Prepared for:

Western States Air Resources Council
Western Regional Air Partnership

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MODELING PLAN ADDENDUM

WESTERN REGIONAL MODELING AND ANALYSIS 2014 PLATFORM DEVELOPMENT AND SHAKE-OUT

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Modeling Plan Addendum

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1.0 INTRODUCTION

This document is an Addendum to the Modeling Plan (Ramboll, 2019a[1]) for the Western Regional Air Partnership (WRAP) 2014 Platform Development and Shake-Out Study (WRAP 2014 Shake-Out Study). The WRAP 2014 Shake-Out Study Modeling Plan dated March 9, 2019 describes the procedures for conducting Phase I and II of the study that developed a 2014 photochemical model (PGM) modeling platform for the western United States.

1.1 Phase I and II of the WRAP 2014 Shake-Out Study

Phase I and II of the WRAP 2014 Shake-Out study developed version 1 (2014v1) of the WRAP 2014 modeling platform that was documented on a webpage[2] on the Intermountain West Data Warehouse (IWDW) and a final report (Ramboll, 2019b[3]). The WRAP 2014 Shake-Out Study developed 2014v1 annual modeling databases for version 5.2.1 of the Community Multiscale Air Quality (CMAQ[4]) and version 6.5 of the Comprehensive Air Quality Model with extensions (CAMx[5]), both PGMs were released in April 2018. The annual 2014v1 simulations of the CMAQ and CAMx models were performed on a 36-km grid resolution domain (36US) covering most of North America and a western US (12WUS2) domain at 12-km grid resolution. PGM sensitivity tests were also conducted on a 12-km grid resolution continental U.S. domain (12US2). The PGM modeling domains used in Phase I and II of the WRAP 2014 Shake-Out Study are shown in Figure 1-1.

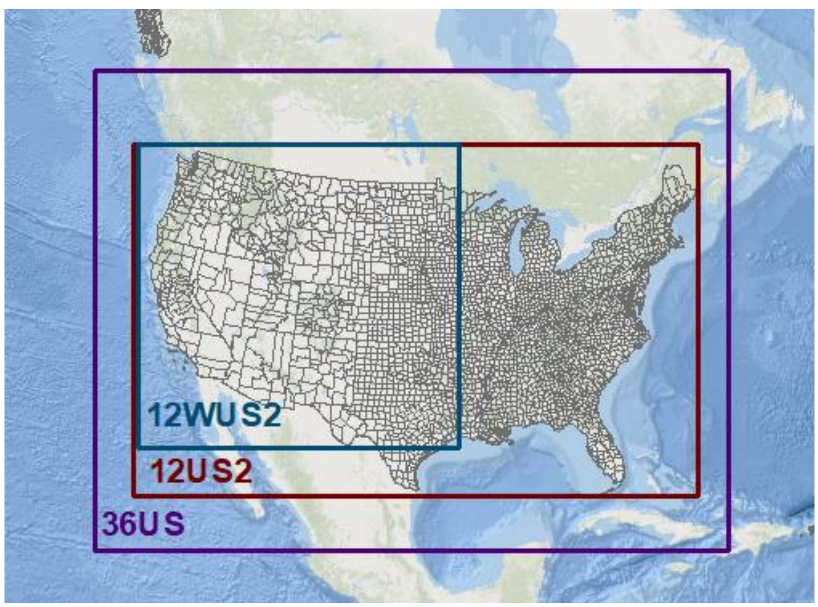

Figure 1-1. 2014 36-km CONUS (36US), 12-km 12US2 and 12-km WESTUS (12WUS2) modeling domains to be used for PGM modeling.

[1] http://views.cira.colostate.edu/documents/Projects/IWDW/WAQS_2014_Shakeout_Study_Overview/WRAP_2014_Shake-Out_Plan_Phase-I_v4_2019-03-09.pdf

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

[3] http://views.cira.colostate.edu/documents/Projects/IWDW/WAQS_2014_Shakeout_Study_Overview/WRAP_2014_Shake-Out_Phase-I&II_Final_v2_2019-05-21.pdf

[4] https://www.epa.gov/cmaq/access-cmaq-source-code

[5] http://www.camx.com/

1.2 Phase III of the WRAP 2014 Shake-Out Study

Phase III of the WRAP 2014 Shake-Out Study is being performed during the summer/fall of 2019 and will develop version 2 of the 2014 modeling platform (2014v2) and consists of the following activities:

- Initial PGM sensitivity tests were performed using the 2014v1 platform to investigate the CAMx coastal sulfate (SO4) overestimation tendency and explore options for alleviating the CAMx and CMAQ underestimation of elevated observed nitrate (NO3) concentrations.
- Revised 2014 GEOS-Chem global chemistry modeling to generate Boundary Conditions (BCs) for the CMAQ and CAMx regional 36US domain modeling (Figure 1-1) that is intended to alleviate the ozone overestimation tendency of the 2014v1 BCs that were based on EPA's 2014 GEOS-Chem modeling.
- 2014v2 emission updates[6] to the 2014v1 emissions that includes minor updates to several states (e.g., Montana, Arizona and North Dakota), revised oil and gas emissions for western states and completely new anthropogenic emissions for California.
- Development of Representative Baseline emissions for Electrical Generating Units (EGUs[7]), western state oil and gas emissions[8], and fires[9].
- Revised PGM 2014v2 annual simulations and model performance evaluation using new versions of the CMAQ (v5.3) and CAMx (v7.0) models.
- Conduct linked global (GEOS-Chem) and regional (PGM 36/12-km) Natural (i.e., no global anthropogenic emissions) and ZROW [Zero-Out Rest of World, no non-US (International) anthropogenic emissions] simulations.
- Broad-based Source Sector ozone and particulate matter source apportionment modeling (i.e., separate contributions of U.S. and International anthropogenic, plus fires and other natural sources).
- Scoping study for dynamic model evaluation (i.e., evaluate PGM ability to simulate changes in observed visibility over time).

