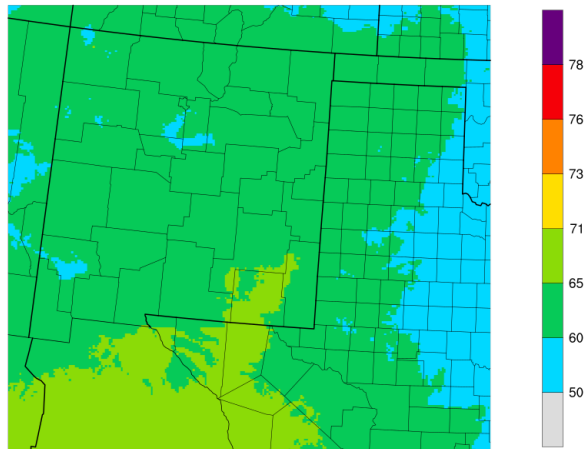
DVC₂₀₁₇₋₂₀₁₉

2014 Basecase
DVC 2017_2019
O3 Design Value UAA



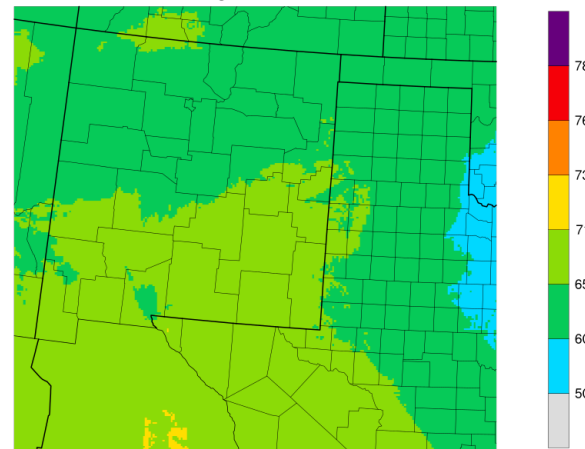
max(127,75) = 78.9 ppb
min(93,169) = 66.1 ppb

2028 Oil and Gas Control
DVC 2012_2016
O3 Design Value UAA



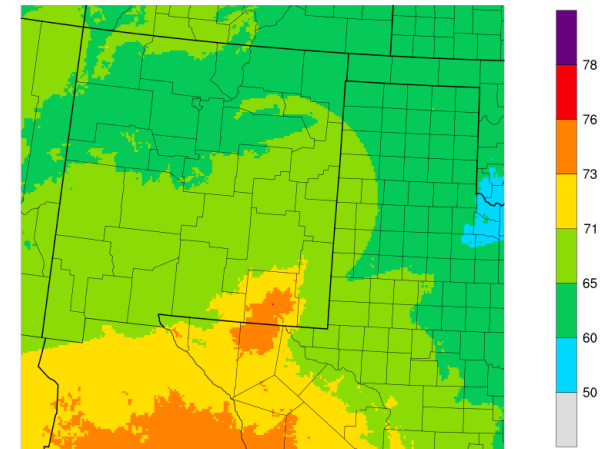
max(79,59) = 67.2 ppb
min(243,116) = 54.7 ppb

2028 Oil and Gas Control
DVC 2015_2019
O3 Design Value UAA



max(78,62) = 71.5 ppb
min(243,116) = 57.3 ppb

2028 Oil and Gas Control
DVC 2017_2019
O3 Design Value UAA

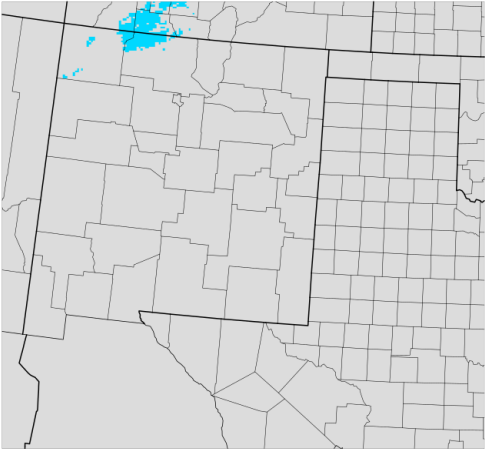


max(127,75) = 76.1 ppb
min(243,116) = 57.5 ppb

SMAT UAA – 2028 DVF NO INTL (TOP) AND DIFFERENCE (BOTTOM)

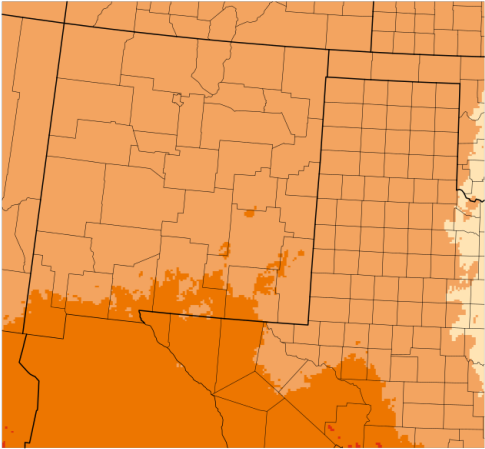
DVC₂₀₁₂₋₂₀₁₆

2028 No International
DVC 2012_2016
O3 Design Value UAA



max(44,204) = 52.5 ppb
min(176,2) = 33.8 ppb

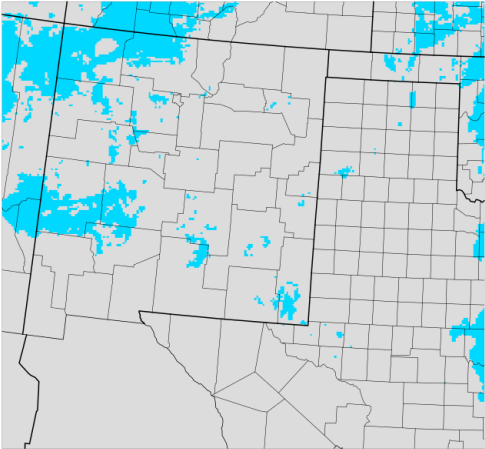
2028 OilandGas control - 2028 No_International
DVC 2012_2016
O3 Design Value UAA



max(176,2) = 30.748 ppb
min(241,59) = 7.247 ppb

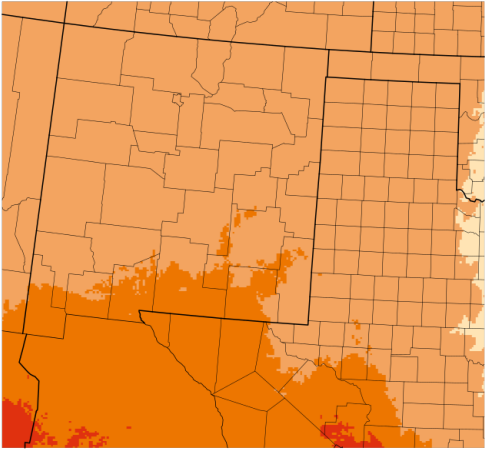
DVC₂₀₁₅₋₂₀₁₉

2028 No International
DVC 2015_2019
O3 Design Value UAA



max(44,204) = 55.2 ppb
min(176,2) = 35.6 ppb

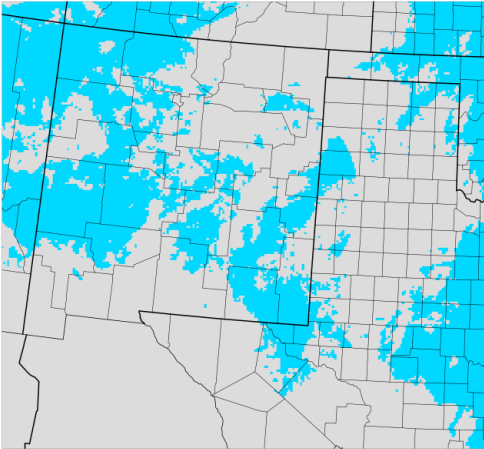
2028 OilandGas control - 2028 No_International
DVC 2015_2019
O3 Design Value UAA



max(2,2) = 32.562 ppb
min(241,59) = 7.636 ppb

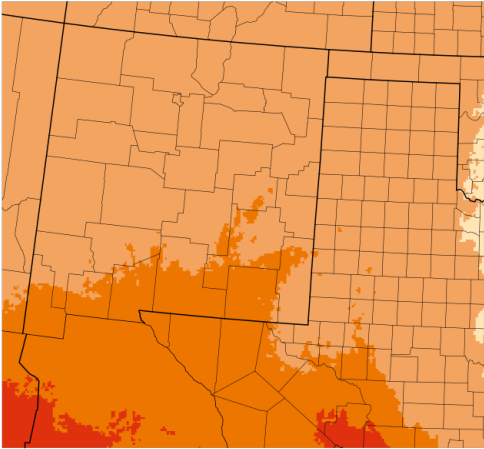
DVC₂₀₁₇₋₂₀₁₉

2028 No International
DVC 2017_2019
O3 Design Value UAA



max(44,204) = 56.4 ppb
min(176,2) = 37.4 ppb

2028 OilandGas control - 2028 No_International
DVC 2017_2019
O3 Design Value UAA



max(176,2) = 34.092 ppb
min(241,59) = 7.932 ppb

SECOND DRAFT AQTSD (DUE APRIL 4, 2021)

1. Introduction
2. 2014 WRF Meteorological Modeling
3. Boundary Condition Inputs
4. 2014 Emission Inputs
5. Diagnostic Sensitivity Tests
6. 2014 Base Case Modeling and Model Performance Evaluation
7. 2028 Base Case Modeling and Ozone Design Value Projections
8. 2028 Oil and Gas Control Strategy Modeling and Ozone Design Value Projections
9. Sensitivity of 2028 Ozone Design Value Projections to Current Year Design Values
10. APCA Source Sector Ozone Source Apportionment Modeling

11. Summary and Conclusions

12. References

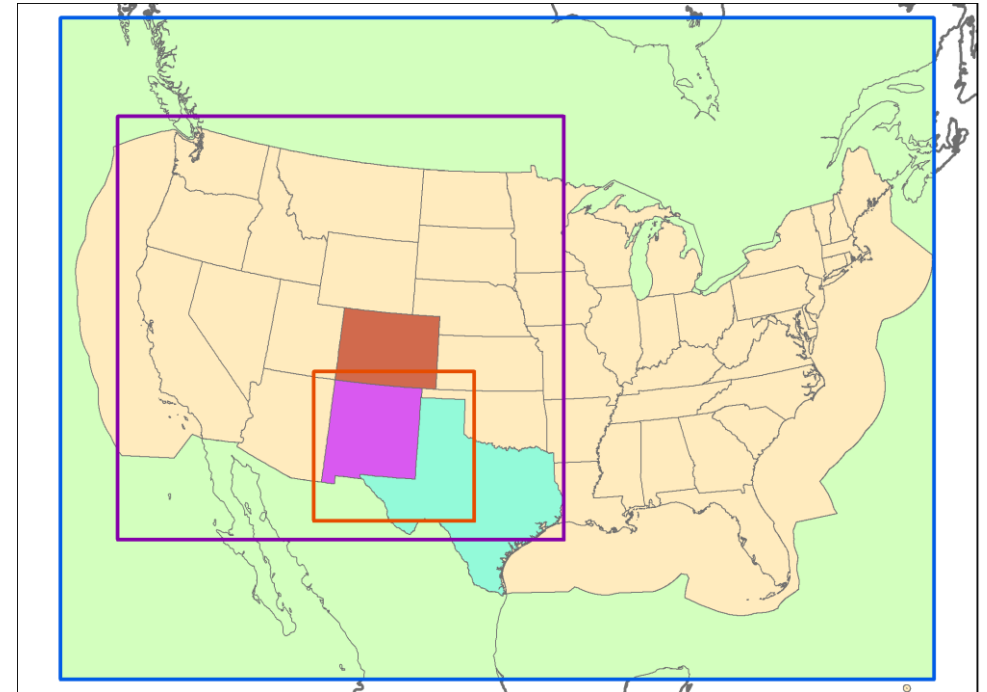
To Come:

11. OSAT VOC/NOx Sensitivity Ozone Source Apportionment Modeling



CAMX 2028 O&G CS OSAT OZONE SOURCE APPORTIONMENT

- Use the OSAT version of CAMx ozone source apportionment tool
 - OSAT O3V and O3N tracers give indication of amount of VOC-limited and NOx-limited ozone formation
- Definition of Source Groups
 - Source Regions (5):
 - Use same 5 Source Regions as APCA SA run
 - Source Categories (3):
 - Anthropogenic Emissions
 - Natural (Biogenic, lightning NOx, WBD, oceanic)
 - Fires (WF, Rx, Ag and other)
 - 17 Source Groups (5 x 3 + 2 [IC,BC])
 - Will run faster than CAMx APCA SA Run (50 Source Groups)
- Post-Processing
 - Amount of VOC-limited vs. NOx-limited ozone across 4-km domain from New Mexico sources alone, and all sources



NEW MEXICO OZONE ATTAINMENT INITIATIVE

2028 VOC and NOx Sensitivity OSAT Ozone Source Apportionment Modeling and Draft Final Air Quality Technical Support Document

Marco Rodriguez, Pradeepa Vennam, Jung Chien, John Grant, Tejas Shah and Ralph Morris, Ramboll

Tom Moore and Mary Uhl, WESTAR

NM OAI Study Webinar

April 21, 2021



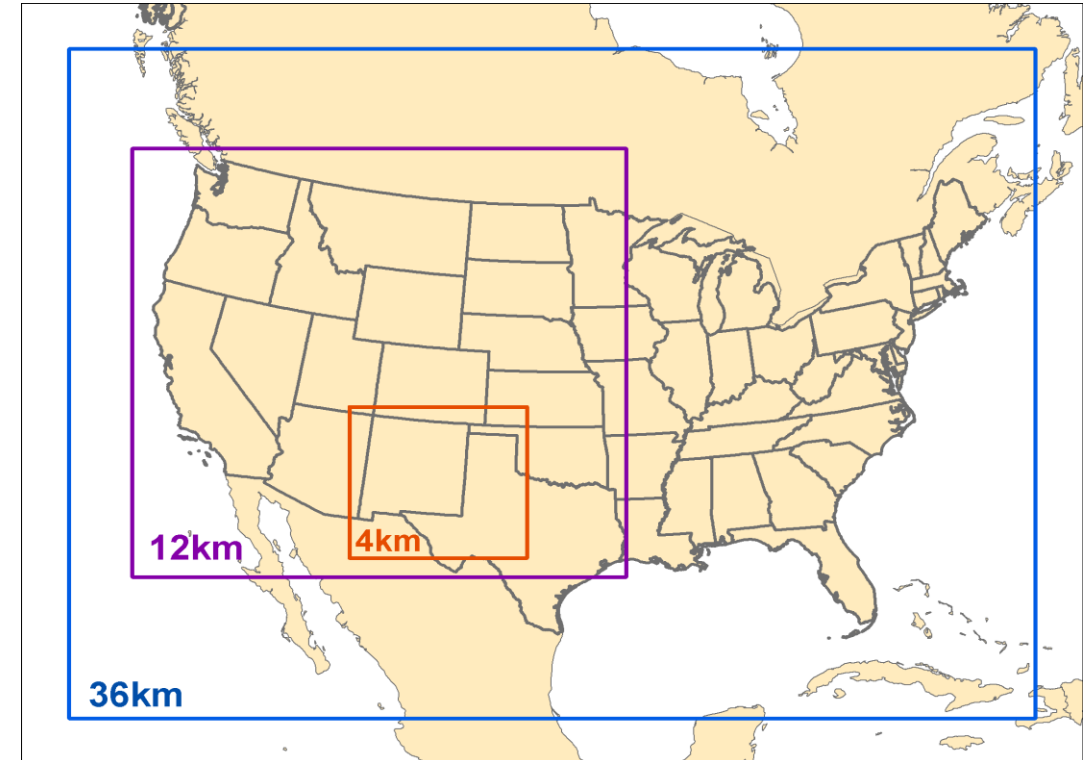
Bright ideas. Sustainable change.

2028 VOC/NOX SENSITIVITY OSAT OZONE SOURCE APPORTIONMENT

- 01** CAMx Ozone Source Apportionment Tools and Differences Between OSAT and APCA
- 02** Highlights of 2028 Source Sector APCA Ozone Source Apportionment Modeling (presented at April 2, 2021 Webinar)
- 03** 2028 VOC/NOx Sensitivity OSAT Ozone Source Apportionment Modeling Results
- 04** Draft Final Air Quality Technical Support Document (AQTSD)

CAMX 2014 NM OAI STUDY MODEL CONFIGURATION

- Episode: May-August 2014
 - 16-day spin-up before first high ozone day in NM
 - 68 ppb on May 17
- 36/12/4-km Modeling Domains
 - 36/12-km domains same as WRAP Regional Haze
 - New 4-km New Mexico domain
- Boundary Conditions (BC) WRAP 2014 GEOS-Chem
- Four Meteorological Diagnostic Sensitivity tests
 - Selected WRF/NAM with Kv=CMAQ
- WRAP 2014v2 base year emissions
 - EPA NEI2014v2 w/ western state updates
- WRAP 2028OTBa2 for future year w/ 2014 actual fires and new 2028 NM O&G



CAMX OZONE SOURCE APPORTIONMENT TOOLS

- **Ozone Source Apportionment Technology (OSAT)**
 - OSAT uses tagged species/reactive tracers to calculate contributions of VOC and NO_x emissions from user-defined Source Groups to ozone concentrations that are VOC sensitive (O3V) and ozone concentrations that are NO_x sensitive (O3N)
 - Accounting system that operates in parallel to host model extracting ozone source apportionment information
 - User-defined Source Groups can be Source Regions and/or Source Categories and includes all sources (including BCs) of ozone (e.g., on-road mobile sources from New Mexico)
 - When ozone is formed, OSAT determines whether ozone formation is more sensitive to VOC or NO_x emissions and allocates it to Source Group's ozone tracers (O3V or O3N) based on the relative contribution of the more sensitive ozone precursor (VOC or NO_x)
- 10 Reactive Tracers used for each Source Group
 - V_i = VOC emissions
 - NIT_i = Nitric oxide (NO) & nitrous acid (HONO) emissions
 - RGN_i = Nitrogen dioxide (NO₂), nitrate radical (NO₃) and dinitrogen pentoxide (N₂O₅)
 - TPN_i = Peroxyl acetyl nitrate (PAN), analogues of PAN and peroxy nitric acid (PNA)
 - NTR_i = Organic nitrates (RNO₃)
 - $HN3_i$ = Gaseous nitric acid (HNO₃)
 - $O3N_i$ = Ozone formed under NO_x-limited conditions from N_i
 - $O3V_i$ = Ozone formed under VOC-limited conditions from V_i
 - OON_i = Odd-oxygen in NO₂ formed from $O3N_i$
 - OOV_i = Odd-oxygen in NO₂ formed from $O3V_i$

CAMX OZONE SOURCE APPORTIONMENT TOOLS

- **Anthropogenic Precursor Culpability Assessment (APCA)**

- APCA differs from OSAT in that it only allocates ozone formed to the Natural (e.g., biogenic) Source Groups when it is due to Natural VOC reacting with Natural NOx
 - For example, ozone formed due to biogenic VOC reacting with anthropogenic NOx under VOC emissions sensitive conditions, a case OSAT assigns to Natural Source Group O3V, APCA redirects ozone formed to anthropogenic Source Group O3N
- APCA provides more control strategy relevant information and is used in ozone contribution assessments, while OSAT provides information on whether ozone formation is more sensitive to VOC or NOx emissions
 - APCA used in EPA's Cross State Air Pollution Rule (CSAPR) to identify when an upwind state's anthropogenic emissions contributes significantly to nonattainment in a downwind state
 - APCA also used in NMED OAI Study 2028 Local Source APCA ozone source apportionment modeling
- If analyzing whether ozone formation is more sensitive to VOC or NOx emissions, then OSAT source apportionment or a sensitivity method (e.g., DDM/HDDM or Brute Force) must be used
 - NM OAI Study 2028 VOC/NOx sensitivity OSAT ozone source apportionment modeling

CAMX 2028 O&G CS SOURCE SECTOR APCA OZONE SA

• Definition of Source Groups

○ Boundary Conditions (BCs) from WRAP 2014 GEOS-Chem runs:

- BC_{Intl} - International anthropogenic emissions
- BC_{USA} - U.S. anthropogenic emissions
- BC_{Natural} - Natural sources
- BC_{Top} - BC above the top of domain

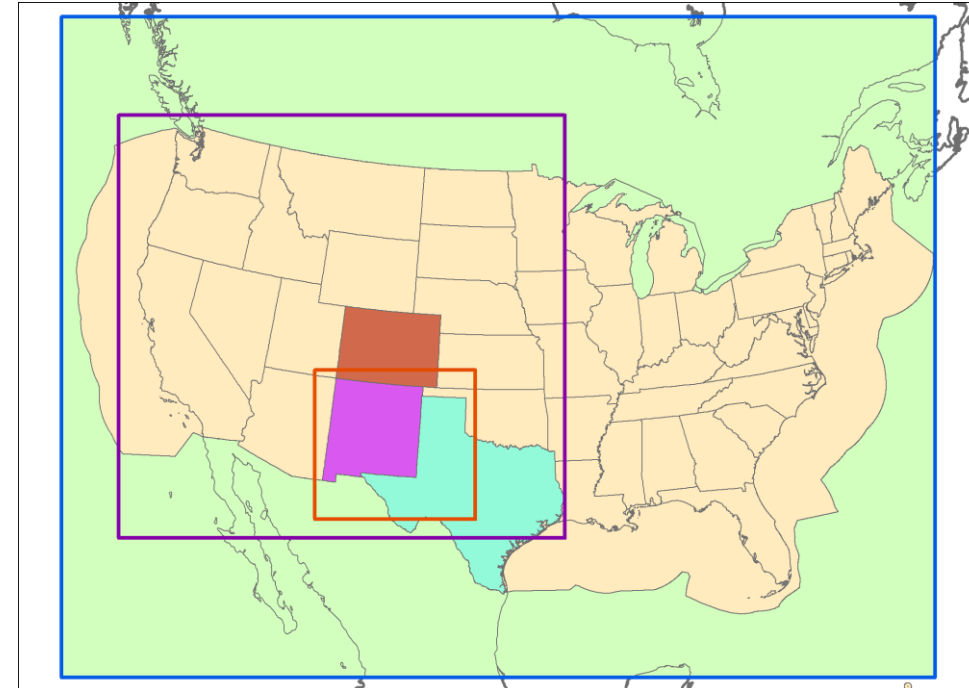
○ Source Categories (9):

1. Natural (biogenic, lightning NO_x, etc.);
2. Fires (WF, Rx, Ag, other);
3. Oil and gas point sources (surrogate for midstream);
4. Oil and gas non-point sources (surrogate for upstream);
5. EGU point;
6. Non-EGU point;
7. On-road mobile;
8. Non-road mobile; and
9. Remainder anthropogenic.

