Southern New Mexico Ozone Study
Technical Support Document

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ACRONYMS AND ABBREVIATIONS

3SAQS	Three-State Air Quality Study
AIRS	Aerometric Information Retrieval System
AMET	Atmospheric Model Evaluation Tool
APCA	Anthropogenic Precursor Culpability Assessment
AQ	Air Quality
AQS	Air Quality System
BC	Boundary Condition
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
NO_2	Nitrogen Dioxide
NO_3	Nitrate Fine Particulate Matter
NOAA	National Oceanic and Atmospheric Administration
OA	Organic Aerosol Fine Particulate Matter
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
PPM	Piecewise Parabolic Method
QA	Quality Assurance
QC	Quality Control
RMP	Resource Management Plan
RRF	Relative Reduction 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
WESTUS	Western United States
WRAP	Western Regional Air Partnership
WGA	Western Governors' Association
WRF	Weather Research Forecasting model

1.0 EXECUTIVE SUMMARY

The Southern New Mexico Ozone Study (SNMOS) studied the factors contributing to high ozone in Doña Ana County. Photochemical modeling was carried out for May 1 – September 30, 2011 using emissions scenarios for a 2011 base year and a 2025 future year. The SNMOS modeling platform was derived from the Western Air Quality Study (WAQS) regional modeling platform that was available through the Intermountain West Data Warehouse (IWDW) with adjustments and updates to the meteorology and modeling domains to optimize the platform for application to Southern New Mexico and surrounding regions.

The Weather Research Forecasting (WRF) model was used to provide meteorology data for use in the photochemical modeling. Emissions processing was primarily conducted using the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system using emissions data from the EPA 2011-based modeling platform (2011v6) version 2 and the WAQS (2011b) inventories. Photochemical grid modeling was done with the Comprehensive Air-quality Model with extensions (CAMx) version 6.20. A model performance evaluation was carried out for the meteorological and photochemical models; performance was determined to be acceptable through comparison with EPA Modeling Guidance (EPA, 2014) and to be consistent with performance in similar regional modeling studies. The major findings of the SNMOS are listed below:

- 2025 future year design value projections indicate that all Doña Ana County ozone monitors are expected to attain the 70 ppb National Ambient Air Quality Standard for ozone (NAAQS) in 2025.
- The modeled decreases in Doña Ana County ozone design values between 2011 and 2025 are mainly driven by projected reductions in emissions from cars, trucks and other on-road mobile sources
- All Doña Ana County ozone monitors would have attained the 70 ppb ozone NAAQS in 2011 but for the ozone contribution due to anthropogenic emissions from Mexico
- Regional emissions sources contributing the most ozone to 2011 Doña Ana County ozone were: (1) on-road mobile emissions from Texas, Mexico and New Mexico; (2) power plant emissions from Mexico; and (3) natural emissions (mainly from plants as well as lightning and fires) from Mexico.
- Regional emissions sources contributing the most ozone to Doña Ana County ozone monitors in 2025 were: (1) on-road mobile emissions from Texas and Mexico; (2) power plant and non-power plant point source emissions from Mexico; and (3) natural emissions from Mexico.
- Ozone transport plays an important role in determining ozone levels in Doña Ana County. Ozone from emissions sources outside the region was the largest contributor of ozone; this is a typical result for a regional modeling study. For all Doña Ana County monitors except Solano, the individual ozone contribution from Texas and Mexico was larger than that of New Mexico.

- New Mexico anthropogenic emission sources that contributed the most ozone to Southern New Mexico monitors were: (1) on-road mobile; (2) offroad mobile; (3) oil and gas; and (4) power plants.

We provide recommendations for model improvement and further study at the end of this report.

2.0 INTRODUCTION

2.1 Project Background

Doña Ana County in Southern New Mexico experiences some of the highest observed ground-level ozone concentrations in the state. The Sunland Park Ozone Nonattainment Area (NAA) which lies within Doña Ana County was designated as marginal nonattainment for the 1-hour ozone standard on June 12, 1995 (60 FR 30789). With the revocation of the 1-hour ozone standard in 2004, the Sunland Park NAA was designated a maintenance area for 8-hour ozone (NMED, 2007). Lowering of the 8-hour ozone standard by EPA in 2008 to 0.75 ppm (75 ppb) and again in 2015 to 0.70 ppm (70 ppb) will likely lead to the Sunland Park NAA receiving a nonattainment designation for 8-hour ozone. In addition, the New Mexico Air Quality Control Act (NMAQCA) requires the New Mexico Environment Department (NMED) to develop a plan for reducing ozone levels in areas that are within 95% of the ozone standard (NMSA 1978, § 74-2-5.3). Table 2-1 shows the 1st through 4th highest daily maximum 8-hour average ozone (MDA8) concentrations measured from 2011 to 2014 at the EPA Air Quality System (AQS) monitors in Doña Ana County. This table shows that all but a handful of the measurements at these monitors exceeded either the 2015 NAAQS for ozone (orange) or the NMAQCA 95% threshold (yellow).

Table 2-1. Daily maximum 8-hour average ozone measurements from 2011-2014 at AQS sites in Doña Ana County, NM.

Station	1st Highest		2nd Highest		3rd Highest		4th Highest	
	Date	ppmV	Date	ppmV	Date	ppmV	Date	ppmV
La Union	5/24/2011	0.064	6/22/2011	0.064	7/28/2011	0.064	4/26/2011	0.063
SPCY	6/22/2011	0.078	6/4/2011	0.076	7/28/2011	0.068	6/27/2011	0.067
Chaparral	8/2/2011	0.074	5/24/2011	0.073	5/25/2011	0.071	6/22/2011	0.07
Desert V	6/4/2011	0.084	6/22/2011	0.081	8/27/2011	0.073	7/28/2011	0.072
Sta Teresa	6/22/2011	0.078	5/24/2011	0.074	4/26/2011	0.07	6/27/2011	0.07
Solano	5/24/2011	0.068	5/25/2011	0.068	8/6/2011	0.068	8/27/2011	0.067
La Union	8/31/2012	0.079	7/13/2012	0.078	6/28/2012	0.075	7/14/2012	0.074
SPCY	8/31/2012	0.078	7/13/2012	0.076	7/12/2012	0.075	6/28/2012	0.073
Chaparral	6/2/2012	0.075	6/1/2012	0.07	7/13/2012	0.069	6/3/2012	0.067
Desert V	7/13/2012	0.077	8/31/2012	0.077	7/12/2012	0.076	6/28/2012	0.075
Sta Teresa	8/31/2012	0.083	7/13/2012	0.08	7/12/2012	0.078	9/1/2012	0.077
Solano	5/16/2012	0.069	6/3/2012	0.068	7/13/2012	0.067	6/2/2012	0.066
La Union	8/17/2013	0.066	8/16/2013	0.065	8/21/2013	0.065	8/4/2013	0.064
SPCY	7/3/2013	0.068	6/11/2013	0.063	6/9/2013	0.063	8/17/2013	0.062
Chaparral	5/24/2013	0.074	6/15/2013	0.074	7/3/2013	0.071	7/5/2013	0.07
Desert V	7/3/2013	0.076	8/16/2013	0.072	7/27/2013	0.072	6/9/2013	0.071
Sta Teresa	7/27/2013	0.089	7/3/2013	0.081	7/25/2013	0.081	7/7/2013	0.08
Solano	7/31/2013	0.066	7/27/2013	0.065	7/16/2013	0.065	5/20/2013	0.064
La Union	6/10/2014	0.07	5/29/2014	0.07	8/18/2014	0.068	5/28/2014	0.066
SPCY	6/10/2014	0.073	5/29/2014	0.068	8/30/2014	0.068	7/22/2014	0.068
Chaparral	8/6/2014	0.075	6/10/2014	0.071	7/18/2014	0.069	5/29/2014	0.068
Desert V	6/10/2014	0.077	5/29/2014	0.074	7/15/2014	0.073	5/28/2014	0.072

Station	1st Highest		2nd Highest		3rd Highest		4th Highest	
	Date	ppmV	Date	ppmV	Date	ppmV	Date	ppmV
Sta Teresa	7/15/2014	0.071	8/18/2014	0.07	7/31/2014	0.069	6/10/2014	0.067
Solano	6/10/2014	0.072	6/7/2014	0.069	5/29/2014	0.068	6/9/2014	0.067

The statutory requirements of both the NAAQS and the NMAQCA include the development of a plan to control the emissions of sources pursuant to attainment and maintenance of the NAAQS. In the case of a NAAQS NAA State Implementation Plan (SIP), air quality modeling is required to identify the causes of high pollution and to propose emissions control strategies that will bring the area into attainment.

The Southern New Mexico Ozone Study (SNMOS) studied the factors contributing to high ozone in Doña Ana County and investigated future emissions scenarios that will produce NAAQS attainment. The SNMOS is a collaborative project between NMED, the Western Regional Air Partnership (WRAP), the Western Air Resources Council (WESTAR), Ramboll Environ US Corporation (RE), and the University of North Carolina Institute for the Environment (UNC-IE). This Study built off of the Western Air Quality Study (WAQS), a cooperative project that is intended to facilitate air resource analyses for federal and state agencies in the intermountain western U.S. toward improved information for the public and stakeholders as a part of air quality planning. The Intermountain West Data Warehouse (IWDW) at the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University was the source for the regional air quality modeling data and software resources from the WAQS. The SNMOS leveraged the WAQS 2011 version B (WAQS_2011b) modeling platform to conduct base and future year air quality modeling for Doña Ana County.

2.2 Organization of the Technical Support Document

This Technical Support Document (TSD) summarizes the objectives, methods and results of the SNMOS. In the remainder of Section 2, we provide a summary of the SNMOS modeling approach. In Section 3, we present an overview of the results of the study. The organization of Section 3 of the TSD follows that of the SNMOS, which was broken into 13 separate Tasks:

- **Task 1**: 2011 WRF 36/12/4-km modeling with 4-km grid focused on Dona Ana/El Paso/Juárez and Data Analysis/Modeling Work Plan
- **Task 2**: 2011 update of Permian Basin oil and gas emission inventory
- **Task 3**: 2011 update of emissions inventories for Juárez and nearby Mexico and 2025 Mexico emissions
- **Task 4**: SMOKE modeling of current 2011 National Emission Inventory for 4-km domain
- **Task 5**: Gridded 2011 biogenic, fires, wind-blown dust, lightning emissions for 4-km domain
- **Task 6**: Develop 2011 4-km CAMx database and perform base case modeling
- **Task 7**: 2011 CAMx model performance evaluation and sensitivity modeling for Doña Ana County
- **Task 8**: SMOKE current 2025 US emission inventory and Mexico emissions update

- **Task 9**: Future year (2025) 12/4-km CAMx simulation
- **Task 10**: FY (2025) ozone design value projections (MATS)
- **Task 11**: 2025 emissions sensitivity tests/controls
- **Task 12:** Ozone source apportionment modeling of 2011 and 2025
- **Task 13**: Technical Support Document (TSD)

For each Task, we outline the methods, data used and results. Then we summarize the major findings of the Task. Finally, we list the Task deliverables and their completion dates. A PowerPoint presentation and/or written documentation describing each Task in more detail are available on the WRAP SNMOS website.

In Section 4, we provide a summary of results and conclusions of the SNMOS and make recommendations for future work.

2.3 Overview of the SNMOS Modeling Approach

The SNMOS modeling platform was derived from the WAQS_2011b regional modeling platform. A regional modeling platform is the suite of data and software required for conducting a regional-scale air quality modeling study. The procedures for the SNMOS 2011 modeling followed those performed for the 2011 WAQS with adjustments to the meteorology and modeling domains to optimize the modeling platform for application to southern New Mexico. The SNMOS 2011 modeling platform included nested 36, 12 and 4-km resolution meteorology modeling domains. The regional air quality modeling was conducted at 12 and 4-km resolution.

The SNMOS modeling domains were selected to facilitate high resolution modeling for sources around Doña Ana County and to enable regional source apportionment modeling among all of the surrounding Western states. The SNMOS 12 and 4-km domains, shown in Figure 2-1, were designed to encompass the meteorology and emissions features that are most important to ground-level ozone formation in southern New Mexico. Also shown in Figure 2-1 are the locations of EPA's Air Quality System (AQS) ozone monitors (green) and point sources of nitrogen oxide (NOx) emissions (blue).

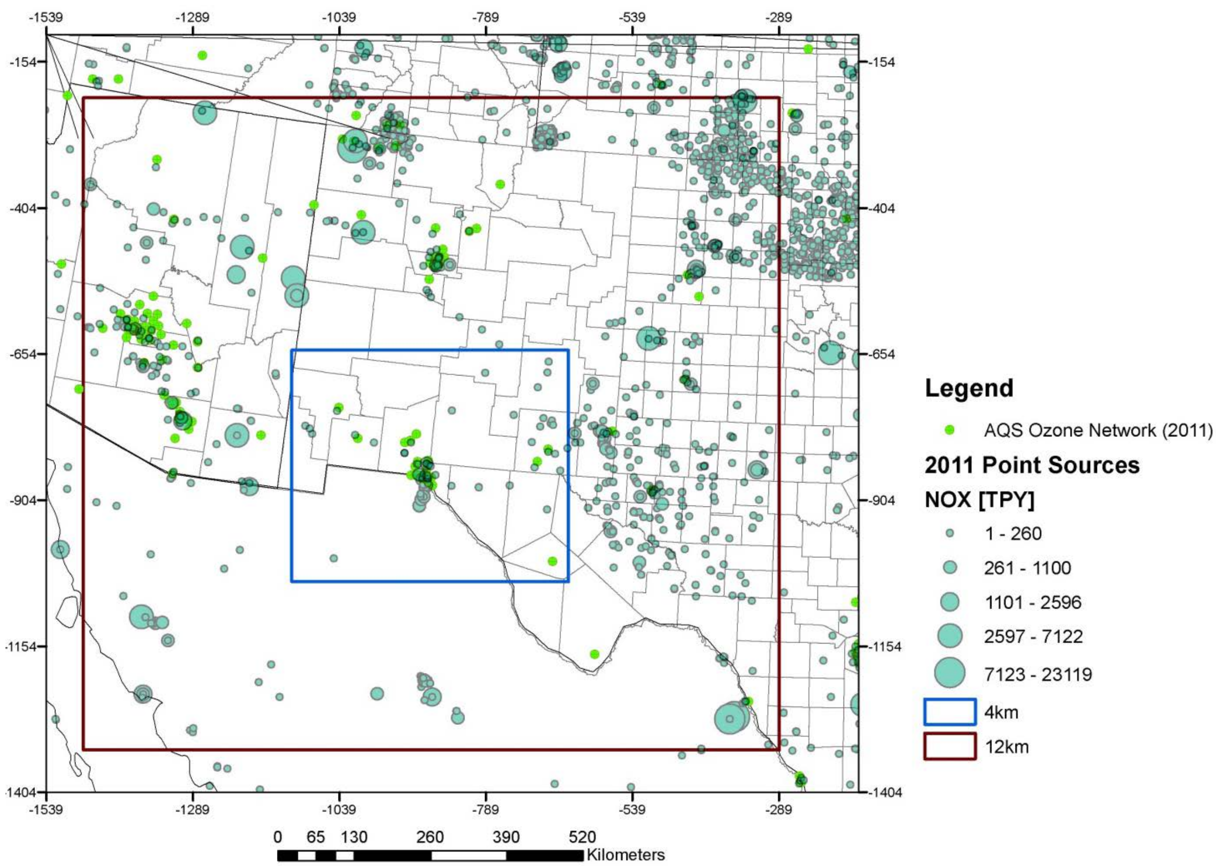

Figure 2-1. SNMOS 2011 CAMx 12/4-km modeling domains.

The CAMx and emissions domains for modeling of 2011 were chosen for the following reasons:

- New continental-scale coarse grid modeling was not needed for the SNMOS because we were able to extract BCs for the 12-km domain from the WAQS 2011 CAMx modeling results. The WAQS modeling used the 36-km RPO grid and a 12-km modeling domain that encompassed much of the western U.S. As we used the same emissions data and CAMx configuration for the SNMOS as were used for the WAQS, there was consistency between these simulations enabling the use of the WAQS modeling as lateral boundary conditions (BCs) for the SNMOS domains.
- The SNMOS 12-km CAMx domain encompasses all of New Mexico, extends west to include the metropolitan area of Phoenix, east to include East Texas, and south to include the Carbon II power plant in Coahuila, Mexico. This facility is a large source of NOx emissions and lies in a region that was sometimes upwind of Doña Ana County on high ozone days during 2011. The SNMOS 12-km domain was designed to balance computational efficiency and the need to model transport from sources likely to influence Doña Ana County at 12-km resolution.
- The SNMOS 4-km Doña Ana County domain focuses on Southern New Mexico and the major emissions source regions in the immediate vicinity, including Ciudad Juárez, Mexico and El Paso, TX.

We simulated the 2011 ozone season and evaluated the meteorology and air quality model performance against surface and aloft monitors that operated in the modeling domains during the study period. Following the base year model performance evaluation, we used projected emissions data to simulate air quality in the year 2025. Along with future year attainment tests, the future year modeling included emissions sensitivity testing and ozone source apportionment modeling of emissions source region and source category contributions to ozone concentrations and ozone design values at ozone monitoring sites in Doña Ana County (and elsewhere in the region). A summary of the SNMOS modeling approach is given below.

- The 2011 ozone season for New Mexico (May 1 – September 30) was selected for the modeling period.
- Year 2011 and 2025 inventories were used to estimate base and future year emissions.
- The Weather Research Forecasting (WRF) version 3.7.1 was used to simulate meteorology data for this study.
- Emissions processing was primarily conducted using the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system version 3.7 using emissions data from the EPA 2011-based modeling platform (2011v6) version 2 and the WAQS (2011b).
- Photochemical grid modeling (PGM) was done with the Comprehensive Air-quality Model with extensions (CAMx) version 6.20. The Carbon Bond 6 revision 2 (CB6r2) photochemical mechanism was used for the SNMOS modeling.
- For the SNMOS 2011 modeling, hourly BCs for the portion of the lateral boundaries of the SNMOS 12-km PGM domain that lies within the larger WAQS 12-km domain were extracted from the WAQS 36-km continental U.S. CAMx modeling.

- Model performance evaluation was conducted for meteorology, ozone, and ozone precursor and product species.
- Diagnostic sensitivity testing was conducted to determine sensitivity of the PGM model estimates to the WRF model configuration and to improve the 2011 base year model performance in simulating ground-level ozone in Southern New Mexico and the surrounding region.
- Future year modeling was used to estimate air quality in 2025 and to conduct attainment tests for Doña Ana County.
- Future year emissions sensitivity modeling was used to evaluate the impacts of emissions reductions on future attainment of the ozone NAAQS.
- Future year CAMx source apportionment modeling was used to quantify the source region and source category contributions to ozone concentrations and ozone design values at ozone monitoring in Dona Ana County.

2.4 Project Participants

The SNMOS was facilitated and managed by the Western States Air Resources Council (WESTAR). RE and UNC-IE conducted the meteorology, emissions, and air quality modeling and analysis. Key contacts and their roles in the SNMOS are listed in Table 2-2.

Table 2-2. SNMOS key contacts.

Name	Role	Organization/Contact
Tom Moore	Project Manager	WESTAR c/o CSU/CIRA 1375 Campus Delivery Fort Collins, CO 80523 (970) 491-8837 tmoore@westar.org
Zac Adelman	UNC-IE Lead	University of North Carolina Institute for the Environment 100 Europa Dr., Suite 490, CB 1105 Chapel Hill, NC 27517 (919) 962-8510 zac@unc.edu
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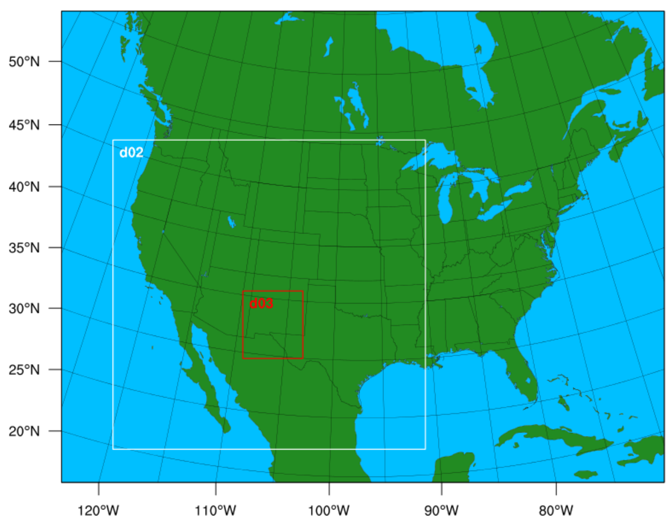
3.0 SNMOS TASK SUMMARIES

3.1 Task 1: Weather Research Forecast (WRF) Meteorological Modeling

3.1.1 Task Summary

The objective of this task was to simulate and evaluate WRF meteorology for modeling 2011 summer season ozone in Doña Ana County, New Mexico. We coordinated with WRF modelers in the western U.S. to find a candidate model configuration for best simulating ozone in the southwestern U.S. We used the most recent version of WRF (v3.7.1) available at the time of the study to test four different WRF configurations in simulating summer season (April 15-August 30, 2012) meteorology on 33 vertical layer (Table 3-1) 36-km U.S. EPA Continental U.S. (CONUS), 12-km Western U.S. and 4-km SNMOS modeling domains (Figure 3-1). After conducting an operational model performance evaluation on all of the WRF simulations and selecting the best performing configuration, we converted the WRF output to CAMx inputs using the WRFCAMx software. Additional details of the WRF sensitivities, evaluation, and final configuration are provided below.



Parameter	Value
Projection	Lambert-Conformal
1st True Lat	33 degrees N
2nd True Latitude	45 degrees N
Central Lon	97 degrees W
Central Lat	40 degrees N
dX (km)	d01 = 36, d02 = 12, d03 = 4
dY (km)	d01 = 36, d02 = 12, d03 = 4
X-orig (km)	d01 = -2736, d02 = -2196, d03 = -912
Y-orig (km)	d01 = -2088, d02 = -1728, d03 = -828
# cols	d01 = 165, d02 = 256, d03 = 148
# rows	d01 = 129, d02 = 253, d03 = 166

Figure 3-1. WRF modeling domains.

Table 3-1. Vertical layer interfaces for the WRF and CAMx simulations

WRF and CAMx Levels				
WRF Level	Sigma	Pressure (mb)	Height (m)	Thickness (m)
33	0.0000	50.00	19260	2055
32	0.0270	75.65	17205	1850
31	0.0600	107.00	15355	1725
30	0.1000	145.00	13630	1701
29	0.1500	192.50	11930	1389
28	0.2000	240.00	10541	1181
27	0.2500	287.50	9360	1032
26	0.3000	335.00	8328	920

WRF and CAMx Levels				
WRF Level	Sigma	Pressure (mb)	Height (m)	Thickness (m)
25	0.3500	382.50	7408	832
24	0.4000	430.00	6576	760
23	0.4500	477.50	5816	701
22	0.5000	525.00	5115	652
21	0.5500	572.50	4463	609
20	0.6000	620.00	3854	461
19	0.6400	658.00	3393	440
18	0.6800	696.00	2954	421
17	0.7200	734.00	2533	403
16	0.7600	772.00	2130	388
15	0.8000	810.00	1742	373
14	0.8400	848.00	1369	271
13	0.8700	876.50	1098	177
12	0.8900	895.50	921	174
11	0.9100	914.50	747	171
10	0.9300	933.50	577	84
9	0.9400	943.00	492	84
8	0.9500	952.50	409	83
7	0.9600	962.00	326	83
6	0.9700	971.50	243	81
5	0.9800	981.00	162	65
4	0.9880	988.60	97	41
3	0.9930	993.35	56	32
2	0.9970	997.15	24	24
1	1.0000	1000	0	

The WRF configuration sensitivity tests that we ran were based on previous WRF modeling studies of the region. Our objective for these tests was to maximize the skill of the model in simulating conditions conducive to surface ozone build up in southern New Mexico. One key issue that we wanted to address was the known performance problem that WRF has in simulating precipitation in the Western U.S. Accurately capturing the timing and location of both convective precipitation events and events driven by the North American monsoon is important in developing a reliable model of ozone formation in the region. The prior WRF modeling studies that we considered in our design for the SNMOS included,

- The Bureau of Land Management's Montana-Dakotas (BLM-MT/DK) Study examined the sensitivity of WRF model performance in the Montana/Dakotas region for different WRF model configurations used in recent studies (McAlpine et al., 2014). In the initial Montana-Dakotas modeling, WRF overstated precipitation over the 4-km modeling domain during the summer months. The initial WRF run used surface temperature and humidity observation nudging in the 4-km domain. The temperature and humidity observation nudging introduced instabilities in the WRF simulation that resulted in increased convective activity and rainfall. BLM-MT/DK Study sensitivity testing demonstrated that removing temperature and humidity observation nudging and using the Grell-Freitas cumulus parameterization on the 4-km domain for the final WRF simulation improved rainfall, wind speed, and wind direction model performance. The reduction in explicit convective activity allowed WRF to more accurately simulate the observed winds.

- In the San Juan Mercury Modeling (Ramboll Environ and Systech Water Resources, 2015), WRF overpredicted precipitation in a 12-km domain focused on the Four Corners region, but was much more accurate at the 4-km resolution. Observational nudging was applied to the 12-km and 4-km domains for winds, but not for temperature or humidity. Several cumulus parameterizations were evaluated to determine their effect on modeled precipitation.
- The 2011 WRF evaluation for the 3-State Air Quality Study (3SAQS) compared WRF 3.6.1 estimates to monthly PRISM observations (UNC and ENVIRON, 2014). While summertime WRF precipitation was generally too high relative to PRISM and the model did not resolve the local convective features well, there were questions about the PRISM analysis fields and their reliability at capturing isolated convective cells.

In consideration of these studies, we conducted a series of WRF simulations and selected the best performer (lowest bias and error for surface temperature, winds, humidity, and precipitation at sites in the 4-km SNMOS domain) for the operational simulations. The sensitivities were based off of the WAQS (UNC and ENVIRON, 2014) and San Juan Mercury Modeling (Ramboll Environ and Systech Water Resources, 2015) studies. Table 3-2 summarizes the base configuration that we used for the SNMOS WRF sensitivities and compares this configuration to the WAQS WRF modeling. The WRF version 3.7.1 sensitivity simulations that we ran included the following:

- Configuration 1 (NAM KF Mods): Base WRF configuration using settings from the 3SAQS/WAQS 2011 configuration. The key parameters here for the WRF sensitivity tests are the North American Model (NAM) Initial and Boundary Conditions (ICBCs) and the modified Kain-Fritsch (KF) cumulus scheme (Alapaty et al., 2012). The modified convective parameterization scheme provides subgrid-scale cloud fraction and condensate feedback to the shortwave and longwave radiation schemes. The impact of including the subgrid-scale cloud fraction is a reduction in the shortwave radiation, leading to less buoyant energy, thereby alleviating the overly energetic convection and reducing precipitation.

- Configuration 2 (NAM MSKF): Same as Configuration 1 with the multi-scale (grid-aware) Kain-Fritsch (MSKF) cumulus scheme (Alapaty et al., 2014). Additional changes were made to the modified KF scheme to improve the accuracy of precipitation at grey zone resolutions (<10 km). These include scale dependent features of convection such as scale dependent consumption of the convective available potential energy and entrainment of environmental air.

- Configuration 3 (ERA MSKF): Same as Configuration 2 but using the European Centre for Medium-range Weather Forecasts (ECMWF) ERA-Interim analysis as the ICBC fields.

Experience from the San Juan Hg WRF tests indicate that the ERA-Interim ICBC fields may improve simulated precipitation associated with the North American Monsoon.

- Configuration 4 (ERA MSKF No AN): Same as Configuration 3 but based on prior experiences from the San Juan Hg study, analysis nudging was not applied in domain 2.

Table 3-2. Base configuration for the SNMOS WRF sensitivity modeling.

WRF Treatment	3SAQS/WAQS	SNMOS
Microphysics	Thompson	Thompson
Longwave Radiation	RRTMG	RRTMG
Shortwave Radiation	RRTMG	RRTMG
Minutes between radiation physics calls	20	20
Land Surface Model (LSM)	NOAH	NOAH
Planetary Boundary Layer (PBL) scheme	YSU	YSU
Cumulus parameterization	Kain-Fritsch in the 36-km and 12-km domains only.	Multiscale (grid-aware) Kain-Fritsch.
Analysis nudging	Applied to winds (uv), temperature (t) and moisture (q) in the 36-km and 12-km domains	Applied to winds (uv), temperature (t) and moisture (q) in the 36-km and 12-km domains
Analysis nudging coefficients	uv: 5e-4 (d01), 3e-4 (d02) t: 5e-4 (d01), 3e-4 (d02) q: 1e-5 (d01 and d02)	uv: 5e-4 (d01), 3e-4 (d02) t: 5e-4 (d01), 3e-4 (d02) q: 1e-5 (d01 and d02)
Observation Nudging	Applied to surface wind and temperature in the 4-km domain	None
Observation nudging coefficients	uv: 1.2e-3 (d03) t: 6e-4 (d03)	N/A
Initialization Dataset	12-km North American Model (NAM)	12-km (NAM)
Top (mb)	50	50
Vertical Levels (Layers)	37 (36)	33 (32)

We ran the WRF model in 5-day blocks initialized at 12Z every 5 days with a 90-second integration time step. Model results were output every 60 minutes and output files split at 24-hour intervals. Twelve hours of spin-up were included in each 5-day block before the data were used in the subsequent evaluation. The model was run at 36-km, 12-km and 4-km grid resolution from May 15 through September 1, 2011 using one-way grid nesting with no feedback (i.e., the meteorological conditions are allowed to propagate from the coarser grid to the finer grid but not vice versa).

The evaluation for these simulations focused on simulating the North American Monsoon with an emphasis on the timing, location, and magnitude of precipitation in southern New Mexico. The model evaluation approach was based on a combination of qualitative and quantitative analyses. The quantitative analyses were divided into monthly summaries of 2-m temperature, 2-m mixing ratio, and 10-m wind speed using the boreal seasons to help generalize the model bias and error relative to a standard benchmark. We supplemented the WRF evaluation with select diurnal and time series analyses at specific sites in the 4-km SNMOS modeling domain. Additional analysis included a qualitative evaluation of the daily total WRF precipitation fields against PRISM fields. The PRISM data were mapped to the WRF domains and grid resolution. The observed database for winds, temperature, and water mixing ratio used in this analysis were the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) Meteorological Assimilation Data Ingest System (MADIS).

Table 3-3 shows the 4-km domain average performance statistics for temperature, moisture, and winds. The performance trends illustrate that initializing WRF with the North American Model (NAM) produces a WRF model that has a warm and dry bias with underestimated wind speeds. The ERA initialization produces a WRF model with a warm and wet bias that also underestimates the wind speeds. Including the MSKF convective cloud module slightly improved the moisture bias in the model and we found that the performance of this option was sensitive to the initialization dataset that we selected.