1.3 Purpose

The purpose of this Modeling Protocol Addendum is to provide potential options of the types of analysis that can be performed using the WRAP 2014v2 Shake-Out modeling platform, as well as 2016v1 modeling platform being developed by EPA and others, that will benefit the western states in their air quality planning activities. This includes analysis that can be used for the regional haze SIPs due in July 2021 and analysis relating to ozone and $PM_{2.5}$ transport and nitrogen deposition.

[6] http://wrapair2.org/RTOWG.aspx
[7] https://www.wrapair2.org/EGU.aspx
[8] https://www.wrapair2.org/Oil_Gas.aspx
[9] https://www.wrapair2.org/FSWG.aspx

2.0 2016 MODELING PLATFORM

The EPA and Multi-Jurisdictional Organizations (MJOs) are conducting a joint 2016 inventory collaborative study[10] to develop a 2016 emissions inventory of comparable quality to the NEI. EPA is developing a 2016 PGM modeling platform using the joint EPA/MJO emissions inventory collaborative 2016 emissions. A 2016 Alpha[11] platform was released in 2018 that is based mostly on EPA's 2014v7.1 emissions inventory. The 2016 Beta platform was released in April 2019[12] and consists of more year 2016 emissions, but no future year projections. EPA's 2016 modeling platform uses a 12-km 12US2 domain embedded in a North America 36-km 36US3 domain, that are shown in Figure 2-1. The current release of the 2016 Beta modeling platform includes databases for both the CMAQ and CAMx PGMs using one-way grid nesting between the 36-km and 12-km domains.

EPA released a 2016 beta-prime CAMx modeling platform with 2028 visibility projections and source apportionment modeling in September 2019.[13] The 2016 beta-prime emissions[14] were updated from the 2016 beta platform.

The release of the 2016v1 PGM modeling platform is expected in October 2019 and is supposed to include future year emission projections for 2028 and 2023, and possibly some source sectors for 2020. It is important to note that 2028 and 2023 emission projections that are expected to be provided with the 2016v1 modeling platform are mostly consistent with the 2014 emissions, except for source sectors that are tied to the 2016 base meteorological year (e.g., EGUs, on-road mobile, biogenic, lightning, sea salt, fires).

[10] http://views.cira.colostate.edu/wiki/wiki/9169
[11] https://www.epa.gov/air-emissions-modeling/2016-alpha-platform
[12] https://views.cira.colostate.edu/iwdw/RequestData/Default.aspx
[13] https://www3.epa.gov/scram001/reports/Updated_2028_Regional_Haze_Modeling-TSD-2019.pdf
[14] https://www.epa.gov/sites/production/files/2019-09/documents/2016v7.2_regionalhaze_emismod_tsd_508.pdf