○ Source Regions (5):

- New Mexico
- Texas
- Colorado
- Remainder U.S.
- International (Mex, Can, CMV > 200 nmi)

○ 50 Source Groups (50 = 5 x 9 + 5)



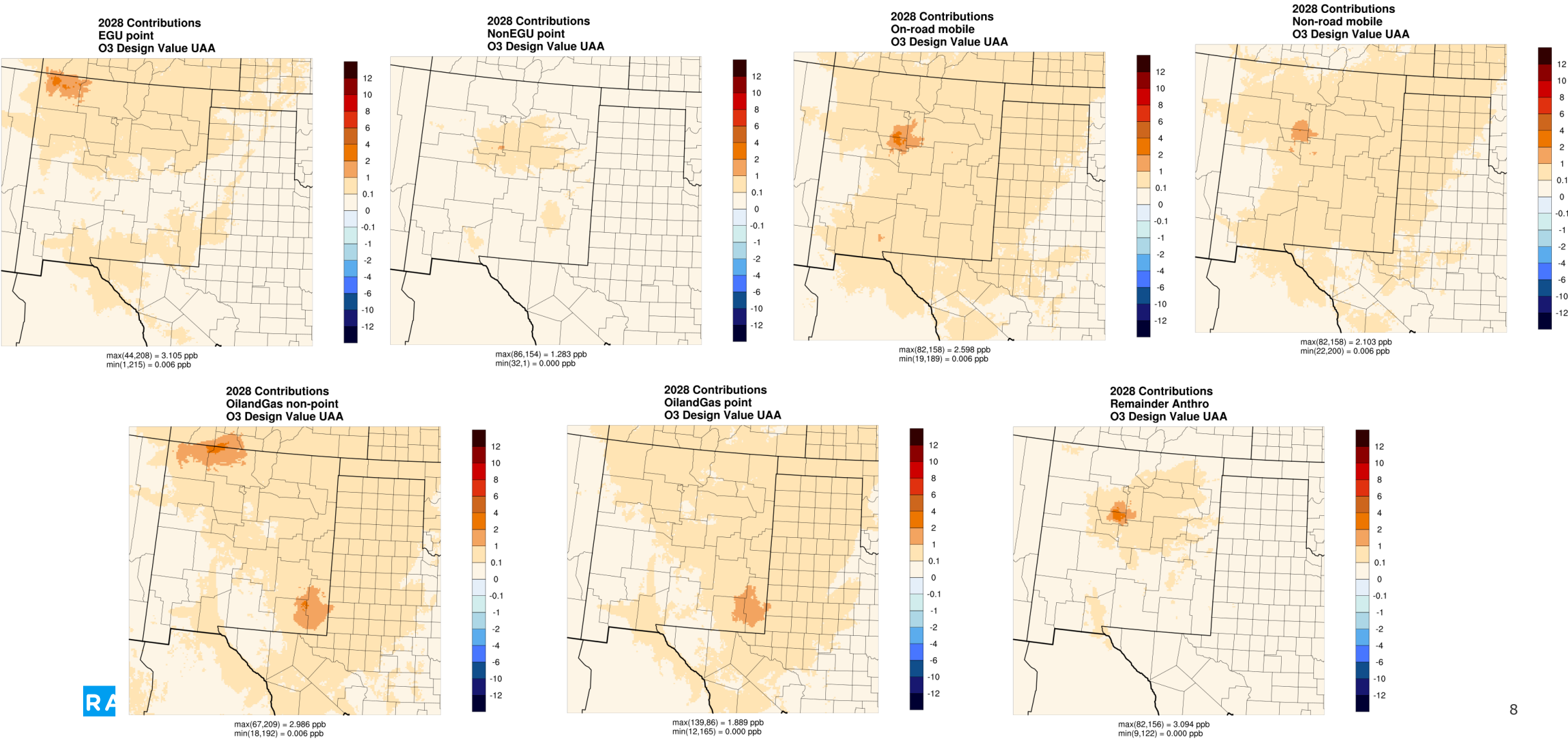
REDUCTIONS 2028 OZONE DVFS NEW MEXICO SOURCE SECTORS

- 2028 ozone DVF Reductions from New Mexico Source Sectors

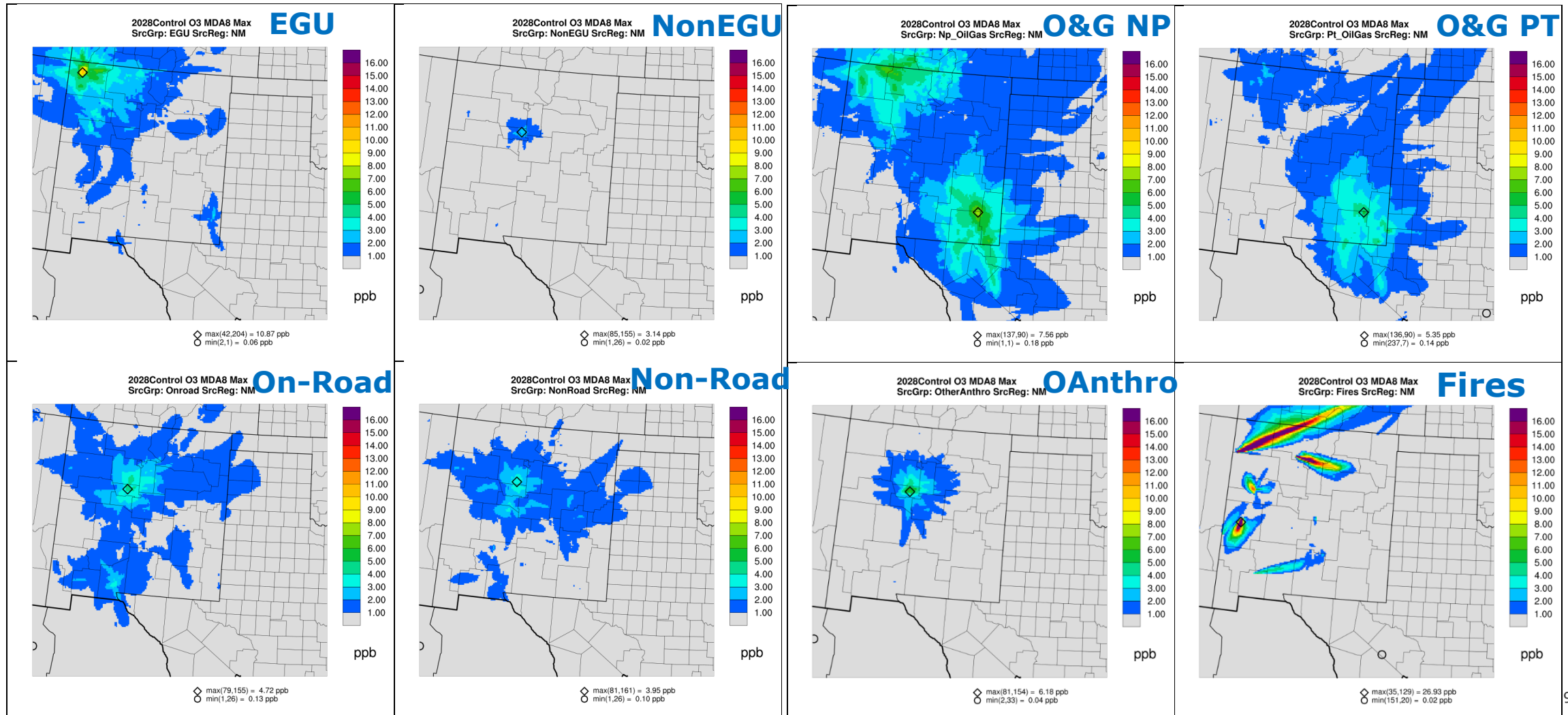
- O&G Point: -0.1 to -0.9 ppb
- O&G Non-Pt: -0.1 to -2.1 ppb
- EGU Point: 0.0 to -3.1 ppb
- Non-EGU Pt: 0.0 to -1.1 ppb
- On-Road: -0.1 to -2.7 ppb
- Non-Road: -0.1 to -1.9 ppb
- Other Anthro: 0.0 to -3.6 ppb

AQS_ID	Site_ID	DVC	DVF	O&GPT	O&GNP	EGU	NonEGU	OnRoad	NonRoad	OAnth
350010023	NORTE	66.3	60.7	-0.2	-0.3	-0.5	-1.0	-2.7	-2.0	-3.6
350010024	SEHGS	68.0	62.0	-0.2	-0.3	-0.5	-1.1	-2.5	-1.9	-3.2
350010029	STHVA	66.0	60.5	-0.3	-0.5	-0.5	-1.0	-2.2	-1.7	-2.4
350010032	WSTSD	67.0	62.1	-0.2	-0.4	-0.4	-0.4	-1.6	-1.2	-1.8
350011012	FTHIL	65.0	58.8	-0.2	-0.3	-0.5	-0.7	-2.5	-2.0	-3.0
350130008	UNION	66.3	59.8	-0.2	-0.2	-0.7	0.0	-0.5	-0.3	-0.1
350130017	SPARK	67.0	61.8	-0.2	-0.2	-0.9	0.0	-0.4	-0.2	-0.2
350130020	CHAPA	67.0	62.2	-0.1	-0.1	-0.3	0.0	-0.2	-0.1	-0.1
350130021	DSVIE	72.0	66.8	-0.2	-0.3	-0.9	-0.1	-0.5	-0.3	-0.2
350130022	TERES	71.3	66.0	-0.3	-0.3	-0.7	-0.1	-0.5	-0.3	-0.2
350130023	SOLAN	65.0	60.2	-0.2	-0.2	-0.2	-0.2	-1.2	-0.7	-0.3
350151005	CARLS	69.0	66.4	-0.5	-0.5	-0.2	-0.1	-0.3	-0.2	-0.1
350171003	GRANT	62.0	58.9	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
350250008	HOBBS	66.0	63.3	-0.9	-1.1	-0.2	0.0	-0.3	-0.2	-0.1
350290003	DEAIR	66.0	62.5	-0.2	-0.1	-0.2	0.0	-0.6	-0.4	0.0
350390026	COYOT	64.0	60.0	-0.2	-0.5	-0.5	0.0	-0.2	-0.1	0.0
350431001	BERNA	64.0	58.1	-0.1	-0.2	-0.4	-0.4	-2.1	-1.5	-1.9
350450009	BLOOM	64.3	60.2	-0.7	-1.4	-1.9	0.0	-0.4	-0.1	-0.1
350450018	NAVAJ	67.0	63.3	-0.9	-2.1	-1.7	-0.1	-0.4	-0.2	-0.1
350451005	SUBST	63.7	59.6	-0.6	-1.5	-3.1	-0.1	-0.5	-0.2	-0.2
350490021	SNTFE	64.3	60.4	-0.2	-0.3	-0.2	-0.3	-1.2	-0.7	-0.8
350610008	LUNAS	66.3	62.0	-0.2	-0.3	-0.3	-0.3	-1.1	-1.0	-0.4

SMAT UAA (DVC₂₀₁₂₋₂₀₁₆) 2028 DVF NM SOURCE CONTRIBUTIONS



HIGHEST NEW MEXICO SOURCE SECTOR OZONE CONTRIBUTIONS TO MDA8 OZONE DURING EPISODE

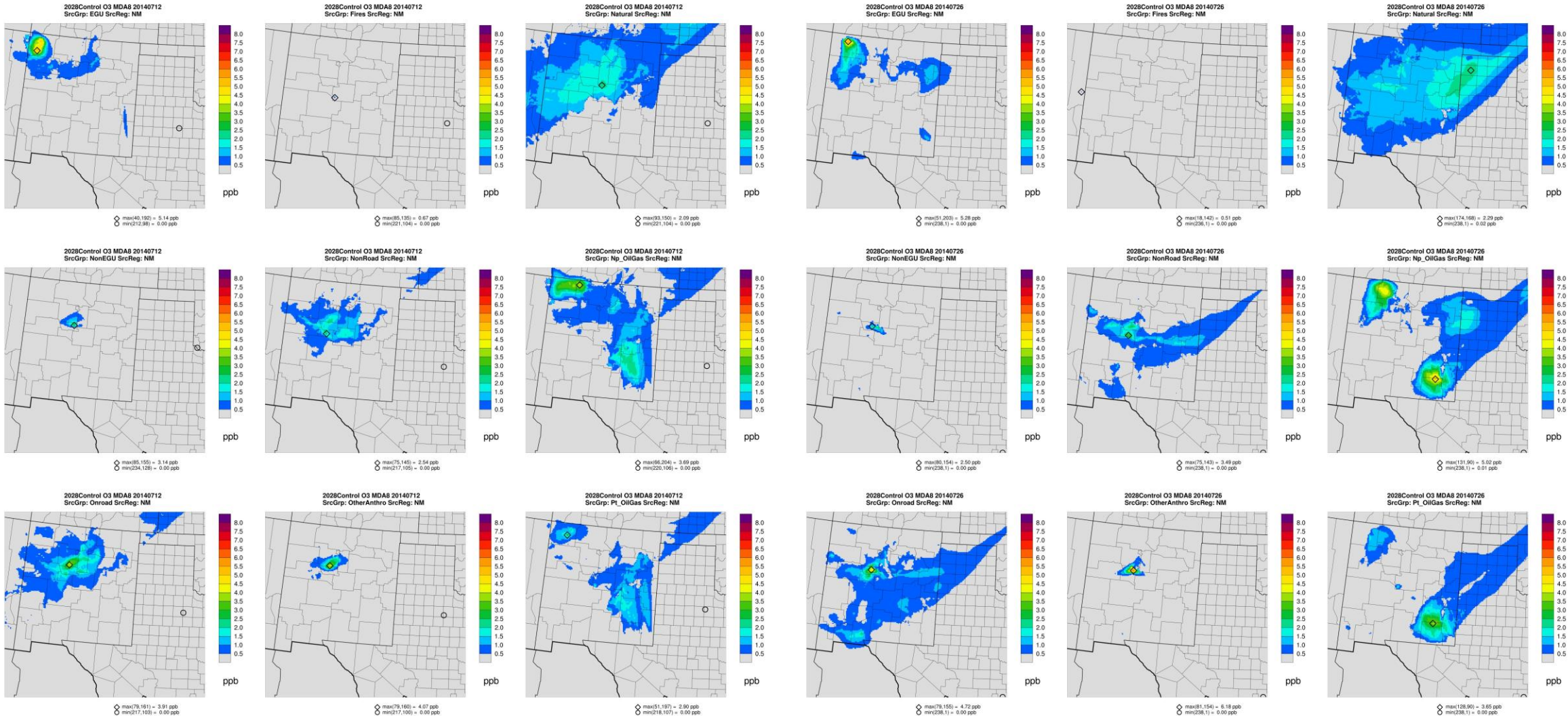


2028 NEW MEXICO SOURCE SECTOR

EGU	Fires	Natural
NonEGU	Non-Road	O&G_NP
On-Road	OAnthro	O&G_PT

July 12, 2014

July 26, 2014



2028 OZONE DVF NO INTERNATIONAL ANTHRO EMISSIONS

- 2028 ozone DVF projections using $DVC_{2012-2016}$, $DVC_{2015-2019}$ and $DVC_{2017-2019}$
- Elimination of international anthropogenic emissions reduces 2028 ozone DVF by 13 to 25 ppb
- 2028 ozone DVF w/ no international anthropogenic emissions range from 38 to 53 ppb

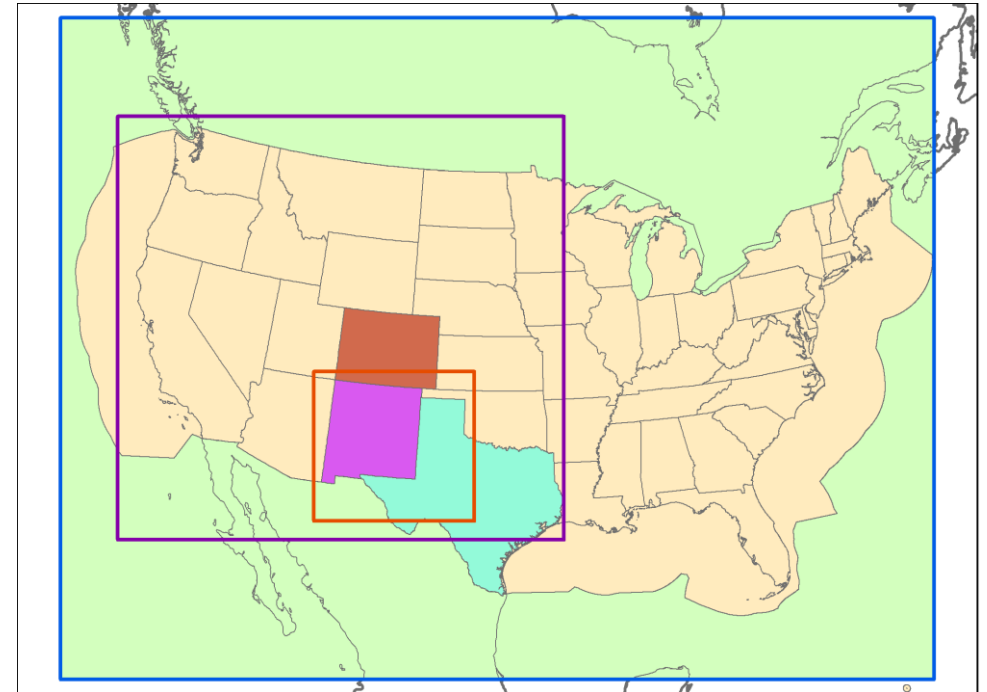
2012-14 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS-INTL (ppb)	Site Name
66.3	60.7	47.2	-13.5	Del Norte HS
68.0	62.0	48.5	-13.5	South East Heights
66.0	60.5	47.1	-13.4	South Valley
67.0	62.1	48.5	-13.6	Westside
65.0	58.8	45.7	-13.1	Foothills
66.3	59.8	39.9	-19.9	La Union
67.0	61.8	38.4	-23.4	Sunland Park
67.0	62.2	39.6	-22.6	Chaparral
72.0	66.8	42.6	-24.2	Desert View
71.3	66.0	42.2	-23.8	Santa Teresa
65.0	60.2	41.5	-18.7	Solano
69.0	66.4	46.1	-20.3	Carlsbad
62.0	58.9	43.0	-15.9	Chino Copper Smelt
66.0	63.3	44.9	-18.4	Hobbs Jefferson
66.0	62.5	43.3	-19.2	Deming Airport
64.0	60.0	47.4	-12.6	Coyote Ranger Dist
64.0	58.1	44.4	-13.7	Bernalillo (E Avenida)
64.3	60.2	46.4	-13.8	Bloomfield
67.0	63.3	50.2	-13.1	Navajo Lake
63.7	59.6	48.5	-11.1	Substation
64.3	60.4	47.9	-12.5	Santa Fe Airport
66.3	62.0	47.5	-14.5	Los Lunas (Los Lentos)

2015-19 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS-INTL (ppb)	Site Name
69.0	63.1	49.2	-13.9	Del Norte HS
66.0	60.5	47.1	-13.4	South Valley
69.0	62.4	48.5	-13.9	Foothills
68.7	62.0	41.3	-20.7	La Union
70.7	65.7	41.8	-23.9	Chaparral
74.3	68.9	43.9	-25.0	Desert View
74.0	68.5	43.8	-24.7	Santa Teresa
67.7	62.7	43.3	-19.4	Solano
73.7	70.9	49.2	-21.7	Carlsbad
71.0	69.3	44.1	-25.2	Carlsbad NP
69.3	66.5	47.1	-19.4	Hobbs Jefferson
66.3	62.2	49.1	-13.1	Coyote Ranger Dist
67.0	60.9	46.5	-14.4	Bernalillo (E Avenida)
67.0	62.8	48.3	-14.5	Bloomfield
69.0	65.2	51.7	-13.5	Navajo Lake
67.3	62.9	51.2	-11.7	Substation
65.0	61.0	48.4	-12.6	Santa Fe Airport
66.7	62.3	47.8	-14.5	Los Lunas (Los Lentos)

2017-19 DVC (ppb)	2028OGCS DVF (ppb)	2028INTL DVF (ppb)	2028 DVF Difference OGCS-INTL (ppb)	Site Name
70.0	64.0	49.9	-14.1	Del Norte HS
67.0	61.4	47.8	-13.6	South Valley
71.0	64.2	49.9	-14.3	Foothills
70.0	63.2	42.1	-21.1	La Union
73.0	67.8	43.1	-24.7	Chaparral
77.0	71.4	45.5	-25.9	Desert View
76.0	70.3	45.0	-25.3	Santa Teresa
70.0	64.8	44.7	-20.1	Solano
79.0	76.0	52.8	-23.2	Carlsbad
71.0	68.1	48.3	-19.8	Hobbs Jefferson
67.0	62.8	49.6	-13.2	Coyote Ranger Dist
68.0	61.8	47.2	-14.6	Bernalillo (E Avenida)
68.0	63.7	49.1	-14.6	Bloomfield
69.0	65.2	51.7	-13.5	Navajo Lake
69.0	64.5	52.5	-12.0	Substation
66.0	62.0	49.1	-12.9	Santa Fe Airport
68.0	63.5	48.7	-14.8	Los Lunas (Los Lentos)

