May 2020

NEW MEXICO OZONE ATTAINMENT INITIATIVE PHOTOCHEMICAL MODELING STUDY - DRAFT WORK PLAN

RAMBOLL

WESTAR
Western States Air Resources Council

NEW MEXICO OZONE ATTAINMENT INITIATIVE PHOTOCHEMICAL MODELING STUDY - DRAFT WORK PLAN

Project name	**New Mexico Environmental Division**
Project no.	**1690017454**
Recipient	**New Mexico Environmental Division**
Document type	**Work Plan**
Version	**V1.0**
Date	**May 26, 2020**
Prepared by	**Ralph Morris, Marco Rodriguez, Tejas Shah, Jeremiah Johnson, Fiona Jiang, Ramboll US Corporation**
	Tom Moore and Mary Uhl, Western states Air Resources Council

Ramboll
7250 Redwood Blvd.
Suite 105
Novato, CA 94945

T +1 415 899 0700
www.ramboll.com

CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

ACRONYMS AND ABBREVIATIONS

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

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

1. INTRODUCTION

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

1.1 NM OAI Project Genesis

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

To address the high observed ozone concentrations in New Mexico, the NMED has embarked on an OAI[3] to protect the ozone attainment status of the state and ensure health and welfare of the residents of the state for future generations. The OAI was initiated in Spring 2018.

1.2 Overview of NM OAI Study Modeling Approach

This Draft Work Plan describes the modeling activities to be performed under the NM OAI Study. The NM OAI Study will conduct PGM modeling by enhancing the WRAP/WAQS 2014 modeling platform[4] to use a 4-km grid resolution domain covering New Mexico and surrounding areas, especially the oil and gas (O&G) production regions in the Permian and San Juan Basins. The NM OAI Study PGM modeling will conduct 2014 base year modeling and model performance evaluation as well as 2023 future year modeling. The 2023 future year modeling will include ozone source apportionment

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

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

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

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

and control measure sensitivity modeling. Details on the NM OAI Study PGM modeling approach are provided in a Modeling Protocol (WESTAR and Ramboll, 2020).

1.3 Overview of the Modeling Approach

The NM OAI Study will conduct photochemical modeling for a 2014 base and 2023 future year and perform 2023 ozone source apportionment and control strategy sensitivity modeling as outlined in the draft Modeling Protocol (WESTAR and Ramboll, 2020Z).

1.3.1 Episode Selection

The May-August 2014 modeling period was selected as it has elevated ozone concentrations, a high quality emissions inventory with western state updates and has a PGM platform already developed from the WRAP/WAQS regional haze modeling.

1.3.2 Model Selection

The Weather Research Forecast (WRF; Skamarock et al., 2004,22008, 2019; Michalakes et al., 1998, 2001, 2004) prognostic meteorological model was selected with the 4-km grid covering New Mexico. Emissions modeling will be performed using the Sparse Matric Operator Kernel Emissions (SMOKE; Coats, 1995; UNC, 2015) model for most source categories. The Model of Emissions of Gases and Aerosols from Nature (MEGAN; Guenther and Wiedenmyer, 2004; Guenther et al., 2014; Wiedenmyer et al., 2007) will be used for biogenic emissions and there are special processors for fires, windblown dust (WBD), lightning NOx (LNOx) and oceanic sea salt (NaCl) and Dimethyl Sulfide (DMS) emissions. The 2014 version of the MOtor Vehicle Emissions Simulator (MOVES2014b; EPA, 2014a,b,c) on-road mobile source emissions model will be used with SMOKE-MOVES and WRF meteorological data to generate on-road mobile source emissions for the 4-km New Mexico and 12-km western U.S. modeling domains. The Comprehensive Air-quality Model (CAMx; Ramboll, 2018a) PGM will be used because it supports two-way grid nesting, includes a subgrid-scale Plume-in-Grid module, contains a well-vetted ozone source apportionment tool and has a rich and successful history of application to the region.

1.3.3 Domain Selection

The same 36-km 36US and 12-km 12WUS2 modeling domains as used in the WRAP/WAQS 2014 modeling will be used in the NM OAI Study. A higher resolution 4-km domain will be added covering New Mexico and adjacent areas. New 2014 36/12/4-km WRF meteorological modeling will be conducted to provide the higher resolution meteorological fields needed for the 4-km New Mexico domain. Figure 1-1 displays the 36/12/4-km nested grid structure to be used in the NM OAI Study PGM modeling. Figure 1-2 shows the 4-km New Mexico modeling domain and the locations of ozo0ne monitoring sites in New Mexico.

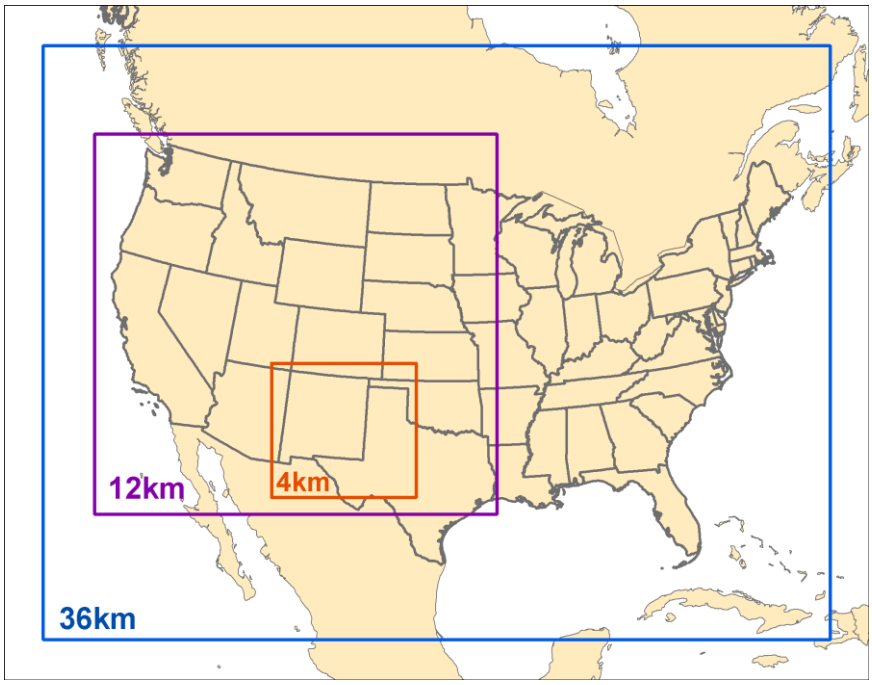

Figure 1-1. NM OAI Study modeling 2014 36/12/4-km PGM and emissions modeling domains.

