ENVIRONMENT
& HEALTH

Procedures for Making 2028 Visibility Projections using the WRAP-WAQS 2014 Modeling Platform

draft - July 24, 2020 - draft

RECOMMENDATION

Based on the technical analysis presented in this document and Regional Haze planning goals in rule and guidance, of the three projection methods presented, tested, and analyzed, the EPAwoF visibility projection method described below is recommended for consistent 2028 Class I area visibility projections for Reasonable Progress Goals across the contiguous WESTAR-WRAP region. It will be implemented as the default setting on the WRAP Technical Support System (TSS[1]) visibility projection tools, while the other two methods (EPA and ModMID) will also be accessible on TSS.

INTRODUCTION

The Western Regional Air Partnership (WRAP)[2] and the Western Air Quality Study (WAQS) Cooperators[3] have developed a 2014 Photochemical Grid Model (PGM) modeling platform that is being used to support the development of western states' Regional Haze Rule (RHR) State Implementation Plans (SIPs) due July 2021. In the RHR SIPs, individual states will set 2028 Reasonable Progress Goals in deciviews for each Class I area (CIA) in their jurisdiction. One important use of the WRAP-WAQS 2014 PGM modeling platform is to make 2028 visibility projections for comparison with the Uniform Rate of Progress (URP) Glidepath. The URP Glidepath is a straight line of visibility impairment in deciview from the observed 2000-2004 baseline period visibility conditions average for the IMPROVE 20 percent Most Impaired Days (MID) to progress toward better visibility and estimated natural conditions in 2064 at IMPROVE monitoring sites that represent CIAs. The 2028 visibility projection is compared against the URP Glidepath 2028 value to see whether a projected visibility condition estimate at the CIA will be on, above, or below the Glidepath to judge how well the modeled trend in visibility is tracking the straight-line rate of progress to the estimated natural conditions in 2064. The EPA method for identifying the IMPROVE MID uses a statistical procedure that is designed to identify the days at IMPROVE monitoring sites that are most impaired by anthropogenic emissions, primarily relying on measured ammonium sulfate and ammonium nitrate species quantities as proxies for manmade emissions. The IMPROVE MID statistical procedure estimates the contributions of routine natural haze and natural haze due to episodic events (i.e., fires and windblown dust) to measured daily light extinction with the remainder extinction assumed to be mainly anthropogenic in origin, using the IMPROVE sampling record from 2000-2014. The IMPROVE Most Impaired Days (MID) visibility metric is then obtained for each year as the 20% highest days average with anthropogenic visibility impairment after the statistical procedures have removed days with high estimated fire and dust contributions from carbon and geogenic filter mass measurements. The IMPROVE MID is the metric required in the Regional Haze Rule (RHR) January 2017 changes by EPA to evaluate progress for the 2028 planning milestone toward reaching the distant long-term goal of achieving estimated natural conditions at CIAs by 2064. To help assess whether a CIA is on a path toward this RHR long-term goal, the trends in the IMPROVE MID visibility impairment are compared against the URP Glidepath. As part of an RHR SIP, future year visibility projections are made

[1] https://views.cira.colostate.edu/tssv2/

[2] http://www.wrapair2.org/

[3] https://views.cira.colostate.edu/iwdw/About/Default.aspx#agencies

at CIAs with PGM results for comparison against the URP Glidepath with the current (second) round of RHR SIPs to estimate whether a CIA is progressing reasonably by the 2028 milestone planning year toward estimated natural conditions in 2064.

Purpose

This document discusses the approaches being used for making 2028 future year visibility projections for the MID using current and future year emission scenario simulations with the WRAP-WAQS 2014 CAMx PGM modeling platform.

Example URP Glidepath Calculations

The WRAP version 2 of the TSS includes numerous tools and products based on analysis of air quality, emissions and modeling data that western states can use as the technical basis for their RHR SIPs. With more than 100 CIAs in the WESTAR-WRAP region, a regional technical decision support system is necessary since most, if not all, CIAs have notable amounts of international, natural, and interstate transport impacts on visibility, in addition to the host state's sources impacting their CIAs. One such TSS2 product is the Glidepath Tool that includes the URP Glidepath and 2028 visibility projections using CAMx modeling results from the WRAP 2014 photochemical modeling platform.

Figure 1 displays a URP Glidepath and 2028 visibility projections for Yellowstone (YELL) CIA that was obtained from the WRAP TSS2 Glidepath Tool. The upper part of Figure 1 is the URP Glidepath for the IMPROVE MID where the goal is to achieve natural conditions by 2064, and the bottom part of the Glidepath is the IMPROVE Clearest 20% days (cleanest 20% of measured days for total light extinction) where the goal is no worsening in visibility from the Baseline. The MID URP Glidepath starts with the IMPROVE MID 2000-2004 5-year Baseline average (green, 8.4 dv) and the Glidepath is a straight trend line (red) in deciview (dv) to natural conditions of 4 dv in 2064. The annual IMPROVE MID observations are shown by the dots connected by the red line. The two symbols at 2028 are the projected 2028 visibility MID using the RepBase/2028OTBa and 2014v2/2028OTBb CAMx modeling results and the EPA default visibility projection method. In this case for YELL, the 2028 visibility projections are above the URP Glidepath so are above the trend line toward natural conditions in 2064.

The lower part of Figure 1 is information on the clearest days where the RHR goal is no degradation in visibility from the Baseline. Again the green line is the 20% clearest days IMPROVE 2000-2004 Base line and since the goal is no degradation, the line to 2064 is flat. In this case, both the observed clearest day visibility and the 2028 visibility projections for the 20% clearest days are showing visibility improvements over the Baseline so there is no degradation for the clearest days.

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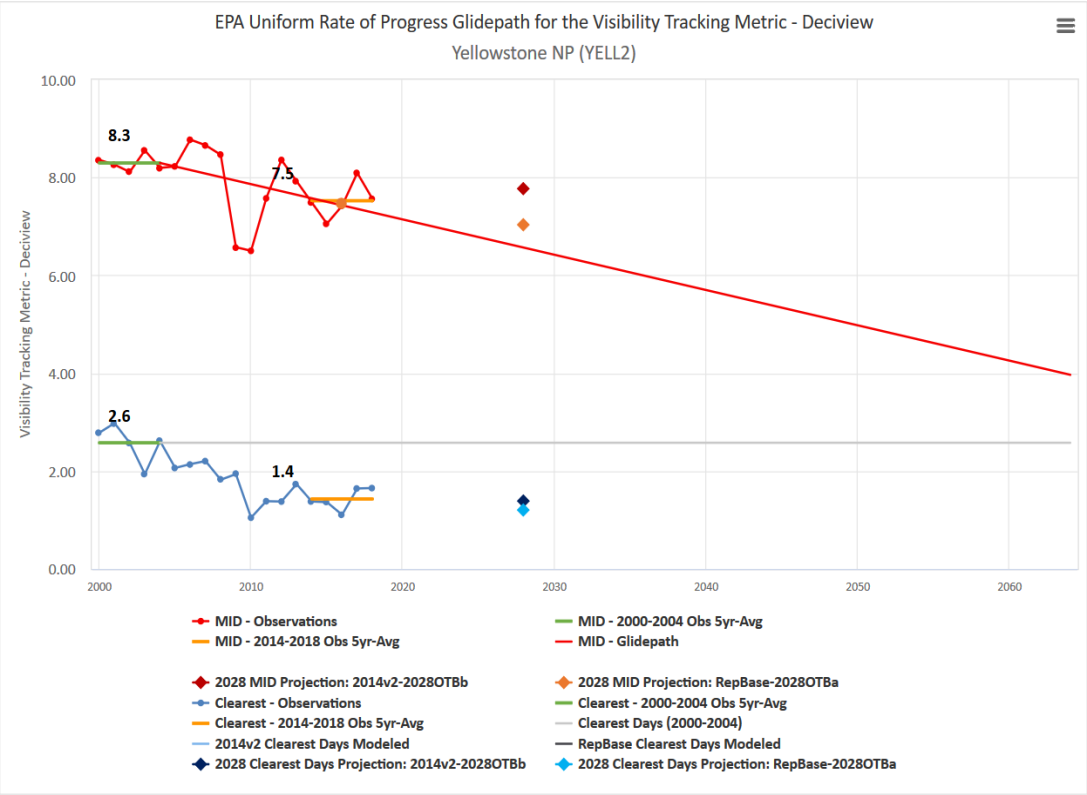

Figure 1. URP Glidepath and 2028 visibility projections for Yellowstone National Park, Wyoming from the WRAP TSS2 (accessed July 10, 2020).