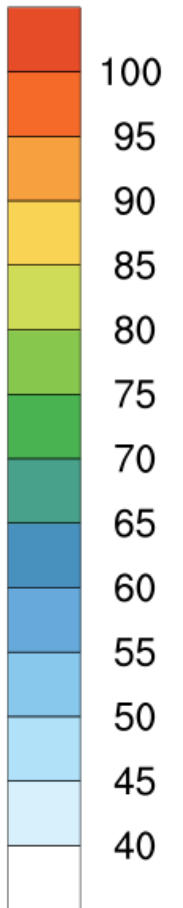
CAMX 2028 O&G CS OSAT OZONE SOURCE APPORTIONMENT

- Use the OSAT version of CAMx ozone source apportionment tool
 - OSAT O3V and O3N tracers give indication of whether ozone formation is more VOC or NOx sensitive
- Definition of Source Groups
 - Source Regions (5):
 - Use same 5 Source Regions as APCA SA run
 - Source Categories (3):
 - Anthropogenic Emissions
 - Natural (Biogenic, lightning NOx, WBD, oceanic)
 - Fires (U.S. WF, Rx and Ag and other)
 - 17 Source Groups (5 x 3 + 2 [IC,BC])
 - Runs faster than CAMx APCA SA Run (50 Source Groups)
- Post-Processing
 - Compare amount of ozone that is formed under more VOC sensitive vs. NOx sensitive conditions



SPATIAL MAPS OF OSAT VOC/NOX OZONE SENSITIVITY

- Use O3N and O3V tracers from emissions-based Source Groups to determine amount of ozone formed under VOC sensitive versus NOx sensitive conditions:
 - Percent NOx Sensitive Ozone Formation = $100 \times O3N / (O3V + O3N)$ Scale Used →
- Daily spatial maps of MDA8 ozone concentrations and percent ozone formed under NOx emissions sensitive conditions
 - Total MDA8 ozone from all Source Groups ($O3V + O3N + O3_{BC}$)
 - Boundary Condition (BC) ozone defined by 2014 GEOS-Chem run so no information on VOC/NOx sensitivity
 - MDA8 ozone and percent NOx sensitive ozone for all emissions-based Source Groups
 - ($O3V + O3N$) from anthropogenic, fire and natural emissions Source Categories and all 5 Source Regions
 - MDA8 ozone and percent NOx sensitive ozone for all anthropogenic emissions Source Groups
 - MDA8 ozone and percent NOx sensitive ozone for New Mexico anthropogenic emissions
 - Provide control strategy relevant information on relative importance of New Mexico VOC and NOx emissions

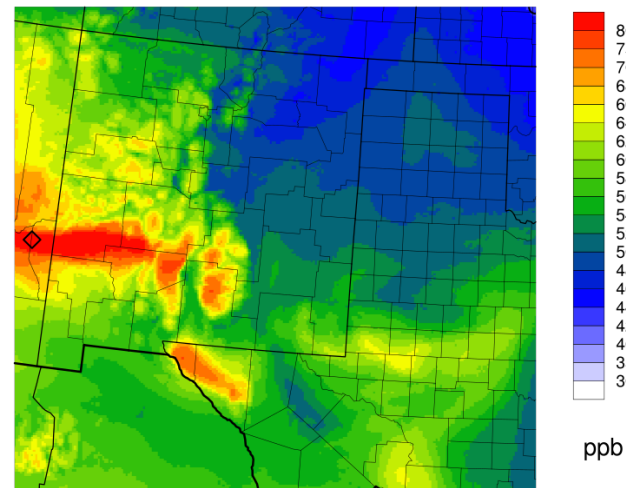


%

2028 OSAT SA RESULTS FOR MAY 17, 2014

All Source Regions/Categories

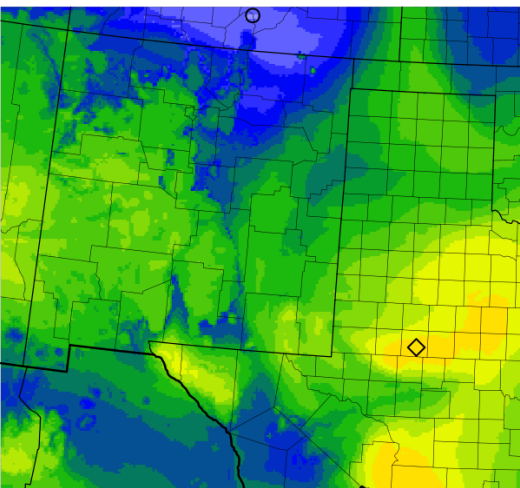
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat 20140517



max(9,117) = 128.6 ppb
min(243,225) = 43.7 ppb

All Regions Anthro

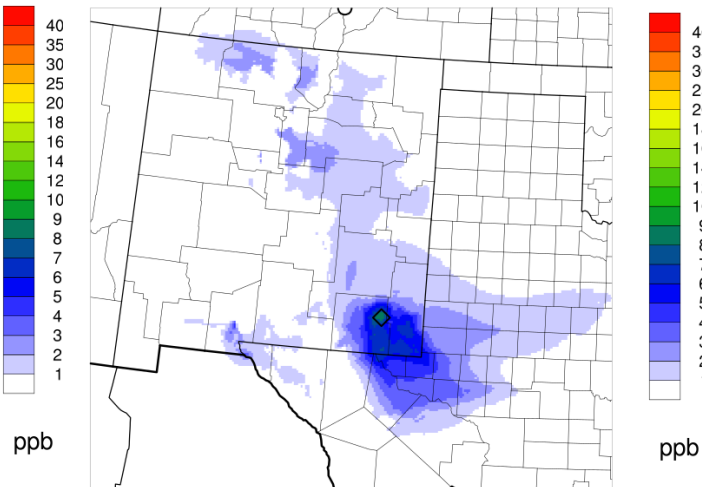
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_all_anthro 20140517



max(194, 67) = 22.7 ppb
min(118,221) = 3.0 ppb

New Mexico Anthro

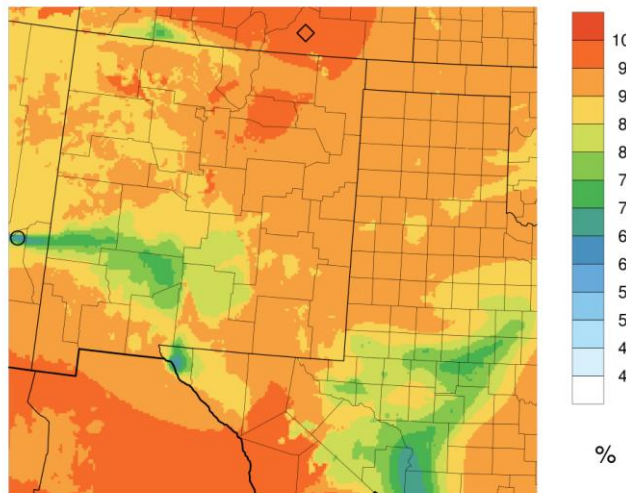
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_NM_anthro 20140517



max(136, 81) = 8.9 ppb
min(119,225) = 0.0 ppb

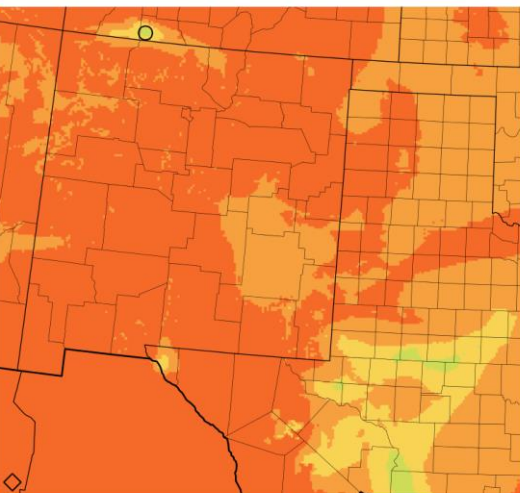
Ozone
Concentrations
(ppb)

2028cntl_osat_all_emis 20140517



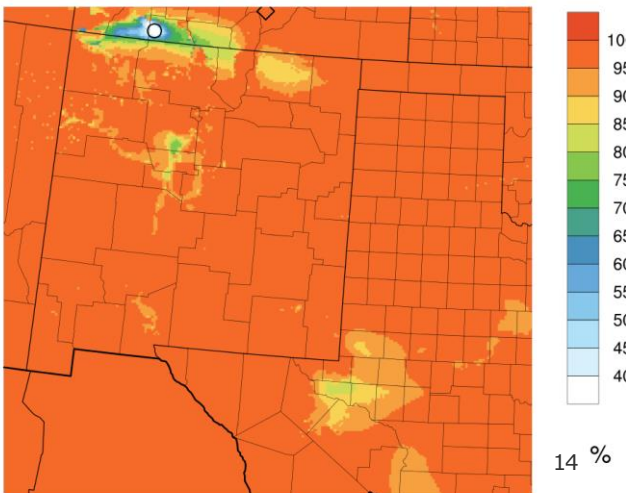
max(137,213) = 97.3%
min(5,119) = 63.9%

2028cntl_osat_all_anthro 20140517



max(9, 7) = 98.3%
min(70,213) = 82.1%

2028cntl_osat_NM_anthro 20140517



max(121,223) = 99.6%
min(70,214) = 31.6%

14 %

RAMBOLL

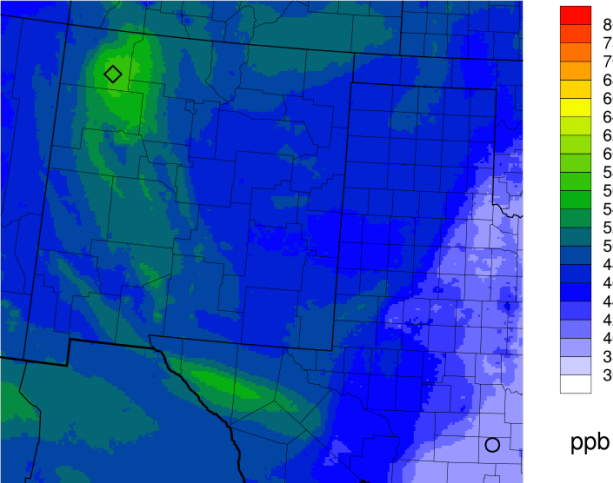
Percent NOx
Sensitive
Ozone

2028 OSAT SA RESULTS FOR MAY 26, 2014

Ozone Concentrations (ppb)

All Source Regions/Categories

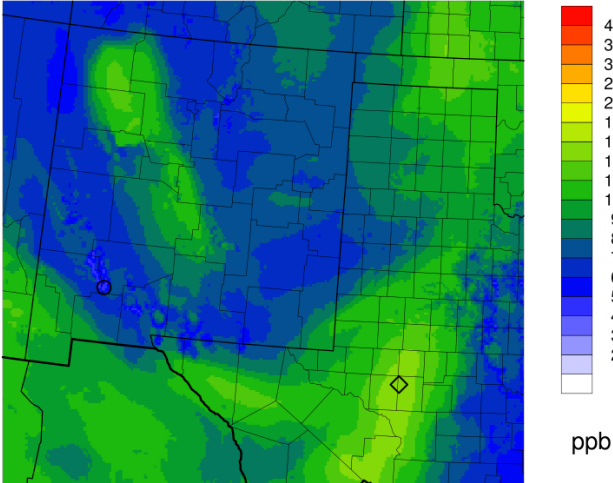
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat 20140526



max(53,191) = 57.6 ppb
min(229, 19) = 36.5 ppb

All Regions Anthro

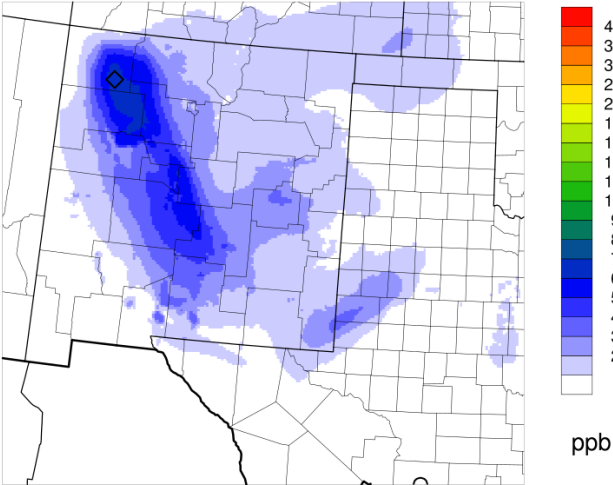
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_all_anthro 20140526



max(185, 47) = 15.0 ppb
min(48, 92) = 4.2 ppb

New Mexico Anthro

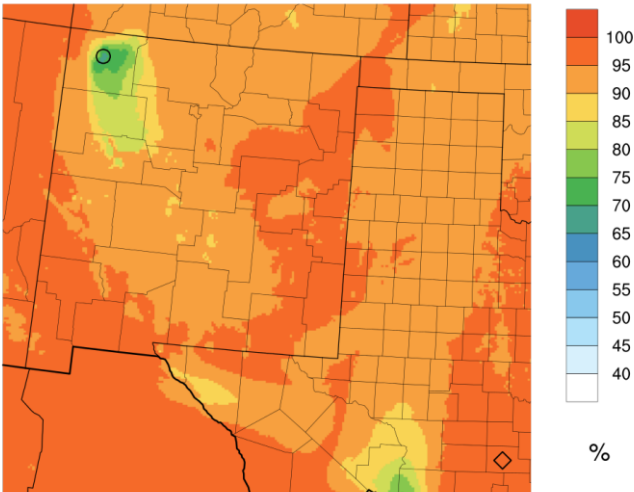
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_NM_anthro 20140526



max(53,189) = 6.8 ppb
min(195, 1) = 0.0 ppb

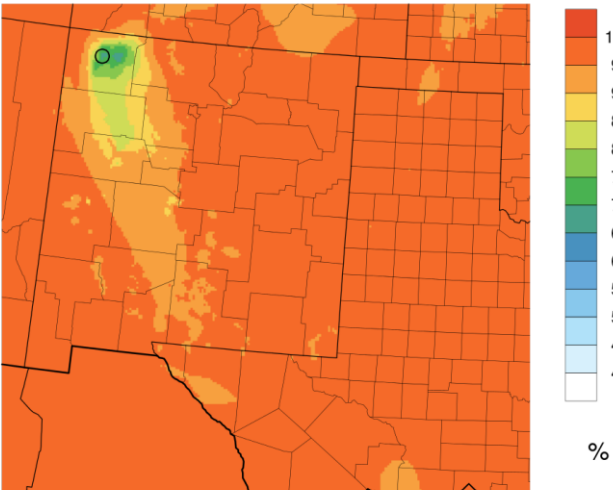
Percent NOx Sensitive Ozone

Percent NOx-limited Ozone formation 4km
2028cntl_osat_all_emis 20140526



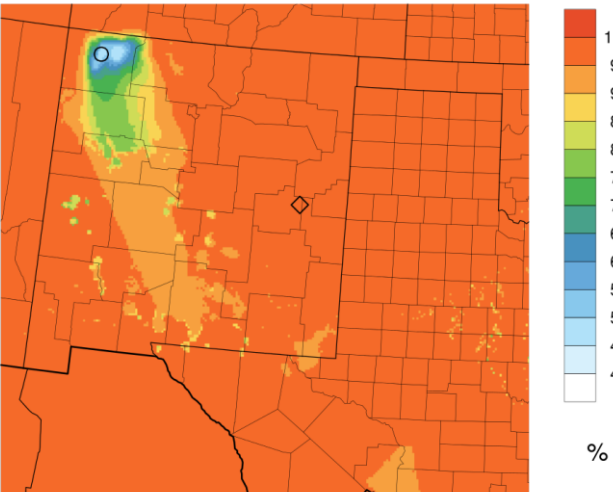
max(230, 16) = 98.1%
min(47,201) = 68.0 %

Percent NOx-limited Ozone formation 4km
2028cntl_osat_all_anthro 20140526



max(215, 1) = 98.7%
min(47,201) = 68.6 %

Percent NOx-limited Ozone formation 4km
2028cntl_osat_NM_anthro 20140526

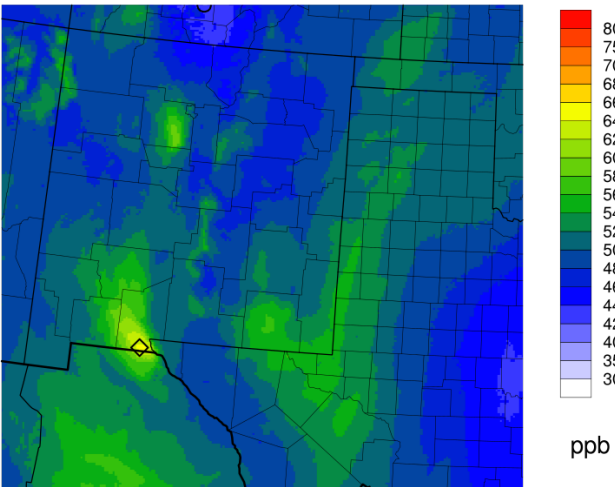


max(138,133) = 98.8%
min(47,202) = 45.2 %

2028 OSAT SA RESULTS FOR MAY 28, 2014

All Source Regions/Categories

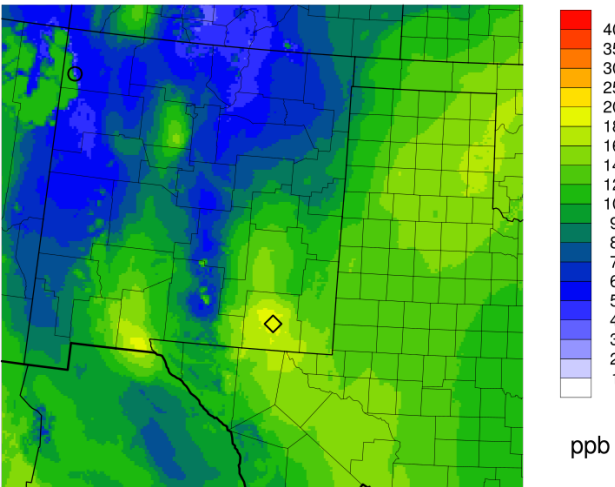
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat 20140528



◇ max(65, 66) = 64.3 ppb
○ min(95, 225) = 41.8 ppb

All Regions Anthro

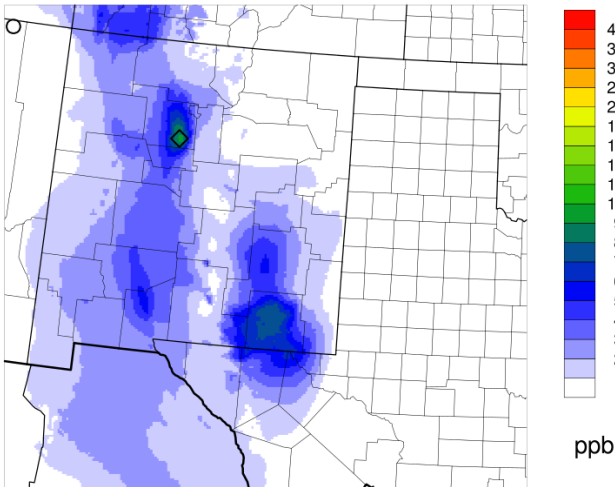
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_all_anthro 20140528



◇ max(127, 77) = 18.9 ppb
○ min(35, 193) = 3.6 ppb

New Mexico Anthro

Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_NM_anthro 20140528

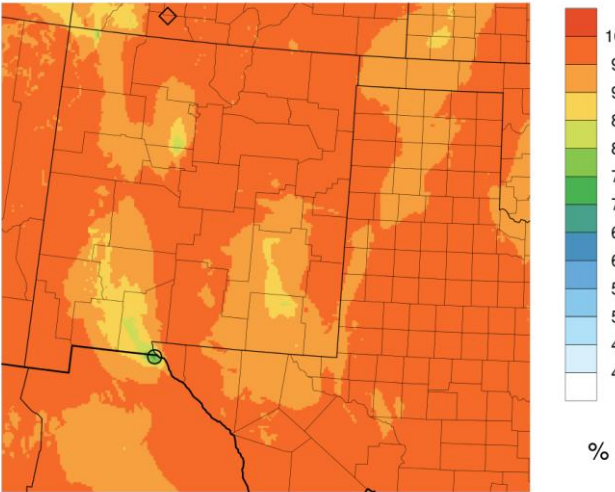


◇ max(82, 163) = 9.3 ppb
○ min(5, 215) = 0.1 ppb

Ozone
Concentrations
(ppb)