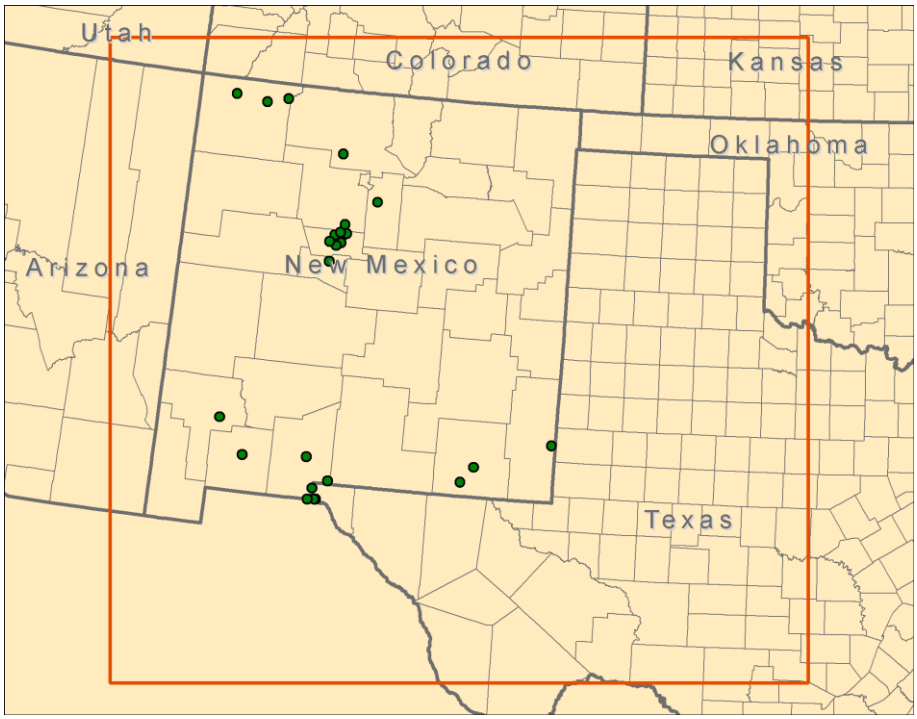

Figure 1-2. 4-km New Mexico modeling domain for PGM and emissions modeling, with locations of ozone monitors that were operating during some portion of 2014.

1.3.4 Base and Future Year Emissions Data

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

1.3.5 Meteorology Input Preparation

The CAMx 2014 36/12/4-km meteorological inputs will be based on new 2014 WRF meteorological modeling conducted by the WESTAR/Ramboll Team. The new WRF 2014 36/12/4-km modeling will be evaluated against measured meteorological parameters in a model performance evaluation. The 2014 36/12/4-km WRF output will be processed by WRFCAMx processors to generate meteorological inputs for CAMx.

1.3.6 Initial and Boundary Conditions Development

The first two-weeks of May will be run on the 36/12/4-km domains to spin-up the model before the first high ozone day in New Mexico (68 ppb on May 17). This will "wash out" the influence of the initial concentrations (ICs) before elevated ozone concentrations occur in New Mexico.

Boundary Conditions (BCs) for the lateral boundaries of the 36-km 36US domain (Figure 1-1) will be based on a 2014 simulation of the GEOS-Chem global chemistry model conducted by WRAP that was processed by the GC2CAMx converter to generate CAMx BC inputs. The result is day-specific diurnally varying BCs for the lateral boundaries around the 36-km 36US modeling domain (i.e., GCBC). The top BC (TopCon) will be based on a zero-gradient assumption where concentrations above the top of the model (at 50 mb, or ~19-km above sea level) are assumed to be the same as in the top vertical layer of CAMx.

1.3.7 Model Performance Evaluation

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

1.3.8 Diagnostic Sensitivity Analyses

Depending on the results of the CAMx 2014 base case modeling and MPE, diagnostic sensitivity tests may be conducted to try and improve model performance. The definition of these diagnostic sensitivity tests will depend on the results of the initial

MPE. The WRAP/WAQS development of the CAMx 2014v2 36/12-km modeling database conducted numerous sensitivity tests[5] leading to the final 2014v2 base case. Under the NM OAI Study we expect most of the sensitivity modeling to be conducted for the 2023 future-year where both emissions control strategy sensitivity and ozone source apportionment modeling is planned.

1.3.9 Future Year Control Strategy Modeling

Future year modeling for ozone will be performed for the 2023 future year. A CAMx 2023 36/12/4-km base case simulation will be conducted and projected 2023 ozone DVs calculated. The procedures to calculate projected 2023 ozone DVs will follow EPA's latest guidance (EPA, 2018b). These procedures use the modeling results in a relative fashion to scale the current year observed 8-hour ozone Design Values (DVCs) to project future year ozone Design Values (DVFs). The scaling factors are called Relative Response Factors (RRFs) and are the ratio of the future-year to current-year modeling results for the 10 highest base year modeled MDA8 ozone days near the monitoring site. EPA has developed the Speciated Modeled Attainment Test (SMAT[6]; Abt, 2014) tool that includes the recommended procedures in the latest EPA guidance for projecting ozone DVFs. 2023 future year control strategy sensitivity modeling will also be performed to evaluate the effects alternative control measures will have ozone concentrations in New Mexico.