Table 3-3. 4-km domain average model performance statistics

	Temperature (deg K)		**Mixing Ratio (g/kg)**		**Wind Speed (m/s)**		**Wind Direction (degrees)**	
	Bias	Error	Bias	Error	Bias	RMSE	Bias	Error
Benchmark: Simple	≤ ±0.5	≤ 2.0	≤ ±0.5	≤ 1.0	≤ ±0.5	≤ 2.0	≤ ±5	≤ 40
Benchmark: Complex	≤ ±1.0	≤ 3.0	≤ ±1.0	≤ 2.0	≤ ±1.0	≤ 3.0	≤ ±10	≤ 80
NAM KFmods	**0.21**	**1.77**	-0.53	1.05	**-0.30**	2.12	5.46	43.6
NAM MSKF	0.22	**1.77**	-0.46	**1.03**	-0.34	2.12	5.02	43.9
ERA MSKF	0.24	1.87	**0.14**	1.12	-0.43	**2.08**	**3.95**	**42.8**
ERA MSKF no AN	0.40	2.05	-0.39	1.18	-0.34	2.28	4.73	49.1

Figure 3-2 shows August 2011 wind roses, indicating the mean monthly wind direction and speeds, for all sites in the 4-km SNMOS modeling domain. The figures in this plot compare the wind data for observations relative to the four WRF configurations that we tested. Figure 3-3 is a plot of PRISM precipitation observations compared to the WRF modeling results. We generated and evaluated many of these types of plots for all simulation months, for days during high ozone episodes, and where applicable, for each meteorological observation site in southern Doña Ana County. Additional evaluation plots included time series plots, bias-error (soccer) plots, temperature spatial plots with wind vector overlays, and scatter plots.

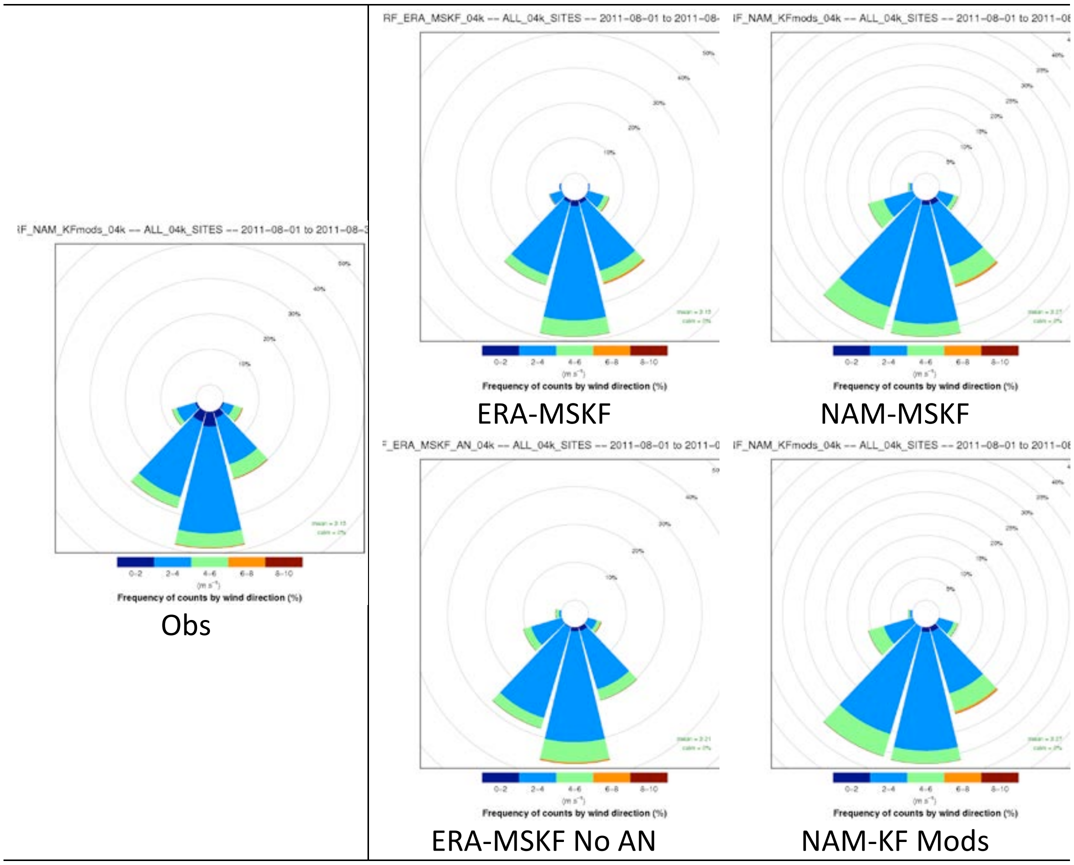


Figure 3-2. August 2011 wind roses, all sites in the 4-km domain

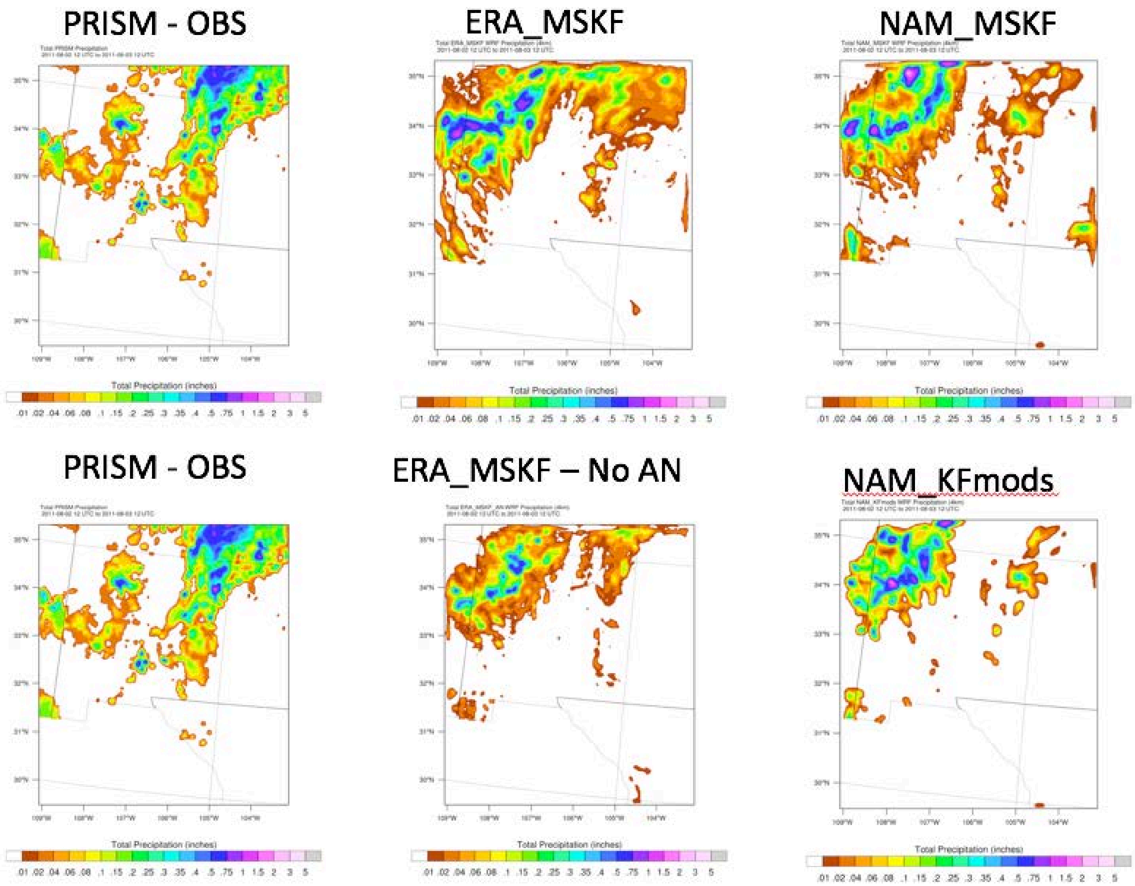


Figure 3-3. August 3, 2011 PRISM precipitation plots.

We ultimately selected NAM as the initialization dataset for the SNMOS WRF modeling. While NAM and ERA had comparable performance in simulating winds, we selected the NAM configuration with the MSKF convection cloud option because it tended to be dryer than ERA and exhibited better skill at simulating temperature. We judged that for ozone simulations, it was better to have simulated meteorology with a dry rather than wet bias in order to allow more solar insolation for ozone production.

Additional details about the WRF evaluation and configurations are available in the final Power Point deliverable for this task (UNC-IE and Ramboll Environ, 2015).

3.1.2 Significant Findings

The North American Model (NAM) and the European Centre for Medium Range Weather Forecasts model (ERA) initialization datasets provided comparable performance for WRF simulations of warm season meteorology in Southern New Mexico. While WRF performance was improved using the Multiscale (grid-aware) Kain-Fritsch cumulative cloud scheme, the model was still unable to consistently simulate precipitation patterns related to the North American monsoon. With the focus of the SNMOS on warm season ozone, we selected the NAM configuration with the multiscale Kain-Fritsch option because it tended to be dryer than ERA and exhibited better skill at simulating temperature. We judged that for ozone simulations, it was better to have simulated meteorology with a dry rather than wet bias in order to allow more solar insolation for ozone production.

3.1.3 Milestones and Deliverables

- Prepare a work plan for the WRF modeling and other aspects of study. (Completed 11/30/2015)
- Power Point Presentation of WRF Results/Recommendations (Completed 11/30/2015)

3.2 Task 2: Permian Basin Oil & Gas Inventory

3.2.1 Task Summary

Ramboll Environ reviewed available Permian Basin oil and gas (O&G) inventories and recommended 2011 and future year inventories for the SNMOS. Figure 3-4 shows Permian Basin active O&G well locations circa-2014 in New Mexico and Texas. The Doña Ana study base and future year Permian Basin emission inventories were based on the 2011NEIv2-based Platform (2011v6.2). The 2011NEIv2-based Platform base year emission inventory is for 2011, the base year of the Doña Ana County study; it includes the 2011 TCEQ well site emission inventory for Texas, and is consistent with the latest available well site emission inventory inputs for the Permian Basin in New Mexico. 2011 base year emissions from the 2011NEIv2-based Platform and 2025 2011NEIv2-based Platform emission inventories were used as is.

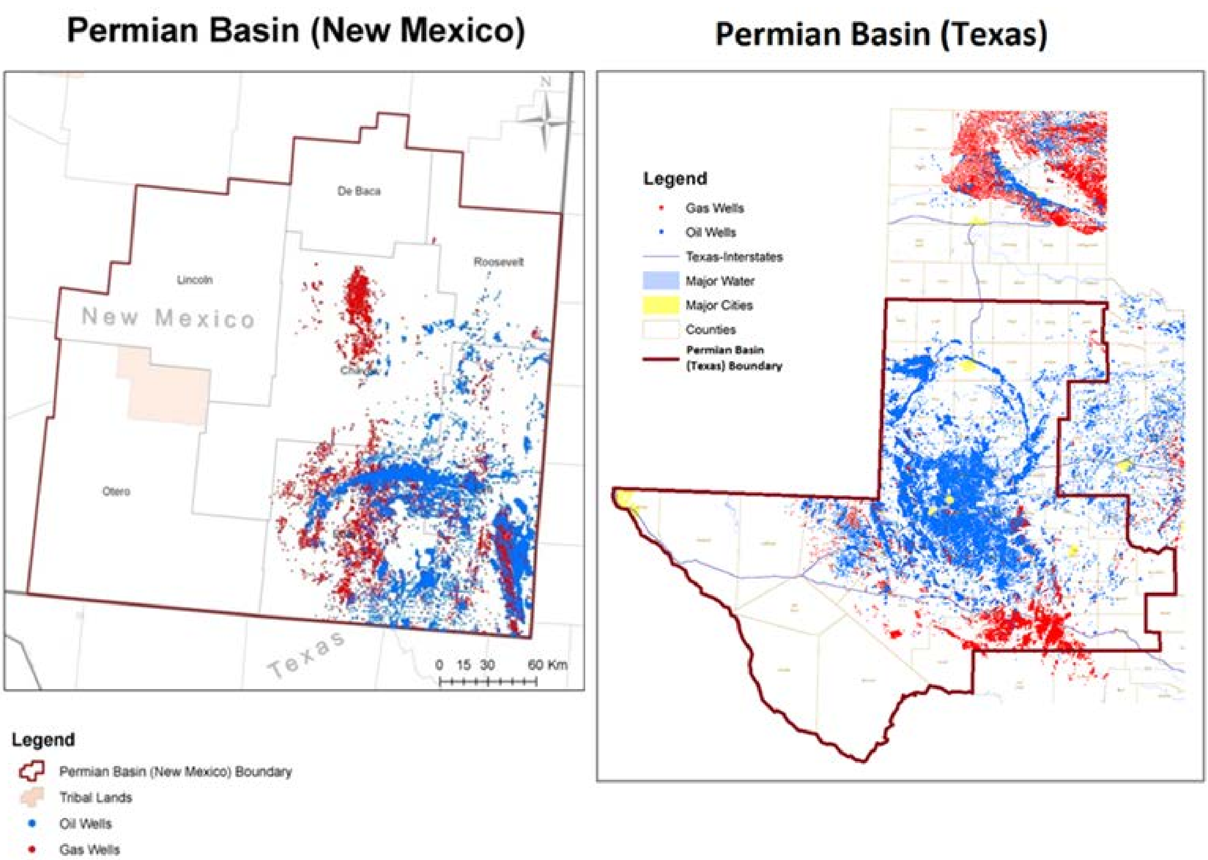


Figure 3-4. Permian Basin Well Locations (circa 2014). Source: Adapted from TCEQ Texas Oil and Gas Wells Map[1].

Figure 3-5 shows 2011 Permian Basin NOx and VOC Emissions broken down by state. NOx emissions totalled 99,577 tpy; 60% of the NOx emissions were from area sources and 40% were from point sources. Of the area source emissions (59,275 tpy), 50% were from compressor engines, 26% from artificial lift engines, 15% from heaters, and 7% from drill rigs (Figure 3-6). The sum of the other remaining categories was <3% of the emissions total. Texas was the source of 71% of the NOx emissions, and 29% of NOx emissions were from New Mexico (Figure 3-5).

Permian Basin 2011 VOC emissions were 507,813 tpy, and nearly all (99 %) emissions were from area sources, and 1% were from point sources. The largest category of VOC area sources (498,889 tpy) was oil tanks (55%) followed by wellhead venting (18%). Pneumatic devices, truck loading, and produced water each contributed 4% of area source VOC emissions and the remaining categories total <11%. Like NOx emissions, VOC emissions were heavily concentrated in Texas (83%) with New Mexico contributing the other 17% of emissions.

[1] http://www.tceq.state.tx.us/assets/public/implementation/barnett_shale/bs_images/txOilGasWells.png

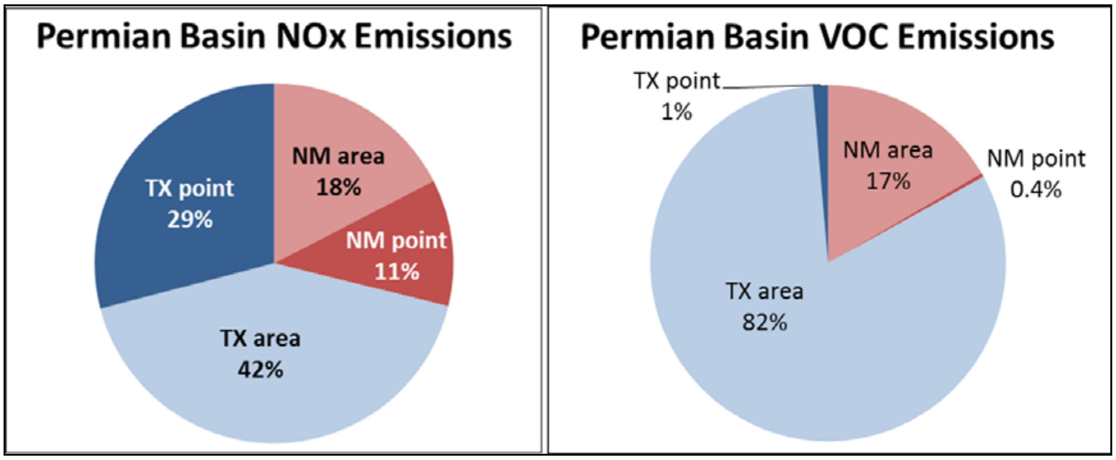


Figure 3-5. Permian Basin 2011 NOx and VOC emissions breakdown by state.

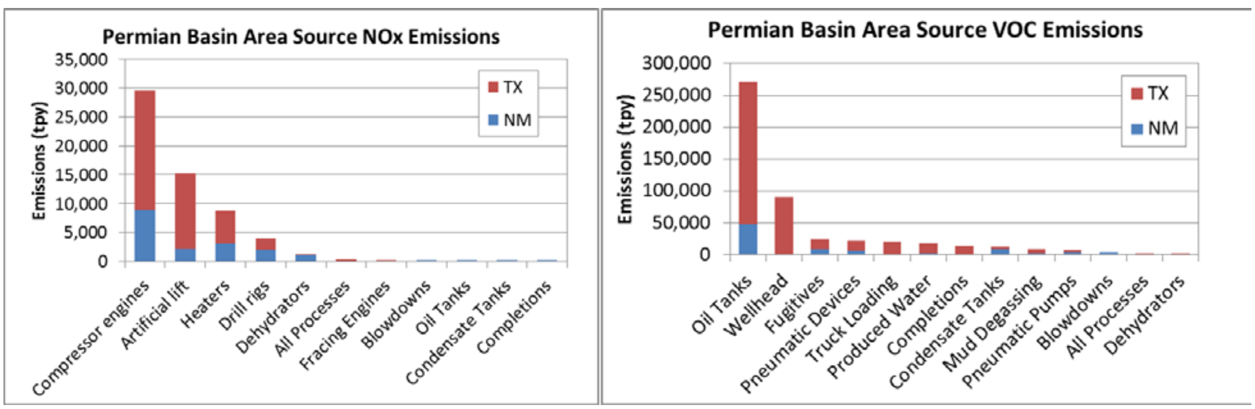


Figure 3-6. Permian Basin 2011 NOx and VOC emissions breakdown by emissions source category.

2011 point source emissions sources (40,302 tpy) were comprised of emissions from gas plants (59%), compressor stations (39%) and other sources such as tank batteries (3%) (Figure 3-7). A summary of Permian Basin-wide emissions for 2011 is given in Table 3-4.

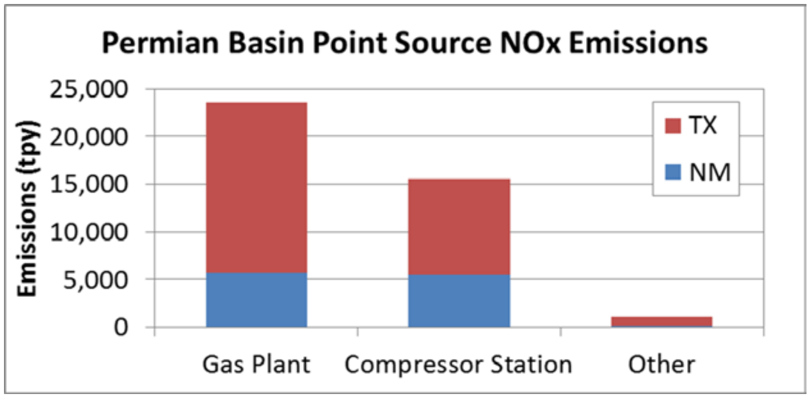


Figure 3-7. Permian Basin 2011 NOx point source emissions breakdown by state and emissions source category.

Table 3-4. Permian Basin 2011 inventory criteria pollutant emissions summary.

State	Type	2011 Permian Basin O&G Emissions (tpy)					
		NOX	VOC	CO	SO_2	PM_{10}	$PM_{2.5}$
NM	area	17,354	84,140	20,694	190	518	516
	point	11,367	1,887	5,428	12,340	171	170
NM Total		***28,721***	***86,027***	***26,123***	***12,530***	***689***	***686***
TX	area	41,921	414,749	36,820	2,728	707	705
	point	28,935	7,036	16,699	5,136	935	920
TX Total		***70,856***	***421,786***	***53,519***	***7,864***	***1,642***	***1,626***
Grand Total		**99,577**	**507,813**	**79,642**	**20,395**	**2,331**	**2,312**

For the SNMOS future year emissions modeling, activity growth for the Permian Basin was forecast. O&G activity growth factors for each play within the Permian Basin were based on the U.S. Energy Information Administration's Annual Energy Outlook (AEO) for 2014[2] (Figure 3-8). Southwest region growth factors were used outside of the specified plays. Table 3-5 shows the ratio of 2025:2011 sources for oil, gas and oil/gas wells. For all three defined plays within the Permian Basin and the Southwest Region, the number of oil, gas and oil/gas wells is forecast to increase.

AEO 2014 forecasts were released in April 2014, when the Cushing, Oklahoma (OK) West Texas Intermediate (WTI) crude oil price was about $100 per barrel. In August 2014, crude oil prices began to decline sharply and since November 2014, the Cushing, OK WTI crude oil price has

[2] http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf

remained between $40 and $60 per barrel[3]. The AEO 2015 forecast for the Cushing, OK WTI crude oil price for calendar year 2025 is 12% lower than the AEO 2014 estimate; AEO 2015 forecasts overall Southwest Region oil production to be 21% higher than the AEO 2014. While any oil and gas production forecasts are uncertain, the consistency in forecast crude oil production increases for the AEO 2014 and AEO 2015 indicate that the sharp increases in EPA's forecasts based on the AEO 2014 are reasonable, even with marked decreases in crude oil prices since August 2014.

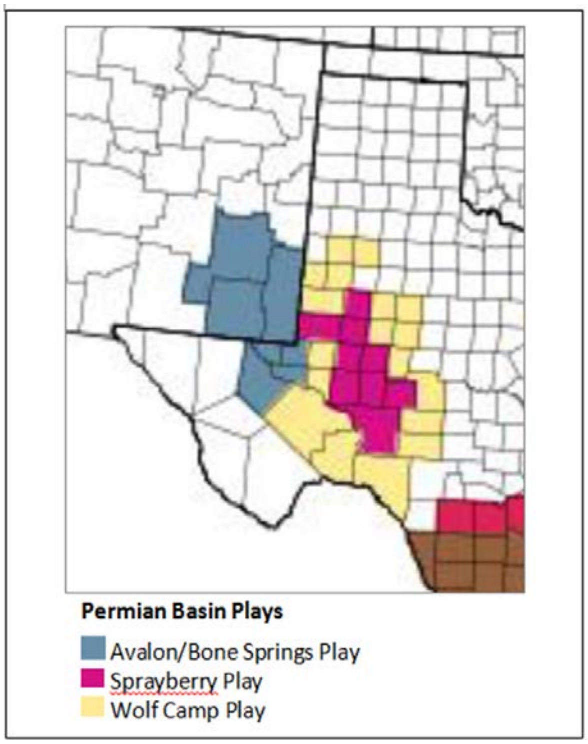


Figure 3-8. Permian Basin plays. Source: 2011v6.2 Modeling Platform TSD, excerpt from Figure 4-1.

Table 3-5. Permian Basin growth forecast by play.

Play / US Region	Oil Well Sources	Gas Well Sources	Oil and Gas Well Sources
Ratio 2025:2011			
Sprayberry Play	2.500	2.500	2.500
Wolfcamp Play	2.500	2.500	2.500
Avalon/Bone Springs Play	1.862	1.571	1.841
Southwest Region	1.448	1.384	1.006

In addition to the effects of activity growth, EPA considers the control effects of on-the-books regulations for the O&G sector (EPA, 2015) when developing emissions forecasts. The control

[3] Spot Prices for Crude Oil and Petroleum Products, http://www.eia.gov/dnav/pet/PET_PRI_SPT_S1_M.htm

effects of the following rulemakings are considered in the 2011NEIv2-based Platform 2017 and 2018 forecasts:

- New Source Performance Standards (NSPS) Subpart OOOO (area and point sources)
- Reciprocating internal combustion engine (RICE) NSPS Subparts JJJJ and IIII and NESHAP Subpart ZZZZ (area and point sources)
- Industrial/Commercial/Institutional Boilers and Process Heaters Maximum Achievable Control Technology (MACT) Rule (point sources)
- Standards of Performance for Turbines 40 CFR Part 60 - Subpart KKKK (point sources)
- Process Heaters NSPS (point sources)

3.2.2 Significant Findings

Emissions for the Permian Basin for 2011 and 2025 were developed using 2011NEIv2-based platform, growth based on the U.S. EIA AEO for 2014 and controls from pertinent rulemakings. Growth in activity is projected for the Permian Basin between 2011 and 2025; therefore, emissions of ozone precursors are projected to increase in 2025 relative to 2011.

3.2.3 Milestones and Deliverables

- Power Point Presentation on Permian Basin oil and gas 2011 and future year emission update (Completed 11/30/2015)
- Memo on available Permian Basin oil and gas 2011 and future year emissions data (Completed 11/10/2015)

3.3 Task 3: Juárez and Mexico Border Inventory (Current and Future Years)

3.3.1 Task Summary

The objective of this task was to recommend 2011 and future year emission inventory data covering the Mexico Border States and Ciudad Juárez for use in the SNMOS. We coordinated with NMED and the U.S. EPA to gather the best available data. We reviewed the available emissions data for these regions, including both inventories and ancillary data, and determined that the 2008-based Mexico National Emission Inventory (MNEI) were the best available data and the most appropriate of the available data to use for the SNMOS. These data were available as part of the U.S. EPA 2011v6.2 National Emissions Inventory (NEI) Emissions Modeling Platform (EMP).

The U.S. EPA distributed Mexico emissions data as part of the 2011v6.0 and 2011v6.2 EMPs. The 2011v6.0 EMP included a 1999-based version of the MNEI with projections to 2008, 2012, and 2030 (USEPA, 2014; Wolf et al., 2009). The 2011v6.2 EMP included a 2008-based version of the MNEI with projections to 2018 and 2025 (ERG, 2014). Figure 3-9 shows state total comparisons of the two Mexico inventories for the three major inventory sectors: on-road mobile, nonpoint, and point sources.

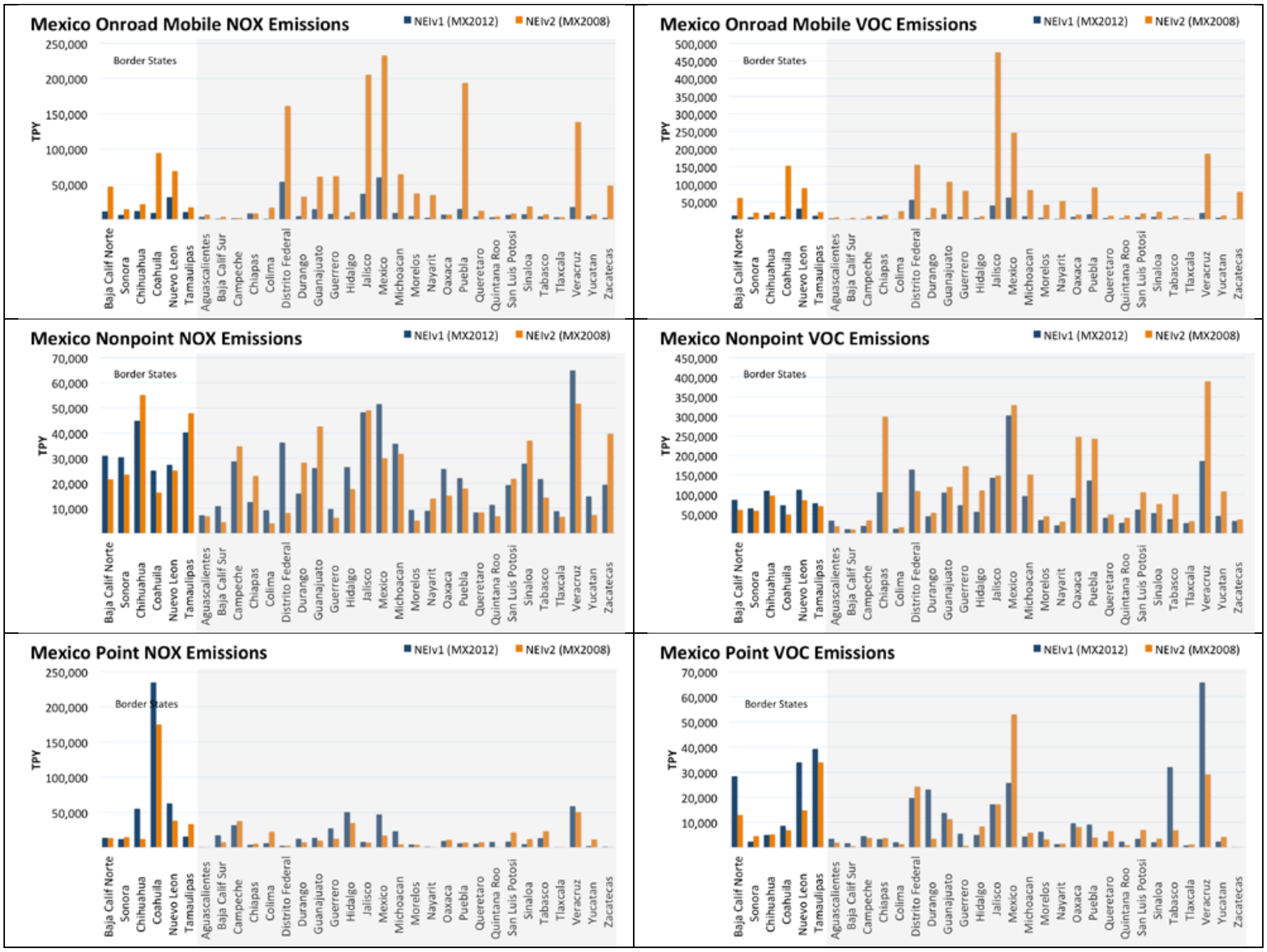


Figure 3-9. Mexico state inventory comparisons

As the 2008-based MNEI uses the most recent activity data that are publically available for Mexico, we decided with NMED that we would use these data for the SNMOS ozone modeling. We determined that this version of the MNEI, which is distributed with the U.S. EPA 2011v6.2 EMP, is the best available anthropogenic emissions data for Mexico. We used the 2008 MNEI as is for the 2011 SNMOS modeling and the 2025 projections for the future year SNMOS modeling. Natural emissions sources in Mexico were estimated using the same data and approaches used to estimate these emissions for the U.S. (see Task 5).

Our analyses of the MNEI anthropogenic emissions data included comparisons of the emissions totals between 2008 and 2025 at the state level (Figure 3-10) and for the municipalities in the immediate vicinity of Doña Ana County.