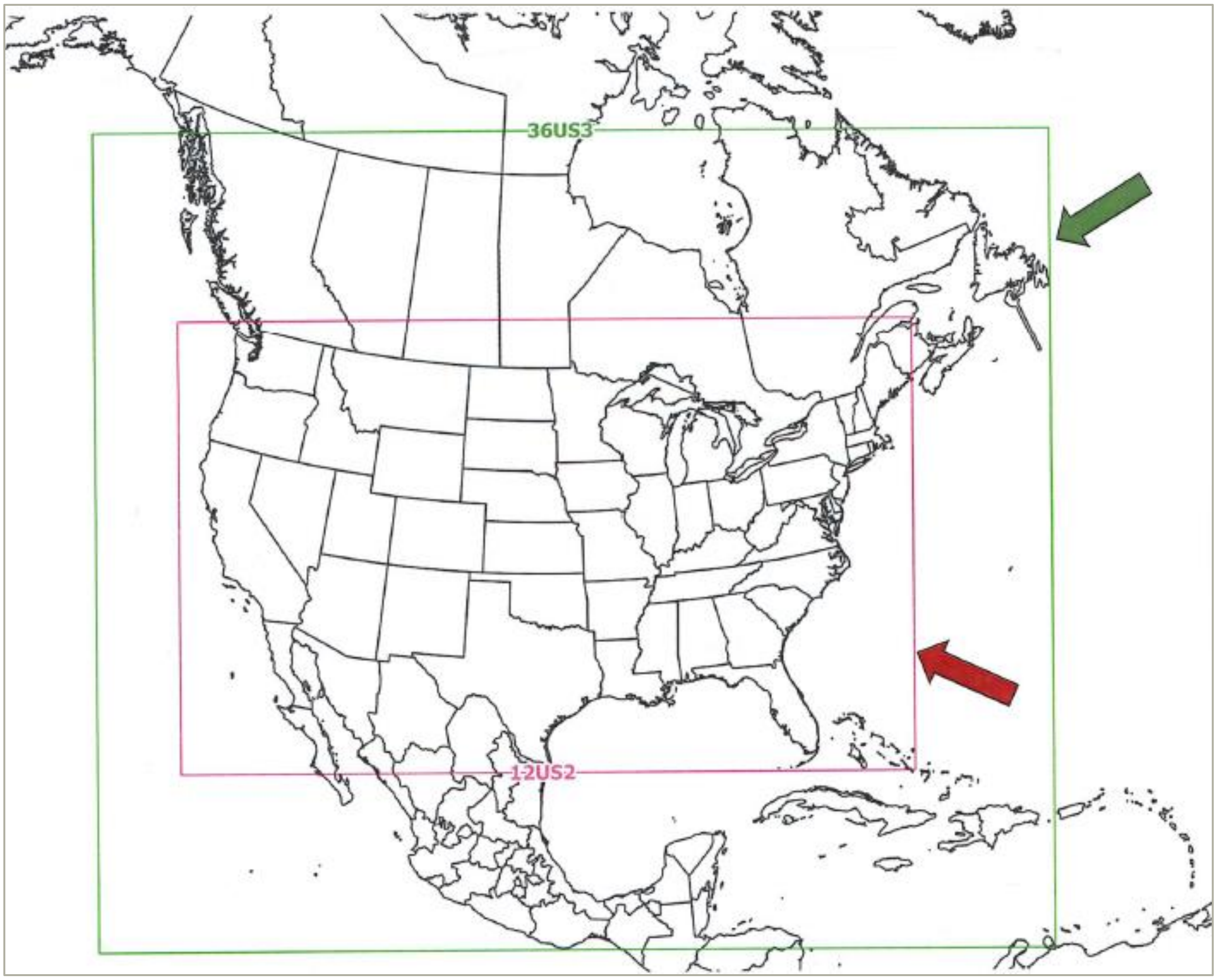

Figure 2-1. 12-km grid resolution 12US2 domain (red) and 36-km grid resolution 36US3 domain (green) used in the EPA/MJO 2016 modeling platforms.

2.1 Denver Ozone SIP 2016 Modeling Platform

The Denver Regional Air Quality Council (RAQC[15]), with the Colorado Department of Public Health and Environment (CDPHE), is developing a new 2016 36/12/4-km PGM modeling platform to address 2020 and 2023 attainment of the, respectively, 2008 and 2015 ozone National Ambient Air Quality Standard (NAAQS). New 2016 WRF meteorological modeling was conducted to generate PGM meteorological inputs for 36-km 36US3, 12-km 12US2 and 4-km Colorado domains as shown in Figure 2-2. The Denver ozone SIP modeling will apply both the CAMx and CMAQ models with CAMx using two-way grid nesting among the 36/12/4-km domain (CMAQ does not support two-way grid nesting). 2016 base year and 2020 and 2023 future year emissions for Colorado will come from the CDPHE with the rest of the emissions leveraged from the joint EPA/MJO 2016v1 emissions inventory collaborative project and EPA's 2016 PGM platform. The Denver 2016 36/12/4-km modeling platform will be developed in 2019 shortly after the release of EPA's 2016v1 modeling platform.

[15] https://raqc.org/

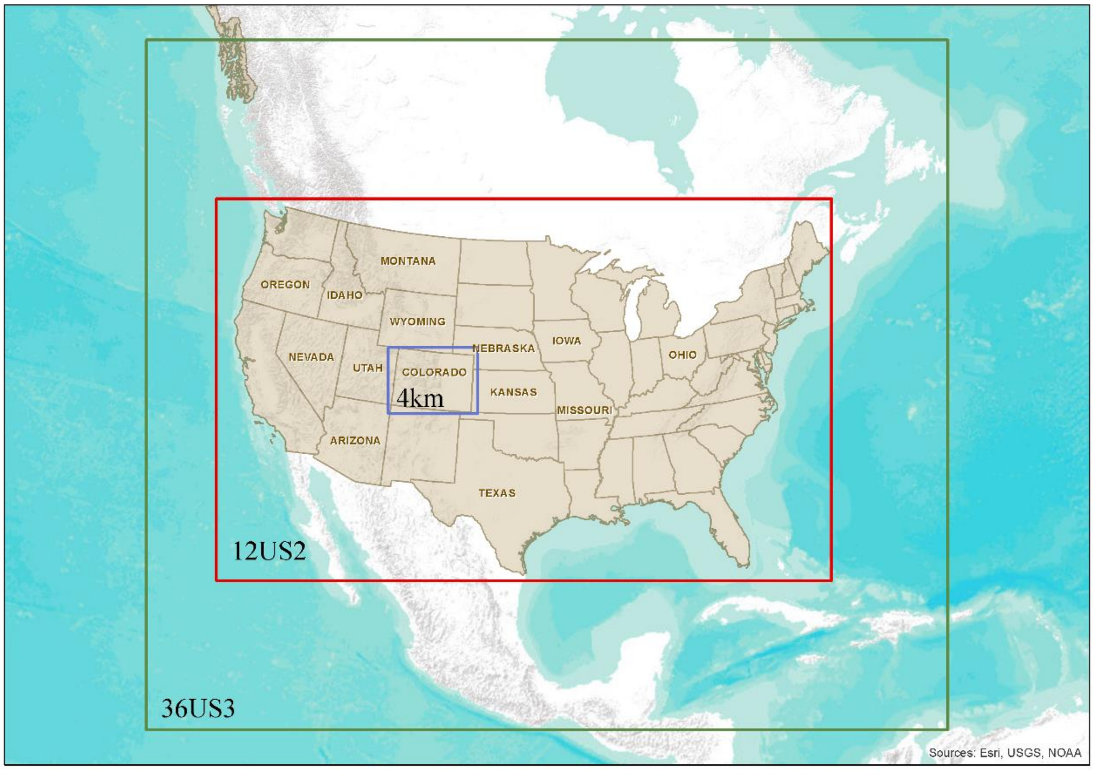

Figure 2-2. 36/12/4-km grid resolution domain structure used in the Denver 2020 and 2023 ozone attainment demonstration modeling.

2.2 EPRI International Emissions Contribution Study

The Electric Power Research Institute (EPRI) is performing a global and regional modeling stud to estimate the contributions of International emissions (i.e., anthropogenic emissions from outside of the U.S.) on visibility impairment at Class I Areas through-out the U.S. The EPRI study is conducting three linked GEOS-Chem global and CAMx 36/12-km simulations using 2016 base year meteorological conditions:

- 2016 Base case emissions and model performance evaluation.
- 2028 Base case emissions.
- 2028 ZROW case emissions (i.e., no non-U.S. anthropogenic emissions).