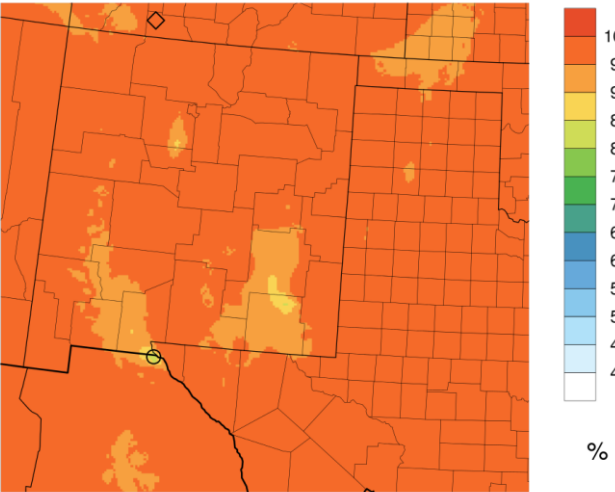
Percent NOx
Sensitive
Ozone

2028cntl_osat_all_emis 20140528



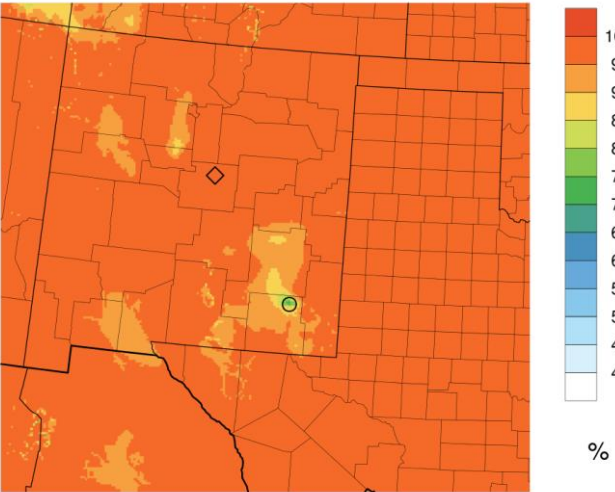
◇ max(77, 219) = 97.7%
○ min(71, 63) = 72.8 %

2028cntl_osat_all_anthro 20140528



◇ max(72, 217) = 98.7%
○ min(71, 63) = 81.2 %

2028cntl_osat_NM_anthro 20140528

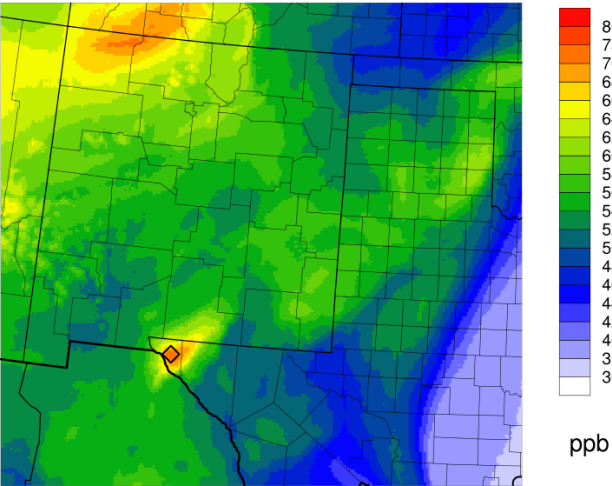


◇ max(99, 146) = 99.3%
○ min(133, 87) = 74.6 %

2028 OSAT SA RESULTS FOR JUNE 5, 2014

All Source Regions/Categories

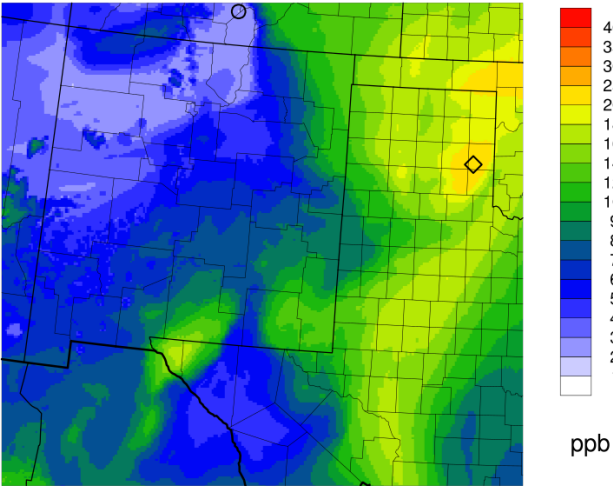
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat 20140605



◇ max(80, 62) = 71.4 ppb
◇ min(242, 2) = 34.0 ppb

All Regions Anthro

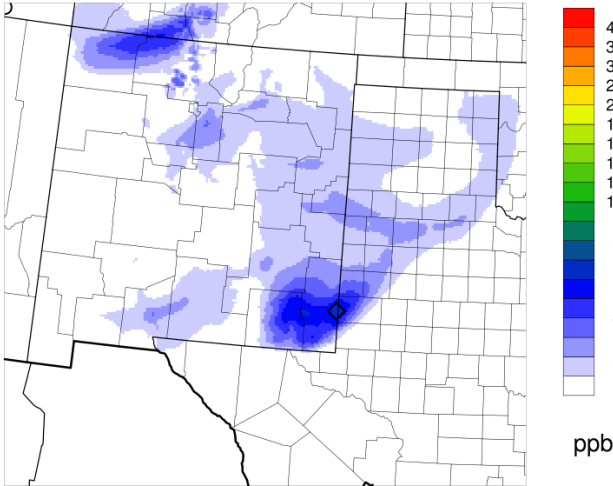
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_all_anthro 20140605



◇ max(220, 150) = 22.9 ppb
◇ min(111, 221) = 1.9 ppb

New Mexico Anthro

Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_NM_anthro 20140605

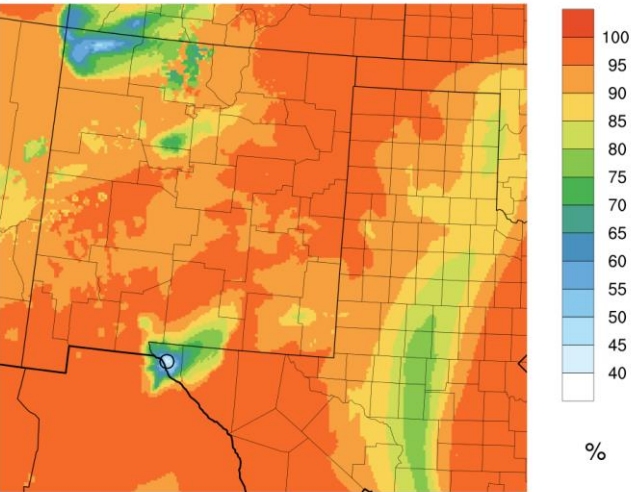


◇ max(155, 82) = 6.8 ppb
◇ min(1, 223) = 0.0 ppb

Ozone
Concentrations
(ppb)

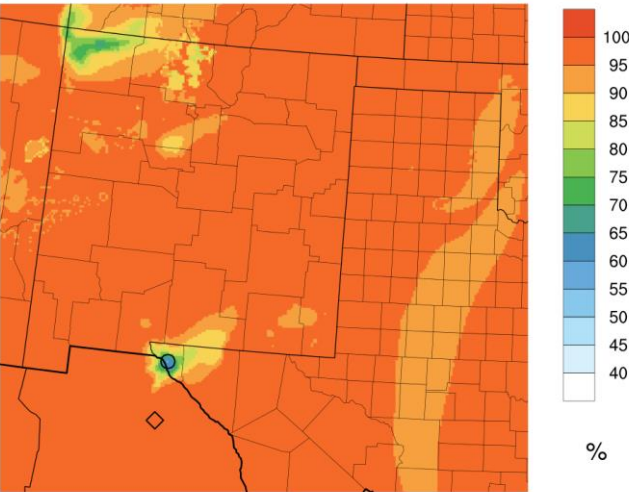
Percent NOx
Sensitive
Ozone

2028cntl_osat_all_emis 20140605



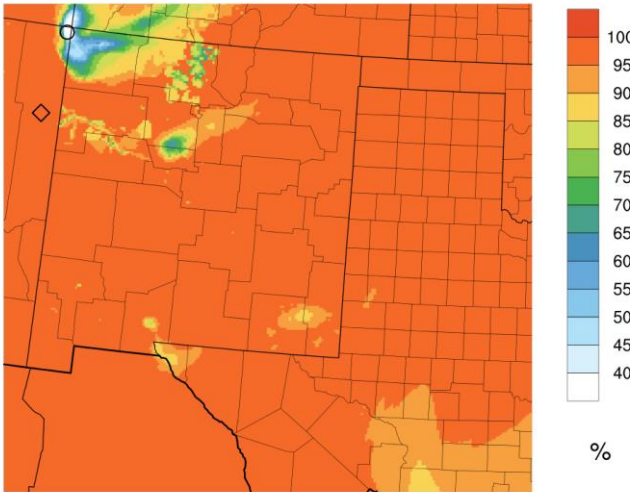
◇ max(243, 60) = 98.3%
◇ min(78, 61) = 43.9 %

2028cntl_osat_all_anthro 20140605



◇ max(72, 34) = 99.0%
◇ min(78, 61) = 59.9 %

2028cntl_osat_NM_anthro 20140605

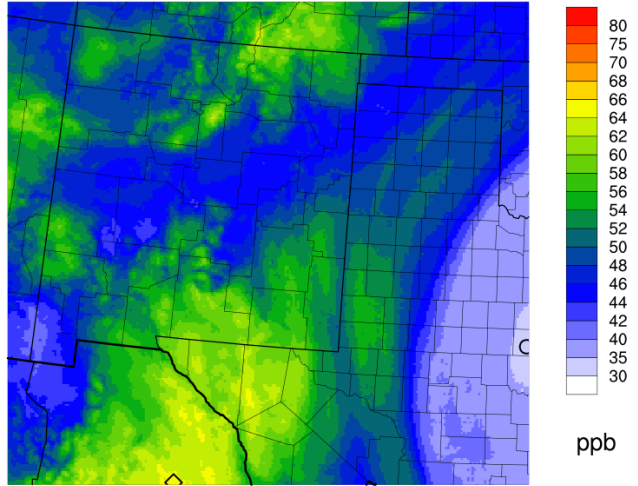


◇ max(18, 175) = 99.9%
◇ min(30, 212) = 25.9 %

2028 OSAT SA RESULTS FOR JULY 12, 2014

All Source Regions/Categories

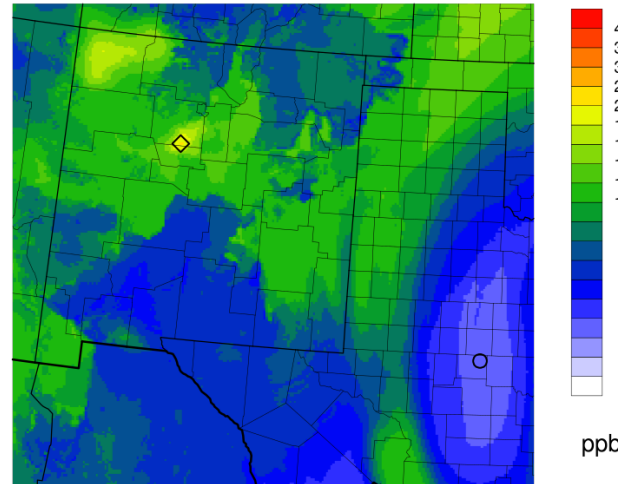
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat 20140712



◇ max(78, 2) = 65.5 ppb
○ min(242, 65) = 34.0 ppb

All Regions Anthro

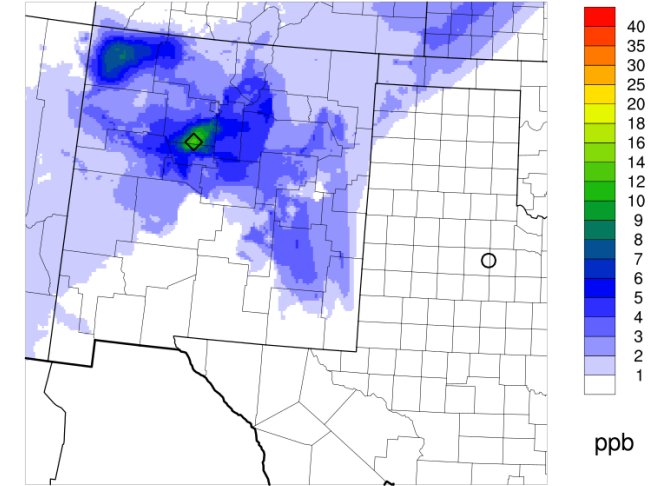
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_all_anthro 20140712



◇ max(79, 160) = 20.3 ppb
○ min(218, 59) = 3.0 ppb

New Mexico Anthro

Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_NM_anthro 20140712

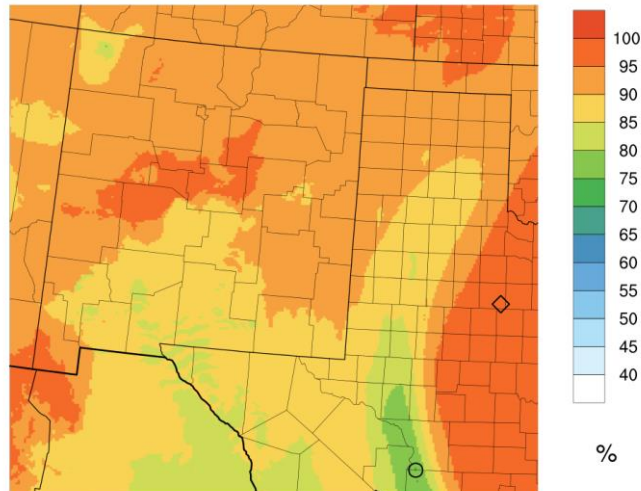


◇ max(79, 160) = 12.4 ppb
○ min(216, 105) = 0.0 ppb

Ozone
Concentrations
(ppb)

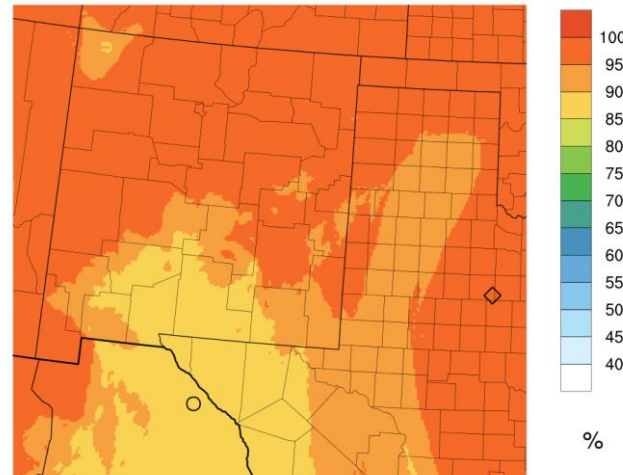
Percent NOx
Sensitive
Ozone

2028cntl_osat_all_emis 20140712



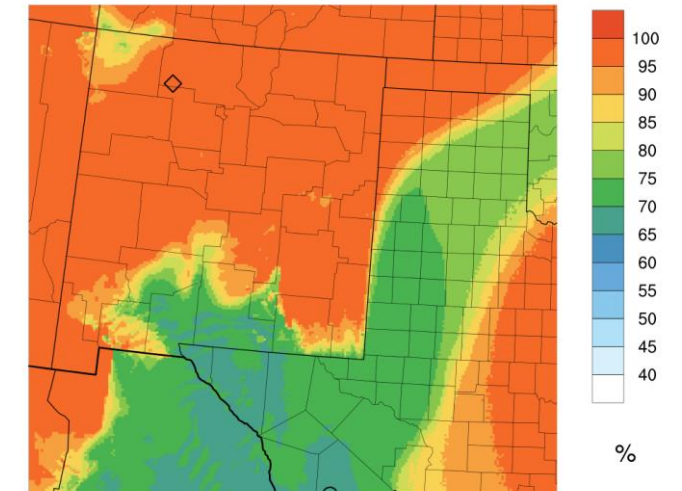
◇ max(226, 88) = 99.5%
○ min(187, 12) = 74.6 %

2028cntl_osat_all_anthro 20140712



◇ max(227, 88) = 99.6%
○ min(86, 37) = 85.8 %

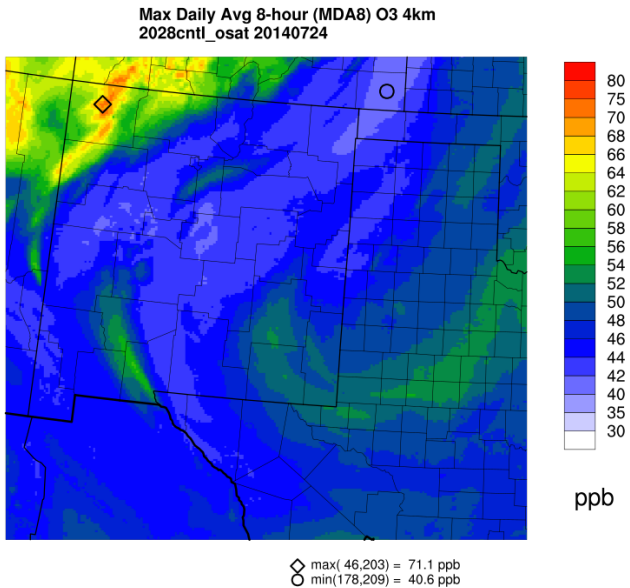
2028cntl_osat_NM_anthro 20140712



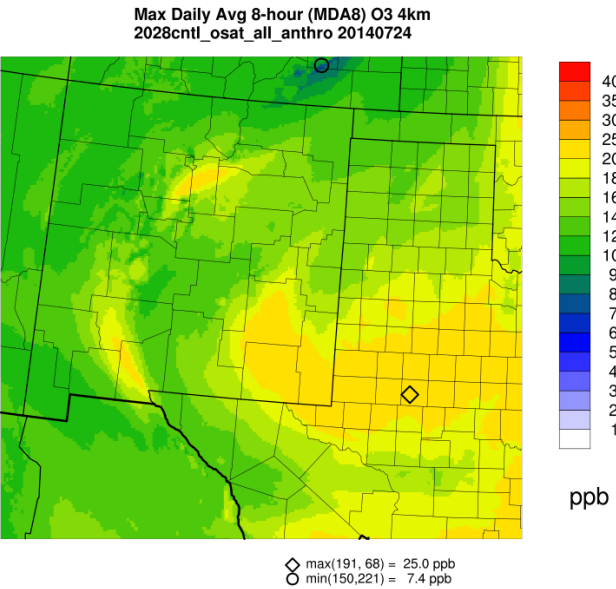
◇ max(67, 189) = 99.2%
○ min(139, 1) = 64.6 %

2028 OSAT SA RESULTS FOR JULY 24, 2014

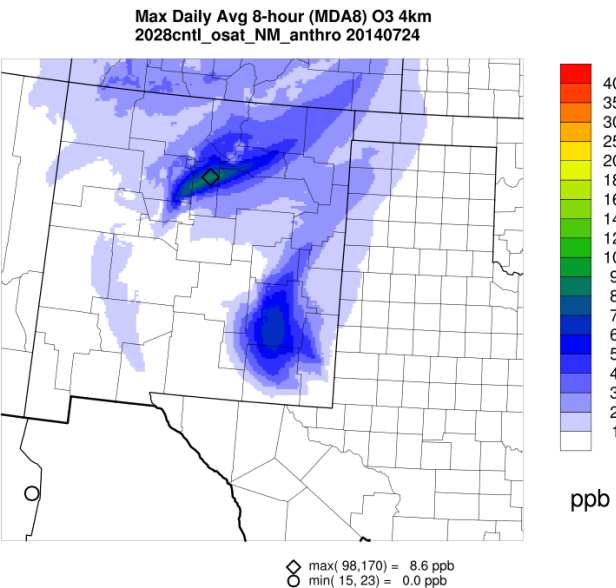
All Source Regions/Categories



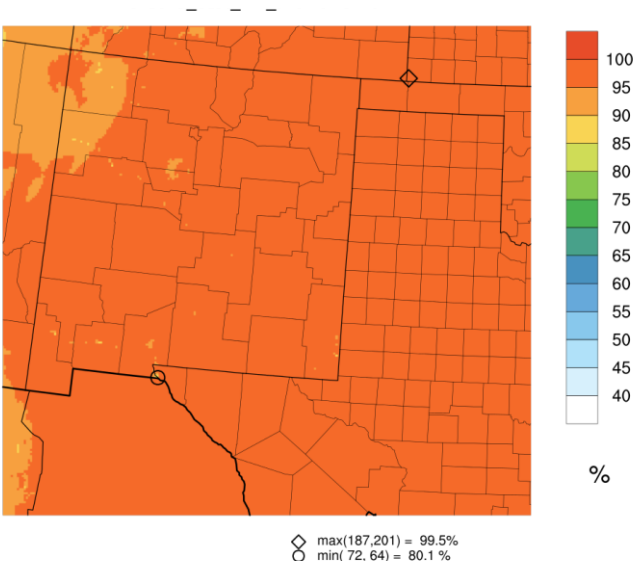
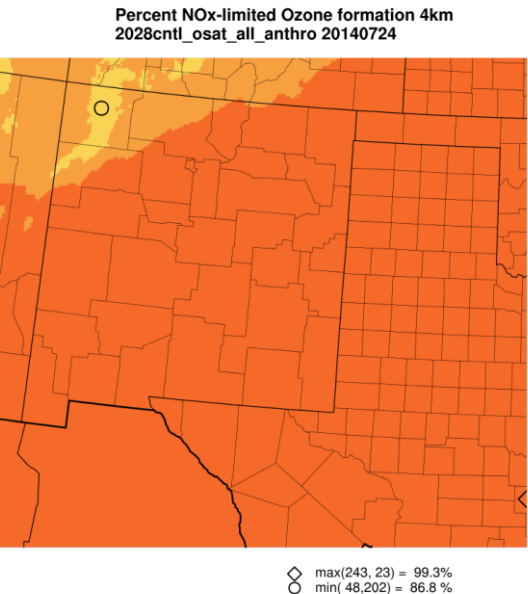
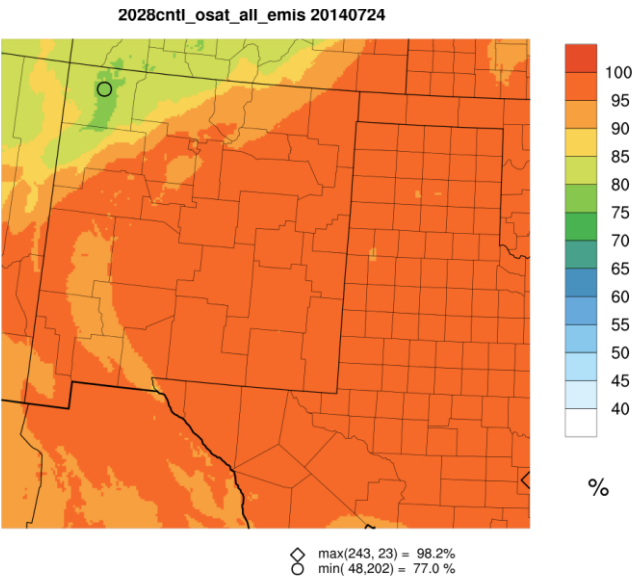
All Regions Anthro