1.3.10 Future Year Source Apportionment Modeling

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

[5] http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx

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

2. SCOPE OF WORK

The WESTAR/Ramboll Team will conduct the NM OAI Study photochemical modeling in 7 Tasks as given below. Details of the procedures are provided in the Modeling Protocol (WESTAR and Ramboll, 2020)

2.1 Task 1: Formal Modeling Protocol and Quality Assurance Project Plan and Work Plan

Objective: To prepare a hybrid Modeling Protocol/Quality Assurance Project Plan (Protocol/QAPP) following EPA's latest emissions and modeling guidance to provide a roadmap for how the NM OAI Study PGM modeling will be conducted. This task will also prepare a Work Plan (this document) that includes an updated SOW, schedule and list of deliverables.

Approach: We will prepare a Modeling Protocol/QAPP following EPA's latest guidance for preparing ozone Modeling Protocols for ozone SIP modeling (EPA, 2018b[7]), implementation of the 2015 ozone NAAQS (EPA, 2016a; 2017d; 2018a) and preparing QAPPs.[8] We will also prepare a Work Plan under this task. EPA's latest ozone SIP modeling guidance lists the elements that should be included in a Modeling Protocol that was included in the WESTAR/Ramboll NMED OAI Proposal dated January 20, 2020. A draft Modeling Protocol/QAPP will be provided to the NMED who will provide comments. The contents of the Modeling Protocol/QAPP will be discussed with NMED in a webinar where additional comments may be received. We will prepare a Response-to-Comments (RtC) document and update the Modeling Protocol/QAPP and Work Plan. Also under this task we will develop a NM OAI Study webpage on the WRAP website similar to the Southern New Mexico Ozone Study (SNMOS[9]) webpage. With NMED concurrence, the first things posted on the NM OAI Study webpage will be the final Modeling Protocol/QAPP, RtC document, Work Plan and presentation from the first project webinar in May.

Deliverables:

- Draft Work Plan
- Draft Modeling Protocol/QAPP
- Webinar with PPT on Final Approach and Work Plan
- Final Modeling Protocol/QAPP
- Final Work Plan
- Response-to-Comments (RtC) document
- NM OAI Study Webpage.

2.2 Task 2: Base Year Meteorological Modeling

The 2014 base year meteorological modeling will be conducted in three subtasks.

2.2.1 Subtask 2.1: Evaluate Existing Base Year Meteorological Modeling

Objective: To evaluate existing 2014 WRF simulations in New Mexico to help define the WRF configuration for the NM OAI Study 36/12/4-km meteorological modeling (Subtask 2.2).

[7] https://www3.epa.gov/ttn/scram/guidance/guide/O3-PM-RH-Modeling_Guidance-2018.pdf
[8] https://www.epa.gov/quality/quality-assurance-project-plan-development-tool
[9] https://www.wrapair2.org/SNMOS.aspx

Approach: The WAQS 2014 36/12-km and EPA 12-km WRF simulations will be evaluated using surface meteorological data at monitoring sites in New Mexico. The two 2014 WRF simulations will be evaluated for wind speed, wind direction, temperature and humidity using the METSTAT software. A qualitative evaluation of the WRF precipitation estimates will be made by comparing them to the PRISM data (Daly et al., 2008). The results will be documented in a PowerPoint presentation that will be presented to the NMED at the first NM OAI Study Webinar and posted to the NM OAI Study Webpage.

Deliverables:

- PowerPoint (PPT) presentation presented at first NM OAI Study Webinar in May 2020 on the evaluation of the existing WAQS and EPA 2014 WRF meteorological model performance within New Mexico and recommendations for how the new NM OAI Study 2014 36/12/4-km WRF modeling will be conducted.

2.2.2 Subtask 2.2: Additional Meteorological Modeling

Objective: To develop 36/12/4-km meteorological inputs for PGM modeling of New Mexico for summer 2014 using 4-km grid resolution over New Mexico

Approach: We will conduct summer 2014 WRF 36/12/4-km resolution domain modeling with the 4-km domain focused on New Mexico and surrounding areas. The 2014 WRF configuration will be defined based on analysis of previous WRF simulations. The WRF 2014 36/12/4-km simulation will be subjected to a model performance evaluation for surface meteorology and precipitation with particular focus on performance within New Mexico.

Deliverables:

- Webinar with PPT on application and evaluation of WRF for summer 2014 and a 4-km modeling domain covering New Mexico and surrounding areas that will be presented at the second project Webinar in June 2020.

2.2.3 Subtask 2.3: Process Meteorological Data

Objective: To generate CAMx 36/12/4-km meteorological inputs for the May-August 2014 period.

Approach: The Task 2.2 2014 36/12/4-km WRF output will be processed using the WRFCAMx processor to develop CAMx 36/12/4-km meteorological inputs for the May-August 2014 period. WRFCAMx will be run to develop vertical turbulent exchange coefficient (Kz) using both the YSU and CMAQ-like options.

Deliverables:

- CAMx 2014 36/12/4-km meteorological inputs for the May-August 2014 period.

2.3 Task 3: Evaluate 2014 Boundary Conditions

Objective: To define 2014 Boundary Conditions (BCs) for the 36-km 36US modeling domain for the summer 2014 36/12/4-km ozone modeling of New Mexico.

Approach: Under this task we will evaluate the 2014v2 BCs based on the WRAP revised 2014 GEOS-Chem modeling focusing on ozone performance at sites in New Mexico. We will also review updates to the GEOS-Chem model and model inputs since the WRAP revised 2014 GEOS-Chem

simulation was performed (Q3 2019) to see whether there are any GEOS-Chem model improvements available.