At this time (September 2019), EPRI's contractor (Ramboll) has conducted GEOS-Chem global chemistry modeling using 2016 meteorological conditions for 2016 and 2028 emission scenarios. EPRI is waiting for the release of the 2016v1 modeling platform and 2028 future year emission projections for use in conducting CAMx 2016 and 2028 simulations. The EPA 2016v1 modeling platform does not include windblown dust (WBD) and lightning NOx (LNOx) so these natural source category emissions will be added in the EPRI study.

2.3 2016 Modeling Platform Recommendations for WRAP

There is a lot of activity already underway that is using the 2016 Beta and will use the EPA 2016 Beta-prime and EPA/MJO 2016v1 36/12-km modeling platform as well as the Denver ozone SIP 2016 36/12/4-km modeling platform. The WRAP should closely monitor these other studies and assess how they want to use the 2016 modeling platform in their regional haze and air quality planning activities when it is available at a later date. Except for the 2016 base year dependent anthropogenic emissions (e.g., SMOKE-MOVES on-road mobile sources and EGUs), the EPA/MJO 2028 and other future year emission projections should be mostly compatible for use with the WRAP 2014 Shake-Out modeling platform.

3.0 CURRENT AND FUTURE-YEAR REPRESENTATIVE BASELINE MODELING

To make future year visibility or air quality design value projections, EPA guidance (EPA, 2018a) recommends using the relative change in modeled concentrations between the base and future year to scale current year observed PM concentrations on the 20% most impaired days (MID) or design value concentrations, respectively. The model derived scaling factors are called relative response factors (RRFs) and are defined as the ratio of the future year (FY) to base year (BY) modeling results averaged over multiple days. For ozone design values, the average of the 10 highest base year ozone days are used to calculate the RRF that is used to project the current year design value (DVC) to the future year (DVF):

$$RRF = \sum O3_{FY} / \sum O3_{BY}$$

$$DVF = DVC \times RRF$$

Similar scaling procedures are used to project future year $PM_{2.5}$ design values and visibility impairment for the MID (see EPA, 2018a for details).

The current year design value (DVC) and visibility impairment for the MID are typically averaged over 5-years of observations. For the second round of regional haze SIPs, the current year 20% MID days will be based on 2014-2018 IMPROVE observations (or 2014-2017 if 2018 data are not available). Because we are using the relative change in the FY to BY modeling results when making design value and MID visibility projections, it is important that consistent emissions be used in the BY and FY and the emissions are representative of current years, not just the actual base meteorological year. For example, if an Electrical Generating Unit (EGU) that is expected to be operating in the FY is down for a large portion of base meteorological year more typical representative emissions should be used for the BY modeling that are consistent with the FY EGU emissions when making FY projections.

For the WRAP 2014 Shake-Out Study, two 2014 BY emission scenarios are being used:

- **Actual Base Case** that represents actual emissions that occurred during 2014 and are used in the 2014 base case PGM simulations and model performance evaluation; and

- **Representative Baseline** that represents typical current year emissions consistent with the future year emissions scenarios that are used to make future year projections.

The current Representative Baseline differs from the Actual Base Case for three source categories: (1) Electrical Generating Units (EGUs); (2) upstream Oil and Gas (O&G) sources; and (3) open land fires, which include wildfires (WF), prescribed burns (Rx) and agricultural burning (Ag).

3.1 Representative Baseline EGU Emissions

The Center for the New Energy Economy (CNEE) at Colorado State University (CSU) conducted the WRAP EGU Emissions Analysis Project to characterize current and future EGU emissions in the 13 WRAP states. The two main objectives of the EGU Emissions Analysis Project were as follows:

1. Develop a comprehensive database of information on the fleet of fossil fuel-fired EGUs in 13-Western states (circa 2014-2018) that contains information on the plants operating characteristics and NOx and SO2 emissions; and

2. Develop a projection of EGU 2028 NO_X and SO_2 emissions based on expected plant closures, fuel switching, and emission controls under a “rules on the books” scenario.

Details on the WRAP WGU Emissions Analysis Project are contained in the final report (CNEE, 2019[16]) and project website[17].

3.2 Representative Baseline O&G Emissions

The WRAP Oil & Gas Work Group (OGWG) has developed 2014 Actual Base case and Representative Baseline oil and gas (O&G) emissions for 7[18] of the 8 WRAP western states that have upstream O&G exploration and production. The 8th state is California where the California Air Resources Board is developing the O&G emission inventories and the Actual Base Case and Representative Baseline O&G emissions are the same.

Details on the WRAP OGWG activities can be found on their website[19]. The O&G Actual Base Case emissions were develop during the end of 2018 and represent actual 2014 O&G emissions using 2014 activity data and emission factors. The OGWG surveyed O&G Operators to obtain better information on the current practices in O&G exploration and development. Based on the O&G survey results, the Actual Base Case O&G emissions were updated to make the Representative Baseline O&G emission scenario.

3.3 Representative Baseline Fire Emissions

The WRAP Fire & Smoke Work Group (FSWG) has developed Actual Base Case and Representative Baseline fire emissions for WRAP western states. Details on the FSWG activities are available on their website[20].

The FSWG formed the Representative Baseline and Future Fire Scenarios (RBFFS) Working Group to examine methods used to incorporate fire into the regional haze modeling process. The Representative Baseline and Future Fire Scenarios (RBFFS) Working Group will address four topics related to fire characterization for regional haze planning:

1. Develop methods for building a planning emissions inventory of fire representative of the Baseline Period;

2. Develop methods and scenarios for examining future fire emissions;

[16] https://www.wrapair2.org/pdf/Final%20EGU%20Emissions%20Analysis%20Report.pdf
[17] https://www.wrapair2.org/EGU.aspx
[18] Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah and Wyoming
[19] http://wrapair2.org/OGWG.aspx
[20] https://www.wrapair2.org/FSWG.aspx

3. Determine when and what contract work is needed and assist in preparation of contract tasks and evaluation of work products; and

4. Evaluate existing plume rise methods and recommend approaches for model implementation and sensitivity analyses.

The FSWG RBFFS has developed Representative Baseline open land fire emissions for western states to represent the 2013-2017 5-year time period. The procedures used to develop the Representative Baseline fires emissions are described in a whitepaper[21].