WRAP-WAQS 2014 Modeling Platform Modeling Results

WRAP and WAQS have jointly developed a 2014 PGM modeling platform using a 36-km grid resolution continental U.S. (36US1) and 12-km grid resolution western U.S. (12WUS2) modeling domains, as shown in Figure 2. Sensitivity modeling and an initial 2014v1[4] base case simulations and model performance evaluation (MPE) were conducted using the CAMx and CMAQ PGMs. Improvements were made and a second 2014v2 base case was conducted using just the CAMx PGM with the MPE in preparation.

A Representative Baseline (RepBase) CAMx simulation was also conducted that used anthropogenic emissions representative of the 2014-2018 5-year planning period, natural emissions and Boundary Conditions (BCs) the same as the 2014v2 simulation and Representative Baseline fire emissions developed by the WRAP Fire and Smoke Work Group (FSWG[5]). Two 2028 on-the-book (OTB) future year emission scenarios were conducted where anthropogenic emissions were projected to 2028 and natural emissions and BCs were held constant at 2014v2 levels. The two 2028 emission scenarios differ in that 2028OTBa uses the RepBase fires and 2028OTBb uses the 2014v2 actual fires. Details on the RepBase and 2028OTB emission scenarios are contained in their run specification sheet.[6] This results in

[4] http://views.cira.colostate.edu/iwdw/docs/waqs_2014v1_shakeout_study.aspx
[5] https://www.wrapair2.org/FSWG.aspx
[6] https://views.cira.colostate.edu/docs/iwdw/platformdocs/WAQS_2014/Run_Spec_WRAP_2014_Task1-8_Ant-Nat-SA_v5.pdf

the WRAP-WAQS 2014 PGM modeling platform having two pairs of current and future year CAMx modeling results that can be used to project the observed current year IMPROVE MID visibility to 2028:

- RepBase/2028OTBa, using RepBase fires.
- 2014v2/2028OTBb, using actual 2014v2 fires.

Additional 2028 simulations will also be run, including the first Potential Additional Controls (PAC1) scenario that is based off of 2028OTBa so projections will be made using the RepBase current year modeling results.

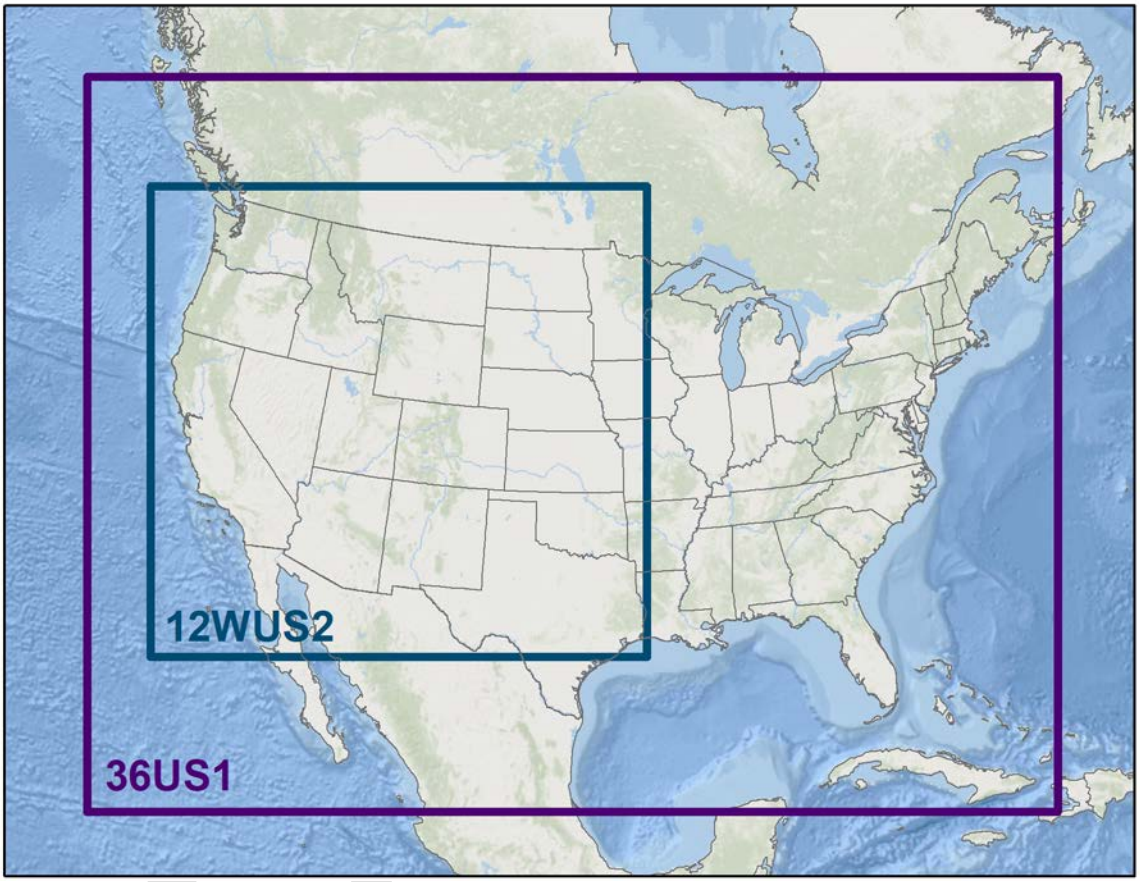

Figure 2. WRAP-WAQS 36/12-km 36US1/12WUS2 modeling domains used in the WRAP-WAQS 2014 modeling platform current (2014v2 and RepBase) and future (2028OTB) year CAMx simulations.

VISIBILITY PROJECTION APPROACHES USING THE WRAP-WAQS 2014 PLATFORM

Below we discuss several approaches for using the WRAP-WAQS 2014 modeling platform CAMx current year (e.g., RepBase) and 2028 future year (e.g., 2028OTBa) modeling results to project the observed IMPROVE MID visibility. The EPA recommended visibility projection procedures are outlined in Section 5.3 of their ozone, $PM_{2.5}$ and regional haze modeling guidance.[7] The projection procedure uses the CAMx RepBase and 2028OTBa modeling results in a relative fashion to scale the observed IMPROVE concentrations from the 2014-2018 MID to obtain 2028 future year MID concentrations. The model derived scaling factors are obtained as the ratio of the CAMx future (2028OTBa) to current (RepBase) year modeling results averaged across several days. For example, the equation for SO4 concentrations from the 2014-2018 IMPROVE MID:

$$RRF_{SO4} = \sum 2028OTBa_{SO4} / \sum RepBase_{SO4}$$

$$Projected_SO4_{2028} = IMPROVE_SO4_{2014\text{-}2018} \times RRF_{SO4}$$

The daily projected 2028 species concentrations for each day from the 2014-2018 IMPROVE MID are converted to extinction using the second IMPROVE extinction equation and then into deciview to obtain the 2028 visibility projection.