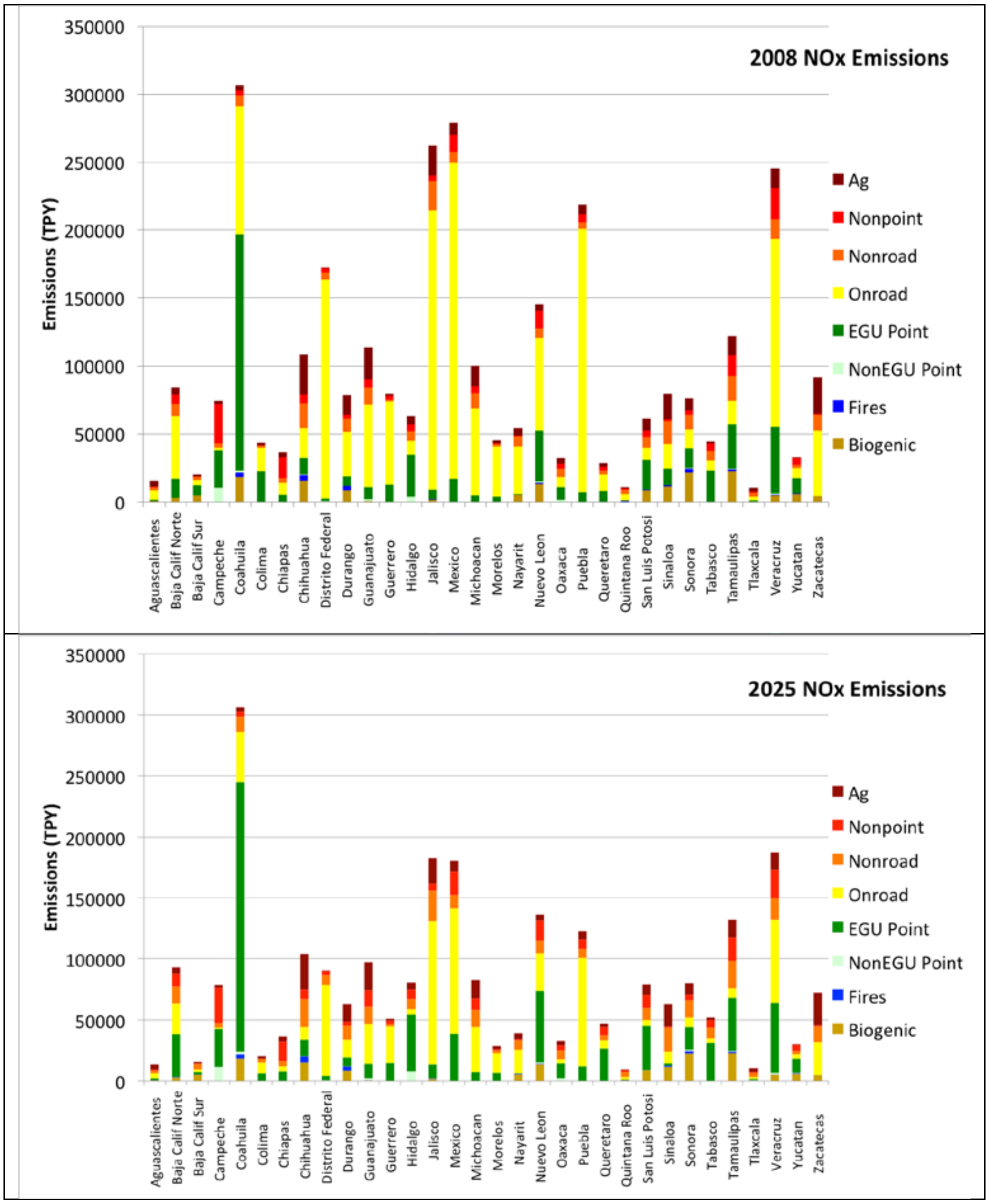


Figure 3-10. 2008 (top) and 2025 (bottom) Mexico state total NOx emissions

Additional details about the Mexico emissions data evaluation are available in the final Power Point deliverable for this task (UNC-IE and Ramboll Environ, 2015).

3.3.2 Significant Findings

The 2008-based Mexico NEI, which is distributed with the U.S. EPA 2011v6.2 emissions modeling platform, is the best available database of current and future year emissions estimates for Mexico. The 2008 base year emissions and 2025 emissions projections for Mexico were selected for the SNMOS.

3.3.3 Milestones and Deliverables

- Power Point presentation on Mexico emissions to be used in 2011 base and future year modeling (Completed 11/30/2015).

3.4 Task 4: Prepare Base Year Emissions with SMOKE

3.4.1 Task Summary

We developed anthropogenic emissions estimates for the SNMOS from the WAQS 2011 version B (2011b) emissions modeling platform available from the IWDW[4]. The data sources for the WAQS 2011b emissions estimates included the U.S. EPA, Ramboll Environ, and the states of Colorado, Utah, and Wyoming. As part of the WAQS, UNC-IE formatted the data for input to the Sparse Matrix Operator Kernel Emissions (SMOKE[5]) system, processed the data into CAMx input files with SMOKE, and performed quality assurance and quality control (QA/QC) on the emissions data and modeling.

We used all of the anthropogenic emissions data (e.g., non-road mobile, nonpoint, electricity generating units) collected and prepared for the WAQS 2011b simulation to generate CAMx-ready emissions for the SNMOS. The significant effort invested in the WAQS in collating and quality assuring these data was inherited by the SNMOS through adaptation of the WAQS 2011b modeling platform. As the modeling domains and meteorology data are different between the studies, adapting the WAQS data involved generating emissions for the SNMOS modeling domains and time period.

The SNMOS used 12-km and 4-km modeling domains focused on southern New Mexico. The standard continental U.S. (CONUS) Lambert Conformal Conic Projection (LCP) was used in the SNMOS for the domains shown in Figure 3-11 and described below.

- The SNMOS WESTUS12 CAMx domain encompasses all of New Mexico, extends west to include the metropolitan area of Phoenix, east to include West Texas, and South to include the Carbon II power plant in Coahuila, Mexico. This facility is a large source of NOx emissions and lies in a region that was sometimes upwind of Doña County on high ozone days during 2011. The SNMOS WESTUS12 domain was designed as a trade-off between computational efficiency and the need to model transport from sources likely to influence Doña Ana County at 12-km resolution.
- The SNMOS 4-km Doña Ana County domain focuses on Southern New Mexico and the major source regions in the immediate vicinity, including Ciudad Juárez, Mexico and El Paso, TX.

[4] http://views.cira.colostate.edu/tsdw

[5] http://www.smoke-model.org

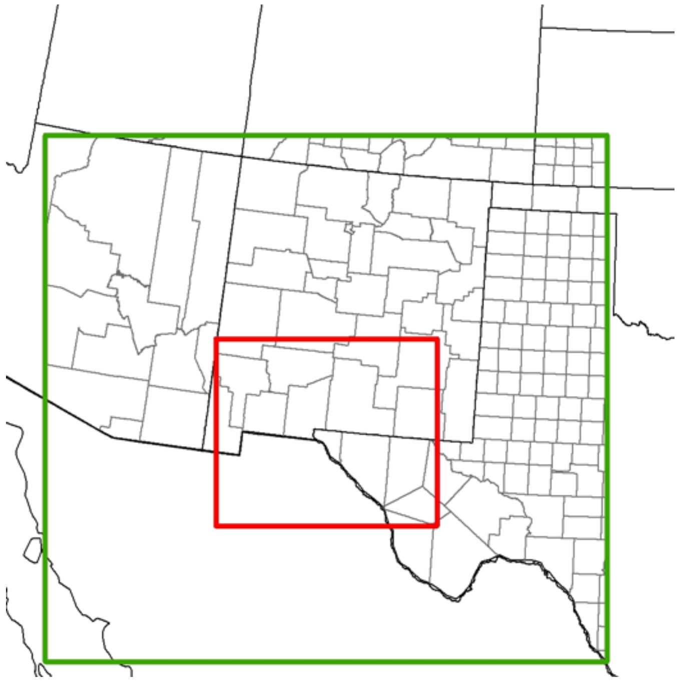


Figure 3-11. SNMOS 12-km (green) and 4-km (red) nested CAMx modeling domains.

We prepared emissions on these domains for April 15 through August 30, 2011 using SMOKE version 3.7. The first 15 days of emissions (April 15-30) were prepared to initialize the CAMx simulation for the air quality analysis period beginning on May 1.

Consistent with the WAQS 2011b emissions modeling platform, all of the non-O&G anthropogenic emission inventories for the SNMOS base year 2011 simulations were taken from the U.S. EPA National Emission Inventory (NEI). EPA publically released the 2011v6 platform in February 2014 and updated it twice, version 6.2 being the most recent. Details of the inventory, sectors, and preparation procedures for these data are available in the NEI2011v6.2 Technical Support Document (US EPA, 2015). The exception was the O&G inventories for most of the basins in Northern New Mexico, Colorado, Utah, and Wyoming, which were provided by Ramboll Environ. Ramboll Environ also developed emissions estimates for natural emissions sources for the SNMOS, including fires, biogenics and lightning (see Task 5 summary).

In coordination with NMED, we determined that the 2008 Mexico National Emission Inventory (MNEI), which is packaged with the NEI2011v6.2, was the most appropriate publically available Mexico inventory to use for the SNMOS (see Task 3 summary).

Ramboll Environ also conducted a review of the available Permian Basin O&G inventories and determined that the inventory and ancillary emissions data that are part of the NEI2011v6.2 are the best available data for these sources (Grant and Kemball-Cook, 2015; and see Task 2 summary).

The SNMOS project used MOVES to estimate on-road mobile emissions for U.S. sources. The U.S. EPA provided MOVES input emission-factors for 2011. The SMOKE-ready on-road mobile inventory data are a combination of county-level activity data and emissions factor look-up tables output from MOVES for representative counties. The on-road mobile activity data included county-level vehicle miles travelled (VMT), vehicle population (VPOP), and averaged speed profiles by vehicle type and road class. The look-up tables for representative counties, which are output from MOVES emissions rate mode simulations, contained county-level emissions factors as a function of temperature, relative humidity, and speeds. Land cover data and biogenic emissions factors by land cover type were used to estimate biogenic emissions fluxes. We used non-inventory, or ancillary emissions data provided by the U.S. EPA, to convert the inventories into the format required by CAMx.

Part of the preparation process for the inventory data included splitting the inventories into detailed subsectors. We split up many of the U.S. EPA NEI inventories to support the application of source-specific parameterizations of temporal and spatial patterns, to facilitate source-based emissions sensitivities, and to support targeted quality assurance of important inventory sectors. Although anthropogenic inventories can be generally classified as point, non-point, or mobile sources, we used over 20 individual anthropogenic inventory sectors in the SNMOS modeling. Table 3-6 is a listing of the inventory processing sectors used for the SNMOS. The table lists the inventory processing sectors, the source of the inventory data, the type of inventory (i.e., point, nonpoint, or gridded), the inventory year, and brief descriptions of the inventory sources included in the sector.

Table 3-6.SNMOS emissions processing sectors

Sector	Source	Type	Inventory Period and Year	Description
Locomotive/ marine	NEI 2011v6.2	Point and Nonpoint	Annual 2011 and 2025	The locomotive/marine sector is a subset of the non-point/area sector. It includes county-level emissions for line haul locomotives (nonpoint), train yards (point), and class 1 and 2 in- and near-shore commercial marine.
Off-road mobile	NEI 2011v6.2	Nonpoint	Monthly 2011 and 2025	NMIM county-level inventories for recreational vehicles, logging equipment, agricultural equipment, construction equipment, industrial equipment, lawn and garden equipment, leaf and snow blowers, and recreational marine. The CA and TX NONROAD estimates were normalized to emissions values provided by these states.
On-road mobile (US)	NEI 2011v6.2	MOVES	Annual and Daily 2011 and 2025	EPA ran MOVES2014 for 2011 in emissions factor mode. The MOVES lookup tables include on-network (RPD), on-network for CA (RPD_CA), off-network starts/stops (RPV), off-network starts/stops for CA (RPV_CA), off-network vapor venting (RPP), off-network vapor venting sources for CA (RPP_CAT, off-network hotelling (RPH). These data include the reference county and reference fuel month assignments that EPA used for the MOVES

Sector	Source	Type	Inventory Period and Year	Description
				simulations. The CA MOVES estimates were normalized to emissions values provided by these states.
Non-point/ Area	NEI 2011v6.2	Nonpoint	Annual 2011 and 2025	County-level emissions for sources that individually are too small in magnitude or too numerous to inventory as individual point sources. Includes small industrial, residential, and commercial sources; broken out into nonpoint, residential wood combustion, livestock, and fertilizer processor sectors.
Refueling	NEI 2011v6.2	Nonpoint	Annual 2011 and 2025	Nonpoint, gasoline stage 2 refueling.
Area Oil & Gas	WAQS 2011 and NEI 2011v6.2	Nonpoint	Annual 2011 and 2020	Non-point oil and gas sources are survey-based and typically unpermitted sources of emissions from up-stream oil and gas exploration, development, and operations. The non-point O&G sector consists of the WAQS Phase II and the NEI 2011v6.2 inventory for all basins outside of the WAQS inventory coverage area.
Point Oil & Gas	WAQS 2011 and NEI 2011v6.2	Point	Annual 2011 and 2020	Point oil and gas sources are permitted sources of emission from up-stream oil and gas exploration, development, and operations. The point O&G sector consists of the WAQS Phase II and the NEI 2011v6.2 inventory for all areas outside of the WAQS inventory coverage area.
CEM Point	2011v6.2 and CAMD	Point	Hourly 2011 and 2025	2011 Clean Air Markets Division (CAMD) hourly Continuous Emissions Monitor (CEM) data and Integrated Planning Model (IPM) projections to 2025.
non-CEM Point	2011v6.2	Point	Annual 2011 and 2025	Elevated and low-level combustion and industrial sources, airports, and offshore drilling platforms.
Offshore Shipping	2011v6.2	Point	Annual 2011 and 2025	Elevated point C3 commercial marine sources in offshore commercial shipping lanes.
Fires	PMDETAIL	Point	Daily 2011	PMDETAIL version 2 wildfire, prescribed burns and agricultural burning open land fires.
Canada Sources	NPRI 2010	Nonpoint and Point	Annual 2010	Canadian 2010 National Pollutant Release Inventory; there are no future year projections from the 2010 NPRI.
Mexico Sources	MNEI 2012	Nonpoint and Point	Annual 2008 and 2025	Mexican NEI 2008 and projections to 2025.
Biogenic	MEGAN v2.10	Gridded	Hourly 2011	MEGANv2.10 estimated with 2011 meteorology.
Lightning	Ramboll Environ	Gridded	Daily 2011	Lightning NOx emissions estimated with 2011 meteorology.

Several gridded emissions datasets were used for either directly estimating air emissions or as ancillary data for processing/adjusting the emissions data. The following datasets are key gridded data used in the SNMOS. We included neither sea salt nor windblown dust emissions in the SNMOS because of the study emphasis on O_3.

In addition to the inventory and gridded emissions data, ancillary datasets provide temporal, chemical, and spatial allocation specifications to the emissions. The ancillary data for SNMOS were taken directly from the WAQS 2011b modeling, which was derived primarily from the EPA 2011v6.2 modeling platform.

Additional details about the U.S. emissions data used for the SNMOS is available in the final emissions modeling memo for this task (Adelman and Baek, 2016).

3.4.2 Significant Findings

The Western Air Quality Study 2011b emissions modeling platform was used to develop summer season 2011 emissions for the SNMOS. On an annual basis, on-road mobile sources were the largest source of NOx and biogenic sources the largest source of VOC in Doña Ana County in 2011. In the immediate vicinity of Doña County, El Paso County, TX was the largest source NOx and Ahumada Municipality the largest source of VOC in 2011.

3.4.3 Milestones and Deliverables

- Technical memo for 2011 base year emission modeling with SMOKE (Completed 2/29/2016)

- CAMx-ready 2011 base year emissions on the project 12-km and 4-km modeling domains (Completed 2/29/2016)

3.5 Task 5: Prepare Natural Emissions for the Project Modeling

3.5.1 Task Summary

Ramboll Environ prepared natural emissions for the SNMOS 2011 Base Case 12/4 km domain CAMx modeling. Natural emissions are unrelated to human activities and for SNMOS, the natural emission inventory consisted of biogenic emissions and emissions from fires and lightning.

3.5.1.1 Biogenic Emissions Modeling

The Model of Emissions of Gases and Aerosols in Nature (MEGAN) is a modeling system for estimating the net emission of gases and aerosols from terrestrial ecosystems into the atmosphere (Guenther et al., 2006; Guenther et al., 2012). Driving variables include land cover, weather, and atmospheric chemical composition. MEGAN is a global model with a base resolution of ~1 km and so is suitable for regional and global models. A FORTRAN code is available for generating emission estimates for the CAMx regional air quality model. WRAP has recently updated the MEGAN biogenic emissions model using western U.S. data and higher resolution inputs (Sakulyanontvittaya et al., 2012). MEGAN v2.1 was used for the SNMOS biogenic emissions modeling

MEGAN generates hourly, gridded biogenic emissions and requires gridded inputs. Land cover data specify the type of plants present in each model grid box as well as the density of the foliage. Global distributions of land cover variables (Emission Factors, Leaf Area Index, and Plant

Functional Types) are available for spatial resolutions ranging from ~ 1 to 100 km. Leaf Area Index (LAI) quantifies the amount of foliage at a given location and the age of the foliage and is derived from satellite measurements. Satellite-observed radiances at several wavelengths are related to chlorophyll activity and leaf area. The LAI variable defines the number of equivalent layers of leaves relative to a unit of ground area. The data are composited every 8 days at 1-kilometer resolution. Plant functional type data are developed from high resolution satellite land cover/crop data and species composition is averaged over ecoregion. The National Land Cover Database (NLCD) includes three products that are used in the development of the MEGAN land cover: tree-cover fraction impervious cover fraction, and a land cover dataset.

Weather determines how active the plants are. MEGAN requires gridded hourly temperature, solar radiation and soil moisture data, which were supplied by the SNMOS 2011 WRF MSKF NAM meteorological model run outputs. The final input data for MEGAN are emission factor maps which are based on vegetation species composition.

Ramboll Environ ran MEGAN for the SNMOS 2011 episode and performed quality assurance of the MEGAN emissions. We prepared county-level emission summaries for NOx, CO and VOC and reviewed spatial maps of the biogenic emissions. The review focused on whether the pattern of emissions appeared reasonable. For example, we expect to see higher biogenic emissions over heavily vegetated regions and that urban areas and deserts should have lower biogenic emissions. Figure 3-12 is an example of the spatial quality assurance of the biogenic emission inventory and shows the episode average isoprene emissions on the 4-km grid. The isoprene emissions show minima in emissions where there is little vegetation (urban areas, deserts) and maxima in emissions in forested areas such as the Lincoln National Forest. Overall, isoprene emissions are larger in Mexico than in the U.S. There is a discontinuity in emissions at the U.S.-Mexico border (white arrow) that is not apparent in the vegetation distribution in the Google Earth satellite imagery. This suggests that there is uncertainty in biogenic emission inventory related to differences in MEGAN inputs for the U.S. and Mexico.

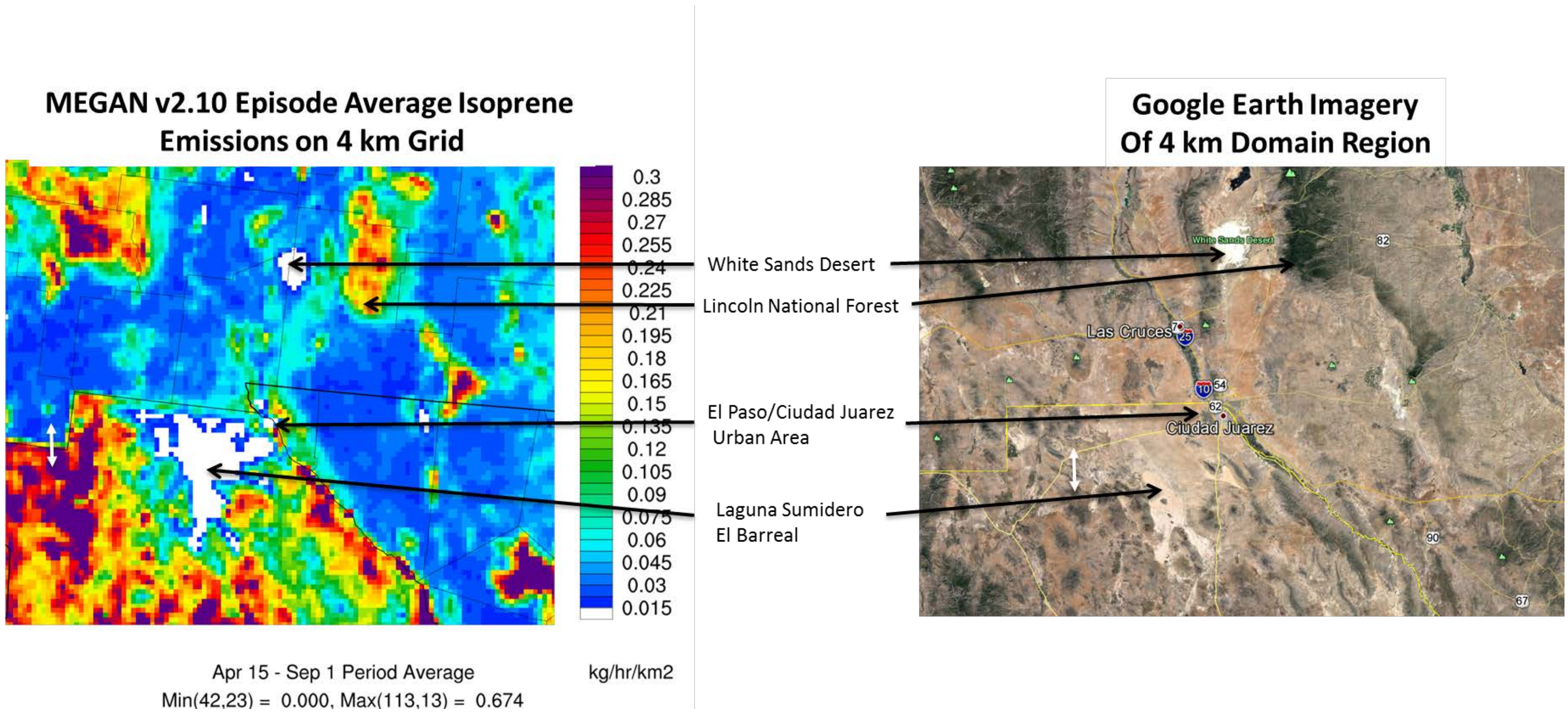


Figure 3-12. Example of biogenic emissions quality assurance. Left panel: SNMOS MEGAN v2.10 2011 episode average isoprene emissions on the 4-km grid. Right panel: Google Earth visible imagery of the region shown in the left panel.

3.5.1.2 Fire Emissions Modeling

Open biomass burning makes up an important part of the total global emissions of greenhouse gases, reactive trace gases, and particulate matter. Although episodic in nature and highly variable, open biomass burning emissions can contribute to local, regional, and global air quality problems and climate forcing. The SNMOS used fire emissions for 2011 that were generated by the Particulate Matter Deterministic and Empirical Tagging and Assessment of Impacts on Levels (PMDETAIL) study. PMDETAIL developed 2011 fire emission using satellite data and ground detect and burn scar, in addition to other data, with a slight modification (Mavko, 2014) to the methodology used in the Deterministic and Empirical Assessment of Smoke's Contribution to Ozone Project (DEASCO3) study for the 2008 modeling year (DEASCO3, 2013). We used a similar plume rise approach as PMDETAIL/DEASCO3 where plume rise depends on fire size and type (Mavko and Morris, 2013). The PMDETAIL 2011 fire inventory was selected over the 2011 Fire INventory from NCAR (FINN) and Smartfire 2011 inventory because it uses a more complete satellite and surface fire dataset.

Day-specific FETS fire activity data was used for all wildfire, agricultural, and prescribed fires within the 12/4 km modeling domain. FETS data included size, location, timing, fuel loading, moisture, and emission fluxes and chemical parameters. Fire emissions were gridded to the SNMOS modeling domains and speciated for the CAMx CB6r2 chemical mechanism. The plume characteristics for each fire event were prescribed based on the fire type and size. Plume rise is weather-dependent is and is characterized by smoldering fraction, plume bottom and plume top. Once PMDETAIL fire emissions were developed for the SNMOS Base Case 2011 modeling period, we developed separate county-level emissions summaries for agricultural burns, wildfires, and prescribed fires. We also made spatial plots of the daily fire emissions and performed spot checks to ensure that the PMDETAIL fire locations matched satellite fire detections from NOAA's Hazard Mapping System (HMS) Fire and Smoke Analysis Product. The HMS product uses data from the GOES Imager, the AVHRR (Advanced Very High Resolution Radiometer) instrument, and MODIS (Moderate Resolution Imaging Spectroradiometer). Fire locations derived by thee algorithms based on different satellite retrievals reviewed by an analyst, who removes false detections and reconciles the three fire location data sets. The analyst outlines the locations of smoke plumes inferred from satellite aerosol optical depth retrievals.

Figure 3-13 shows an example of the fire emissions quality assurance for June 5, 2011. On this day, there were several large fire complexes burning in the 4-km domain. The Wallow Fire in eastern Arizona, the Horseshoe 2 fire in southeastern Arizona and the Monument Fire on the U.S.-Mexico border are shown in the fire emissions plot in the left hand panel and match the satellite fire detections shown in the HMS product.

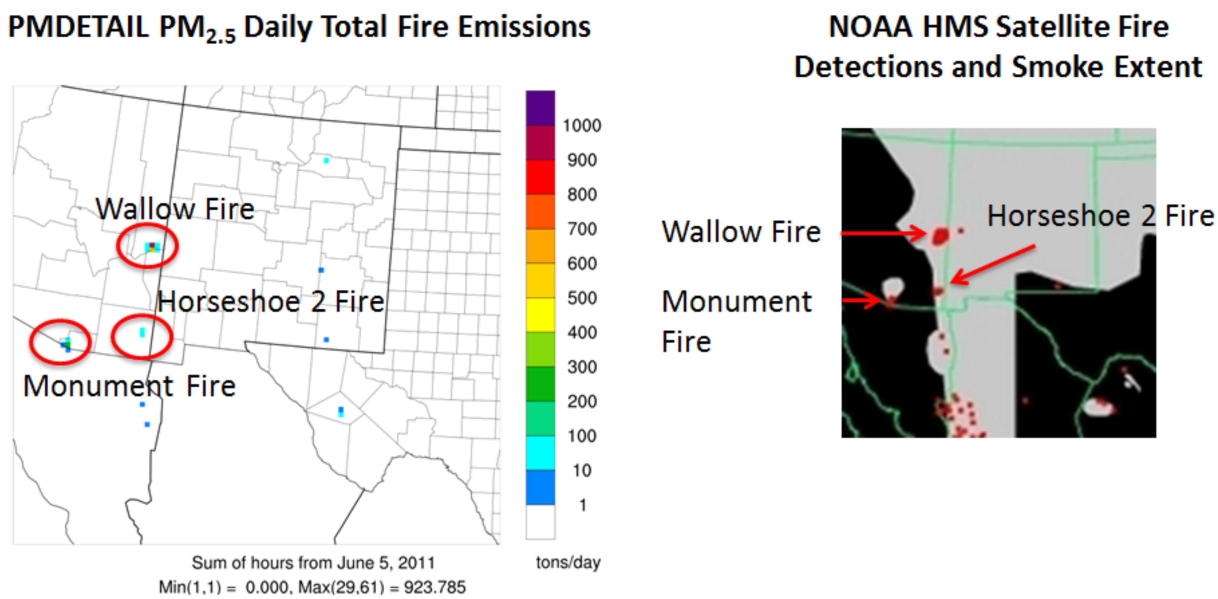


Figure 3-13. Example of fire emissions quality assurance. Left panel: June 5, 2011 PMDETAIL daily total $PM_{2.5}$ emissions HMS product showing fire locations (red dots) and smoke plume (gray area).

3.5.1.3 Lightning Emissions Modeling

NO_X is formed in lightning channels as the heat released by the electrical discharge causes the conversion of N_2 and O_2 to NO. Lightning NOx emissions (LNOx) can be estimated directly based on the number of lightning flashes, the intensity of each flash, the lightning type (cloud-to-ground vs. cloud-to-cloud), and the amount of NOx emitted per flash. Because formation of LNOx is associated with deep convection in the atmosphere, LNOx production is typically parameterized in terms of the modeled convective activity. LNOx production is often assumed to be related to cloud top height or convective rainfall. The modified lightning NOx emissions model of Koo et al. (2010) was used to estimate lightning NOx emissions for the SNMOS. Koo et al. use a hybrid approach that preserves the consistency of the WRF modeled convection and the location of LNOx emissions, but also attempts to constrain the LNOx emissions to match observed distributions of lightning or an estimate of total emissions. Additional details on the development and evaluation of the lightning emissions processor used in the SNMOS are available in the WestJumpAQMS Sea Salt and Lightning memo (Morris et al., 2012) [6]. LNOx emissions were allocated to WRF grid columns where modeled convection occurred using WRF convective precipitation as a proxy for lightning activity. LNOx emissions were distributed in the vertical using profiles derived from aircraft measurements and cloud-resolving models. LNOx emissions were modeled as point sources with zero plume rise in appropriate layer.

Once the LNOx emissions had been generated, we performed quality assurance of the emissions by comparing maps of vertically integrated LNOx emissions with WRF modeled precipitation. An example of this quality assurance is shown in Figure 3-14, which compared

[6] http://www.wrapair2.org/pdf/memo_12_seasalt_lightning_june25_2012_final.pdf

the daily total precipitation from WRF (left panel) with the column-integrated LNOx emissions for a 24-hour period in July 2011. The locations of locally intense (convective) rainfall align well with the maxima in the LNOx emissions, which indicates that the LNOx emissions have been correctly allocated in space.