[21] http://wrapair2.org/pdf/baseline_period_methods_20190419_v1_DRAFT.pdf

4.0 POTENTIAL SOURCE APPORTIONMENT AND SENSITIVITY MODELING

The WRAP Shake-Out Study 2014 and EPA 2016 modeling platforms can be used to conduct source apportionment and source sensitivity modeling to analyze numerous issues. In this Chapter we discuss some, but not all, of the types of analysis that source apportionment and sensitivity modeling to support the development of regional haze SIPs. Although some of this analysis can also be used to support ozone, particulate matter and deposition planning activities as well.

4.1 Differences Between Source Apportionment and Source Sensitivity

The basic difference between source apportionment and sensitivity is that source apportionment estimates the contribution of a source's emissions to concentrations under fixed atmospheric chemistry (emission) conditions (e.g., a specific emissions scenario). Whereas, source sensitivity estimates what the change in a source's concentration contribution would be due to a change in a source's emissions (or other model perturbation). Sometimes a sensitivity method is used to estimate source contributions, such as the elimination (zero-out) of all of a state's emissions to estimate the states contributions to ozone and PM concentrations and resultant visibility impairment. However, the sum of the source contributions from the zero-out of emissions in all geographic regions (e.g., states) will not equal the total concentration. In source apportionment, the sum of contributions of all sources will equal the total concentration produced by the model. Whether one uses source apportionment or sensitivity depends on the question being asked and other factors (e.g., resource and time constraints). For example, if the 2014 contribution of a state's emissions to a downwind concentration is desired source apportionment is the appropriate method. However, if one wants to know the effect of reducing a state's emissions by 20% on downwind concentrations, then a sensitivity method should be used.

The most common sensitivity method is called the Brute Force (BF) method that involves two simulations of a PGM, a base case and an emissions reduction sensitivity case and examining the concentration differences in the two simulations. For example, running a base case and state's emissions zero-out case to estimate a state's contributions. The BF method can be used with any model.

4.1.1 Available Source Apportionment Tools

The CMAQ and CAMx PGMs come instrumented with several Probing Tools that use reactive tracers (tagged species) that run in parallel to the host model to extract source apportionment and sensitivity information from the model. Both CMAQ and CAMx include the Decoupled Direct Method (DDM and HDDM) probing tool that can track sensitivities of concentrations to emissions or other model parameter. CAMx includes the Particulate Source Apportionment Technology (PSAT) and the Ozone Source Apportionment Technology (OSAT) probing tools. The latest version and some earlier versions of CMAQ also include the Integrated Source Apportionment Method (ISAM), although it is not as widely used as PSAT/OSAT.

Cost and other considerations (e.g., computational requirements and run times) also play a role on whether source apportionment or sensitivity is used. When examining the contributions of a single-source or single-source type, the BF sensitivity approach will be slightly more computationally intensive than source apportionment but not prohibitively so. However, when examining the contributions of numerous sources or source types, the BF approach computational requirements can be quite extensive as a separate model simulation must be conducted for each source contribution/sensitivity. When examining many source contributions, the source apportionment approach is much more computational efficient than the sensitivity approaches (e.g., BF and DDM).

4.1.2 Source Apportionment Modeling Strategy

Source apportionment simulation run times and other computational requirements (e.g., memory and disk space) depend on the number of sources ("Source Groups") being tracked. It is more efficient to conduct a series of faster source apportionment simulations that examine various aspects of source contributions rather than one large simulation tracking all geographic region and source sector contributions trying to answer all source contribution questions in one simulation that can take months to complete. As photochemical modeling databases are constantly evolving undergoing improvements and refinements, the staging of a series of source apportionment runs is also desirable so that the latest modeling platform is being used.

After discussing a couple brute force sensitivity simulations designed to address contributions of International and all anthropogenic emissions, we present a potential staged ozone and PM source apportionment analysis that examines:

- Broad based contributions of anthropogenic contributions from U.S. and non-U.S. (International) sources.
- Contributions of International Anthropogenic Emissions and Natural Sources.
- Contributions of State-Specific Anthropogenic Emissions.
- Contributions of Source Sectors by State.

4.2 Contributions of International Emissions

The contributions of anthropogenic emissions from outside of the U.S. (i.e., International emissions contribution) is an important parameter in both regional haze and ozone and $PM_{2.5}$ attainment SIPs. The regional haze rule allows an adjustment to the uniform rate of progress "to account for impacts of anthropogenic emissions outside the United States." This is done by adding the contributions of International anthropogenic visibility impairment to the 2064 natural conditions thereby making the slope of the uniform rate of progress glidepath less steep so that is it easier to demonstrate that reasonable progress is being met (see Figure 4-1). EPA's September 2018 guidance for tracking progress discusses approaches for doing this and recommends using a recent year and performing either a "brute force" zero-out International emissions modeling analysis or using source apportionment to obtain the contributions of International emission to visibility impairment (EPA, 2018b).

For ozone, Section 179B of the Clean Air Act (CAA) allows states to demonstrate they would be in attainment of the ozone or $PM_{2.5}$ NAAQS "but for" emissions emanating from outside of the U.S.