Deliverables:

- PPT on the evaluation of the BCs based on WRAP 2014 GEOS-Chem modeling.

2.4 Task 4: Base Year (2014) and Future Year (2023) Emission Inventories

Under this task we will collect data and develop Base Year (BY) 2014 and Future Year (FY) 2023 emission inventories for photochemical modeling of the summer 2014 and 4-km New Mexico and 36/12-km regional modeling domains. Task 4 will be carried out in five (5) subtasks as given below.

2.4.1 Subtask 4.1: Emissions Inventory of Sources in New Mexico

Objective: To develop updated 2014 and 2023 emission inventories for the 4-km New Mexico modeling domain.

Approach: We will first review and compare the available O&G, major point, other industrial and other sources emissions developed for the BY 2014 and FY 2023 for sources within New Mexico and neighboring areas of the New Mexico 4-km domain (e.g., San Juan and Permian Basin O&G sources). The proposed 2014 base year emissions and 2023 future year emissions for New Mexico will be provided to NMED who will make comments and update as needed. The 2014/2023 emissions will be discussed in the first project Webinar in May 2020. The 2014 and 2023 emissions for New Mexico will be updated to address NMED comments as needed.

Deliverables:

- PPT that will discuss available 2014 and 2023 emission sources for New Mexico and adjacent areas and recommended emission sources for use in the NM OAI Study.
- PPT that describes the final 2014 and 2023 emissions selected for use and the QA results and displays.

2.4.2 Subtask 4.2: Mobile Source Inventories

The 2014 and 2023 mobile source emissions will be prepared in two Subtasks as follows..

2.4.2.1 Subtask 4.2.1: Evaluate Existing Mobile Source Emissions

Objective: To review, evaluate and select mobile source emissions for use in the 2014 and 2023 modeling.

Approach: We will review and evaluate available on-road and non-road mobile source emissions, such as those from the EPA 2014 NEI and WAQS 2014v2 emissions and EPA 2016v1 platform emissions that include 2023 and 2028 emission projections. We will provide NMED with the mobile source activity data and settings for the MOVES2014 model used to model New Mexico on-road mobile source emissions for 2014 and 2023. NMED will review and update the 2014 and 2023 mobile source activity and MOVES2014 assumptions as necessary.

Deliverables:

- PPT on approaches for generating 2014 and 2023 on-road mobile source emissions and assumptions for 2014 on-road mobile source activity data and MOVES options.

2.4.2.2 Subtask 4.2.3: Prepare 2014 and 2023 Mobile Source Emissions

Objective: To develop 2014 and 2023 on-road mobile source emission inputs for the 4-km New Mexico modeling domain using SMOKE-MOVES.

Approach: We will conduct SMOKE-MOVES modeling for the 4-km New Mexico domain using EPA's 2014 and 2023 MOVES Emissions Factor (EF) Lookup Tables and the 2014 4-km gridded hourly meteorological data from Task 2.2 WRF modeling to generate model-ready 2014 and 2023 4-km on-road mobile source emission inputs. SMOKE-MOVES will also be run for the 12-km 12WUS2 domain using EPA's 2023 MOVES EF Lookup Table and 2014 12-km meteorology to generate 2023 on-road mobile source emission inputs. The existing WAQS 2014v2 12-km on-road mobile source emissions were generated using SMOKE-MOVES so will not have to be re-run.

Deliverables:

- On-road mobile source emissions inputs for 2014 and 2023 and the 4-km New Mexico domain.
- On-road mobile source emission inputs for 2023 and the 12-km domain.
- PPT on final 2014 and 2023 SMOKE-MOVES modeling.

2.4.3 Subtask 4.3: Biogenic and "Natural" Emissions

Objective: To develop 2014 biogenic and other "natural" emission inputs for the 36/12/4-km modeling domains.

Approach: There are five types of biogenic and "natural" emission sources that will be generated for the 2014 year and the 4-km NM modeling domain: (1) Biogenic VOC and NO_X emissions from vegetation and soils; (2) lightning NO_X emissions (LNOx); (3) oceanic Sea Salt (SSA) and Dimethyl Sulfide (DMS); (4) Windblown Dust (WBD); and (5) fire emissions, including wildfires (WF), prescribed burns (Rx) and agricultural burning (Ag) open land fire emissions. Natural emissions will be held constant at 2014 levels for the 2023 modeling. The MEGAN biogenic emissions model will be used with the 2014 WRF data to develop biogenic emissions for all three domains. 4-km resolution natural emissions will be generated for the NM domain. The WAQS 2014v2 natural emissions will be used for the 36/12-km domains.

Deliverables:

- Model-ready 2014 4-km NM modeling domain emission inputs for the 5 types of natural emissions.
- PPT on the natural emissions modeling.

2.4.4 Subtask 4.4: Prepare Base and Future Year Emissions with SMOKE

Objective: To conduct SMOKE emission modeling to prepare PGM inputs for the 2014 and 2023 emission years.

Approach: For 2014 and the 36/12-km domains, the WAQS 2014v2 model-ready PGM anthropogenic emissions will be used as is. For the 4-km New Mexico domain, SMOKE will be used to process the WAQS 2014v2 anthropogenic emissions, which may have been updated by NMED.

The 2023 emissions identified under Subtask 4.1 will be processed by SMOKE to generate emission inputs for the remaining source categories and the 4-km New Mexico domain. The EPA 2023 model-ready emissions will be used for the 36/12-km North America domains.

Deliverables:

- Model-ready 2014 and 2023 emission inputs for the 36/12/4-km domains and summer of 2014.
- PPT on the emissions modeling and results showing summary tables and tile plots of NO_X and VOC emissions.

2.4.5 Subtask 4.5: Prepare Alternative Future Year Emissions with SMOKE

Objective: To develop 2023 future year emission inputs for alternative control strategies.