Three separate visibility projections procedures are being used with the WRAP modeling results that differ in the days used to develop the RRFs and how days with modeled fire impacts are treated. The three visibility projection procedures are as follows:

> EPA: The EPA default projection approach that uses RRFs based on average modeled concentrations across the days in the observed 2014 IMPROVE MID.
>
> EPAwoF: Even though the IMPROVE MID are obtained using a statistical procedure to limit the influence of fires on the MID, modeled fire impacts can still occur on the MID. The EPA without fire method uses the RepBase Source Apportionment (SA) to eliminate the contributions of fires in the RepBase and 2028OTBa modeling results that are used in the RRFs. Thus, the EPAwoF method RRFs are based on the same days in the 2014 IMPROVE MID as used by the EPA default method, only the contributions from fires have been removed.
>
> ModMID: The third method uses the modeled most impaired days (ModMID). The contributions of fires are removed from the RepBase modeling results for the 2014 IMPROVE sample days using SA and the days are ranked by U.S. anthropogenic emissions extinction and the 20% days with the highest U.S. anthropogenic extinction selected for use in the ModMID RRFs.

EPA Recommended Default Visibility Projection Procedures (EPA)

EPA's recommended procedure for projecting IMPROVE measured PM species concentrations from the 2014-2018 IMPROVE MID to the 2028 future year uses RRFs based on modeled concentrations from the base year IMPROVE MID, which would be 2014 in this case. The EPA recommended procedures are described in EPA's 2018 regional haze, ozone and $PM_{2.5}$ modeling guidance and codified in the Software for the Modeled Attainment Test (SMAT[8]) tool[9]. The application of these procedures for the RepBase and 2028OTBa CAMx modeling results involves the following steps.

[7] https://www3.epa.gov/ttn/scram/guidance/guide/O3-PM-RH-Modeling_Guidance-2018.pdf

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

[9] The SMAT tool source code is not publicly available nor has it received independent quality assurance. EPA controls the SMAT tool and how it works. It requires input files of monitoring data and model results.

1. For each aerosol species (SO4, NO3, EC, OA, Soil and CM),
    a. Calculate Relative Response Factor (RRF) using modeled aerosol concentration:
        i. Use modeling results for the same days from the 2014 IMPROVE MID in the CAMx RepBase and 2028OTBa modeling results.
        ii. Calculate average model species concentrations on days in the 2014 IMPROVE for CAMx RepBase and 2028OTBa scenarios.
        iii. Calculate RRF for each species using the ratio of the average species concentrations across the 2014 IMPROVE MID from the RepBase and 2028OTBa CAMx modeling results.
    b. Apply average RRF for each aerosol species to aerosol concentration for every IMPROVE MID in 5-year period 2014-2018 to obtained 5-years of 2028 daily species concentrations.
    c. Convert daily species concentrations to extinction using the second IMPROVE extinction equation and sum the species daily extinction to obtained daily 2028 extinction values for each day from the 2014-2018 IMPROVE MID.
2. Convert daily total extinction to 5-year average of annual deciview
    a. For each day from 2014-2018 MID, convert projected 2028 daily extinction to deciview.
    b. Average daily deciview across MID for each of the 5 years.
    c. Average annual deciview MID across 5 years to obtain the 2028 MID visibility projection.
3. Compare 2028 MID visibility projection to the 2028 point on URP Glidepath.

The EPA recommended visibility projection approach was used to make the 2028 visibility projections using the WRAP RepBase/2028OTBa and 2014v2/2028OTBb CAMx modeling current/future year modeling results with an example for Yellowstone shown in Figure 1. Additional examples are available on the WRAP TSS2 Glidepath Tool discussed previously

<u>Discussion of EPA's Recommended Visibility Projection Approach</u>

EPA's recommended visibility projection approach using RRFs based on modeling results from days in the 2014 IMPROVE MID could theoretically be appropriate for making 2028 visibility projections using WRAP's 2014v2/2028OTBb CAMx modeling results that use 2014 actual fire emissions. However, it may be inappropriate for use with the RepBase/2028OTBa CAMx modeling results that use RepBase fires because the RepBase fires are not specific to 2014 so modeled fire concentration impacts could occur on the observed 2014 IMPROVE MID. As the RRFs are supposed to represent changes in concentrations on the IMPROVE MID that are calculated to minimize fire influences, the presence of fires in the RRF numerator and denominator is inappropriate and makes the RRFs stiff (unresponsive to emissions changes) so that they could underestimate the actual improvement in 2028 MID visibility.

The issue of potential RepBase modeled fire impacts on 2014 IMPROVE MID was examined by comparing observed and modeled 2014v2 and RepBase daily PM species light extinction on the 2014 IMPROVE MID. The top panel in Figure 3 shows the observed, 2014v2 and RepBase visibility extinction by species for the 2014 IMPROVE MID at the Canyonlands (CANY1) IMPROVE monitoring site. There are no readily apparent fire impacts in either the observed or modeled extinction on the CANY 2014 IMPROVE MID, which are indicated by large extinction values due to organic aerosol (also called OMC) and elemental carbon (EC), so the EPA recommended visibility projection approach would be appropriate using both the 2014v2 and RepBase modeling results[10]. The lower panel in Figure 3 shows

[10] Note that the large wind blow dust contribution at Canyonlands on 11/1/2014 indicates strong winds that could be associated with atypically large transport of sulfate from Mexico. The model RRF will be insensitive to U.S. emissions reductions if days are included that have large international transport contributions to impairment, and an alternate method to address this concern is to identify the MID based on the days with the largest U.S. contribution to impairment.

the 2014 IMPROVE MID extinction bar charts for Mount Rainier (MORA1). At MORA1 there are 2014 IMPROVE MID in August that have elevated carbon (OA and EC) in the RepBase scenario that are likely due to fires, but the high OA/EC extinction are not apparent in the 2014v2 scenario. Here the EPA projection approach would be not appropriate for the RepBase/2028OTBa projections as the RRFs for OA and EC would be very stiff (i.e., near 1.0). Although fires are most pronounced in the OA and EC concentrations/extinctions, fires also emit SOx and NOx species so would also reduce the effect of any response to reductions in US anthropogenic emissions contributing to AmmSO4 or AmmNO3.

The top panel in Figure 4 shows the stacked extinction bar charts on the 2014 IMPROVE MID at Point Reyes (PORE1) IMPROVE site. At PORE1, the 2014v2 CAMx simulations has elevated OA (attributed to fire) on IMPROVE MID on September 11 and 14, 2014 that are not seen in the observed or RepBase modeling results. Thus, the EPA recommended approach may not even be appropriate to make projections using the 2014v2/2028OTBb actual 2014 fires CAMx modeling results at PORE1. The bottom panel in Figure 4 show the stacked extinction bar charts on the 2014 IMPROVE MID for the Lassen Volcanic (LAVO1) site in northern California where the 2014v2 (August 3, 2014) and RepBase (August 24, 2014) CAMx simulations each have one day of elevated OA and EC concentrations (attributed to fire) that would dominate the OA and EC RRFs using the EPA recommended visibility projection approach.

Figures 3 and 4 confirm that using RepBase fires could result in modeled fire impacts on the 2014 IMPROVE MID that would result in biased RRFs using the EPA recommended visibility projection approach potentially resulting in understated visibility improvements in 2028. But they also raise concerns that even using 2014 actual fires in the 2014v2/2028OTBb projections there could be modeled fire impacts on the 2014 IMPROVE MID resulting in biased RRFs that understate projected 2028 visibility improvements on the MID. That said, numerous other important PGM source categories use the same emissions from RepBase and 2014 in the 2028 projection emissions, meaning the projected visibility change is based on assuming only the U.S. anthropogenic emissions would be changing by 2028. We know from numerous peer-reviewed studies, including EPA climate change assessments, that quasi-natural emissions such as fire, dust, and biogenic emissions that greatly affect Regional Haze are not constant into the future.

