DRAFT RUN SPECIFICATION SHEET

SOURCE APPORTIONMENT MODELING USING THE 2028 ON-THE-BOOKS EMISSIONS SCENARIO

WRAP Regional Modeling Study
Revised March 31, 2020

Run Names:	**Task 4.7: 2028 Geographic Region and Source Sector PM and Ozone Source Apportionment Modeling using the 2028 On-the-Books (OTB) Emissions Scenario**
Model:	CAMx v7.0
Domains:	36US1 and 12WUS2 two-way nesting (see Figure 1)
Period:	2014 meteorology with annual anthropogenic emissions projected to represent 2028
Emissions:	2028OTBa with RepBase Fires
Boundary Conditions:	WRAP Revised 2014 GEOS-Chem Base Case
Source Apportionment:	WRAP States, Natural Sources and U.S. and International Anthropogenic Emissions
Purpose:	The 2028OTBa Source Apportionment simulation has multiple uses: • Estimate contributions of international and U.S. anthropogenic emissions to visibility impairment and ozone under 2028OTBa conditions. • Estimate contribution of contiguous WRAP region states' anthropogenic emissions to visibility impairment at Class I Areas (CIAs). • Estimate contribution of contiguous WRAP region states' anthropogenic emissions to ozone at rural and CIAs' monitoring sites • Estimate WRAP state-specific source sector contributions to visibility impairment at CIAs for key source sectors that may be considered for reasonable progress controls.

DESCRIPTION

The CAMx model has been run for two 2028 On-the-Books (OTB) emission scenarios that differ in the open land fire emissions used:

- 2028OTBa or 2028OTBw/RepBase Fires that uses the Representative Baseline (RepBase) fire emissions[1] developed by the WRAP Fire and Smoke Work Group (FSWG[2]).
- 2028OTBb or 2028OTBw/Actual 2014 Fires that uses actual 2014v2 fire emissions.

This simulation will simultaneously conduct a CAMx Particulate Source Apportionment Technology (PSAT) and an Ozone Anthropogenic Precursor Source Apportionment (APCA) source apportionment

[1] https://www.wrapair2.org/pdf/baseline_period_methods_20190419_v1_DRAFT.pdf
[2]https://www.wrapair2.org/FSWG.aspx

study for the 2028OTBa emission scenario that uses RepBase fire emissions. The definition of the 2028OTBa and Representative Baseline (RepBase) emission scenarios are contained in their run specification sheet.[3] The 2028OTBa and RepBase emissions scenarios both use the representative baseline fire emissions[4] that was developed by the WRAP Fire and Smoke Work Group (FSWG[5]).

The CAMx 2028OTBa PSAT and APCA source apportionment simulations will using the 36-km 36US1 and 12-km 12WUS2 domains shown in Figure 1 using two-way interactive grid nesting and will obtain WRAP region state-specific contributions of anthropogenic source sectors to PM and ozone concentrations and for PM, the resultant visibility at CIAs under 2028OTBa conditions. It will also obtain separate contributions of international anthropogenic and regional fire emissions.