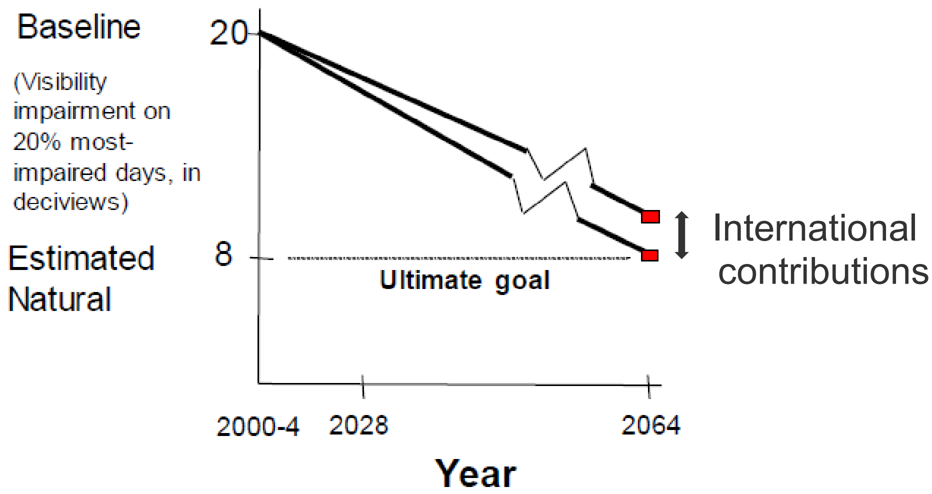

Figure 4-1. Hypothetical example of how International emissions contributions can be added the natural conditions 2064 goal to change the slope of the glidepath.

4.2.1 Brute Force International Emissions Contribution

The basic steps in doing an International emissions regional haze sensitivity analysis using a Brute Force zero-out emissions approach with the 2014 WRAP modeling platform (or 2016 platform) would be as follows:

- Base case modeling of all emissions using a global chemistry model (e.g., GEOS-Chem or Hemispheric CMAQ) that provides Boundary Conditions (BCs) for the PGM (e.g., CMAQ or CAMx) 36/12-km North America domain modeling.
- Eliminate all non-U.S. anthropogenic emissions (i.e., Zero Rest of World, or ZROW) from the global chemistry model and conduct ZROW global model and generate BCs for PGM modeling.
- Zero-out all non-U.S. anthropogenic emissions in the PGM 36/12-km domain (i.e., Mexico and Canada) and conduct PGM 36/12-km ZROW simulation.
- Conduct visibility projections using EPA guidance (EPA, 2018a) that is coded in SMAT, or other technique and estimate what is the visibility contribution of International emissions on the 20% MID.

The procedures for estimating the International emissions to ozone or $PM_{2.5}$ design values are the same as above only SMAT is used to make design value projections. The International emissions brute force zero-out analysis could be performed for either the base meteorological year or a future year emission scenario, although for the future year two SMAT visibility projections would have to be performed from the base meteorological year to the Base Case and ZROW Case. On the one hand, doing the International visibility contributions for 2028 may be more appropriate since it is closer to the 2064 year. On the other hand, the 2028 emission inventory is more uncertain. EPA guidance recommends using a more recent year for the analysis (EPA, 2018b).

For an ozone or $PM_{2.5}$ CAA Section 179B "but for" doing the analysis for a recent year is more appropriate since the question asked is whether the region would have attained the NAAQS without International emissions.

4.2.2 Source Apportionment International Emissions Contribution

Source apportionment can also be used to obtain the contributions of emissions from outside the U.S. However, prior to CAMx v7.0 there was no way to separately track international anthropogenic emissions and natural sources through the CAMx BCs in a source apportionment simulation. EPA's release of updated 2028 visibility modeling results in September 2019 exploited this new source apportionment feature in CAMx v7.0 to separately track International anthropogenic versus natural contributions through the CAMx BCs for a 2028 emissions scenario using EPA's 2016 beta-prime modeling platform (EPA, 2019b). EPA processed a 2028 Hemispheric CMAQ base case and no International anthropogenic emission scenario to provide BC inputs to CAMx stratified by anthropogenic and natural sources. The EPA CAMx 2028 PSAT source apportionment simulation also separately tracked Canada and Mexico anthropogenic emissions as well as several U.S. source sectors From this they were able to develop the contributions of International anthropogenic emission to visibility impairment and construct URP glideslopes adjusted to include International contributions added to the 2064 glidepath endpoint. Figure 4-2 shows an example adjusted and unadjusted URP glidepath and CAMx absolute and observed 2016 and CAMx absolute and projected 2028 visibility modeling results for the 20% MID at Grand Canyon National Park CIA.

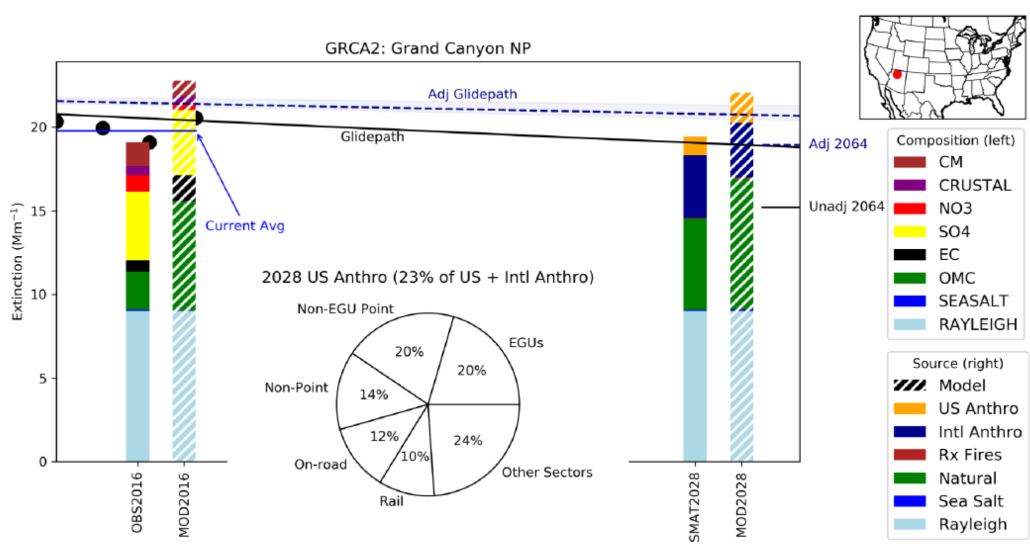

Figure 30: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GRCA2. Used for Class I areas: Grand Canyon NP.