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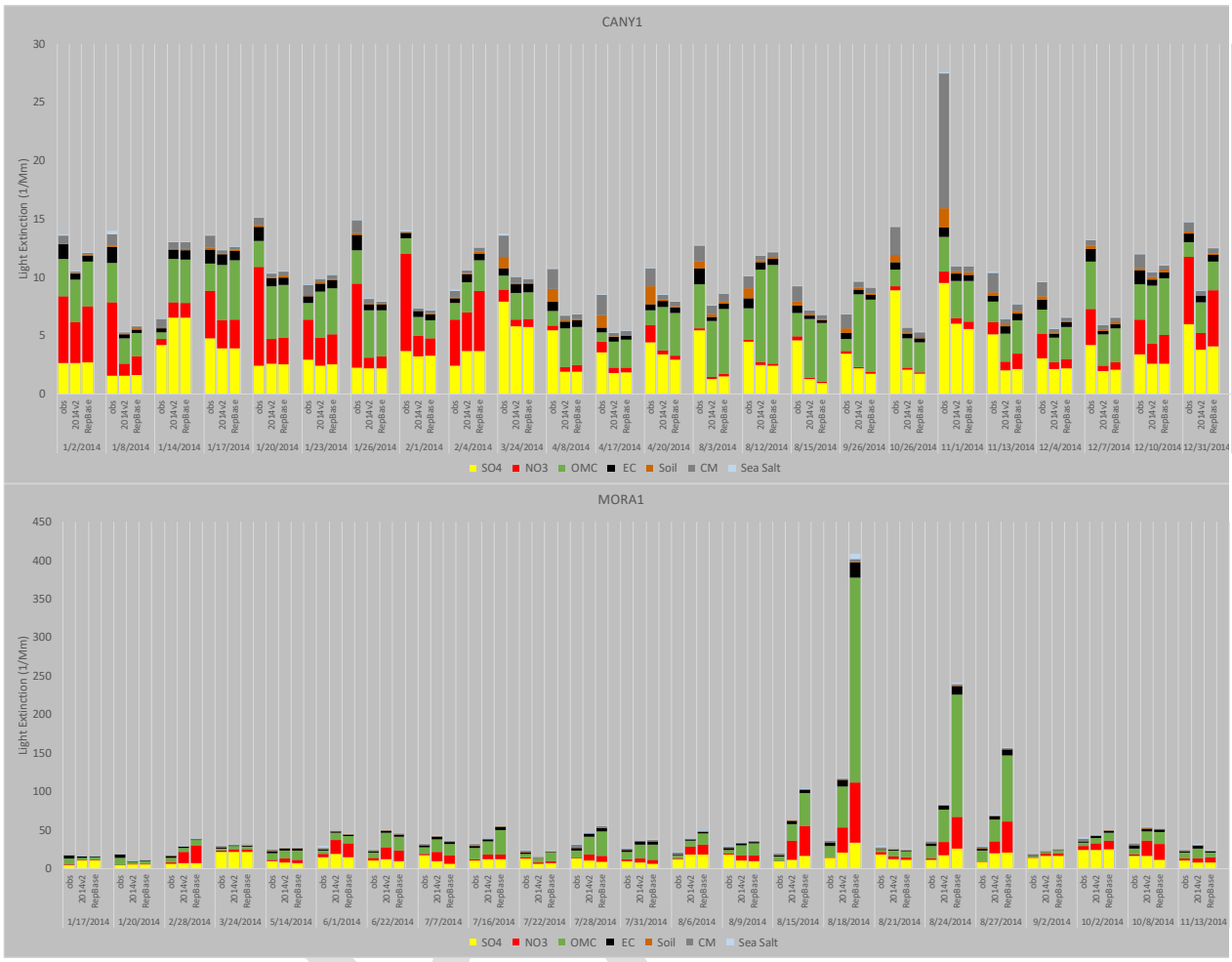

Figure 3. Visibility extinction stacked bar charts for Canyonlands UT (top) and Mount Rainer WA (bottom) IMPROVE sites on the 2014 IMPROVE MID for the observed (obs), and modeled 2014v2 actual base case and Representative Baseline (RepBase) emission scenarios using the WRAP 2014 CAMx modeling platform.

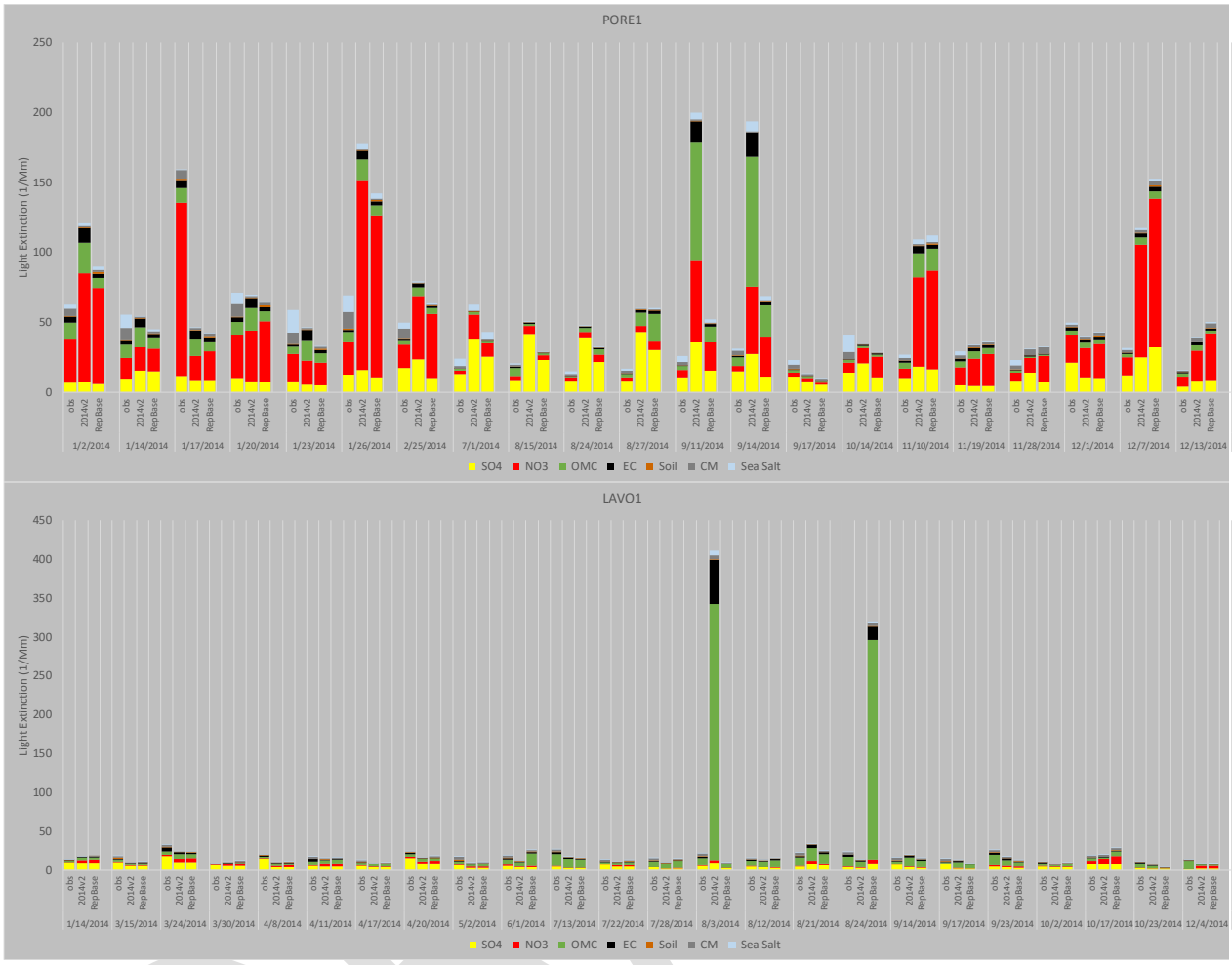

Figure 4. Stack visibility extinction bar charts for Point Reyes CA (top) and Lassen Volcanic National Park CA (bottom) IMPROVE monitors on the 2014 IMPROVE MID for the observed (obs), and modeled 2014v2 actual base case and Representative Baseline (RepBase) emission scenarios using the WRAP 2014 CAMx modeling platform.