Approach: The NMED will provide the WESTAR/Ramboll Team with the definitions of future year control strategies for modeling and we will implement the controls in the 2023 emissions and process them with SMOKE. We are assuming that the NMED will define and we will implement three (3) different 2023 control strategies for SMOKE emissions modeling.

Deliverables:

- Model-ready 2023 emission inputs for three control strategies
- PPT on the 2023 control strategies with summary tables and tile plots of NOx and VOC emissions.

2.5 Task 5: Base Year (2014) Air Quality Modeling

Objective: To conduct 2014 CAMx base case modeling and model performance evaluation and document the results from Tasks 2-5 in a formal report.

Approach: Using the 2014 36/12/4-km meteorological inputs from Task 2, 2014 BC inputs for the 36-km domain from Task 3 and 2014 36/12/4-km emission inputs from Task 4, we will conduct a summer of 2014 CAMx 36/12/4-km base case simulation. The PGM configuration will be the same as used in the WAQS 2014v2 base case simulation with any updates as identified in the Task 1 Modeling Protocol/QAPP. Potentially diagnostic sensitivity tests will be conducted (e.g., using the YSU and CMAQ-like Kz profiles). A model performance evaluation (MPE) of the CAMx 2014 base case simulation will be conducted focusing on ozone, NO_X (mainly NO_2), VOC and CO performance within the 4-km New Mexico domain.

Deliverables:

- PPT on 2014 base case simulation and MPE
- 2014 base case and MPE draft and final reports that includes detailed descriptions of Tasks 2-5 and includes an MPE.

2.6 Task 6: Future Year (2023) Air Quality Modeling and Ozone Projections

Task 6 will conduct 2023 future year modeling and analysis using four subtasks as follows.

2.6.1 Subtask 6.1: Future Year Air Quality Modeling

Objective: To conduct future year 2023 36/12/4-km base case modeling.

Approach: CAMx will be run for the summer of 2014 using 2023 anthropogenic emissions using the same configuration as in the Task 5 2014 36/12/4-km CAMx base year base case simulation. The only differences between the Task 5 2014 and this task's 2023 CAMx base case simulations will be the anthropogenic emissions (e.g., natural emissions and BCs will be unchanged from the 2014 base case). The 2023 CAMx simulation will be compared against the 2014 base case results

using spatial maps of DMAX8 ozone and their differences and time series at monitoring sites in the 4-km New Mexico domain.

Deliverables:

- CAMx 2023 36/12/4-km base case modeling output
- PPT on the 2023 base case simulation that includes ozone difference plots with 2014.

2.6.2 Subtask 6.2: Future Year Modeled Attainment Test

Objective: To make 2023 ozone Design Value (DV) projections using the final 2014 and 2023 CAMx base case simulations.

Approach: EPA's Software for Modeled Attainment Test (SMAT[10]) tool will be used to make 2023 ozone DV projections for monitoring sites within the 4-km New Mexico domain. The CAMx 2014 and 2023 base case 4-km output will be reformatted for SMAT and SMAT will be run to make the 2023 ozone DV projections at each monitoring site.

In addition to making 2023 ozone DV projections using the EPA recommended approach (EPA, 2018b) implemented in SMAT, we propose to make 2023 ozone DVs using some alternative approaches as well:

- Imposing a model performance criterion when selecting the top 10 modeled days for the RRFs by requiring the modeled and observed MDA8 ozone concentrations for the 10 selected high ozone days to be within, say, 10%, 15% and 20% of each other.
- Using more recent years starting observed DVCs in the ozone projections as compared to using DVCs based on ozone DVs from 2012-2016 as in EPA guidance by using DVCs from the 2013-2017 and 2014-2018 periods that also overlap with the 2014 base year.

We will also use SMAT's Unmonitored Area Analysis (UAA) algorithm that interpolates the observed current year observed ozone DVs to each 4-km grid cell in the 4-km New Mexico domain to generate 2023 ozone DVs throughout the 4-km domain.

Deliverables:

- PPT on the 2023 ozone DV projections including sensitivity analysis to model performance and base year observed DC and the results of the UAA analysis.
- Excel spreadsheet of observed current year and projected 2023 ozone DVs using EPA default and alternative ozone DVF projection approaches.

2.6.3 Subtask 6.3: Future Year Ozone Source Apportionment Modeling

Objective: To conduct 2023 ozone source apportionment modeling.

Approach: The approach for conducting the 2023 ozone source apportionment modeling will be detailed in a white paper after discussions with the NMED. We anticipate that the separate ozone contributions from anthropogenic emissions in several nearby states (e.g., AZ, CA, CO, UT, OK and TX) and from Mexico will be separately tracked. Within New Mexico we anticipate that the contributions from several Source Sectors will also be separately tracked, such as: (1) O&G Point (midstream); (2) O&G area (upstream); (3) EGU Point; (4) Non-EGU Point; (5) ON-Road Mobile; (6) Non-Road Mobile; and (7) remaining anthropogenic. The 2023 ozone source apportionment whitepaper will be reviewed by NMED and updated to address any comments.

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

The 2023 CAMx ozone source apportionment (SA) modeling results will be post-processed to obtain the contribution of each Source Group to modeled 2023 DMAX8 ozone concentrations at each monitoring site and each day of the summer of 2014 modeling period. The 2023 SA results will also be processed to input into SMAT to get the contribution of each Source Group to projected 2023 ozone DVs at each monitoring site in the 4-km New Mexico domain.

The processed 2023 SA modeling results will be loaded into two Excel interactive spreadsheets. The first will have all of the modeled SA contributions to modeled total DMAX8 ozone concentrations for each day and each monitoring site. The user can select a monitoring and time period and the spreadsheet will generate time series of stacked Bar Chart of ozone contributions to modeled DMAX8 ozone. The second interactive spreadsheet will display the stacked Bar Chart of Source Group contributions to the projected 2023 ozone DVs at monitoring sites selected by the user.