Figure 4-2. EPA's 2016 and 2028 modeling results at Grand Canyon National Park and comparison with the URP glideslope that is adjusted and unadjusted for the contributions of International anthropogenic emissions (Source: EPA, 2019b).

WRAP could conduct similar source apportionment modeling results using their 2014 CAMx modeling platform. The CAMx PSAT simulation to obtain anthropogenic versus natural and broad-based source sector contributions can be done with just a few (<15) Source Groups so can be fairly computationally efficient.

Although EPA just conducted this broad-based anthropogenic versus natural source apportionment modeling for 2028, we also see benefits for conducting it for the 2014 base meteorological years as well. In addition to the 2014 year being consistent with EPA's guidance recommendation (EPA, 2018b) for conducting the International emissions contributions analysis for a recent current year, it would also allow a comparison of the modeled and IMPROVE statistically derived 20% MID for 2014. Such an analysis for the 2008 and 2011 modeling years provided much information on using models to project MID (Brewer et al., 2019).

4.3 Natural Contribution

Natural visibility and air quality conditions is the level of visibility impairment on concentrations in the absence of any anthropogenic emissions. Natural visibility conditions are extremely important for regional haze as it is the ultimate goal at CIAs in 2064. Natural conditions are also important when setting new National Ambient Air Quality Standards (NAAQS) for ozone and $PM_{2.5}$ as standards set below or near natural background may not be achievable.

Natural conditions can be estimated using Brute Force zero-out of all anthropogenic emissions sensitivity modeling similar to the procedures described above for International emissions (ZROW) anthropogenic emissions contributions only eliminating all anthropogenic emissions across the globe. Although you can also estimate natural conditions using source apportionment, it is not as good of a metric for estimating what would be natural conditions in the absence of anthropogenic sources since the anthropogenic emissions affect chemistry that in turn will affect the contributions of natural sources.

4.4 Broad-Based Anthropogenic Emissions Source Apportionment Modeling

Phase III of the WRAP Platform Development and Shake-Out Study has a task to perform a broad-based anthropogenic emissions PSAT/APCA PNM/ozone source apportionment simulation that is designed to assess the contributions anthropogenic and natural emissions to ozone, PM concentrations and visibility impairment using the 2014v2 CAMx modeling platform. CAMx v7.0 is being used that has the capability of tracking separate contributions from BCs on a 36/12-km two-way nested grids. CAMx APCA and PSAT source apportionment tools are being run for a base year (i.e., 2014) for an annual period to obtain separate PM contributions for the following Source Groups:

> <u>International Anthropogenic BC</u>: BCs due to International anthropogenic emissions (i.e., BCs from the difference between a GEOS-Chem Base and ZROW case).
>
> <u>U.S. Anthropogenic BC</u>: BCs due to U.S. anthropogenic emissions (i.e., BCs from the difference of a GEOS-Chem ZROW and Natural cases).
>
> <u>Natural BC</u>: BCs due to natural sources (i.e., EOS-Chem Base BCs minus the BCs from International and U.S. anthropogenic emissions described above).

Mex/Can/Off-Shore Anthro: International Mexico/Canada anthropogenic emissions within the CAMx 36/12-km modeling domain.

Wildfires: All Wildfire emissions within CAMx 36/12-km domain

Prescribed Burns: Prescribe Burns and Agricultural Burning within CAMx 36/12-km domain.

Other Natural Emissions: Oceanic Sea Salt and DMS, WBD and LNOx within CAMx domain.

U.S. Anthropogenic: U.S. anthropogenic emissions within 38 contiguous states.

CAMx v7.0 is being applied with the SO4, NO3/NH4 and primary PM families of reactive tracers. The SOA family of reactive tracers will not be used because it is very costly (requires many reactive tracers to track SOA formation) and we can obtain an operational definition of SOA due to anthropogenic (SOAA) and biogenic (SOAB) emissions from the host model by assuming all SOA due to isoprene, terpenes and sesquiterpenes are SOAB and all other species (mainly benzene, aromatics and higher molecular weight alkanes) are SOAA. Note that there are some anthropogenic isoprene emissions, but they are dwarfed by biogenic isoprene. Also note that we will not be able to distinguish between U.S. and International SOAA, but past source apportionment simulations have found SOAA to be small so assuming it is all due to U.S. sources should be an adequate assumption.

With less than 10 Source Groups, the CAMx/PSAT/APCA simulation will run relatively quickly. The types of analysis the Broad-Brush Anthropogenic Emissions Source Apportionment Modeling could examine includes the following:

- Contributions of International anthropogenic emissions in 2014, which could be compared to the BF sensitivity International emissions contributions that is also funded under Phase III of the WRAP 2014 Shak-Out Study (i.e., International visibility impairment and International contributions to ozone and $PM_{2.5}$ design values).

- Contributions of natural sources, which could be compared to the BF sensitivity natural contributions.

- Calculation of the modeled Most Impaired Days (MID) by calculating visibility impairment of the anthropogenic (U.S. and International) and natural contributions, which could be compared against the estimate of observed MIDs at IMPROVE sites using the statistical procedure.

This last analysis was done using 2011 and 2008 source apportionment modeling results from the WAQS and WestJumpAQMS studies, respectively, and documented in a paper by Brewer et al., (2018). The Brewer and co-workers (2018) analysis provided insight into the differences between the modeled and statistical MID.