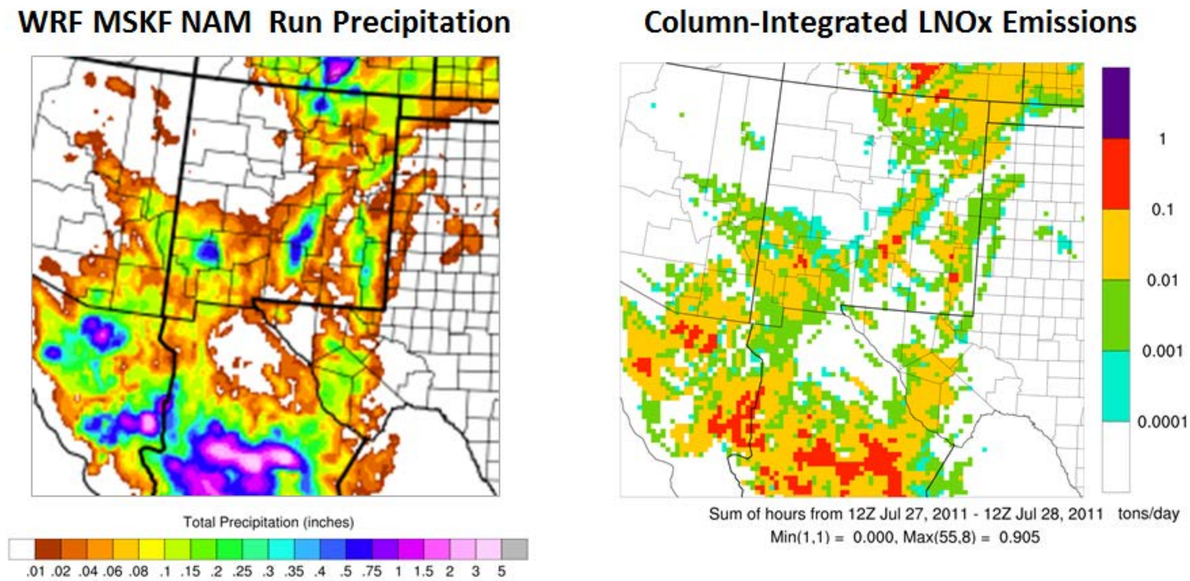


Figure 3-14. LNOx emissions quality assurance for July 27-28, 2011. Left panel: daily total precipitation from the WRF MSKF NAM model run. Right panel: column-integrated LNOx emissions for the July 27-28 period matched in time to the precipitation total shown in the left panel.

3.5.2 Significant Findings

The results of the quality assurance for the natural emissions suggest that the emissions modeling was correctly executed. However, there are significant uncertainties in all three components of the natural emission inventory. For the biogenic inventory, there is a discontinuity in emissions at the U.S.-Mexico border and emissions are larger over Mexico than the U.S. for environments that appear from Google Earth imagery to have comparable vegetation cover. Further investigation of differences in MEGAN inputs for the U.S. and Mexico should be undertaken to understand these differences and to ensure that the most accurate inventories possible are used on both sides of the border. Modeling of fire and lightning emissions are active areas of scientific research, and the SNMOS emission inventories should be considered to have considerable uncertainty associated with them.

3.5.3 Milestones and Deliverables

- Prepared gridded, CAMx ready MEGAN version 2.10 biogenic emissions. (Completed 1/12/2016)
- Prepared gridded, CAMx ready lightning NOx emissions. (Completed 1/15/2016)
- Prepared gridded, CAMx ready PMDETAIL fire emissions. (Completed 1/18/2016)

- Provided natural emissions on the 12/4 km grids to UNC for SMOKE emissions modeling/merge (Completed 1/18/2016)
- PowerPoint presentation on results of natural emissions modeling. (Completed 2/16/2016)

3.6 Task 6: Base Year Air Quality Modeling

3.6.1 Task Summary

The SNMOS performed photochemical grid modeling for the year 2011 using the Comprehensive Air Quality Model with Extensions (CAMx) version 6.20. The SNMOS Work Plan for the 2011 Modeling Year (Adelman et al., 2015a) details the CAMx configuration and justification for the model's selection for the SNMOS. CAMx was run for April–October, 2011 and configured as in the WAQS 2011b study. The model configuration is summarized in Table 3-7.

The SNMOS CAMx modeling grids are shown in Figure 3-15. The 3SAQS 36-km grid 3D CAMx output fields were used as BCs for the SNMOS 12-km grid. While the SNMOS modeling leveraged the WAQS/3SAQS modeling platforms, some changes to the WAQS/3SAQS modeling grids were required simulate ozone in Southern New Mexico as accurately as possible. The brown rectangle in Figure 3-15 shows the extent of the 3SAQS 12-km modeling grid. The SNMOS 12-km modeling domain, shown in green, is smaller than the 3SAQS 12-km grid and is focused on the region surrounding southern New Mexico. The southern boundary of the SNMOS 12-km grid was extended southward beyond the southern boundary of the 3SAQS 12-km grid in order to encompass the NOx emissions sources that are most important to ground-level ozone formation in southern New Mexico (Figure 2-1). The SNMOS 12-km grid boundary lies south of the Carbon II power plant in Coahuila, Mexico. This facility is a large source of NOx emissions and lies in a region that was sometimes upwind of Doña Ana County on high ozone days during 2011. The spatial extent of the SNMOS 12-km domain strikes a balance between computational efficiency and the need to model transport from sources likely to influence Doña Ana County at 12-km resolution. The SNMOS 4-km Doña Ana County domain (shown in red in Figure 3-15) focuses on Southern New Mexico and the major emissions source regions in the immediate vicinity, including Ciudad Juárez, Mexico and El Paso, TX. The 12-km domain provided the BCs for the 4-km domain.

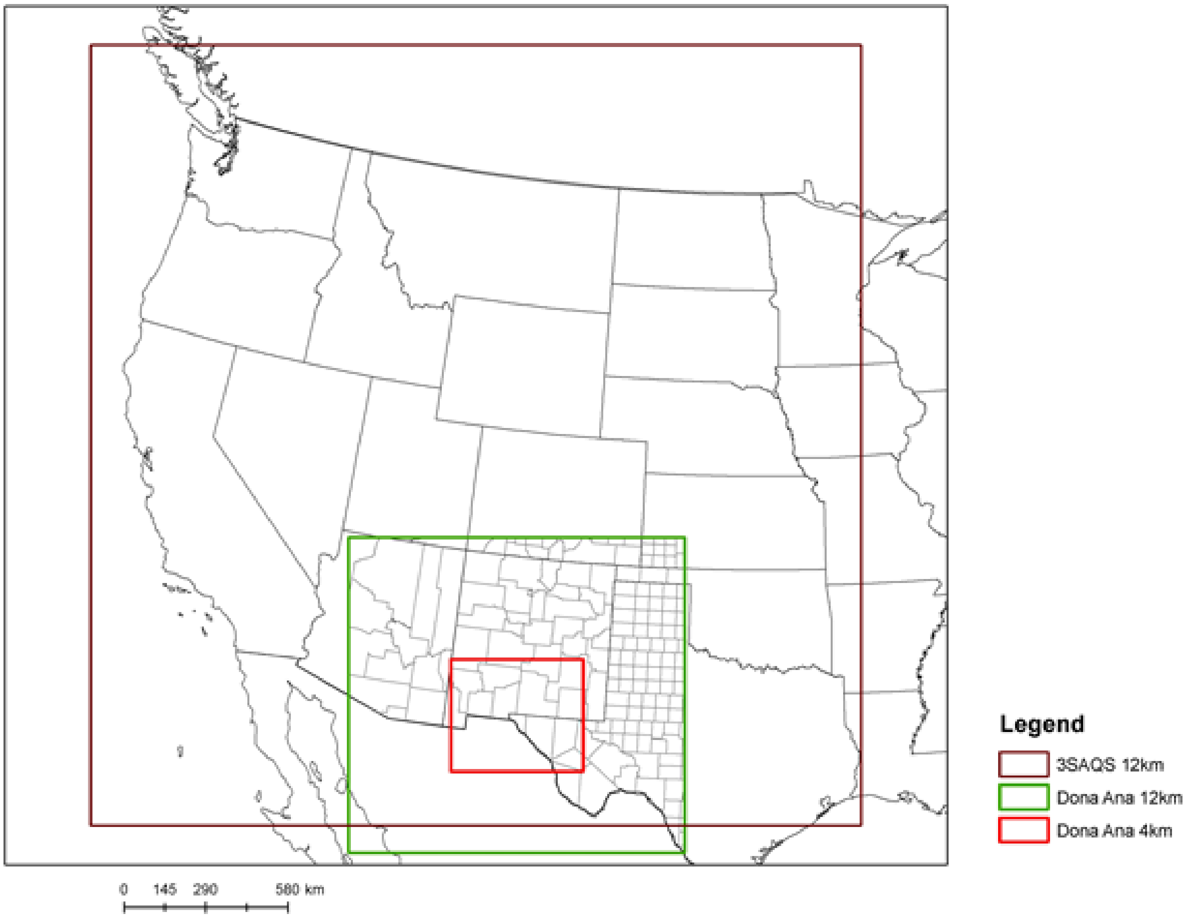


Figure 3-15. CAMx Modeling Domains and Boundary Conditions.

Table 3-7. SNMOS CAMx version 6.20 configuration.

Science Options	Configuration	Details
Model Codes	CAMx V6.20 – March 2015 Release	
Horizontal Grid Mesh	36/12/4 km	
36-km grid	148 x 112 cells	36-km CONUS domain
12-km grid	99 x 93 cells	12-km SNMOS WESTUS12 regional domain
4-km grid	117 x 99 cells	4-km Dona Ana domain
Vertical Grid Mesh	34 vertical layers defined by WRF; no layer collapsing	Layer 1 thickness ~12 m. Model top at ~19-km above MSL
Grid Interaction	12/4-km two-way nesting for CAMx (2011) 36/12/4-km two way nesting for CAMx (2025)	
Initial Conditions	10 day spin-up on 12/4 km grid before first day with MDA8 ozone>70 ppb at any Doña Ana County monitor (2011) 14 day spin-up on 36/12/4 km grid (2025)	Clean initial conditions
Boundary Conditions	12-km SNMOS grid from 36/12-km WAQS modeling (2011) 36-km grid from global chemistry model (2025)	MOZART GCM data for 2011; zero out dust and sea salt.
Emissions		
Baseline Emissions Processing	SMOKE, MOVES and MEGAN	
Sub-grid-scale Plumes		
Chemistry		
Gas Phase Chemistry	CB6r2	Active methane chemistry and ECH4 tracer species
Meteorological Processor	WRFCAMx	Compatible with CAMx V6.20
Horizontal Diffusion	Spatially varying	K-theory with Kh grid size dependence
Vertical Diffusion	CMAQ-like in WRF2CAMx	
Diffusivity Lower Limit	Kz_min = 0.1 to 1.0 m^2/s or 2.0 m^2/s	Land use dependent
Deposition Schemes		
Dry Deposition	Zhang dry deposition scheme (CAMx)	Zhang 2003
Wet Deposition	CAMx-specific formulation	rain/snow/graupel/virga
Numerics		
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) -- Fast Solver	
Vertical Advection Scheme	Implicit scheme w/ vertical velocity update	

Science Options	Configuration	Details
	(CAMx)	
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM) scheme	Collela and Woodward (1984)
Integration Time Step	Wind speed dependent	~0.1-1 min (4-km), 1-5 min (1 -km), 5-15 min (36 km)

3.6.2 Significant Findings

The CAMx modeling of 2011 was completed successfully.

3.6.3 Milestones and Deliverables

- 2011 base year air quality modeling presentation (Completed 2/22/2016)
- Carry out SNMOS 2011 Base Case CAMx modeling (Completed 3/25/2016)

3.7 Task 7: Model Performance Evaluation and Sensitivity Modeling

3.7.1 Task Summary

Following the completion of the SNMOS 2011 base case modeling, we performed a CAMx model performance evaluation (MPE) for the entire modeling episode. In this section, we present the evaluation of CAMx model performance against concurrent measured ambient concentrations using graphical displays of model performance and statistical model performance measures. We compared these measures against established model performance goals and criteria following the procedures recommended in EPA's photochemical modeling guidance documents (EPA, 2014).

Model performance was evaluated in New Mexico and surrounding regions for two CAMx runs that used different meteorological inputs, but were otherwise identical. UNC-IE carried out a series of Weather Research and Forecasting Model (WRF; Skamarock et al., 2005) meteorological model simulations of the SNMOS modeling episode and compared model performance in each run against observed weather data (Section 3.1; UNC-IE and Ramboll Environ, 2015). The WRF model runs differed in their cumulus parameterizations and the datasets used for initial conditions and analysis nudging. The two WRF runs that produced the best model performance over the SNMOS WRF 12/4 km modeling domains used the MSKF cumulus scheme (Alapaty et al., 2014; Herwehe et al., 2014). One of the MSKF WRF runs used the NCEP NAM analysis for initial conditions and analysis nudging, while the other MSKF run used the ECMWF ERA-Interim analysis. We refer to the two WRF simulations hereafter as the WRF ERA and WRF NAM runs and the two CAMx runs that used these WRF runs as the CAMx ERA and CAMx NAM runs.

For both CAMx runs, model performance was acceptable for daily maximum 8-hour average (MDA8) ozone based on comparison with EPA statistical performance benchmarks (Figure 3-16). Both CAMx runs had an overall high bias when all episode days were considered, but underestimated ozone on high ozone days, which were defined to be days with observed MDA8 ozone > 60 ppb. The CAMx run using ERA WRF meteorology performed slightly better than CAMx with NAM WRF meteorology on days when MDA8 > 60 ppb (Figure 3-16). The CAMx NAM run performed slightly better when all days were considered (i.e., on lower MDA8 ozone days) (Figure 3-16; Figure 3-17).

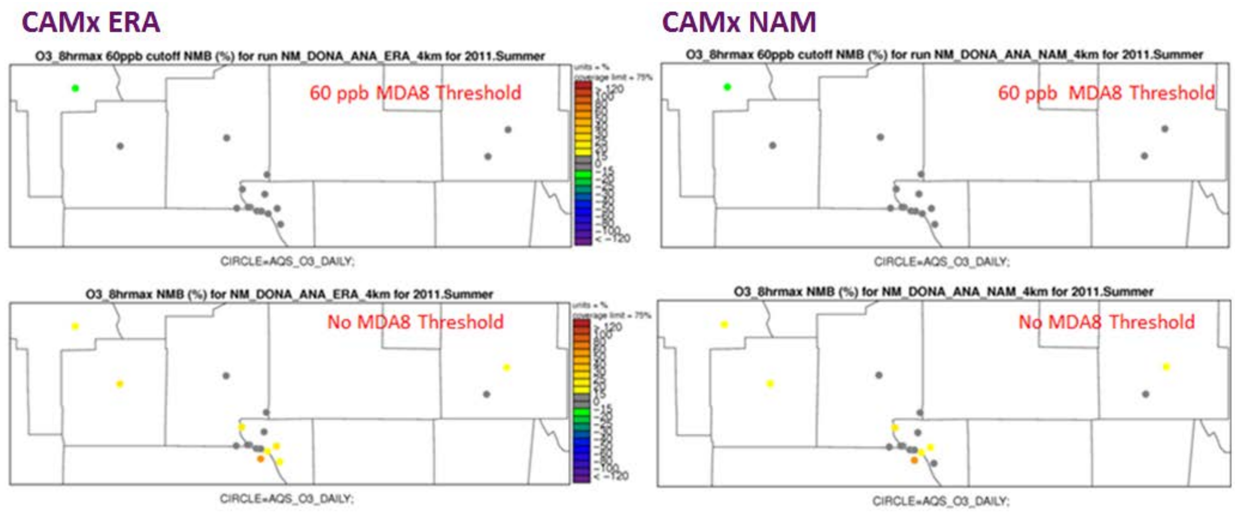


Figure 3-16. Comparison of NMB for the CAMx ERA (left) and CAMx NAM (right) model runs. Upper figures have 60 ppb MDA8 threshold and no threshold was used for the lower figures.

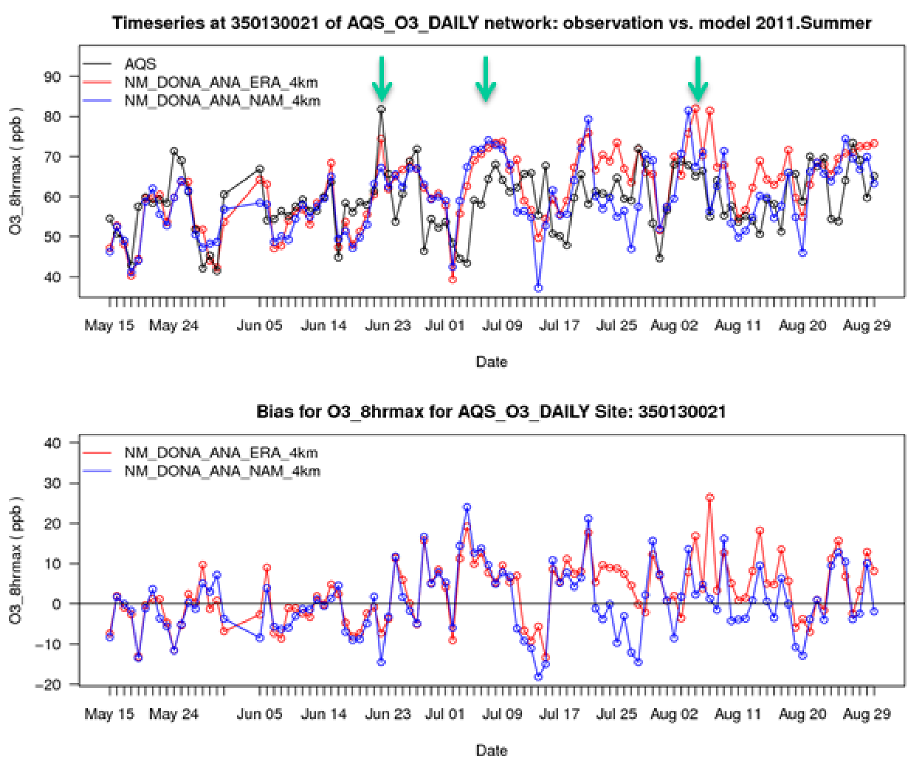


Figure 3-17. Upper panel: time series of observed (black) and modeled MDA8 ozone for the CAMx ERA (red) and CAMx NAM (blue) runs at the Desert View monitor. Lower panel: Model bias in MDA8 ozone for the CAMx ERA (red) and CAMx NAM (blue) runs at the Desert View monitor. Left green arrow shows a day when the model underestimated high values of observed ozone (June 22). Center and right green arrows show examples of July and August periods when the model had a persistent regional high bias for ozone.

We examined performance at the ground level ozone monitors within Doña Ana County in light of the form of the NAAQS for ozone and the EPA's recommended method for performing modeled attainment demonstrations (EPA, 2014) using the Modeled Attainment Test Software (MATS). The MPE focused on the MDA8 ozone on the highest modeled days because the modeling plan called for a modeled attainment demonstration for Doña Ana County using the 2011 base case model and the 2025 future year model. In carrying out the base case model performance, we considered how CAMx performance in the 2011 base year runs would affect the modeled attainment demonstration and selected the CAMx model run that would provide the more reliable future year ozone projection.

Figure 3-18 presents ranked lists of the 10 days with the highest modeled values of modeled MDA8 ozone at the Desert View, NM monitor for the CAMx ERA and CAMx NAM runs. The highest modeled MDA8 ozone days do not correspond well to high observed MDA8 ozone in either CAMx run. In general, the highest modeled days are days on which the model greatly overestimates the observed MDA8 ozone. For example, on the highest modeled MDA8 ozone day in the CAMx ERA run, the modeled MDA8 ozone was 82 ppb, while the observed MDA8 ozone was 65 ppb, corresponding to a model bias of 17 ppb in the MDA8. There was only one day out of the 10 highest modeled days in the CAMx ERA run that corresponded to a day when the observed MDA8 ozone exceeded 70 ppb: June 22. The CAMx ERA bias on June 22 was -7 ppb, consistent with the MPE statistical analysis that showed that CAMx ERA tended to underestimate observed ozone on high observed ozone days.

NM_DONA_ANA_ERA_4km				
Rank	Date	Obs_Average	Model_Average	Bias_Average
1	8/5/2011	65.13	81.97	16.84
2	8/7/2011	55.00	81.43	26.43
3	7/21/2011	58.13	75.84	17.71
4	8/4/2011	67.88	75.79	7.91
5	6/22/2011	81.75	74.45	-7.30
6	7/9/2011	64.13	73.71	9.58
7	7/20/2011	65.50	73.57	8.07
8	7/25/2011	64.63	73.44	8.82
9	7/8/2011	68.00	73.34	5.34
10	8/30/2011	65.13	73.31	8.18

NM_DONA_ANA_NAM_4km				
Rank	Date	Obs_Average	Model_Average	Bias_Average
1	8/4/2011	67.88	81.49	13.62
2	7/21/2011	58.13	79.34	21.22
3	8/26/2011	64.00	74.45	10.45
4	7/7/2011	64.38	74.05	9.67
5	7/8/2011	68.00	72.93	4.93
6	7/20/2011	65.50	72.03	6.53
7	7/9/2011	64.13	71.94	7.81
8	7/6/2011	58.00	71.82	13.82
9	7/5/2011	59.13	71.76	12.64
10	8/9/2011	55.25	71.40	16.15

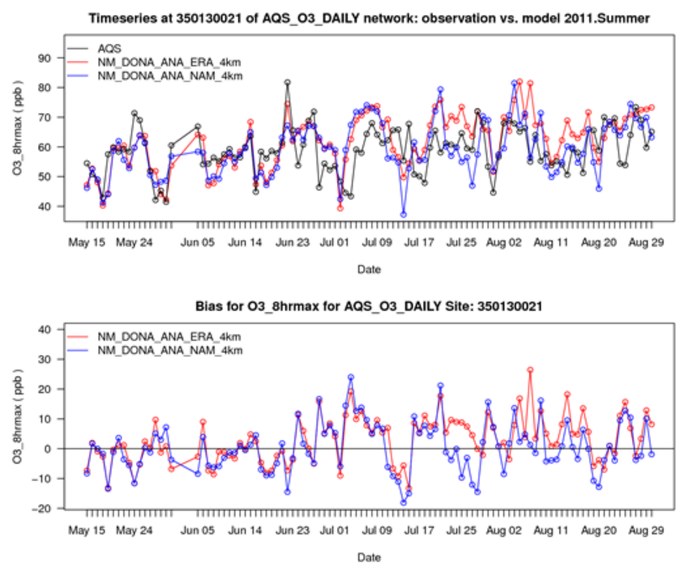


Figure 3-18. Upper (lower) left panel: Ranked list of the 10 days with the highest modeled values of modeled MDA8 ozone (ppb) at the Desert View, NM monitor for the CAMx ERA (NAM) run. Also shown are date, observed MDA8 (ppb) and the model bias (ppb). Upper right panel: time series of observed (black) and modeled MDA8 ozone for the CAMx ERA (red) and CAMx NAM (blue) runs at the Desert View monitor. Lower right panel: Model bias in MDA8 ozone for the CAMx ERA (red) and CAMx NAM (blue) runs at the Desert View monitor.

In the CAMx NAM run, none of the 10 highest modeled days corresponded to a day with observed MDA8 exceeding 70 ppb. The CAMx NAM run bias was positive on all 10 of the highest modeled days. For both the CAMx ERA and CAMx NAM runs, the 10 highest modeled days occurred mainly during July and August, which are periods when both runs saw persistent overestimates of MDA8 ozone at the Desert View monitor.

For both CAMx runs, the 10 highest MDA8 ozone days that would form the relative reduction factor (RRF) in the design value calculation for Doña Ana County monitors had significant regional overestimates of ozone, and most of the 10 highest modeled MDA8 ozone days did not have high observed ozone. It is therefore uncertain whether either model run could provide useful results for analyzing local emissions control strategies for Doña Ana County using the EPA MATS default RRF method. Local controls would not be predicted to reduce Doña Ana County ozone if the RRF is formed from days when modeled ozone is driven by an overestimated regional background.

Therefore, we evaluated use of an ozone model performance criterion in selecting days for making RRFs and future year design value projections and using this procedure to determine whether the CAMx NAM or CAMx ERA run should be used as the 2011 base case in the SNMOS. We used only modeled days in which the observed and modeled MDA8 ozone are within a specified % bias of each other. We therefore formed RRFs based on more days with observed high ozone and better model performance. Days on which the model performed poorly would not be used in the RRF. There are precedents for using an MPE filter in selecting days for use in RRFs in making future year ozone projections including modeling done in California (e.g., SCAQMD AQMP[7]).

To illustrate the procedure, we apply a ±10% bias criterion to the 10 highest modeled MDA8 ozone days at the Desert View monitor. If we were to apply the default MATS method to calculate the RRF, the days shaded in blue in Figure 3-19 would be selected. Only one of the top 10 observed MDA8 ozone days (shaded yellow) at the Desert View monitor would be included using this method.

[7] http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2012-air-quality-management-plan/final-2012-aqmp-(february-2013)/appendix-v-final-2012.pdf

		MDA8 (ppb)		Bias	
Rank	Date	Observed	Modeled	(ppb)	(%)
1	8/5/2011	65.125	81.966	16.841	25.86%
2	8/7/2011	55	81.433	26.433	48.06%
3	7/21/2011	58.125	75.839	17.714	30.48%
4	8/4/2011	67.875	75.785	7.91	11.65%
5	6/22/2011	81.75	74.447	-7.303	-8.93%
6	7/9/2011	64.125	73.708	9.583	14.94%
7	7/20/2011	65.5	73.573	8.073	12.33%
8	7/25/2011	64.625	73.442	8.817	13.64%
9	7/8/2011	68	73.339	5.339	7.85%
10	8/30/2011	65.125	73.307	8.182	12.56%

Top 10 observed MDA8 days

Top 10 modeled MDA8 days

Figure 3-19. Desert View monitor: default MATS method for selecting 10 highest modeled days for the RRF.

		MDA8 (ppb)		Bias	
Rank	Date	Observed	Modeled	(ppb)	(%)
1	6/22/2011	81.75	74.447	-7.303	-8.93%
2	7/8/2011	68	73.339	5.339	7.85%
3	8/28/2011	69.125	72.483	3.358	4.86%
4	7/28/2011	72	71.9	-0.1	-0.14%
5	8/18/2011	66	71.665	5.665	8.58%
6	8/27/2011	73.375	70.966	-2.409	-3.28%
7	8/6/2011	66.375	70.191	3.816	5.75%
8	8/2/2011	68	69.984	1.984	2.92%
9	6/26/2011	68.75	68.794	0.044	0.06%
10	8/22/2011	67.5	68.517	1.017	1.51%

Top 10 observed MDA8 days

Top 10 modeled MDA8 days

Figure 3-20. Desert View monitor: alternate method for selecting 10 highest modeled days for the RRF.

If we select only the top 10 modeled MDA8 ozone days on which the bias was < ±10%, we obtain a different population of days (Figure 3-20). The 10 days to be used in the RRF now include 4 of the 10 highest observed days at Desert View, and model performance is reasonably good on all days that would go into the RRF. Observed and modeled MDA8 values are now closer to the observed base year design value than would be the case using the default MATS method shown in Figure 3-19.

We tested this procedure using bias thresholds ranging from 5% to 20% for the CAMx ERA and CAMx NAM runs. For each bias threshold, we determined the number of modeled MDA8 ozone days in the RRF (top 10 days) that were also among the 10 highest observed MDA8 ozone days. For all values of the bias threshold, using the CAMx ERA run produced a higher number of days in the ranked list of the 10 highest modeled MDA8 ozone days that also corresponded to days that were among the top 10 observed MDA8 ozone days at the Doña Ana County monitors. Therefore, the CAMx ERA run was better suited for making future year ozone projections and for emissions control strategy development. The bias threshold that produced the highest number of top 10 observed MDA8 ozone days in the list of 10 highest modeled MDA8 ozone days was the 10% threshold, and we recommended that this threshold be used in making future year ozone projections in the SNMOS in addition to the default method outlined in the EPA Modeling Guidance (EPA, 2014).

Once the ozone MPE was completed, we conducted a model performance evaluation for the CAMx ERA run for ozone precursors and fine particulate matter ($PM_{2.5}$) and its component species with a focus on the modeling results for Doña Ana County. We evaluated the ozone precursors carbon monoxide (CO) and nitrogen dioxide (NO_2), but did not include volatile organic compound (VOC) species due to lack of observed data. Although the main focus of this study was ozone, the $PM_{2.5}$ evaluation included total $PM_{2.5}$ along with the component species sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), elemental carbon (EC), and organic carbon (OC).

NO_2 and CO performance are typical of photochemical model simulations of the Western U.S. and are comparable to performance noted in the WAQS 2011b modeling (Adelman et al., 2016) and the Three State Air Quality Study (3SAQS; Adelman et al., 2015b). The SNMOS PM performance evaluation showed that $PM_{2.5}$ was underestimated across the New Mexico and the surrounding region and that the underestimate of total $PM_{2.5}$ was consistent with modeled underestimates of several of its component species including NH_4, NO_3, and SO_4. While there were shortcomings in model performance for the CAMx ERA simulation of $PM_{2.5}$ and its component species, performance was roughly comparable to that of other similar studies in the western U.S. such as the WAQS and 3SAQS. PM performance was not the main focus of the SNMOS, and so no effort was expended to try to diagnose and improve model performance for PM. We noted the reasonable model performance and concluded that the CAMx 2011 SNMOS model was functioning as expected.

3.7.2 Significant Findings

CAMx base year 2011 model performance was evaluated on the 12/4 km SNMOS domains for two CAMx runs that used different meteorological inputs. For both CAMx runs, model performance for MDA8 ozone was acceptable based on comparison with EPA statistical performance benchmarks.

In both runs, CAMx had an overall high bias when all days were considered, but underestimated ozone on days with observed MDA8 ozone > 60 ppb. The CAMx run using ERA WRF meteorology performed slightly better than CAMx with NAM WRF meteorology when MDA8 ozone > 60 ppb. The CAMx NAM run performed slightly better when all days were considered.

For both CAMx runs, many of the 10 highest MDA8 ozone days that would be used to form an RRF for future year design value projections for Doña Ana County monitors had significant region-wide overestimates of ozone. Most of the 10 highest modeled MDA8 days did not have high observed MDA8 ozone. We proposed an alternate method of making future year projections using a model performance criterion that selects only days when modeled ozone is high and model performance is within acceptable bias limits. When this alternate procedure was used, the CAMx ERA run used more of 10 highest observed days corresponding to high modeled MDA8 ozone days in the projection calculation. In a perfect model run, the 10 highest model days would correspond to the 10 highest observed days, so we selected the run that came closer to this ideal.

We therefore selected the CAMx ERA run as the SNMOS 2011 base year run due to its better performance within the 4-km and 12-km domain on days where observed MDA8 ozone > 60 ppb as well as the fact that RRFs formed with this run had a better correspondence between high modeled and high observed MDA8 days.

In summary, we conclude that model performance for ozone, ozone precursors NO_2 and CO and PM was adequate for the SNMOS in the CAMx ERA run.

3.7.3 Milestones and Deliverables

- Base case modeling and model performance evaluation report. (Completed 4/17/2016)

3.8 Task 8: Prepare Future Year Emissions with SMOKE

3.8.1 Task Summary

The objective of this task was to combine the U.S. EPA 2011v2 modeling platform 2025 projection inventory, WAQS future year O&G inventories, and future year Mexico inventories to estimate future year emissions for the SNMOS. For this task we collected the 2025 emissions inventory and ancillary data from the US EPA 2011v6.2 modeling platform (US EPA, 2015). We applied the same version and configuration of SMOKE used for the SNMOS base year modeling to prepare future year, CAMx-ready emissions on the project 12-km and 4-km modeling domains. All of the natural source emissions and ancillary data were held constant with the 2011 base year modeling. Table 3-8 lists the emissions data used for the SNMOS future year modeling. We summarized the future year emissions inventories and processing results in a series of plots and developed a Power Point presentation on future year emissions modeling.