Deliverables:

- PPT presentation on the 2023 ozone source apportionment modeling results
- Two interactive Excel spreadsheets of the contributions to 2023 MDA8 ozone and 2023 ozone DVs at monitoring sites in 4-km New Mexico domain

2.6.4 Subtask 6.4: Future Year Emissions Control/Sensitivity Modeling

Objective: To conduct 2023 emissions control/sensitivity simulations and analyze their effects on ozone concentrations.

Approach: We will conduct three (3) future year control strategy/sensitivity simulations using the future year emissions developed under Task 4.6. SMAT will be used to project the 2023 ozone DVFs at the monitors and across the domain using the UAA that will be compared with the 2023 base case ozone DV results.

Deliverables:

- PPT on the 2023 control strategy modeling and results
- Excel spreadsheet of 2023 ozone DVs for all of the 2023 emission scenario and projection approaches.

2.7 Task 7: Air Quality Technical Support Document and Technology Transfer

Objective: To prepare final documentation of the NM OAI Study and transfer modeling databases and results to the NMED.

Approach: We will prepare a draft Air Quality Technical Support Document (AQTSD) summarizing Tasks 2-6 and submit it to NMED for review and comment. The AQTSD is designed to be a concise complete documentation of all aspects of the NM OAI Study suitable for inclusion within an ozone SIP. Since details on the development of the 2014 36/12/4-km modeling platform and MPE are contained in the Task 5 2014 base case modeling report, those results will only be briefly discusses while more details will be provided in the AQTSD on the 2023 modeling and results. Based on comments received from the NMED on the draft AQTSD, a final AQTSD will be prepared along with a Response-to-Comments (RtC) document.

Also under this task we will transfer the NM OAI Study CAMx 2014 and 2023 modeling databases and results to the Intermountain West Data Warehouse (IWDW) where they will be available for

the NMED and others to download. The final documentation and posting for the NM OAI Study Webpage will also be made under this task.

Deliverables:

- Draft AQTSD
- Final AQTSD
- RtC document
- Transfer of CAMx 2014 and 2023 modeling platform a results to IWDW.
- Final updates to the NM OAI Study Webpage.

3. SCHEDULE AND DELIVERABLES

The task structure and schedule for the NM OAI Study key deliverables are shown in Table 3-1. The study will be continuously documented with PowerPoint presentations and other documents that will be presented to the NMED each month in a Webinar whose current schedule and topics are shown in Table 3-2. After each Webinar, and with approval of the NMED, the presentations will be posted to a NM OAI Study Webpage[11] that will be hosted on the WRAP website. There are two formal reports for the study: (1) a 2014 base case modeling and model performance evaluation report prepared under Task 5, with a draft report currently scheduled for delivery in September 2020; and (2) an Air Quality Technical Support Document (AQTSD) that documents the entire study including the 2023 modeling prepared under Task 7, with a draft report currently scheduled for delivery in November 2020.

Table 3-1. Current schedule for NM OAI Study.

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

[11] https://www.wrapair2.org/NMOAI.aspx

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

Task	Deliverable	Date
6.3 FY Controls Modeling	Excel Spreadsheet of 2023 ozone DV projections	Nov 2020
7. Air Quality Technical Support Document and Data Transfer		
	Draft Air Quality Technical Support Document (AQTSD)	Nov 2020
	Final Air Quality Technical Support Document (AQTSD)	Dec 2020
	RtC document on AQTSD comments	Dec 2020
	Data Transfer of BY and FY modeling databases and results	Dec 2020

Table 3-2. Current schedule and topics for monthly webinars for the NM OAI Study.

Webinar No.	Webinar Topics by Task	Date
1.	1. Modeling Protocol and Work Plan 2.1 Evaluate Existing Met 4.1 Recommend 2014 and 2023 Emissions 4.2.1 Recommend 2014 & 2023 Mobile Source Emissions	May 2020
2.	2.2 Additional Met Modeling 3.1 Evaluate BC Data 4.1 Summary of 2014 and 2023 Emissions	Jun 2020
3.	4.2.1 Summary of 2014 and 2023 Mobile Source Emissions 4.3 2014 Natural Emissions Results (e.g., Biogenic and LNOx)	Jul 2020
4.	4.2.3 2014 & 2023 SMOKE-MOVES Results for 4-km NM Domain 4.4 2014 & 2023 SMOKE Emissions Modeling Results	Aug 2020
5.	4.5 FY Emissions Strategy Results 5. 2014 CAMx Base Case Modeling and MPE	Sep 2020
6.	6.1 2023 CAMx Modeling Results 6.2 2023 Ozone Design Value Projections	Oct 2020
7.	6.3 2023 Control Strategy Results 6.4 2023 Source Apportionment Modeling Results	Nov 2020

4. REFERENCES

Abt. 2014. Modeled Attainment Test Software – User's Manual. Abt Associates Inc., Bethesda, MD. April. (http://www.epa.gov/ttn/scram/guidance/guide/MATS_2-6-1_manual.pdf).

Appel, W., R. Gilliam, N. Davis, A. Zubrow, and S. Howard. 2011. Overview of the atmospheric model evaluation tool (AMET) v1.1 for evaluating meteorological and air quality models. Environmental Modeling & Software. 26. 434-443. 10.1016/j.envsoft.2010.09.007.

Boylan, J. W. and A. G. Russell. 2006. PM and light extinction model performance metrics, goals, and criteria for three-dimensional air quality models. *Atmos. Env.* Vol. 40, Issue 26, pp. 4946-4959. August. (https://www.sciencedirect.com/science/article/pii/S1352231006000690).

Coats, C.J. 1995. Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System, MCNC Environmental Programs, Research Triangle Park, NC.