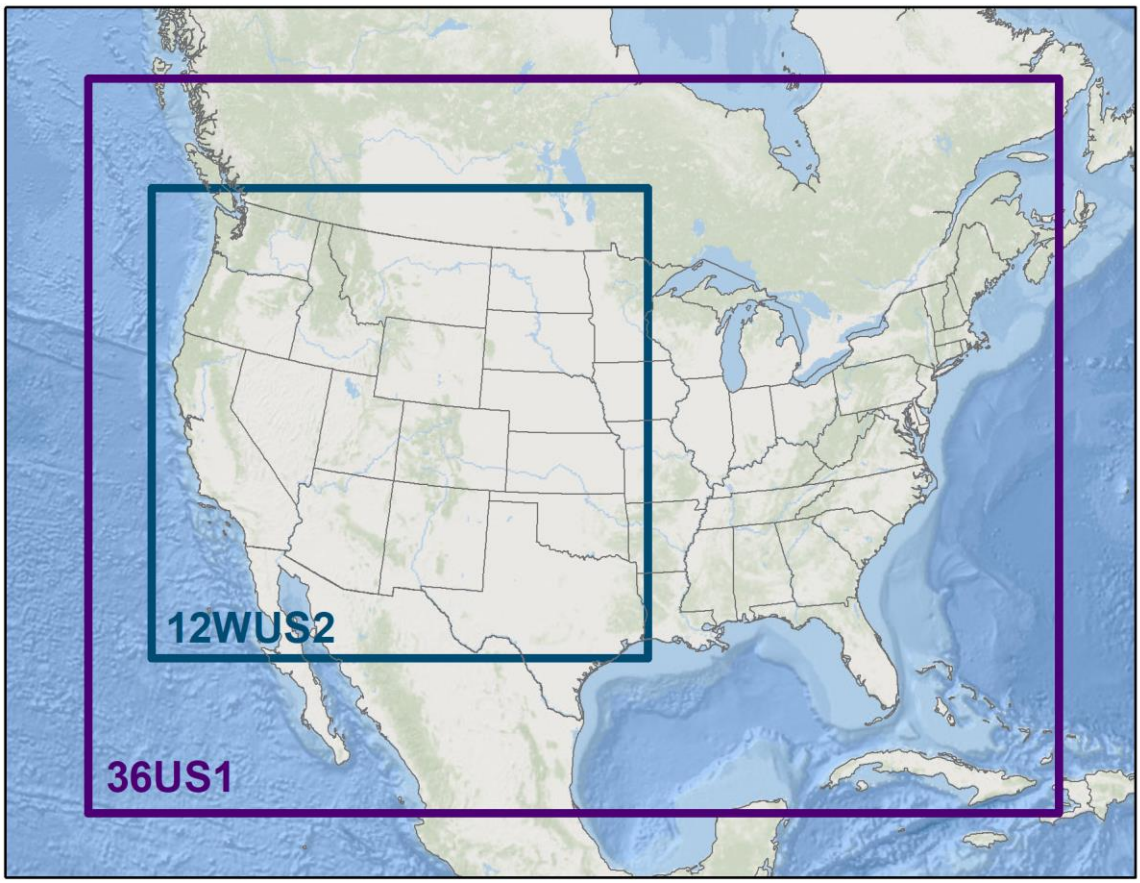

Figure 1. WRAP/WAQS 36-km 36US1 and 12-km 12WUS2 modeling domains used in the WRAP 2014v2, RepBase and 2028OTB CAMx simulations.

[3] https://views.cira.colostate.edu/docs/iwdw/platformdocs/WAQS_2014/Run_Spec_WRAP_2014_Task2.3-RepBase_Task%204.4-2028_CAMx_v3.pdf
[4] http://wrapair2.org/RBFFSWG.aspx
[5] http://wrapair2.org/FSWG.aspx

SOURCE APPORTIONMENT SPECIFICATIONS

Source apportionment modeling is being conducted for the RepBase emissions scenario[6] to obtain separate contributions of U.S. and International anthropogenic emissions, fires and natural emissions at rural and ClA monitoring sites to ozone, and to the particulate matter (PM) concentrations from which light extinction can be calculated. The 2028OTBa source apportionment modeling will be performed in a consistent fashion to obtain the same source sector U.S. and international anthropogenic emission contributions as the RepBase source apportionment run, only for the 2028 emissions scenario and expanded to also obtaining contributions from geographic regions (i.e., WRAP states) and source sectors.

Source Apportionment Families of Tracers to be Used

The CAMx PSAT tool will be used with the SO4 (3), NO3/NH4 (8) and Primary PM (14) families of reactive tracers resulting in 25 reactive tracers used to track PM source apportionment for each Source Group. The Secondary Organic Aerosol (SOA) family of PSAT tracers (which requires 14 tracers for each Source Group) will not be used because it will increase the run time by ~50% and the standard model output SOA species can be used to operationally[7] distinguish between anthropogenic (SOAA) and biogenic (SOAB) SOA.

The CAMx APCA tool will also be used to obtain ozone contributions for the same Source Groups as PSAT. There are two versions of ozone source apportionment in CAMx, the Ozone Source Apportionment Technology (OSAT) and APCA. They differ in how ozone is attributed to natural sources (e.g., biogenic VOC and NOx, lightning NOx [LNOx], etc.). APCA will only assign ozone formed to the natural Source Group when it is due to natural NOx emissions interacting with natural VOC emissions. In the case ozone is formed due to chemical reactions involving natural VOC and anthropogenic NOx emissions under VOC-limited ozone formation conditions, a case where OSAT would assign the ozone formed to the natural emissions Source Group, APCA recognizes that natural emissions cannot be controlled so redirects the ozone formed to the anthropogenic emissions Source Group. APCA is used for the 2028 ozone source apportionment as it provides more control strategy relevant information than OSAT.