Table 3-8. SNMOS future year emissions data summary

Category	Data Source	Projection Year	Notes
Non-oil and gas	EPA 2011NEIv6.2	2025	Same categories as base year.
Oil and gas	Ramboll Environ and WAQS	2020 (Phase 2)	Permian basin projections for 2025 from NEI2011v6.2.
Mexico	ERG and EPA	2025	

	2011NEIv6.2		
Biogenic	SNMOS	Same as base year	No projection.
Fires	PMDETAIL version 2	Same as base year	No projection.
Lightning	SNMOS	Same as base year	No projection.
Ancillary Data	WAQS	Same as base year	No projection.

Figure 3-21 through Figure 3-26 summarize the New Mexico county base and future year NOx and VOC emissions. Figure 3-22 illustrates that Doña Ana County is projected to experience a 59.6% decrease in NOx emissions from 2011 to 2025, the majority of which will come from reductions in on-road mobile source emissions. Figure 3-25 shows that Doña Ana County is projected to experience a 42.1% decrease in VOC emissions, also primarily from decreases in on-road mobile emissions.

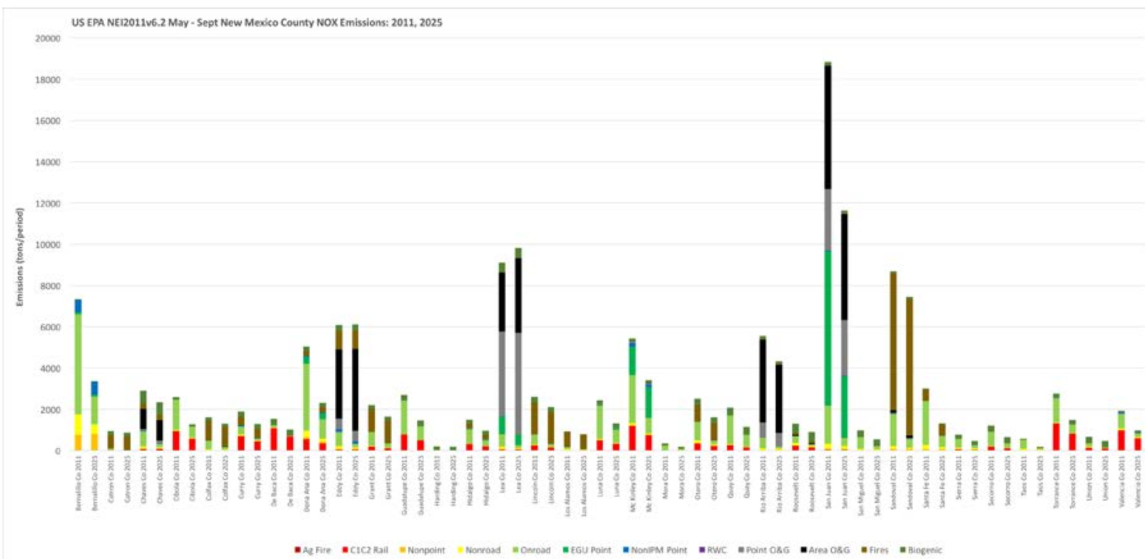


Figure 3-21.New Mexico county 2011 and 2025 NOx emissions.

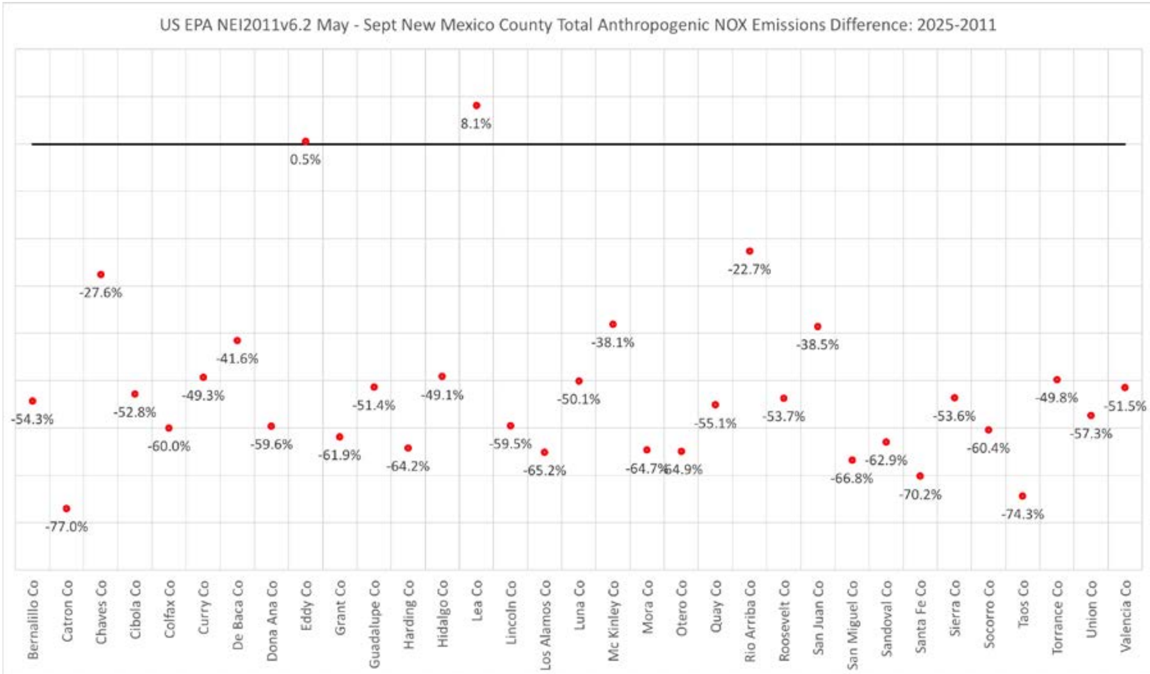


Figure 3-22. New Mexico county total anthropogenic NOx emissions change.

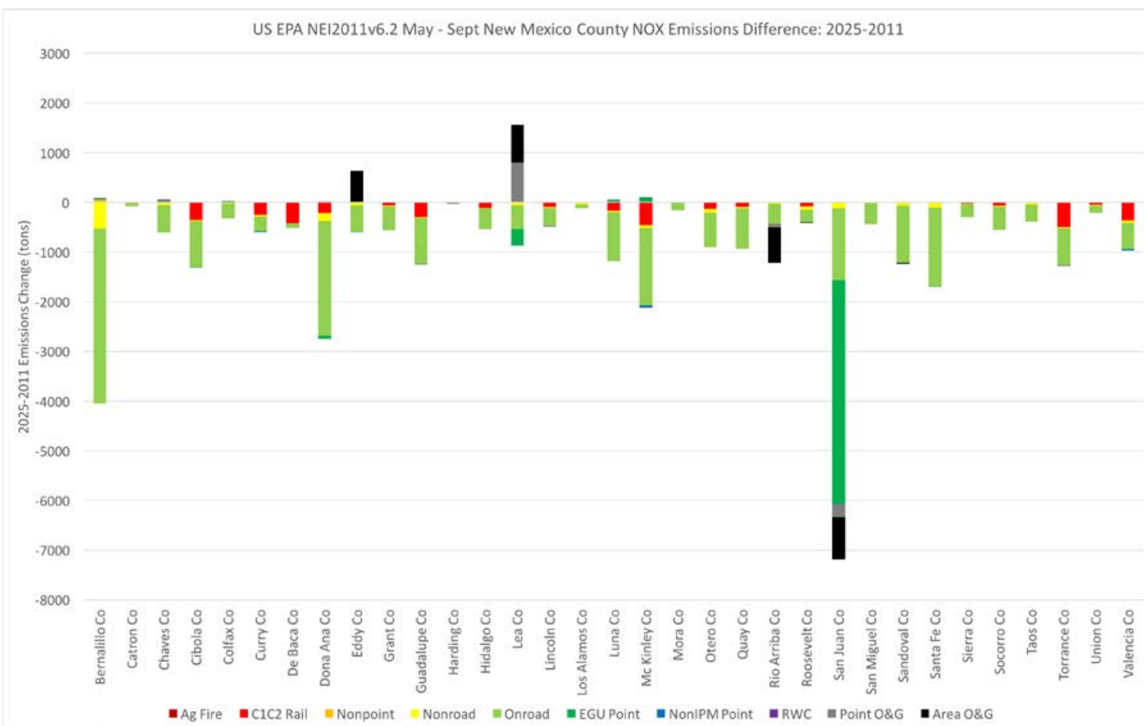


Figure 3-23. New Mexico 2011 and 2025 NOx emissions differences.

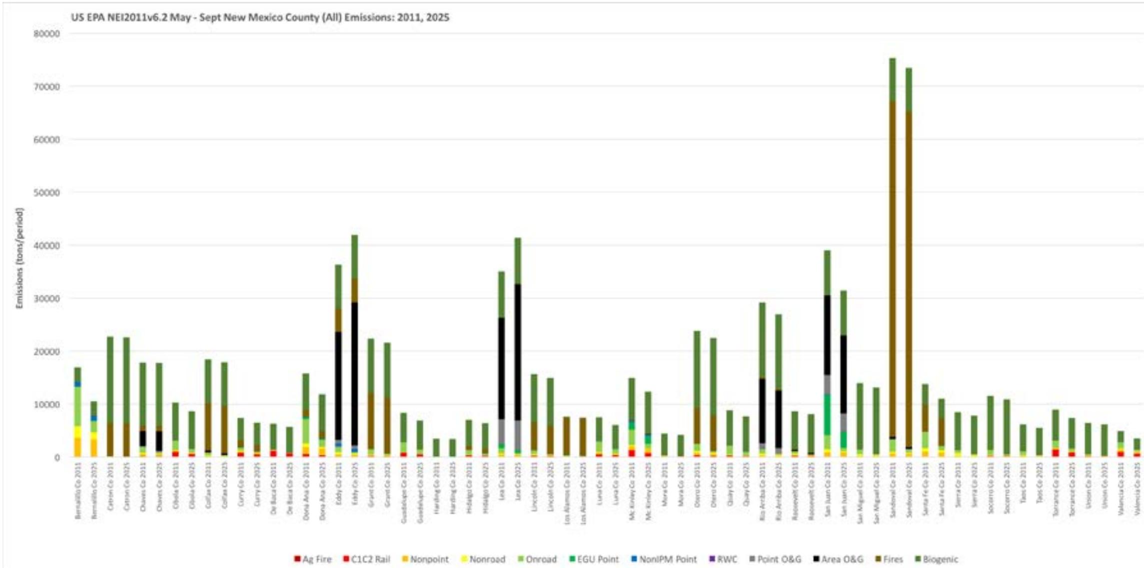


Figure 3-24. New Mexico county 2011 and 2025 VOC emissions.

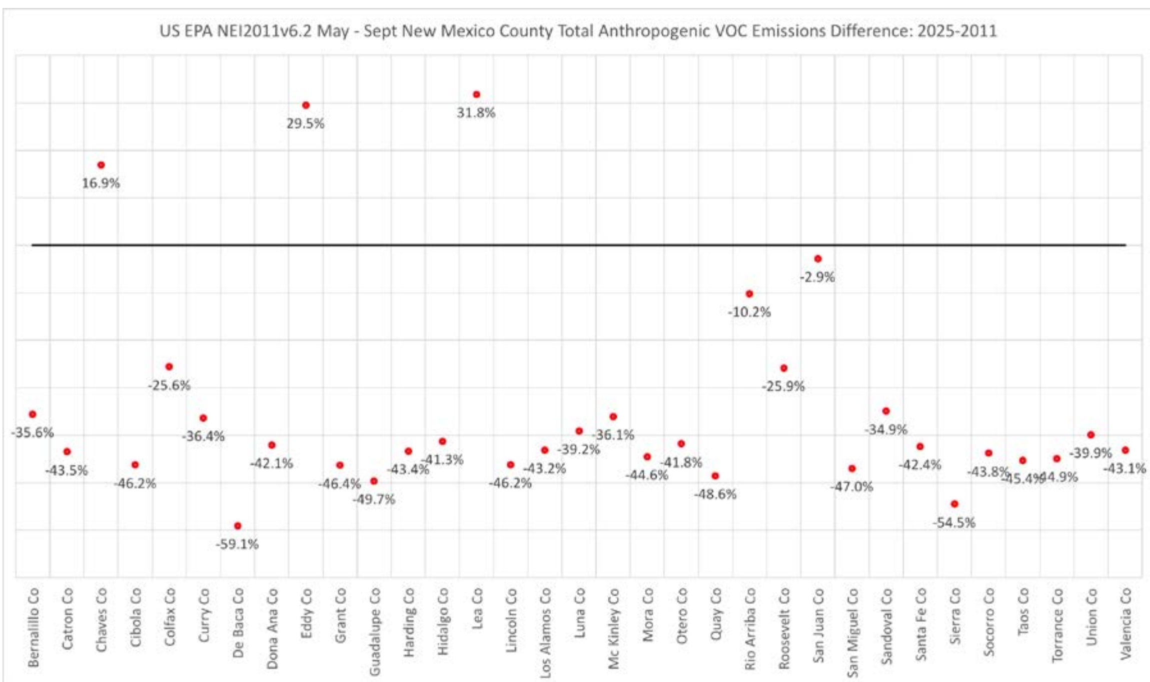


Figure 3-25. New Mexico county total anthropogenic VOC emissions change.

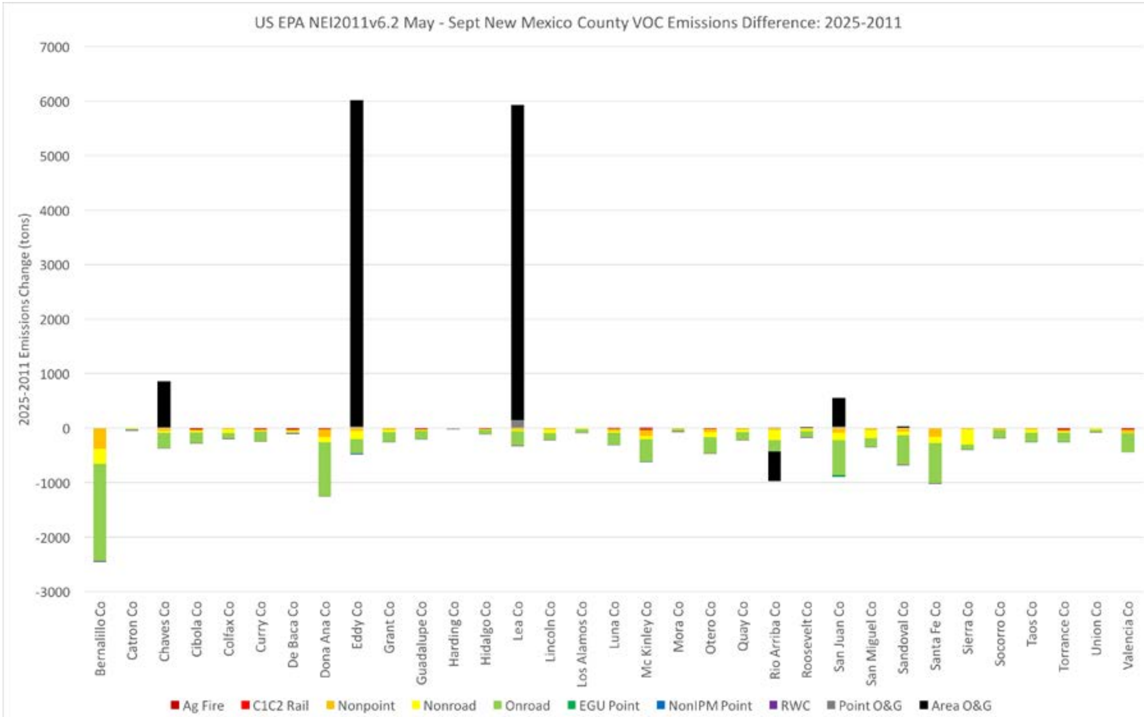


Figure 3-26. New Mexico 2011 and 2025 VOC emissions differences.

Additional details about the future year emissions data used for the SNMOS is available in the final Power Point presentation for this task (UNC-IE and Ramboll Environ, 2016a).

3.8.2 Significant Findings

In most of the New Mexico counties, ozone precursor (NOx and VOC) emissions are projected to decrease in 2025 relative to 2011. The exceptions are the oil and gas counties in the Permian Basin, which are projected to experience increases in both NOx and VOC emissions. Doña Ana County ozone precursor emissions are projected to decrease in 2025 relative to 2011, primarily as a result of ~70% reductions in on-road mobile NOx and VOC emissions.

3.8.3 Milestones and Deliverables

- Summarize the future year emissions inventories and processing results (Completed 4/30/2016)
- Power Point Presentation on future year emissions modeling (Completed 4/30/2016)
- CAMx-ready 2025 base year emissions on the project 12-km and 4-km modeling domains (Completed 4/30/2016)

3.9 Task 9: Future Year Air Quality Modeling

3.9.1 Task Summary

The objective of this task was to simulate future year summer season air quality using CAMx. In coordination with NMED we selected 2025 as the future year. We ran CAMx using the same configuration and, with the exception of the emissions, input data as the SNMOS 2011 CAMx simulation (see Task 6). We prepared the 2025 future year emissions estimates in Task 8. Upon completion of the CAMx simulation, we compared the 2025 ozone air quality projections with the 2011 estimates at the locations of ozone air quality monitors in Doña Ana County. The results of the simulation and the comparison to the base year were summarized in a final PowerPoint presentation.

Figure 3-27 compares differences between the CAMx estimates of 2025 and 2011 air quality. This figure also shows differences in the corresponding primary emissions (NOx and VOC) that drive ozone formation. As seen in this figure, CAMx predicted that ozone concentrations will generally decrease across the modeling domain in the entire summer season in 2025 relative to 2011. Large projected decreases in NOx and VOC emissions from on-road mobile sources appeared to be the factor driving the ozone reductions in 2025. Projected increases in oil and gas source emissions in the Permian basin were not predicted to impact future year air quality in Doña Ana County.

Additional details about the future year air quality modeling are available in the final Power Point presentation for this task (UNC-IE and Ramboll Environ, 2016b).

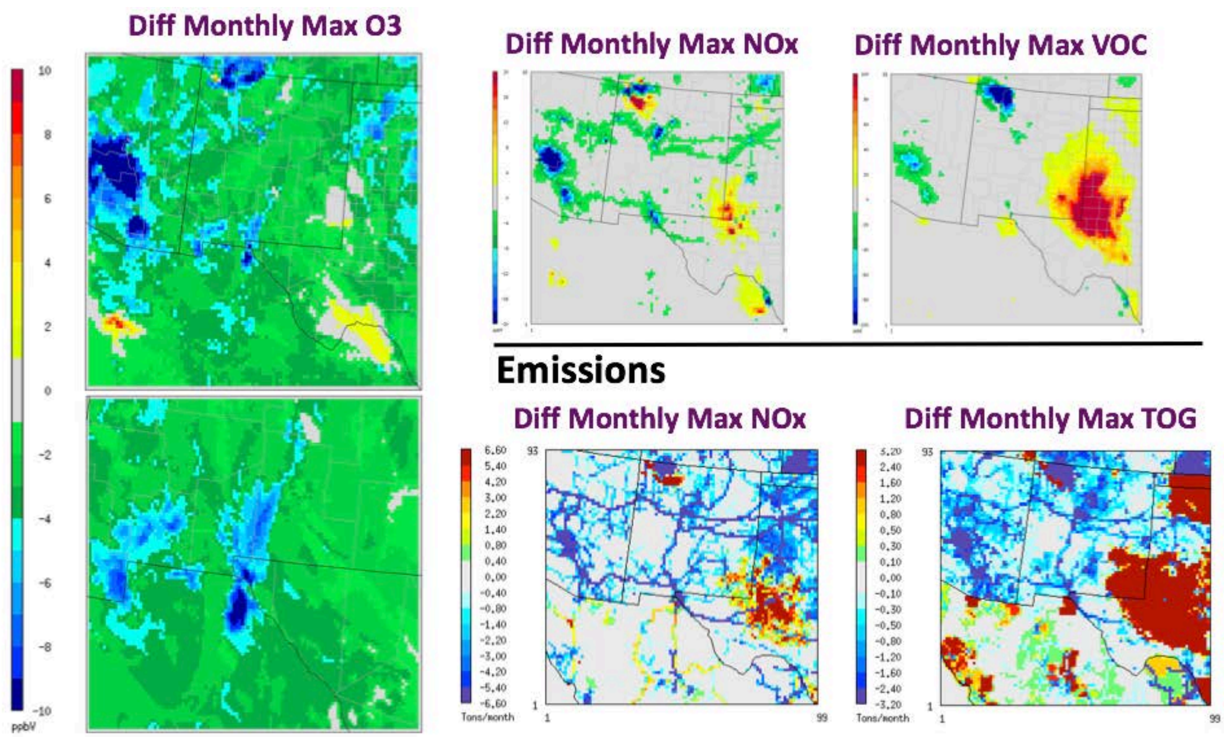


Figure 3-27. July 2011 differences (2025-2011) in CAMx monthly maximum O_3, NOx, VOC and corresponding emissions differences.

3.9.2 Significant Findings

CAMx predicted future year ozone reductions on most days of the summer season in Doña Ana County. The ozone reductions are consistent with significant reductions in ozone precursor emissions (NOx and VOC) in the area around Doña Ana County, particularly from the on-road mobile sector.

3.9.3 Milestones and Deliverables

- Power Point Presentation on future year air quality modeling (Completed 5/31/2016)

3.10 Task 10: Modeled Attainment Test

3.10.1 Task Summary

The objective of this task was to conduct a model attainment test using the U.S. EPA Model Attainment Test Software (MATS)[8] to estimate future design values (DVFs), relative response factors (RRFs), and unmonitored area analysis (UAA) for the SNMOS 12 and 4-km modeling domains. We used MATS version 2.6.1. to estimate DVFs and RRFs with the EPA default MATS configuration. In addition to the EPA defaults, we tested two different MATS configuration options to quantify how they impacted the attainment test results. Based on analysis conducted in Task 6, we also conducted an alternative MATS analysis that used the top 10 modeled 8-hour ozone days for days in which CAMx had a normalized mean bias < 10%. We

[8] https://www3.epa.gov/scram001/modelingapps_mats.htm

created plots of all the MATS simulations and prepared a Power Point presentation of the results.

Under this task we compared ten years of design values at the Doña Ana County monitors and recent projections from the EPA to the SNMOS 2025 design values. Figure 3-28 compares the official ozone design values at each of the Doña Ana County monitors from 2006 to 2015. This plot illustrates that 2011 was the lowest reported year for several of the sites. The plot also compares the 2011 DVCs, EPA modeling 2017 DVFs, and SNMOS 2025 DVFs for the Doña Ana County monitors. While the 2025 DVFs appear consistent with the EPA 2017 modeling, it is important to note that as the SNMOS projections were made from 2011, they may be biased low because they are based off of an historically low concentration base year.

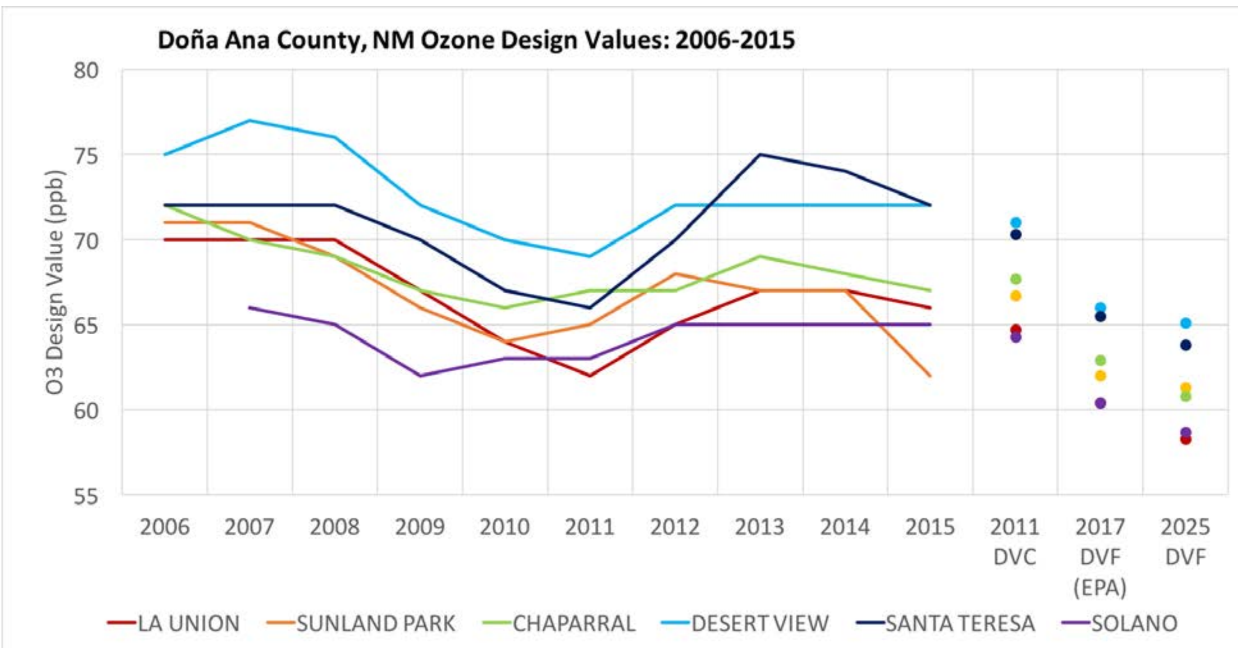


Figure 3-28. Annual ozone design values and a comparison of DVFs for EPA 2017 and SNMOS 2025 modeling.

Using the EPA default MATS configuration, we demonstrated that all of the monitors in the SNMOS 12-km domain, including all of the sites in Doña Ana County, are projected to be in attainment of the 2015 NAAQS for 8-hour ozone (70 ppb) in 2025 (Figure 3-29).

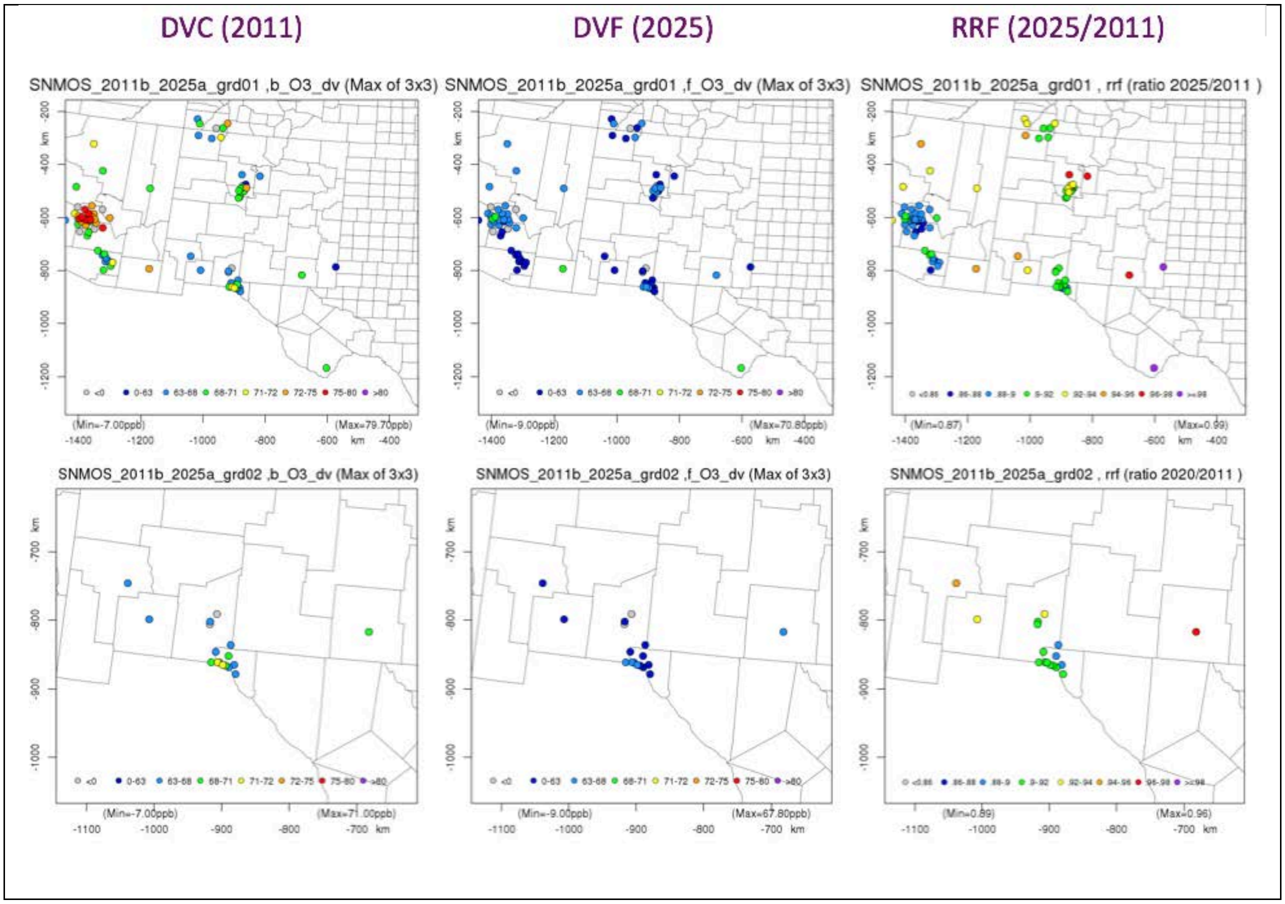


Figure 3-29. SNMOS 12-km (top) 4-km (bottom) domain MATS results.

In order to evaluate the sensitivity of the calculated DVFs to the MATS configuration and to biases in the CAMx ozone model, we conducted the following MATS sensitivity experiments:

- Spatial Matrix Experiment: test the impact of the size of the spatial matrix surrounding each monitor. MATS finds the maximum concentration from a matrix of modeled grid cells surrounding a monitor in the RRF calculation. We changed the EPA default from a 3x3 matrix to a 7x7 matrix.

- Temporal Averaging Experiment: test the impact of using fewer averaging days. Current EPA guidance uses the top 10 modeled daily maximum 8-hour average ozone in the RRF calculation. We tested the impact of using the top 5 modeled days.

- Model Performance Filter Experiment: test the impact of using only model days where the bias < 10%. We filtered the base year CAMx results to select the top 10 modeled days from only those days in which the Normalized Mean Bias was <= 10%. As this experiment required a separate MATS run for each monitor, we only used it for the Doña Ana County monitors in the 4-km modeling domain.

All of the experiments that we tested had little impact on the future year attainment status for the Doña Ana County monitors; they all continued to project attainment of the NAAQS. While the ozone bias filtering changed the DVF predictions by up to a few percent and resulted in a mix of higher and lower DVFs at the Doña Ana County monitors relative to the EPA default MATS configuration, none of the DVFs were greater than 65 ppb (Table 3-9).