Daley, C., M. Halbleib, J. Smith, W. Gibson, M. Doggett, G. Taylor, J. Curtis and P. Pasteris. 2008. Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. *Intl. J. Climate*. (http://prism.oregonstate.edu/documents/Daly2008_PhysiographicMapping_IntJnlClim.pdf).

Emery, C., E. Tai, and G. Yarwood. 2001. Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Episodes, report to the Texas Natural Resources Conservation Commission, prepared by ENVIRON, International Corp, Novato, CA.

Emery, C.E., Z. Liu, A.G. Russell, M.T. Odman, G. Yarwood and N. Kumar. 2016. Recommendations on statistics and benchmarks to assess photochemical model performance. J. of the Air and Waste Management Assoc., Vol. 67, Issue 5. DOI: 10.1080/10962247.2016.1265027. (https://www.tandfonline.com/doi/full/10.1080/10962247.2016.1265027).

EPA. 2014a. Motor Vehicle Emissions Simulator (MOVES) – User Guide for MOVES2014. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency. (EPA-420-B-14-055). July. (http://www.epa.gov/oms/models/moves/documents/420b14055.pdf).

EPA. 2014b. Motor Vehicle Emissions Simulator (MOVES) –MOVES2014 User Interface Manual. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency. (EPA-420-B-14-067). July. (http://www.epa.gov/oms/models/moves/documents/420b14057.pdf).

EPA. 2014c. Motor Vehicle Emissions Simulator (MOVES) –MOVES2014 Software Design Reference Manual. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency. (EPA-420-B-14-058). December. (http://www.epa.gov/oms/models/moves/documents/420b14056.pdf).

EPA. 2015a. Recommendations for Evaluating the Performance of the 3SAQS Photochemical Grid Model Platform. U.S. Environmental Protection Agency,

Region 8. April 2. (http://vibe.cira.colostate.edu/wiki/Attachments/Modeling/DRAFT_EPAR8_Recommended_PGM_MPE_Analyses_3SAQS_04022015.pdf).

EPA. 2016a. Implementation of the 2015 National Ambient Air Quality Standards for Ozone: Nonattainment Area Classifications and State Implementation Plan Requirements. Federal Register / Vol. 81, No. 243 / Monday, December 19, 2016 / Proposed Rules. 40 CFR Parts 50 and 51, [EPA–HQ–OAR–2016–0202; FRL–9956–97–OAR]. (https://www.gpo.gov/fdsys/pkg/FR-2016-12-19/pdf/2016-30365.pdf).

EPA. 2016b. Guidance on the Use of Models for Assessing the Impacts of Emissions from Single Sources on the Secondarily Formed Pollutants: Ozone and $PM_{2.5}$. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Assessment Division. Research Triangle Park, NC. EPA-454/R-16-005. December. (https://www3.epa.gov/ttn/scram/appendix_w/2016/EPA-454_R-16-005.pdf).

EPA. 2017a. Revisions to the Guideline on Air Quality Models: Enhancements to the AERMOD Dispersion Modeling System and Incorporation of Approaches To Address Ozone and Fine Particulate Matter. 40 CFR Part 51 [EPA–HQ–OAR–2015–0310; FRL–9956–23– OAR]. Federal Register / Vol. 82, No. 10 / Tuesday, January 17, 2017 / Rules and Regulations. (https://www3.epa.gov/ttn/scram/appendix_w/2016/AppendixW_2017.pdf).

EPA. 2017b. Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Assessment Division. Research Triangle Park, NC. EPA-454/B-17-003. July. (https://www.epa.gov/sites/production/files/2017-07/documents/ei_guidance_may_2017_final_rev.pdf).

EPA. 2017c. Use of Photochemical Grid Models for Single-Source Ozone and secondary PM2.s impacts for Permit Program Related Assessments and for NAAQS Attainment Demonstrations for Ozone, PM2.s and Regional Haze. Memorandum from Tyler Fox, Group Leader, Air Quality Modeling Group. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. August 4. (https://www3.epa.gov/ttn/scram/guidance/clarification/20170804-Photochemical_Grid_Model_Clarification_Memo.pdf).

EPA. 2017d. Implementation of the 2015 National Ambient Air Quality Standards for Ozone: Nonattainment Area State Implementation Plan Requirements. Federal Register / Vol. 83, No. 234 / Thursday, December 6, 2018 / Rules and Regulations. 40 CFR Part 51, [EPA–HQ–OAR–2016–0202; FRL–9986–53–OAR]. (https://www.gpo.gov/fdsys/pkg/FR-2018-12-06/pdf/2018-25424.pdf).

EPA. 2017e. Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Assessment Division. Research Triangle Park, NC. EPA-454/B-17-003. July. (https://www.epa.gov/sites/production/files/2017-07/documents/ei_guidance_may_2017_final_rev.pdf).

EPA. 2018a. Implementation of the 2015 National Ambient Air Quality Standards for Ozone: Nonattainment Area State Implementation Plan Requirements, Final Rule.

40 CFR Part 51, [EPA-HQ-OAR-2016-0202; FRL- -OAR] RIN 2060-AS82. U.S. Environmental Protection Agency. Signed November 7, 2018. (https://www.epa.gov/sites/production/files/2018-11/documents/2015_ozone_srr_final_preamble_20181101.pdf).

EPA. 2018b. Modeling Guidance for Demonstrating Air Quality Goals for Ozone, PM2.5, and Regional Haze. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Assessment Division. Research Triangle Park, NC. EPA 454/R-18-009. November 29. (https://www3.epa.gov/ttn/scram/guidance/guide/O3-PM-RH-Modeling_Guidance-2018.pdf).

EPA. 2019. Technical Support Document for EPA's Updated 2028 Regional Haze Modeling. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. September. (https://www3.epa.gov/ttn/scram/reports/Updated_2028_Regional_Haze_Modeling-TSD-2019.pdf).