Boundary Conditions

The CAMx v7 source apportionment tool has a new capability to provide separate contributions due to stratified boundary conditions (BCs). Typically, these stratifications will be different source sectors from outside of the CAMx modeling domain. A BC source apportionment stratification pre-processor has been developed that can provide stratified BCs for the CAMx v7 source apportionment tool two ways: (1) processing of an existing larger scale source apportionment simulations into stratified BCs (e.g., one-way nesting among CAMx runs); and (2) using global chemistry model base case and zero-out emission simulations processed for BCs to define BCs stratified as the zero-out component of the global model zero-out simulation. The CAMx v7 BC source apportionment pre-processor used this second approach with the Task 1.2 2014 GEOS-Chem base case (BASE) and Task 1.7 2014 GEOS-Chem Natural (NAT, i.e., no anthropogenic emissions anywhere) and no international anthropogenic emissions (ZROW) cases that were processed to generate boundary conditions (BCs) for the CAMx 36-km 36US1 modeling

[6] https://views.cira.colostate.edu/docs/iwdw/platformdocs/WAQS_2014/Run_Spec_WRAP_2014_Task1-8_Ant-Nat-SA_v5.pdf

[7] In the operational definition of SOAA and SOAB we are assuming that all SOA from isoprene, terpene and sesquiterpene species are biogenic and SOA from aromatic species are anthropogenic even though there are some anthropogenic isoprene emissions, but they are miniscule compared to the biogenic isoprene.

domain. These three 2014 GEOS-Chem runs were processed to generate CAMx BC input files (i.e., GCBC_BASE, GCBC_NAT and GCBC_ZROW). They were then processed so that CAMx can separately track BC contributions due to natural sources ($BC_{Natural}$), International anthropogenic emissions (BC_{Intl}) and U.S. anthropogenic emissions (BC_{USA}). The CAMx BC tool has to be provided with the GEOS-Chem base case and the GEOS-Chem zero-out CAMx BCs for each of the source categories to be separately tracked. This results in the following BC zero-out emission inputs into the CAMx BC stratification source apportionment pre-processer so that separate tracking of International anthropogenic, U.S. anthropogenic and Natural sources could be obtained.:

1. BC_{Base} = GCBC_Base
2. $BC_{Zero\text{-}Out\_Natural}$ = GCBC_Base – GCBC_NAT
3. $BC_{Zero\text{-}Out\_Intl\text{-}Anthro}$ = GCBC_Base - GCBC_ZROW
4. $BC_{Zero\text{-}Out\_USA\text{-}Anthro}$ = GCBC_Base - (GCBC_ZROW - GCBC_NAT)

Source Groups

When analyzing the contributions of geographic source regions and source emission sectors, the CAMx source apportionment tools (PSAT and APCA) allow the use of a Source Region Map that defines the grid cell definitions of the source regions from which contributions will be tracked. For example, the 2011 Western Air Quality Study (WAQS) platform was used to conduct 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 2. Using the Source Region Map, emissions by Source Categories can be separately provided so that contributions are obtained for each Source Group that is the intersection of Geographic Regions by Source Categories. For example, if the 21 geographic area Source Regional Map in Figure 2 was used with 6 Source Categories (e.g., Natural, Mobile (On-road and Non-Road), O&G, EGU Point, non-EGU Point and remainder Anthropogenic) there would be 128 Source Groups (21 x 6 + 2 for initial and boundary conditions However, computer run times depend on the number of Source Groups specified so source apportionment simulations need to be defined to obtain the information required using as few Source Groups as possible. In the example above that used 128 Source Groups, it could be better optimized as natural source contributions from 21 geographic regions are being obtained when such geographic distinction for natural sources is likely not needed and separate source contributions are being obtained from O&G sources from states that have minimal to no O&G sources.