Table 3-9. Low model bias MATS configuration 4-km domain results

Site ID	DVC	DVF (Base)	DVF (Bias < 10%)	RRF (Base)	RRF (Bias < 10%)	Site Name
350130008	64.7	58.3	60.2	0.9026	0.9306	LA UNION
350130017	66.7	61.3	60.9	0.9195	0.9136	SUNLAND PARK
350130020	67.7	60.8	62.9	0.8985	0.9293	CHAPARRAL
350130021	71	65.1	64.5	0.9183	0.9092	DESERT VIEW
350130022	70.3	63.8	64.3	0.9086	0.9158	SANTA TERESA
350130023	64.3	58.7	59.5	0.9136	0.9263	750 N.SOLANO DRIVE

The unmonitored area analysis that we conducted showed that all but a few cells in the 4-km domain will be in attainment in 2025 (Figure 3-30). The nonattainment cells in northern Grant County resulted from poor model performance related to a wildfire plume.

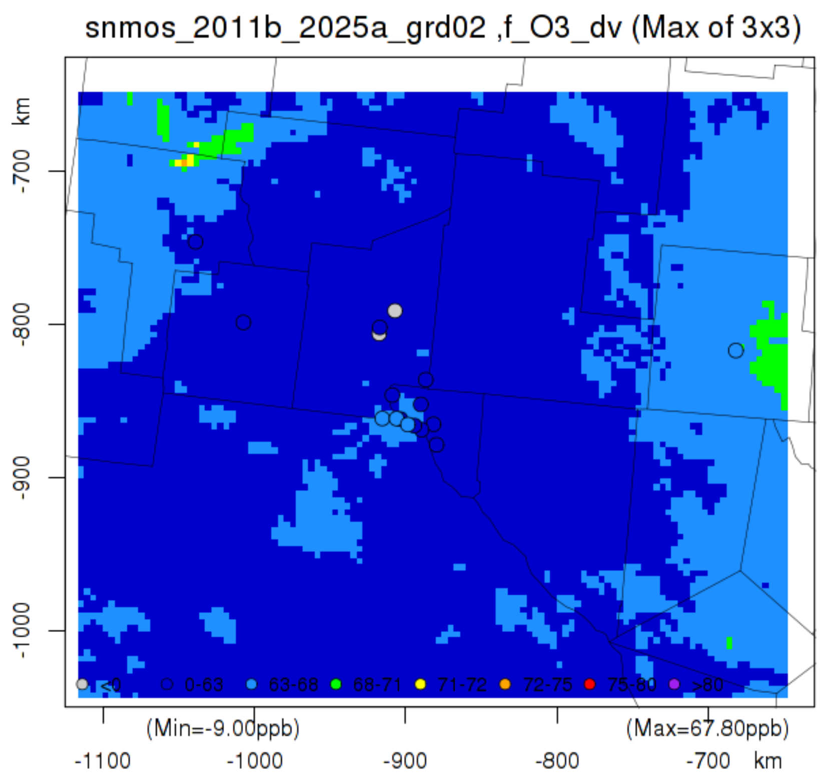


Figure 3-30. MATS unmonitored area analysis for 2025.

Additional details about the future year ozone projections using MATS is available in the final Power Point presentation for this task (UNC-IE and Ramboll Environ, 2016b).

3.10.2 Significant Findings

All of the Doña Ana County monitors are projected to be in attainment of the 2015 ozone NAAQS in 2025 (Table 3-10). We ran a series of experiments that showed despite fairly large changes to the EPA default MATS configuration, the projections of the future year attainment status did not significantly change.

Table 3-10. SNMOS 4-km CAMx modeling DVFs and RRFs

Site ID	DVC	DVF	RRF	County	Site Name
350130008	64.7	58.3	0.9026	Dona Ana	LA UNION
350130017	66.7	61.3	0.9195	Dona Ana	SUNLAND PARK
350130019	-7	-9	0.9239	Dona Ana	LAS CRUCES WELL STATION #41;HOLMAN ROAD
350130020	67.7	60.8	0.8985	Dona Ana	CHAPARRAL
350130021	71	65.1	0.9183	Dona Ana	DESERT VIEW
350130022	70.3	63.8	0.9086	Dona Ana	SANTA TERESA
350130023	64.3	58.7	0.9136	Dona Ana	750 N.SOLANO DRIVE
350131012	-7	-9	0.9198	Dona Ana	HOLIDAY INN
350151005	70.3	67.8	0.9646	Eddy	HOLLAND ST;SE OF WATER TANK;CARLSBAD;NM
350171003	65	62	0.955	Grant	CHINO BLVD NR HURLEY PARK; HURLEY;NM
350290003	63	58.6	0.9311	Luna	310 AIRPORT ROAD; DEMING; NM 88030
481410029	65	58.4	0.8996	El Paso	10834 IVANHOE; IVANHOE FIRE STATION
481410037	71	65.2	0.9186	El Paso	RIM RD. NEAR HAWTHORNE NEXT TO UT POLICE
481410044	69	62.7	0.9098	El Paso	800 S. SAN MARCIAL STREET
481410055	66.3	60.1	0.9069	El Paso	650 R.E. THOMASON LOOP
481410057	66	59.8	0.9071	El Paso	201 S. NEVAREZ RD.
481410058	69.3	61.7	0.8917	El Paso	5050 A YVETTE DRIVE

3.10.3 Milestones and Deliverables

- Power Point Presentation on future year ozone projections (5/31/2016)

3.11 Task 11: Future Year Emissions Sensitivity/Control Modeling

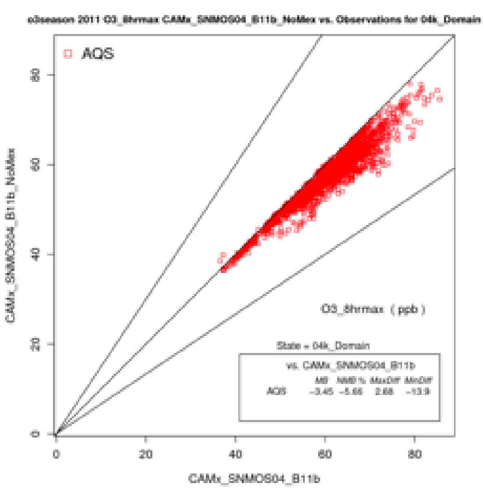
3.11.1 Task Summary

The objective of this task was to conduct CAMx sensitivity modeling to evaluate the impacts of emissions reductions on attainment of the ozone NAAQS. We ran two CAMx sensitivity simulations to quantify the impacts of emissions from anthropogenic sources in Mexico and from U.S. on-road mobile sources on ozone concentrations at monitors in Doña Ana County. We used MATS to estimate the changes in the design values and RRFs resulting from the sensitivity simulations. We created model evaluation plots comparing the base CAMx and sensitivity results and bubble plots of the results from the MATS simulations. We summarized this task and presented some of the key figures in a Power Point presentation.

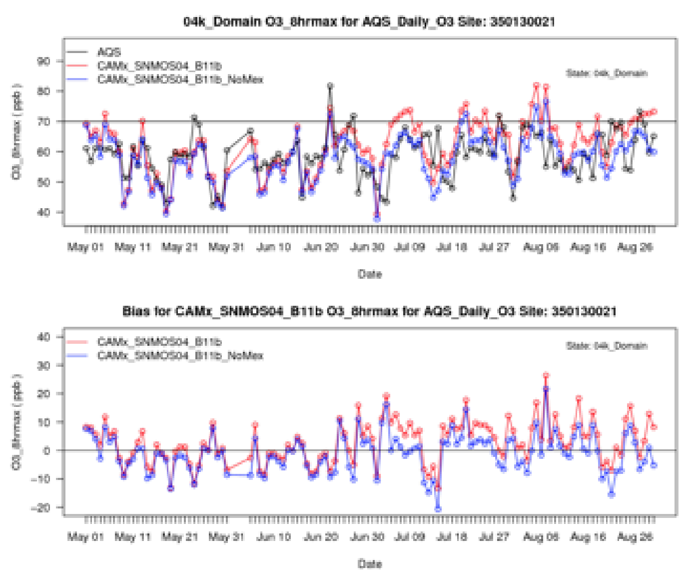
We prepared the emissions and ran CAMx for two sensitivity simulations to test the impacts of key emissions sources on ozone concentrations in Doña Ana County. With the exception of the emissions changes in the designed sensitivity, all of the other CAMx inputs and configuration remained the same as the base CAMx simulation. We ran the sensitivities for the full SNMOS modeling period (April 15 – August 31, 2011) and for both the 12-km and 4-km modeling domains.

In the first sensitivity simulation we evaluated the impact of Mexico emissions sources on 2011 air quality by removing ("zero out") all of the anthropogenic emissions in Mexico (SNMOS simulation ID: NoMex). The concept of this simulation was to estimate the ozone levels in Doña Ana County minus the influence of sources in Mexico. In the second sensitivity simulation we evaluated the sensitivity of 2025 projected U.S. air quality to the magnitude of the future year on-road mobile emissions estimates. We doubled the 2025 U.S. on-road mobile emissions (SNMOS simulation ID: 2xUSOR) to determine the sensitivity of the future year design values to this emissions source category. The concept of this simulation was to consider if a less conservative on-road mobile source projection scenario would still lead to ozone NAAQS attainment for the Doña Ana County monitors.

The NoMex simulation estimated that 2011 MDA8 ozone reduced by an average of 5.1 ppb (range -3.7 to -6.3 ppb) for the modeling period across all Doña Ana County monitors (Figure 3-31). The same figure shows a time series of observed (black) and modeled MDA8 at the Desert View monitor. The time series also shows the systematic ozone reductions in the NoMex simulation (blue) relative to the base 2011 CAMx simulation (red). The MATS results in Table 3-11 show that all of the monitors in the 4-km modeling domain reach NAAQS attainment in 2011 in the NoMex simulation. The design value at the Desert View monitor (2011 design value: 71 ppb) decreased by 6.2 ppb to 64.8 ppb. The results of the NoMex simulation provide evidence that in 2011 the monitors in Doña Ana County would have been in attainment of the ozone NAAQS but for the influence of anthropogenic emissions in Mexico.



Daily Max 8-hr O3, all NM 4-km AQS Monitors: May-August 2011 NoMex vs Base11b



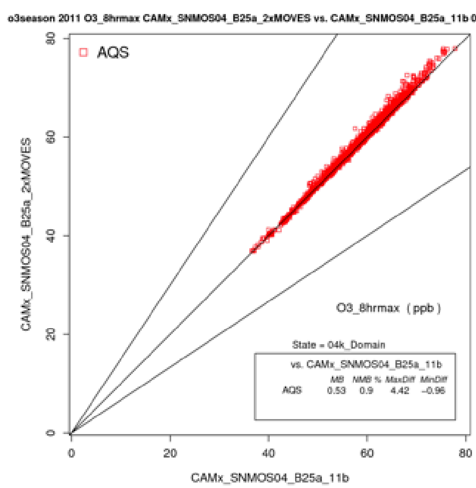
Desert View AQS Monitor Daily Max 8-hr O3: Obs, Base11b, NoMex

Figure 3-31. SNMOS 4-km domain 2011 zero out Mexico CAMx performance summary.

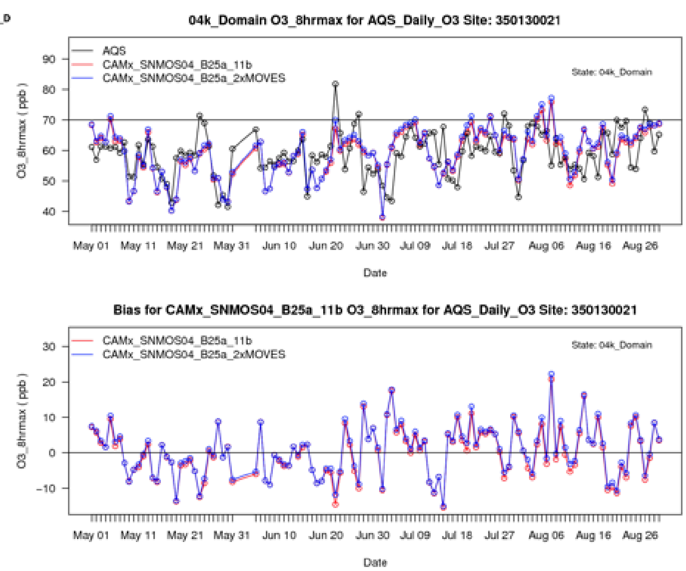
Table 3-11. SNMOS 4-km domain 2011 zero out Mexico MATS results

Site ID	DVC (2011)	DV No Mex (2011)	DV Diff	Site Name
350130008	64.7	59.6	-5.1	LA UNION
350130017	66.7	60.4	-6.3	SUNLAND PARK
350130020	67.7	63.3	-4.4	CHAPARRAL
350130021	71	64.8	-6.2	DESERT VIEW
350130022	70.3	65.2	-5.1	SANTA TERESA
350130023	64.3	60.6	-3.7	750 N.SOLANO DRIVE

The 2xUSOR simulation estimated that 2025 MDA8 ozone would increase by an average of 1.5 ppb (range: +1.3 to +1.6 ppb) for the modeling period across all Doña Ana County monitors. Despite doubling the 2025 emissions from on-road mobile sources (which contributed 70% of the anthropogenic NOx emissions in Doña Ana County), the projected air quality impacts were small. Table 3-12 shows that the DVFs for the Doña Ana County monitors were projected to increase by an average of 1.47 ppb and none of the monitors were predicted to be close to nonattainment of the 2015 ozone NAAQS (maximum 65.1 ppb at Desert View). The results of the 2xUSOR simulation demonstrate that a less conservative 2025 future year emissions scenario for U.S. on-road mobile sources than is currently estimated by MOVES will still lead to attainment of the 2015 ozone NAAQS for all monitors in Doña Ana County.



Daily Max 8-hr O3, all NM 4-km AQS Monitors: May-August 2011
2xUSOR vs Base25a_11b



Desert View AQS Monitor
Daily Max 8-hr O3: Obs, Base25a_11b, 2xUSOR

Figure 3-32. SNMOS 4-km domain 2025 double U.S. on-road emissions CAMx performance summary.

Table 3-12. SNMOS 4-km domain 2025 double U.S. on-road emissions MATS results

Site ID	DVC (2011)	DVF (2025)	DV 2xUSOR (2025)	DV Diff	RRF (2025)	RRF 2xUSOR (2025)	RRF % Change	Site Name
350130008	64.7	58.3	66.0	1.6	0.9026	0.9271	+2.71%	LA UNION
350130017	66.7	61.3	67.7	1.4	0.9195	0.9403	+2.26%	SUNLAND PARK
350130020	67.7	60.8	68.7	1.5	0.8985	0.9210	+2.50%	CHAPARRAL
350130021	71	65.1	71.9	1.5	0.9183	0.9388	+2.23%	DESERT VIEW
350130022	70.3	63.8	71.2	1.5	0.9086	0.9297	+2.32%	SANTA TERESA
350130023	64.3	58.7	65.2	1.3	0.9136	0.9341	+2.24%	750 N.SOLANO DRIVE

Additional details about the future year ozone projections using MATS are available in the final Power Point presentation for this task (UNC-IE and Ramboll Environ, 2016c).

3.11.2 Significant Findings

The results of the NoMex simulation provide evidence that in 2011 the monitors in Doña Ana County would have been in attainment of the ozone NAAQS but for the contribution of emissions from anthropogenic sources in Mexico. Despite doubling the 2025 emissions projections for U.S. on-road mobile sources, all of the monitors in Doña Ana County are projected to be well in attainment of the ozone NAAQS.

3.11.3 Milestones and Deliverables

- Power Point Presentation on future year air quality modeling (Completed 8/15/2016)

3.12 Task 12: Future Year Source Apportionment Modeling

3.12.1 Task Summary

The purpose of Task 12 was to conduct CAMx source apportionment simulations to better understand the source regions and source categories that contribute to elevated ozone concentrations in Doña Ana County and vicinity. These simulations will help set the ground work for the development of a potential State Implementation Plan (SIP) to demonstrate attainment of the ozone NAAQS. CAMx source apportionment modeling will be used to provide a complete accounting of the contributions of all sources delineated by the defined Source Groups that contribute to ozone concentrations at the Doña Ana monitoring sites and throughout the 12/4 km modeling domain.

Ozone is formed in the atmosphere by reactions of NOx and VOC in the presence of sunlight. Once formed, ozone persists and can be transported by prevailing winds. The Ozone Source Apportionment Tool (OSAT) in CAMx uses tracers to keep track of ozone production and transport (Yarwood et al., 1996; Ramboll Environ, 2015). The OSAT algorithm performs source attribution of ozone within a CAMx simulation, i.e., it provides a quantitative accounting of where ozone originated for any and all locations in the CAMx simulation. Within photochemical models like CAMx, ozone can originate from the initial conditions, the boundary conditions and emissions of ozone precursors (NOx and VOC). The OSAT method allows the emission inventory to be disaggregated to geographic regions and/or source categories for purposes of source apportionment. This allows an assessment of the role of transported ozone and precursors in contributing to ozone episodes in Doña Ana County. The methodology is designed so that all ozone and precursor concentrations are attributed among the selected source groupings at all times. Thus, for all receptor locations and times, ozone (or ozone precursor concentrations) predicted by CAMx is attributed among the source groupings.

Source Groups are typically defined as the intersection between source regions (e.g., states) and source categories (e.g., on-road mobile sources). For the CAMx 12/4 source apportionment simulation defined four Source Regions and seven Source Categories as follows (Figure 3-33):

Source Regions (4):

- New Mexico
- Texas
- Mexico
- Arizona and remainder of other states in the 12-km domain

Source Categories (8):

- Natural (biogenics and lighting NOx)
- On-Road Mobile
- Non-Road Mobile
- Oil and Gas (point and non-point)
- Electrical Generating Unit (EGU) Point
- Non-EGU Point
- Open Land Fires (wildfire, prescribed, and agricultural burning)
- Remainder Anthropogenic.

Initial concentrations (IC) and boundary condition (BC) are always included as Source Groups, so that there were a total of 30 Source Groups (30 = 4 x 7 + 2) for the source apportionment modeling. The BCs represent the contribution from transport from outside of the 12/4 km SNMOS domain. This includes transport from sources in the remainder of U.S. outside the 12/4 km domain, international transport, and the natural global ozone background including stratospheric ozone intrusions. The boundary conditions as defined for the SNMOS includes contributions from additional sources of emissions relative to the North American background (NAB)[9] or the U.S. background (USB)[10].

[9] North American Background Ozone (NAB) is defined by the U.S. EPA to be as the ozone levels that would exist in the absence of continental North American (i.e., Canadian, U.S., and Mexican) anthropogenic emissions

[10] U.S. background (USB) ozone is defined by the U.S. EPA to be any ozone formed from sources or processes other than U.S. manmade emissions of NOx, VOC, methane and CO. USB ozone does not include intrastate or interstate transport of manmade ozone or ozone precursors.

Figure 3-33. 12/4 km domain source regions used in source apportionment modeling.

We performed the source apportionment simulation using both the 2011 and 2025 emissions in order to:

- Obtain the contributions of Mexico to 2011 ozone design values and demonstrate that, without anthropogenic emissions from Mexico, Doña Ana County would have attained the ozone NAAQS;
- Calculate 2025 ozone projections removing the contributions of fires that have high uncertainties as well as year-to-year variations.
- Determine changes in contributions between 2011 and 2025 to explain the reductions in Doña Ana County design values and provide a rough estimate of ozone levels if the emission reductions are not as large as projected.
  - For example, the reductions in ozone due to on-road mobile sources were examined to determine what the 2025 ozone design values would be if we obtained a lower level of emission reductions.
- Provide an accounting of ozone contributions in 2025 that can be used to identify those sources that contribute the most to ozone levels in Doña Ana County.

We ran the CAMx model on the SNMOS 12/4 km grids using ozone source apportionment for April–August 2011 and 2025. CAMx was configured as in the SNMOS 2011 Base Case modeling (Table 3-7). 2011 calendar dates were used for the 2025 run. The modeling setup was identical to that used in the Task 11 Sensitivity Modeling except for the use of the use of the CAMx source apportionment tools and the unperturbed Base Case emission inventory for 2025. The 2025 Base Case emission inventory is described in Section 3.8.

We used EPA's MATS together with the CAMx OSAT results for 2011 and 2025 to calculate design values for 2025 and carry out the following analyses:

- Determine the source regions and source categories that contribute to elevated ozone concentrations in Doña Ana County and vicinity
- Obtain the contributions of Mexico emissions to 2011 ozone design values (DVs)
- Calculate 2025 ozone DVs without the contributions of fire emissions

We followed current EPA guidance on the use of MATS. The DVF calculation used the maximum concentration from a matrix 3 x 3 matrix (9 cells) of modeled grid cells surrounding each monitor. In the RRF calculation for each monitor in the 4-km grid, we used the top 10 modeled days (10 days with the highest modeled MDA8 ozone). We used a 70 ppb threshold and set the minimum number of days at or above the threshold to one day.

To calculate the contribution of each source group to each monitor's ozone design value, we first ran MATS with the full CAMx output for the base year ($CAMx\_total_{2011}$) and the future year ($CAMx\_total_{2025}$) and calculated the future year design value (DVF_{2025}) for each monitor using following EPA Guidance:

$$DVF_{2025} = \frac{CAMx\_total_{2025}}{CAMx\_total_{2011}} \times DVC_{2011}$$

where DVC_{2011} is the base year design value based on observed ozone. Next, we subtracted the ozone contribution from the i^{th} source group (for example, New Mexico on-road mobile emissions) ($SrcGrpContrib^{i}_{2025}$) from the full model output ($CAMx\_total_{2025}$) and reran MATS without contribution from the i^{th} source group.

$$DVF^{i}_{2025} = \frac{CAMx\_total_{2025} - SrcGrpContrib^{i}_{2025}}{CAMx\_total_{2011}} \times DVC_{2011}$$

The incremental contribution to the 2025 DVF from the i^{th} source group is

$$\Delta DVF^{i}_{2025} = DVF_{2025} - DVF^{i}_{2025}.$$

We define the DVF for the year 2011 to be:

$$DVF^{i}_{2011} = \frac{CAMx\_total_{2011} - SrcGrpContrib^{i}_{2011}}{CAMx\_total_{2011}} \times DVC_{2011}$$

so that the contribution to the 2011 current year design value from source group i is

$$\Delta DVC_{2011}^{i} = DVC_{2011} - DVF_{2011}^{i}.$$

3.12.1.1 <u>OSAT Results</u>

In this section, we present results of the OSAT analysis. We begin with detailed source apportionment results for the Desert View monitor. Results for this monitor were similar to those for the other Doña Ana monitors, so we focus on Desert View only for the sake of brevity and because it is the only Doña Ana County monitor with a DVC_{2011} that exceeds the 2015 NAAQS of 70 ppb. Results for the other Doña Ana County monitors may be found in the Task 12 Summary PowerPoint presentation.

We used the source apportionment results to assess the importance of transport in determining ozone design values at Doña Ana monitors. We reviewed the effect of boundary conditions and transport from within the 12-km domain, but outside New Mexico. The results for the Desert View monitor are shown in Figure 3-34 and Figure 3-35. The DVC_{2011} for Desert View is 71.0 ppb and the DVF_{2025} is 65.1 ppb. The contribution from each of the 12/4 km domain source regions for both years is shown in the stacked bar charts.

The BC contribution includes the effects of sources within the U.S. (e.g., Los Angeles and Phoenix) as well as sources outside the US (Asia, regions of Mexico outside the 12/4 km grid) and the stratospheric contribution. The contribution to the Desert View DVC_{2011} and DVF_{2025} from the12-km BC contribution is far larger than those of regions within the 12-km domain and decreases from 54 ppb in 2011 to 50 ppb in 2025. The total contribution from transport is indicated by the red brackets in Figure 3-34 and includes the BC contribution as well as contributions from Mexico, Texas and the Other 12 km region that includes parts of Colorado, Oklahoma, Kansas, Utah and Arizona. In 2011, transport contributed 68.6 ppb to the Desert View design value of 71.0 ppb, while New Mexico emissions sources contributed 2.4 ppb. In 2025, transport contributed 63.5 ppb to the design value of 65.1 ppb and New Mexico sources contributed 1.6 ppb.

The New Mexico contribution to the Desert View DVC_{2011} and DVF_{2025} is smaller than the Texas and Mexico contributions in both 2011 and 2025. In 2011, New Mexico emissions sources contributed 2.4 ppb to the Desert View design value while Texas contributed 6.9 ppb and Mexico contributed 7.6 ppb. In 2025, New Mexico emissions sources contributed 1.6 ppb to the Desert View design value while Texas contributed 5.0 ppb and Mexico contributed 7.8 ppb.

The reduction in the Desert View DVF_{2025} is driven by the decrease in BCs from 54 ppb to 50 ppb and in reductions contributions from New Mexico (2.4 ppb to 1.6 ppb), Texas (6.9 ppb to 5.0 ppb). The contribution from Mexico, on the other hand, increases slightly from 7.6 ppb to 7.8 ppb.

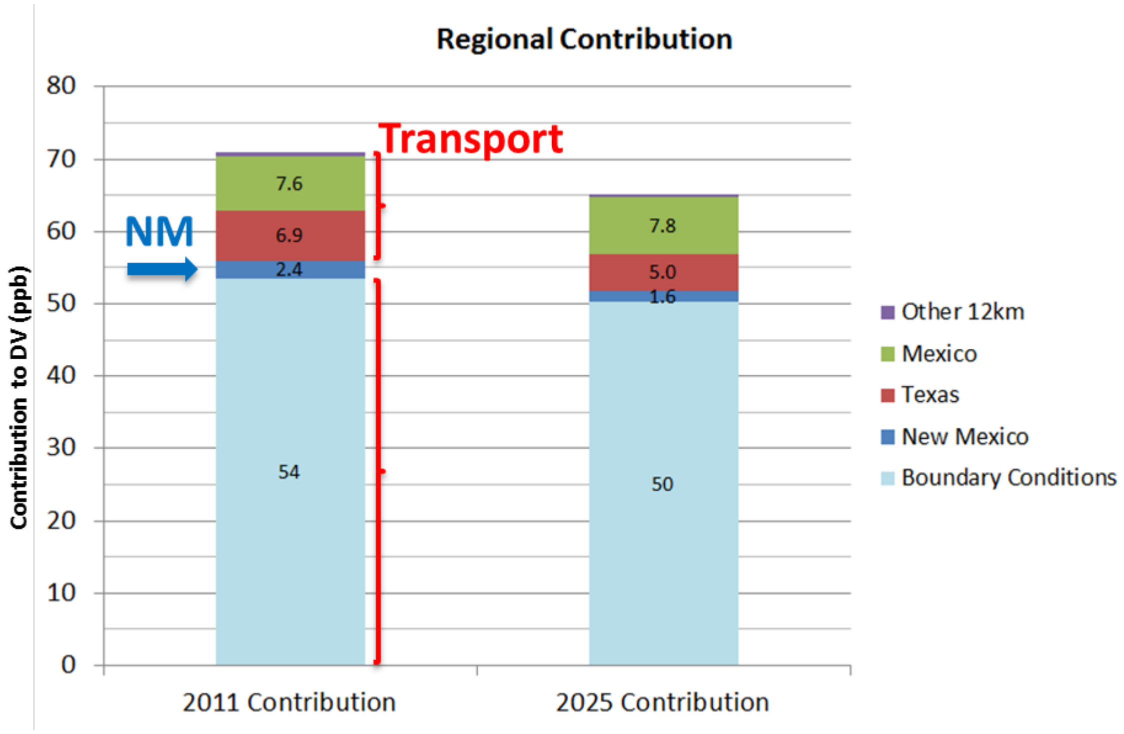


Figure 3-34. Contribution from source regions shown in Figure 3-33 and 12-km grid boundary conditions to 2011 and 2025 design values at the Desert View monitor. The contribution from New Mexico is shown in darker blue and the contribution from all sources outside New Mexico ("Transport") is indicated by the red bracket.

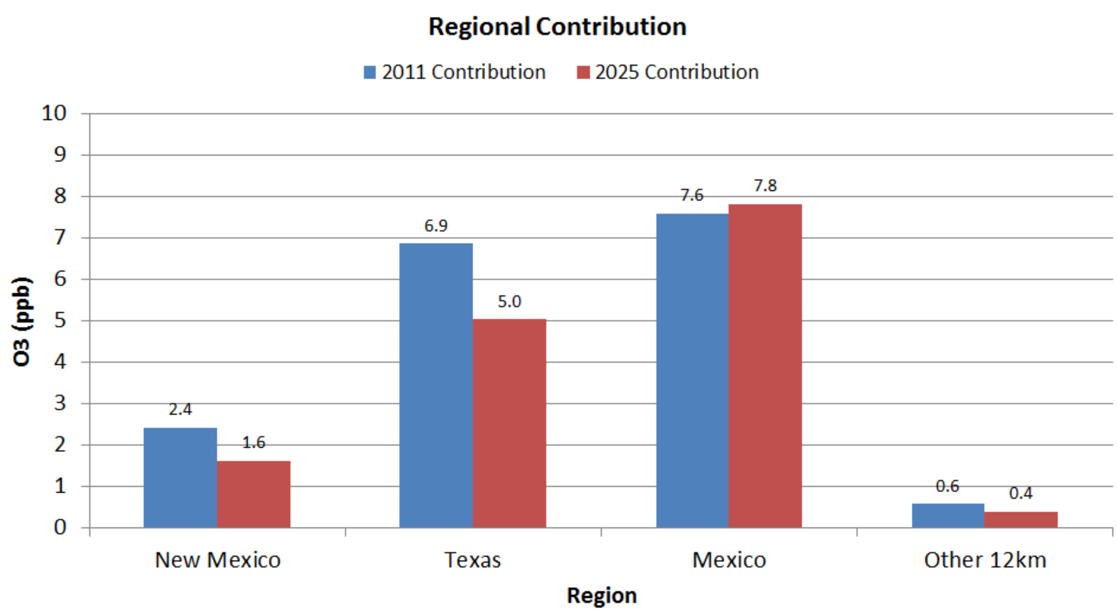


Figure 3-35. Contribution from source regions shown in Figure 3-33 to 2011 and 2025 design values at the Desert View monitor.

Figure 3-36 shows the contributions to the Desert View design values from the different emissions source categories. The largest contributions to the Desert View DVC_{2011} are from on-road mobile sources, natural sources, EGUs and non-road mobiles emissions. By 2025, the contribution of on-road mobile emissions decreases, but on-road mobile still contributes the most of any emissions source category to the Desert View design value. Natural emissions are the next largest contributor in 2025, followed by EGU and non-EGU point sources.

Figure 3-37 shows the top five contributing source groups to the DVC_{2011} at Desert View ranked by the value of their 2011 contribution alongside their 2025 contribution. The largest contributions to the Desert View DVC_{2011} are from Texas and Mexico on-road emissions and Mexico EGU and natural emissions. The largest 2025 contributions are from Mexico EGU and non-EGU point sources and on-road emissions from Texas and Mexico. Reductions in Texas, New Mexico and Mexico on-road contributions are responsible for much of the ozone decrease in the Desert View design value from 2011 to 2025.