New Mexico Anthro



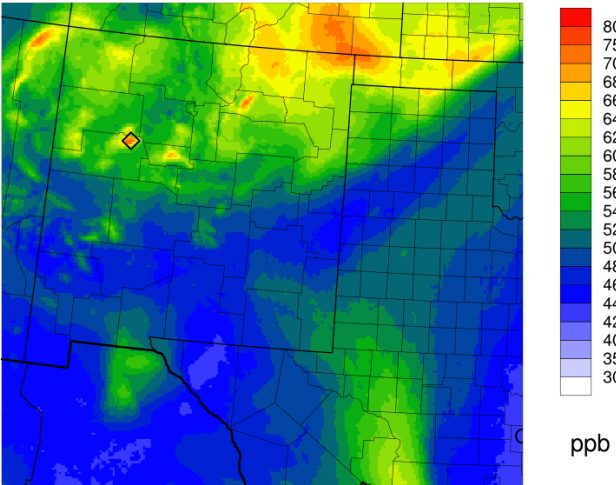
Percent NOx Sensitive Ozone



2028 OSAT SA RESULTS FOR JULY 26, 2014

All Source Regions/Categories

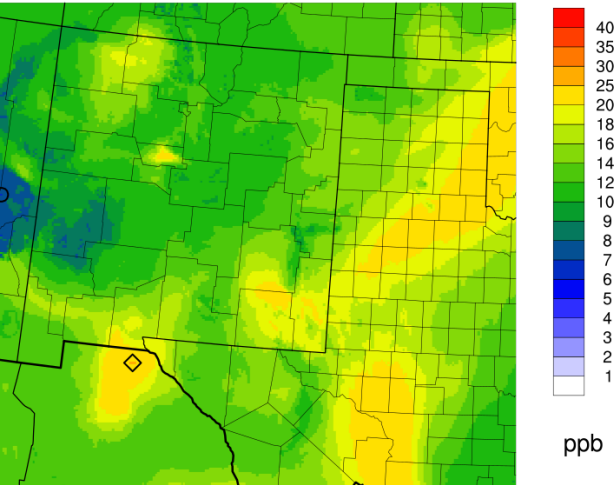
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat 20140726



max(61, 161) = 72.0 ppb
min(243, 24) = 42.4 ppb

All Regions Anthro

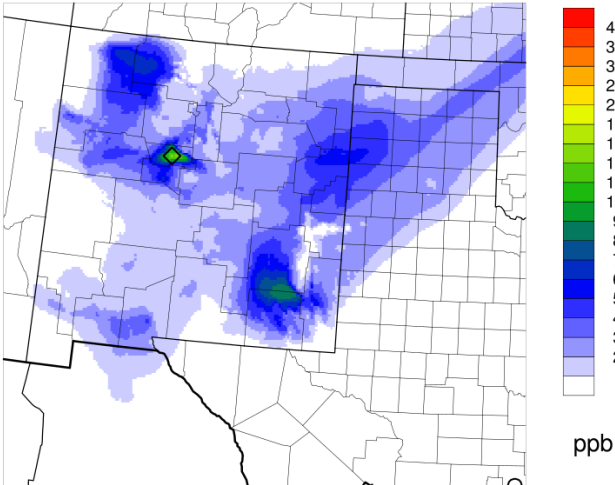
Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_all_anthro 20140726



max(65, 58) = 25.1 ppb
min(4, 136) = 6.9 ppb

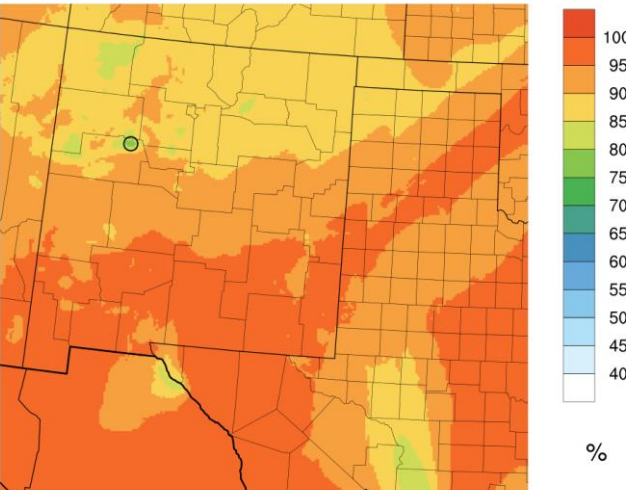
New Mexico Anthro

Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_NM_anthro 20140726



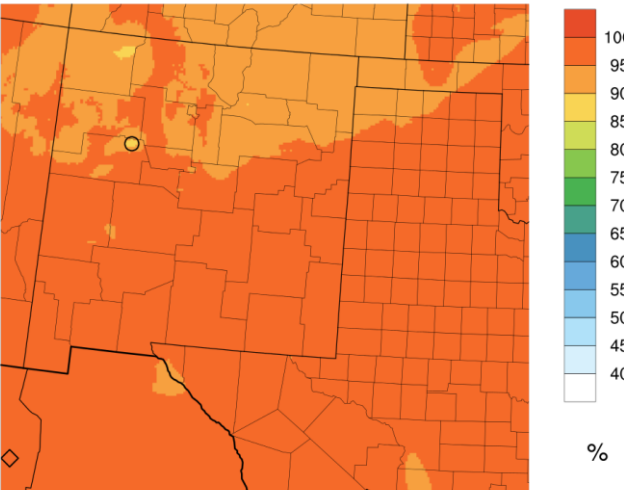
max(79, 154) = 14.4 ppb
min(238, 1) = 0.0 ppb

2028cntl_osat_all_emis 20140726



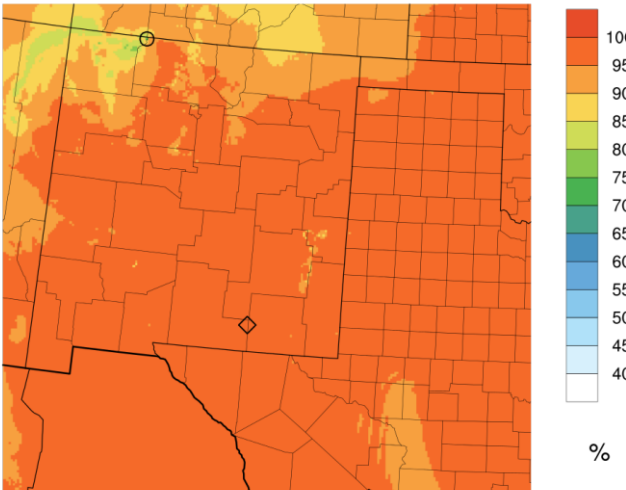
max(1, 2) = 97.7%
min(61, 161) = 77.9 %

2028cntl_osat_all_anthro 20140726



max(5, 17) = 99.0%
min(61, 161) = 87.9 %

2028cntl_osat_NM_anthro 20140726



max(113, 78) = 99.4%
min(67, 209) = 72.4 %

Ozone
Concentrations
(ppb)

Percent NOx
Sensitive
Ozone



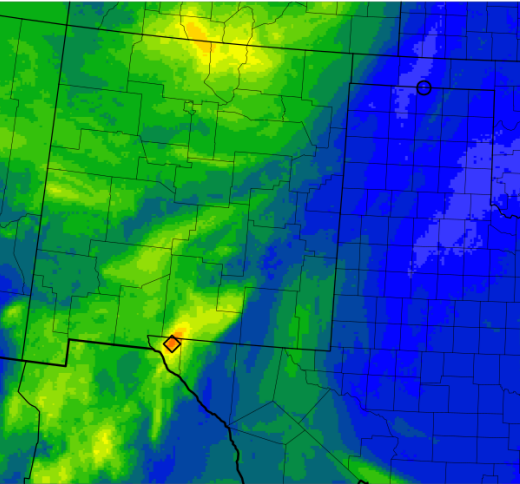
2028 OSAT SA RESULTS FOR AUGUST 14, 2014

All Source Regions/Categories

All Regions Anthro

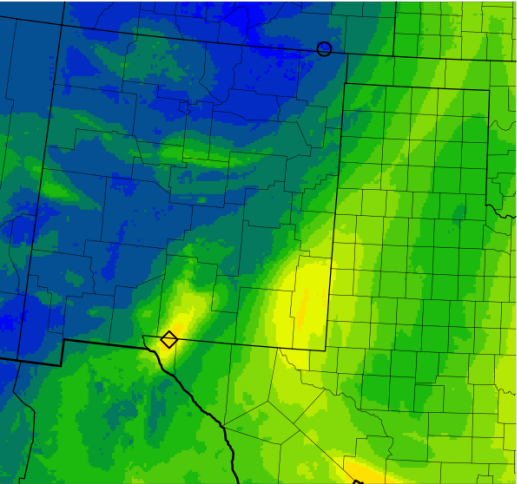
New Mexico Anthro

Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat 20140814



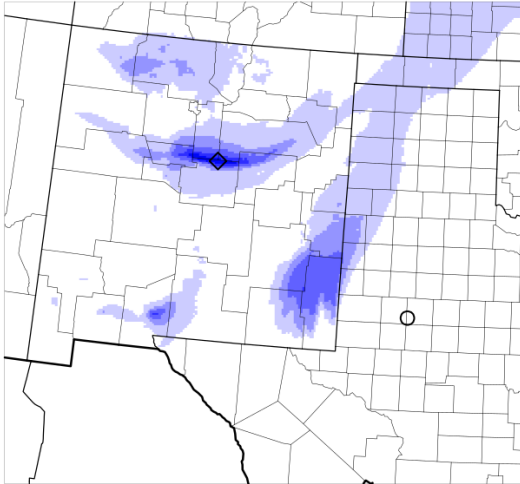
⊠ max(81, 66) = 71.2 ppb
⊠ min(198, 185) = 42.5 ppb

Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_all_anthro 20140814



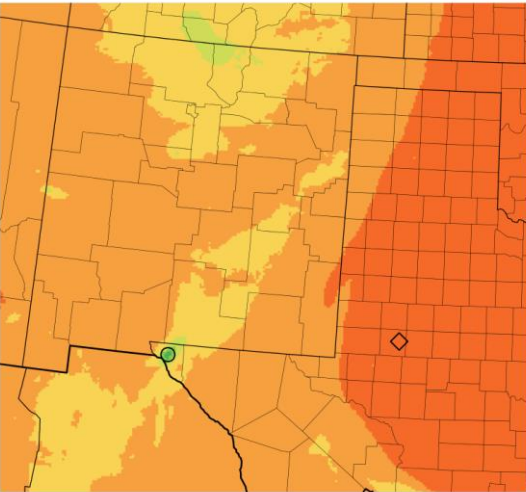
⊠ max(82, 68) = 23.2 ppb
⊠ min(154, 203) = 5.3 ppb

Max Daily Avg 8-hour (MDA8) O3 4km
2028cntl_osat_NM_anthro 20140814



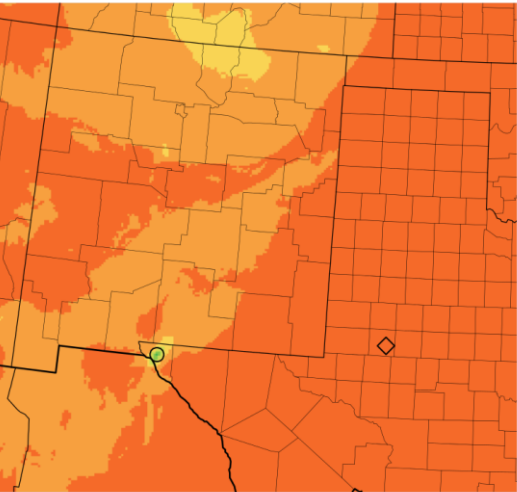
⊠ max(100, 151) = 5.6 ppb
⊠ min(188, 78) = 0.0 ppb

2028cntl_osat_all_emis 20140814



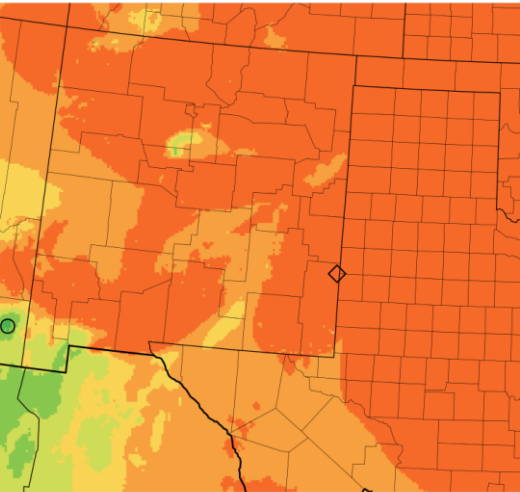
⊠ max(184, 70) = 97.7%
⊠ min(78, 64) = 71.3%

2028cntl_osat_all_anthro 20140814



⊠ max(183, 68) = 99.0%
⊠ min(78, 64) = 74.5%

2028cntl_osat_NM_anthro 20140814

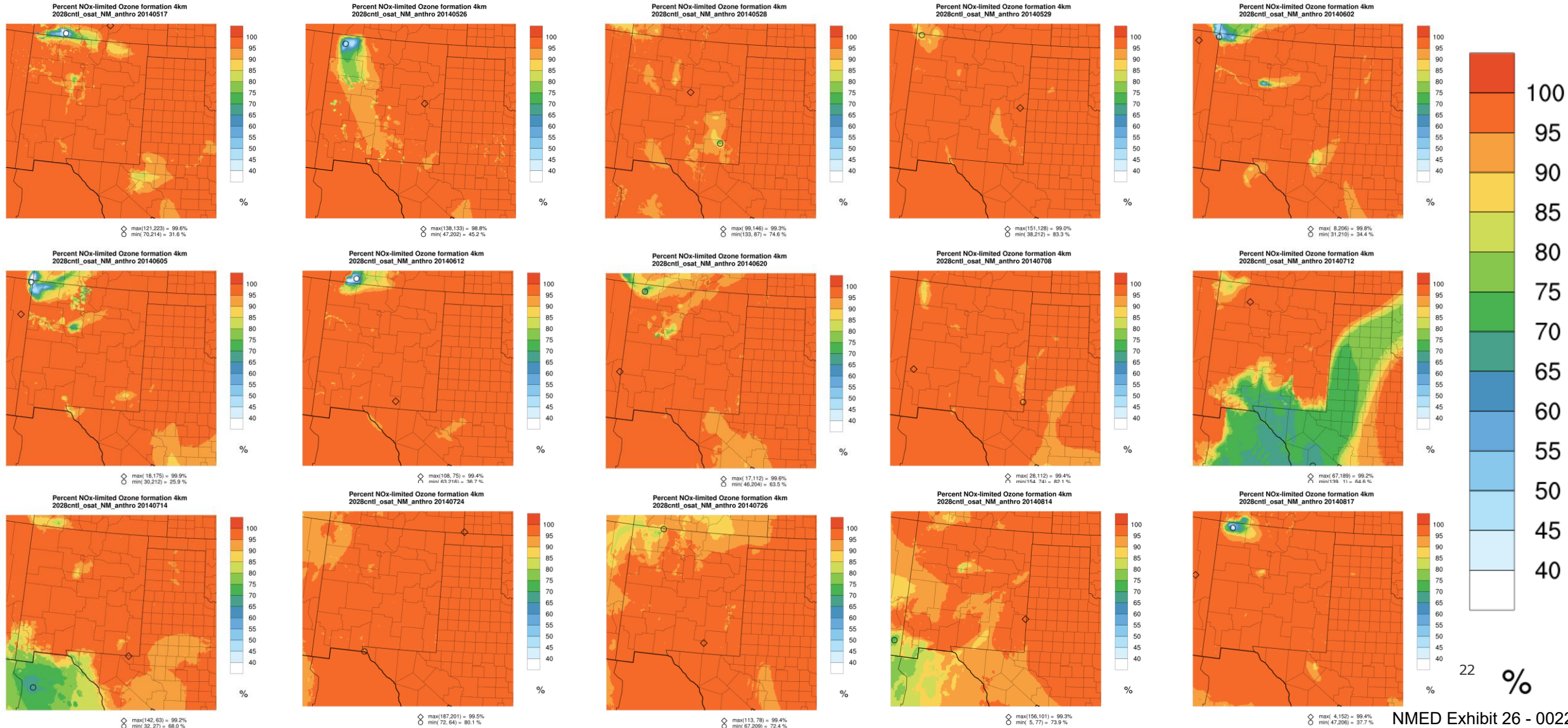


⊠ max(156, 101) = 99.3%
⊠ min(5, 77) = 73.9%

Ozone
Concentrations
(ppb)

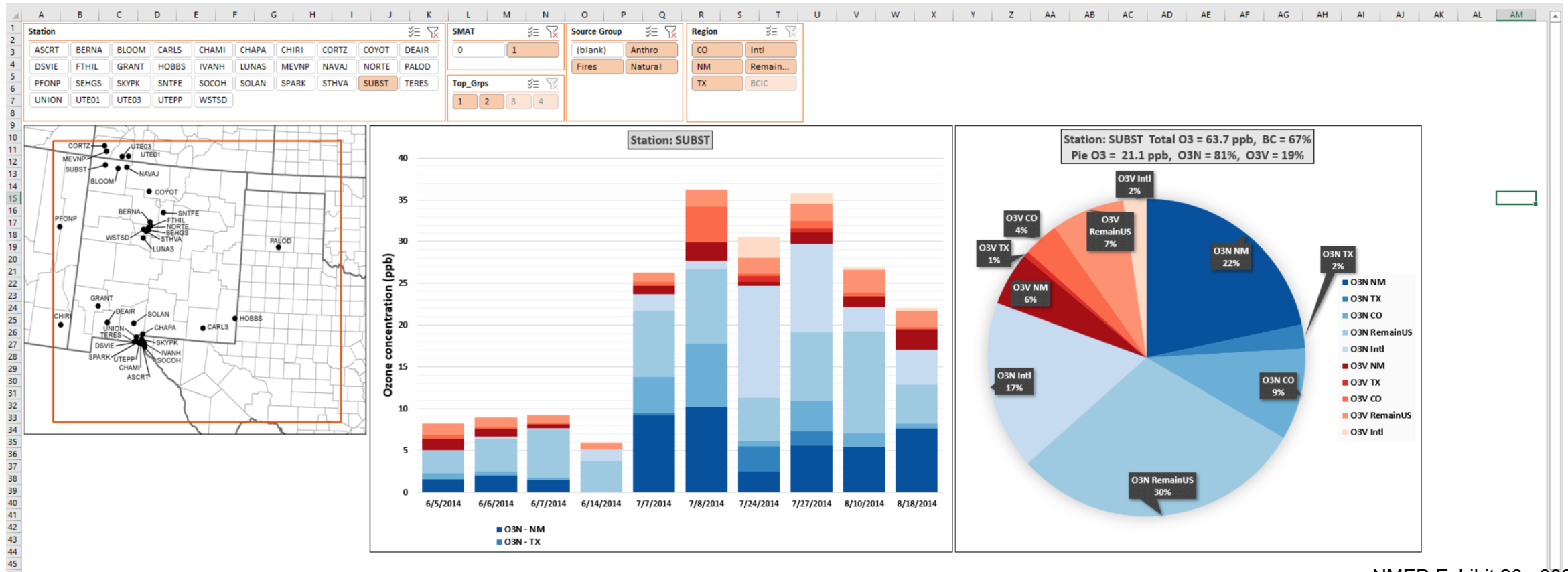
Percent NOx
Sensitive
Ozone

PERCENT NOX SENSITIVE OZONE FROM NEW MEXICO ANTHROPOGENIC EMISSIONS ON 15 HIGHER OZONE DAYS



DASHBOARD OF OSAT RESULTS AT MONITORING SITES

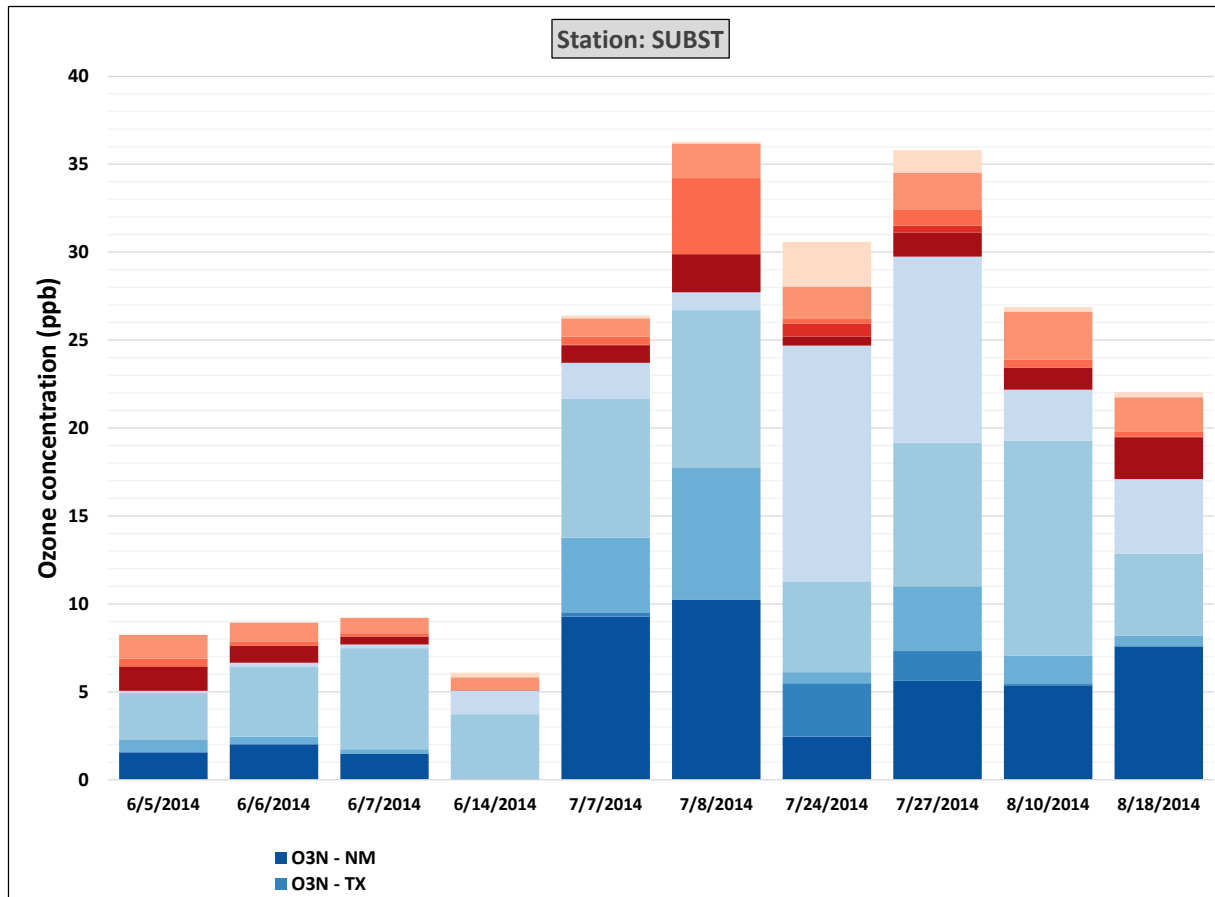
- Select display: monitoring site; 10 days to visualize (SMAT, 2028 1-10, 11-20, etc.); Source Categories (Anthro, Fires, Natural); Source Regions (NM, CO, TX, Remaining U.S. Intl.)
- Displays: Stacked Bar Charts of 10 days O3V and O3N; Pie Chart average across 10 days
 - Cooler colors for NOx sensitive ozone, warmer colors for VOC sensitive ozone