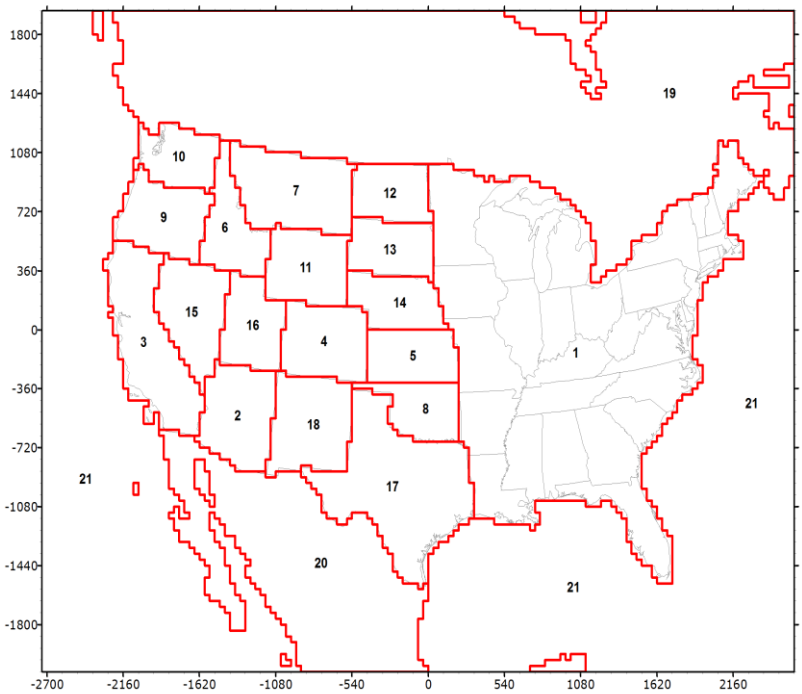

Figure 2. Example Source Region Map used in the WAQS 2011 source apportionment modeling that obtained contributions from state geographic regions using grid cell definitions of states.

Geographic Regions

Although use of a Source Region Maps is a convenient way to obtain source contributions from geographic regions, it is inefficient for minimizing the number of Source Groups that is critically important for developing the most computationally efficient source apportionment configuration possible. The purpose of the 2028 source apportionment modeling by geographic regions are as follows:

- To obtain separate 2028 contributions of U.S. and international anthropogenic emissions. Thus, at a minimum the same geographic stratification used in the RepBase source apportionment simulation that distinguishes between anthropogenic emissions from the U.S. vs. non-U.S. sources (i.e., Canada, Mexico and non-U.S. off-shore anthropogenic emissions within the CAMx domain and stratify the BCs to obtain separate U.S. vs. international anthropogenic emissions).
- To obtain contributions of anthropogenic emissions from WRAP states to visibility impairment at CIAs for all and selected anthropogenic source categories.

Based on this we have identified the 13 contiguous WRAP region states[8], remainder U.S. (including U.S. off-shore) and non-U.S. (Canada, Mexico and non-U.S. off-shore) anthropogenic sources as potentially the 15 geographical regions that 2028 anthropogenic emission contributions are desired.

[8] The 13 contiguous WRAP states are Arizona, California, Colorado, Idaho Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington and Wyoming,

Source Categories

The distinction between anthropogenic and natural sources is needed as well as fires, with separation of fire contributions by type of fire (WF, Rx and Ag) is desirable as was done in the RepBase source apportionment simulation. However, the geographic region where natural and fire sources come from is not as important leading to five initial Source Categories whose contributions will be obtained for all sources within the 36/12-km modeling domain (Figure 1):

Region-Wide Contributions (4)

- Natural Sources (biogenic, LNOx, oceanic [Sea Salt and DMS], WBD and Canada/Mexico Fires)
- Wildfires (WF)
- Prescribed Burns (Rx)
- Agricultural Fires (Ag)

As part of their regional haze SIPs, WRAP states are conducting four factor analyses as they consider reasonable controls on a variety of anthropogenic emission sources so their 2028 contributions to visibility impairment will be valuable information. Thus, we are considering separate contributions for the following Source Categories in the WRAP states:

Anthropogenic Emission Source Categories (5) for the 13 WRAP States (65 Source Groups)

- EGU Point Sources
- Non-EGU Point Sources
- Oil and Gas Area and Point Sources
- Mobile (On-Road and Non-Road, including locomotive, CMV and airports) Sources
- Remainder Anthropogenic (Non-Point, RWC, fugitive dust, ammonia)

With two more Source Groups to separately track anthropogenic emissions from the remainder of the U.S. (e.g., eastern US and U.S. offshore) and non-U.S. anthropogenic emissions (i.e., Canada, Mexico and Off-shore) that results in a starting point of 75 Source Groups (75 = 4 + (5 x 13) + 2 + 4), with the last 4 Source Groups being the BCs stratified into 3 components listed previously plus IC.