EPA Recommended Visibility Projection Approach Without Fire Impacts (EPAwoF)

Several different approaches were examined to determine the best methodology for limiting the effects of fire contributions on RRFs based on the 2014 MID, like the EPA default method.[11] In the final EPA without fire (EPAwoF) approach, the CAMx RepBase and 2028OTBa concentrations for the days from the 2014 IMPROVE MID are used in the RRFs, as used in the EPA default projection approach. Only the aerosol concentrations attributed to wildfires (WF) and wildland prescribed (Rx) fires are excluded when the RRFs are calculated. The RepBase Source Apportionment results are used to remove the contributions of wildfires and wildland prescribed fires from the CAMx RepBase and 2028OTBa modeling results when calculating the RRFs.

For example, Figure 5 shows the RepBase SA contributions at the Crater Lake, Oregon IMPROVE site for the 2014 IMPROVE MID from all source categories (top) and for source categories with the contributions of fires removed. That is, the top panel in Figure 5 show the source contributions on the 2014 IMPROVE MID that are used in the EPA default projection method, whereas the bottom panel shows the source

[11] https://www.wrapair2.org/pdf/VisProj_Alt-EPAwoF-ModMID_RTOWG_2020-07-16v1.pptx

contributions used in the EPAwoF alternative projection method. There are two days with large fire contributions, July 10 when WF fires (dark green) is almost 80% of the daily extinction and October 8 where WF (dark green) and Rx (light green) fires together contribute over 50% of the daily extinction (Figure 5, top panel); these high fire contributions are used in the EPA default method RRFs. Note that we also evaluated an alternative EPAwoF projection method that excluded days with significant fire contributions, like the two days discussed above (see Figure 5 top panel). Even with the removal of fires from the RRFs as used in the EPAwoF method (Figure 5, bottom panel), the RepBase daily extinction on the 2014 MID (and other days) is still dominated by sources that are assumed to remain mostly unchanged between the current and future year, such as boundary conditions (BC) from international anthropogenic emissions (black), BC from natural sources (tan) and secondary organic aerosol from biogenic (SOAB) emissions (white).

Figure 6 is like Figure 5 only for the Redwood IMPROVE site on the coast in the northwestern corner of California. May 26 has a very large WF contribution with smaller WF contributions on other days in June, July, August and September, and even Rx fire contributions on May 14. These fire contributions are used in the RRFs in the EPA default method. The bottom panel of Figure 6 shows the contributions without the three types of fires and represent the data used in the RRFs for the alternative EPAwoF projection method.

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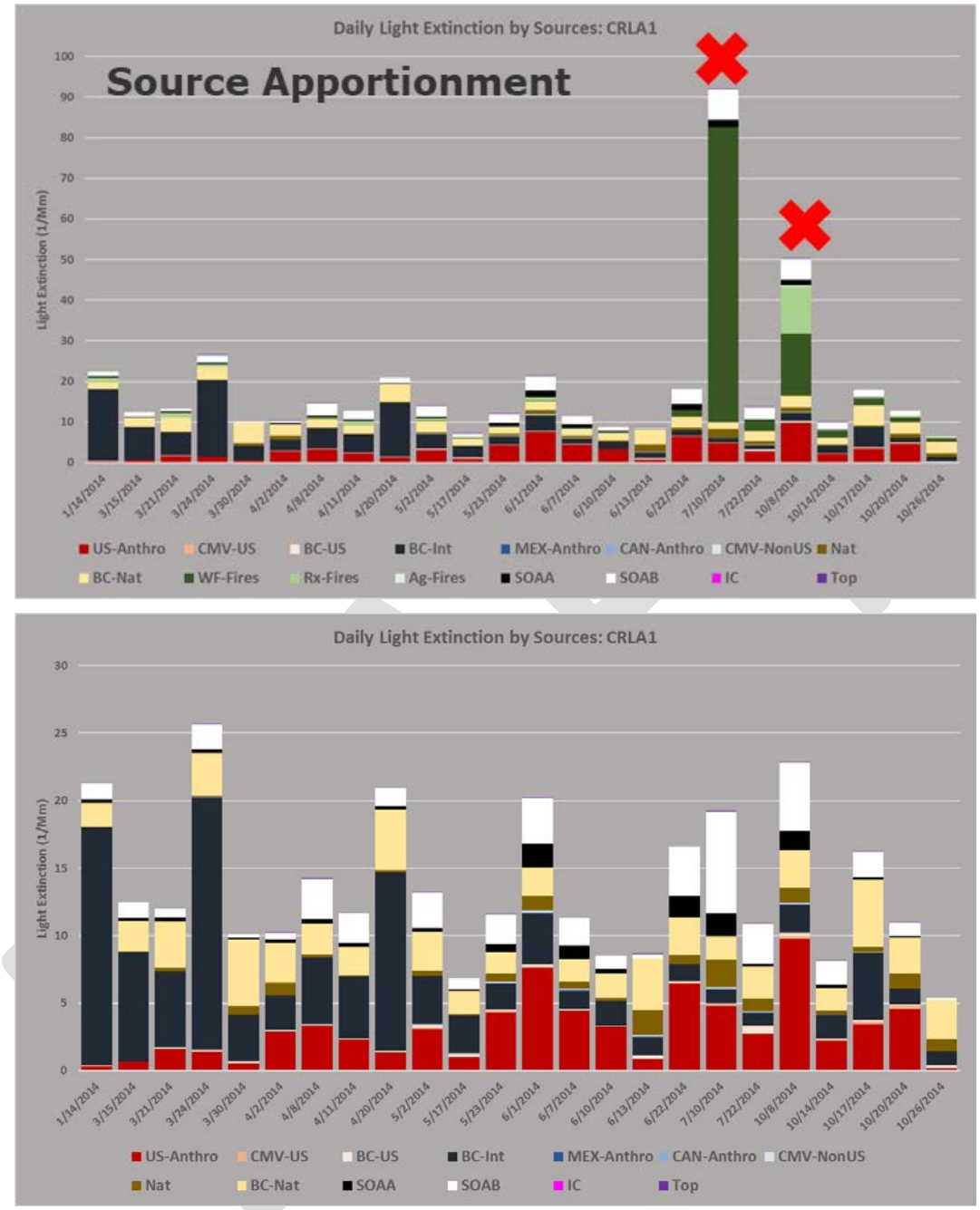

Figure 5. CAMx RepBase source apportionment results at Crater Lake (CRLA) Oregon for 2014 IMPROVE MID for all source categories (top) and with contributions of three types of fires (WF, Rx and Ag) removed (bottom).