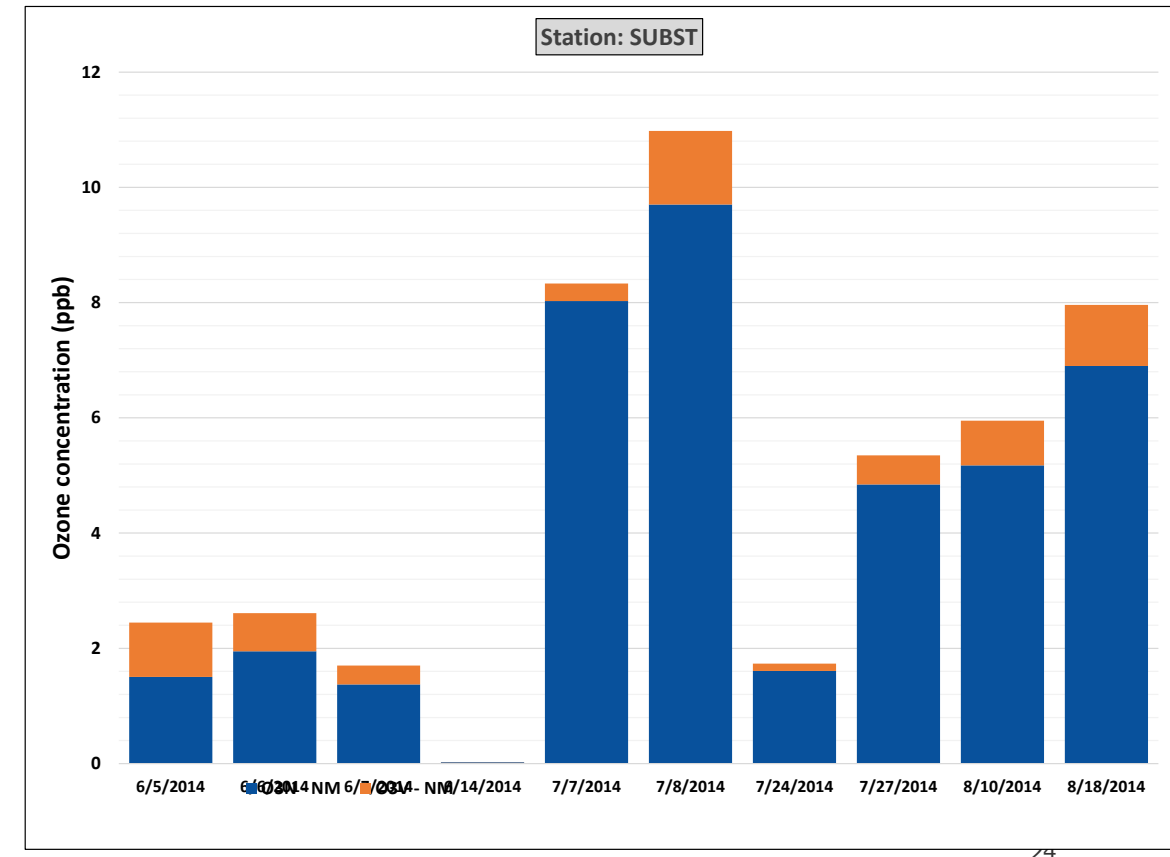
SUBSTATION, SAN JUAN COUNTY – 10 SMAT DAYS

- Lots of day-to-day variation in ozone contributions and percent VOC vs. NOx sensitive ozone
- 70% - 90% NOx sensitive MDA8 ozone

All Source Categories and Regions



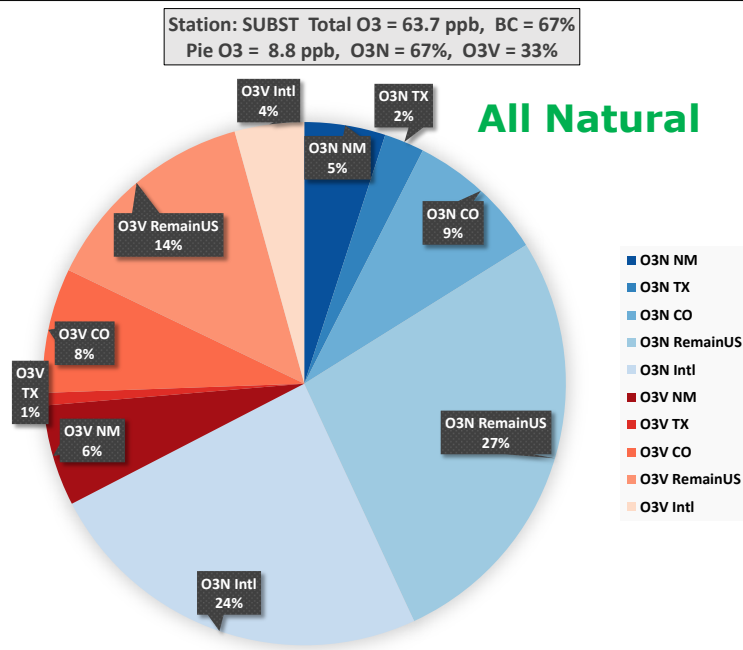
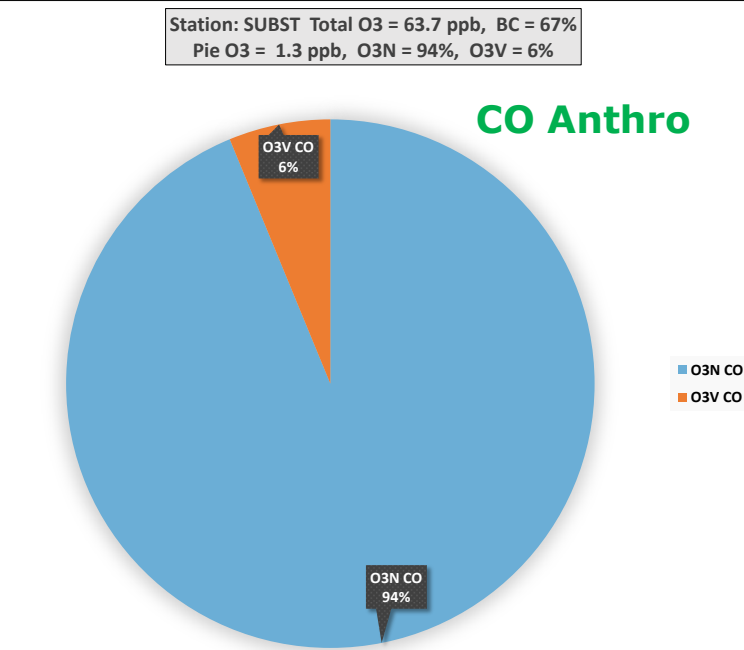
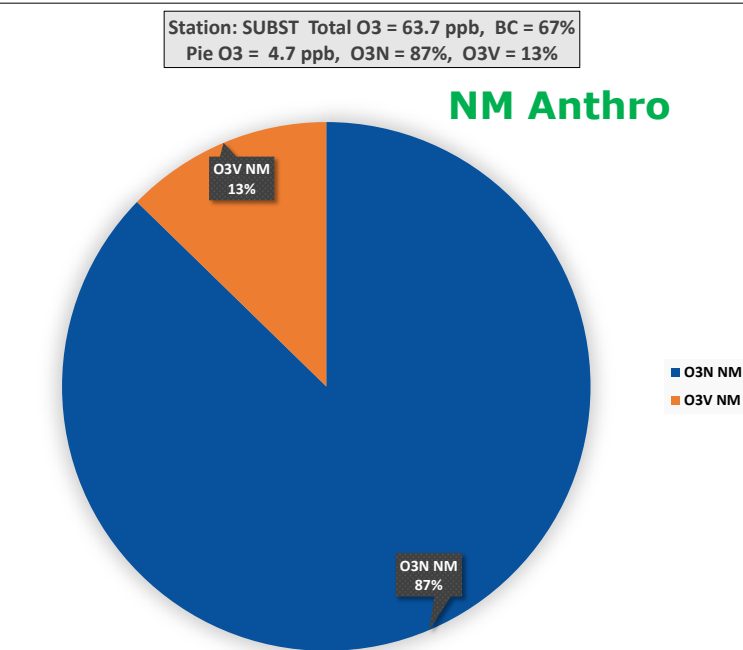
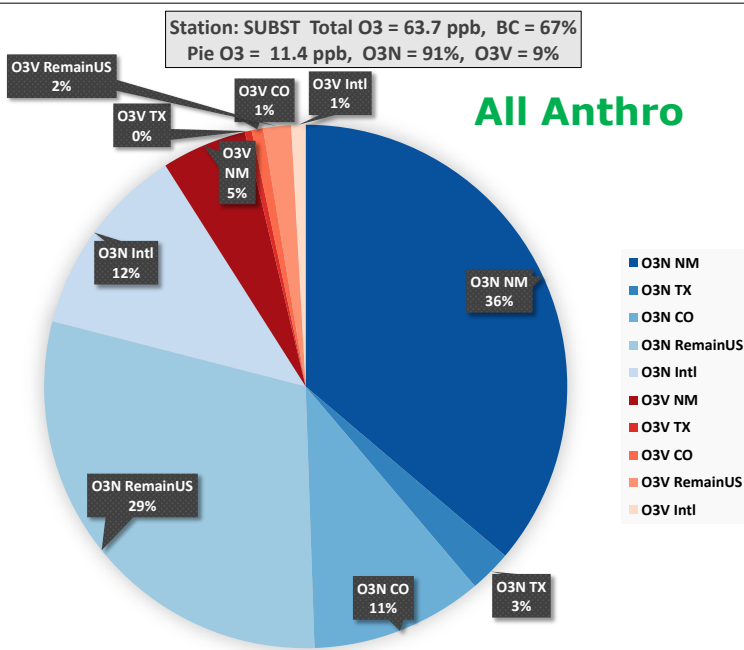
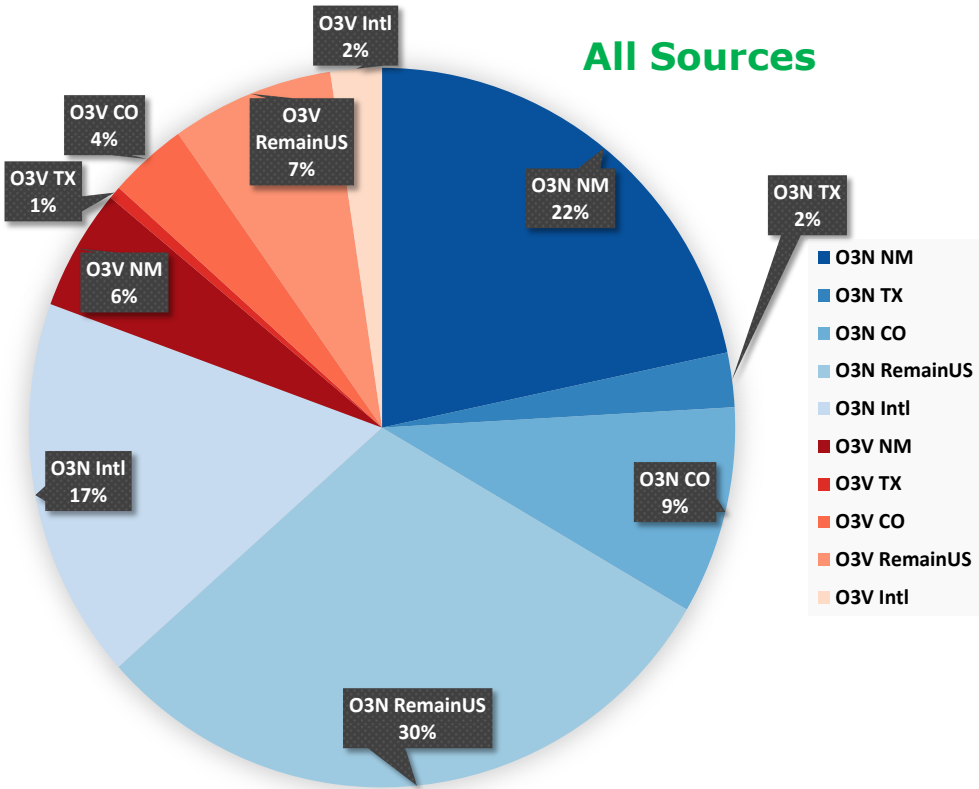
New Mexico Anthropogenic



Substation, San Juan County

Average 10 SMAT Days

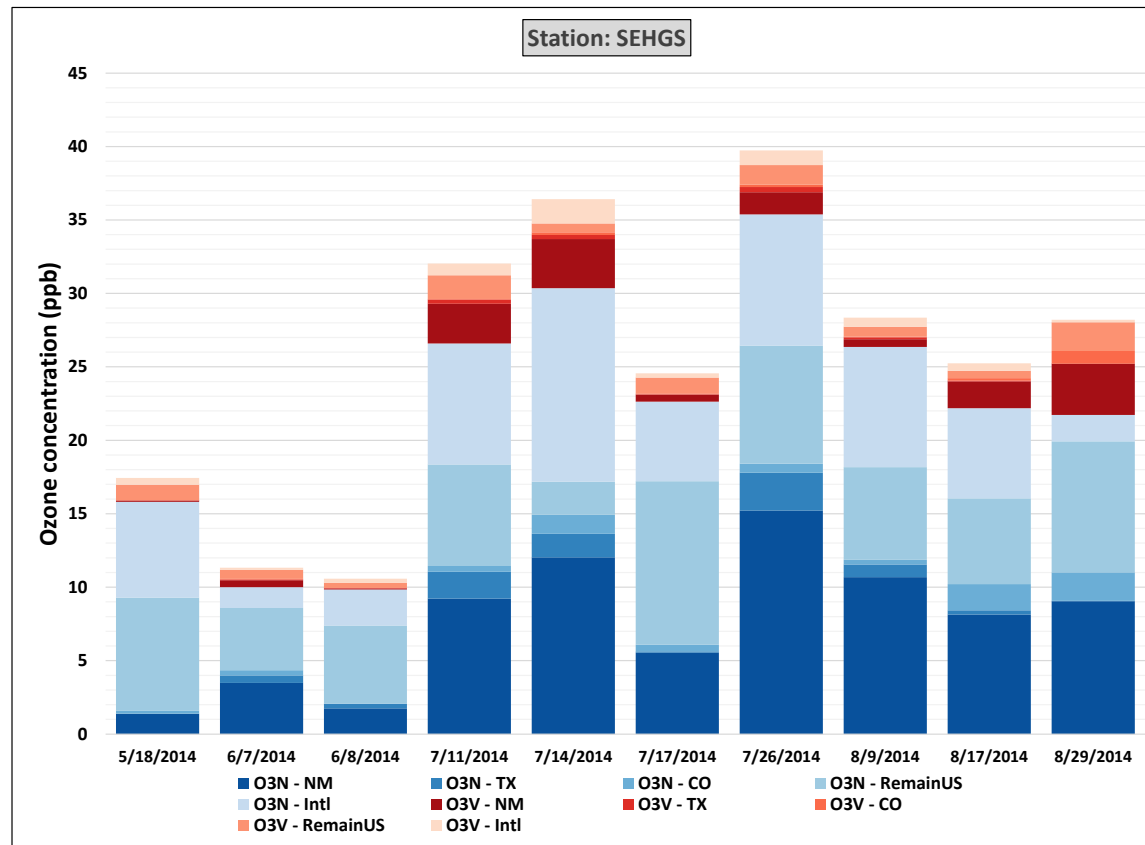
Station: SUBST Total O3 = 63.7 ppb, BC = 67%
Pie O3 = 21.1 ppb, O3N = 81%, O3V = 19%



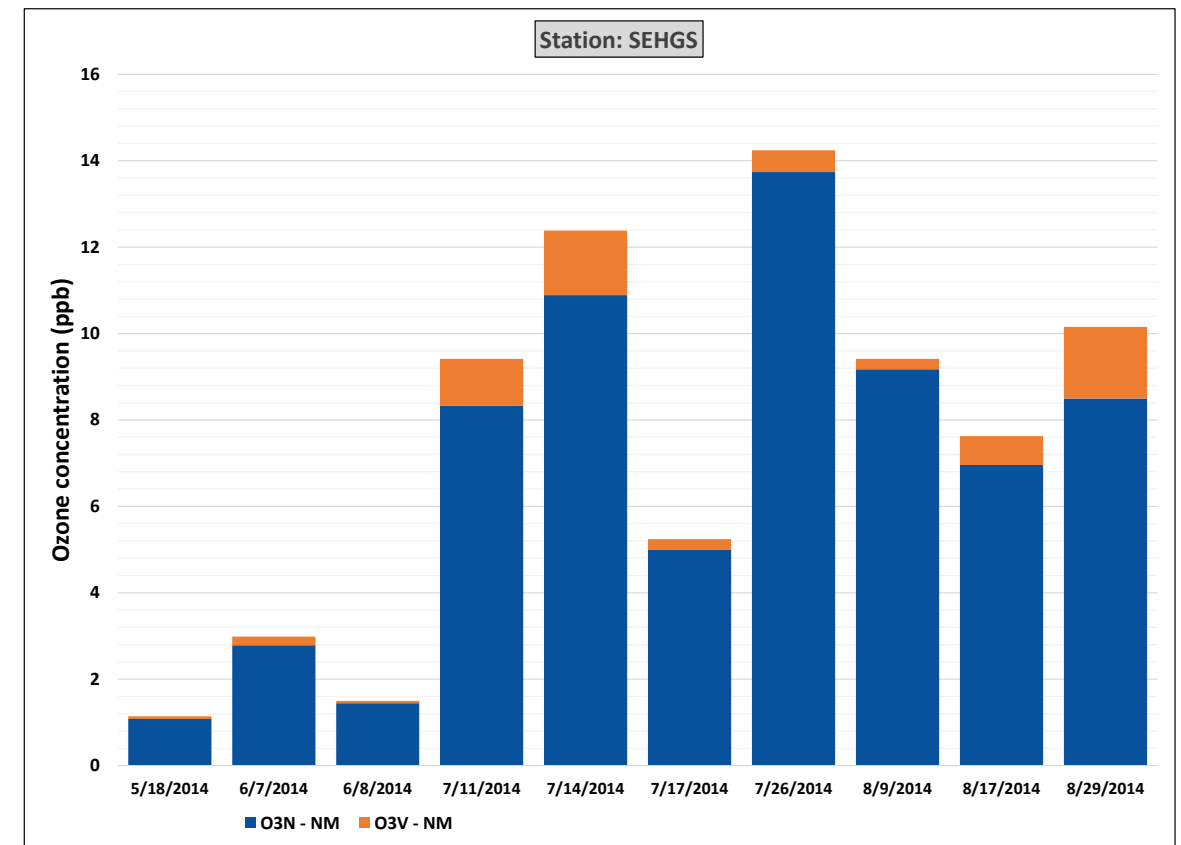
SOUTH EAST HEIGHTS, BERNALILLO COUNTY – 10 SMAT DAYS

- Lots of day-to-day variation in ozone contributions and percent VOC vs. NOx sensitive ozone
- Vast majority is NOx sensitive ozone, a little less VOC sensitive ozone than Substation