Guenther, A. and C. Wiedinmyer. 2004. User's Guide to the Model of Emissions of Gases and Aerosols from Nature (MEGAN). National Center for Atmospheric Research (NCAR), Boulder, Colorado (http://acd.ucar.edu/~christin/megan1.0_userguide.pdf).

Guenther, A., X. Jiang, T. Duhl, T. Sakulyanontvittaya, J. Johnson and X. Wang. 2014. MEGAN version 2.10 User's Guide. Washington State University, Pullman, WA. May 12. (http://lar.wsu.edu/megan/docs/MEGAN2.1_User_GuideWSU.pdf).

Michalakes, J., J. Dudhia, D. Gill, J. Klemp and W. Skamarock. 1998. Design of a Next-Generation Regional Weather Research and Forecast Model. Mesoscale and Microscale Meteorological Division, National Center for Atmospheric Research, Boulder, CO. (http://www.mcs.anl.gov/~michalak/ecmwf98/final.html).

Michalakes, J., S. Chen, J. Dudhia, L. Hart, J. Klemp, J. Middlecoff and W. Skamarock. 2001. Development of a Next-Generation Regional Weather Research and Forecast Model. Developments in Teracomputing: Proceedings of the 9th ECMWF Workshop on the Use of High Performance Computing in Meteorology. Eds. Walter Zwieflhofer and Norbet Kreitz. World Scientific, Singapore. Pp. 269-276. (http://www.mmm.ucar.edu/mm5/mpp/ecmwf01.htm).

Michalakes, J., J. Dudhia, D. Gill, T. Henderson, J. Klemp, W. Skamarock and W. Wang. 2004. The Weather Research and Forecast Model: Software Architecture and Performance. Proceedings of the 11th ECMWF Workshop on the Use of High Performance Computing in Meteorology. October 25-29, 2005, Reading UK. Ed. George Mozdzynski. (http://wrf-model.org/wrfadmin/docs/ecmwf_2004.pdf).

Ramboll. 2013. METSTAT Meteorological Model Statistical Evaluation Package. Ramboll, Novato, California. December 9. (http://www.camx.com/download/support-software.aspx).

Ramboll. 2018a. User's Guide Comprehensive Air-quality Model with extensions Version 6.5. Ramboll, Novato, California. April. (http://www.camx.com/files/camxusersguide_v6-10.pdf).

Sakulyanontvittaya, T., G. Yarwood and A. Guenther. 2012. Improved Biogenic Emission Inventories across the West. ENVIRON International Corporation, Novato, CA. March 19.

(http://www.wrapair2.org/pdf/WGA_BiogEmisInv_FinalReport_March20_2012.pdf).

Simon, H., K. Baker and S. Phillips. 2012. Compilations and Interpretation of Photochemical Model Performance Statistics Published between 2006 and 2012. *Atmos. Env.* 61 (2012) 124-139. December. (http://www.sciencedirect.com/science/article/pii/S135223101200684X).

Skamarock, W. C. 2004. Evaluating Mesoscale NWP Models Using Kinetic Energy Spectra. *Mon. Wea. Rev.*, Volume 132, pp. 3019-3032. December. (http://www.mmm.ucar.edu/individual/skamarock/spectra_mwr_2004.pdf).

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, W. Wang and J. G. Powers. 2005. A Description of the Advanced Research WRF Version 2. National Center for Atmospheric Research (NCAR), Boulder, CO. June. (http://www.mmm.ucar.edu/wrf/users/docs/arw_v2.pdf)

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, M. G. Duda, X-Y. Huang, W. Wang and J. G. Powers. 2008. A Description of the Advanced Research WRF Version 3. National Center for Atmospheric Research (NCAR), Boulder, CO. June. (https://opensky.ucar.edu/islandora/object/technotes%3A500/datastream/PDF/view)

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, Z. Liu, J. Berner, W. Wang, J. G. Powers, M. G. Duda, D. M. Barker and X-Y. Huang. 2019. A Description of the Advanced Research WRF Model Version 4 (No. NCAR/TN-556+STR). doi:10.5065/1dfh-6p97 (https://opensky.ucar.edu/islandora/object/technotes%3A576/datastream/PDF/download/citation.pdf)

Skamarock, W. C. 2006. Positive-Definite and Monotonic Limiters for Unrestricted-Time-Step Transport Schemes. *Mon. Wea. Rev.*, Volume 134, pp. 2241-2242. June. (http://www.mmm.ucar.edu/individual/skamarock/advect3d_mwr.pdf).

UNC. 2008. Atmospheric Model Evaluation Tool (AMET) User's Guide. Institute for the Environment, University of North Carolina at Chapel Hill. May 30. (https://www.cmascenter.org/amet/documentation/1.1/AMET_Users_Guide_V1.1.pdf).

UNC. 2015. SMOKE v3.6.5 User's Manual. University of North Carolina at Chapel Hill, Institute for the Environment. (https://www.cmascenter.org/smoke/documentation/3.6.5/html/).

UNC. 2018. SMOKE v4.6 User's Manuel. University of North Carolina at Chapel Hill, Institute for the Environment. Chapel Hill, North Carolina. September 24. (https://www.cmascenter.org/smoke/documentation/4.6/manual_smokev46.pdf)

WESTAR and Ramboll. 2020. New Mexico Ozone Attainment Initiative Photochemical Modeling Study – Draft Modeling Protocol. WESTAR, Santa Fe, NM and Ramboll, Novato, CA. May.

Wiedinmyer, C., T. Sakulyanontvittaya and A. Guenther. 2007. MEGAN FORTRAN code V2.04 User Guide. NCAR, Boulder, CO. October 29. (http://acd.ucar.edu/~guenther/MEGAN/MEGANguideFORTRAN204.pdf).