Optimization of 2028 Source Apportionment Simulation

The following are ways the 75 Source Group 2028 source apportionment can be optimized to reduce the number of Source Groups and consequently the computational requirements without sacrificing the ultimate objectives of the simulation (number of Source Groups saved in parenthesis):

- Only obtain separate O&G contributions for the 8[9] WRAP states with significant oil and gas emissions, for the other 5 WRAP states include any O&G emissions sources with the remainder anthropogenic Source Category (5).
- Break up 2028OTBa Source Apportionment simulation into two runs:
    1. In the first run obtain total anthropogenic emissions for the 13 WRAP states along with the other sources discussed above for 23 Source Groups (23 = 4 + 13 + 2 + 4); and
    2. The second run would run a Natural Source Group plus the 5 anthropogenic Source Sectors (where O&G for the 5 non-O&G WRAP states is combined with Remainder Anthropogenic) for the 13 WRAP states plus a leftover group for a total of 64 Source

[9] The 8 WRAP O&G states are: California, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah and Wyoming

Groups (64 = [5 x 13] – 5 + 1 + 1 + 2; 5 source categories for 13 WRAP states minus 5 non-O&G WRAP states plus natural plus leftover plus IC/BC)

EMISSIONS

The 2028OTBa emissions scenario will be used for the 2028OTB source apportionment simulation. Table 1 summarizes the source of emissions for the RepBase and 2028OTBa emission scenarios with details provided in the RepBase and 2028OTB Run specification Sheet.[10]

Table 1. Source of emissions for the WRAP current Representative Baseline (RepBase) and 2028OTBa emission scenarios.

Source Sector	RepBase	2028 OTB
California All Sectors	CARB-2014v2	CARB-2028
WRAP Fossil EGU w/ CEM	WRAP-RB-EGU[1]	WRAP-2028-EGU[1]
WRAP Fossil EGU w/o CEM	WRAP-RB-EGU	WRAP-2028-EGU
WRAP Non-Fossil EGU	EPA-2016fh	EPA-2028fh
Non-WRAP EGU	EPA-2016fh	EPA-2028fh
O&G WRAP O&G States	WRAP-RB-O&G	WRAP-2028-O&G
O&G WRAP Other States	EPA-2016fh	EPA-2028fh
O&G non-WRAP States	EPA-2016fh	EPA-2028fh
WRAP Non-EGU Point	WRAP-2014v2	EPA-2028fh[2]
Non-WRAP non-EGU Point	EPA-2016fh	EPA-2028fh
On-Road Mobile 12WUS2	WRAP-2014v2	WRAP-2028-Mobile
On-Road Mobile 36US	EPA-2016fh[4]	EPA-2028fh[4]
Non-Road 12WUS2	EPA-2016fh	WRAP-2028-Mobile
Non-Road non-WRAP 36US	EPA-2016fh	EPA-2028fh
Other (Non-Point) 12WUS2	EPA-2016fh	EPA-2028fh
Can/Mex/Offshore 12WUS2	EPA-2016fh	EPA-2028fh
Fires (WF, Rx, Ag)	WRAP-RB-Fires	WRAP-RB-Fires[3]
Natural (Bio, etc.)	WRAP-2014v2	WRAP-2014v2
Boundary Conditions (BCs)	WRAP-2014-GEOS	WRAP-2014-GEOS

1. The CNEE WRAP-RB-EGU and WRAP-2028-EGU emissions have updates from WRAP states.
2. The WRAP-2014v2 non-EGU point sources have updates from WRAP states.
3. The 2028OTBb differs from 2028OTBa in that actual 2014v2 fires will be used.

[10] https://views.cira.colostate.edu/docs/iwdw/platformdocs/WAQS_2014/Run_Spec_WRAP_2014_Task2.3-RepBase_Task%204.4-2028_CAMx_v3.pdf

The RepBase and 2028OTB anthropogenic emissions are processed in several separate streams of emissions processing using the Spare Matrix Operator Kernel Emissions (SMOKE[11]) processing tool. Each separately processed stream of emissions by SMOKE generates a "pre-merged" gridded low level or point source emissions input file for photochemical grid model modeling. Table 2 shows the different anthropogenic emission source categories and how they were combined in the SMOKE emissions processing streams to generate the pre-merged model-ready emission files. Note that since the California ARB originally provided separate emissions for 2014 and 2028 used in the, respectively, RepBase and 2028 emission scenarios that California source sectors are processed separately from the other WRAP states and did not have as much source type distinction. The CARB is currently disaggregating their emission source categories to be consistent with the WRAP source sector SMOKE processing streams that will be used in the 2028 source apportionment modeling so we will be able to define 2028 source apportionment Source Categories in a consistent fashion for California and the other WRAP states.