All Source Categories and Regions

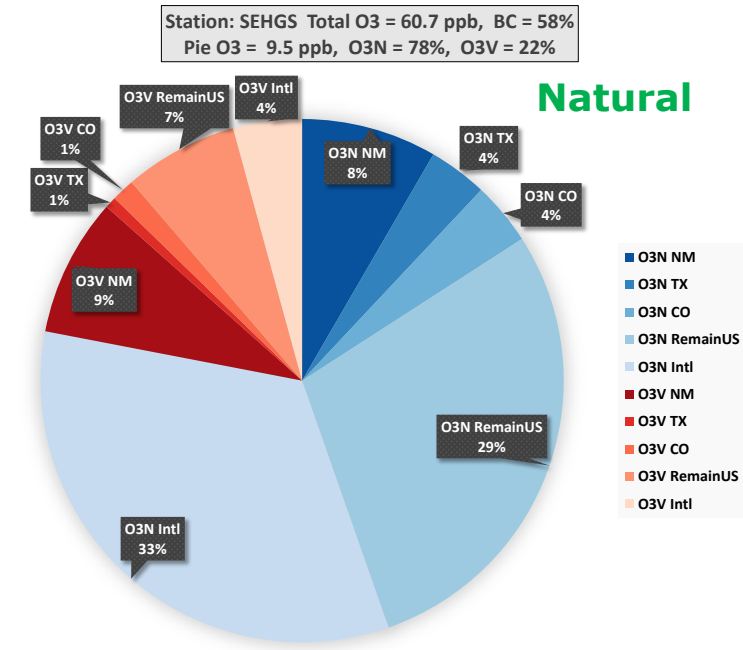
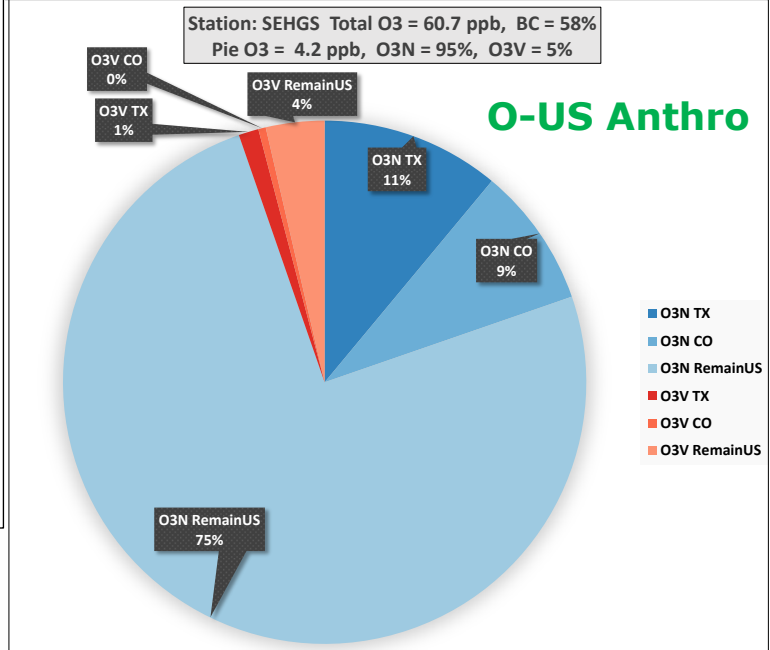
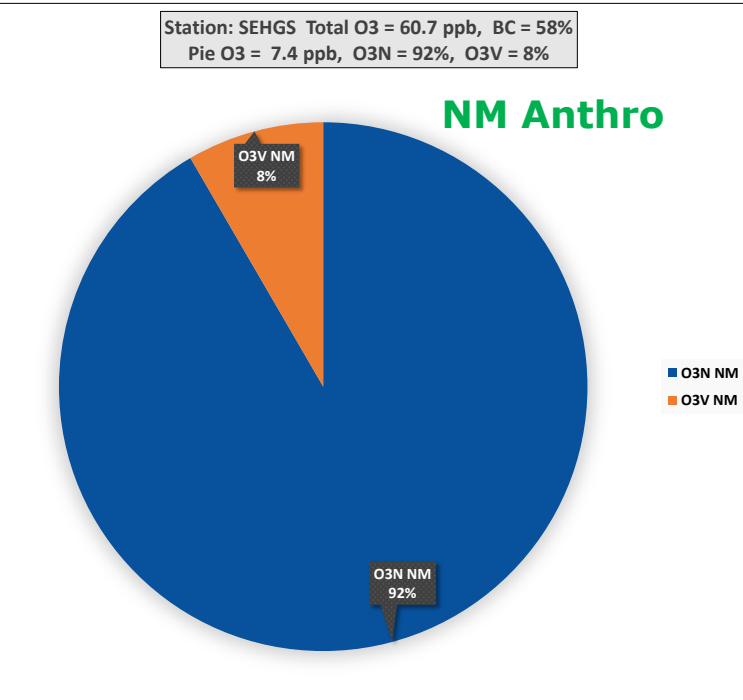
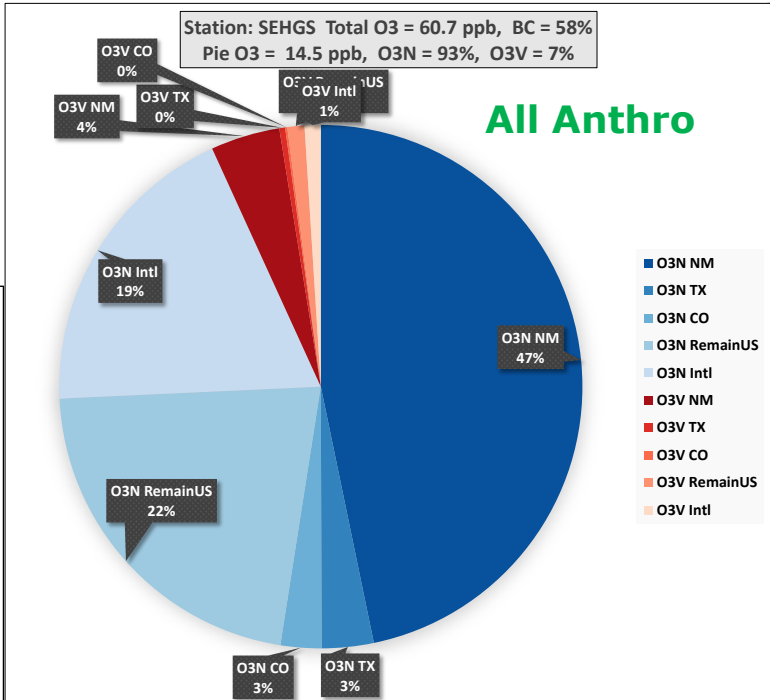
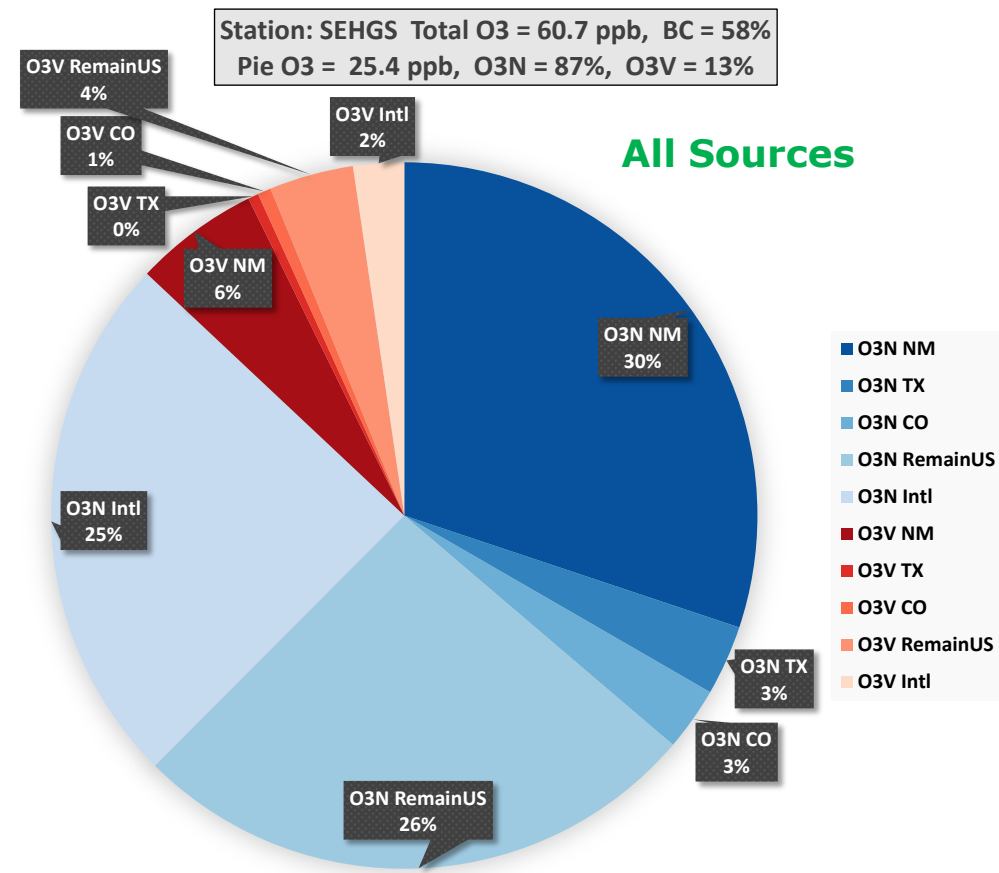


New Mexico Anthropogenic



SE Heights, Bernalillo County

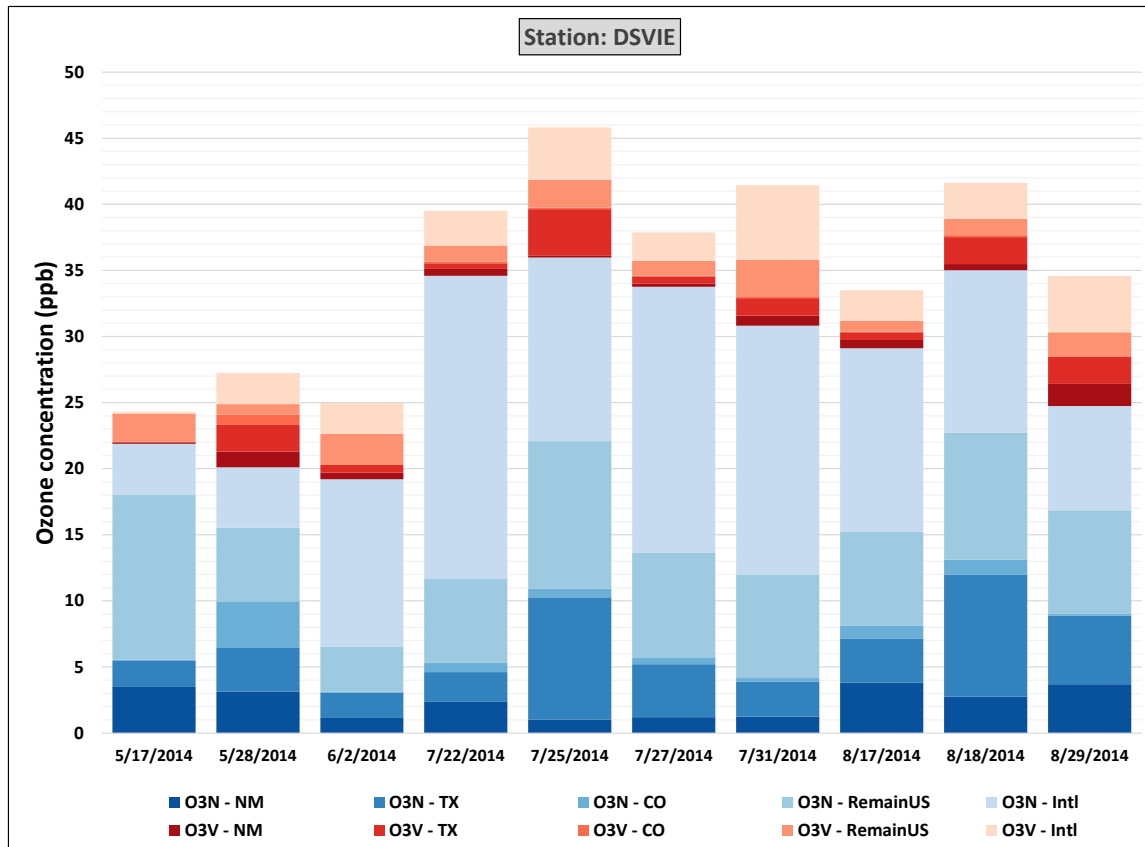
Average 10 SMAT Days



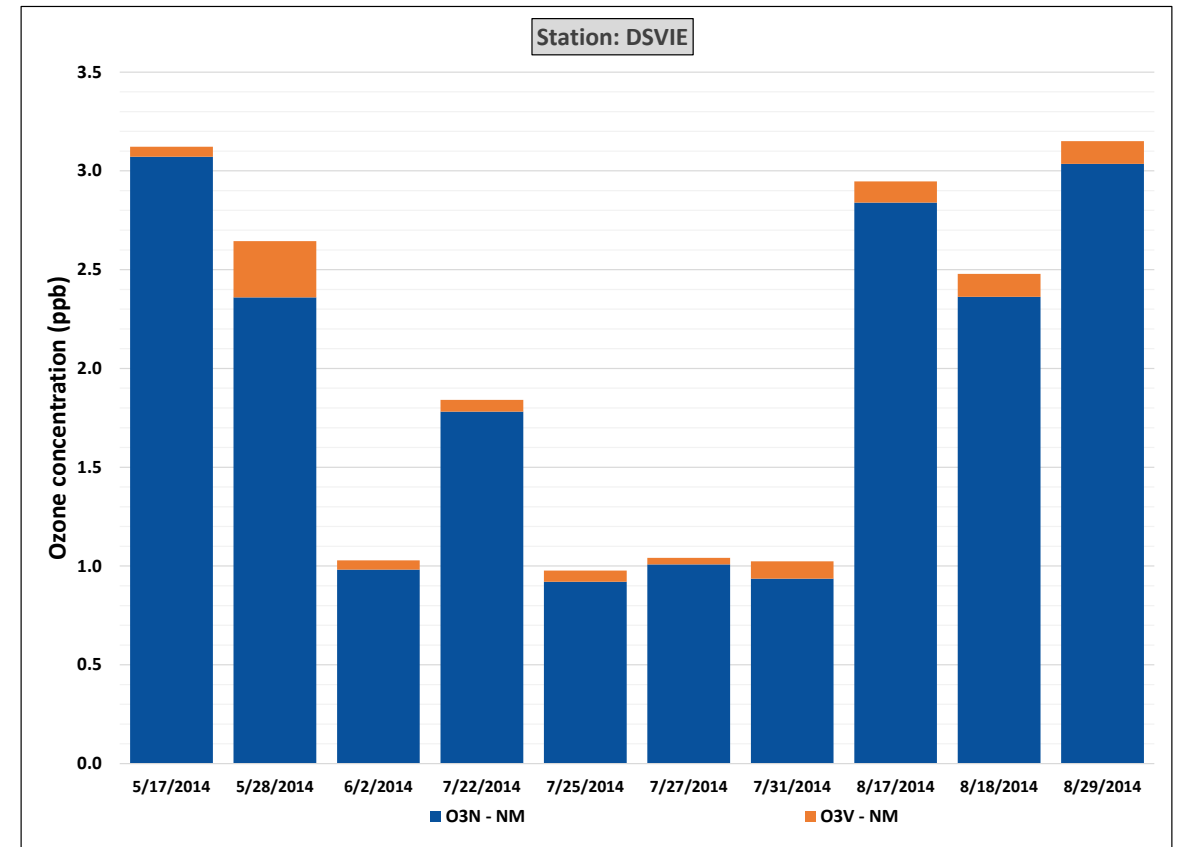
DESERT VIEW, DONA ANA COUNTY – 10 SMAT DAYS

- Mostly NOx sensitive ozone, but more VOC sensitive than other sites due to El Paso
- New Mexico contributions NOx sensitive

All Source Categories and Regions

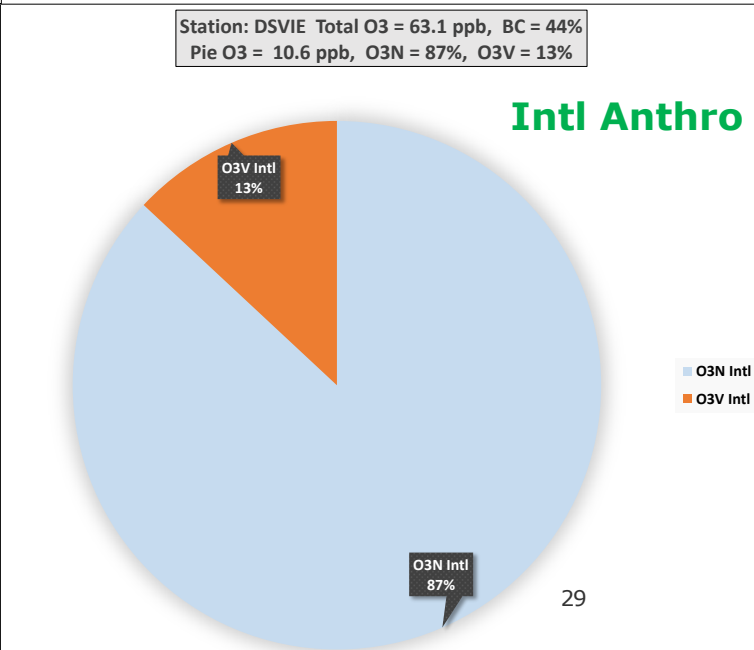
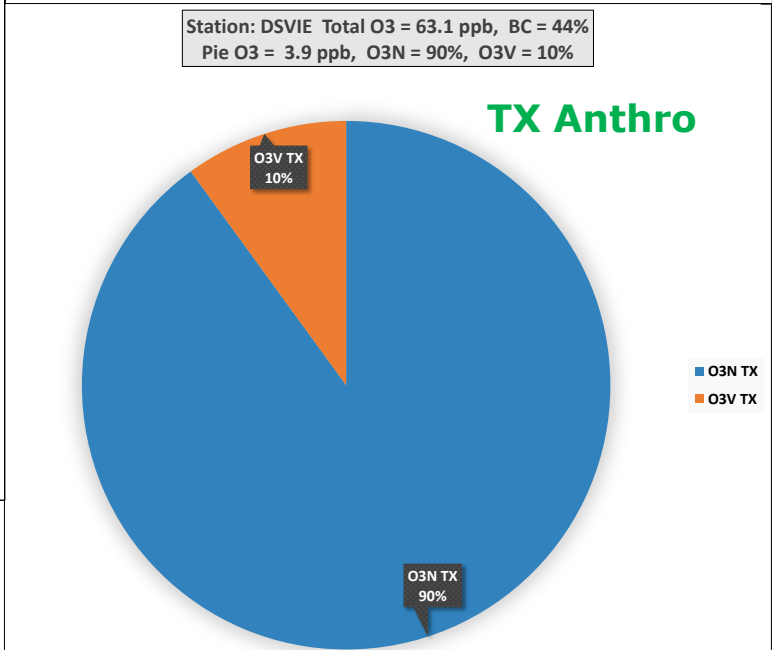
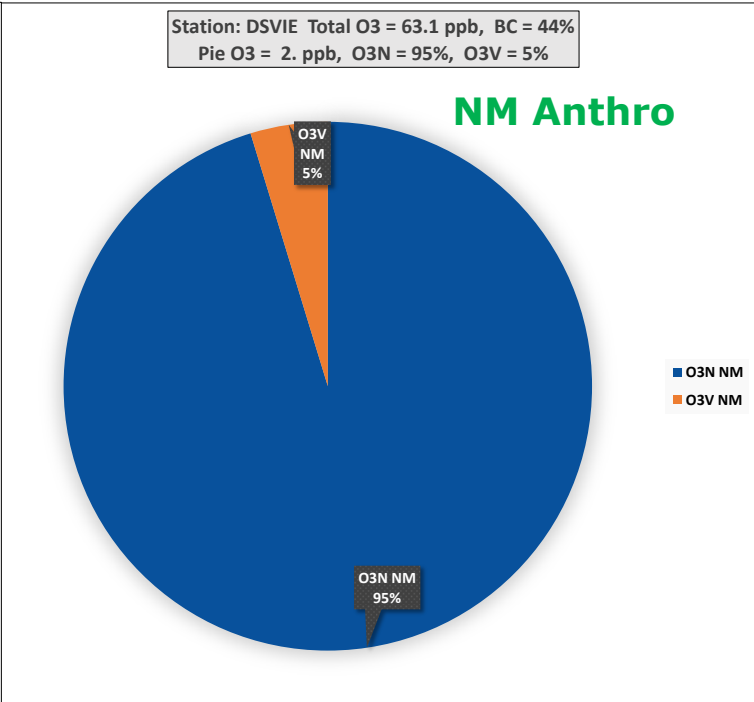
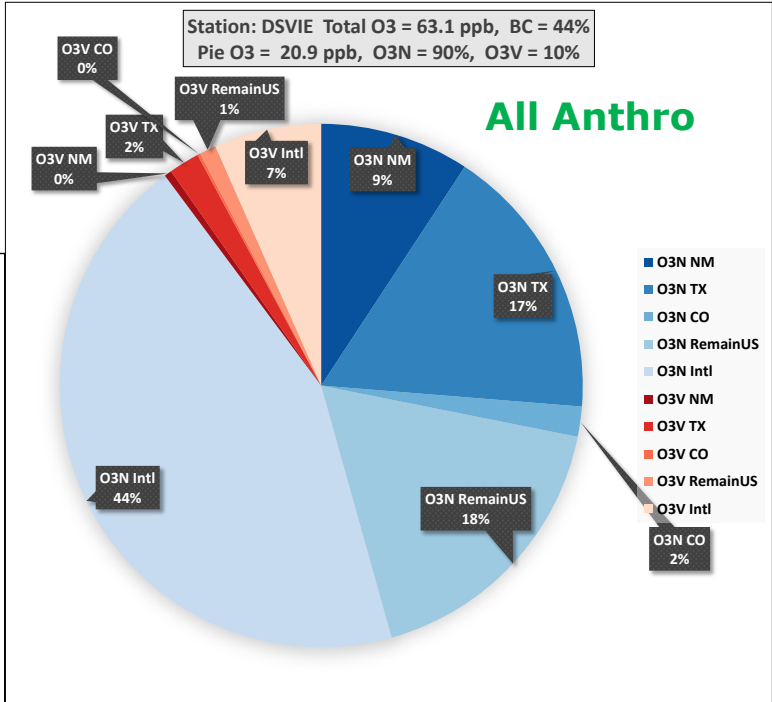
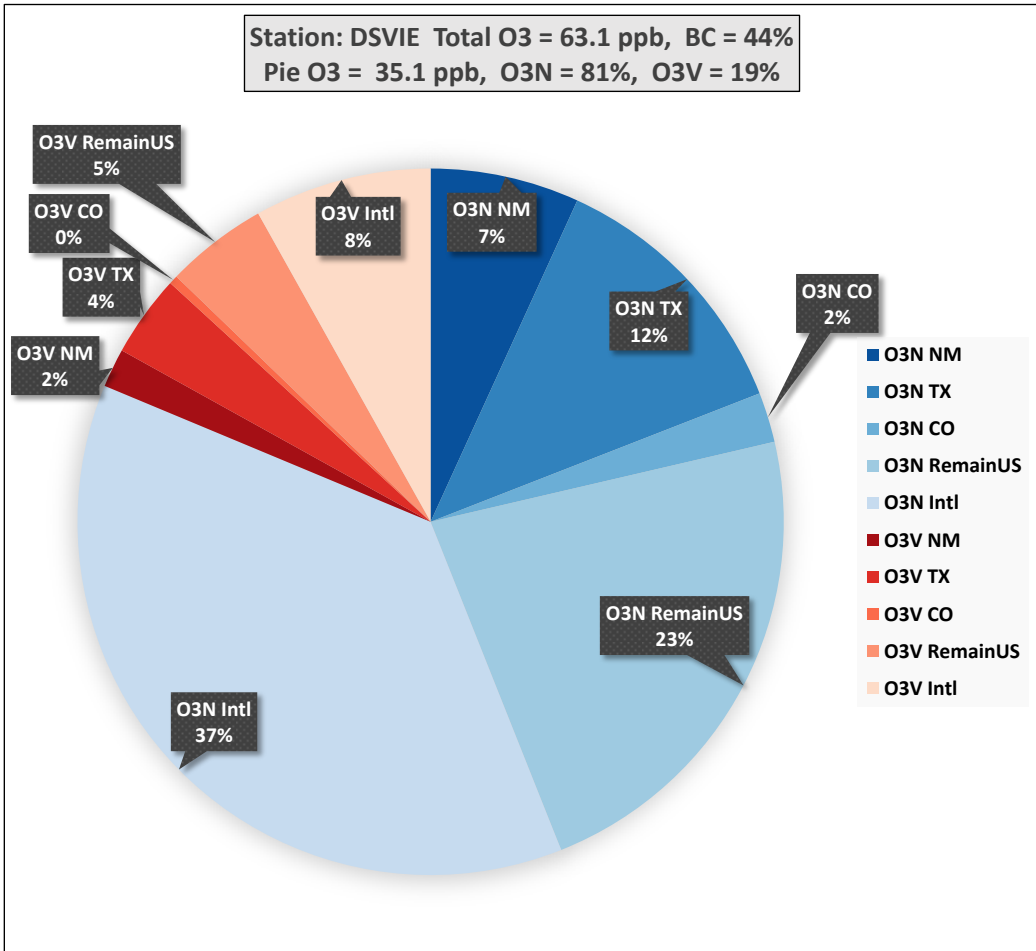