4.4.1 State-Specific Anthropogenic Emissions Contributions

CAMx could also be run using APCA and PSAT source apportionment to separately track contributions due to each western state's anthropogenic emissions. This is the similar to the approach used by EPA in the Cross-State Air Pollution Rule (CSAPR) and CSAPR Update that was used to determine which upwind state had a significant contribution to downwind nonattainment. The WAQS conducted such a state-specific source apportionment analysis where a source region map was used to divide the modeling domain into 21 geographic regions that consisted of grid cell definitions of 18 western states, plus Canada, Mexico and off-shore sources as shown in Figure 4-3. Four source categories would also be tracked:

- Anthropogenic Emissions;
- Wildfires;
- Prescribed Burns and Agricultural Burning; and
- Natural Sources (Biogenic, SSA, DMS, WBD and LNOx).

Since Initial Concentrations (IC) and Boundary Conditions (BC) always have to be tracked this results in 86 total separate Source Groups whose contributions are separately tracked (86 = 21 x 4 + 2). Note that if another layer of additional states to the east is desired then the 5 states bordering the Mississippi River (MN, IA, NB, MO and AR) that would result in 106 Source Groups to be tracked and the simulation would take 23% longer to run.

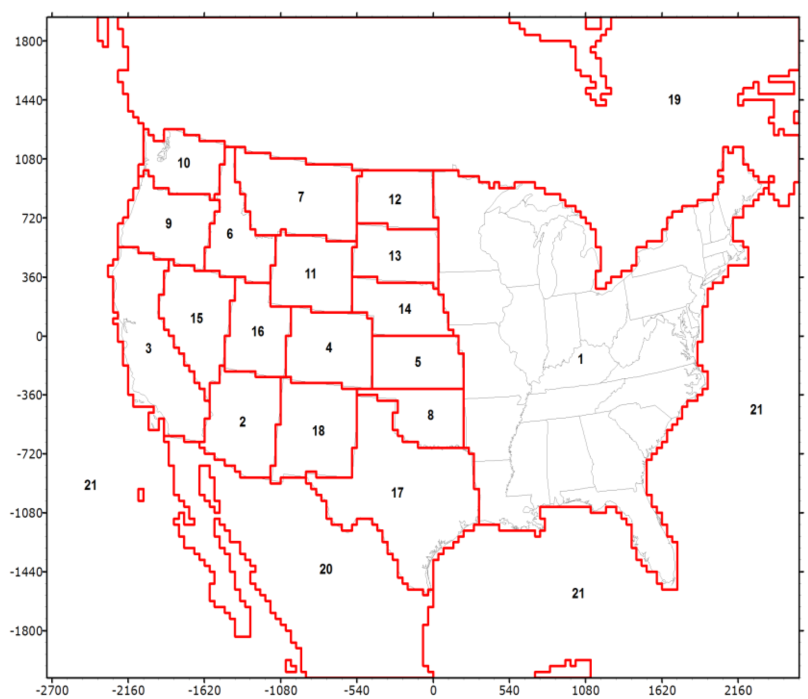

Figure 4-3. Geographic region source region map used in the WAQS State-Specific Source Apportionment Modeling.

The types of analysis the State-Specific Source Apportionment Modeling could be used for includes:

- Determining state anthropogenic emissions contributions to visibility impairment at CIA on the MID to help define which states should be in discussions for potential emission controls to help a specific CIA achieve reasonable progress toward natural conditions.

- A CSAPR-type analysis to determine which upwind states have a significant contribution to nonattainment, or interferes with maintenance of, nonattainment of the ozone and $PM_{2.5}$ NAAQS in a downwind state.

Note that when EPA conducted the CSAPR state-specific CAMx source apportionment modeling they treated all sources as point sources and used the point source override feature to define which sources should be tagged to each state. The EPA approach provides a more accurate assignment of emissions to a state than the source region map grid cell definition of states that we are proposing to use where a grid cell's emissions are assigned to a state based on the state with the largest overlap with the grid cell. EPA's CSAPR state assignment approach requires very complex and computational extensive SMOKE emissions modeling exercise.

4.5 Detailed Source Sector Source Apportionment

The SMOKE emissions processing for the WRAP 2014v2 emissions scenario uses several different streams of emissions processing to generate pre-merged PGM-ready emissions. Source apportionment can easily be performed with these different source sectors to obtain detailed contributions of different source sectors (see for example the breakdown in anthropogenic emission contributions to 2028 visibility in Figure 4-2). Example source sector categories that pre-merged emissions will be available for the WRAP 2014v2 emissions scenario include:

1. Biogenic emissions.
2. Oceanic emissions (SSA and DMS).
3. Lightning NOX (LNOx).
4. Windblown Dust (WBD).
5. Wildfires.
6. Prescribed Burns.
7. Agricultural Burning.
8. On-Road Mobile Sources.
9. Non-Road Mobile Sources.
10. Rail.
11. Airports.

12. Commercial Marine.

13. Upstream Oil & Gas Point and Non-Point Sources.

14. Electrical Generating Units (EGUs) Point Sources.

15. Non-EGU Point Sources.

16. Consumer Products.

17. Residential Wood Combustion (RWC).

18. Fugitive Dust.

19. Other Sources.

Ideally the combination of the 19 source sectors above with the 21 state-specific geographic regions in Figure 4-4 would provide detailed contributions and allow the identification of the source categories and states with the highest contributions to visibility impairment at CIAs or to ozone and $PM_{2.5}$ concentrations and design values. However, that would likely be a prohibitive number (> 400; 19 x 21 +2) of source groups that would take several months to run, assuming there was enough memory to run the source apportionment simulation at all.

It would be better to focus on a particular set of CIAs or nonattainment areas and look at contributions of a subset of states and source sectors. For example, if focused on CIAs in AZ could obtain contributions from surrounding states and Mexico (i.e., CA, NV, UT, CO, NM and Mexico) and collapse some of the source categories (e.g., combined first 4 natural sources; Rx+Ag fires; etc.) to say 12 source categories so there would be a more manageable number of Source Groups to track (87 = 12 x 7 + 2).

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