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

Table 2. Original anthropogenic source sectors for the WRAP RepBase and 2028OTB emission scenarios and how they are processed through SMOKE to generate the pre-merged PGM emissions input files (Combined Sector). California emissions are being disaggregated and re-processed by SMOKE to be consistent with the other WRAP States.

WRAP2014v2	WRAP RepBase	2028OTB	Combined Sector
afdust_wrapv2_adj	afdust_adj	afdust_adj	**afdust_adj**
ag_wrapv2	ag	ag	**ag**
cmv_c1c2_wrapv2	cmv_c1c2 (point only)	cmv_c1c2 (point only)	**CMV_c1c2c3**
cmv_c3 (point only)	cmv_c3 (point only)	cmv_c3 (point only)	
nonpt_wrapv2	nonpt	nonpt	**nonpt**
nonroad_wrapv2	nonroad	nonroad	**nonroad**
np_oilgas_wrapv2_only	np_oilgas	np_oilgas_wrap_only	**np_oilgas**
np_oilgas_wrapv2	np_oilgas_Nowrap	np_oilgas	
onroad	onroad	onroad	**onroad**
onroad_can	onroad_can	onroad_can	**Non-US**
onroad_mex	onroad_mex	onroad_mex	
othafdust_adj	othafdust_adj	othafdust_adj	
othar	othar	othar	
othpt (point only)	othpt (point only)	othpt (point only)	
	othptdust_adj	othptdust_adj	
ptegu_wrapv2	ptegu_nonwrap (point only)	ptegu_nonwrap (point only)	**ptegu**
	ptegu_wrap (point only)	ptegu_wrap	
	airport	airport	**ptnonipm**
ptnonipm_wrapv2	ptnonipm_nonwrap (area+point)	ptnonipm_nonwrap (area+point)	
	ptnonipm_wrap (area+point)	ptnonipm_wrap (area+point)	
pt_oilgas_wrapv2_only	pt_oilgas (area+point)	pt_oilgas_wrapv4_only	**pt_oilgas**
pt_oilgas_wrapv2	pt_oilgas_NOwrap (area+point)	pt_oilgas_wrapv4	
rail_wrapv2	rail	rail_wrapv4	**Rail**
rwc_wrapv2	rwc	rwc_wrapv4	**Rwc**
aircraft (area+point)	aircraft (same as base)	aircraft 2028 (area+point)	**CARB-aircraft**
Area	Area	Area 2028	**CARB-area**
FertNH3_gentpro	FertNH3_gentpro	FertNH3_gentpro 2028	**CARB-Ag**
LivestockNH3_gentpro	LivestockNH3-gentpro	LivestockNH3-gentpro 2028	
OGV_Area	OGV_Area (same as base)	OGV_Area 2028	**CARB-OGV**
OgvPorts (point only)	OgvPorts (same as base)	OgvPorts 2028 (point only)	
onroad	onroad	onroad 2028	**CARB-onroad**
Point (point)	Point (same as base)	Point 2028 (point)	**CARB-Point**
RoadDust_Paved	RoadDust_Paved	Roaddust_Paved 2028	**CARB-Roaddust**
RoadDust_Unpaved	RoadDust_Unpaved		
RWC	RWC	RWC 2028	**CARB-RWC**

USES OF 2028OTBa SOURCE APPORTIONMENT SIMULATION

There are several uses for the 2028OTBa source apportionment results.

2028 WRAP State Source Contributions

The contributions of each of the 13 WRAP state anthropogenic emissions to visibility impairment at all CIAs in the western states will be obtained. These state-specific anthropogenic emissions contributions will be further broken down by major source category (e.g., EGU Point, non-EGU Point, O&G, etc.). These results will be useful for states to know which upwind states are contributing to visibility impairment at CIAs as well as which source sectors are contributing.

International Contributions

The contributions of international anthropogenic emissions under the 2028OTB emissions scenario will also be obtained. These contributions can be compared with those for the RepBase source apportionment and zero-out (ZROW) modeling and potentially used to adjust Glideslopes..

Dynamic Evaluation

The CAMx 2028OTBa will also be used with the RepBase source apportionment and Task 2 Dynamic Evaluation 2002 CAMx modeling to evaluate the changes in U.S. anthropogenic emissions contribution to visibility impairment on the MID from past year (2002) to current year (RepBase; 2014-2018) to future year (2028) time periods.