New Mexico Anthropogenic



Desert View, Dona Ana County

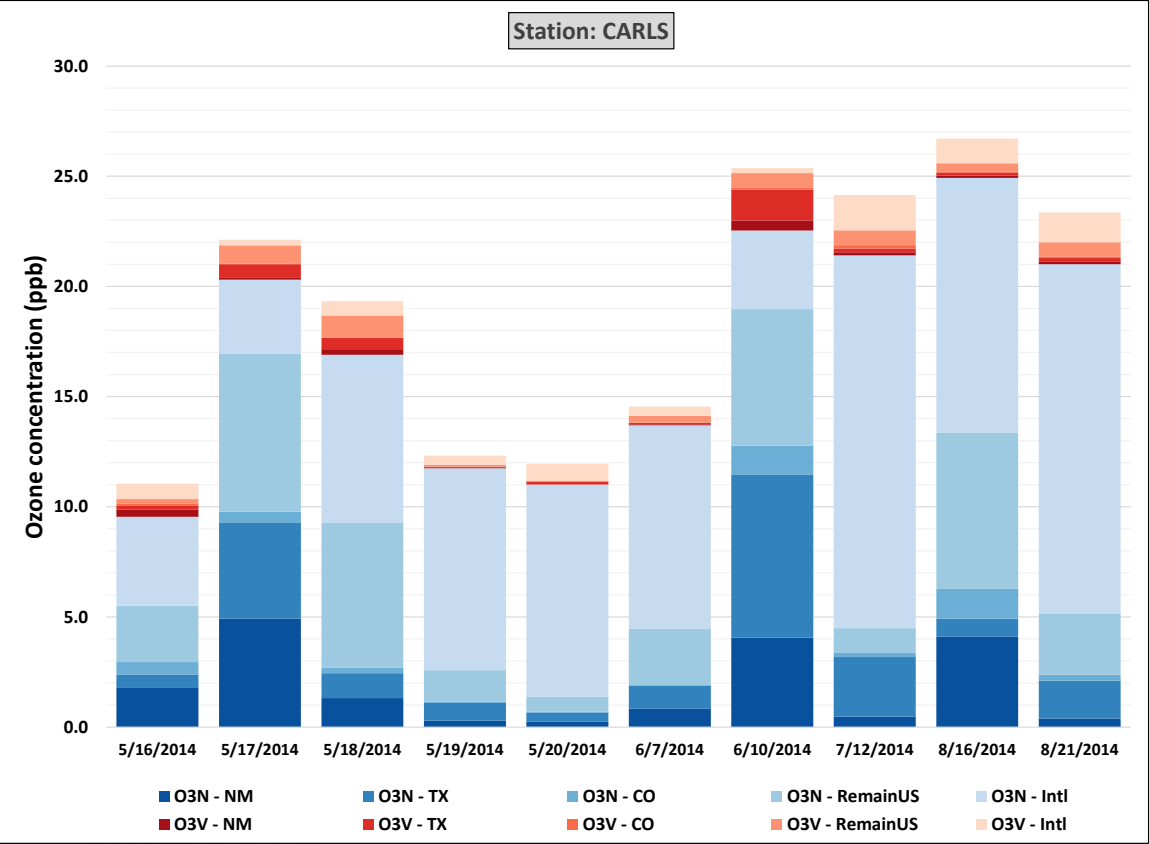
Average 10 SMAT Days



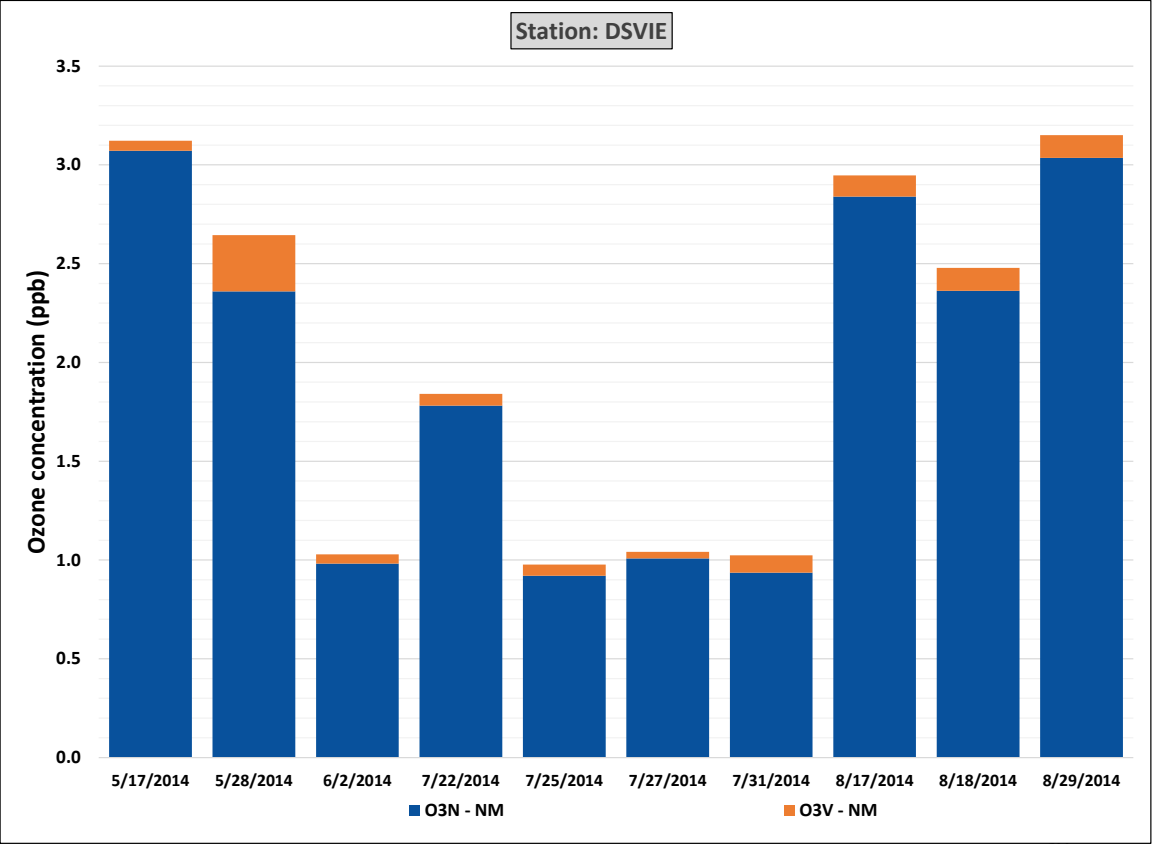
CARLSBAD, EDDY COUNTY – 10 SMAT DAYS

- Mostly NOx sensitive ozone with New Mexico contributions even more NOx sensitive

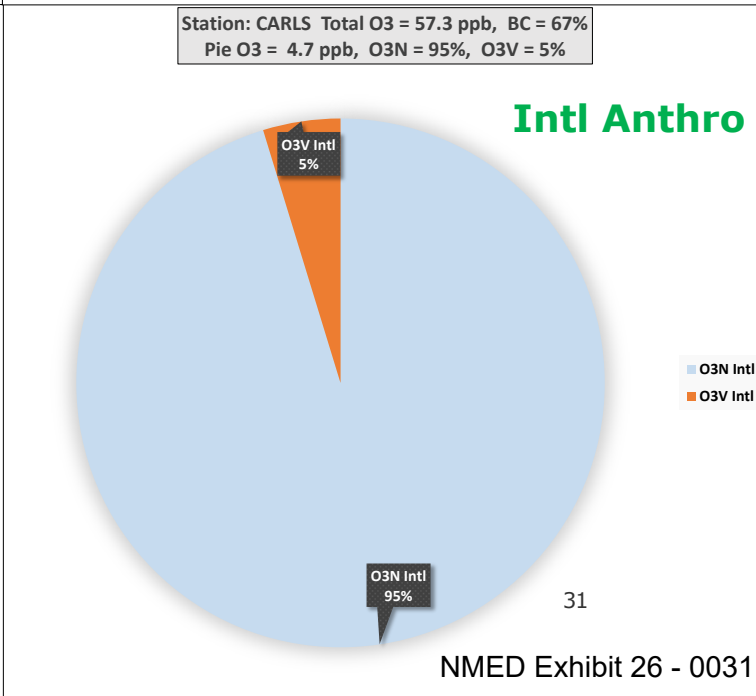
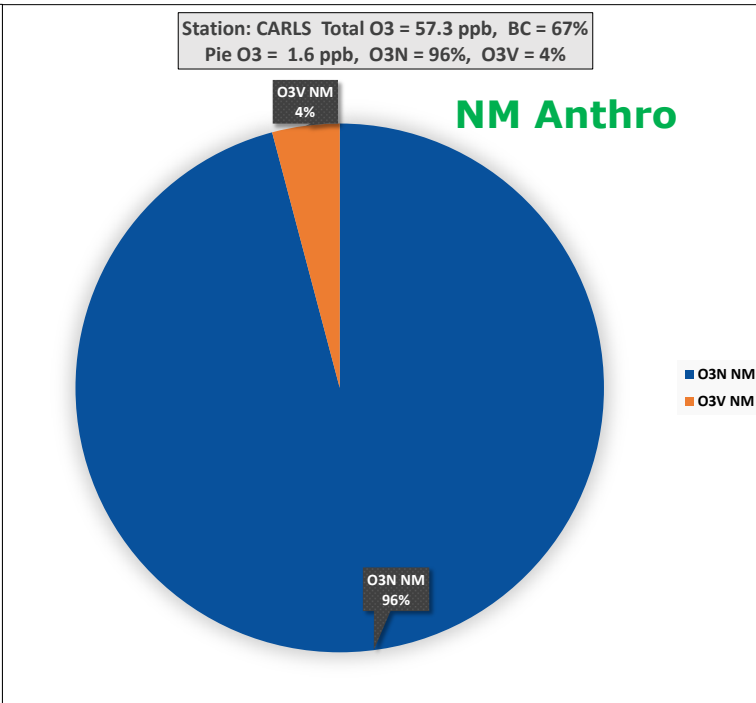
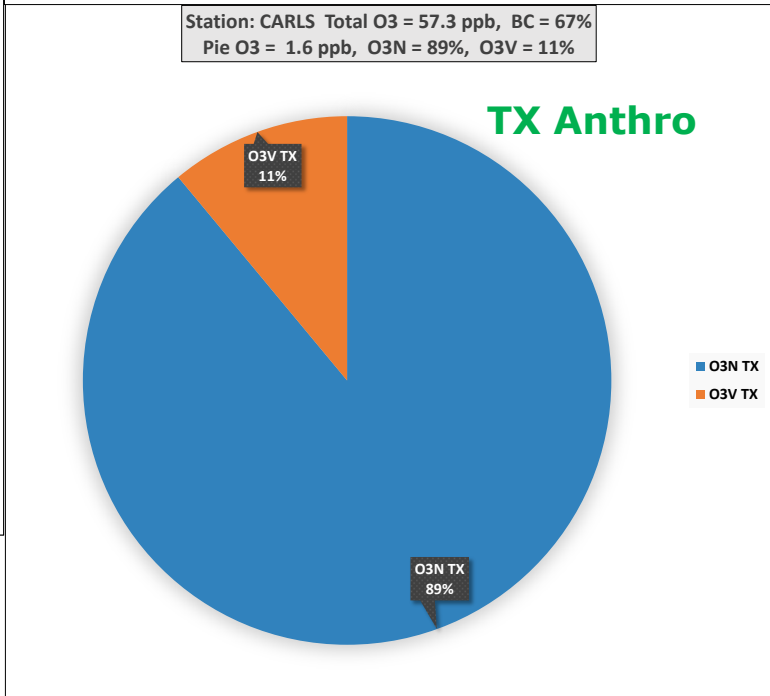
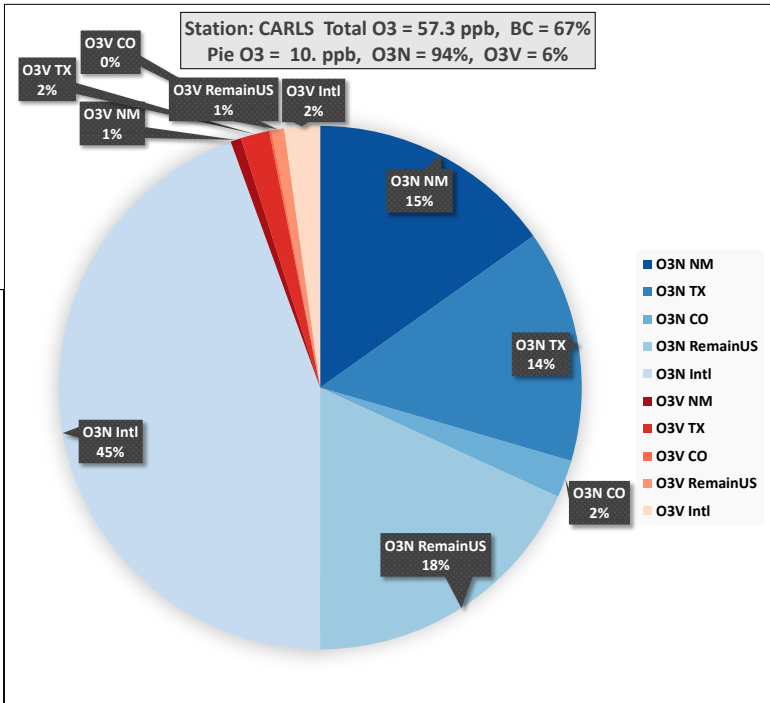
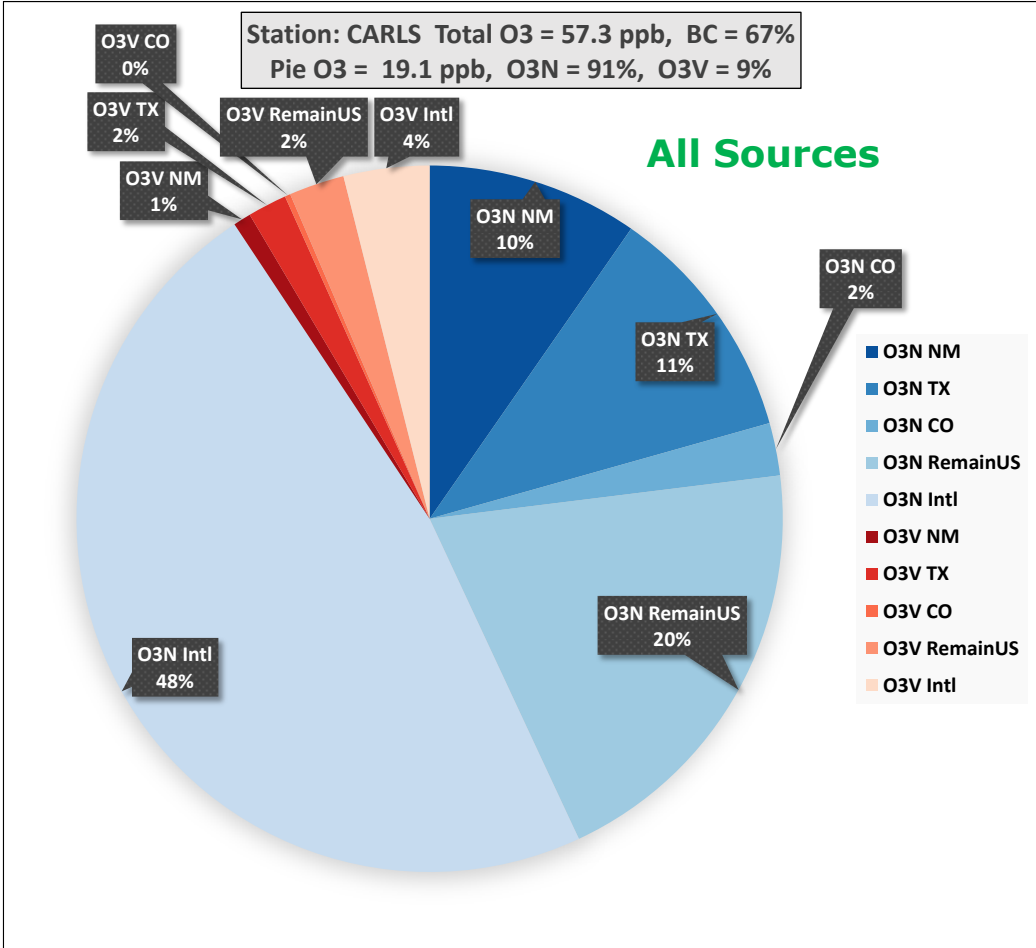
All Source Categories and Regions



New Mexico Anthropogenic



Carlsbad, Eddy County Average 10 SMAT Days



CONCLUSIONS VOC/NOX SENSITIVE OZONE OSAT SA

- The OSAT source apportionment suggests that ozone formation leading to elevated ozone concentrations in New Mexico is primarily NOx sensitive
 - Consistent with regional ozone modeling studies (e.g., OTAG) that found regional NOx emissions controls most effective at reducing regional ozone concentrations and ozone transport
 - VOC controls can also be effective in urban areas and other areas with concentrated emissions
- There are locations and days when there are higher amounts of VOC sensitive ozone formation:
 - San Juan Basin, El Paso-Juarez, Albuquerque and, to a lesser extent, Permian Basin
- The OSAT source apportionment provides a general indication of potential relative effectiveness of NOx vs. VOC controls for reducing ozone concentrations. It is not a substitute for actual control strategy modeling with explicit emission reductions of targeted sources.
 - Ozone formation is complex and reducing emissions changes the chemistry from the previous state that can cause non-linear responses in ozone concentrations

DRAFT FINAL AQTSD (DUE MAY 4; ACTUAL WEEK OF APR 26)

1. Introduction
2. 2014 WRF Meteorological Modeling
3. Boundary Condition Inputs
4. 2014 Emission Inputs
5. Diagnostic Sensitivity Tests
6. 2014 Base Case Modeling and Model Performance Evaluation
7. 2028 Base Case Modeling and Ozone Design Value Projections
8. 2028 Oil and Gas Control Strategy Modeling and Ozone Design Value Projections
9. Sensitivity of 2028 Ozone Design Value Projections to Current Year Design Values
10. APCA Source Sector Ozone Source Apportionment Modeling
11. OSAT VOC/NO_x Sensitivity Ozone Source Apportionment Modeling
12. Summary and Conclusions
13. References