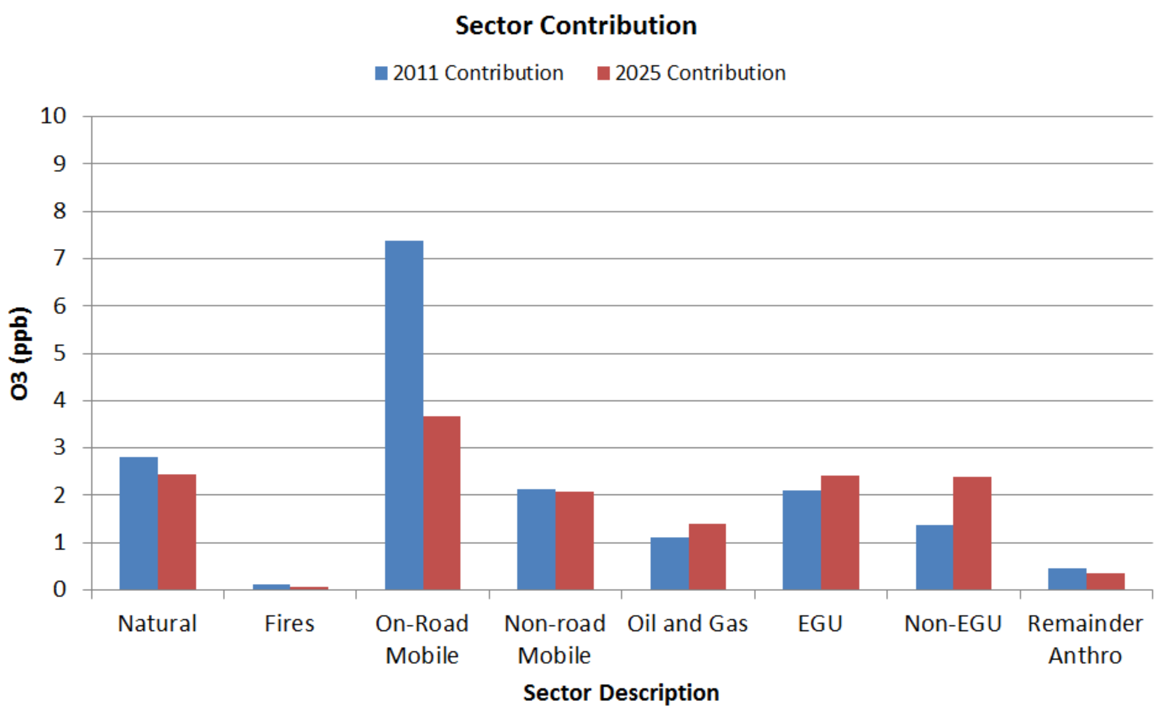


Figure 3-36. Contribution from emissions source categories to 2011 and 2025 design values at the Desert View monitor.

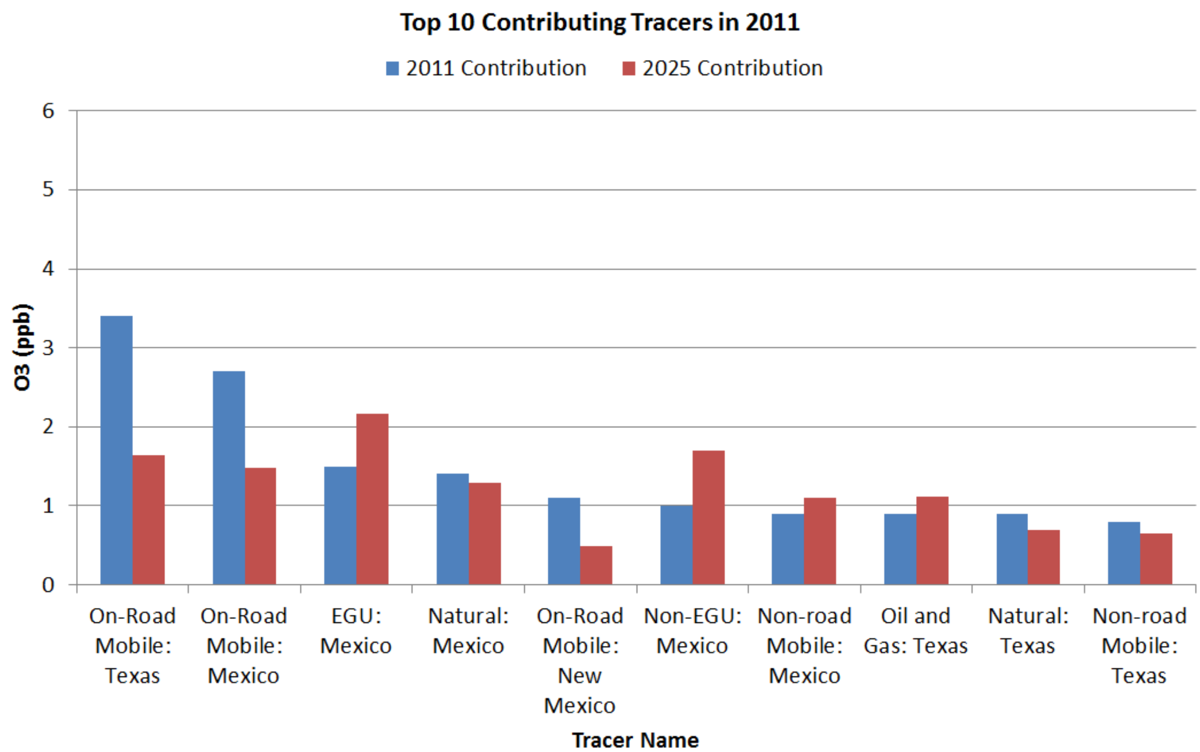


Figure 3-37. Contributions to the 2011 (blue) and 2025 (red) design values for the top ten contributing source groups in 2011 for the Desert View monitor. Source groups are ranked from left to right based on their contribution to the 2011 design values.

As noted above, results for the other Doña Ana County monitors are similar to those of Desert View and are available in the Task 12 PowerPoint. Next, we identify source groups that had the largest impact on Doña Ana County monitors. Figure 3-38 shows the frequency (as a count) with which each source group appears in the list of top five contributing source groups for the Doña Ana County monitors. We selected the top five source groups because contributions to design values tended to drop below 1 ppb for source groups outside the top five, so that focusing on the top five isolates the most important source groups. There were six Doña Ana County monitors active during this modeling episode (Figure 3-39), so that when the count for a source group is six (such as for natural emissions in Mexico in 2025) that source group was in the top five contributing source groups for all Doña Ana County monitors in that year.

Figure 3-37 shows that on-road, natural (Mexico) and EGU (Mexico) emissions appeared most frequently in the list of top five contributors to Doña Ana County monitor design values. All six Doña Ana County monitors had Texas on-road mobile sources appearing in the list of top five contributors in 2011. While New Mexico on-road mobile sources appeared in the list of the top five sources for five Doña Ana County monitors in 2011, reductions in on-road mobile emissions by 2025 meant that on-road mobile emissions from New Mexico appeared in the list of top five contributors for only one monitor (Solano) in 2025. Oil and gas emissions growth in the

Permian Basin is the cause of the increased frequency of appearance of Texas oil and gas sources in the list of top five contributors in 2025.

Mexico is the most frequently appearing source region, with emissions from Mexican natural sources, on-road mobile and EGU point sources appearing the most frequently in 2011 and Mexican natural emissions, on-road mobile sources and EGU and non-EGU point sources appearing most frequently in 2025. Next, we focus on the contribution from Mexico.

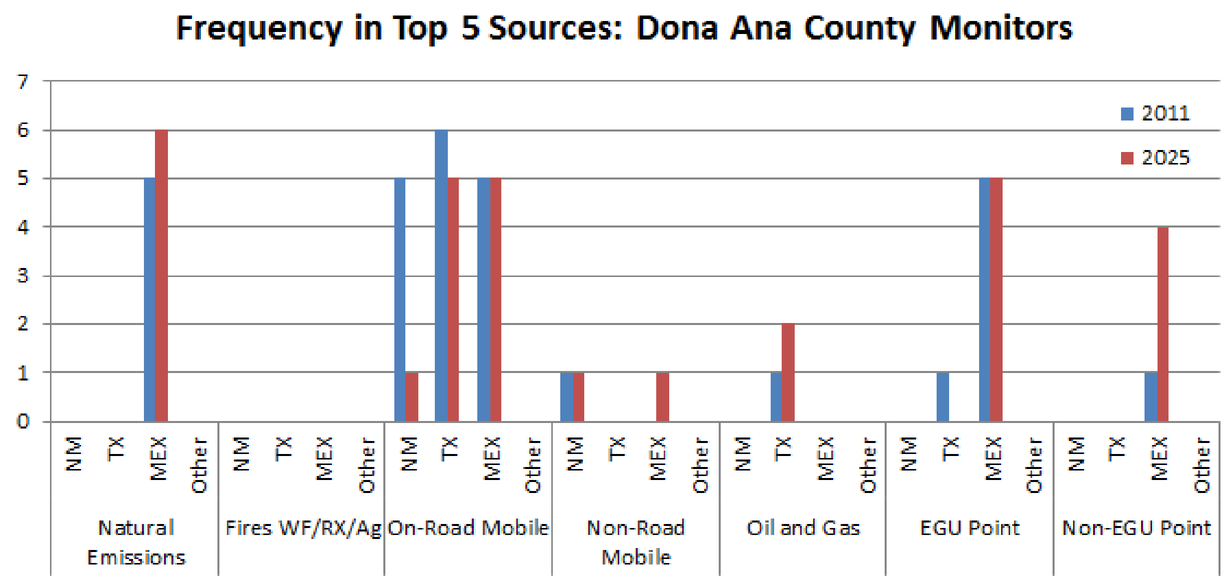


Figure 3-38. Frequency with which each source group appeared in the list of top five contributing source groups for the Doña Ana County monitors in 2011 and 2025.

Figure 3-40 shows the contributions to monitors within the 4-km domain due to emissions from Mexico along with a map of the monitors within and nearby Doña Ana County. The full map of monitors within the 4-km domain is shown in Figure 3-39. Contributions from Mexico emissions to 2011 and 2025 design values range from ~2-6 ppb at Doña Ana monitors and are similar in magnitude in 2011 and 2025. Monitors in New Mexico that are located near the U.S.-Mexico border (Desert View, Sunland Park) and El Paso monitors have larger contributions from Mexico emissions than monitors located further from the border (Carlsbad, Hurley). The contribution from Mexico emissions is significant and in 2011 is sufficiently large to affect the attainment status of the monitors. (See additional discussion below). The contribution from Mexico does not change substantially from 2011 to 2025; the contribution increases for some monitors (Sunland Park, El Paso UTEP) and decreases for other monitors (Santa Teresa, Ascarate Park).

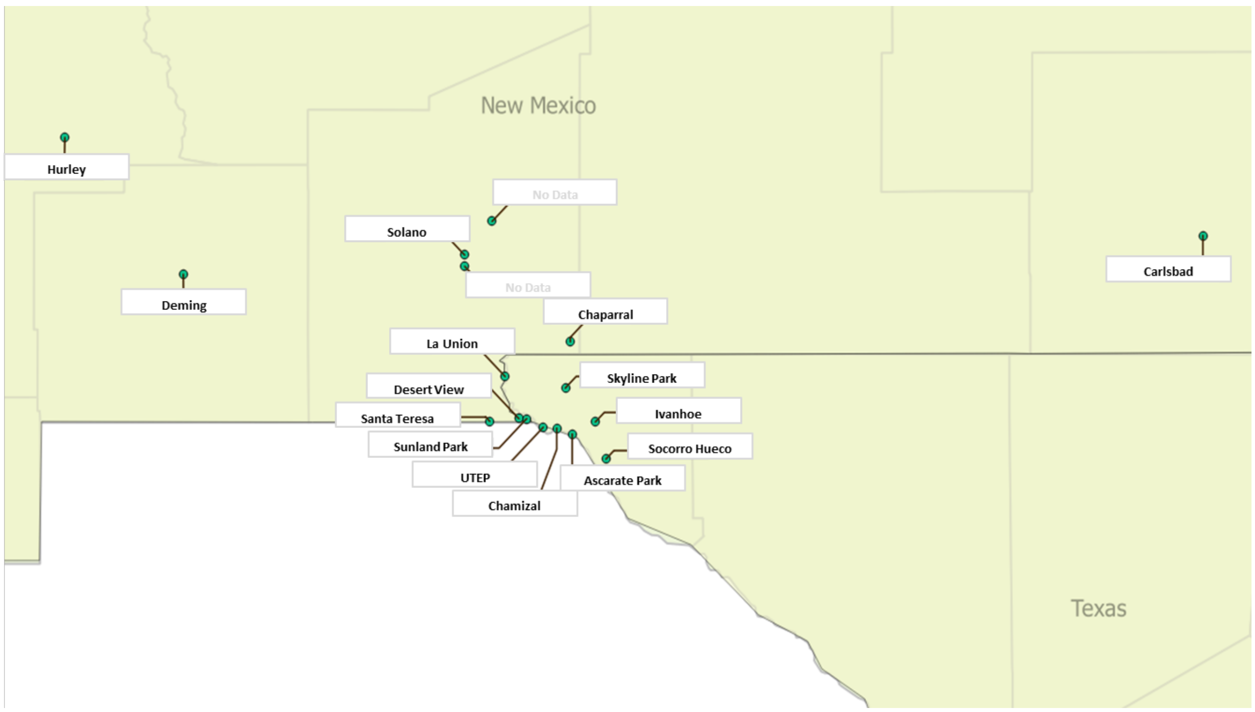


Figure 3-39. Map of ozone monitors within the SNMOS 4-km domain. Sites that were not active during the 2011 SNMOS modeling episode are indicated by "No Data".

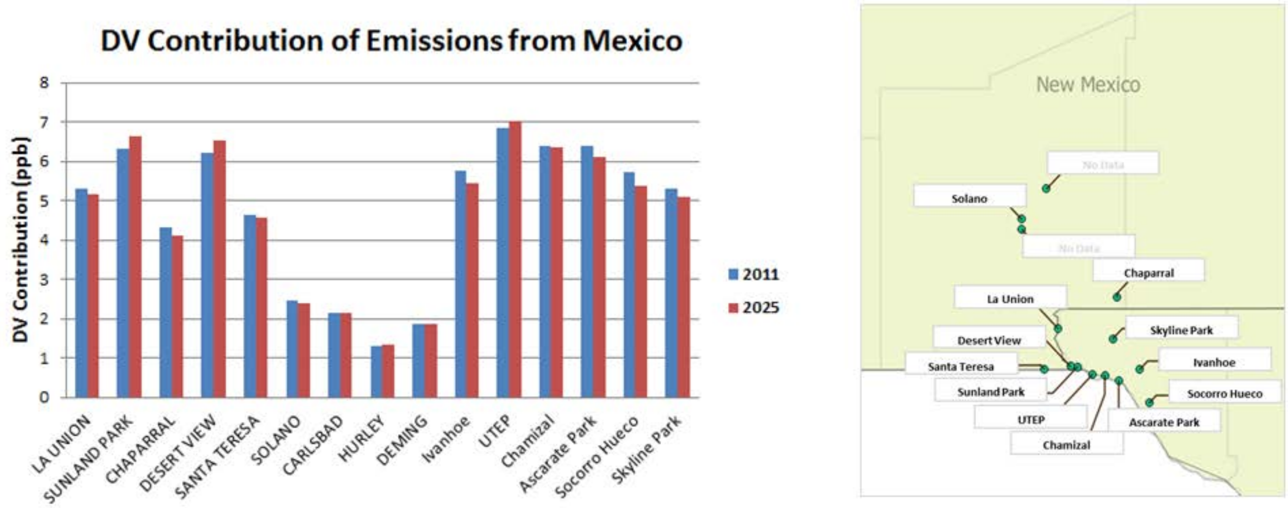


Figure 3-40. Left: contribution of Mexico anthropogenic emissions to 2011 and 2025 DVs for monitors in the 4-km grid. Right: map of ozone monitors within and nearby Doña Ana County.

The contribution to 4-km grid monitors from on-road mobile sources is shown in Figure 3-41. There are large (>7 ppb) 2011 contributions from on-road emissions to design values at Doña Ana and El Paso monitors. Decreases in U.S. and Mexico 2025 on-road mobile emissions relative to 2011 cause large decreases in the on-road mobile contribution in 2025 for all sites.

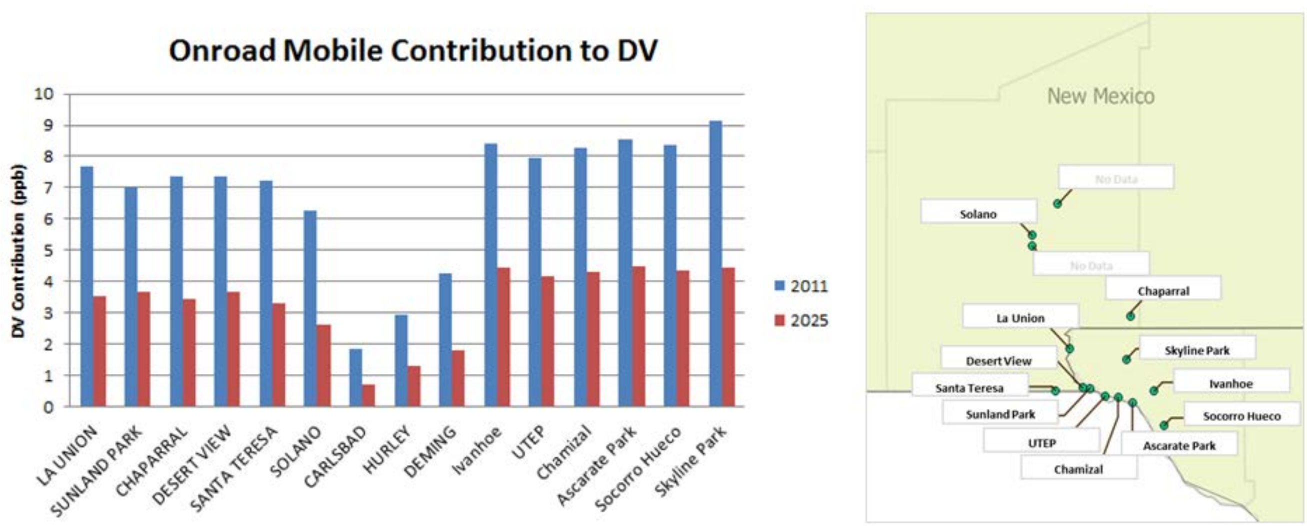


Figure 3-41. Left: contribution of on-road mobile emissions to 2011 and 2025 DVs for monitors in the 4-km grid. Right: map of ozone monitors within and nearby Doña Ana County.

Figure 3-42 shows the contribution of New Mexico anthropogenic emissions to design values of monitors in New Mexico. This represents the portion of the design values that are subject to local control. On-road mobile emissions make the largest anthropogenic contribution to design values at most New Mexico monitors. The Solano monitor has the largest contribution from on-road mobile sources. This monitor is located within the Las Cruces urban area and is also close to Interstate I-15. The contribution from on-road mobile sources decreases in 2025 for all New Mexico monitors, consistent with the decrease in New Mexico on-road mobile emissions in 2025 relative to 2011.

Non-road mobile and oil and gas sources make next largest contributions, followed by EGU point sources. Oil and gas sources make the largest contribution at the Carlsbad monitor, which is the monitor located closest to the Permian Basin (Figure 3-39). The magnitude of the oil and gas impact increases in 2025 consistent with projected growth in emissions in the Permian Basin in 2025 relative to 2011 (Section 3.2.1).

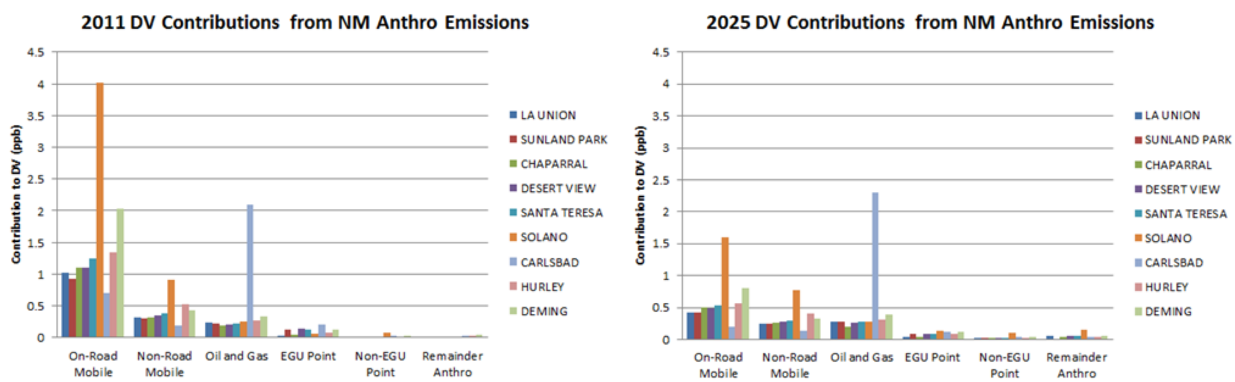


Figure 3-42. Contribution of New Mexico anthropogenic emissions to 2011 and 2025 design values for New Mexico monitors within the 4-km grid.

3.12.1.2 Contribution of Emissions from Mexico to Doña Ana County Ozone

We assessed the contribution of Mexico emissions to design values at Doña Ana monitors in 2011 and 2025 and compared the results with those of the Task 11 Sensitivity Test in which the ozone impacts of zeroing out Mexico anthropogenic emissions were quantified. This assessment is aimed at assessing whether a Section 179B "But For" test would be appropriate for Doña Ana monitors.

Section 179B of the Clean Air Act addresses impacts on U.S. air quality due to transport of pollution from outside the U.S. Section 179B provides relief from some requirements for areas that would be able to meet the NAAQS "but for" ozone impacts of emissions from another country. In preparing a Section 179B demonstration, an air agency must show that the area would attain the NAAQS but for the ozone contribution from outside the U.S. In Table 3-13, the contributions from Mexico anthropogenic emissions ("Mexico Anthro Contribution") to 2011 design values from the Task 12 source apportionment modeling as well as the Task 11 sensitivity modeling are shown. For the source apportionment results, the Mexico Anthro Contribution ranges between 1.3-6.8 ppb for monitors in the 4-km grid. Contributions to Dona Ana monitor design values from Mexico emissions range from ~2-6 ppb at Doña Ana monitors and are similar in 2011 and 2025. Subtracting the Mexico Anthro Contribution from the 2011 DVC yields the 2011 DV NoMexAnthro, the value of the 2011 DVC at the monitor when the contribution from Mexico anthropogenic emissions is removed. When the ozone contribution from Mexico anthropogenic emissions is subtracted, the Desert View 2011 DVC drops from 71 ppb, which exceeds the 70 ppb NAAQS, to 64.8 ppb, which attains the 70 ppb NAAQS. Table 3-13 indicates that but for the contribution of emissions from Mexico, the Desert View monitor would have attained the 70 ppb NAAQS in 2011. The same is true for the UTEP monitor in El Paso; the UTEP monitor's 2011 design value drops from 71 ppb to 64.2 ppb when the contribution from Mexican anthropogenic emissions is removed.Table 3-13 indicates that monitors closer to the U.S.-Mexico border have a larger Mexico contribution (e.g., El Paso monitors) than monitors which are more distant from the border (Carlsbad, Deming).

Table 3-13. Ozone contribution to 2011 DVs from Mexico anthropogenic emissions (Mexico Anthro Contribution) for all monitors in the 4-km grid. Results are shown for the sensitivity test (Task 11) and source apportionment (Task 12) analyses. Orange shading of the 2011 DVC indicates that the DVC exceeds the 2015 ozone NAAQS of 70 ppb. Yellow shading indicates 70 ppb < DVC < 71 ppb.

Site ID	Observed	CAMx Source Apportionment		CAMx Sensitivity Test		County	Site Name
	2011 DVC	2011 DV NoMexAnthro	Mexico Anthro Contribution	2011 DV NoMexAnthro	Mexico Anthro Contribution		
350130008	64.7	59.4	5.3	59.6	5.1	Dona Ana	LA UNION
350130017	66.7	60.4	6.3	60.4	6.3	Dona Ana	SUNLAND PARK
350130020	67.7	63.4	4.3	63.3	4.4	Dona Ana	CHAPARRAL
350130021	71	64.8	6.2	64.8	6.2	Dona Ana	DESERT VIEW
350130022	70.3	65.7	4.6	65.2	5.1	Dona Ana	SANTA TERESA
350130023	64.3	61.8	2.5	60.6	3.7	Dona Ana	750 N.SOLANO DRIVE
350151005	70.3	68.2	2.1	65.2	5.1	Eddy	CARLSBAD
350171003	65	63.7	1.3	62.2	2.8	Grant	HURLEY
350290003	63	61.1	1.9	59.2	3.8	Luna	DEMING
481410029	65	59.3	5.7	59.5	5.5	El Paso	Ivanhoe
481410037	71	64.2	6.8	64.5	6.5	El Paso	UTEP
481410044	69	62.6	6.4	63.1	5.9	El Paso	Chamizal
481410055	66.3	59.9	6.4	60.4	5.9	El Paso	Ascarate Park
481410057	66	60.3	5.7	60.7	5.3	El Paso	Socorro Hueco
481410058	69.3	64	5.3	64.4	4.9	El Paso	Skyline Park

We compared the sensitivity and source apportionment results to see whether they are consistent in their estimates of the importance of the ozone contribution from Mexico. The Mexico Anthro Contribution is similar in magnitude in the source apportionment and the sensitivity testing results (Table 3-14).

Table 3-14. Contribution of Mexico emissions to 2011 DVs for Doña Ana County monitors (4-km grid results): comparison of CAMx zero out sensitivity test (Task 11) and source apportionment (Task 12) results.

	Average (ppb)	Maximum (ppb)	Minimum (ppb)
Sensitivity Test Results	5.1	6.3	3.7
Source Apportionment Results	4.9	6.3	2.5

The source apportionment and sensitivity test results are consistent in showing that Mexico emissions had a significant impact on Doña Ana County design values in 2011 and that the Desert View monitor would have attained the 70 ppb NAAQS but for the contribution of anthropogenic emissions from Mexico. The source apportionment results and the sensitivity test show similar maximum and average impacts and the sensitivity test has a higher minimum impact.

3.12.1.3 Contribution of Fire Emissions to Doña Ana County Ozone

In 2011, the southwestern U.S. had an active fire season, with a number of large fires occurring in the SNMOS 12-km domain. The CAMx modeling of 2011 showed intermittent large impacts from fire emissions. For example, on June 5, 2011, there were several large wildfires burning within the 12-km domain. In the left panel of Figure 3-43, there are areas of $PM_{2.5}$ emissions at the location of these fires, which were also apparent in satellite imagery for June 5 (Figure 3-13). The right hand panel of Figure 3-43 shows CAMx modeled 1-hour ozone for 0Z on June 5, and the plumes from the wildfire emissions in the left panel are apparent as regions of enhanced ozone. The Wallow Fire plume has modeled 1-hour ozone values exceeding 160 ppb, while ozone outside the plume ranges from ~50-70 ppb. The Wallow Fire plume passes over several ozone monitors in northern New Mexico and southern Colorado, but the monitors do not show enhanced ozone concentrations comparable to the modeled plume. The model overestimates ground level ozone impacts from the Wallow Fire plume as well as the other fires in the 12-km domain on June 5. This overestimate of fire plume ozone impacts was typical of SNMOS CAMx model performance.

The modeled ozone impacts of fires depend on accurate characterization of fire emissions and simulation of the transport, chemical transformation, and fate of emitted ozone precursors and the ozone that forms from them. Fire emissions contain uncertainties in both their magnitude and their chemical composition (e.g,. Wiedinmyer et al. 2011; Jaffe and Wigder, 2012). The chemical composition of the emissions plays a role in the photochemistry of the resulting fire plume and therefore the resulting ozone impact.

The chemistry of ozone production in fire plumes is an area of active research. Measurement campaigns in which aircraft made transects through fire plumes and measured ozone and other trace gases have produced a range of results regarding the magnitude of ozone production in fire plumes (e.g., Bertschi et al., 2004; Alvarado et al; 2010). Jaffe and Wigder (2012) note that there is not a clear relationship between the quantity of ozone precursor emissions released into the atmosphere and the ozone produced in the plume downwind of the fire. Wigder et al. (2013) hypothesize that plume rise and the altitude of subsequent plume transport can affect ozone production in the plume because temperatures are lower at higher altitudes. The interaction of fire plumes with anthropogenic emissions is not well understood. Singh et al. (2012) and Wigder et al. (2013) found enhanced ozone in fire plumes that mixed with air containing urban emissions. The presence of aerosols (smoke) in the fire plume can reduce the amount of sunlight available to initiate photochemistry, inhibiting ozone formation (e.g. Parrington et al., 2013).

Finally, in order to simulate the transport of ozone and precursors away from a fire, the meteorological model must successfully reproduce the true wind field and accurately represent vertical transport of emitted and secondary pollutants. Even if the photochemical accurately represents the amount of ozone and precursors in the fire plume, there will be bias in the modeled ground level ozone if transport and vertical mixing are not accurately simulated. In the SNMOS modeling, for example, it is possible that the modeled Wallow Fire plume affected the surface while in the real world, the fire plume passed over the monitor aloft without mixing down to the surface.