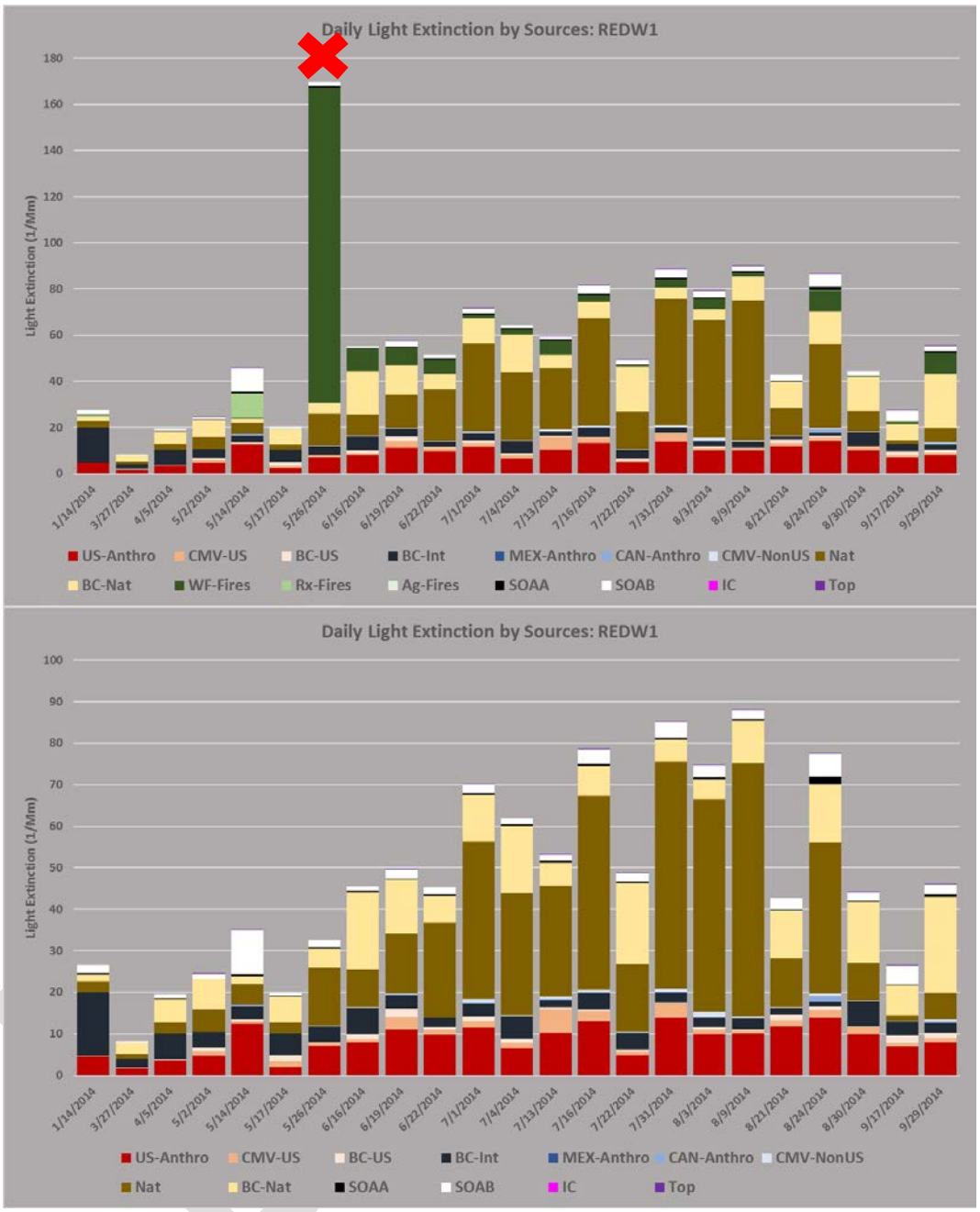

Figure 6. CAMx RepBase source apportionment results at Redwood (REDW) California for 2014 IMPROVE MID for all source categories (top) and with contributions of three types of fires (WF, Rx and Ag) removed (bottom).

Modeled MID Visibility Projection Approach

Another alternative 2028 visibility projection approach (which also avoids days with modeled high fire impacts in the RRFs) is to base RRFs on the modeled Most Impaired Days (ModMID). PM source apportionment modeling is needed to identify the 20% days in the model simulation that have the highest U.S. anthropogenic emissions contribution (i.e., most impaired days).

The issue of modeled vs. IMPROVE days with the most anthropogenic impairment was studied in detail using the WAQS 2008 and 2011 modeling databases (e.g., Brewer et al., 2019[12]; Nopmongcol et al., 2016[13]; Morris et al., 2016a[14]; Morris et al., 2016b[15]). These analyses used results from PM source apportionment modeling to identify the most impaired days, which is discussed in detail on an IWDW website.[16] These analyses suggested that the modeled MID did not necessarily occur on the same days as the observed IMPROVE MID, and the observed IMPROVE MID still had fire influences, especially at sites and years with high fire impacts. Using source apportionment the model could provide a very precise definition of the influences of anthropogenic, natural and fire contributions to the modeled visibility.

WRAP conducted a CAMx Particulate Source Apportionment Technology (PSAT) simulation using the RepBase emissions that provided separate visibility contributions due to fires, natural sources and U.S. and international anthropogenic emissions.[17] Several different techniques for developing RRFs using the ModMID approach were evaluated[18] with the selected ModMID projection method described next.

For the ModMID projection approach, the RepBase PM source apportionment simulation results were used to exclude the contributions of wildfire and wildland prescribed fire in the concentrations used for the RRFs (as in the EPAwoF approach). The MODMid method identifies the 20% of the 2014 IMPROVE sampled days during the year in which the CAMx RepBase source apportionment has the highest absolute visibility impairment due to U.S. anthropogenic emissions in the remaining (i.e., no fire) concentrations. We also evaluated using the highest 20% U.S. anthropogenic emission contributions from all days of the year but the 2028 projection results using just the IMPROVE sampling days were very similar. Thus the ModMID projection approach was based on the 2014 IMPROVE sampling days because it allows the evaluation of the model for the days used in the ModMID RRFs as well as have the ModMID projection RRFs based on a similar number of days as the EPA and EPAwoF projection approaches.

Figure 7 displays the RepBase source apportionment results at Crater Lake (CRLA) for days from the ModMID with (top) and without (bottom) including contributions from the three types of fires. The selection of days for the ModMID doesn't limit the occurrence of fires on those days, just that source apportionment is used so that the fire contributions are not included in the calculation of the RRFs used in the projections (i.e., Figure 7, bottom). In fact, the ModMID at CRLA includes many days in July and August with wildfire contributions and days in October and November with Rx fire contributions (Figure 7, top).

Figure 8 shows similar results to Figure 7 only for the Redwood IMPROVE site in northwest California. Again, the many days used in the ModMID RRFs at Redwood have fire impacts (Figure 8, top). The

[12] https://www.tandfonline.com/doi/pdf/10.1080/10962247.2018.1537985?needAccess=true

[13] http://views.cira.colostate.edu/wiki/Attachments/Source%20Apportionment/Particulates_v6/C55_Nopmongcol_AWMA_vis_Sep2016.pptx

[14] http://views.cira.colostate.edu/wiki/Attachments/Source%20Apportionment/Particulates_v6/RMorris_WRAP_AWMA_Vis_n42_2016-09-29v3.pptx

[15] http://views.cira.colostate.edu/wiki/Attachments/Source%20Apportionment/Particulates_v6/RMorris_WRAP_AWMA_Vis_n116_2016-09-28v4.pptx

[16] http://views.cira.colostate.edu/wiki/wiki/9152/use-of-particulate-source-apportionment-modeling-to-identify-most-impaired-days

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

[18] https://www.wrapair2.org/pdf/VisProj_Alt-EPAwoF-ModMID_RTOWG_2020-07-16v1.pptx

elimination of fire contributions in the ModMID RRFs results in anthropogenic emissions being a larger relative contribution to the extinction in days used in the RRF. Note that Crater Lake and Redwood IMPROVE sites were selected for illustration because they do have significant fire impacts. Most other IMPROVE sites have lower contributions from fires.

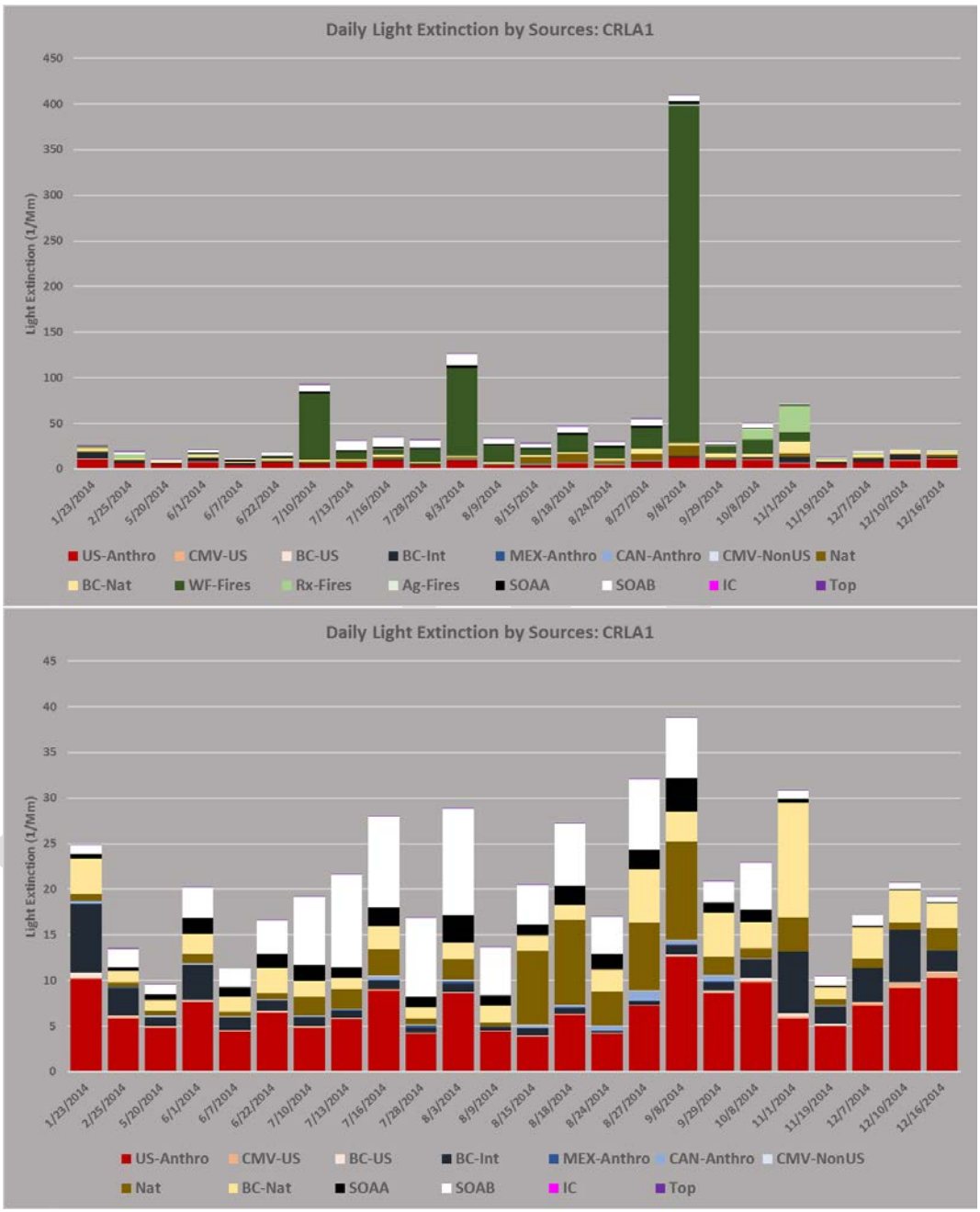

Figure 7. CAMx RepBase source apportionment results at Crater Lake (CRLA) Oregon for modeled most impaired days (ModMID) with all source categories contributions (top) and with contributions of three types of fires (WF, Rx and Ag) removed (bottom).

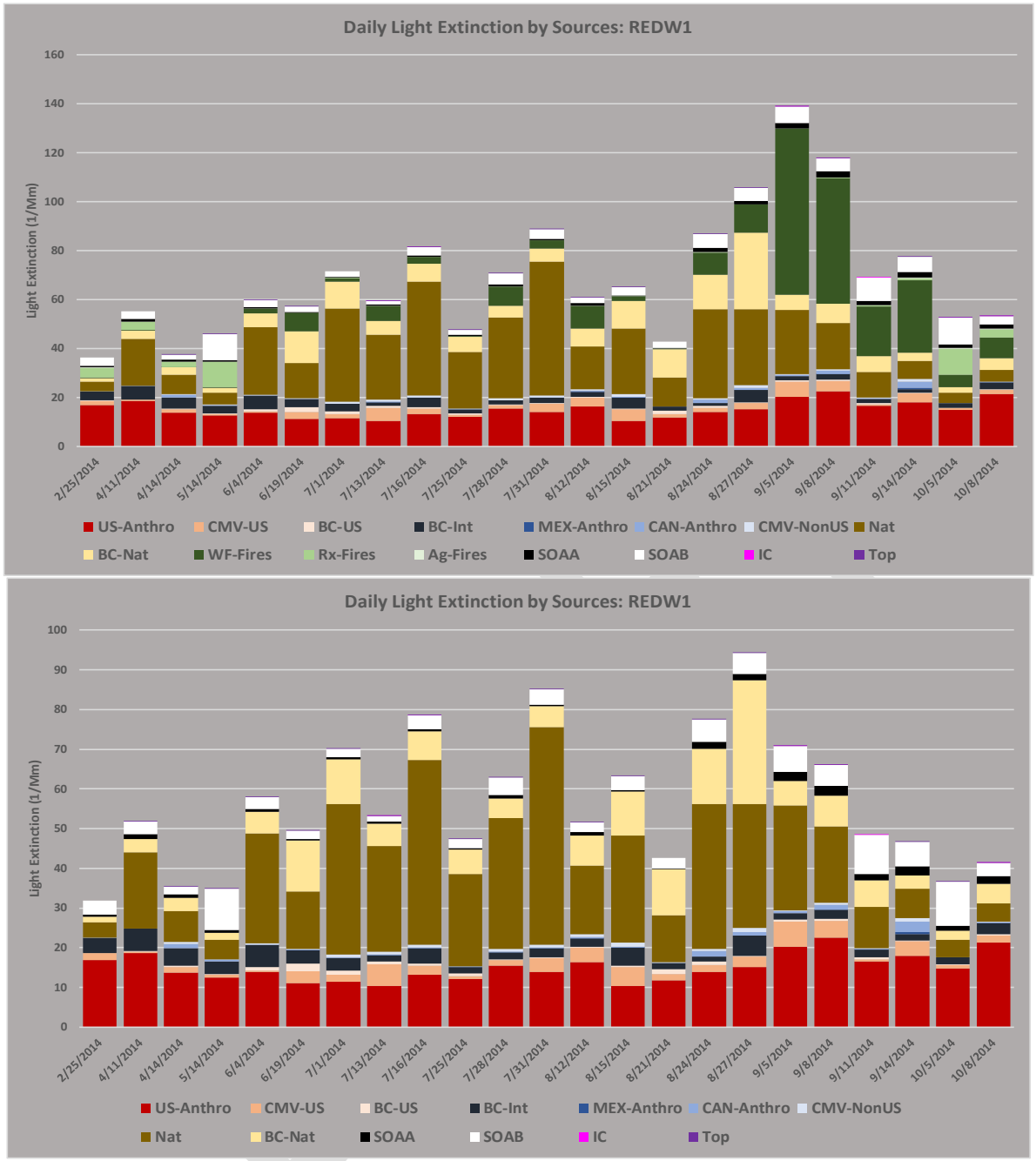

Figure 8. CAMx RepBase source apportionment results at Redwood (REDW) California for modeled most impaired days (ModMID) with all source categories contributions (top) and with contributions of three types of fires (WF, Rx and Ag) removed (bottom).