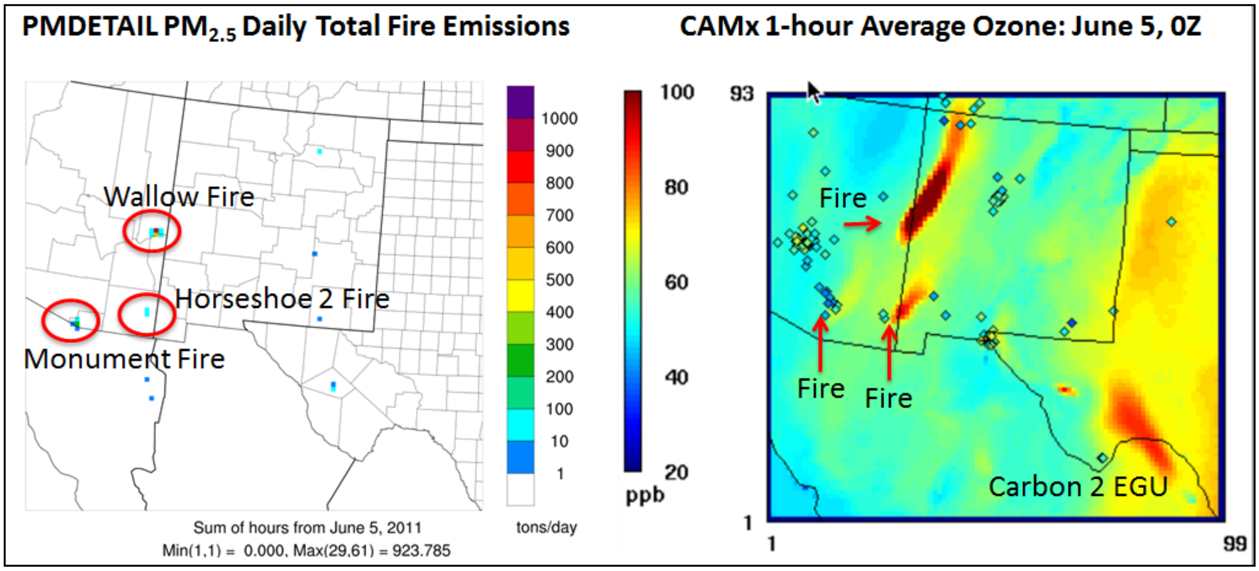


Figure 3-43. Fire emission ozone impacts on June 5, 2011. Left panel: PMDETAIL $PM_{2.5}$ emissions indicating the location of fires on June 5. Larger fires within the 12-km domain are circled in red. Right panel: CAMx 1-hour average modeled ozone for 0Z on June 5. Monitor locations are indicted by diamonds and the observed value for 0Z June 5 is indicated by the color within the diamond. The location of large fires and the ozone plume from the Carbon II Power Plant in Mexico are shown.

In the SNMOS source apportionment modeling, we treated fires separately from the rest of the natural emission inventory so their impacts could be tracked. We used source apportionment to quantify the effect of fire emissions on Doña Ana DVs in order to assess the uncertainty introduced into the design value analysis by the fire emissions modeling. Table 3-15 shows the future year 2025 design values (DVF) with and without the contribution from fire emissions for all monitors in the 4-km domain. The difference between these two DVFs is the impact of fire emissions on each monitor's design value. The impact of fire emissions on the 4-km grid monitor 2025 DVFs was < |0.5| ppb for all monitors. This indicates that fire emissions did not have a substantial effect on the design value results for monitors in the 4-km grid.

Table 3-15. Impact of fire emissions on 4-km grid monitor 2025 design value results.

Site ID	State	County	2011 DVC (ppb)	2025 Design Values (ppb)		Fire Impact on 2025 DVF (ppb)	Site Name
				DVF (without fires)	DVF (with fires)		
350130008	New Mexico	Dona Ana	64.7	58.3	58.3	0.006	LA UNION
350130017	New Mexico	Dona Ana	66.7	61.4	61.3	-0.007	SUNLAND PARK
350130020	New Mexico	Dona Ana	67.7	61.3	60.8	-0.439	CHAPARRAL
350130021	New Mexico	Dona Ana	71.0	65.1	65.1	-0.007	DESERT VIEW
350130022	New Mexico	Dona Ana	70.3	63.8	63.8	-0.007	SANTA TERESA
350130023	New Mexico	Dona Ana	64.3	58.6	58.7	0.108	SOLANO
350151005	New Mexico	Eddy	70.3	67.6	67.9	0.295	CARLSBAD
350171003	New Mexico	Grant	65.0	62.0	62.0	0.013	HURLEY
350290003	New Mexico	Luna	63.0	58.6	58.6	-0.038	DEMING
481410029	Texas	El Paso	65.0	58.4	58.4	0.006	Ivanhoe
481410037	Texas	El Paso	71.0	65.3	65.2	-0.163	UTEP
481410044	Texas	El Paso	69.0	62.5	62.7	0.158	Chamizal
481410055	Texas	El Paso	66.3	60.1	60.1	0.007	Ascarate Park
481410057	Texas	El Paso	58.7	59.8	59.8	0.000	Socorro Hueco
481410058	Texas	El Paso	69.3	62.1	61.7	-0.380	Skyline Park

The MATS design value analysis presented in Table 3-15 applies only to the monitoring sites within the 4-km domain. To determine whether fire emissions influenced ozone design values away from the monitoring sites, we performed a MATS Unmonitored Area Analysis (UAA). The UAA was performed by interpolating DVCs from monitoring sites to each grid cell in the modeling domain using the Voronoi Neighbor Averaging interpolation technique. The modeled ozone gradients are taken into account in the interpolation in order to reflect modeled higher and lower ozone areas in the interpolated DVC field. An unmonitored area analysis was performed that interpolated the 2011 DVCs across the modeling domain and performed ozone projections using the modeling results within each grid cell only. Figure 3-44 shows the results of the UAA for 2011 with the impacts of fire emissions included (left panel) and excluded (right panel). The difference of these two fields is shown in Figure 3-45. Figure 3-45 shows that larger fire impacts on design values (> 5 ppb) occurred away from monitoring sites within the 4-km domain downwind of 2011 fires. For example, the plume from the Horseshoe 2 Fire (Figure 3-43) in eastern Arizona extends into southwestern New Mexico and the ozone impacts of a number of other fires are apparent within the 4-km grid. Impacts away from the monitors exceeded 5 ppb in some of these plumes. Given the high bias seen in the CAMx simulated ozone downwind of fires in the 2011 model performance evaluation, these impacts may be overestimated and must be considered highly uncertain. However, because of the location of the fires in 2011 and wind patterns that caused plumes to miss the monitors in the 4-km domain, this uncertainty does not affect the design value results at the monitors. Results for the future year 2025 modeling are shown in Figure 3-46 and Figure 3-47and are similar to those of 2011.

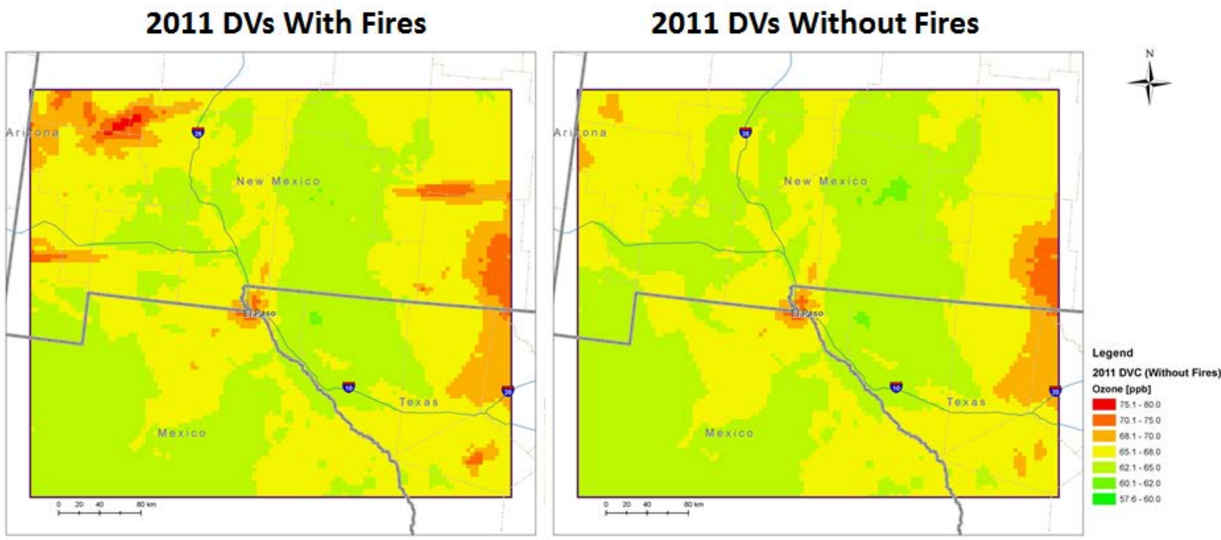


Figure 3-44. Impact of fire emissions on 4-km grid design value results: 2011 MATS Unmonitored Area Analysis.

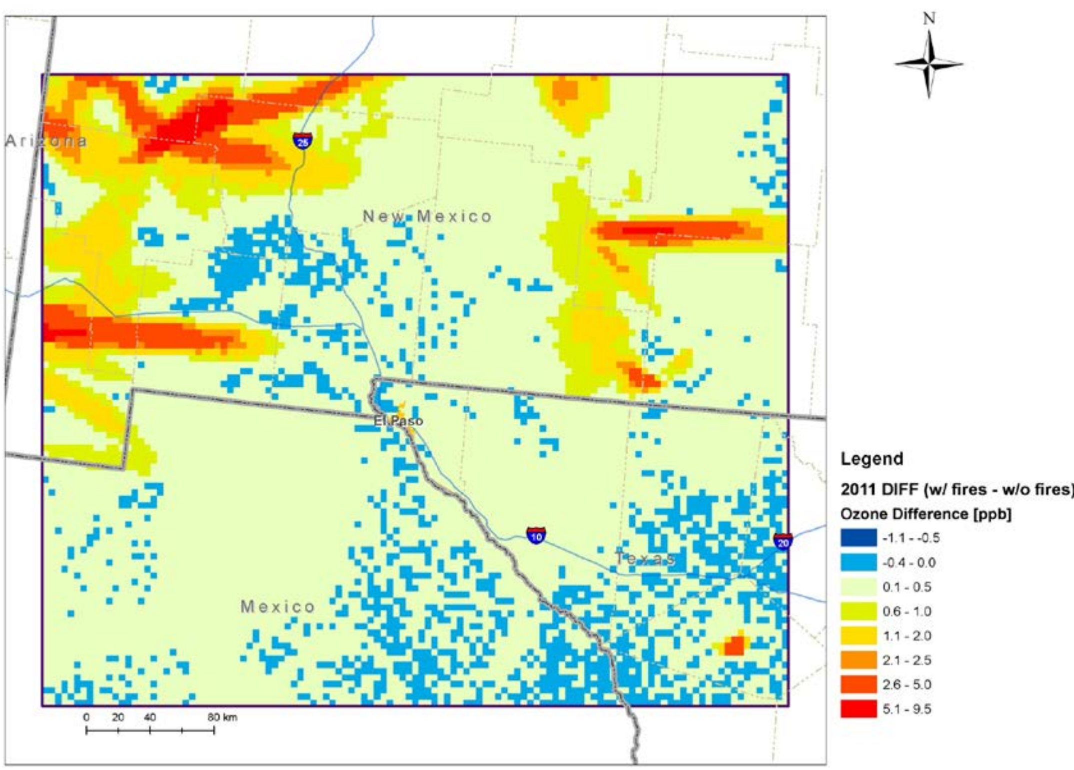


Figure 3-45. Impact of fire emissions on 4-km grid design value results: 2011 MATS Unmonitored Area Analysis: DVC(with fire contribution) - DVC(without fire contribution).

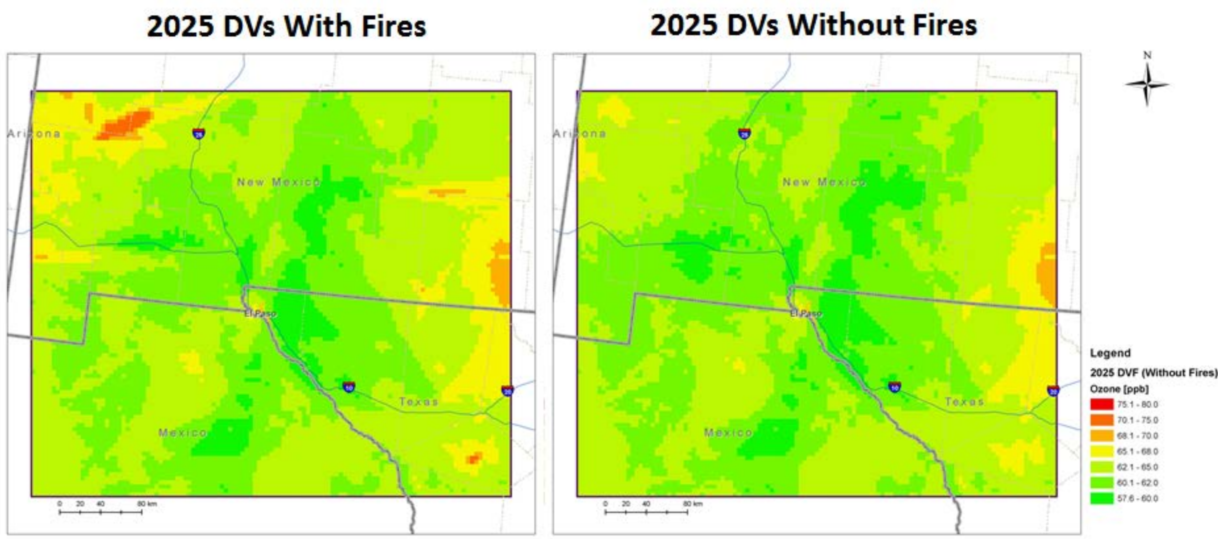


Figure 3-46. Impact of fire emissions on 4-km grid design value results: 2025 MATS Unmonitored Area Analysis.

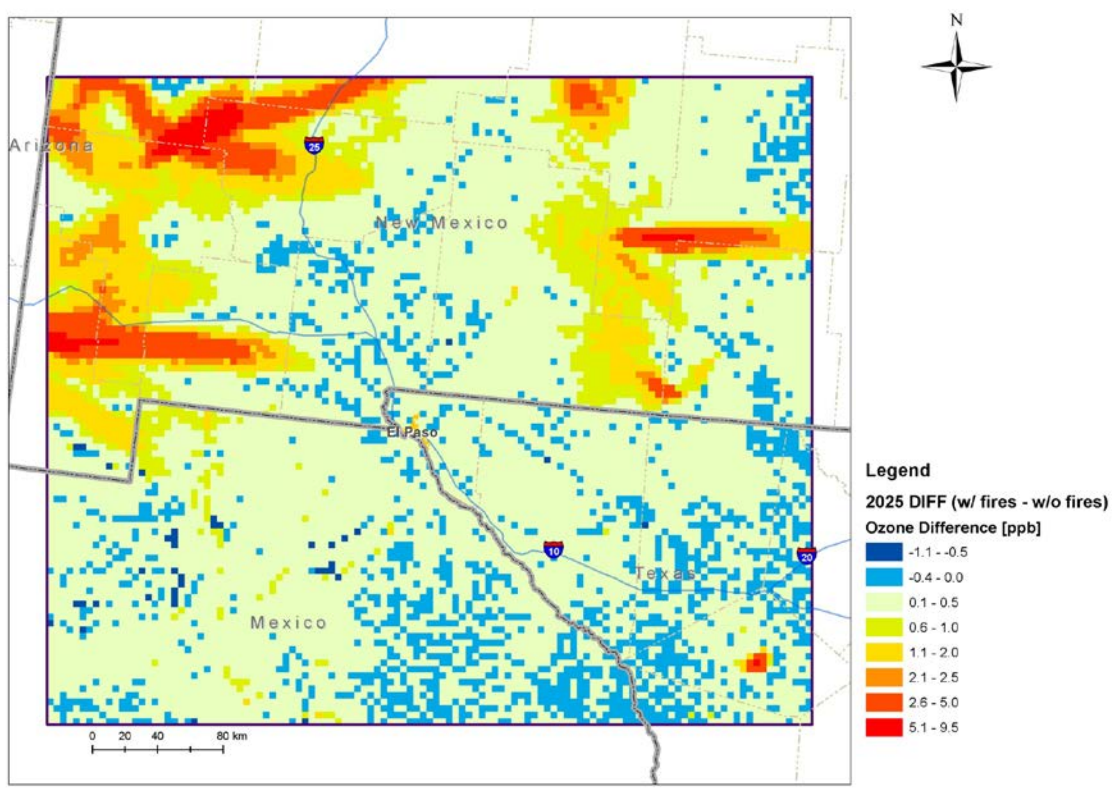


Figure 3-47. Impact of fire emissions on 4-km grid design value results: 2011 MATS Unmonitored Area Analysis: DVF(with fire contribution) - DVF(without fire contribution).

3.12.1.4 Source Apportionment Visualization Tools Overview

The SNMOS modeling results were loaded into a web-based Source Apportionment Visualization Tool (SA Vis Tool) on the Intermountain West Data Warehouse website (**http://views.cira.colostate.edu/tsdw/**). Documentation of the source apportionment results may be found in the SNMOS wiki on the IWDW website[11] (Figure 3-48).

Figure 3-48. IWDW web page.

The SNMOS ozone design value source apportionment modeling analysis is available in an interactive Excel spreadsheet that can be accessed through a link in the SNMOS wiki page. To display the Source Group contributions to 2011 and 2025 MDA8 ozone concentrations, the user can access the SNMOS 2011 and 2025 SA Vis Tool through the SNMOS wiki. The SA Vis Tools generate pie charts of 2011 and 2025 ozone contributions by Source Region, Source Category or both (i.e., Source Groups) for monitoring sites within the SNMOS 4-km modeling domain. The SA Vis Tools can be used to display base (2011) and future (2025) year MDA8 SA results. The SA Vis Tools provide source apportionment results as well as information on CAMx model performance by monitor and by date.

[11] http://vibe.cira.colostate.edu/wiki/wiki/9131/southern-new-mexico-ozone-study-snmos-2011-and-2025-ozone-source-apportionm

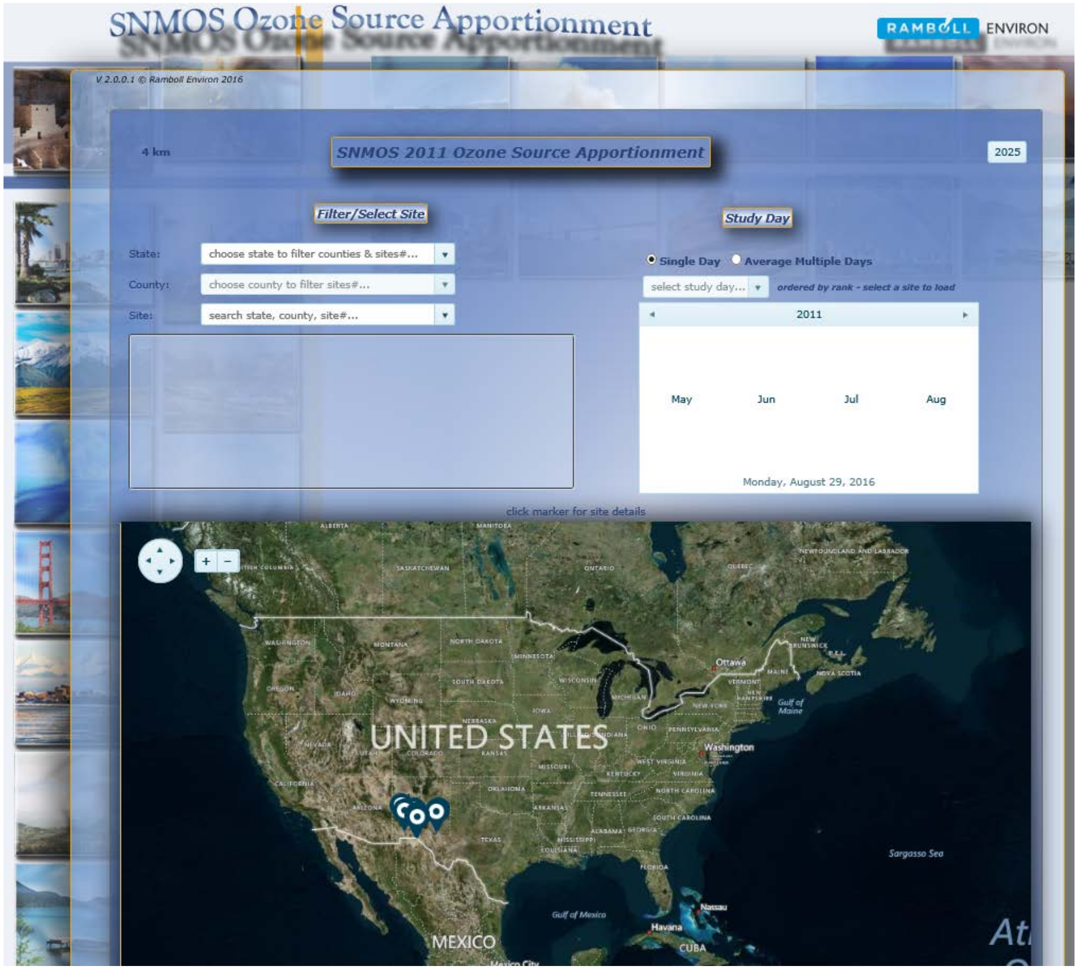


Figure 3-49. SNMOS SA Vis Tools website.

3.12.2 Significant Findings

Transport plays an important role in determining ozone levels in Doña Ana County. For Doña Ana County monitors, the 12-km grid boundary conditions were the largest contributor of ozone; this is a typical result for a regional modeling study. The contribution of New Mexico emissions to Doña Ana County monitor design values is smaller than the contributions of Texas and Mexico for all Doña Ana monitors except Solano, which has a large on-road mobile contribution from New Mexico on-road mobile emissions.

The source apportionment results indicate that the contribution of Mexico anthropogenic emissions to Doña Ana monitor 2011 design values ranges from 2.5 – 6.3 ppb with an average of 4.9 ppb. The source apportionment results confirm that all Doña Ana County ozone monitors, including Desert View, would have attained the 70 ppb ozone NAAQS in 2011 but for the ozone contribution due to anthropogenic emissions from Mexico.The source apportionment (Task 12) and Sensitivity Test (Task 11) model analyses are consistent in showing this result.

The emissions sources within the 12/4 km modeling domains that contributed the most ozone to Doña Ana County ozone monitors in 2011 were: (1) on-road mobile emissions from Texas, Mexico and New Mexico; (2) power plant emissions from Mexico; and (3) natural emissions from Mexico. In 2025, the emissions sources within the 12/4 km modeling domains that contributed the most ozone to Doña Ana County ozone monitors were: (1) on-road mobile emissions from Texas and Mexico; (2) power plant non-power plant point source emissions from Mexico; and (3) natural emissions from Mexico.

Of all New Mexico anthropogenic emissions sources, on-road mobile emissions make the largest contribution to design values at Doña Ana monitors. New Mexico anthropogenic emission sources that contributed the most ozone to New Mexico monitors in the SNMOS 4-km grid were: (1) on-road mobile; (2) offroad mobile; (3) oil and gas; and (4) power plants. Oil and gas emissions made the largest New Mexico anthropogenic contribution at the Carlsbad monitor due to its closer proximity to the Permian Basin. The impact of oil and gas sources increases in 2025 due to projected growth in Permian Basin emissions.

Fire emissions had a small (≤ |0.5| ppb) effect on 2011 and 2025 DVs at Doña Ana County monitors. These impacts are too small to affect the attainment status results for 2011 and 2025. The small magnitude of the impacts is due to location of monitors relative to 2011 fires and 2011 winds. Fire emissions had a larger effect on 2011 and 2025 DVs at grid cells elsewhere in the 4-km domain with the UAA showing design value impacts exceeding 5 ppb downwind of the fire locations.

3.12.3 Milestones and Deliverables

- Carry out SNMOS ozone source apportionment CAMx modeling of 2011 and 2025 (Completed July 18, 2016)
- PowerPoint presentation on ozone source apportionment modeling (Completed September 8, 2016)
- Wiki and SA Vis Tools Provide interactive spreadsheet source apportionment results on ozone DVs(Completed September 8, 2016)
- Provide SA Visualization Tool for 2011 and 2025 ozone contributions to MDA8 ozone at monitors (hosted on IWDW and available through wiki) (Completed September 8, 2016)

3.13 Task 13: Technical Support Document

3.13.1 Task Summary

A Technical Support Document that (TSD) that summarizes the SNMOS (this document) was prepared and submitted to the NMED.

3.13.2 Significant Findings

UNC-IE and Ramboll Environ prepared a draft TSD documenting Tasks 1-12 and submitted the draft TSD for review. The draft TSD will be updated to reflect comments received and a Response to Comments (RtC) document will be prepared and submitted along with the final AQTSD.

3.13.3 Milestones and Deliverables

- Draft Technical Support Document (TSD) (completed September 30, 2016)
- Final TSD (to completed by November 18, 2016)
- Response to Comments (RtC) document for NMED (to completed by November 18, 2016)
- Modeling data, RtC document, and final TSD posted on WAQS data warehouse (to completed by November 18, 2016)

4.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

In this section, we summarize the main findings of the SNMOS. We discuss the major sources of uncertainty noted during the study and provide recommendations for future work to reduce these uncertainties.

4.1 SNMOS Major Findings

- 2025 future year design value projections indicate that all Doña Ana County ozone monitors are expected to attain the 70 ppb ozone NAAQS in 2025.
  - o The finding of attainment was not sensitive to the method used in the MATS design value projection procedure, the model's bias in simulating ozone, or to the modeling of fire emissions
  - o The finding of attainment was robust under a sensitivity test in which projected reductions in on-road mobile emissions by 2025 were smaller than EPA MOVES model estimates
- The projected decreases in Doña Ana County ozone design values between 2011 and 2025 are mainly driven by projected reductions in on-road mobile source emissions.
- All Doña Ana County ozone monitors would have attained the 70 ppb ozone NAAQS in 2011 but for the ozone contribution due to anthropogenic emissions from Mexico.
- Emissions sources within the 12/4 km modeling domains that contributed the most ozone to Doña Ana County ozone monitors in 2011 were: (1) on-road mobile emissions from Texas, Mexico and New Mexico; (2) power plant emissions from Mexico; and (3) natural emissions from Mexico.
- Emissions sources within the 12/4 km modeling domains that contributed the most ozone to Doña Ana County ozone monitors in 2025 were: (1) on-road mobile emissions from Texas and Mexico; (2) power plant non-power plant point source emissions from Mexico; and (3) natural emissions from Mexico.
- Ozone transport plays an important role in determining ozone levels in Doña Ana County. For Doña Ana County monitors, the 12-km grid boundary conditions were the largest contributor of ozone; this is a typical result for a regional modeling study. For all Doña Ana County monitors except Solano, the ozone contribution from Texas and Mexico was larger than that of New Mexico.
- New Mexico anthropogenic emission sources that contributed the most ozone to New Mexico monitors in the SNMOS 4-km grid were: (1) on-road mobile; (2) offroad mobile; (3) oil and gas; and (4) power plants.
- Oil and gas emissions are the largest New Mexico anthropogenic contribution at the Carlsbad monitor due to its closer proximity to the Permian Basin. The impact of oil and gas sources increases in 2025 due to projected growth in Permian Basin emissions.

4.2 Recommendations for Future Work

Based on our evaluation of model performance and the major uncertainties in the SNMOS, we make the following recommendations for future work.

4.2.1 WRF Meteorological Modeling

WRF meteorological model performance is a source of uncertainty in the SNMOS. While WRF performance was improved using the Multiscale (grid-aware) Kain-Fritsch cumulative cloud scheme, the model was still unable to consistently simulate precipitation, temperature and wind patterns related to the North American monsoon. This likely degraded the CAMx model's simulation of ozone in southern New Mexico.

Recommendation: Perform additional sensitivity testing to refine the WRF configuration with the aim of improving model performance in simulating temperatures, winds and precipitation improves during the months when the North American Monsoon is active.

4.2.2 Natural Emissions

Modeling of natural emissions (biogenics, fire and lightning) is an active area of scientific research, and the SNMOS emission inventories should be considered to have considerable uncertainty associated with them. In order to understand and possibly reduce this uncertainty, additional study of these emissions and their effect on Doña Ana County ozone should be undertaken.

In the MEGAN v2.1 biogenic inventory, there is a discontinuity in isoprene and monoterpene emissions at the U.S.-Mexico border with emissions larger in Mexico than in the U.S. for environments that appear from Google Earth imagery to have comparable vegetation cover.

Recommendation: Further investigation of differences in U.S. and Mexico MEGAN inputs should be undertaken to understand their origin and to ensure that the most accurate and consistent input data available are used as well as using the most up-to-date calculation methods to develop emissions on both sides of the border.

While modeling of fire emissions did not have a substantial effect on the design value analysis at Doña Ana County monitors, fires had impacts exceeding 5 ppb on design values for grid cells elsewhere in the modeling domain. In an episode in which fires are in different locations and wind patterns are different, fire emissions may have a large influence on Doña Ana County monitors and may introduce significant uncertainty, complicating air quality planning efforts.

Recommendation: Perform a detailed analysis of the fire emissions, their modeling, and the resulting CAMx air quality model simulation of the fire plume in order to better understand the reasons for CAMx overestimates of ozone at ground level monitoring sites during 2011.

LNOx emissions are intermittent, but can contribute to regional background ozone. In the SNMOS model performance evaluation, CAMx had a high bias during July and August and better performance earlier in the episode, before the onset of the monsoon, when intense convection and associated lightning occur across the region.

Recommendation: Investigate the effect of LNOx emissions on modeled ozone by zeroing out the SNMOS LNOx emissions and comparing the resulting ozone with the 2011 model base case. If there is a significant effect on model performance (such as a reduction in model high bias in July and August), efforts should be made to improve the treatment of LNOx emissions in the Southern New Mexico ozone modeling. We recommend a review of current parameterizations for specifying LNOx emissions to determine whether an alternate approach would be beneficial and whether satellite data can be used to constrain LNOx emissions over Southern New Mexico and the surrounding region, including Mexico.

4.2.3 Anthropogenic Emissions

The SNMOS used the best available anthropogenic emission inventories for the region. However, uncertainties in these inventories may affect the SNMOS modeling results as well as future air quality planning efforts for Doña Ana County.

Much of the reduction in Doña Ana County design values between 2011 and 2025 is driven by reductions in on-road mobile emissions. Therefore, the projection of attainment of the NAAQS by 2025 for Doña Ana monitors depends on the accuracy of these estimates of on-road mobile emissions. In the SNMOS, we used EPA's NEI on-road mobile emission estimates, which were calculated using the MOVES model. Given the importance of on-road mobile emissions for air quality planning in Doña Ana County, we recommend further evaluation of the inventory.

Recommendation: Review the MOVES inputs and model configuration for the emissions modeling in the 2011 NEI platform with the goal of evaluating the likelihood of the modeled reductions in regional on-road mobile emissions between 2011 and 2025.

Anthropogenic emissions from Mexico are a source of uncertainty in the SNMOS modeling. The data used in the SNMOS were determined to be the most complete and accurate available information, but are based on 2008 data.

Recommendation: We recommend that the NMED continue to work with air quality planning partners in Mexico to ensure that the most complete and recent available emissions data available for Mexico are integrated into modeling efforts for Southern New Mexico.

New Mexico and Texas Counties within the Permian Basin showed increases in oil and gas emissions between 2011 and 2025, and the increased emissions were reflected in the increased ozone contribution from oil and gas sources in 2025. Oil and gas emissions in these counties were among the few U.S. source groups to show an increase in projected emissions in 2025 relative to 2011. Permian Basin emissions are based on 2014 AEO activity projections. Because the oil and gas industry undergoes rapid changes in response to fluctuations in pricing and domestic and foreign production, we recommend that the Permian Basin projections be revisited before any future modeling effort is carried out.

Recommendation: Update activity projections for the Permian Basin in advance of future ozone modeling efforts.

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