Summary of 2028 Visibility Projection Approaches

Three 2028 visibility projection approaches have been developed that use the WRAP 2014 RepBase/2028OTBa CAMx modeling results to project the observed IMPROVE MID for 2014-2018 to 2028. These methods are:

> EPA: Use RRFs based on modeled concentrations on the 2014 IMPROVE MID (i.e., EPA recommended approach that is codified in SMAT).
>
> EPAwoF: RRFs based on same days from 2014 IMPROVE MID, only contributions of fires (WF, Rx and Ag) have been removed from the CAMx RepBase and 2028OTBa concentrations estimates using source apportionment.
>
> ModMID: Use the modeled most impaired days (ModMID) that are defined as the days from the 2014 IMPROVE sampling days that have the 20% highest U.S. anthropogenic emissions impairment with the RRFs defined without using contributions from fires (like in EPAwoF).

Figures 9 and 10 display the average extinction across days used for the RRFs in the three projections methods at Crater Lake and Redwood, respectively. The left panels in the two figures show the average modeled extinction by species for all source categories, whereas the right panels show the source apportionment extinction results averaged across just the days used in the RRFs for the three projection methods (e.g., no fire contributions in the EPAwoF and ModMID methods). The average species extinction are the same for the EPA and EPAwoF methods as they use the same days from the 2014 IMPROVE MID in their RRFs (top and middle left panels). And the EPA and EPAwoF method source apportionment are the same except for EPAwoF eliminates the fire contributions (top and middle right panels). The average species extinction across the days used in the RRF for the ModMID approach has higher sulfate and nitrate extinction than the EPA and EPAwoF approaches (bottom left panel). And the U.S. anthropogenic extinction on the ModMID RRF days is approximately twice as high as the EPA and EPAwoF RRF days (bottom right panel). Thus, the ModMID RRFs are based on days with higher U.S. anthropogenic emissions contribution so provide a better representation of the changes in visibility between the current and future years on the most impaired days than the days used in the EPA and EPAwoF RRFs.

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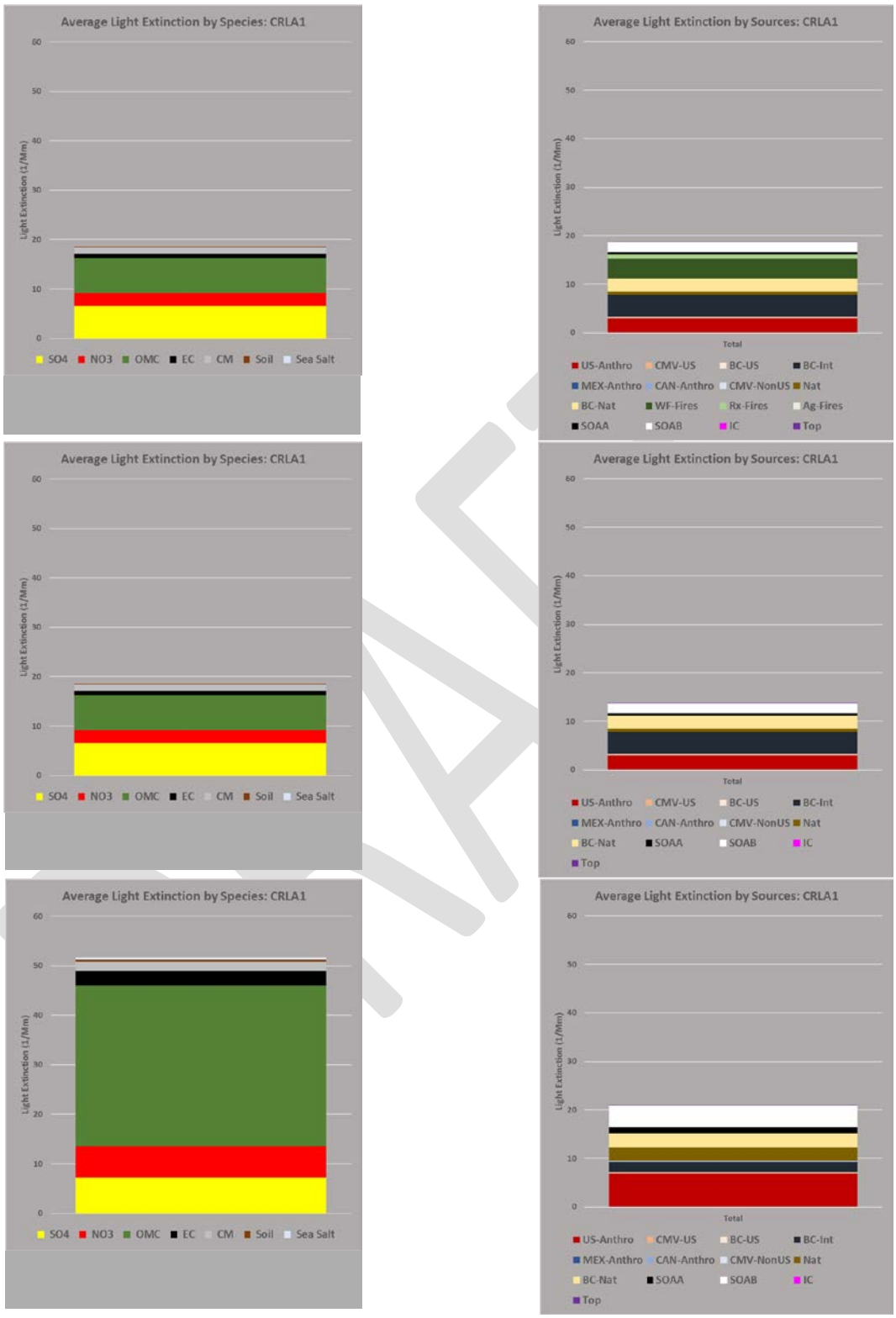

Figure 9. Average species concentrations across the days used in the RRFs (left) and source apportionment of the extinction averaged across days used in the RRFs at Crater Lake and for the EPA (top), EPAwoF (middle) and ModMID (bottom) visibility projection approaches.

Figure 10 Average species concentrations across the days used in the RRFs (left) and source apportionment of the extinction for days used in the RRFs for Redwood and the EPA (top), EPAwoF (middle) and ModMID (bottom) visibility projection approaches.

Species Held Constant in the Visibility Projection

Some measured visibility extinction species at an IMPROVE site may be dominated by natural sources that are not well simulated by the model so it may be appropriate to hold them constant between the current and future years (i.e., RRF = 1.0). For example, although the model simulates Sea Salt, we would expect it to remain unchanged between the current and future year so EPA guidance and the SMAT projection tool holds the measured extinction due to Sea Salt constant between current and future years. In Round 1 of the regional haze modeling, we assumed that Soil and Coarse Mass (CM) remained unchanged between the current and future years (i.e., set the Soil and CM RRFs = 1.0). When Soil and CM are large components of the daily visibility extinction it is usually due to windblown dust (WBD) storms or localized dust impacts for CM, neither of which is well simulated by our current regional modeling systems due to difficulties in simulating WBD storms and subgrid-scale processes for localized CM impacts. For example, Figure 3 top panel shows very high CM and relatively high fine Soil observed extinction at Canyonlands on November 1, 2014 that is likely due to natural WBD that is not captured by the model.

An examination of the CAMx RepBase source apportionment results reveals that a vast majority of the modeled CM is of anthropogenic in origin. Thus, if there are large natural WBD storms causing high observed CM extinction at an IMPROVE site (e.g., the November 1, 2014 Canyonlands example given above), the changes in anthropogenic CM from the current to future will be used to adjust the natural WBD CM extinction, which would be inappropriate. Thus, for the current round of visibility SIPs we will also set the RRF for CM to 1.0.

Soil in the model is also mainly anthropogenic in origin, although it appears Mexico and Canada have larger contributions than the U.S. One update over the Round 1 regional haze modeling is that CAMx v7.0 being used now has explicit treatment of the same elemental species as used in the IMPROVE Soil extinction equation so there is consistency between the observed and modeled Soil Species. Given that Soil is a small fraction of extinction for the current visibility projections and improvements in modeling Soil between Rounds 1 and 2 of the RHR SIP developments, the modeled Soil RRFs will be used in the current 2028 visibility projections.

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